VSWIR-Dyson Imaging Spectrometer and an ISS option

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Overview

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• 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

VSWIR Dyson (380-2510 nm)

Payload supporting 185 km at 30 VSWIR

Configured for Pegasus
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**

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<th>Characteristics</th>
<th>Range</th>
<th>380-2510 nm</th>
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<td>Spectral</td>
<td>Sampling</td>
<td>7.4 nm</td>
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<tr>
<td>Spectral</td>
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<td>Radiometric</td>
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<td>Uniformity</td>
<td>Spectral cross-track</td>
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<td>Spectral IFOV</td>
<td>&lt; 95% **</td>
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*: 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).
- CaF₂-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

Box is 30 µm square

2500 nm

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.
• 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.
Optical Design

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.
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 (2200 nm)

• 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

Spectrometer: 240 K
FPA: 140 K
Integration: 4.39 ms
\(\Delta \lambda: 7\) nm

Radiance Level
- 1%, 45 deg
- 5%, 45 deg
- 25%, 23.5 deg
- 50%, 23.5 deg

- SNR Limit

Wavelength [nm]

S/N
Field of Regard Swath

3 months Full Coverage

1 year

30.5° Pointing

5.5° FOV

5-25 Views

25-75 Views
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

Species

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.