Pre-launch Radiometric Characterization of the Operational Land Imager 2 (OLI-2)

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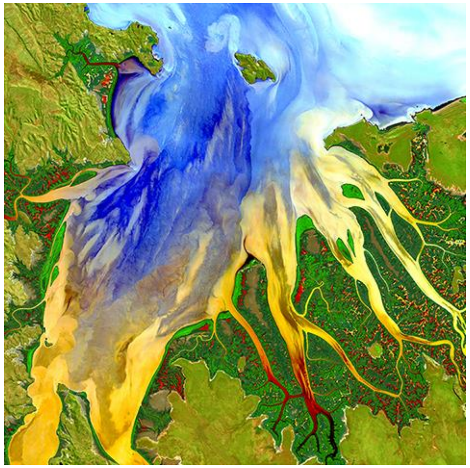
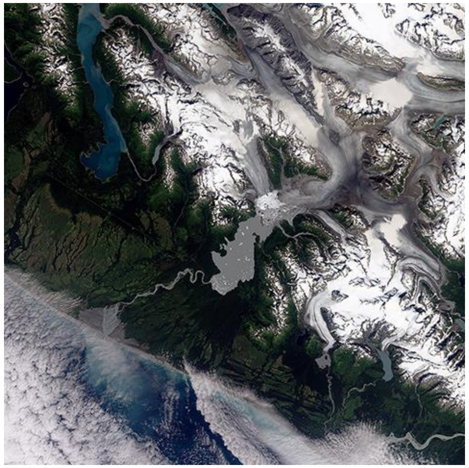
Ball Aerospace & Technologies Corp.





Imagery Credit: **USGS/NASA Landsat**

CALCON 2019

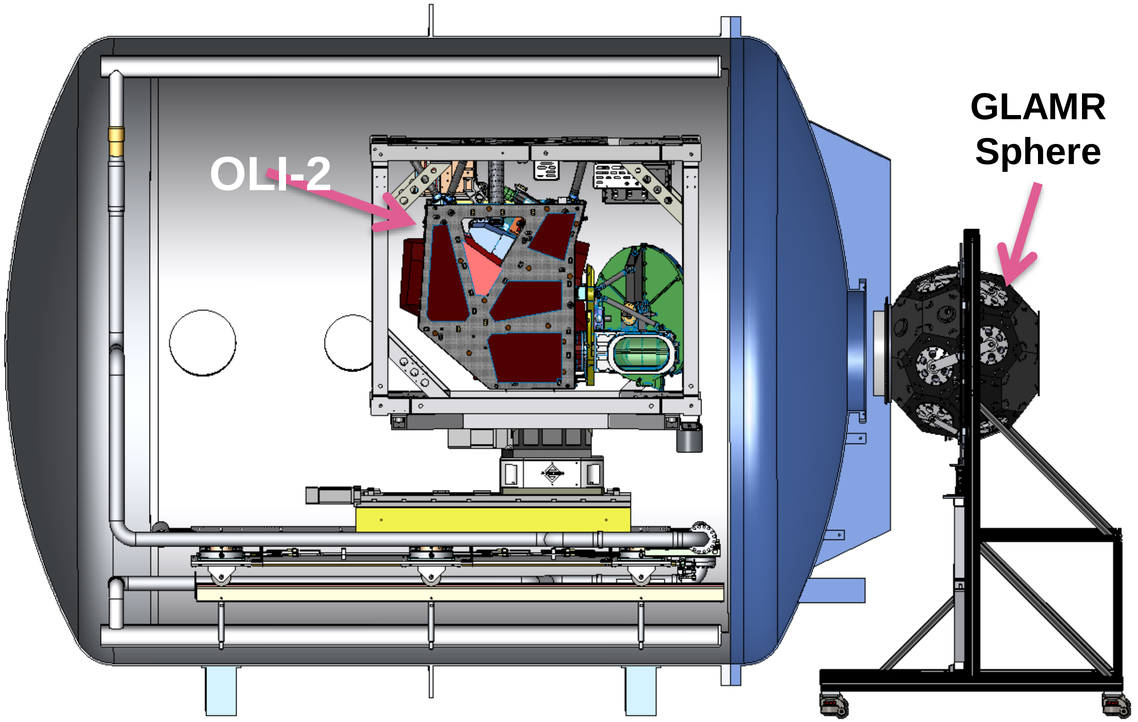
www.calcon.sdl.usu.edu

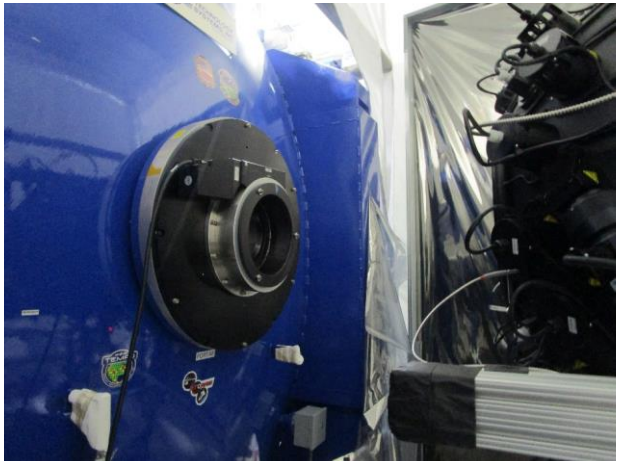
Overview

- **Facilities**
- **Noise Characterization**
- **Non-Uniformity Characterization**
  - **Of the calibration source**
  - **Of spectral non-uniformities using GLAMR data**
- **Non-Linearity**
  - **Using varying integration times**
- **Stability**

Radiometric, Spectral, and Polarization Characterization done together

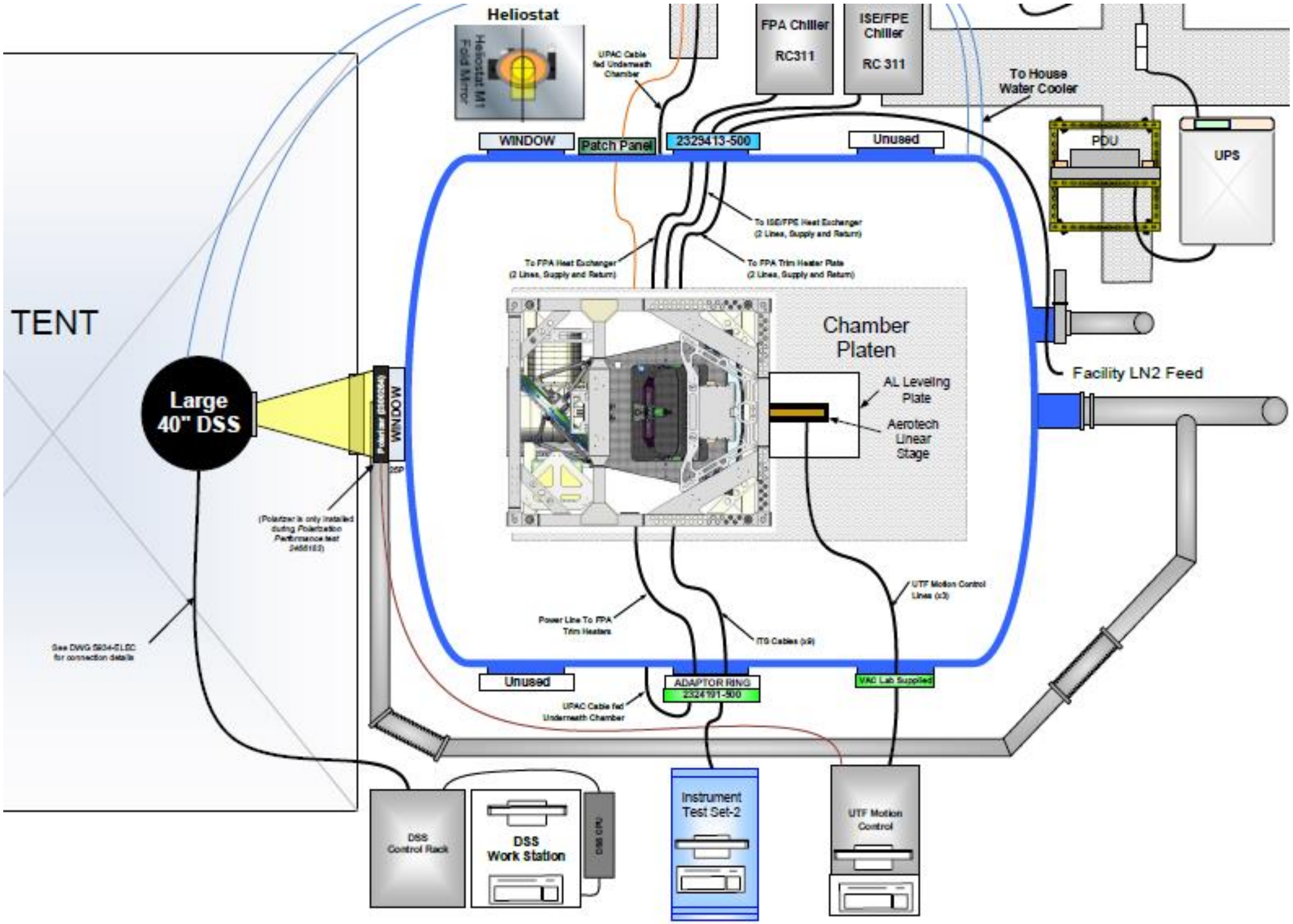
- **The Calibration Test Station (CATS) put the instrument inside a vacuum chamber with sources outside the window**
  - **Large integrating sphere (radiometric characterization/calibration)**
  - **Integrating Sphere with large sheet polarizer (polarization)**
  - **NASA provided GLAMR source (tunable lasers pumping a sphere)**





Rotating Polarizer in front of window

CATS Enables Use of Multiple Sources



CATS is well suited for characterization of OLI-2

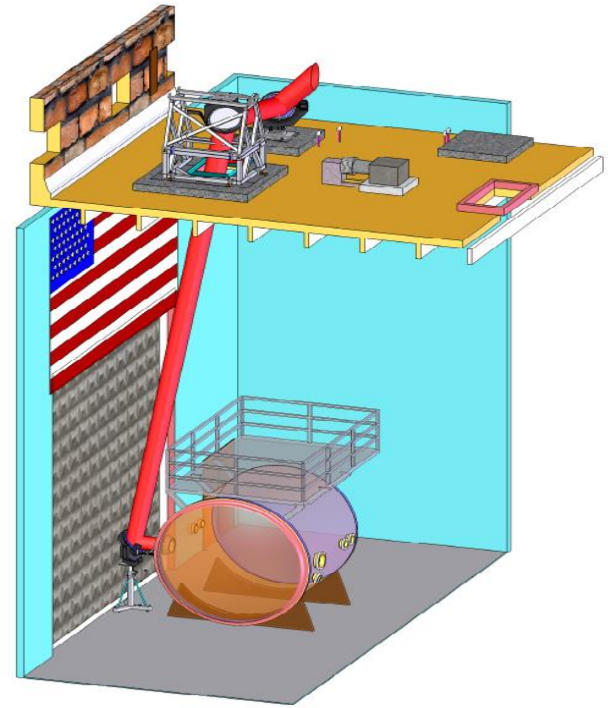
- This test setup allowed for efficient radiometric characterization in 3 domains:
  - Radiometric, Spectral and Polarization
- The design of CATS addressed several challenges:
  - OLI-2 15° cross track field of view
  - Tight spatial uniformity requirements
  - Solar illumination of the diffusers by the heliostat, inside the chamber
  - Practical sizes of the:
    - DSS
    - Heliostat beam size
- The test set was designed to cover the field of view in segments by rotating about the OLI-2 entrance pupil.
- The forward location of the OLI-2 entrance pupil had several benefits for test and allowed:
  - Rotation of OLI-2 inside the chamber to illuminate any desired portion of the field of view, without bumping into the chamber walls.

Death Star Source (DSS)

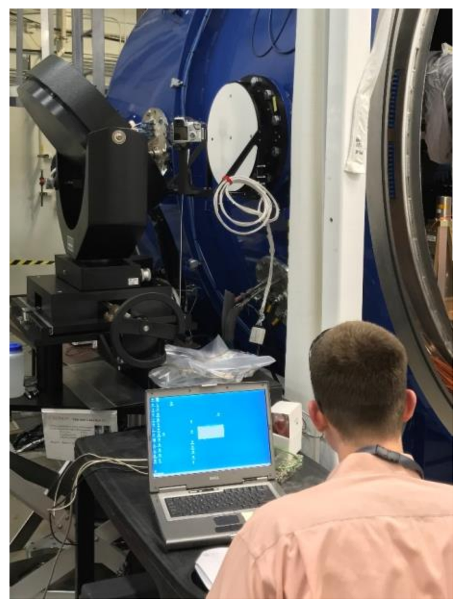
- **The DSS is a 40 in. BaSO4 integrating sphere with 14 in. aperture.**
  - **The DSS covers the dynamic range of all OLI-2 bands.**
- **Two internal diodes (one Si, one Ex-InGaAs) view the sphere wall.**
  - **Each diode can be filtered to have a spectral response corresponding to an OLI spectral band.**
  - **Each diode/filter combination is roughly calibrated by the sphere software.**
  - **One diode actively controls the sphere output while the other passively monitors it.**
  - **The current from one diode is used to control a variable attenuator on a set of low power bulbs.**
- **To select an output radiance the operator requests a band and radiance and the sphere controls bulb combinations and aperture position.**
  - **Knowledge of the DSS output radiance is based on the diode set-points, not the combination of bulbs used.**
- **OLI-2 viewed 2x more radiance levels than OLI and each radiance level was controlled in band.**
  - **This greatly increases (180 vs 49) the number of levels required**
- **Extensive pre-CATS characterization allowed efficient testing.**

Heliostat Brings Sunlight into the same Thermal Vacuum Chamber

- **The Heliostat is a Three Mirror Relay**
  - **First Mirror is on a rotation stage programmed to track the sun**
  - **Second Mirror angles the beam through the roof**
  - **Third Mirror directs the beam into the Ball 10 chamber**
  - **Second and Third Mirrors are aligned so that the beam is perpendicular to the chamber window**



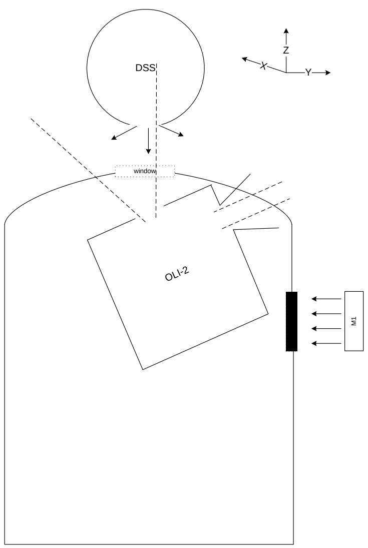
Tracking Mirror on roof



Third mirror outside of chamber and closed chamber port

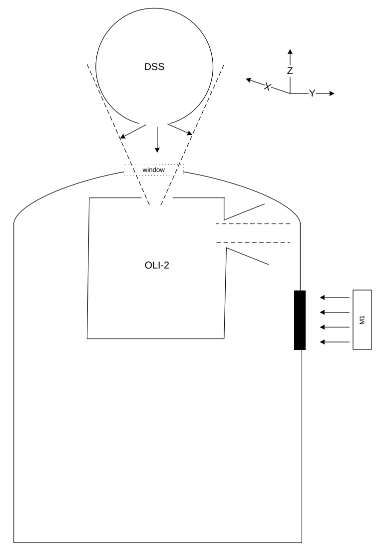
Stages Allow Calibration of the Entire FOV With In the Ball-10 Spatial Constraints

Top View



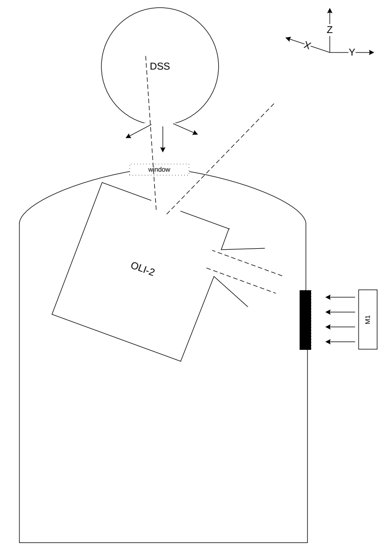
Look Left

Top View



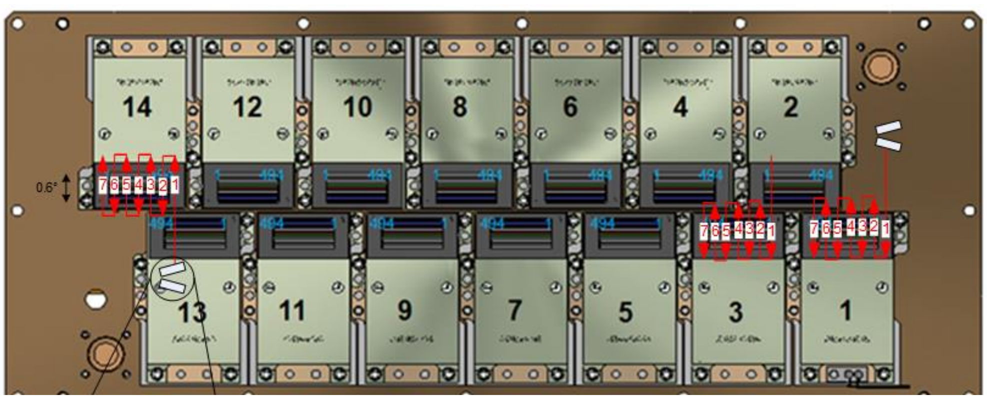
Look Straight

Top View



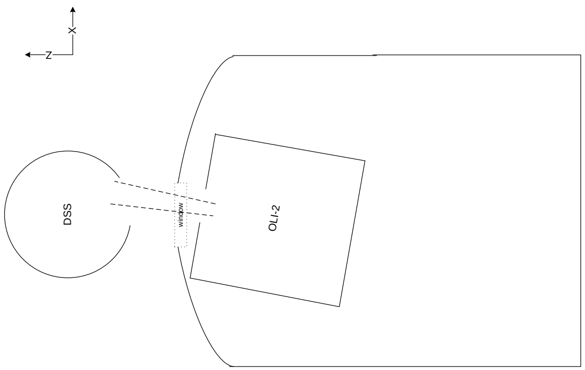
Look Right

Axes
Z : Chamber Long Axis
Y: Chamber Short Axis
X : Y x Z (Vertical)



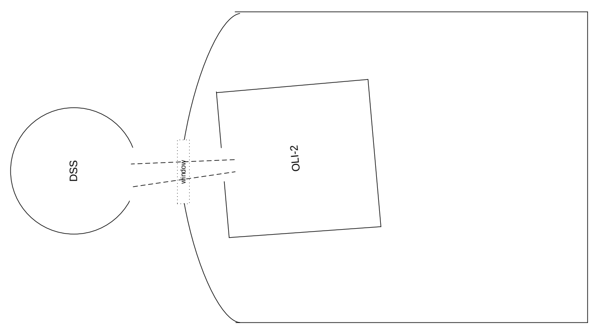
Stages Allow Mapping of the DSS Non-Uniformity and Observation of the Heliostat in Ball-10

Side View



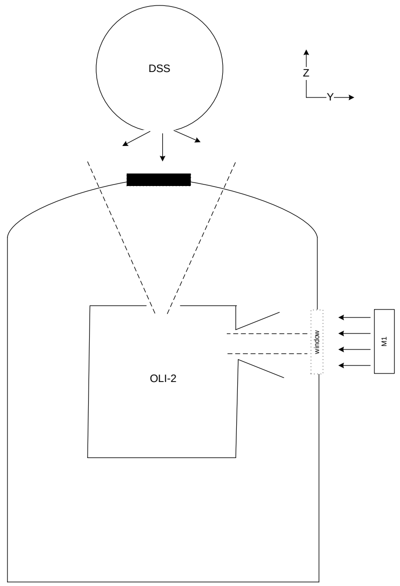
Look Up

Side View



Look Down

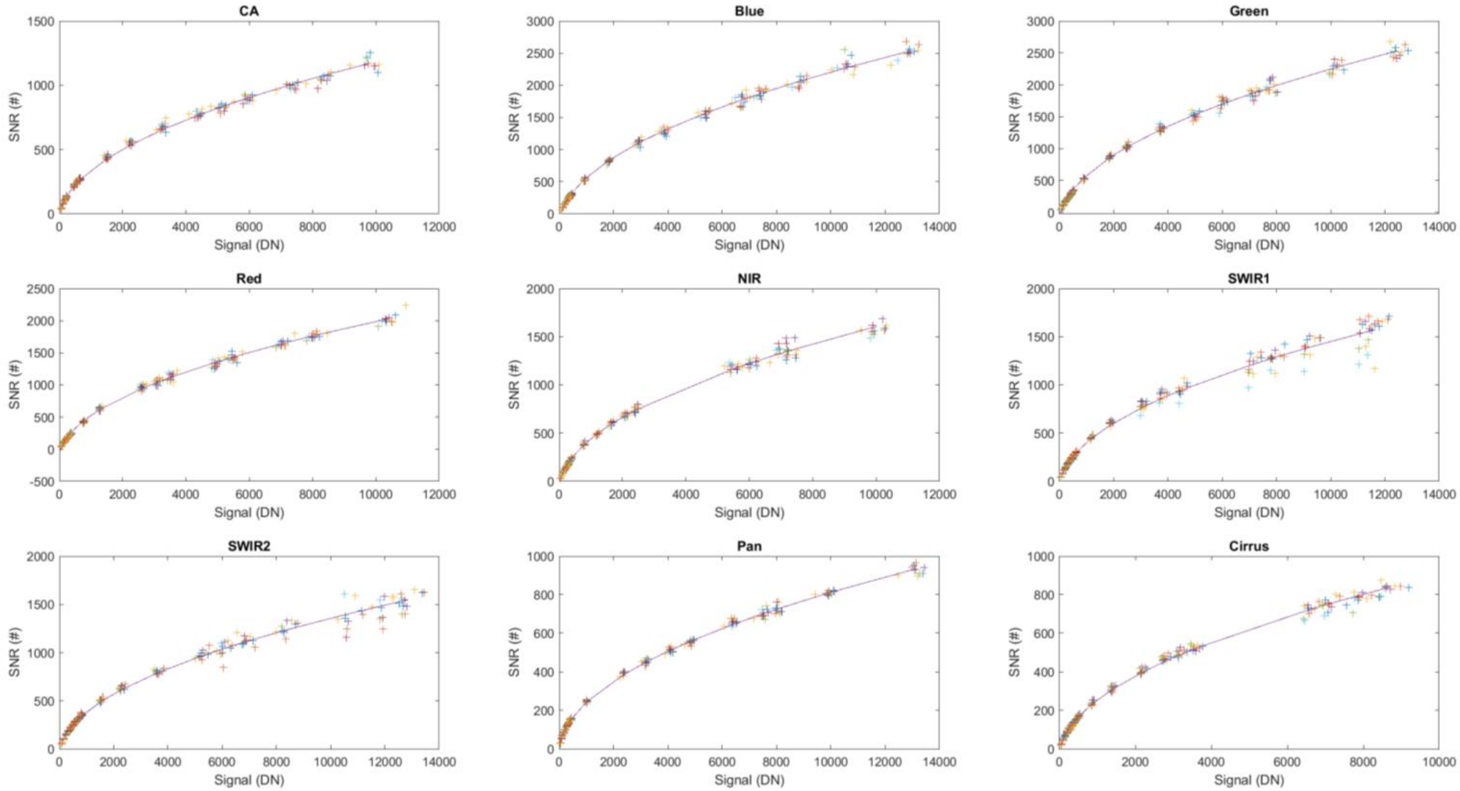
Top View



Pull Back

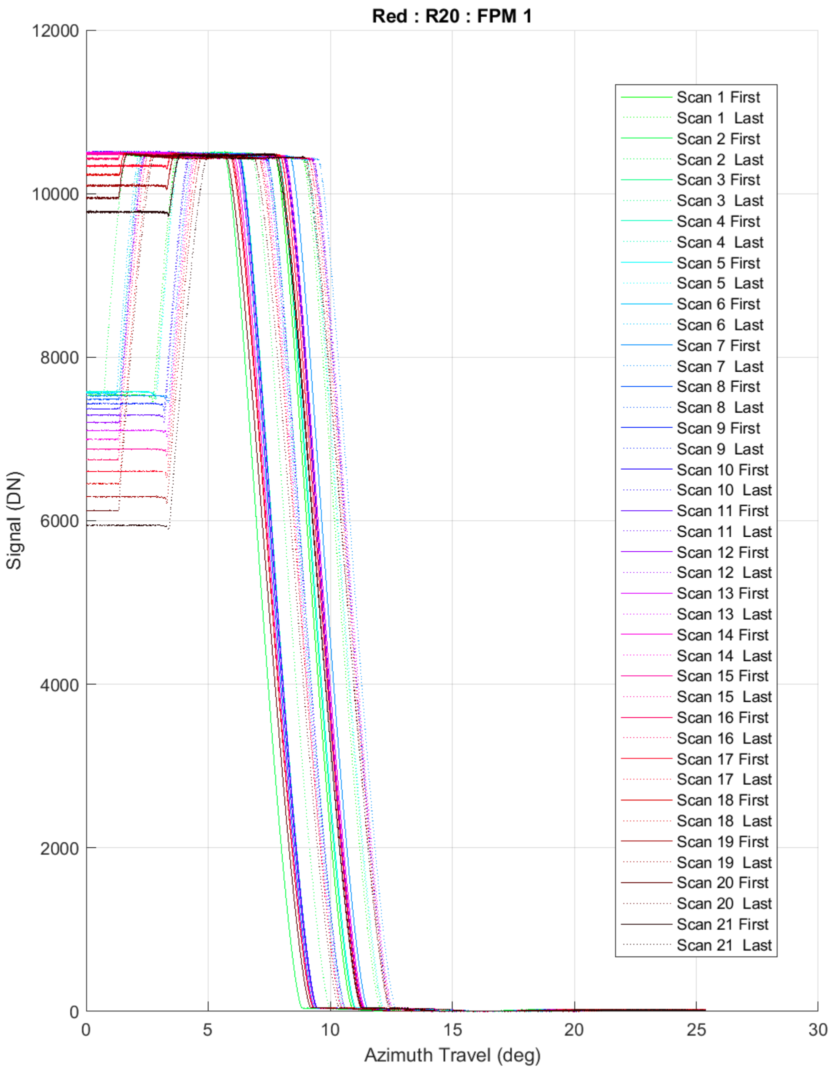
SNR Data Show OLI-2 is close to Shot Noise Limited

- **OLI-2 easily meets its noise specifications.**

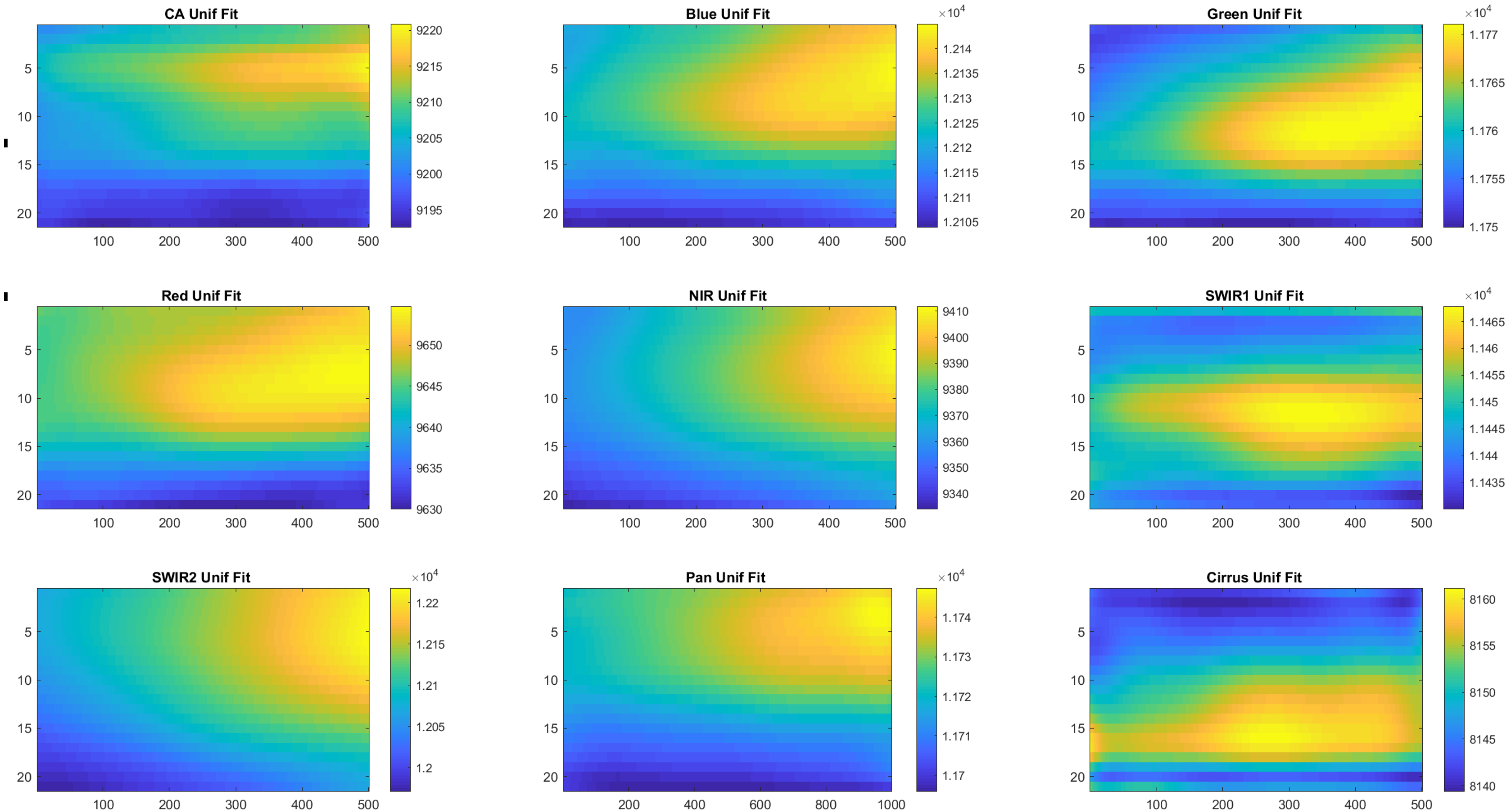


Uniformity is Measured Using a Continuous Scan for OLI-2

- **By azimuthally scanning the DSS with OLI-2 at 21 elevations from -1° to +1° we can create a map of it’s non-uniformity, as viewed by OLI-2.**



DSS Non-Uniformity Measured By OLI-2



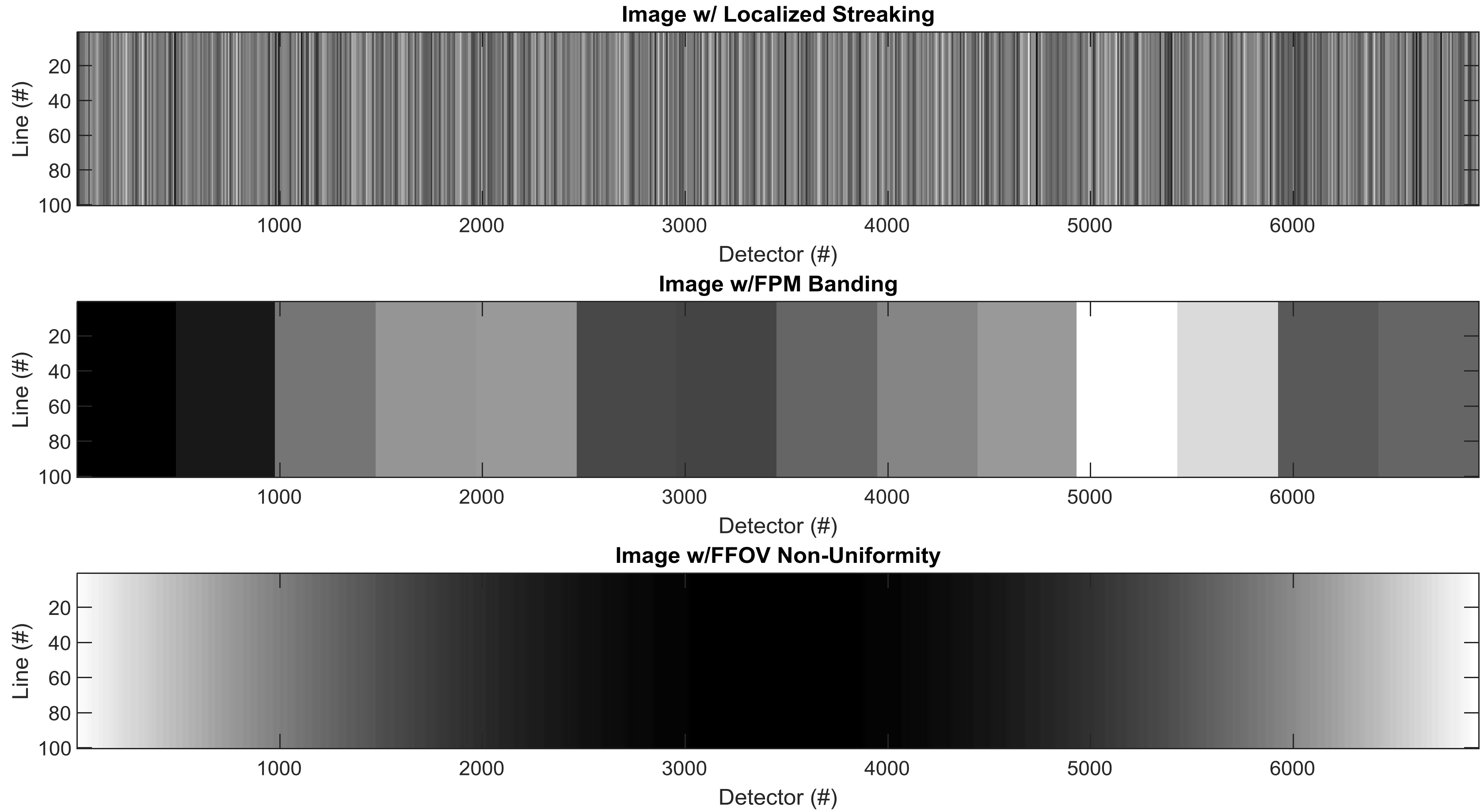
- **Each image is a map of the central 2° by 2° region the DSS used for radiometric characterization.**

8 of 9 Bands Show Comparable Non-Uniformity

Band	Name	CW	NU
#	string	um	#
1	CA	0.443	0.07%
2	Blue	0.482	0.09%
3	Green	0.562	0.05%
4	Red	0.655	0.07%
5	NIR	0.865	0.19%
6	SWIR1	1.610	0.08%
7	SWIR2	2.200	0.48%
8	Pan	0.590	0.12%
9	Cirrus	1.375	0.07%

- **SWIR-2 (2.2 μm) is out of family.**
- **This is probably due to sensitivity to thermal variation caused by cooling lines on the back of the sphere.**

OLI-2 Characterizes Images Non-Uniformity with Three Metrics



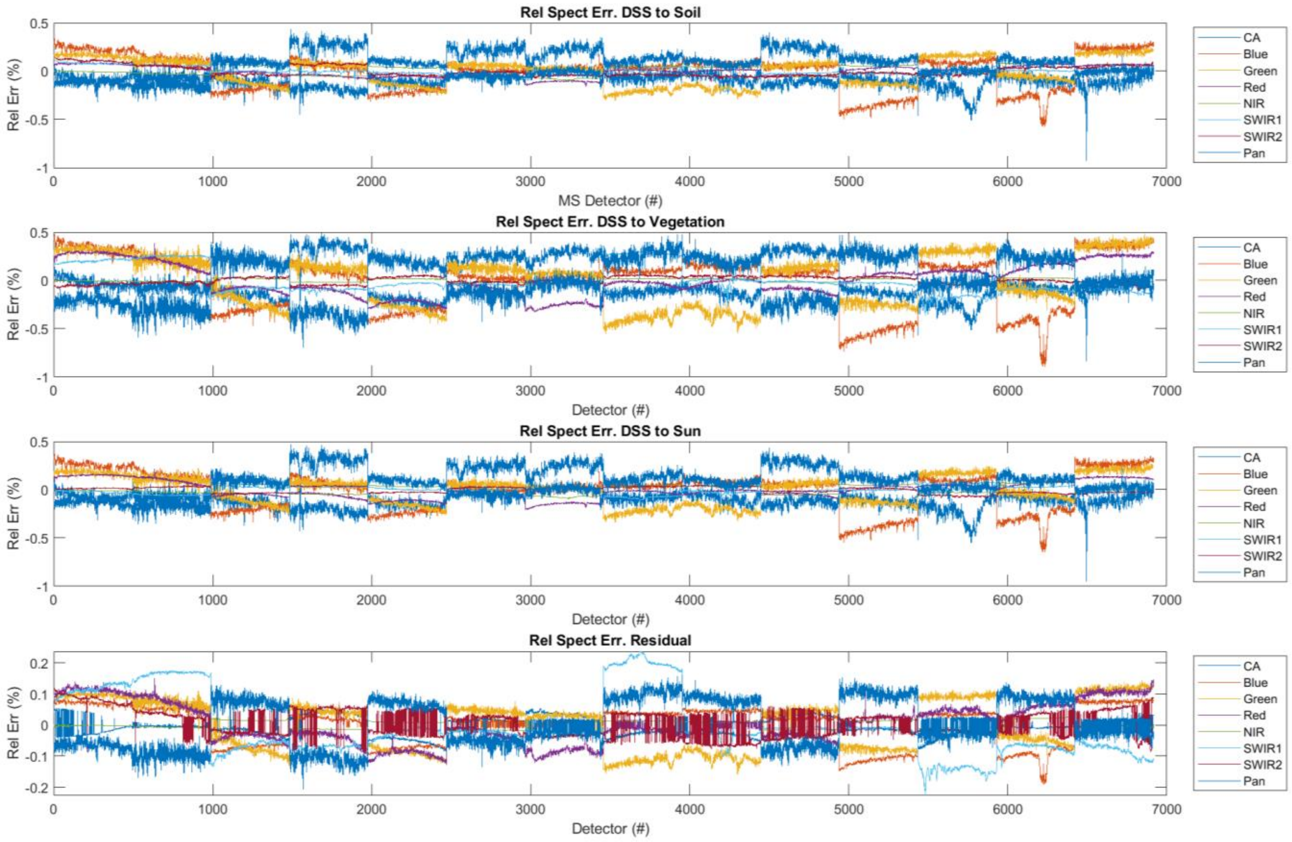
- **The non-uniformity of the OLI-2 spectral response contributes to each metric.**

Per-Detector RSR's Allow Detailed Evaluation of Spectral Non-Uniformities

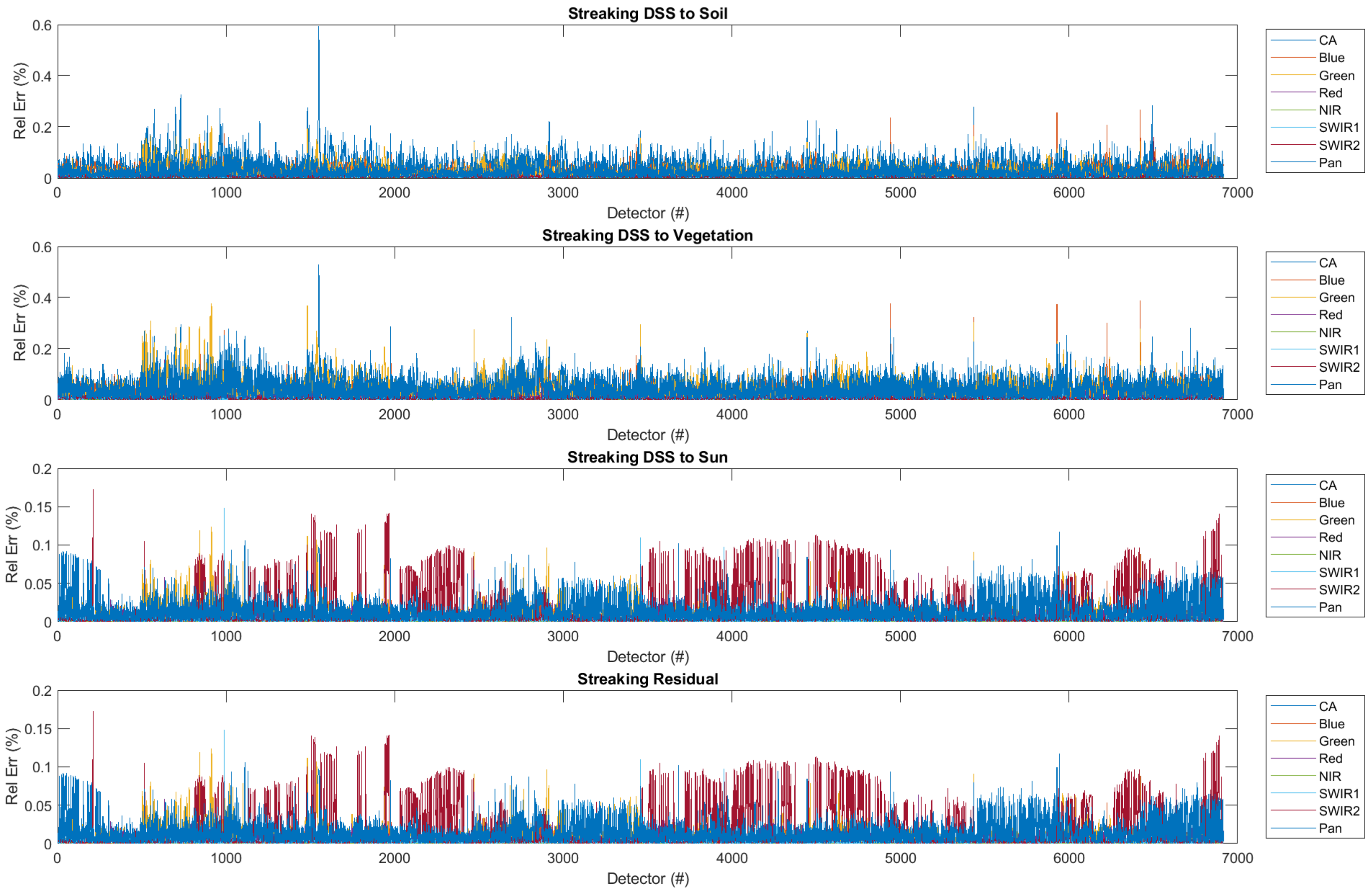
- **The OLI-2 specification mandates evaluation of flat-fielding quality against several scene spectra.**
- **Variations in spectral response are caused by:**
  - **Variation in angle of incidence of illumination on the filters.**
  - **Spatial variation of the response of the filters.**
- **Because:**
  - **The spectral response of each detector varies slightly,**
  - **Each band is required to report band-weighted radiance with a single weighting function (RSR)**
- **When calibrating against a spectrum (DSS) that is not the same as the scene (solar, vegetation, soil). There is unavoidable per-detector:**
  - **Radiometric error**
  - **Non-uniformity**

GLAMR Allows Detailed Characterization of Spectral Errors

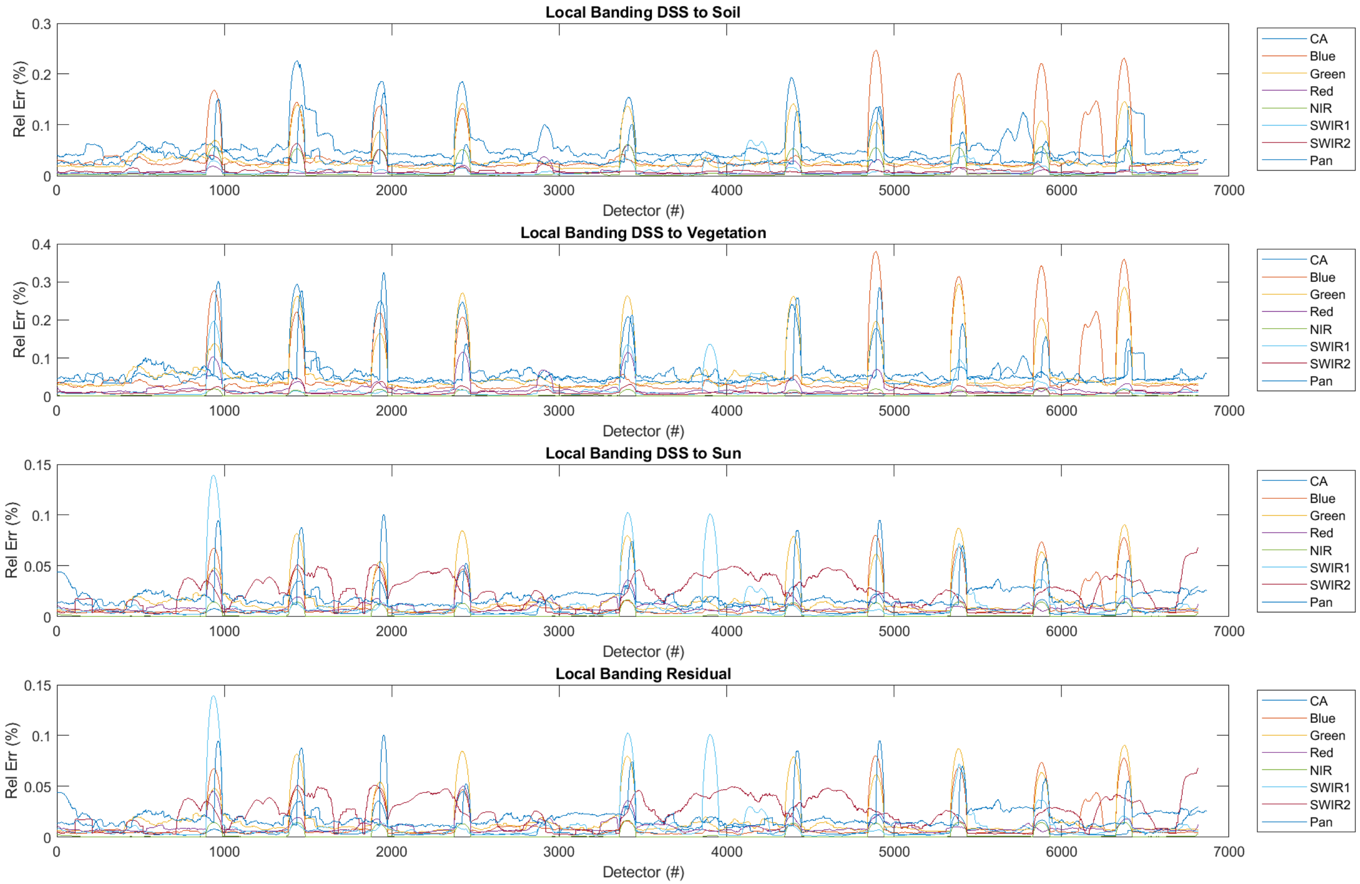
- **Knowledge of … :**
  - **the calibration source (DSS) spectrum**
  - **the scene spectral content**
  - **RSR for each detector**
- **... Allows calculation of the radiometric error associated with each detector.**
- **These errors are small relative to our radiometric specifications…**
- **… However the detector to detector variation in these errors introduces significant non-uniformity errors.**

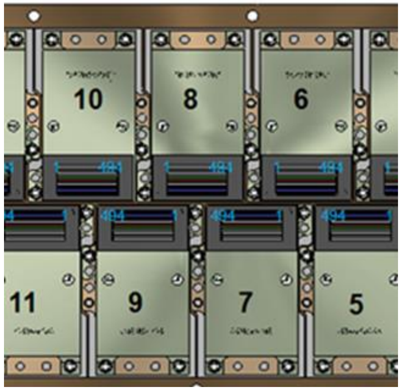


The Streaking Metric Evaluates High Spatial Frequency (detector to detector) Non-Uniformity



The Banding Metric Evaluates Medium Spatial Frequency (100 detector) Non-Uniformity

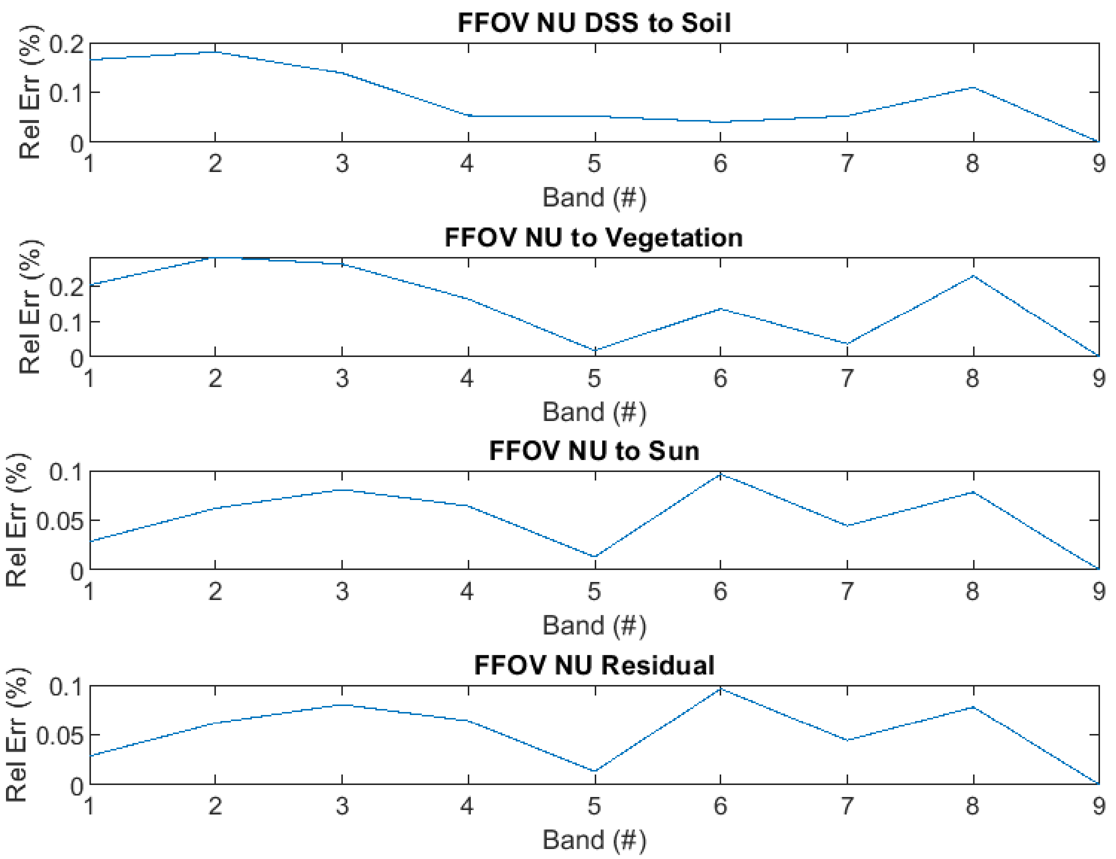




- **Banding is largely driven by discontinuities in illumination geometry at the focal plane module boundaries.**

The Full Field of View (FFOV) Metric Evaluates Low Spatial Frequency Non-Uniformity

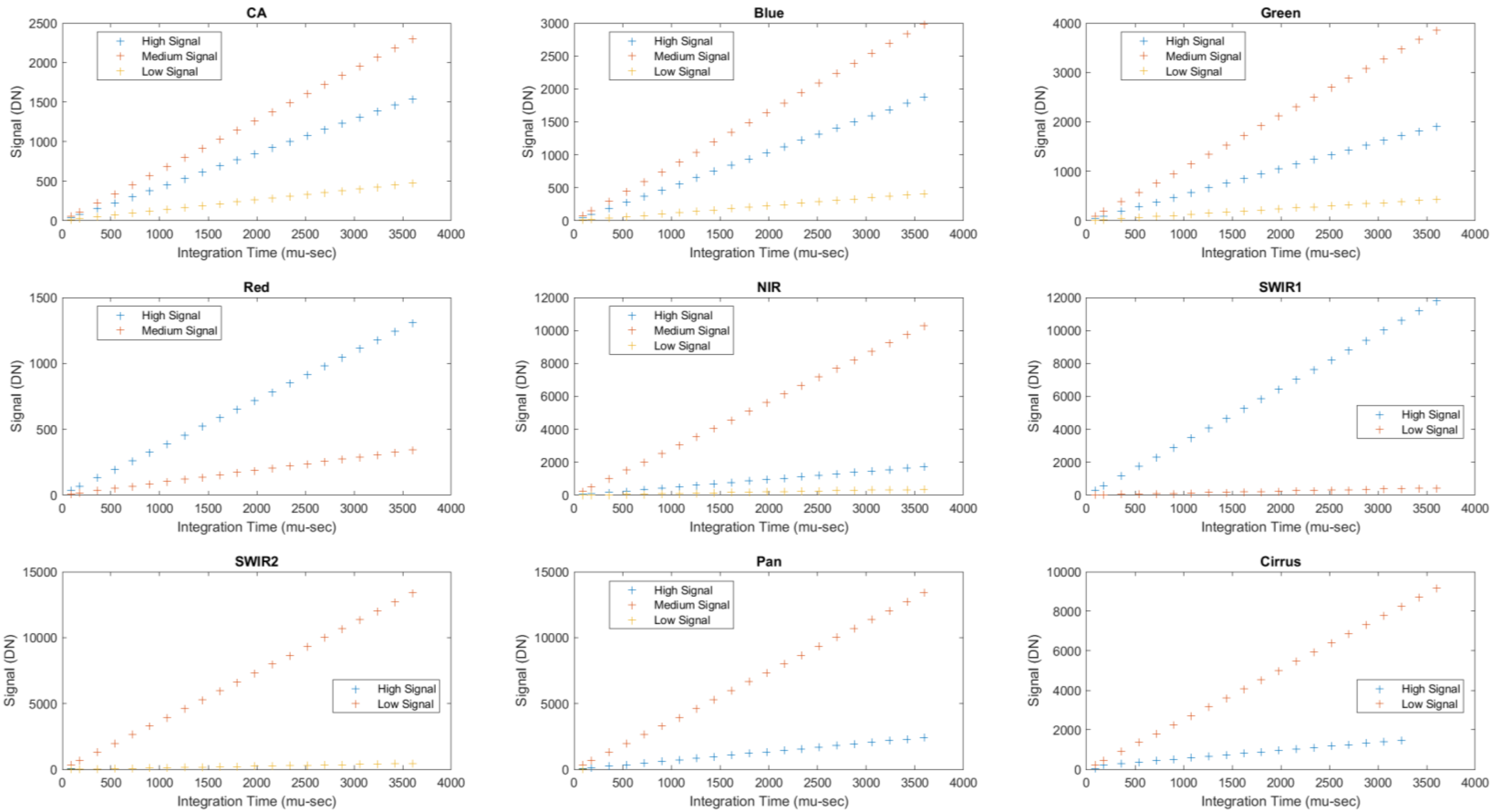
- **FFOV Non-Uniformity is driven by all effects.**



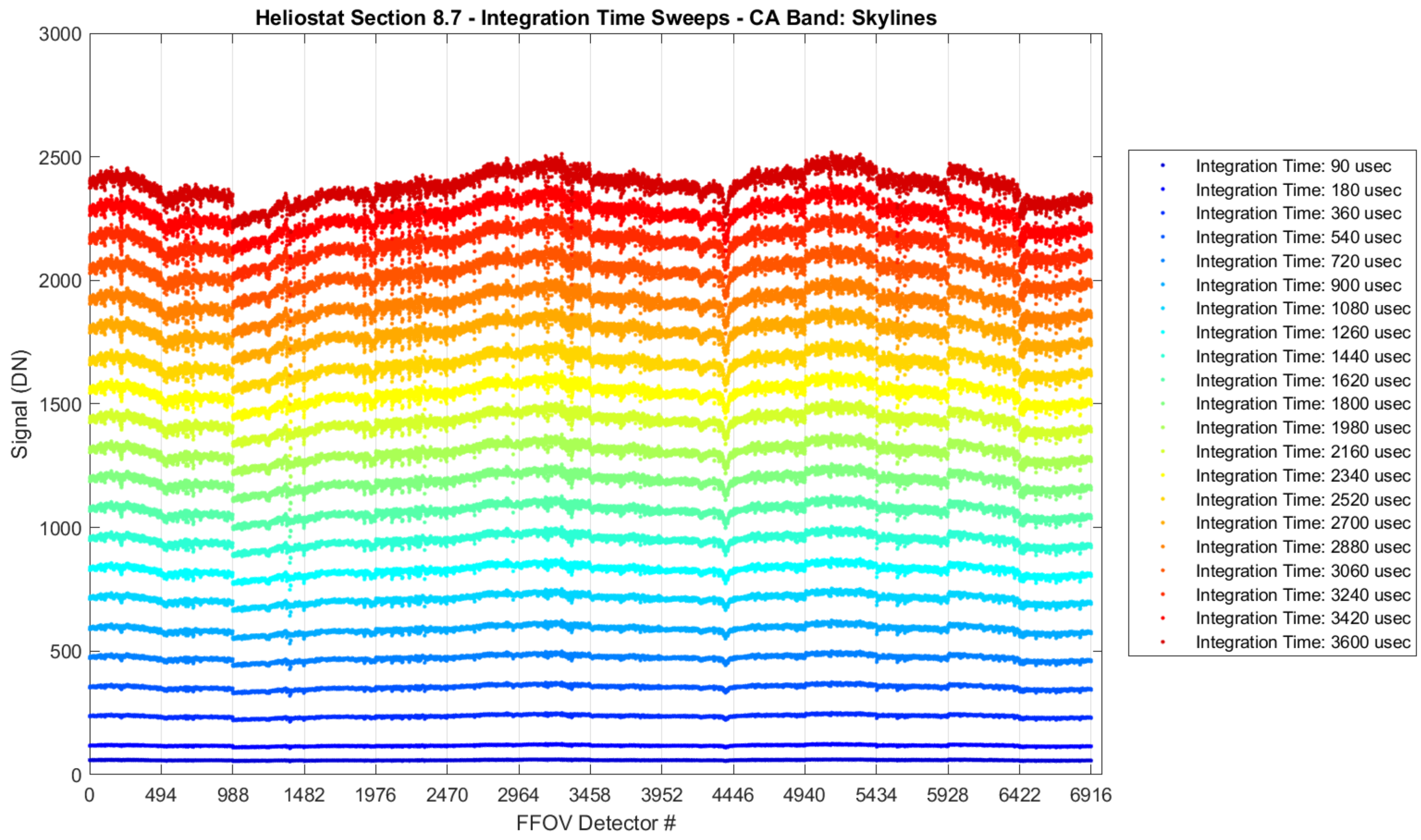
Detailed RSR Knowledge Makes Scene Dependent Tuning of Relative Gains a Possibility

- **No single set of calibration coefficients can eliminate spectrally induced radiometric error for all scenes.**
- **The spectral non-uniformities are significant contributors to the overall OLI-2 non-uniformity budgets.**
- **Given knowledge of spectral non-uniformities we can adjust calibration coefficients to minimize non-uniformity errors for the scenes of interest, or create special coefficients for particular scenes.**
- **This potentially has several consequences:**
  - **It improves the OLI-2 reported performance.**
  - **It allows for the possibility of tuning calibration coefficients for scenes (such as Oceans and Ice) where:**
    - **Scene spectral content is spatially uniform**
    - **Scene spatial content is also uniform and hence de-striping is of interest**

Varying Integration Times At A Variety of Signal Levels Allows Detailed Evaluation of Linearity

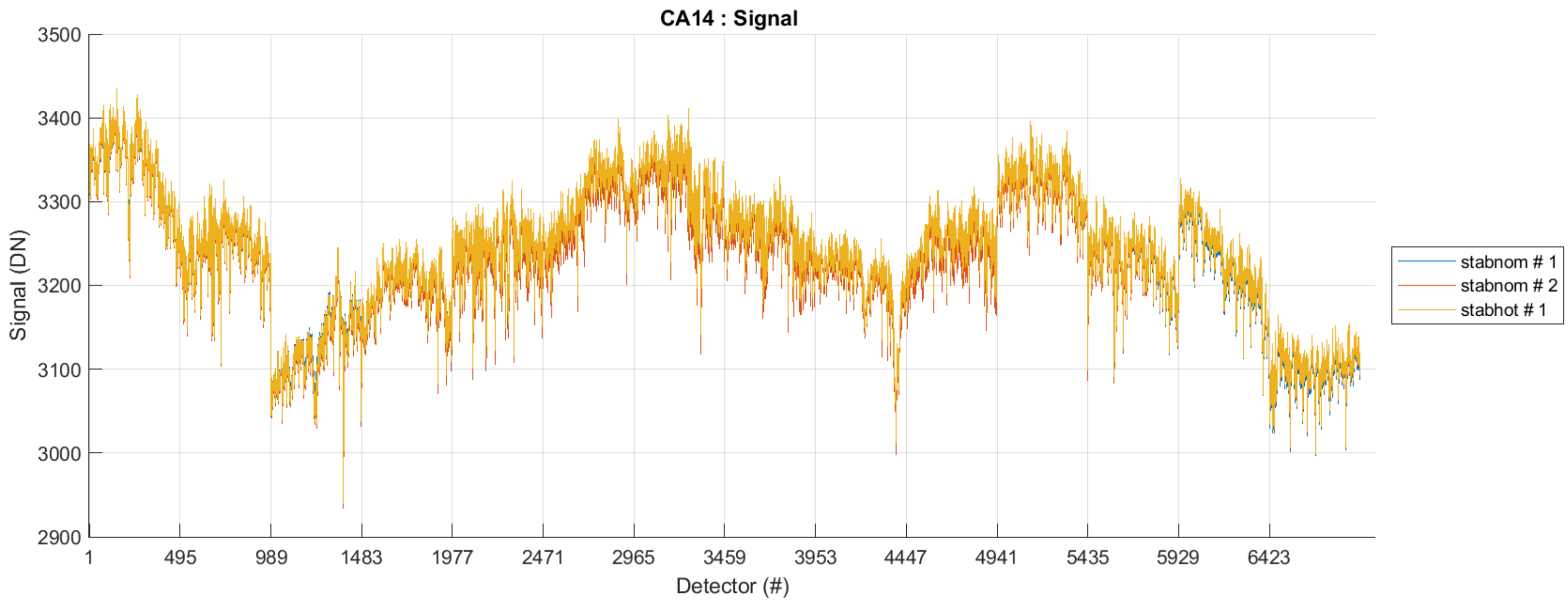


OLI-2 Can Monitor Linearity On-Orbit w/Variable Integration Time



- **On-orbit OLI-2 can observe the diffuser at varying integration times.**

Stability



- OLI-2 has a 16 day radiometric stability requirement.
- Since radiometric instability is expected to be driven by thermal variation as opposed to time, per-se, we evaluated performance by modifying the chamber shroud temperature to simulate the range of on-orbit operating temperatures.
  - This provided a more stringent test case than just examining images taken by OLI-2 in the chamber 16 days apart.
  - It expedited testing.

Summary

- OLI-2 is complete; on schedule for December 2020 launch
  - Minimal changes from OLI
  - Maintained strong emphasis on calibration and characterization
- Characterization and Calibration testing is complete
  - Results are comparable or better to OLI
    - Spectral and spatial uniformity characterizations more complete
    - Linearity measured more precisely
    - More NIST traceable radiance levels

Acknowledgements

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