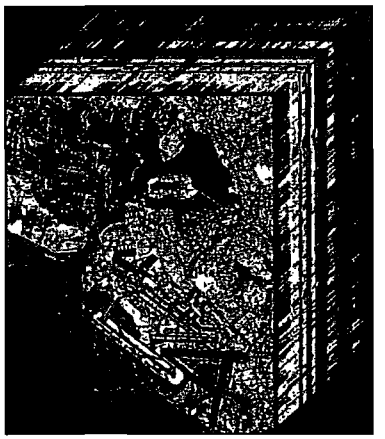
# Science and Measurement Requirements for a Plant Physiology and Functional Types Mission



*Measuring the composition, function and health of global land and coastal ocean ecosystems*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# Overview

- Context
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# Scientific and Societal Context

The US National Academy of Sciences Decadal Survey (2007) placed "critical priority" on a:

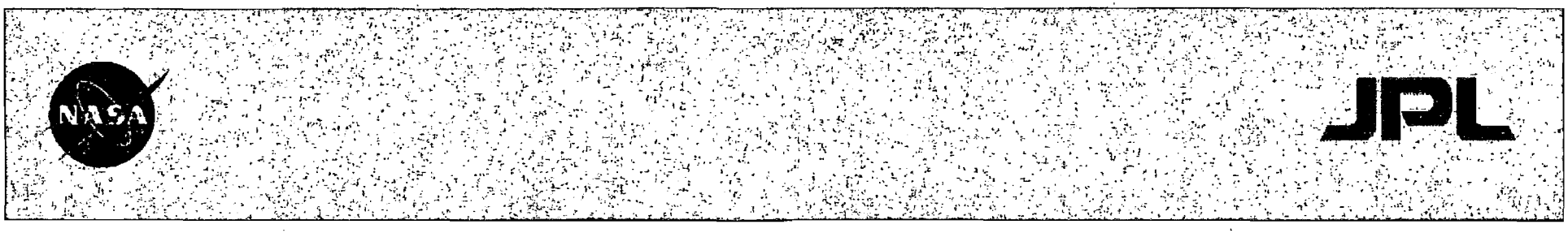
"**Mission to observe distribution and changes in ecosystem function:** An optical sensor with spectral discrimination greatly enhanced beyond the LANDSAT and MODIS class is required to detect and diagnose changes to ecosystem function such as water and nutrient cycling and species composition. Such observations include **nutrient** and **water status**, presence and responses to **invasive species**, **health of coral reefs**, and **biodiversity**. We propose a **hyperspectral** sensor with pointability for observing disturbance events such as fire and droughts when and where they occur at higher temporal frequency."

# Scientific and Societal Context

This mission concept addresses critical issues outlined in the Millennium Ecosystem Assessment (2005):

"The most important direct drivers of **biodiversity** loss and **ecosystem** service changes are **habitat** change (such as land use changes, physical modification of rivers or water withdrawal from rivers, loss of **coral reefs**, and damage to sea floors due to trawling), climate change, **invasive alien species**, overexploitation, and pollution."

The PPFT satellite mission provides the essential measurements needed to assess drivers of change in biodiversity and ecosystem services that affect human welfare.




# Science Questions


# Science Questions
## Overarching

JPL

- What is the composition, function, and health of terrestrial and aquatic 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?

# Science Questions
# Topic Areas

- Ecosystem Function and Diversity:
  - What are the spatial distributions of different plant functional groups, diagnostic species, and ecosystems?
  - How do their locations and function change seasonally and from year to year?
  - What are the trends?

- Biogeochemical Cycles:
  - How do changes in the physical, chemical, and biotic environment affect the productivity, carbon storage and biogeochemical cycling processes of ecosystems?
  - How do changes in biogeochemical processes feed back to other components of the Earth system?

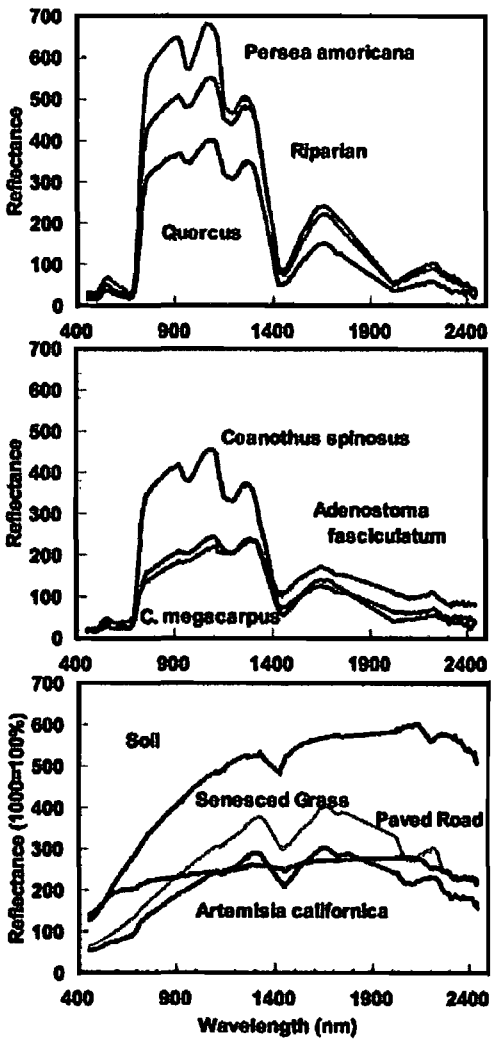
- Ecosystem Response to Disturbance:
  - How do human-caused and natural disturbances affect the distribution, biodiversity and functioning of ecosystems?

- Ecosystems and Human Well-being:
  - How do changes in ecosystem composition and function affect human health, resource use, and resource management?

# Science Questions

# Ecosystem Function and Diversity

Reflectance Spectra
400 to 2500 @ 10 nm




Species Type 87% Accurate


- *Adenostoma fasciculatum*
- *Ceanothus megacarpus*
- *Arctostaphylos spp.*
- *Quercus agrifolia*
- Grass
- Soil

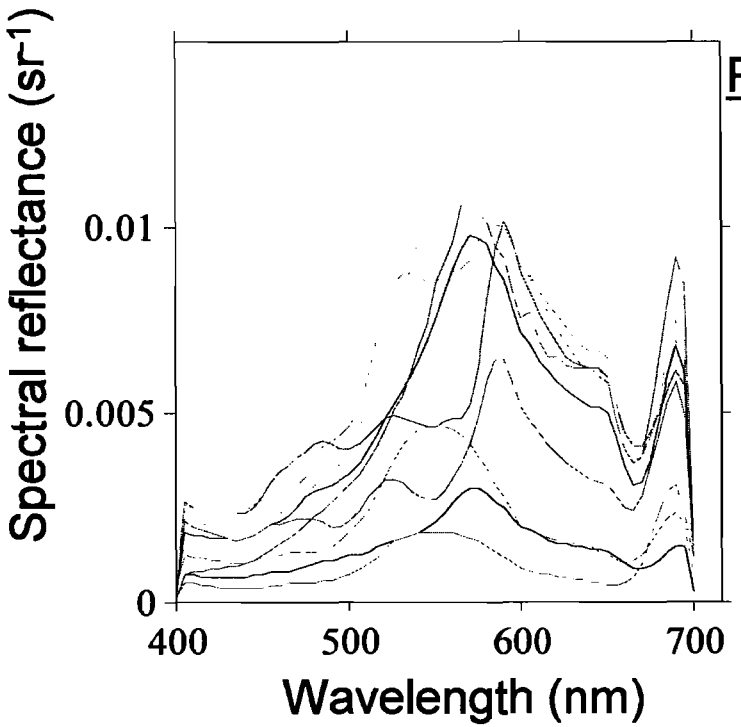
Measurement of the spectral signature of vegetation over this complete spectral range at 10 nm resolution enables direct mapping of species-type and fractional cover.

With measurement of species-type and fractional cover the ecosystem functional type, diversity, and status is determined

Santa Ynez Front Range, California (Dennison and Roberts 2003)

# Science Questions
# Ecosystem Function and Diversity

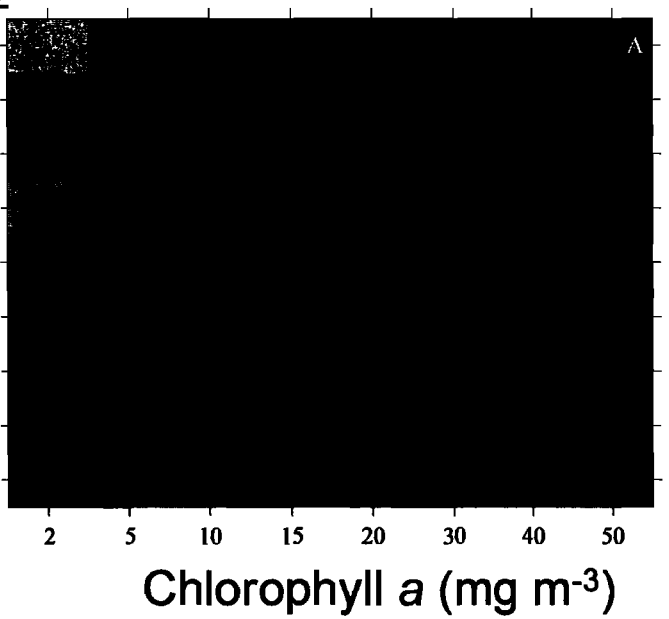
Phytoplankton groups have different pigment suites that give them unique spectral "fingerprints" that can be used to measure their presence and to understand their roles in aquatic ecosystems.




**Phytoplankton Groups**

- *Chlorophyceae*
- *Proclorococcus*
- *Cryptophyceae*
- *Dinophyceae*
- *Raphidophyceae*
- *Haptophyceae*
- *Bacillariophyceae*
- *Synechococcus*
- *Rhodophyceae*

Perceived water color



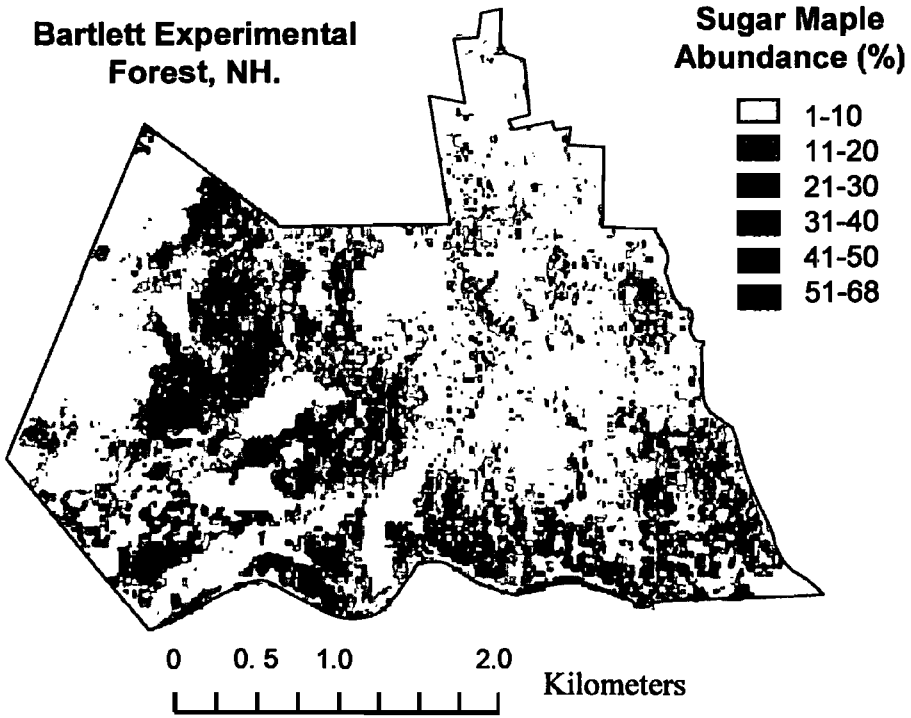

Dierssen et al. 2006

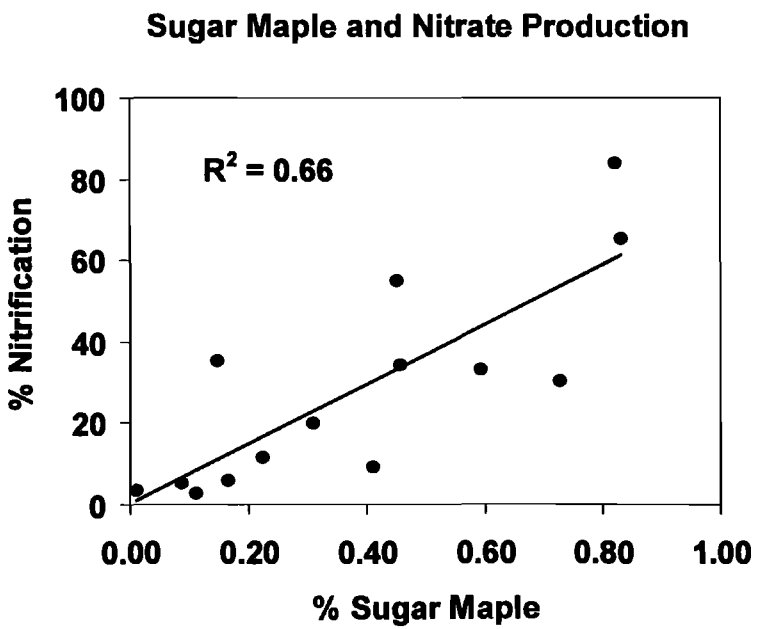
# Science Questions
# Species Composition and Biogeochemical Cycles

***Nitrate ($NO_3^-$)*** *production in northeastern forest soils has been related to:* ***(1)*** *the abundance of sugar maple and* ***(2)*** *the N concentration of soil organic matter. Imaging spectroscopy is uniquely capable of providing information about both.*

## *#1. SUGAR MAPLE ABUNDANCE THROUGH SPECTRAL UNMIXING WITH AVIRIS*

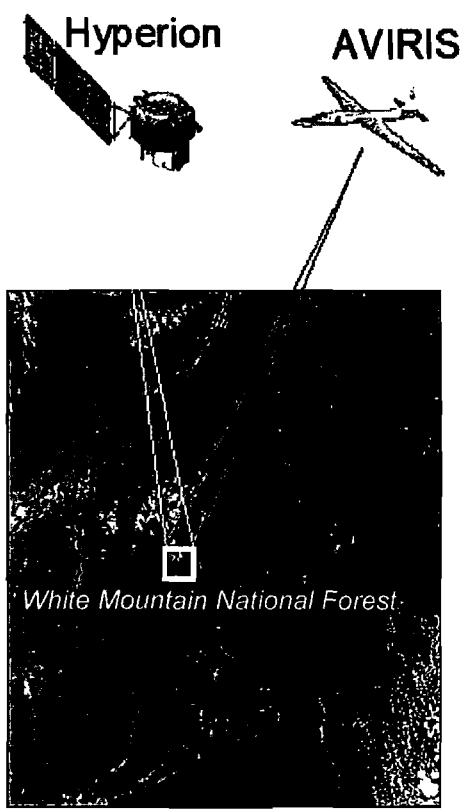
(Plourde et al. 2007).

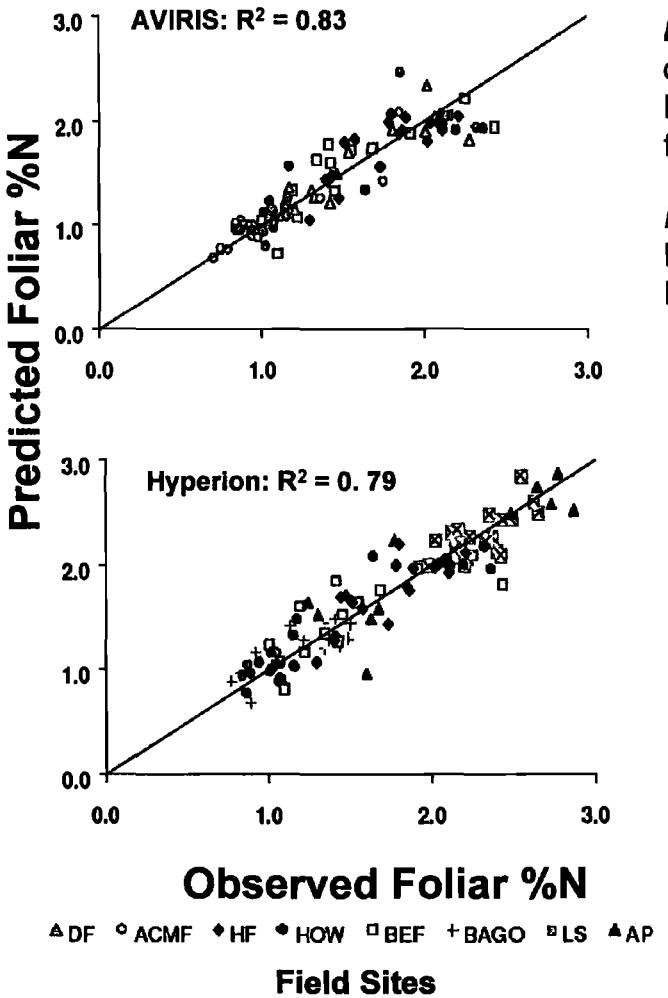


# Science Questions
# Biogeochemical Cycles

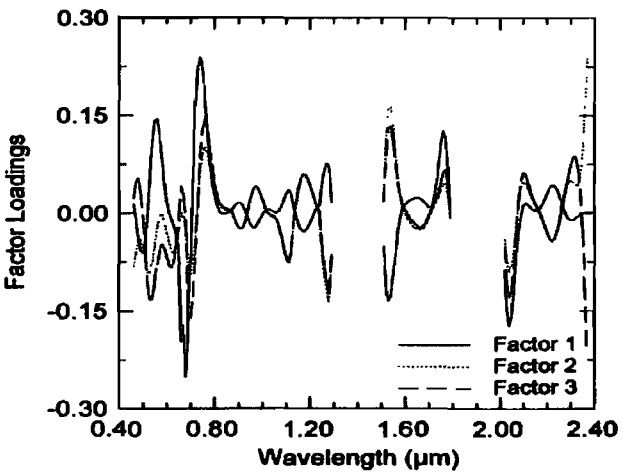
## *#2. SOIL N STATUS THOUGH REMOTE DETECTION OF FOLIAR NITROGEN AND OBSERVED RELATIONSHIPS WITH N CYCLING VARIABLES.*




***LEFT:*** Predicted versus observed foliar N, derived from cross-calibration of a 3 factor PLS model to 123 plots across a diverse set of forested research sites.

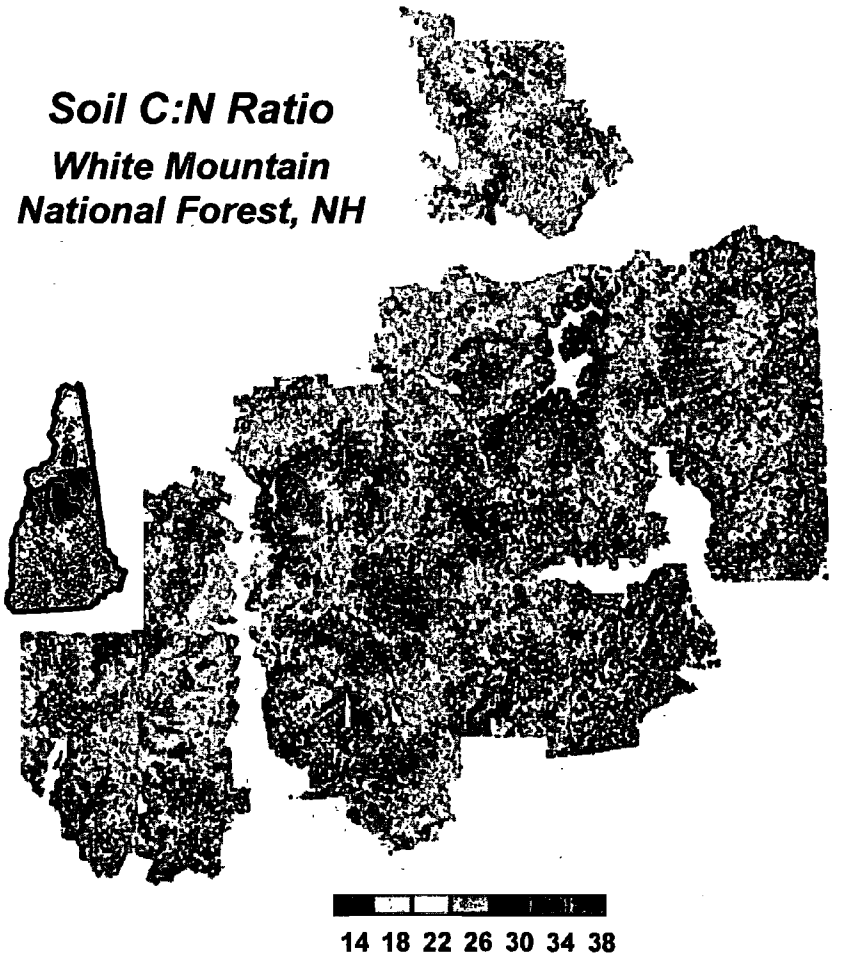
***BELOW:*** Importance values, or factor loadings, for image spectra as derived through Partial Least Squares (PLS) Regression.

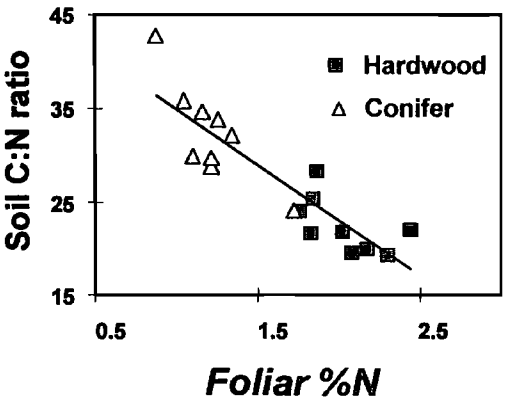


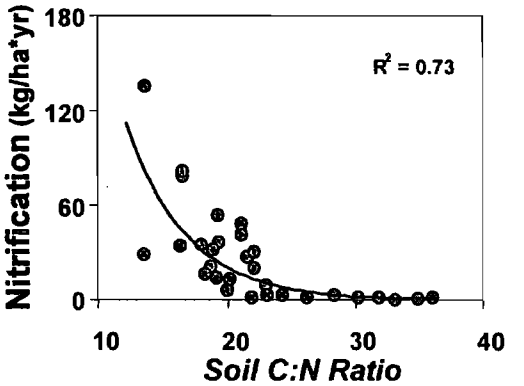

*Smith et al. 2003, Martin et al. submitted*

# Science Questions
# Biogeochemical Cycles

## #2 (cont'd). SOIL N STATUS THOUGH REMOTE DETECTION OF FOLIAR NITROGEN AND OBSERVED RELATIONSHIPS WITH N CYCLING VARIABLES.



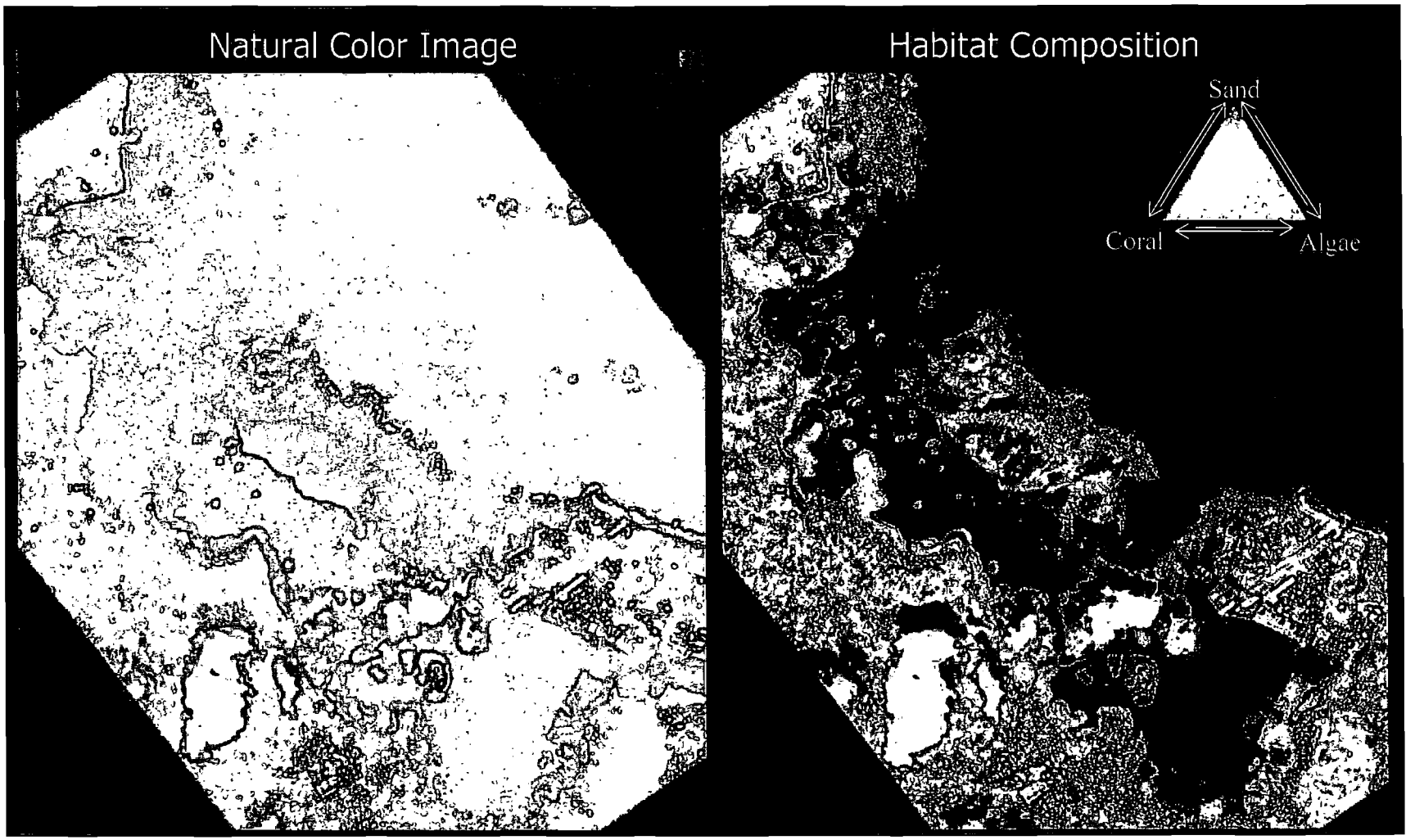




*Together, remote sensing of N concentrations and sugar maple abundance reveal spatial patterns in soil chemistry and help shed light on ecosystem vulnerability to atmospheric N deposition.*

*Ollinger et al. 2002*

# Science Questions
# Response to Disturbance

**Imaging spectroscopy is used to measure the functional types and fractions in a coastal coral ecosystem in order to ascertain the impacts of nutrients on habitat composition.**




Airborne imaging spectroscopy measurements of coral reef ecosystem, Hawaii.

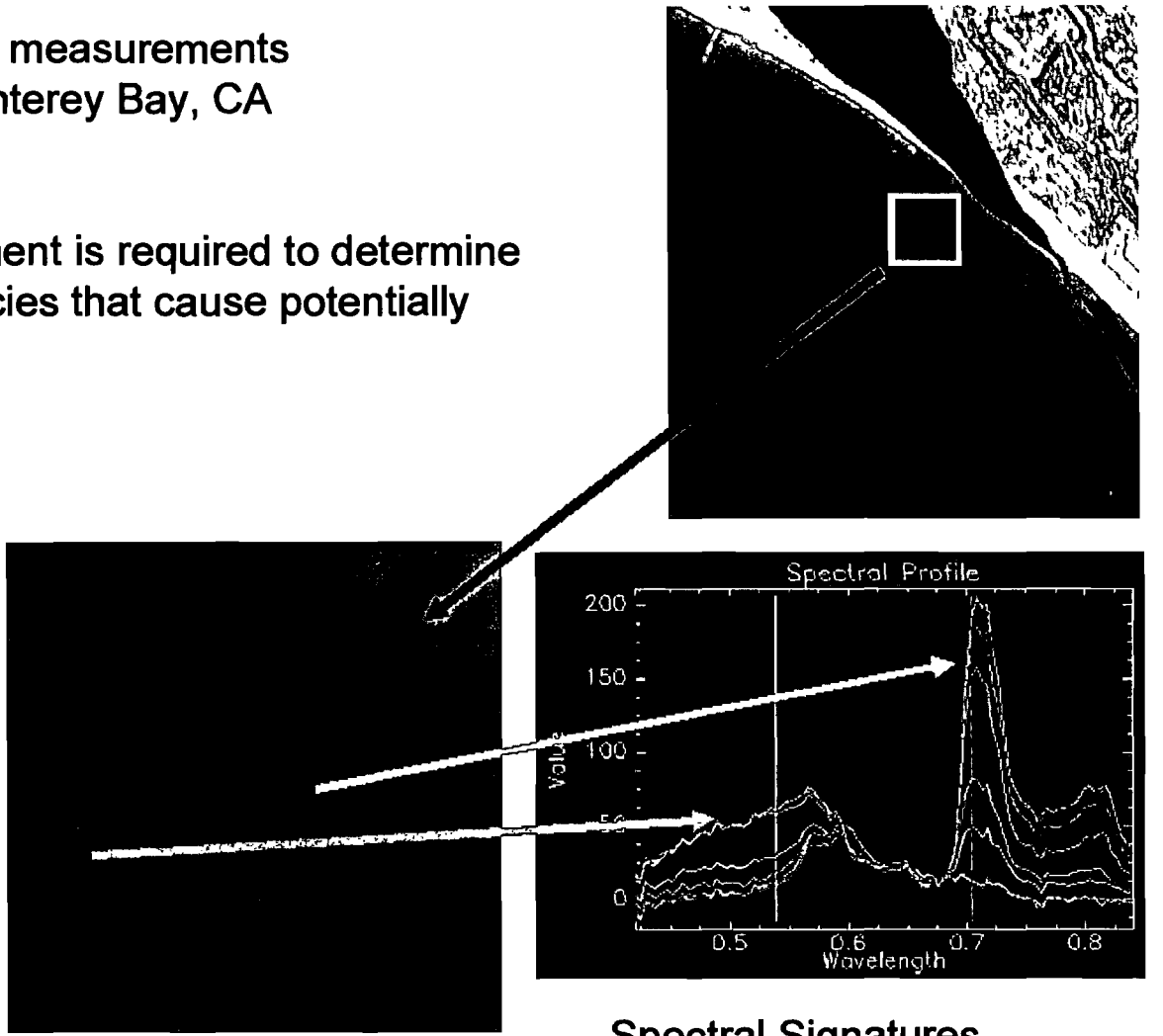
# Science Questions
# Ecosystems and Human Well-Being

Airborne imaging spectrometer measurements of a red tide algal bloom in Monterey Bay, CA

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

October 2002

*Ceratium spp. bloom*

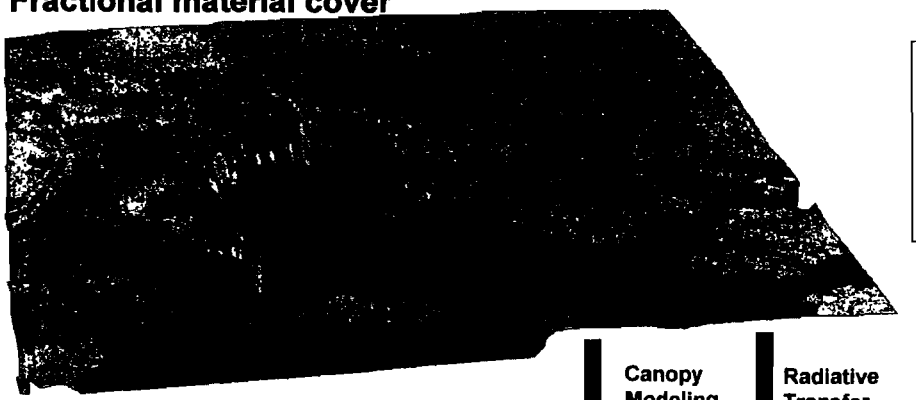



Spectral Signatures

Paul Bissett, Florida Environmental Research Institute.

# The Complete PPFT Data Stream for Ecosystem Composition, Function and Health

**Fractional material cover**



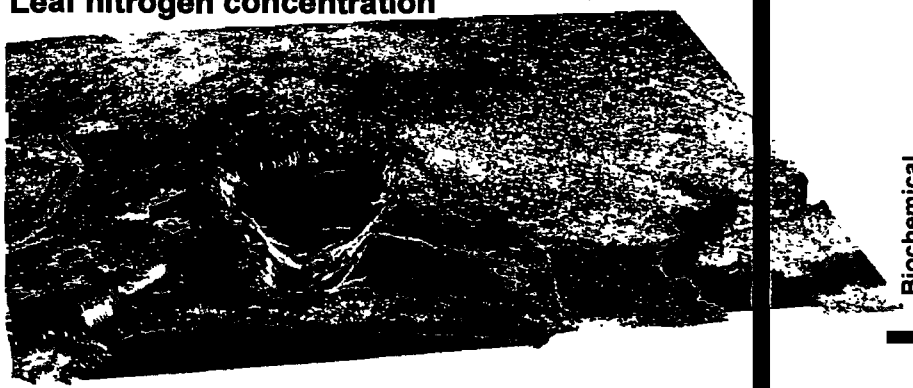
**Invasive Species in the Hawaiian Rainforest from Airborne Imaging Spectrometer data: Patterns of Invasion and Biogeochemical Consequences**


**Invasive species and nitrogen-fixing PFT**

Canopy Modeling

Radiative Transfer

**Leaf nitrogen concentration**

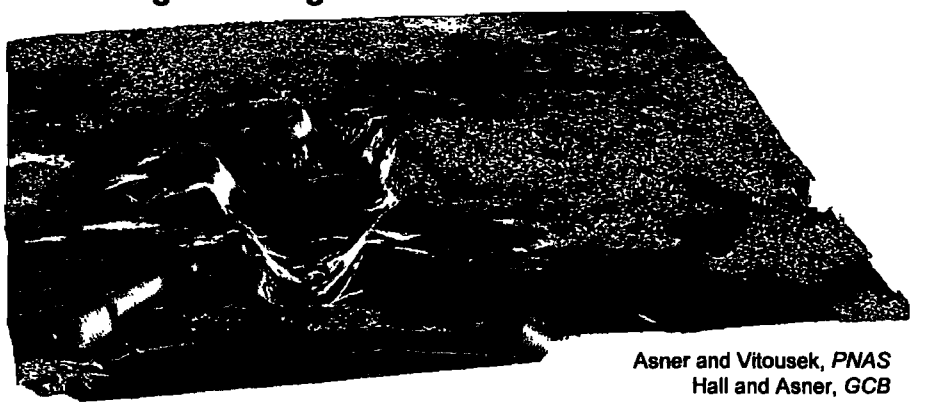


Biochemical Fingerprinting

Biogeochemical Analysis

**Canopy water content**

**Soil nitrogen trace gas emissions**



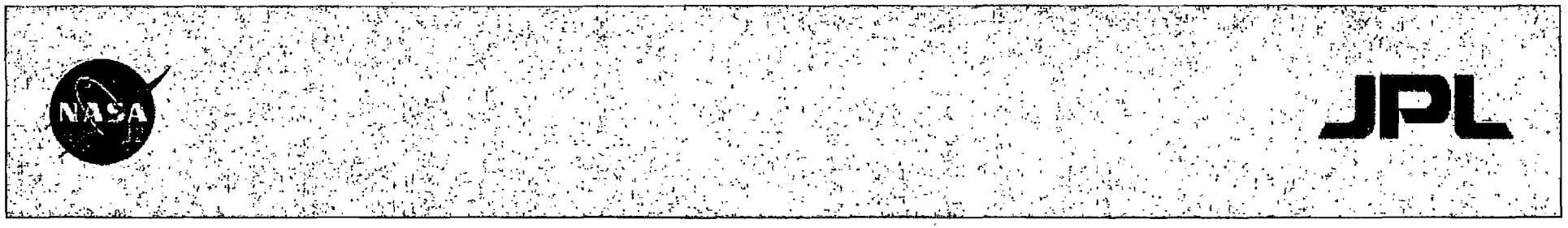
Asner and Vitousek, *PNAS*
Hall and Asner, *GCB*

# Science Questions
# Summary

- A set of overarching science question have been defined
  - What is the composition, function, and health of terrestrial and aquatic 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?

- These overarching questions are best addressed with detailed science question defined for each of the following topic areas
  - Ecosystem Function and Diversity
  - Biogeochemical Cycles
  - Ecosystem Response to Disturbance
  - Ecosystems and Human Well-Being

- Antecedent measurements and derived products have been shown as pathfinder examples to address the PPFT overarching and topic area science questions.

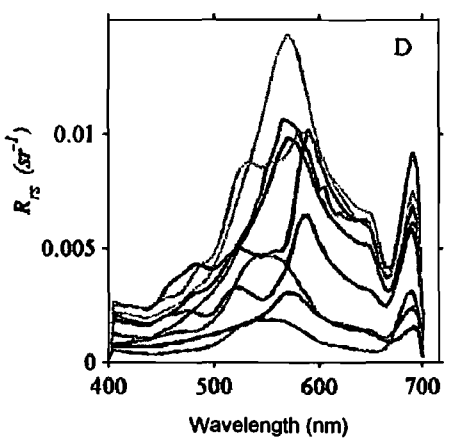


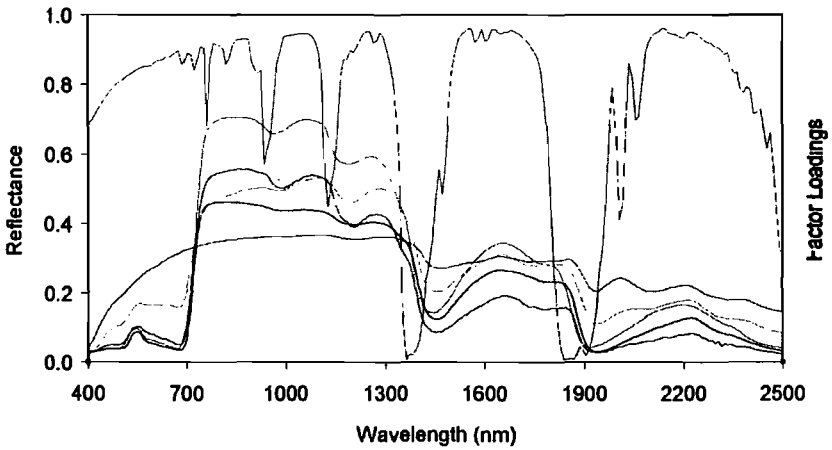

# Science Rationale

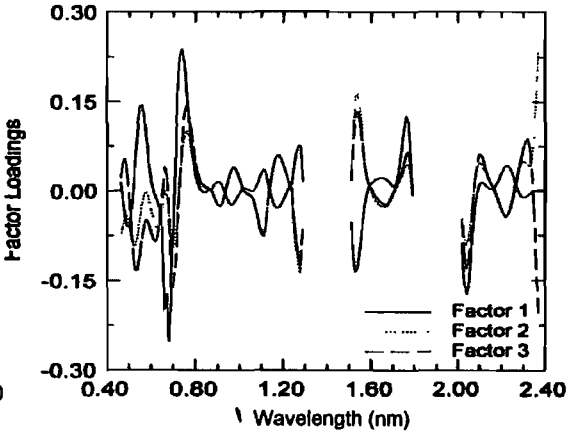
Science Rationale

# The Need for Continuous Spectral Measurements

- 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.
- Important atmospheric correction information and calibration feedback is contained within the spectral measurement.



# Science Rationale
# STM Ecosystem Function and Diversity

Summary STM

| Science Objectives | Measurement Objectives | Measurement Requirements | Instrument Requirements | Other Mission Requirements |
|---|---|---|---|---|
| **Ecosystem Function and Diversity** | | | | |
| Changes in regional and global extent of plant and plankton functional types (PFT) | Dominant PFT fractions (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology | PFT fraction uncertainty: ±10% | Imaging spectrometer: SNR: 600 VNIR, 300 SWIR (ZA=23.5°, 25% reflectance) | Surface reflectance for solar zenith angles ≤70° |
| | | Annual products of ≤ monthly observations | >95% abs. radiometric cal., >98% on-orbit rel. reflectance | Monthly lunar cal. maneuvers; design for daily solar cal. |
| | | Sampling $10^5$ $m^2$ patches | ≤60 m pixels | ~840 Mbps raw data rate |
| | | Regionally important PFT | | Regional algorithm development |
| | (a) Dominant functional types (aquatic): e.g. phytoplankton (diatoms, dinoflagellates, coccolithophores, N-fixers), kelp, seagrass, mangroves, *Spartina*, etc.<br>(b) Aquatic biogeochemical constituent: (phytoplankton, sediment, CDOM, benthos) | 380-2500 nm reflectance, high dynamic range (dark aquatic targets near bright surfaces) | SNR—violet/blue/green: 400:1, yellow/orange/red: 300:1, wavelength >900 nm: ≥100:1; 14 bit digitization | Terra-like sun-synchronous, repeat-track, low Earth orbit; local equatorial crossing time:10:30 to 11:30 am |
| | | Global coverage: full resolution for shallow water < 50 m deep and coarse resolution (~1 km) data for deeper water | > 99.5% radiometric calibration relative stability | Reversible high resolution data calibration |
| | | | Rapid (<2 pixel) bright target recovery (no significant ringing) | High-throughput on-board processing for spatial aggregation of open ocean data |
| Changes in spatial extent of certain diagnostic species | Diagnostic species/taxa: e.g., (terrestrial) pine, juniper, larch, *Cecropia*; (aquatic) sea grass, live coral, *Trichodesmium*, diatoms, dinoflagellates | Regional coverage with annual products | >95% cross-track uniformity & spectral uniformity | Data corrected for atmosphere & observing geometry |
| Changes in global extent of ecosystems | Refined ecosystem types (terrestrial): e.g. grasslands, shrublands, broadleaf evergreen forests, needleleaf evergreen woodlands, etc. | Classification accuracy ≥90% | High-fidelity imaging spectrometer: 0.4 - 2.5 µm; ≤10 nm resolution; >99% linearity (2 to 98% saturation) | Landsat-like sun-synchronous, repeat-track orbit; local equatorial crossing time 10-11 am |
| | Refined ecosystem types: (a) shallow/clear water: tropical coral reef, macroalgal beds, sediments; (b) shallow/turbid: estuaries, river plume, harmful and benign blooms; (c) lakes | Annual products of ≤ monthly observations | High-fidelity imaging spectrometer: 0.38 - 2.5 µm; polarization sensitivity <2% | Rigorous cal/val program |
| | | | No significant cross-talk between bands, stray light, or ghosting (<0.2% ocean TOA) | Pointing strategy to avoid sunglint pattern and hot spot |

# Science Rationale
# STM Biogeochemical Cycles

Summary STM

| Science Objectives | Measurement Objectives | Measurement Requirements | Instrument Requirements | Other Mission Requirements |
|---|---|---|---|---|
| **Biogeochemical Cycles** | | | | |
| Environmental change effects on productivity, carbon storage and biogeochemical cycles of ecosystems; | Refined ecosystem types | ≥90% complete for ice-free land and coastal/marine waters shallower than 50 m deep | Average duty cycle 12-15% at full resolution | Weekly science processing: 9-10 Tbytes of spectrometer data |
| | Leaf and canopy water content (terrestrial) | Quantify liquid water and water vapor absorption | Spectral resolution ≤10 nm for 800-1300 nm range | Compatible data over full seasonal cycles |
| | Phytoplankton type and benthic type (aquatic) | Quantify phytoplankton cell sizes, N-fixers; substrate living, non-living, seagrass, coral | Spectral resolution ≤10 nm for 380-2500 nm range | Linked automated observations using in situ observatories to assess water clarity and other parameters in real-time |
| | Leaf and canopy pigment and nutrient content (terrestrial) | Spectral feature analysis of the 400-2500 nm range | High data quality 400-750 nm, including UV-blue transition | Data corrected for atmosphere & observing geometry |
| How these effects feed back to other components of the Earth system | Community pigment and nutrient content (aquatic) | Spectral feature analysis of the 380-2500 nm range | Spectral range: 0.38 to 2.5 μm | Normalized water-leaving radiance |
| | Canopy light-use efficiency and gross/net primary production (terrestrial) | Pigment analyses, nitrogen analyses, canopy water data | Swath width: 145 km (baseline) | Revisit interval: Goal 3-5 days; Baseline 19 days |
| | | Canopy cover phenology data at weekly time scales | *Option:* 2nd spectrometer with ≥600 km swath | Modeling community engaged in product definition and evaluation. |
| | Community light-use efficiency and gross/net primary production (aquatic) | Pigment analyses, nitrogen analyses, fluorescence line height, CDOM, suspended sediment distribution | High SNR near solar-stimulated chlorophyll fluorescence peak (683 nm) | Access to ancillary data: Wind Speed, Mixed-Layer-Depth, Sea Surface Temperature |

# Science Rationale
# Ecosystem Response to Disturbance

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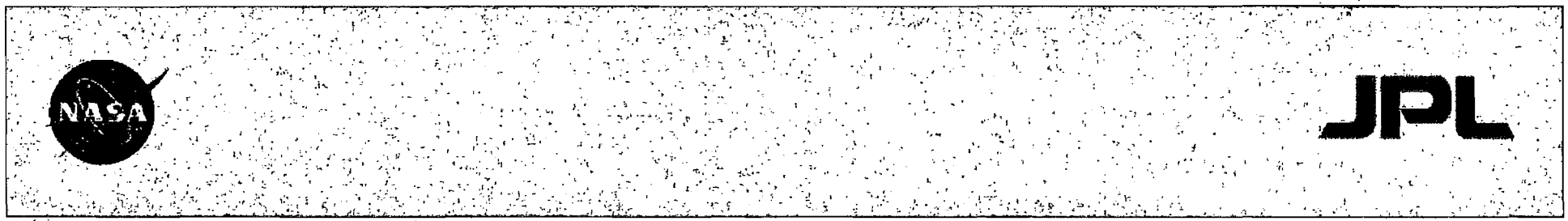
Summary STM

| Science Objectives | Measurement Objectives | Measurement Requirements | Instrument Requirements | Other Mission Requirements |
|---|---|---|---|---|
| **Ecosystem Response to Disturbance** | | | | |
| Disturbance effects on the distribution of ecosystems | Fractional cover of photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV), soil, ice/snow (terrestrial) | Cover uncertainty: ±5%; dynamic range: 5-95% | Spectral quality sufficient to control for variable soil reflectance in cover estimates | Mission life: 3 years; 6-year goal |
| | | Measured at 2 X $10^3$ $m^2$, changes at $10^4$ $m^2$ grain, sampling $10^5$ $m^2$ patches | Re-sampled effective ground resolution ≤ 120 m; pixel resolution ≤ 60 m | Time-tagging, pointing & position knowledge provide for ≤30 m mapping uncertainty (3 σ) |
| | Size and distribution of aquatic plant blooms and patches (including plankton and benthic species), colored dissolved organic carbon (DOC) and suspended sediment distrib. | Separate absorption effects due to pigments and CDOM; separate water column effects when assessing benthic cover | Spectral quality and resolution sufficient to control for CDOM and water column effects | Robust cross-discipline program (terrestrial and aquatic linked ecosystem studies, to examine ridges-to-reefs types of ecosystem linkages) |
| | Refined ecosystem types | Global coverage | Stable response (>99.5 %) over orbit segments ≥ 40 min. | 3-axis pointing control; with real-time position knowledge; robust cross-discipline program |
| Disturbance effects on the biodiversity of ecosystems | Fractional cover (terrestrial); Bloom/patch abundance | Detect and quantify fractional cover and phytoplankton abundance changes: ≥ 10% | Long-term: >95% absolute radiometric calibration, >98% on-orbit relative reflectance | Seasonally matched, stable, high-quality level 3 data |
| | (a) Dominant functional types; (b) Biogeochemical constituents (aquatic) | ≥ 80% complete per seasonal (≤ 96-day) re-observation | Average duty cycle 12-15% at full resolution | Operations optimized for seasonal repeat coverage |
| | Diagnostic species/taxa | Annual products of ≤ monthly observations | same as above | Consistent distribution data for diagnostic species (level 3) |
| Disturbance effects on the functioning of ecosystems | Fractional cover (terrestrial); Bloom/patch abundance | Full global coverage | Average duty cycle 12-15%; maximum: 2 orbits at 40% | Storage & downlink of ~1.9 Tbits in 2 orbits (2:1 data reduction) |
| | Leaf and canopy water (land); Phytoplankton type and benthic type (aquatic) | ≤ monthly observations and data products | same as above | Seasonally matched high-quality canopy water data (level 3) |
| | Pigment and nutrient content | Quantify changes in pigments/nutrients | same as above | Seasonally matched pigment & nutrient content data (level 3) |
| | Canopy/community light-use efficiency and gross/net primary production | Estimate the global amount and intensity of disturbance in modeling grid cells ½° × ½° | Aggregate duty cycle 40%, with coarse resolution data | Sufficient sampling to estimate disturbance distribution functions at ≤ 3000 $km^2$ scales |

# Science Rationale
# STM Ecosystems and Human Well-Being

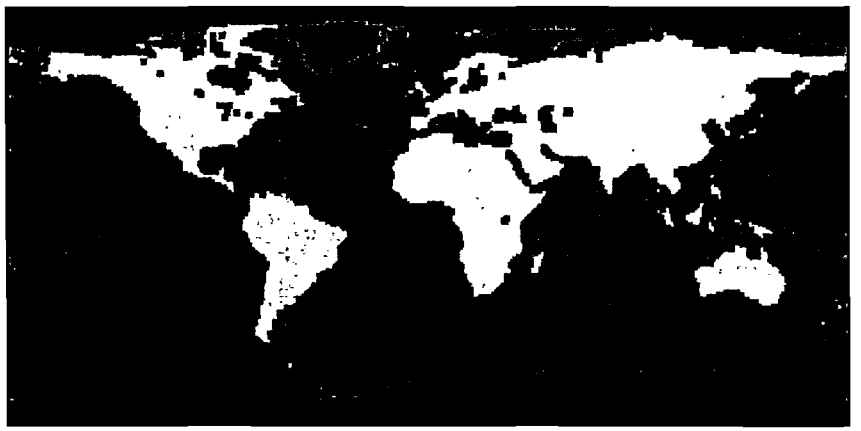
Summary STM

| Science Objectives | Measurement Objectives | Measurement Requirements | Instrument Requirements | Other Mission Requirements |
|---|---|---|---|---|
| Ecosystem change effects on human health, resource use, and resource management | (a) Dominant functional types; (b) Biogeochemical constituents (aquatic) | Annual products from ≤ monthly observations | >95% abs. radiometric cal., >98% on-orbit rel. reflectance | Watershed-based data retrieval for ridge to reef assessments |
| | Diagnostic species/taxa | Regional coverage | same as above | Simple off-track imaging requests |
| | Refined ecosystem types | Global coverage | Stable response (>99.5 %) over orbit segments (≥ 40 min.) | Decision support system development that includes ecosystem-based models |
| | Fractional cover (terrestrial); Bloom/patch abundance | ≤ monthly observations (more frequent for targeted events) | Swath width: 145-150 km | Revisit interval (tropics): 3-30 days (with cross-track pointing) |
| | Leaf and canopy water (land); Phytoplankton type and benthic type (aquatic) | ≤ monthly observations and products | Spectral resolution ≤10 nm | Comparable coincident data over full seasonal cycles |
| | Pigment and nutrient content | Spectral feature analysis of the 380-2500 nm range | Spectral range: 0.38 - 2.5 µm | Spectra corrected to apparent reflectance/normalized water-leaving radiance |
| | Canopy/community light-use efficiency and gross/net primary production | Pigments, nitrogen, canopy water content, phytoplankton type and benthic type | High SNR, particularly around solar-stimulated chlorophyll fluorescence peak | Global biosphere carbon-based production estimates |



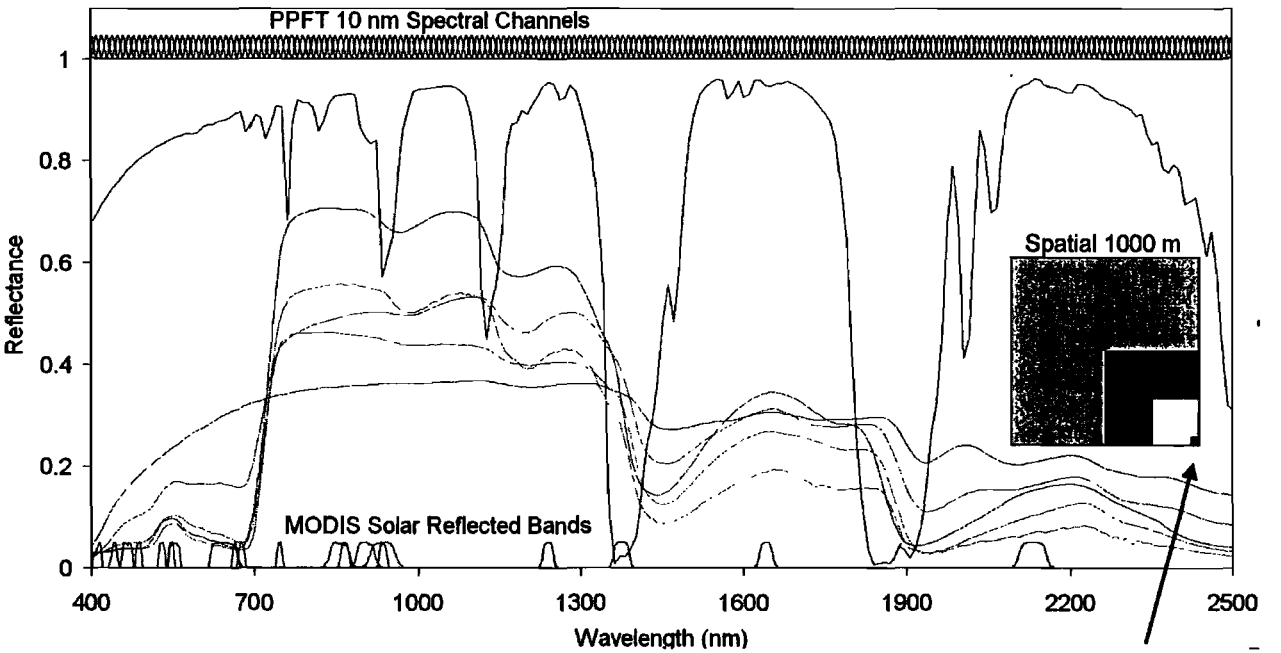

# Science Measurements

# Science Measurements Approach



- 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.



# Science Measurements
## Summary Measurement Characteristics

| | |
|---|---|
| **Spectral** | |
| Range | 380 to 2500 nm in the solar reflected spectrum |
| Sampling | <= 10 nm {uniform over range} |
| Response | <= 10 nm (full-width-at-half-maximum) {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 | >145 km (12 degrees at 700 km altitude) |
| Cross-Track Samples | >2400 |
| Sampling | <=60 m |
| Response | <=60 m 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} |

# Science Measurements
# Characteristics Continued

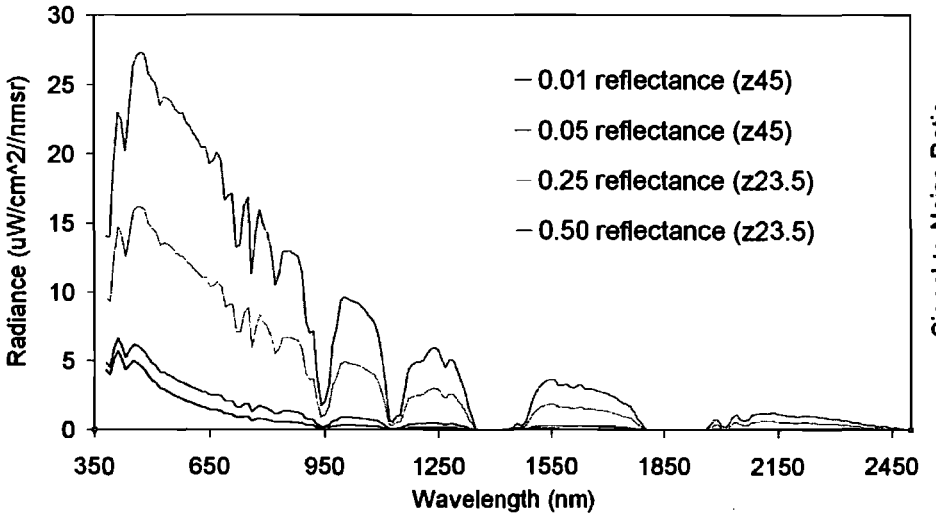
JPL

| | |
|---|---|
| **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 Avoidance** | |
| Cross Track Pointing | 4 degrees in backscatter direction |
| **OnOrbit Calibration** | |
| Lunar View | 1 per month {radiometric} |
| Solar Cover Views | 1 per week {radiometric} |
| 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 | Averaged to 1km spatial sampling |
| Compression | >=3.0 lossless |

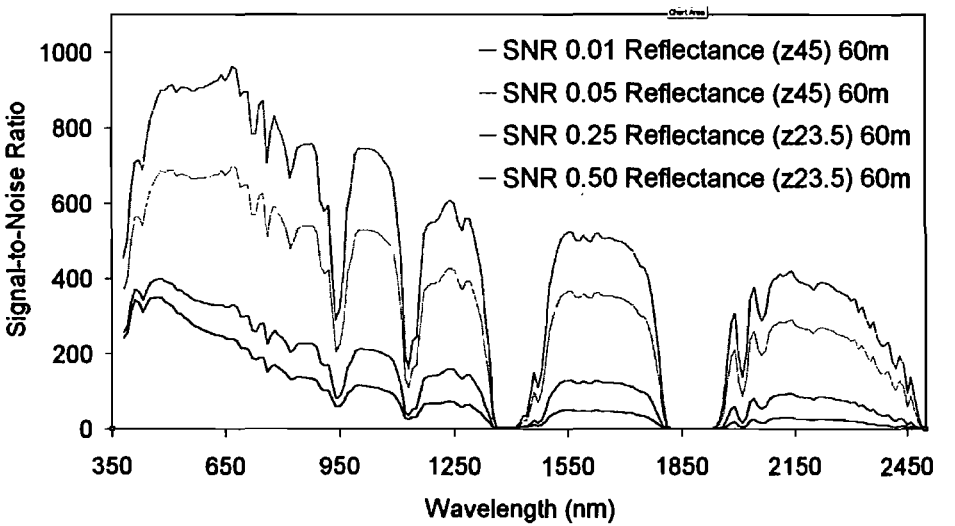
Science Measurements

# Key SNR and Uniformity Requirements

## Benchmark Radiances

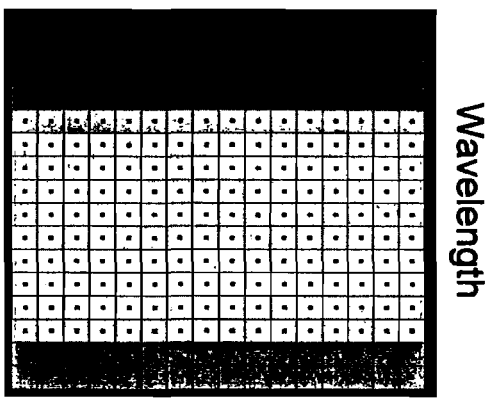



## Required SNR




## Uniformity Requirement

Cross Track Sample




**Depiction**

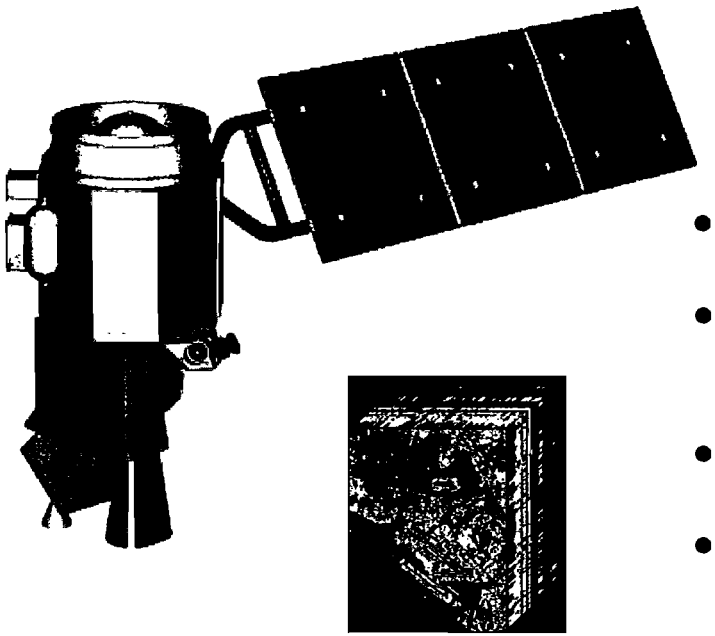
-Grids are the detectors
-dots are the IFOV centers
-Colors are the wavelengths

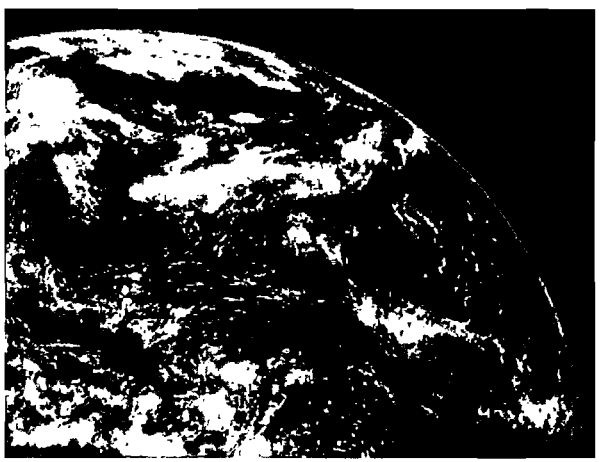
**Requirement**

| | |
|---|---|
| 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} |


# Mission Concept

# Mission Concept
# PPFT Overview

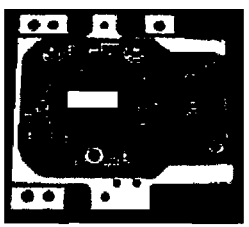




- Duration: 4 years implementation, 3 years science
- Coverage: Global land and coast/shallow water every 19 days
- 3 day event revisit capability
- Data are acquired over all reasonably illuminated areas (Sun elevation > 20 deg).
- Data download using dual-polarization X-band at high-latitude stations
- Instrument: 67W, 100kg, 1.6X1.6X1 m
- Spacecraft: LEO RSDO bus (SA-200HP)
- Launch: Taurus-class launch vehicle.

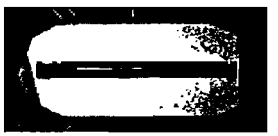
# Mission Concept
# Instrument: Offner Spectrometer

- The instrument design selected is an Offner imaging spectrometer with extensive relevant heritage
  - Hyperion, CRISM, COMPASS$^{air}$, TB$^{air}$, ARTEMIS, M3
- At the core of the PPFT instrument is a pair of f/2.5, high signal-to-noise ratio, uniform, full-spectral-range Offner spectrometers
- Each spectrometer has two full range detector arrays that cover the spectral range from 380 to 2500 nm @ 10 nm intervals with 610 cross-track spatial elements used
  - CRISM, TB$^{air}$, ARTEMIS$^{full_range}$, M3$^{full_range}$

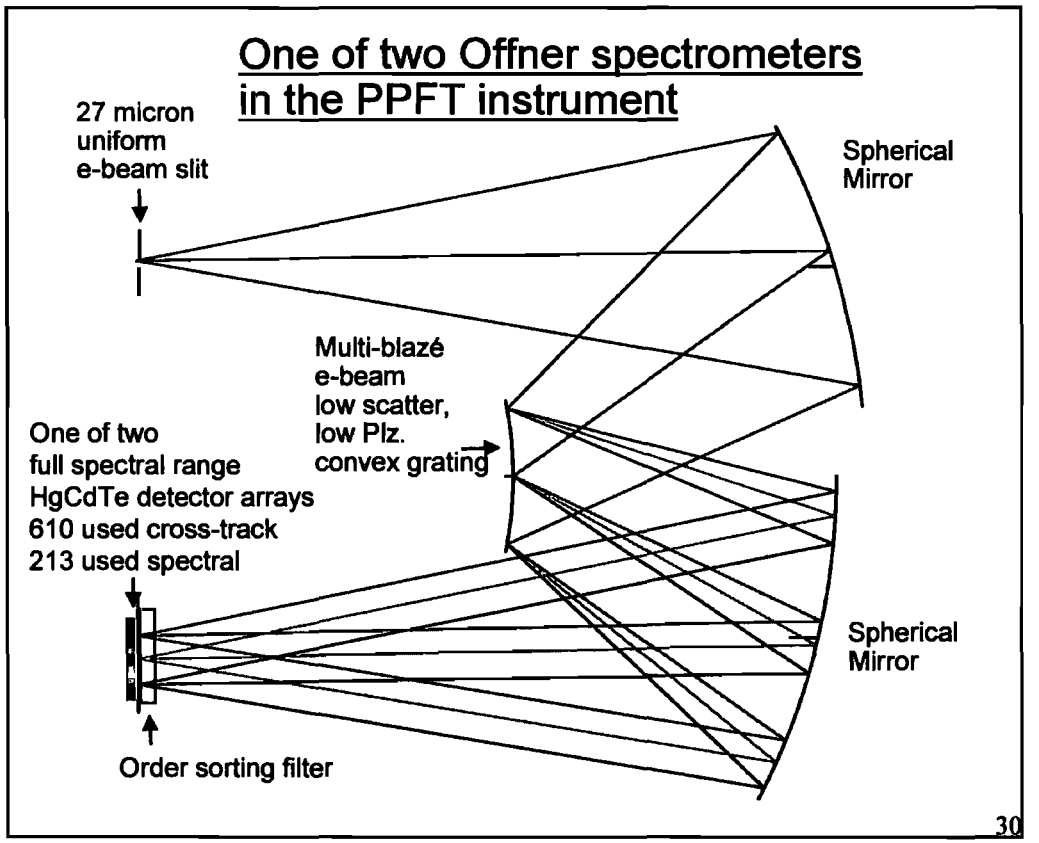


Full range Detector array and filter

Convex multi-blaze grating



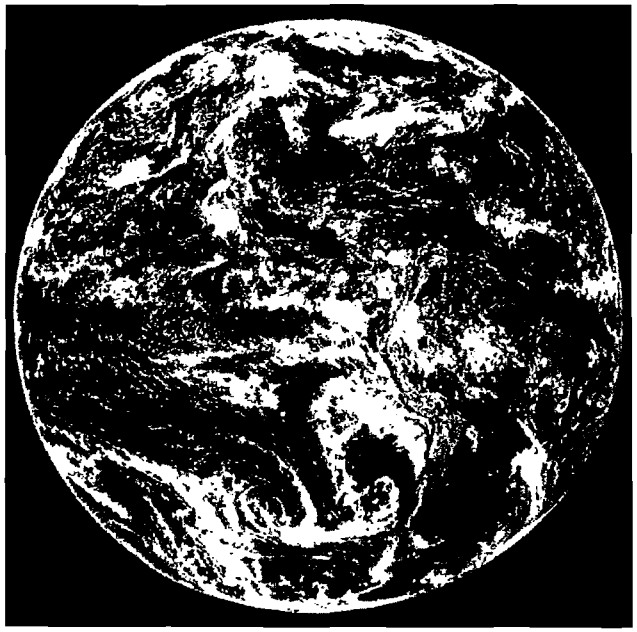
Uniform air slit

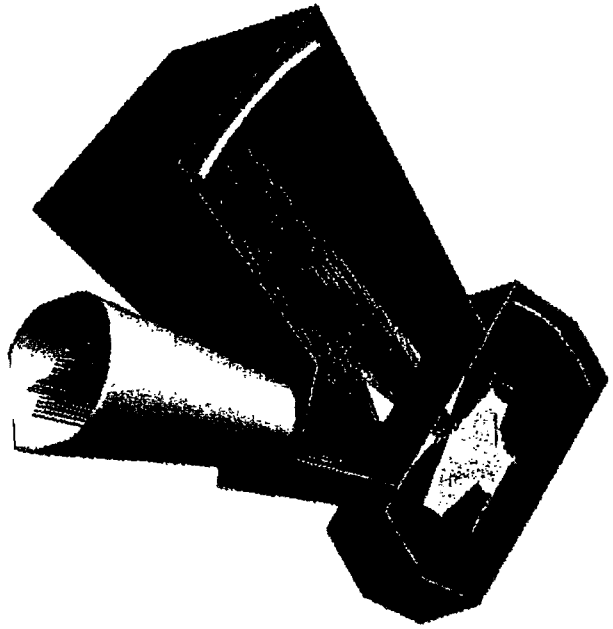


# Mission Concept
# Instrument with Telescope with Spectrometers

- The light from the PPFT telescope is field split in order to feed the two spectrometers (A,B).
- In each spectrometer two detector arrays provide 610 cross-track by 213 spectral detector elements.
- Each spectrum is read out as a snap-shot, so that there is no time delay, yaw, or jitter impact to the spectral-IFOV-uniformity

- Total coverage 2440 cross-track by 213 spectral
- Mirror coating for high reflectivity 380 to 2500 nm

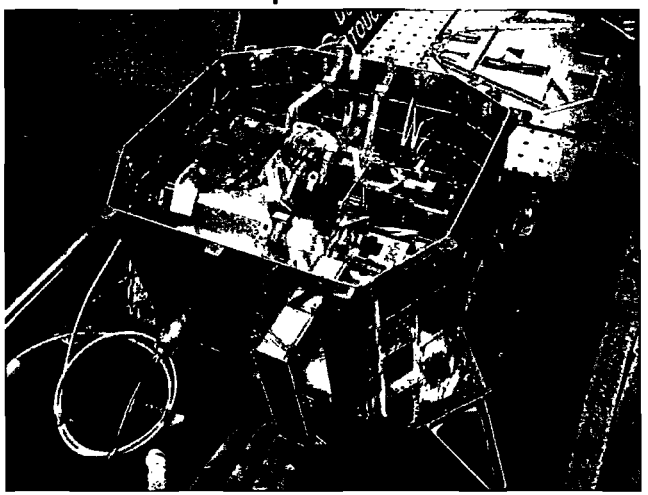




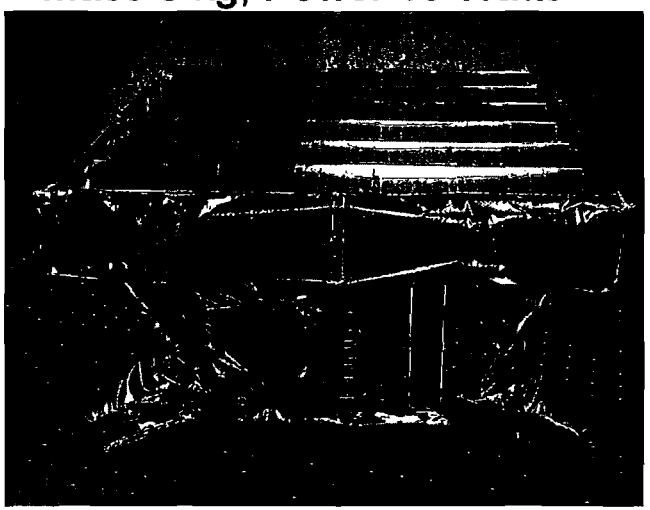
- Mirror surface specified for extremely low scatter
- Mirror orientations and coatings specified to minimize polarization < 2%
- Detectors and spectrometer are passively cooled

# Mission Concept
# Heritage: NASA Moon Mineralogy Mapper (M3)
## Called for in the NRC Decadal Survey

M3 Spectrometer

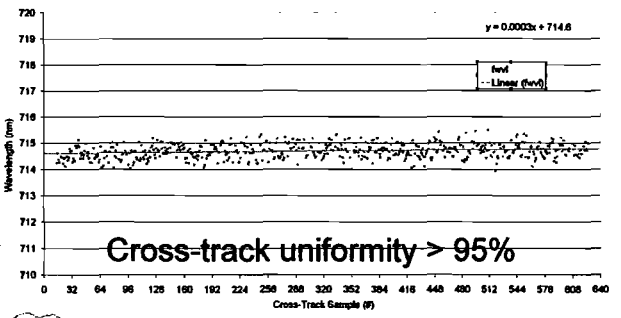


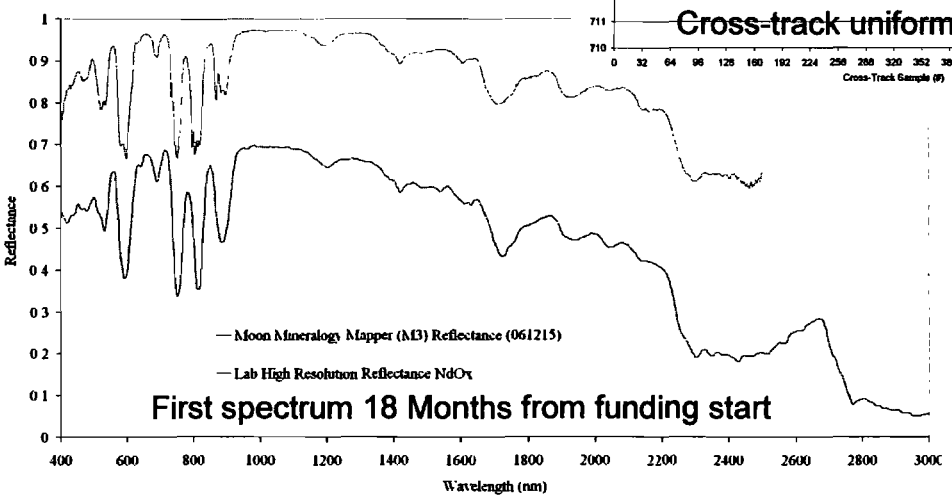
Mass 8 kg, Power 15 Watts



**Passed Preship review 3 May 2007**

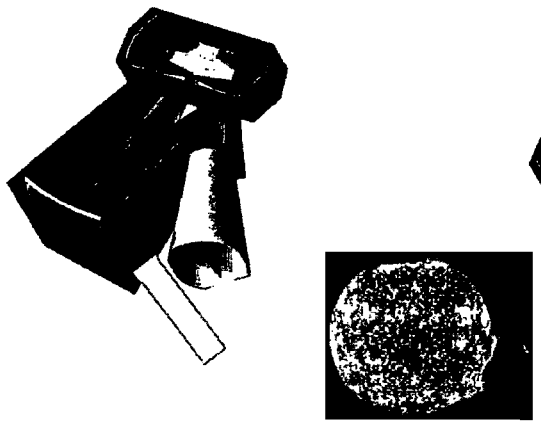
- Mouroulis Offner Design (PPFT)
- Convex e-beam grating (PPFT)
- 6604a MCT full range detector array, multiplexor & signal chain (PPFT)
- Uniform slit (PPFT)
- 0.5 micron adjustment mounts lockable for flight
- Aligned to 95% cross-track uniformity (PPFT)
- Aligned to 95% spectral IFOV uniformity (PPFT)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



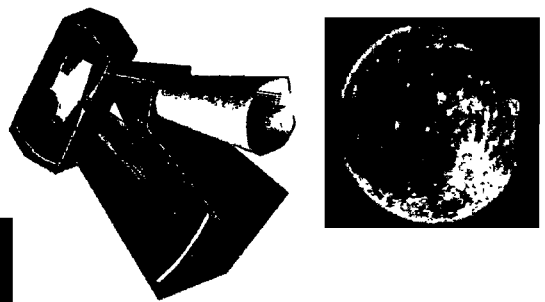



# Mission Concept
# Instrument Calibration

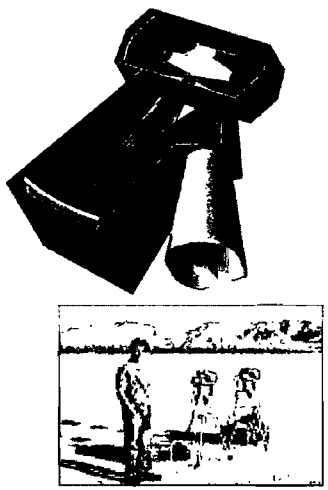
- Every week at the end of the sunlit pass, once the surface illumination is below threshold. The instrument cover will be brought to 45 degrees of the closed position and be illuminated by the sun with the spacecraft holding an inertially fixed attitude.
- Once a month (fixed Moon phase), the spacecraft attitude will be adjusted during the eclipsed part of the orbit to make the Moon cross the instrument field-of-view.
- Three times a year, calibration data of chosen test sites will be acquired.



Solar Calibration

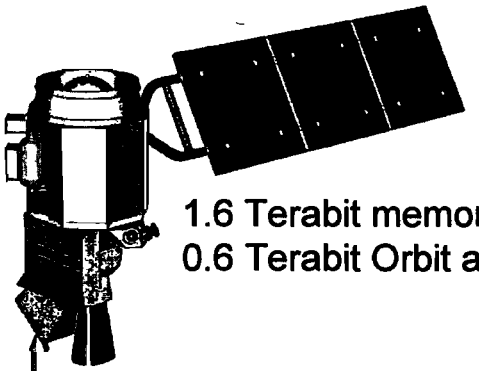


Lunar Calibration

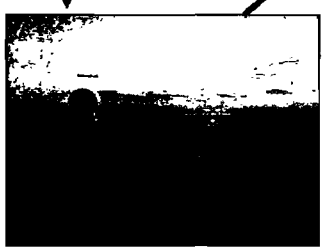


Ground Calibration

# Mission Concept
# Ground Data System



1.6 Terabit memory
0.6 Terabit Orbit average 3X compressed



Polar Ground Station
X-band dual polarization
640 mbits/sec
7 min/orbit average

Science Data Processing and Distribution Center
Level 1, 2 and selected Level 3

Instrument Science Team

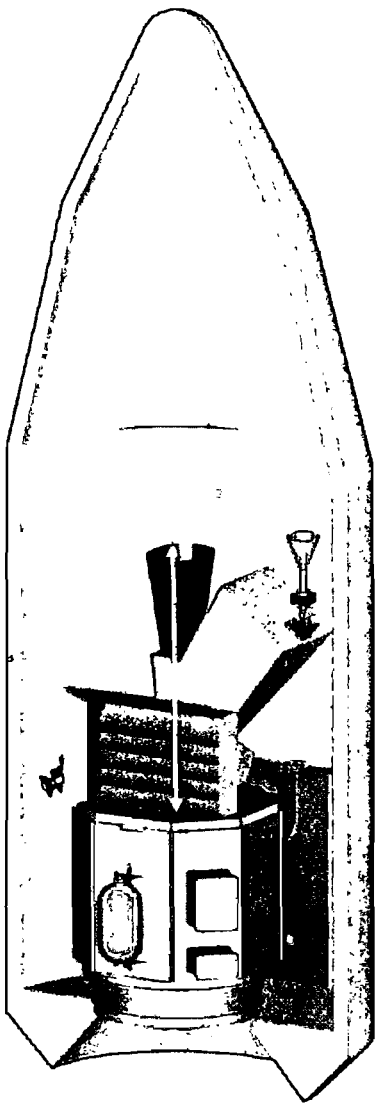
Multidisciplinary Science Team

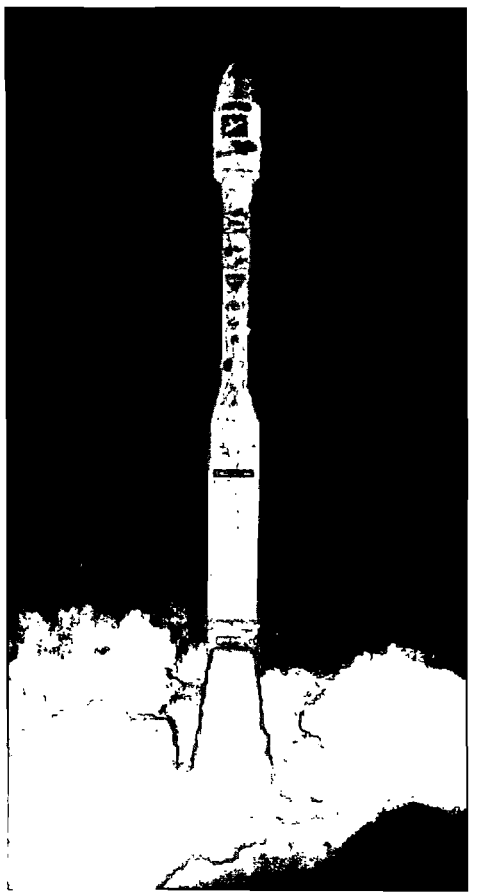
| PPFT Terabytes of Data | Uncompressed | Spectral Compressed |
|---|---|---|
| Orbit Average | 0.26 | 0.09 |
| 1 Day | 3.80 | 1.27 |
| 19 Days | 72.12 | 24.04 |
| 1 year | 1385.54 | 461.85 |
| 3 years | 4156.62 | 1385.54 |
| North America one season composite | 2.90 | 0.97 |
| Global one season composite | 18.19 | 6.06 |
| Cost of one Terabyte disk in 2007 | $400.00 | $400.00 |

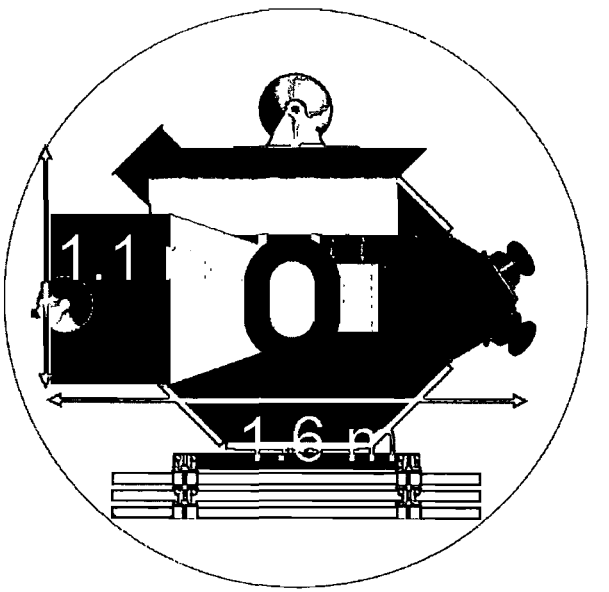
# Mission Concept
# Launch Vehicle

**Taurus 3210**

**Capability to 694 km sun-sync (per KSC website): 765 kg**






JPL

# Summary

# Summary
# Plant Physiology and Functional Types

JPL

Three fundamental components required for understanding ecosystems are: **function**, **composition**, and **structure**.

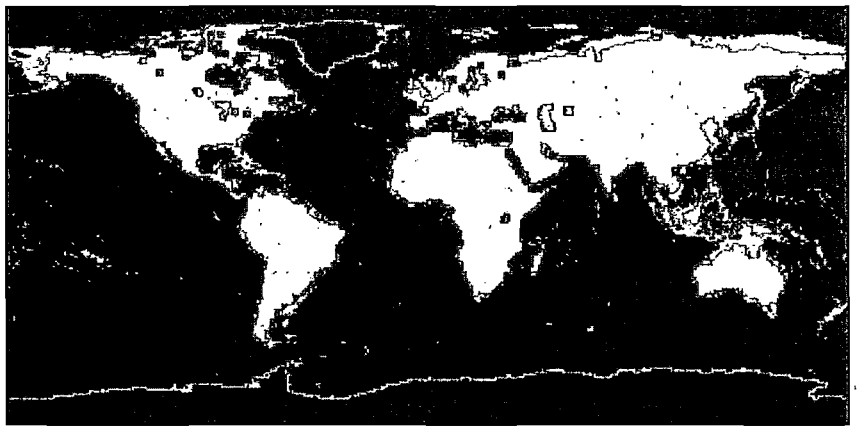
This mission for the first time provides global measurements of **function** with vastly improved measures of **composition** including biodiversity.

The science, measurements, and algorithms enabling this mission have been consistently demonstrated with antecedent airborne and ground measurements and experiments.

This PPFT mission addresses a set of compelling science questions that have been repeatedly identified as critical to science and society by independent assessments and scientific panels. Recent examples include: the NRC Decadal Survey, the 4th assessment of the IPCC and the Millennium Ecosystem Assessment (2005).

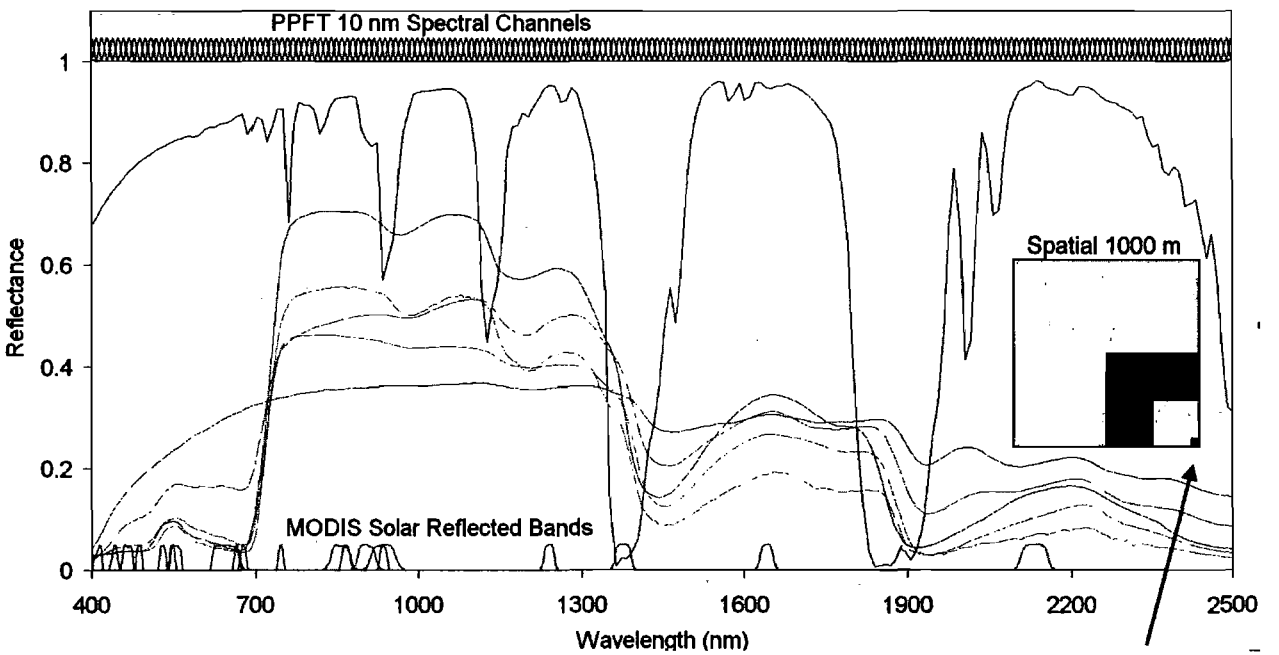
The PPFT instrument and mission have high relevant heritage, and correspondingly low risk, in conjunction with a modest cost.

# Summary
# Approach



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

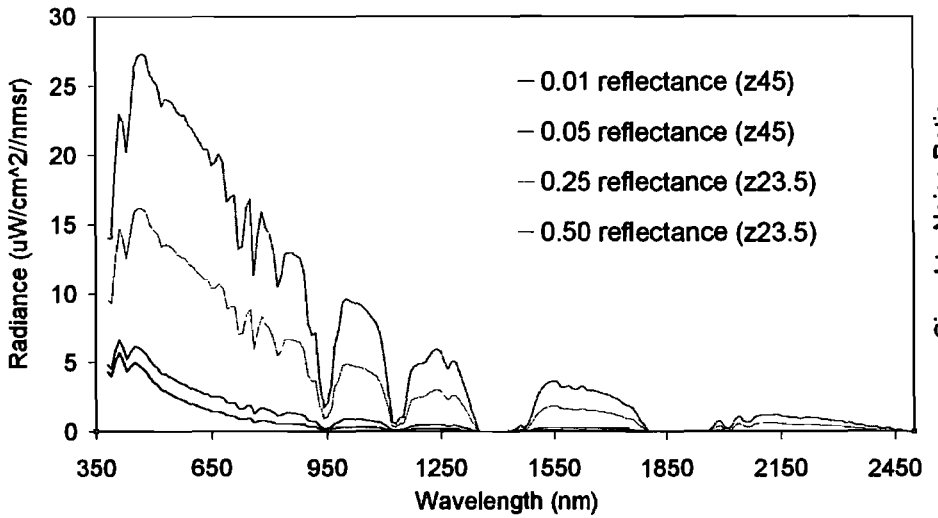
- Measure the molecular absorption and constituent scattering signatures in the spectral range from 380 to 2500 nm at 10 nm, and at 60 m spatial sampling.



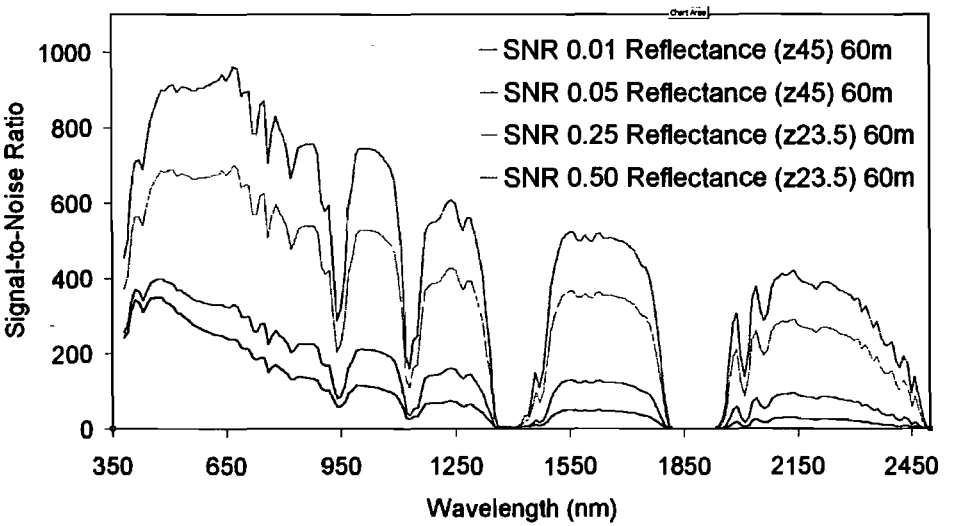
Summary

# Key SNR and Uniformity Requirements

## Benchmark Radiances

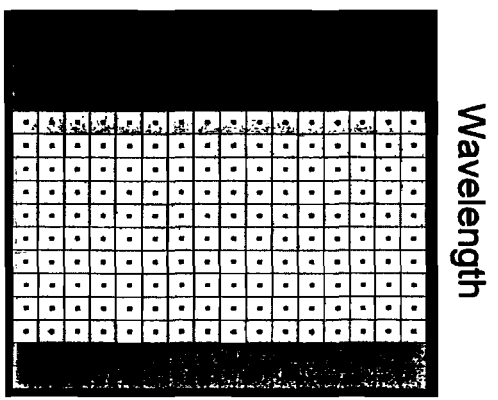



## Required SNR




## 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} |
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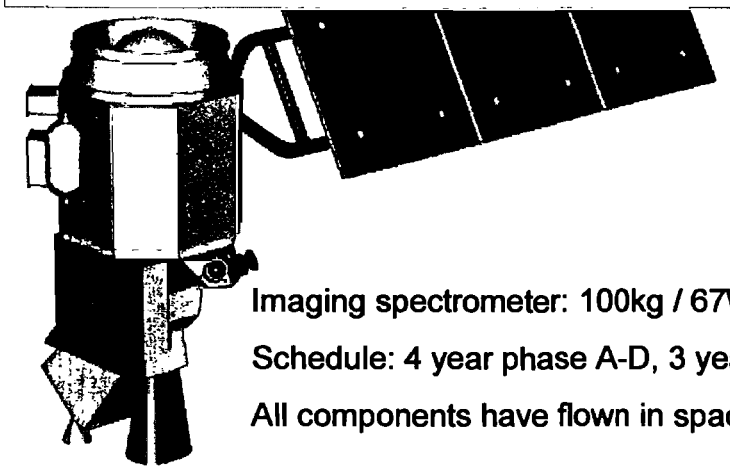
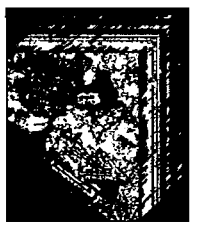
# Plant Physiology and Functional Types
# NASA Mission Concept Study

JPL





Imaging spectrometer: 100kg / 67W

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

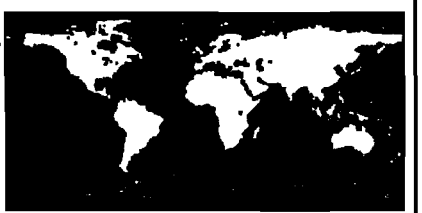
All components have flown in space

*Science Questions:*

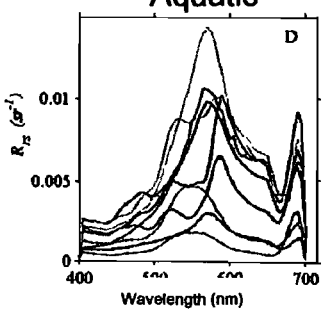
- *What is the composition, function, and health of land and water ecosystems?*
- *How are these ecosystems being altered by human activities and natural causes?*
- *How do these changes affect fundamental ecosystem processes upon which life on Earth depends?*

Measurement:

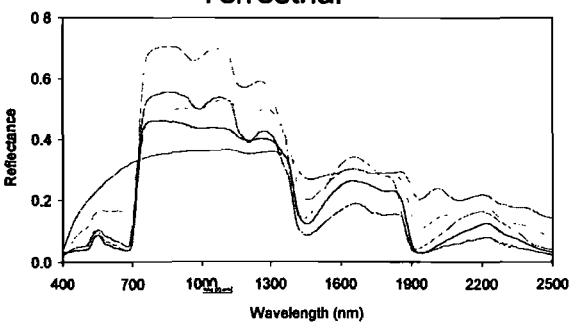
- 380 to 2500 nm in 10nm bands
- 60 m resolution
- 19 days revisit
- Global land and shallow water



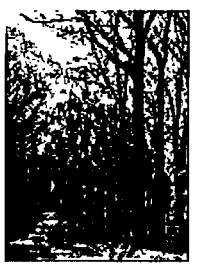
Aquatic

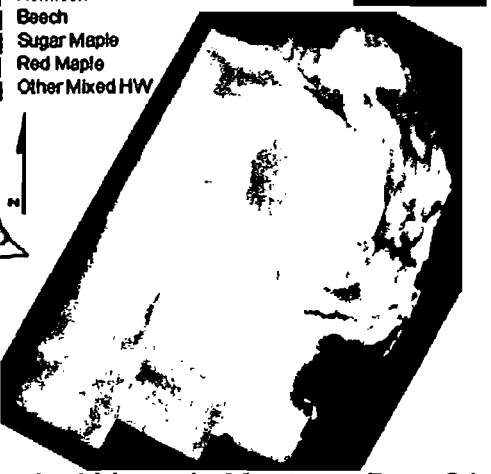



Terrestrial




Map of dominant tree species, Bartlett Forest, NH



Red tide algal bloom in Monterey Bay, CA

# End of File