

Radiometric Performance of Landsat 8

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Sioux Falls, South Dakota

March 27, 2014

***Work performed under USGS contract G10PC00044**

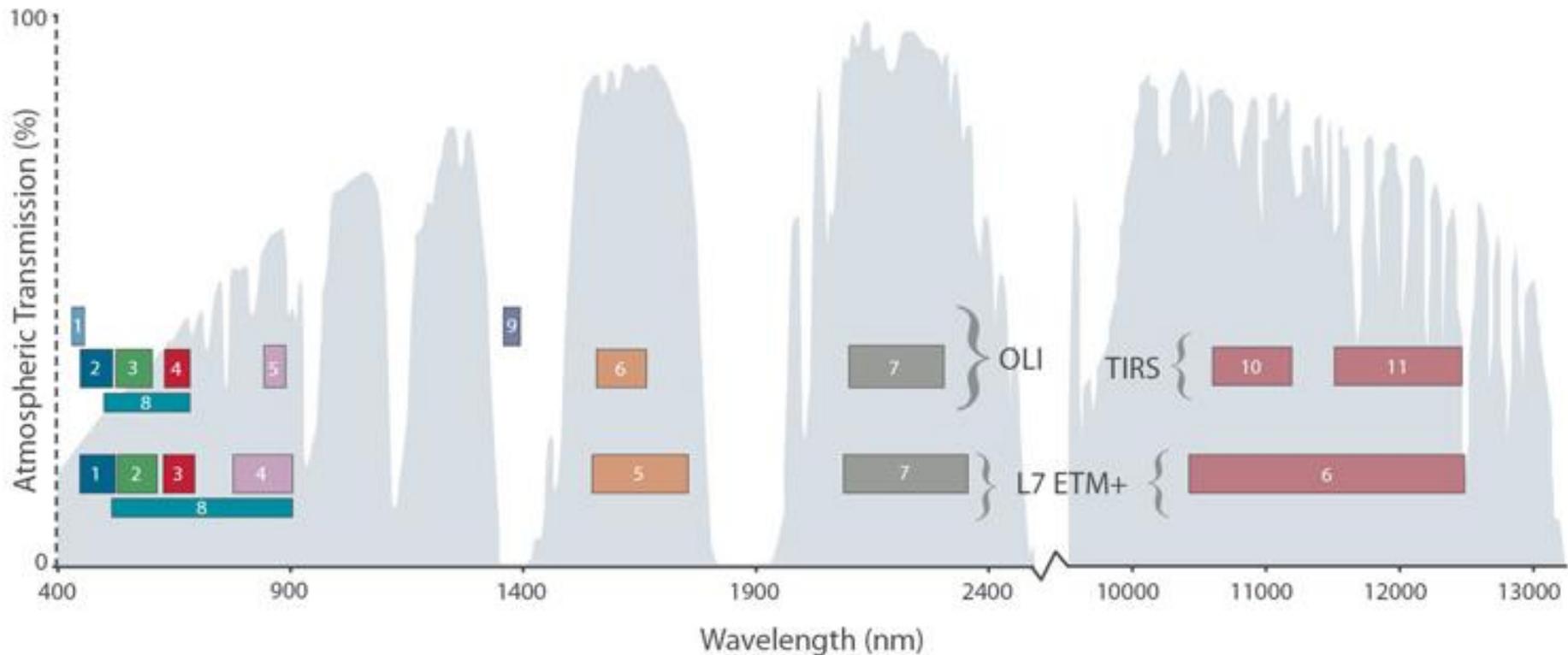
Overview

- **Landsat Cal/Val Team**
- **Brief summary of Landsat 8 Sensors**
- **Radiometric Performance**
 - ◆ Noise
 - ◆ Radiometric Stability
 - ◆ Artifacts
 - ◆ Pixel-to-Pixel Uniformity
 - ◆ Radiometric Accuracy
 - ◆ Summary

Landsat Calibration Validation Team

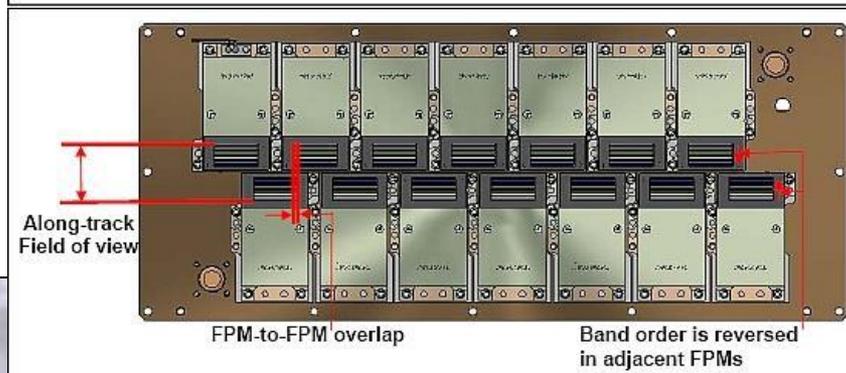
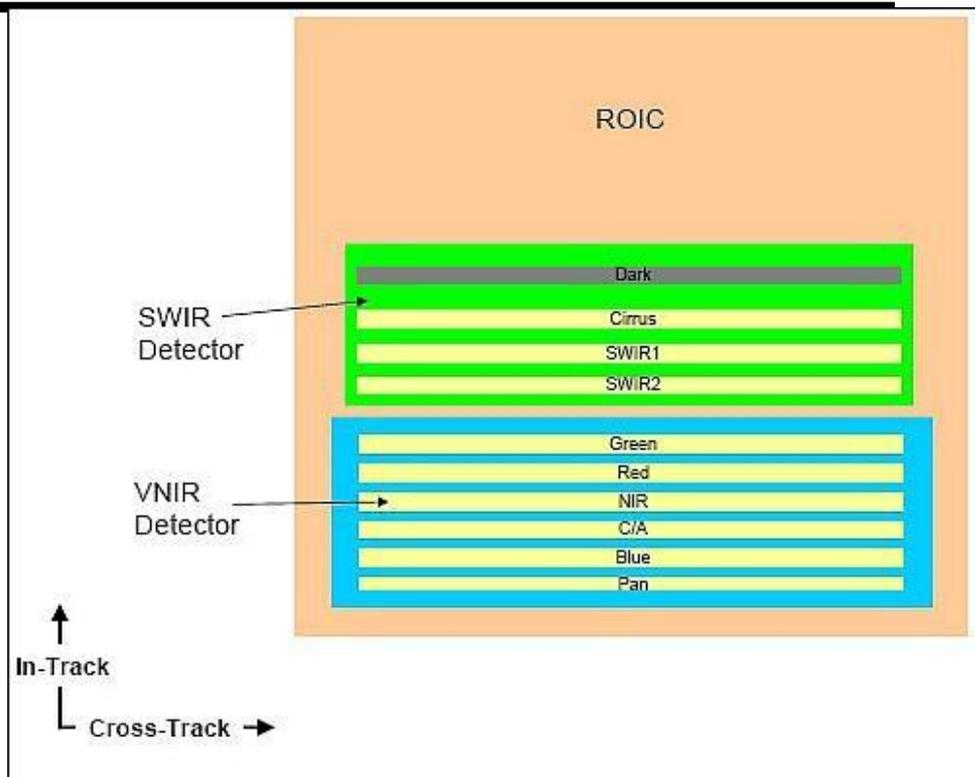
- **USGS Earth Resources Observation and Science (EROS)**
 - ◆ <http://landsat.usgs.gov/>
- **NASA Goddard Space Flight Center (GSFC)**
 - ◆ <http://landsat.gsfc.nasa>
- **NASA Jet Propulsion Laboratory (JPL)**
 - ◆ <http://www.jpl.nasa.gov/>
- **Rochester Institute of Technology (RIT)**
 - ◆ <http://www.cis.rit.edu/>
- **South Dakota State University (SDSU) Image Processing (IP) Laboratory**
 - ◆ <http://iplab2out.sdstate.edu/>
- **University of Arizona (UofA) Optical Sciences Laboratory**
 - ◆ <http://www.optics.arizona.edu/>

L7 vs. L8 spectral bands

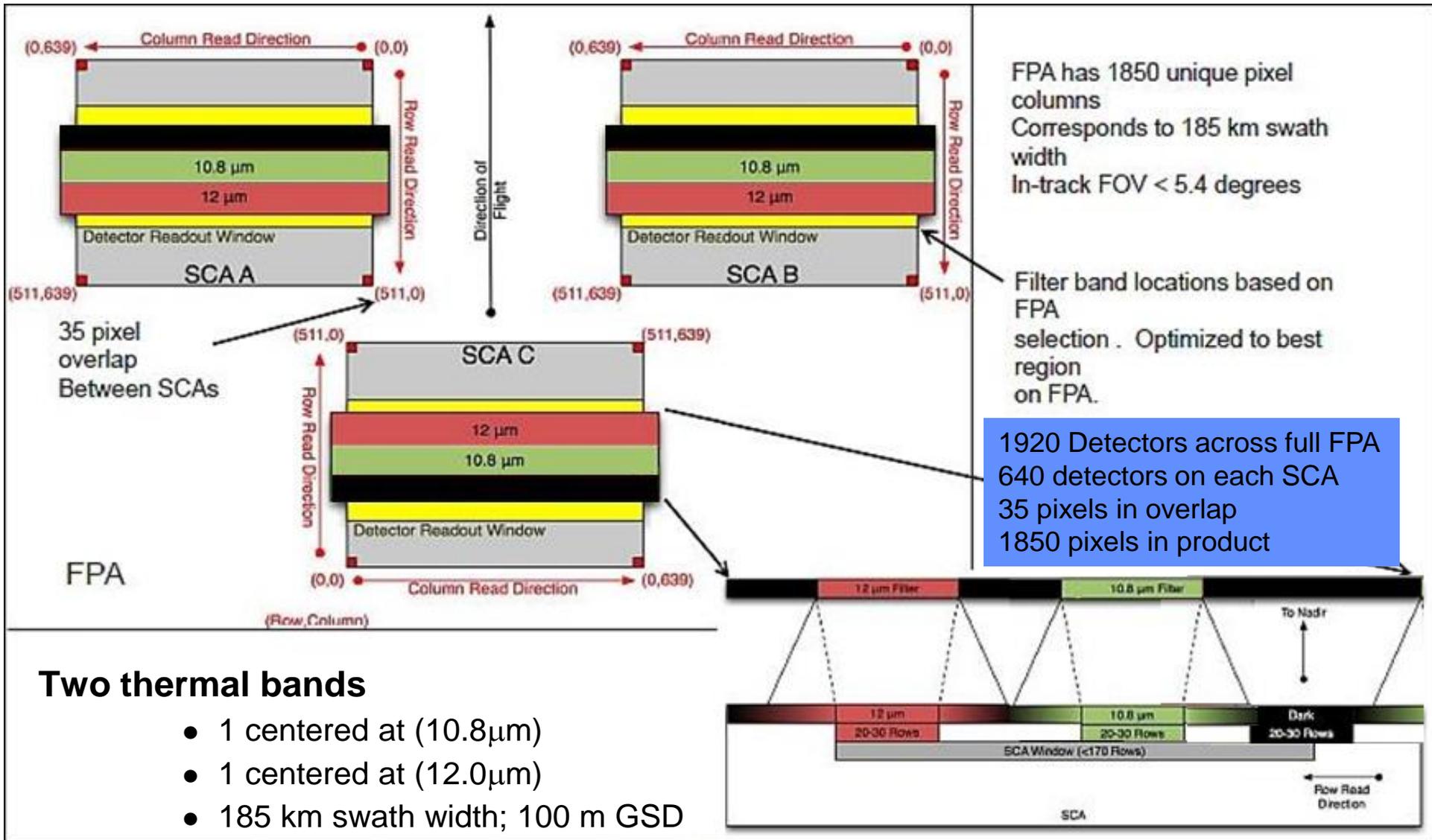


Operational Land Imager (OLI)

- 6916 active detectors per band (13,832 pan)
- Each Focal Plane Module (FPM) is 494 detectors wide (988 pan)
- Each FPM has its own spectral filters
- 14 FPMs make up the Focal Plane Assembly (FPA).
- FPMs also called Sensor Chip Assemblies (SCA)



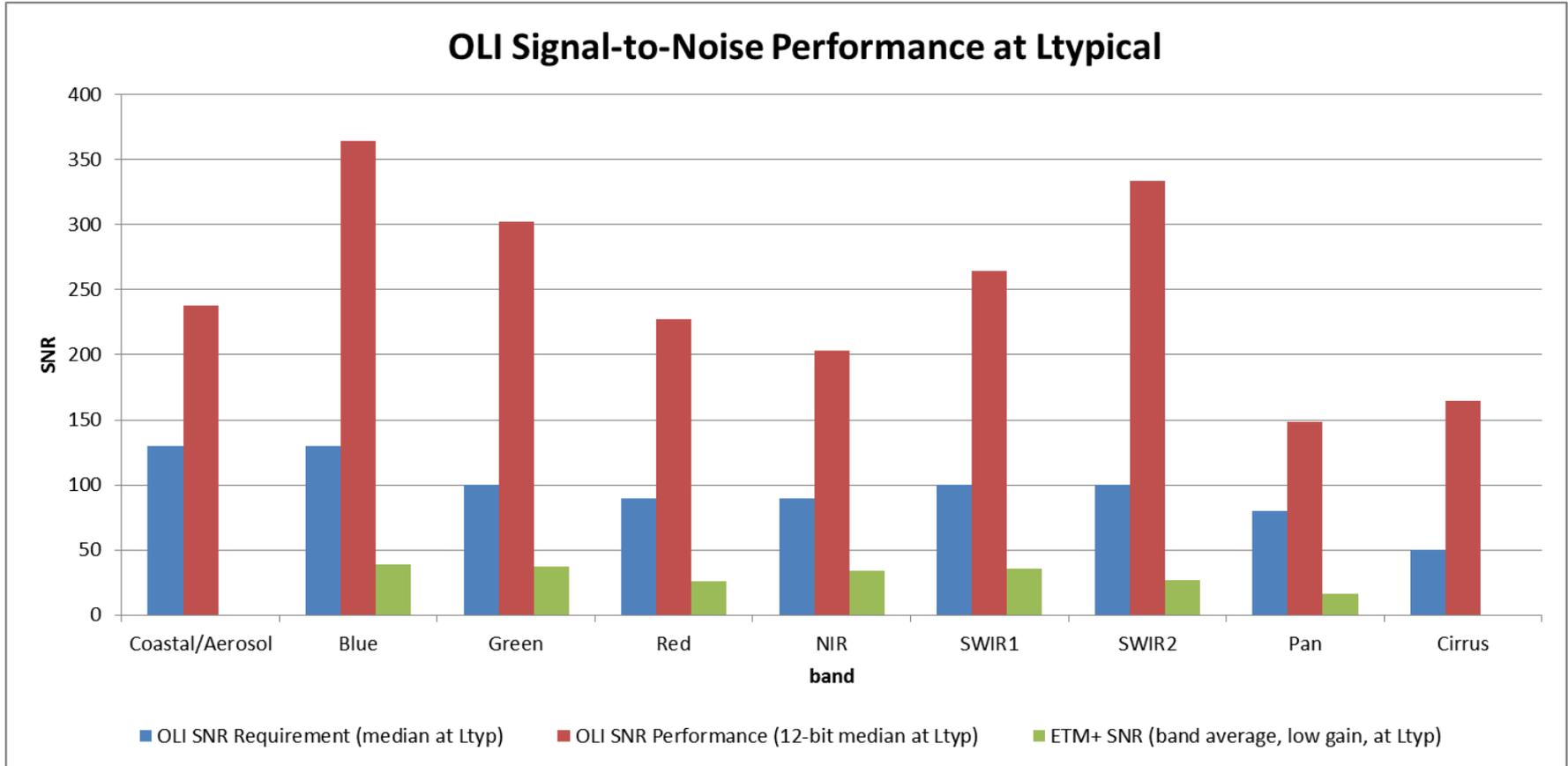
Thermal Infrared Sensor (TIRS)



Two thermal bands

- 1 centered at (10.8 μm)
- 1 centered at (12.0 μm)
- 185 km swath width; 100 m GSD

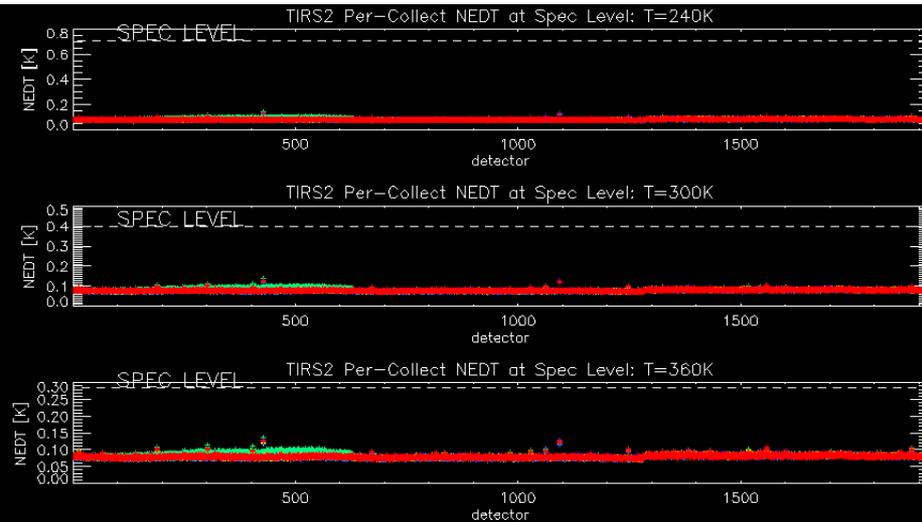
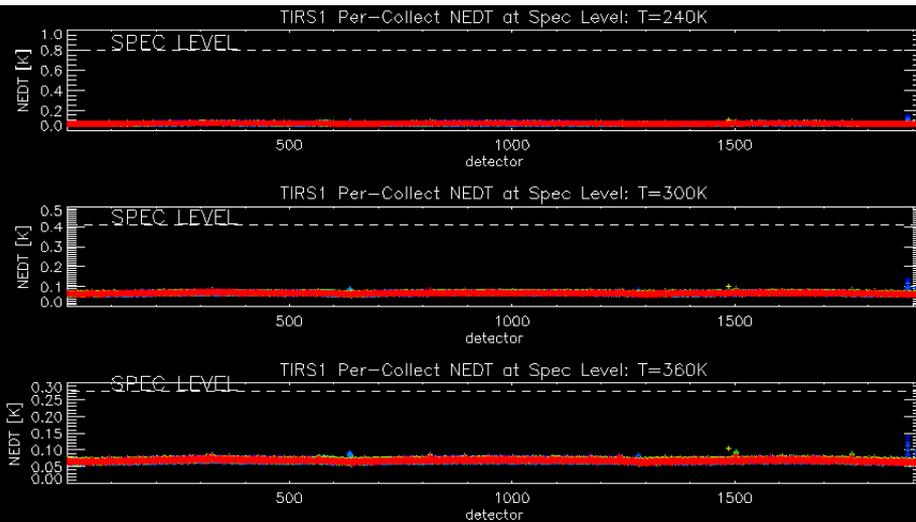
Noise: OLI SNR



OLI SNR consistent with pre-launch at typically 2-3x better than requirements, 8x better than heritage

Noise: TIRS NE Δ T

- All TIRS detectors have similar NE Δ T
- Band averages:
 - ◆ B10: 0.048
 - ◆ B11: 0.052



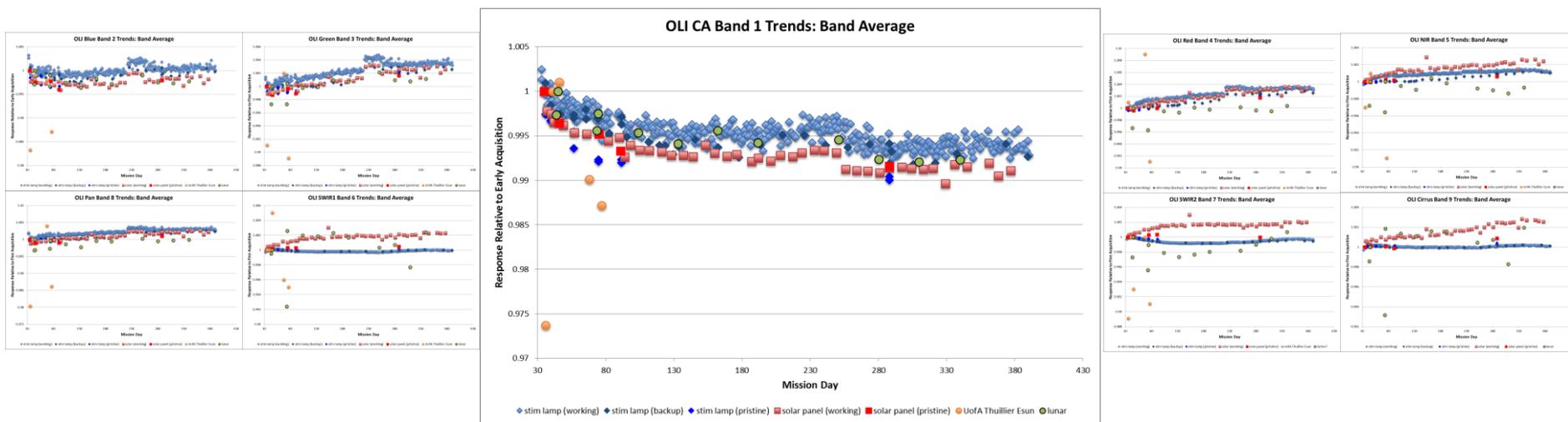
Noise is about 8x better than requirements; about 4x better than heritage

OLI Radiometric Stability

- Around orbit [measured with stim lamps taken at different positions in the orbit]
 - ◆ No orbital position sensitivity observed
- Since launch [measured with daily stim lamps]
 - ◆ Better than 0.3% (2 sigma) over 60 days; requirement is 1% (2 sigma) over 16 days!

C/A	Blue	Green	Red	NIR	SWIR 1	SWIR 2	Pan	Cirrus
0.29%	0.25%	0.20%	0.12%	0.02%	0.01%	0.01%	0.13%	0.01%

- ◆ Trends less than 0.5% over 60 days, i.e., no significant contamination apparent

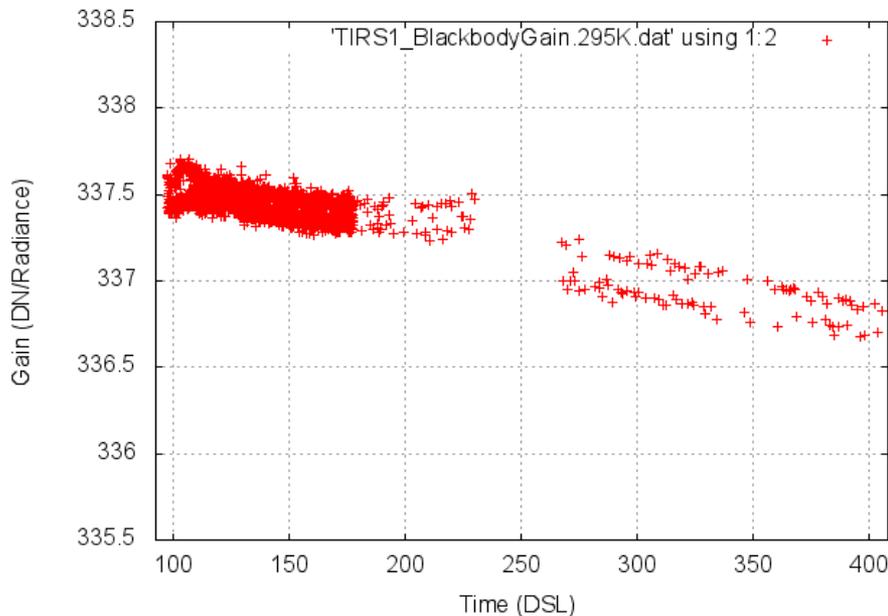


JACIE-ASPRS 2014
March 27, 2014

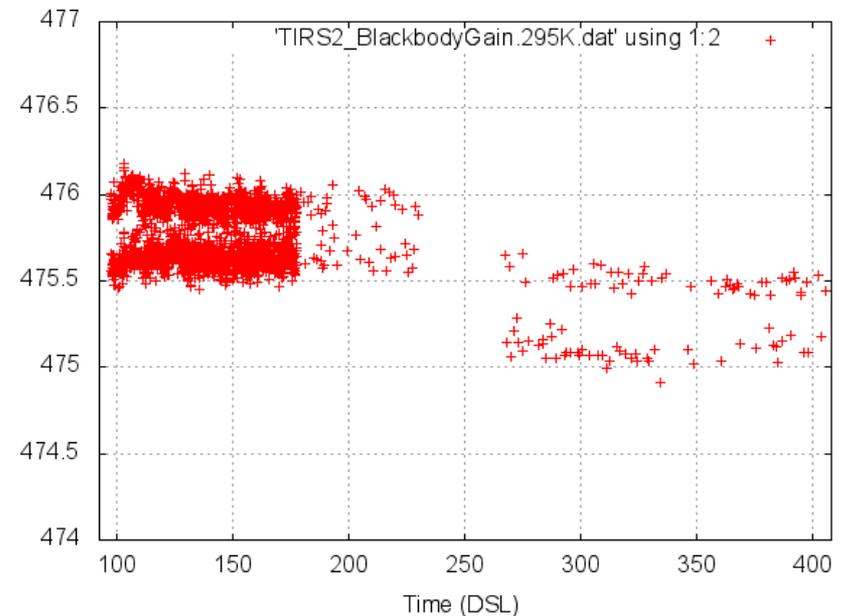
TIRS Radiometric Stability

- **Within Interval (between calibrations)**
 - ◆ Typically $<0.1\%$ (1 sigma) over 40 minutes; requirement is 0.7% (1 sigma)
 - ◆ Similar performance over $1\frac{1}{2}$ orbits
- **Since Achieving Final Telescope Temperature**
 - ◆ Typically range of $\pm 0.02\%$ over ~ 30 days; slight variation within interval

TIRS B10 Blackbody Gain

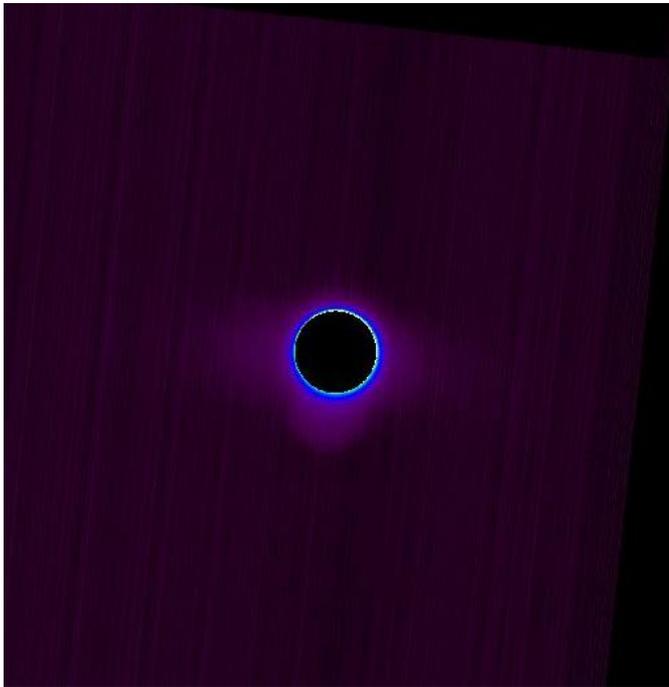


TIRS B11 Blackbody Gain

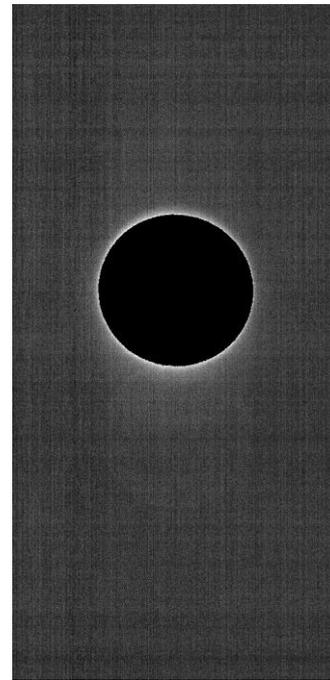


Artifacts

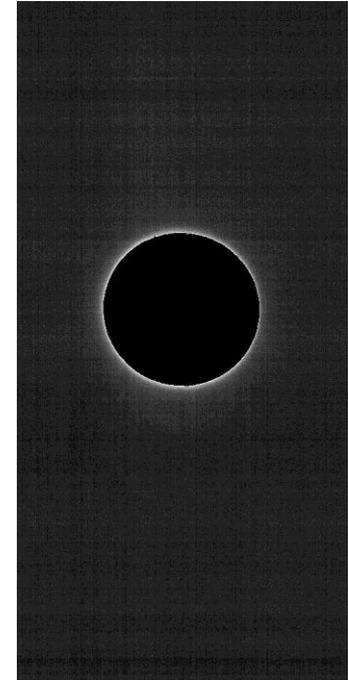
- No coherent (a.k.a. pattern noise) observed in either instrument
- Spatial artifacts (i.e., ghosting, crosstalk) within requirements on both instruments



TIRS band 10 – weak ghost ~0.1% of lunar signal



OLI Band 9 (Cirrus)

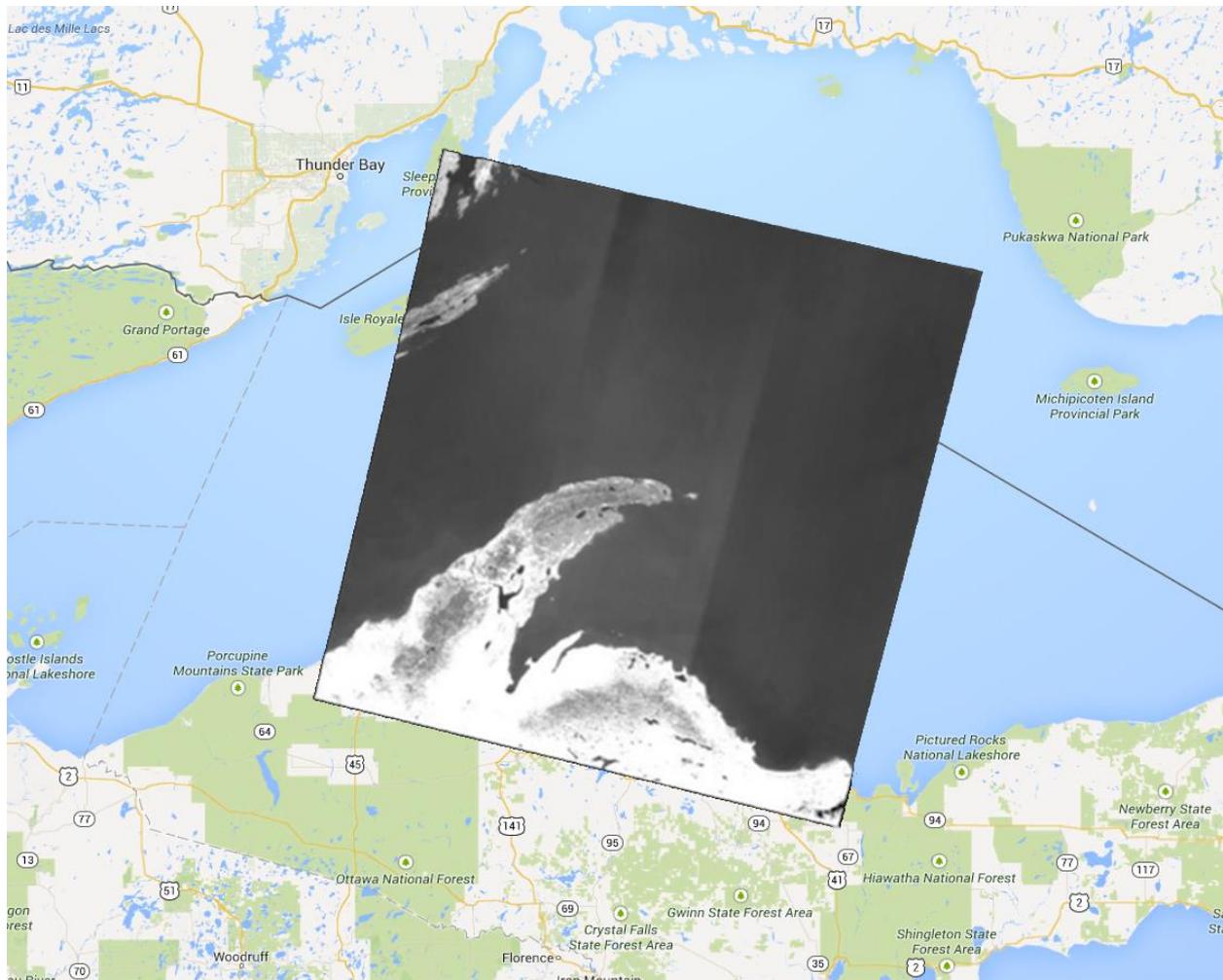


OLI Band 6 (SWIR 1)

very weak ghost/ halo

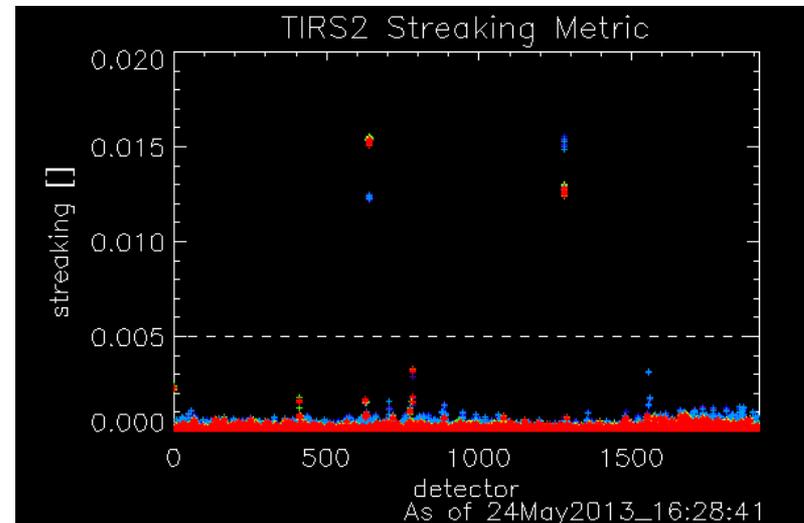
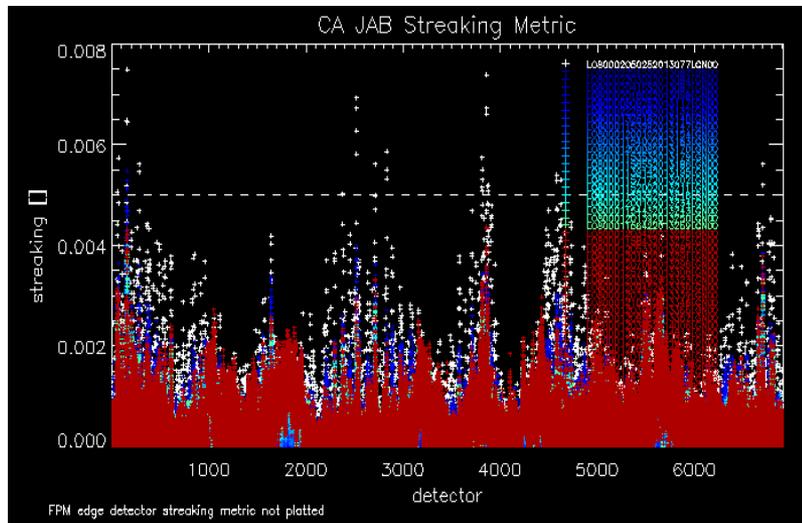
Artifacts

TIRS Out-of-field Stray Light



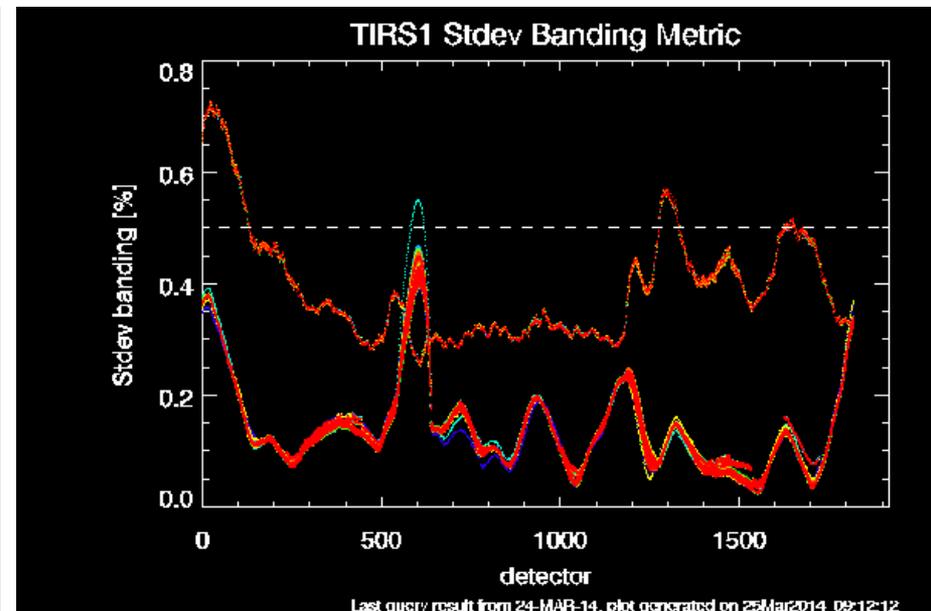
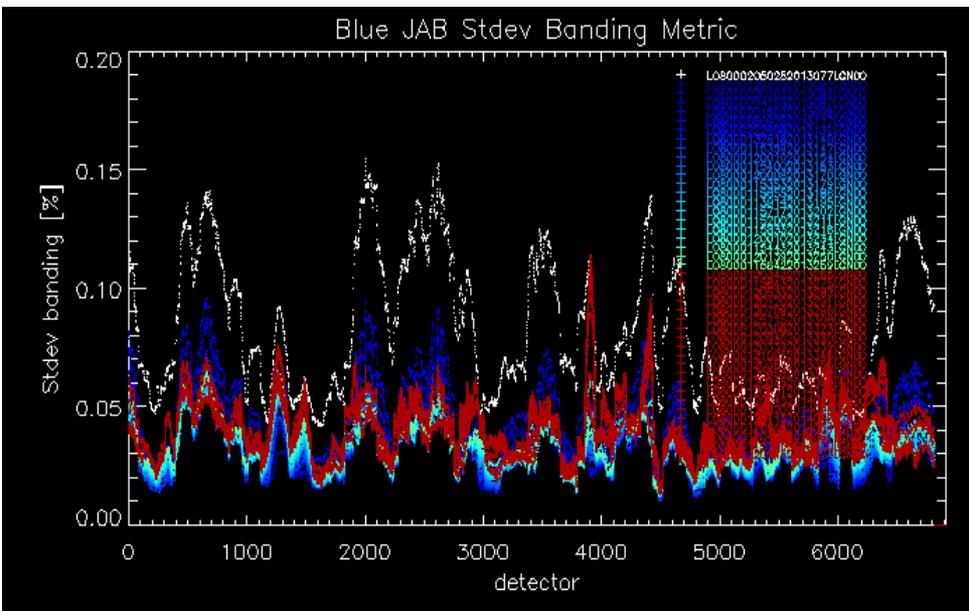
Pixel-to-Pixel Uniformity - Streaking

- **Streaking is uncorrected individual detector-to-detector variation**
 - ◆ Requirement is $<0.5\%$ [1% for band 8]; limited number of failing detectors allowed in out-of-spec bin (99.75% of detectors in a band must be within spec)
- **Most bands meet streaking requirements with current calibration parameters w/o excluding any detectors**
 - ◆ OLI: occasionally some SWIR detectors (all bands in spec after allowed exclusions)
 - ◆ TIRS: few detectors fail, mainly in band 11, though not real streaking (in spec after allowed exclusion)



Pixel-to-Pixel Uniformity – Banding (type 2)

- **Banding, under this definition, is the standard deviation across a 100-pixel wide moving window**
 - ◆ Requirement is 0.25% for OLI and 0.5% for TIRS
 - ◆ Usually associated with radiometric discontinuities between adjacent Focal Plane Modules or Sensor Chip Assemblies
- **Most bands meet this banding requirement**
 - ◆ OLI: All bands exceed this requirement
 - ◆ TIRS: Does not consistently meet requirement at either SCA boundary

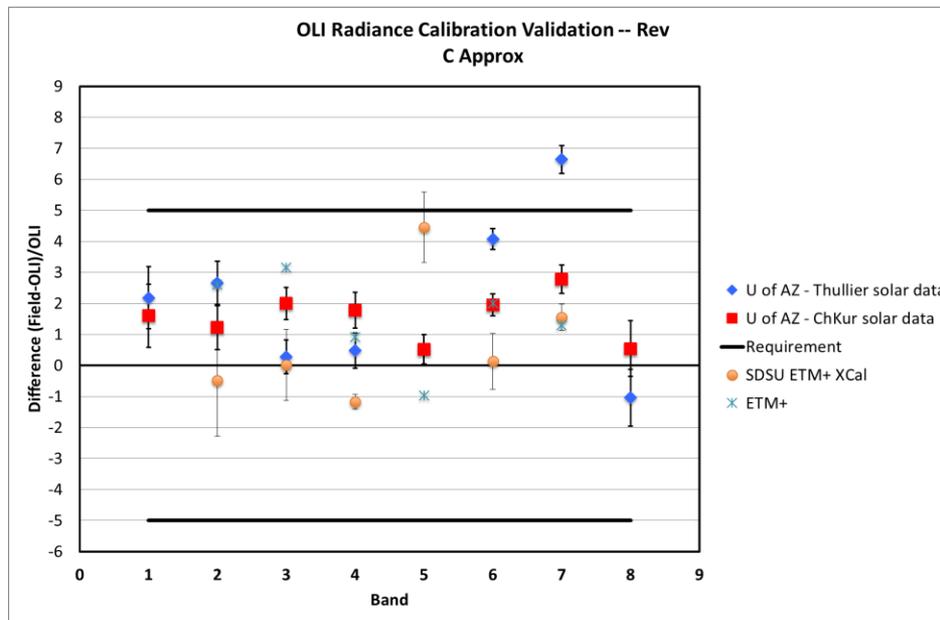


Radiometric Accuracy - Radiance

- **Across primary range of radiance levels:**
 - ◆ OLI absolute radiance uncertainty requirement is $< 5\%$ (1 sigma)
 - ◆ TIRS absolute radiance uncertainty requirement is $< 2\%$ (1 sigma)
- **Requirement is met prior to launch via sources traceable to NIST**
- **On-orbit confirmation involves ground reflectance or temperature measurements and atmospheric propagation or comparison to other sensors, which typically have higher uncertainty, so process typically takes time to tie down. SWIR bands still have significant solar irradiance uncertainty ($\sim 4\%$)**
- **Ground “vicarious” teams have been in place and will continue to be in place to provide needed measurements**
- **Between some very dedicated ground teams, well developed techniques and cooperative weather, we have better information at this point than in any previous mission**

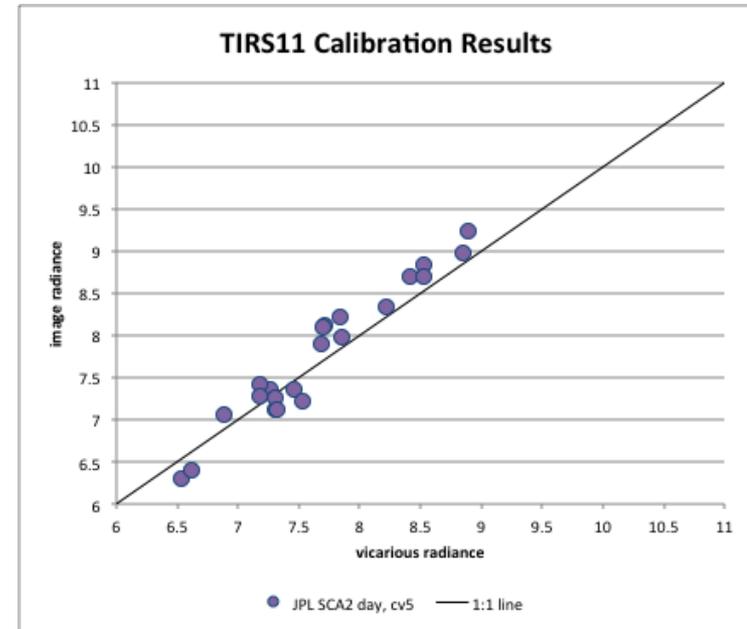
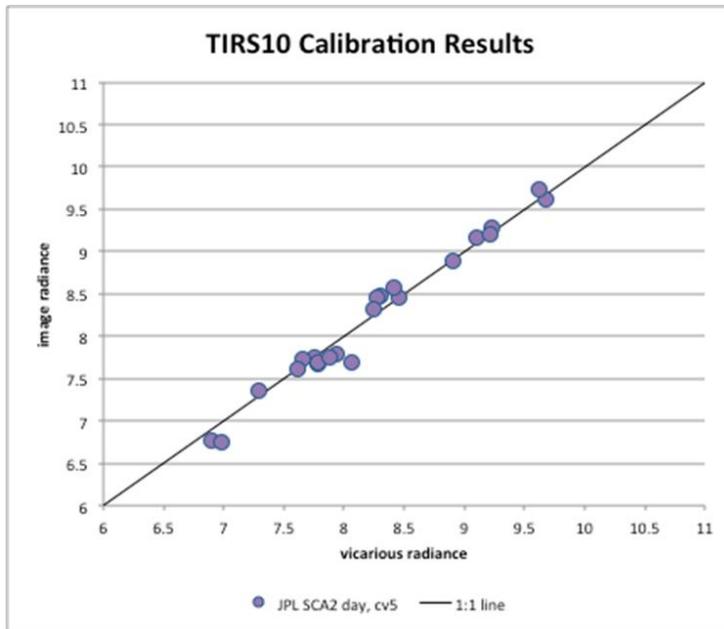
Radiometric Accuracy - Reflective

- Our primary reflective band vicarious cal team (U of Arizona) has obtained 10 good calibrations of OLI with excellent reproducibility (circa 1% one sigma)
- Initial analysis shows good agreement to operational OLI calibration (within ~3%, depending which solar spectrum is used)
- Initial analysis of cross calibration with Landsat-7 ETM+ (South Dakota S U) also shows consistent results within 2%



TIRS Radiometric Accuracy

- Thermal calibration teams (RIT and JPL) acquired data from Lake Tahoe, Salton Sea, numerous ocean and Great Lakes buoy data
- Offset determined based on initial calibration, likely due to stray light
- Current accuracy after offset correction:
 - ◆ B10: 1.2% 1σ
 - ◆ B11: 2.2% 1σ



OLI Radiometric Performance Summary

- On-orbit characterization of radiometric performance has confirmed that the vast majority of evaluated requirements have been met; some uncertainties remain

Requirement	Measured Value (worst case)	Required Value	Units	Margin (worst case)	Requirement Reference
OLI Ghosting	meets	varies	percent	----	OLI-788
OLI Absolute Radiance Uncertainty	4*	<5	percent	20%*	OLI-792
OLI Absolute Reflectance Uncertainty	reanalysis	<3	percent	TBD	OLI-792
OLI Median SNR Ltypical	meets	varies	-	83%	OLI-875
OLI Median SNR Lhigh	meets	varies	-	87%	OLI-875
OLI Uniformity Full Field of View	0.35	0.5	percent	30%	OLI-951
OLI Uniformity Banding RMS	0.8	1	percent	20%	OLI-955
OLI Uniformity Banding Stdev	0.15	0.25	percent	40%	OLI-962
OLI Uniformity Streaking	0.5***	0.5, 1	percent	---***	OLI-973
OLI Coherent Noise	meets	<equation	---	----	OLI-761
OLI Saturation Radiances	meets	varies	W/m ² sr μm	8%	OLI-996
OLI 16-day Radiometric Stability	0.23****	1	Percent (2 sigma)	77%+	OLI-1001
OLI 60 second Radiometric Stability	0.1	0.5	Percent (2 sigma)	80%	OLI-1003
OLI Inoperable Detectors	0	<0.1	Percent	100%	OLI-1013
OLI Out-of-Spec Detectors	0.14	<0.25	Percent	44%	OLI-1020

* Band 7 compliance depends on solar spectrum used

*** Few intermittently streaky detectors above requirement level placed in out-of-spec bin as allowed

**** 60 days

TIRS Radiometric Performance Summary

- TIRS product uniformity is current focus of CVT and TIRS team analyses. Significant improvements to the uniformity are expected with updated parameters and/or algorithms

Requirement	Measured Value (worst case)	Required Value	Units	Margin (worst case)	Requirement Reference
TIRS Ghosting	meets	varies	percent	----	TIRS-403
TIRS Absolute Radiance Uncertainty	2.2	2	percent	----*	TIRS-427
TIRS NEAT (@300K)	0.05	0.4	K	80%	TIRS-441
TIRS Uniformity Full Field of View	1	0.5	percent	----*	TIRS-503
TIRS Uniformity Banding RMS	1	0.5	percent	----*	TIRS-507
TIRS Uniformity Banding Stdev	1	0.5	percent	----*	TIRS-514
TIRS Uniformity Streaking	0.4	0.5	percent	20%	TIRS-525
TIRS Coherent Noise	meets	<equation	---	----	TIRS-532
TIRS Saturation Radiances	28.4, 19.2	20.5, 17.8	W/m ² sr μm	8%	TIRS-545
TIRS 40 minute Radiometric Stability	0.1	0.7	percent (1 sigma)	86%	TIRS-547
TIRS Inoperable Detectors	0	<0.1	percent	----	TIRS-550
TIRS Out-of-Spec Detectors	0.21	<0.25	percent	16%	TIRS-555

*Likely due to stray light; Cal/Val team working with TIRS team on potential correction algorithm