HysplRI

VSWIR Science Measurement Baseline

NASA Earth Science and Applications Decadal Survey

Robert O. Green and HysplRI Team

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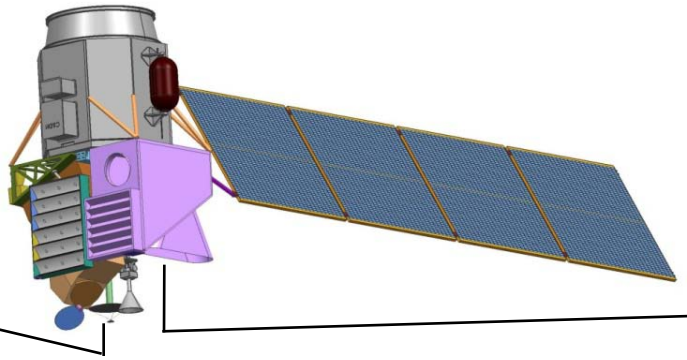
NRC Decadal Survey - HyspIRI

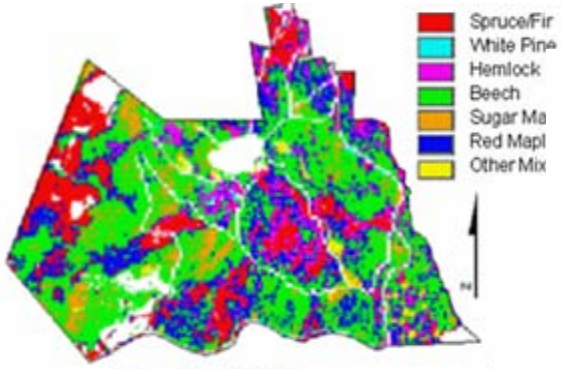
Global vegetation species-type and physiological condition, including agricultural lands, for biosphere feedback and land-atmosphere interactions; Spectroscopically derived terrestrial land cover composition/albedo including snow, ice, dust climate interaction; Fire: fuel, occurrence, intensity and recovery globally, as well as volcano emissions; Fine spatial & temporal scale measures of surface temperature and energy balance, including urban heat Islands.

Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer



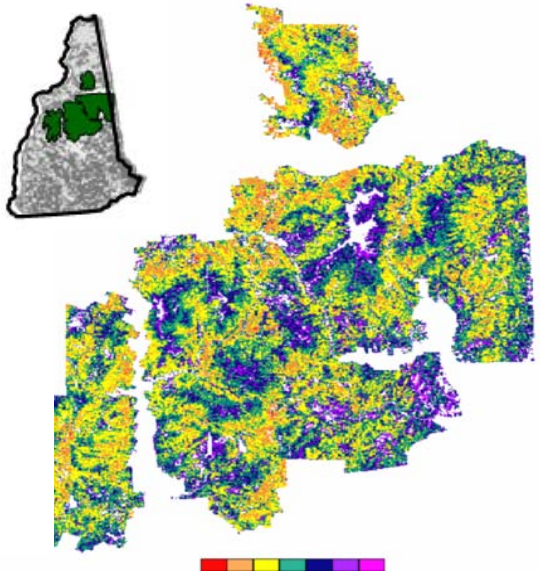
Multispectral Thermal InfraRed (TIR) Scanner

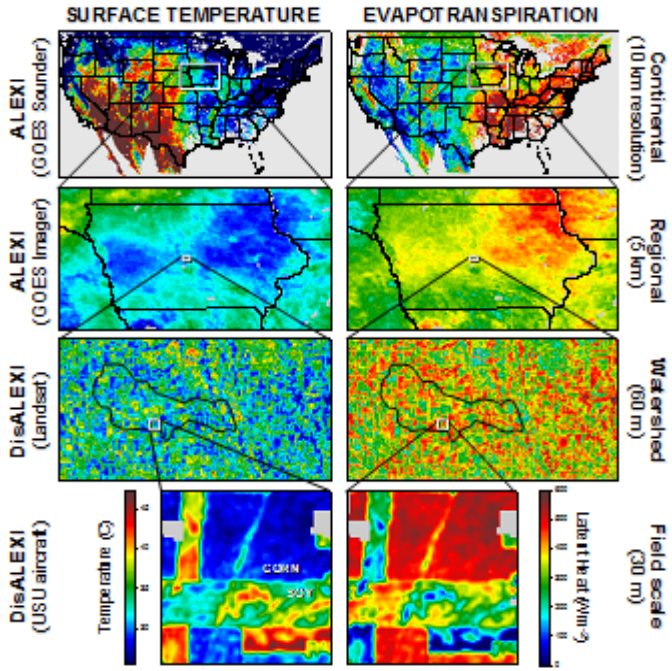
Map of dominant tree species, Bartlett Forest, NH



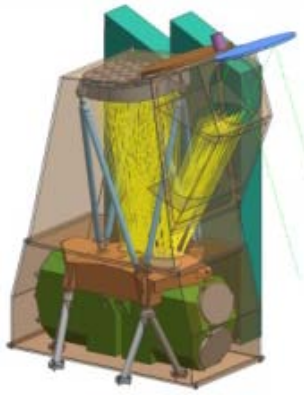
Soil C:N Ratio

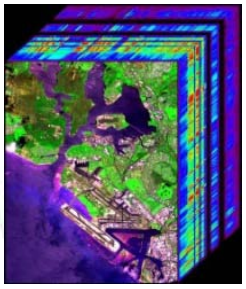
White Mountain National Forest, NH





HyspIRI - Imaging Spectroscopy (VSWIR) Science Measurements





Mature Instrument concept: All components have flown in space.

Imaging spectrometer: 55kg / 41W

Schedule: 4 year phase A-D, 3 years operations (5 years consumables)

Full terrestrial coverage downlinked every 19 days

VQ1. Pattern and Spatial Distribution of Ecosystems and their Components

– What is the pattern of ecosystem distribution and how do ecosystems differ in their composition or biodiversity?

VQ2. Ecosystem Function, Physiology and Seasonal Activity

– 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?

VQ3. Biogeochemical Cycles

– How are biogeochemical cycles for carbon, water and nutrients being altered by natural and human-induced environmental changes?

VQ4. Changes in Disturbance Activity

– How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?

VQ5. Ecosystem and Human Health

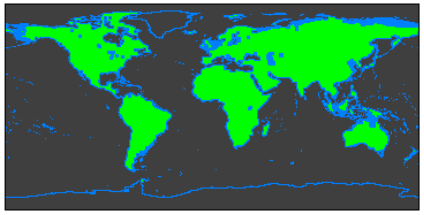
– How do changes in ecosystem composition and function affect human health, resource use, and resource management?

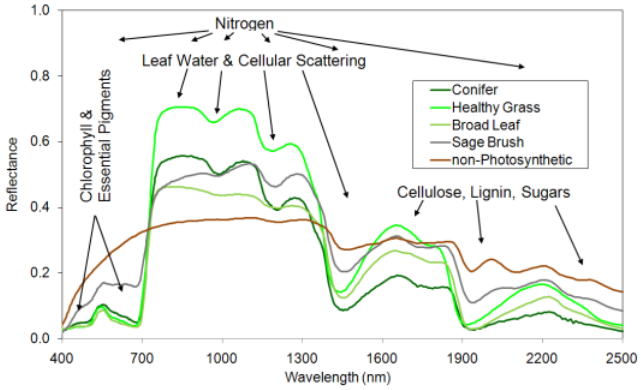
VQ6. Land Surface and Shallow Water Substrate Composition

– What is the land surface soil/rock and shallow water substrate composition?

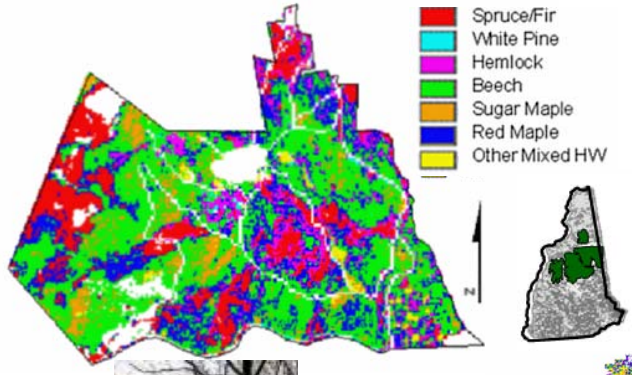
Measurement:

- 380 to 2500 nm at 10 nm
- Accurate 60 m resolution
- 19 days equatorial revisit
- Global land and shallow water





Map of dominant tree species, Bartlett Forest, NH



Soil C:N Ratio

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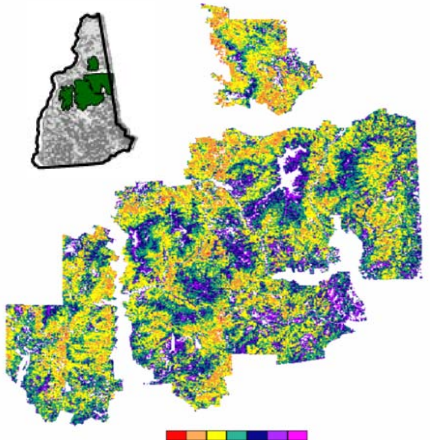
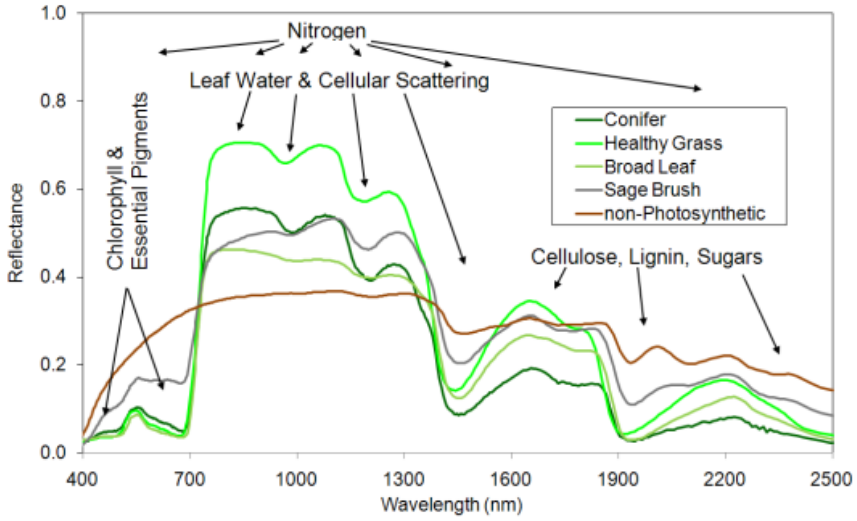
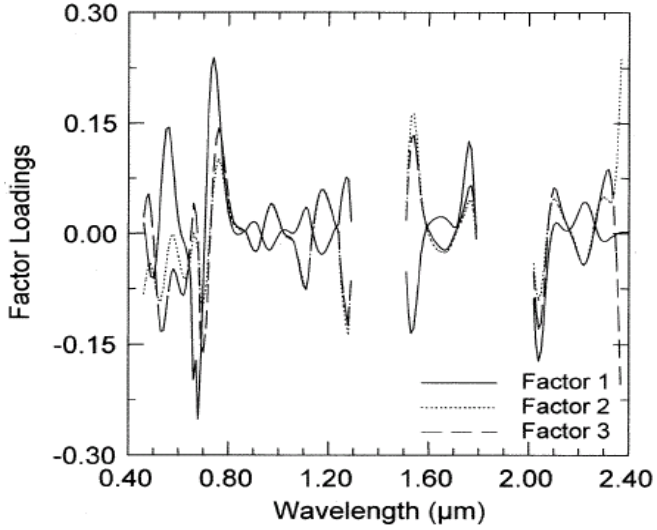


The Need for Continuous Spectral Measurements

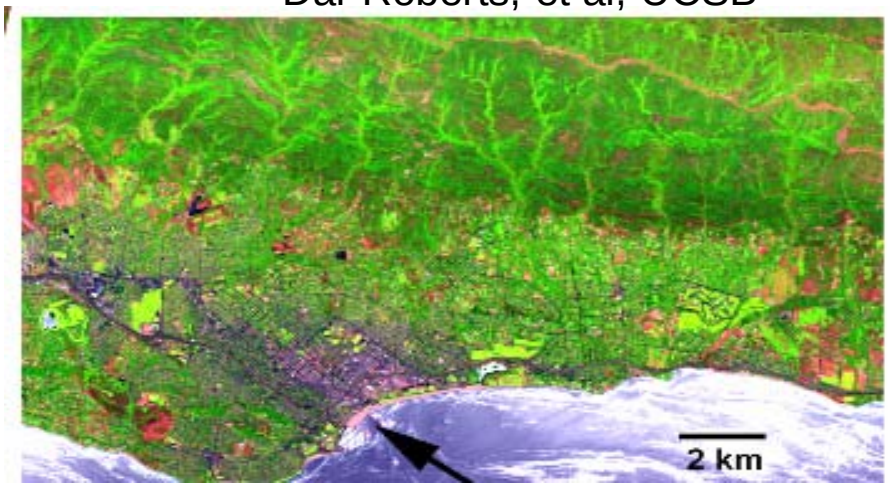
- Plant functional types and species have biochemical and biophysical properties that are expressed as reflectance absorption and scattering features spanning the spectral region from 380 to 2500 nm.
- Individual bands do not capture the diversity of biochemical and biophysical signatures of plant functional types, species or physiological condition.
- Changes in the chemical and physical configuration of ecosystems are expressed as changes in the contiguous spectral signatures related to plant functional types, physiological condition, vegetation health, and species distribution.
- Important atmospheric correction information as well as calibration feedback is contained within the spectral measurement.



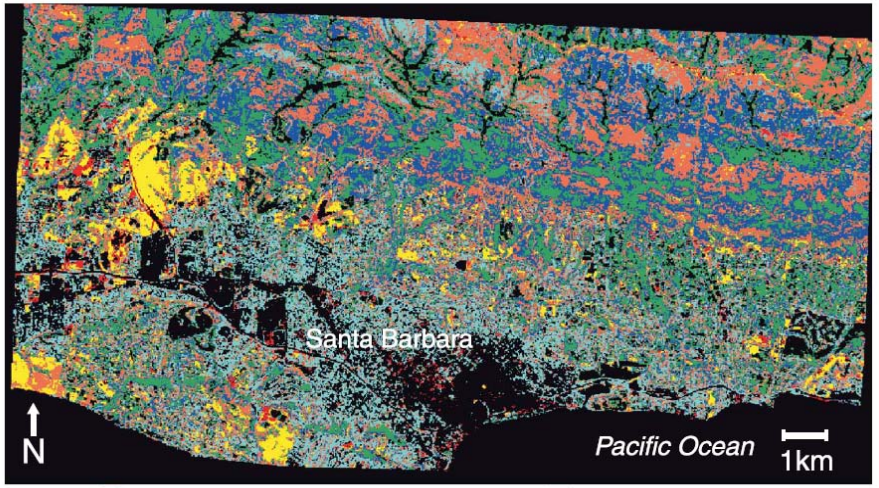


Vegetation Functional Type Analysis, Santa Barbara, CA

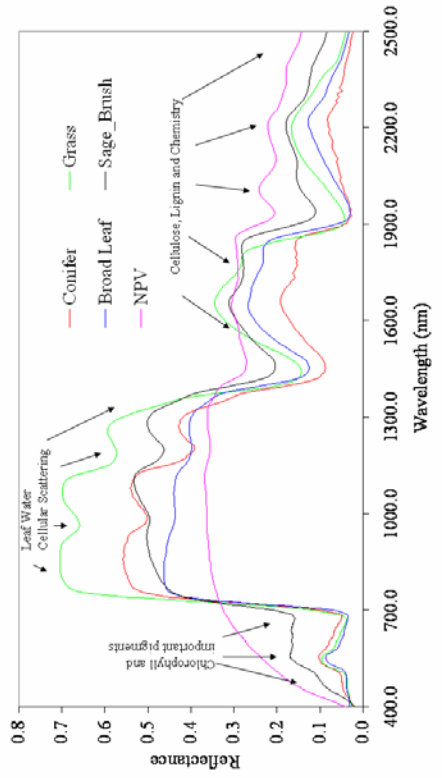
Dar Roberts, et al, UCSB

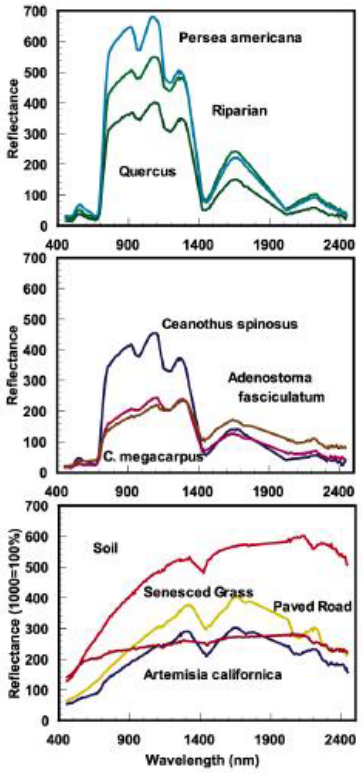


MESMA Species Type 90% accurate

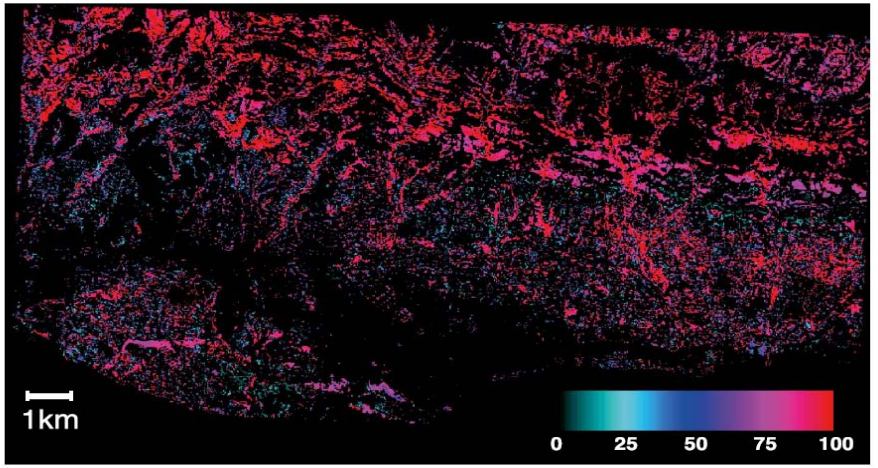


Adenostoma fasciculatum
Ceanothus megacarpus
Arctostaphylos spp.
Quercus agrifolia
Grass
Soil



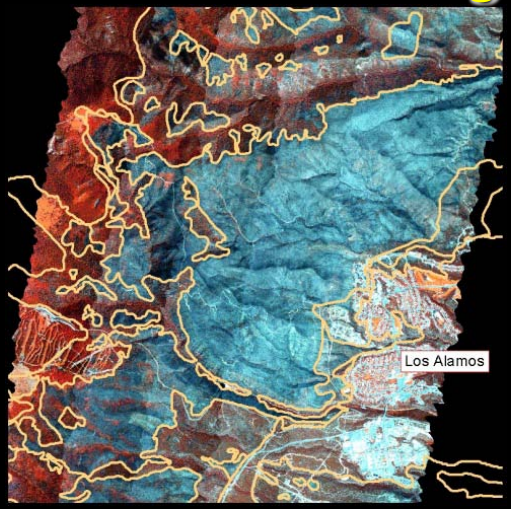


Species Fractional Cover

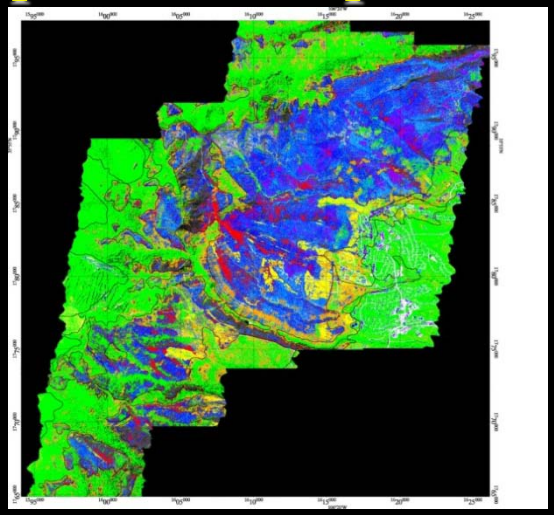


Example Measurement of Plant Biochemistry with Imaging Spectroscopy (Ray Kokaly, USGS)

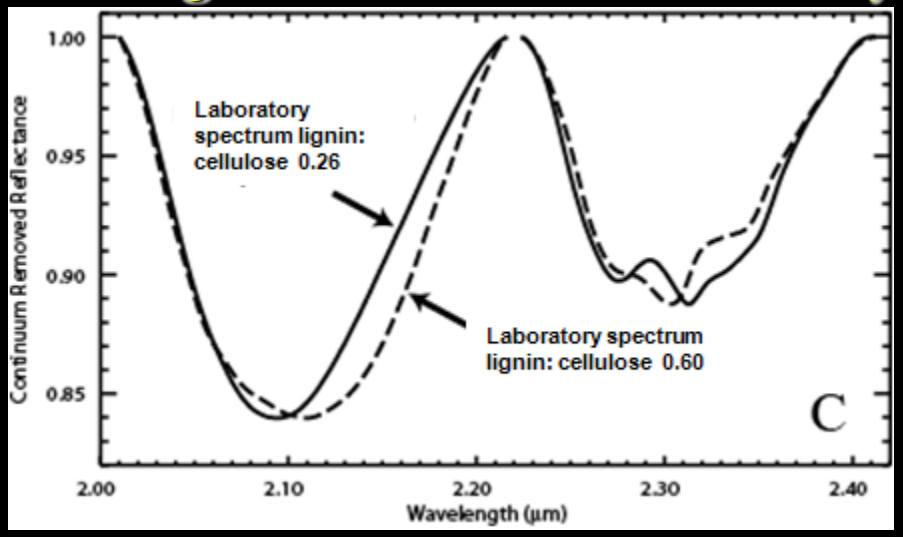
AVIRIS Coverage



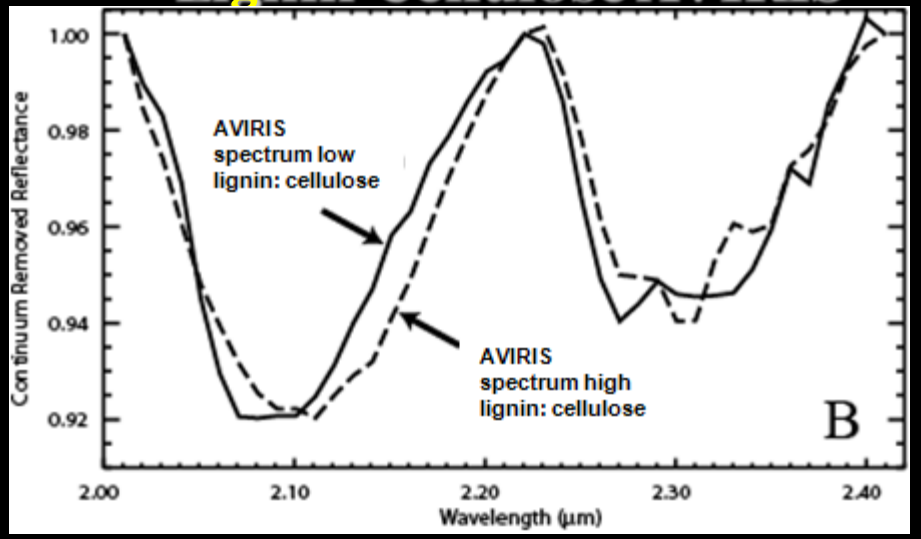
Spectral Composition Map



Lignin-Cellulose Laboratory



Lignin-Cellulose AVIRIS

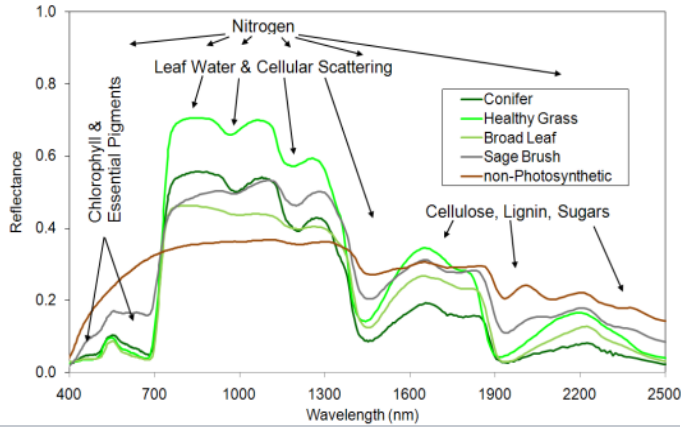


Ecosystem physiological conditions

Imaging spectroscopy measurements are required to measure the physiological condition (PC) of ecosystems for the global terrestrial biosphere to provide understanding and constraint of uncertainties in the climate change.

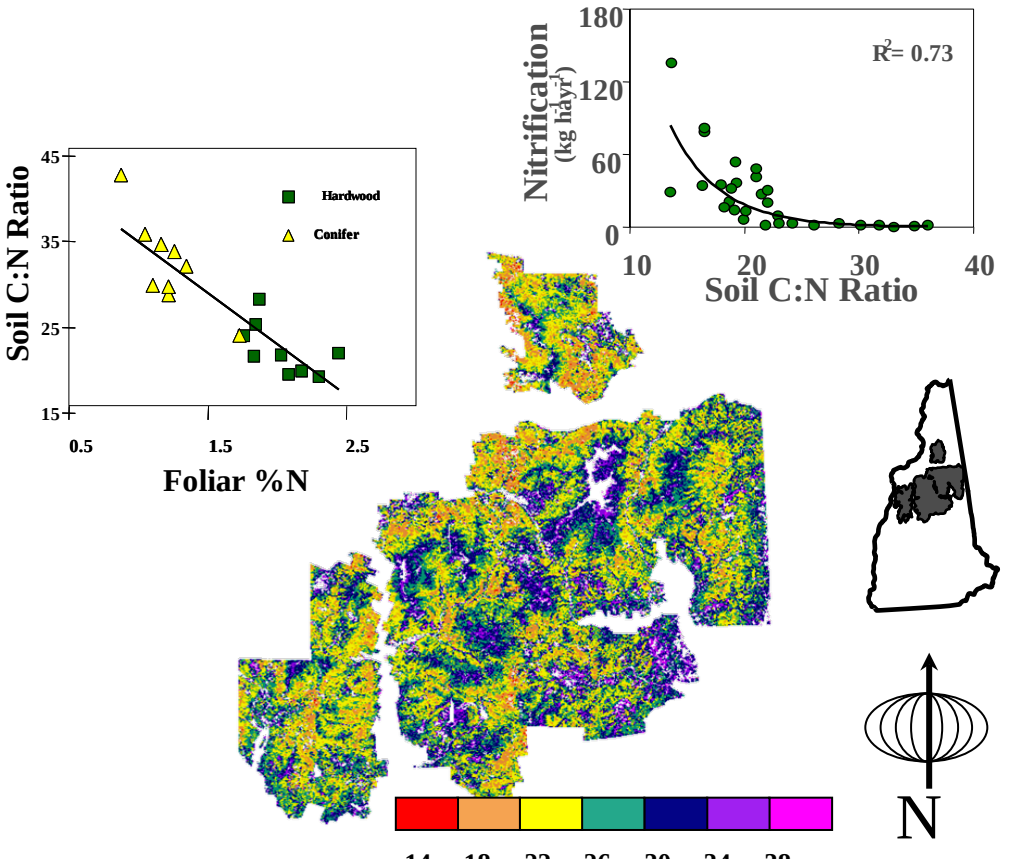
- **Detect and quantify changes in biogeochemical cycles and processes (PC)**
- **Map and monitor productivity changes (PC) at seasonal and spatial scales relevant for policy decisions.**
- **Reduce uncertainties in ecosystem feedbacks from multiple stressors (T, precip., CO_2, N deposition, etc.) to Improve prediction of future ecosystem condition (PC).**

Biosphere-climate feedbacks

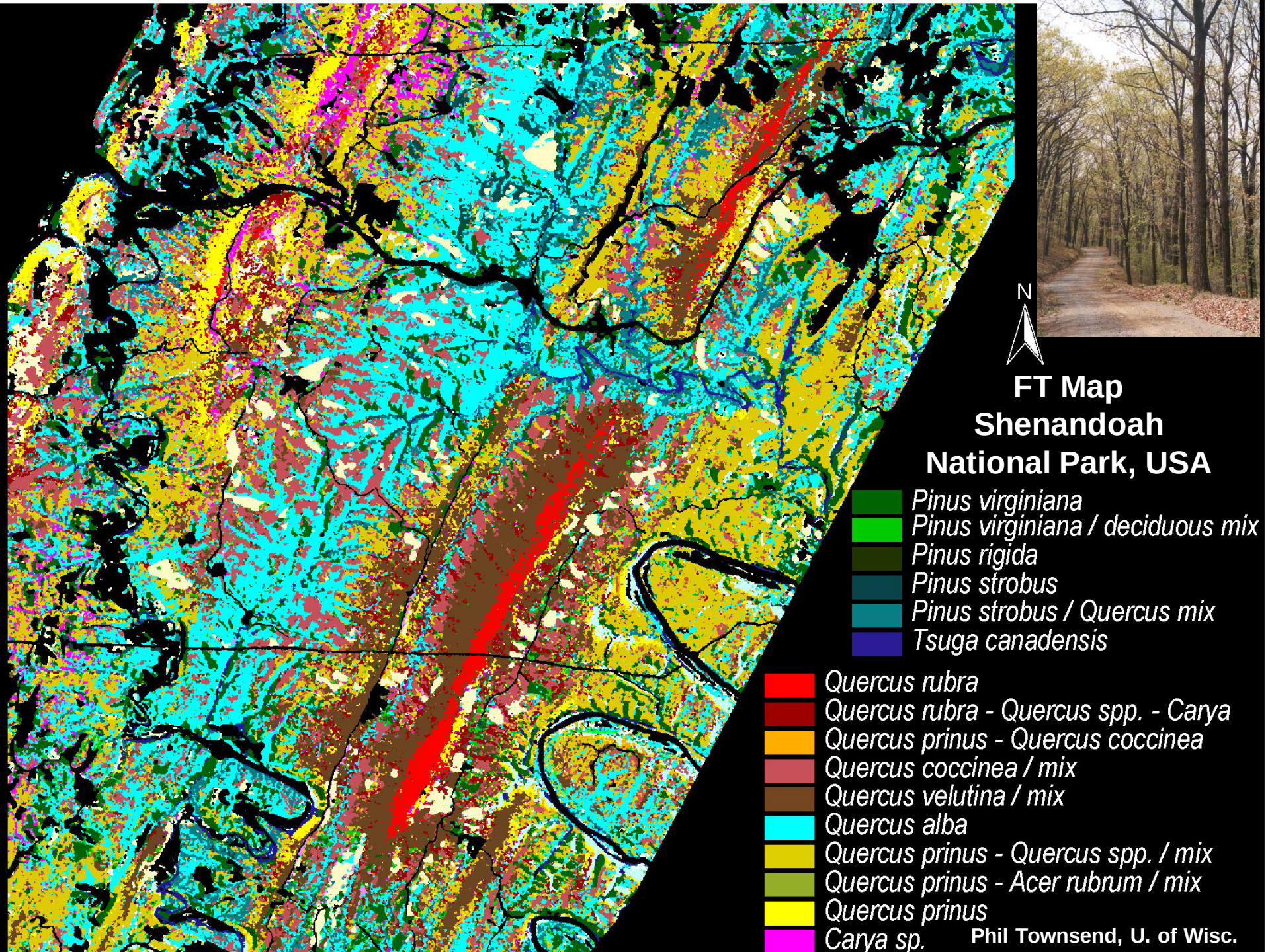


Reflectance spectrum are used to quantify bio-physiological conditions

Predicted Foliar Chemistry (PC) from Spectroscopy Is Used to Estimate Soil Nitrogen Cycling



Ollinger et al. 2002


N
FT Map
Shenandoah
National Park, USA
Pinus virginiana
Pinus virginiana / deciduous mix
Pinus rigida
Pinus strobus
Pinus strobus / Quercus mix
Tsuga canadensis
Quercus rubra
Quercus rubra - Quercus spp. - Carya
Quercus prinus - Quercus coccinea
Quercus coccinea / mix
Quercus velutina / mix
Quercus alba
Quercus prinus - Quercus spp. / mix
Quercus prinus - Acer rubrum / mix
Quercus prinus
Carya sp.
Phil Townsend, U. of Wisc.

HysplRI VSWIR – Science Measurement Characteristics

Spectral

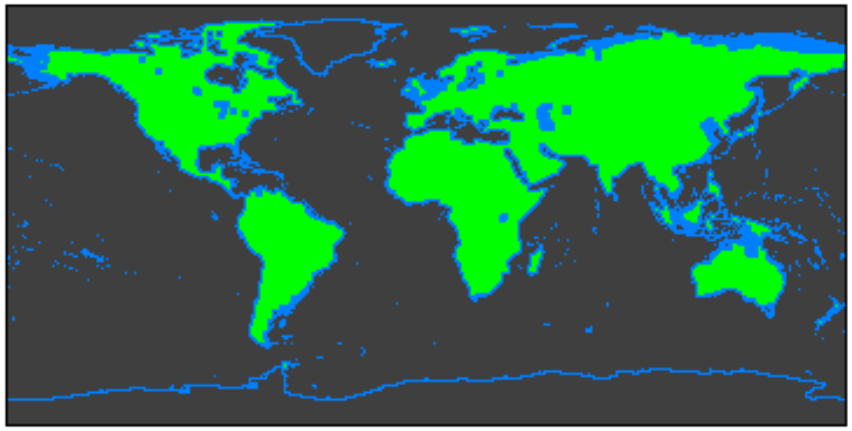
Radiometric

Spatial

Uniformity

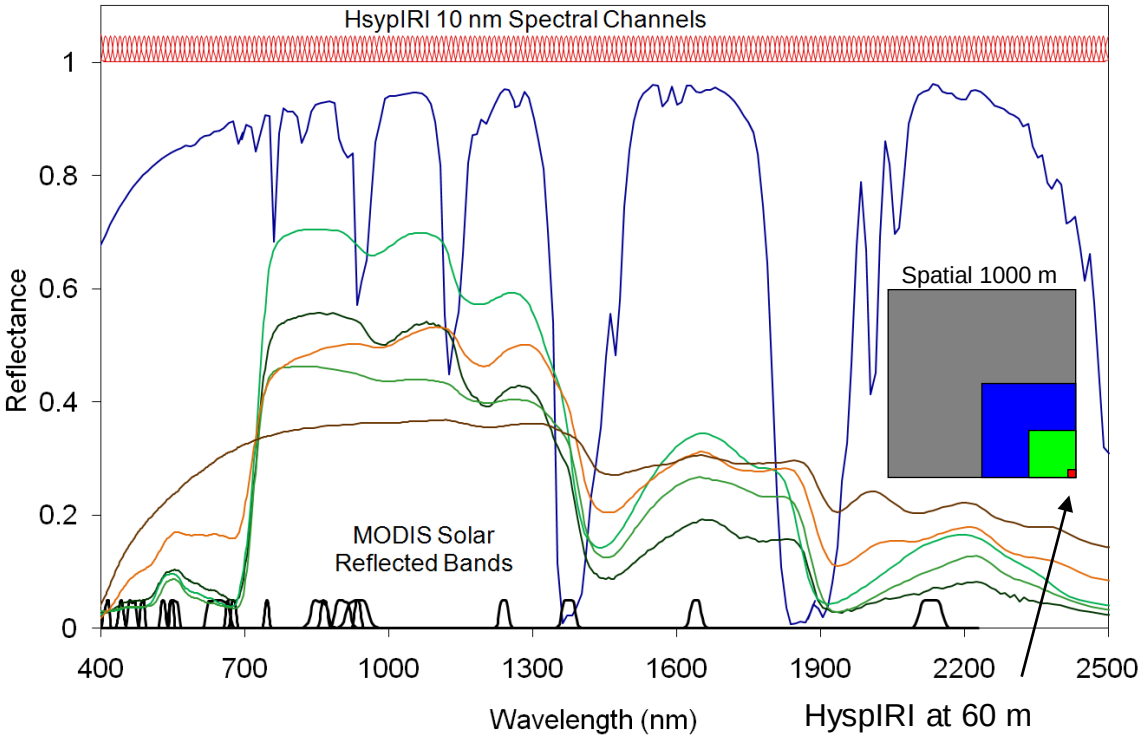
Temporal

HyspIRI VSWIR Science Measurements



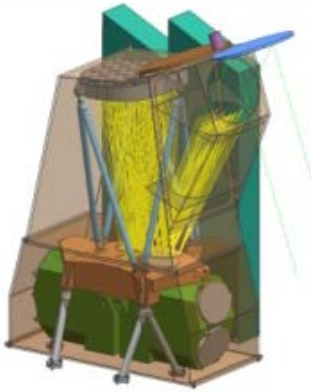
- Measure the **global** land and coastal/shallow water (> -50m).
- 19 day equatorial revisit to generate seasonal and annual products.
- Full terrestrial and shallow water data set returned.

- 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.



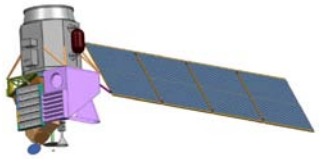
HysplRI VSWIR
Science Measurement Characteristics

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
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}



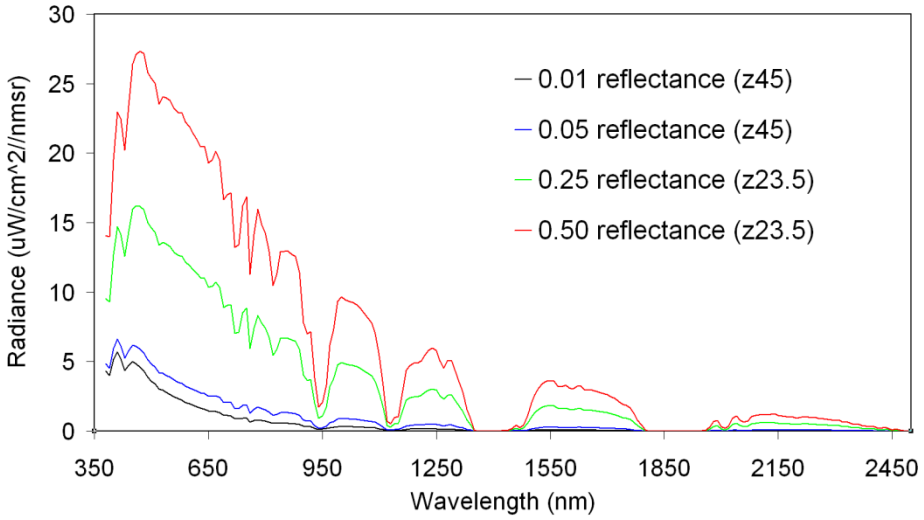
HyspIRI VSWIR Science Measurements Characteristics

Temporal	
Orbit Crossing	10:30 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

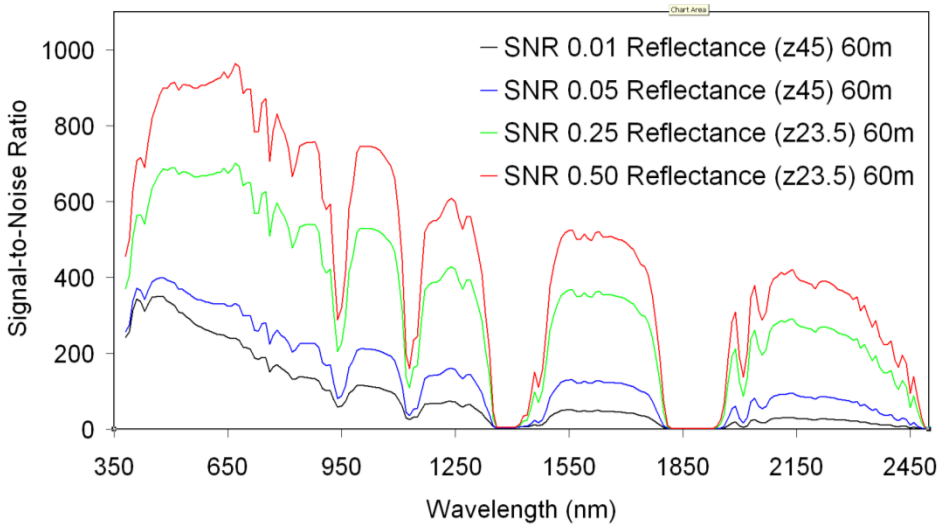


HyspIRI VSWIR Science Measurements
Key SNR and Uniformity Requirements

Benchmark Radiances

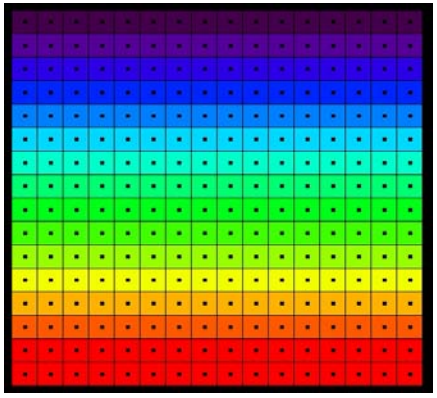


Required SNR



Uniformity Requirement

Cross Track Sample



Depiction

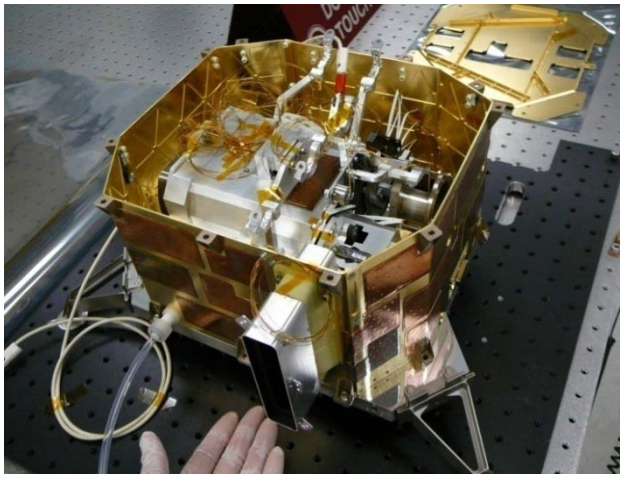
-Grids are the detectors
-dots are the IFOV centers
-Colors are the wavelengths

Requirement

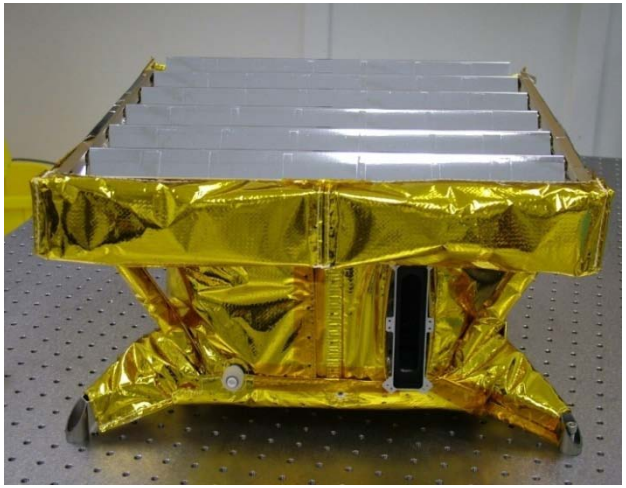
Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}

Heritage: NASA Moon Mineralogy Mapper

M3 Spectrometer

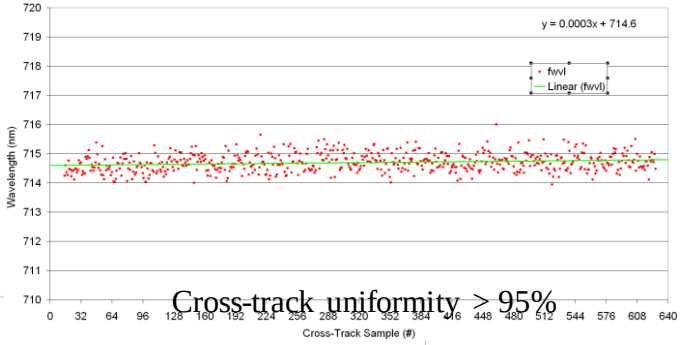


Mass 8 kg, Power 15 Watts

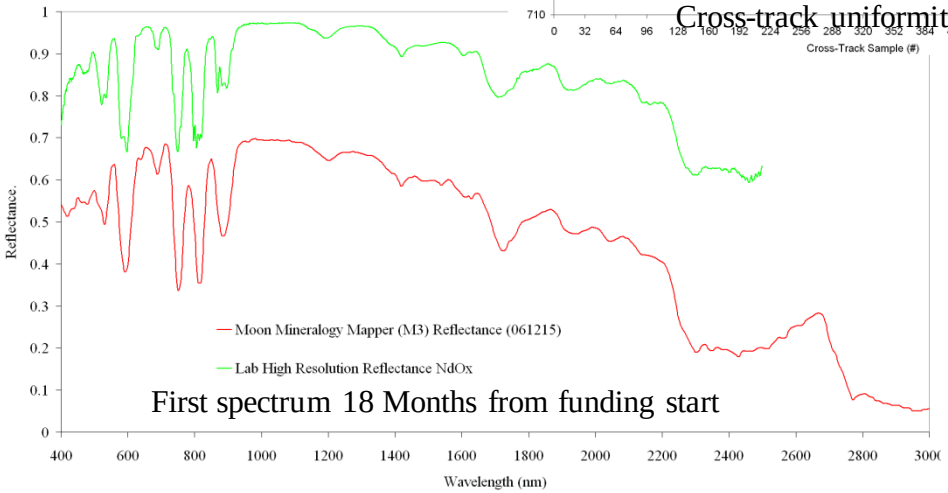


Passed Preship review 3 May 2007

- 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)



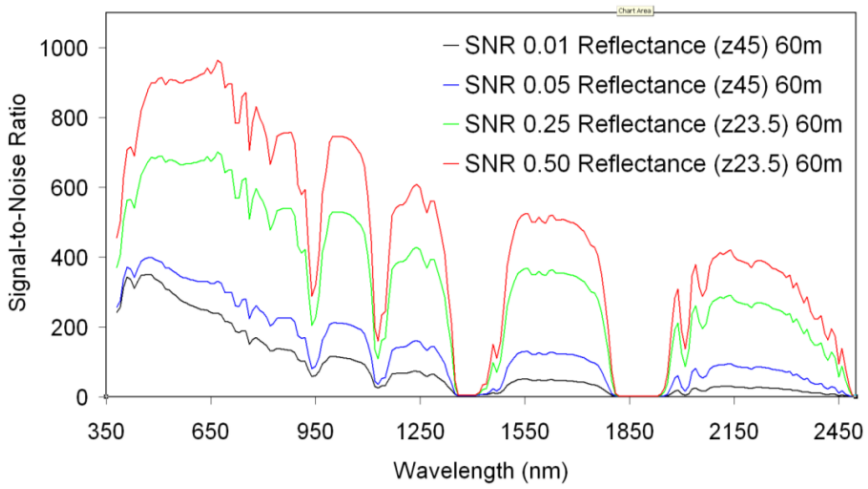
Cross-track uniformity > 95%



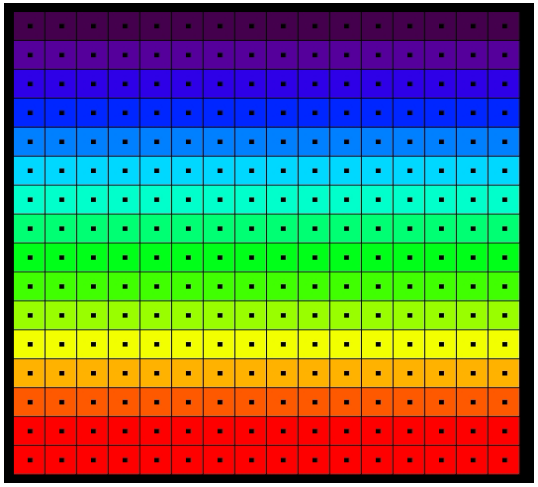
First spectrum 18 Months from funding start

HyspIRI: Building on NASA Hyperion Technology Demonstration

SNR > 10X



Uniformity > 10X



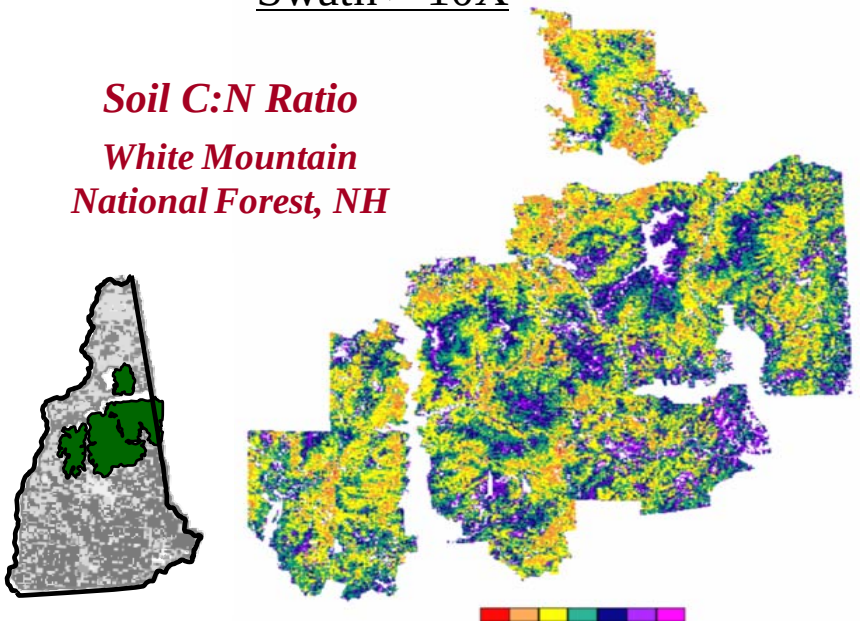
Wavelength

Cross Track Sample

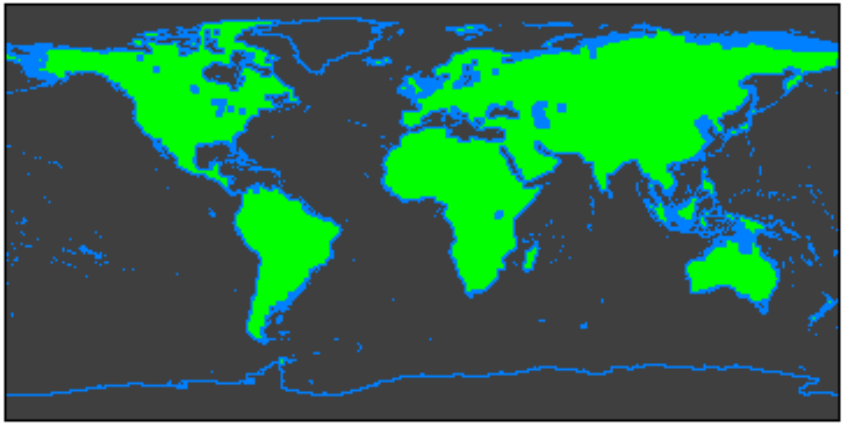
Swath > 10X

Soil C:N Ratio

White Mountain National Forest, NH

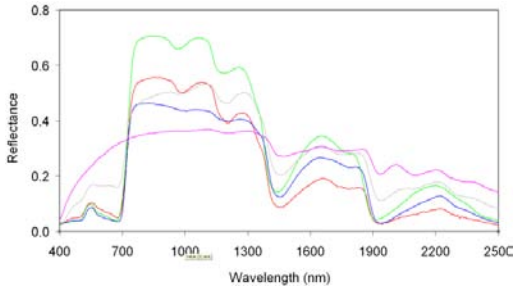


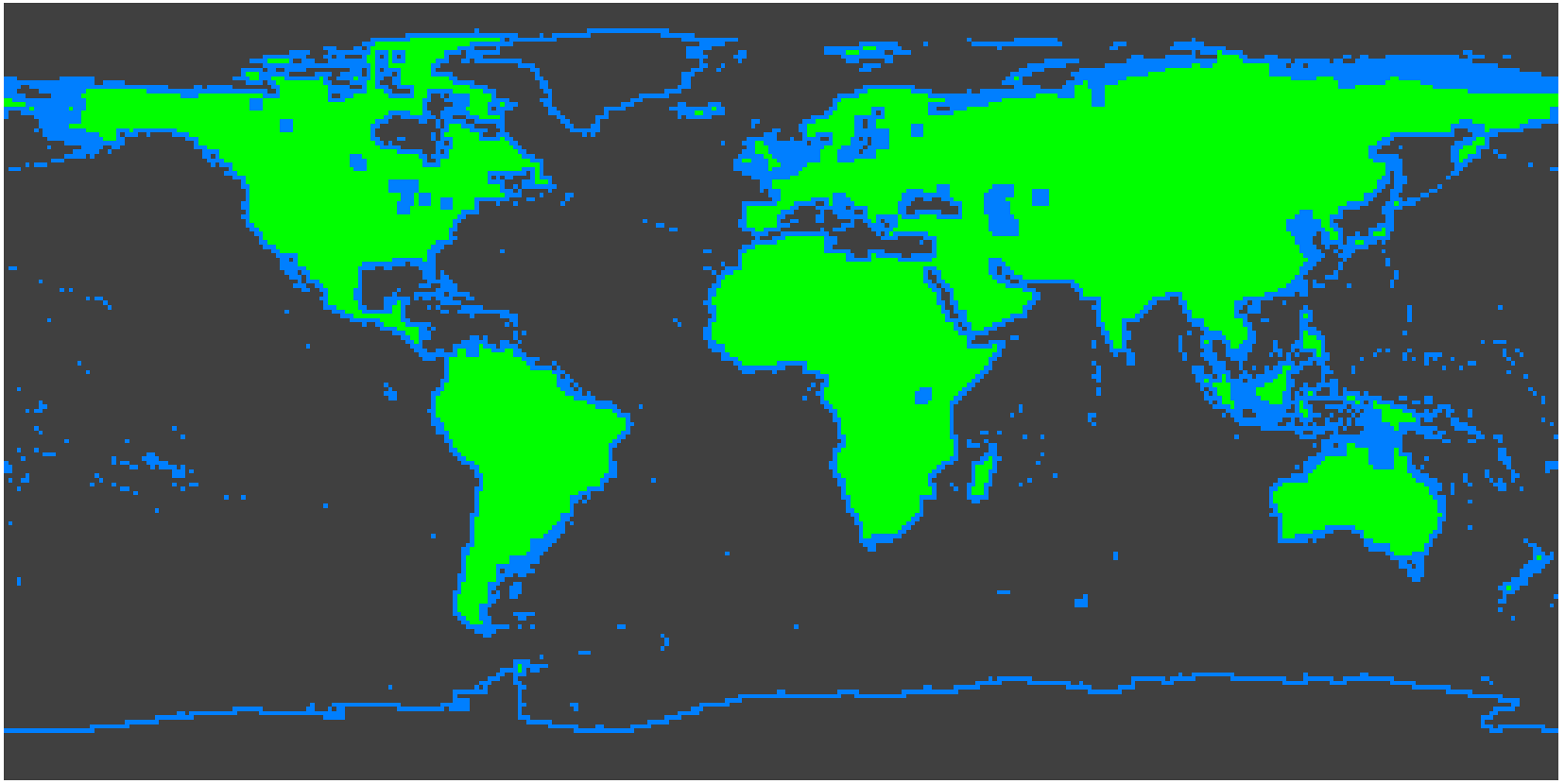
Global Coverage >> 10X



HyspIRI: A Decadal Survey **Global** Mapping Mission (VSWIR)

- Full Spectrum 380 to 2500 at 10 nm
- 60 m spatial with 150 km swath
- Full terrestrial surface downlinked every 19 days





Oceans and ice sheets at 1 km

VSWIR coverage map

HyspIRI compared with possible International Imaging Spectroscopy Missions

Only HyspIRI provides the full spectrum of data required to address climate-carbon cycle feedbacks articulated in the NRC Decadal Survey

HyspIRI Provides Seasonal and Annual Global Coverage that Uniquely Addresses Critical Gaps in Climate Research and Ecosystem Understanding.

>100 years for international mission to equal 1 year of HyspIRI

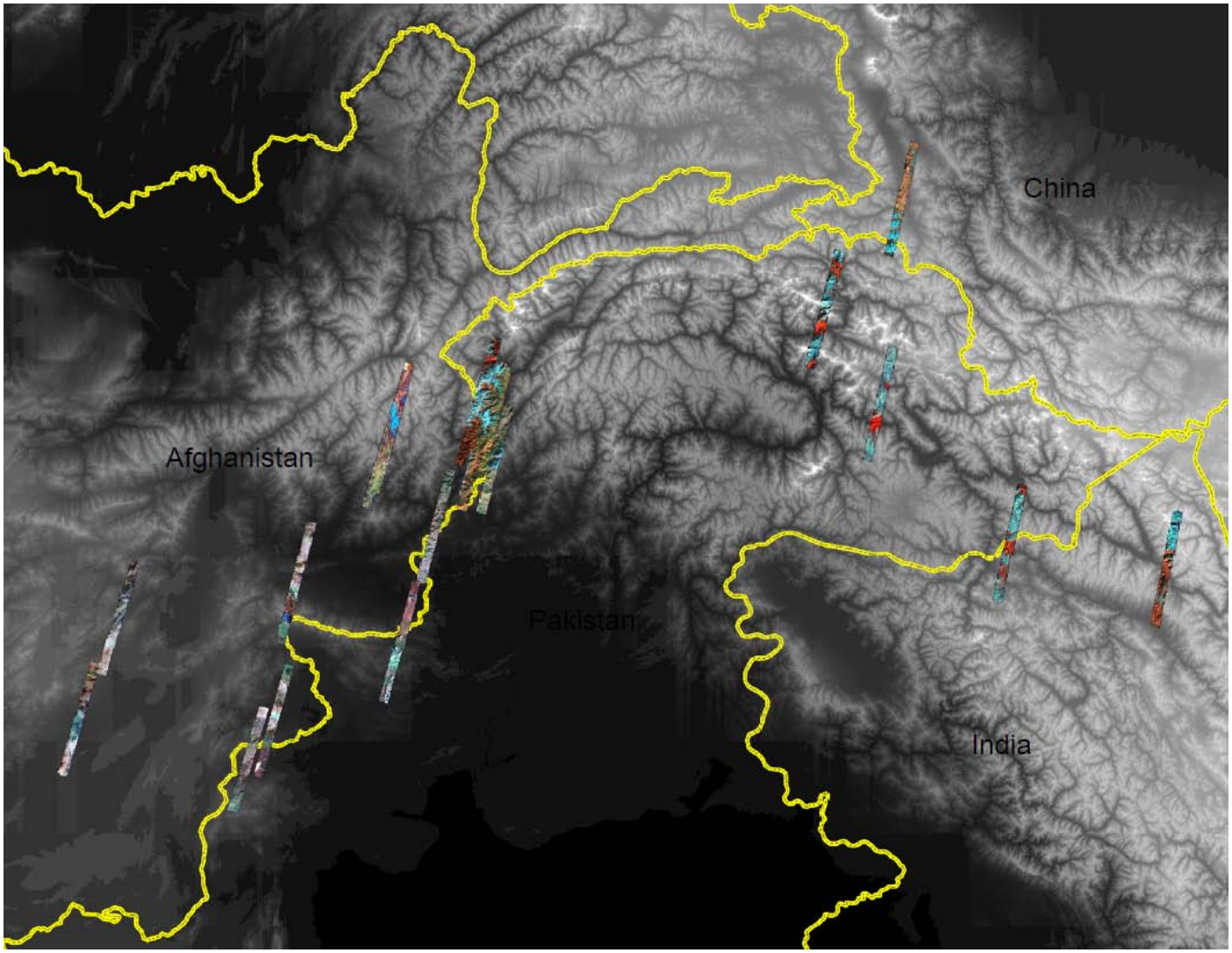
Country	Instrument	Swath km	Pixel Size, m	Terrestrial Coverage in 19 days	Repeat interval, days	TIR capability
USA	**HyspIRI**	**150**	**60**	**100%**	**19**	**8 TIR bands**
Germany	EnMAP	30	30	<1%	--	NO
Italy	PRISMA	30-60	20-30	<1%	--	NO
Japan?	ALOS3	30	30	<1%	--	NO
India?	IMS Resource Sat-3	25	25	<1%	--	1 TIR band

US, HyspIRI: a full spectral range (380 to 2500 at 10 nm), high SNR, uniform, 60m spatial with 150 km swath imaging spectrometer and multiband thermal imager (8 band thermal imager from 3-12 μm).

Other countries are occasionally mentioned (China, South Africa, South Korea, etc.). All are proposing first generation small sample process/application missions with scattered terrestrial coverage and no TIR imager

EO1-Hyperion Coverage for Himalaya Study

- Example of study for snow and ice science in the Himalaya with EO1-Hyperion
  - Coverage is a severe limitation of regional and global **climate** investigations.



- **<u>HyspIRI would measure the full area every 19 days returning all the data</u>**

HyspIRI VSWIR Science Measurement Summary

The National Research Council of the United States National Academies released the Decadal Survey: Earth Science and Applications from Space that included a global mapping imaging spectrometer as part of the HyspIRI Mission.

The NASA designated HyspIRI Science Study Group developed a set of science questions to address the call of the Decadal Survey including critical climate measurements.

From these science question as set of Science Traceability Matrixes were development with corresponding science measurement requirements.

A VSWIR imaging spectrometer instrument concept was developed to meet these science measurement requirements and provide a high heritage and low risk concept for acquiring the HyspIRI VSWIR science measurements.

The science measurement characteristics of the HyspIRI VSWIR instrument have been described in terms of: **Spectral, Radiometric, Spatial, Uniformity, Temporal**

The HyspIRI VSWIR science requires full coverage of the terrestrial and coastal areas at a 19 revisit to address key elements of the Decadal Survey science including critical climate measurements of the terrestrial biosphere.

Backup

HyspIRI Concept - 2010

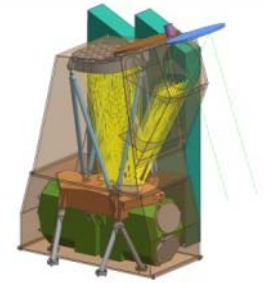
Payload

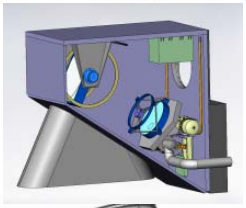
Science Instruments:

- VSWIR: Imaging Spectrometer
  - 380-2500 nm in 10 nm bands
  - 60m spatial resolution
  - Day-side (23% duty cycle)
  - 55 Kg, 41 W
- TIR: Thermal Infrared Scanner
  - 8 bands between 3-12 μm
  - 60m spatial resolution
  - Day and night-side (100% duty cycle)
  - 60 Kg, 103 W

Intelligent Payload Module (IPM)

- 24/7 Direct Broadcast capability
- subset of science data
- X-band @ 20 Mbps
- 11 Kg, 86 W





Mission Architecture

- Orbit: 626 km Sun-Synchronous, 10:30am LTDN
- Repeat: 19 day VSWIR / 5 day TIR
- Downlink: Contacts nearly every orbit to Svalbard (North) and Troll (Antarctica)
- Science Data: 5.7 Tbits/day
- Launch Vehicle: Taurus 3210, 2m fairing, 790 kg capability

Spacecraft

Launch Mass: 687 kg, JPL DP Margin: 30%

Required Power: 680W, 7.1 m^2 array (965 W capability)

P/L Data Rate: 384 Mbps

Downlink Data Rate: 800 Mbps Dual-pol X-band

Stabilization: 3-axis

Pointing: Control =720 arcsec (per axis 3σ)
Knowledge = 2 arcsec (Pitch/Yaw axis 3σ);
8 arcsec (Roll axis 3σ)
Stability = 5 arcsec/sec (per axis 3σ)

Implementation

Launch Date: ≥ 2016

Lifetime: 3 years, with consumables for 5

Cost Category: Low Cost Decadal Survey

Partners: JPL, GSFC

Mission Class: C, with selected redundancy

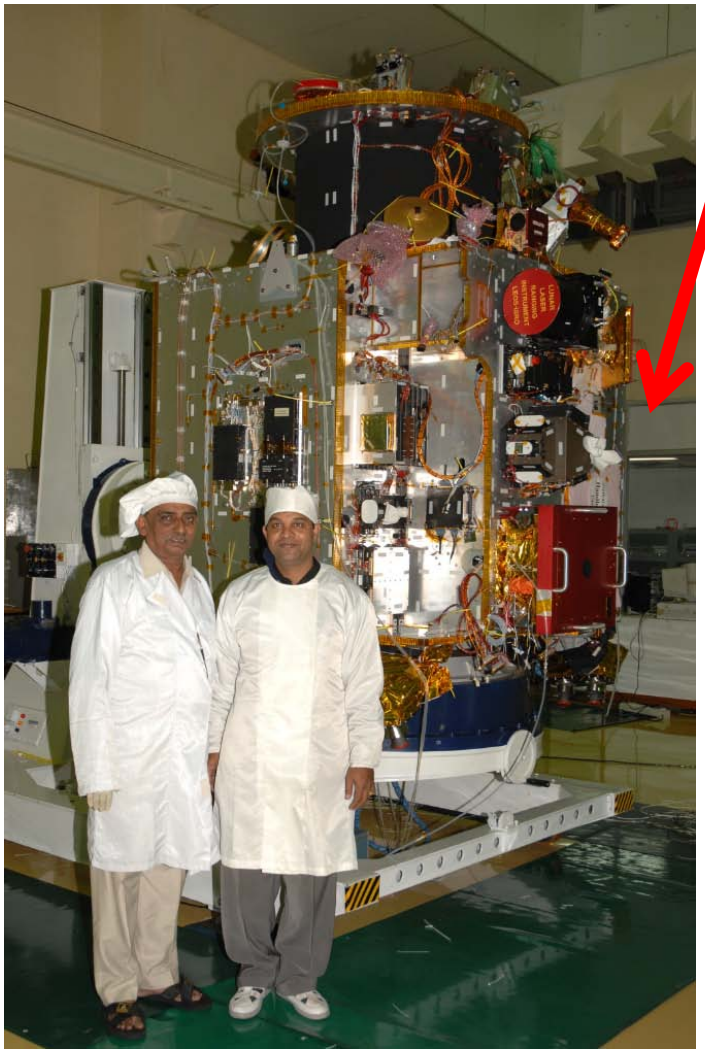
Hardware Model: Protoflight

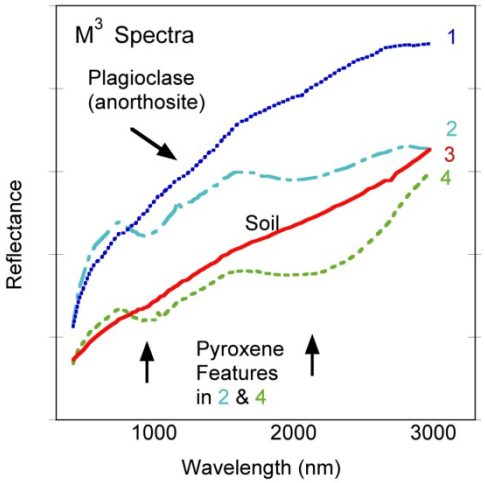
No new technology required

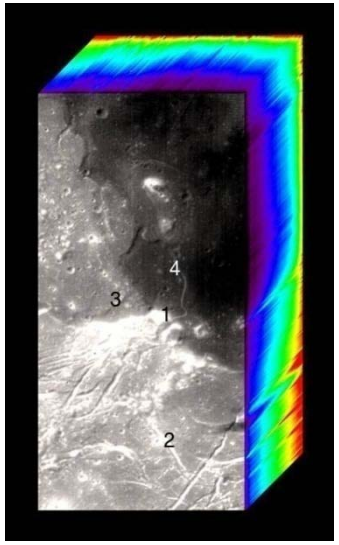
Heritage: M3 NASA Imaging Spectrometer

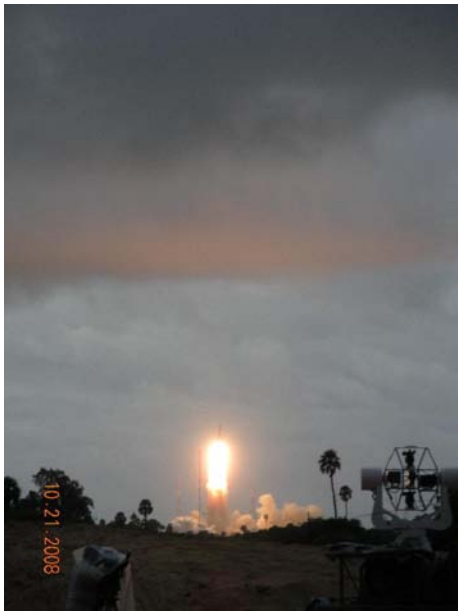
M3 Installed on ISRO Chandraayan-1 spacecraft, Launched 22 Oct 2008

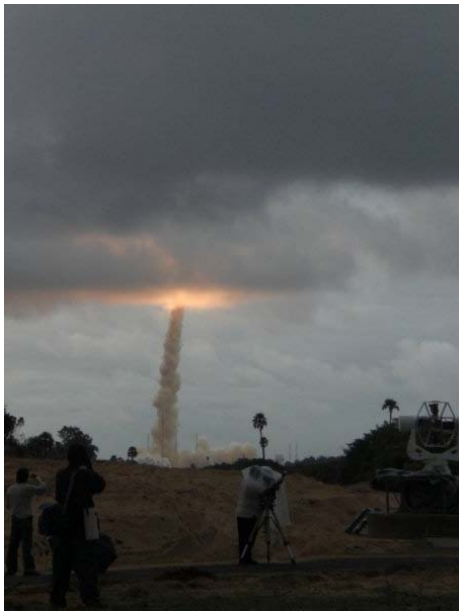
- First light in lunar orbit 19 Nov 2008



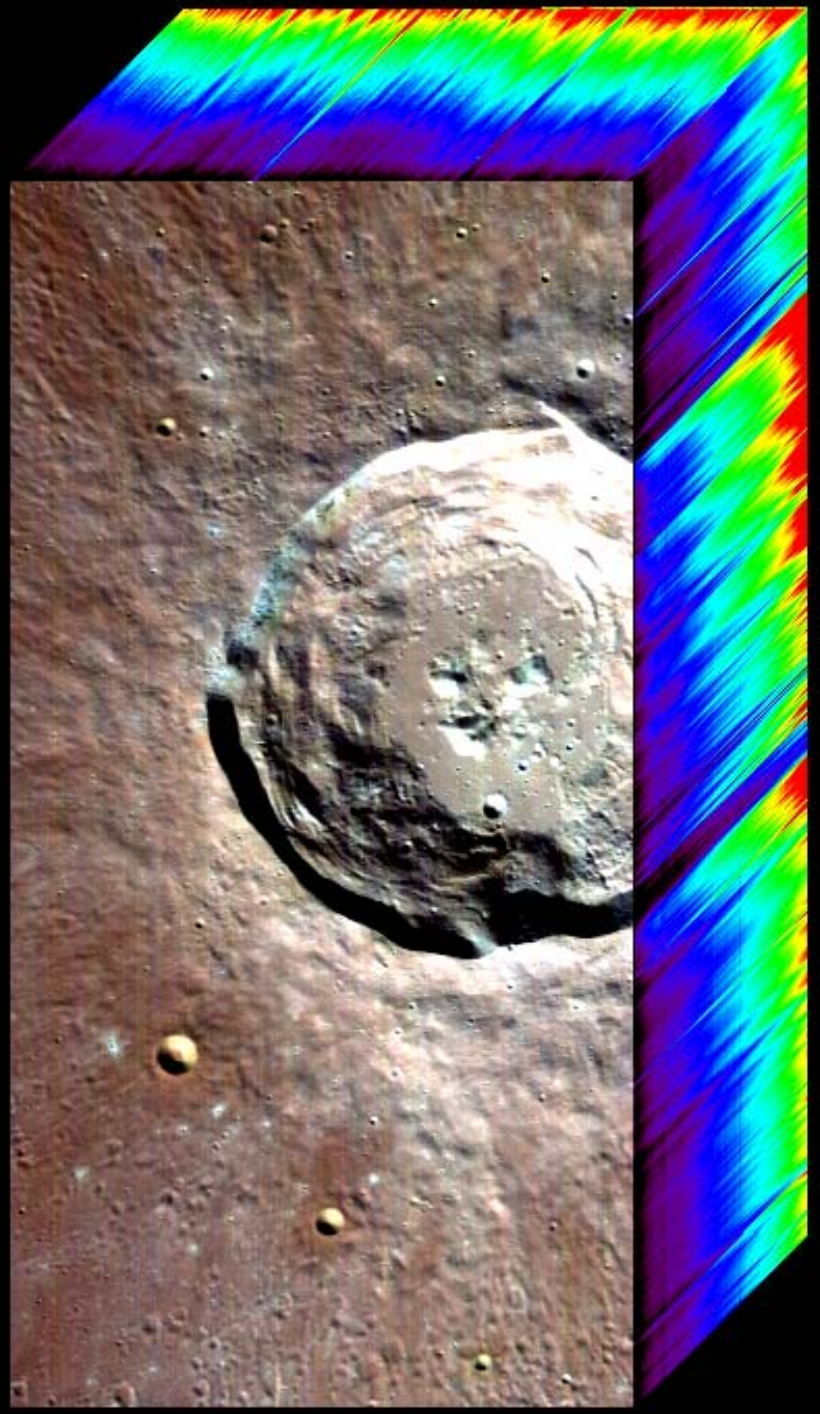




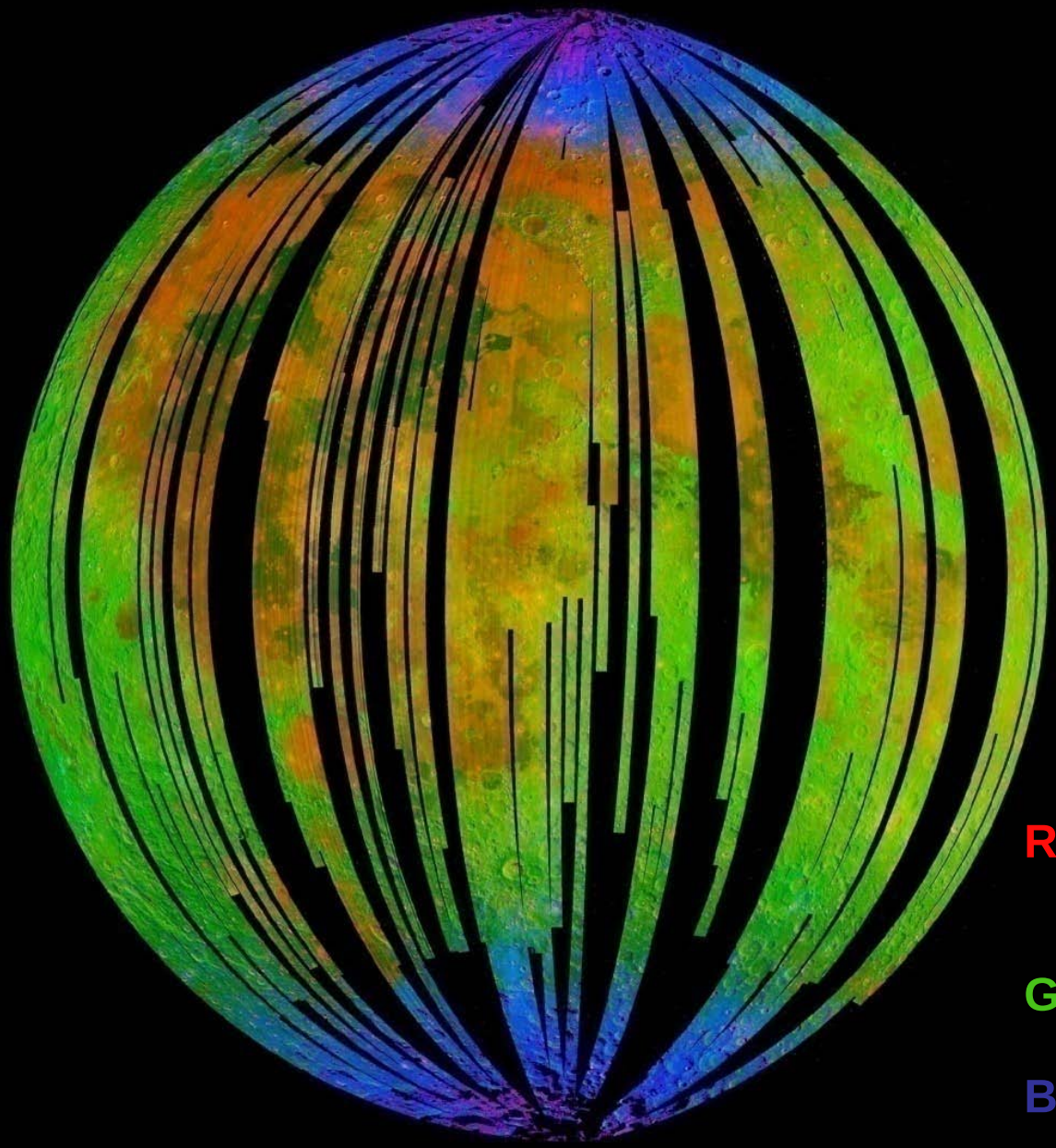




M^3
First Spectral Light
19 Nov 2008



Cover of Science 23 October 2009



R 2-μm absorption largely pyroxene

G Brightness

B 3-μm absorption OH/H2O

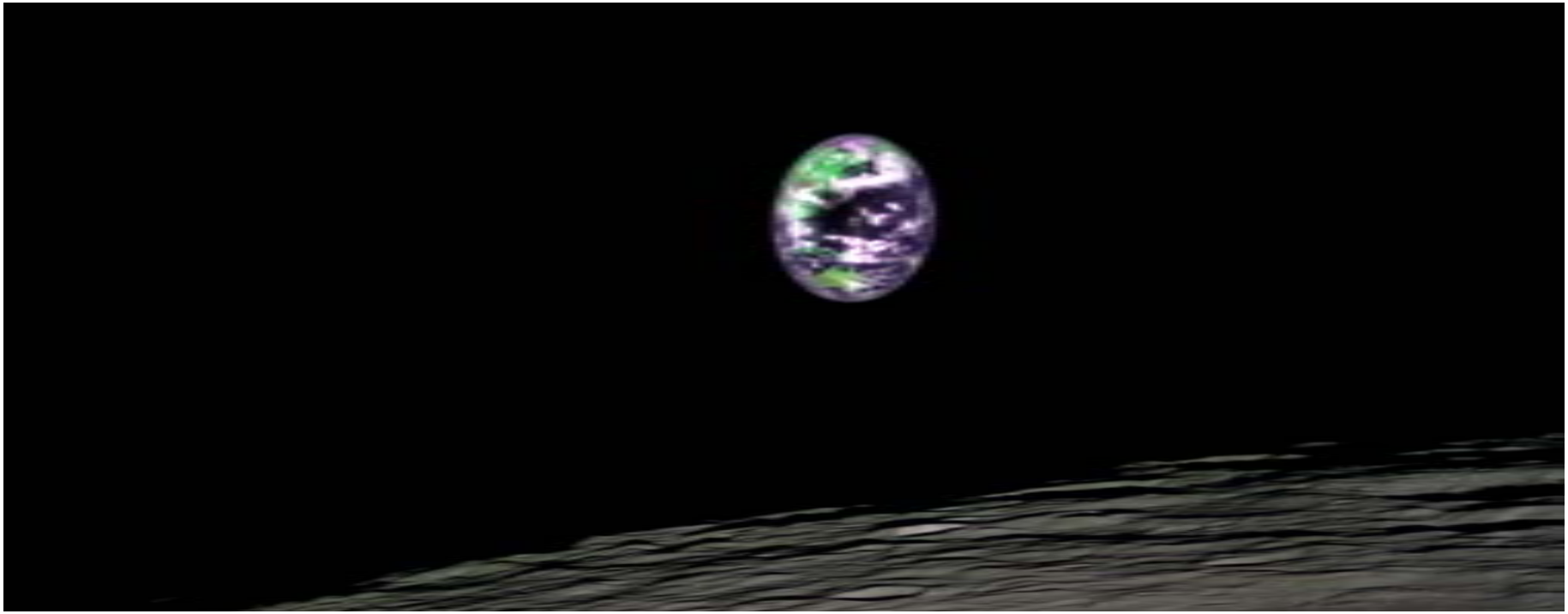


Image of Earth from the Moon acquired by the NASA Discovery Moon Mineralogy Mapper (M3) that is a guest instrument onboard the ISRO Chandrayaan-1 Mission to the Moon. Australia is visible in the lower center of the image. The image is presented as a false color composite with oceans dark blue, clouds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

M^3 On-Orbit Spectral