Landsat 8 Geometry Status

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Topics

- **TIRS SSM Mode 0 Operation**
  - Alternate operations concept
  - Real-time data performance using predicted SSM model
  - TIRS-to-OLI registration accuracy

- **Landsat / Sentinel-2 Registration**
  - Estimated GLS accuracy (post-GCP improvement)
  - Predicted and measured L8 OLI – S2A MSI registration accuracy
  - GLS global re-triangulation plan and status
TIRS Scene Select Mechanism Status

- The TIRS SSM is now being operated in a manner designed to extend its operational life
  - Open loop (mode 0) control is used for most Earth imaging
  - Closed loop (mode 4) control is only used for periodic radiometric calibration operations
- Calibration operations are nominally conducted every 14 days, linked to the lunar calibration cycle
  - The SSM position encoder is turned off (to extend its life) once the calibration is completed and the SSM has been returned to mode 0 operation
- Real-time SSM position telemetry is not available once the encoder is turned off
  - SSM position is estimated off-line and provided to ground processing as a table of estimated SSM angles vs. time
TIRS SSM Position Variation

- TIRS cal events reset the SSM position model every ~14 days
  - SSM exhibits considerable variation in the magnitude of initial motion, so the initial motion is measured by leaving the encoder on for ~40 minutes

- Subsequent motion is monitored using image measurements from cal scenes
  - A model of SSM position is fitted to the encoder and scene data
  - SSM position angles vs. time are used in ground processing
  - The latest event follows an unusually long encoder off time

Each return to zero is a calibration event

Note event-to-event variability
Assessing Real-Time Data Accuracy

- SSM calibration scenes provide measure of SSM model prediction accuracy
  - To estimate the accuracy of the predicted SSM model values used to perform real-time processing, we looked at the pre-fit residuals from the SSM calibration scenes
  - Of particular interest is the accuracy in the first few days following a mode switch when the SSM behavior is changing the most rapidly

- Critical thresholds
  - TIRS-OLI registration cannot meet specifications if the prediction error is $> 28.4$ microradians
  - Nominal performance is expected if the error is $< 10 \, \mu \text{rad}$
    - This is not as accurate as the encoder, BUT the image-based calibration also absorbs slowly varying roll-axis TIRS-to-OLI alignment error
SSM Model Prediction Accuracy

- Computed RMSE statistics as a function of time since mode switch for all events since November 2015

First few orbits without encoder data are the most problematic.

Note: Results reflect performance when telemetry and calibration scene data are available when and where expected.

Encoder is still on.

Initial cal scene updates improve accuracy.

Additional model parameters can be estimated as a longer data record becomes available.
TIRS-OLI Registration After Reprocessing

TIRS-OLI Band Registration by Quarter

Note similar performance with (left) and without (right) encoder data.
Landsat – Sentinel-2 Harmonization

- Sentinel-2 will use a set of global reference images (GRI) to ensure multi-temporal registration
  - This reference is being established through a series of continental-scale triangulation blocks of MSI data
  - High resolution Pleiades imagery is being used as control
    - There is no explicit tie to the GLS
  - These blocks will be completed during 2016-2017 with operational implementation (and reprocessing) to follow

- Given the respective accuracies of the GLS (17 m RMSE$_{r}$) and GRI (10 m 2-sigma), Landsat / Sentinel misregistration of up to ~26 m 2σ can be expected
  - Better registration is required by the science community
  - Provides motivation to improve the GLS while making it consistent with the Sentinel-2 GRI framework
L8 Estimate of GLS Horizontal Error

Slivers that were missed in reprocessing.
Phase 4 – Approach and Status

- Perform a global readjustment of the GLS using L8 data with sparse ties to Sentinel-2 GRI
- Thirteen triangulation blocks have been defined
  - Islands will be updated where MSI data are available
- Initial (L8 only) triangulations have been performed for the Europe, NW Africa, SE Africa, South America, CONUS, Alaska, Greenland, and West Asia blocks
  - New OLI GCPs have been extracted for these blocks
  - Australia block has been triangulated but needs OLI GCPs
  - Central Asia and SE Asia blocks are in work
- Once the GRI is operational, MSI control will be added to support a second, constrained triangulation
- Readjusted control will be implemented in Collection 2
Triangulation Blocks & S2 Tie Sites

- GLS Control
- CONUS and Eastern Canada
- Northern and Western Africa
- Central Asia
- Australia
- Greenland and Canadian Arctic
- South America
- Southern and Eastern Africa
- Northeast Asia
- Oceania and Islands
- Alaska and Western Canada
- Europe and the Levant
- Western Asia
- Southeast Asia
- S2 Tie Points

Landsat Science Team – January 2017
**Measured Landsat 8 / Sentinel 2 Misregistration**

- L8/S2 registration accuracy was measured at 255 sites.
- Actual results before and after L8-only triangulation:

<table>
<thead>
<tr>
<th>Block</th>
<th># Scenes or Blocks</th>
<th>Net RMSEr</th>
<th>2σ Difference</th>
<th># Scenes or Blocks Completed</th>
<th>L8 Trig RMSEr</th>
<th>L8 Trig 2σ</th>
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<tr>
<td>Alaska and Western Canada</td>
<td>13</td>
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<td>13</td>
<td>10.953</td>
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<tr>
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<td>Northeast Asia</td>
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<tr>
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</table>

26m 2σ predicted
S2 / L8 Comparison Sites

The image shows a world map with various locations marked by red squares, indicating MSI/OLI test sites. The map is labeled with latitude and longitude axes, allowing for a global perspective of the comparison sites.
Summary

- Supporting TIRS mode 0 as an operational capability
  - TIRS performance using the alternate operations concept is equivalent to the nominal (mode 4) configuration after switch event close-out and reprocessing
  - Real-time data accuracy is degraded somewhat, especially immediately following a mode switch event

- Fourth phase of Landsat GCP improvement is underway to improve L8/S2 registration
  - Completed L8-only triangulation for 9 of 13 blocks and OLI GCP extraction for 8 of 13 blocks
  - Final block adjustment will include GRI tie points to link to Sentinel-2 MSI geometric framework
  - Measured OLI to (pre-GRI) MSI registration is slightly better than predicted => 22.3 meters $2\sigma$ based upon 255 test sites