Radiometric Source Uniformity Characterization with Angular Scans: Landsat-9 OLI-2 Experience

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www.calcon.sdl.usu.edu

Overview

- Test setup and test plan description
- Data processing
- Results
- Conclusion

Radiometric Test Setup

- **OLI2 Focal Plane Detectors.**

  inside a TVAC chamber mounted on a test-fixture that is controlled by **3 motorized stages**

  Rotation stage (**Yaw**) , a Goni-stage (**Pitch**) and a **Linear** stage (Aerotech)

  Controlling pointing in 2-axes (along and across tack the FPA coordinate system)

- **Calibration Integrating Sphere – a.k.a Death Star Source (DSS) with variable signal levels and radiance controlled in-band for increase source stability.** (LabSphere)

  - monitor detector uncertainty is <0.028% for 2hrs

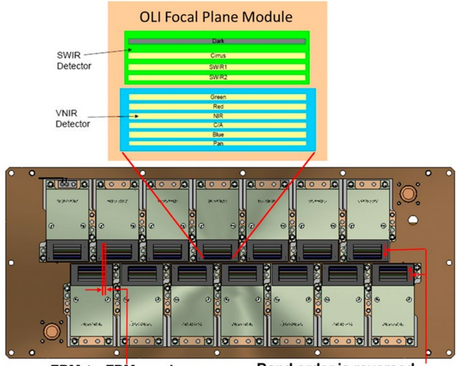
  - radiance stability in closed loop over 25min having <0.096% (evaluated at 5% of Lmax)

- **Uniformity characterization of Sphere source done using all of OLI imaging detectors**

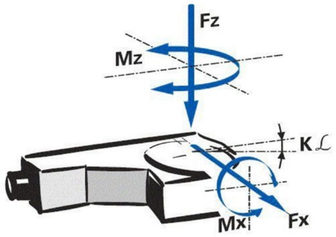
Test sequence named : DSS uniformity Mapping.

The Mapping collects occurred with one radiance levels per band – (OLI2 peak level of each band)

The sphere source mappings are followed with quick (<2min) **Yaw** collect sets at multiple radiance levels per band that centers the sphere exit port pointing vector **Pitch** angle on the line of sight on the centerline of either the even or odd FPMs for every band. Those collects are used primarily as characterization of OLI relative gains. A subset of the such collects is also used as validation data for the OLI2 uniformity and non-linearity calibration.



https://doi.org/10.3390/rs61111127



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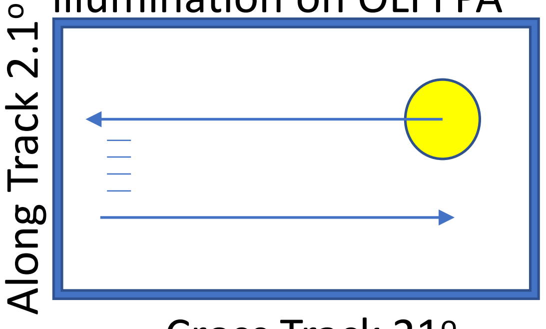
BATC - Death Star Source (DSS) Integrating Sphere (Labsphere)

DSS Mapping collect sequence

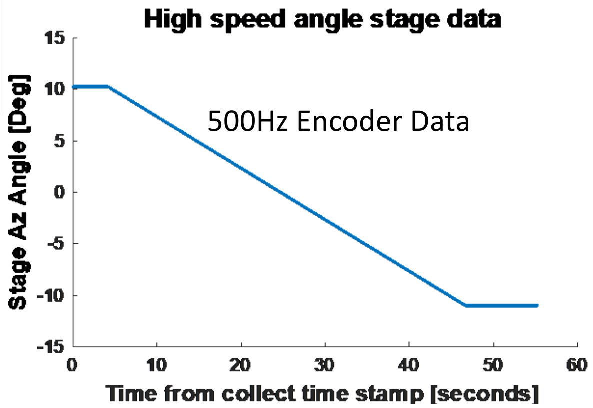
Advantages

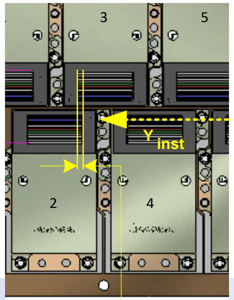
- Quick collect – illuminating all detectors and all bands – assuring known repeatable source profile, **can help finding best calibration zone - optimized for the sphere uniformity.** Provide a 2D illumination profile that can assist analysis of the step-stare collects and other yaw collects.
- **During full mapping collect - the stability of the DSS is better than 0.03% for Lmax of the band**
- **Produces FPM overlap statistics data** similar to on-orbit collect analysis used for improving the across track uniformity.
- **- Still in evaluation – extraction residual non-linearity per FPM with same source uncertainty throughout the dynamic range (not possible for all FPMs)**

Diagram of DSS illumination on OLI FPA



Band	Saturation Radiances, L_{Max} (W/m^2 sr µm) Requirement
Coastal Aerosol	555
Blue	581
Green	544
Red	462
NIR	281
SWIR 1	71.3
SWIR 2	24.3
Panchromatic	515
Cirrus	88.5





FPA-to-FPM overlap

Mapping collects

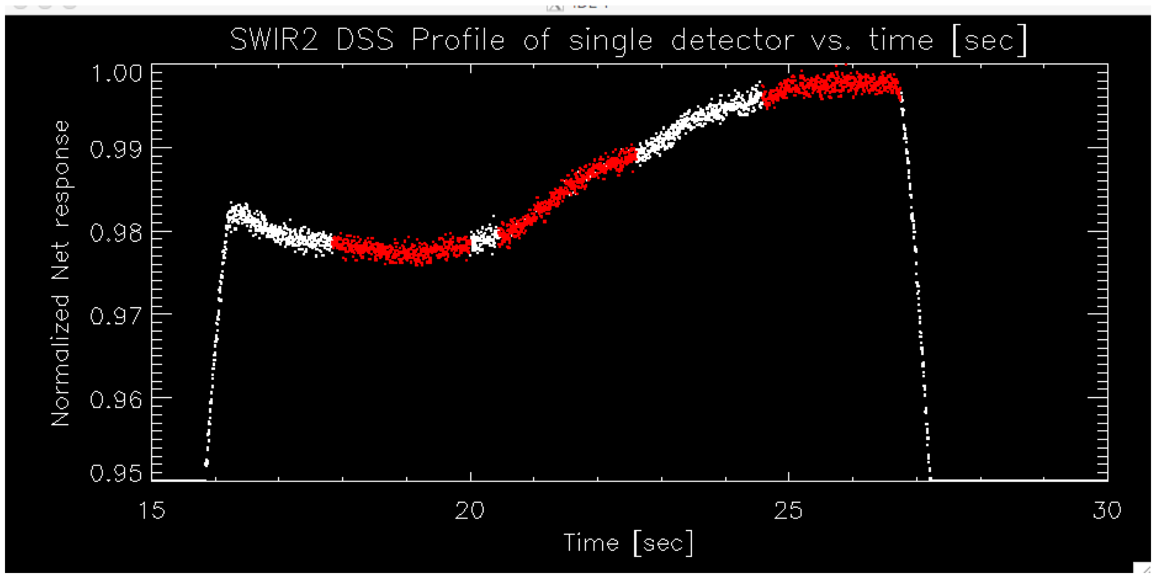
- Sweeps through DSS at **0.5° per second** (all detectors within an FPM see the same sphere profile)
- Repeated at 21 elevations stepped in 0.1° covering a 2.1° along-track
- For each detector locate 3 zones of 1deg segment within the Sphere Plateau of (~5deg)
  - one near peak response
  - one where the signal has the lowest Stdev (i.e. most uniform zone)
  - middle of plateau (i.e. the default pointing center for other DSS collects)

For all zones compute the Signal uniformity as (1-sigma stdev) and mean signal per detector.

- Total of 17 Mapping Collect sets where made with repeats collects for select bands (CA, Blue, Pan , SW1, SW2, Red)

A commutative 6.5hrs about 0.8Tb of data

Additional 57 sets with 2 Yaw sweeps collects added 2 hours for a complete uniformity/linearity check collects



Best data for estimating relative gains

Reasons it is better

- Sphere maps helps us understand what gets measured during other primary calibration sphere collects.
- View of common angular zone of sphere are seen by both even/odd FPMs.
- Sphere signal is stable.
- For bands with higher non-uniformity in the source can be compensated for the sphere as measured illumination profile.
- Per FPM get multiple repeats of FPM relative gain estimates – 3 zones and 21 elevations scans.
- Value in consideration per detector is an average of about 1deg FOV on the sphere rather the narrow FOV during other collects.
- Free of non-linearity effects impacts.
- To lock FPM to FPM relative gains - overlap detectors can be used to between two elevation collects that are going to "see" the same part of the sphere on the neighboring FPM.
- Better matching of the uncertainty of the calibration of uniformity to the stability and noise level of the OLI2 system.
- In-band Yaw collects can be used as verification data for FPM relative gains computed from Mapping collects.

Data Processing Plans

- From Mapping collects – evaluate 3 zones within the sphere signal plateau (near peak response, center of sphere and lowest non-uniformity) and compute from it the find the most uniform 1deg across track zone and compute relative gains for detectors.
- Repeat for each band.
- Using Non-uniformity corrections derived from Mapping data use it and the non-linearity correction to flat field the characterization Yaw collects – and report the residual error. **(Work in progress)**
- Non-linearity and linearity correction derivations using the sphere yaw data. **(Work in progress)**

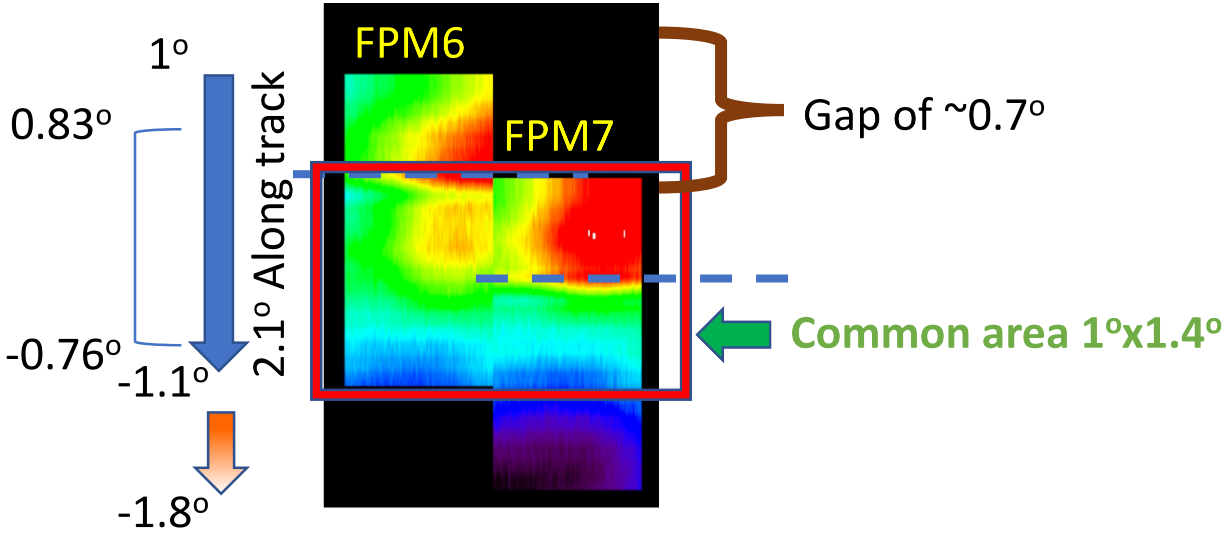
Ultimate Goal of this effort is to compute the most accurate baseline for pre-launch FPM to FPM relative gain correction and per detector relative gain corrections.

FPM to FPM response statistics

- Ratio of response average in overlap detectors.
- Odd and Even FPMs see along-track different part of the sphere due to angular separation.

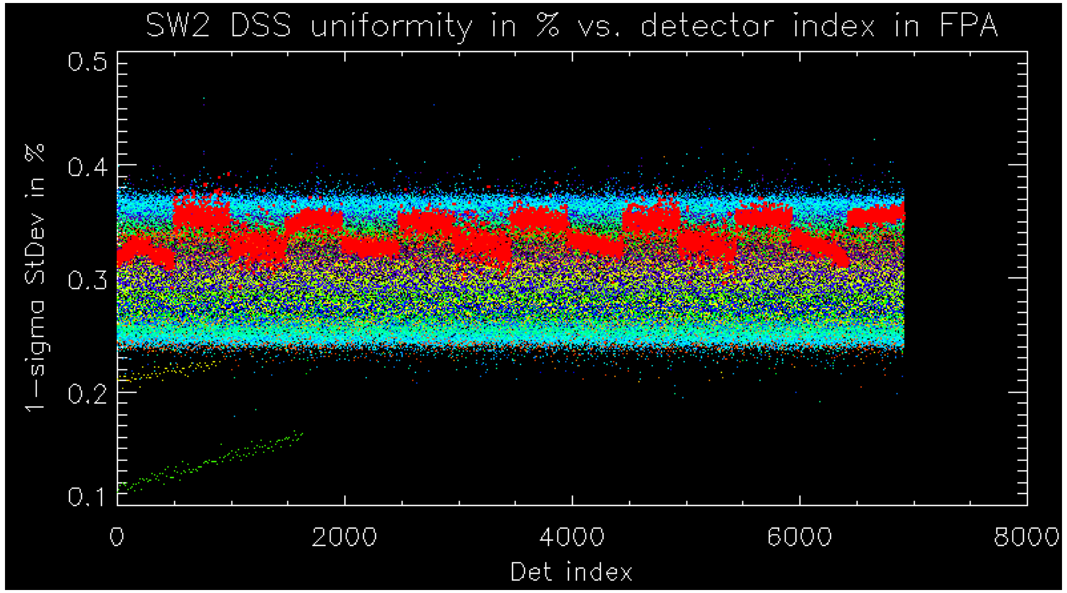
OLI2	Pitch Angles settings in Deg for Even and Odd FPMs Yaw Scans		
Band name	Odd # FPMs	Even # FPM	Delta Scans in Mapping
CA	0.38	-0.31	7
Blue	0.31	-0.24	6
Green	0.59	-0.53	11
Red	0.52	-0.45	10
NIR	0.45	-0.38	8
SWIR1	0.76	-0.69	15
SWIR2	0.69	-0.63	13
Pan	0.24	-0.17	4
Cirrus	0.83	-0.76	16

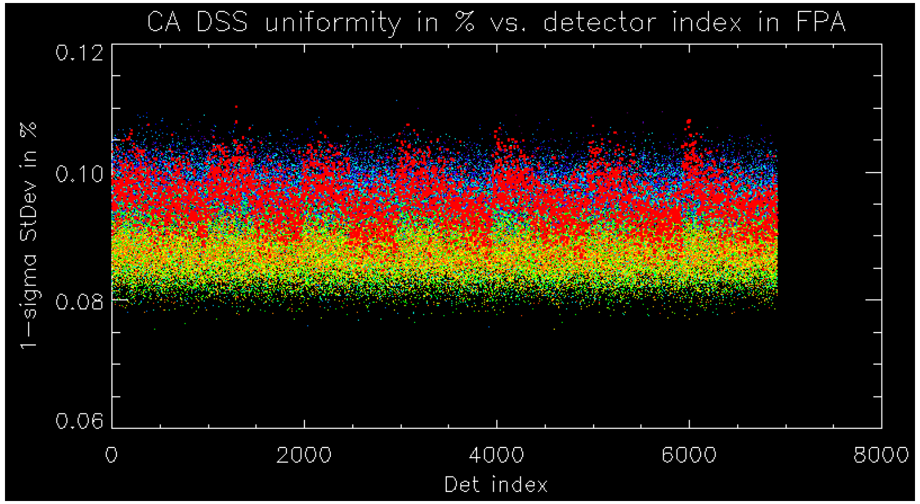
Normalized CA band sphere view illustration
P-P ~ 0.385% (2D Stddev <0.097%)



Sphere Uniformity Samples

- Uniformity of DSS as measured by all detectors for every band



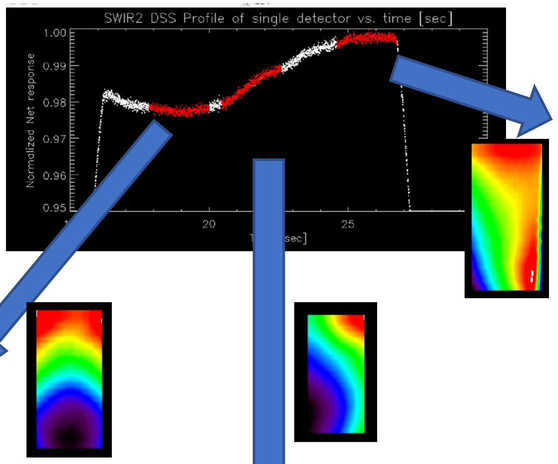


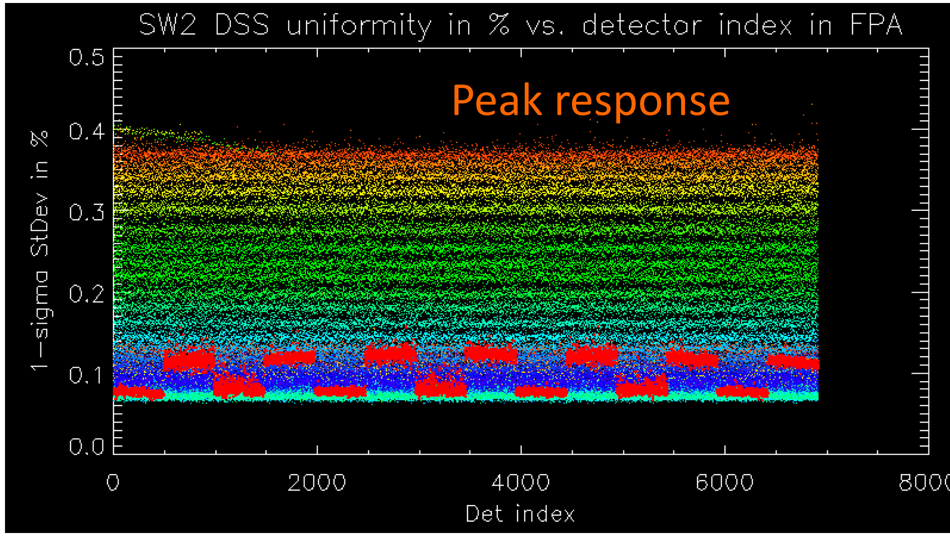
Band	Uniformity along track 1-Sigma	Uniformity across Track 1-Sigma
CA	0.096%	0.091%
SWIR2	0.340%	0.307%

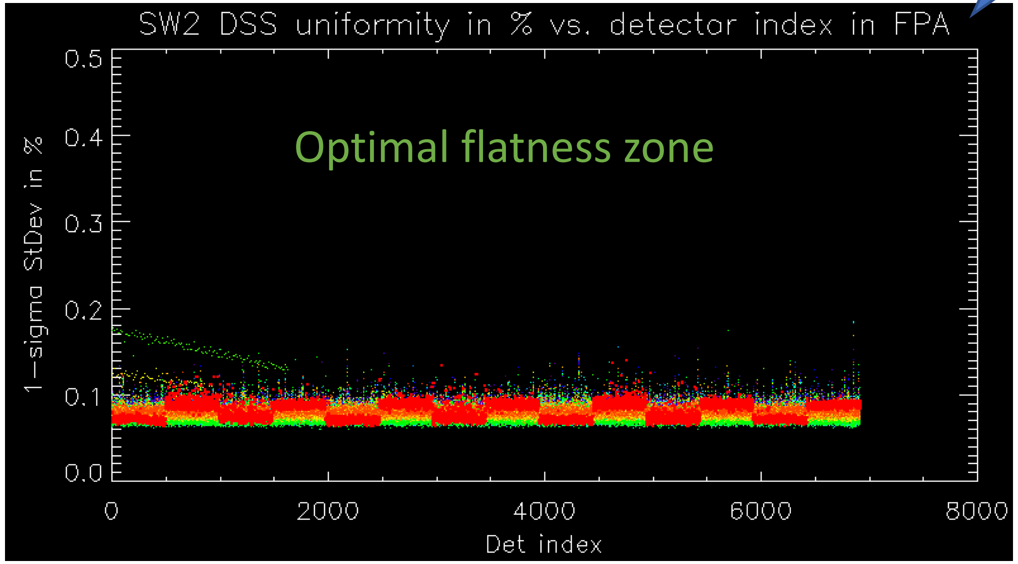
3 variables are checked here: sphere output vs. angle in two orthogonal directions relative to the sphere exit port – line-of-sight through the dynamic range, at each wavelength.

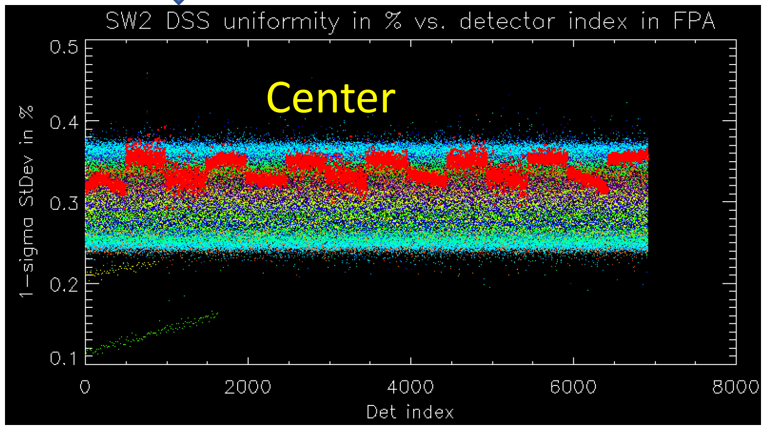
Portion of sphere view

- SWIR2 data – shows very different results depending in the section of the profile selected









Uncertainties

- Core uncertainty factors impacting analysis error bars.

For relative gains inputs:

Sphere output stability during full collect set – <0.056% @Lmax

OLI detector noise/stability - <0.66% below 5% of Lmax and getting to about 0.1% near the plateau at Lmax – OLI 1min stability is better than 0.26% 2-sigma

Constant scan rate assumption during collect – angular range error between FPMs or detectors (not too critical)

For FPM to FPM tie points.

Timing of collect – (maximum is about 14min vs. milliseconds on-orbit)

GSE stability – Jitter etc… (14ifov vs. 1/5 ifov on orbit)

Pointing repeatability/uncertainty during collect – impact ability to find same source zone for all pixels in overlap. (mitigated by very uniform sphere)

DSS source uniformity & stability

- Stability measured externally confirmed expected results prior to CATS testing – any deviations are due to non-uniformity.
- Uniformity measured with OLI2 mapping
- After removing low frequency variations in each zone of the sphere collect – we get a stable repeatable level of uncertainty about 0.11%
- Results for most bands and FPMs are within requirements of 0.25% stability
- Non-uniformity need to be corrected per FPM per band when impact of across track stability rises to >0.25%. (only select bands)

Conclusion

- OLI2 pre-launch calibration demonstrated an improved procedure for sensor response non-uniformity parameters derivation. – A matched quality between the calibration tools and the sensor was achieved.
- Data demonstrate the DSS is a very uniform calibration sphere <0.4% at Lmax with matching non-uniformity between along track and across track direction in a sphere box of 1°x2.1°
- Reduction of uncertainties during collect compared to OLI collects was due to 3 main factors: Short collect duration under 25min for a grid of 21x2.1 degrees, uniform sphere source, optimized sphere source stability.