# USGS Agency Update

**Presented to CEOS WGCV**
**October 1, 2014**



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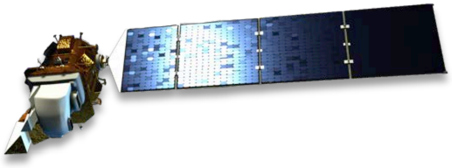
# Agenda

- Follow up to USGS Welcome from Tom Cecere, *International Liaison, USGS Land Remote Sensing Program, 9/30/14*
- *Landsat -7 Status and Calibration*
- *Landsat-8 Status and Calibration*
- *Landsat IGS*
- *Sustainable Land Imaging*
- *EO Requirements Capabilities and Analysis*
- *System and Data Characterization  (and Quality)*

# Operational Status

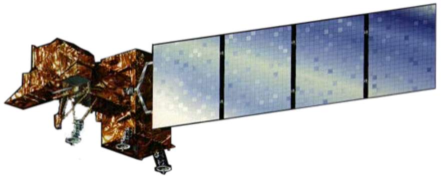
***Landsat 8***

- Collection increased from approximately 550 to 725 new scenes per day; supports 8-day revisit cycle
- Improvements:  better signal-to-noise, new bands (coastal blue, cirrus, thermal)
    - Crisper images; less color saturation
    - Better resolution of snow and ice-covered regions
    - Detection of water-column constituents
    - Better cloud screening



***Landsat 7***

- Collecting over 400 new scenes per day; about 22% of pixels missing per scene (faulty scan-line corrector)
- L7 collection strategy modified to concentrate on continental coverage; L8 capturing islands & reefs
- Sufficient fuel until 2018; limited subsystem redundancy; satellite could fail at any time



***8-day revisit cycle is at significant risk of interruption***

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From USGS Tom Cecere Introduction, 9/30/14

# Operational Status

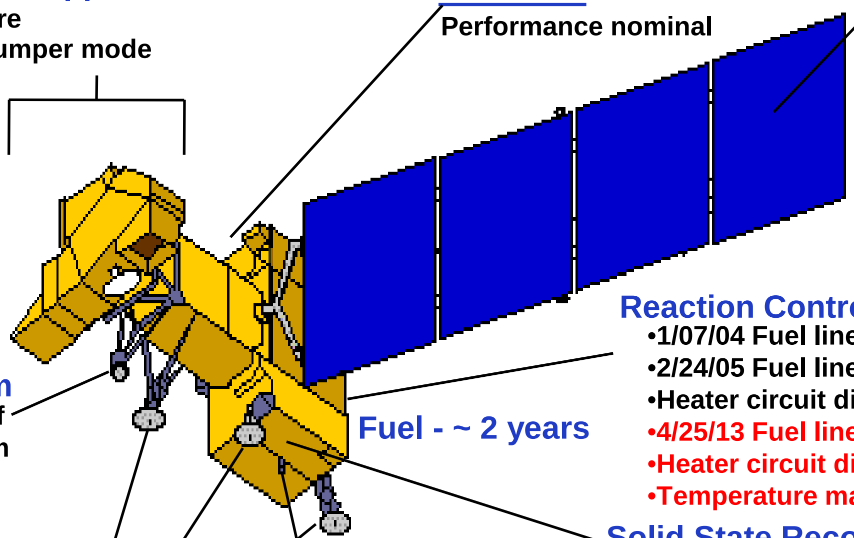
***(continued)***

***Landsat-based Information Products***

- Standard orthorectified L1T calibrated radiance Landsat scenes
- LandsatLook (full-resolution JPEGs browse/print images)
- New TM/ETM+ surface reflectance Climate Data Record (CDR) products currently available on-demand for any WRS-2 path/row
- New TM/ETM+ surface temperature CDR products under development; will soon be available for evaluation on-demand for North America
- New OLI surface reflectance CDR in development and will be made available on-demand for any WRS-2 path/row
- New OLI surface temperature CDR in development and will be made available on-demand for North America
- Surface Water Extent, Burned Area Extent Essential Climate Variable (ECV) products available soon for evaluation for CONUS and Alaska
- Snow-covered area ECV due late next year for CONUS and Alaska

# Landsat 7 Spacecraft Status

Launched 15 Apr 1999
> 14 years of on-orbit operations



**Electrical Power System**

**Batteries:**
Performance nominal

**Solar array:**
- 5/14/2002 Circuit #14 Failure
- 5/16/2005 Circuit # 6 Failure
- 8/13/2008 Circuit #14 partial recovery
- 14 circuits remain operating
- no impact to ops

**Enhanced Thematic Mapper +**
- 5/31/2003 SLC Failure
- 4/01/2007 SAM -> Bumper mode

**Attitude Control System**
- 05/05/2004 Gyro 3 Shut Off
- Single gyro control system in development

**Reaction Control System**
- 1/07/04 Fuel line #4 thermostat #1a failure
- 2/24/05 Fuel line #4 thermostat #1b failure; Primary
- Heater circuit disabled
- 4/25/13 Fuel line #2 thermostat 2a failure; Redundant
- Heater circuit disabled
- Temperature manually controlled

**Fuel - ~ 2 years**

**Solid State Recorder**
- 11/15/1999 SSR PWA #23 Loss
- 02/11/2001 SSR PWA #12 Loss
- 12/07/2005 SSR PWA #02 Loss
- 08/02/2006 SSR PWA #13 Loss
- 03/28/2008 SSR PWA #22 Loss
- 09/03/2008 SSR PWA #23 Recovered
- 10/12/2013 SSR PWA #11 Loss
- Each PWA is 4% loss of launch capacity
- Boards are likely recoverable

**X-band System**
Performance nominal

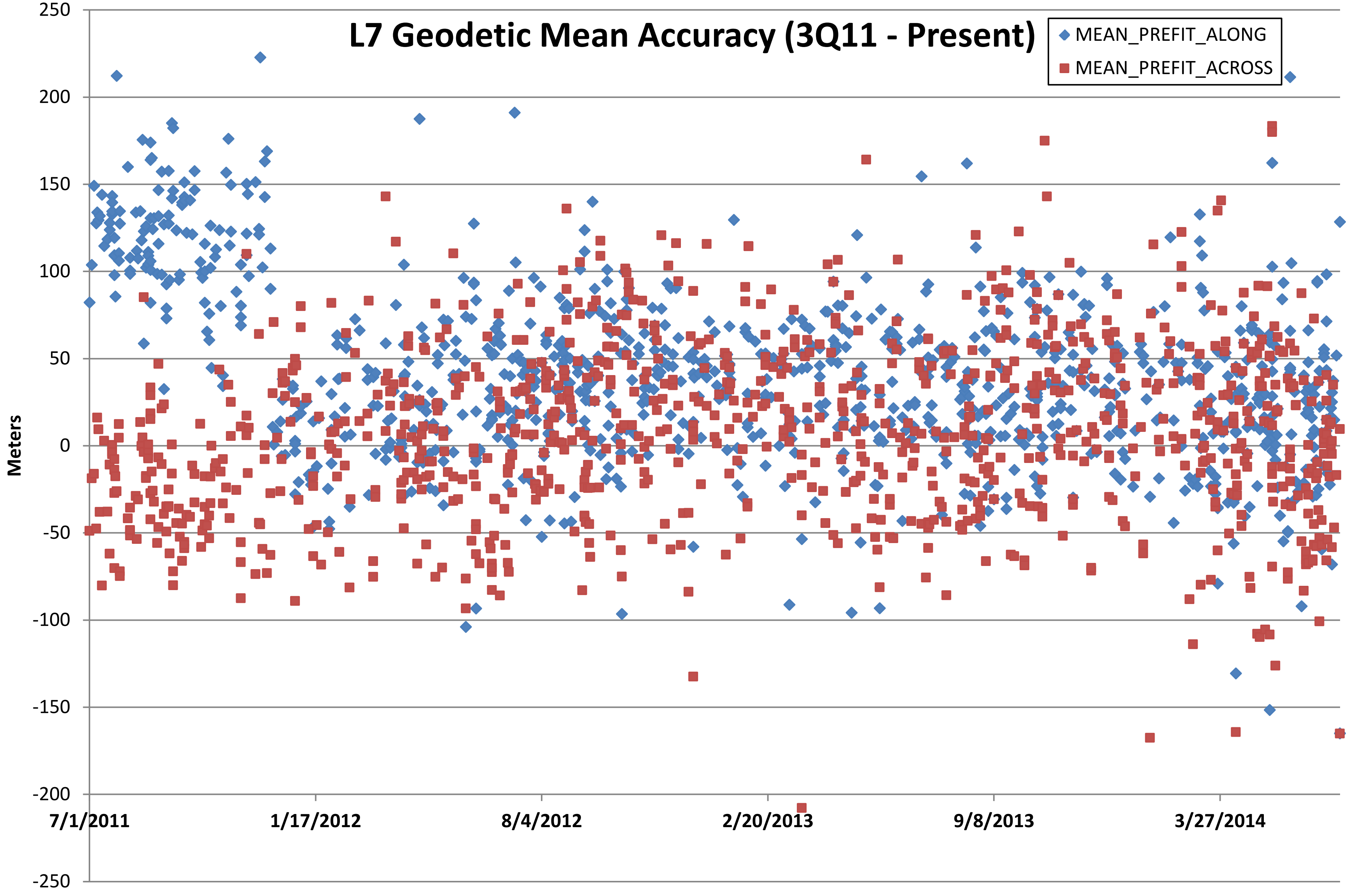
**S-band System**
Performance nominal

# L7 Geodetic Characterization

- **Sensor Alignment update issued 1Q2012 has corrected large offsets observed in 2010 and 2011**
- **Both along and across scans have remained stable since last sensor alignment update**

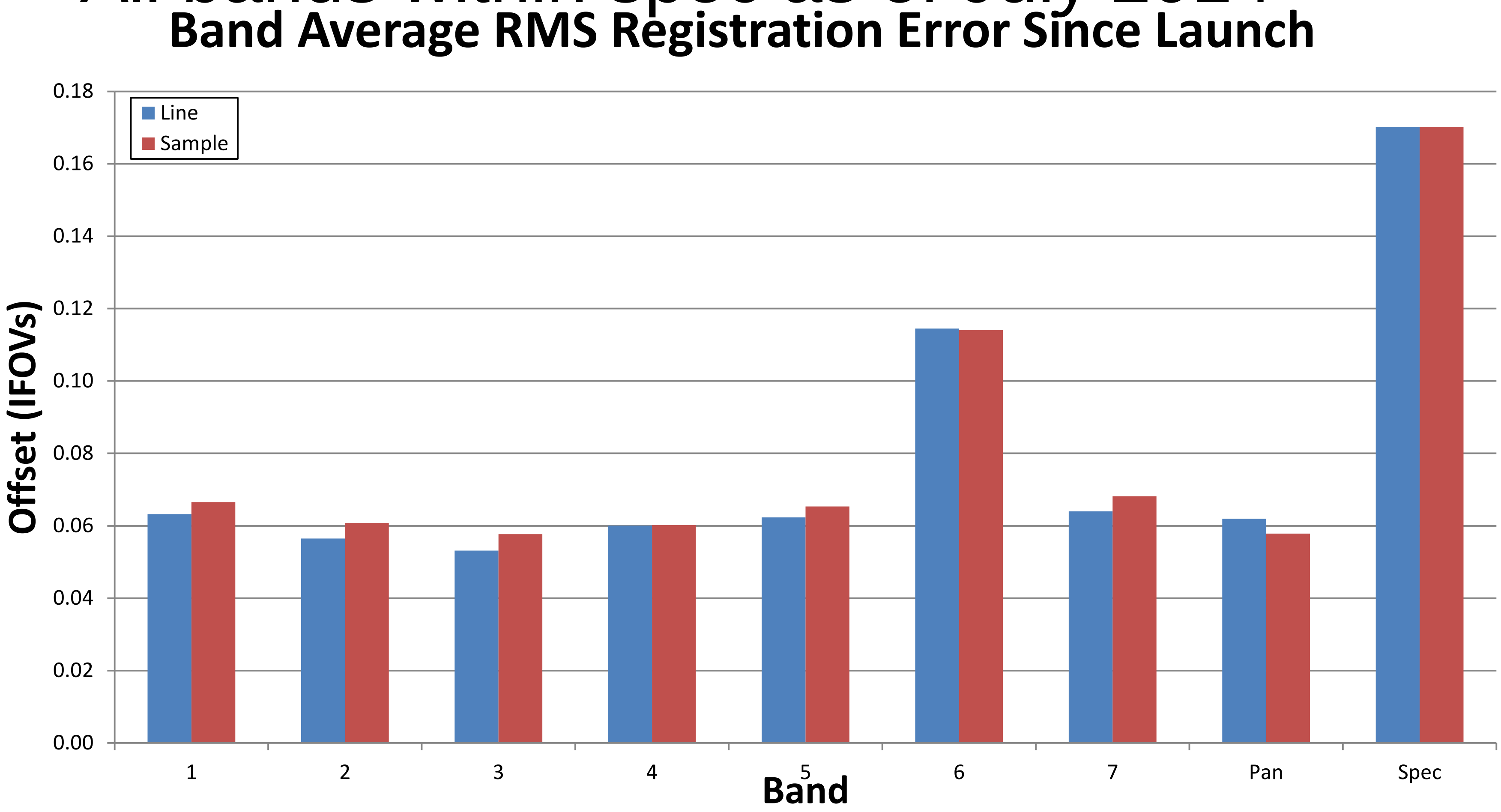
| Quarter | Along Scan Mean (m) | Across Scan Mean (m) | Along Scan RMSE (m) | Across Scan RMSE (m) |
|---|---|---|---|---|
| 2Q11 | 102.758 | -13.456 | 107.538 | 42.366 |
| 3Q11 | 123.087 | -23.747 | 126.379 | 39.406 |
| 4Q11 | 84.282 | -8.082 | 101.346 | 43.329 |
| 1Q12 | 13.782 | 6.320 | 35.402 | 48.470 |
| 2Q12 | 29.281 | -5.289 | 51.082 | 44.816 |
| 3Q12 | 36.130 | 14.949 | 53.002 | 46.594 |
| 4Q12 | 39.139 | 27.906 | 52.634 | 57.910 |
| 1Q13 | 32.158 | 23.453 | 47.287 | 52.665 |
| 2Q13 | 32.393 | 13.142 | 52.497 | 50.438 |
| 3Q13 | 30.985 | 10.871 | 49.649 | 50.911 |
| 4Q13 | 36.324 | 24.873 | 49.403 | 53.100 |
| 1Q14 | 24.651 | 16.036 | 50.260 | 59.789 |
| 2Q14 | 19.670 | -1.513 | 51.610 | 56.232 |
| 3Q14 | 5.943 | -19.739 | 68.194 | 55.001 |

# L7 Geodetic Accuracy Characterization



# L7 Band to Band Characterization

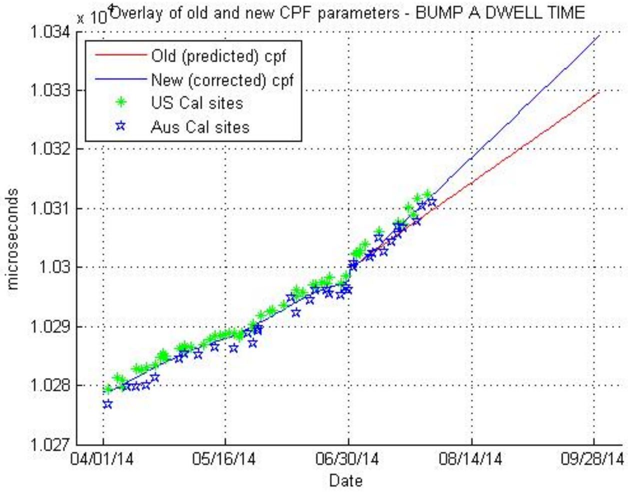
- All bands within spec as of July 2014

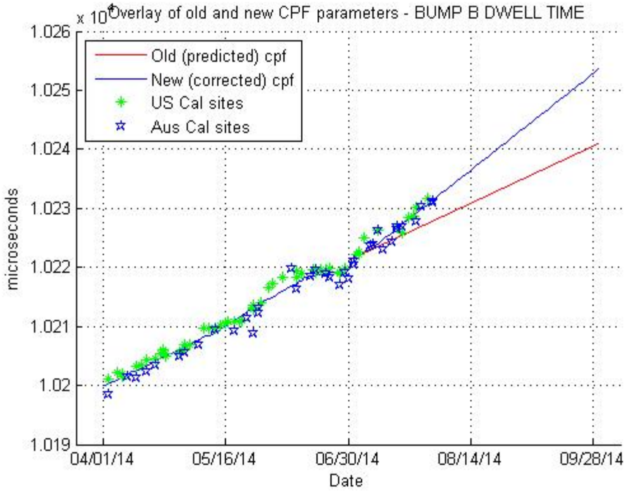


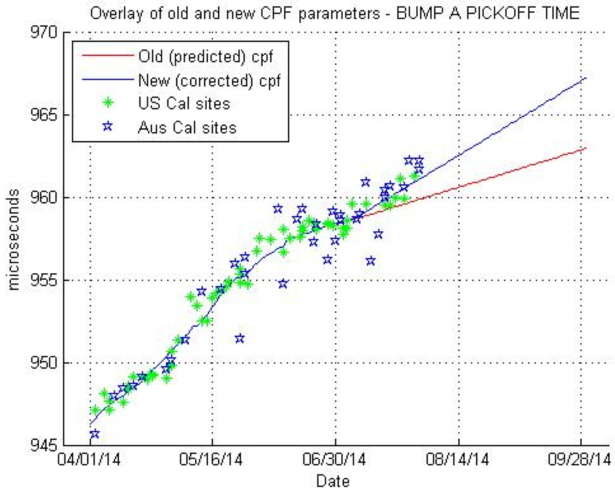
# L7 Bumper Mode Mirror Calibration

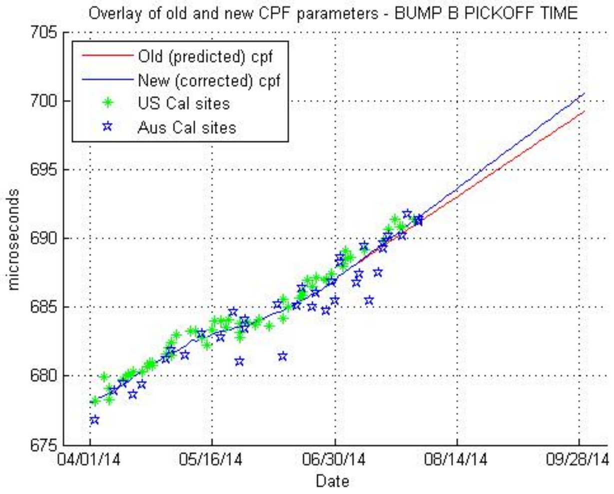
- ETM+ bumper mode parameters have remained stable since switch from SAM mode
- Both US and Australian geometric supersites are used for calibration
  - Dwell times for Australian sites trend shorter than those for US sites
- Predicted bumper mode parameter updates are issued as needed, typically every 2 weeks or 6-7 times per quarter
  - Monitoring of bumper mode parameters is constant and on-going
  - 0 updates so far this quarter (initial prediction holding)

# L7 Bumper Mode Mirror Calibration Trended Scenes as of July 31, 2014

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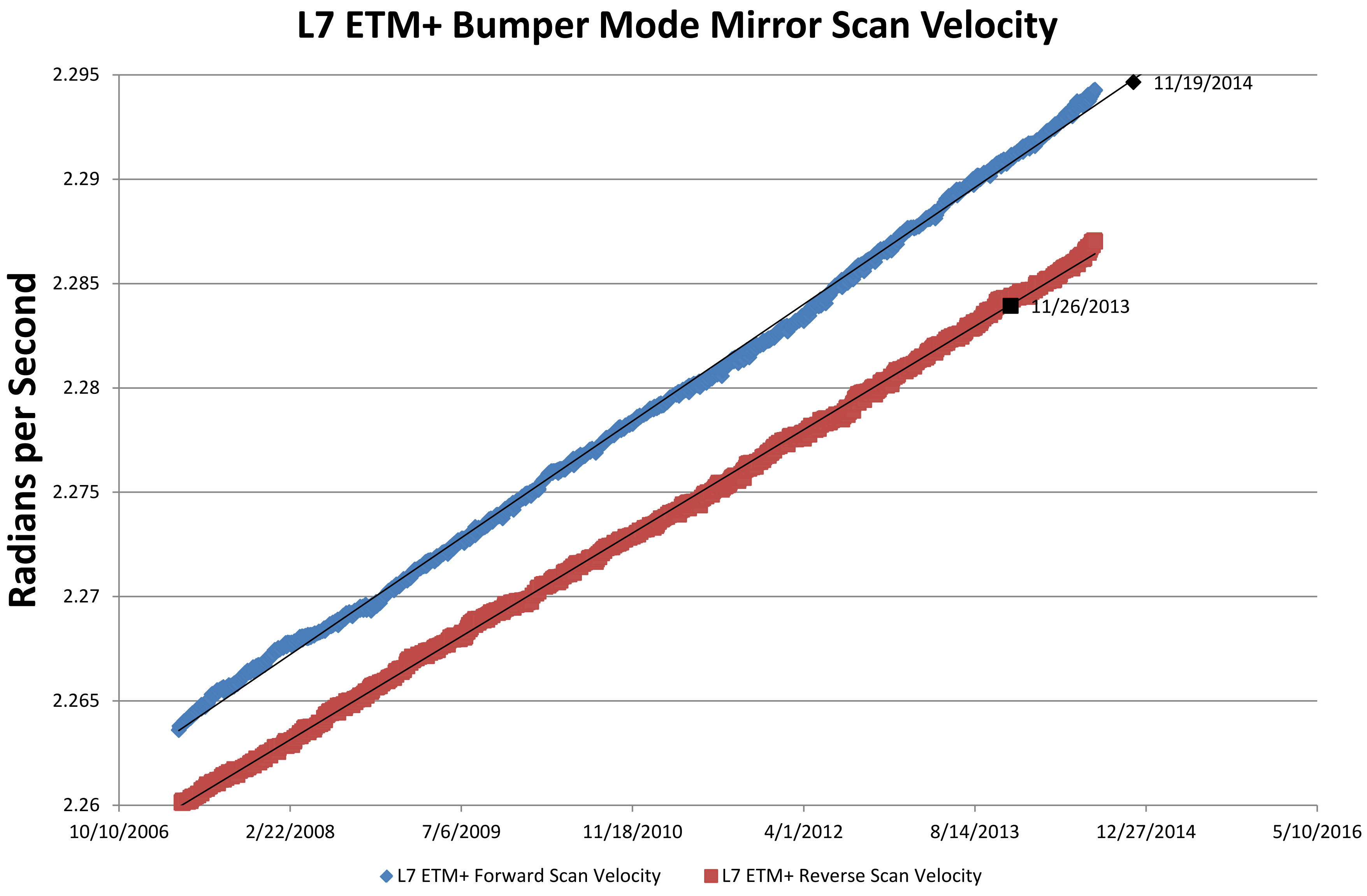
# L7 Bumper Mode Mirror Calibration

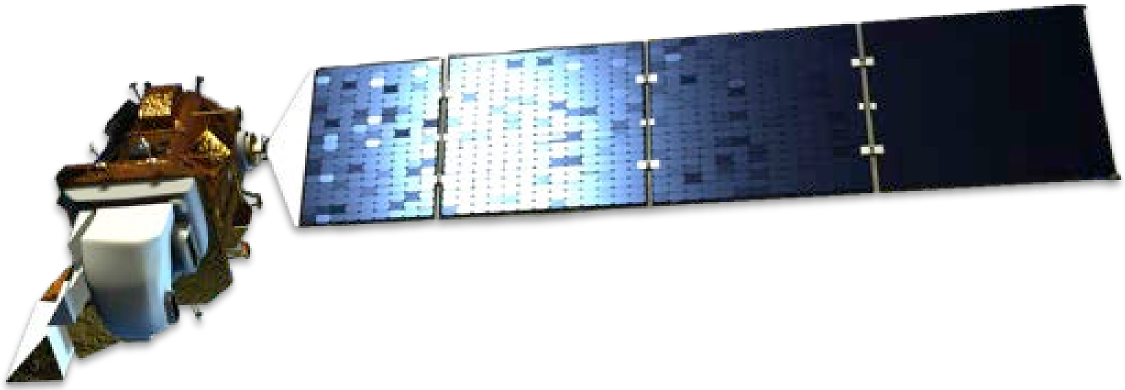


# Landsat 8 Spacecraft

**COMMUNICATIONS**
- *S-band to LGN: 1, 32kbps uplink: and 2k,16k, 32k, or 1 Mbps downlink*
- *Omni antennas*
- *TDRSS - SA: 1 kbps return and 2 or 32 Kbps forward*
- *X-band: 384 Mbps science data*

**THERMAL CONTROL**
- *Passive with heaters*
- *Constant conductance heat pipes*

**STRUCTURE**
- *Aluminum primary structure*
- *Externally mounted components*
- *Clear instrument FOVs*
- *Clear instrument radiative paths*



**PROPULSION**
- *Hydrazine blow-down propulsion module*
- *Eight 22N Redundant Thrusters*

**GUIDANCE, NAVIGATION & CONTROL**
- *1 of 2 star trackers active*
- *High precision IRU*
- *Honeywell reaction wheels*
- *SADA with damper*
- *3-axis stabilized*
- *Zero momentum biased*

**ELECTRICAL POWER**
- *Single wing single axis articulated Gallium Arsenide (GaAs) solar array provides 4300 W at EOL*
- *125 amp-hour Nickel hydrogen $NiH_2$ battery*
- *Unregulated 22 V - 36 V power bus*
- *Two power distribution boxes*

**COMMAND & DATA HANDLING**
- *cPCI architecture; RAD750 CPU*
- *4.0 Tbit (BOL) 3.1 Tbit (EOL) solid state recorder*
- *265 Mbps peak OLI data transfer*
- *26.2 Mbps peak TIRS data transfer*
- *High rate PB at 384 Mbps*

All systems working

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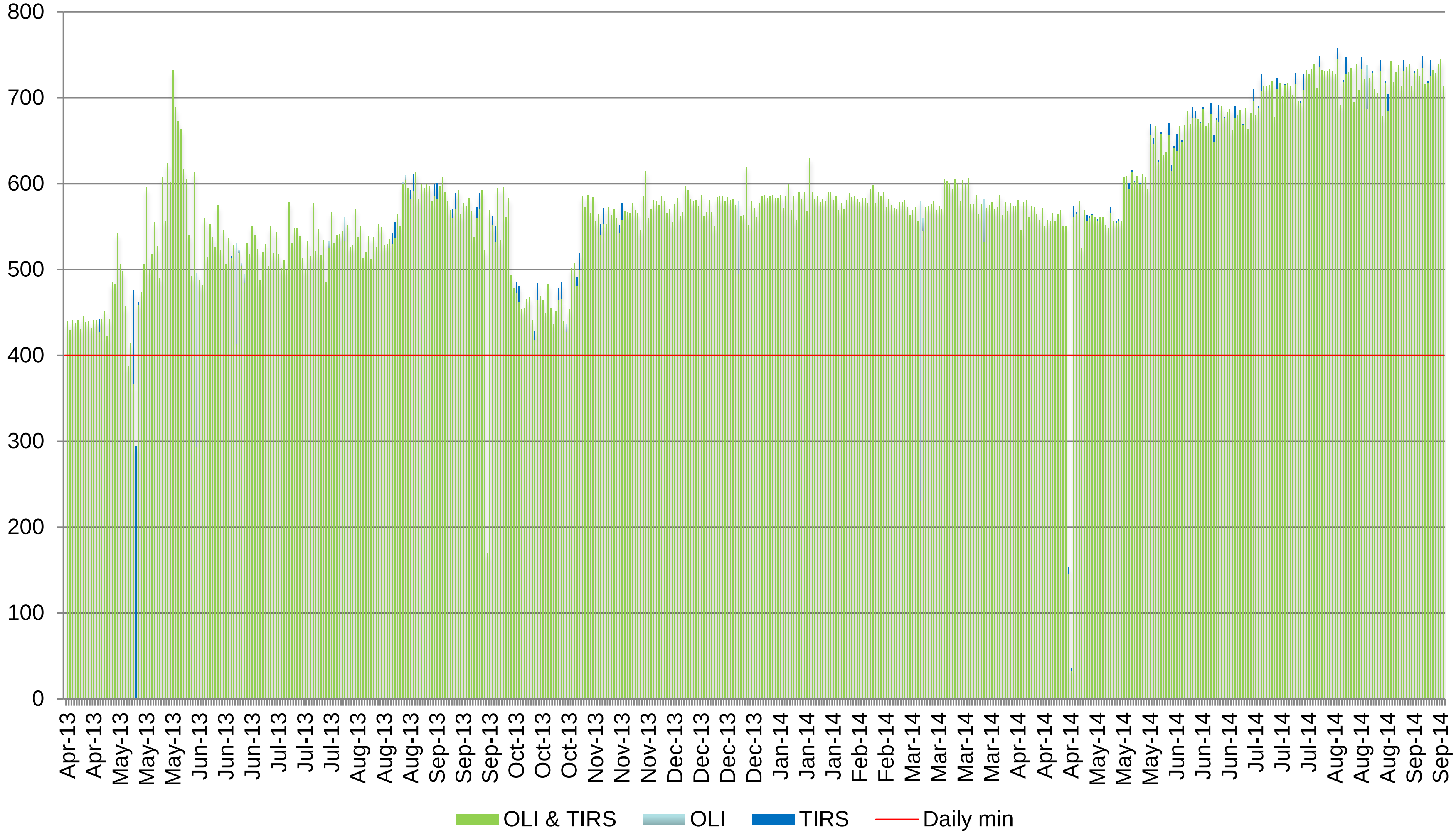
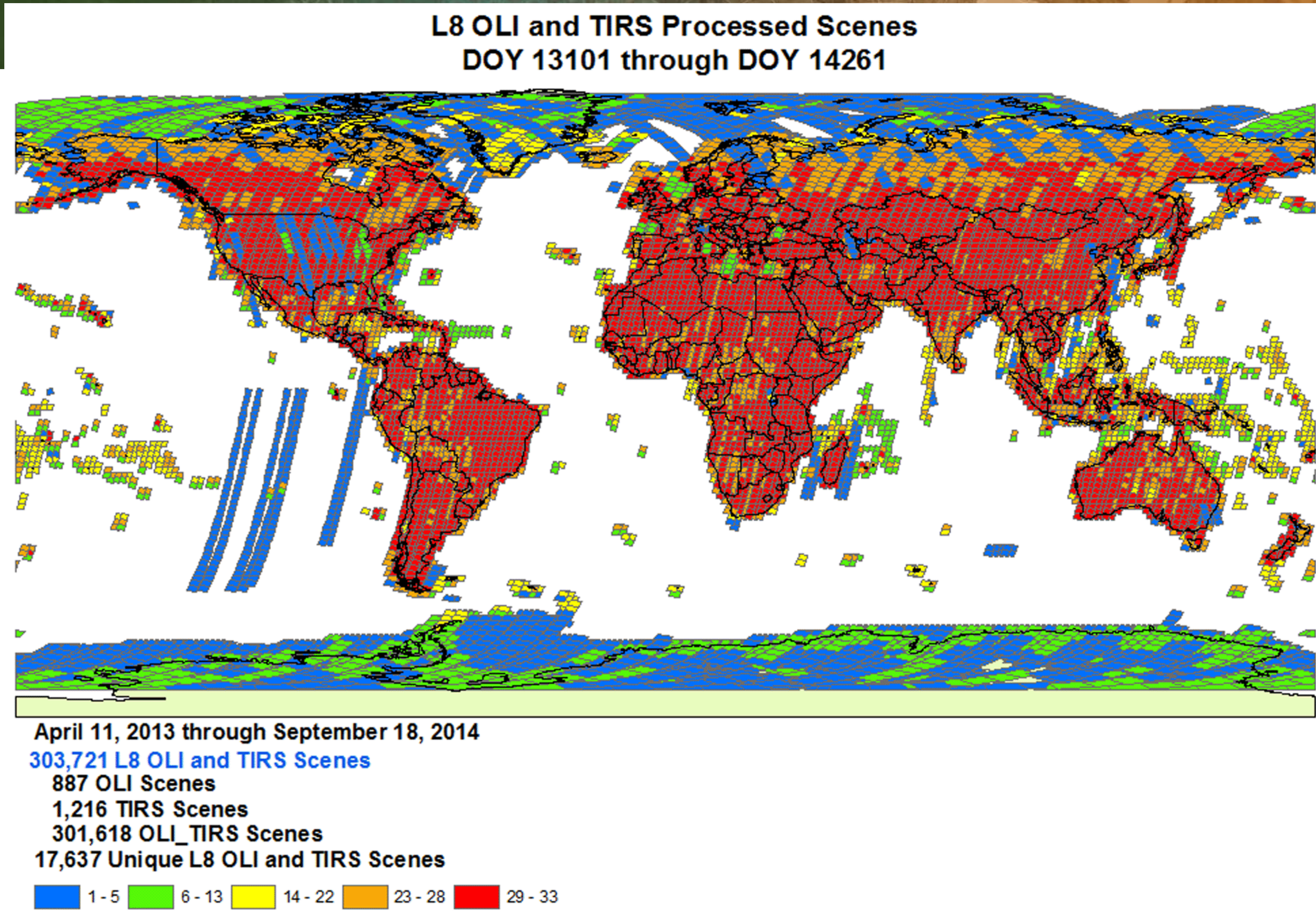
# Landsat 8 Scenes Acquired per day



# L8 OLI TIRS processed scences



# New Landsat 8 Capabilities

Spectral band improvements

- Landsat 7 has 8 spectral bands (3 VIS, 1 NIR, 2 SWIR, 1 TIR, and pan band)
- Landsat 8 has 11 spectral bands (4 VIS, 1 NIR, 3 SWIR, 2 TIR, and a pan band)
  - New VIS “coastal aerosol” band allows detection of water column constituents (e.g., chlorophyll, suspended materials, etc.)
  - New SWIR “cirrus” band will improve overall image quality because of better cloud screening
  - Addition of a 2nd thermal band will improve the accuracy and precision of temperature measurements. Note, however, that TIR resolution decreases from 60m to 100m.
  - Changes in panchromatic band spectral range will increase the overall use of this band for image sharpening and other applications.

Detection, quantification, and mapping of surface (land and water) characteristics will improve because of:

- 5x improvement of signal-to-noise ratios of spectral measurements
- 12 bit quantization of spectral signals (Landsat 7 was 8 bit)

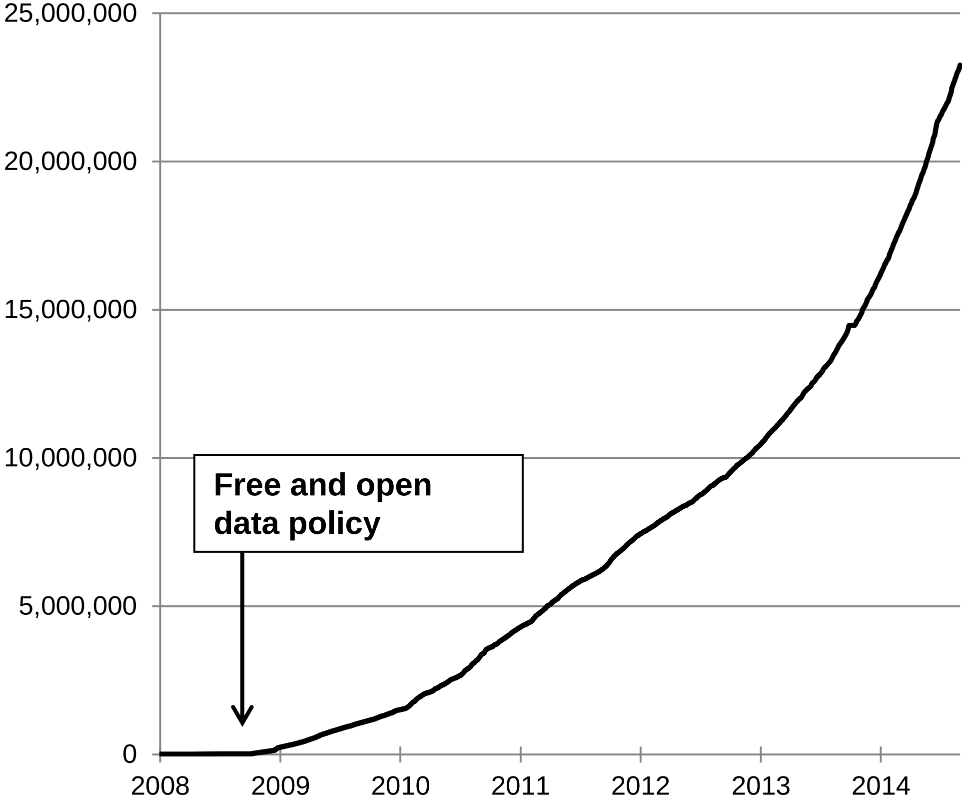
# Users and uses are rapidly increasing

Before the free data policy, the USGS distributed approx. 20,000 Landsat scenes/year. In the last 6 months alone (Mar-Aug 2014), the USGS distributed over 5 million Landsat scenes; the rate of downloads is still increasing.

The free data policy is relatively new, but Landsat is already critical to many operational applications.

- Landsat ranked 3rd "most critical" of 362 observing systems in the National Plan for Civil Earth Observations largely because it's relied on in almost every societal benefit area. [1]

**Landsat Scenes Downloaded from USGS EROS Center[2] (Cumulative)**




[1] OSTP 2014, National Plan for Civil Earth Observations

[2] Includes only downloads from the USGS EROS. (Google Earth delivers approximately 1 billion Landsat scenes to users per month.)

# Sample findings on users' needs for spectral bands and 8-day revisit

Green: Required for application
Blue: Helpful for application

| Application | Landsat Information Product | Spectral Requirements VIS | NIR | SWIR | TIR | Revisit (days) 4d | 8d | 16d | 30d |
|---|---|---|---|---|---|---|---|---|---|
| USGS/MRLC National Land Cover Database | Cover type/change | Green | Green | Green | | | | Green | |
| | % Tree cover | Green | Green | Green | | | | Green | |
| | % Impervious surface | Green | Green | Green | Green | | | Green | |
| USGS/USFS Landfire | Vegetation characteristics | Green | Green | Green | Green | | Green | | |
| | Disturbance | Green | Green | Green | Green | | Green | | |
| USGS/USFS Burned Area Emergency Resp. | Burn severity maps (dNDVI, dNBR) | Green | Green | Green | | Blue | Green | | |
| UN FAO Global Forest Resources Assess. | Forest change maps | Green | Green | Green | | | | Green | |
| Foreign Agricultural Service (FAS) | Crop area | Green | Green | Green | | | Green | | |
| | Crop production | Green | Green | Green | | | Green | | |
| | Crop health | Green | Green | Green | | | Green | | |
| USDA National Agricultural Statistics Service | National cropland data layer (crop type) | Green | Green | Green | | | Green | | |
| USDA Risk Management - Crop Insurance | Verify crop insurance/damage claims | Green | Green | Green | | | Green | | |
| Western States Evapotranspiration | Land surface temperature | | | | Green | Blue | | Green | |
| | Surface reflectance | Green | Green | Green | | | Green | | |
| | NDVI | Green | Green | | | | Green | | |
| | Cloud/shadow mask | Green | Blue | | Green | | Green | | |
| USDA Ag. Research - Tillage/crop residue | Tillage/Crop residue | | Green | Green | | | Green | | |
| Landsat Image Mosaic of Antarctica (LIMA) | Ice sheet features | | Green | | | | Blue | | Green |
| Minnesota Lake Clarity Monitoring | Water clarity | Green | | | | Blue | Green | | |
| USFS Forest Management | Terrestrial Ecological Unit Inventory | Green | Green | Green | | | Green | | |
| | Mid-level Vegetation Classification | Green | Green | Green | | | Green | | |
| | National insect disease risk map (NIDRM) | Green | Green | Green | | Blue | Green | | |
| | Post-storm damage assessments | Green | Green | Green | | Green | | | |
| | Rapid Assessment of Vegetation (RAVG | Green | Green | Green | | Green | | | |
| MDA/NGA Land Change | Correlated land change (new construction) | Green | Green | Green | Blue | | Blue | Blue | Green |
| Ohio Agricultural Tax Verification | NDVI (to establish presence of crops) | Green | Green | | | | Blue | Green | |
| USGS Volcano monitoring | At-sensor radiance (plumes, minerals) | Green | Green | Green | Green | | Blue | Green | |
| | Surface temperature | | | | Green | | Blue | Green | |
| USGS Flood monitoring | At-sensor radiance (flooded area) | Green | Green | Green | Green | | Green | | |
| USGS Landsat science products (Essential Climate Variables) | Surface reflectance | Green | Green | Green | | | Green | | |
| | Surface temperature | | | | Green | | Green | | |
| | Land Cover / Surface Water | Green | Green | Green | Green | | | Green | |
| | Leaf Area Index/fPAR | Green | Green | Green | | | Green | | |

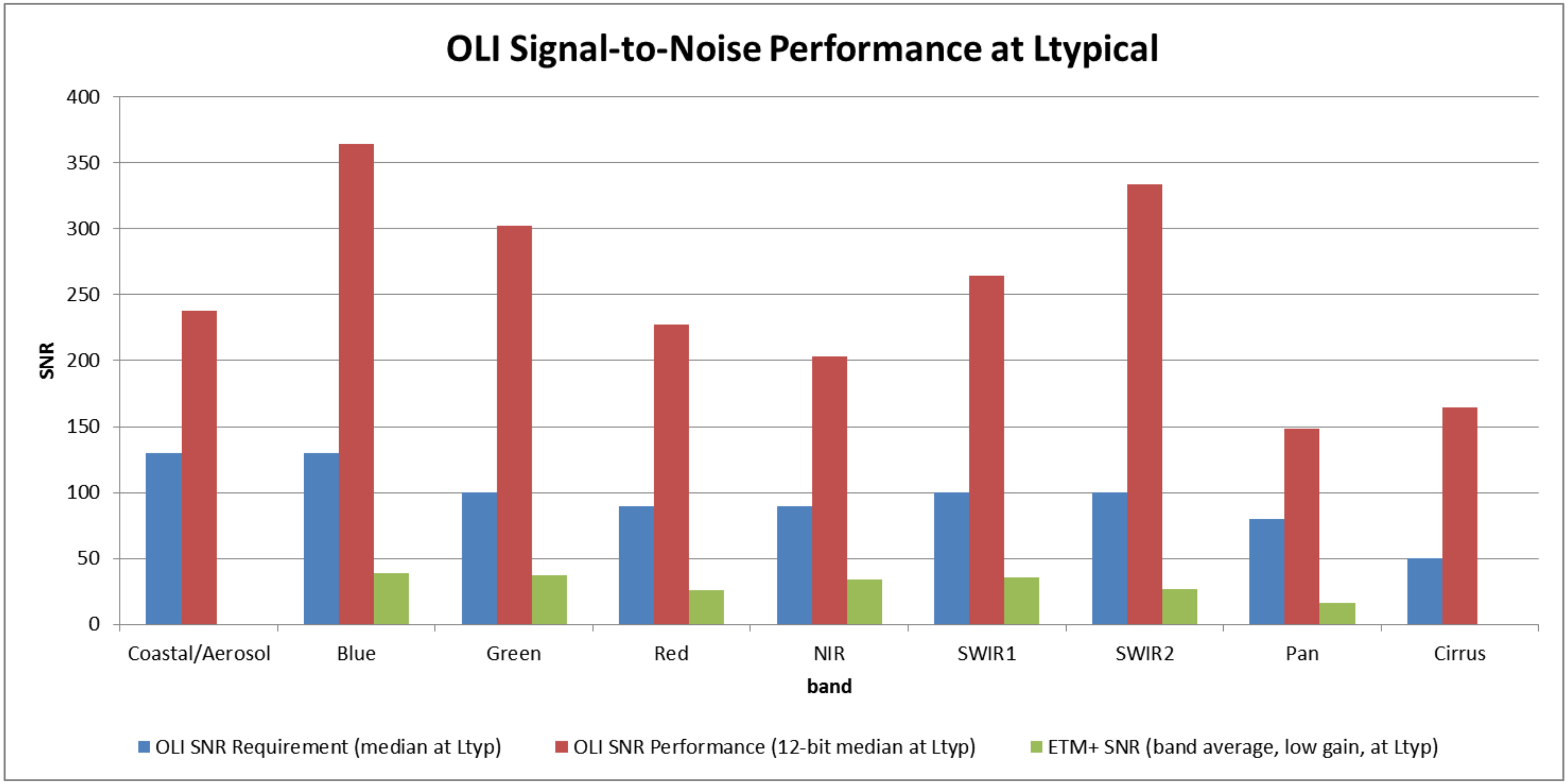
# L-8 OLI Overview

- Pushbroom sensor with eight 30m spectral bands and one 15m panchromatic band
- 6916 detectors per 30m band, distributed over 14 staggered SCAs
- Total: 69160 operational detectors (to characterize)
- Acquires data with 14 bits of radiometric precision, but only 12 bits are sent to the ground systems
  - For normal Earth images – upper 12 bits
  - For dark shutter collects – lower 12 bits
- The ground processing system converts all input data to the equivalent 14 bits
  - The output (L1T product) is in 16 bits precision
- Processing and characterization data are stored to the database for consequent assessment

# L-8 OLI On-orbit Performance Summary

- OLI maintains high SNR, well above requirements
- Noise sources are generally low and do not significantly impact the product quality
- Bias is stable, which helps maintain uniformity
- Impulse noise behaves as expected with a negligible impact on Landsat products
- Saturation and oversaturation do happen, but their occurrences are very uncommon
- Spectral crosstalk between Cirrus and SWIR 1 bands does not violate any requirements
- SCA discontinuities occasionally visible in images
  - New approaches are being developed to try to improve it
- Detector Select Anomaly resolved

# Signal-to-Noise Ratio (SNR)




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



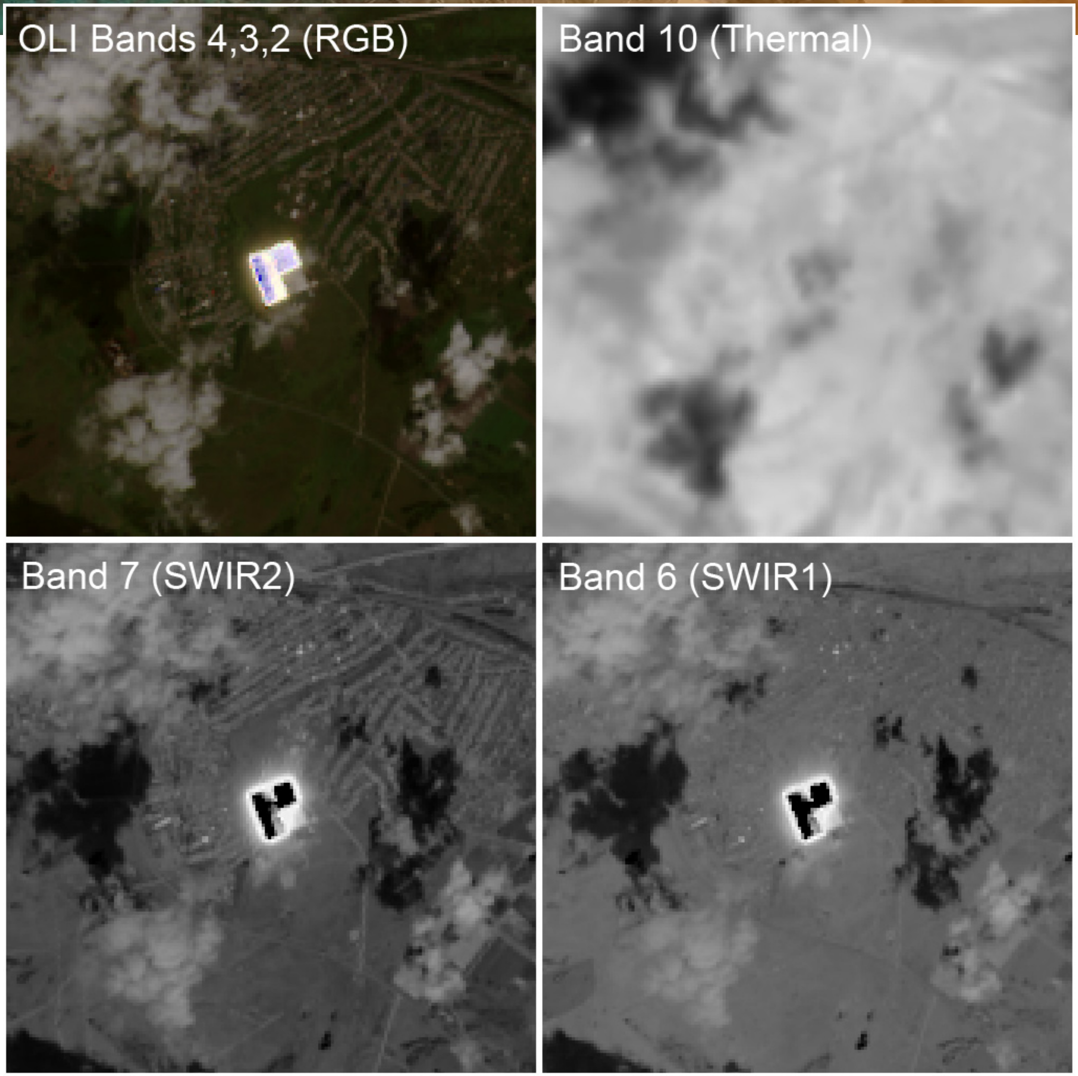
USGS/NASATSSC, Esad Micijevic, Kelly Vanderwerff, Pat Scaramuza, Ron Morfitt, Julia Barsi and Raviv Levy, 8/17/14

# Dynamic Range

- With 12 bits dynamic range, OLI is designed to measure all Earth Lambertian targets without saturation
- However, some specular targets (clouds, fire, volcanos, other objects under specific viewing and illumination geometry) do saturate the sensor

# Greenhouse in Novosibirsk region

- Three complexes with total area of 25 hectares, including 16, 24-hectare greenhouses
- p149r22, 2013, 234

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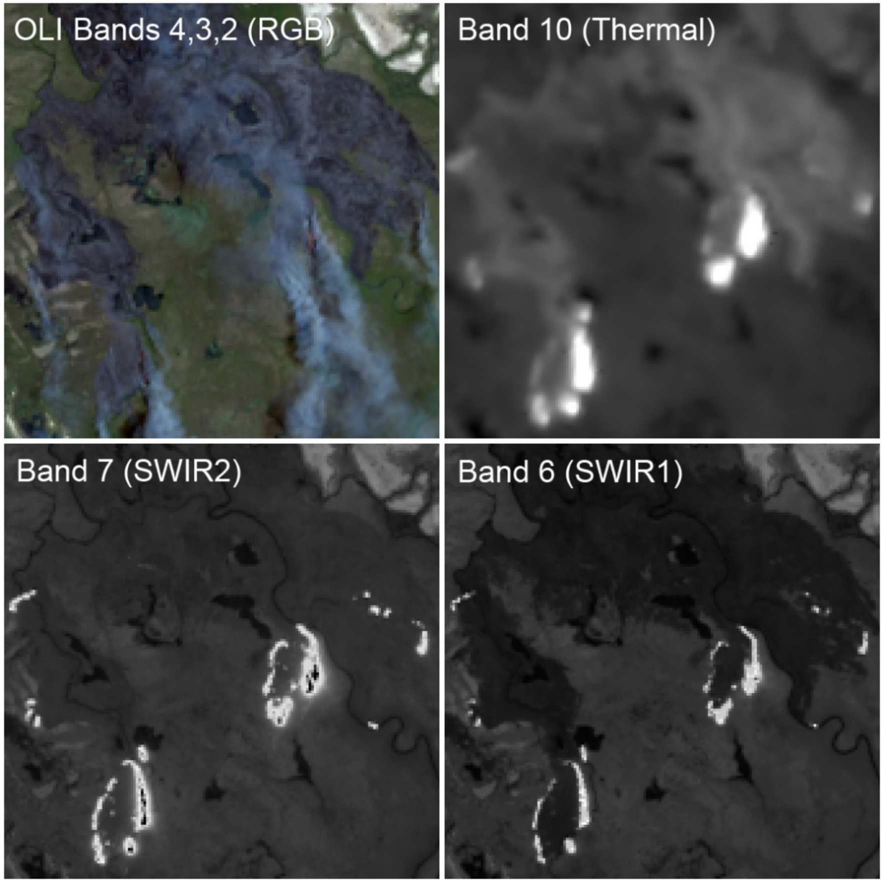
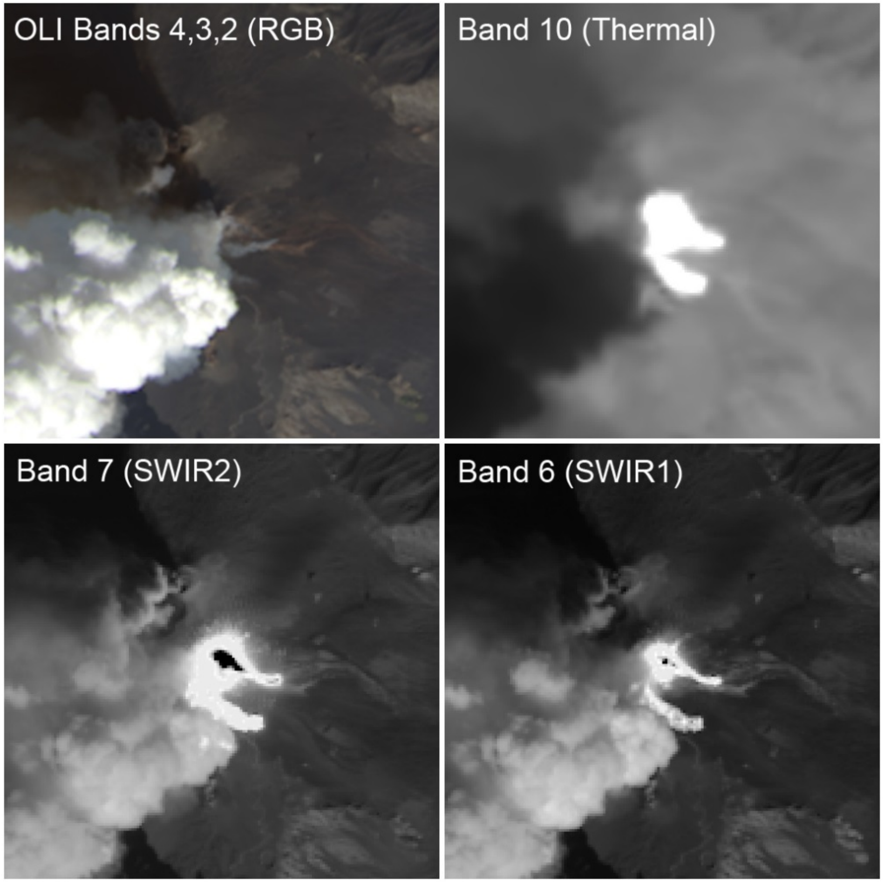
USGS/NASATSSC, Esad Micijevic, Kelly Vanderwerff, Pat Scaramuza, Ron Morfitt, Julia Barsi and Raviv Levy, 8/17/14

# More Saturation / Oversaturation

Volcano
p175r73, 2013, day 304




Fire
p188r34, 2013, day 299






USGS/NASATSSC, Esad Micijevic, Kelly Vanderwerff, Pat Scaramuza,
Ron Morfitt, Julia Barsi and Raviv Levy, 8/17/14

# L8 Geometric Performance Summary

- Landsat 8 on-orbit geometric performance is excellent and meets all requirements

| Requirement | Measured Value | Required Value | Units | Margin |
|---|---|---|---|---|
| OLI Swath | 190.2 | >185 | kilometers | 2.8% |
| OLI MS Ground Sample Distance | 29.934 | <30 | meters | 0.2% |
| OLI Pan Ground Sample Distance | 14.932 | <15 | meters | 0.5% |
| OLI Band Registration Accuracy (all bands) | 4.07 | <4.5 | meters (LE90) | 9.6% |
| OLI Band Registration Accuracy (no cirrus) | 3.31 | <4.5 | meters (LE90) | 26.4% |
| Absolute Geodetic Accuracy | 34.9 | <65 | meters (CE90) | 46.3% |
| Relative Geodetic Accuracy | 20.1 | <25 | meters (CE90) | 19.6% |
| Geometric (L1T) Accuracy | 11.0 | <12 | meters (CE90) | 8.3% |
| OLI Edge Slope | 0.03070 | >0.027 | 1/meters | 13.7% |
| TIRS Swath | 185.9 | >185 | kilometers | 0.5% |
| TIRS Ground Sample Distance | 103.424 | <120 | meters | 13.8% |
| TIRS Band Registration Accuracy | 8.3 | <18 | meters (LE90) | 53.9% |
| TIRS-to-OLI Registration Accuracy | 19.5 | <30 | meters (LE90) | 35.0% |

# On-Orbit Calibration Updates

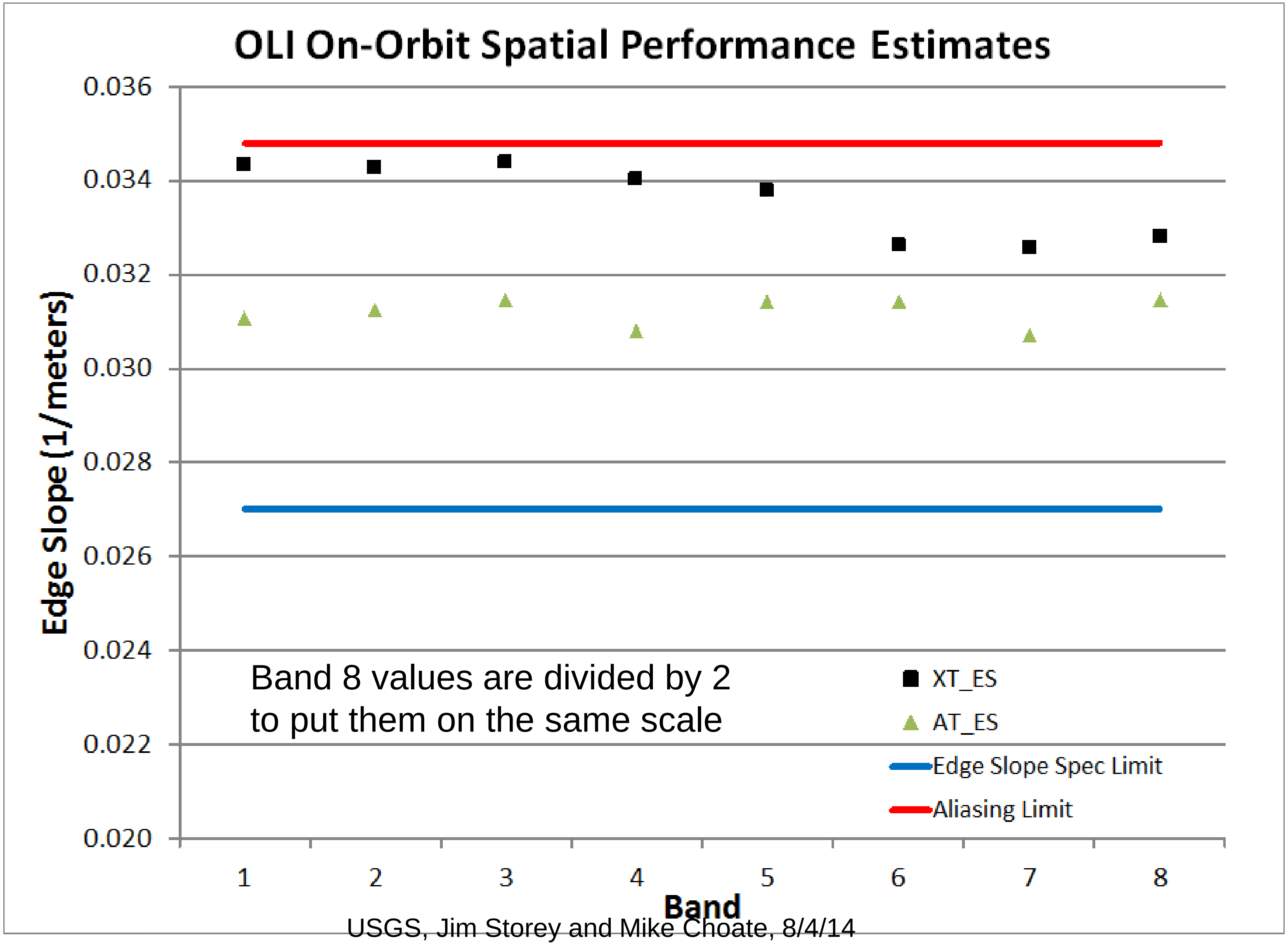
- Initial on-orbit geometric cal was performed during commissioning
- Several additional on-orbit calibration updates have been issued since the end of commissioning
  - All are minor and none involve internal image geometry

| Calibration Parameter | Date of Update | Effective Date | Magnitude | Reason for Update |
|---|---|---|---|---|
| OLI-to-S/C Alignment | 07/01/2013 | Launch | 17 μrad (pitch) | Analysis of additional data from WRS-2 orbit |
| Ground Control Thresholds | 08/21/2013 | Launch | 100 m -> 200 m | Allow scenes with GLS control errors > 100m to process to L1T |
| TIRS-to-OLI Alignment | 09/27/2013 | 09/21/2013 – 09/30/2013 | 25 μrad (pitch) | Step change following late-September spacecraft anomaly |
| TIRS-to-OLI Alignment | 11/27/2013 | 10/01/2013 - | 10 μrad (pitch) | Account for recovery of TIRS alignment following anomaly |
| TIRS-to-OLI Alignment | 11/27/2013 | 04/01/2013 - 09/20/2013 | 12 μrad (pitch) | Improve accuracy for period from arrival in WRS-2 orbit to spacecraft anomaly |
| OLI-to-S/C Alignment | 02/03/2013 | 10/01/2013 - | 13 μrad (roll) | Account for seasonal drift in alignment of both instruments to the spacecraft |

# Geometric Accuracy

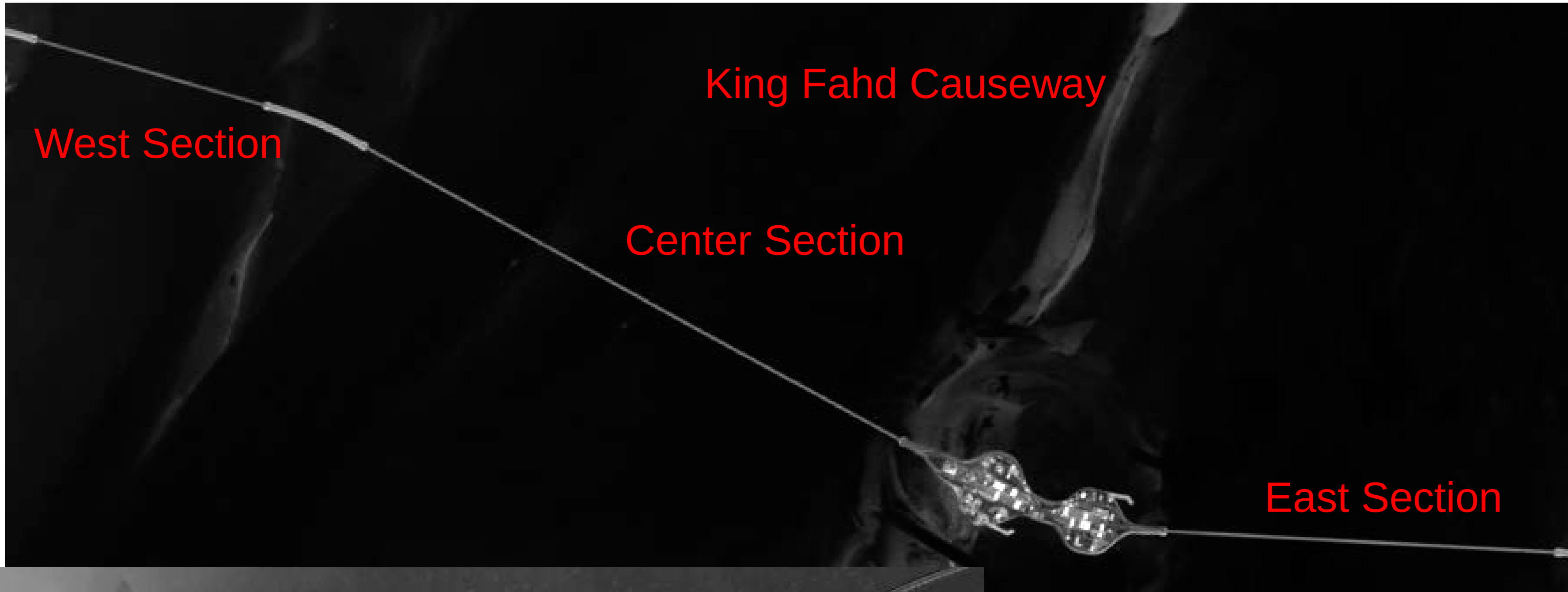
- Geometric (Level 1T product) accuracy is evaluated by measuring the accuracy of L1T products using independent validation GCPs
  - Sites with sufficient GCPs have a subset withheld from the precision correction process to serve as independent validation points
    - Only NGA anchor sites are used for geometric accuracy characterization
- OLI Geometric Accuracy using data acquired since last MMO
- Based upon 75 cal site scenes (DOQ control):
  - L1T Accuracy: 6.7 meters CE90
- Based upon 2678 anchor site scenes (GLS control):
  - L1T Accuracy: 11.0 meters CE90
  - Specification: 12.0 meters CE90

# OLI Edge Slope By Band




USGS, Jim Storey and Mike Choate, 8/4/14

# Bahrain and China Bridge Targets





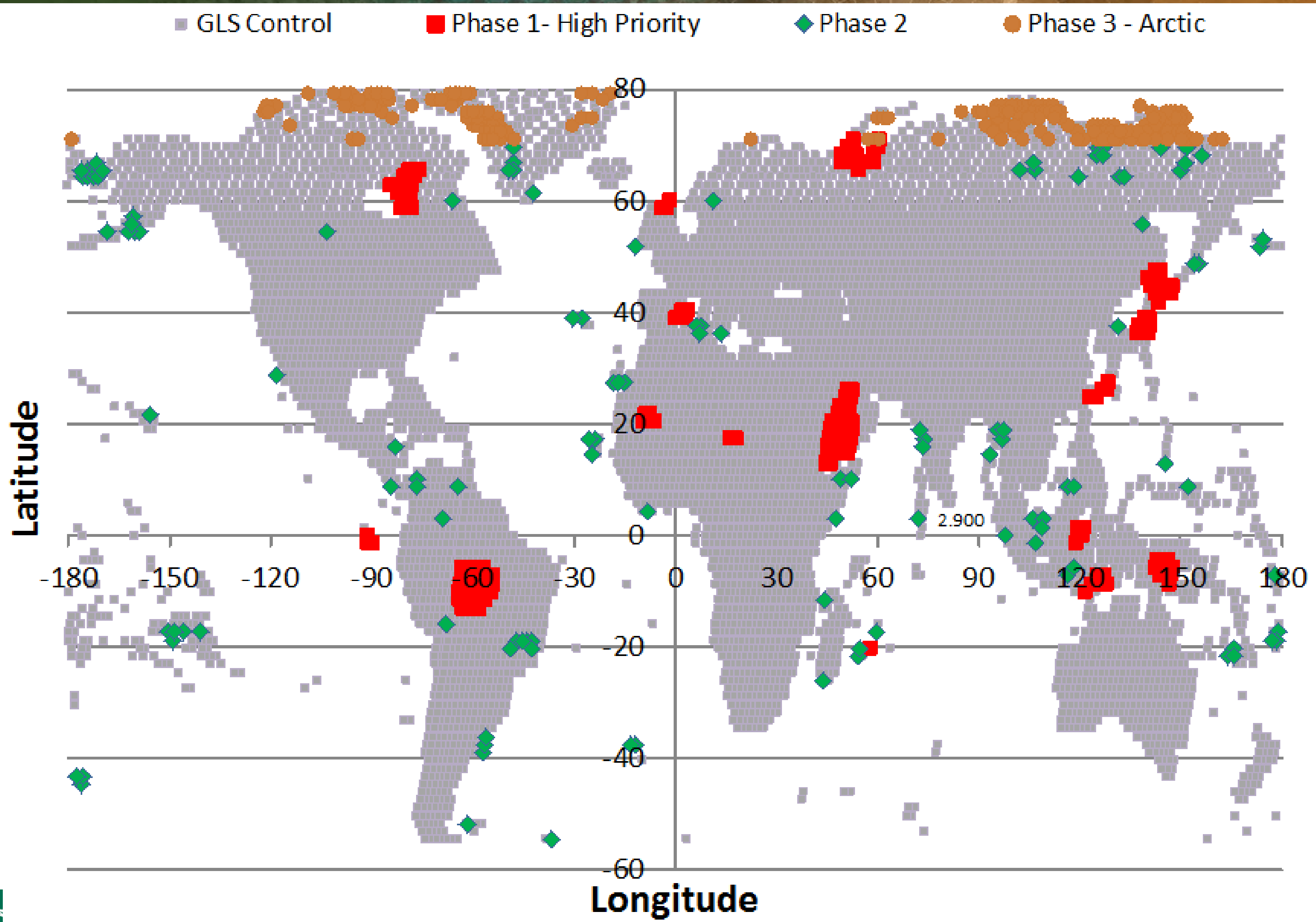
Panchromatic Band Images

Single Span Bridges

# Landsat GCP Improvement Goals

- The highly accurate absolute geolocation of Landsat 8 has allowed us to identify areas where the GLS-derived global control point library is deficient
  - This is manifested as repeatable large (tens of meters) offsets for particular WRS path/row locations
- The existing control library image chips are all Landsat 7 ETM+ (8-bit) circa 2000
  - We want to extract up-to-date 16-bit OLI chips for the GCPs in any event
- A GLS control improvement activity is now underway to upgrade the problem areas
  - Regions of poor accuracy are being re-triangulated using Landsat 8 data, while holding the surrounding area fixed to ensure that scene-to-scene consistency is maintained

# GCP Problem Area Locations




USGS, Jim Storey and Mike Choate, 8/4/14

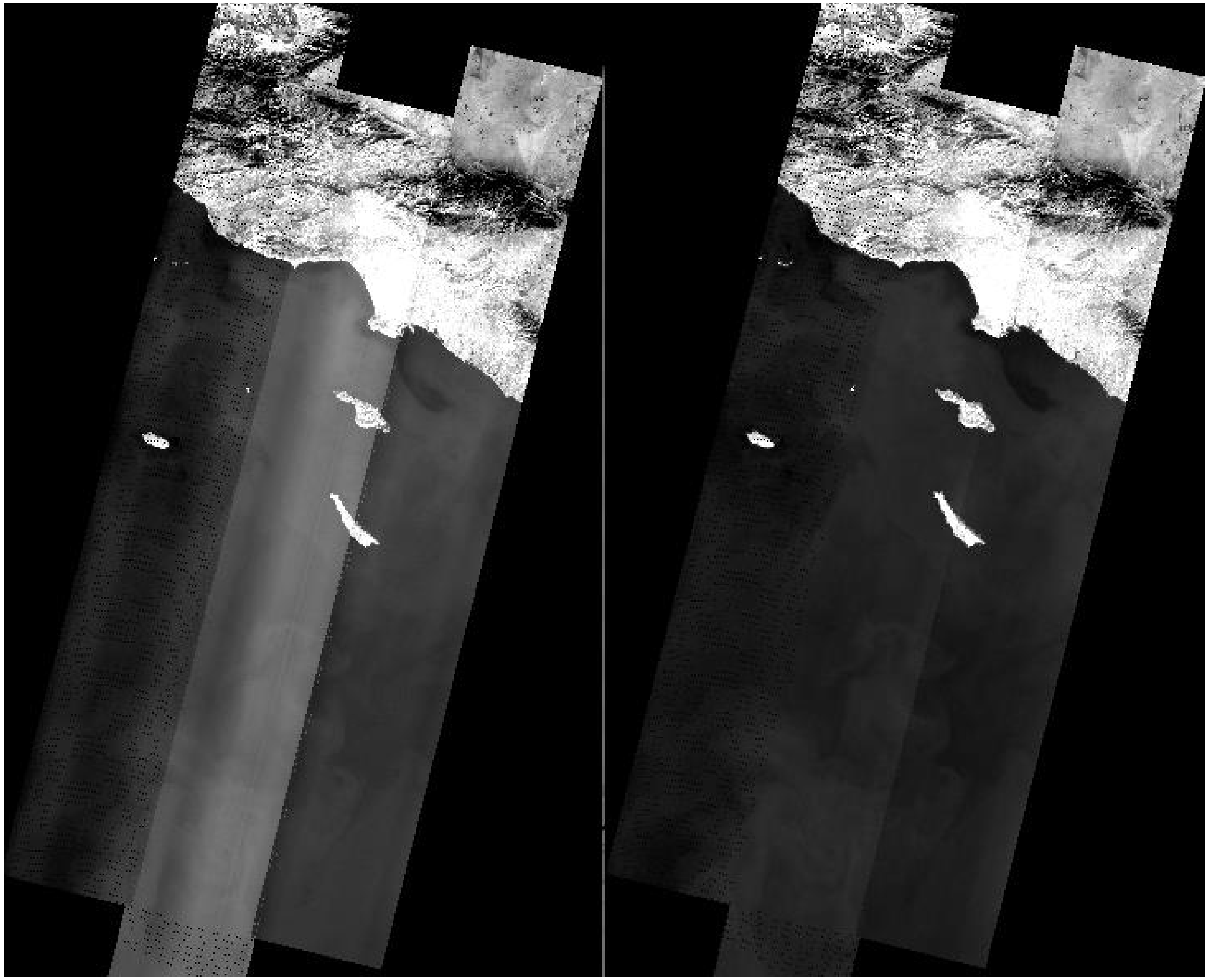
# L-8 Radiometry Summary

- Planning to update relative gains quarterly
  - Effect typically less than 0.1%
  - Worst case individual detectors about 0.4%
    - SWIR2 (2 detectors) and Cirrus bands (1 detectors)
  - Will update all quarterly CPFs with next reprocessing
- TIRS stray light improvements progressing
  - Still hoping for initial correction algorithm this Fall
- All bands continue to be stable
  - No significant change since last reported

# TIRS Stray Light Update

- Aaron (RIT) and Matt (GSFC) developed initial method
- Slow processing
  - Around 5 hours but includes home-built resampler
  - Slow IDL code
  - Not optimized
- Needs external data
  - Near-coincident GOES TOA radiance
  - Near-coincident MODIS sea surface temperature
  - Atmospheric parameters for L8 overflight time
- Results promising
  - Reduces banding
  - Correction in right direction—still looking into absolute accuracy

# Initial Stray Light Correction



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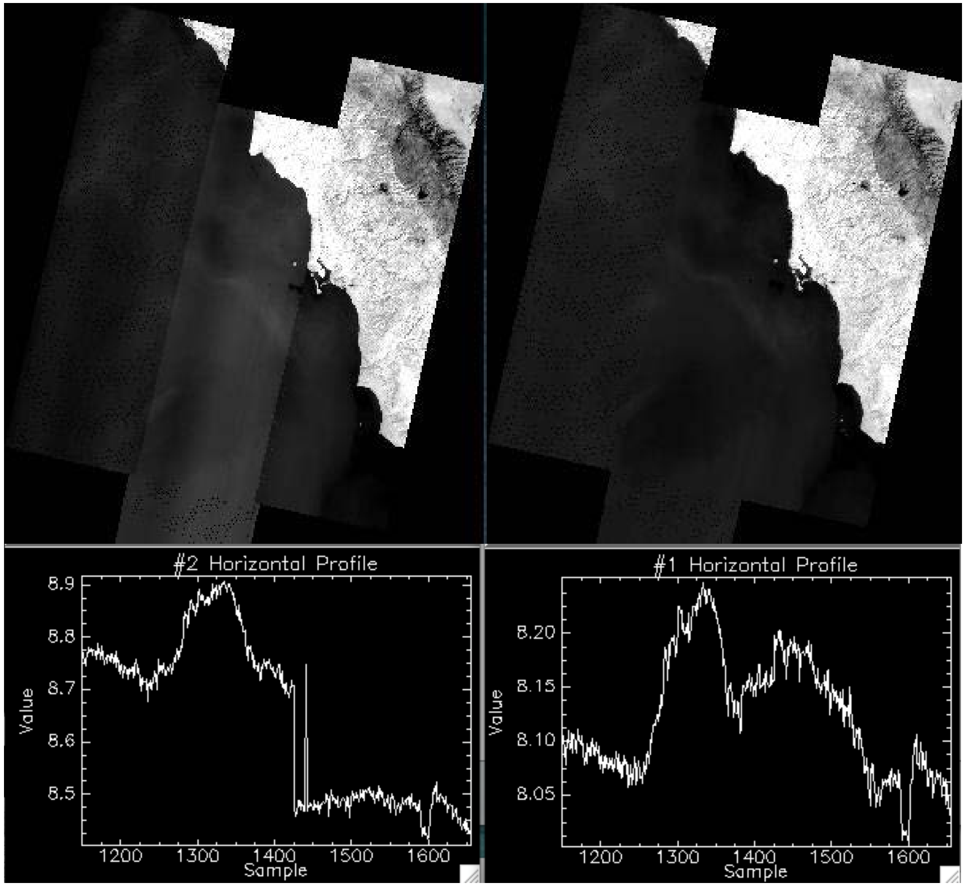

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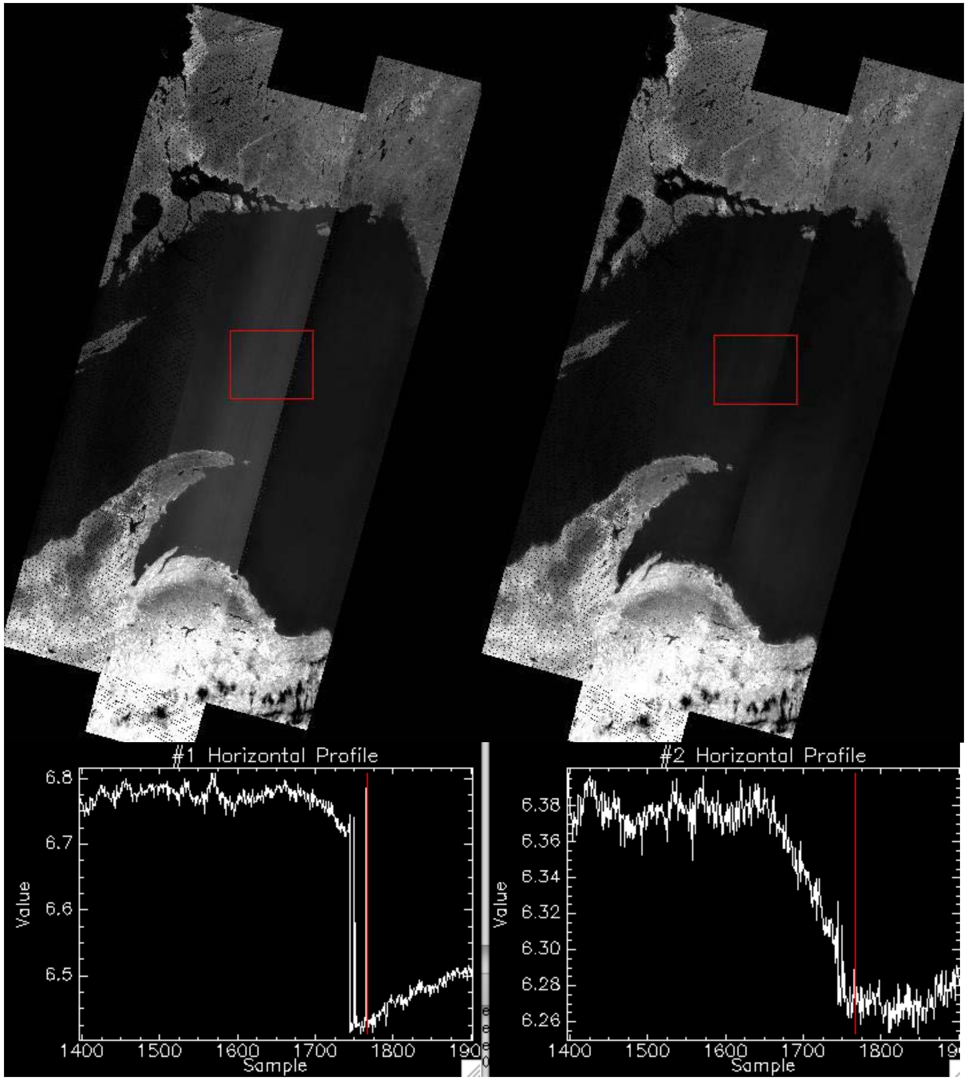
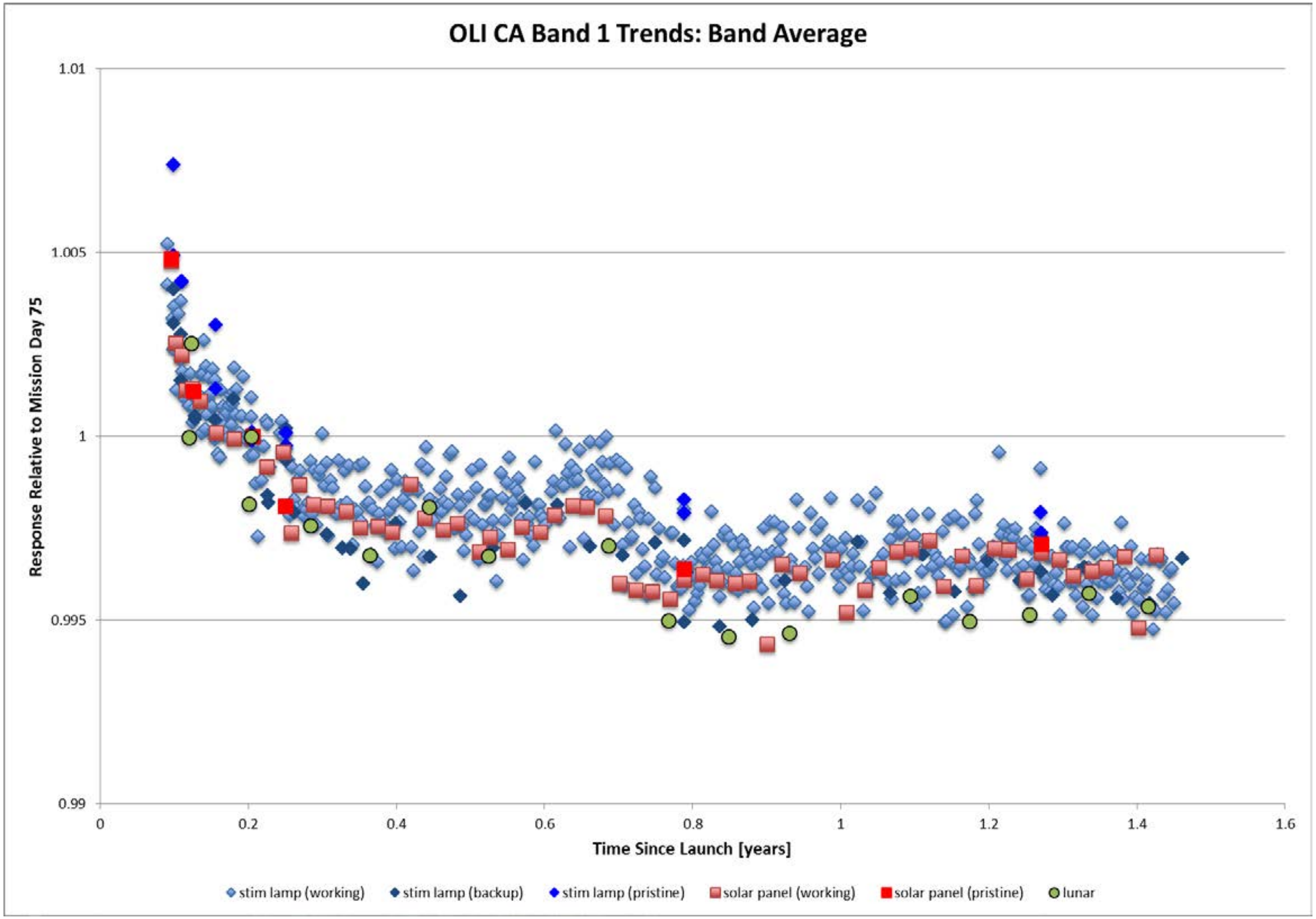
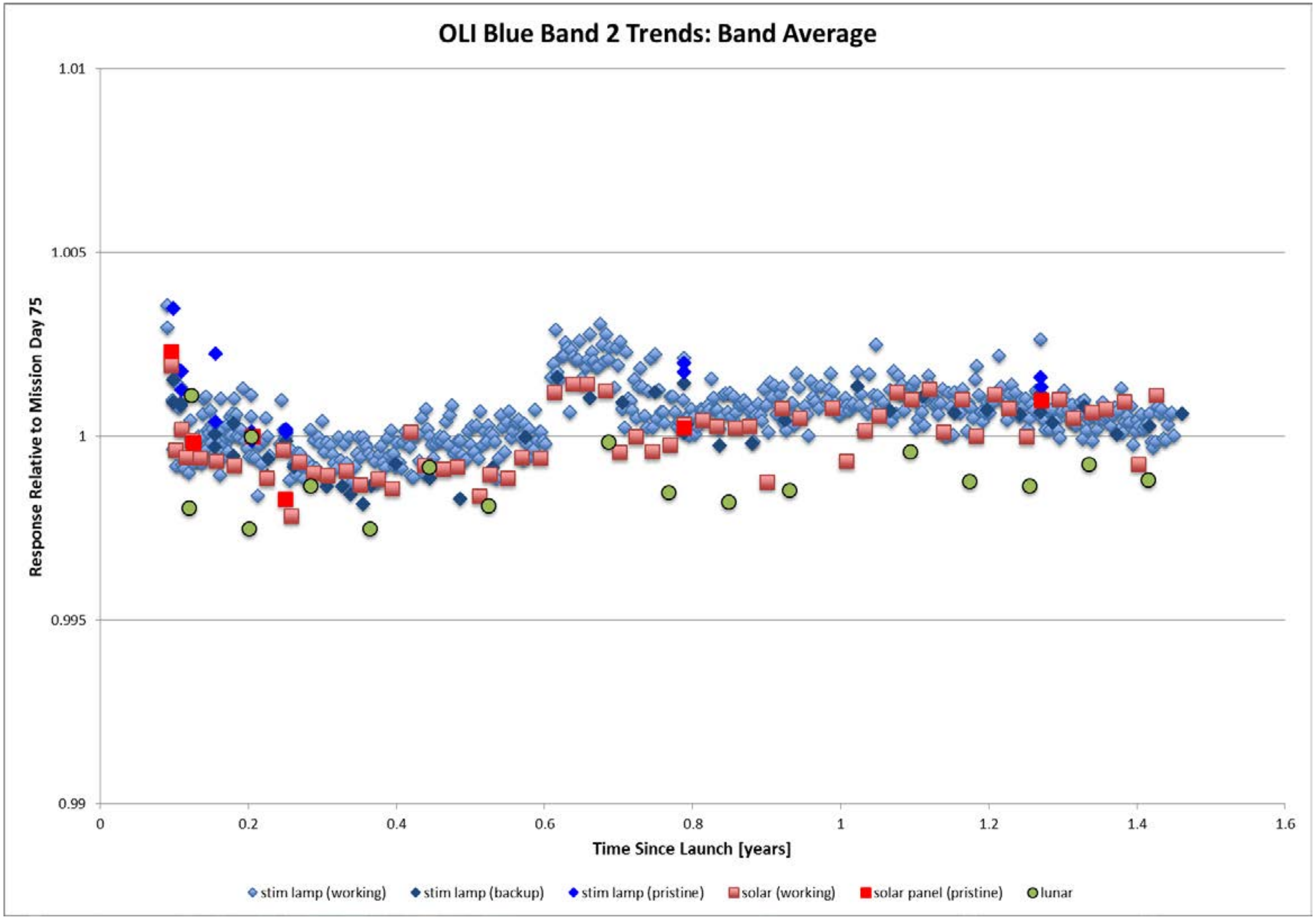



USGS

# Coastal Aerosol



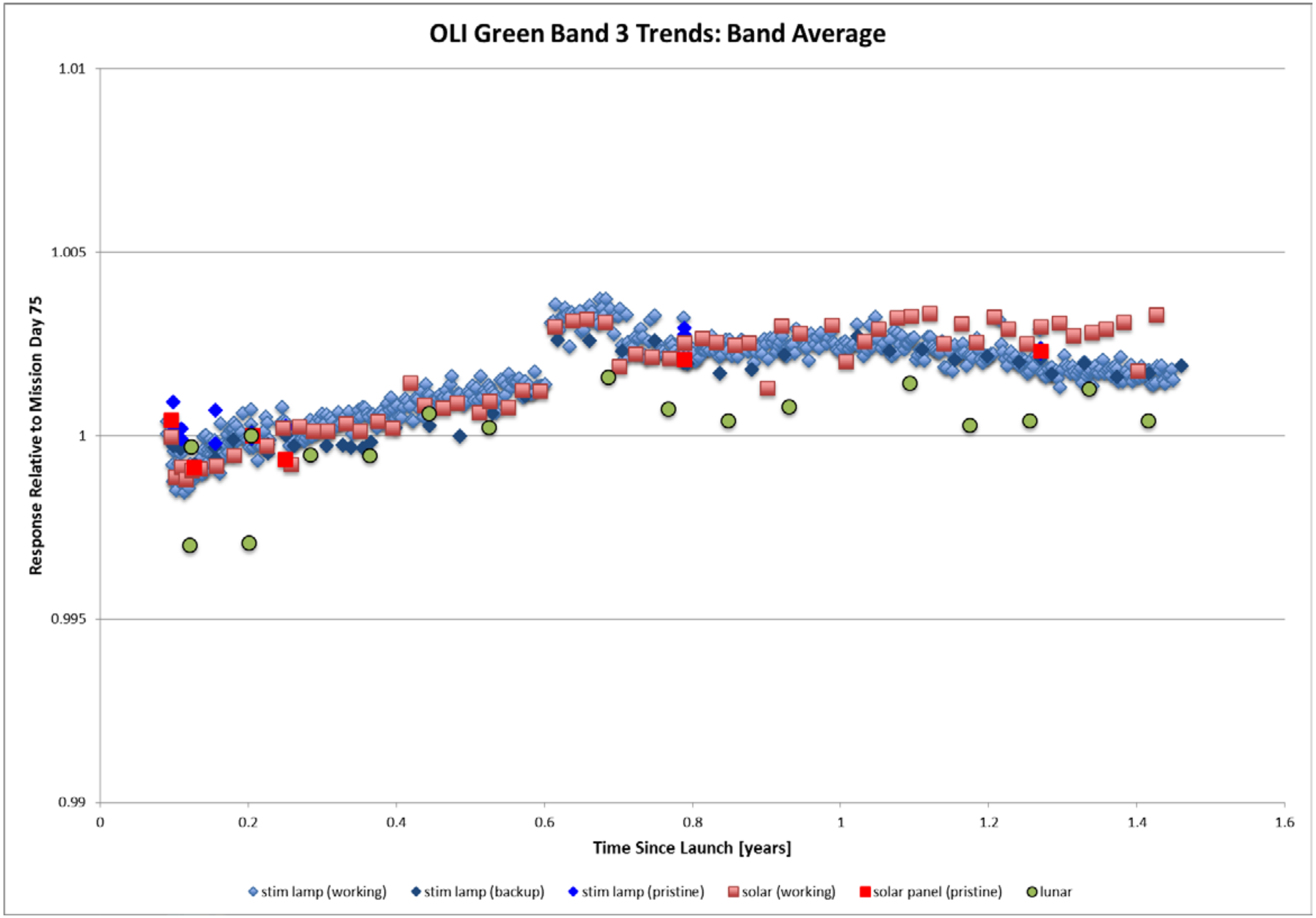
# Blue



OLI Blue Band 2 Trends: Band Average
Response Relative to Mission Day 75
1.01
1.005
1
0.995
0.99
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Since Launch [years]
stim lamp (working)
stim lamp (backup)
stim lamp (pristine)
solar (working)
solar panel (pristine)
lunar


USGS

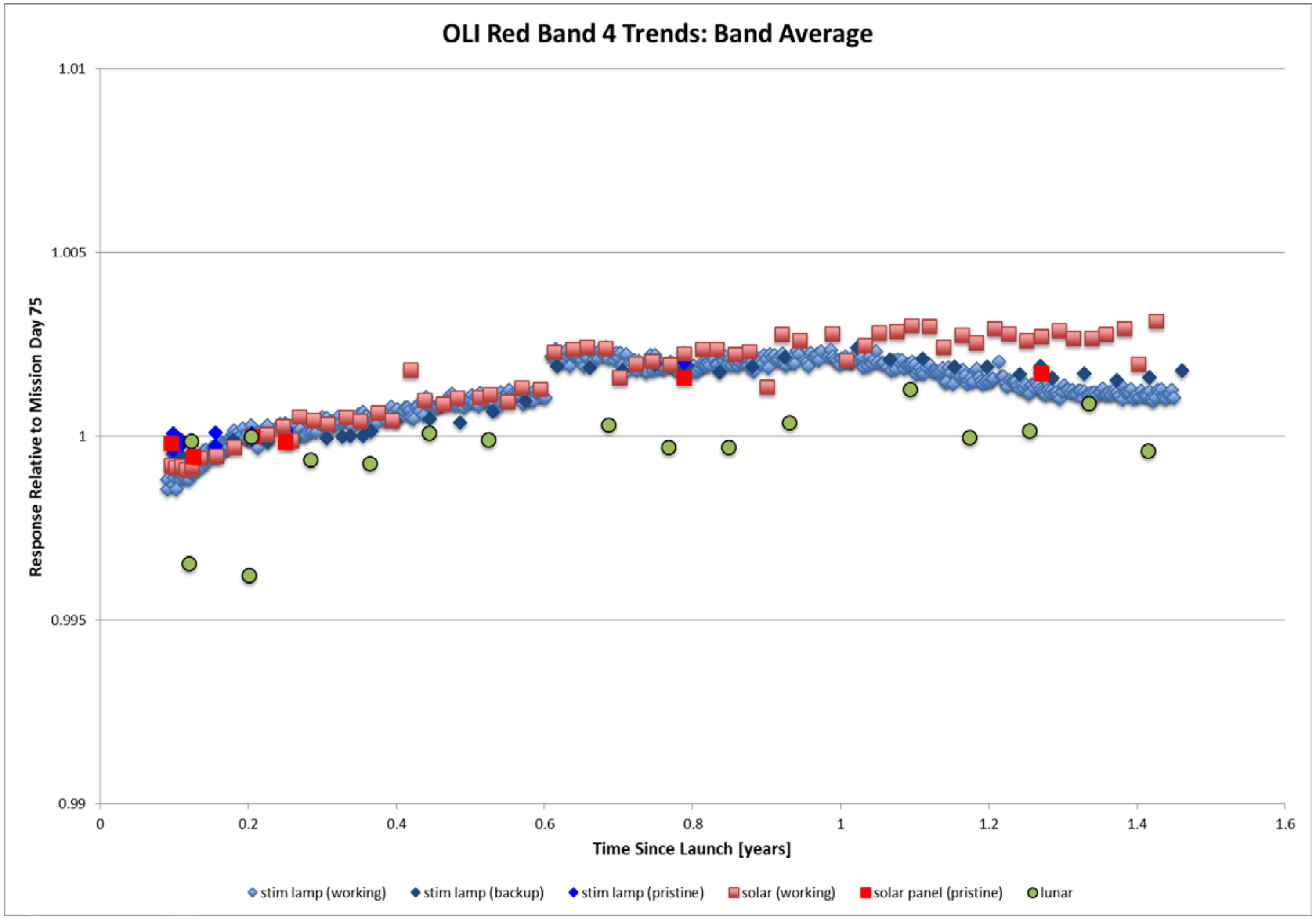
# Green



OLI Green Band 3 Trends: Band Average
Response Relative to Mission Day 75
1.01
1.005
1
0.995
0.99
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Since Launch [years]
stim lamp (working)
stim lamp (backup)
stim lamp (pristine)
solar (working)
solar panel (pristine)
lunar

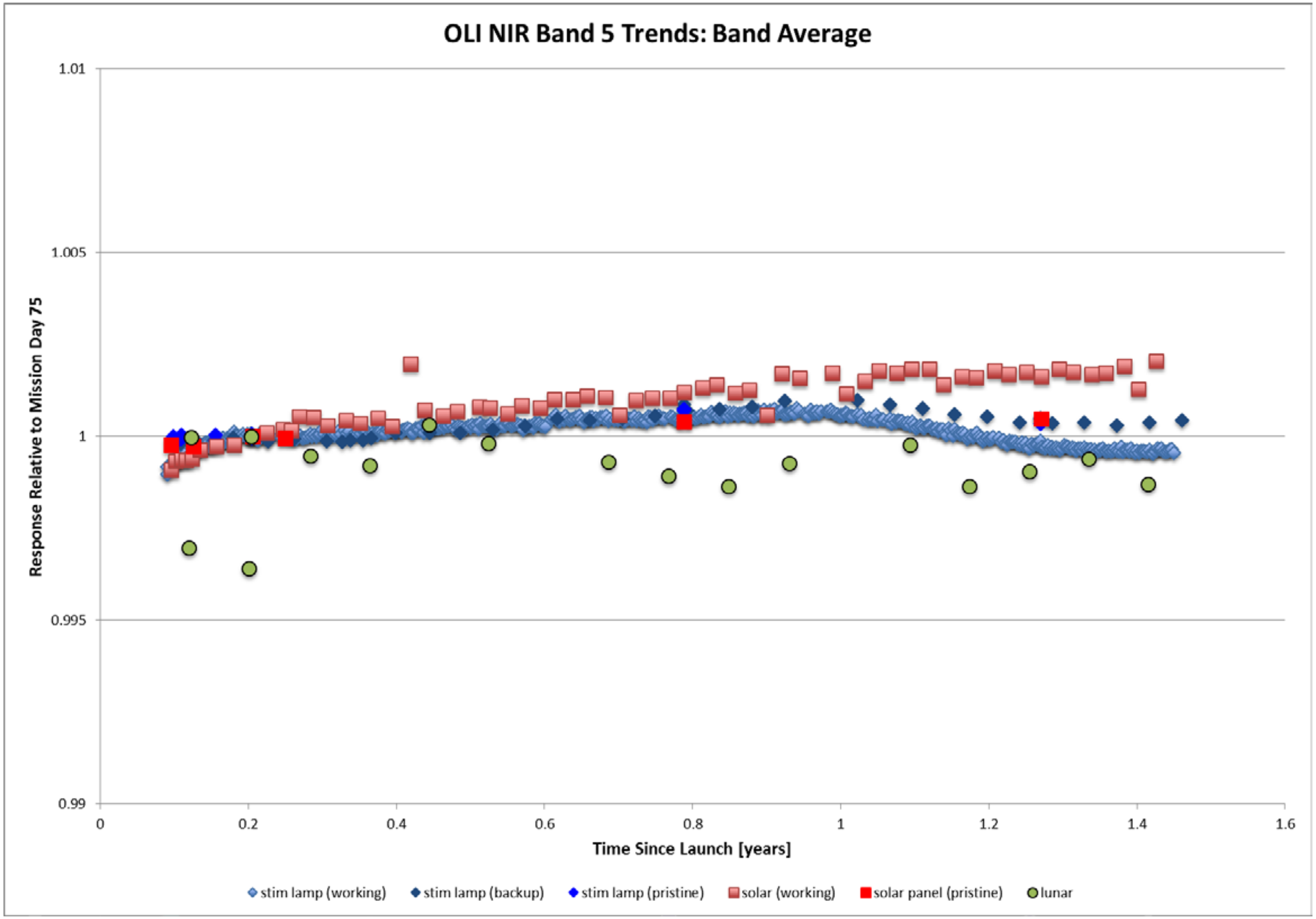

USGS

# Red


OLI Red Band 4 Trends: Band Average
1.01
1.005
1
0.995
0.99
Response Relative to Mission Day 75
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Since Launch [years]
stim lamp (working)
stim lamp (backup)
stim lamp (pristine)
solar (working)
solar panel (pristine)
lunar

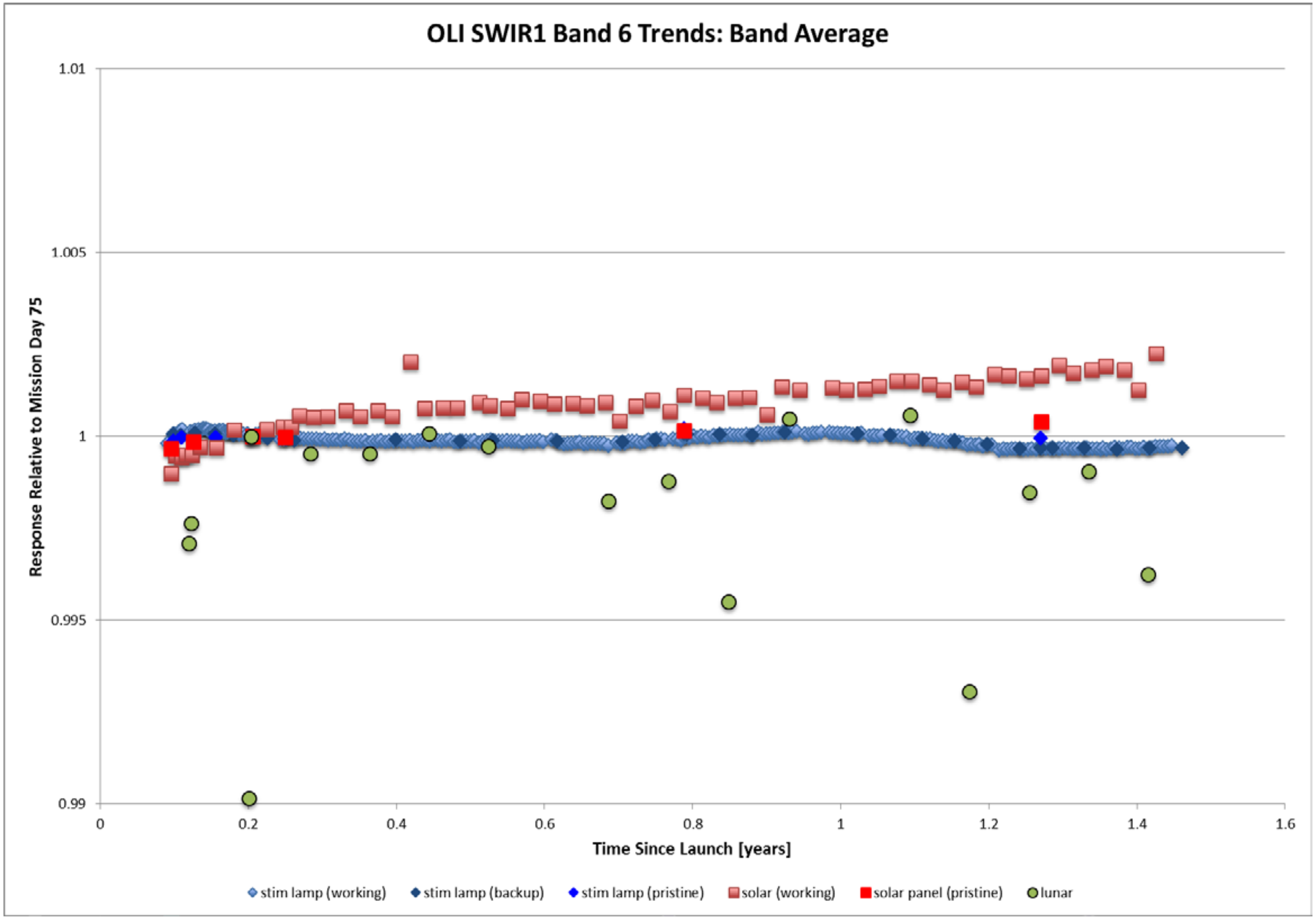
USGS

# Near InfraRed



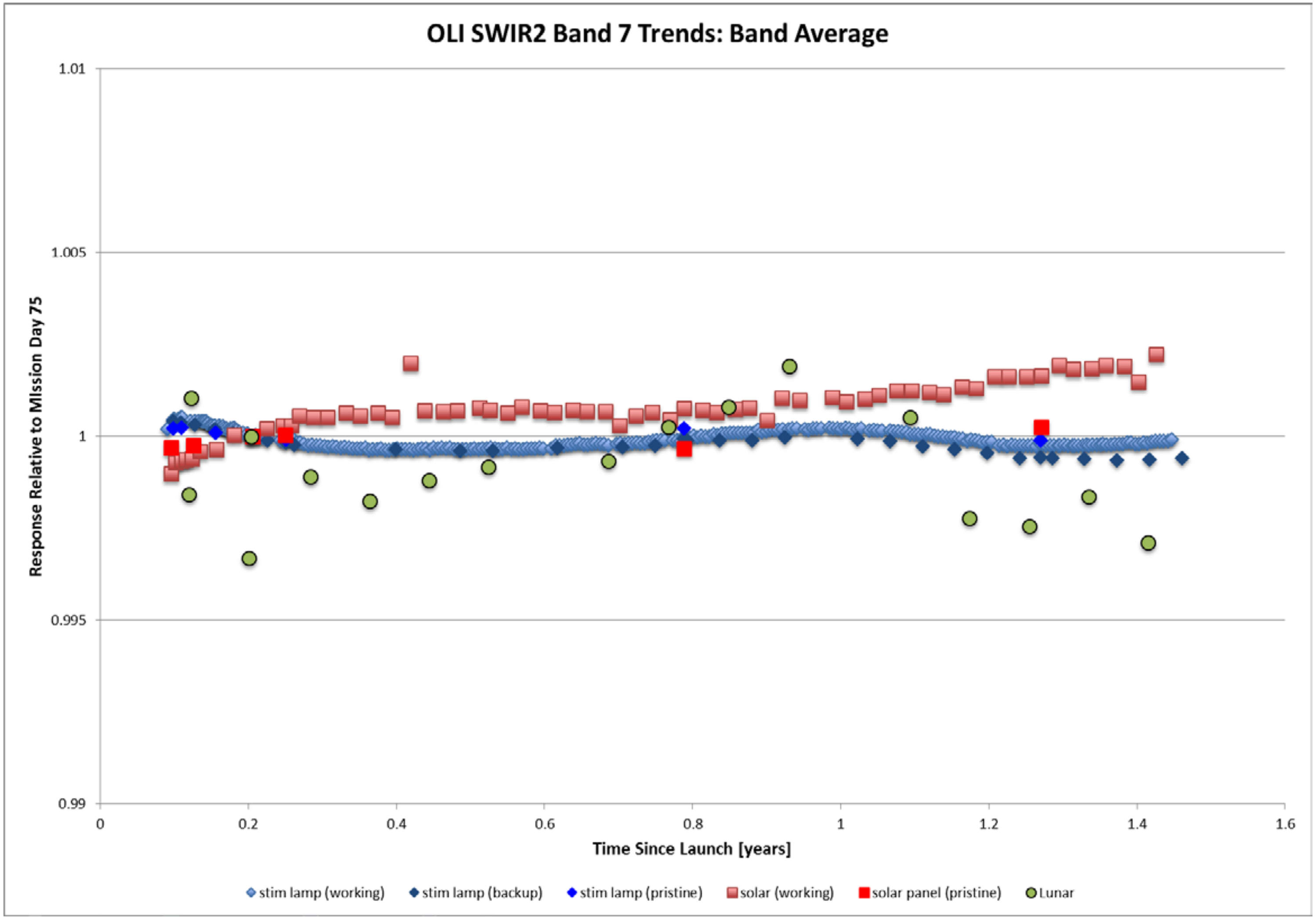

USGS

# Short Wave InfraRed 1

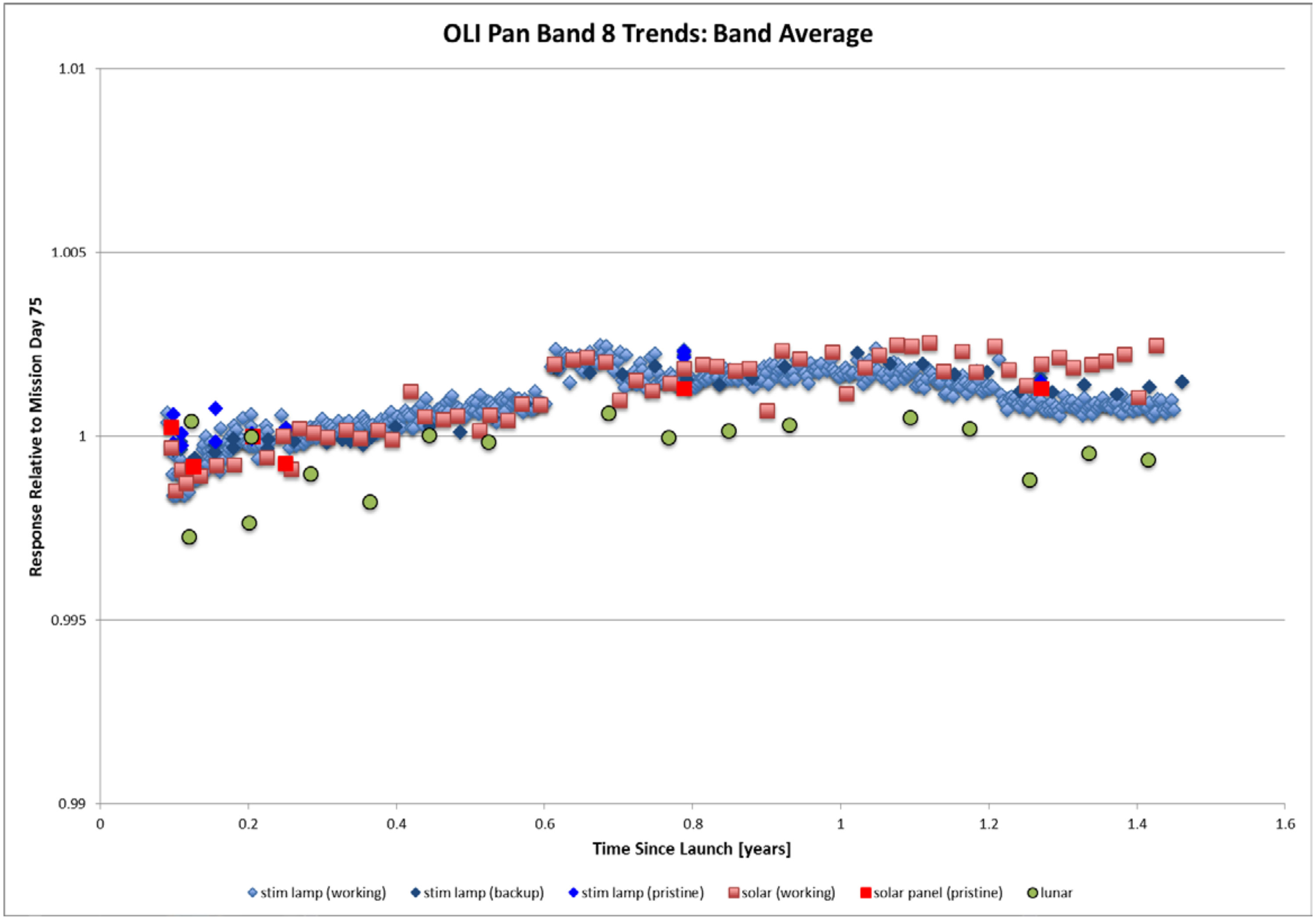



USGS

# Short Wave InfraRed 2



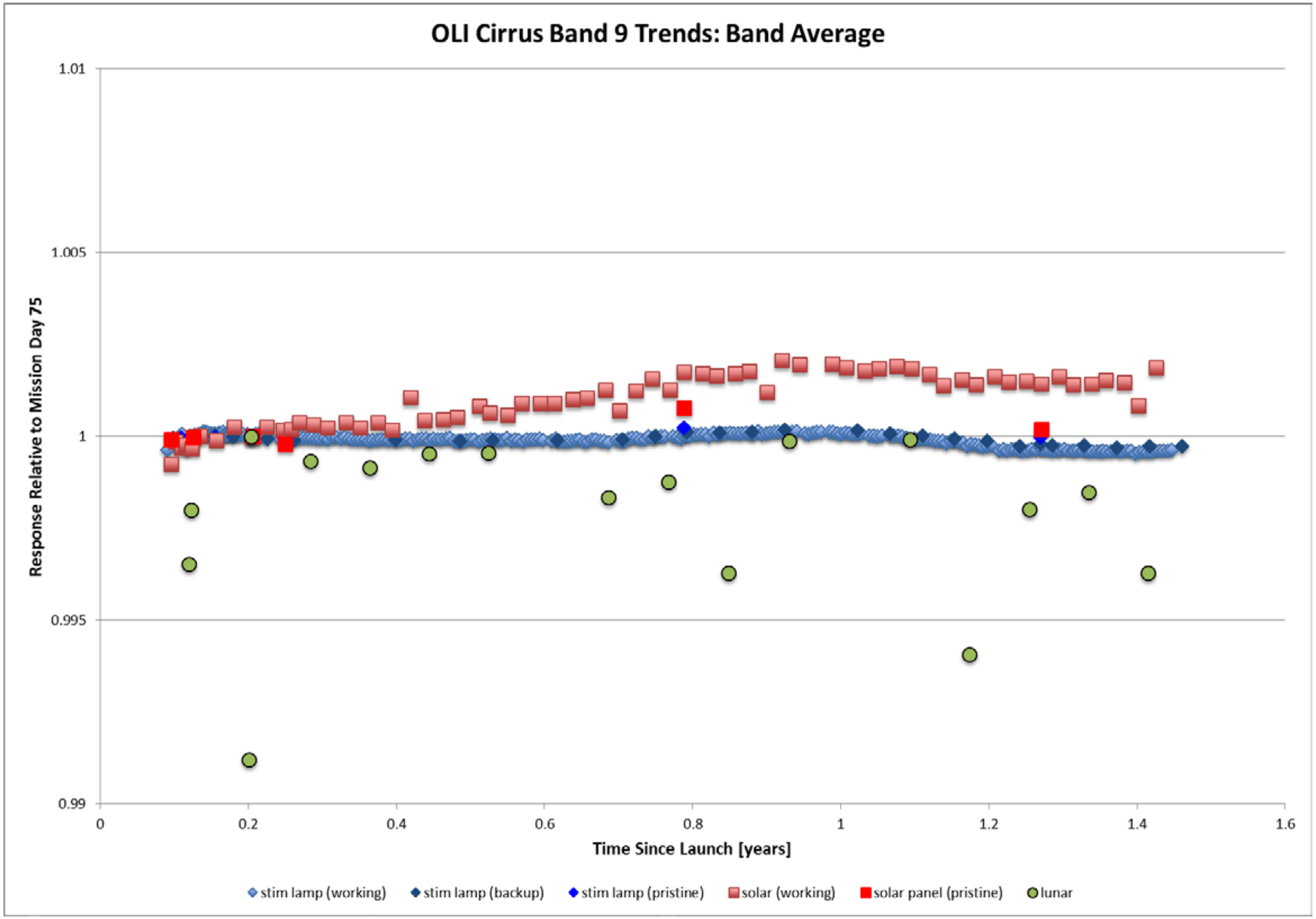
# Pan



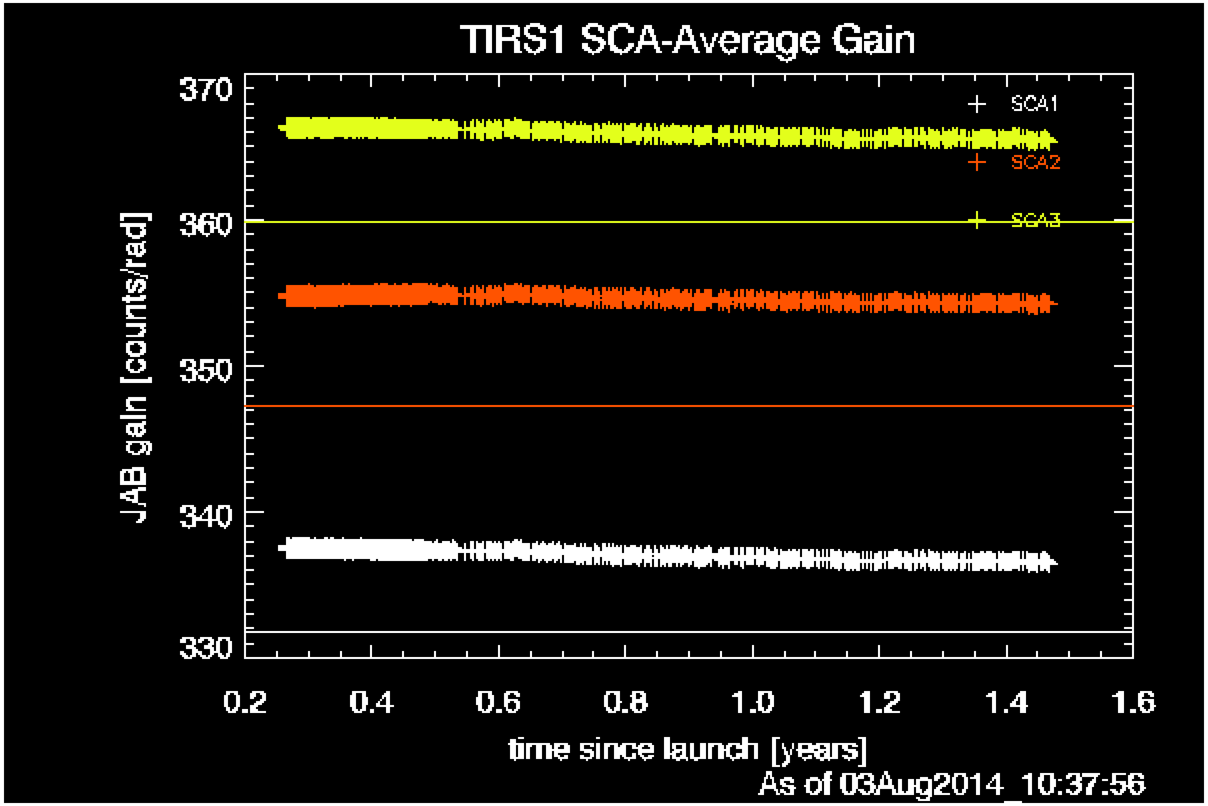
OLI Pan Band 8 Trends: Band Average
1.01
1.005
1
0.995
0.99
Response Relative to Mission Day 75
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Since Launch [years]
stim lamp (working)
stim lamp (backup)
stim lamp (pristine)
solar (working)
solar panel (pristine)
lunar


USGS

# Cirrus

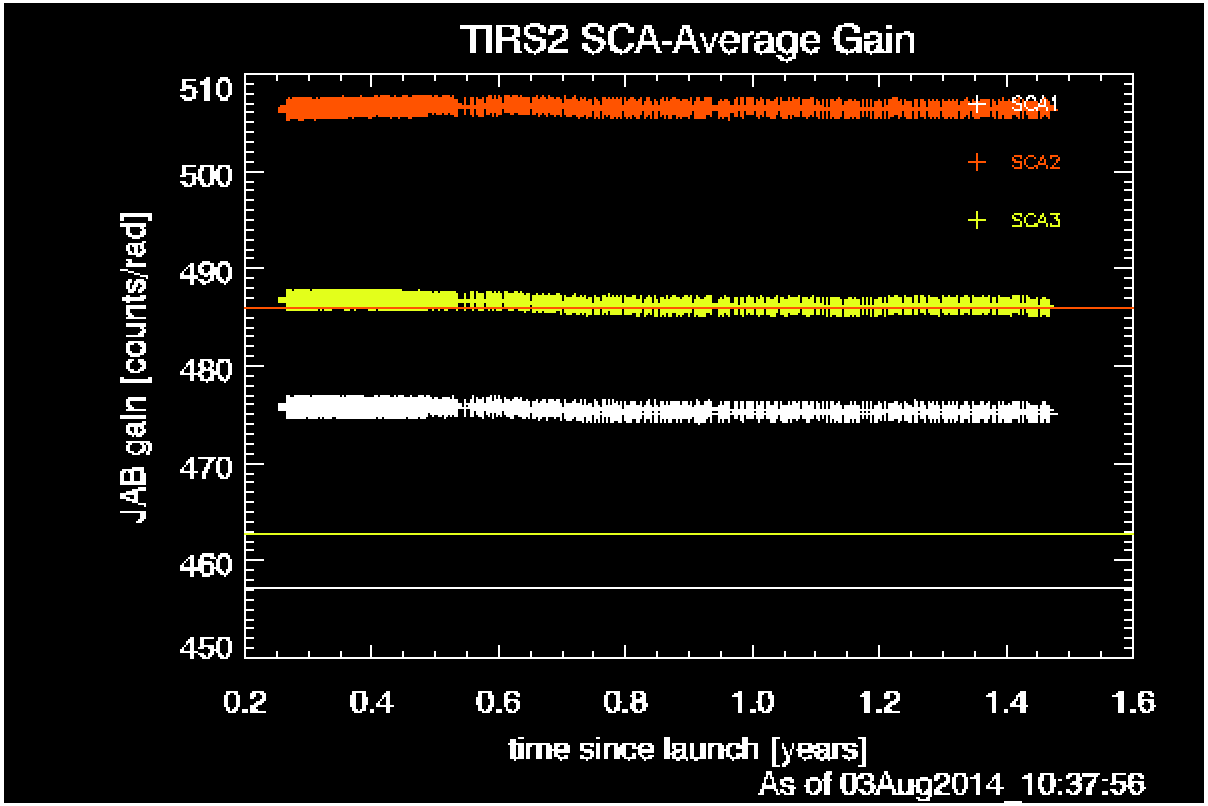

OLI Cirrus Band 9 Trends: Band Average
Response Relative to Mission Day 75
1.01
1.005
1
0.995
0.99
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time Since Launch [years]
stim lamp (working)
stim lamp (backup)
stim lamp (pristine)
solar (working)
solar panel (pristine)
lunar

# Thermal 1



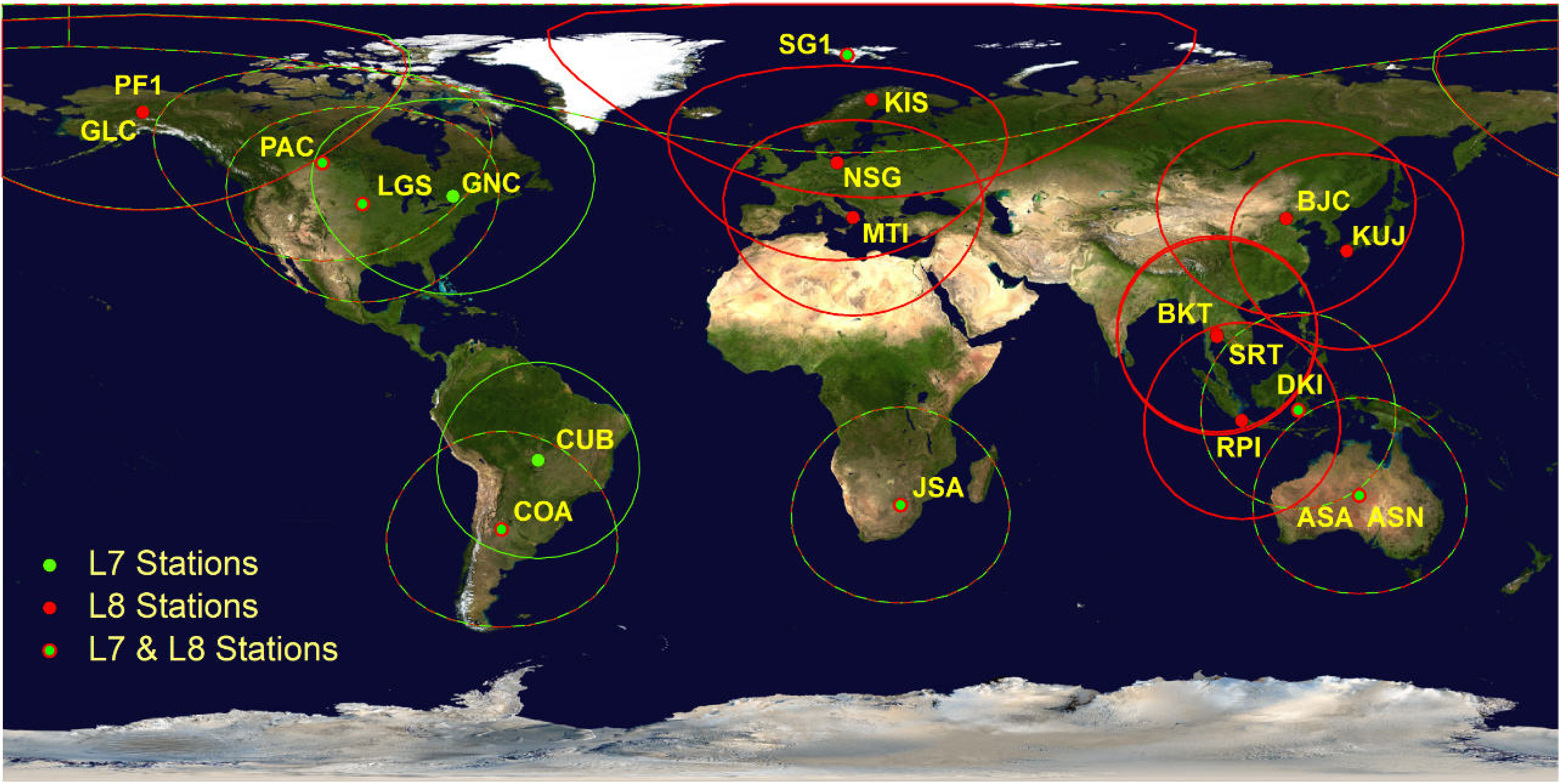
TIRS1 SCA-Average Gain
370
360
350
340
330
JAB gain [counts/rad]
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
time since launch [years]
SCA1
SCA2
SCA3
As of 03Aug2014_10:37:56

# Thermal 2


TIRS2 SCA-Average Gain
JAB gain [counts/rad]
510
500
490
480
470
460
450
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
time since launch [years]
As of 03Aug2014_10:37:56
SCA1
SCA2
SCA3

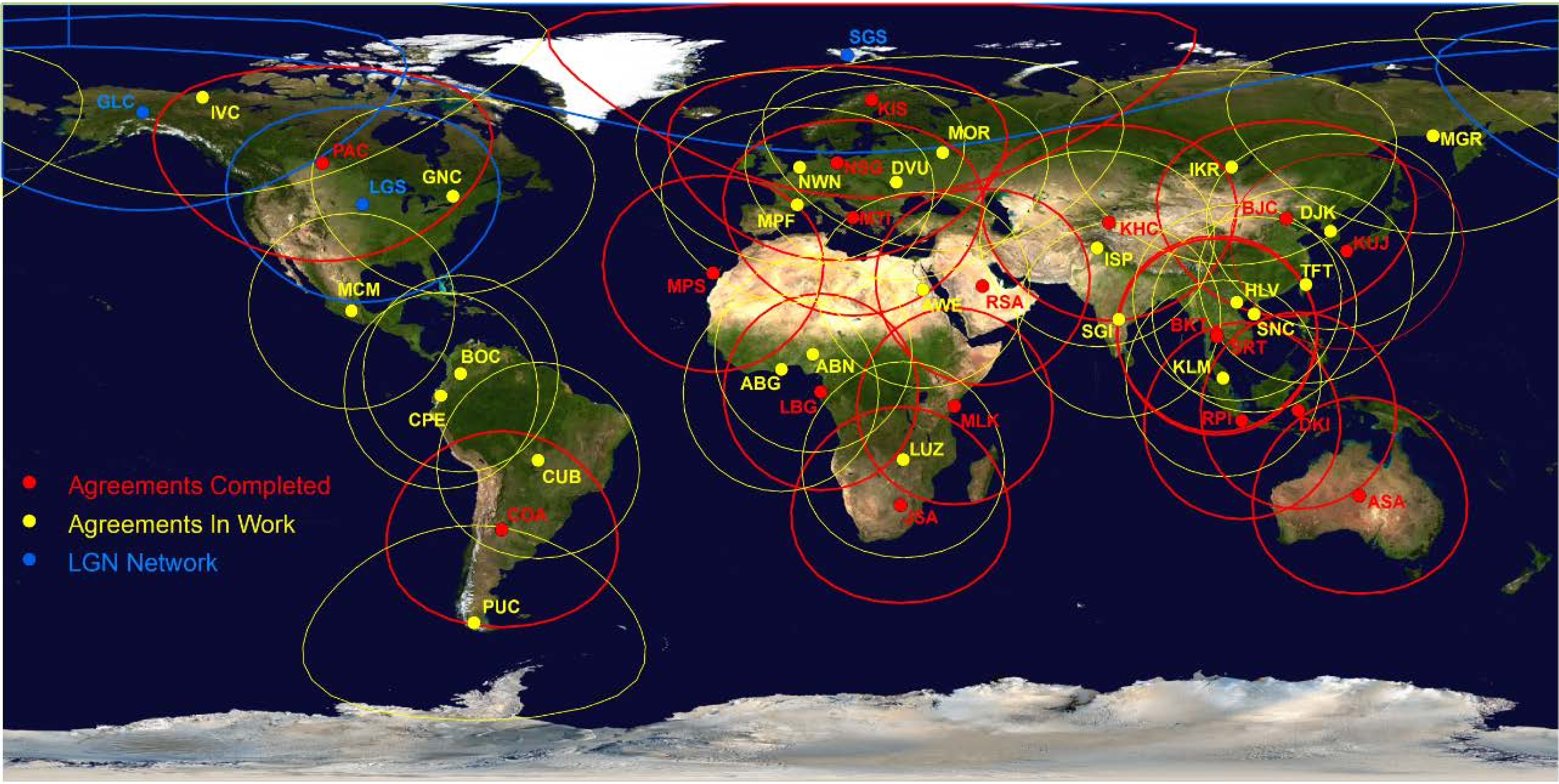
# Active Landsat International Ground Stations

**10 Active L7 Stations** **16 Active L8 Stations**



# Potential Landsat 8 International Ground Stations

36 Countries 38 Organizations 46 Ground Stations



# Landsat 8 Agreement Overview

| Signed (22 ground stations): | | | | |
|---|---|---|---|---|
| 1. | | Australia (GA) | ASA, DWA, HOA | 15 June 2012 |
| 2. | | Europe (ESA) | KIS, MLK, MTI, MPS, NSG | 22 August 2012 |
| 3. | | China (RADI) | BJC, KHC | 20 October 2012 |
| 4. | | Indonesia (LAPAN) | DKI, RPI | 2 November 2012 |
| 5. | | Gabon (AGEOS) | LBG | 11 February 2013 |
| 6. | | Argentina (CONAE) | COA | 15 February 2013 |
| 7. | | Canada (CCMEO) | PAC | 22 March 2013 |
| 8. | | Norway (NSC / KSAT) | SGS | 22 March 2013 |
| 9. | | Saudi Arabia (KACST) | RSA | 27 April 2013 |
| 10. | | Thailand (GISTDA) | BKT, SRT | 29 April 2013 |
| 11. | | South Africa (SANSA) | JSA | 29 May 2013 |
| 12. | | Japan (AIST) | KUJ | 21 November 2013 |
| 13. | | Brazil (INPE) | CUB | TBD |

USGS

# Landsat 8 Ground Station Certification

| Certified (13 ground stations): | | | | |
|---|---|---|---|---|
| 1. | | Germany (DLR) | Neustrelitz (NSG) | 8 July 2013 |
| 2. | | Japan (AIST-GSJ) | Kumamoto (KUJ) | 9 July 2013 |
| 3. | | China (RADI) | Miyun / Beijing (BJC) | 15 July 2013 |
| 4. | | Australia (GA) | Alice Springs (ASA) | 1 August 2013 |
| 5. | | Indonesia (LAPAN) | Parepare (DKI) | 4 September 2013 |
| 6. | | Canada (CCMEO) | Prince Albert (PAC) | 30 September 2013 |
| 7. | | Argentina (CONAE) | Córdoba (COA) | 20 December 2013 |
| 8. | | Europe (ESA) | Matera (MTI) | 9 January 2014 |
| 9. | | South Africa (SANSA) | Hartebeesthoek (JSA) | 10 February 2014 |
| 10. | | Indonesia (LAPAN) | Rumpin (RPI) | 28 February 2014 |
| 11. | | Europe (ESA) | Kiruna (KIS) | 3 April 2014 |
| 12. | | Thailand (GISTDA) | Bangkok (BKT) – Backup | 22 August 2014 |
| 13. | | Thailand (GISTDA) | Si Racha (SRT) | 3 September 2014 |

# RCA-EO Project

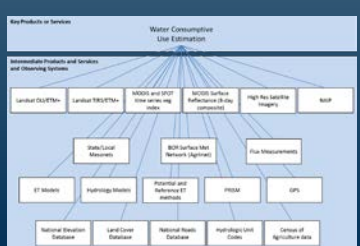
- ***Requirements Capabilities and Analysis for Earth Observations (RCA-EO)***
  - **RCA-EO was structured from the NLIR Project, which began as part of the CRSSP Requirements and the OSTP Future of Land Imaging efforts**
  - **RCA-EO is being used to support civil EO requirements and the EOP Earth Observations Assessments (EOAs) as define in the National Strategy for Earth Observations**
- **3 key areas – Earth Observations Requirements Capabilities and Analysis – tied together via an information evaluation system**

## Requirements Elicitation

**Gathering and Understanding**

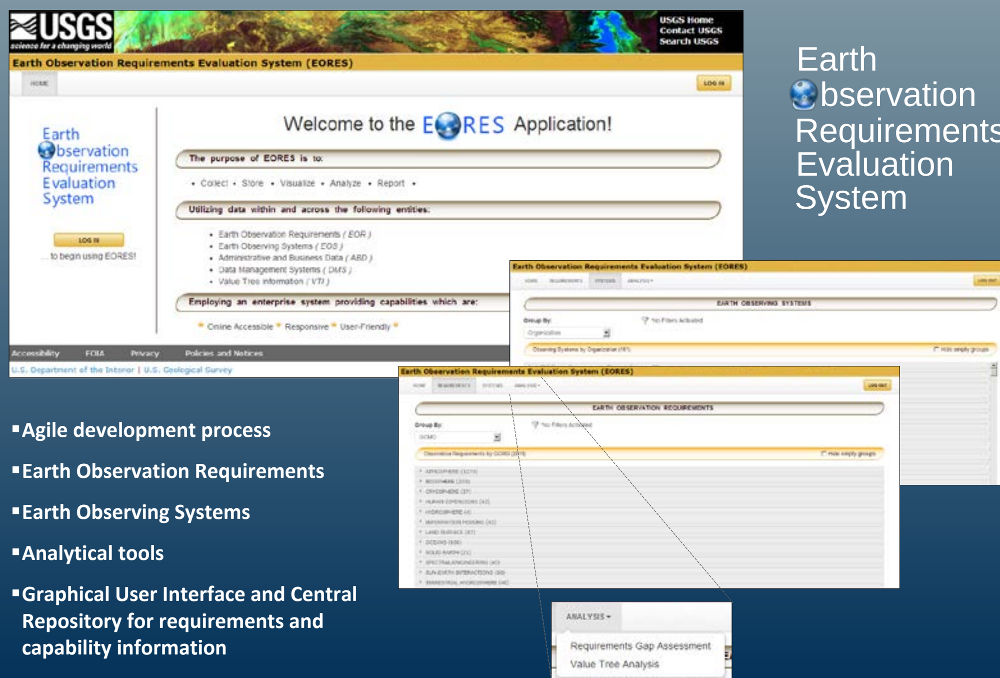

- **Customizable to agency needs**
- **Broad and diverse user community**
- **Traceability via Value Tree**
- **Repeatable and transparent process**

| Performance / Satisfaction Scale | | |
|---|---|---|
| 100 | Ideal | Meets all requirements and exceeds some |
| 90 | Fully Satisfied | Meets all requirements |
| 80 | Good | Meets all major requirements with minor limitations |
| 70 | | |
| 60 | Fair | Meets most major requirements, with significant limitations |
| 50 | | |
| 40 | Poor | Fails to meet many major requirements, but provides some value |
| 30 | | |
| 20 | Very Poor | Fails to meet most major requirements, but provides minor value |
| 10 | | |
| | No Capability | Provides no value |




## Earth Observation Requirements Evaluation System (EORES) Application

**Web Enabled Application**

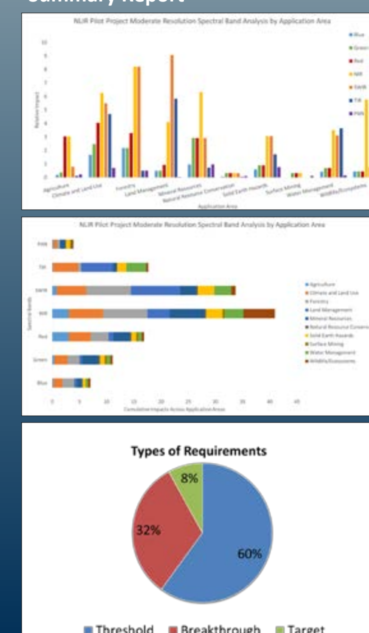



- **Agile development process**
- **Earth Observation Requirements**
- **Earth Observing Systems**
- **Analytical tools**
- **Graphical User Interface and Central Repository for requirements and capability information**

## Assessment / Reporting

**Analysis and Export**

- **Examples from NLIR Pilot Project Summary Report**



# Joint Approach USGS in Partnership with NOAA : Two Complementary Components

<u>System Development</u>

Joint Unified Architecture

- Earth Observation Requirements Evaluation System (EORES)
  - Repository for requirements and capability information
  - Analytical tools

Joint development with NOAA/TPIO And USGS/LRS

**<u>Requirements Elicitation</u>**

**Customizable to Agency Needs**

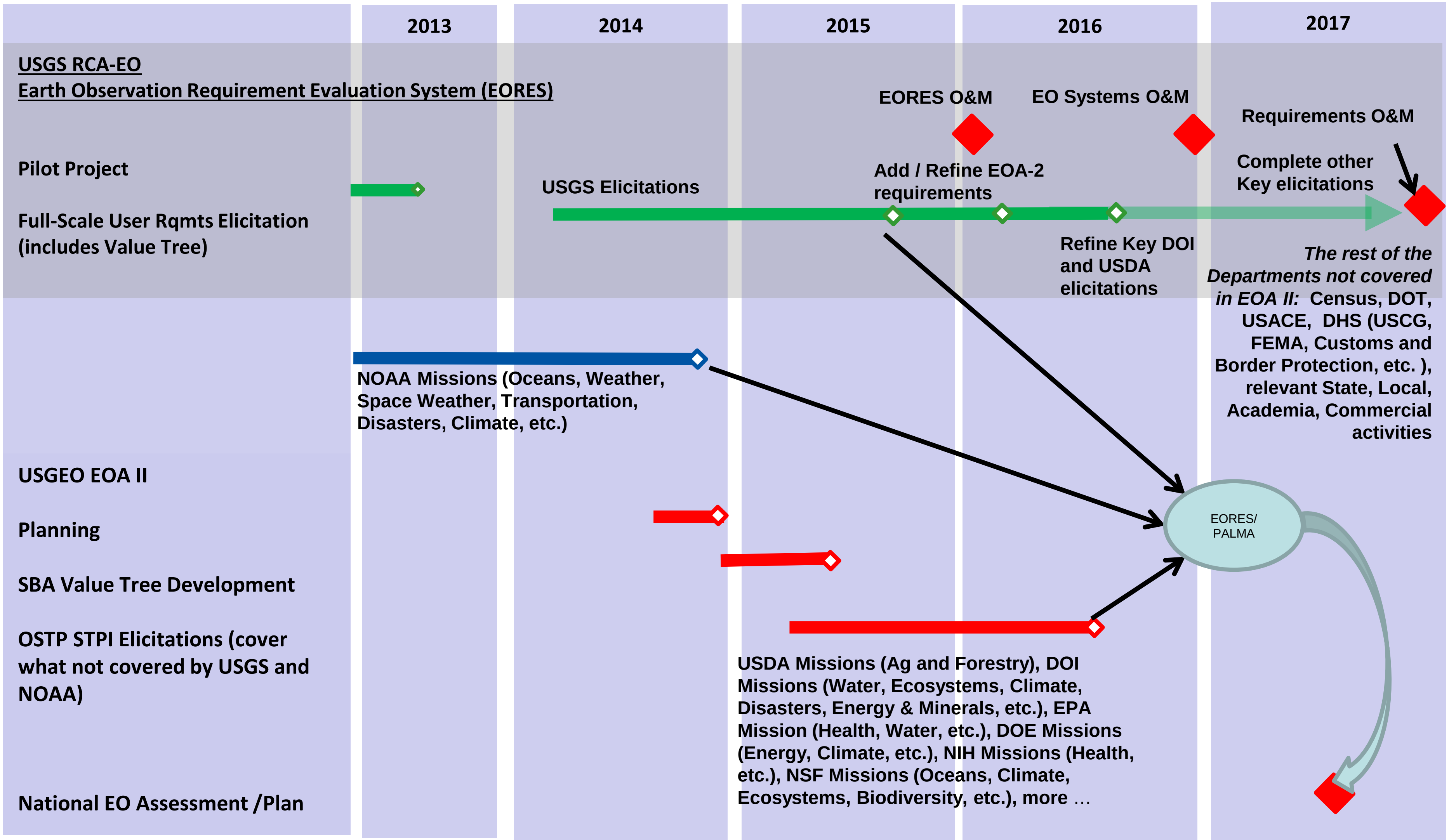
User Requirements Elicitation

- All earth observation needs – broad and diverse user community
- Traceability via value tree
- Repeatable and transparent process

Developed from previous and current efforts: NOSIA, EOA 1, NOSIA II, NLIR Mod Resolution Pilot.
(Value Tree) + Requirements

USGS

# Integrated Plan

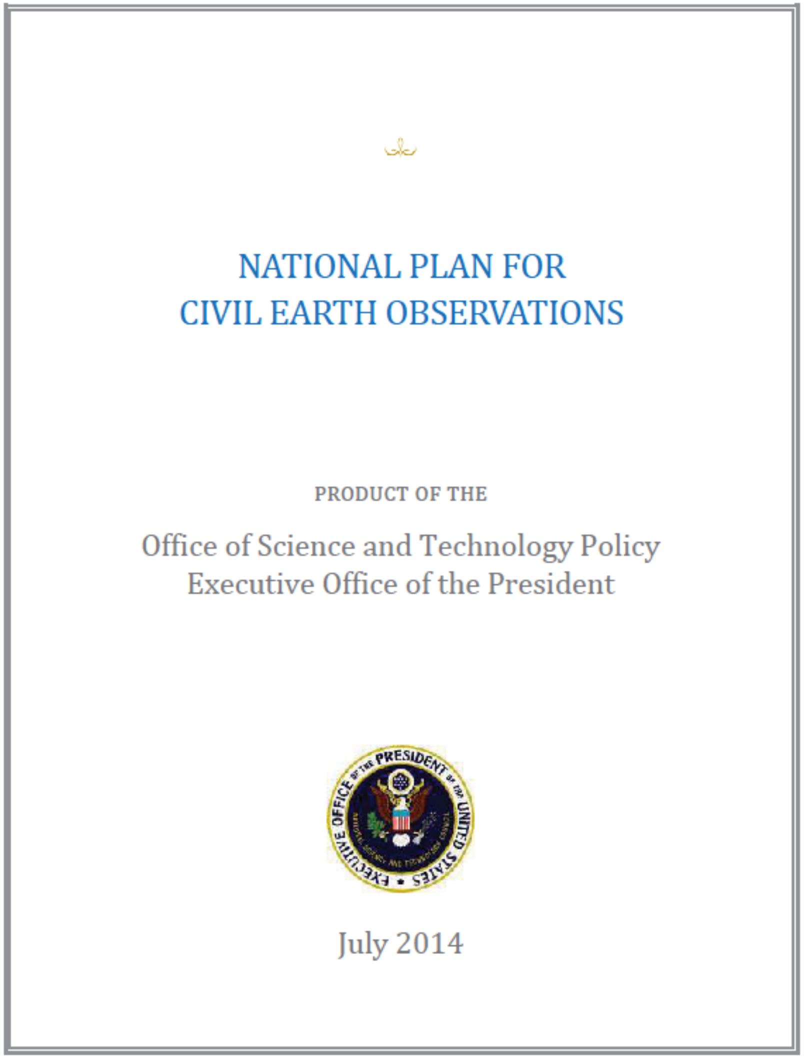



USGS

# EOP's NATIONAL PLAN FOR CIVIL EARTH OBSERVATIONS

- National Earth Observation Assessment (EOA II) and National Plan due every 3 years to EOP OSTP
  - OSTP STPI has defined EO SBA teams

http://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/2014_national_plan_for_civil_earth_observations.pdf



NATIONAL PLAN FOR
CIVIL EARTH OBSERVATIONS

PRODUCT OF THE

Office of Science and Technology Policy
Executive Office of the President

July 2014

# Annex I: 2012 EOA Results

This annex provides results for the 145 high-impact observation systems identified from the 362 observation systems assessed by the 13 SBA teams of approximately 300 Federal subject-matter experts. These 145 observation systems are listed in two tiers in the tables below. Impact is indicated with respect to each of the 13 societal themes (12 SBAs and reference measurements), as described in Section 2.2.

*Table 1: Tier 1 High-Impact Observation Systems (Ranked Order)*

| Observation System (Ranked Order) | Agency | Ag&Frst | BioDiv | Climate | Disasters | Ecosys | Energy | HumanHlth | Ocn&Cstl | Space Wx | Trans | WaterRes | Wx | RefMeas |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Global Positioning System (GPS) satellites | DOD/USAF | High | High | | High | High | Moderate | High | | | Highest | High | | Highest |
| 2. Next Generation Weather Radar (NEXRAD) | DOC/NOAA | Moderate | Moderate | | High | | Very High | High | * | | Highest | High | Very High | |
| 3. Landsat satellite | DOI/USGS, NASA | High | Highest | High | Moderate | Highest | High | Highest | | | * | Very High | | Moderate |
| 4. Geostationary Operational Environmental Satellite System (GOES-NOP) | DOC/NOAA | Moderate | Moderate | * | Very High | * | High | High | High | Very High | Very High | High | Very High | |
| 5. National Agriculture Imagery Program (NAIP) | USDA/FSA | Highest | Very High | | Moderate | Very High | Moderate | High | | | High | High | | Moderate |
| 6. Airborne LIDAR | DOC/NOAA, DOD/USACE, DOI/USGS, NSF | High | High | Moderate | High | High | Moderate | High | | | High | Very High | | Very High |
| 7. Forest Inventory and Analysis (FIA) | USDA/USFS | Highest | Very High | | | Highest | | * | | | | | | |

Impact: Contributes (*), Moderate, High, Very High, Highest

# NASA – USGS Collaboration for Land Imaging

## Landsat System Architecture Study Phase

- NASA is leading the overall system architecture study, utilizing its space systems engineering expertise
- USGS is supporting all aspects of the study; USGS represents the consolidated needs and desires of the Landsat user community and provides expert analyses of the data processing and dissemination aspects of the system

## Landsat System Architecture Implementation Phase

- NASA will be responsible for the overall system design, as well as the implementation, launch, and commissioning of the system's space-borne elements
- USGS will provide unique expertise and guidance in the design of the operations, ground network, data processing, and data dissemination components of the complete system
- USGS will operate the space-borne assets after NASA commissioning, as well as the downlink, ground processing, archiving, and distribution of the system's information and data products
- USGS will maintain the National Satellite Land Remote Sensing Data Archive, distribute data to users, and administer, on behalf of U.S. Government, data acquisition by foreign ground stations

# Sustainable Land Imaging Architecture Study



*September 5, 2014* - The SLI Office is preparing to issue a competitive opportunity in the September/October time frame via FedBizOpps to investigate the potential use of innovative business models to reduce the costs of future land imaging missions. The focus of the study will be to explore contractor experience implementing both commercial and government satellite development efforts to compare business, management, and technical practices for effectiveness and cost efficiency. The study will also solicit feedback on some specific business model ideas. This study will concentrate primarily on acquisition of spacecraft buses and related services rather than science instrument payloads.

*September 5, 2014* - We are pleased to announce that the following companies have been awarded contracts under Solicitation Number NNG14518373Q to carry out the Sustainable Land Imaging (SLI) Reduced Instrument Envelope Study:

- Ball Aerospace & Technologies Corporation of Boulder, CO
- Exelis Inc., Geospatial Systems of Fort Wayne, IN
- Lockheed Martin Space Systems Company of Greenbelt, MD
- Northrop Grumman Systems Corporation, Aerospace Systems of Redondo Beach, CA
- Raytheon Company of El Segundo, CA
- Surrey Satellite Technology US LLC of Englewood, CO

The study focuses on investigating mid-term capabilities and technologies for instruments that may enable more efficient implementation of the SLI program objectives to continue Landsat heritage measurements. The study contract awards are intended to enable contractors to perform a more detailed analysis of techniques and trends that lead to reduction in size and mass of spaceborne Earth-imaging instruments, potentially resulting in cost savings to the U.S. Government while still meeting the SLI program objectives. These studies will be of 6-month duration.

**Additional Reference Documents**

- Operational Land Imager (OLI) Top of Atmosphere Radiance Spectra (.xls) *[Updated 09.05.2014]*
- Landsat Worldwide Reference System-2 (WRS-2) Definition

# About NASA Sustainable Land Imaging

For the past 42 years, Landsat satellites and associated U.S. Government ground processing, distribution, and archiving systems have acquired and made available global, moderate-resolution (5-120m), multispectral measurements of land and coastal regions, providing humankind's longest record of our planet from space. NASA and the U.S. Geological Survey (USGS) of the Department of the Interior (DOI) fully recognize that this information is a national asset, providing an important and unique capability that benefits a broad community, including Federal, state, and local governments; global change science, academia, and the private sector. Landsat data provide a consistent and reliable foundation for research on land use change, forest health, and carbon inventories, and changes to our environment, climate, and natural resources. Additionally, the free and open availability of the Landsat data enables the measurements to be used routinely by decision makers both inside and outside the Government, for a wide range of natural resource issues, including water resource management, wildfire response, agricultural productivity, rangeland management, and the effects of climate change.

The Administration has committed to continue the Landsat program and its invaluable data stream. To continue data collection beyond Landsat-8, the Administration proposes to design and implement a spaceborne system to provide global, continuous Landsat-quality multispectral and thermal infrared measurements for at least the next 25 years. The satellite system may be combined with alternative sources for Landsat-quality data, either procured through commercial approaches or through partnership agreements, as they become available. In accordance with Administration objectives, NASA will lead the system design study in close collaboration with the USGS and be informed by existing knowledge of current and desired capabilities. The aim of the study will be to define a programmatically sustainable system that balances measurement capability, likelihood of data continuity (minimizing risks of gaps to the extent possible), and cost/affordability over the lifetime of the program. Technology infusion over the lifetime of the program will be considered as a feature of the long-term sustainable program.

In FY 2014, NASA will initiate the definition of a sustained, space-based, global land imaging capability for the nation, ensuring continuity following LDCM. Near-term activities led by NASA, in cooperation with USGS, will focus on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system that will achieve national objectives. Evaluations and design activities will include consideration of stand-alone new instruments and satellites, as well as potential international partnerships. It is expected that NASA will support the overall system design, flight system implementation, and launch of future missions, while USGS will continue to fund ground system development, post-launch operations, and data processing, archiving, and distribution.

The basic guidance for the Sustainable Land Imaging Architecture Study is summarized by the following three basic tenets:

## Sustainability

- The SLI program should provide the data products for the long haul, without extraordinary infusions of funds, within the budget guidance provided.
- It should also ensure that the technology required for the program is available and appropriate for the long haul.

## Continuity

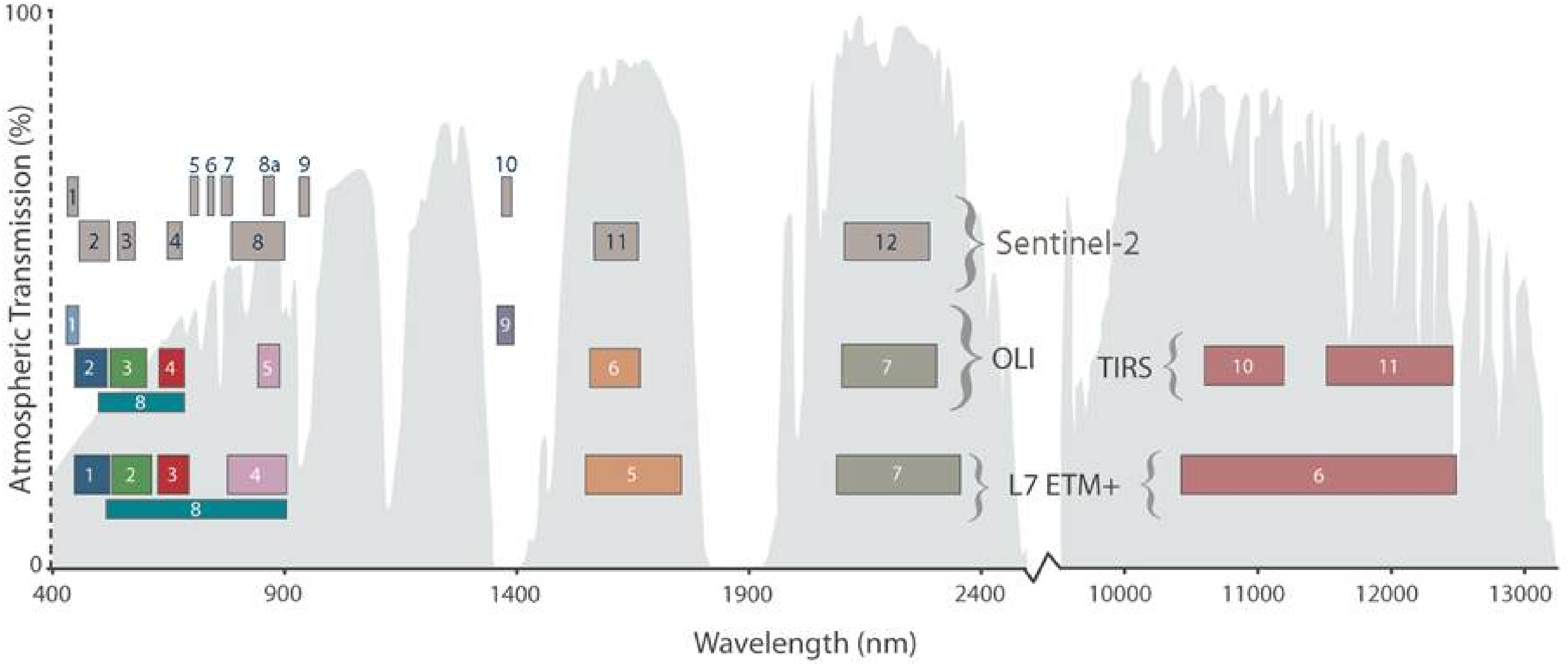
- The SLI program should continue the long term Landsat data record. This does not necessarily mean the imagery per se, but the usable products that define the utility of the data record.
- Understanding how the data are used is essential when considering potential architectures.

## Reliability

- The SLI program should exhibit a form of functional redundancy. The data sets should be able to draw on equivalent or near equivalent deliverables from different sources to provide the data for the highest priority land imaging data products.
- With these "near equivalent" data sources identified in advance, the loss of a single satellite or instrument on orbit should not cripple the program or significantly impact users, and the program will exhibit graceful degradation.

http://sustainablelandimaging.gsfc.nasa.gov/

# Comparison of Landsat & Sentinel-2




From USGS Tom Cecere Introduction, 9/30/14

# EO Systems Database Support

- Supports RCA-EO Requirements vs System Solutions
- The Number of satellites is growing fast!
- Nearly 200 EO satellites to be launched in 2014!

| Satellite Name | Sensor | Nominal Swath | Bits | GSD (m) | Spectral Coverage Representation and Ground Sample Distance (in meters): Visible and Near-IR (0.4-1.0 µm) | Short-Wave IR (1.0-2.5 µm) | Mid-Wave IR (3.5-8.0 µm) | Thermal IR (8.0-14.5 µm) |
|---|---|---|---|---|---|---|---|---|
| Landsat 8 | OLI | 185km | 12 | 30 | | | | |
| | | | | 15 | | | | |
| | TIRS | 185km | 12 | 100 | | | | |
| Landsat 7 | ETM+ | 185km | 8 | 15 | | | | |
| | | | | 30 | | | | |
| | | | | 60 | | | | |
| Landsat 4 & 5 | MSS | 185km | 8 | 79 | | | | |
| | TM | 185km | 8 | 30 | | | | |
| | | | | 60 | | | | |
| Landsat 1-2 | RBV | 183km | | 80 | | | | |
| Landsat 3 | RBV | 183km | | 40 | | | | |
| Landsat 1-3 | MSS | 183km | 8 | 79 | | | | |
| | | | | 240 | | | | (L3 Only) |
| CBERS-3 (lost on launch, 9 Dec. 2013) | MuxCAM | 120km | 8 | 20 | | | | |
| | PanMUX | 60km | 8 | 5 | | | | |
| | | | | 10 | | | | |
| | IRS | 120km | 8 | 40 | | | | |
| | | | | 80 | | | | |
| | WFI | 866km | 10 | 64 | | | | |
| KOMPSAT3 | AEISS | 16.8km | 14 | 0.7 | | | | |
| | | | | 2.8 | | | | |
| NPP (and future JPSS) | VIIRS Day-Night | 3000km | 12 | | | | | |
| | VIIRS Moderate | | | 750 | | | | |
| | VIIRS Imaging | | | 375 | | | | |
| Pleiades 1A & 1B | HiRI | 20km | 12 | 0.7 | | | | |
| | | | | 2.8 | | | | |
| ResourceSat-2 | AWiFS | 740km | 10 | 56 | | | | |
| | LISS-3 | 141km | 10 | 23.5 | | | | |
| | LISS-4 | 70km | 10 | 5.8 | | | | |
| Sentinel-2 | MSI | 290km | 12 | 10 | | | | |
| | | | | 20 | | | | |
| | | | | 60 | | | | |
| SPOT-6 | NAOMI (2x) | 60km | 12 | 2.2 | | | | |
| | | | | 8.8 | | | | |
| Terra | MODIS | 2330km | 12 | 250 | | | | |
| | | | | 500 | | | | |
| | | | | 1000 | | | | |
| | ASTER | 60km | 8 | 15 | | | | |
| | | | | 30 | | | | |
| | | | | 90 | | | | |
| WorldView-2 | WV110 | 16.4km | 11 | 0.46 | | | | |
| | | | | 1.84 | | | | |
| WorldView-3 | | 13.1 km | 11 | 0.31 | | | | |
| | | | | 1.24 | | | | |
| | | | 14 | 3.7 | | | | |
| | CAVIS Atm.Corr. | | | 30 | | | | |

USGS

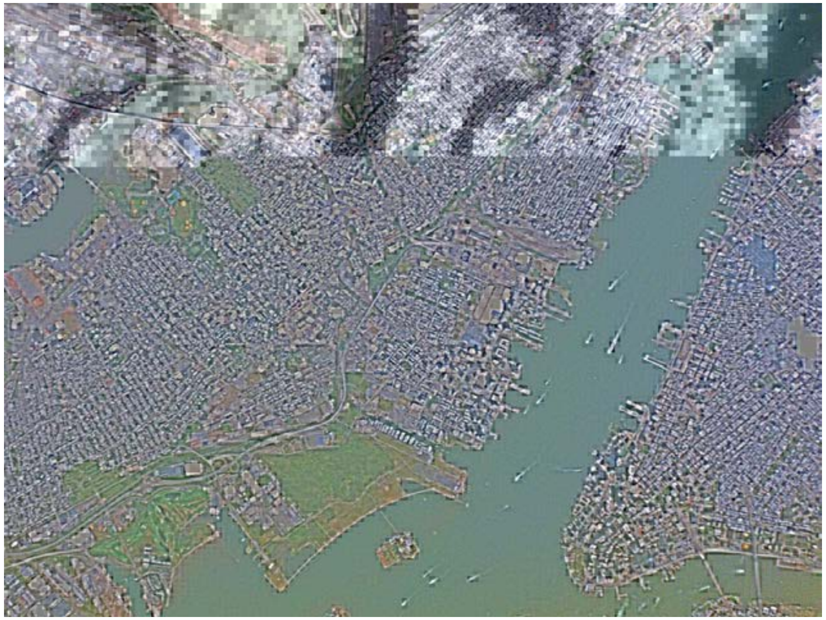
# Many More Planned


| Agency | | Agency Website | # Missions | # Instruments |
|---|---|---|---|---|
| ASI | Italy | click here | 13 - timeline | 16 |
| BELSPO | Belgium | click here | 1 - timeline | - |
| CAST | China | click here | 12 - timeline | 36 |
| CDTI | Spain | click here | 3 - timeline | 3 |
| CNES | France | click here | 26 - timeline | 32 |
| CONAE | Argentina | click here | 9 - timeline | 21 |
| CRESDA | China | click here | 8 - timeline | 6 |
| CSA | Canada | click here | 15 - timeline | 13 |
| CSIRO | Australia | click here | - | 2 |
| DLR | Germany | click here | 10 - timeline | 8 |
| EC | Europe | click here | 14 - timeline | 8 |
| ESA | Europe | click here | 37 - timeline | 38 |
| EUMETSAT | Europe | click here | 23 - timeline | 22 |
| GISTDA | Thailand | click here | 1 - timeline | 2 |
| INPE | Brazil | click here | 5 - timeline | 6 |
| ISRO | India | click here | 26 - timeline | 32 |
| JAXA | Japan | click here | 14 - timeline | 13 |
| JMA | Japan | click here | 4 - timeline | 7 |
| KARI | Korea | click here | 7 - timeline | 9 |
| METI | Japan | click here | 1 - timeline | 2 |
| NASA | U.S.A. | click here | 48 - timeline | 83 |
| NASRDA | Nigeria | click here | 2 - timeline | 2 |
| NOAA | U.S.A. | click here | 35 - timeline | 49 |
| NRSCC | China | click here | 17 - timeline | 20 |
| NSAU | Ukraine | click here | 1 - timeline | 5 |
| NSC | Norway | click here | 4 - timeline | 2 |
| NSMC-CMA | China | click here | 17 - timeline | 22 |
| ROSHYDROMET | Russia | click here | 17 - timeline | 28 |
| ROSKOSMOS | Russia | click here | 17 - timeline | 33 |
| SANSA | South Africa | click here | - | - |
| SNSB | Sweden | click here | 1 - timeline | 3 |
| TUBITAK | Turkey | click here | 1 - timeline | 2 |
| UKSA | United Kingdom | click here | 2 - timeline | 4 |
| USGS | U.S.A. | click here | 2 - timeline | 3 |
| **Totals** | | | **393** | **532** |

USGS

# USGS Assessments 2013-2014

- ResourceSat-2 AWiFS-2
- VNREDSat-1
- KOMPSAT-3
- *WorldDEM™
- PROBA-V
- Planet Labs
  - Doves-3 & 4, Flock-1a, Flock 1-c (sun-synch)
- WorldView-3
- SkyBox-1 & 2
- SPOT-7

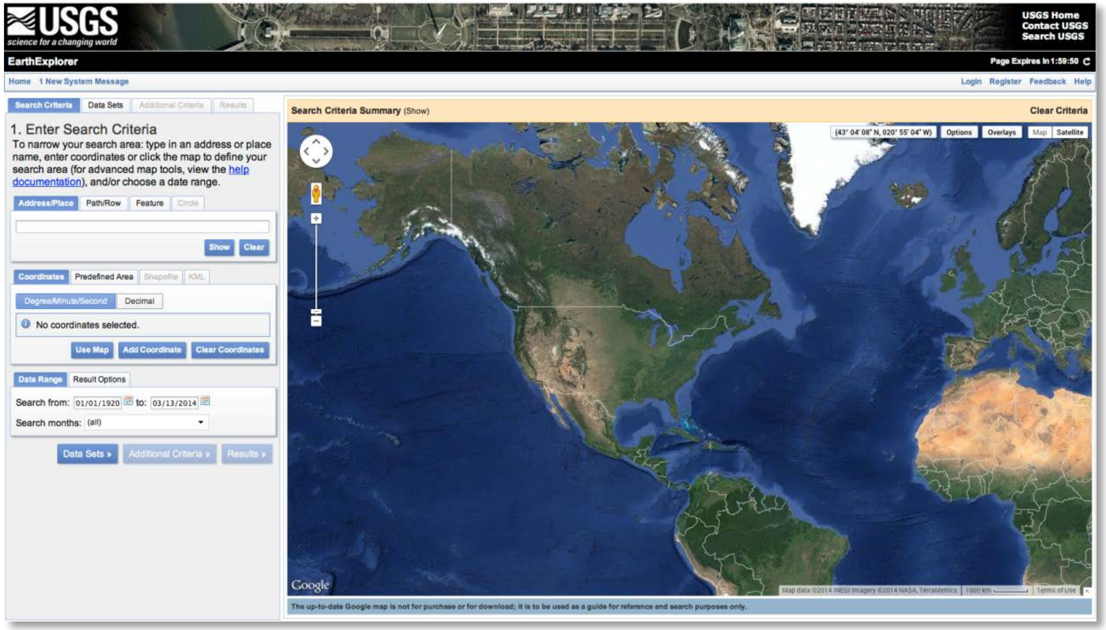


**Dr. DongHan Lee, Kari at USGS EROS for 1 year, lunar calibration and spatial resolution efforts for Landsat and System Characterization efforts**

# Remote Sensing Data Sets from USGS (EROS)

**Currently, more than 286 Data Sets (10 petabytes) are available online through USGS Earth Explorer website**

- Aerial Images – 7.5M Dating from 1937
- Landsat Images – 5.2M Dating from 1972
- Commercial Satellite Images – 1.5M Dating from 1986
  - SPOT, Digital Globe, GeoEye, etc.
- Other Satellite Data:
  - MODIS, ASTER, AVHRR, SRTM, Declassified systems, etc.




http://earthexplorer.usgs.gov/

USGS

# Aerial Photography Collection – Archive

- Contains over 7.5 Million frames acquired by numerous Federal agencies
- The archive contains frames ranging from 1937 to the present
- The collection is made up of natural color, color IR, and black & white photography in both vertical and oblique orientations
- Scales range from 1:1,000 to 1:200,000

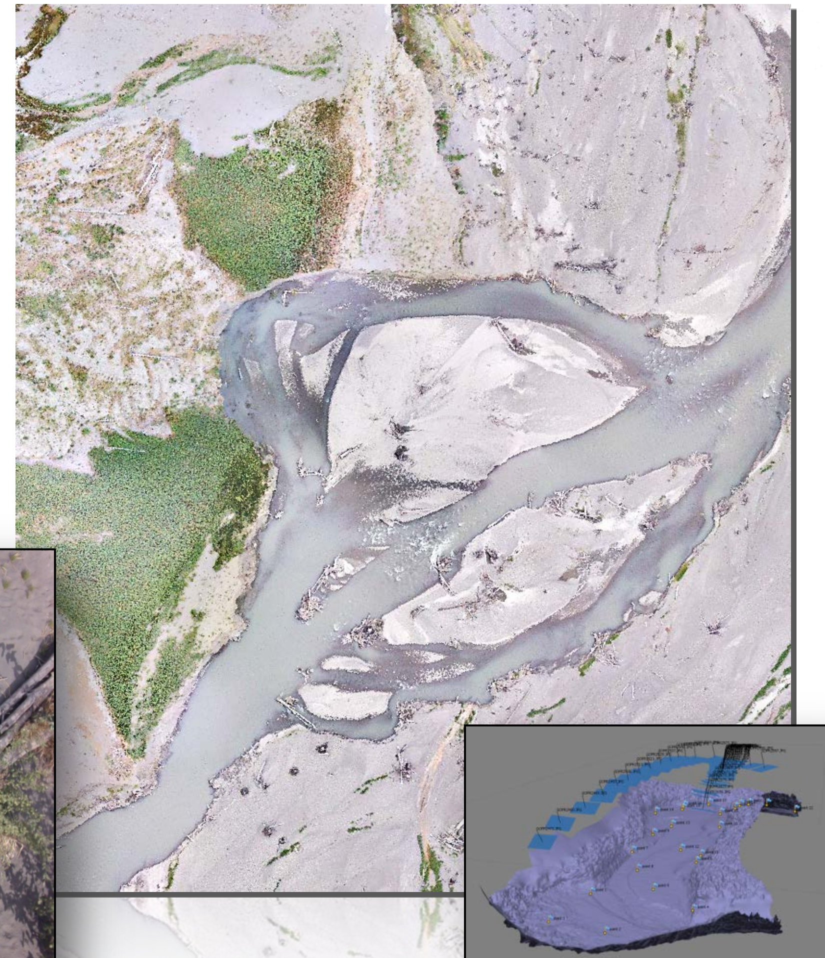
# UAS Imagery

## Elwha Dam Removal and River Restoration

**Olympic National Park, Washington**

RQ-11A Raven

Monitoring sediment volumes eroded from the reservoir and deposited downstream, where the mobile sediment can potentially affect salmon habitat and flood-stage elevation.



# Other Activities

- Joint Agency Commercial Imagery Evaluation (JACIE) collocated with ASPRS
  - http://calval.cr.usgs.gov/jacie/
  - Continue to present system/sensor/data quality (adding GSICS session)
  - Gov't satellite operators outnumbered by commercial!
  - How do we use all the system information to support CEOS/GEOSS?
- Building, coordinating Test Ranges
  - Added spatial test sites to Worldwide Test Site Catalog
  - http://calval.cr.usgs.gov/rst-resources/sites_catalog/spatial-sites/
- Elevation
  - Lidar Data Quality – USGS ASPRS Lidar Data Quality Group and Guideline
  - 3DEP
  - WorldDEM
  - 30 meter NED release (global)
  - and others
- Data and Product Uncertainty and Maturity