



# LDCM Operational Land Imager and Thermal Infrared Sensor Performance

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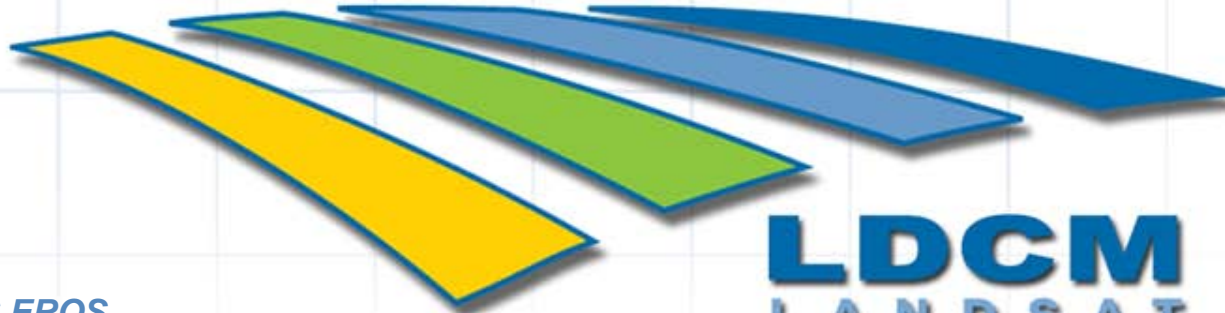
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**Representing NASA/USGS/BATC Instrument and Calibration Teams**

**August 23, 2011**

**SPIE  
Earth Observing  
Systems XVI**



**LDCM**  
LANDSAT

data continuity mission

# Cal/Val Personnel

## ➤ NASA SCIENCE/IMAGE ASSESSMENT

- Brian Markham (Lead)
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  - Raviv Levy /SSAI
  - Julia Barsi /SSAI
  - Lawrence Ong /SSAI
  - Robert Barnes /SAIC
  - Matt Montanaro /Sigma Space
- Phil Dabney (Instrument Scientist)
- Jeff Pedelty (BATC on-site rep)

## ➤ USGS SCIENCE/IMAGE ASSESSMENT

- Ron Hayes/SGT (Lead)
- Ron Morfitt /SGT (Technical Lead)
  - Esad Micijevic /SGT
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  - Kelly Vanderwerff /SGT
- James Storey /SGT (Geometry Lead)
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- Brent Canova (Lead)
  - Geir Kvaran
  - Kenton Lee
  - Eric Donley
  - Brian Donley

## ➤ GSFC TIRS CALIBRATION

- Dennis Reuter (instrument scientist)
- Kurtis Thome (Lead)
  - Brian Wenny
  - Allan Lunsford
  - Matt Montanaro
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  - Ramsey Smith

## UNIVERSITY AFFILIATES

- Dennis Helder (SDSU)
- John Schott (RIT)
  - Orlando/Nina Raqueno
  - Mike Gartley
  - Aaron Gerace

# Landsat and LDCM Spectral and Spatial Requirements

Landsat-5/7 TM/ETM+ Bands ( $\mu\text{m}$ )			LDCM Band Requirements ( $\mu\text{m}$ )		
			30 m Coastal/Aerosol	0.433 - 0.453	Band 1
Band 1	30 m Blue	0.450 - 0.515	30 m Blue	0.450 - 0.515	Band 2
Band 2	30 m Green	0.525 - 0.605	30 m Green	0.525 - 0.600	Band 3
Band 3	30 m Red	0.630 - 0.690	30 m Red	0.630 - 0.680	Band 4
Band 4	30 m Near-IR	0.775 - 0.900	30 m Near-IR	0.845 - 0.885	Band 5
Band 5	30 m SWIR-1	1.550 - 1.750	30 m SWIR-1	1.560 - 1.660	Band 6
Band 6	60/120m* LWIR	10.40 - 12.50	120 m LWIR-1	10.30 - 11.30	Band 10
			120 m LWIR-2	11.50 - 12.50	Band 11
Band 7	30 m SWIR-2	2.090 - 2.350	30 m SWIR-2	2.100 - 2.300	Band 7
Band 8**	15 m Pan	0.520 - 0.900	15 m Pan	0.500 - 0.680	Band 8
			30 m Cirrus	1.360 - 1.390	Band 9

OLI

TIRS

OLI

ETM+

# Operational Land Imager (OLI)

## Key instrument requirements

- Cross-track FOV                    185 km
- S/C altitude                        705 km
- Geodetic accuracy\*
  - ❖ Absolute                         65 m
  - ❖ Relative                         25 m
- Geometric accuracy\*\*
  - ❖ Absolute                         12 m

Band Name	CW (nm)	Bandwidth (nm)	GSD (m)	SNR
Coastal/Aerosol	443	20	30	130
Blue	482	65	30	130
Green	562	75	30	100
Red	655	50	30	90
NIR	865	40	30	90
SWIR 1	1610	100	30	100
SWIR 2	2200	200	30	100
PAN	590	180	15	80
Cirrus	1375	30	30	50



■ Visible/NIR    ■ SWIR

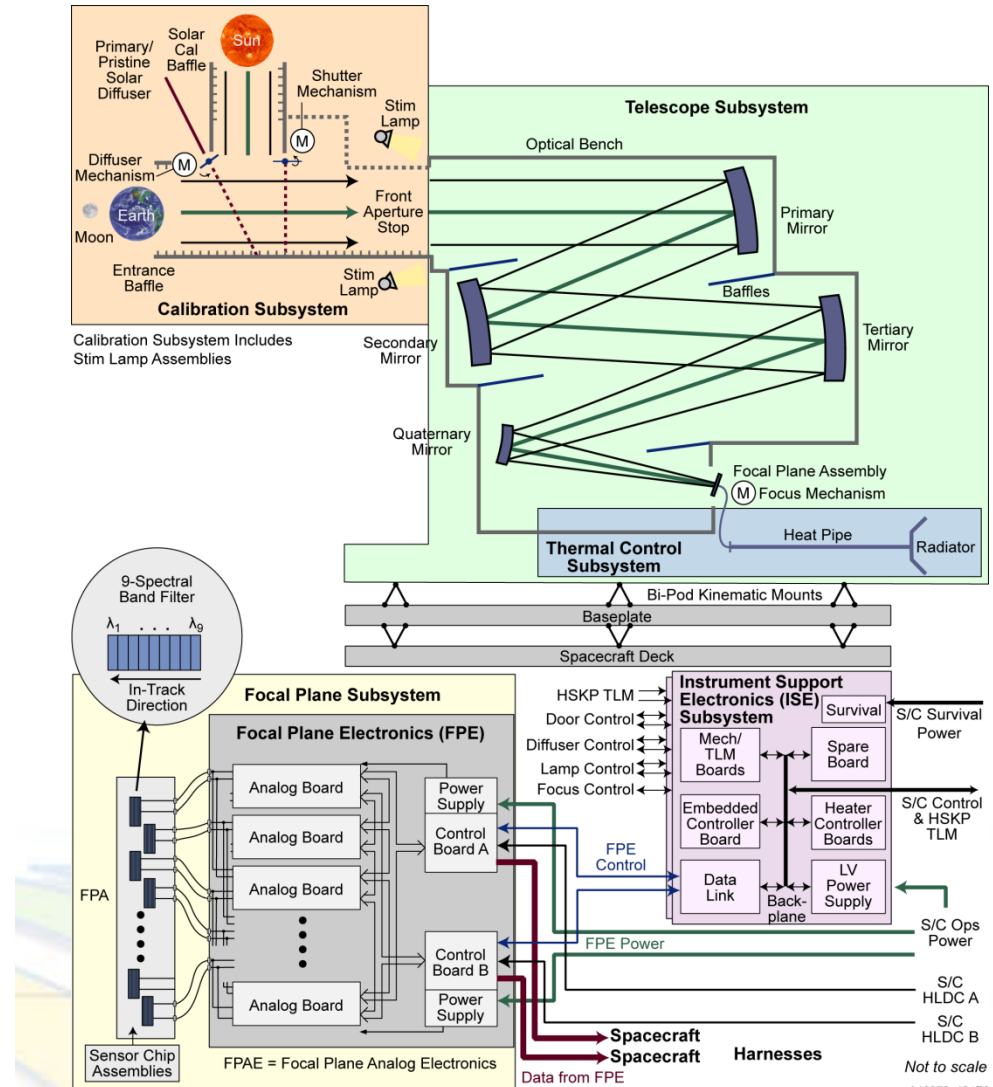
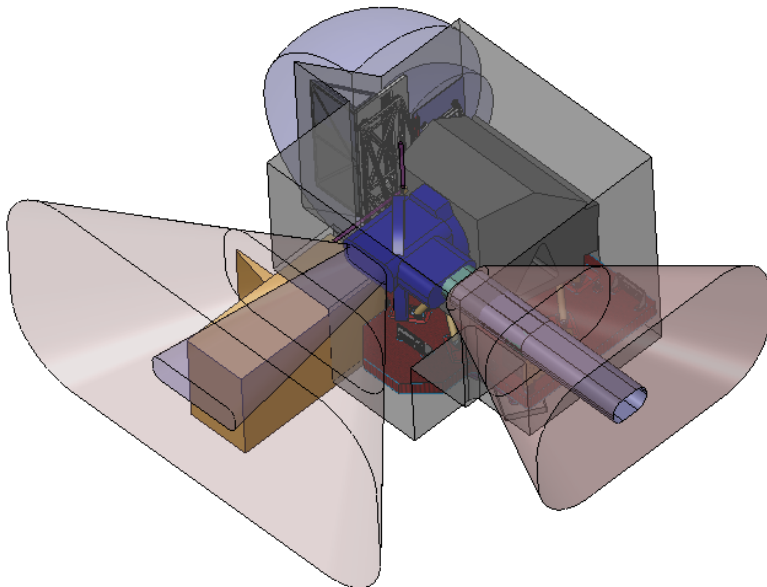
\*No terrain compensation  
 \*\*w/ terrain compensation

Instrument  
Complete

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 NASA GSFC / USGS EROS

# Operational Land Imager (OLI)

- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- On-board calibration with both lamps and full aperture diffusers





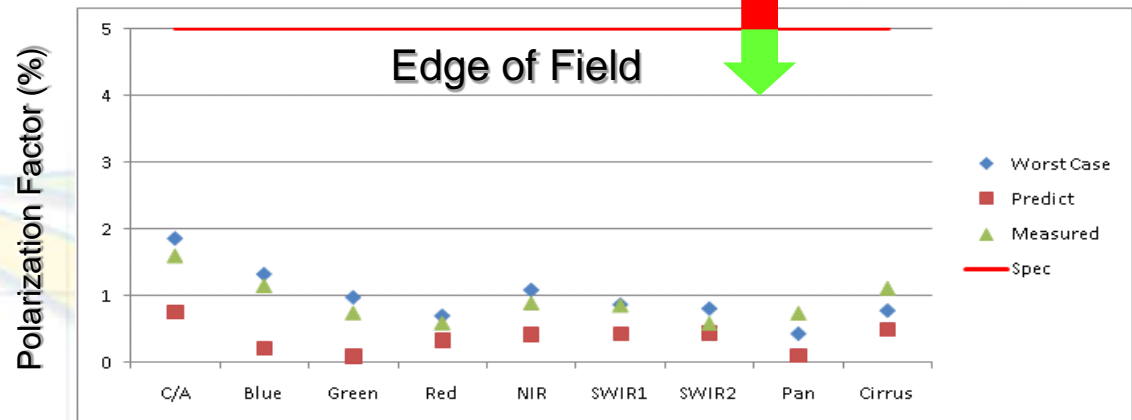
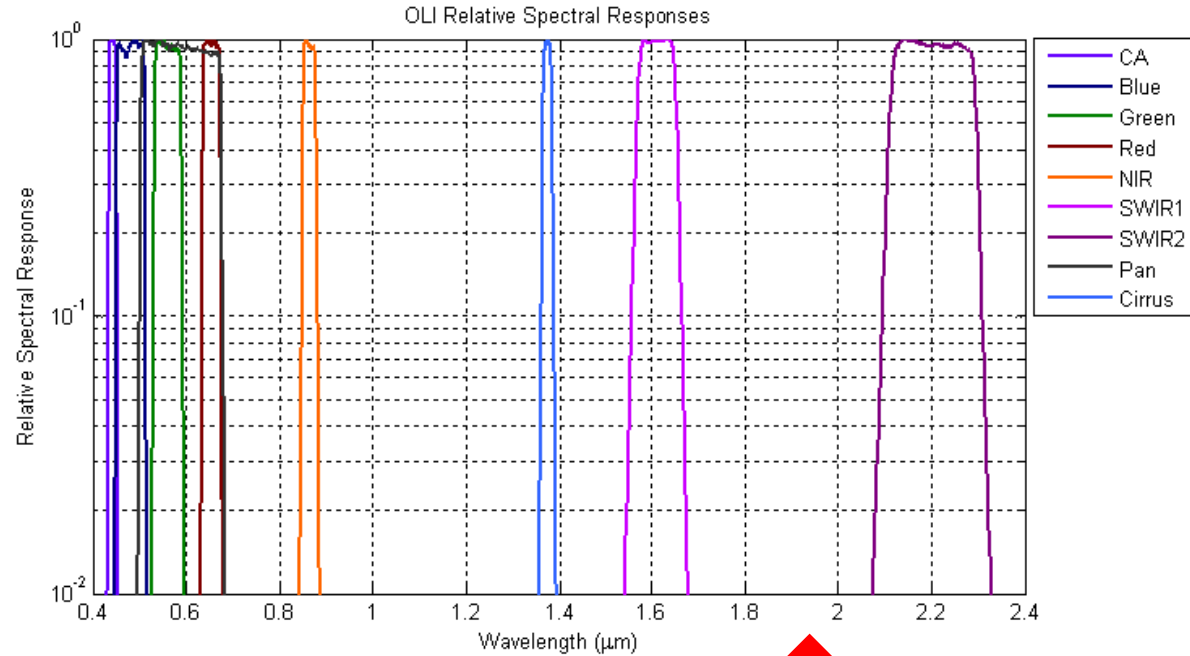
# OLI Spectral and Polarization Performance

## ➤ Spectral Performance

- Measured at instrument level for sampling of detectors from each focal plane module
  - Meets all requirements
- Out-of-Band Response measured at focal plane module level for all detectors
  - typically below  $10^{-4}$

## ➤ Polarization Sensitivity

- Measured at instrument level
- Below 2%



# OLI Radiometric Performance

## ➤ SNR

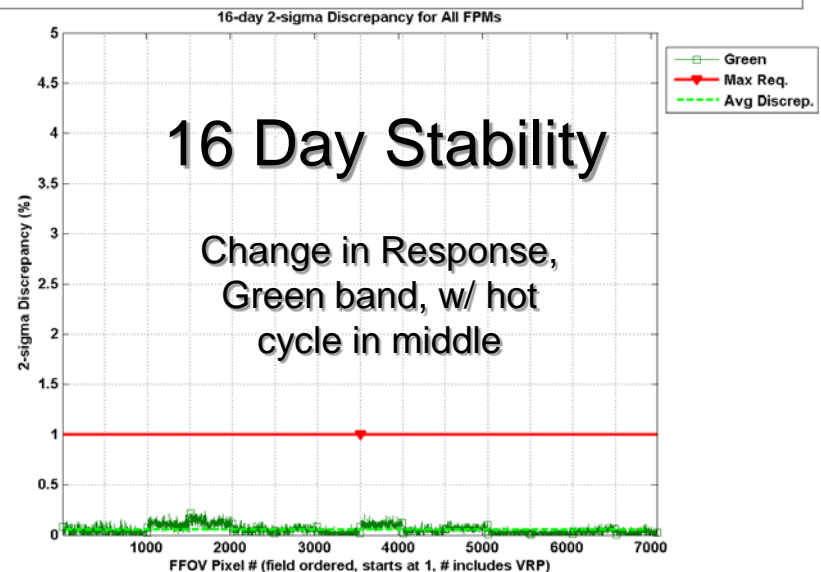
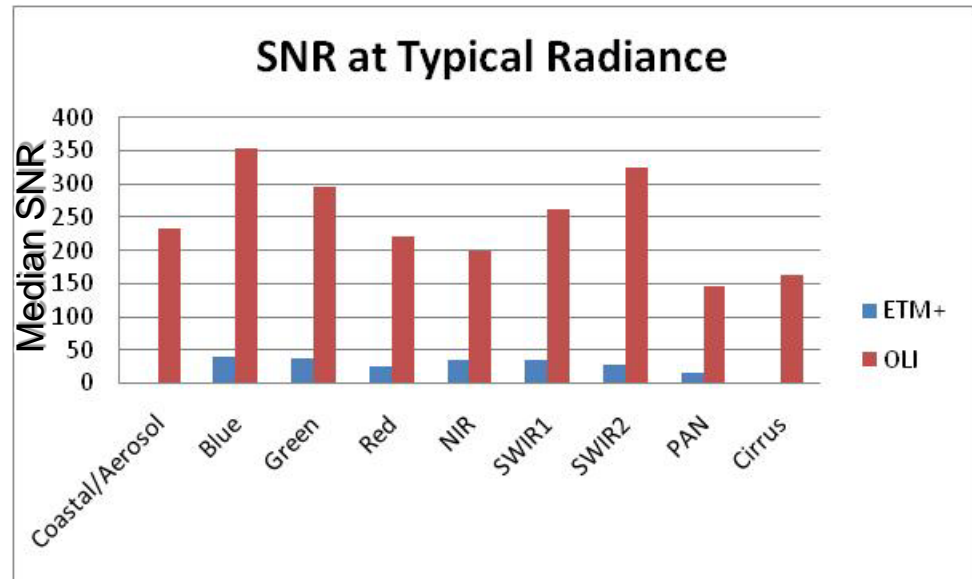
- SNR significantly exceeds requirements and heritage

## ➤ Calibration

- Absolute uncertainty ~4%
  - Extensive round robin for validation
  - Transfer-to-Orbit uncertainties included
- Stability over 60 seconds (2 standard scenes)
  - $<0.02\% 2\sigma$
- Stability over 16 days (time between Solar Diffuser Cals)
  - $<0.54\% 2\sigma$  for all but Cirrus Band which is  $<1.19\%$

## ➤ Uniformity

- Typically better than 0.5%
  - A few detectors and FPM boundaries may exceed this



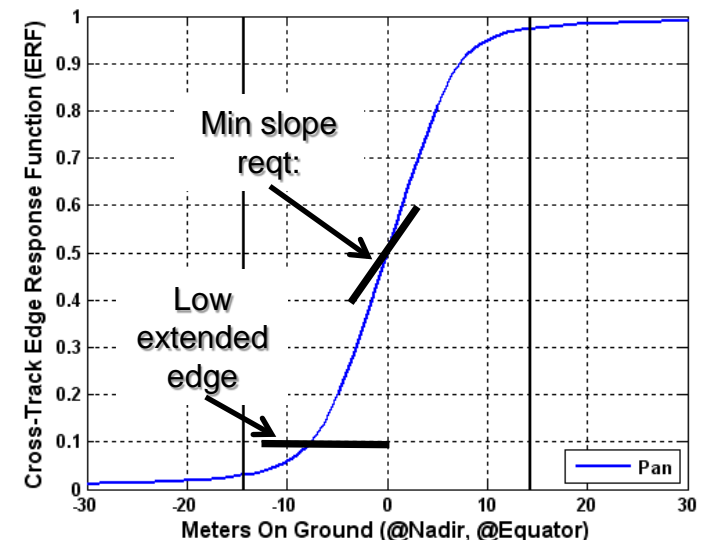
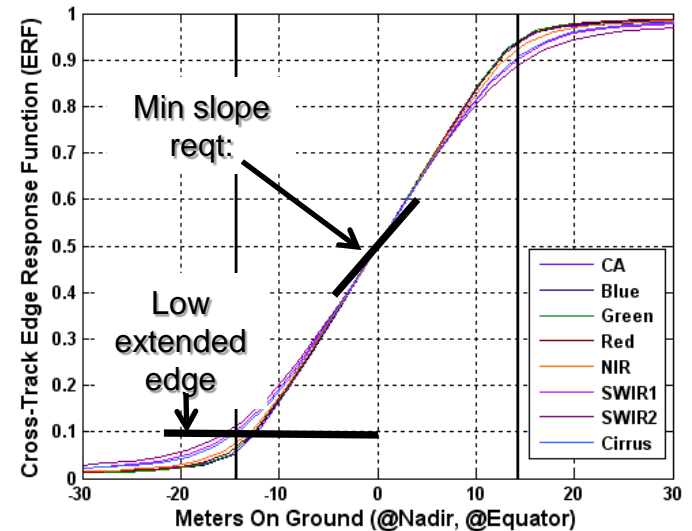
# OLI Spatial Performance

## ➤ Spatial Performance

- Want sharp edges for change detection
- Measured spatial response has:
  - Steep slope (exceeding reqts)
  - Low extended edge (good half edge extent)
  - No ripple/overshoot

## ➤ Geolocation

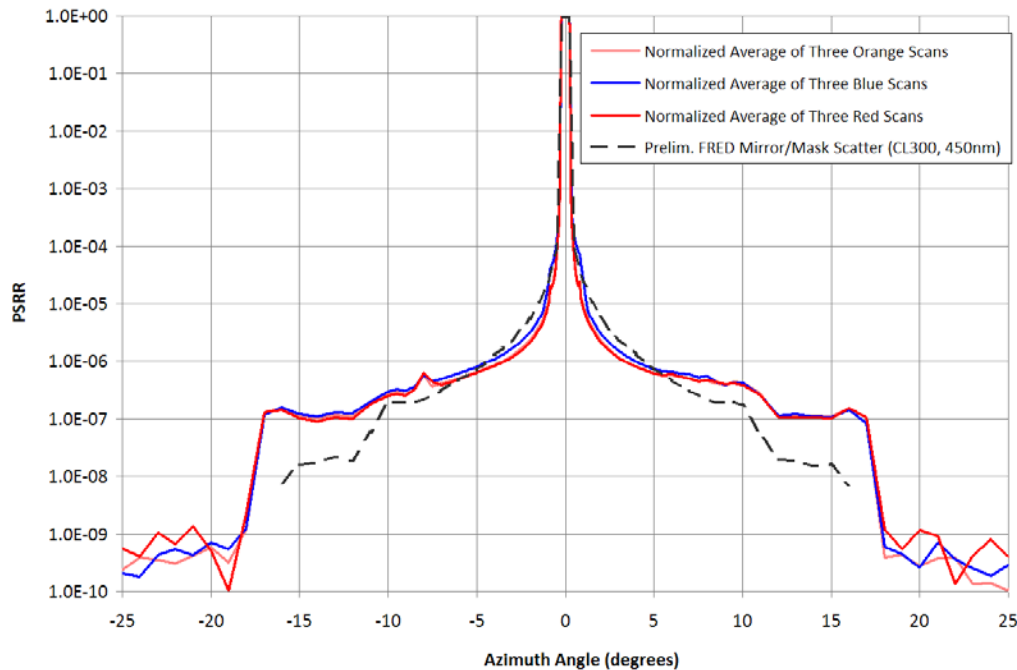
- Want good pointing knowledge, again for change detection
- Performance depends on both instrument and spacecraft; final measurements made during initial on-orbit checkout
- Pre-launch instrument measurements mapped line of sight of all detectors to reference pixel/boresight to  $\sim 1/10^{\text{th}}$  of a pixel
- On target to have absolute geometric accuracy of  $< 1/2$  pixel





# OLI Stray Light

Comparison of Azimuth Scans for Three Filters



- Meets requirements
- Consistent with modeled performance



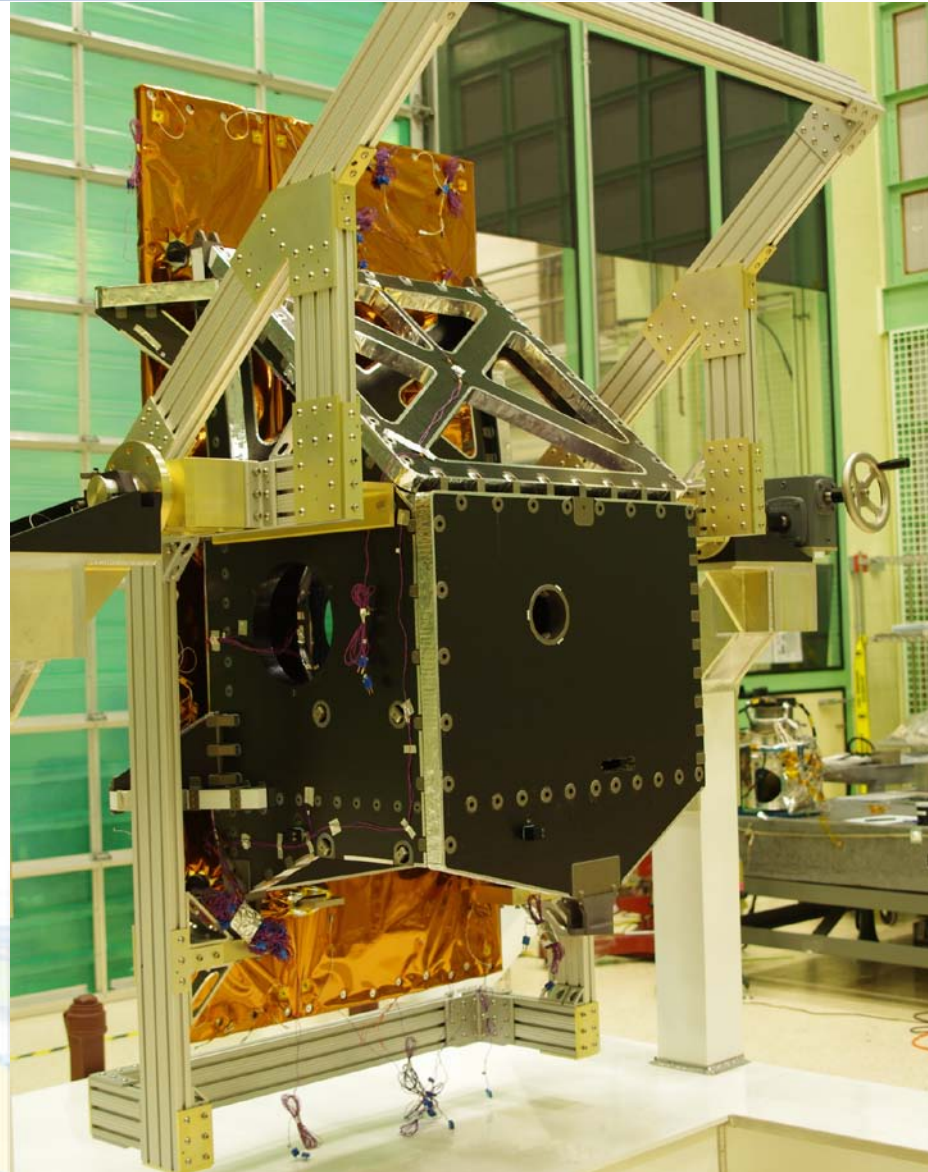
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Stray Light Ninjas

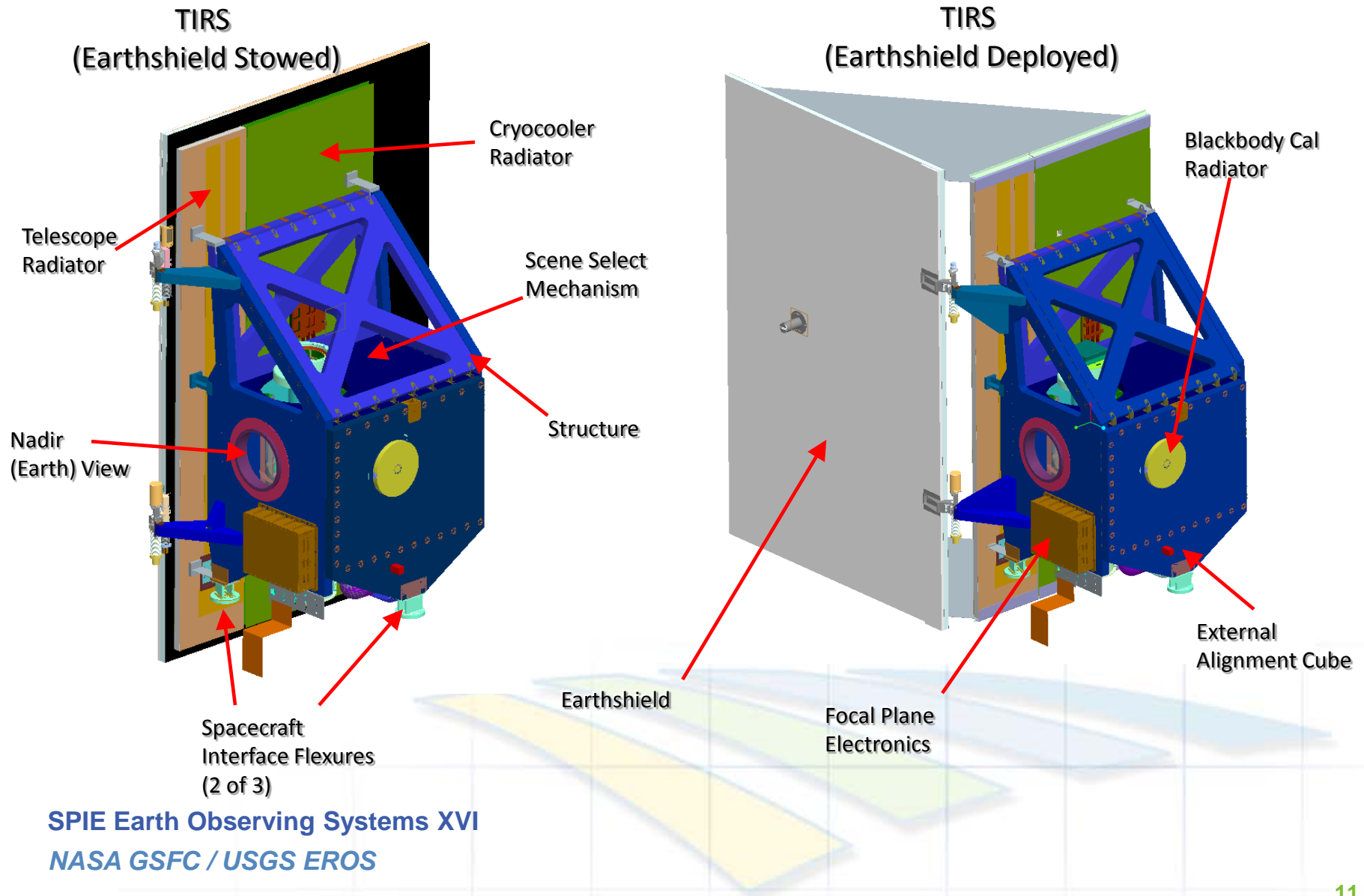
# Thermal Infrared Sensor (TIRS)

- Quantum well infrared photodetector (QWIP) focal plane array (built at GSFC), at 43K
- 2-Channel IR spectral imager
  - 10.8  $\mu\text{m}$  and 12  $\mu\text{m}$
  - Split window atmospheric correction
- Two full aperture calibration sources
  - Onboard blackbody
  - Space view
  - Calibration every 34 minutes
- Scene select mirror selects between calibration sources, nadir
- 185 km ground swath (15° FOV)
- 100 meter resolution
- TIRS delivery December 2011
- 3.25 year life, Class C instrument
- TVAC testing (full instrument) started

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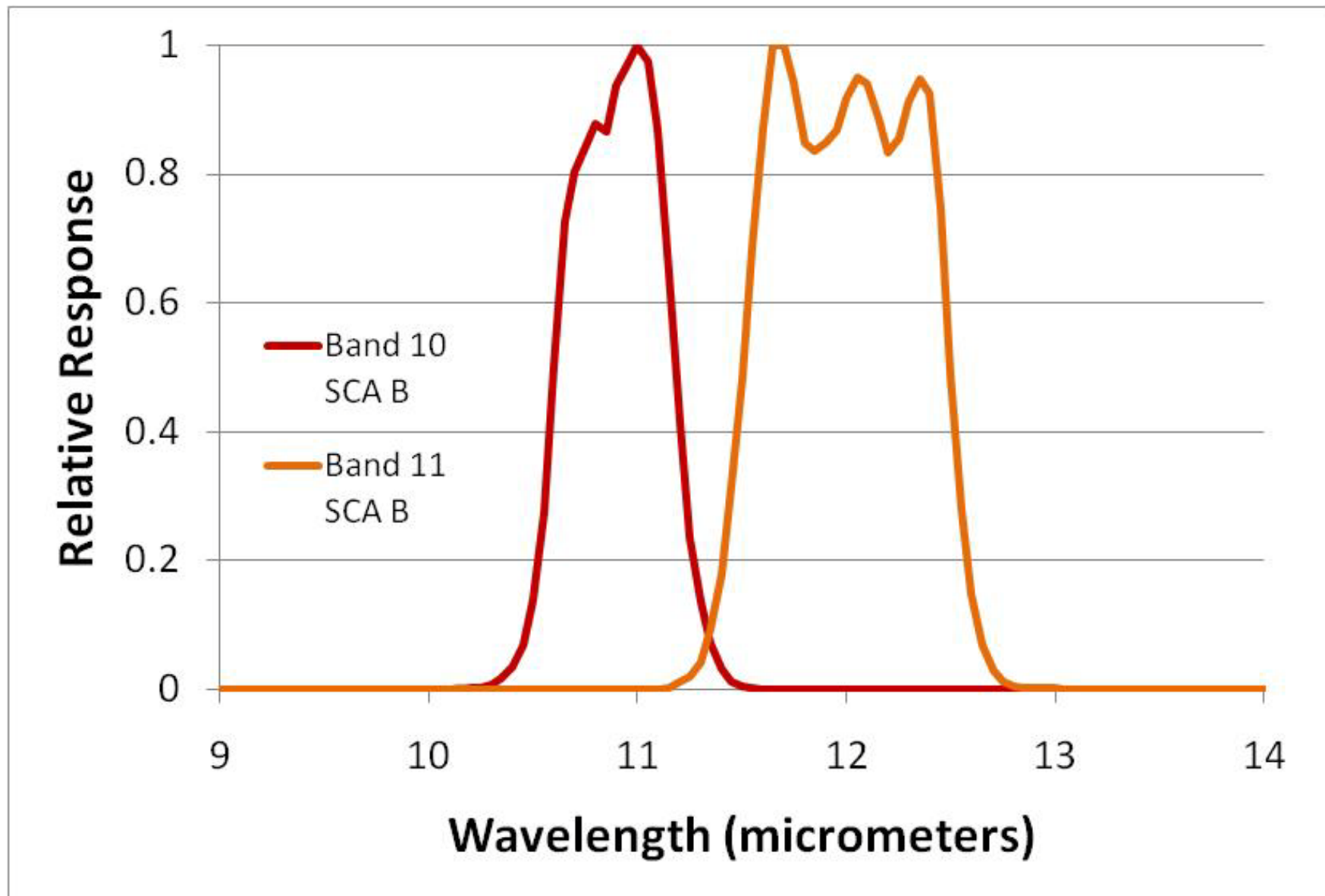
# TIRS Overview



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# TIRS Relative Spectral Response

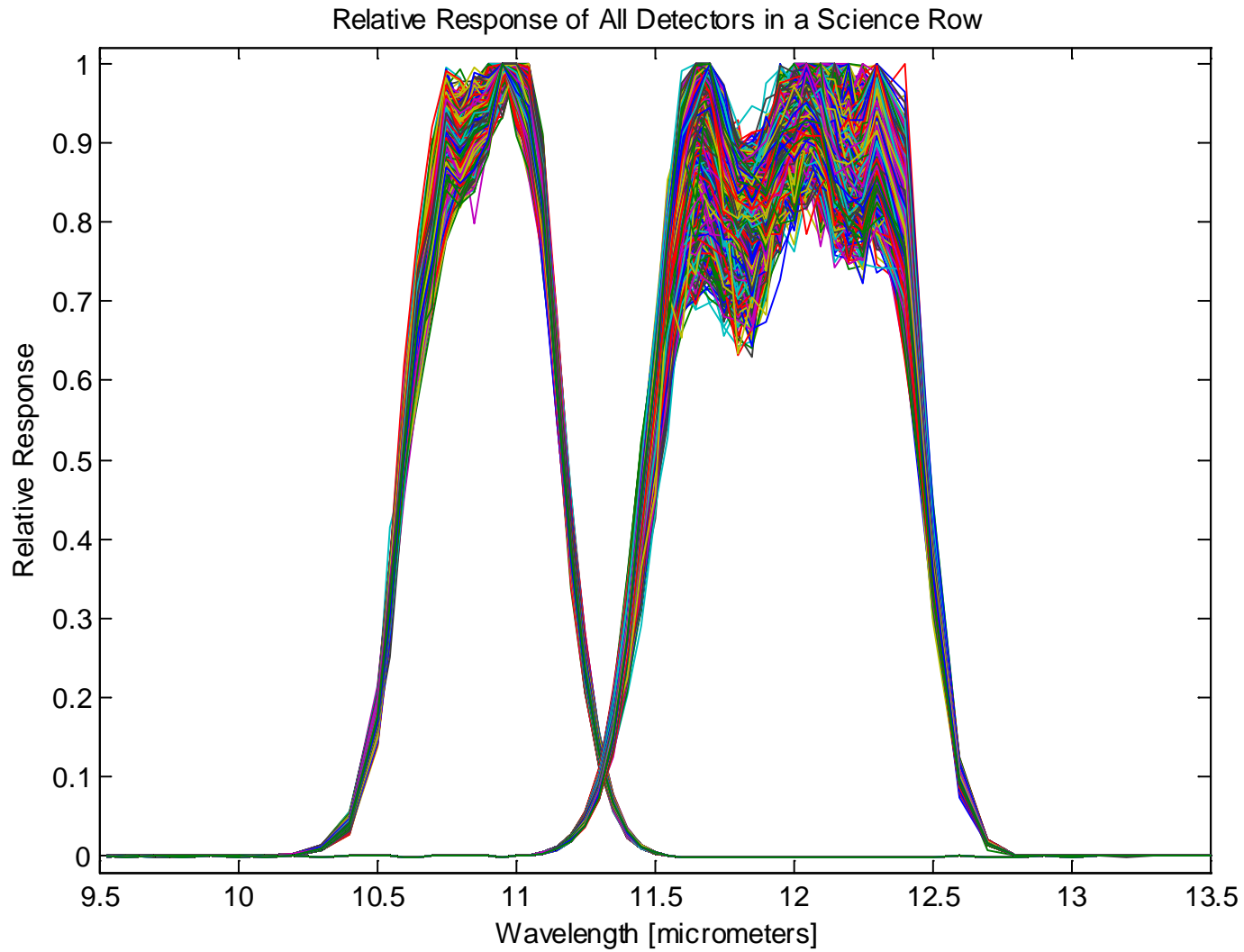
Average: based on component level measurements





# TIRS Relative Spectral Responses

All Detectors – based on component measurements



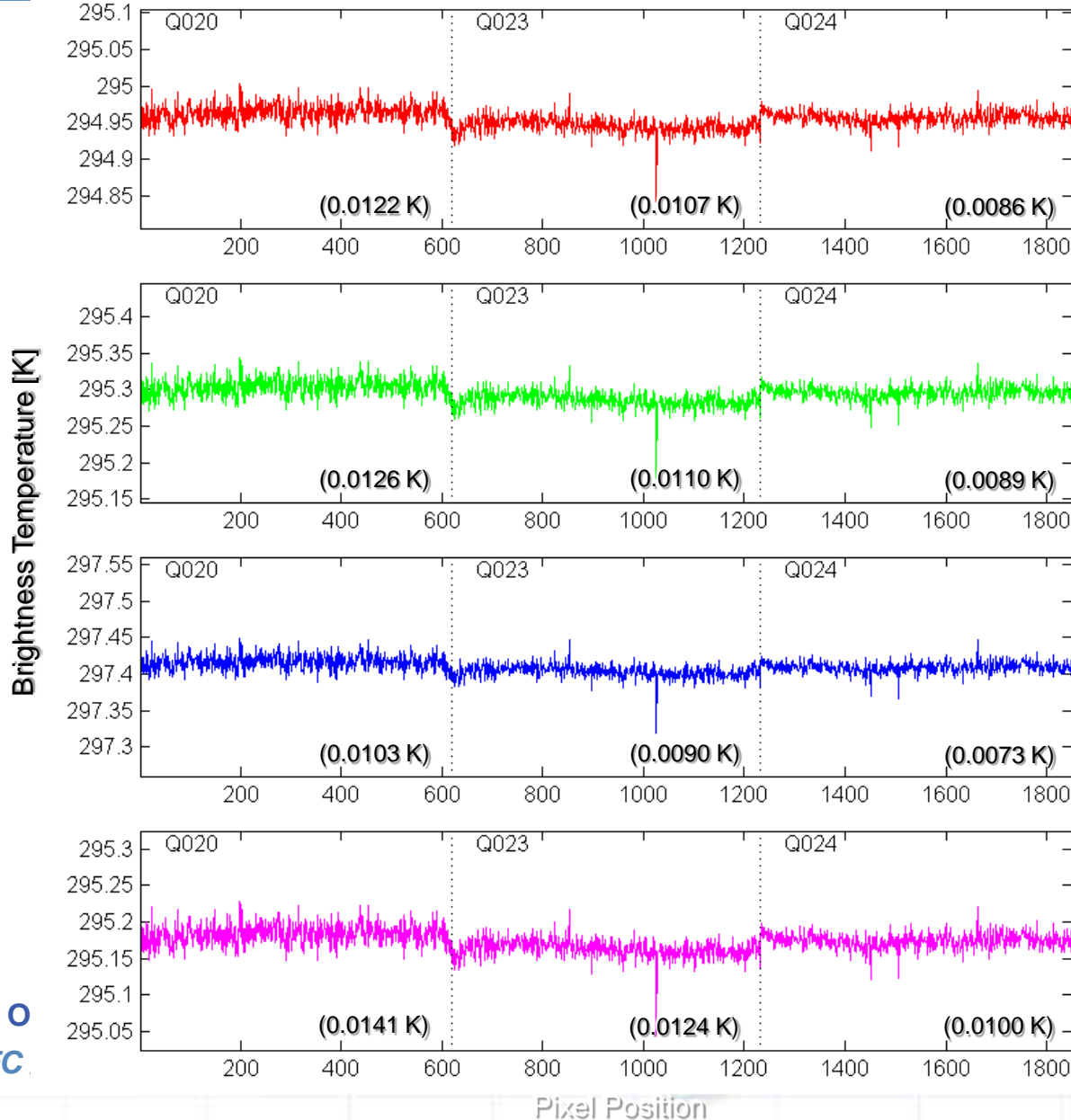
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# Spectral Uniformity Impact

## 300K Surface Target : 10.8 $\mu\text{m}$ band



**Tropical**

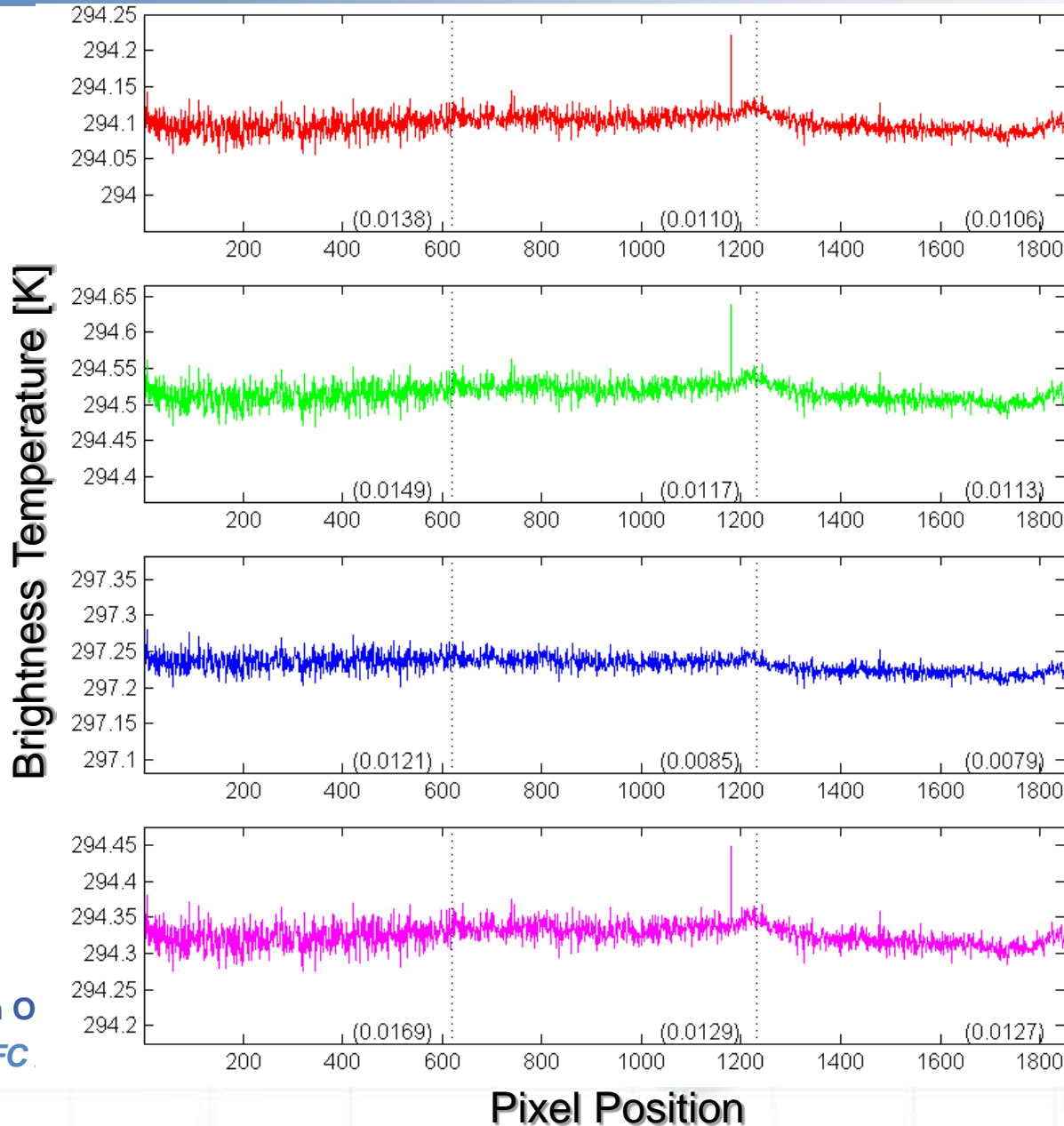
**Mid-Latitude Summer**

**Mid-Latitude Winter**

**Sub-Arctic Summer**

# Spectral Uniformity Impact

## 300K Surface Target : 12.0 $\mu\text{m}$ band



**Tropical**

**Mid-Latitude  
Summer**

**Mid-Latitude  
Winter**

**Sub-Arctic  
Summer**

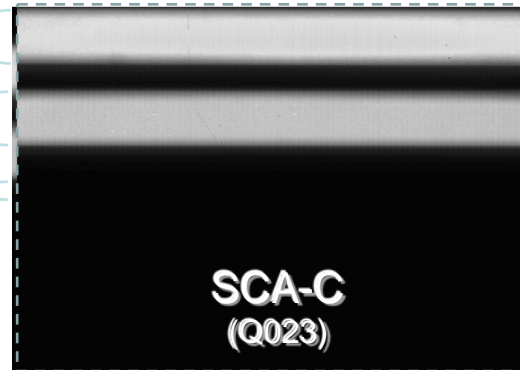
# TIRS Calibration Images



Dark Band  
10.8 um Band  
12 um Band



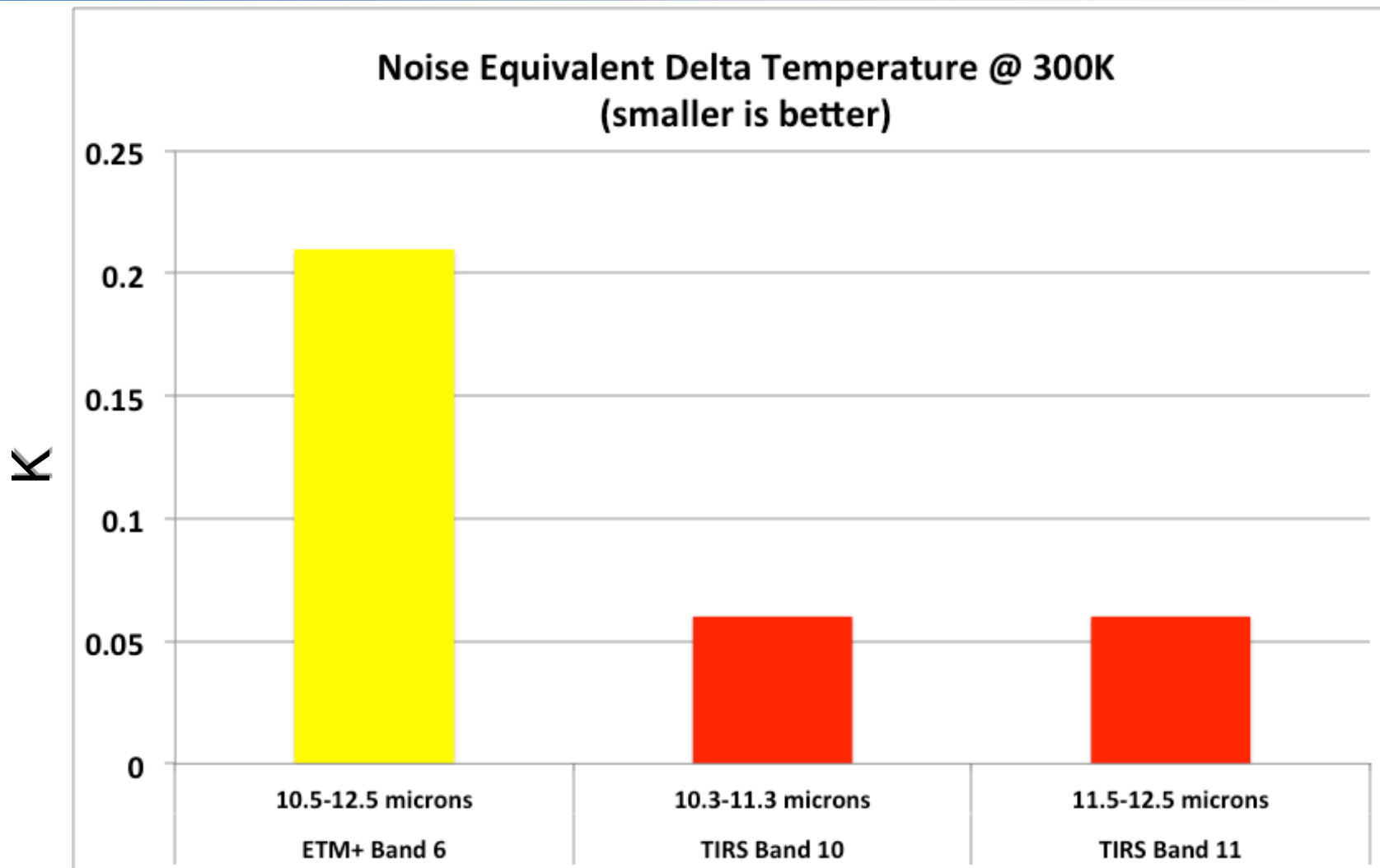
~ 36 un-vignetted rows  
~ 36 un-vignetted rows  
~ 18 dark rows



12 um Band  
10.8 um Band  
Dark Band

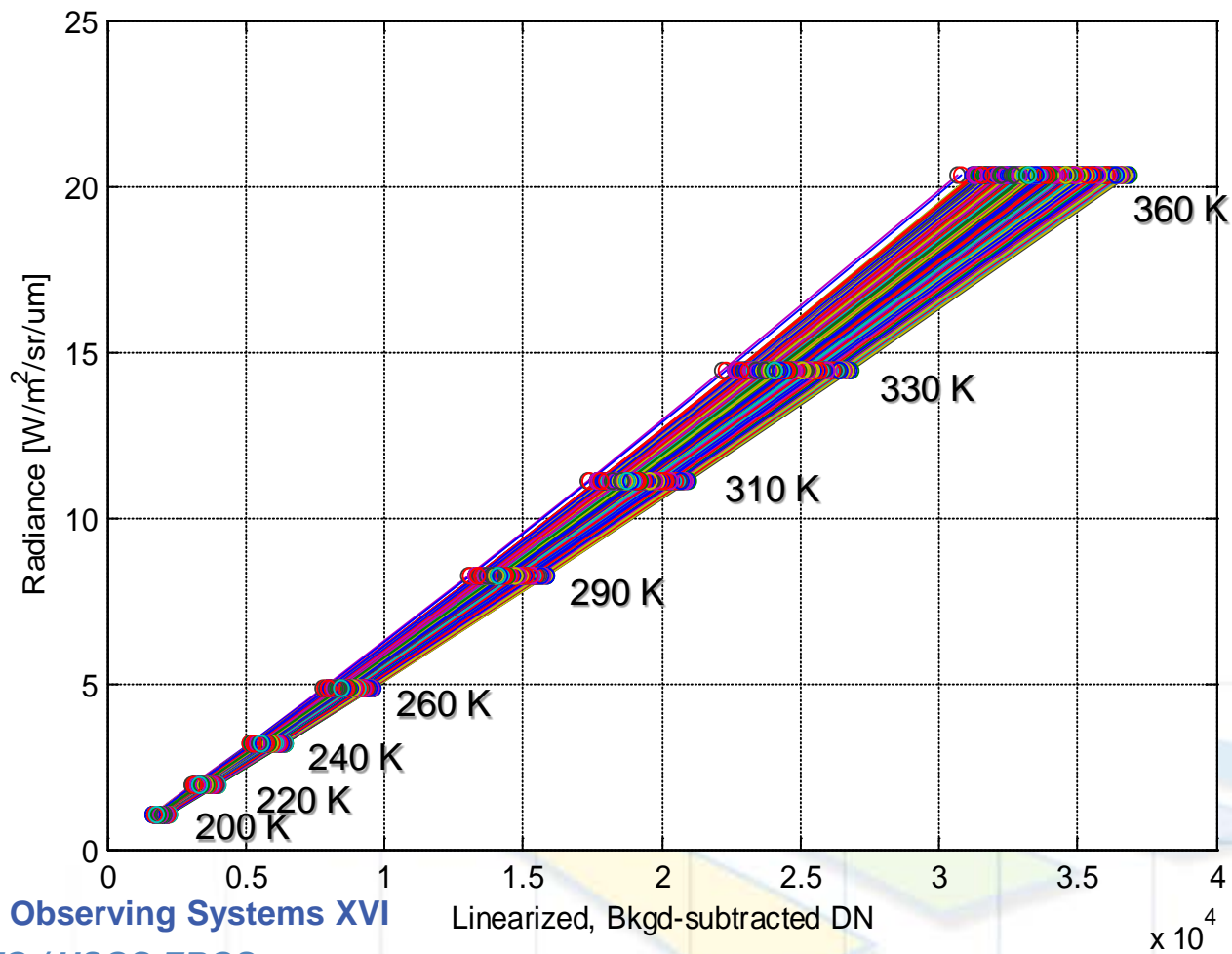
- SNR ~1,500 for 360 K source and ~1,000 for 300 K
- >3X more than required
- Consistent with shot-noise limited

# TIRS Preliminary Radiometric Performance



# Radiometric Responsivity Variation with 12.0 $\mu\text{m}$ Band

Radiance vs. Linearized, Bkgd-subtracted DN for IRSM temperatures of:  
[200 K, 220 K, 240 K, 260 K, 290 K, 310 K, 330 K, 360 K]





# Summary

## ➤ OLI

- Instrument complete – currently investigating heater controller anomaly
- SNR performance substantially exceeds requirements
- Absolute calibration meets requirements
- Relative (detector to detector) calibration meets requirements with possible exception of a few FPM boundaries and a few detectors
- Spatial response meets requirements

## ➤ TIRS

- Instrument now in primary thermal vacuum performance testing
- SNR performance expected to substantially exceed requirements
- Absolute calibration expected to exceed requirements
- Relative (detector-to-detector) calibration expected to meet requirements