Radiometry Characterization and Calibration Overview and Plans

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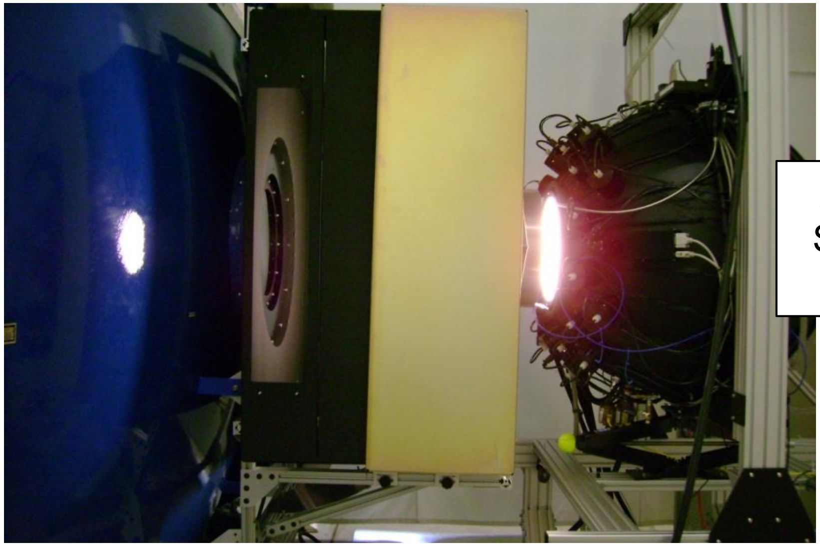
Overview

- **Prelaunch Radiometric Testing**
  - Characterization
  - Calibration
- **On-Orbit Characterization and Calibration**
  - OLI
  - TIRS
- **Worries**
  - Banding and Streaking

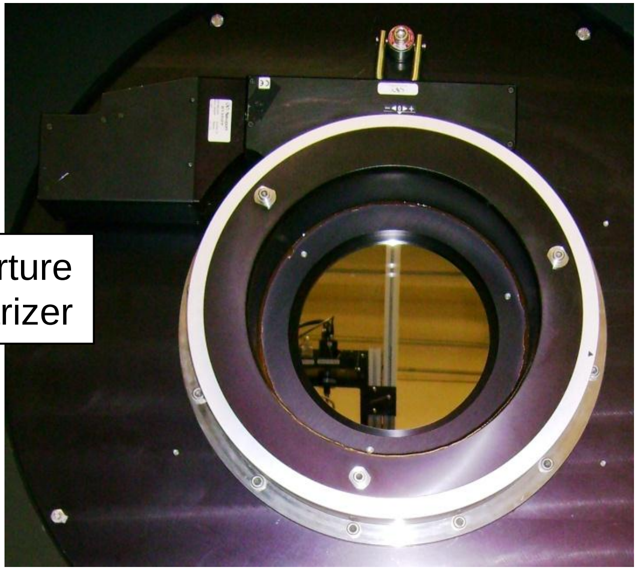
Pre-Launch Radiometric Testing

- **Radiometric Characterization**
  - Test Equipment
  - Spectral Response
  - Polarization Sensitivity (OLI only)
  - Stability
  - Responsivity
  - Linearity
  - Pixel-to-Pixel Uniformity
  - OBC Characterization
- **Radiometric Calibration**
  - Detector Radiometric Response
    - Electronics Linearity LUT's (Counts to Linearized Counts)
    - Gains/Radiometric LUT's (Counts to Radiance)
  - OBC
    - OBC Radiance's
      - TIRS BB Temperature to Radiance Conversion
      - OLI Diffuser
        - Reflectances
        - On-orbit radiances
      - OLI Lamp Radiances

OLI: Radiometric and Spectral Tests Completed with traditional spheres and monochromators



Aligning “Death Star” Calibration Sphere

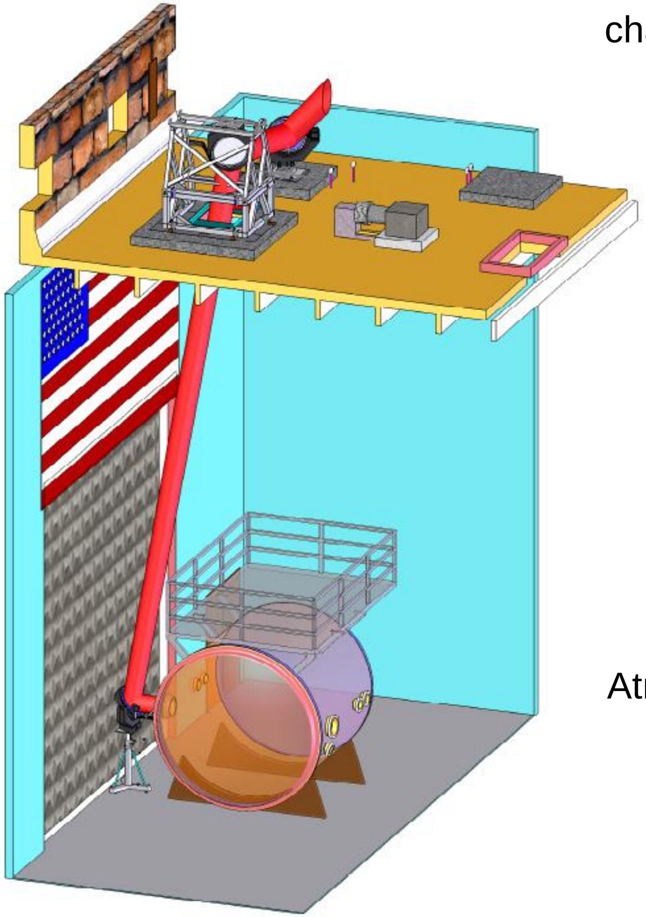


Large aperture linear polarizer

Spectral Measurement Assembly

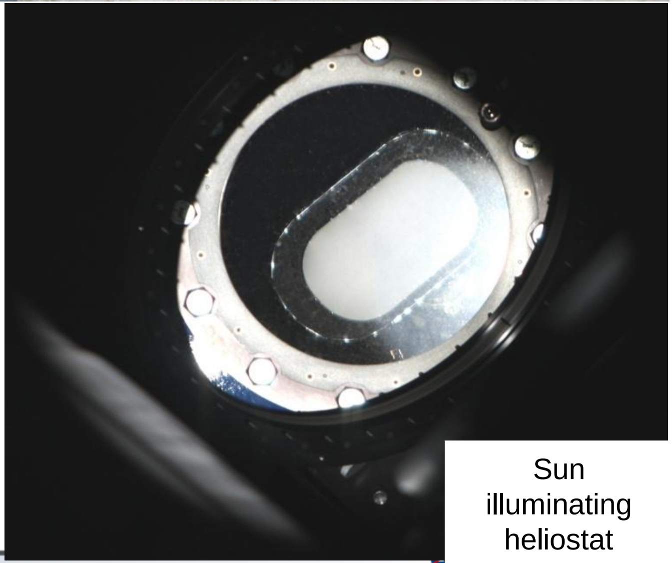
OLI: Heliostat Calibration provides transfer of calibration to orbit

Heliostat steers sunlight into T/V chamber



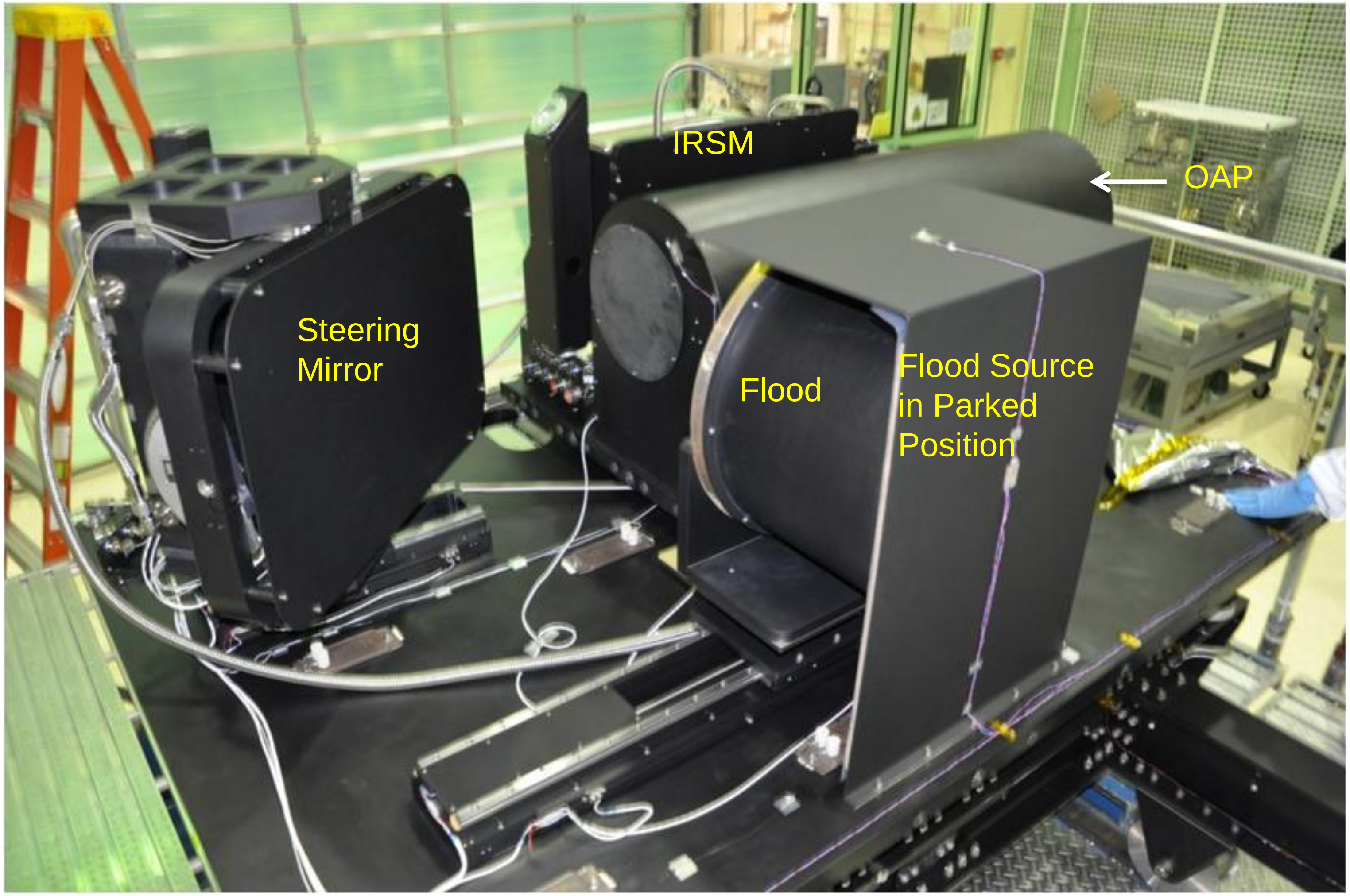
Measuring Heliostat Transmission

Atmospheric transmittance characterized by University of Arizona

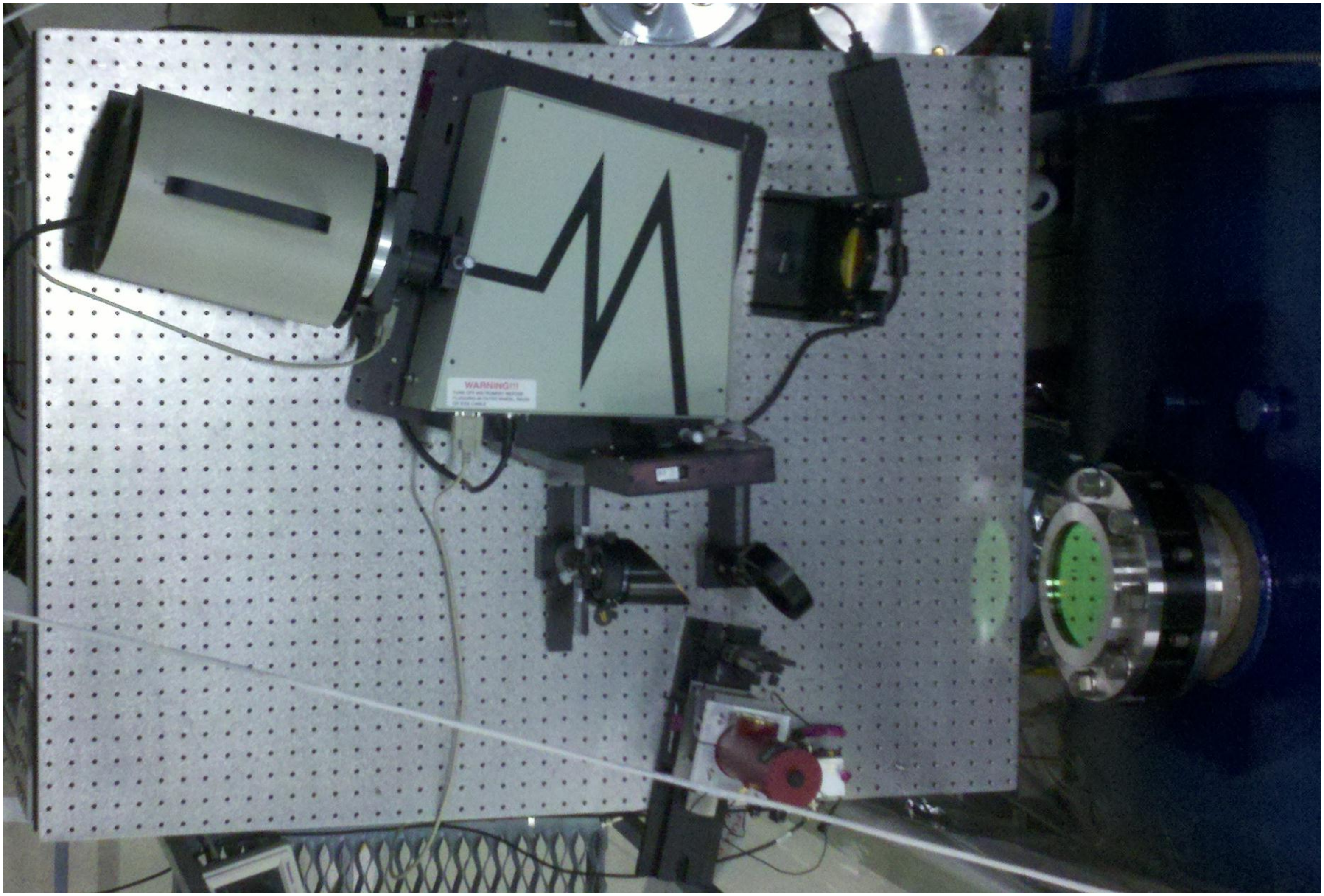


Sun illuminating heliostat

TIRS: In Chamber Calibration GSE



TIRS: Monochromator Set-up Outside Chamber



OLI Spectral Bandpasses

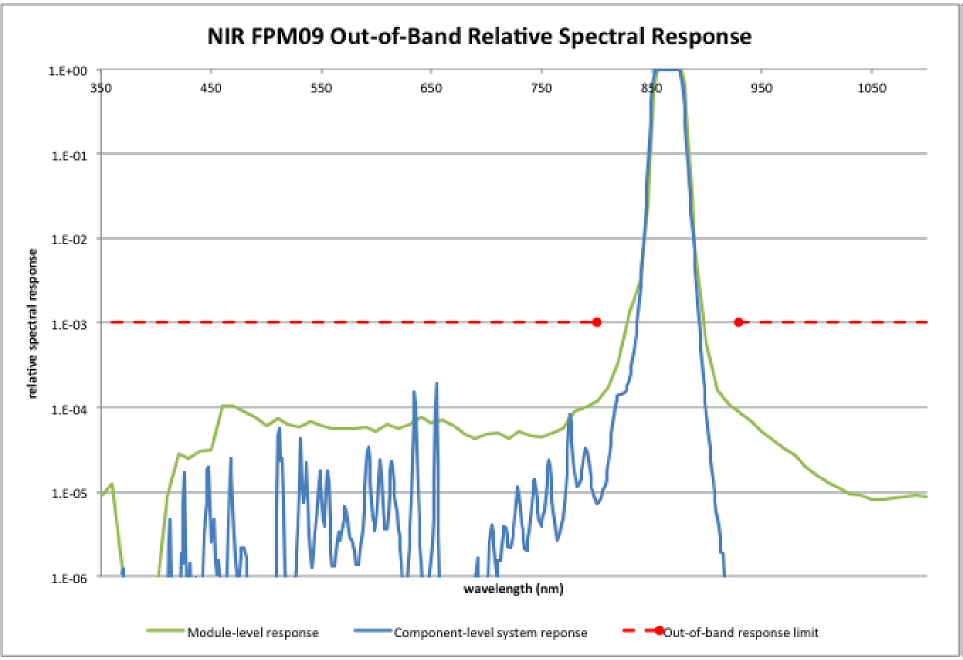
Spectral

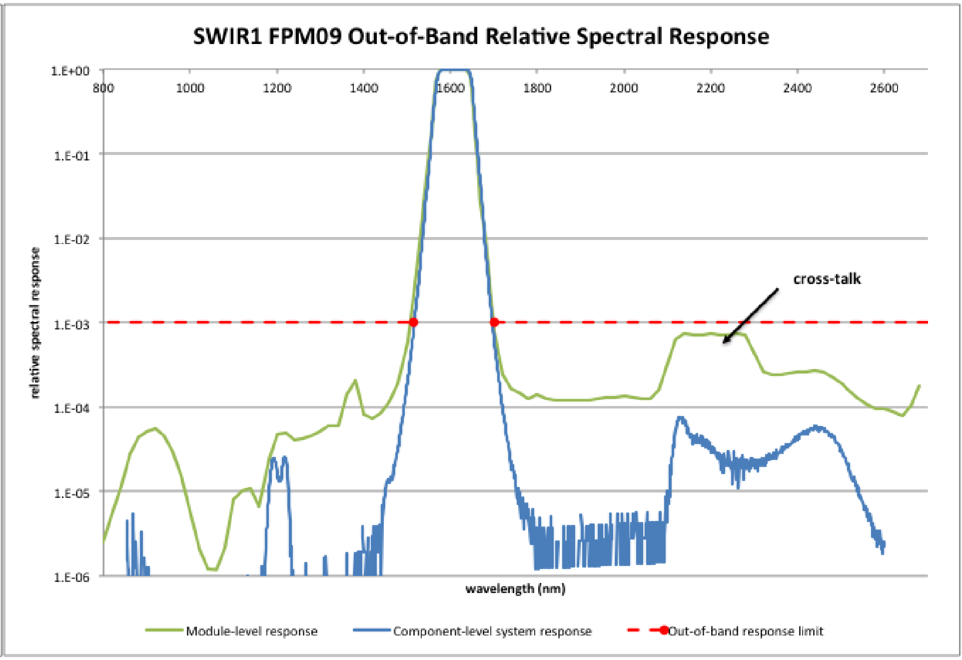
Band (#)	Band	CW (nm)	Bandwidth (nm)
1	Coastal/ Aerosol	442.9	15.9
2	Blue	481.9	60.2
3	Green	561.2	57.2
4	Red	654.5	37.5
5	NIR	864.6	28.1
6	SWIR 1	1608.5	85.1
7	SWIR 2	2200.2	186.9
8	PAN	590.0	172.4
9	Cirrus	1373.4	20.4

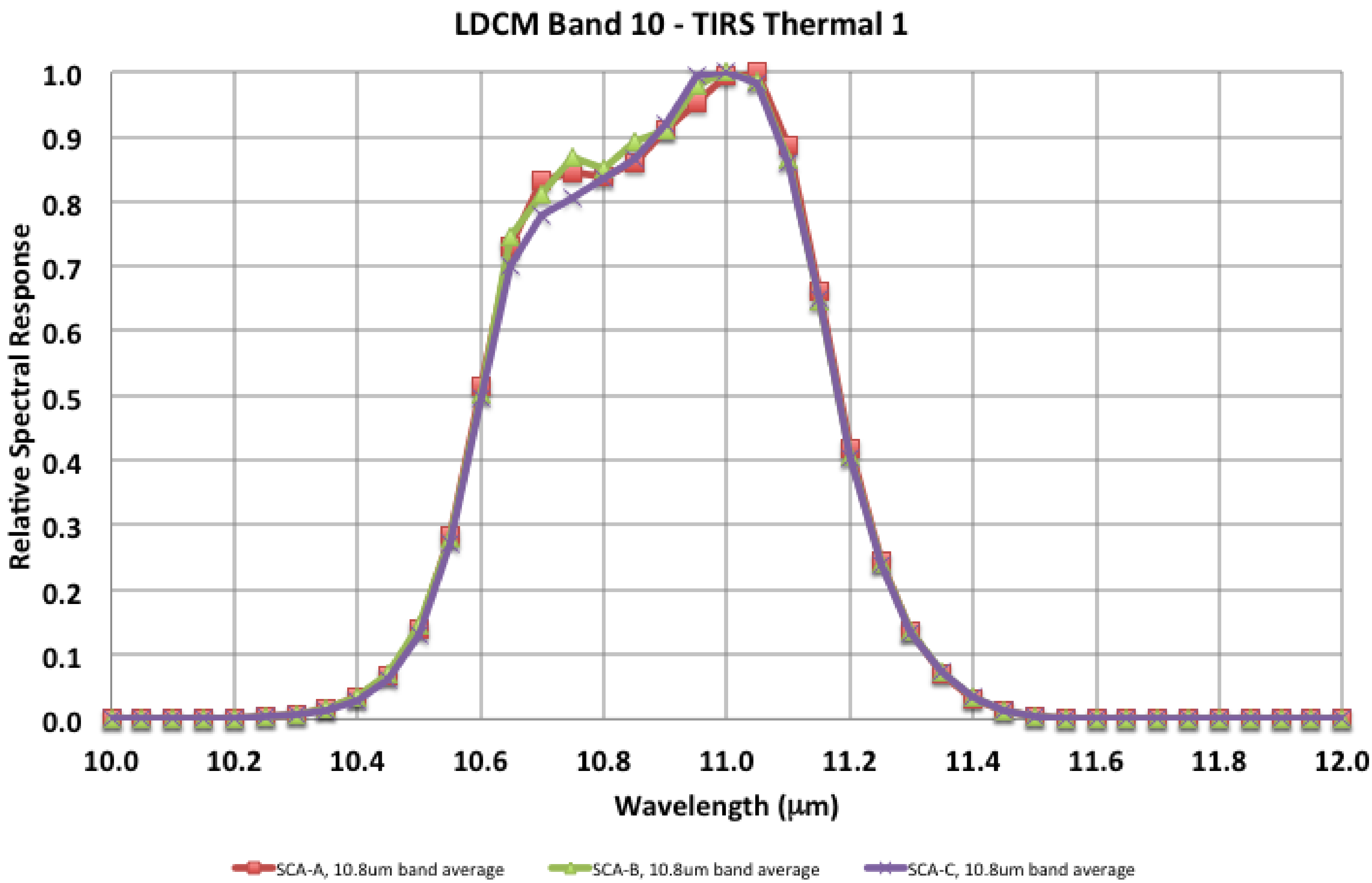
Relative spectral responses available @ landsat.gsfc.nasa.gov

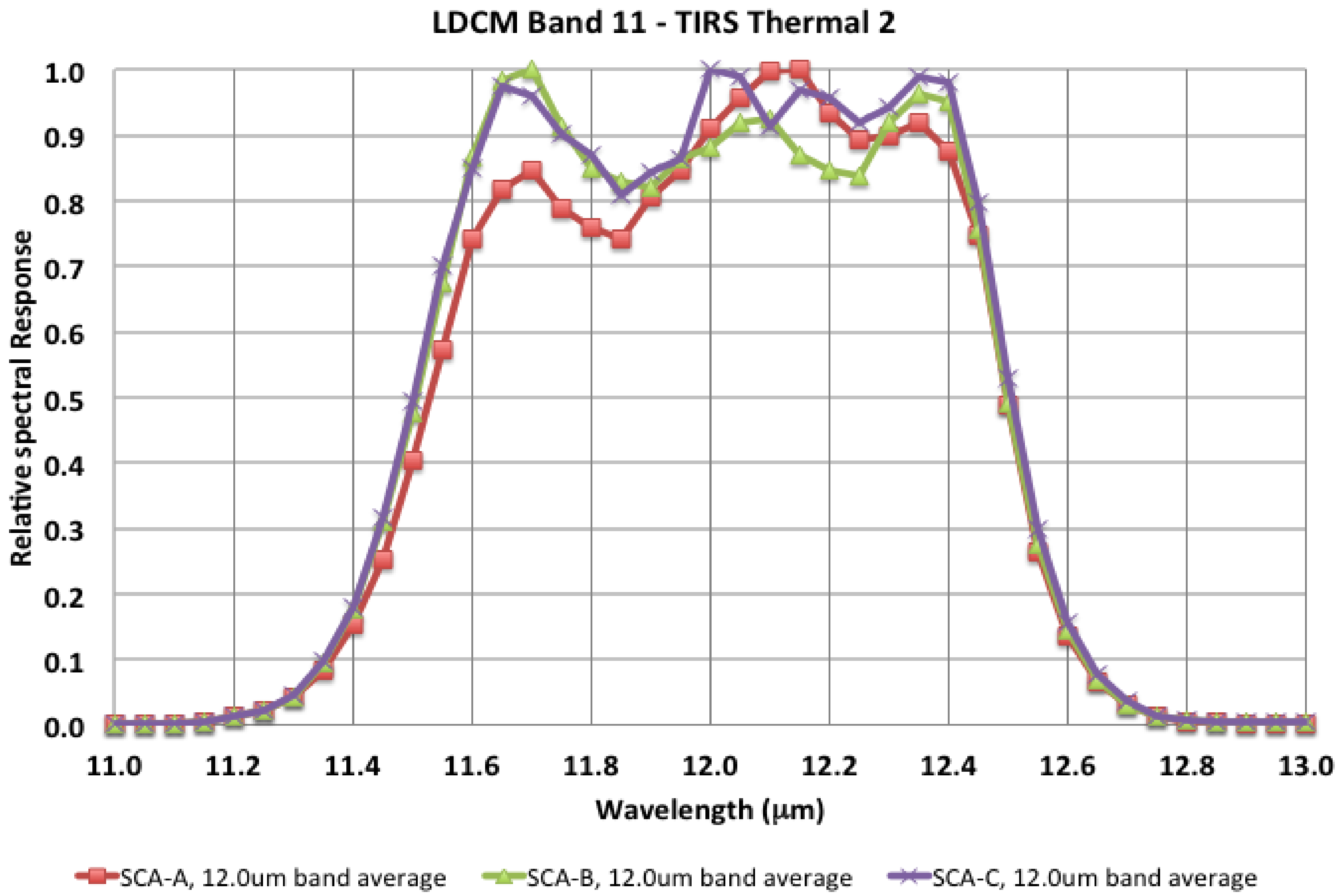
OLI: Spectral Performance – Out-of-band

- **Out-of-band response**
  - Measured at Focal Plane Module (Detectors + filters) level; focal plane fully illuminated; optics contribution (mirrors + window) analytically added
  - Typically 10^{-4} or better (approximate stray light level in test set up)
  - Some SWIR band crosstalk – most likely within detector *material*—within requirements



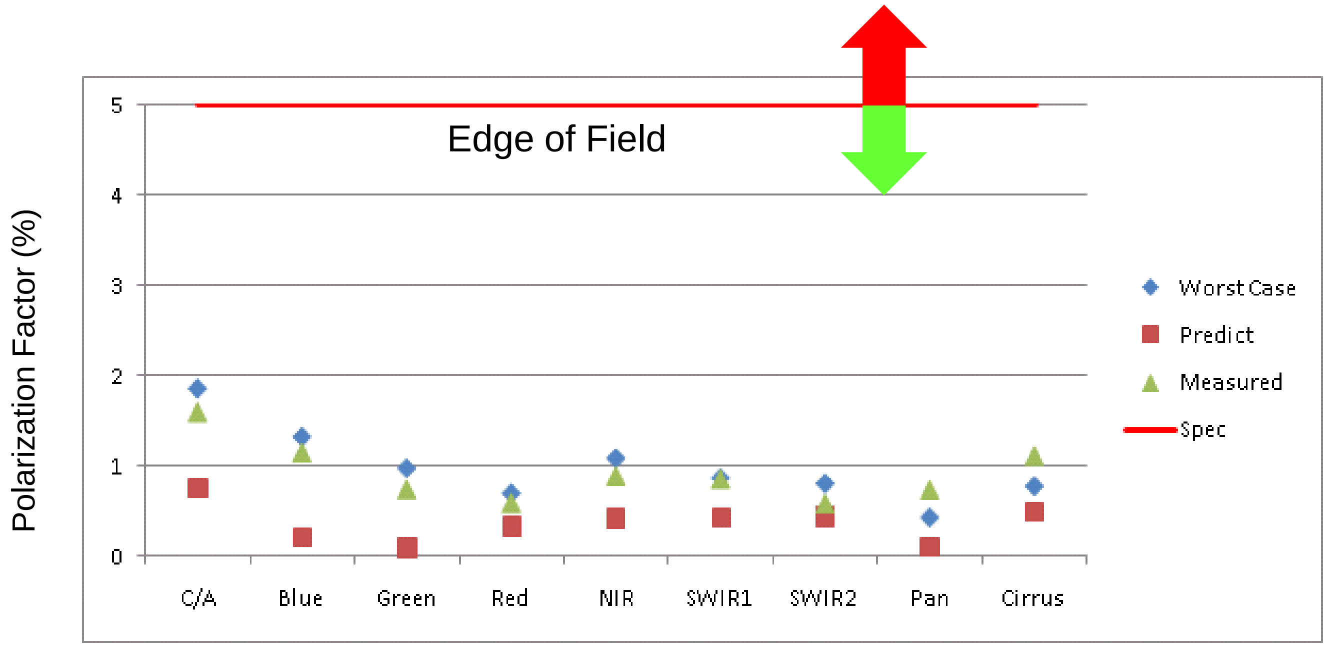



LDCM Band 10 - TIRS Thermal 1
Relative Spectral Response
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10.0
10.2
10.4
10.6
10.8
11.0
11.2
11.4
11.6
11.8
12.0
Wavelength (µm)
SCA-A, 10.8um band average
SCA-B, 10.8um band average
SCA-C, 10.8um band average


LDCM Band 11 - TIRS Thermal 2
Relative spectral Response
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
11.0
11.2
11.4
11.6
11.8
12.0
12.2
12.4
12.6
12.8
13.0
Wavelength (μm)
SCA-A, 12.0um band average
SCA-B, 12.0um band average
SCA-C, 12.0um band average

OLI Polarization Performance

- **Polarization**
  - Polarization Sensitivity well below 2%
  - Will not alter measured signal from highly polarized scenes such as canopies and water



Radiometric Calibrations

- **OLI**
  - Non-linearity
  - Relative Gain
  - **Absolute Gain**
- **OLI Diffuser**
  - BRDF
  - **On-orbit radiance**
- **TIRS**
  - Non-linearity
  - Relative Gain
  - **Absolute Gain**
- **TIRS OBC**
  - **On-orbit radiance**

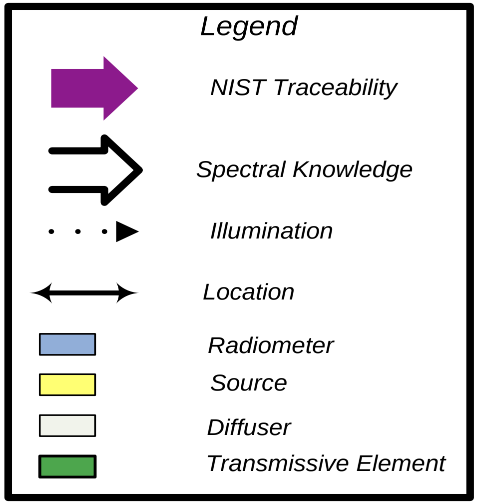
Linearity Challenges

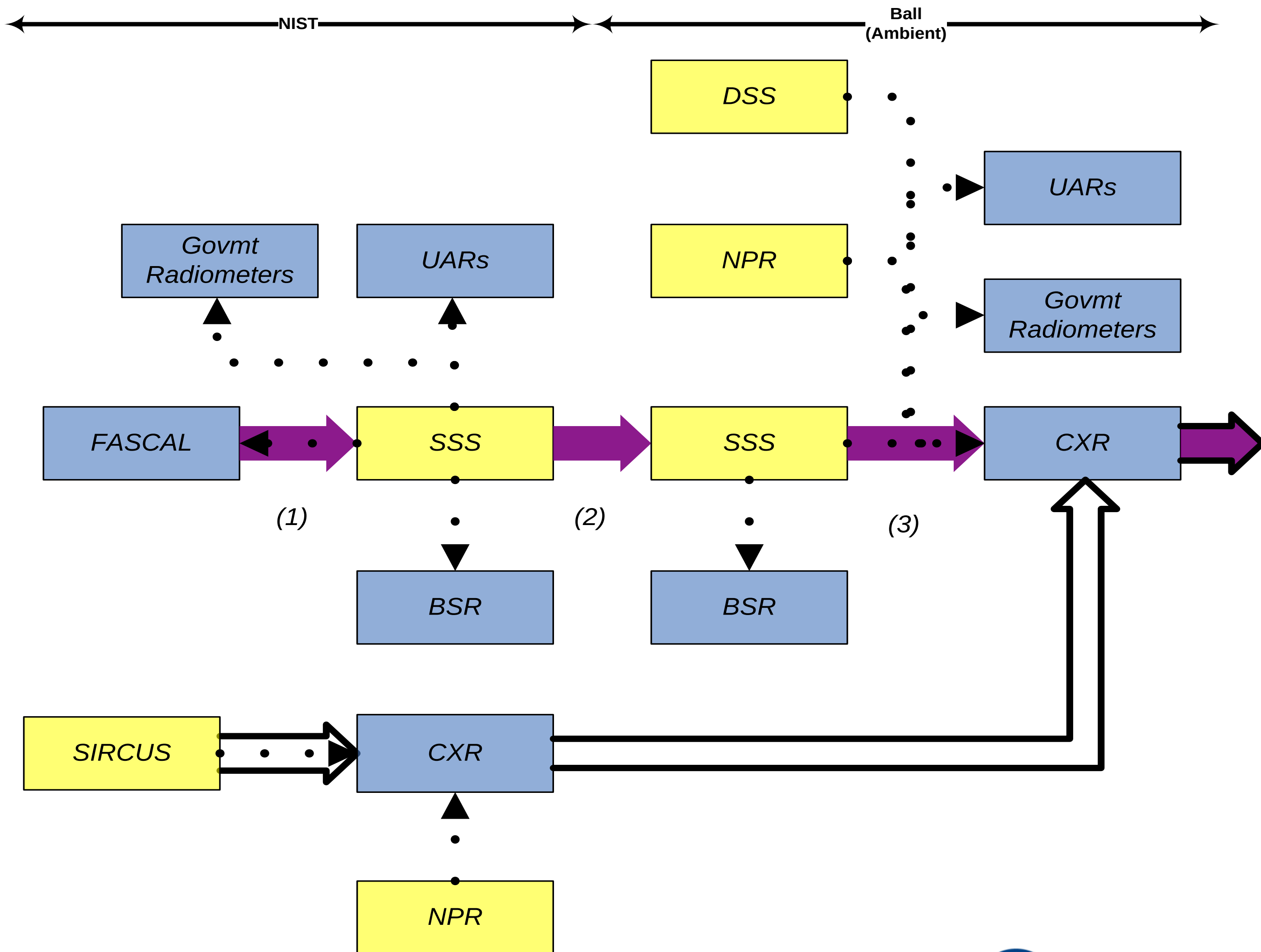
- **Multiple sources of non-linearities**
  - Electronics
    - ROIC
    - A/D
  - Detectors
- **Electronics non-linearities can be characterized by varying the integration time of the electronics when viewing a constant source (with some assumptions)**
  - Both instruments have capability to do this on orbit
- **Detector non-linearities need to be characterized by varying the input radiance in a very well controlled manner (often challenging).**
  - TIRS can do this on-orbit by varying OBC temp
  - OLI can not do this using on-board sources; main concern is in the SWIR

Relative Gain Challenges

- **No Perfectly uniform source to characterize all detectors simultaneously**
- **SDL measurements on flood source did not detect angular or spatial non-uniformity**
  - TIRS calibrations treat flood source as uniform
- **Non-uniformities inherent in most integrating sphere designs**
  - OLI always used lamps in sets of 3 spaced equally apart
  - Each individual FPM was centered on source aperture for cal (i.e., 14 separate collects per sphere level)

OLI Absolute Cal: NIST Radiance Traceability Flow (Part 1) NIST to Ball





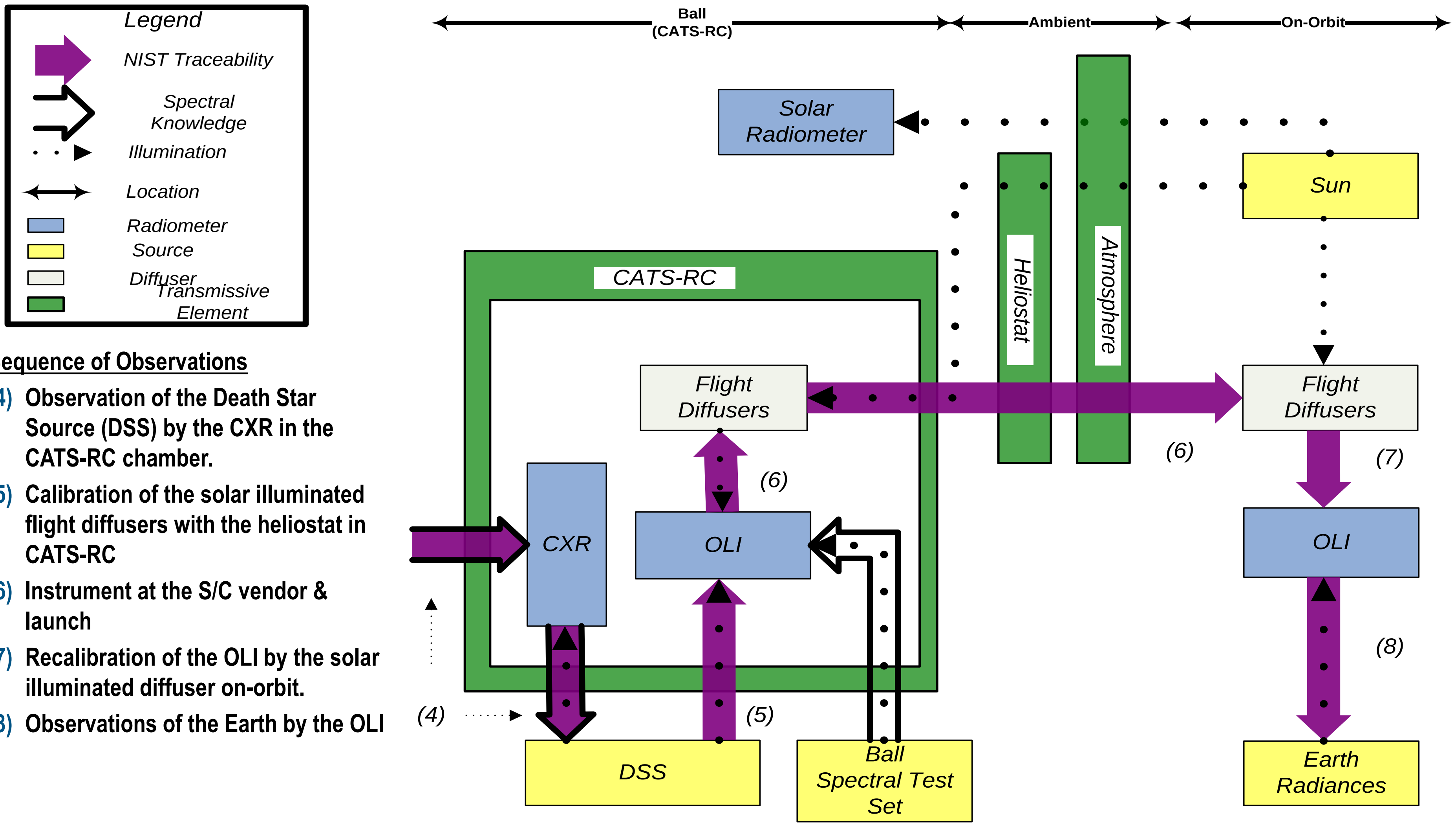
Sequence of Observations

(1) Calibration of the Small Sphere Source (SSS) by FASCAL at NIST

(2) Transport of the SSS from NIST to Ball w/observations by U of A radiometers and Ball Standard Radiometer (BSR)

(3) Observation of the Calibration Transfer Radiometer (CXR) by the SSS at Ball

OLI Absolute Cal: NIST Radiance Traceability Flow (Part 2) –Ball to On-Orbit

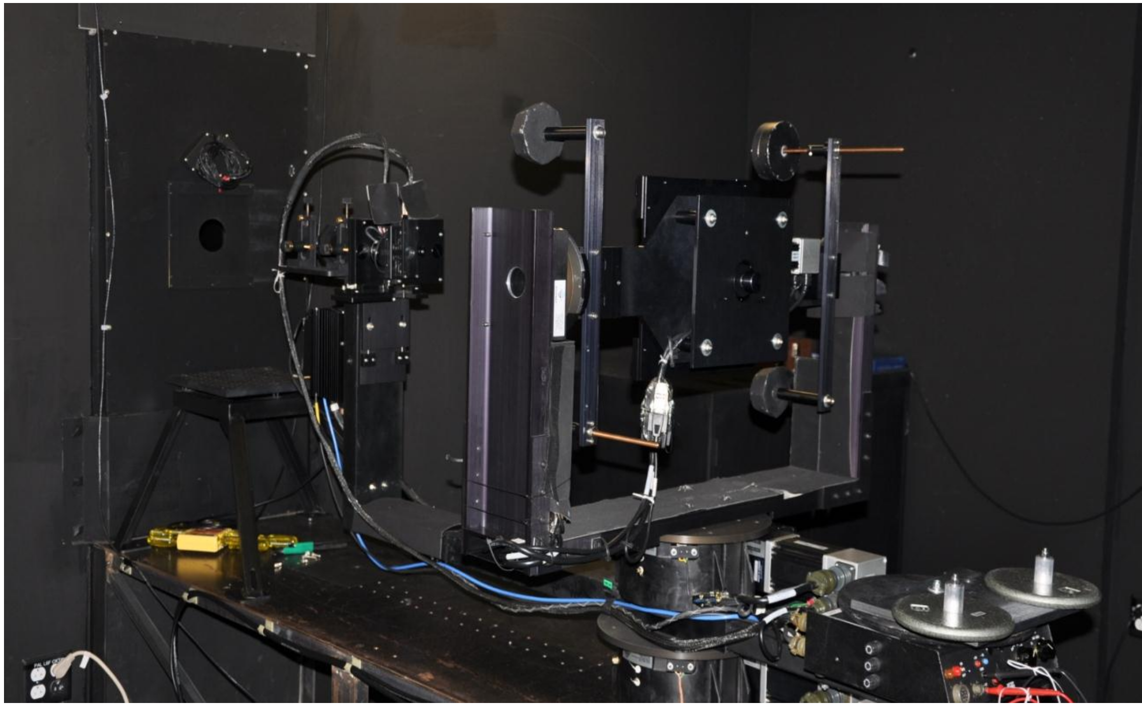


Sequence of Observations

- (4) Observation of the Death Star Source (DSS) by the CXR in the CATS-RC chamber.
- (5) Calibration of the solar illuminated flight diffusers with the heliostat in CATS-RC
- (6) Instrument at the S/C vendor & launch
- (7) Recalibration of the OLI by the solar illuminated diffuser on-orbit.
- (8) Observations of the Earth by the OLI

BRDF Traceability

- Our reference was a diffuse panel characterized by NIST over all OLI wavelengths.
- OLI is the first flight program to utilize the STARR SWIR capabilities
- The flight panel BRDF's were extensively characterized using the U of A BRDF facility as a transfer reflectometer.



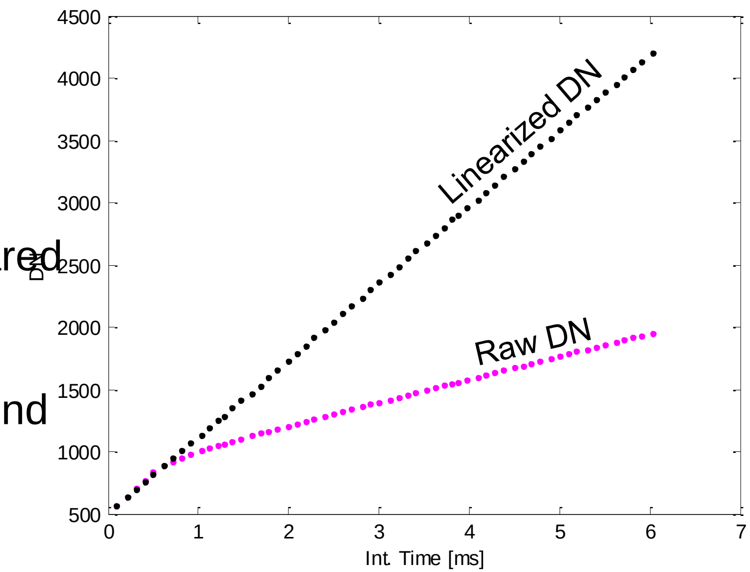
NIST Traceable Calibration of TIRS

1. Linearize background collect (SPACE view)

2. Linearize source collect (Flood source view)
(Flood source calibrated by SDL with radiometer compared To NIST radiometer).

3. Pixel signal = linearized source – linearized background

4. Calculate pixel radiance:

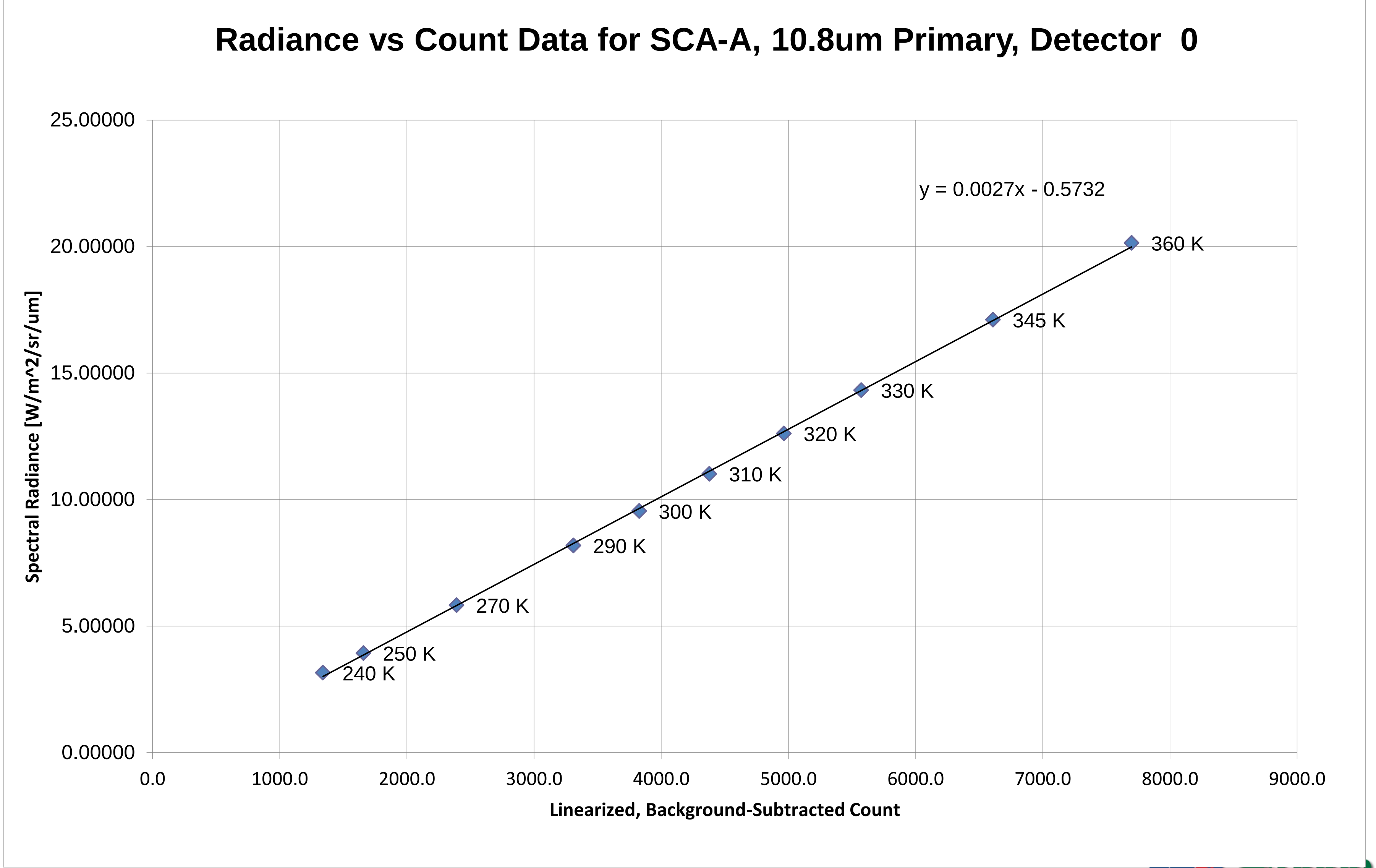


$$\text{Pixel radiance} = \frac{\sum \text{[Planck function at BB Temperature]* [lens * filter * QWIP response]}}{\sum \text{[lens * filter * QWIP response]}}$$

5. Graph Pixel Radiance vs. Pixel Signal data for all source temperatures

6. Fit linear function through required source temperature range (240 K – 360 K)

Radiometric Calibration acquired using flood source



Fractional Difference Using Linear Fit

RMS(Predicted Radiance - Actual Radiance) / Actual Radiance

Source Temp. [K]	10.8 um	12.0 um
240	-0.045	-0.029
250	-0.018	-0.009
270	-0.001	-0.001
290	0.011	0.008
300	0.012	0.007
320	0.010	0.008
330	0.007	0.007
345	0.000	-0.002
360	-0.001	-0.002

- Requirement for 4% accuracy for temperatures of 240 K – 260 K and from 330 K – 360 K
- Requirement for 2% accuracy for temperatures of 260 K – 330 K
- Table indicates NIST traceable calibration of flood source will generally provide required accuracy
- Fitting used global linearization function. Plan to use piece-wise linearization to improve.

OBC Calibration

- **Using "gains and relative gains" obtained using sphere or flood calibration source, OBC is viewed with instrument and the calibration transferred (a.k.a., non-uniformity mapped)**
- **For OLI, the OBC (diffuser) was illuminated by a heliostat**
  - Diffuser non-uniformity calculated and stored in CPF
  - Radiance of diffuser was corrected for heliostat, and atmospheric transmission and adjusted for Earth-Sun Distance to provide TOA radiance, once on orbit (check of calibration transfer to orbit)
  - Diffuser non-uniformity was scaled by diffuser BRDF measurements made at University of Arizona to provide absolute reflectance calibration
- **For TIRS, the OBC was operated at a range of temperatures and a LUT calculated to translate the OBC telemetered temperature to radiance for each detector (absolute and relative cal)**

Commissioning Phase Analysis Plans

- Process and Analyze X-Band Test Data
- Assess first TIRS Science Data
- Assess First OLI Science Data
- Process First TIRS Earth Image Acquisition
- Process First OLI Earth Image Acquisition
- OLI Transfer to Orbit Analysis/Initial Gain Update
- OLI Initial CPF Radiometric Update
- TIRS Initial CPF Radiometric Update
- TIRS Calibration Stability Analysis
- OLI Calibration Stability Analysis
- OLI Relative Gain Evaluation
- TIRS Relative Gain Evaluation
- Lunar Data ProcessingTask

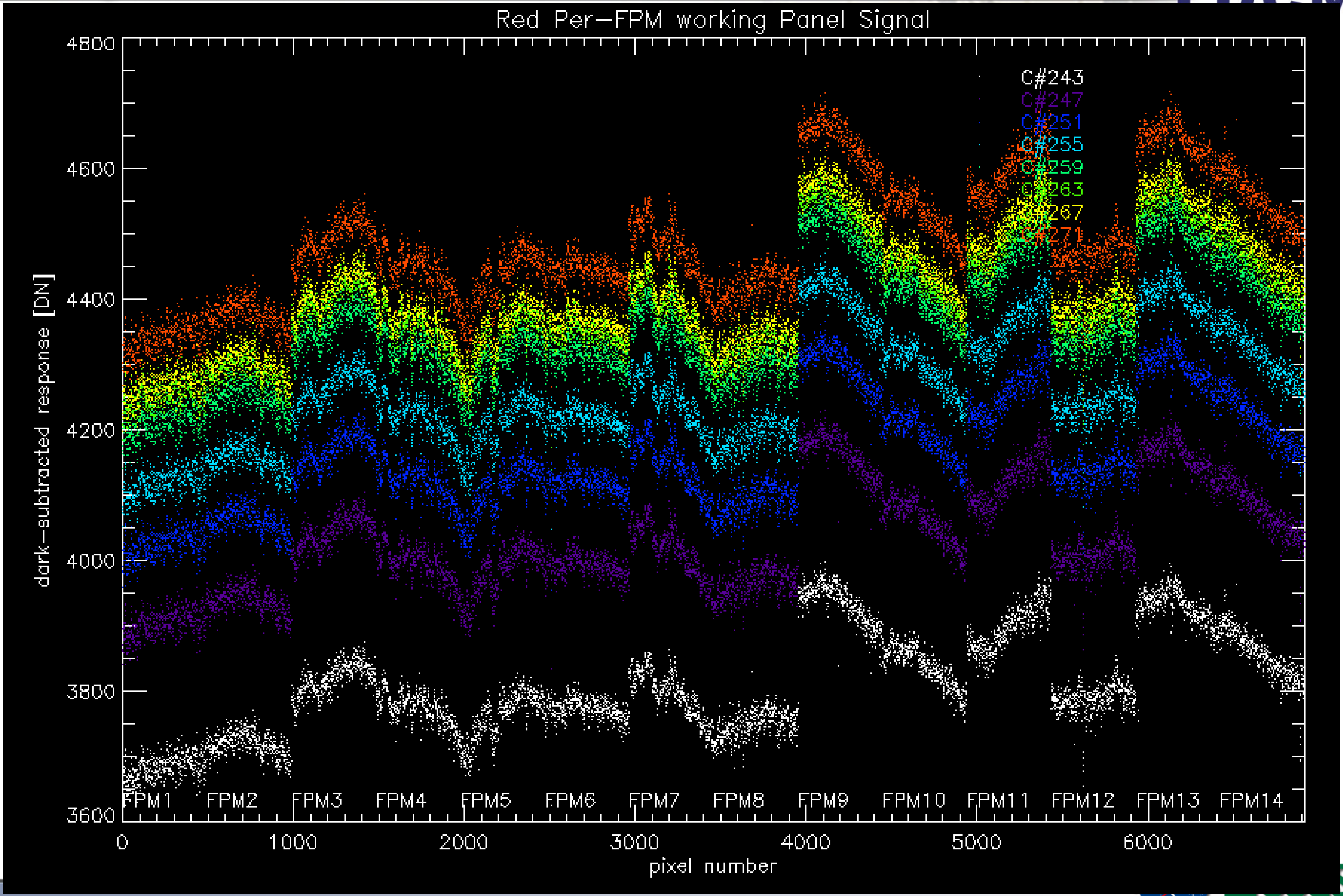
Commissioning Phase Analysis Plans (2)

- Pre-WRS On-Orbit CPF Update
- Landsat-7 ETM+ Cross Calibration with OLI
- Landsat-7 ETM+ Cross Calibration with TIRS
- OLI Absolute Calibration Validation
- TIRS Absolute Calibration Validation
- Run-For-Record CPF Update (on-WRS)
- Run-for-Record Radiometric Performance Characterization
- OLI On-Orbit Requirements Verification
- TIRS On-Orbit Requirements Verification
- Establish OLI Key Performance Requirement (KPR) Baseline
- Radiometric Commissioning Report

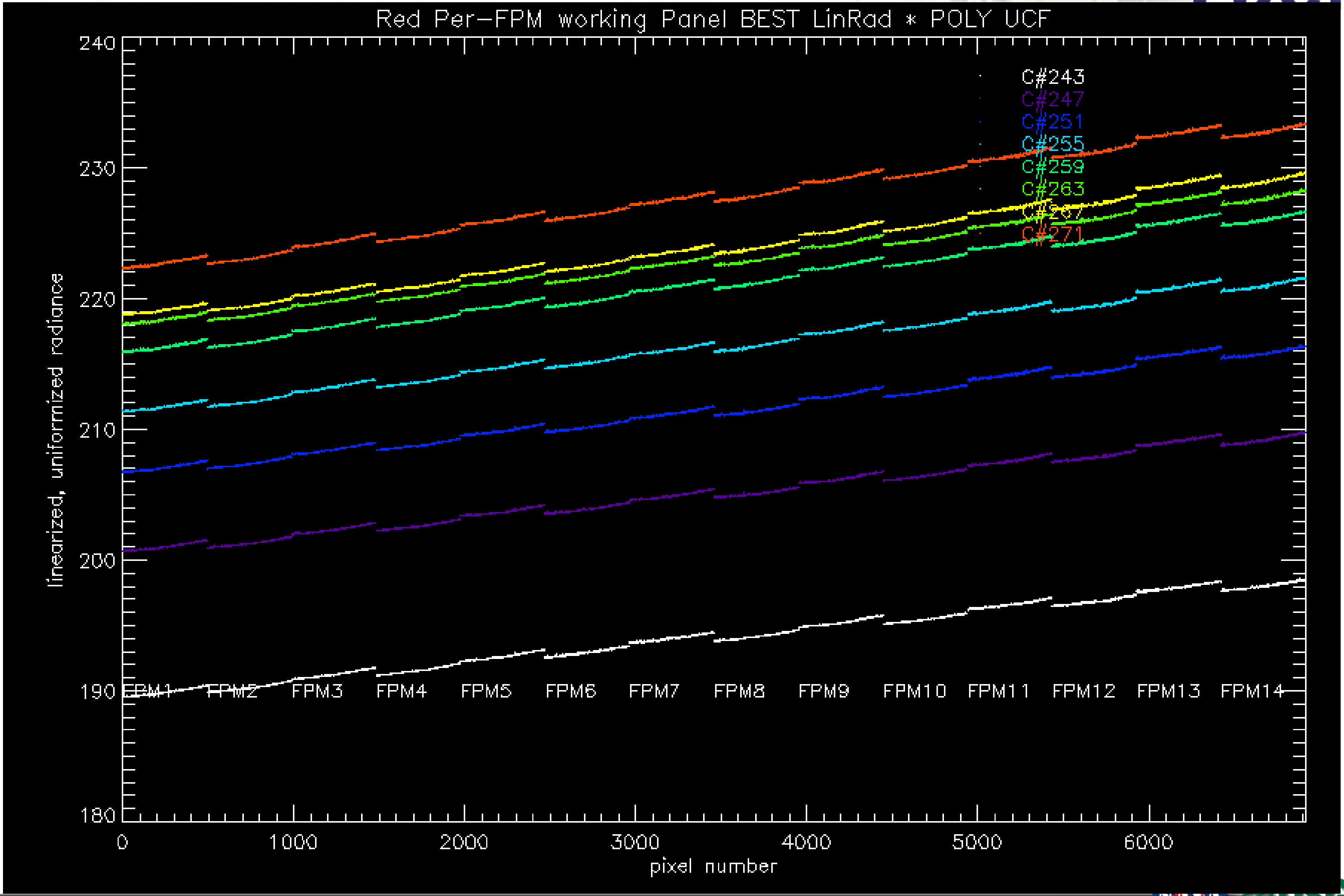
On-Orbit Radiometric Characterization and Calibration Plans (OLI)

- **Characterizations and Calibrations**
  - Detector-to-Detector relative calibration (use solar diffuser, overlap statistics, side slither, scene statistic characterizations)
  - Absolute calibration (solar diffuser, vicarious calibrations)
  - Response Non-linearity calibration (use integration time sweeps)
  - Bias determination (use shutter data)
- **Other Characterizations**
  - SNR – use solar diffuser, lamp and shutter data
  - Uniformity - use solar diffuser
  - Stability – use lamps, solar diffuser, moon, PICS
  - Operability – based on noise, dynamic range, stability
  - Coherent Noise
  - Impulse Noise
  - Ghosting (use Moon)

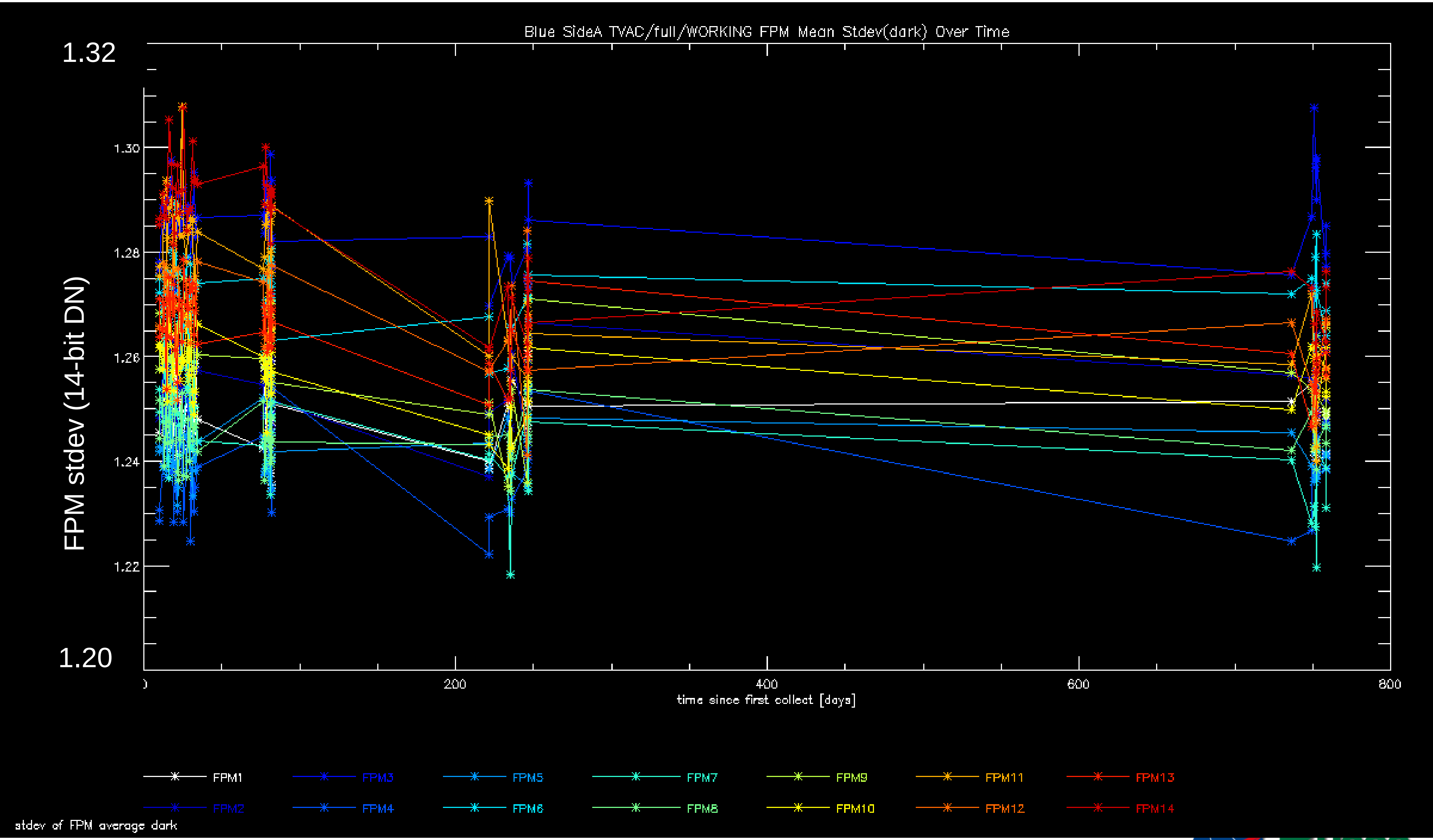
OLI Observations of Working Diffuser using Heliostat



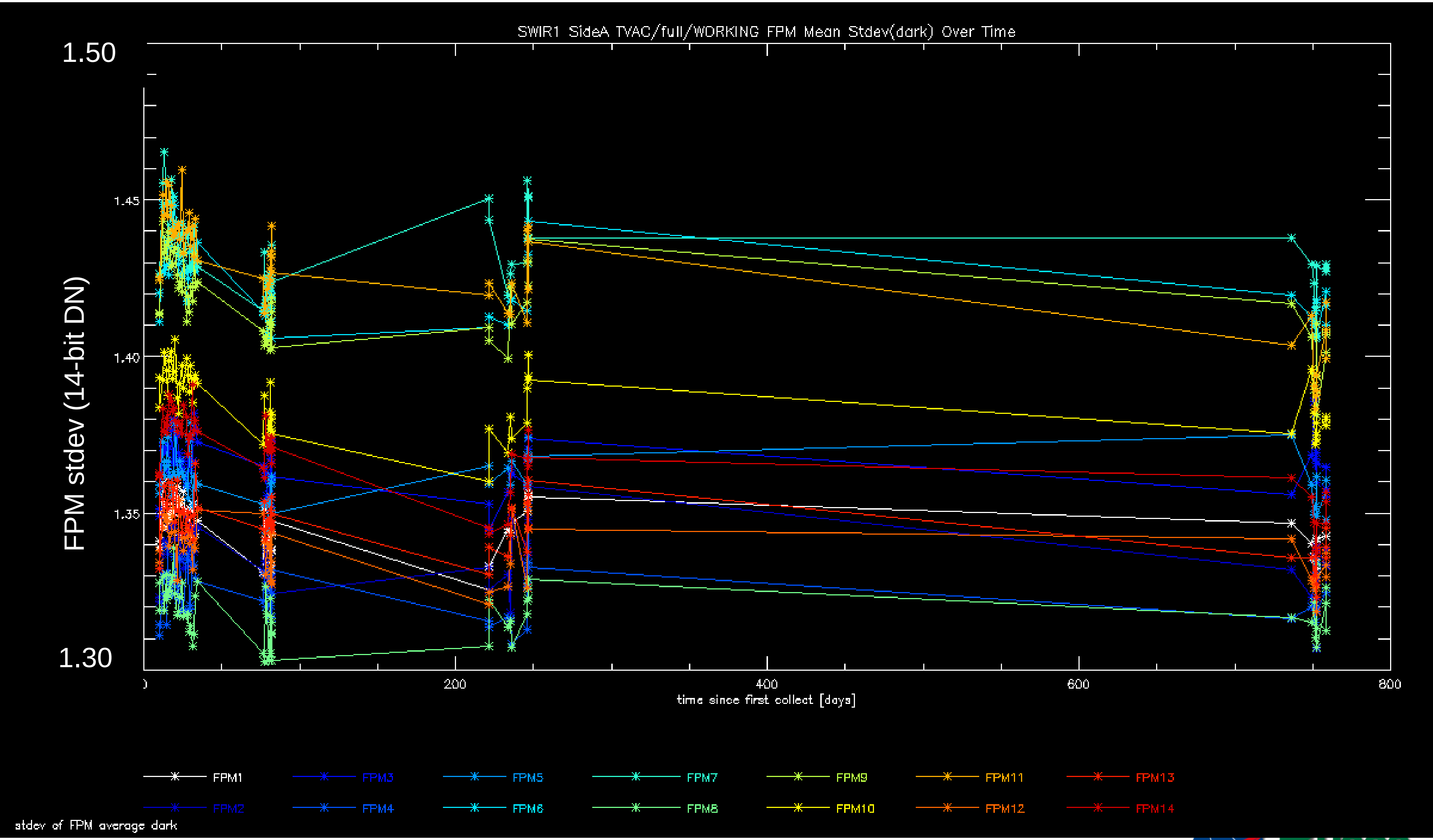
OLI Diffuser Radiances



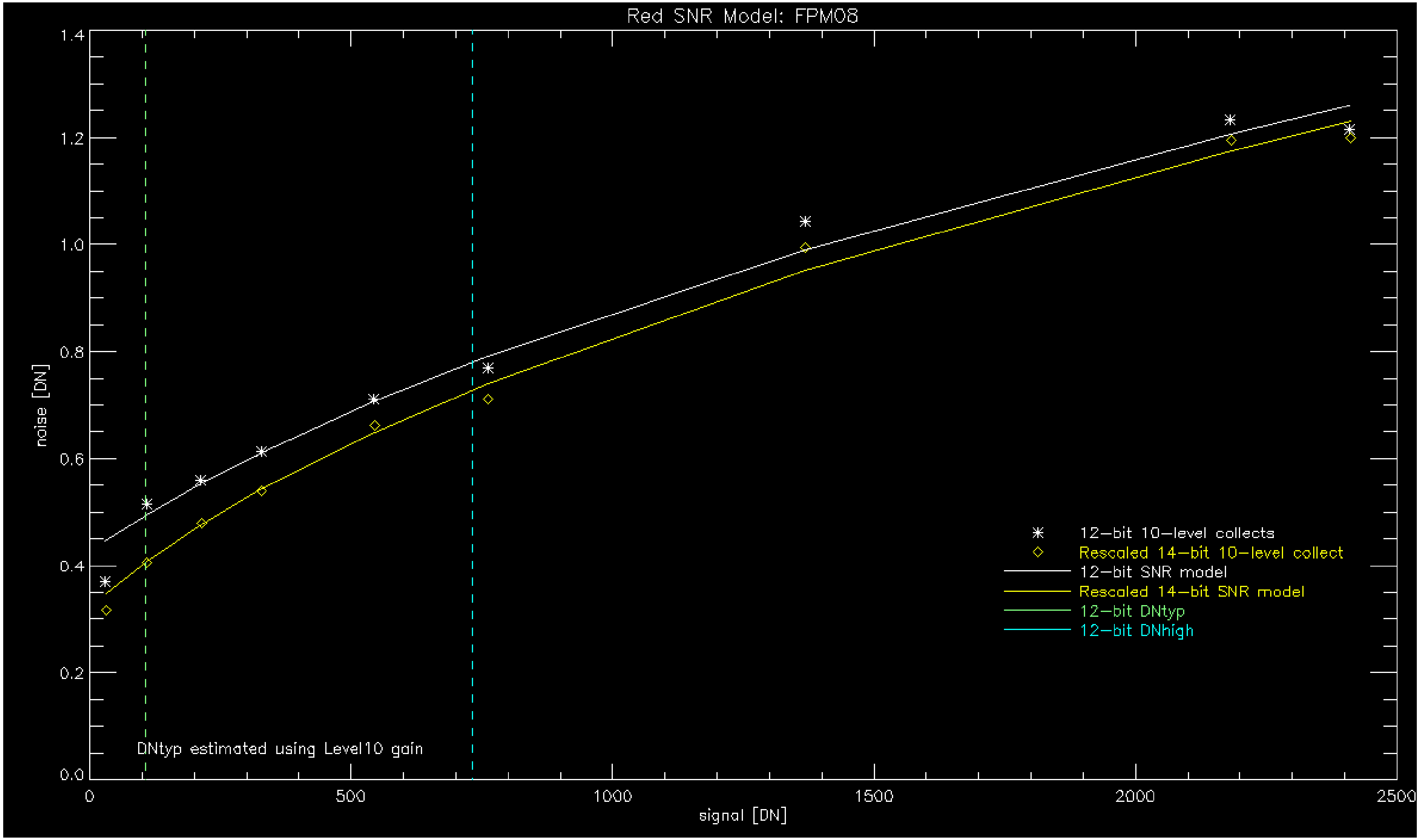
Dark Noise Over Time Blue band



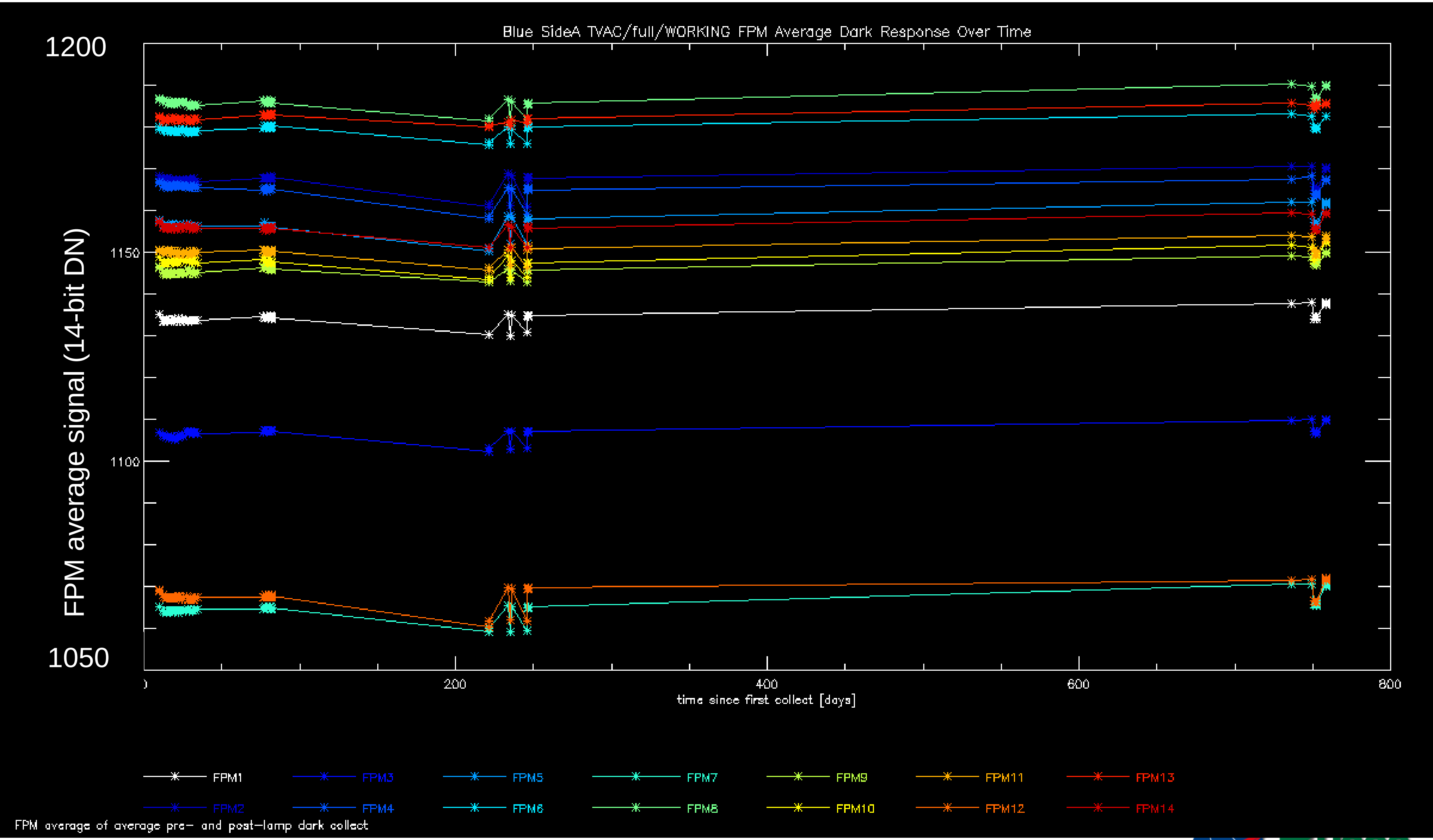
Dark Noise Over Time SWIR1 band



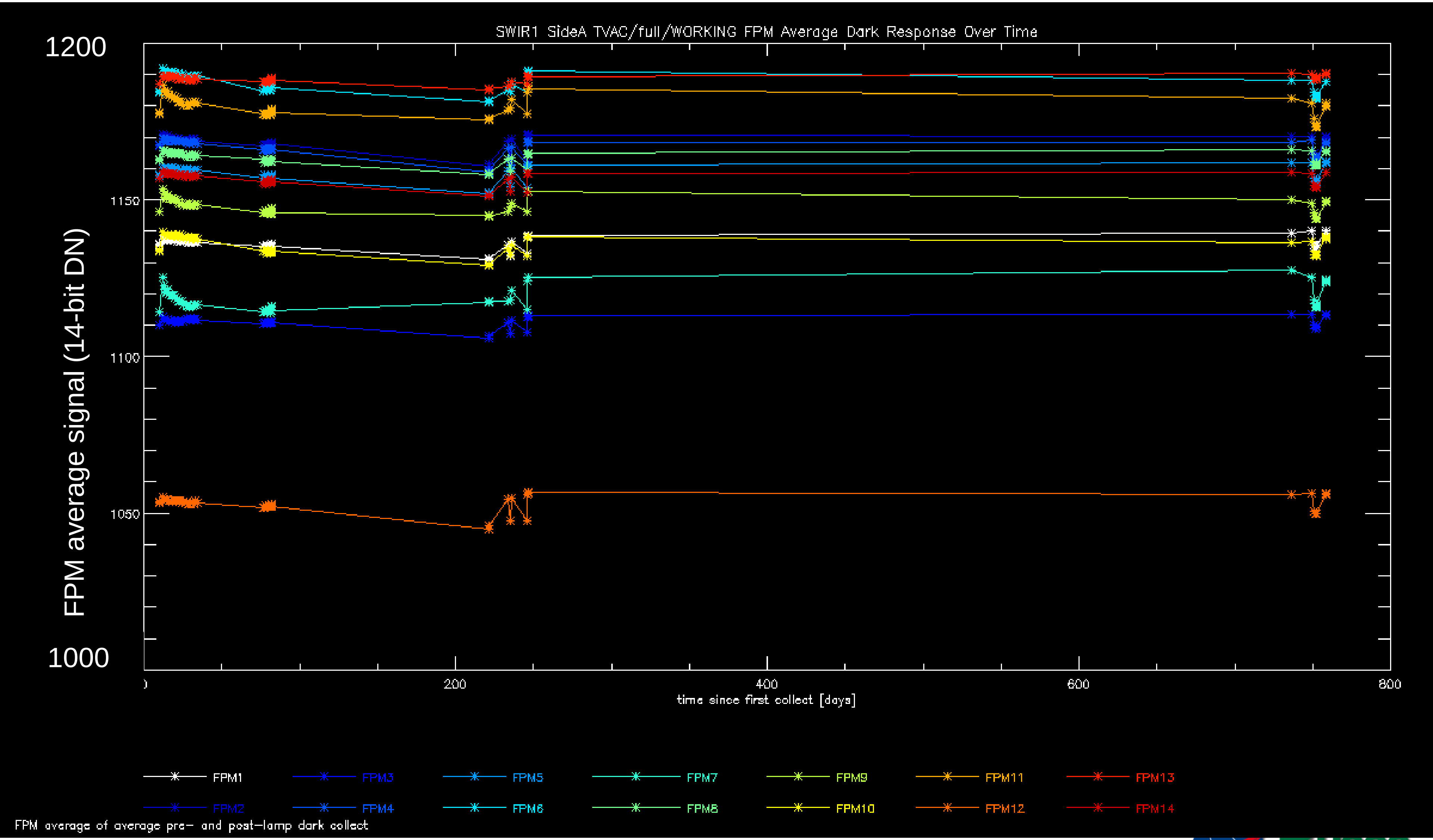
OLI SNR Measurement



Dark Signal Over Time Blue band



Dark Signal Over Time SWIR1 band



On-Orbit Radiometric Characterization and Calibration Plans (TIRS)

- **Characterizations and Calibrations**
  - Detector-to-Detector relative calibration (use black body and deep space)
  - Absolute calibration (use blackbody, deep space, vicarious calibrations)
  - Response Non-linearity (vary black body temperature; integration time sweeps)
- **Other Characterizations**
  - Noise using black body (at varying temperatures, deep space)
  - Stability (use black body, deep space)
  - Operability
  - Uniformity (use blackbody)
  - Coherent noise
  - Impulse noise
  - Ghosting

Summary

- OLI and TIRS are new instruments
- CVT has extensive experience with previous whiskbroom Landsat Instrument as well as similar whiskbroom EO-1 ALI instrument
- Having many detectors provides opportunities and challenges
- We are looking forward to science data in less than a month