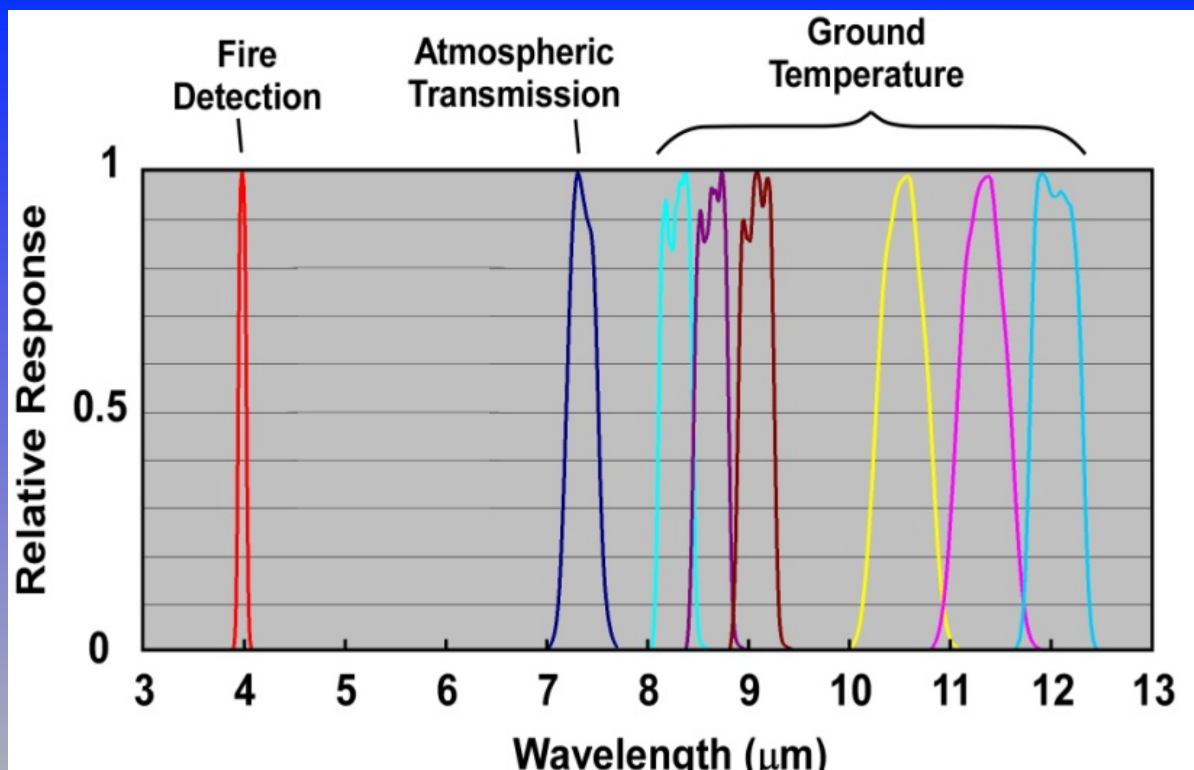
HyspIRI Thermal Infrared Radiometer (TIR) Instrument Conceptual Design

Marc C. Foote
Jet Propulsion Laboratory, California Institute of Technology

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, Oceans at 1 km resolution	Land and coastal regions
Data latency	2 days	< 1 week

TIR Nominal Spectral Bands



Band Center (μm)	Band Width (μm)
3.98	0.015
7.35	0.32
8.28	0.35
8.63	0.35
9.07	0.36
10.53	0.54
11.33	0.54
12.05	0.52

Rationale for Whisk vs. Pushbroom Scanning

Science Requirements
60 m Resolution
5-Day repeat

Instrument Requirements
~10,000 pixels cross track
~600 km swath
51° Cross-track swath

Whiskbroom (Push-Whisk)
- Single telescope with scanning mirror
- Single detector array with 256 pixels per band

Pushbroom
- ~10 detector arrays, each with ~1,000 pixels per band
- ≥3 telescopes

Science Requirements
0.5% Radiometric accuracy for 300 K scenes

Instrument Requirements
Frequent 2-point calibrations (space and blackbody)

Whiskbroom (Push-Whisk)
- Scanning mirror allows easy and frequent 2-point calibrations
- No mapping gaps

Pushbroom
- Calibration mechanism required – must enable multiple telescopes to view space and blackbody
- Gap in mapping during calibration

Rationale for Mercury Cadmium Telleride (MCT) Detectors

Science / Instrument Requirement
0.2 K resolution for 300 K scene

MCT Detectors
- Quantum efficiency ≥ 70%
- 0.06 K resolution at 60 K
  (69 W cooler power)

QWIPs
- Quantum efficiency ~3%
- > 0.3 K resolution at 40 K
  (225 W cooler power)

Uncooled Microbolometers
- Too slow for push-whisk method
- Even with pushbroom, resolution ~0.8 K

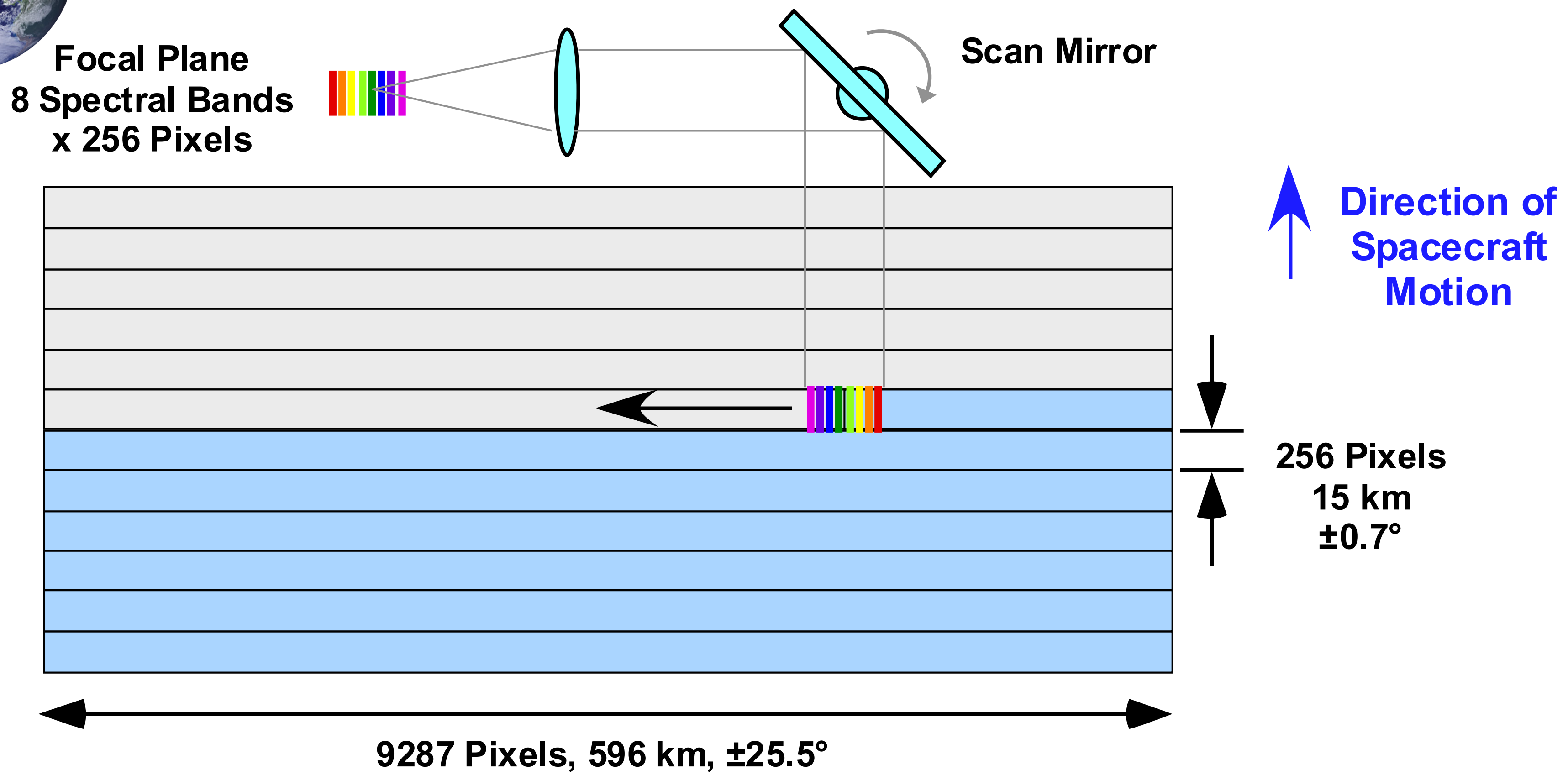
Science / Instrument Requirement
8 spectral bands 4-12 μm

MCT Detectors
- Single band-gap material can cover full spectral range

QWIPs
- Multiple arrays required to cover all bands

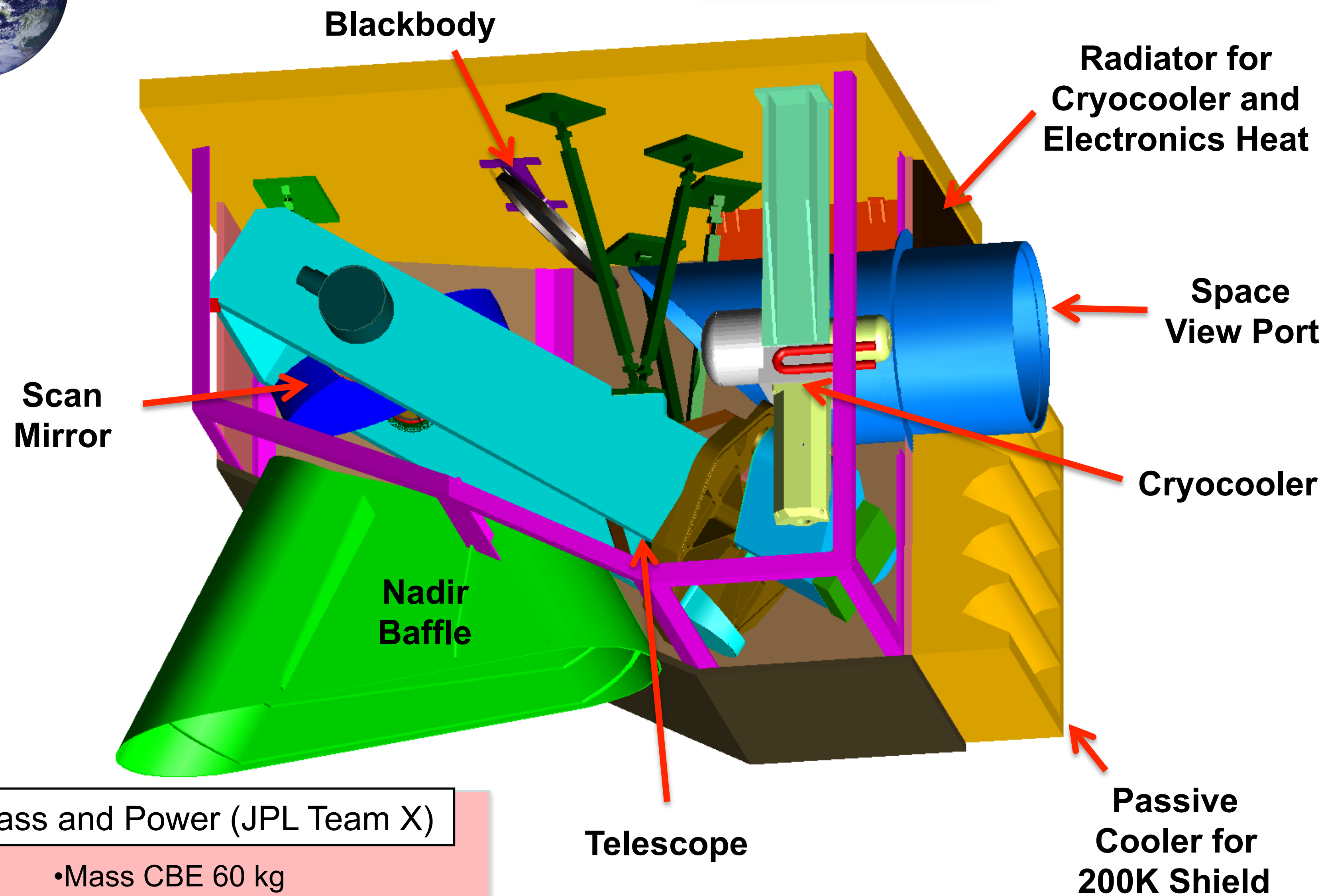
Uncooled Microbolometers
- Not sensitive to 4 μm band

TIR Scanning and Data Rate



- 60 m Pixel Footprint at Nadir
- Time-Averaged Science Data Rate 0.020 Gbps
- Assuming 14 bits, 2:1 Compression, 31% Land
- Scan Mirror Rotation Rate 14.2 RPM
- Pixel Dwell Time 32 microseconds

TIR Instrument Concept

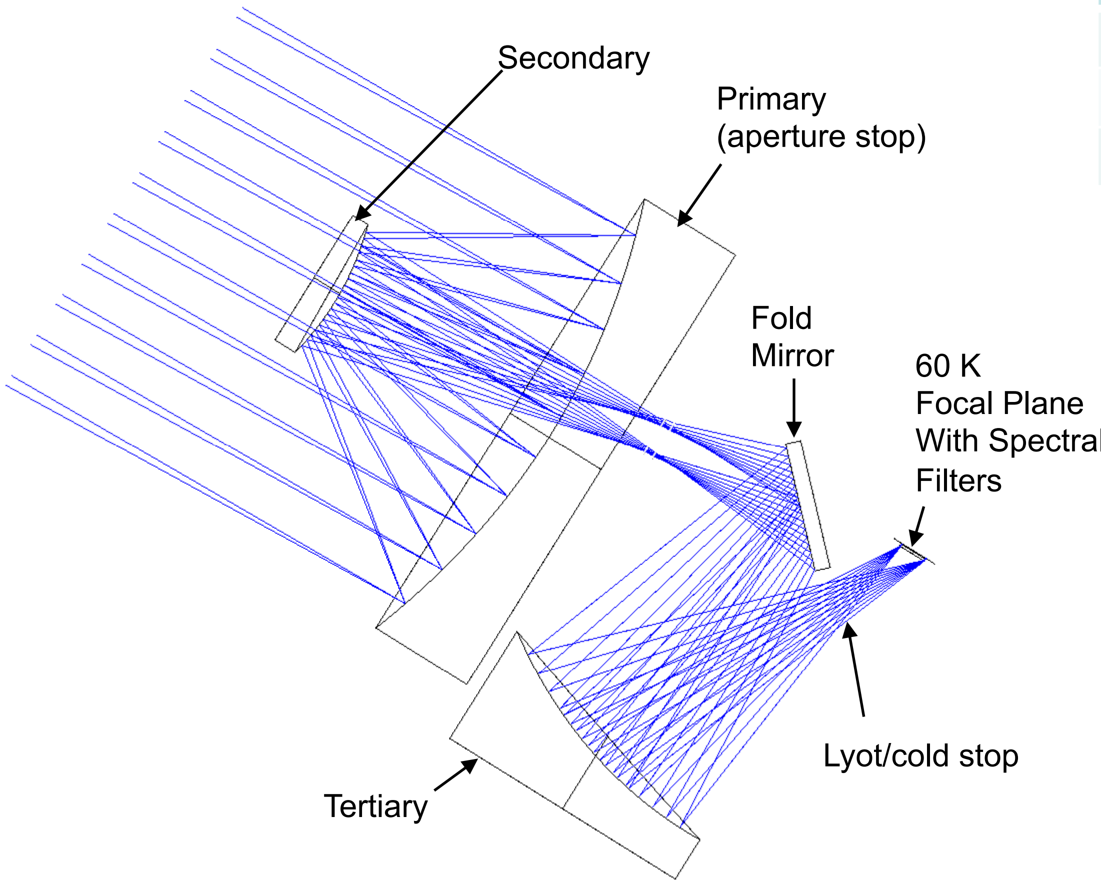


Mass and Power (JPL Team X)

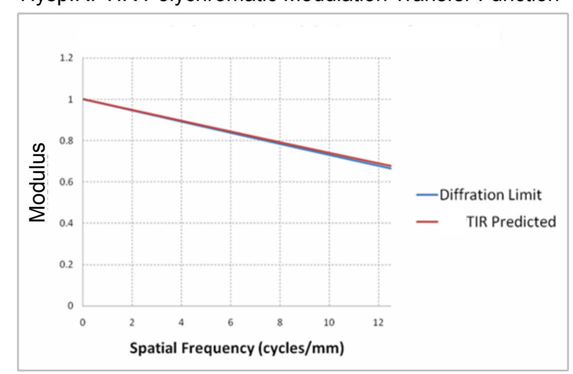
- Mass CBE 60 kg
- Power CBE 103 W

TIR Telescope Concept

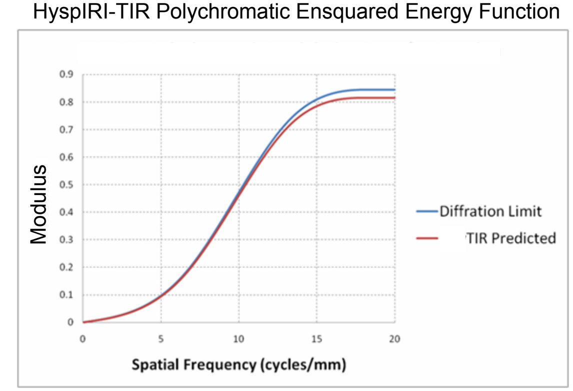
Parameter	Value
Aperture Size	208 mm
f/#	2.0
Focal Length	416 mm



HyspIRI-TIR Polychromatic Modulation Transfer Function



HyspIRI-TIR Polychromatic Ensquared Energy Function



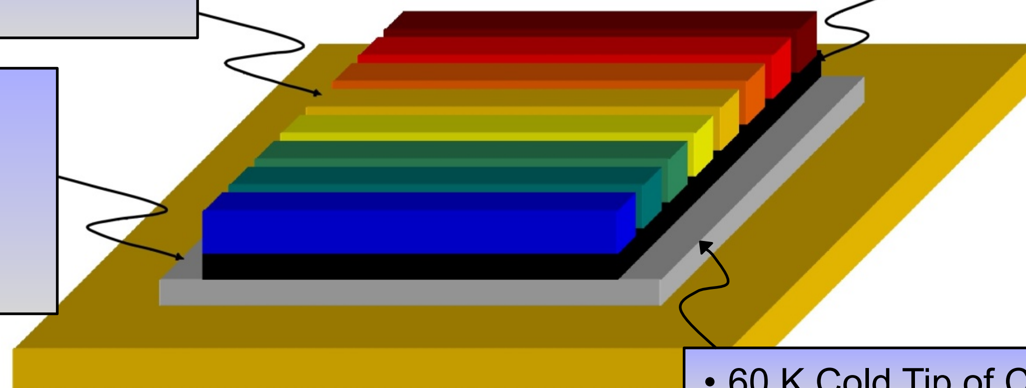
HyspIRI-TIR optics consists of a 3-mirror off axis Cassegrain plus relay optics.

TIR Focal Plane Concept

- Butcher-Block Filter Assembly
- Baffles to Prevent Crosstalk Between Spectral Channels

- CMOS Read-Out Integrated Circuit (ROIC)
- 32 Output Signals to Enable Necessary Pixel Read Rate

- MCT Detector Array – 256 elements cross-sweep
- 1 Bandgap to Cover Full Spectral Range
- ≥ 4 Detector Columns per Spectral Channel to Allow Time Delay and Integration (TDI)



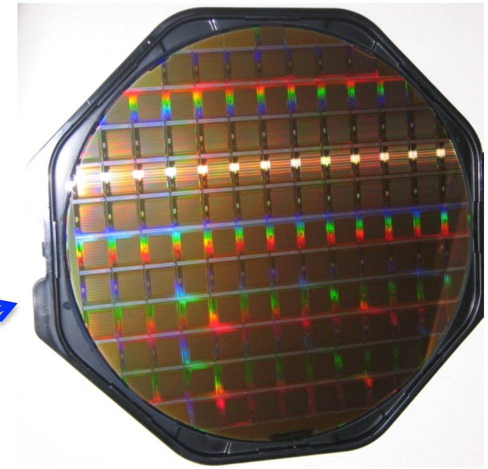
- 60 K Cold Tip of Cryocooler

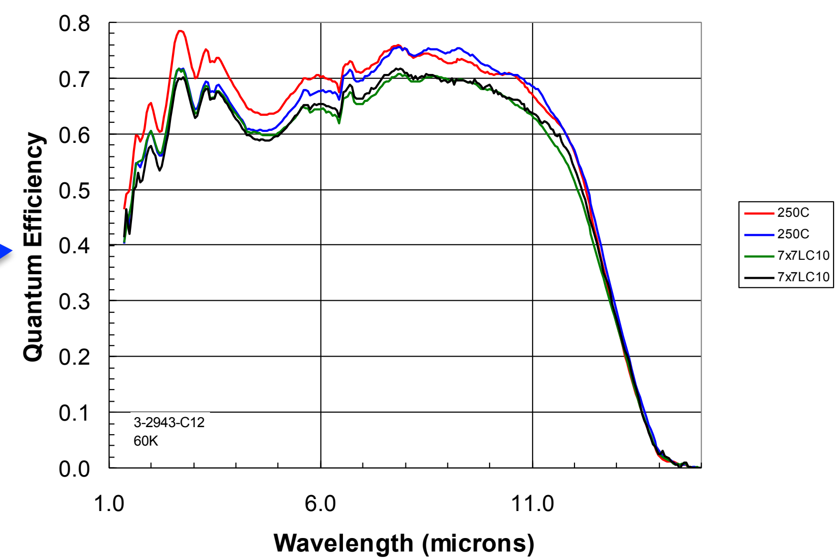
➢Peak Data Rate = 256 Mpixels/sec (256 detectors cross-sweep, x4 for TDI, x8 spectral bands every 32 μs).

- 32 analog output lines, each operating at >10 MHz
- Digitization in off-chip ADCs
- TDI performed by FPGA after digitization

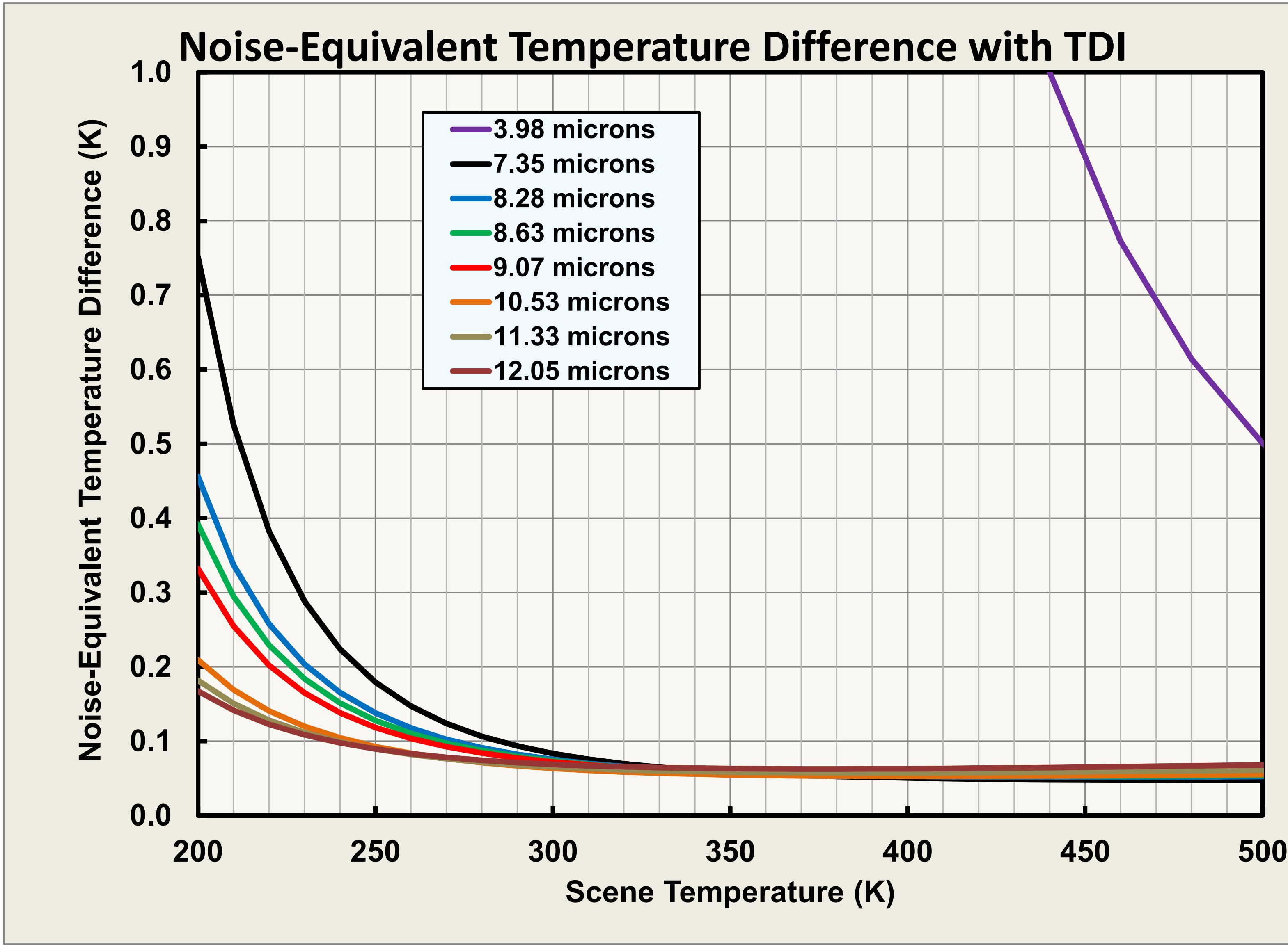
TIR Detector Progress

- ROICS, Detector Arrays, and Hybrids produced by Teledyne Imaging Systems.
- ROICS have been designed, fabricated, and tested at room temperature.
- ROIC functionality confirmed. Noise at room temperature as predicted.
- 13.2 µm cutoff MCT detector arrays have been fabricated.
- Test detectors show specified performance.
- First hybrids will be assembled and tested in December 2012.

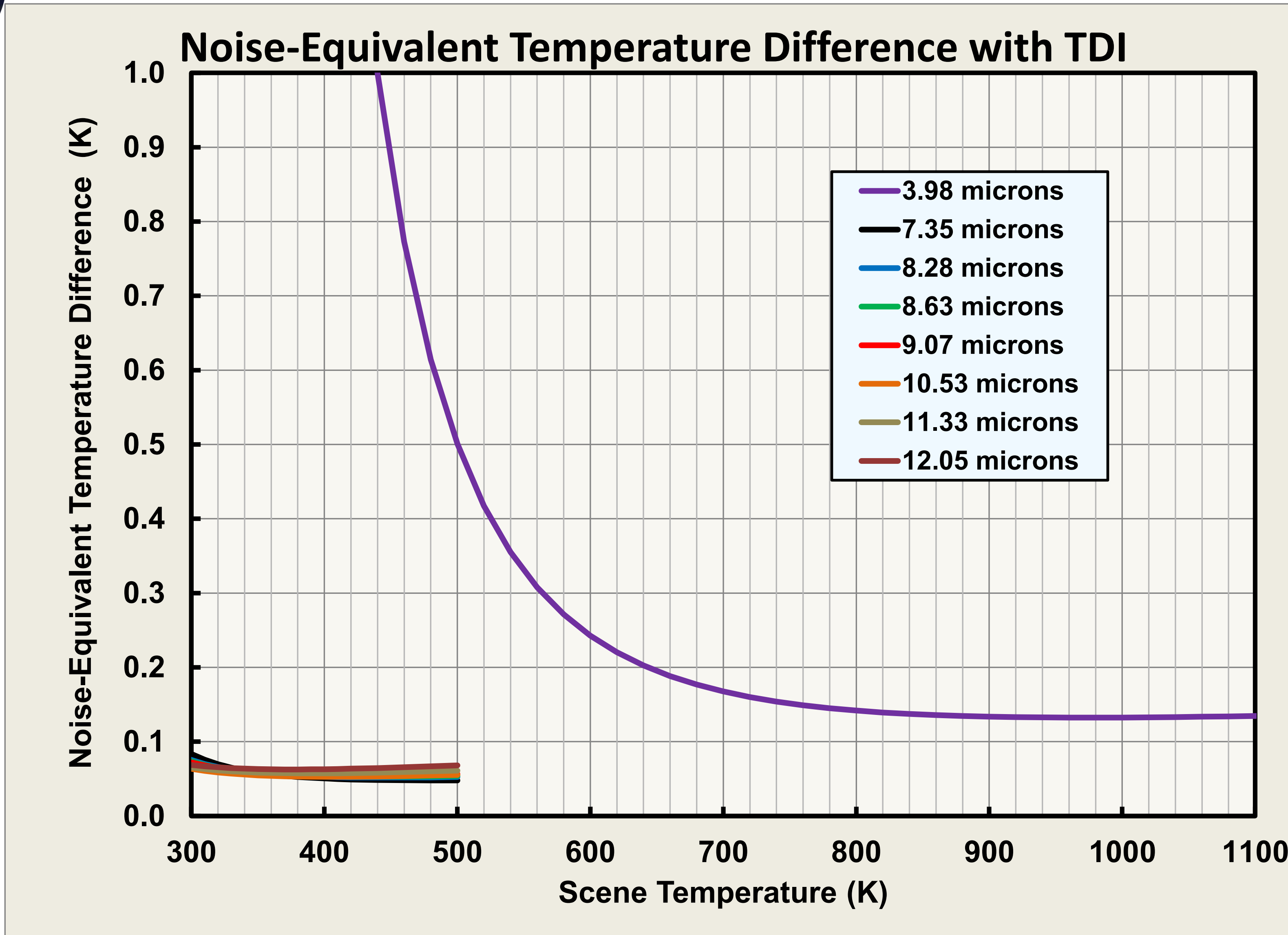




TIR Calculated Performance

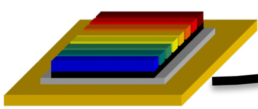


TIR Calculated Performance

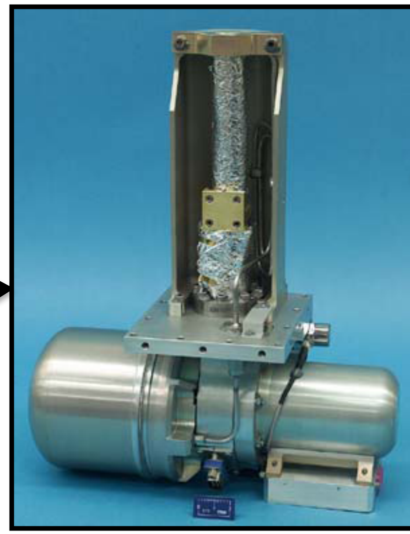


TIR Thermal Concept

NGAS HEC (High-Efficiency Cooler) is fully flight qualified with two units currently operating in space (Japanese Advanced Meterological Imager – JAMI, launched in 2005 and Thermal and Short Wave Infrared Sensor – TANSO, launched in 2009)

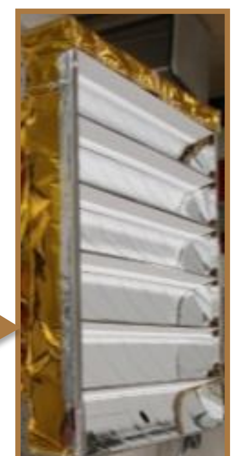


Focal Plane at 60 K



Radiator for cryocooler heat

Thermal Shield at 200 K to Reduce Load on Cryocooler



Passive cooler similar to that flying on the Moon Mineralogy Mapper (M^3)

Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)

- Funded by NASA Instrument Incubator Program (IIP)
- For demonstration of key HyspIRI TIR technologies – focal plane and scan mirror / encoder
- Assembly will start Spring 2013
- Testing in Fall 2013
- More information in Simon Hook's presentation on Thursday