The Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)

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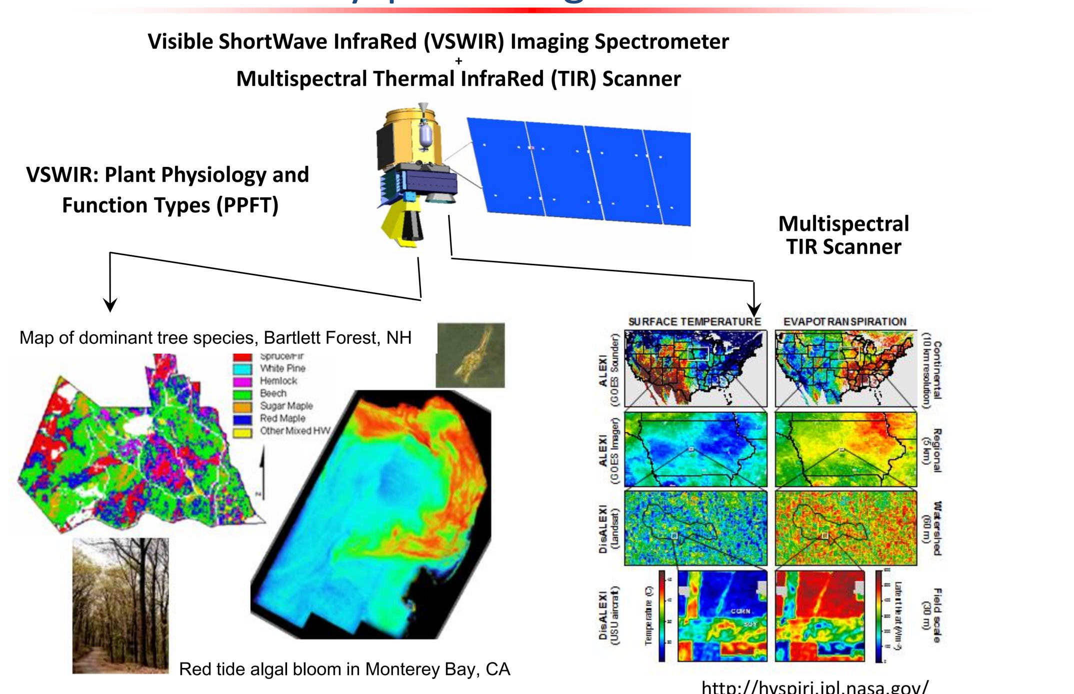
HyspIRI Background



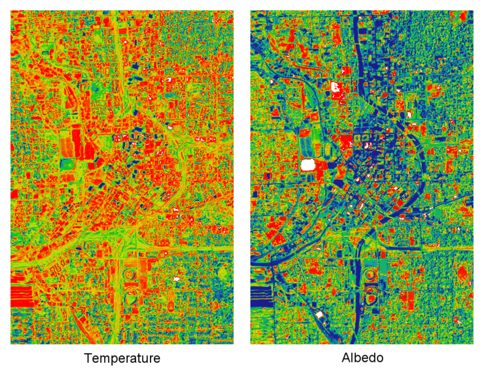
Multispectral Scanner

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

High Heritage

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



Atlanta, GA - May 1997

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)*

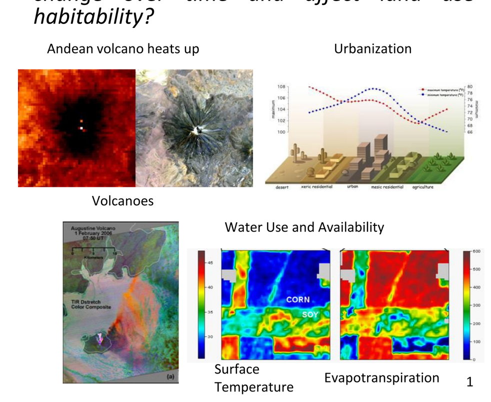
– How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?

- *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?



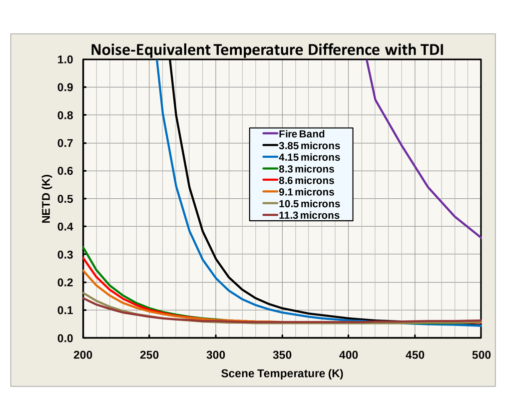
PHyTIR Rational for HyspIRI-TIR

The technology for the HyspIRI-TIR instrument is mature but further work is needed to reduce risk. In particular, the proposed design requires a high sensitivity and high throughput Focal Plane Array (FPA), combined with a scanning mechanism that requires stringent pointing knowledge. The scanning approach, and the high sensitivity and high throughput FPA, are required to meet the revisit time (5 days), the high spatial resolution (60m), and the number of spectral channels (8) specified by the Decadal Survey, and the HyspIRI Science Study Group for the mission. The next step is to reduce the risk associated with the scanning mechanism and the FPA with the development of a laboratory prototype termed the Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR).

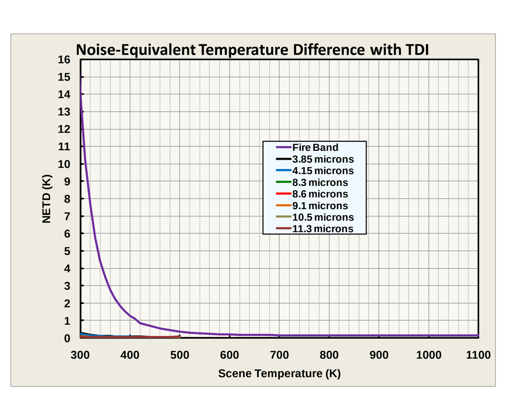
PHyTIR will demonstrate that:

1.The detectors and readouts meet all signal-to-noise and speed specifications.
2.The scan mirror, together with the structural stability, meets the pointing knowledge requirements.
3.The long-wavelength channels do not saturate below 480 K.
4.The cold shielding allows the use of ambient temperature optics on the HyspIRI-TIR instrument without impacting instrument performance.

HyspIRI-TIR Sensor Performance

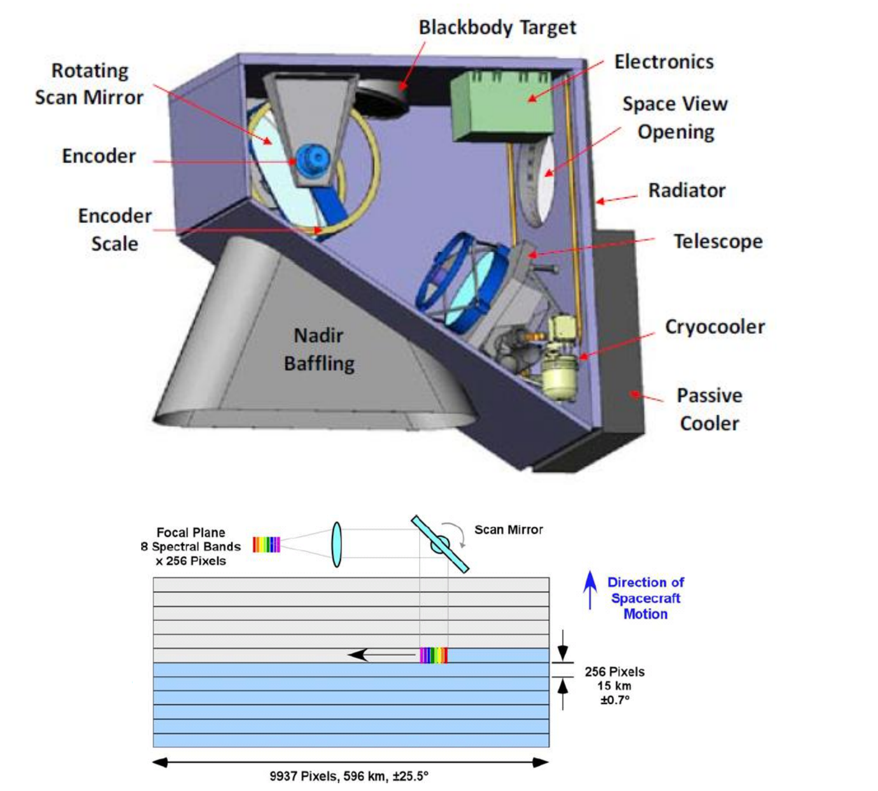


Expected HyspIRI-TIR Sensitivity Metric expressed as Noise Equivalent Delta Temperature (NEDT)



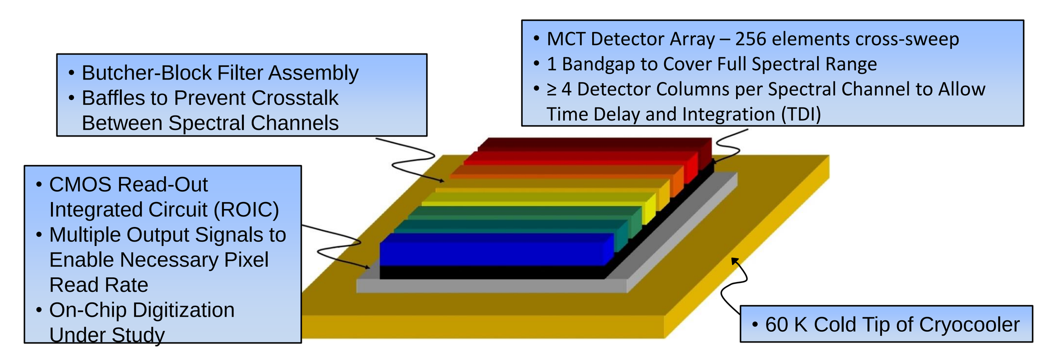
Expected HyspIRI-TIR Sensitivity Metric expressed as Noise Equivalent Delta Temperature (NEDT)

HyspIRI-TIR Instrument Concept



HyspIRI-TIR Sensor Assembly

HyspIRI TIR Instrument Characteristics			
Spectral		**Spatial**	
Bands (8)	3.98 µm, 7.35 µm, 8.28 µm, 8.63 µm, 9.07 µm, 10.53 µm, 11.33 µm, 12.05 µm	IFOV	100 µrad; 60 m at nadir
Bandwidths	0.084 µm, 0.32 µm, 0.34 µm, 0.35 µm, 0.36 µm, 0.54 µm, 0.54 µm, 0.52 µm	MTF	>0.60 at FNy
Accuracy	<0.01 µm	Scan Type	Push-Whisk, 14.2 RPM mirror rotation
Radiometric		Cross-Whisk Samples	256
Temperature Range	Channel 1: 400-1200 K Channel 2–8: 200 K – 480 K	Samples in Whisk Direction (Cross Track)	9,300
Resolution	< 0.05 K, linear quantization to 14 bits	Cross-Whisk Swath Width	15.4 km (±0.7° at 623 km altitude)
Accuracy	< 0.5 K at 250 K	Swath Length in Whisk Direction	596 km (±25.5° at 623 km altitude)
Precision (NETD)	< 0.2 K	Band to Band Co-Registration	0.2 pixels (12 m)
Linearity	>99% characterized to 0.1 %	Pointing Knowledge	10 arcsec (0.5 pixels, 30 m)

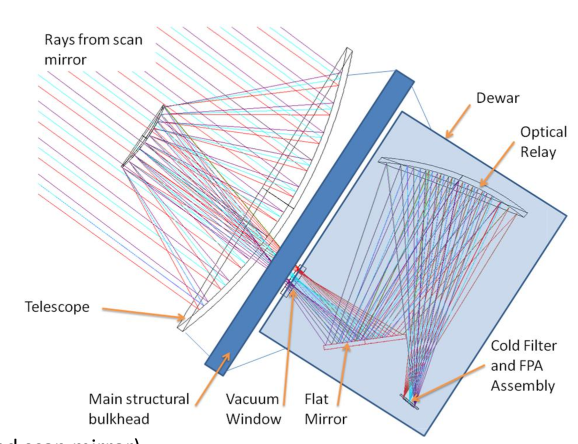


HyspIRI-TIR will use a Butcher-block filter layout on top of focal plane. PHyTIR will not use focal plane filers but will spin a filter wheel in the optical path.

Instrument Optics

Optical Design Assumptions

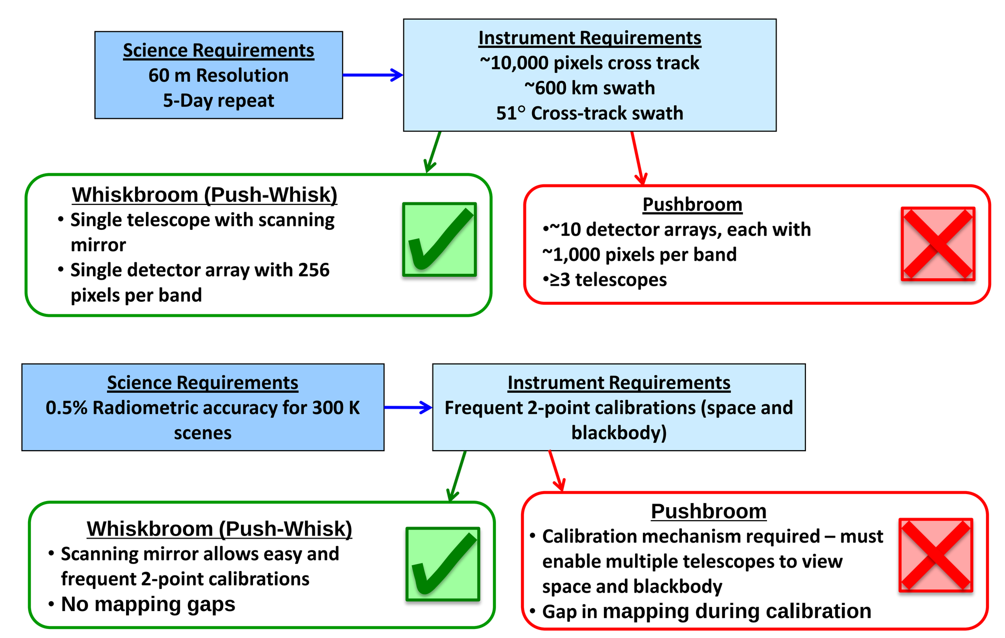
- Altitude: 623km (5-day repeat)
- Ground Sample Distance: 60m (@ NADIR)
- Pixel pitch: 40µm
- Aperture: F/2
- IFOV: 96.308 µrad
- FOV: 1.413° (stationary)
- FOV: 51° (scanning)
- Focal Length: 415.3mm
- Aperture Size: 207.7m
- Cross track pixels: 9242 pixels
- Swath: 600km (R_{earth} = 9378km)
- Swath overlap: 5% along track pixels
- Dwell time: 32.5ms
- Scan Mirror Rotation Rate: 14.15rpm (double sided scan mirror)
- Spectral coverage (Passband) = 4 to12mm
- $MTF_{Nyquist}$ > 60% for all fields and wavelengths
- Obscuration <15% (by area)
- 3 aspheric mirrors (telescope and relay)
- 2 flat mirrors (fold and scan)
- 2 transmissive elements (window and interference filter)
- chromatic aberration negligible



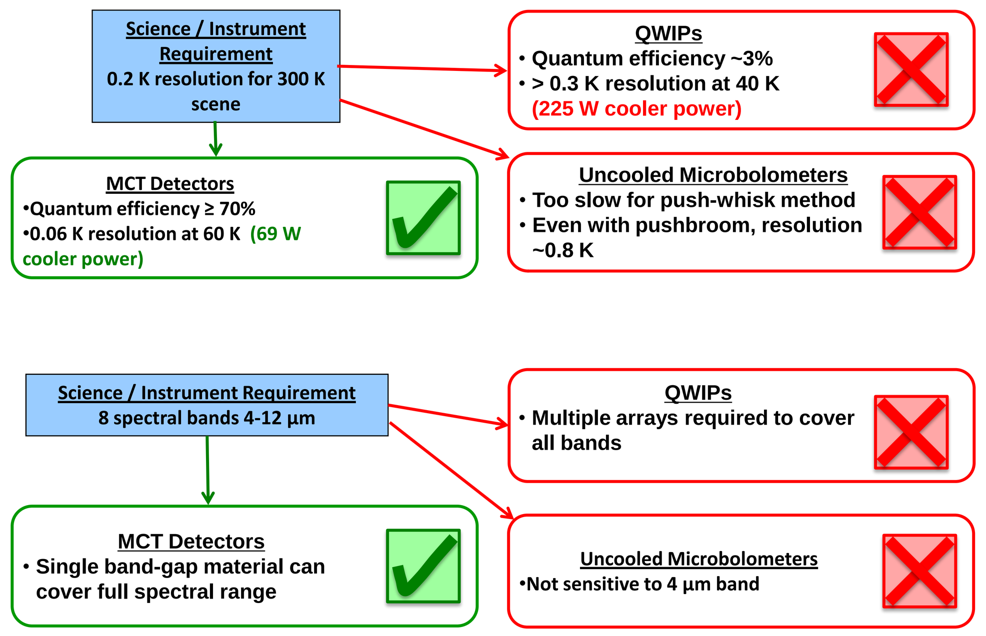
Summary

Parameter	Value
Aperture Size	208 mm (<10% obstruction)
F/#	2
Focal Length	416mm
Optical Throughput	66%

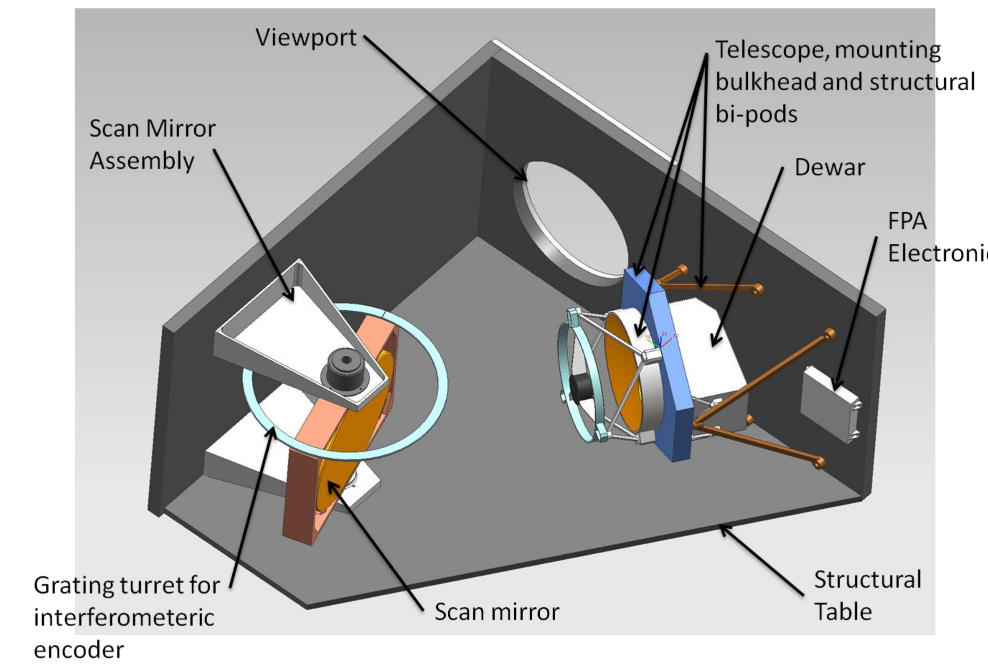
HyspIRI-TIR Sensor Rational

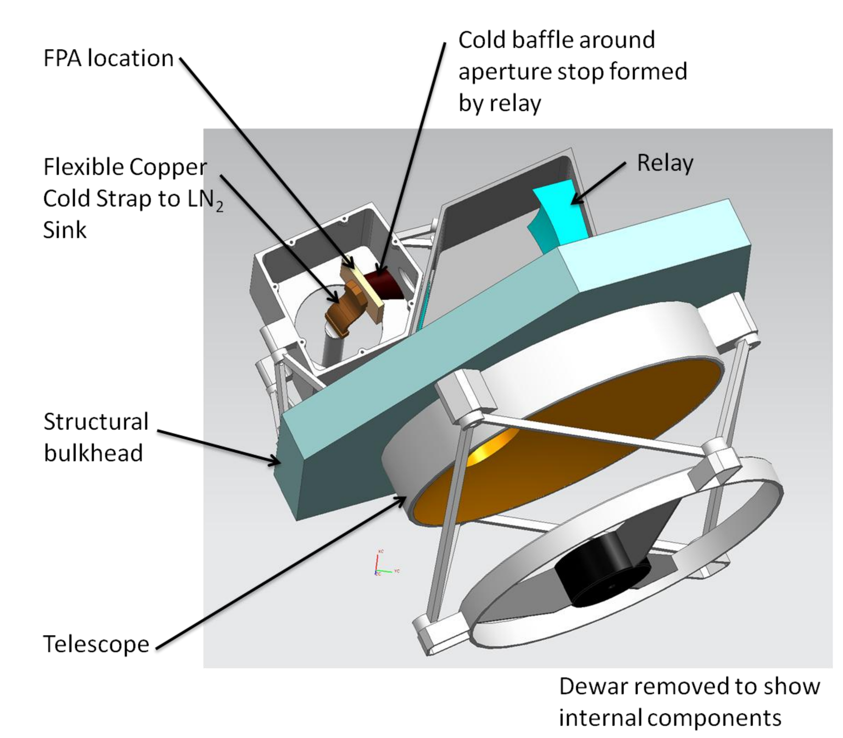


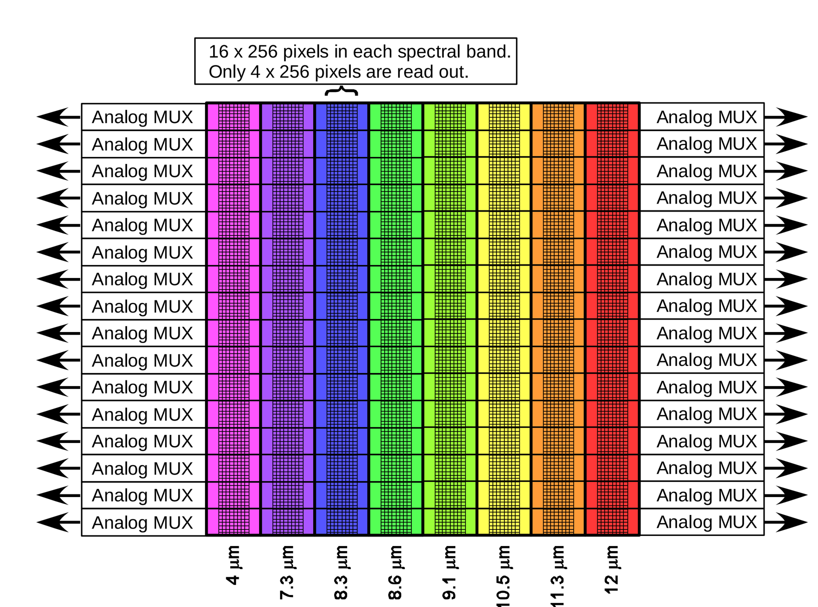
HyspIRI-TIR Sensor Rational



PHyTIR Implementation

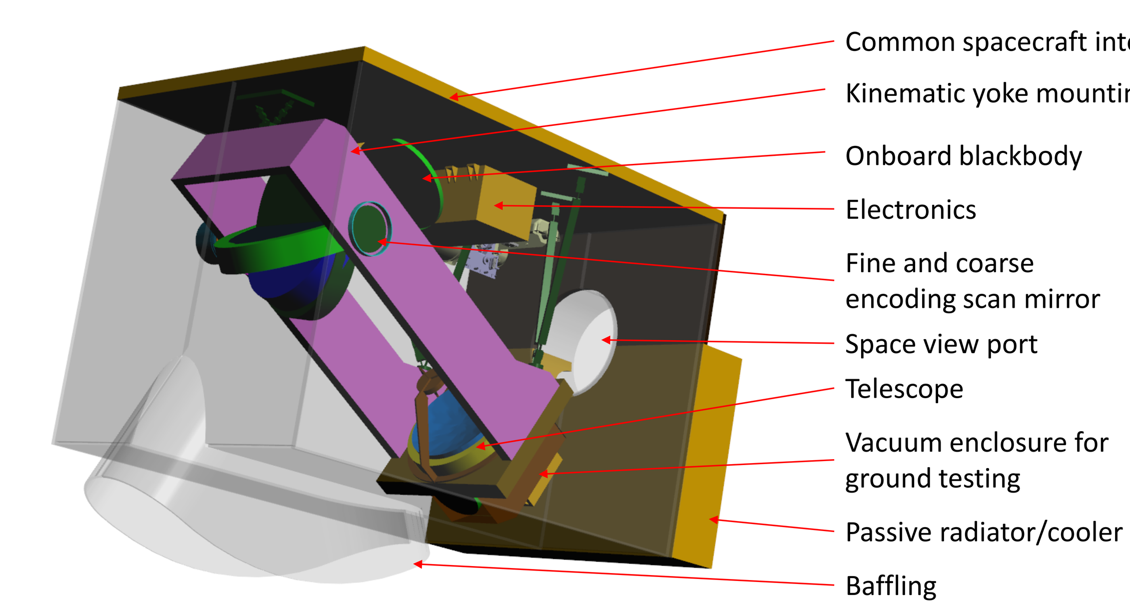






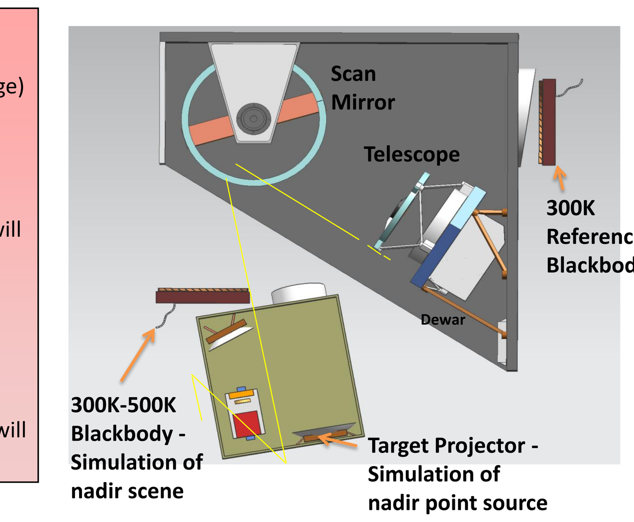
PHyTIR will not have focal plane filters but will implement the identical ROIC design to HyspIRI-TIR.
32 parallel output at ≥ 10 MHz allow 32 µs frame times.

PHyTIR Current Design



PHyTIR Calibration and Validation

- PHyTIR Prototype Consists of
  - Full HyspIRI TIR MCT detector array
  - Spectral range 4-12 µm (TIR spectral range)
  - Scan mirror prototype with precise encoder
- Testing of PHyTIR Prototype
  - Measuring response to two blackbody targets, combined with detector noise, will provide S/N (tested at full frame rate)
  - Imaging of target-projector slit while inducing T gradients will test pointing stability
  - Increasing blackbody T will determine saturation T and high-T S/N
  - Measuring background, noise, and drift will show effects of uncooled optics



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.

This activity will benefit the development of any airborne or spaceborne system that will utilize a high speed scanning mirror coupled with a MCT detector array to obtain a wide swath width, high spatial resolution, thermal infrared measurement with an NEΔT of approximately 0.2K.

Similar systems have been used in the Moderate Resolution Imaging Spectroradiometer (MODIS), Visible Infrared Imaging Radiometer Suite (VIIRS), Advanced Spaceborne Thermal Emission Radiometer (ASTER) and Landsat (TM5/ETM+) instruments (Barnes et. al. 1998; Mitchel 2008; Ohmae and Kitamure, 1994; Barsi et al. 2003).

However, none of these existing systems has sufficient performance to meet the measurement requirements of the HyspIRI-TIR instrument. PHyTIR will demonstrate that HyspIRI-TIR required high accuracy measurements can be made and help enable both the HyspIRI-TIR instrument as well as other future instruments built by Governments or Commercial Companies that utilize similar technology.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.