Characterization and Performance of the Prototype HyspIRI-TIR (PHyTIR) Sensor

Presented at:

HyspIRI Workshop 2014

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Outline

- HyspIRI Background
- ECOSTRESS
- Instrument Design
- Instrument Performance
- Initial Testing Results
- Concluding Remarks

HyspIRI Background

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

Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer

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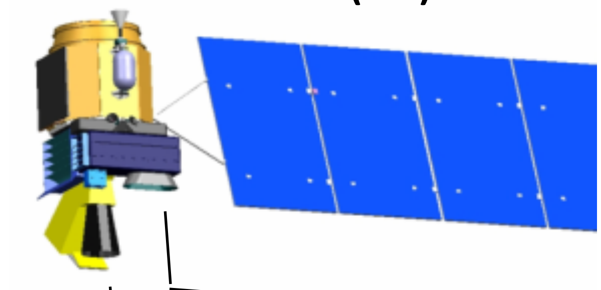
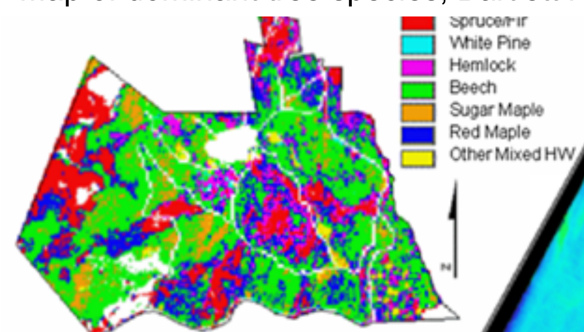
Multispectral Thermal InfraRed (TIR) Scanner

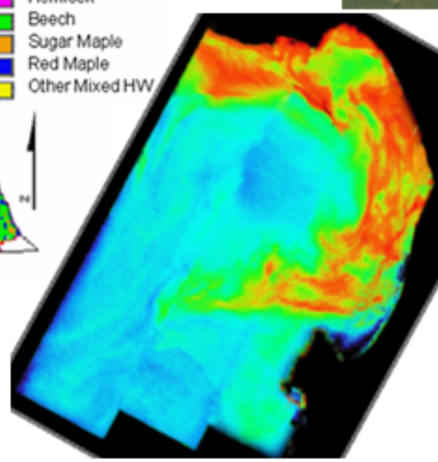


VSWIR: Plant Physiology and Function Types (PPFT)

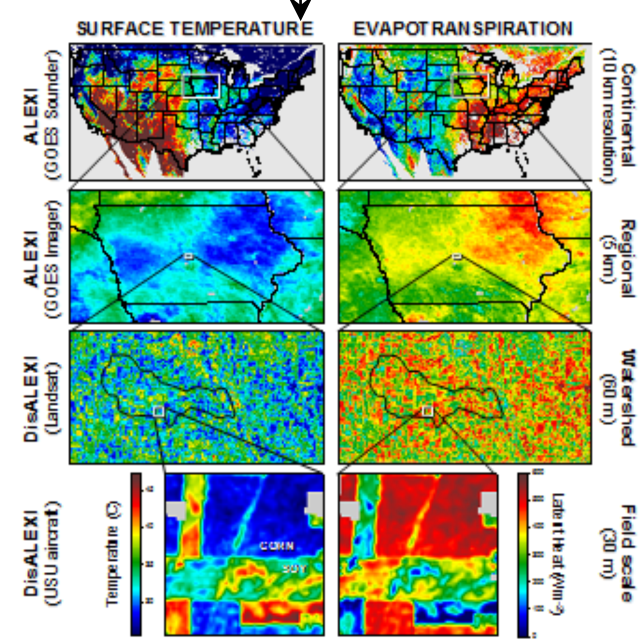
Multispectral TIR Scanner

Map of dominant tree species, Bartlett Forest, NH

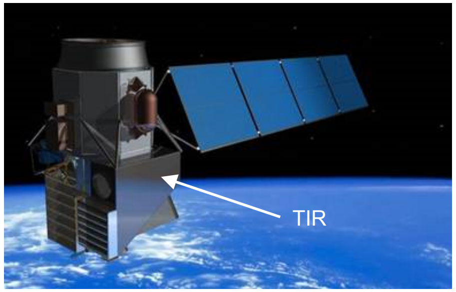


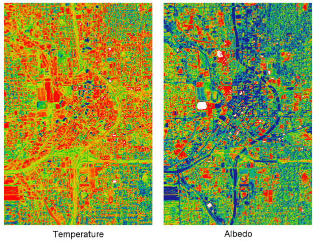


Red tide algal bloom in Monterey Bay, CA



HyspIRI Background





Atlanta, GA - May 1997

Multispectral Scanner

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

High Heritage

http://hyspiri.jpl.nasa.gov

Science Questions:

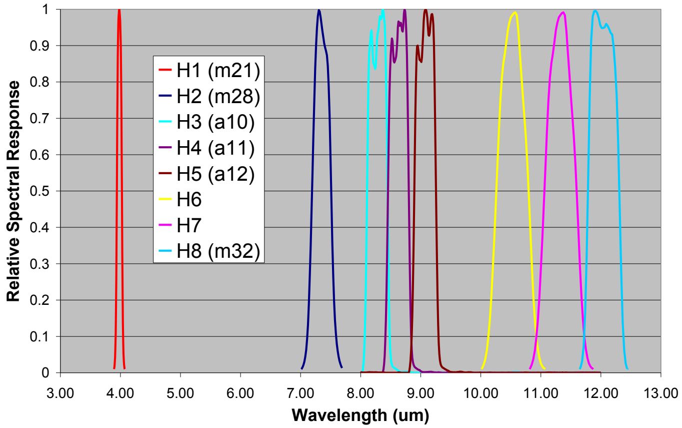
TQ1. Volcanoes/Earthquakes (MA,FF)

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

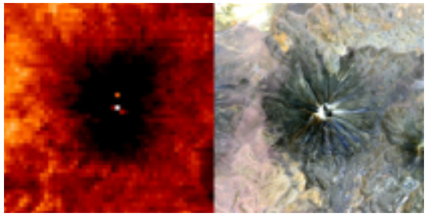
- *TQ2. Wildfires (LG,DR)*
  - *What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?*
- *TQ3. Water Use and Availability, (MA,RA)*
  - *How is consumptive use of global freshwater supplies responding to changes in climate 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:

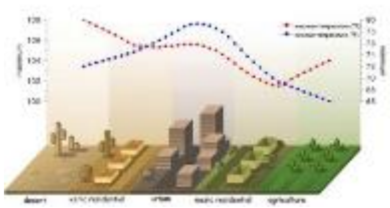
- 7 bands between 7.5-12 μm and 1 band at 4 μm
- 60 m resolution, 5 days revisit
- Global land and shallow water



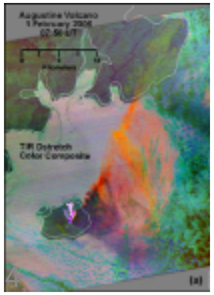
Andean volcano heats up



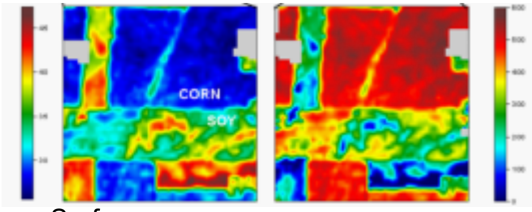
Urbanization



Volcanoes



Water Use and Availability



Surface Temperature

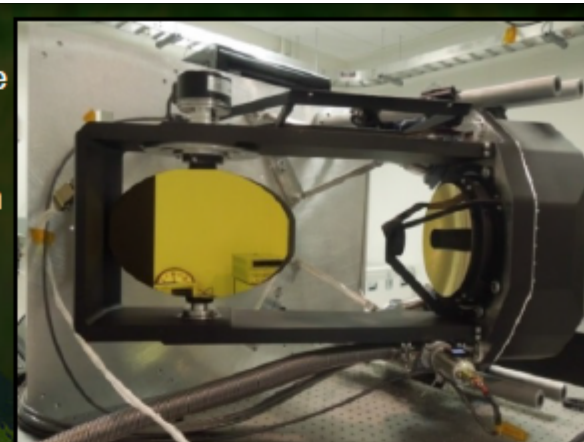
Evapotranspiration

ECOSTRESS

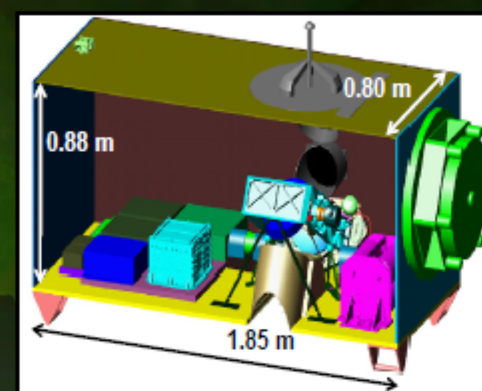
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

Instrument

- Leverages functionally-tested PHyTIR space-ready hardware developed under the NASA Instrument Incubator Program:
  - Spectral resolution: 5 bands in the thermal infrared window (8-12.5 μm) part of the electromagnetic spectrum
  - Noise equivalent delta temperature: ≤ 0.1 K
  - Spatial resolution: 38 m x 57 m
  - Swath width: 384 km (51°)
- *Well understood measurement and algorithms based on prior missions, such as ASTER, MODIS, and Landsat*



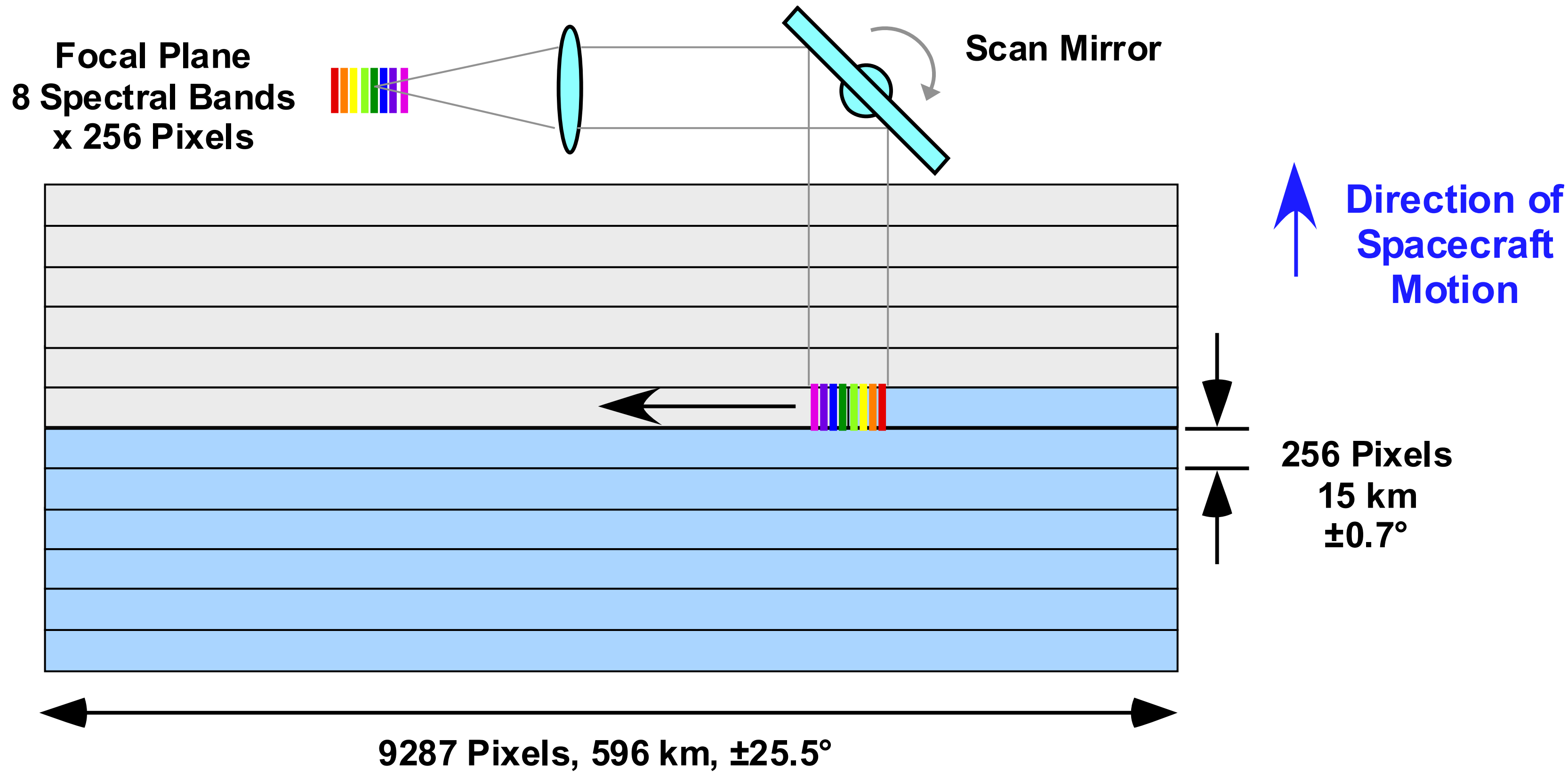
Science Data Products	
L0	Raw data
L1	Radiometrically corrected Brightness Temperature
L2	Surface Temperature and Emissivity
L3	Evapotranspiration
L4	Water Use Efficiency, Evaporative Stress Index



HyspIRI-TIR Science Measurement Requirements

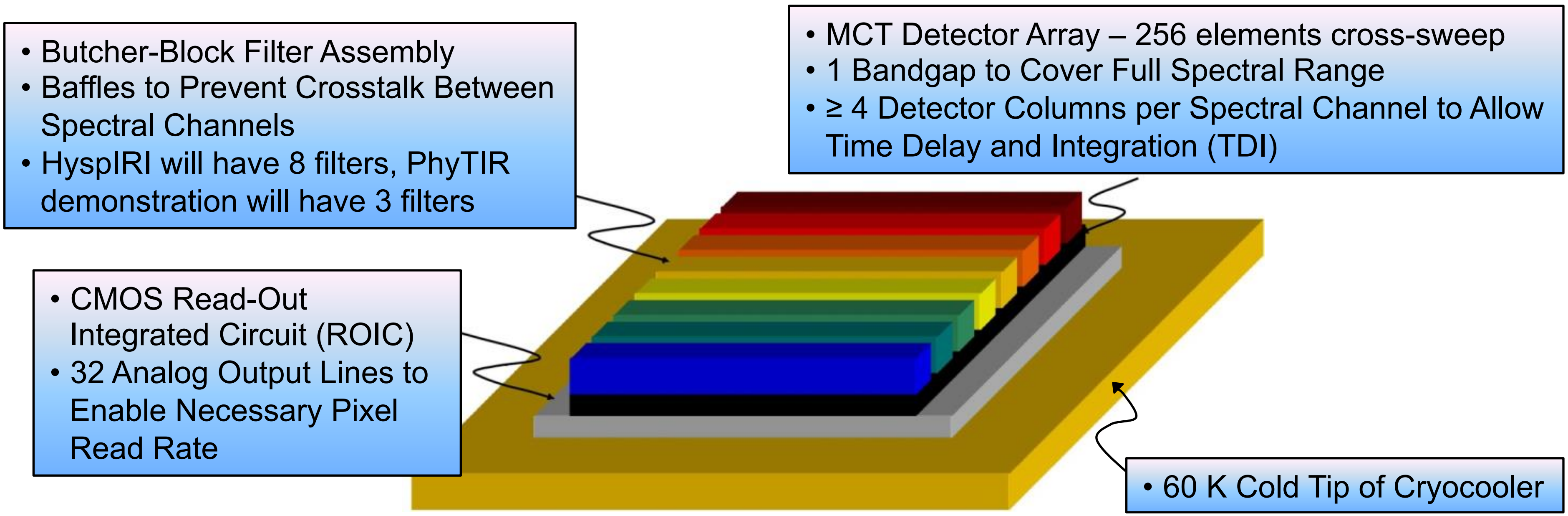
PARAMETER	BASELINE	SCIENCE REQUIREMENT
Ground Resolution (m)	60	<100
Revisit (days)	5	<6
Noise equivalent delta temperature (K)	0.2	<0.3
Absolute accuracy (K)	0.5	<1
Saturation – low temperature bands (K)	500	>400
Saturation – high temperature band (K)	1200	>1100
Overpass time (hh:mm)	10:30am	10-3pm
Nighttime imaging	Yes	Required
Number of Bands (spectral range: 3 – 12 µm)	8	>=8
Coverage	Land and coastal regions	Land and coastal regions
Data latency	2 days	< 1 week

HyspIRI Scan Concept



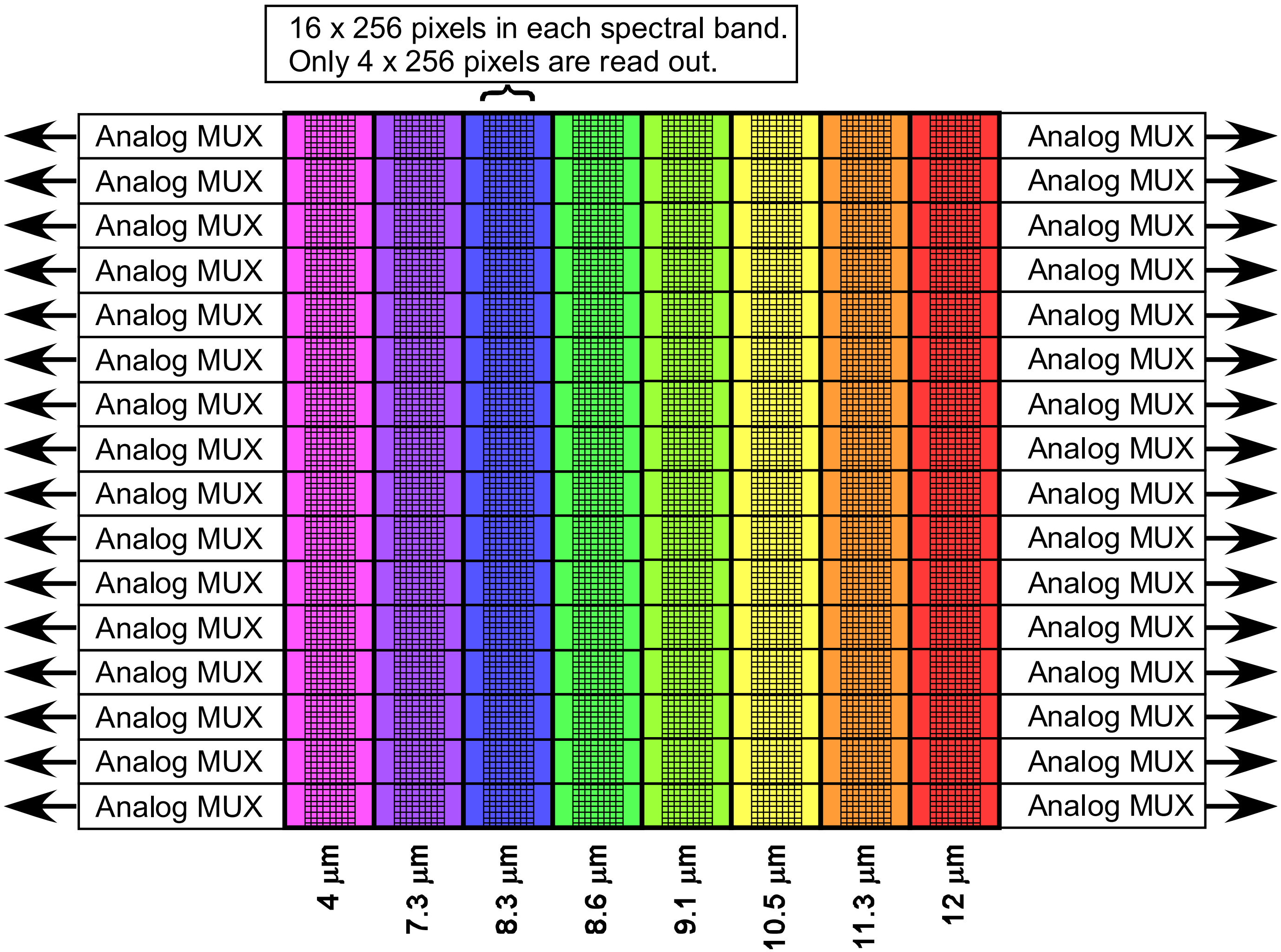
- 60 m Pixel Footprint at Nadir
- Time-Averaged Science Data Rate 0.020 Gbps
- Assuming 14 bits, 2:1 Compression, 34% Land
- Scan Mirror Rotation Rate 14.2 RPM
- Pixel Dwell Time 32 microseconds

TIR Focal Plane Concept



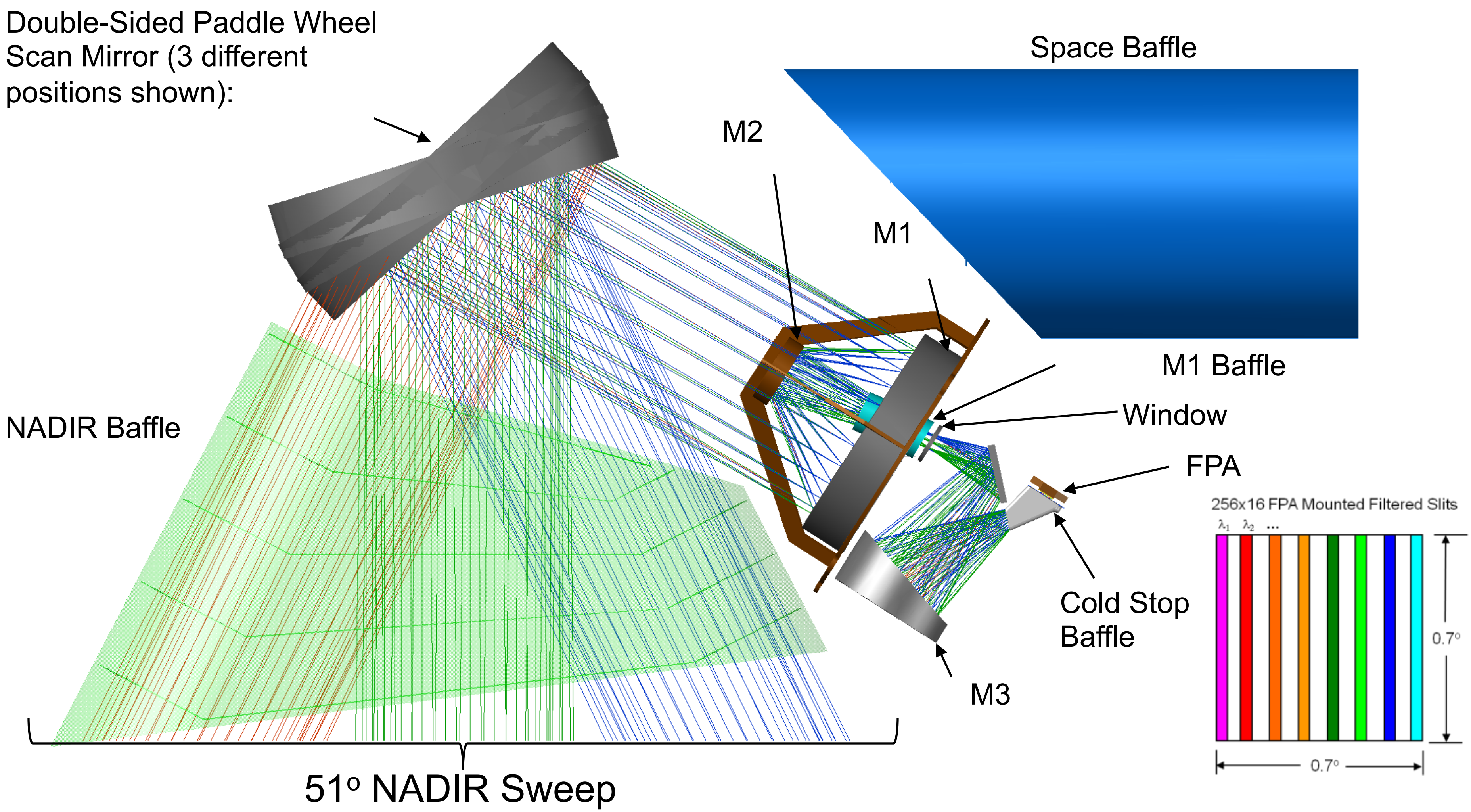
- JPL now has focal plane detectors and readout electronics.
- Digitization is performed using off-chip ADCs
- TDI performed after digitization

Focal Plane Readout Architecture

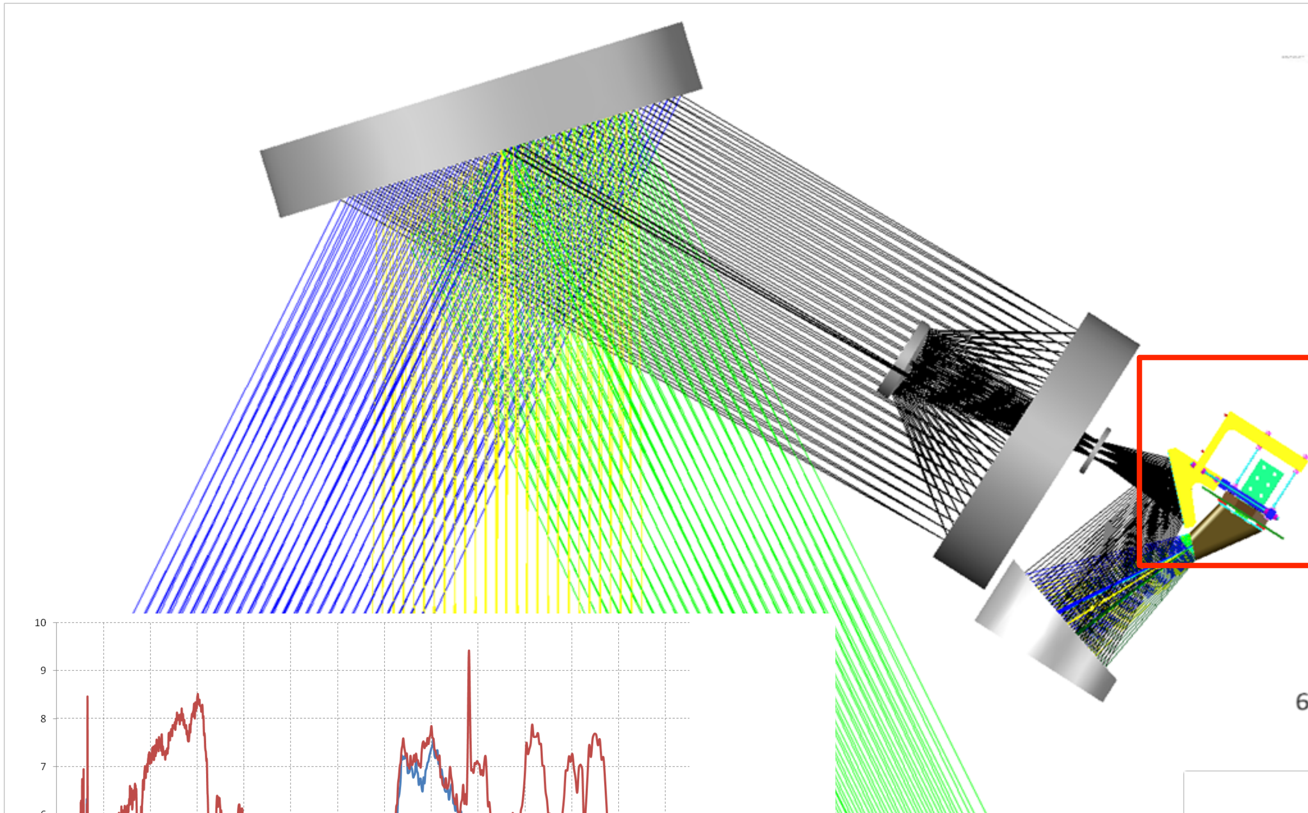


Optics Design

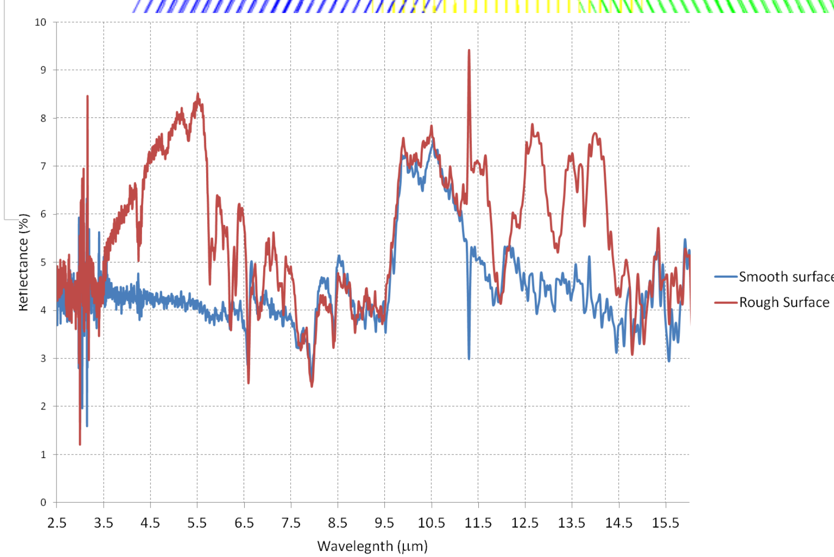
- Optical Prescription: Three-Mirror Anastigmat Telescope with Scan Mirror



PHyTIR Focal Plane Cold Baffling

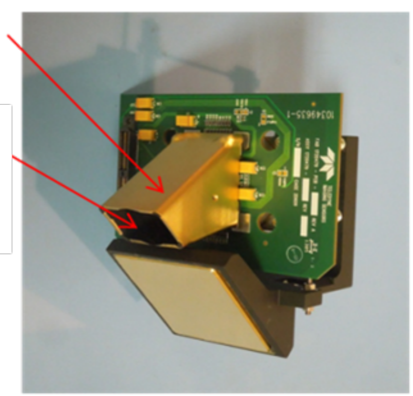


FPA assembly is analogous to an infrared light trap, since it's positioned at an intermediate pupil plane



Full angle reflectance measurement using integrating sphere of paint surface used on cold baffle. Measurement shows good performance for stray light suppression.

60K Housing



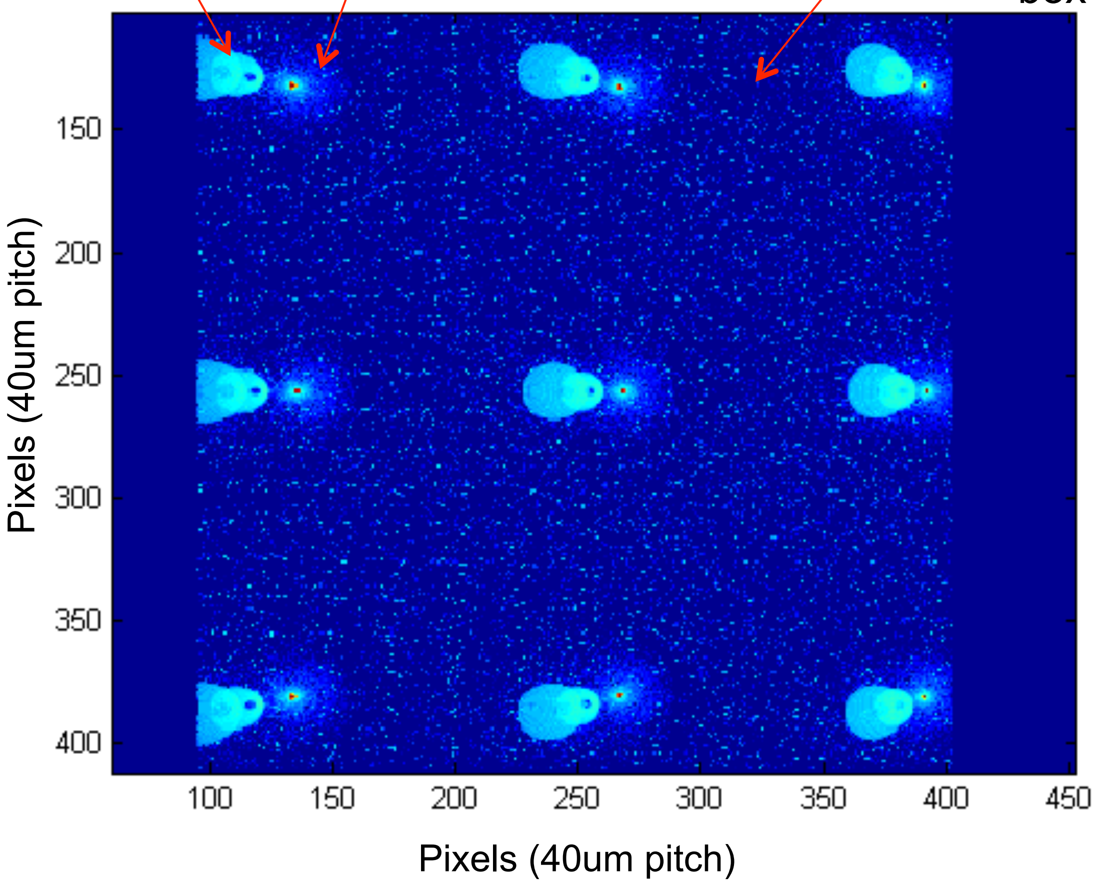
Actual unit in PHyTIR

PHyTIR Focal Plane Cold Baffling

Butcher block filter glass

Halo around each spot due to diamond turned optical polishing

Stray reflections off painted cold box



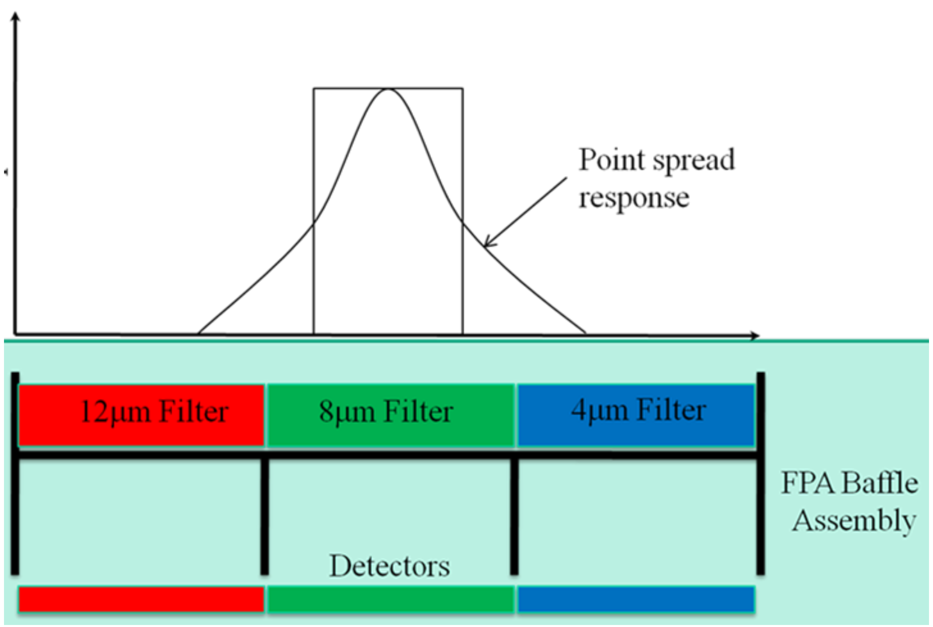
Non-sequential ray trace model developed using ABg scattering for optical surfaces and lambertan for painted surfaces . Implemented in FRED (Photon Engineering).

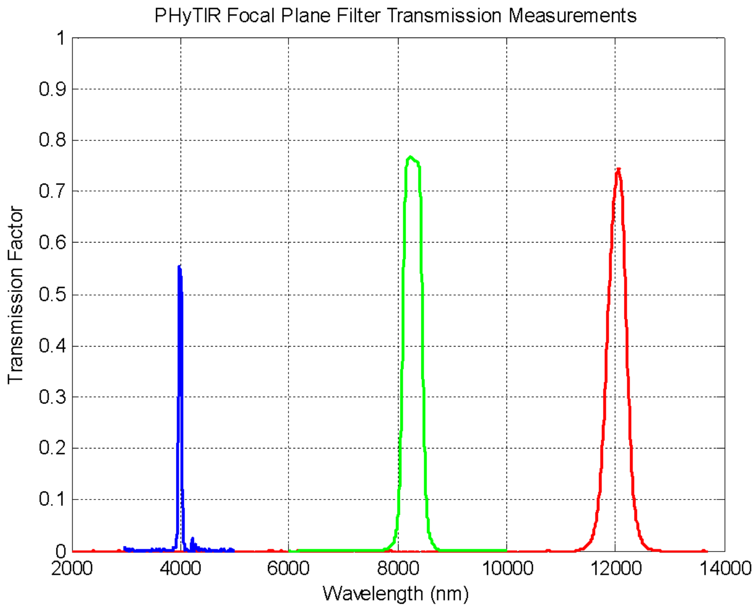
$$\mathrm{BSDF}(\beta-\beta_0)=\frac{A}{B+(\beta-\beta_0)^g}\quad[sr^{-1}]$$

$$\mathrm{BSDF}=\frac{\rho}{\pi}\,[sr^{-1}]$$

PHyTIR Focal Plane Cold Baffling

Cold baffling near the focal plane minimizes stray light from adjacent filters.



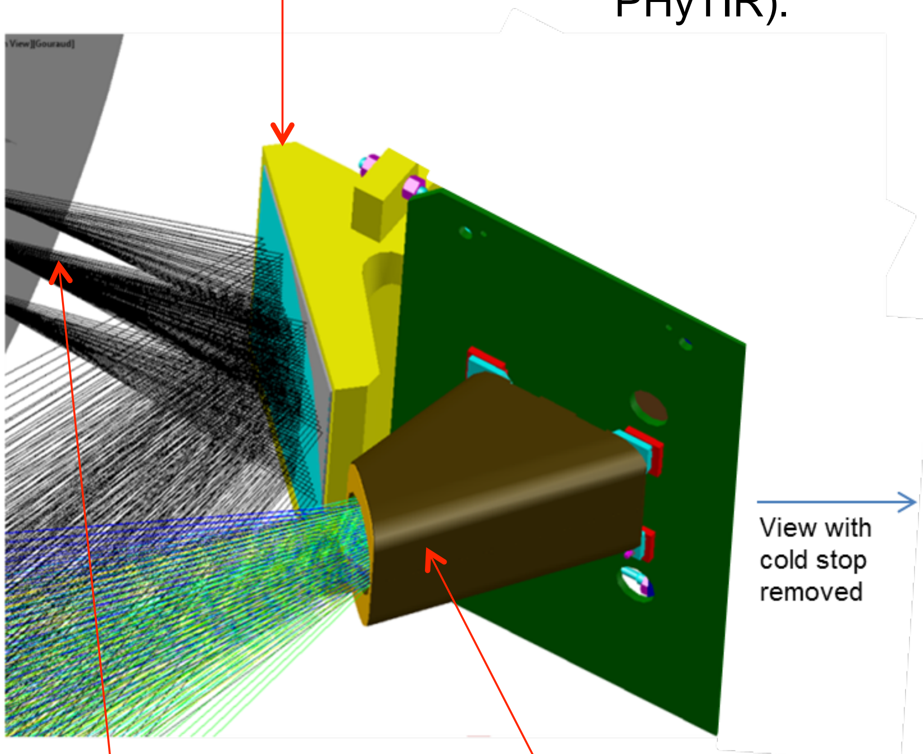


Final filter parameters (as delivered, tested at cryogenic temperatures)	
Wavelength (µm)	Bandwidth (nm)
4.03	60
8.345	310
12.05	444

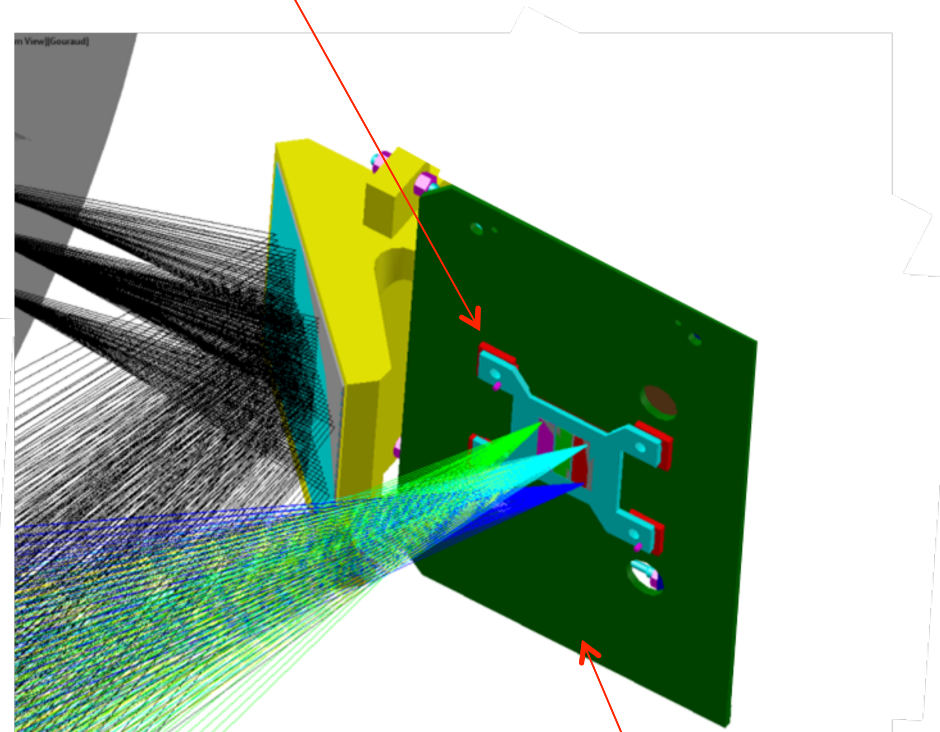
PHyTIR Focal Plane Cold Baffling

Cold (60K) interference filter assembly + fpa filter baffle (3 filters currently used in PHyTIR).

Fold Mirror



View with cold stop removed



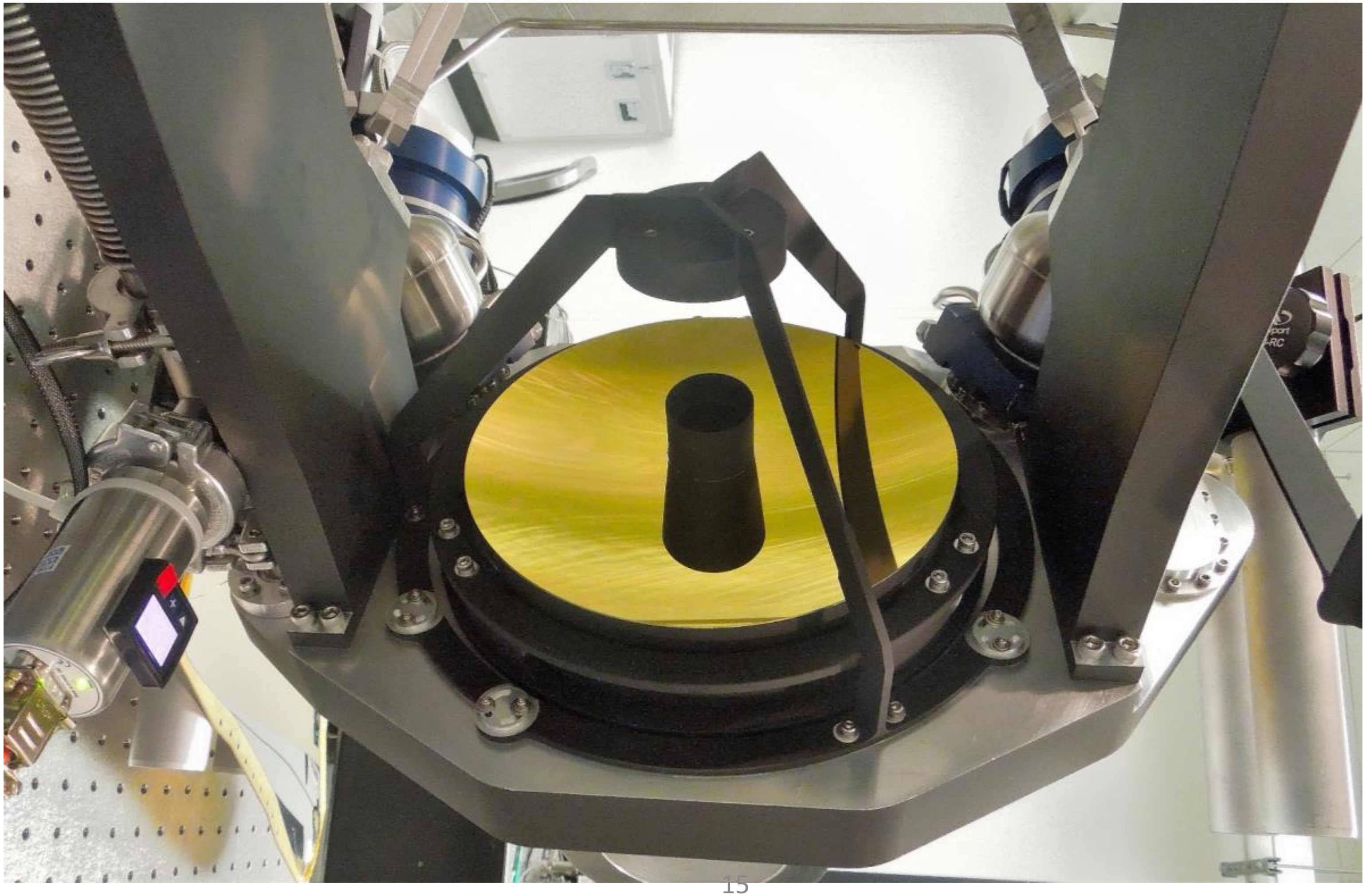
Rays immediately past intermediate focus

Cold (60K) stop baffle directly couples into focal plane thermal sink.

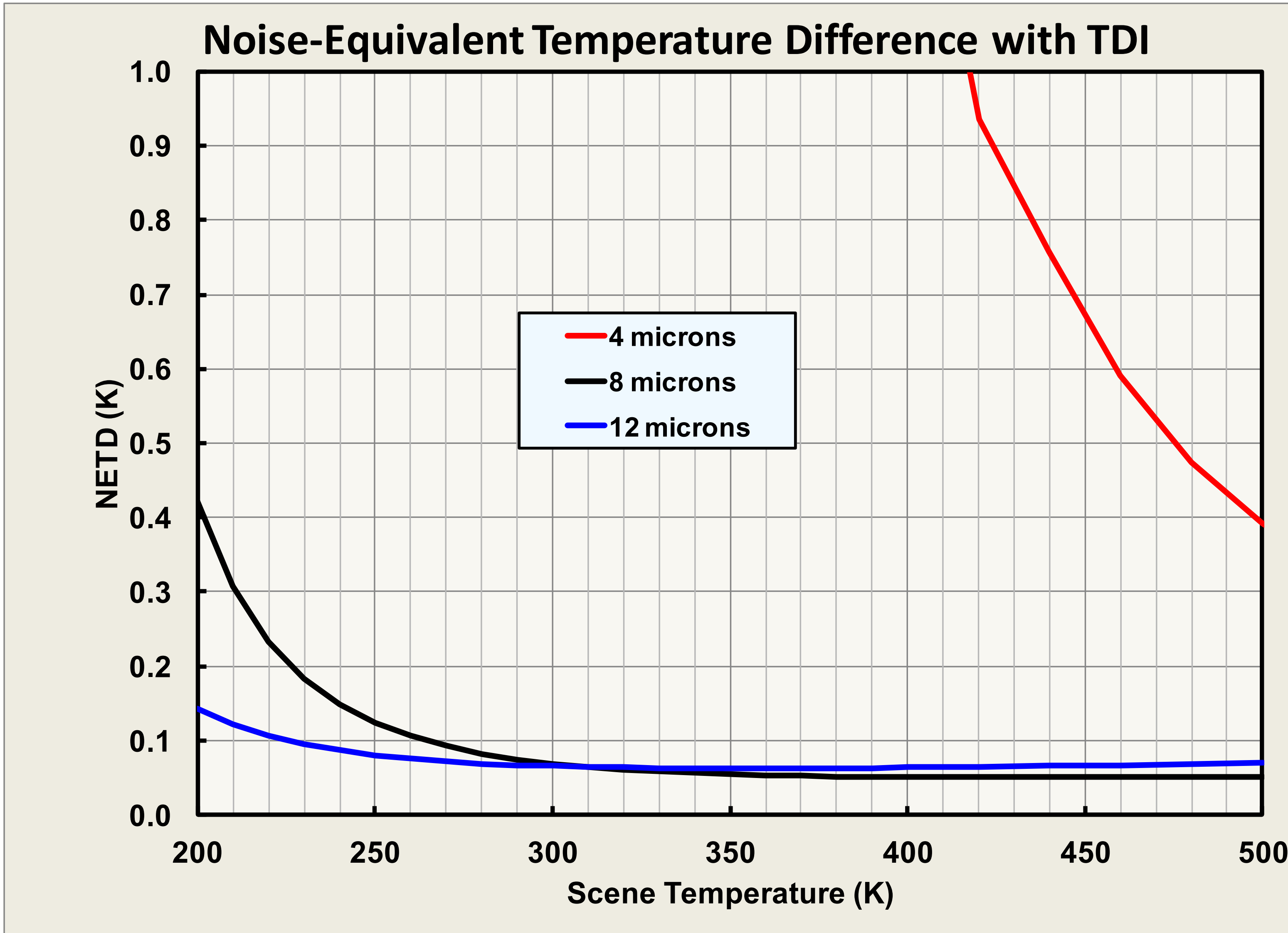
FPA analog board

Entrance telescope baffling

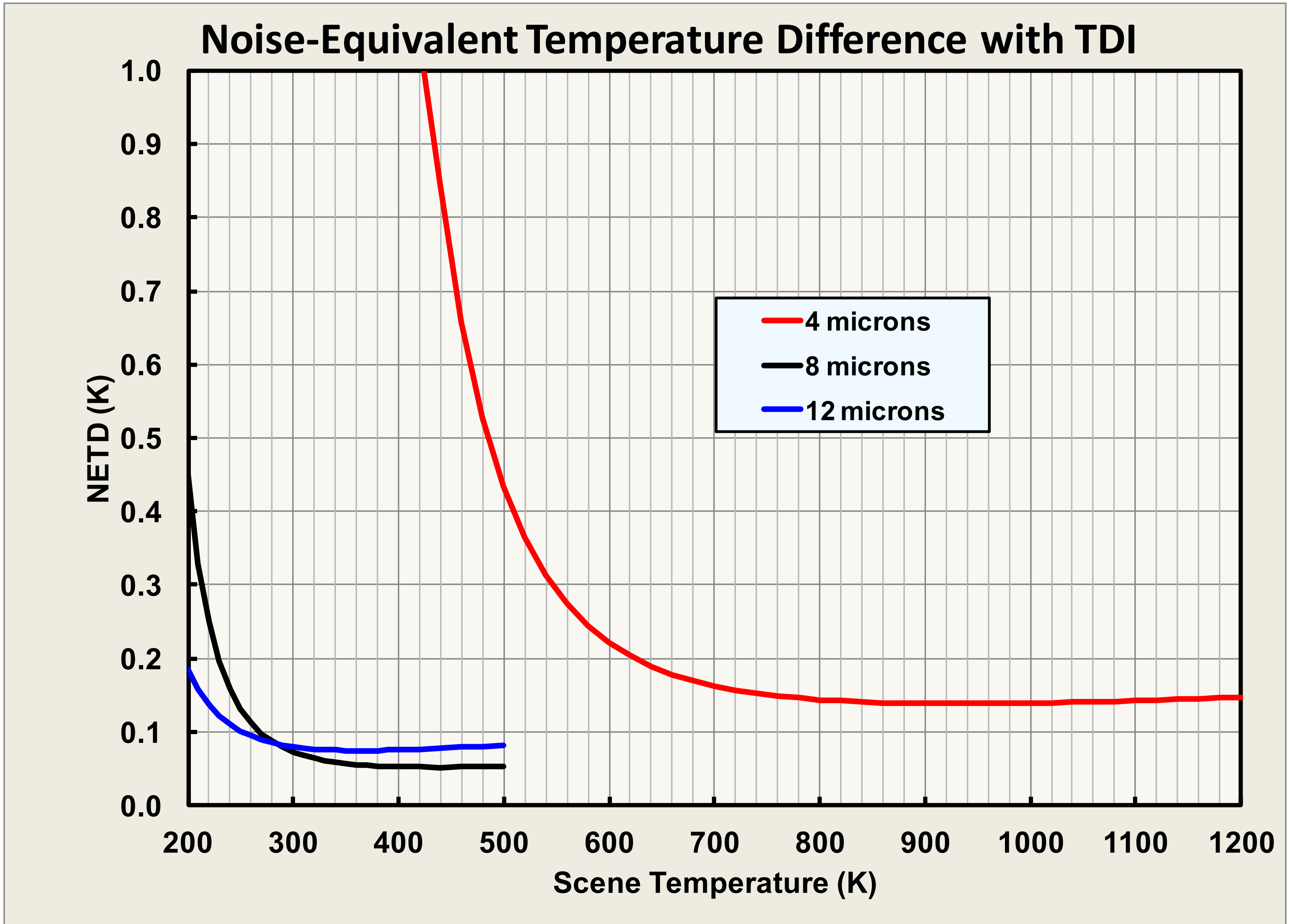
Telescope - Front



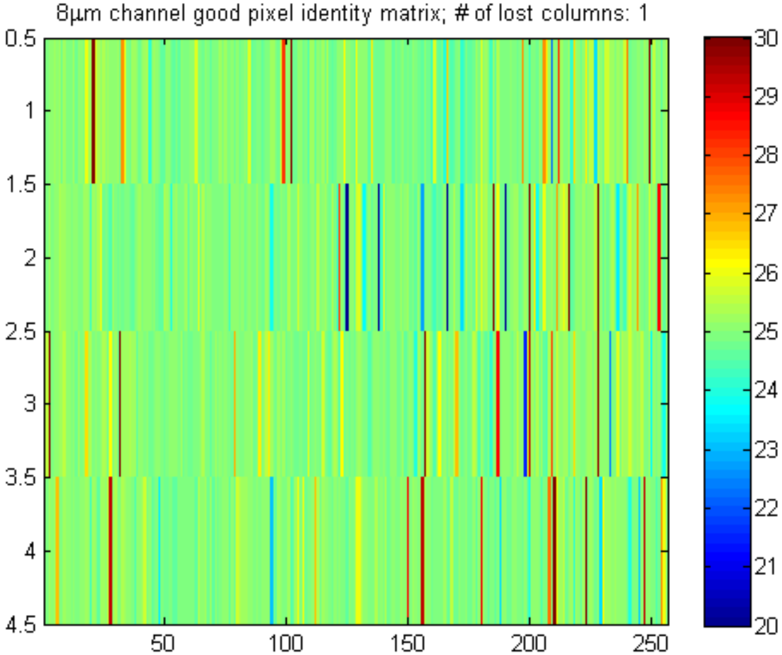
NETD of PHyTIR Bands

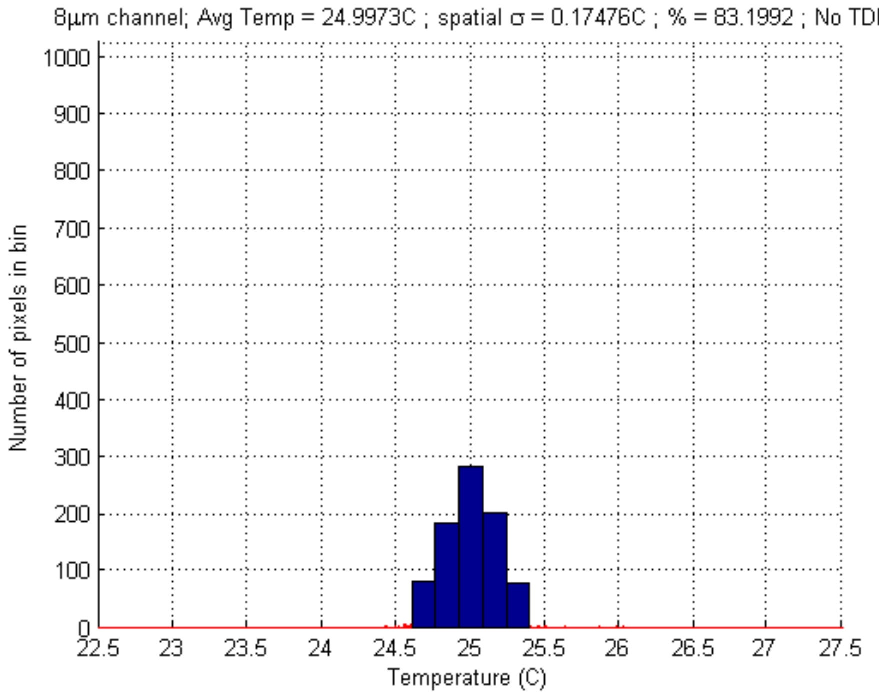


NETD of PHyTIR Bands – Full Temperature Range



Enough spatial columns are present to support 4 pixel TDI

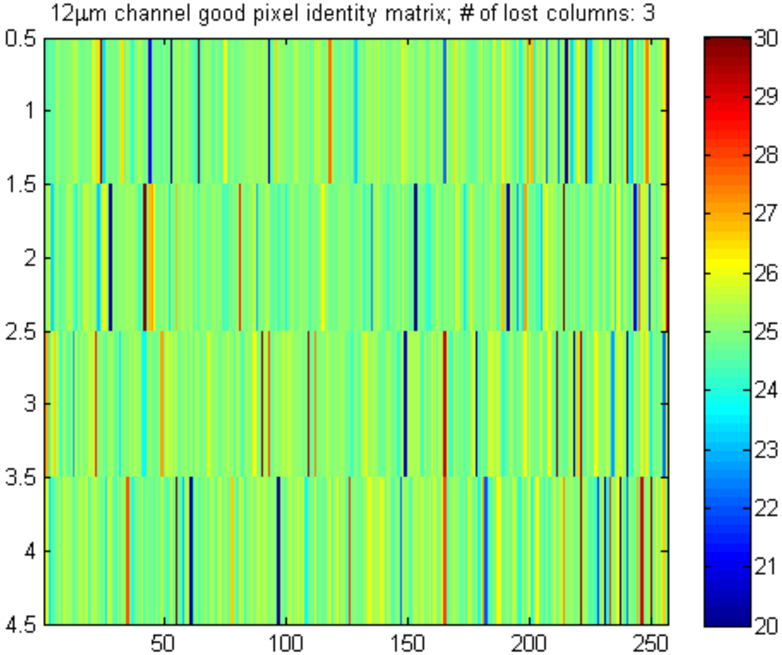


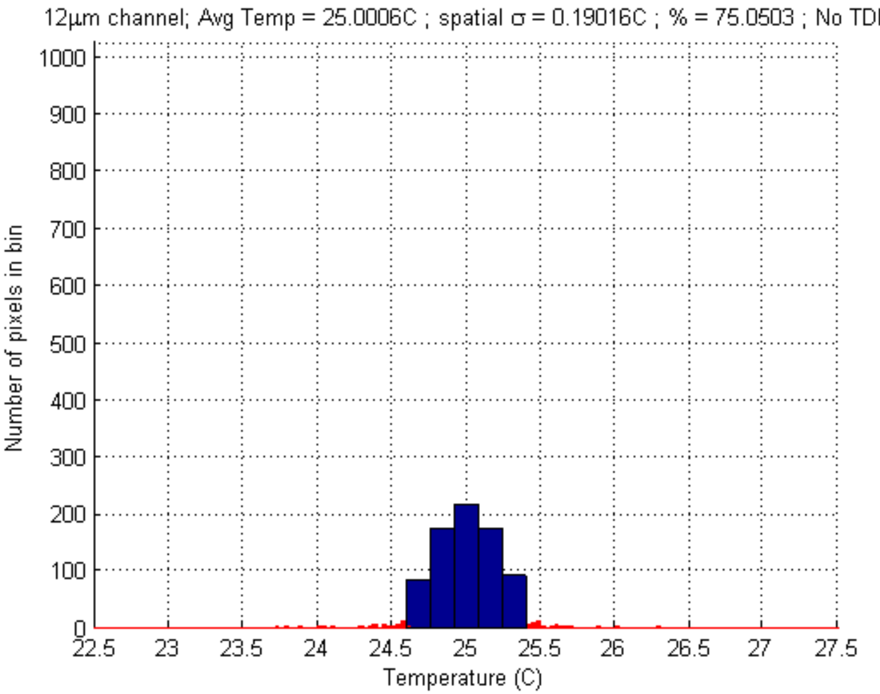


8μm combinatorial optimization

Solve for the maximum number of pixel per column such that the single pixel NEDT < 0.2° C. It's expected that 4 pixel TDI will allow ~0.1° C NEDT.

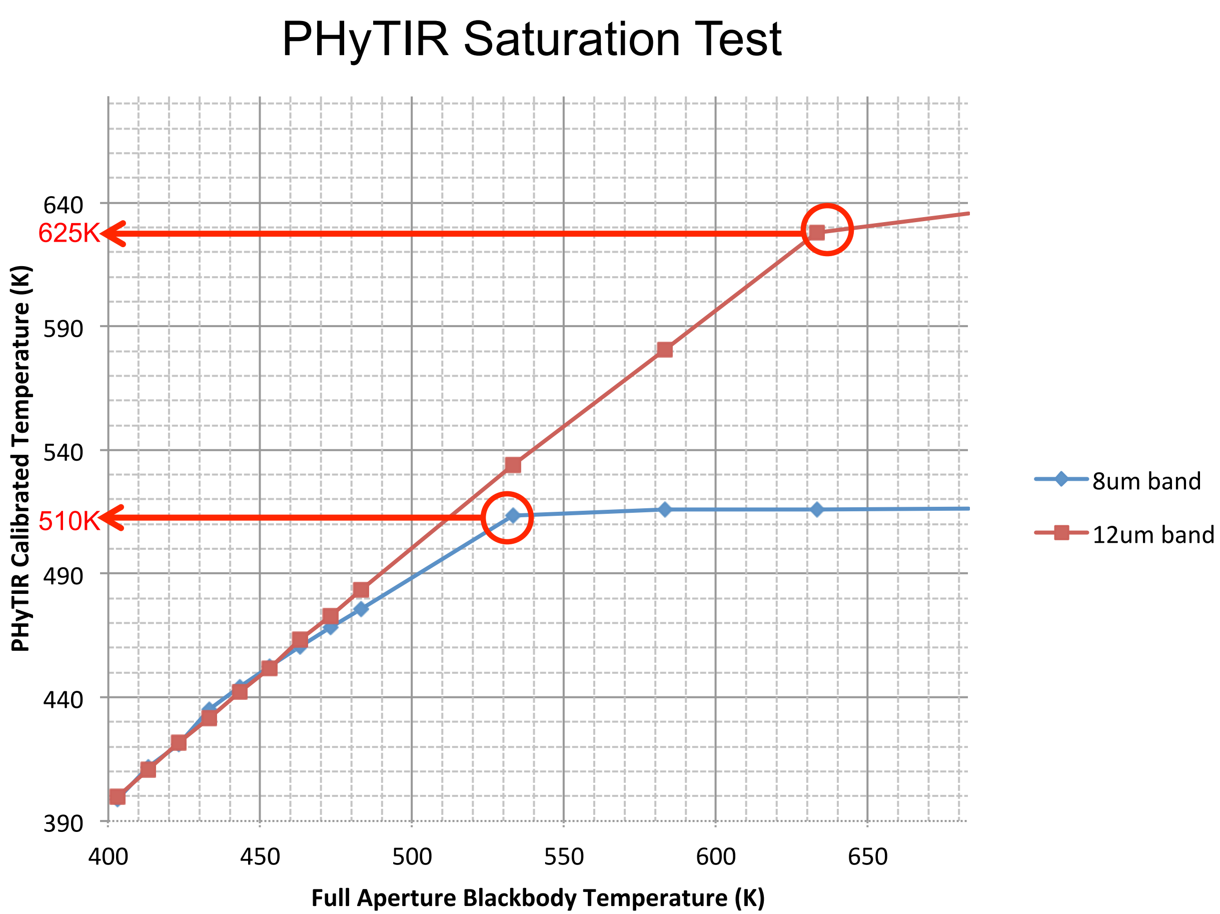
Enough spatial columns are present to support 4 pixel TDI





12μm band combinatorial optimization
Solve for the maximum number of pixel per column such that the single pixel NEDT < 0.2^{o} C. It's expected that 4 pixel TDI will allow ~0.1^{o} C NEDT.

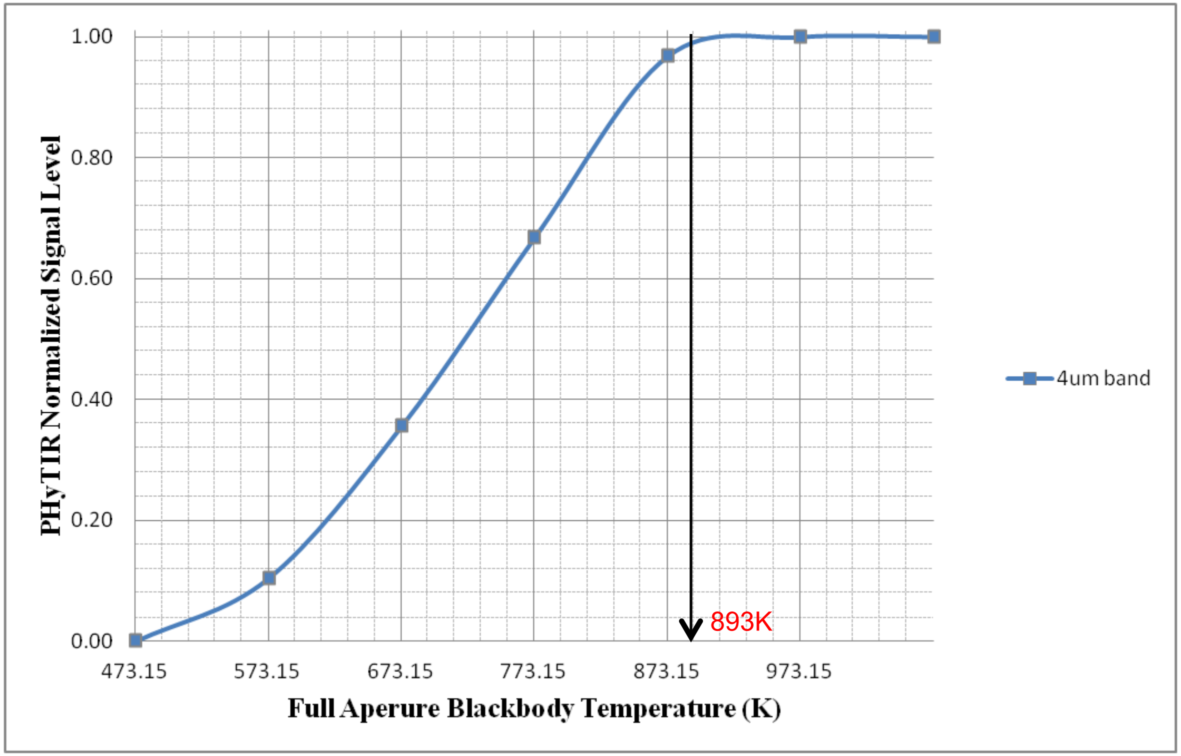
System measurement: Saturation Temperature



Demonstrates that long-wavelength bands (8 and 12 μm in PHyTIR) do not saturate below 480 K, as required.

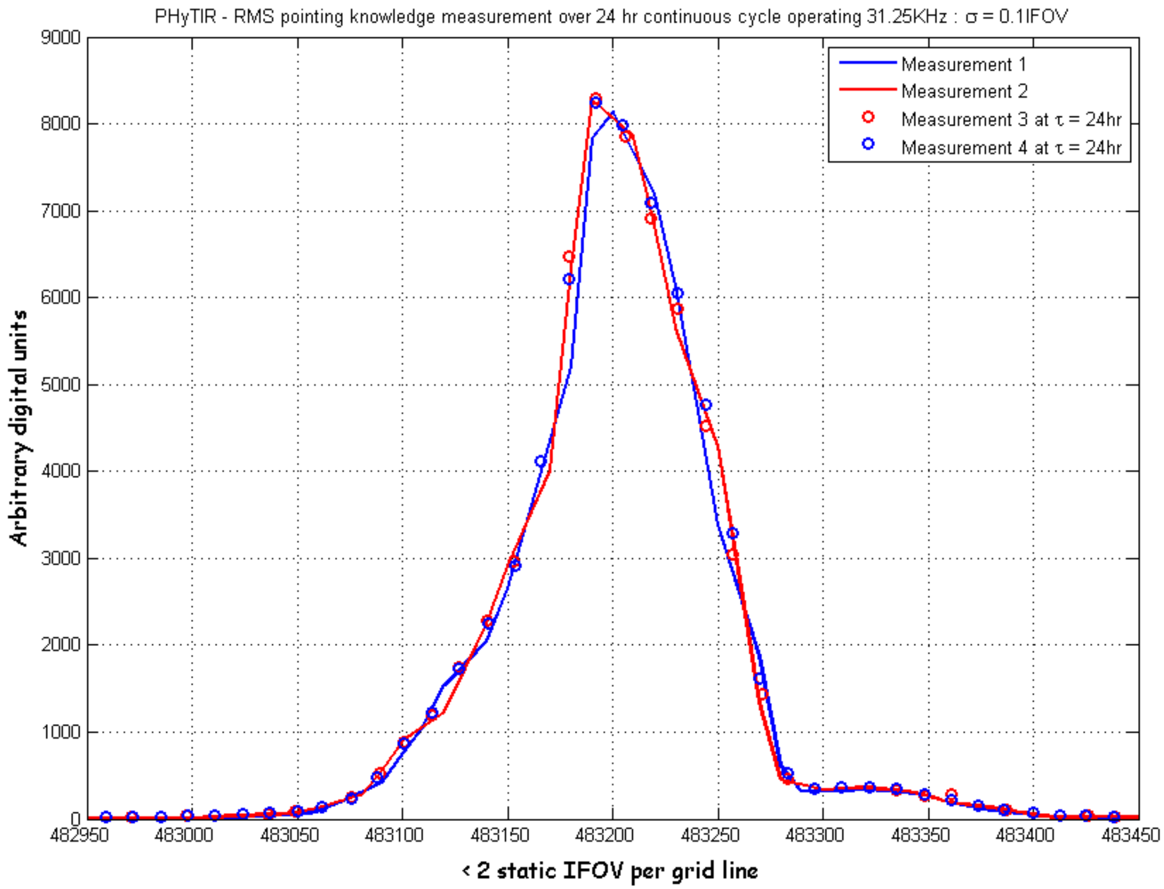
System measurement: Saturation Temperature

PHyTIR Saturation Test



Expected saturation level based on the 6.2 Me- well size was adjusted to 880K for the 4μm channel due to the increased size of the delivered filter bandwidth.

System measurement: Absolute Pointing Knowledge



The scan mirror, together with the structural stability, meet the pointing knowledge requirements.

PHyTIR Summary

- PHyTIR currently demonstrates the state-of-the-art in sensor technology.

A. The detectors and readouts meet all signal-to-noise and speed specifications.

B. The cold shielding allows the use of ambient temperature optics on the HyspIRI-TIR instrument without impacting instrument performance.

C. The pointing knowledge does meet the predefined requirements.

D. The long-wavelength channels do not saturate below 480 K.

- The current design shows no indication of artifacts from stray light in a laboratory environment. An extensive series of tests are planned for further verification/validation.

- Installation on the ISS is expected in 2019.

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