THE PROTOTYPE HYSPIRI THERMAL INFRARED RADIOMETER (PHyTIR) AND HYPERSPECTRAL THERMAL EMISSION SPECTROMETER (HyTES)

Presented at:

2012 IGARRS
Munich Germany.

Simon Hook & The HyspIRI/HyTES/PHyTIR Team(s)
Organization: NASA/Jet Propulsion Laboratory

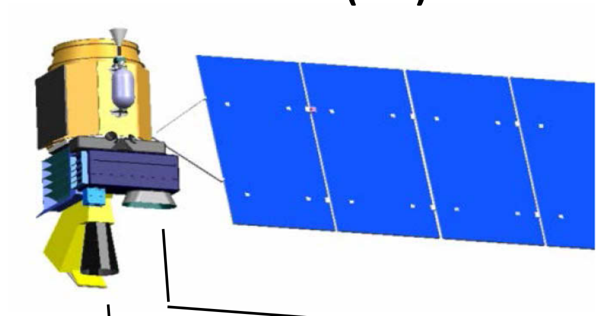
Outline

- Introduction
- The spaceborne Hyperspectral Infrared Imager (HyspIRI)
- Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)
- The airborne Hyperspectral Thermal Emission Spectrometer (HyTES)
- Summary

HyspIRI

http://hyspiri.jpl.nasa.gov/

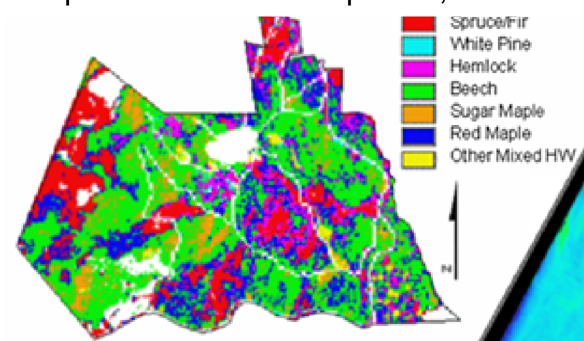
Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer
+
Multispectral Thermal InfraRed (TIR) Scanner

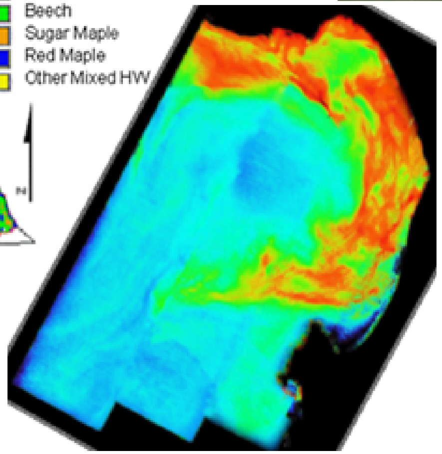


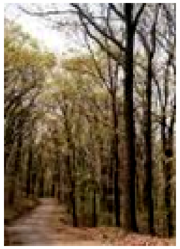
VSWIR: Plant Physiology and Function Types (PPFT)

Multispectral TIR Scanner

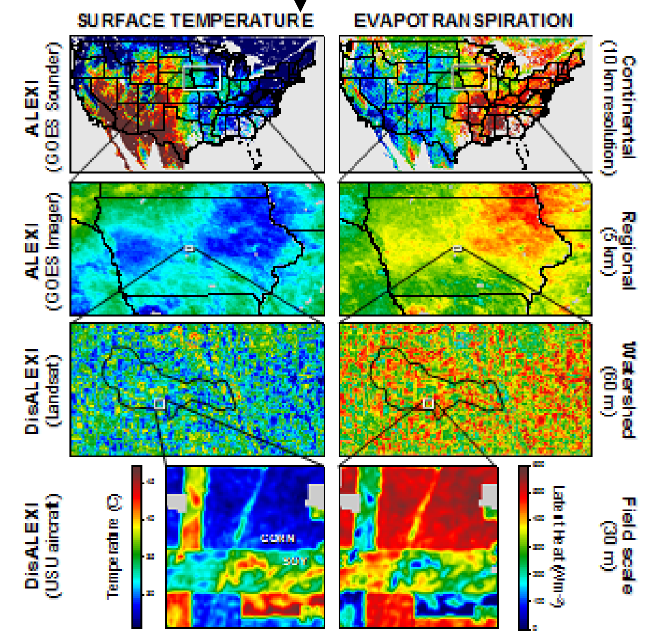
Map of dominant tree species, Bartlett Forest, NH







Red tide algal bloom in Monterey Bay, CA



HyspIRI TIR Quad Chart

Science Questions:

TQ1. Volcanoes/Earthquakes (MA,FF)

– *How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?*

- *TQ2. Wildfires (LG,DR)*

– *What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?*

- *TQ3. Water Use and Availability, (MA,RA)*

– *How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?*

- *TQ4. Urbanization/Human Health, (DQ,GG)*

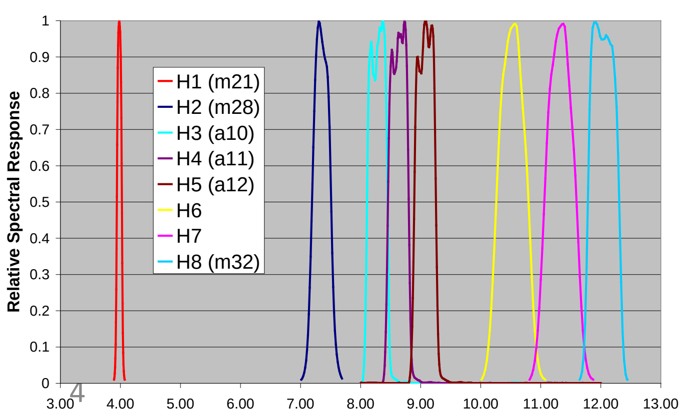
– *How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?*

- *TQ5. Earth surface composition and change, (AP,JC)*

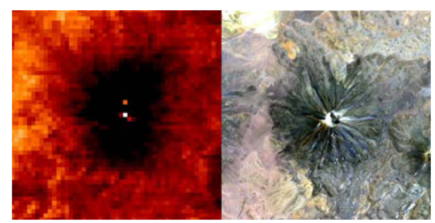
– *What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?*

Measurement:

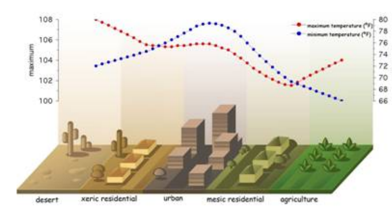
- 7 bands between 7.5-12 μm and 1 band at 4 μm
- 60 m resolution, 5 days revisit
- Global land and shallow water



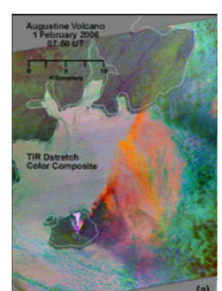
Andean volcano heats up



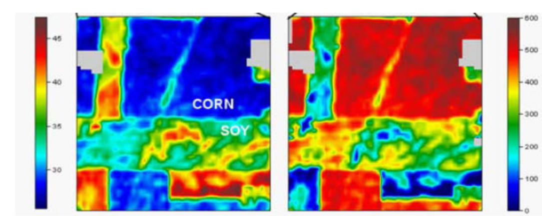
Urbanization



Volcanoes



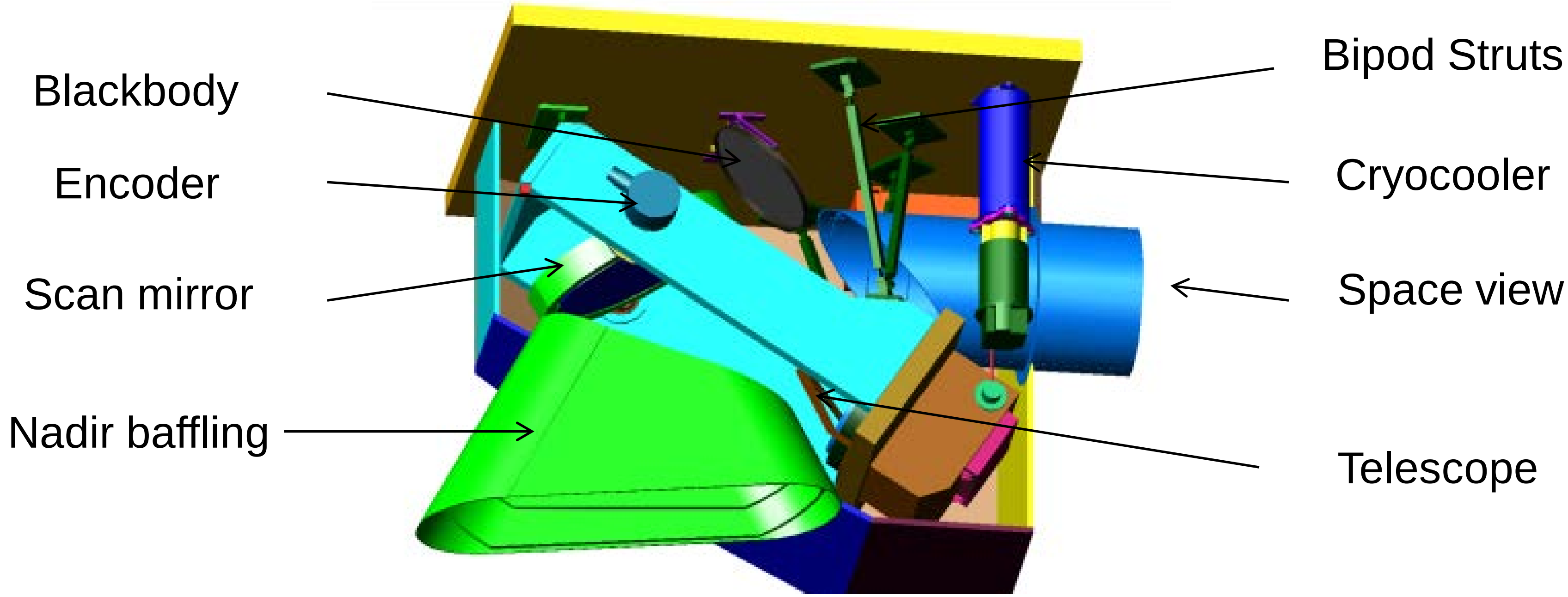
Water Use and Availability

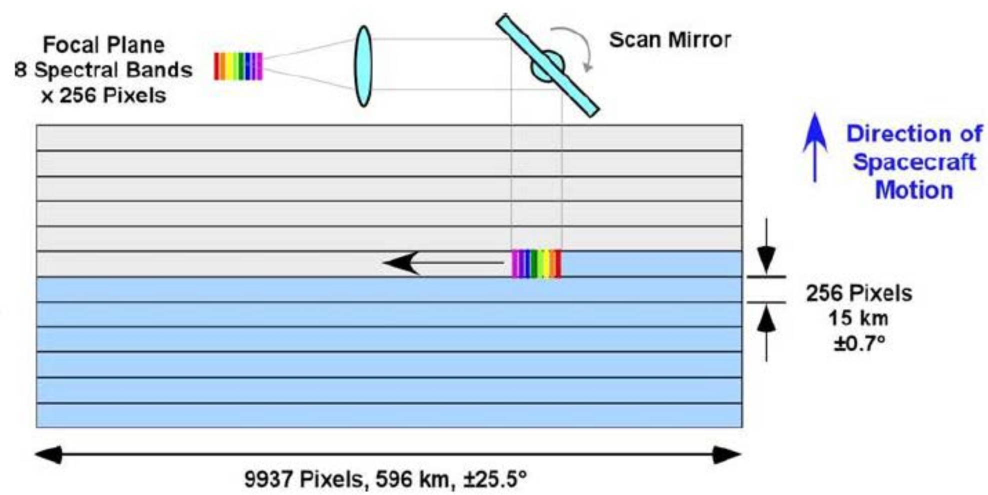


Surface Temperature

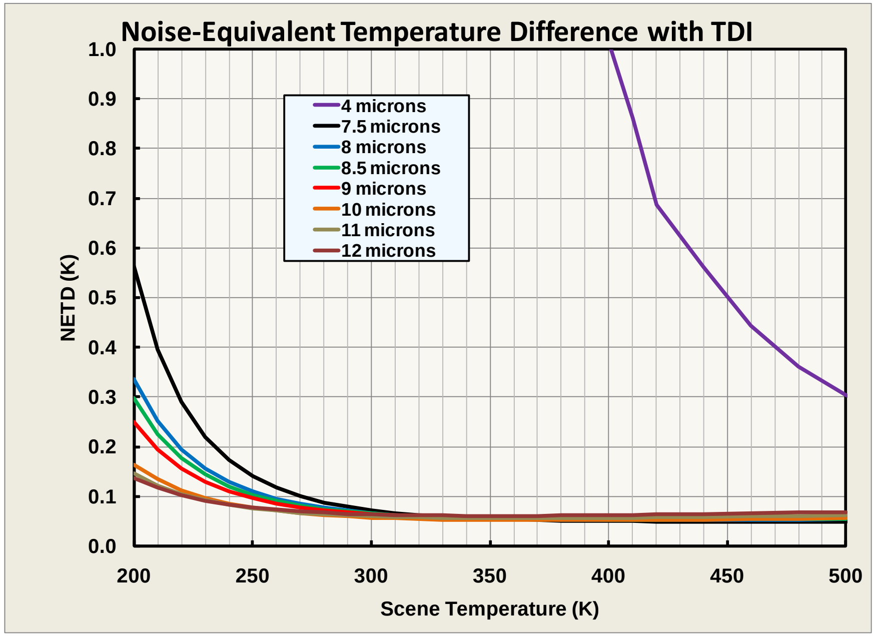
Evapotranspiration

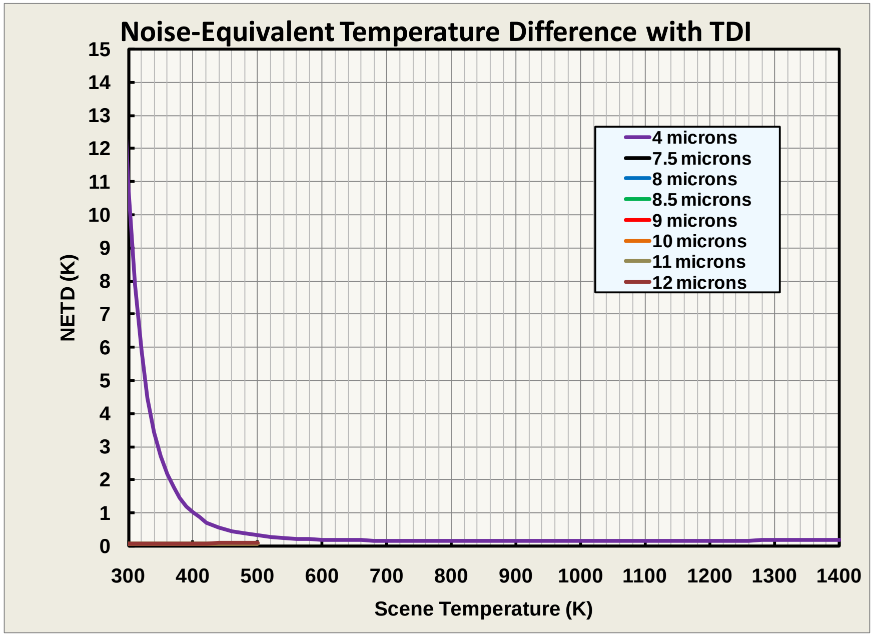
HyspIRI-TIR Instrument Concept





HyspIRI-TIR Instrument Concept





Expected HyspIRI-TIR Sensitivity Metric expressed as Noise Equivalent Delta Temperature (NEDT)

Expected HyspIRI-TIR Sensitivity Metric expressed as Noise Equivalent Delta Temperature (NEDT)

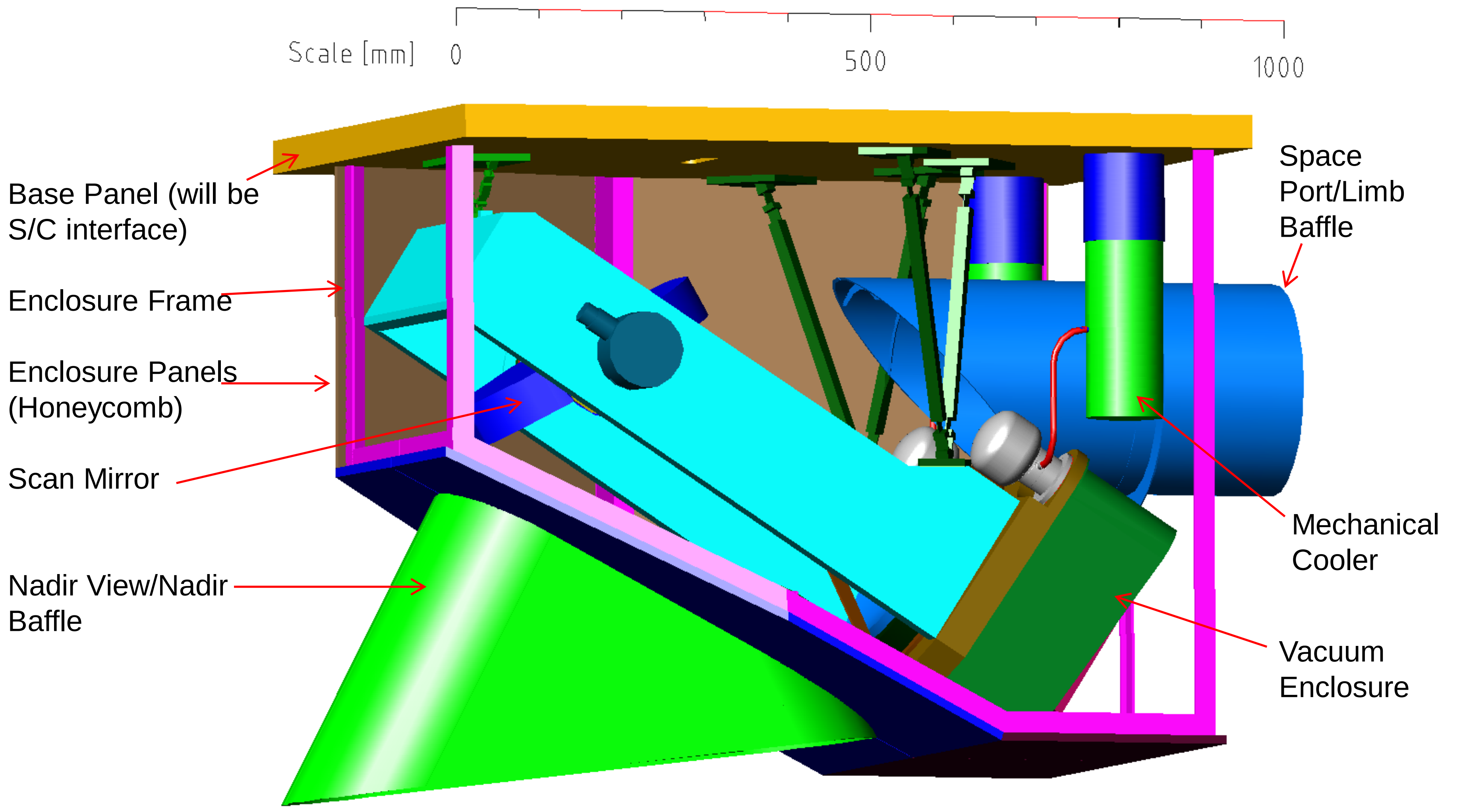
- Predicted sensitivity better than 0.2 K @ 300 K requirement.
- Good sensitivity in overlap region between channel 1 and channels 2-8.
- Expected saturation temperature of 1200K based on HyspIRI: Hot Target Saturation Subgroup (HTSS)

The Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)

PHyTIR Rational

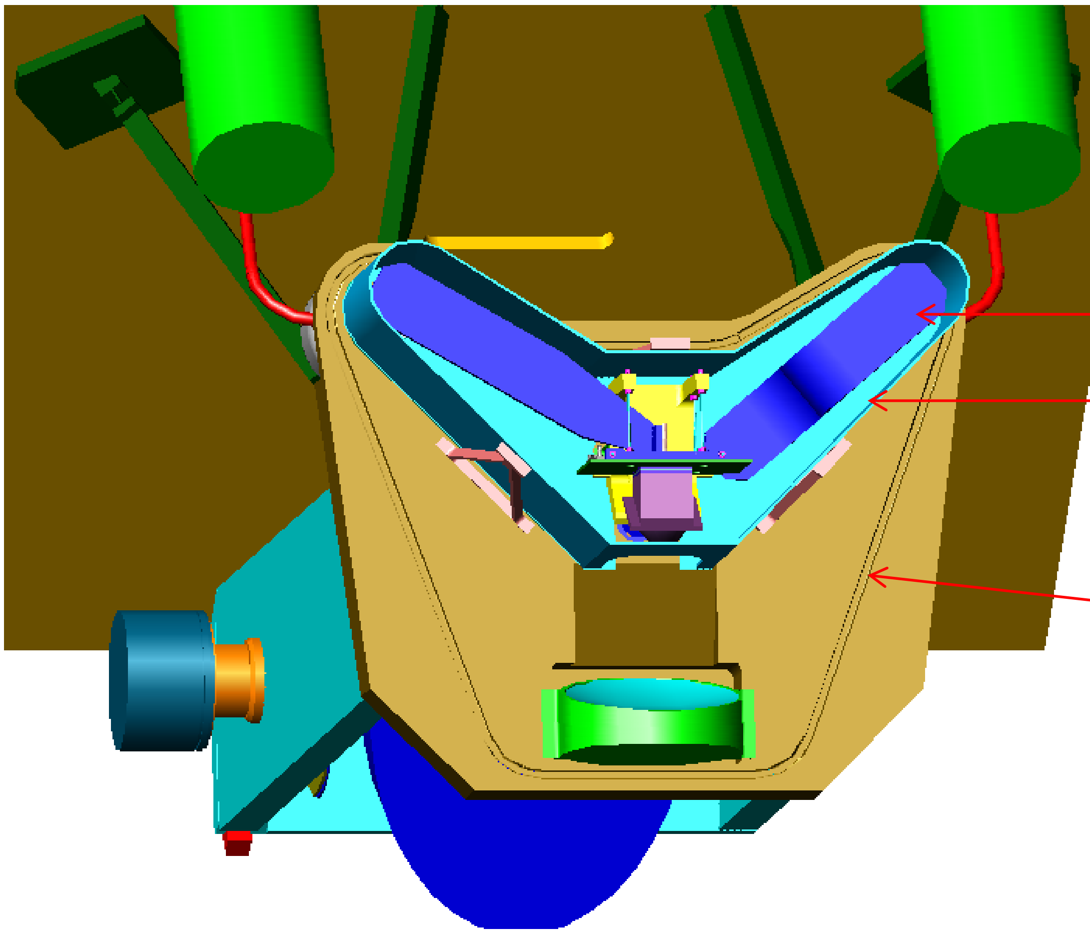
- HyspIRI-TIR requires a high throughput FPA and scanning approach to meet the revisit time (5 days), the high spatial resolution (60m), and the number of spectral channels (8).
- PHyTIR will demonstrate that:
  - The detectors and readouts meet all signal-to-noise and speed specifications
  - The scan mirror, together with the structural stability, meets the pointing knowledge requirements
  - The long-wavelength channels do not saturate below 480 K
  - The cold shielding allows the use of ambient temperature optics on the HyspIRI-TIR instrument without impacting instrument performance.

PHyTIR Mechanical Layout



PHyTIR Cooling

- Inside the Vacuum Enclosure



Sample Thermal Strap:

Thermal Straps

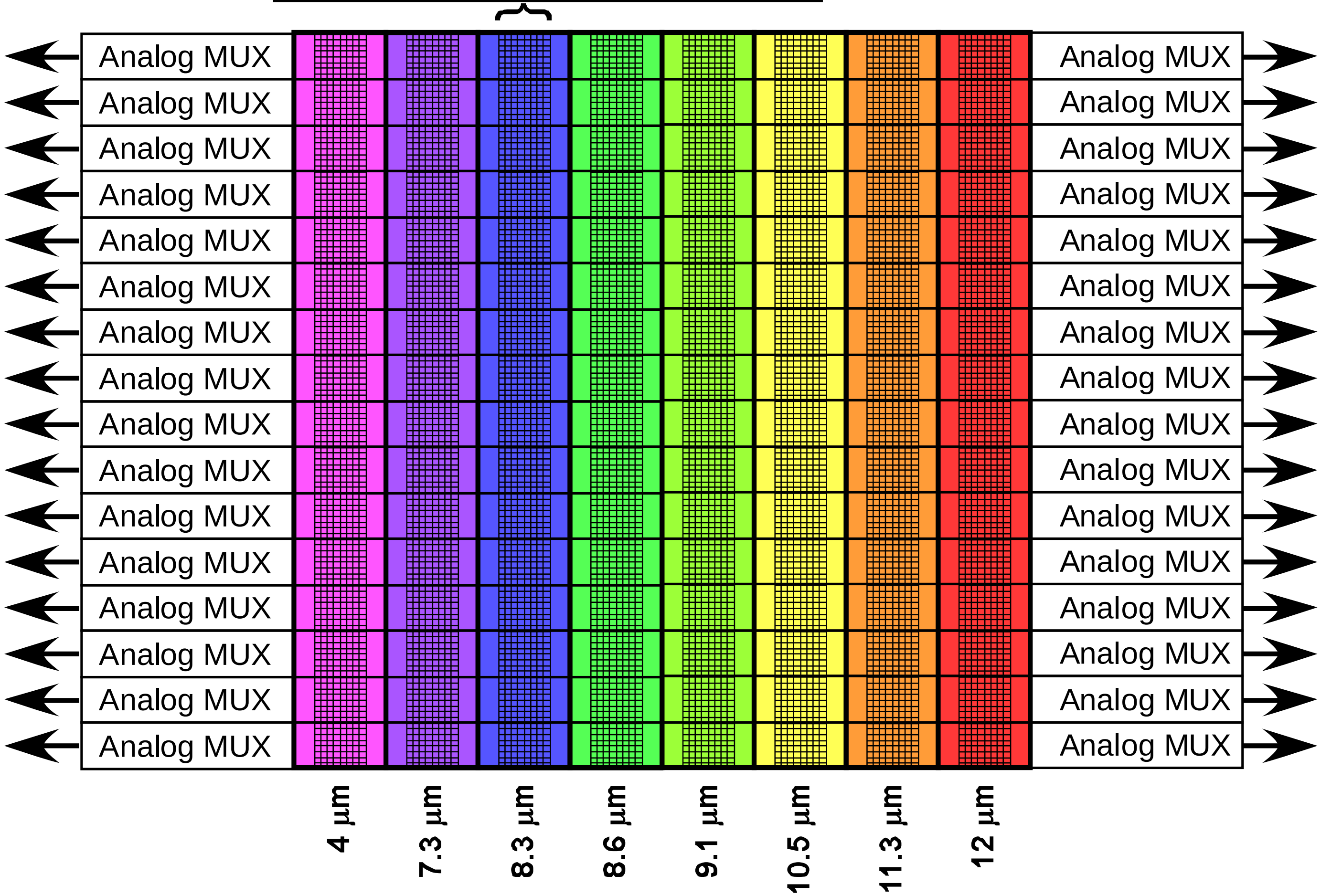
Cold Housing
(top removed to show inside)
Floating Shields at cold housing walls are not shown

O-Ring Groove
for Vacuum Enclosure

Not shown:
- Connector through Bulkhead
- Vacuum Valve (for EM)

PHyTIR Focal Plane

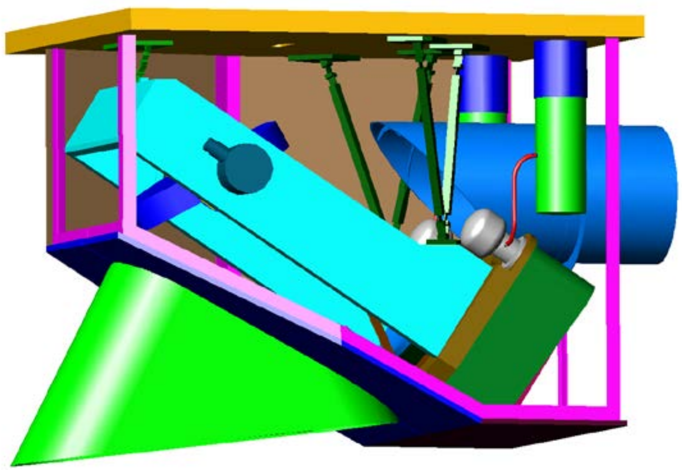
16 x 256 pixels in each spectral band.
Only 4 x 256 pixels are read out.

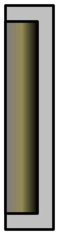


PHyTIR will not have focal plane filters but will implement the identical ROIC design to HyspIRI-TIR. 32 parallel output at ≥ 10 MHz allow 32 µs frame times.

PHyTIR Test Configuration

- Instrument is in air. Vacuum enclosure around focal-plane is evacuated (to be described in detail in mechanical presentation). Scan mirror rotating.





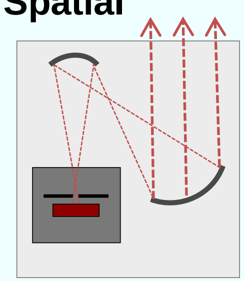
Room-temperature reference blackbody. Flat plate with corrugated, painted surface. Emissivity <1 acceptable.

<u>Test Sources Placed Within PhyTIR Scan Range</u>

Radiometric

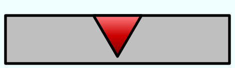
Variable-temperature blackbody: ≥ room temperature. Flat plate with corrugated, painted surface. Emissivity <1 acceptable.

Spatial



MCS Target Projector with slit source. Will underfill PHyTIR aperture.

Saturation



Small hot source. 295K to > 500 K.

PHyTIR Summary

The following steps are currently being undertaken to build PHyTIR:

1) Design and Build the Scan Mechanism
2) Design and Build a Scan Mirror
3) Integrate the Spectral Filters with Focal Plane Array and ROIC
4) Assemble the Dewar with external telescope, internal relay and focal plane assembly
5) Build the prototype Electronics
6) Assemble PHyTIR

Once PHyTIR is assembled it will be used to retire the four key risks as noted earlier. A key part of this effort is the final testing to prove these four key risks.

a) **Detectors and readout meet all signal-to-noise and speed specifications.**
b) **Scan mirror and structure meet pointing knowledge requirements.**
c) **Long-wavelength channels will not saturate below 480 K.**
d) **Background from ambient temperature optics does not affect instrument performance.**

HYPERSPECTRAL THERMAL EMISSION SPECTROMETER

HyTES

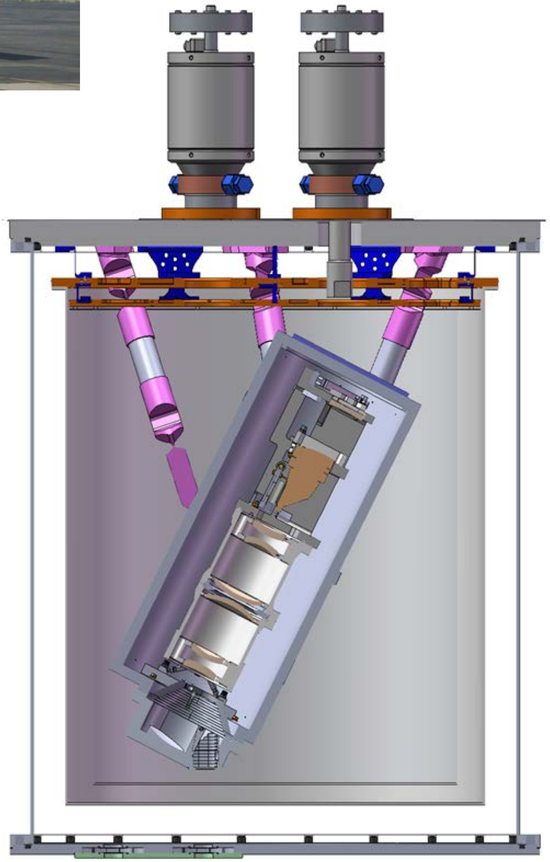
NASA • JET PROPULSION LABORATORY

HyTES Rational

- Determine of the optimum position for the band filters for HyspIRI
- Provide antecedent data for testing HyspIRI algorithms
- Provide a new measurement capability, with high spectral and spatial imaging data useful for a range of applications such as volcanic gas detection
- Capitalize on the Quantum Well Earth Science Testbed (QWEST) an internally funded laboratory demonstration system for component testing, e.g. Detectors (QWIP), diffraction gratings, and slits at the system level.

Hyperspectral Thermal Emission Spectrometer (HyTES)

First Flights in July 2012

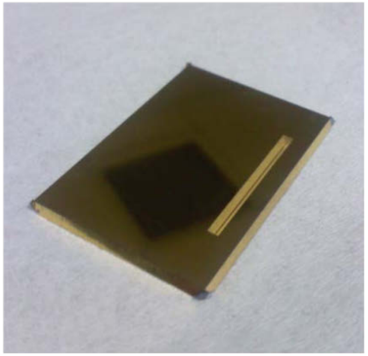


Instrument Characteristic	HyTES
Mass (Scanhead)[1]	12kg
Power	400W
Volume	1m x 0.5m (Cylinder)
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5-12 µm
Frame speed	35 or 22 fps
Integration time (1 scanline)	28 or 45 ms
Total Field of View	50 degrees
Calibration (preflight)	Full aperture blackbody
Detector Temperature	40K
Spectrometer Temperature	100K
Slit Length and Width	20 mm x 39 µm
IFOV	1.7066
Pixel Size/Swath at 2000 m flight altitude[2]	3.41m/1868.33m
Pixel Size/Swath at 20,000 m flight altitude[2]	34.13m/18683.31m

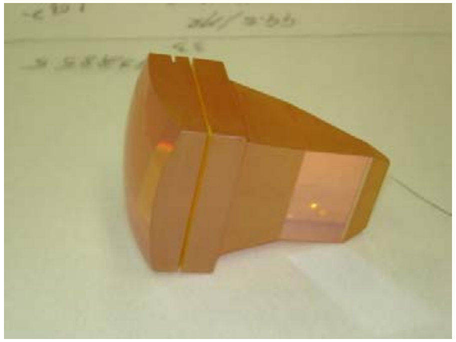
1. Does not include 1 rack of electronics to operate instruments; 2. Includes ~27 calibration pixels

Key JPL developed technologies

- Current instruments provide high spectral and low spatial OR high spatial and low spectral resolution in thermal infrared. HyTES provides BOTH high spectral and spatial resolution. New design can be made very compact.



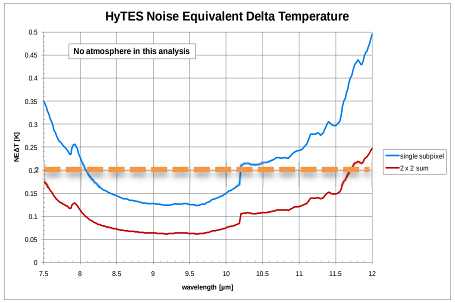
Long, straight slits: Victor White

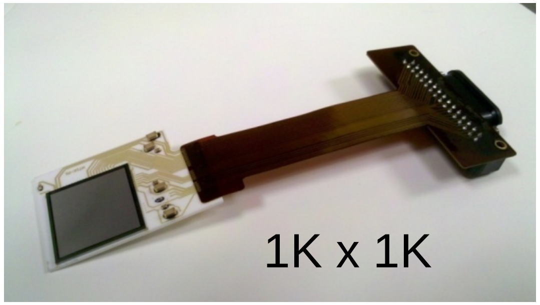


Compact Dyson Spectrometer: Zakos Mouroulis

Concave E-beam diffraction Grating: Dan Wilson

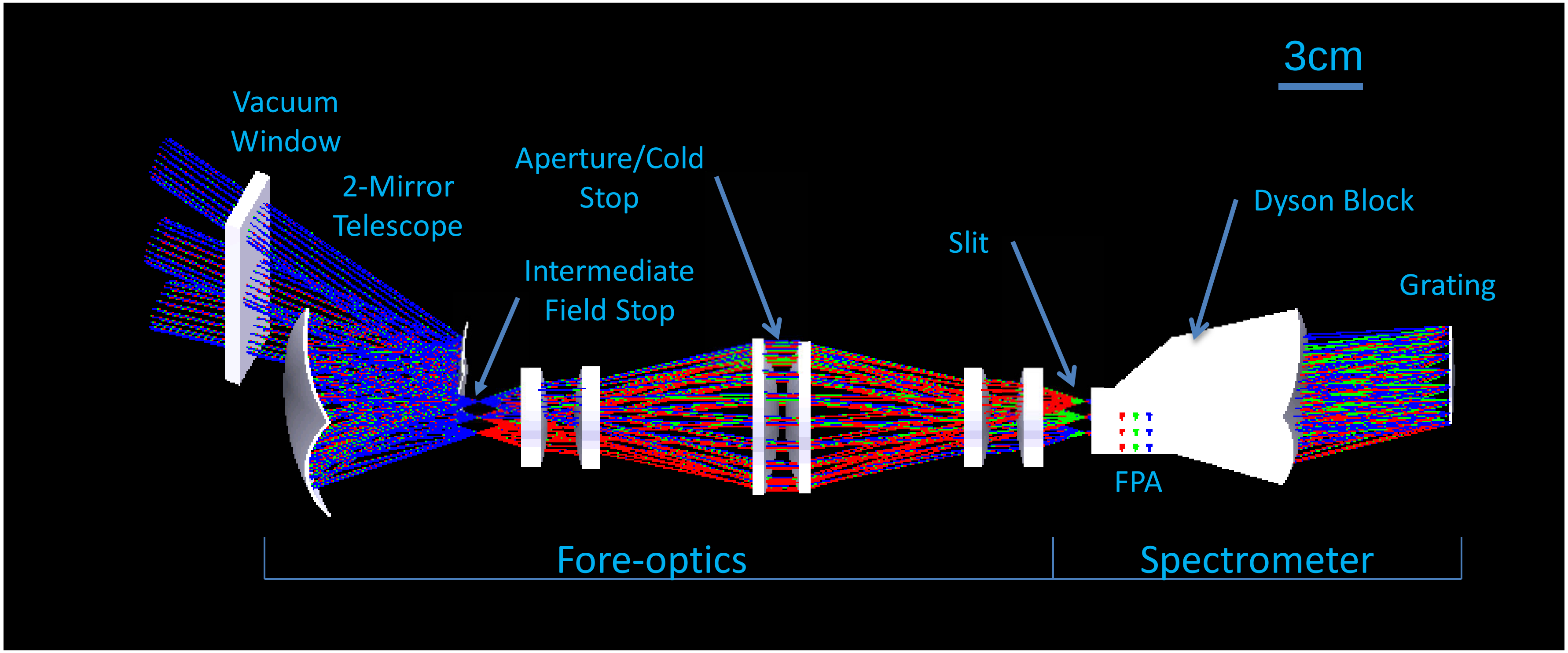
Advanced Designs: William Johnson





Multi-stack large format QWIP arrays: Sarath Gunapala

HyTES Optics

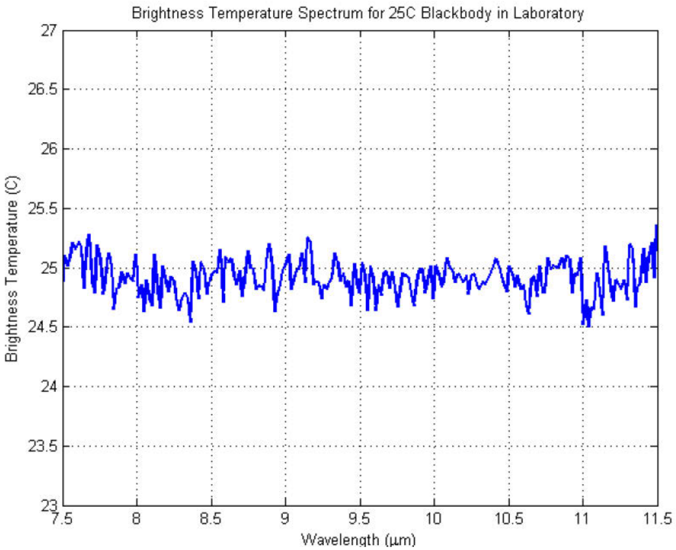


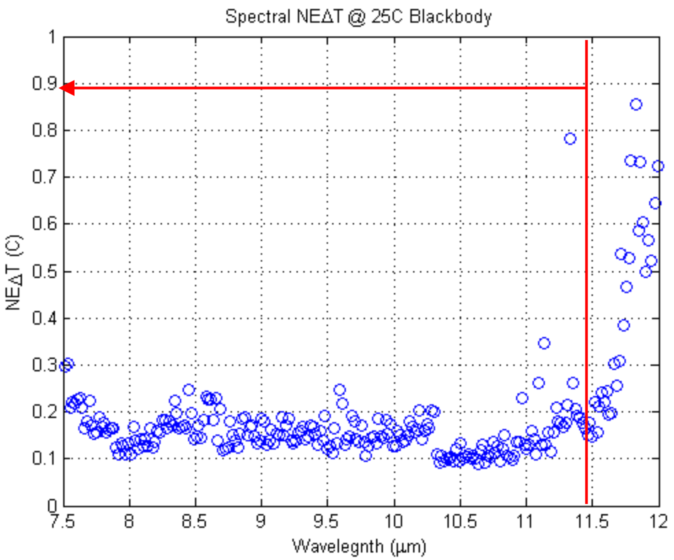
HyTES Optical Layout
(The entire system is cold, so there's no real "cold stop" in the traditional fashion)

HyTES NEDT

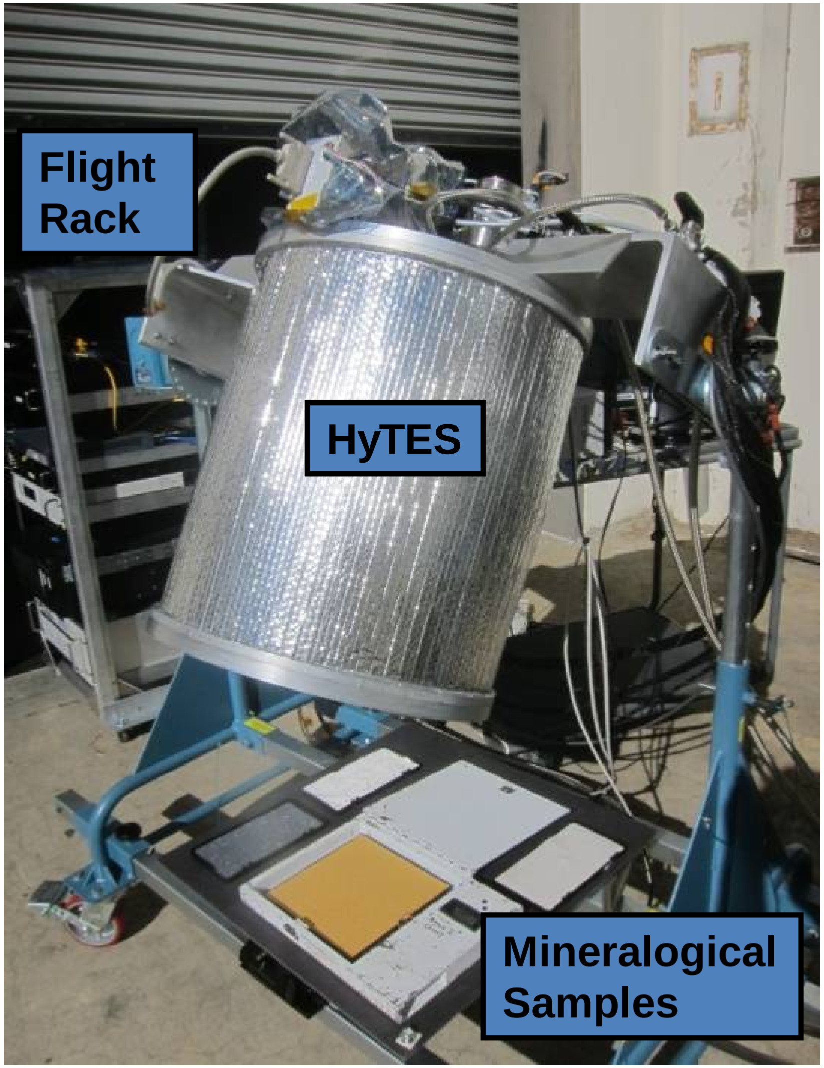
Lab Test Results
<u>10 January 2012</u>

- **Brightness Temperature Within 0.5 ° C of 25 ° C (Black-body Set Point)**
- **Sensitivity (NEDT, Modeled as Standard Deviation) Better than 0.2 ° C Between 7.5 – 11.5 µm**
- **Two-Layer QWIP Detector Array: Substantial Drop in Sensitivity for λ > 11.5 µm**





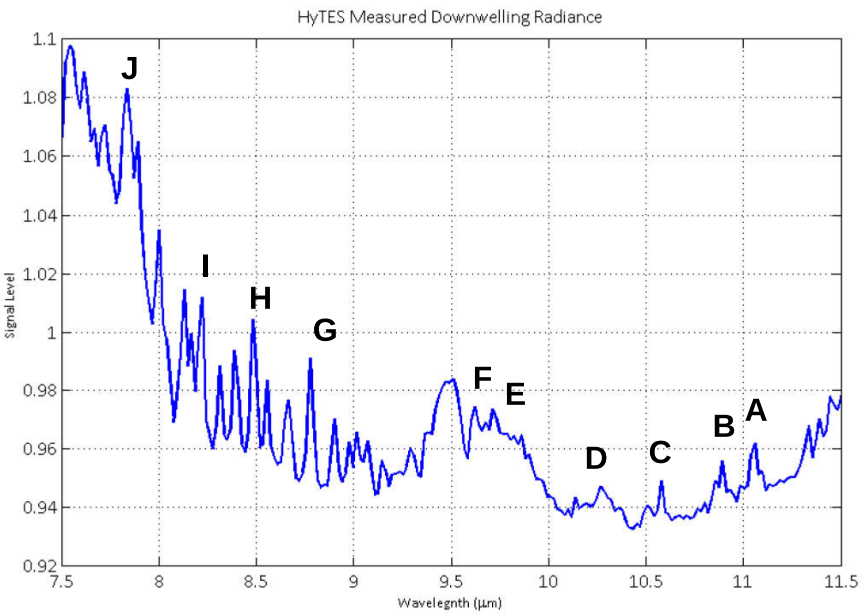
HyTES Outside Setup

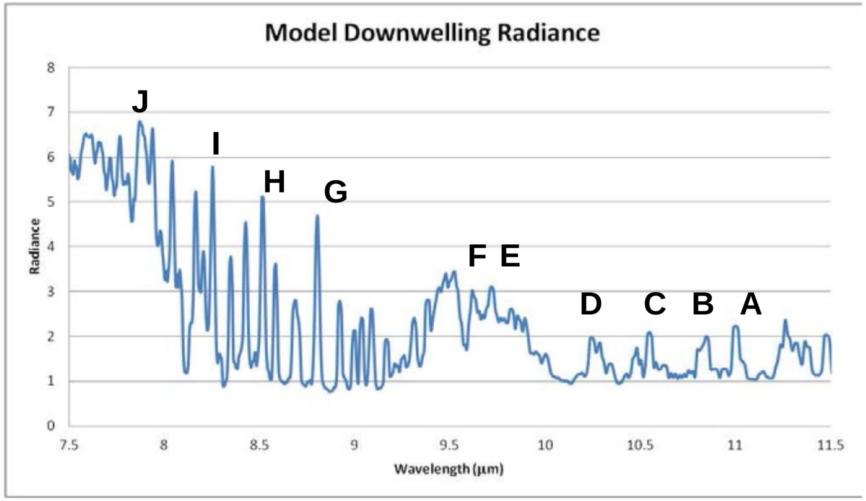


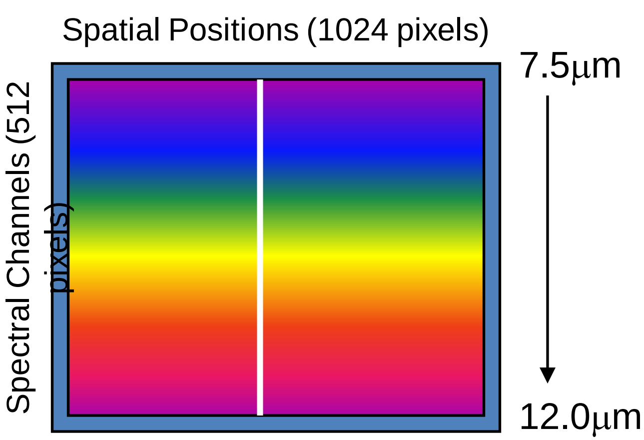
Test Procedure in Direct Sunlight

- **Obtain spectral calibration from downwelling radiance using diffuse gold.**
- **Observe mineralogical species: Quartz, Silicon Carbide**

HyTES Spectral Accuracy



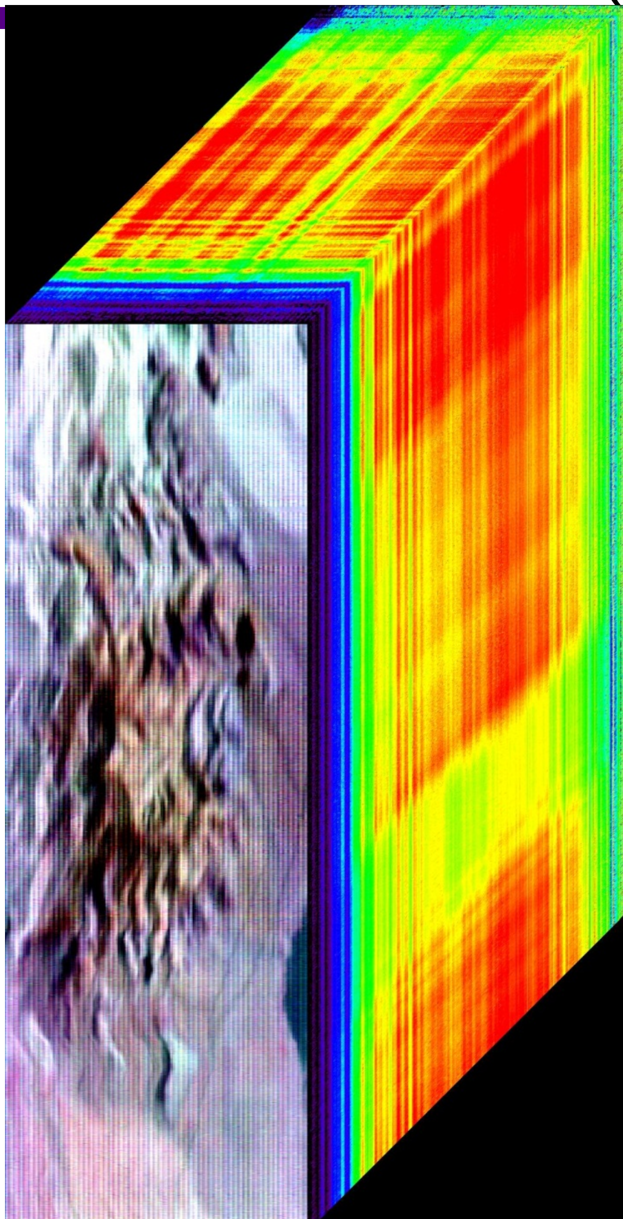




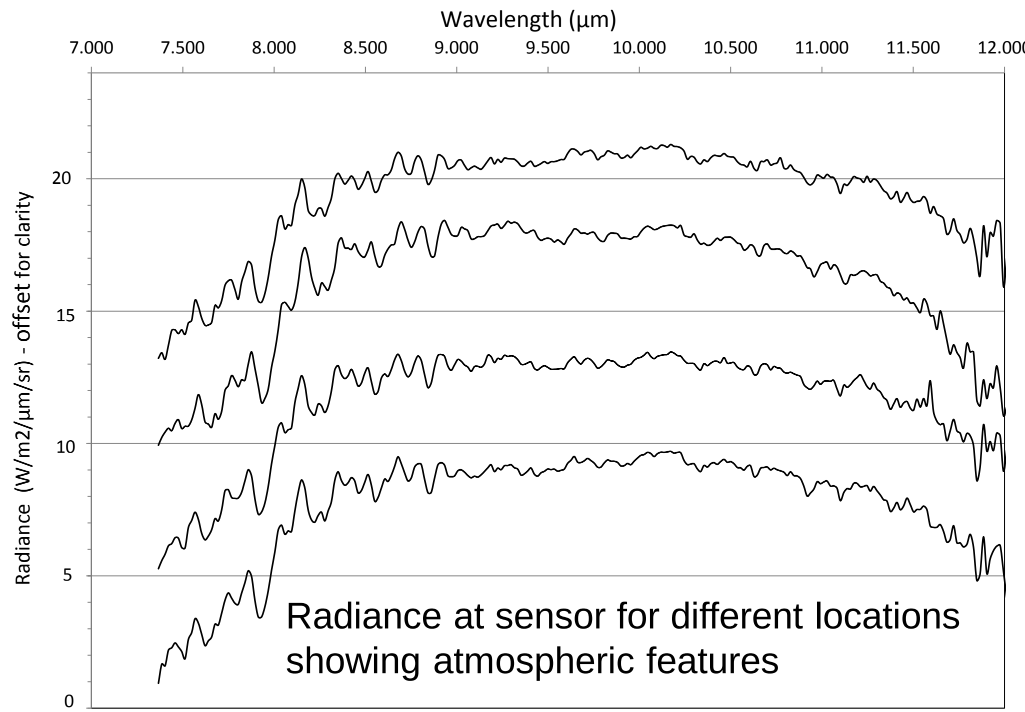
HyTES spectral calibration is very good. Wavelength determination for each features is well within one bandwidth.

	Model	HyTES	Δλ
A	11.0010	11.01	-0.009
B	10.8460	10.853	-0.007
C	10.5485	10.5404	0.0081
D	10.2459	10.237	0.0089
E	9.7180	9.7246	-0.0066
F	9.6150	9.6125	0.0025
G	8.8028	8.8051	-0.0023
H	8.5106	8.5105	0.0001
I	8.2508	8.2524	-0.0016
J	7.8740	7.875	-0.001

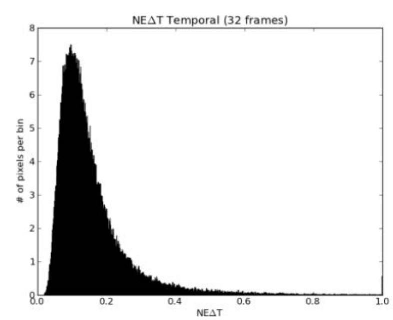
Hyperspectral Thermal Emission Spectrometer (HyTES) First Flights



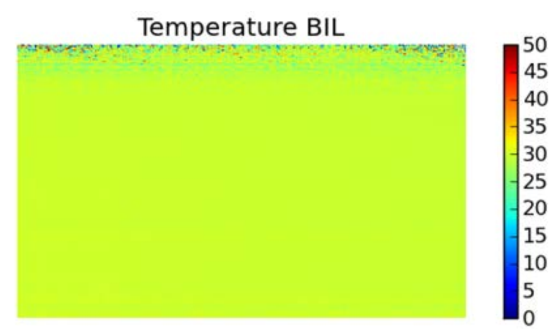
Left: Cuprite, NV 2012-07-20, bands 150 (10.08 μm), 100 (9.17 μm), 58 (8.41 μm) displayed as RGB respectively as image cube.



Noise Equivalent Delta Temperature (NEdT) ~0.2K



Blackbody Cross track uniformity



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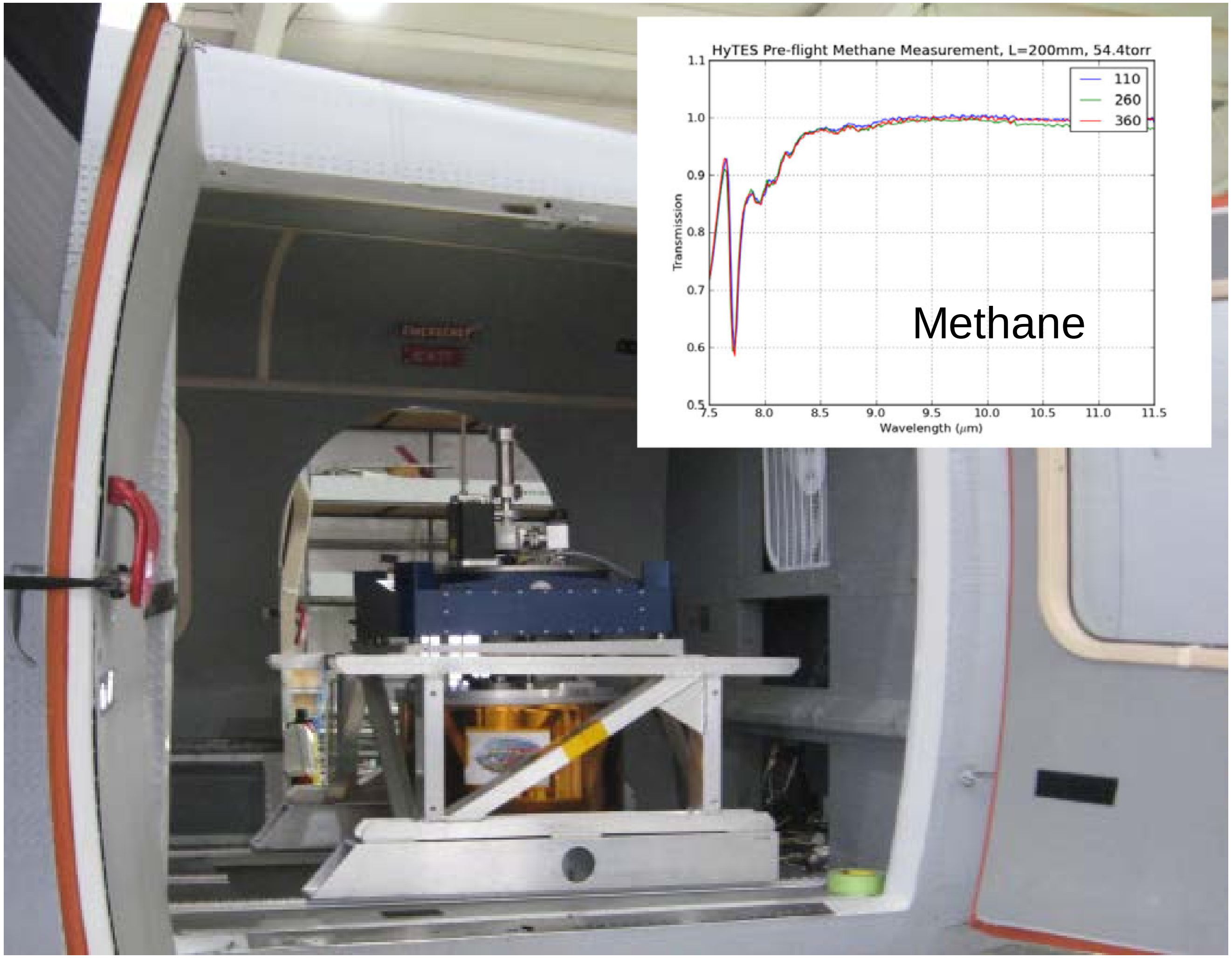
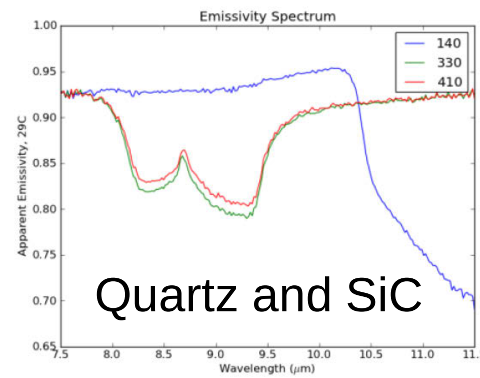
Hyperspectral Thermal Emission Spectrometer (HyTES) First Flights

- Hangar measurements with HyTES in the Twin Otter





HyTES Summary

- HyTES will allow the determination of the optimum position for the band filters for HyspIRI
- HyTES will provide antecedent data for testing HyspIRI algorithms
- HyTES will provide a new measurement capability, with high spectral and spatial imaging data useful for a range of applications such as volcanic gas detection
- HyTES instrument laboratory testing will begin in the next few weeks
- HyTES first airborne flights took place in July 2012

Overall Summary

- Exciting technology development and risk reduction underway for the HyspIRI-TIR program
- PHyTIR provides instrument risk reduction for key components of HyspIRI-TIR in particular the scan mirror and detectors
- HyTES provides science risk reduction for HyspIRI-TIR by allowing the optimum band positions to be determined as well as providing antecedent data at higher spectral and spatial resolution for algorithm development
- Find out more at: http://hyspiri.jpl.nasa.gov

National Aeronautics and Space Administration

HyspIRI Science Workshop
16 to 18 October 2012, Washington, DC

Key Science and Science Applications

Climate: Ecosystem biochemistry, condition & feedback; spectral albedo; carbon/dust on snow/Ice; biomass burning; evapotranspiration

Ecosystems: Global plant functional-type, physiological condition, and biochemistry including agricultural lands.

Fires: Fuel status, fire occurrence, severity, emissions, and patterns of recovery globally.

Coral reef and coastal habitats: Global composition and status.

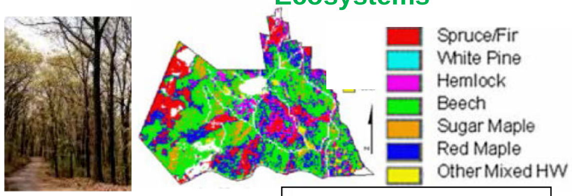
Volcanoes: Eruptions, emissions, regional and global impact.

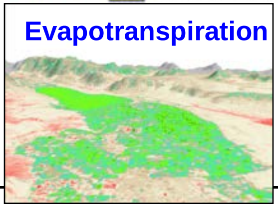
Natural and resources: Global distributions of surface mineral resources and improved understanding of geology and related hazards.

Societal Factors: Urban environment, habitability and resources.

Mission Urgency

The HyspIRI science and application objectives are important today and uniquely addressed by the combined imaging spectroscopy, thermal infrared measurements, and IPM direct broadcast.





Measurement

Imaging Spectrometer (VSWIR)

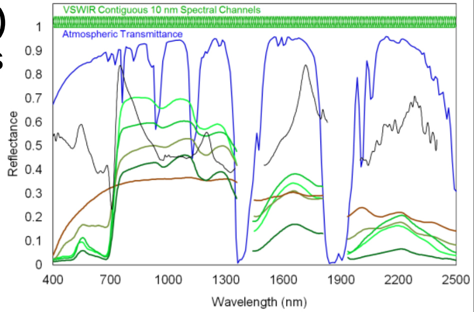
- 380 to 2500 nm in 10nm bands
- 60 m spatial sampling
- 19 days revisit

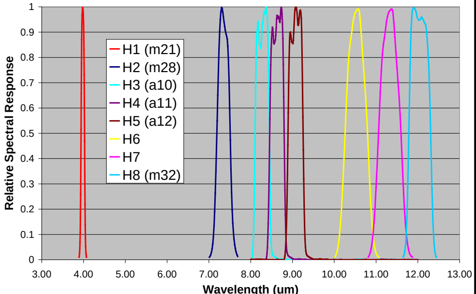
-Global land and shallow water

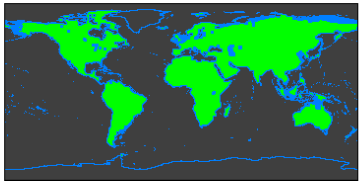
Thermal Infrared (TIR):

- 8 bands between 4-12 µm
- 60 m spatial sampling
- 5 days revisit
- Global land and shallow water

IPM-Direct Broadcast







Workshop Objectives

Review HyspIRI Mission Concept and next steps

Interact with broad science community

Review and refine Science Traceability

Present new relevant Science and Science Applications

Interact with International Science Community

Examine key VSWIR, TIR, IPM requirements

Receive feedback on the Draft Program Level 1 Requirements

Discuss HyspIRI Preparatory Science Activity

Review early results from AVIRIS Next Generation, HyTES and PRISM instruments

Information and Registration at:
http://hyspiri.jpl.nasa.gov