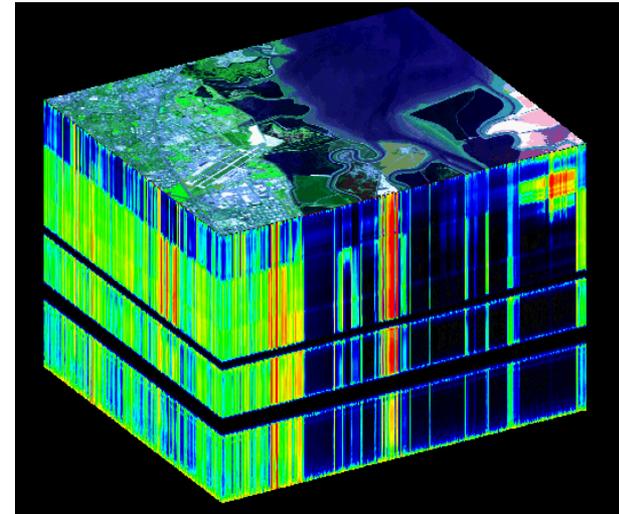
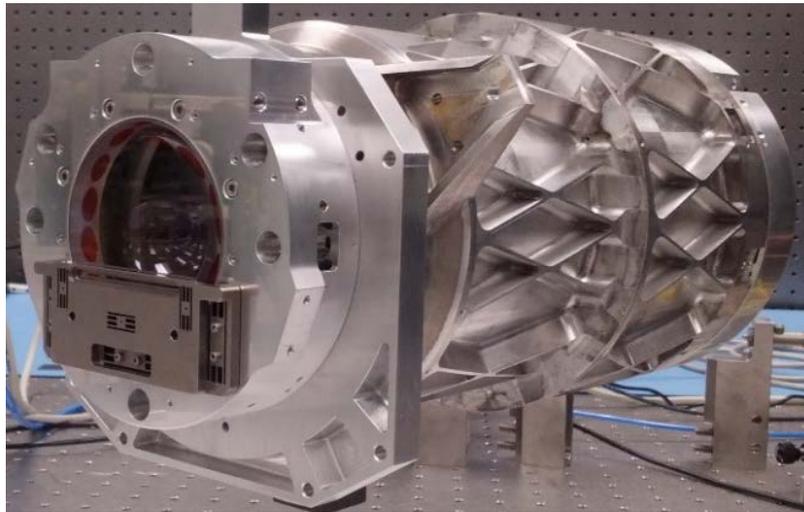




VSWIR-Dyson Imaging Spectrometer and an ISS option



Byron Van Gorp and Robert Green
Jet Propulsion Laboratory, California Institute of Technology



Overview



- Why a VSWIR-Dyson Imaging Spectrometer?
- Current VSWIR-Dyson Characteristics
- Optical Design
- Status Summary
- A quick study for an ISS option
- Characteristics
- Coverage
- Synergies
- Summary

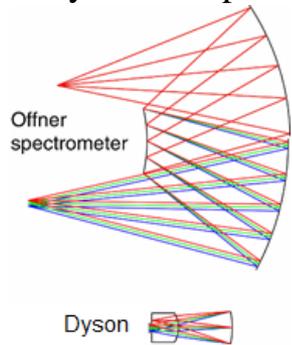


Why a VSWIR-Dyson?

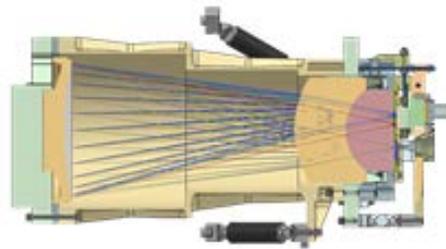


- Through FY13 HypIRI 60 m spatial has used an Offner imaging spectrometer based on the Discovery M3 imaging spectrometer heritage
- With 2014 technology and guidance in FY14 to look at synergies with the SLI program a VSWIR-Dyson imaging spectrometer approach was identified with a swath of 185 km at 30 m spatial consistent with a Pegasus launch
- The Dyson design form has higher throughput and is smaller for the equivalent performance and enables the SLI solution
 - An F/1.8 Dyson has 4 times the throughput of an F/3.6 (M3 on Chandrayaan-1)

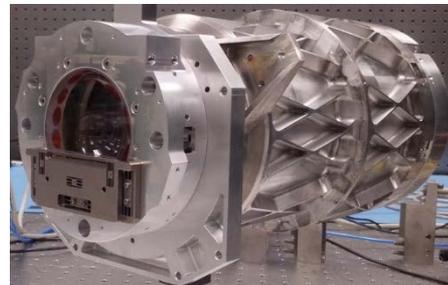
Offner to Dyson Comparison



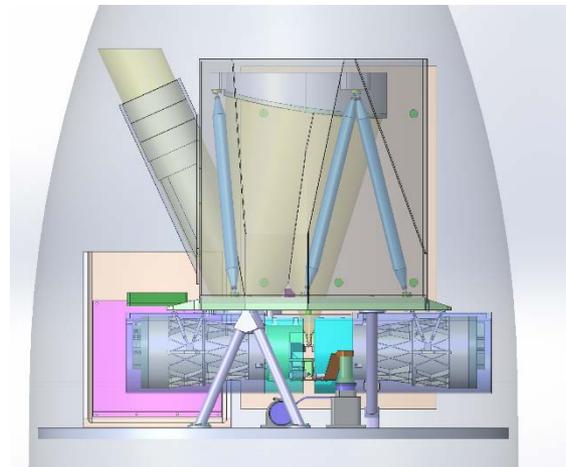
VSWIR Dyson (380-2510 nm)



Qualifiable Unit F/1.8



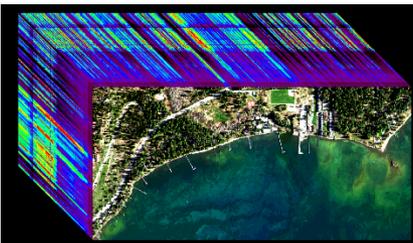
Payload supporting
185 km at 30 VSWIR



Configured
for Pegasus



PRISM is a Dyson (350-1050 nm)





Characteristics



The VSWIR Dyson is a compact imaging spectrometer system for the solar reflected spectrum (380-2500 nm) with wide swath (1280 or 1600 elements), fast optical speed (F/1.8), and high uniformity ($\geq 95\%$). The basic system specifications are given in below.

SPECTROMETER SPECIFICATIONS

Spectral	Range	380-2510 nm
	Sampling	7.4 nm
Spatial	Field of view	from telescope
	Instantaneous FOV	from telescope
	Spatial swath	1280 or 1600 pixels
Radiometric	Range	0 – 100% R
	SNR	See plot
Uniformity	Spectral cross-track	>95% *
	Spectral IFOV	< 95% **

*: straightness of monochromatic slit image (smile <3% of pixel width).

** : misregistration of spectrum to array row (keystone)



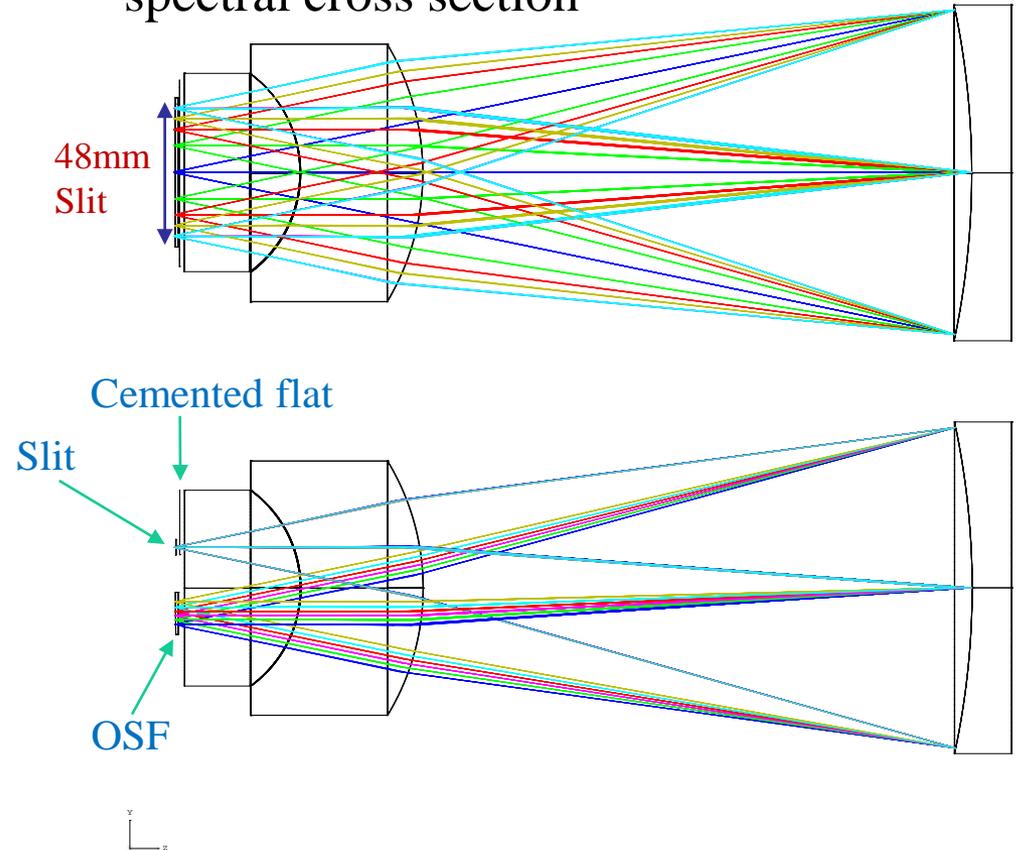
Optical Design



Spectrometer Optical Design:

- Challenging design because of large spectral range (380-2500 nm) and wide swath (48mm/1280 or 1600 pix).
- CaF_2 -Fused Silica doublet was required in order to meet spectrometer uniformity requirement.
- Dyson block has one cemented flat near spectrometer input.
- Spectrometer is 325mm end-to-end with a 125mm diameter grating.
- Diffraction grating substrate is post-polished diamond turned Aluminum.

VSWIR-Dyson spectrometer ray trace; top spatial cross section and bottom spectral cross section

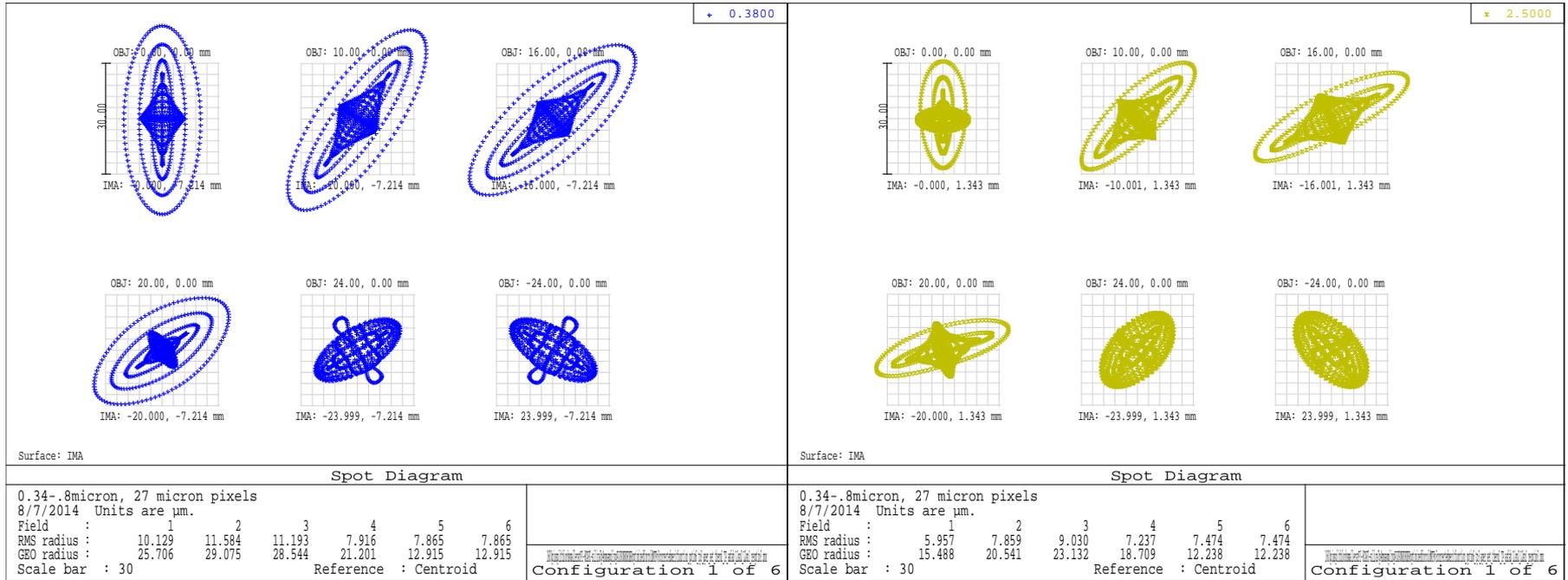


3D Layout
0.38-2.5micron, 30 micron pixels
8/12/2014
Scale: 0.6667
30.00 Millimeters



Optical Design

Spectrometer Spot Diagrams



380 nm

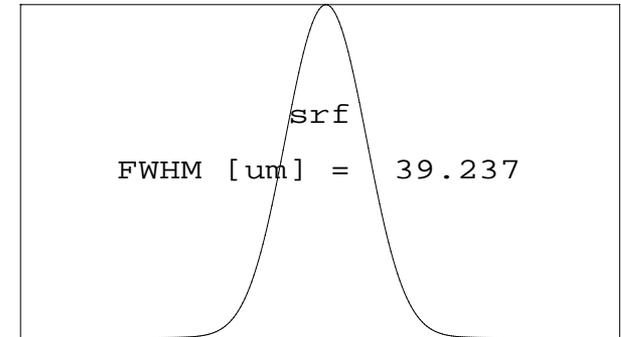
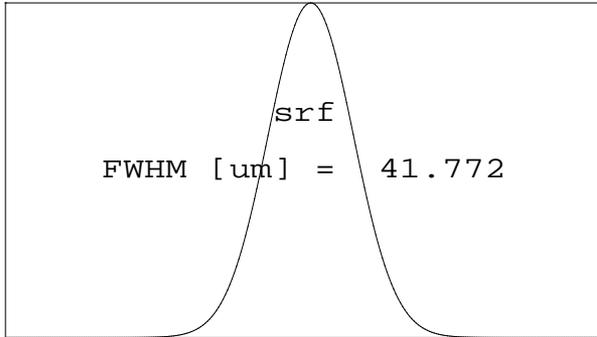
2500 nm

Box is 30 μm square

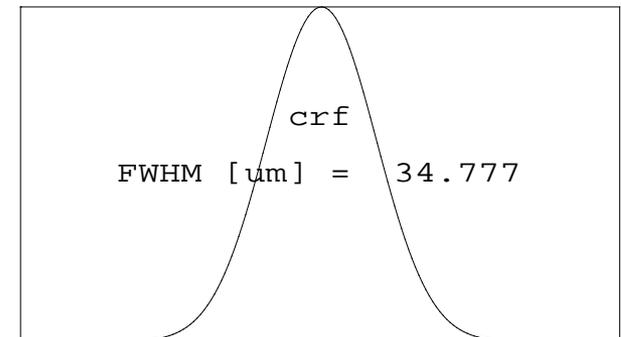
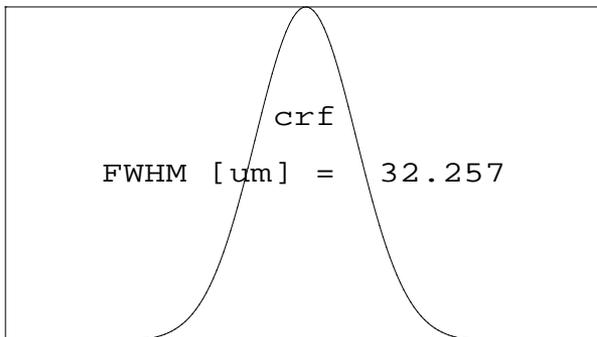
Uniformity errors: Smile 0.65% (0.2 μm), keystone 1% (0.3 μm) < 5%



Optical Design: SRF/CRF Variation



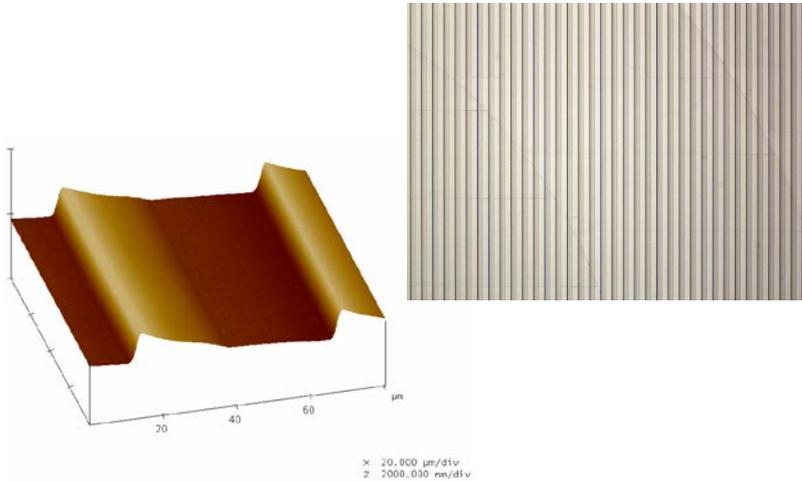
Spectrometer spectral response functions at 380 nm showing the worst-case variation (<6%) with field for all wavelengths and fields.



Spectrometer cross-track spatial response functions for 380 and 1600 nm wavelengths, showing the worst-case variation (<7%) with wavelength, for all fields and wavelengths.

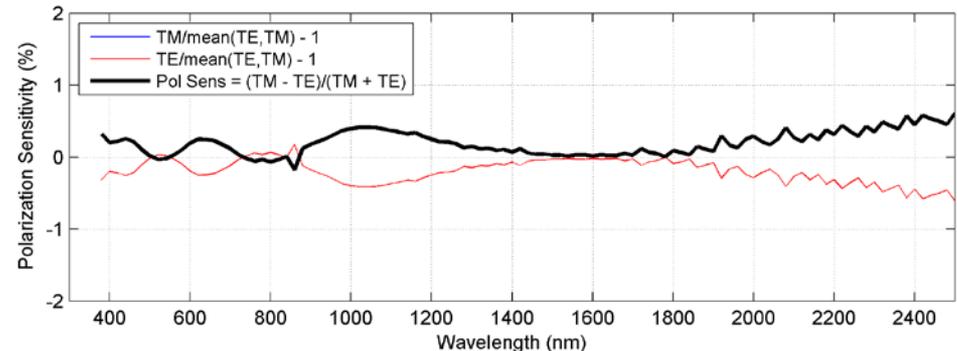
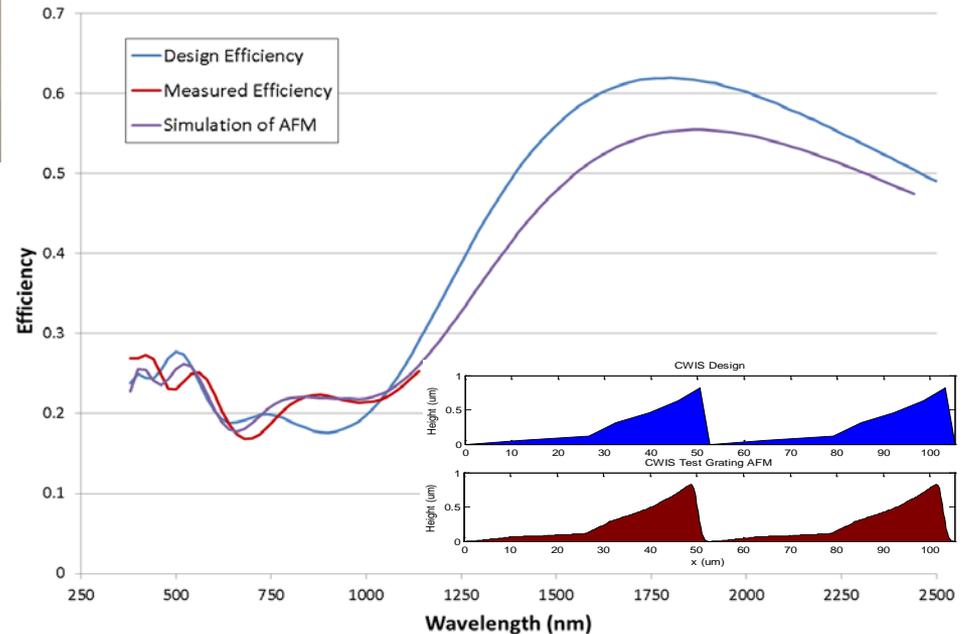


Optical Design: Diffraction Grating



- Groove shape tailored to provide higher efficiency toward longer wavelengths where solar output is weaker.
- The lower curve is the efficiency as derived from the fabricated (measured) groove shape.
- Diffraction grating contributes less than 1% polarization sensitivity.

Simulation of grating efficiency for measured and design groove shape





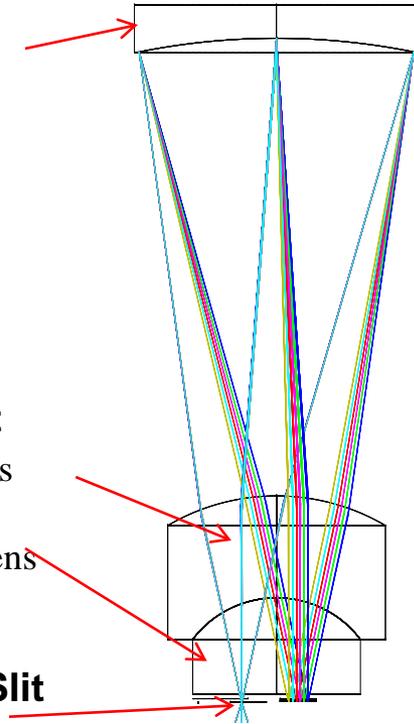
Optical Design

- **E-Beam Fabricated Grating**

- **Dyson Block Doublet**

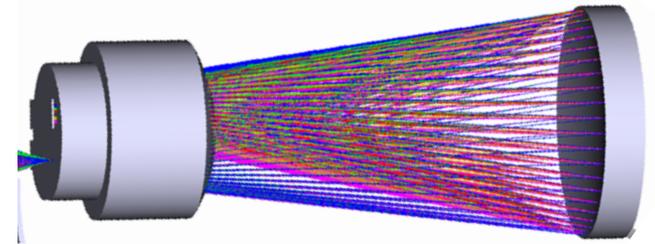
- Fused Silica meniscus lens
- CaF_2 Plano Convex Lens with Cemented Flat

- **E-Beam Lithographic Slit**



Optical Design Key Characteristics:

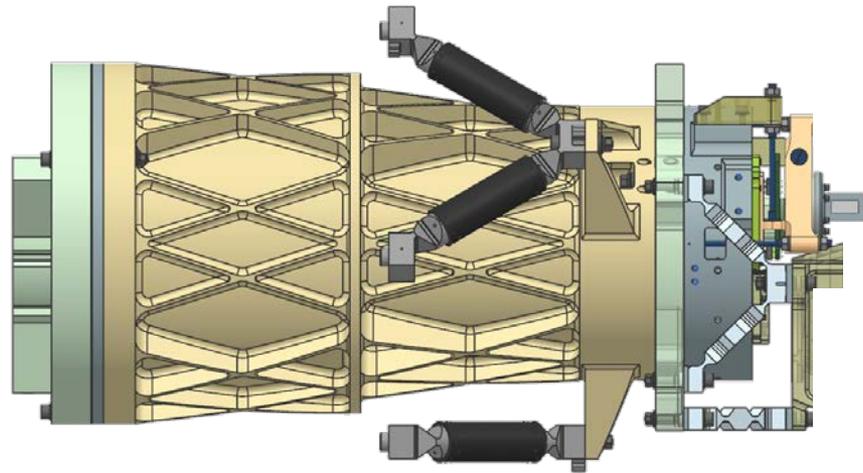
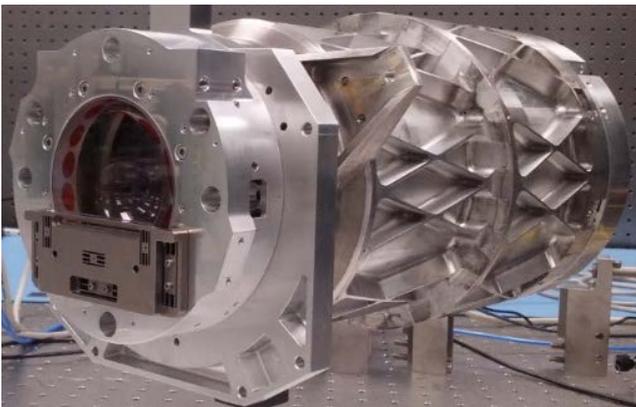
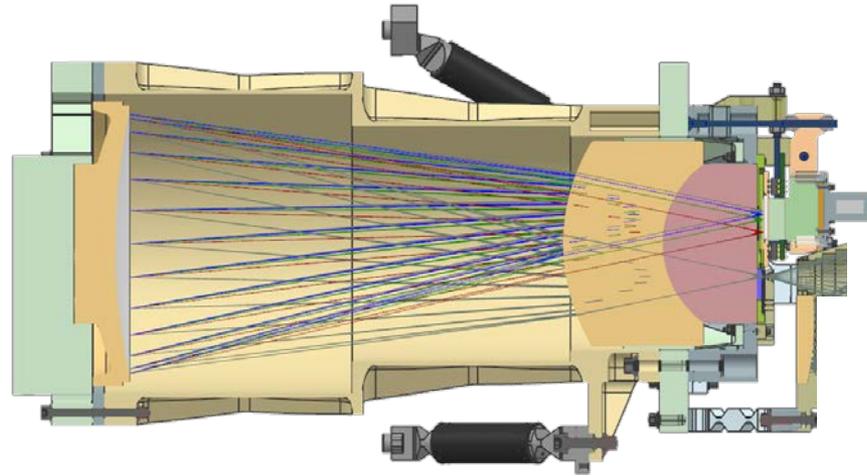
- Minimum number of optical components for high throughput
- Compact Wide-Field design
- Specially designed grating groove profile to tune SNR, reduce polarization dependence and minimize energy in negative orders
- Low angles of incidence on optical components



Instrument Status

- Assembly and warm test results are expected within the next few months.
- The estimated mass of the optical bench is 7 Kg.

Spectrometer assembly in cross section.





HyspIRI October 2014
VSWIR-Dyson Study for
ISS



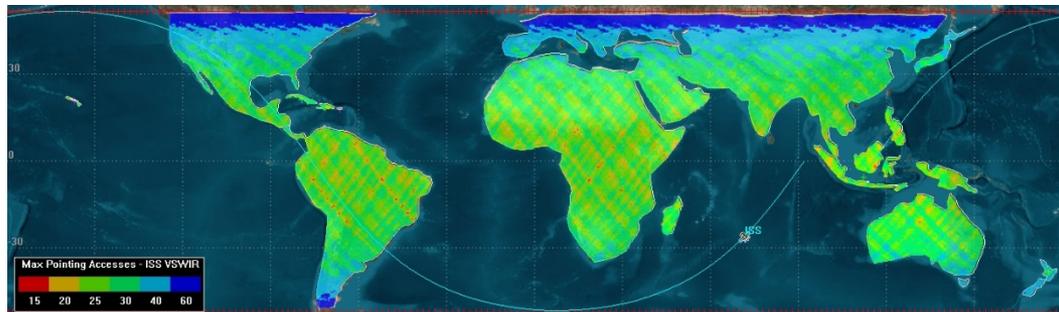
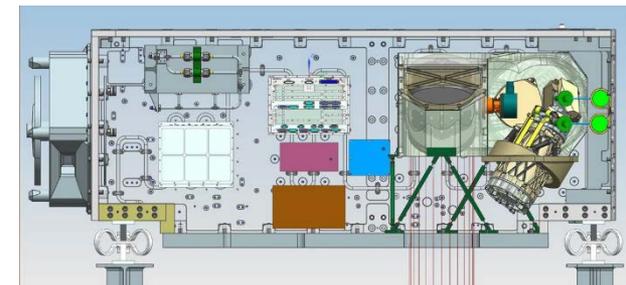
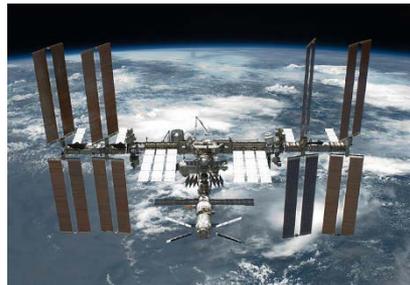
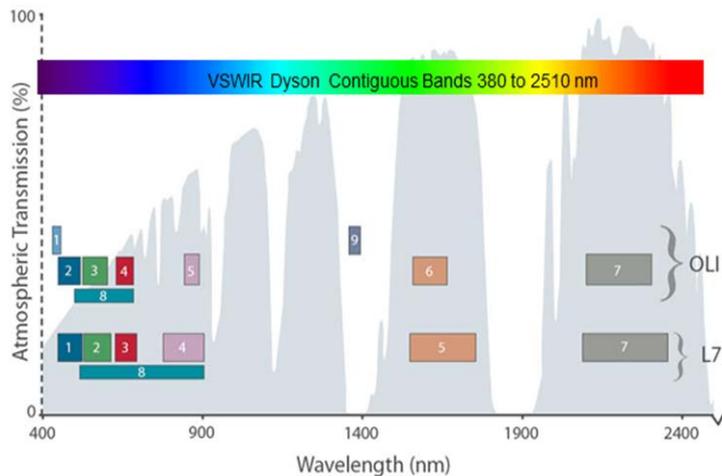
Key Demonstration Objectives



- Mature, Reduce Risk and validate the VSWIR-Dyson imaging spectrometer architecture to support future options for the SLI, HypsIRI, and other NASA Programs
- Delivery of Landsat bands with on-orbit convolution of imaging spectrometer measurements at 30 m spatial
- Demonstrate low distortion, high SNR full VSWIR-Dyson (380 to 2510 nm) imaging spectrometer with 30 m spatial
- Cross-calibration of LandSat & other Multi-spectral instruments
- Demonstrate Lossless spectral compression of $\geq 4X$
- Address subset of HypsIRI VSWIR Science and Applications objectives
- Enable new science in concert with ECOSTRESS and JEDI

Measurement:

380 to 2510 nm in 7nm bands
30 m spatial sampling





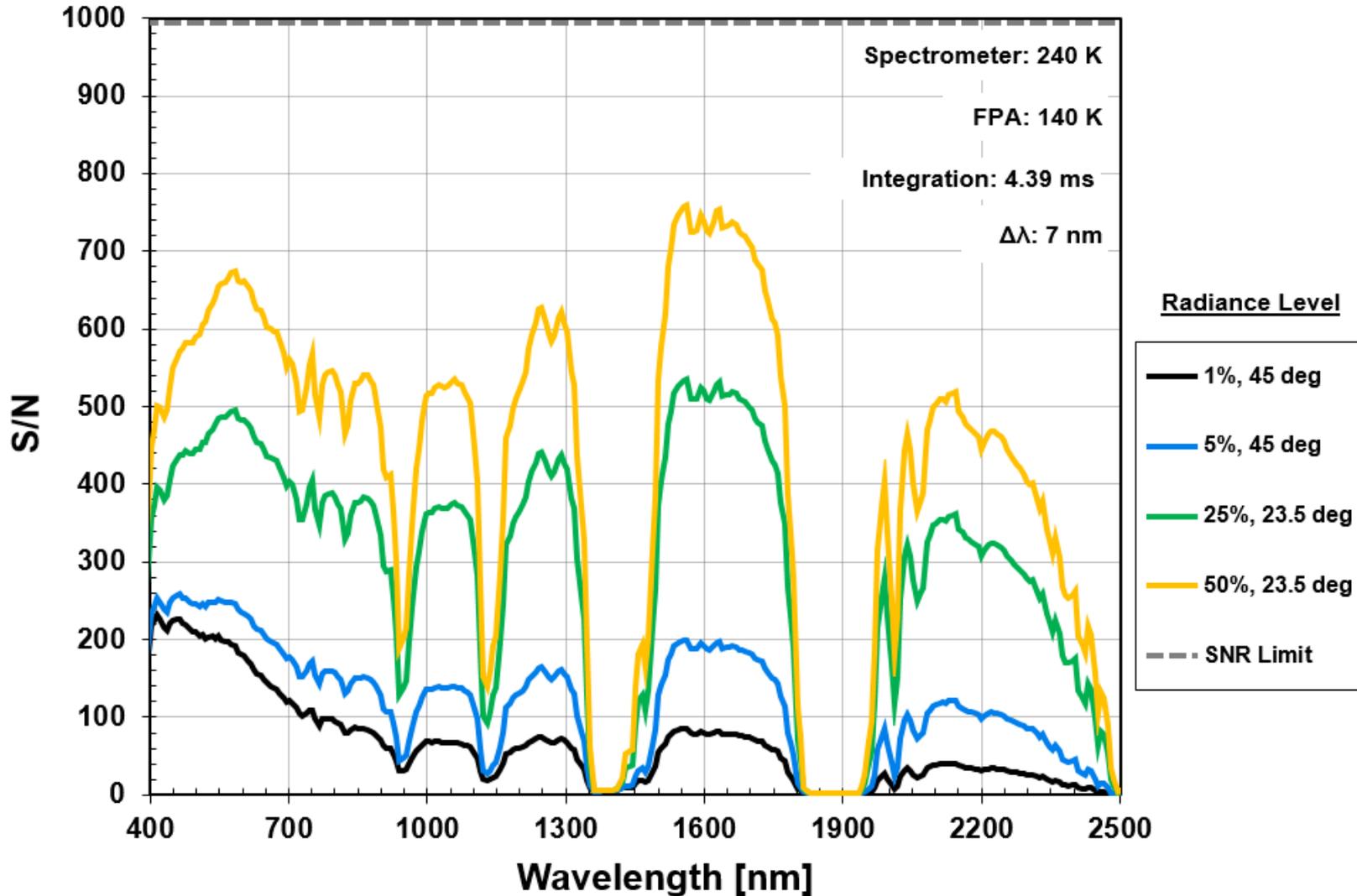
VSWIR Dyson Characteristics



- Spectral
 - Range ≤ 380 to ≥ 2510 nm in a single spectrometer
 - Sampling 7.4 nm {uniform over range}
 - Accuracy ± 0.5 nm
- Radiometric
 - Range & Sampling 0 to max benchmark radiance, 14 bits measured
 - Accuracy $\geq 95\%$ absolute radiometric
 - Precision (SNR) ≥ 600 in VNIR (550 nm) and ≥ 400 SWIR (2200nm)
- Spatial
 - Cross-Track Samples ≥ 1240 (+40 for monitoring)
 - Swath ≥ 37 km
 - Ground Sampling 30 m
 - Pointing ± 15 degrees, > 250 km
- Uniformity
 - Spectral Cross-Track $\geq 90\%$ cross-track uniformity
 - Spectra IFOV-Variation $\geq 90\%$ spectral IFOV uniformity



Signal-to-Noise Ratio @ 30m 4.39 ms

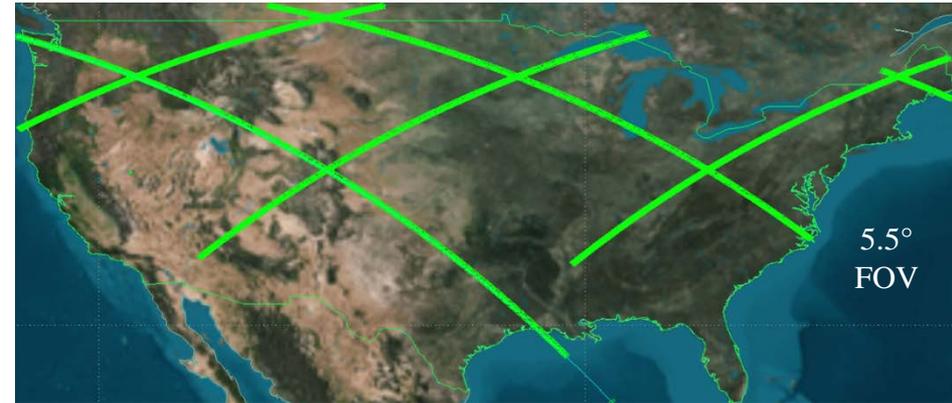




Coverage

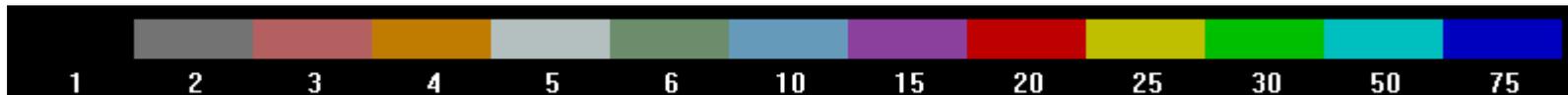
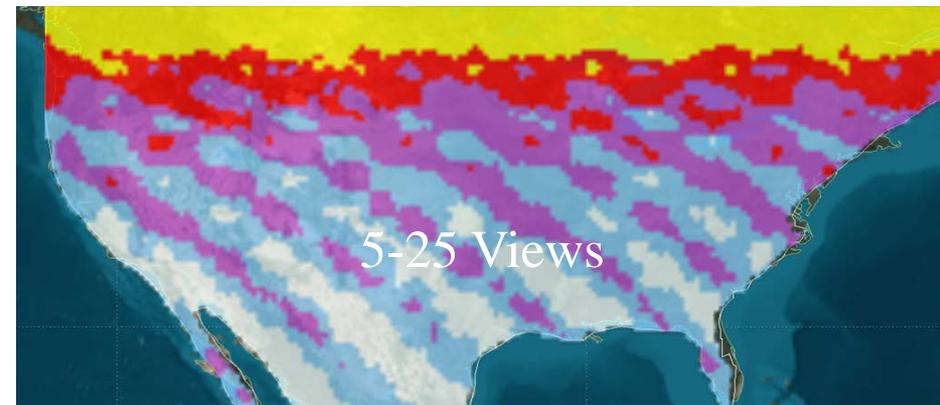
Field of Regard

Swath



3 months Full Coverage

1 year



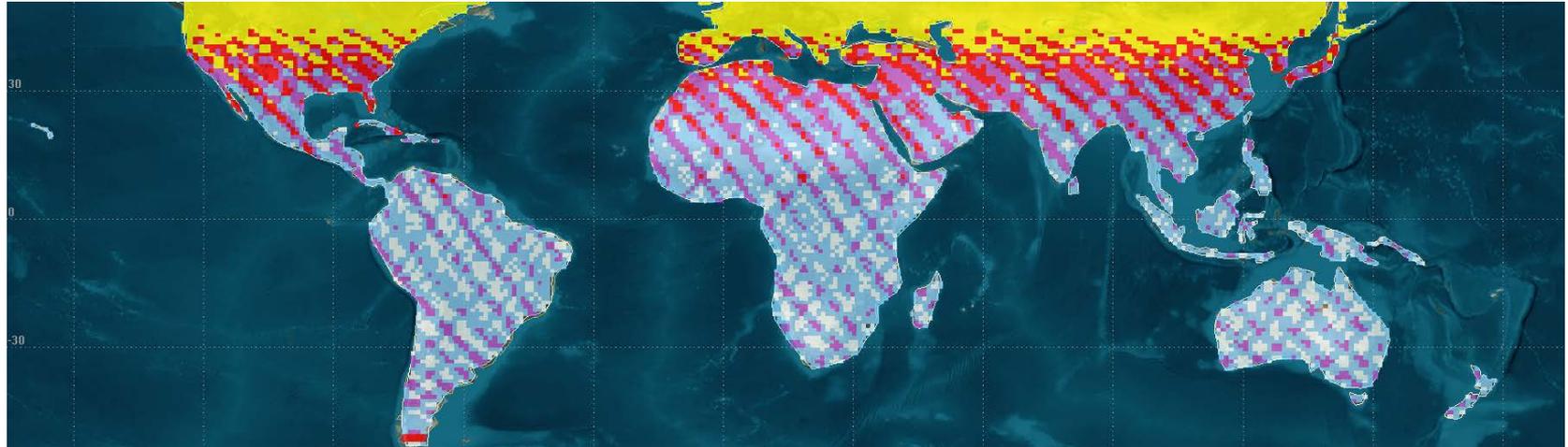


Global Capability 30.5° field of regard (FOR)

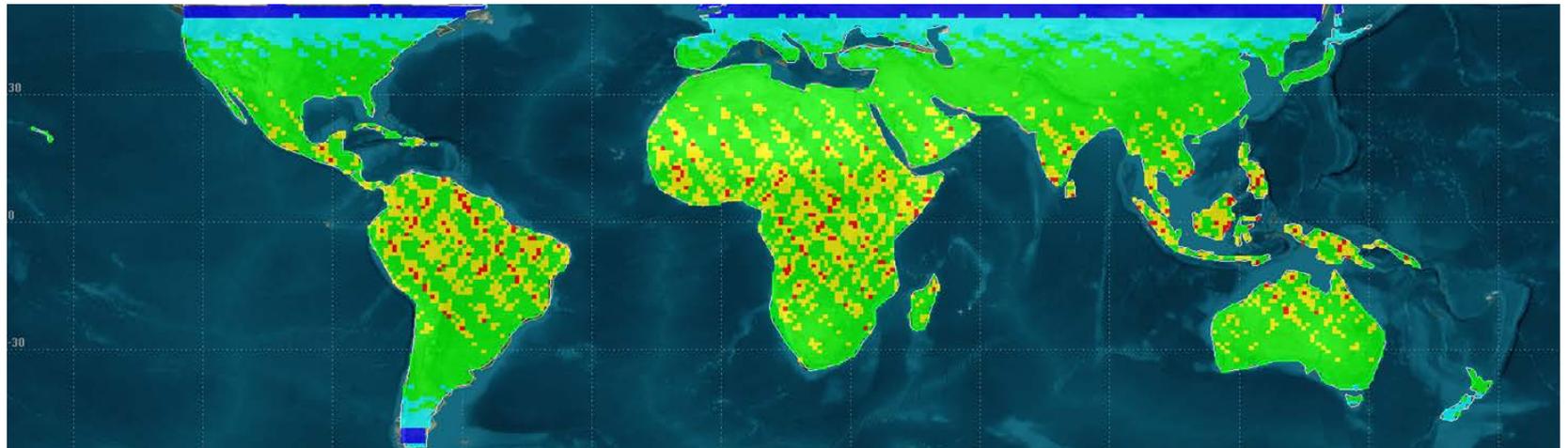


Number of Views

5 months coverage



1 year Views

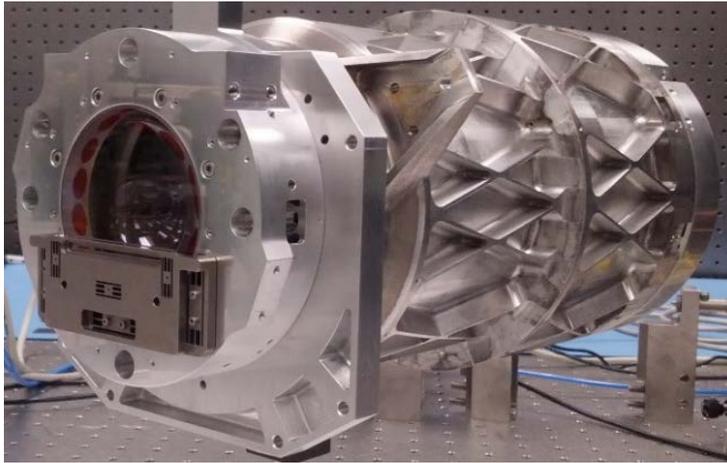




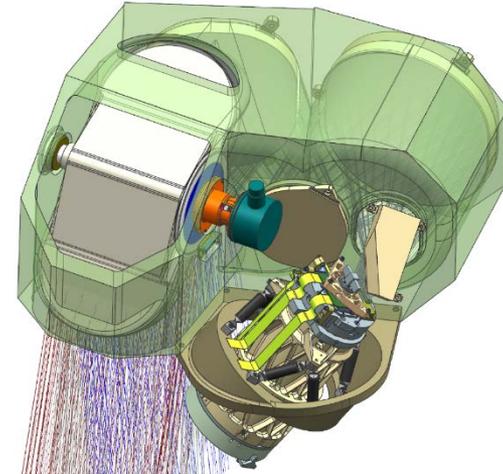
VSWIR-Dyson ISS Option



VSWIR-Dyson Spectrometer



Telescope and Pointing Mirror



Configured for JEM-EF



JEM-EF Locations





Synergy with GEDI and ECOSTRESS



GEDI LIDAR Global Ecosystems Dynamics Investigation

PI: Ralph Dubayah University of Maryland
 Deputy PI, Instrument: J. Bryan Blair NASA Goddard Spaceflight Center
 Deputy PI, Science: Scott Goetz Woods Hole Research Center

DEPARTMENT of GEOGRAPHICAL SCIENCES UNIVERSITY OF MARYLAND

ECOSTRESS

ECOsystème Spaceborne Thermal Radiometer Experiment on Space Station
 Dr. Simon J. Hook, JPL, Principal Investigator

ECOSTRESS will provide critical insight into **plant-water dynamics** and how **ecosystems change with climate** via **high spatiotemporal resolution thermal infrared radiometer measurements of evapotranspiration** from the International Space Station (ISS).

Water Stress Threatens Ecosystem Productivity

High Water Stress █ █ █ █ █ █ █ Low Water Stress

Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.

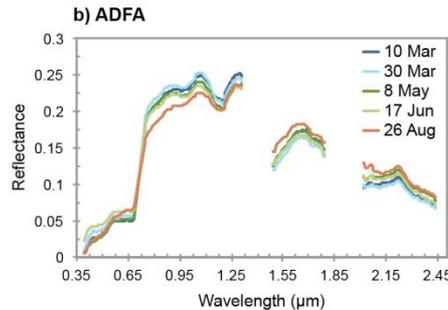
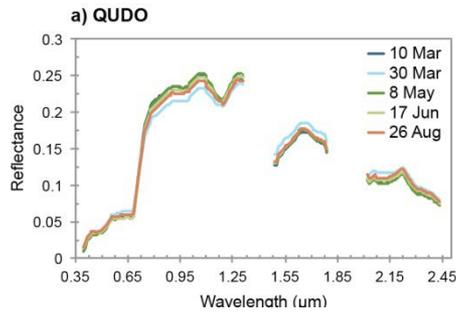
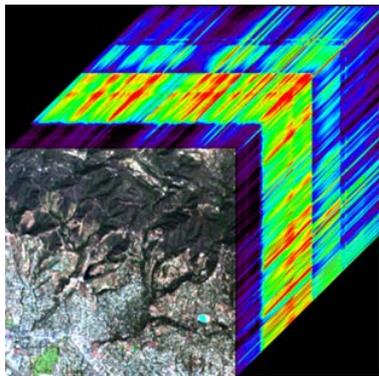
Water Stress Drives Plant Behavior

When stomata close, CO₂ uptake and evapotranspiration are halted and plants risk starvation, overheating and death.

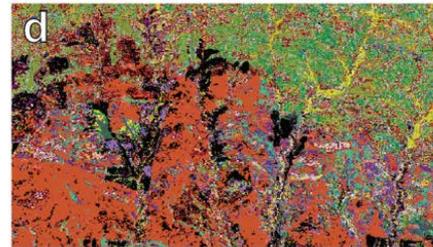
Science Objectives

- Identify critical thresholds of water use and water stress in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the diurnal cycle
- Measure agricultural water consumptive use over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy

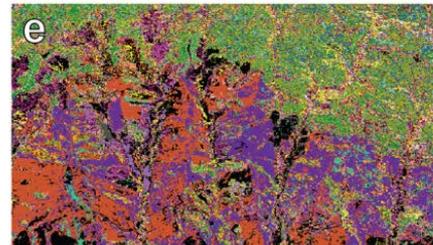
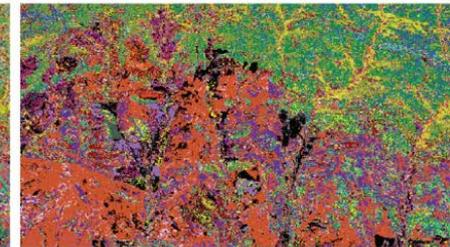
A data cube showing the spectral dimensionality of image spectroscopy data.



Same-date classification



Multi-temporal classification



Species

- █ ADFA
- █ ARCA-SALE
- █ ARGL
- █ BAPI
- █ BRNI
- █ CECU
- █ CEME
- █ CESP
- █ CISP
- █ ERFA
- █ EUSP
- █ IRGR
- █ MAGF
- █ PEAM
- █ PISA
- █ PLRA
- █ QUAG
- █ QUDO
- █ ROCK
- █ SOIL
- █ UMCA
- █ Unclassified



Summary



- The Dyson imaging spectrometer design form has key advantages in terms of throughput and size
- A space flight type VSWIR-Dyson imaging spectrometer (380-2510 nm at 7.4 nm) is in late stages of development
- In late September 2014 HypsIRI was asked to look at the options for putting this VSWIR-Dyson on the ISS
- The study currently shows there is a potentially viable option
- There are clear science synergies with GEDI, ECOSTRESS and OCO3
- Full study results will be provided to NASA the end of this Month.