HysplRI

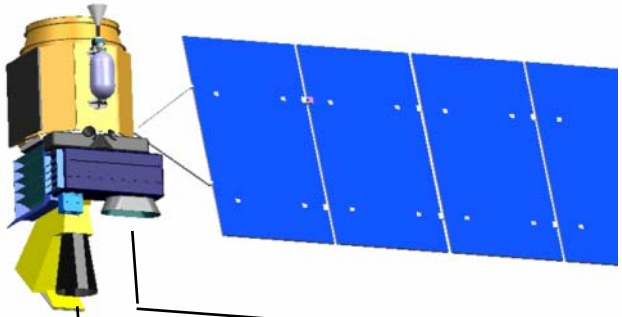
VSWIR Science Measurement Baseline

NASA Earth Science and Applications Decadal Survey

Robert O. Green and HysplRI Team

NRC Decadal Survey HyspIRI

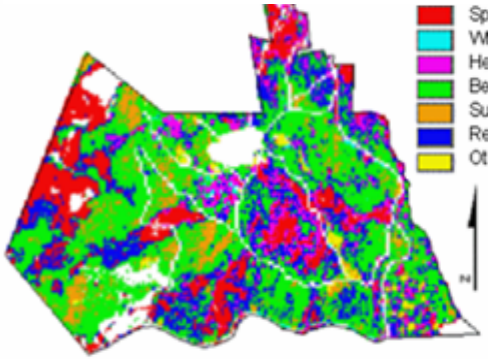
Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer
+
Multispectral Thermal InfraRed (TIR) Scanner

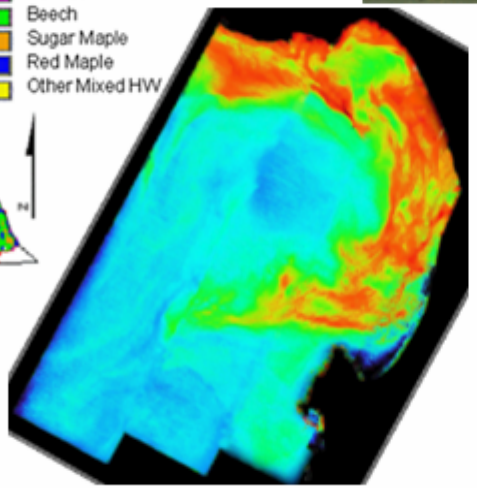


VSWIR: Plant Physiology and Function Types (PPFT)

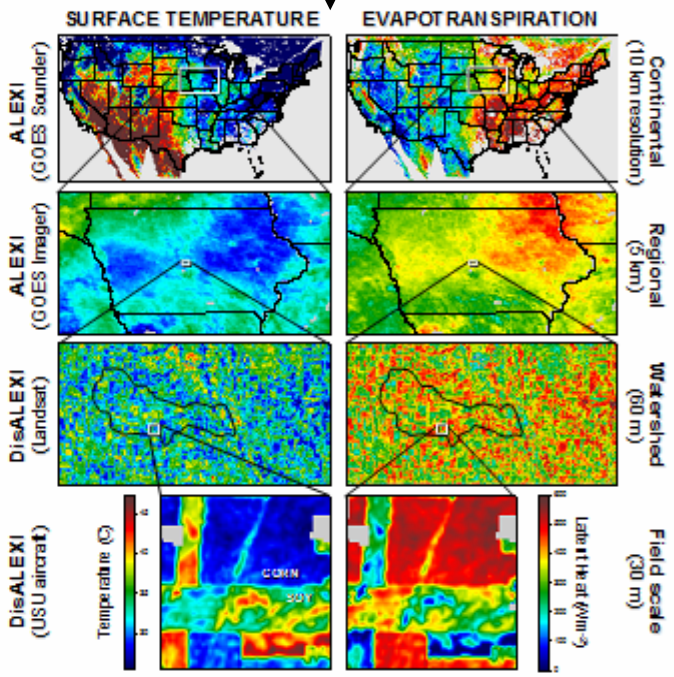
Multispectral TIR Scanner

Map of dominant tree species, Bartlett Forest, NH

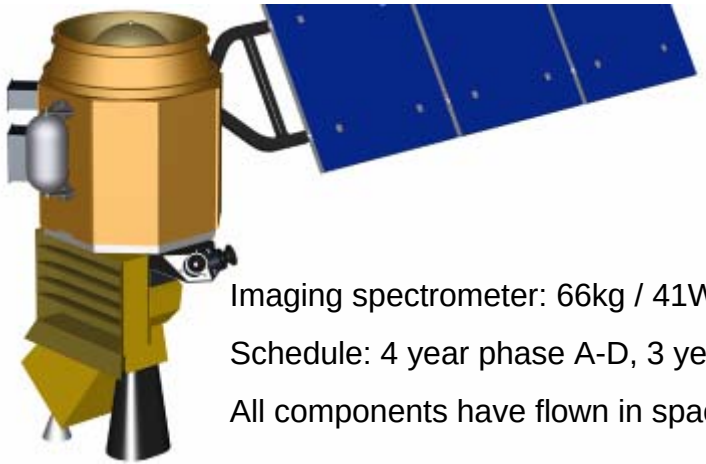


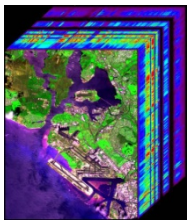


Red tide algal bloom in Monterey Bay, CA



HyspIRI Imaging Spectroscopy Science Measurements





Imaging spectrometer: 66kg / 41W

Schedule: 4 year phase A-D, 3 years operations

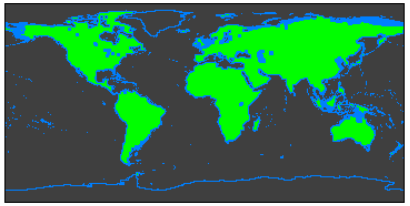
All components have flown in space

Science Questions:

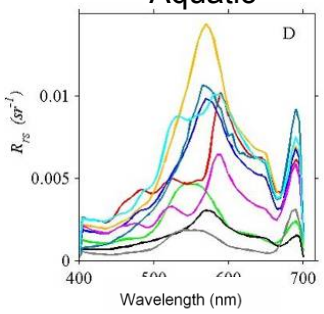
- *What is the composition, function, and health of land and water ecosystems?*
- *How are these ecosystems being altered by human activities and natural causes?*
- *How do these changes affect fundamental ecosystem processes upon which life on Earth depends?*

Measurement:

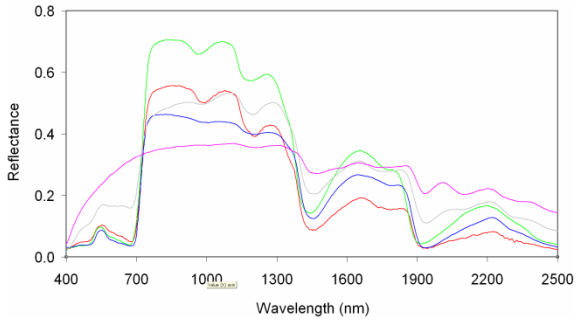
- 380 to 2500 nm in 10nm channels
- Accurate 60 m sampling
- 19 days revisit mapping mission
- Global land and shallow water



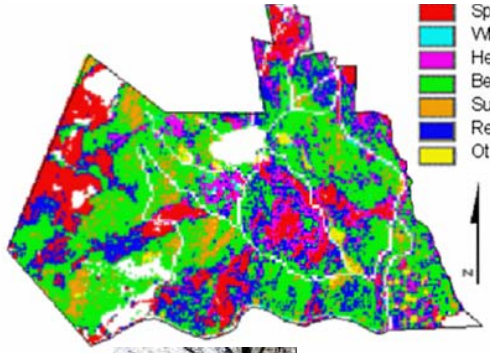
Aquatic

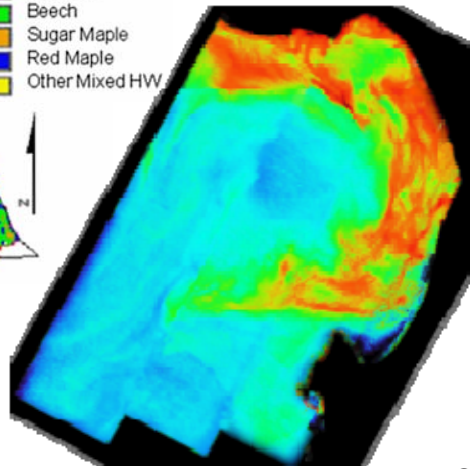


Terrestrial



Map of dominant tree species, Bartlett Forest, NH





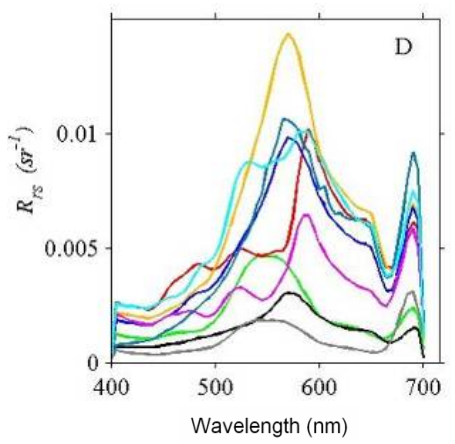
Red tide algal bloom in Monterey Bay, CA

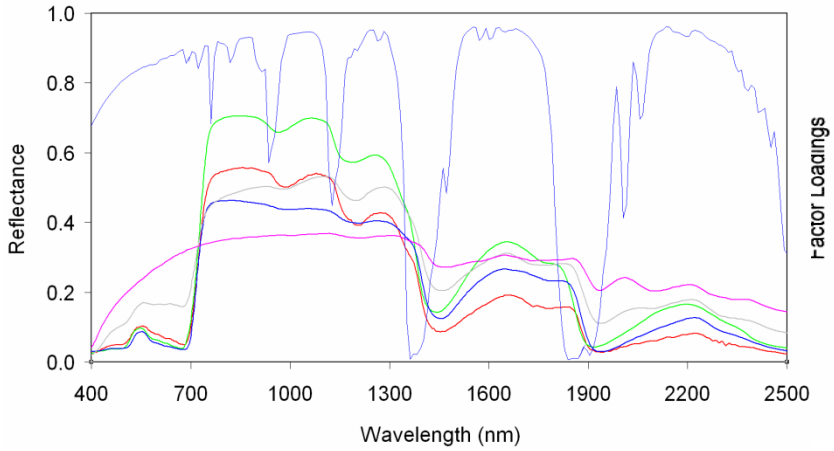
VSWIR Overarching Science Questions

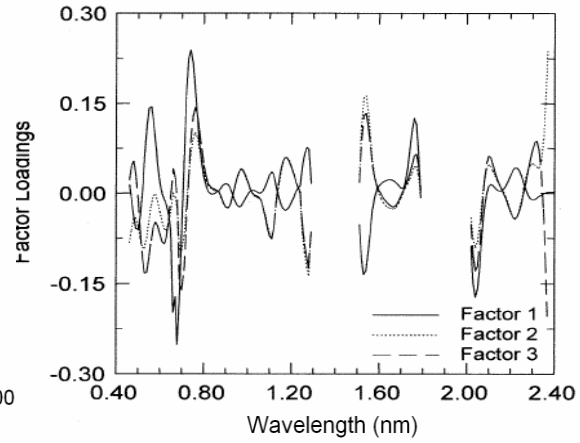
- **VQ1. Pattern and Spatial Distribution of Ecosystems and their Components, (EM,JG)**
  - What is the pattern of ecosystem distribution and how do ecosystems differ in their composition or biodiversity? [DS 195]
- **VQ2. Ecosystem Function, Physiology and Seasonal Activity, (EM,JG)**
  - What are the seasonal expressions and cycles for terrestrial and aquatic ecosystems, functional groups and diagnostic species? How are these being altered by changes in climate, land use, and disturbances? [DS 191, 195, 203]
- **VQ3. Biogeochemical Cycles (SO, SU)**
  - How are biogeochemical cycles for carbon, water and nutrients being altered by natural and human-induced environmental changes?
- **VQ4. Changes in Disturbance Activity (RK,GA)**
  - How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?
- **VQ5. Ecosystem and Human Health, (PT,GG)**
  - How do changes in ecosystem composition and function affect human health, resource use, and resource management?
- **VQ6. Land Surface and Shallow Water Substrate Composition (RG, HD)**
  - What is the land surface soil/rock and shallow water substrate composition?

Basis for Continuous Spectral Measurement

- Plant and phytoplankton functional types and species have biochemical and biophysical properties that are expressed as reflectance and absorption features spanning the spectral region from 380 to 2500 nm.
- Individual bands do not capture the diversity of biochemical and biophysical signatures of plant functional types or species.
- Changes in the chemical and physical configuration of ecosystems are often expressed as changes in the contiguous spectral signatures that relate directly to plant functional types, vegetation health, and species distribution.
- Other constituents of the Earth system (Minerals, Soils, Snow, etc) have spectral characteristics allow use of this spectroscopic measurement approach for corresponding science questions.
- Important atmospheric correction information and calibration feedback is contained within the spectral measurement.

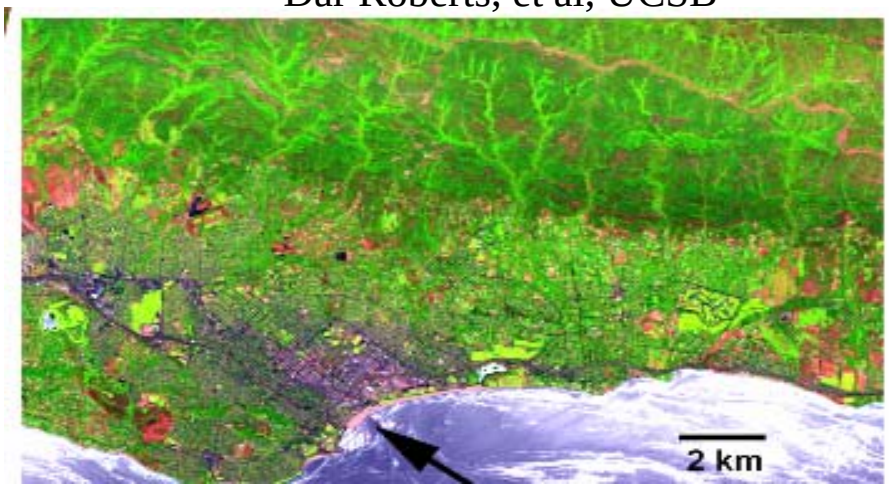


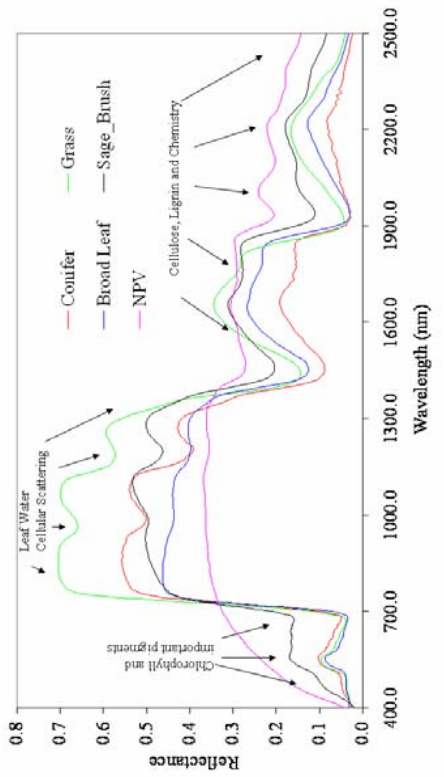


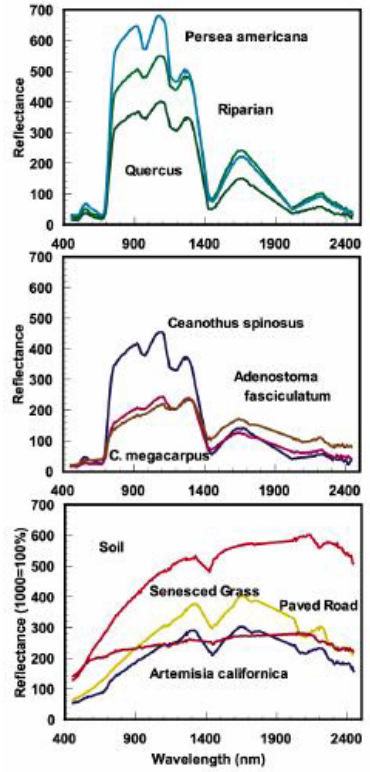


Vegetation Functional Type Analysis, Santa Barbara, CA

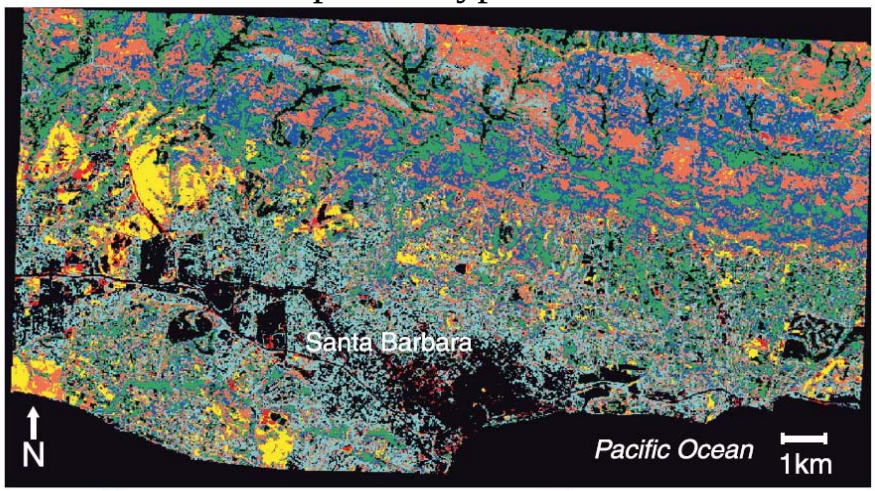
Dar Roberts, et al, UCSB





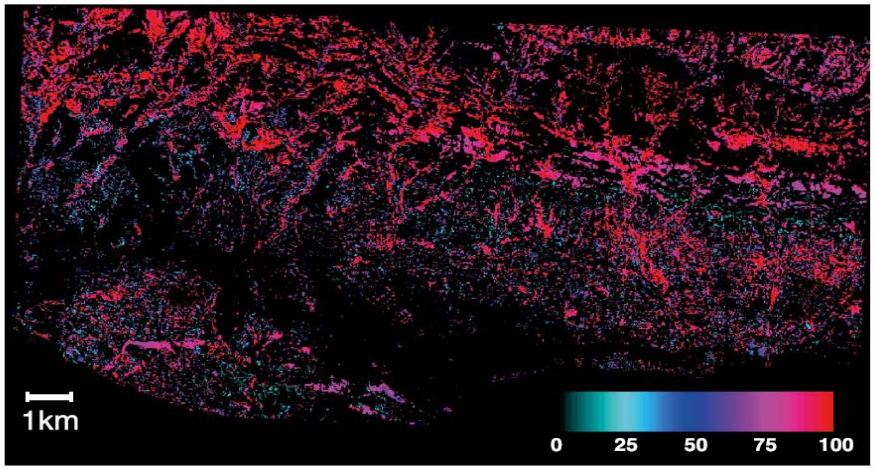


MESMA Species Type 90% accurate

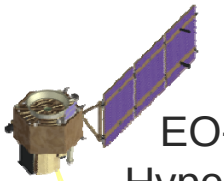


Adenostoma fasciculatum
Ceanothus megacarpus
Arctostaphylos spp.
Quercus agrifolia
Grass
Soil

Species Fractional Cover

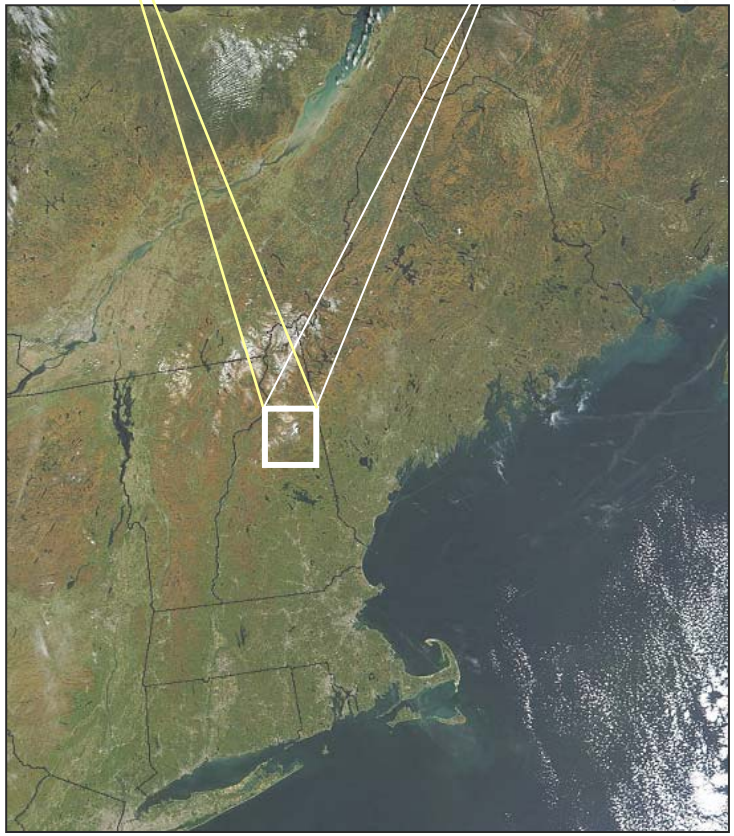


Biogeochemical Cycles

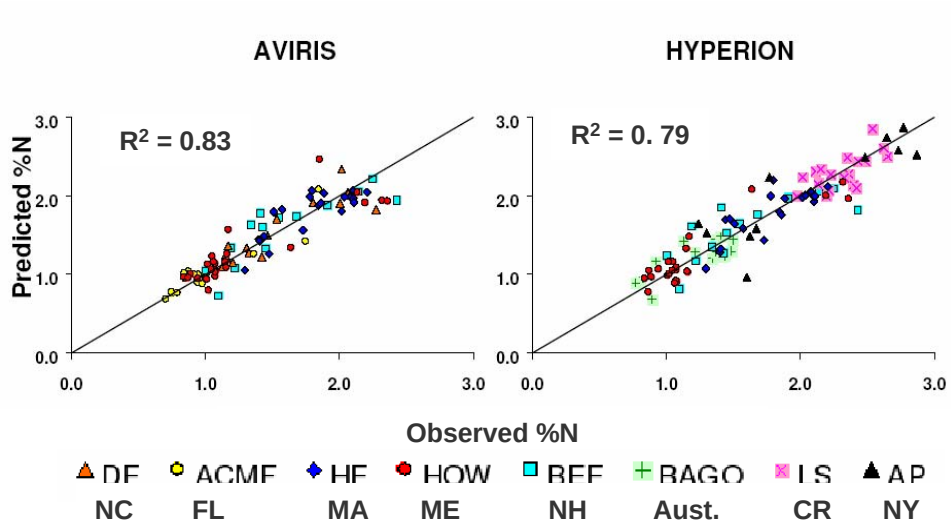


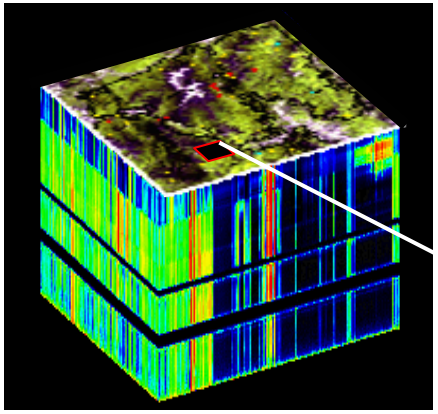
EO-1
Hyperion

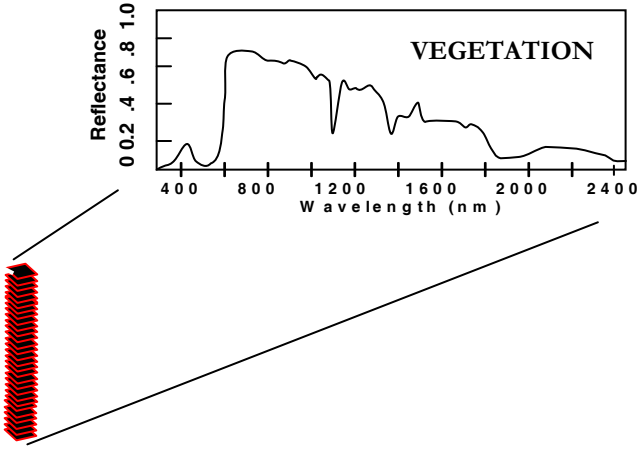
AVIRIS



Canopy Nitrogen from imaging spectroscopy.





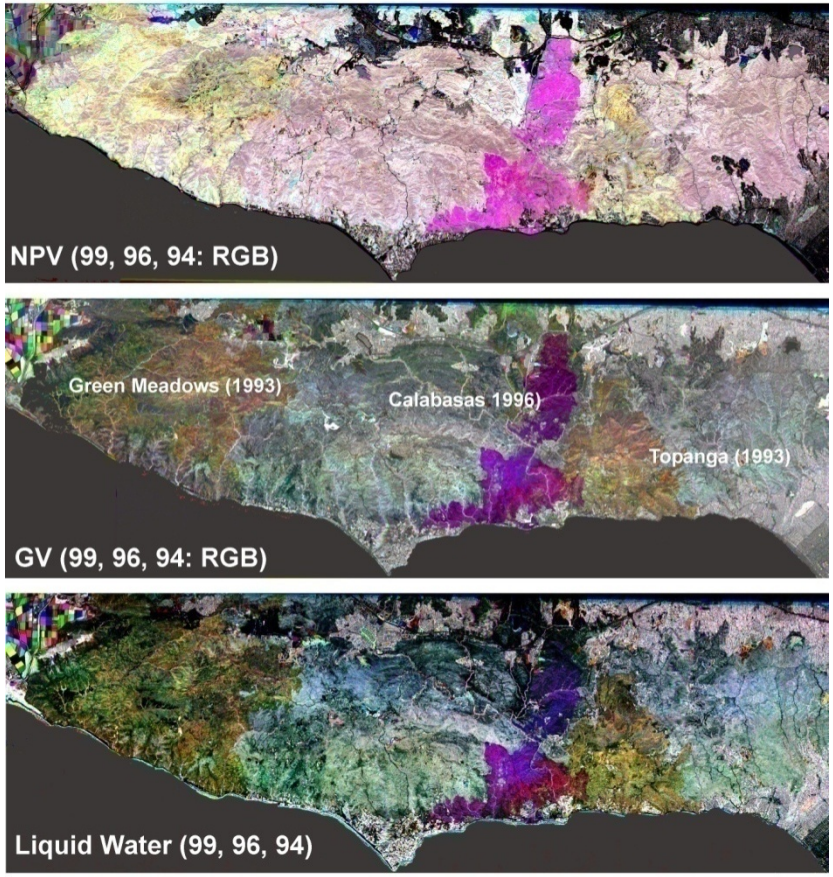


Response to Disturbance

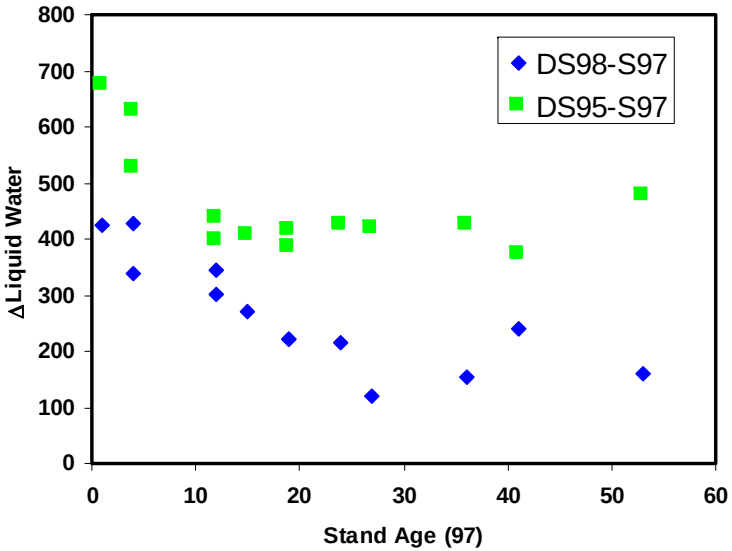
Non photosynthetic Vegetation

Green vegetation

Canopy Liquid Water



Post-fire response to three different fires, two in 1993 and one in 1996. Canopy moisture is the most sensitive measure of change, as shown by overlap between the 1996 and 1993 Calabasas and Topanga fires. High fire return intervals in Southern California are impacting ecosystems, eliminating some shrub species.

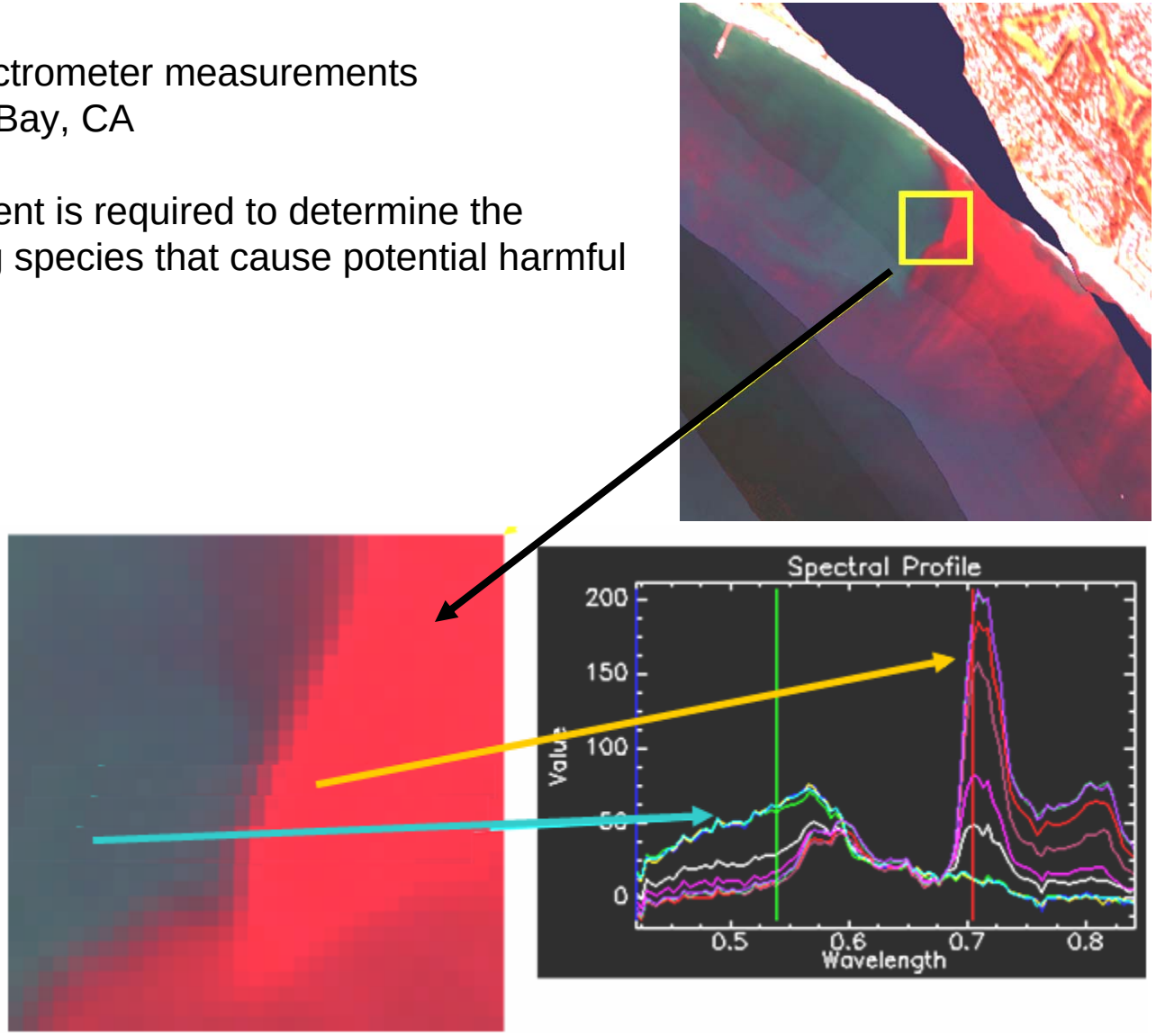


Interannual changes in canopy moisture show significant stand age differences up to 30 years (shown as the difference in canopy moisture between spring98 and spring 97 – blue, and spring97 and spring 95 - green). These results indicate that seasonal drought response is age dependent in shrublands, with older stands less impacted by drought. These results require seasonal imaging spectroscopy observations.

Ecosystems and Human Well-Being

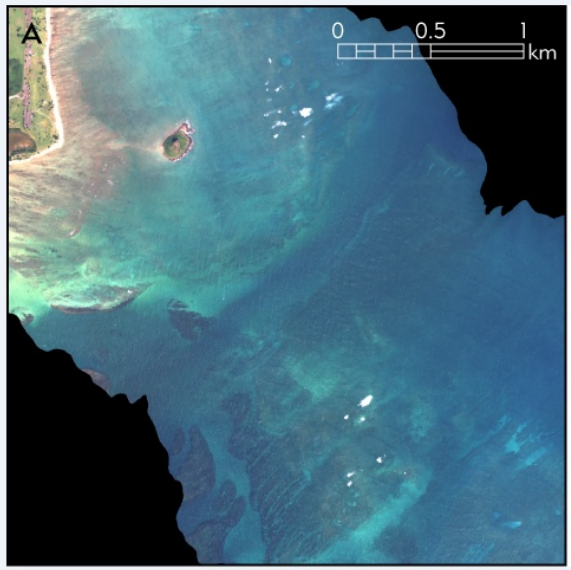
Airborne imaging spectrometer measurements
Red tide in Monterey Bay, CA

A spectral measurement is required to determine the species type including species that cause potential harmful algal blooms.

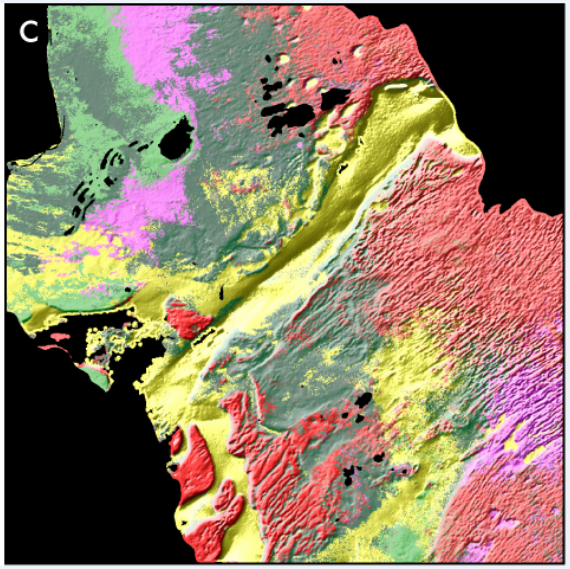


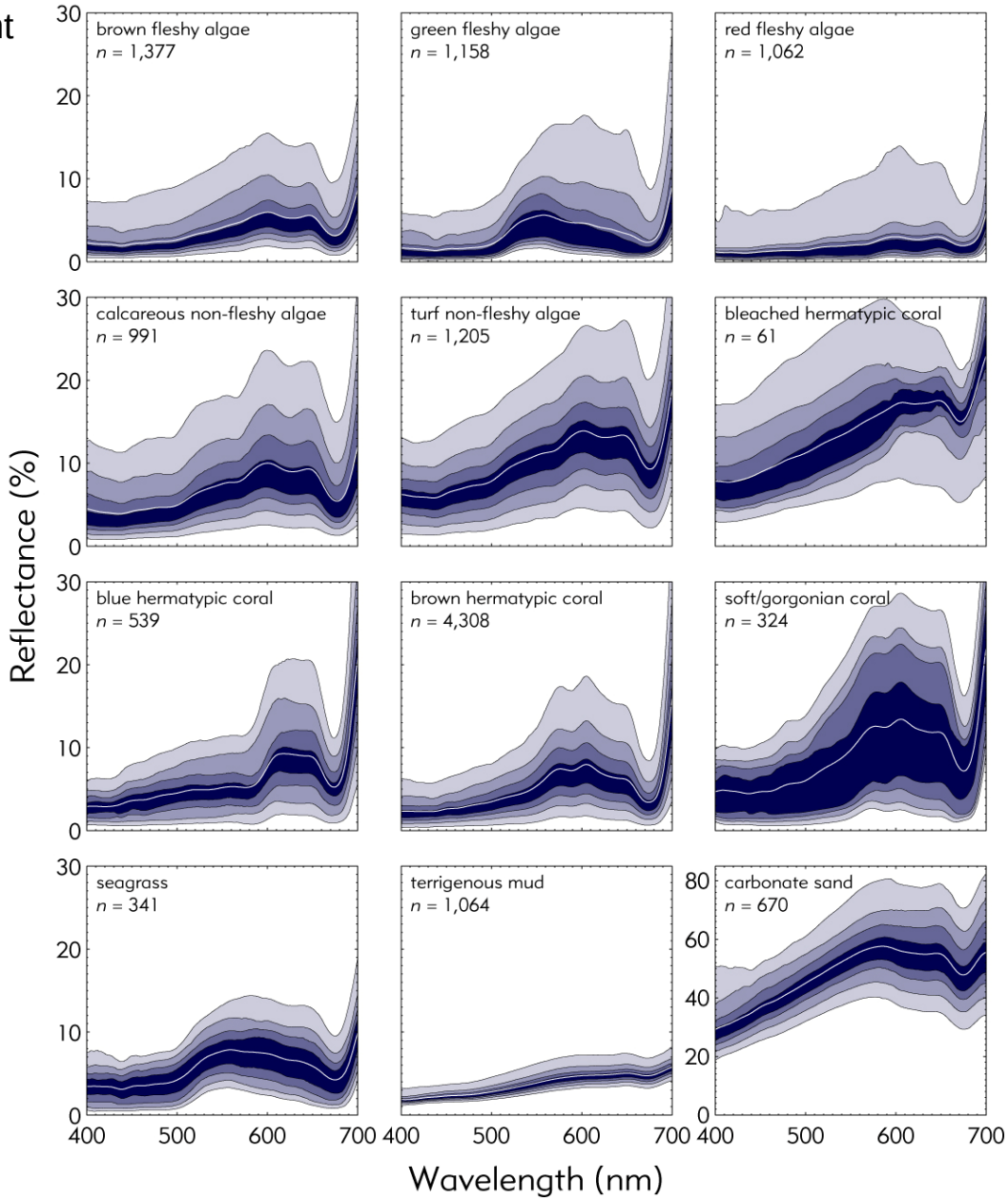
Paul Bissett, Florida Environmental Research Institute.

Imaging Spectrometer Measurement



Benthic Compositional Mapping

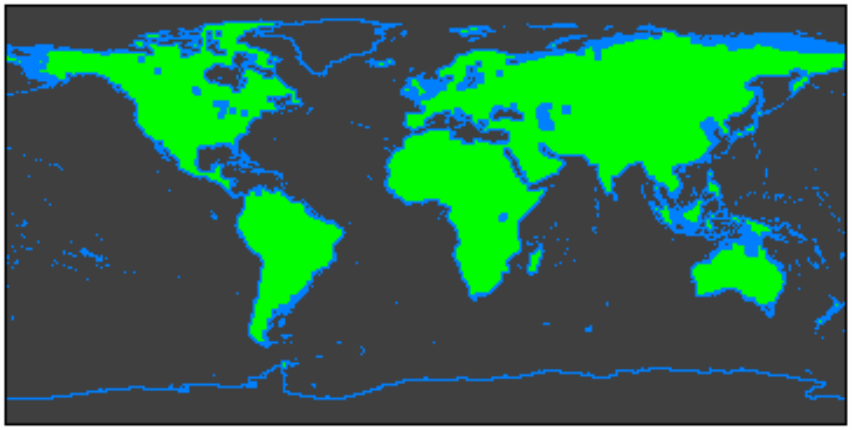




Spectral Measurements of Shallow Water Benthic Composition (E. Hochberg, Nova Southeastern University, FL)

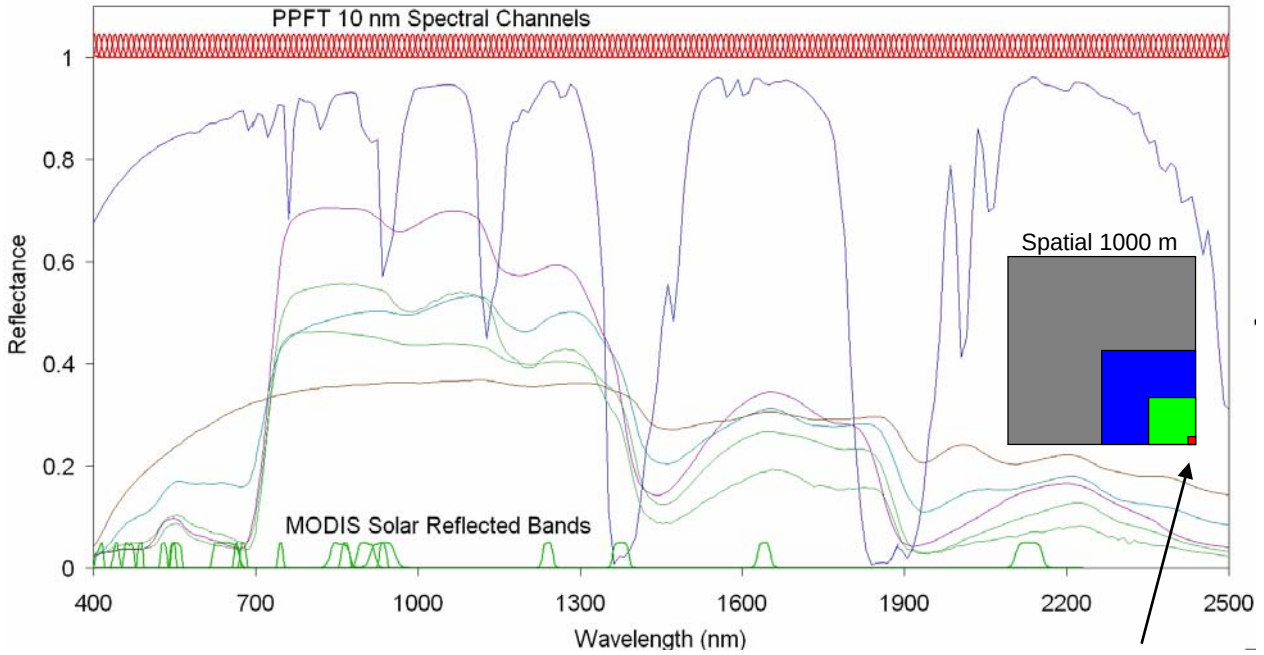
HyspIRI VSWIR – PPFT
Imaging Spectrometer
Measurement Characteristics

HyspIRI VSWIR Science Measurements



- Measure the **global** land and coastal/shallow water (> -50m).
- 19 day equatorial revisit to generate seasonal and annual products.

- Measure the molecular absorption and constituent scattering signatures in the spectral range from 380 to 2500 nm at 10 nm, and at 60 m spatial sampling.



PPFT at 60 m

HysplRI VSWIR
Science Measurement Characteristics

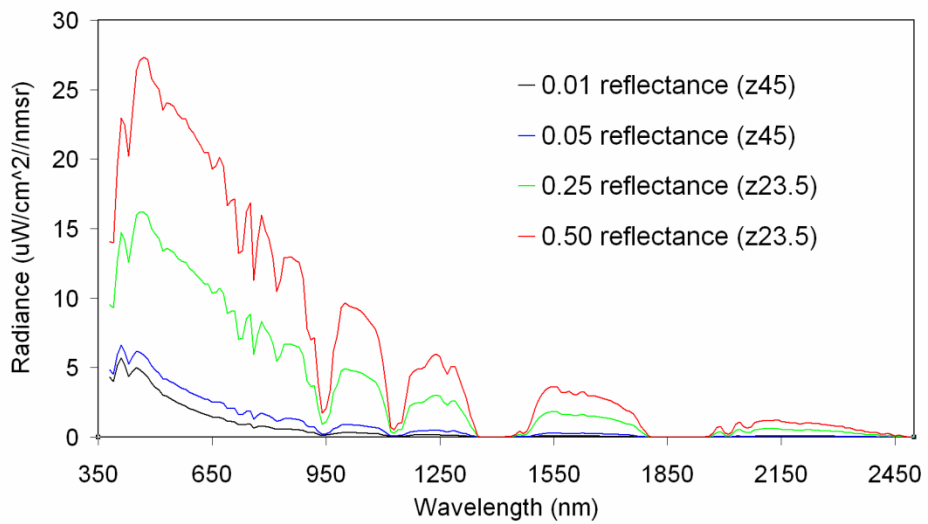
Spectral	
Range	380 to 2500 nm in the solar reflected spectrum
Sampling	<= 10 nm {uniform over range}
Response	<= 1.2 X sampling (FWHM) {uniform over range}
Accuracy	<0.5 nm
Radiometric	
Range & Sampling	0 to 1.5 X max benchmark radiance, 14 bits measured
Accuracy	>95% absolute radiometric, 98% on-orbit reflectance, 99.5% stability
Precision (SNR)	See spectral plots at benchmark radiances
Linearity	>99% characterized to 0.1 %
Polarization	<2% sensitivity, characterized to 0.5 %
Scattered Light	<1:200 characterized to 0.1%
Spatial	
Range	>150 km (12 degrees at 700 km altitude)
Cross-Track Samples	>2500
Sampling	<=60 m
Response	<=1.2 X sampling (FWHM)
Uniformity	
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}

HyspIRI VSWIR Science Measurements Characteristics

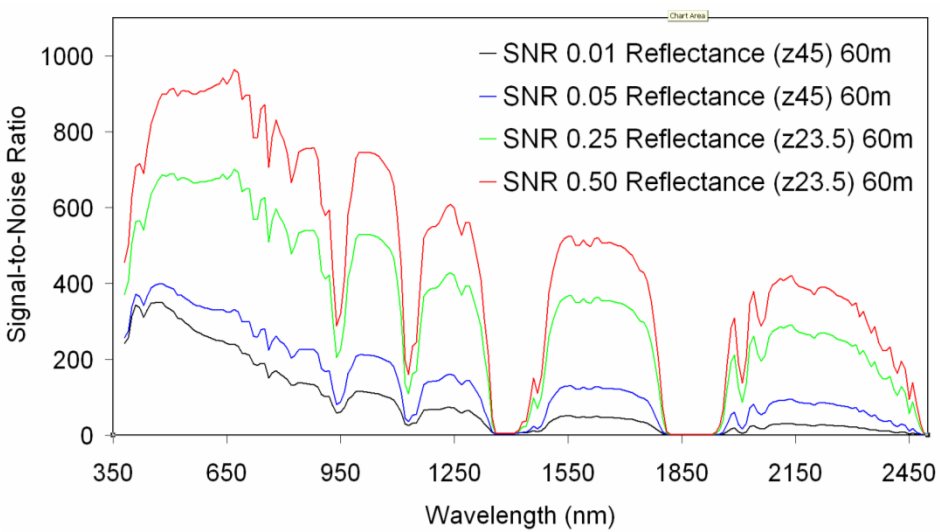
Temporal	
Orbit Crossing	11 am sun synchronous descending
Global Land Coast Repeat	19 days at equator
Rapid Response Revisit	3 days (cross-track pointing)
Sunglint Reduction	
Cross Track Pointing	4 degrees in backscatter direction
OnOrbit Calibration	
Lunar View	1 per month {radiometric}
Solar Cover Views	1 per day {radiometric}
Dark signal measurements	1 per orbit and edge detector tracking
Surface Cal Experiments	3 per year {spectral & radiometric}
Data Collection	
Land Coverage	Land surface above sea level excluding ice sheets
Water Coverage	Coastal zone -50 m and shallower
Solar Elevation	20 degrees or greater
Open Ocean/Ice Sheets	Averaged to 1km spatial sampling
Compression	>=3.0 lossless

HysplRI VSWIR Science Measurements
Key SNR and Uniformity Requirements

Benchmark Radiances

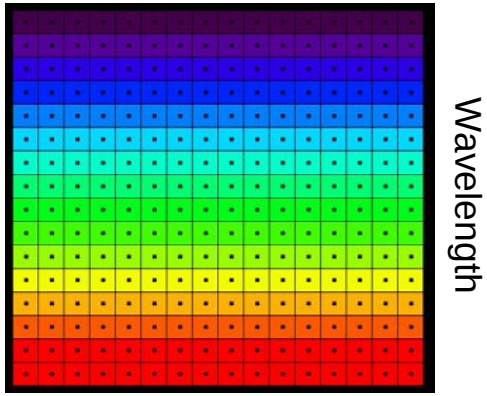


Required SNR



Uniformity Requirement

Cross Track Sample



Depiction

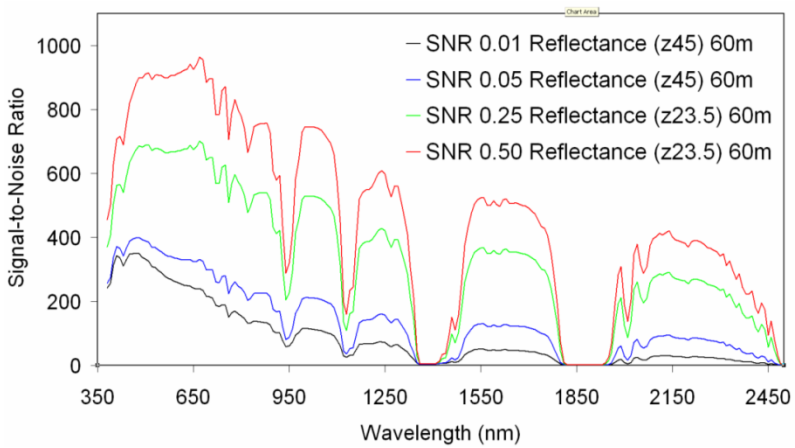
-Grids are the detectors
-dots are the IFOV centers
-Colors are the wavelengths

Requirement

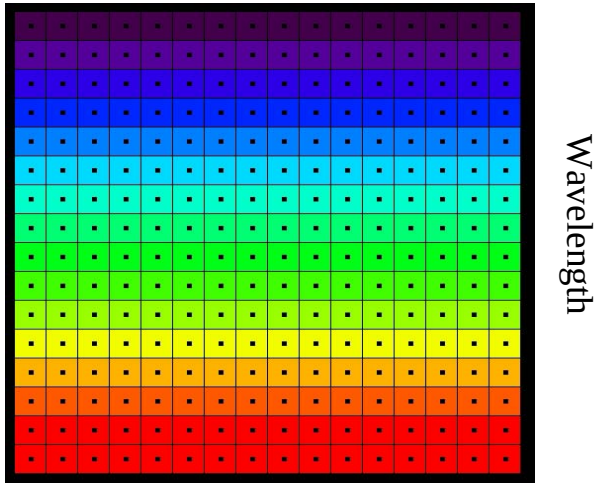
Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}

HysplRI: Building on NASA Hyperion Technology Demonstration

SNR > 10X



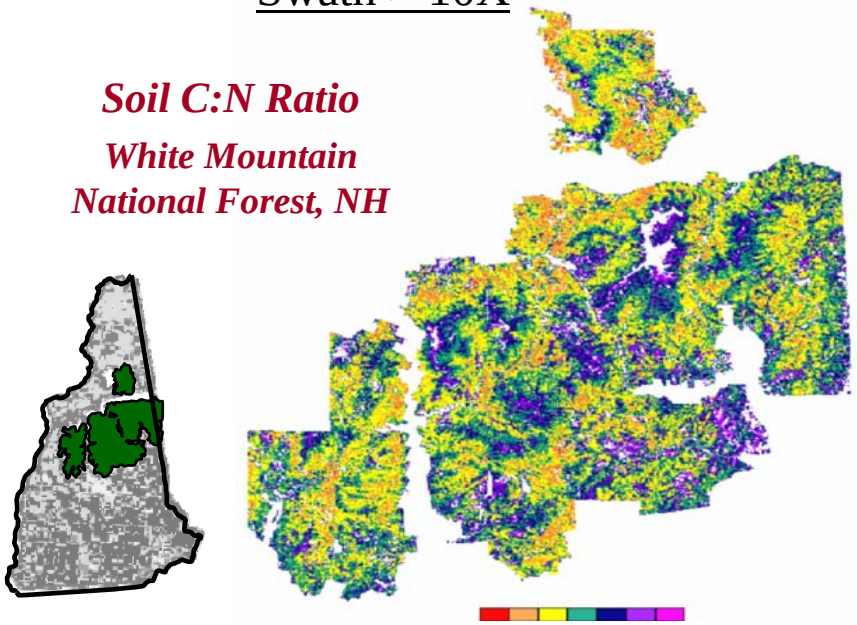
Uniformity > 10X



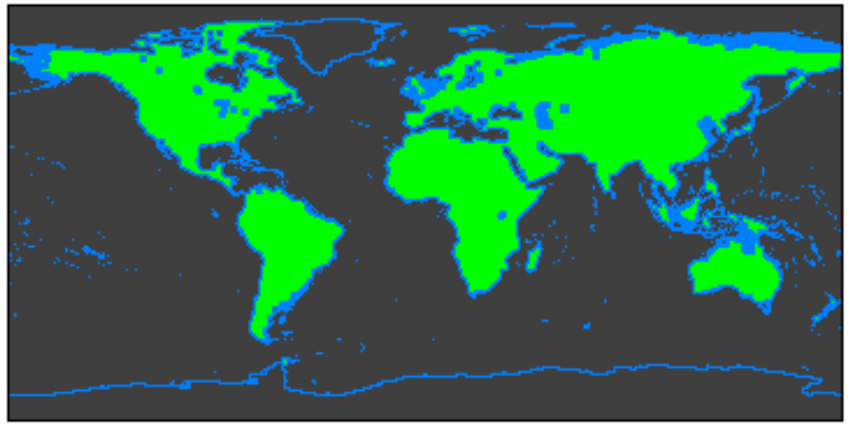
Swath > 10X

Soil C:N Ratio

White Mountain National Forest, NH

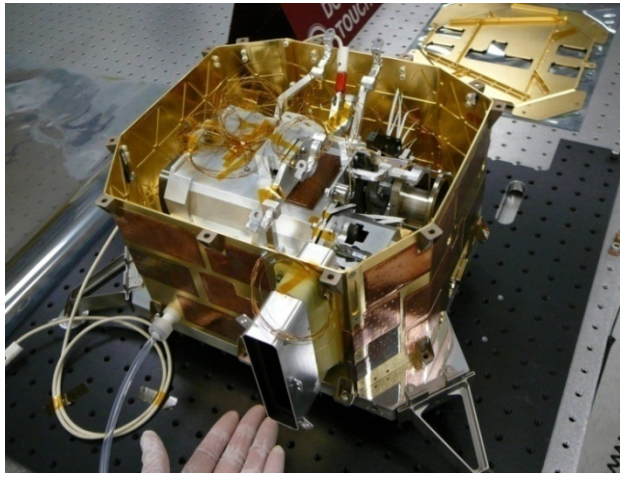


Global Coverage >> 10X

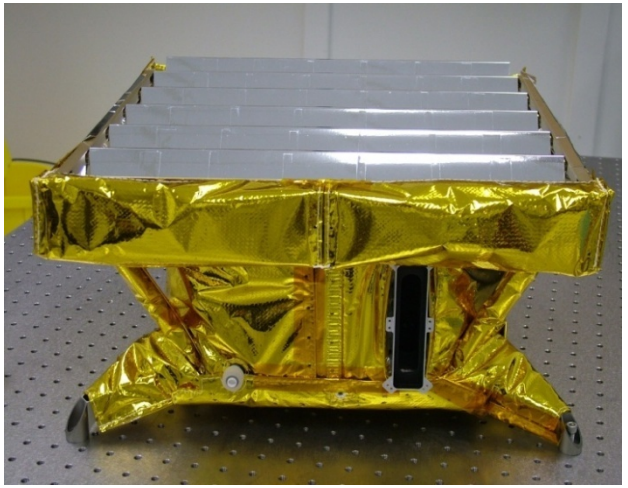


Heritage: NASA Moon Mineralogy Mapper

M3 Spectrometer

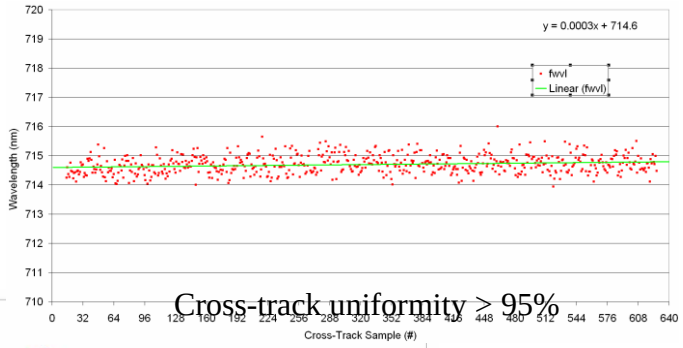


Mass 8 kg, Power 15 Watts

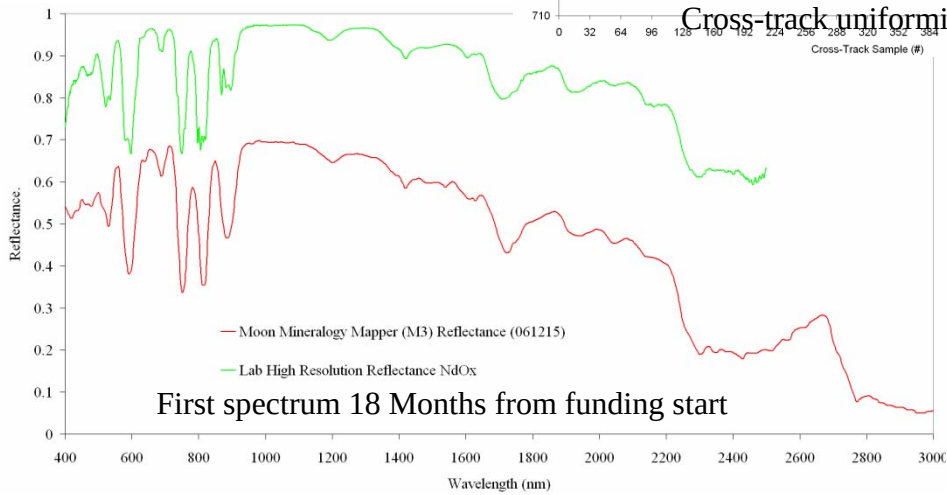


Passed Preship review 3 May 2007

- Mouroulis Offner Design (HyspIRI)
- Convex e-beam grating (HyspIRI)
- 6604a MCT full range detector array, multiplexor & signal chain (HyspIRI)
- Uniform slit (HyspIRI)
- 0.5 micron adjustment mounts lockable for flight
- Aligned to 95% cross-track uniformity (HyspIRI)
- Aligned to 95% spectral IFOV uniformity (HyspIRI)
- Meets high SNR requirements (HyspIRI)
- Passive radiator (HyspIRI)



Cross-track uniformity ≥ 95%

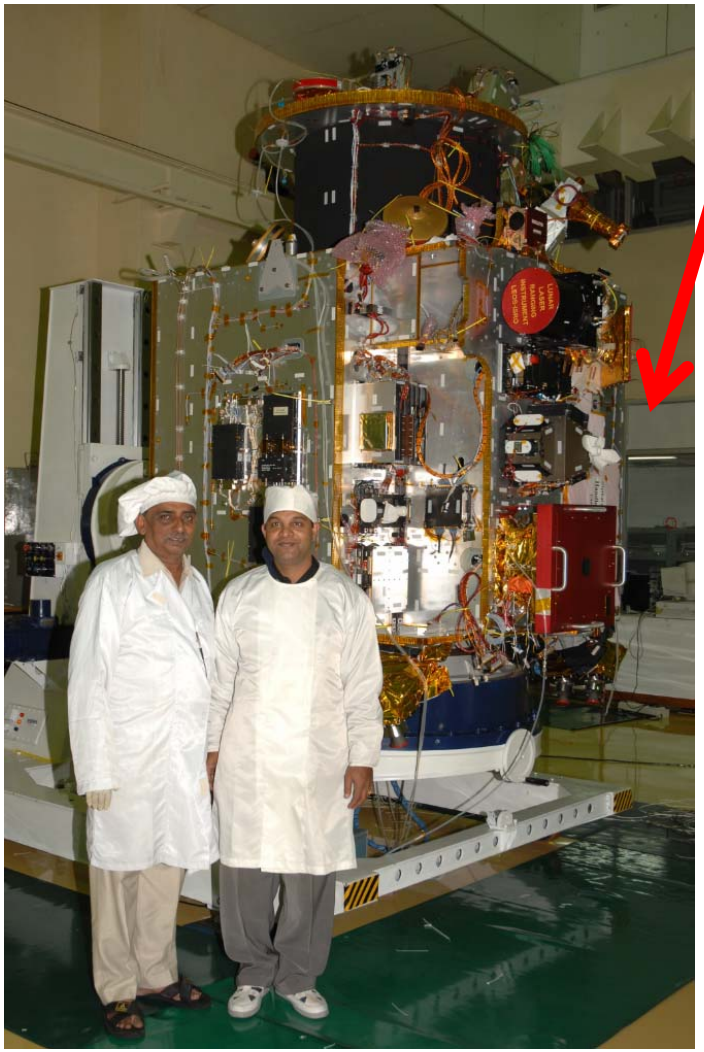


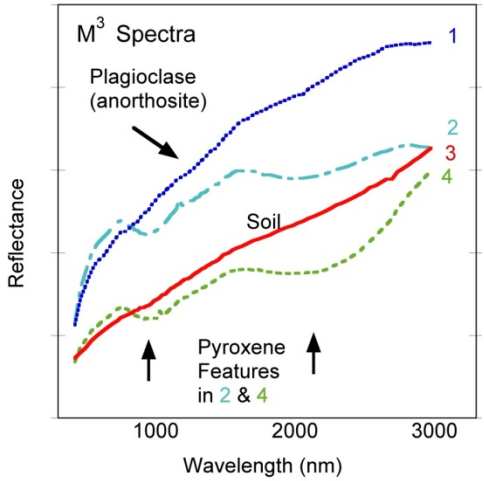
First spectrum 18 Months from funding start

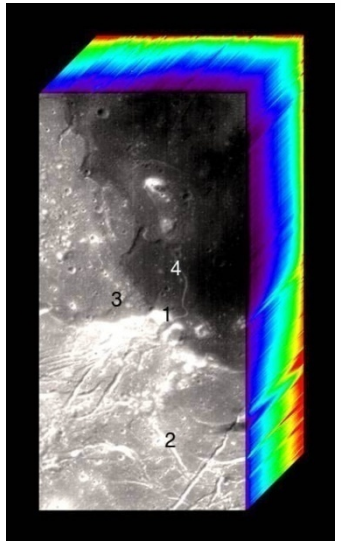
Heritage: M3 NASA Imaging Spectrometer

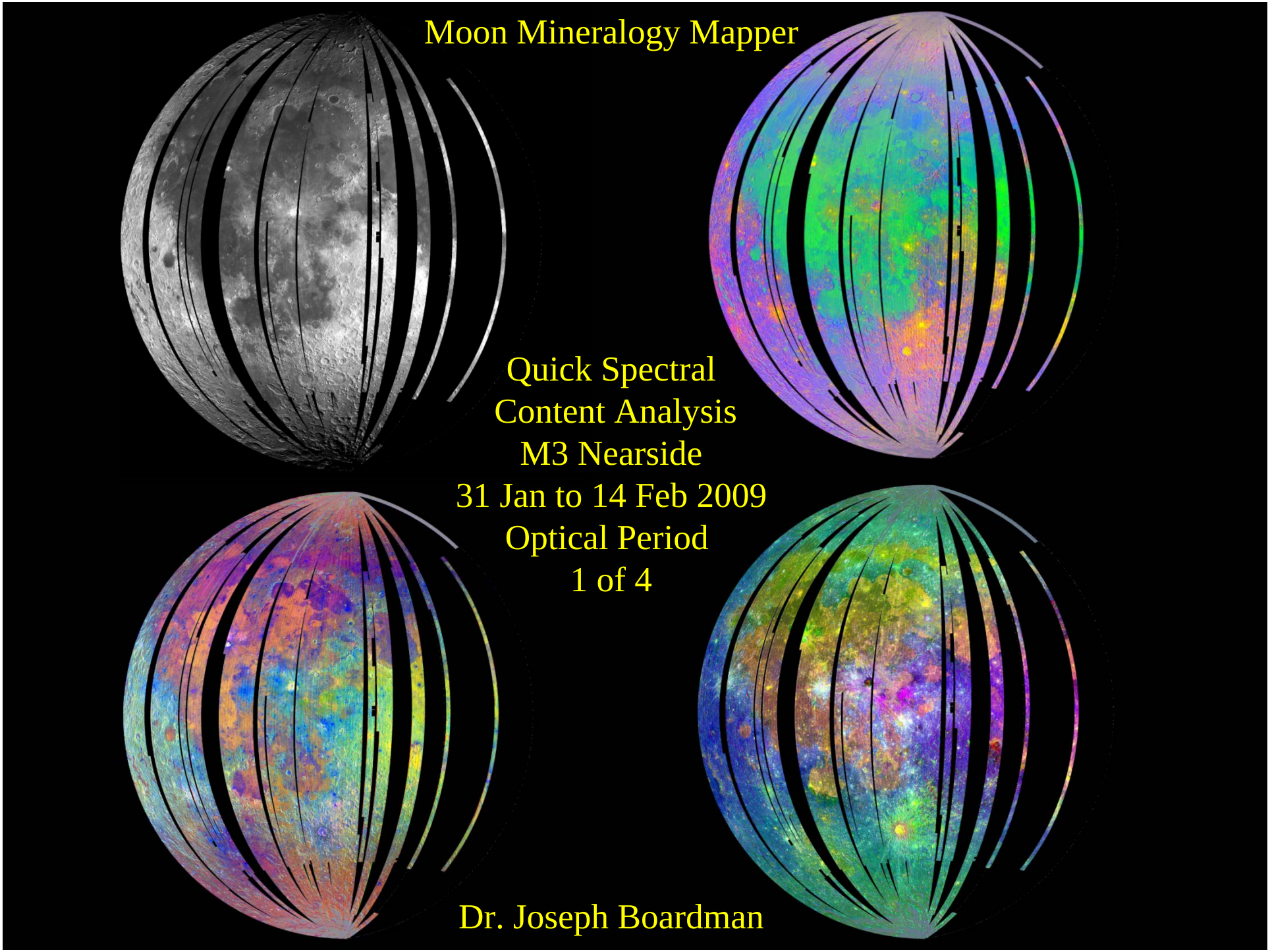
M3 Installed on ISRO Chandraayan-1 spacecraft, Launched 22 Oct 2008

- First light in lunar orbit 19 Nov 2008








Moon Mineralogy Mapper
Quick Spectral
Content Analysis
M3 Nearside
31 Jan to 14 Feb 2009
Optical Period
1 of 4
Dr. Joseph Boardman

NASA M3 Image of Earth from the Moon

Image of Earth from the Moon acquired by the NASA Discovery Moon Mineralogy Mapper (M3) that is a guest instrument onboard the ISRO Chandrayaan-1 Mission to the Moon. Australia is visible in the lower center of the image. The image is presented as a false color composite with oceans dark blue, clouds white, and vegetation enhanced green. The data were acquired on the 22nd of July 2009.

Summary

We have developed a set of VSWIR science questions that are well aligned with the HyspIRI Mission called for in the NASA Earth Science and Applications Decadal Survey.

We have reviewed and refined these questions that relate to both science and applications objectives and developed traceability to a set of science measurements.

In preparation for a NASA Mission Concept Review (MCR) we have established a high heritage and low risk approach for acquiring the HyspIRI VSWIR science measurements