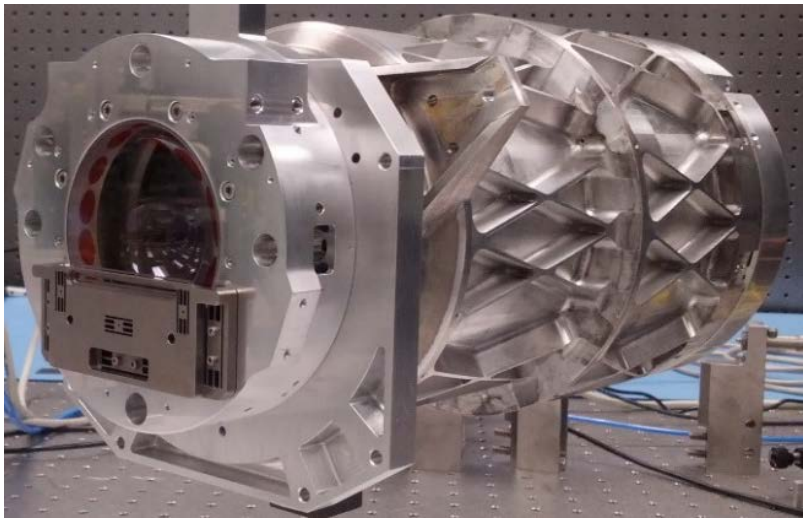
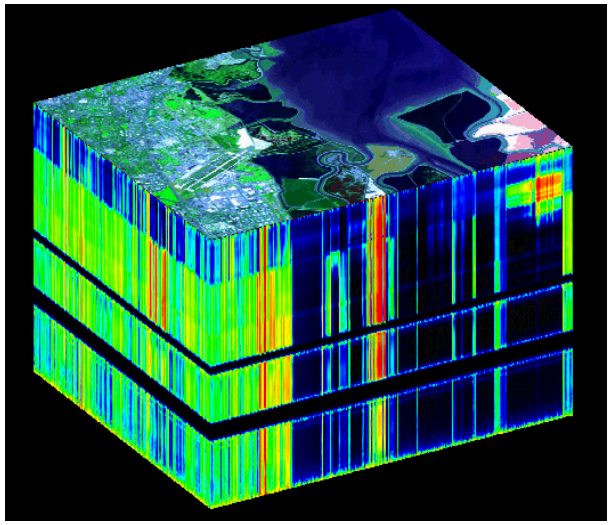
VSWIR-Dyson Imaging Spectrometer and an ISS option





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

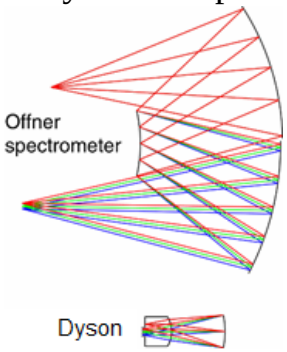
Overview

- 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

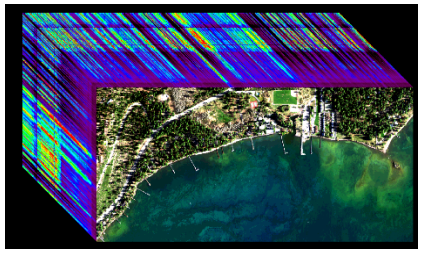
Why a VSWIR-Dyson?

- Through FY13 HyspIRI 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)

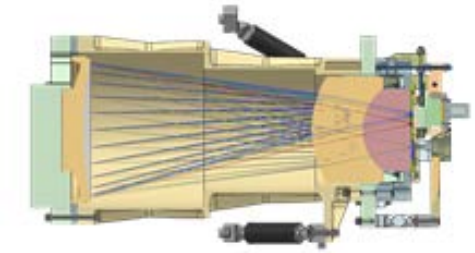
Offner to Dyson Comparison



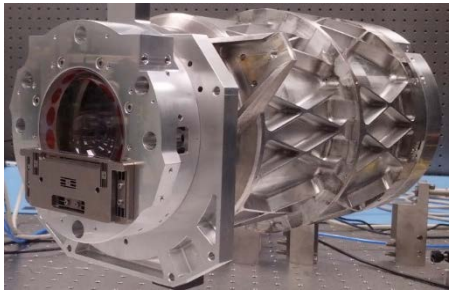
PRISM is a Dyson (350-1050 nm)



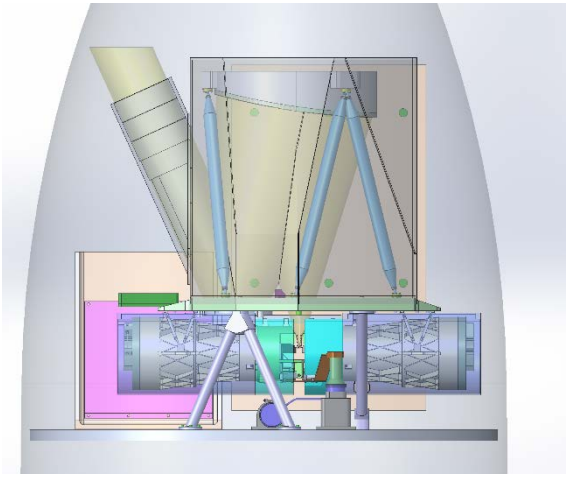
VSWIR Dyson (380-2510 nm)



Qualifiable Unit F/1.8



Payload supporting
185 km at 30 VSWIR



Configured
for Pegasus

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 (≥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).

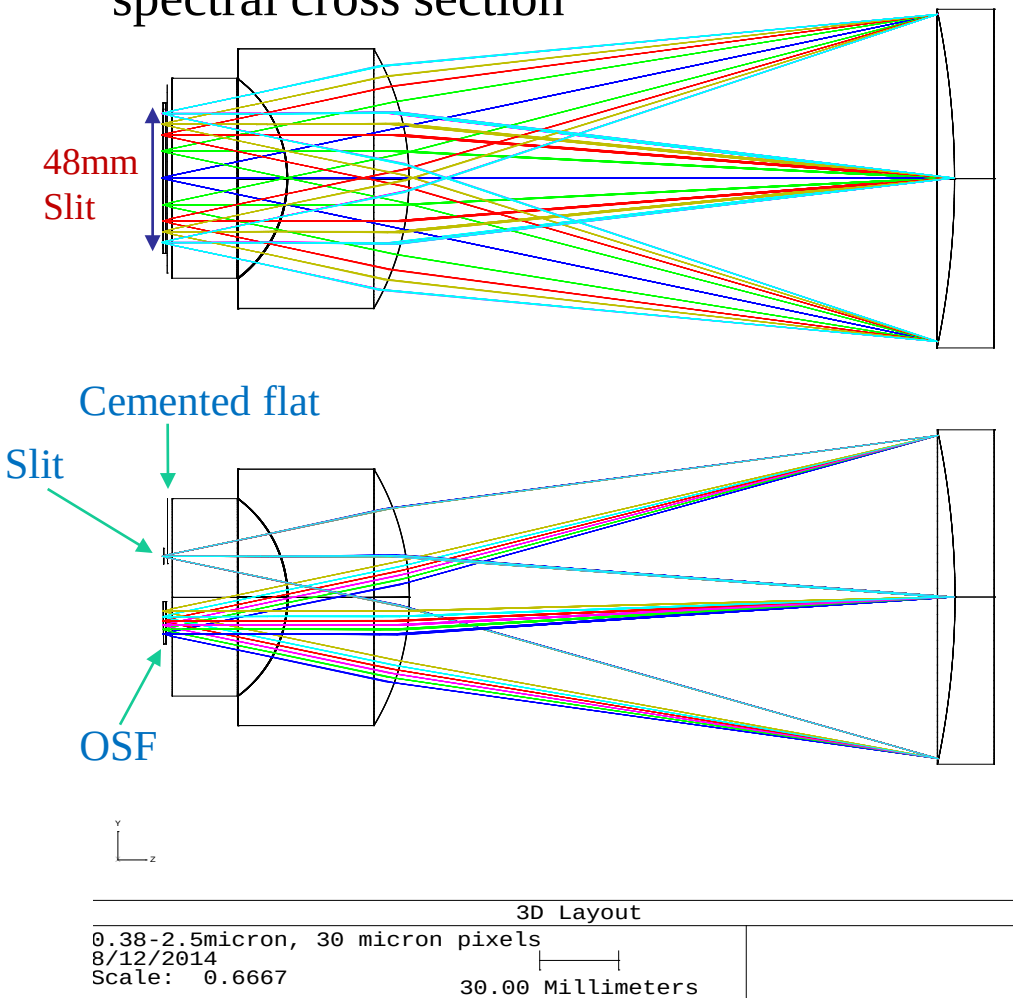
**: misregistration of spectrum to array row (keystone)

Optical Design

Spectrometer Optical Design:

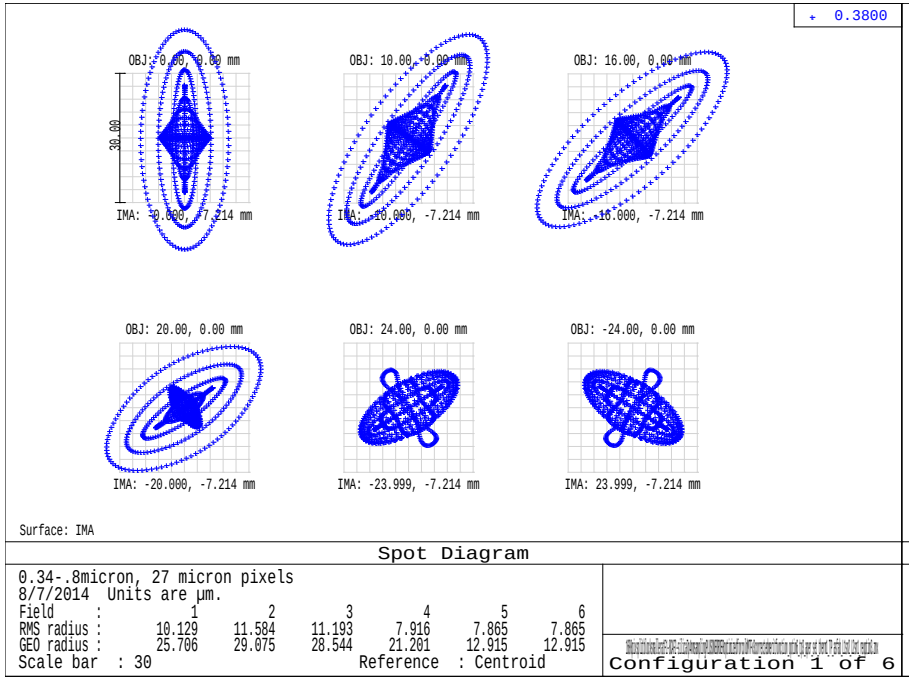
- Challenging design because of large spectral range (380-2500 nm) and wide swath (48mm/1280 or1600 pix).
- CaF_2-Fused Silica doublet was required in order to meet spectrometer uniformity requirement.
- Dyson block has one cemented flat near spectrometer input.
- Spectrometer is 325mm end-to-end with a 125mm diameter grating.
- Diffraction grating substrate is post-polished diamond turned Aluminum.

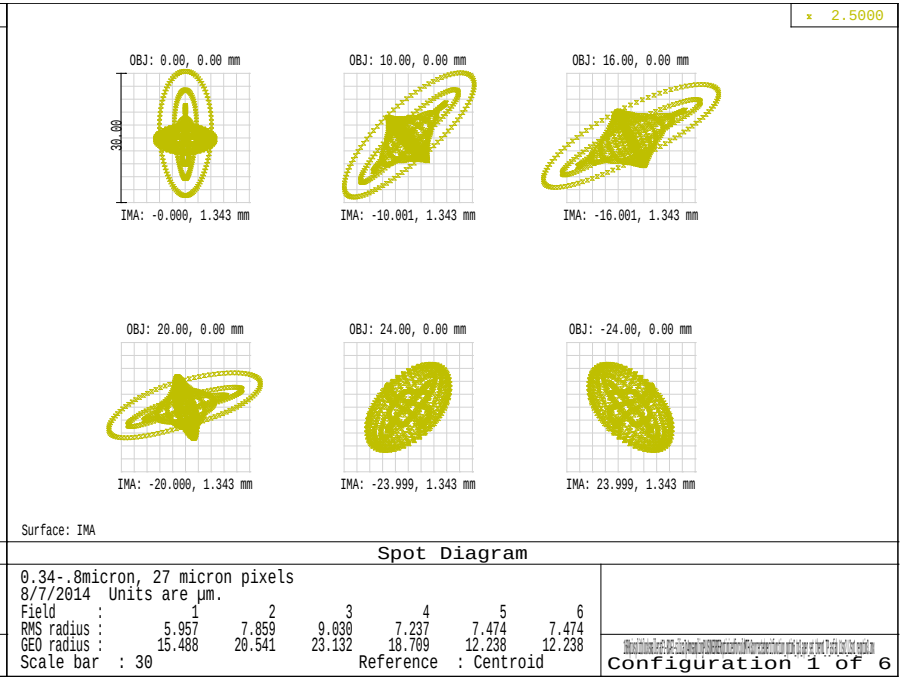
VSWIR-Dyson spectrometer ray trace; top spatial cross section and bottom spectral cross section



Optical Design

Spectrometer Spot Diagrams



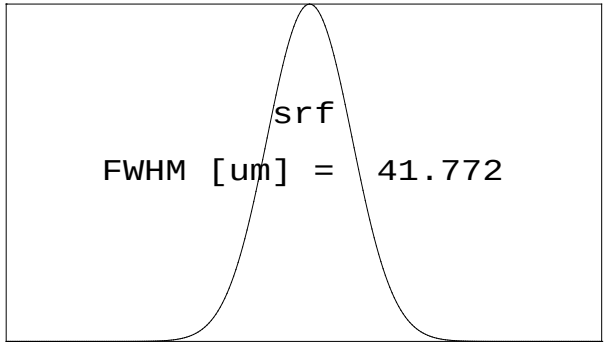


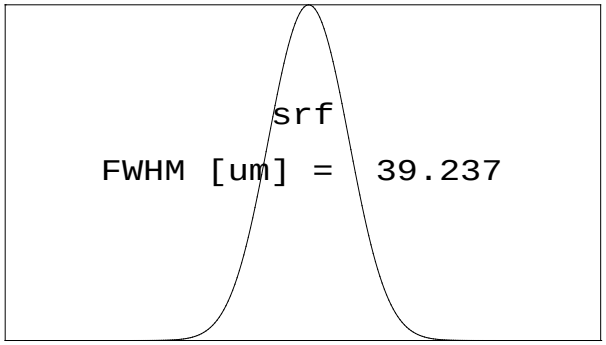
380 nm 2500 nm

Box is 30 µm square

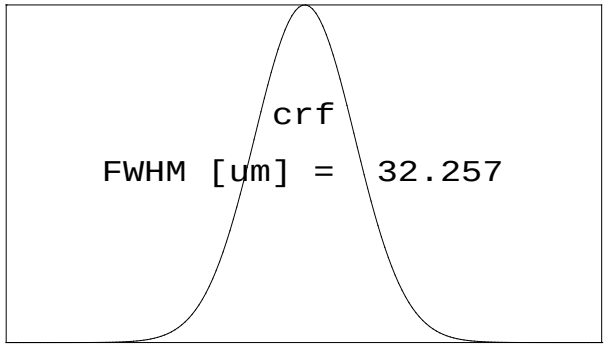
Uniformity errors: Smile 0.65% (0.2 µm), keystone 1% (0.3 µm) < 5%

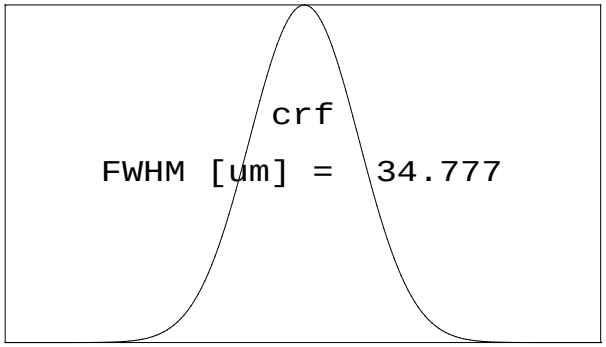
Optical Design: SRF/CRF Variation





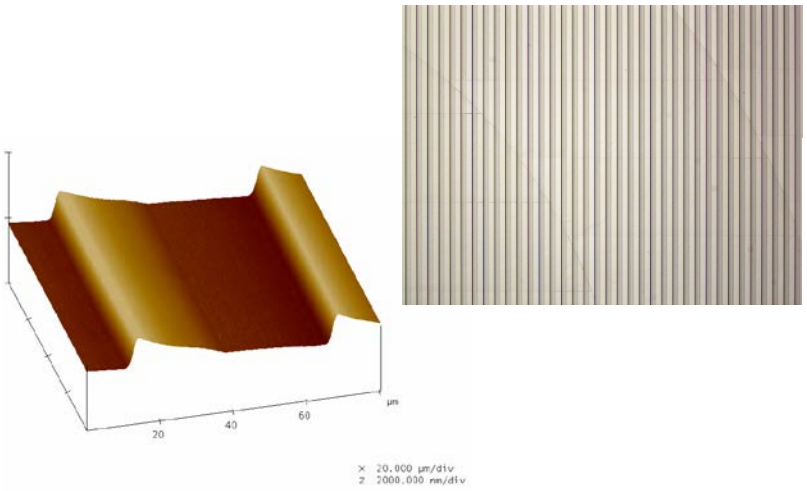
Spectrometer spectral response functions at 380 nm showing the worst-case variation (<6%) with field for all wavelengths and fields.





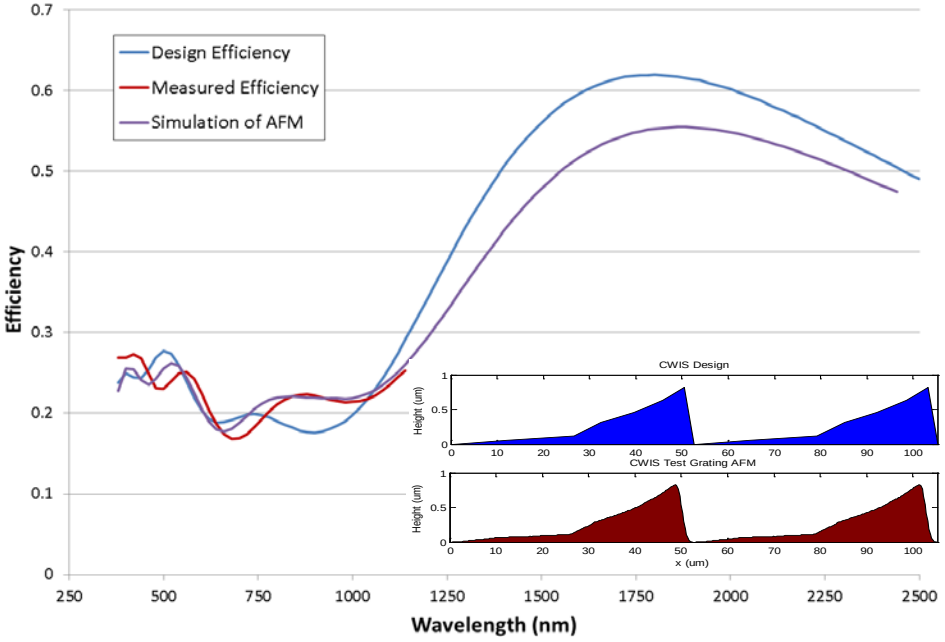
Spectrometer cross-track spatial response functions for 380 and 1600 nm wavelengths, showing the worst-case variation (<7%) with wavelength, for all fields and wavelengths.

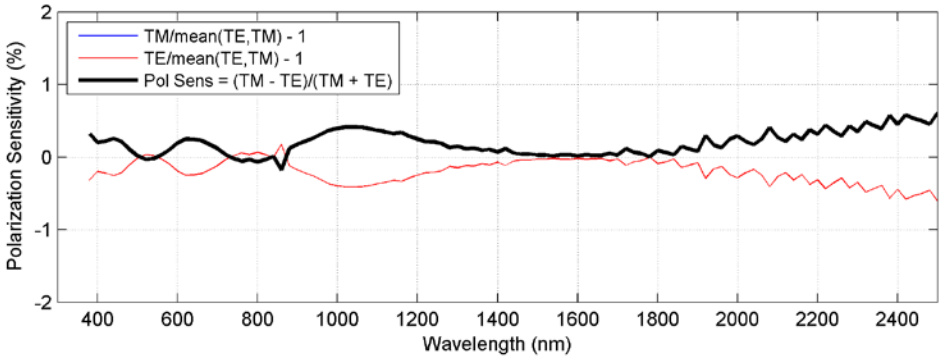
Optical Design: Diffraction Grating



- 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.

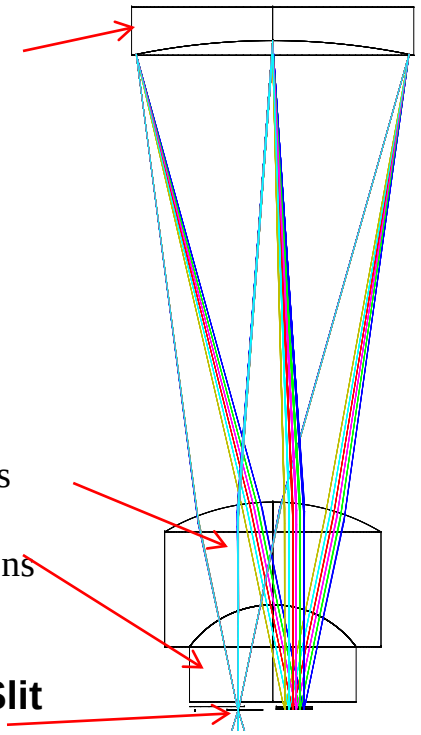
Simulation of grating efficiency for measured and design groove shape





Optical Design

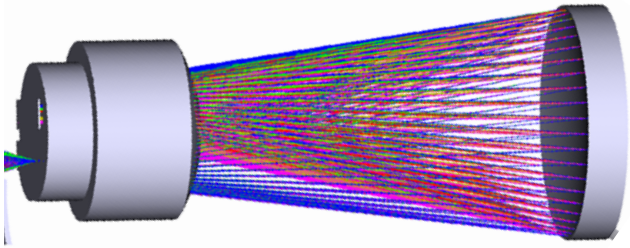
- **E-Beam Fabricated Grating**



- **Dyson Block Doublet**
  - Fused Silica meniscus lens
  - CaF_2 Plano Convex Lens with Cemented Flat
- **E-Beam Lithographic Slit**

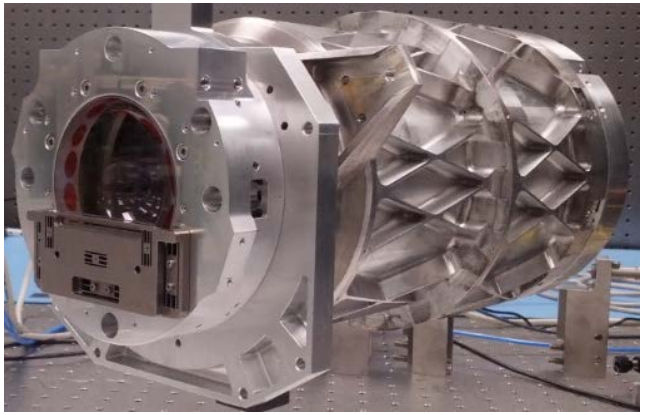
Optical Design Key Characteristics:

- 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

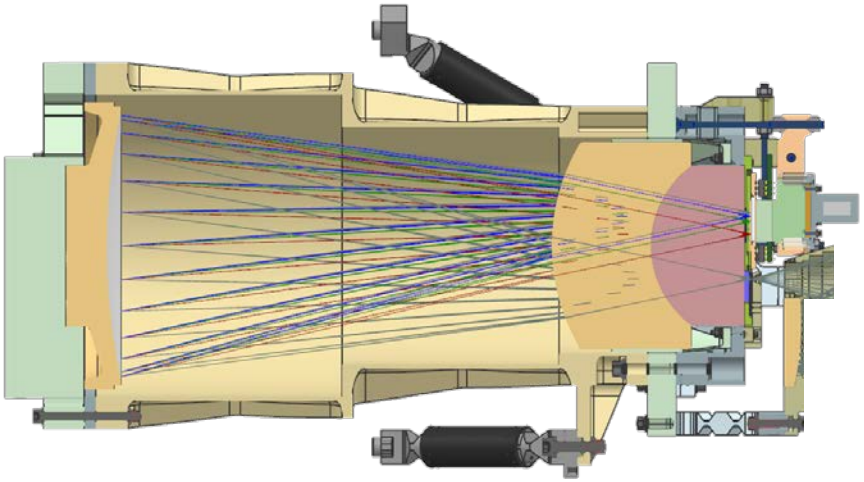


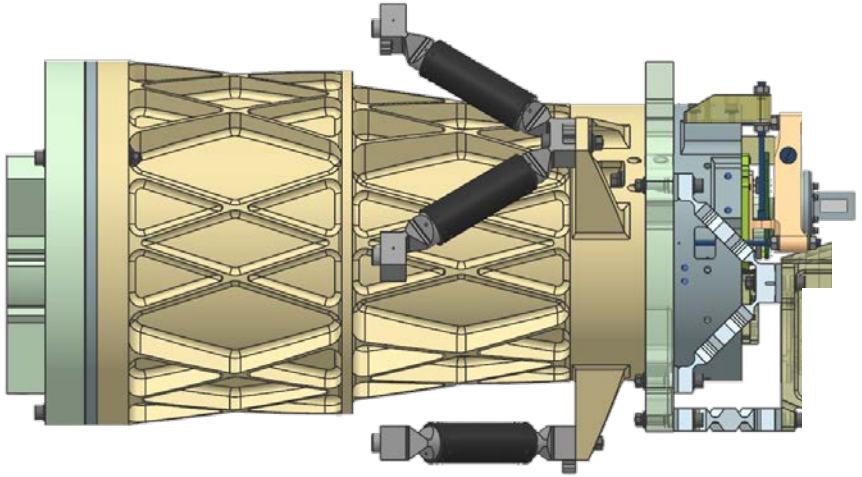
Instrument Status

- 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.





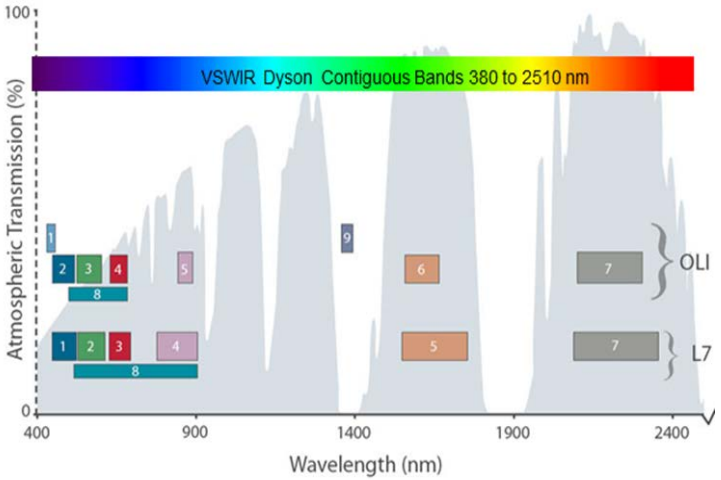
HyspIRI October 2014 VSWIR-Dyson Study for ISS

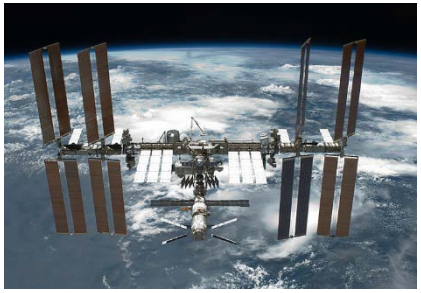
Key Demonstration Objectives

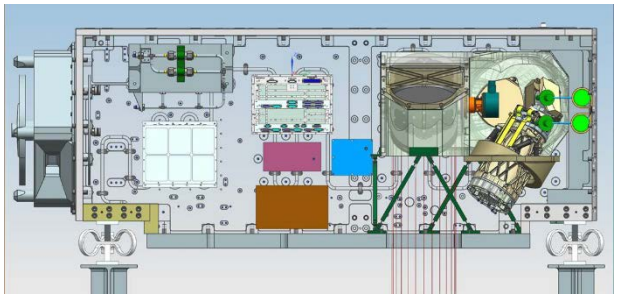
- Mature, Reduce Risk and validate the VSWIR-Dyson imaging spectrometer architecture to support future options for the SLI, HyspIRI, and other NASA Programs
- Delivery of Landsat bands with on-orbit convolution of imaging spectrometer measurements at 30 m spatial
- Demonstrate low distortion, high SNR 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 ≥ 4X
- Address subset of HyspIRI VSWIR Science and Applications objectives
- Enable new science in concert with ECOSTRESS and JEDI

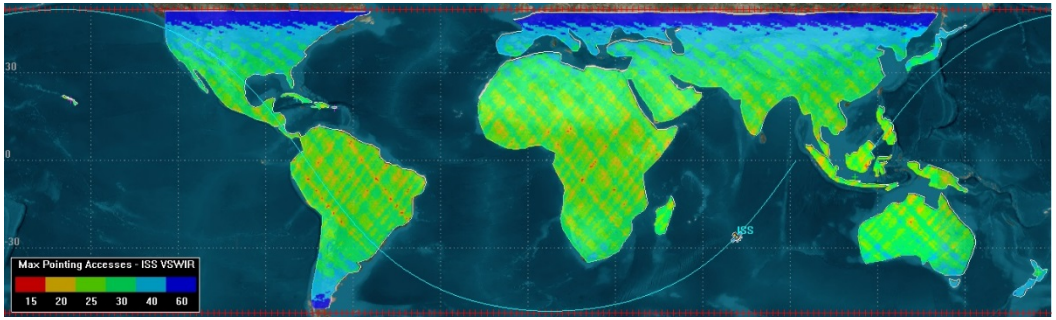
Measurement:

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





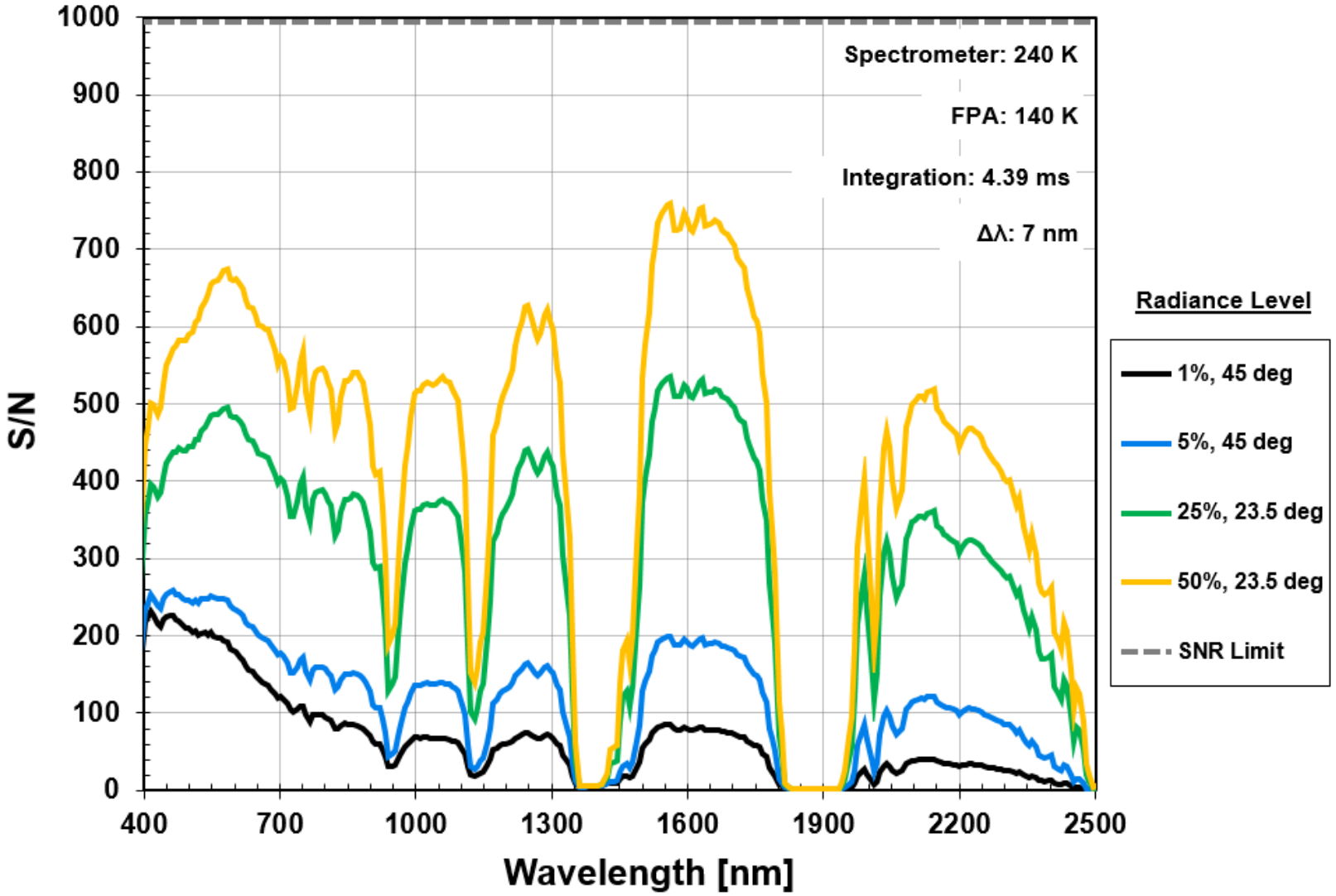




VSWIR Dyson Characteristics

- 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 ≥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 ≥90% cross-track uniformity
  - Spectra IFOV-Variation ≥90% spectral IFOV uniformity

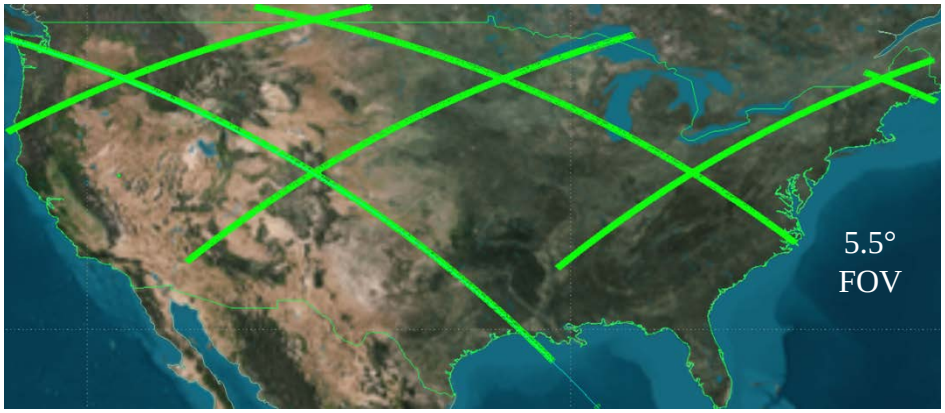
Signal-to-Noise Ratio @ 30m 4.39 ms



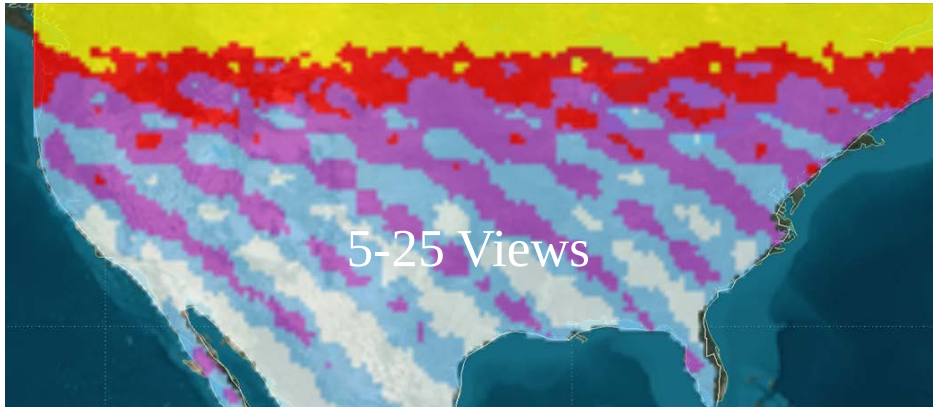
Coverage

Field of Regard

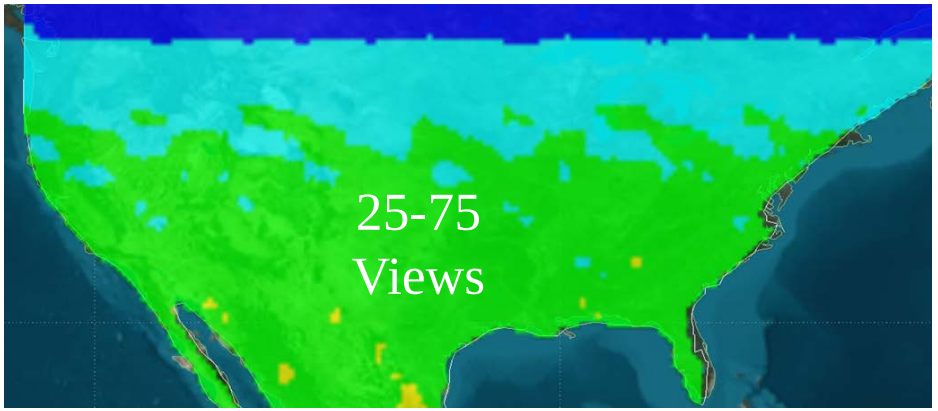
Swath



3 months Full Coverage



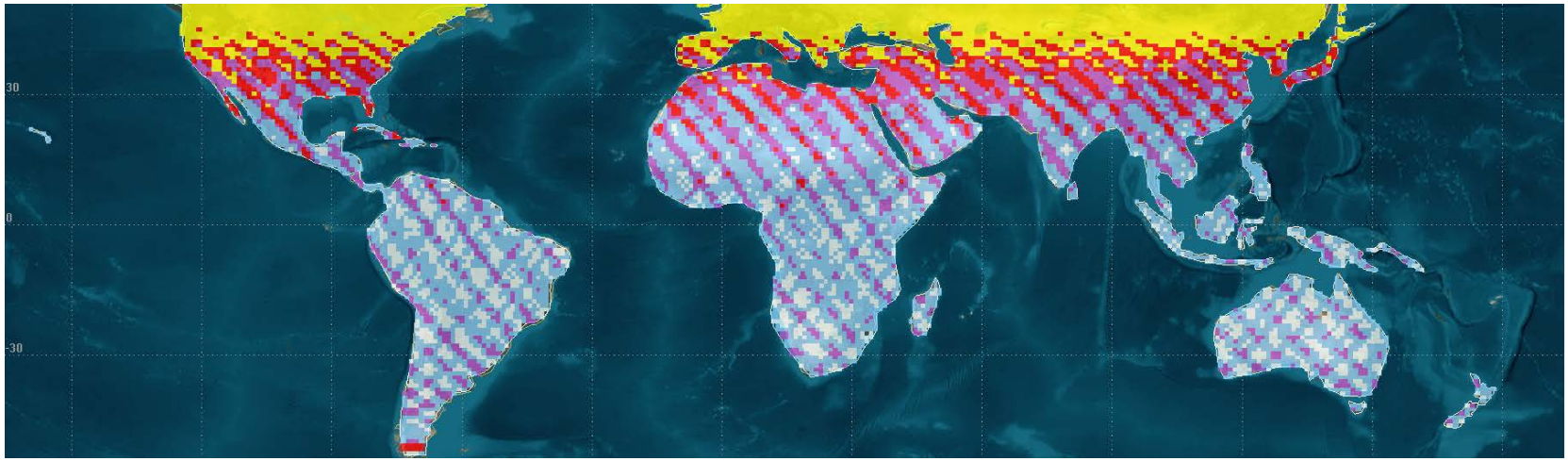
1 year



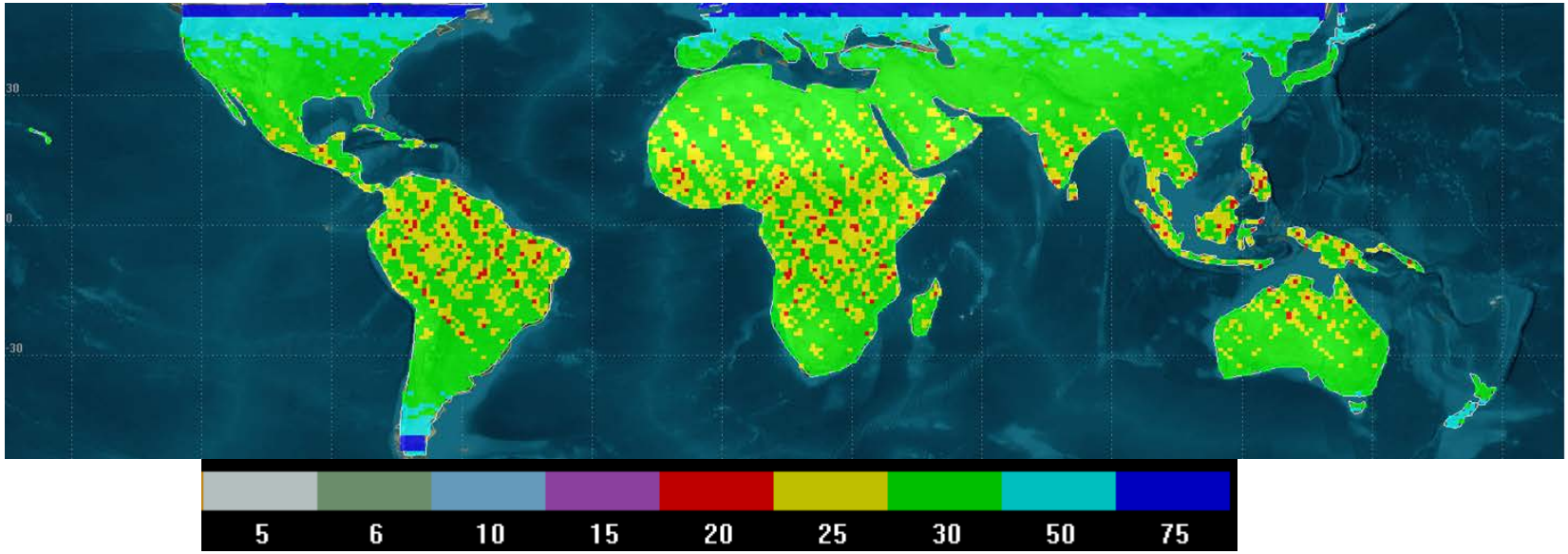
Global Capability 30.5° field of regard (FOR)

Number of Views

5 months coverage

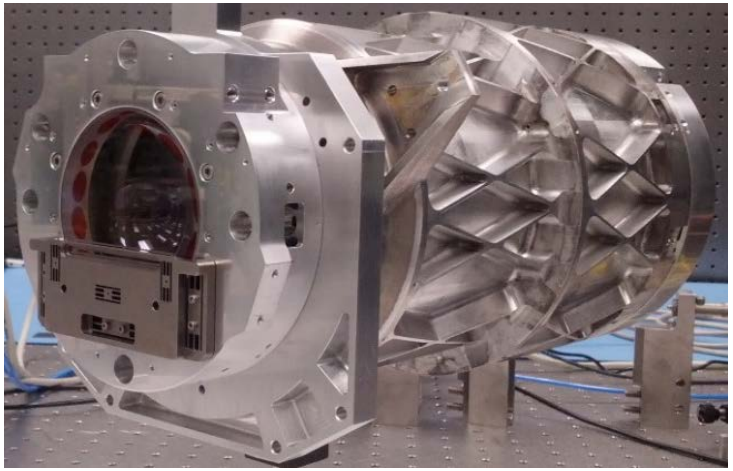


1 year Views

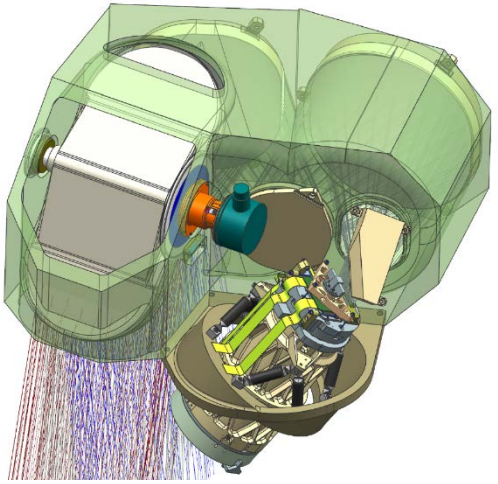


VSWIR-Dyson ISS Option

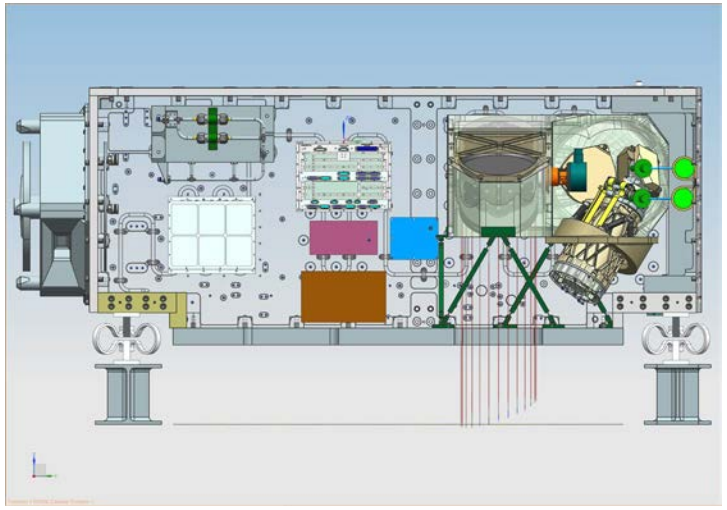
VSWIR-Dyson Spectrometer



Telescope and Pointing Mirror

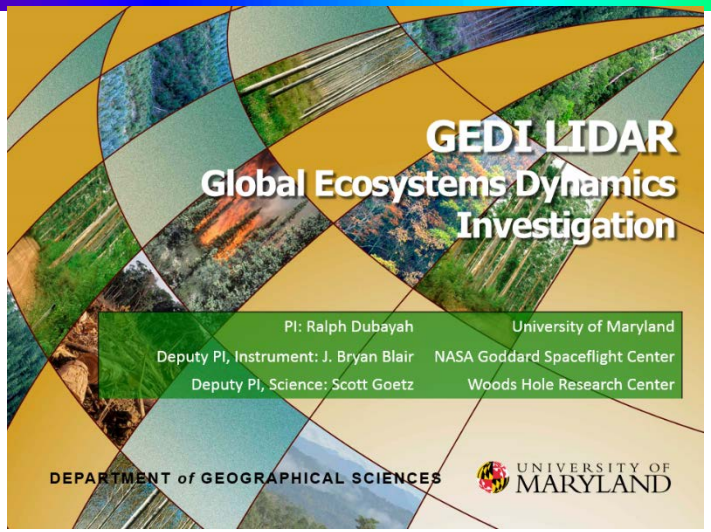


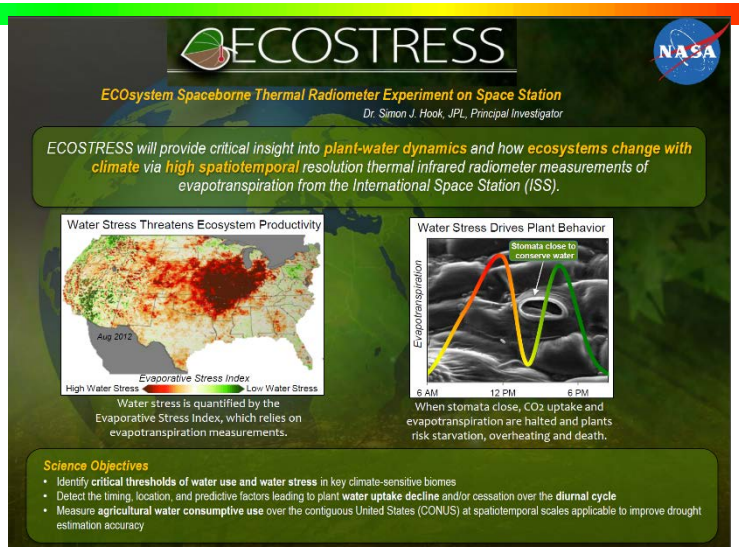
Configured for JEM-EF



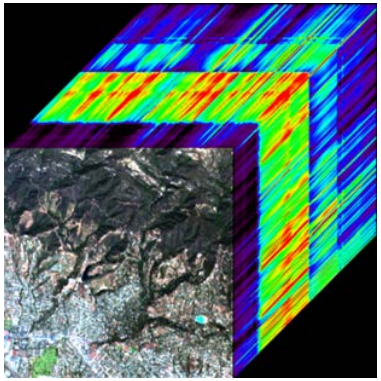
JEM-EF Locations

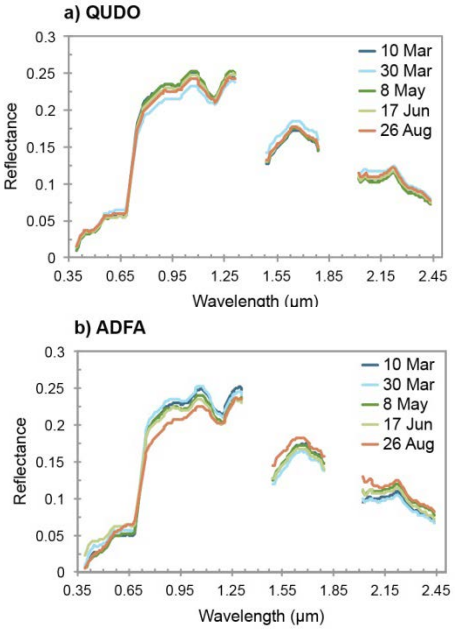
Synergy with GEDI and ECOSTRESS

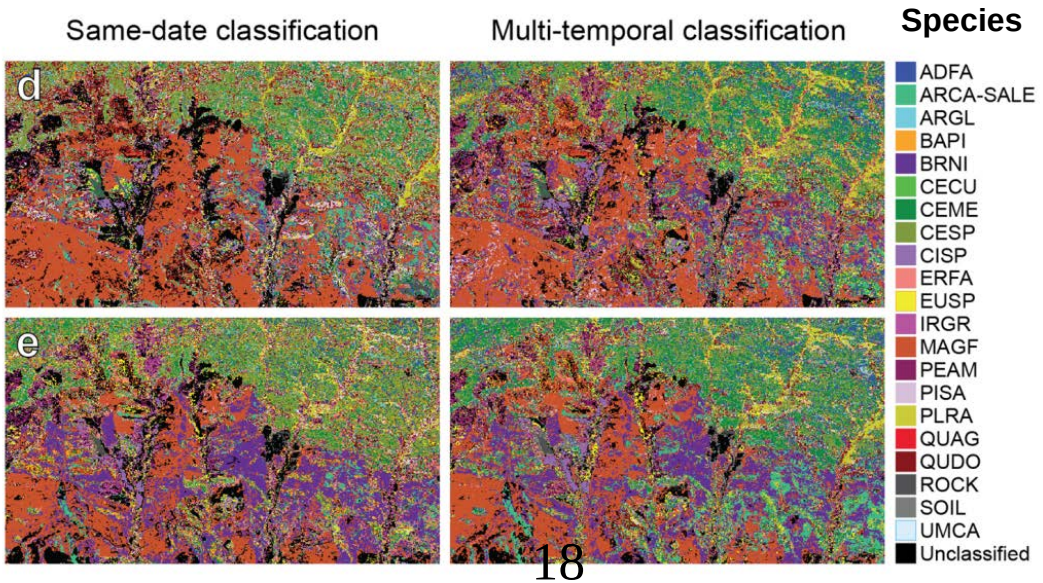




A data cube showing the spectral dimensionality of image spectroscopy data.







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 HyspIRI 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.