HyspIRI VSWIR Science Measurement and Instrument Concept Baseline

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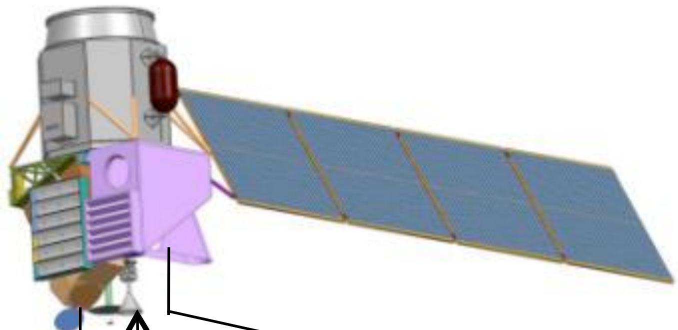
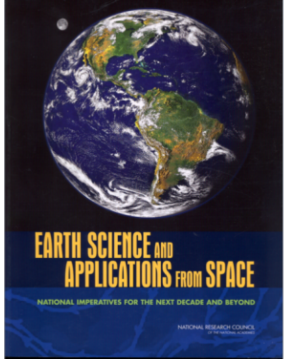
NRD Decadal Survey
HyspIRI Mission Concept



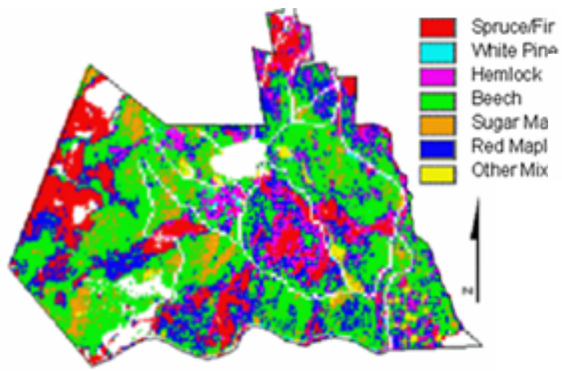


Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer

IPM Low Latency Data

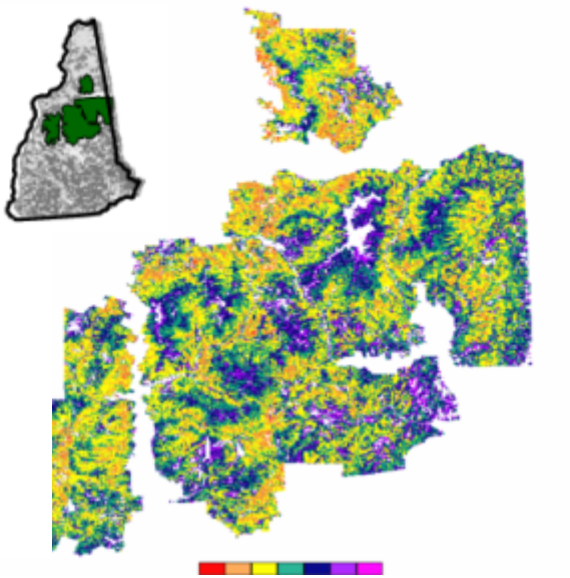
Multispectral Thermal InfraRed (TIR) Scanner

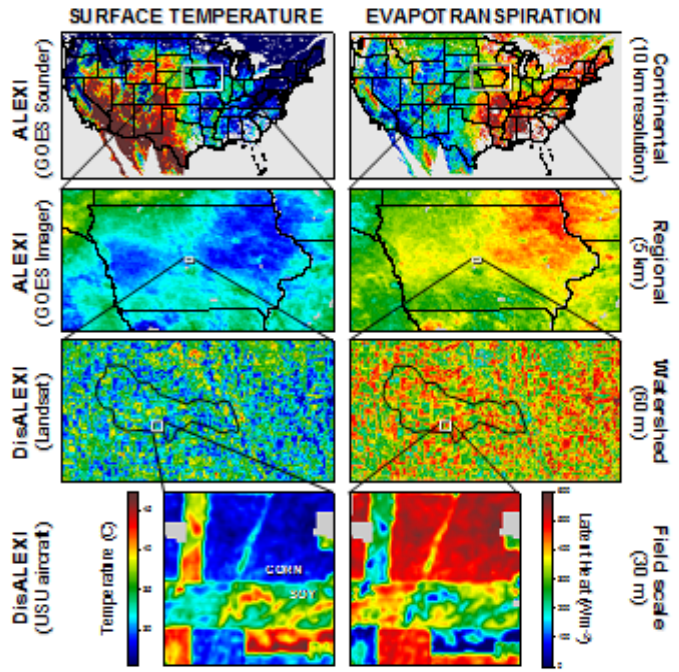
Map of dominant tree species, Bartlett Forest, NH



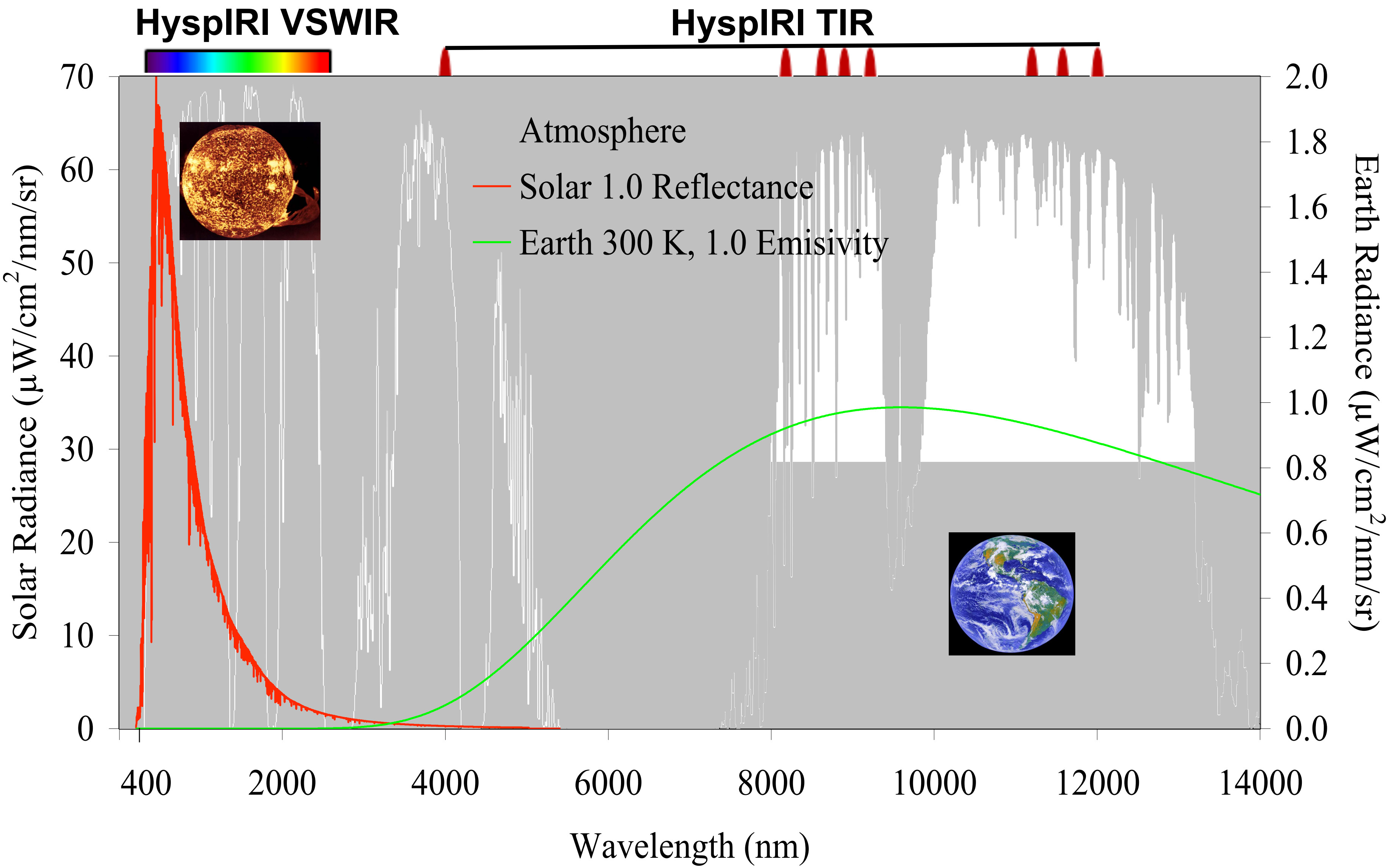
Soil C:N Ratio

White Mountain National Forest, NH

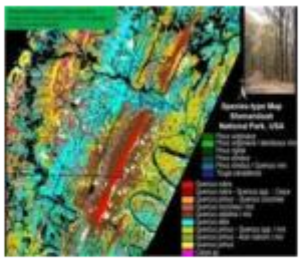


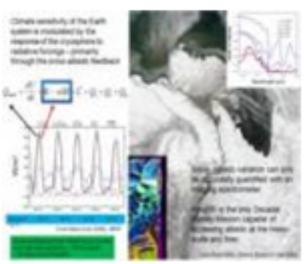


HyspIRI Measures the Optical Spectrum



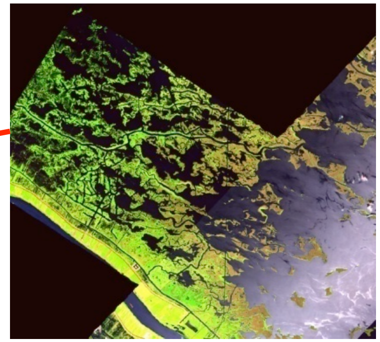
HyspIRI VSWIR Decadal Survey Science and Decadal Survey Climate Science



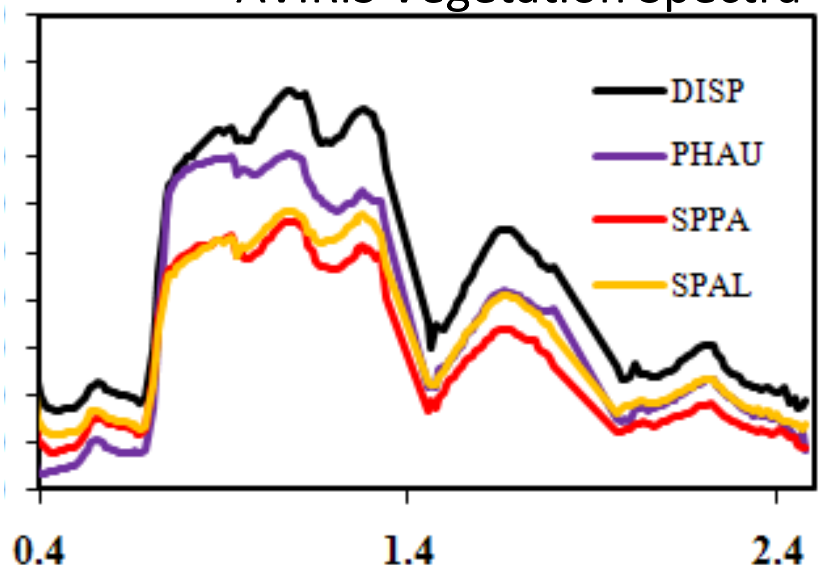


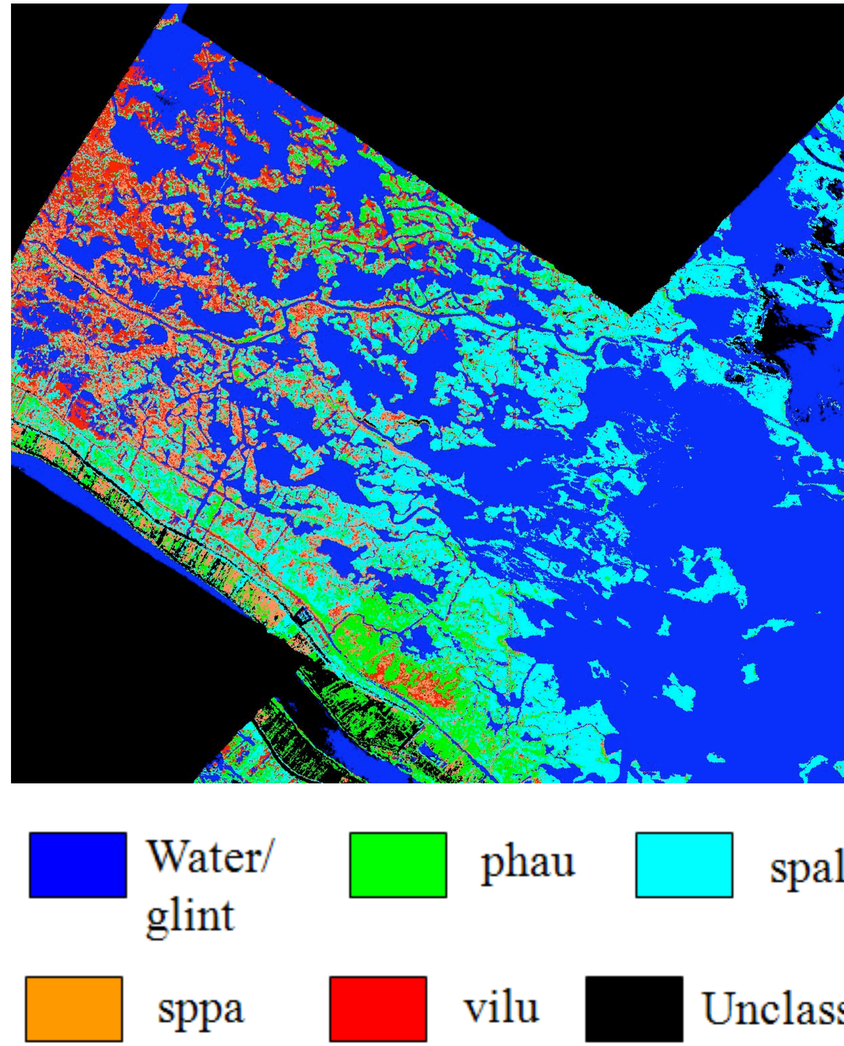
- Key HyspIRI climate objectives from the Decadal Survey and IPCC
  - Ecosystem Measurement for Climate Feedback
  - Black Carbon/Dust Effects on Snow and Ice
  - Carbon Release from Biomass Burning
  - Evapotranspiration and Water Use and Availability
  - Critical Volcanic Eruption Parameters
- Imaging Spectrometer (VSWIR)
  - Pattern and Spatial Distribution of Ecosystems and their Components
  - Ecosystem Function, Physiology and Seasonal Activity
  - Biogeochemical Cycles
  - Changes in Disturbance Activity
  - Ecosystem and Human Health
  - Earth Surface and Shallow Water Substrate Composition
- Combined Imaging Spectrometer and Multi-Spectral Thermal Science
  - Coastal habitats, and inland aquatic environments
  - Wildfires
  - Volcanoes
  - Ecosystem Function and Diversity
  - Land surface composition and change
  - Human Health and Urbanization

Example: Imaging Spectroscopy Mapping Wetland Dominants 2010 LA



AVIRIS Vegetation Spectra





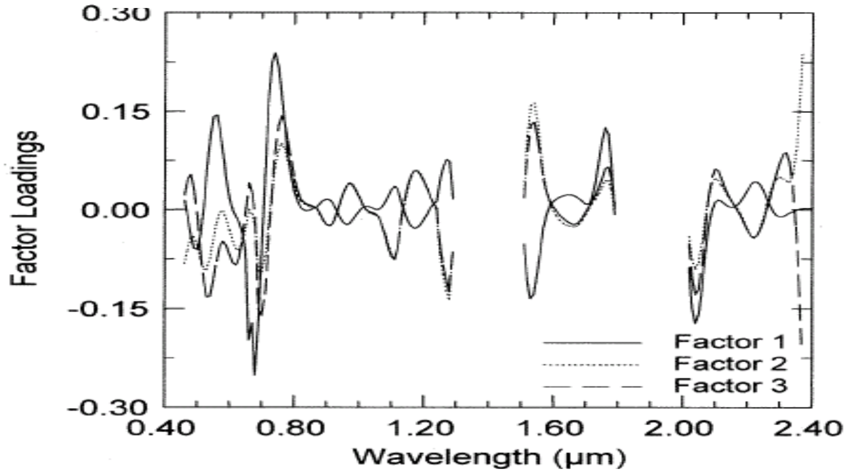
Vegetation mapped cleanly across scene boundaries

- ***Phragmites (phau)***
- ***Spartina alterniflora (spal)***
- ***Spartina patens (sppa)***
- ***Vigna luteola (vilu)***

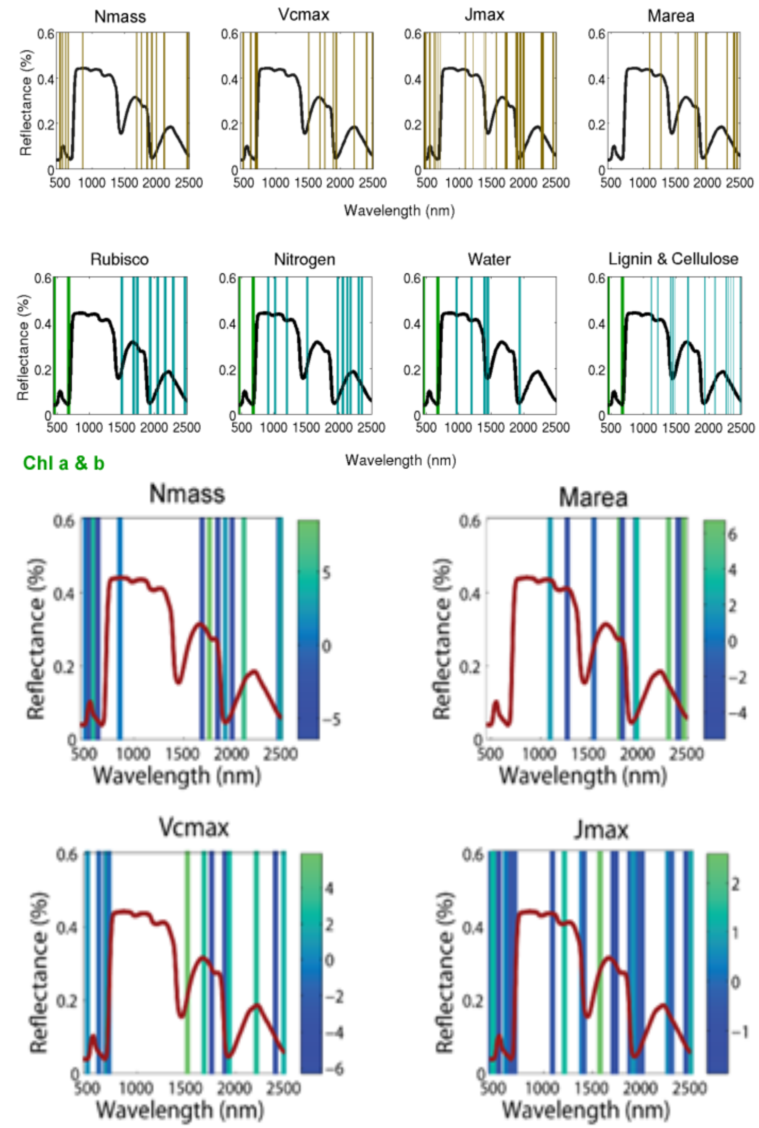
D. Roberts, UCSB

Spectroscopy for Species/Functional-type, Biogeochemistry and Physiological Condition

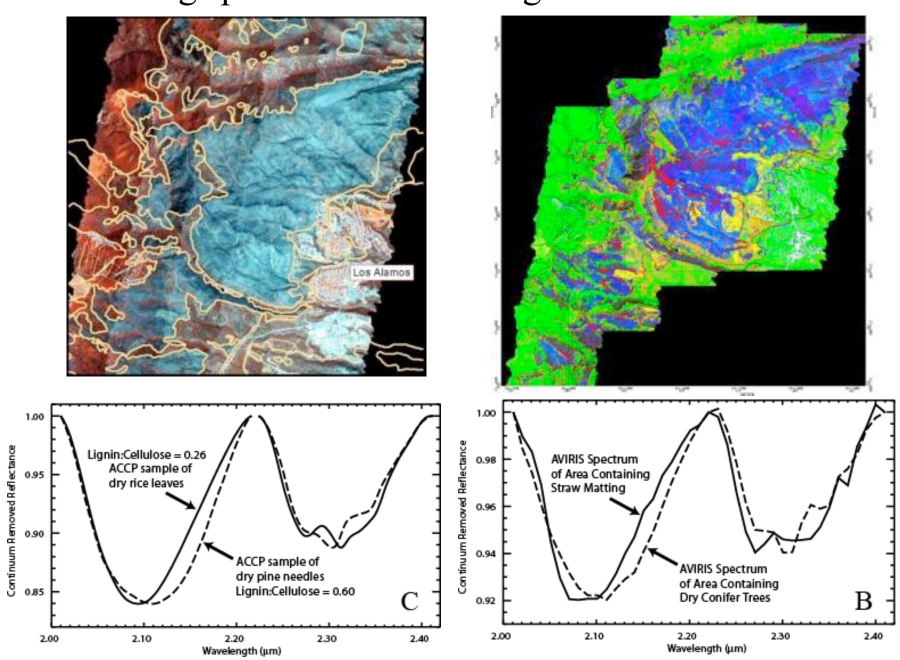
PLSR weighting for foliar Nitrogen



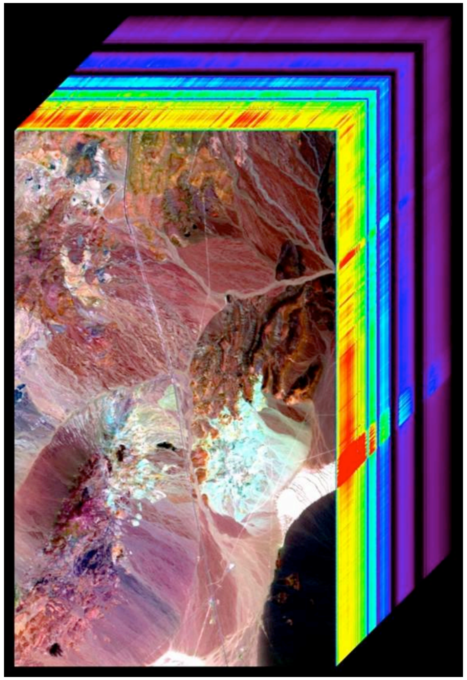
PLSR wavelength selection for one species

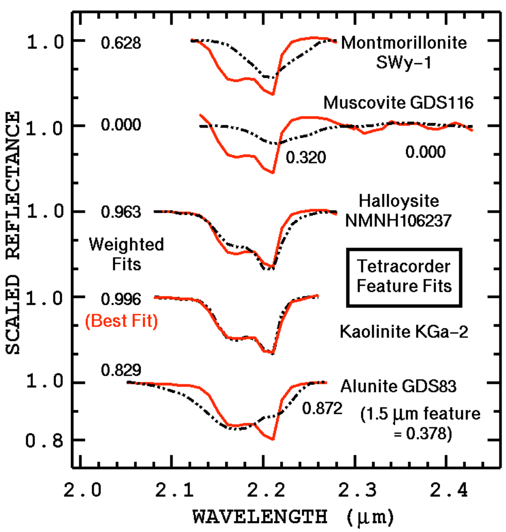


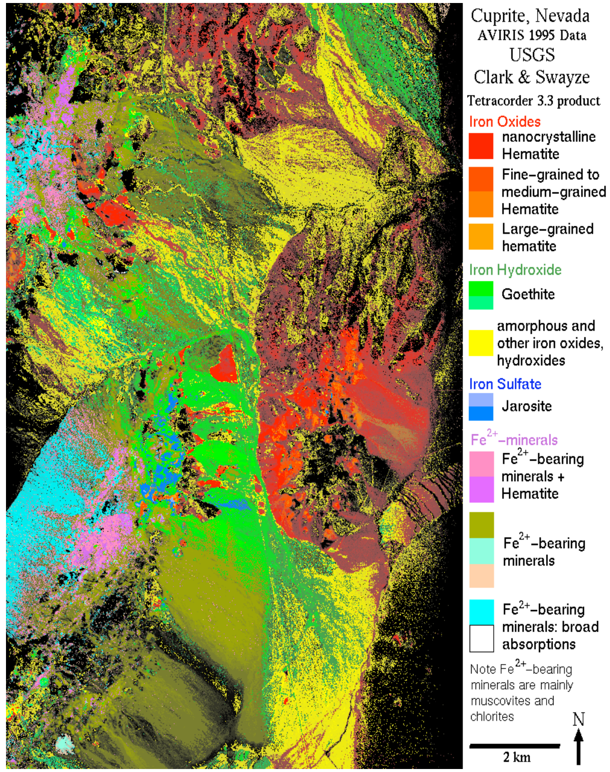
Measuring spectral shift from Lignin : Cellulose ratio

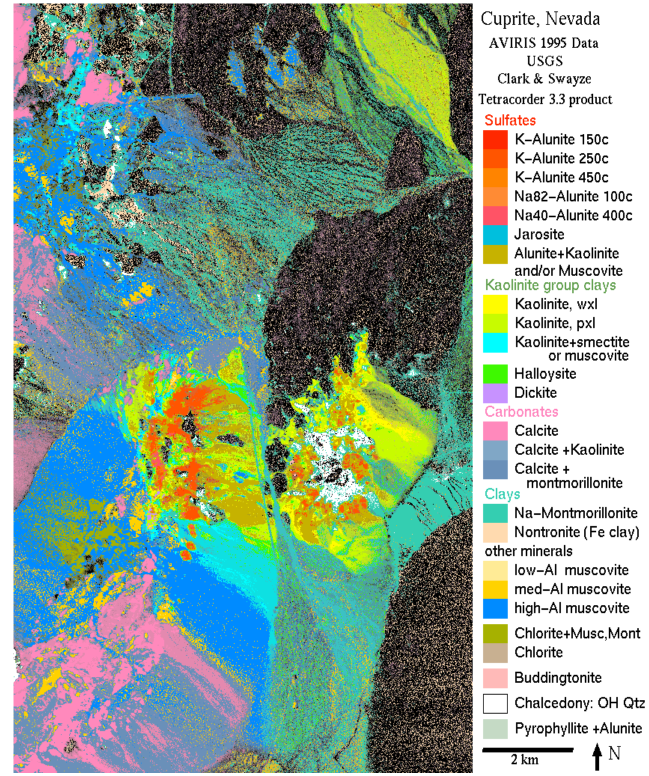


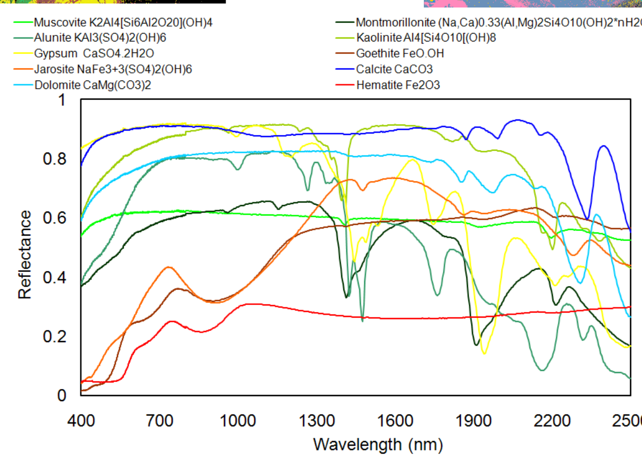
Surface Compositional Derived with Imaging Spectrometer Measurements







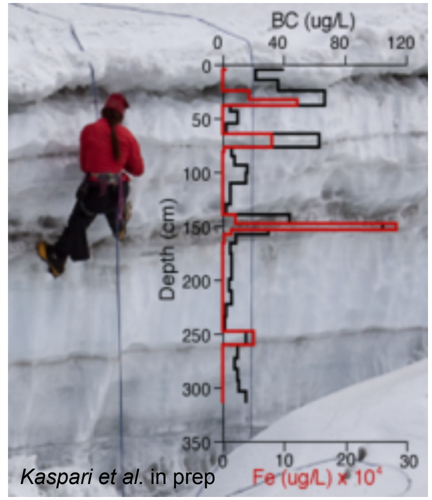


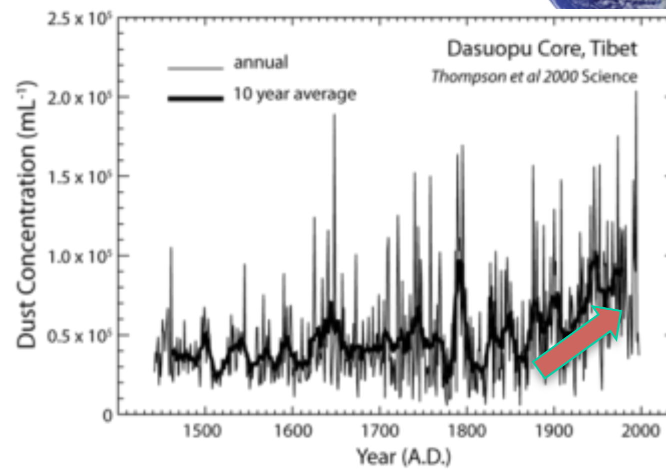


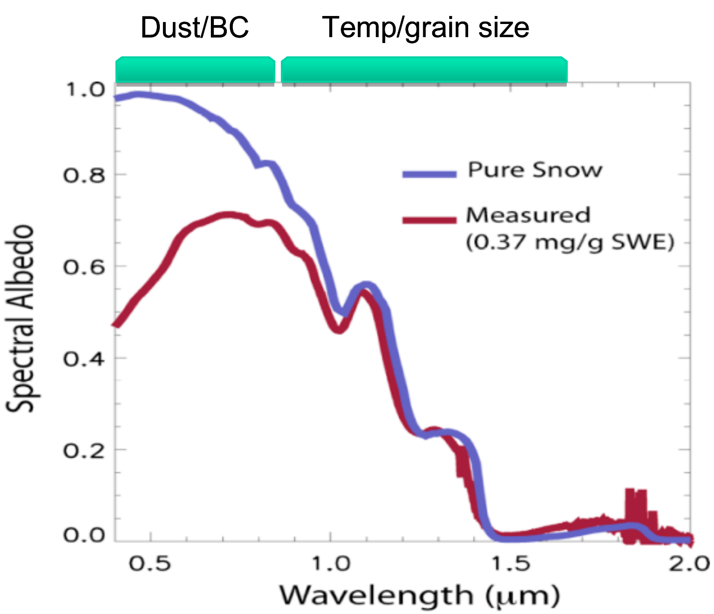
Albedo and Black Carbon/Dust Effects on Snow/Ice

What is causing the downwasting and retreat of Himalayan glaciers and elsewhere?

For snow and ice in the Himalaya, increasing temperatures and increasing dust and soot combine in unknown proportions to accelerate melt through their changes in albedo. Imaging Spectrosocpy is the only approach that allows us to attribute changes in albedo into effects from temperature and dust/black carbon and at a fine enough spatial resolution that heterogeneous terrain can be resolved. Multi-band sensors such as NPOESS VIIRS have neither capacity.

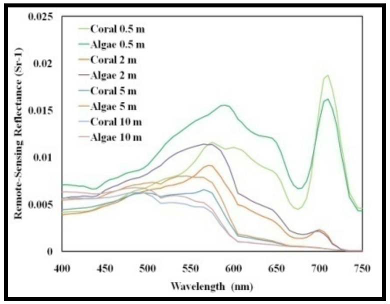


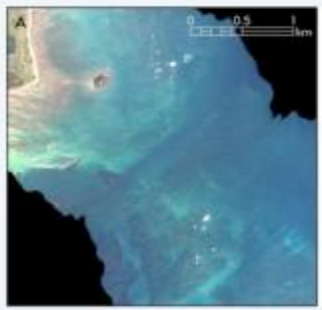


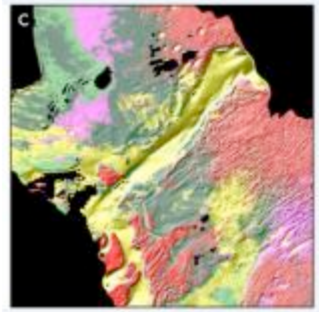


Required Measurement: Global glacial covered area, full solar spectrum, < 100 m spatial, <20 days revisit

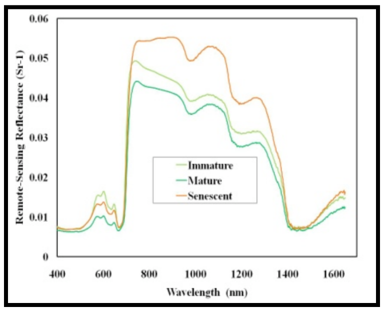
HyspIRI: Coral, Benthic Composition, and Aquatic Vegetation

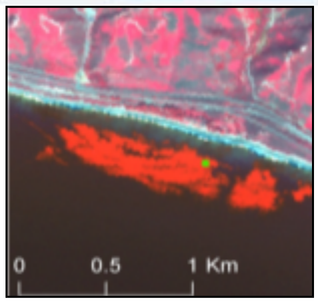


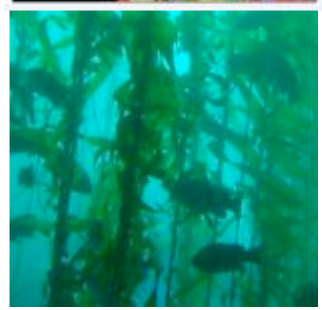




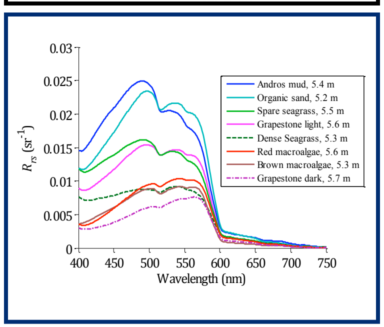
Variation in shallow water HyspIRI-type spectral signatures in coral environments.

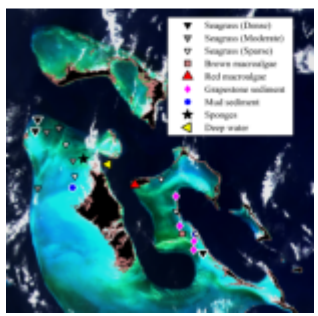




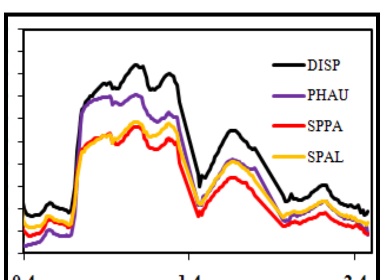


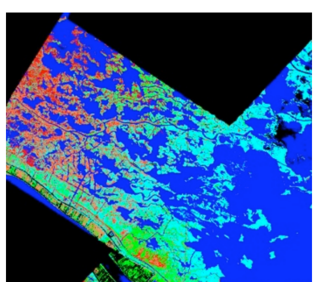
Variation in HyspIRI-type spectral signatures of floating aquatic vegetation (e.g. Kelp)





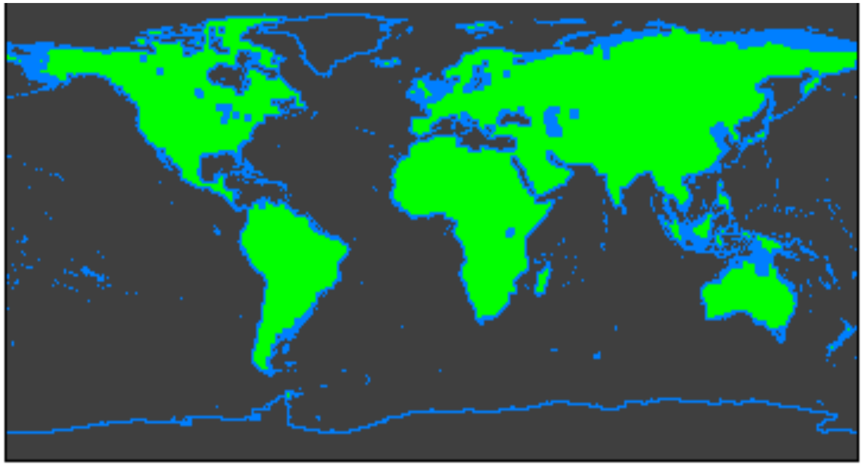
Variation in shallow water HyspIRI-type spectral signatures in seagrass beds and benthic habitat materials



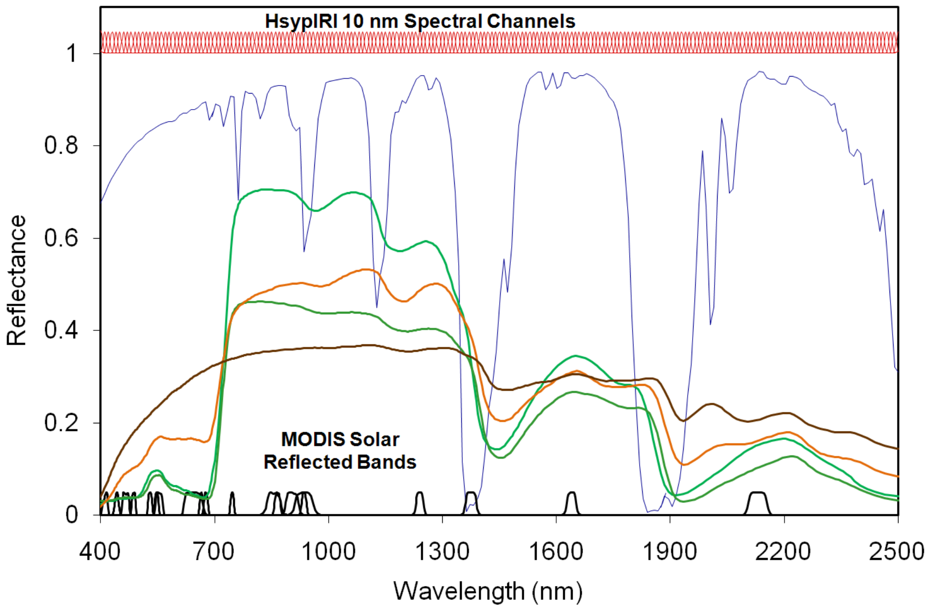


Emergent vegetation signatures are well suited to the HyspIRI measurement. For example mapping in the Gulf of Mexico coastal region with AVIRIS measurements.

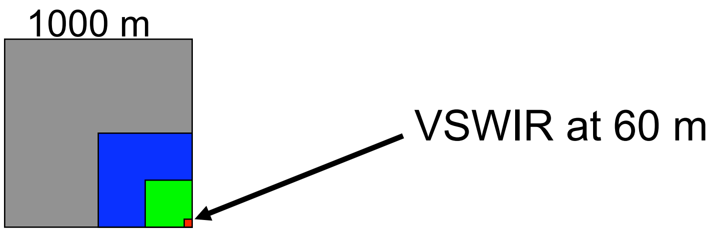
HyspIRI VSWIR Science Measurements



HyspIRI is a global mission, measuring land and shallow aquatic habitats at 60 meters and deep oceans and ice sheets at 1km every 19 days (VSWIR)

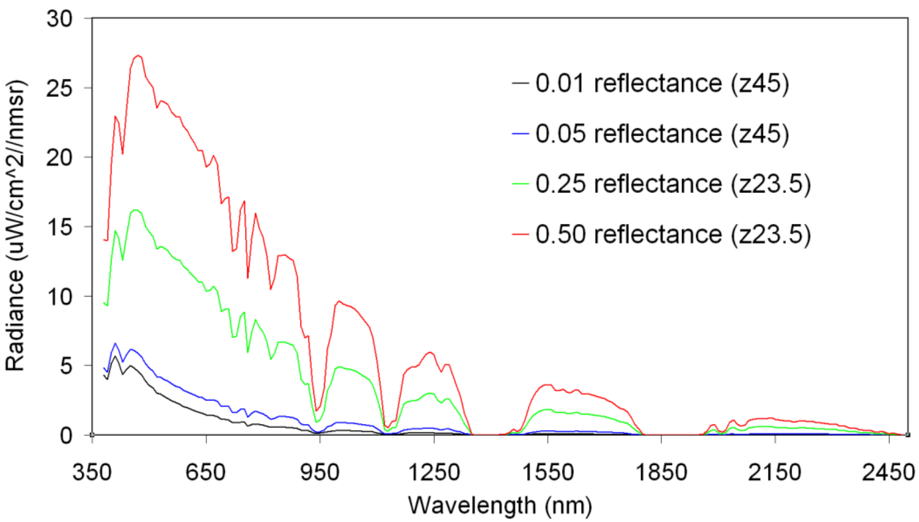


HyspIRI's VSWIR imaging spectrometer directly measures the full solar reflected spectrum of the Earth from 380 – 2500nm at 10 nm.

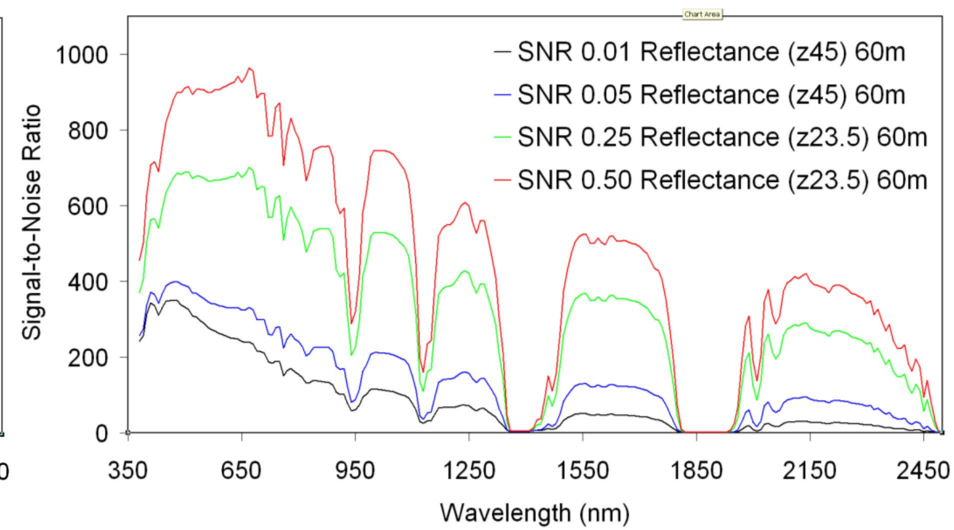


HyspIRI VSWIR SNR and Uniformity Characteristics

Benchmark Radiances

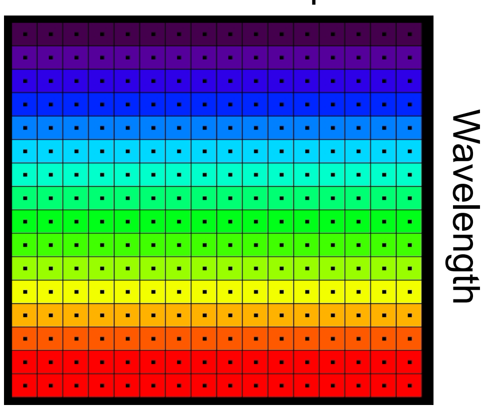


Signal-to-Noise Ratio



Uniformity Requirement

Cross Track Sample

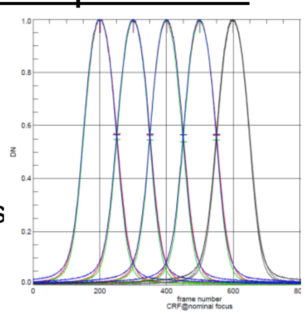


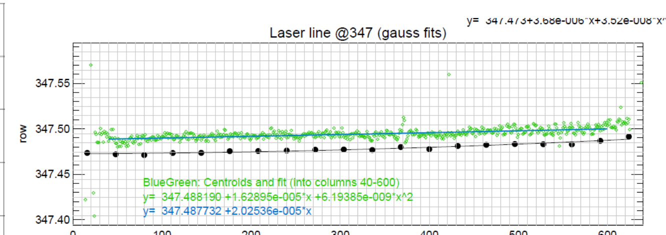
Depiction

-Grids are the detectors

-Dots are the IFOV centers

-Colors are the wavelengths

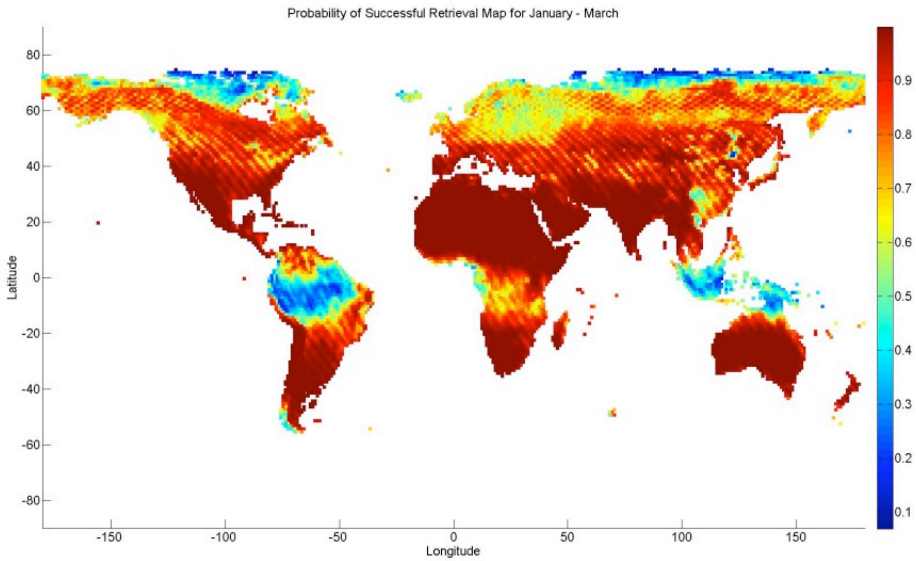


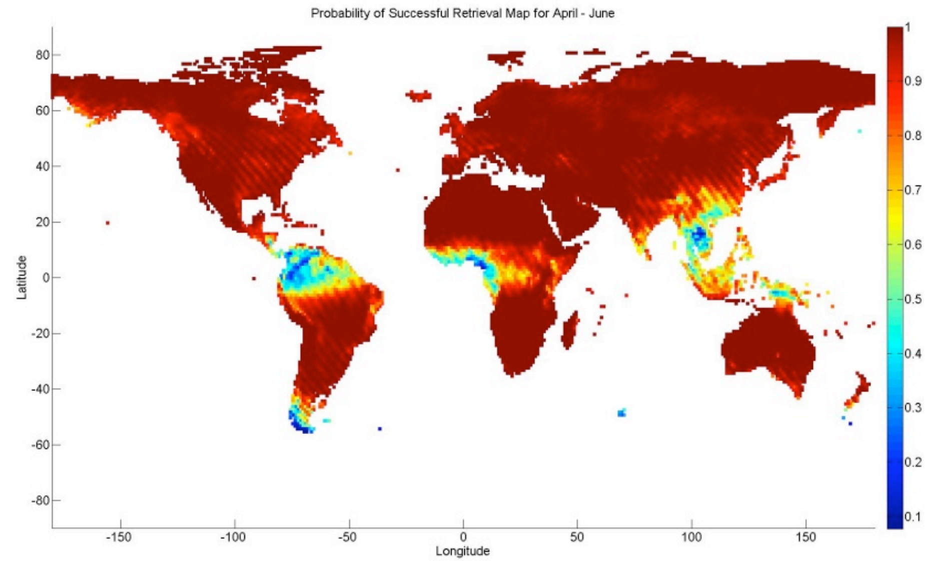


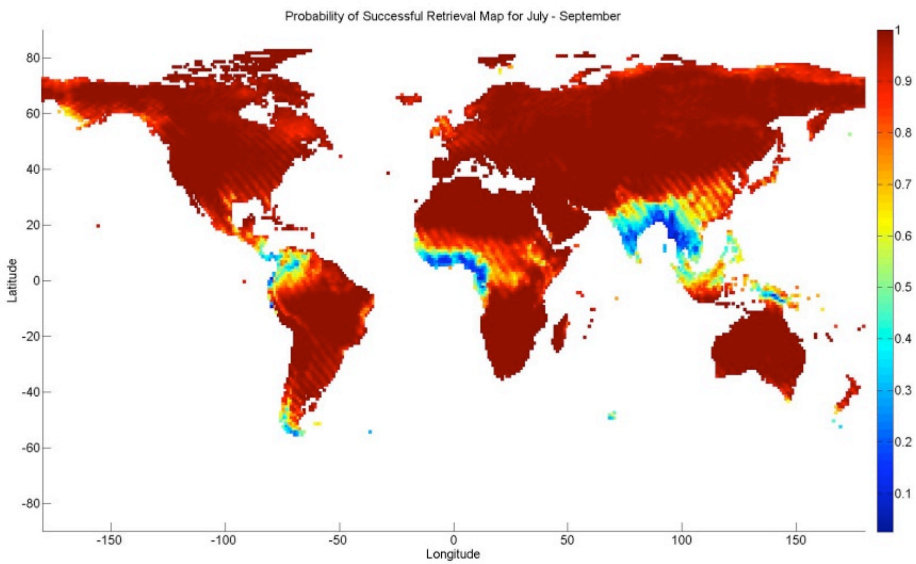
Requirement

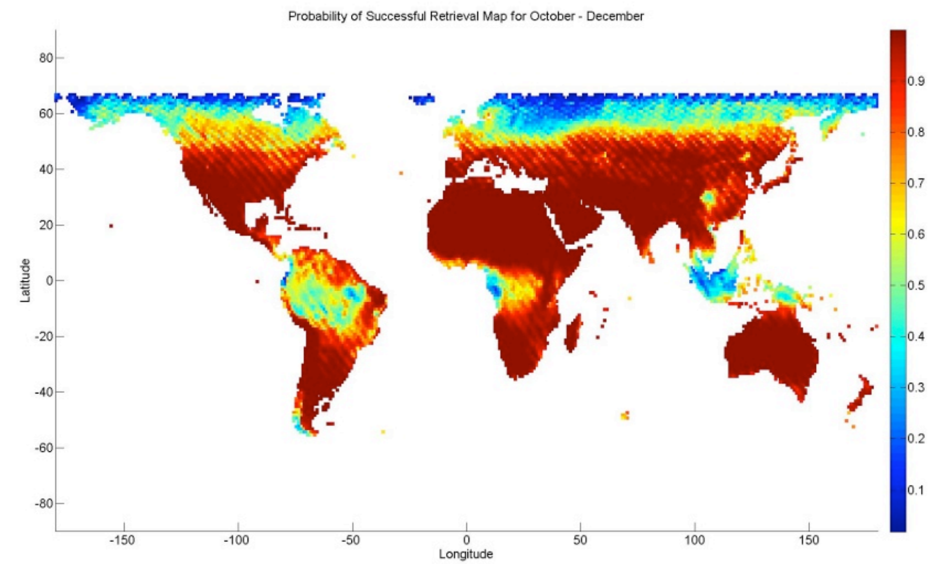
Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}

Seasonal and Annual Cloud Probability Maps Validate the HyspIRI Coverage Requirements

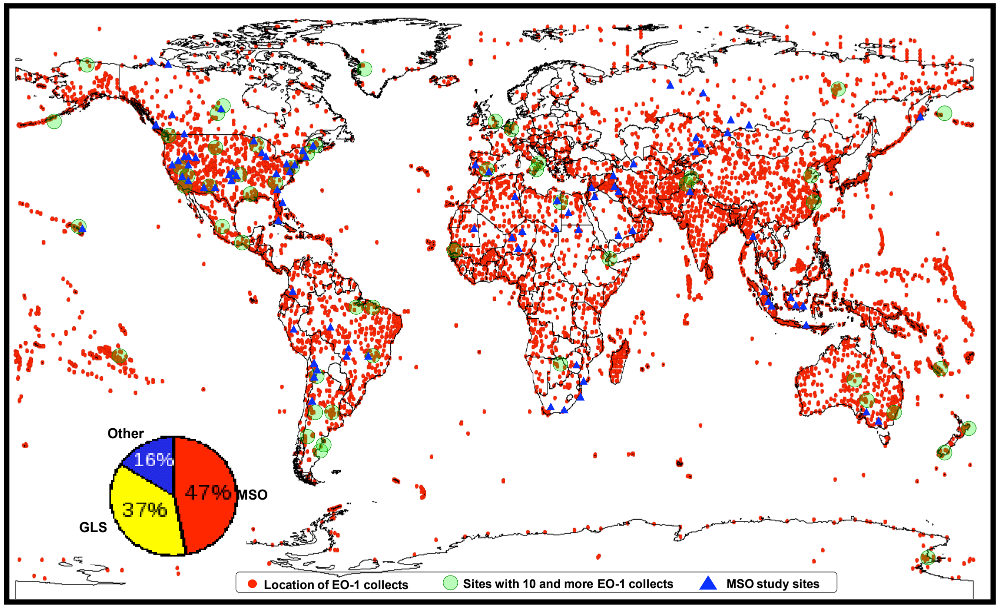




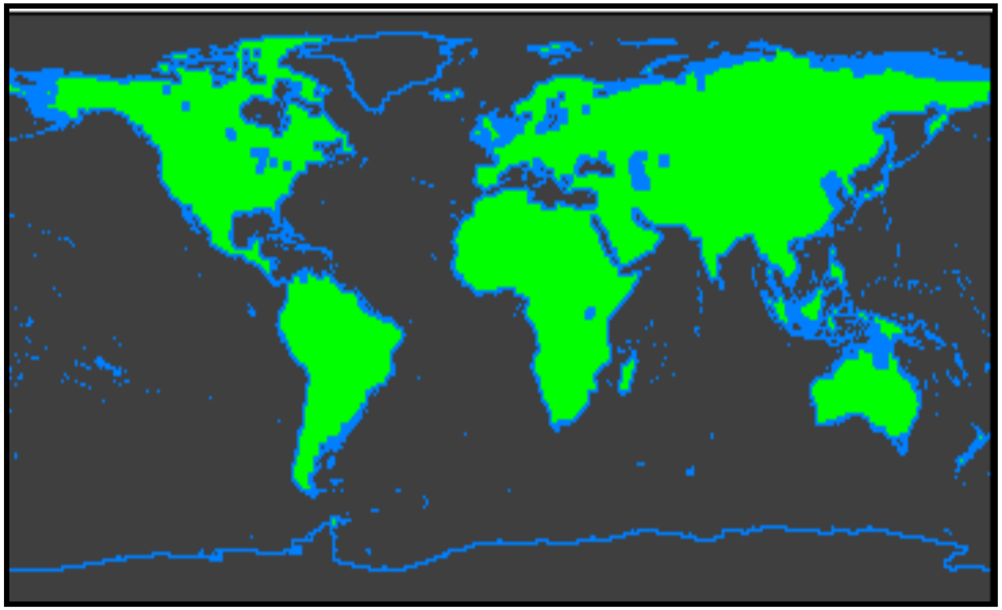




HyspIRI VSWIR Coverage



- EO-1 Hyperion acquisitions in 10 years. Technology demonstration sampling mission with deep ESTO contribution.



- HyspIRI VSWIR provides complete terrestrial coverage every 19 days.

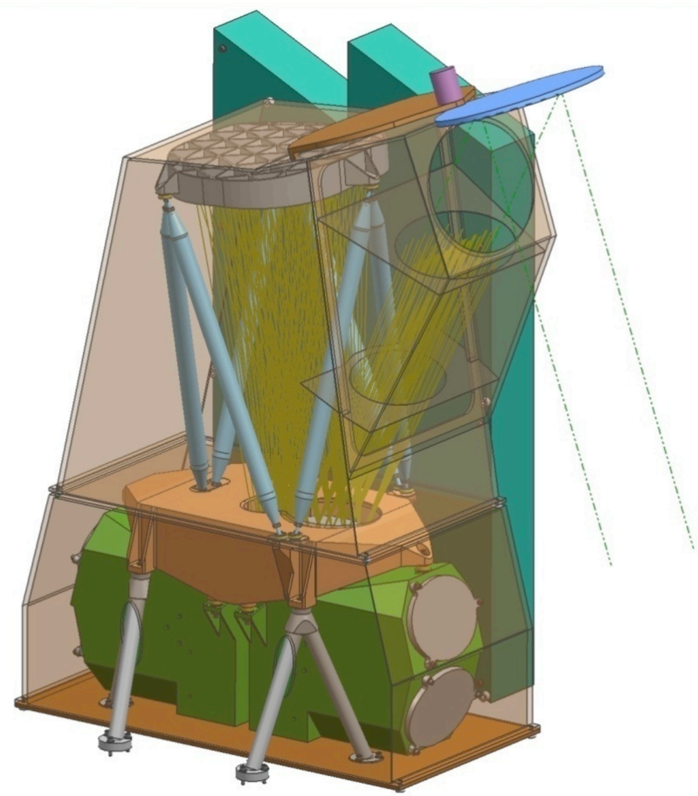
- It would take Hyperion 100 years to acquire what HyspIRI measures in 1 year.

VSWIR - Instrument Concept

OUTLINE

1. Introduction
2. Key Requirements & Performance
3. VSWIR Concept
4. Technology Readiness & Heritage

HyspIRI – VSWIR



Mass (CBE)	***55Kg***
Power (Ave.)	***41Watts***

Key VSWIR Requirements

Spectral	Requirement	Status
Range	380 to 2500 nm (solar reflected spectrum)	Demonstrated – AVRIS, MaRS, M3
Sampling	<= 10 nm {uniform over range}	Demonstrated – MaRS, M3
Response	<= 13 nm (FWHM) {uniform over range}	Demonstrated – MaRS, M3
Accuracy	<0.5 nm	Demonstrated – MaRS, M3, CAO-VSWIR

Radiometric	Requirement	Status
Range & Sampling	0 to 1.5 x benchmark radiance, 14 bits	Demonstrated via analysis and 14 bit ADC bread board electronics
Accuracy	>95% absolute radiometric, 98% on-orbit reflectance, 99.5% stability	Demonstrated – AVIRIS, MaRS
Precision (SNR)	See spectral plots at benchmark radiances	Demonstrated via analysis
Linearity	>99% characterized to 0.1 %	Demonstrated via test, MaRS and CAO-VSWIR
Polarization	<2% sensitivity, characterized to 0.5 %	Demonstrated via analysis of design and test data on the grating
Scattered Light	<1:200 characterized to 0.1%	Demonstrated in MaRS and CAO-VSWIR

Key VSWIR Requirements

Spatial	Requirement	Status
Range	>145 km	Demonstrated by design and analysis (150 km)
X-track Sampling	>2400	Demonstrated by design and analysis (2500)
Sampling	<= 60m (Nadir)	Demonstrated by design and analysis
Response	<= 1.2X sampling (FWHM)	Demonstrated by MaRS and M3
Uniformity		
Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}	Demonstrated by MaRS and M3
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}	Demonstrated by MaRS and M3

Other Key	Requirement	Status
Data rate	~ 300 Mbits per second	Met by preliminary architecture and parts selection – all required parts are at or above TRL 6
Compression	3:1 lossless	Met by algorithm test on MaRS data. Algorithms implemented in breadboard electronics and flight FPGA
Pointing Knowledge	60m radius (3σ)	Met by analysis and the use of ground tie points
Mass	<55 kg	Met by current design with 30% margin – working to increase margin

Instrument Approach

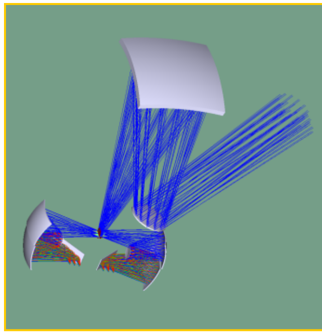
- **Selected: Offner spectrometer (Hyperion, CRISM, M3, ARTEMIS, COMPASS^{air}, NG^{air})**
  - Full range from 380 to 2500 nm demonstrated. Efficiency for high SNR optimized with multiple blaze grating demonstrated. Uniformity from design through alignment demonstrated. Snapshot acquisition detector. Dispersion efficiency tunable to optimize use of detector.

- Prism dispersion spectrometer
  - Dispersion is non-uniform. Cross-track and spectral-IFOV uniformity not inherent in optical design. Dispersion efficiency not tunable in detail to optimize use of detector full well.
- Wedge/Linear-variable filter spectrometer
  - Full spectral range coverage from 380 to 2500 nm has not been demonstrated maintaining 10 nm spectral sampling and response function. Filter uniformity is a concern over wide spectral and spatial domain. Fast, high throughput, beams interplay with filter spectral bandpass undermines uniformity.
- Fourier Transform Spectrometer
  - Dispersion is non constant with wavelength. Not typically built to operate below 1 micron. Detector dynamic range and photon shot noise concern. Architecture for > 2000 cross track elements and >200 spectral channels not identified. Not well suited for wide or moderate field of view. Requires IMC.
- Liquid Crystal Tunable & Acousto-Optical Tunable
  - Time sequential acquisition undermines uniformity. Low TRL, polarization sensitive. Limited spectral range. Requires IMC.

HyspIRI VSWIR Concept

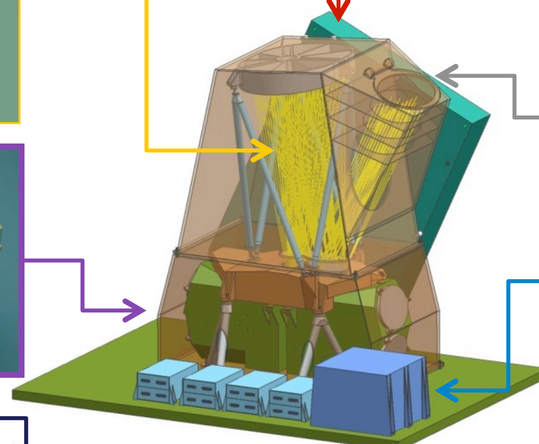
Optics

- Front End Telescope consists of a primary spherical mirror and a secondary aspherical mirror
- Back End Spectrometers consist of 2 optimized Offner spectrometers



Radiator

- Area 0.6m^2
- M3 technology heritage

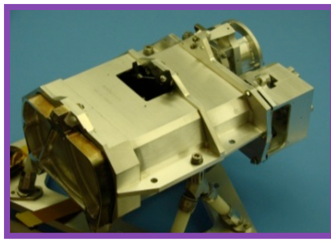


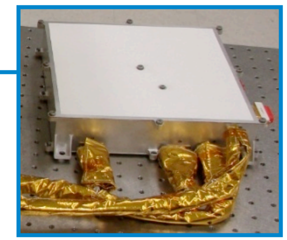
Baffle/Cover/Cal Panel

- *Launch cover*
- *Used as a solar reflectance calibration target*
- *Hyperion Heritage*

Spectrometers (2x)

- 2 identical Offner spectrometers
- Each contains:
  - E-Beam grating
  - Si air slits
  - FPA assembly



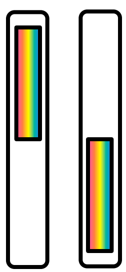


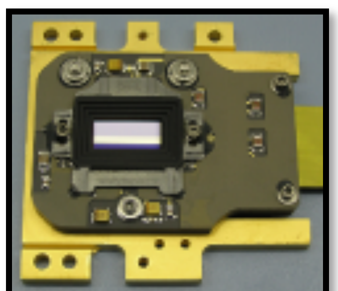
Electronics

- M3 Derivative 4x
- Electronic concept is based upon available flight approved parts
- Ins. control, Data Compression, mode control

FP A (2x)

- Mount is adjustable in 6 DOF
- Thermal strap connects mount to radiator
- Includes integral OSF



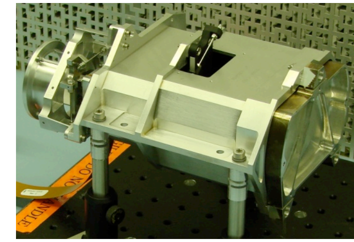


Detectors

- Teledyne 6604b detectors, scaled from 6604a detectors flown on M3
- Analog output
- Each spectrum readout as snapshot, so that there is no time delay, yaw, or jitter impact to the spectral-IFOV-uniformity.

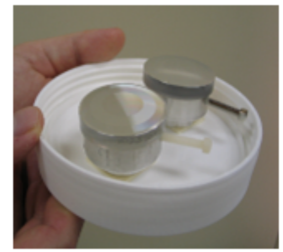
Concept Technologies are Proven
Work Continues to Lower Risk

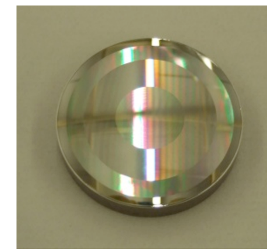
1) Uniform Offner spectrometer (Mouroulis Design)



2) Finely adjustable optics and detector mounts that can be locked within fraction of a micron (0.1 microns)

3) Electron beam fabricated gratings (large ruling period)





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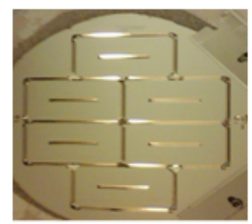

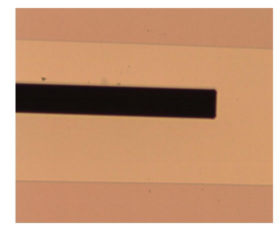

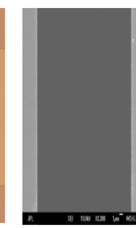

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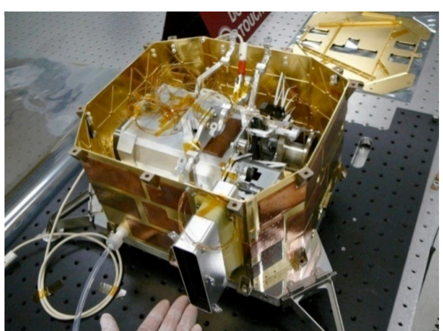
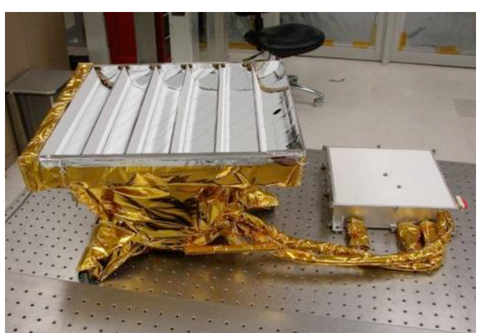
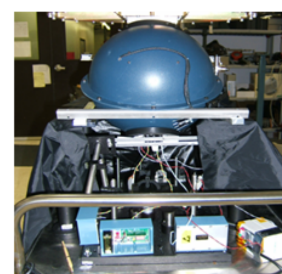
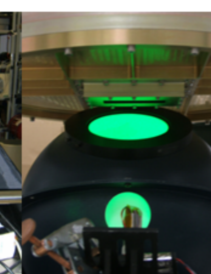
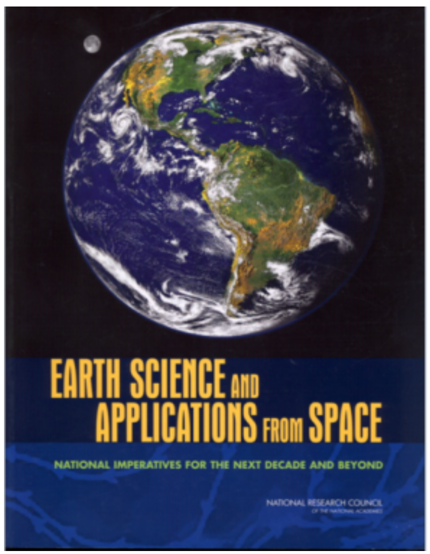








The HyspIRI VSWIR Concept Enables the Full Set of Decadal Survey Science and Science Applications and Climate Science



- Key HyspIRI climate objectives from the Decadal Survey and IPCC
  - Ecosystem Measurement for Climate Feedback
  - Black Carbon/Dust Effects on Snow and Ice
  - Carbon Release from Biomass Burning
  - Evapotranspiration and Water Use and Availability
  - Critical Volcanic Eruption Parameters

Imaging Spectrometer (VSWIR)

- Pattern and Spatial Distribution of Ecosystems and their Components
- Ecosystem Function, Physiology and Seasonal Activity
- Biogeochemical Cycles
- Changes in Disturbance Activity
- Ecosystem and Human Health
- Earth Surface and Shallow Water Substrate Composition

Combined Imaging Spectrometer and Multi-Spectral Thermal Science

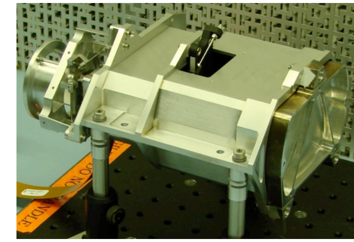
- Coastal habitats, and inland aquatic environments
- Wildfires
- Volcanoes
- Ecosystem Function and Diversity
- Land surface composition and change
- Human Health and Urbanization

Questions?

Backup

Concept Technologies are Proven
Work Continues to Lower Risk

1) Uniform Offner spectrometer (Mouroulis Design)



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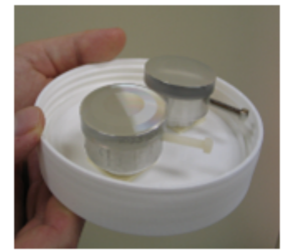

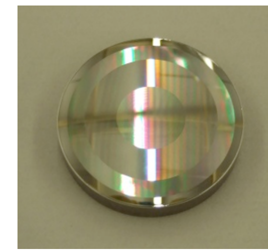

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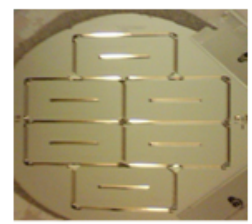

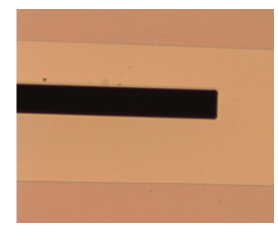

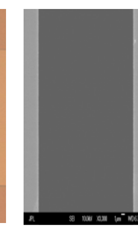

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