USGS Agency Update

Presented to CEOS WGCV
October 1, 2014
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
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
Launched 15 Apr 1999
> 14 years of on-orbit operations

**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

**Fuel**
- ~ 2 years

**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

**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

**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

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

**Launched 15 Apr 1999**

**Landsat 7 Spacecraft Status**
### L7 Geodetic Characterization

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

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Along Scan Mean (m)</th>
<th>Across Scan Mean (m)</th>
<th>Along Scan RMSE (m)</th>
<th>Across Scan RMSE (m)</th>
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<tbody>
<tr>
<td>2Q11</td>
<td>102.758</td>
<td>-13.456</td>
<td>107.538</td>
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<td>3Q11</td>
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<td>126.379</td>
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<td>4Q11</td>
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<td>101.346</td>
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<td>27.906</td>
<td>52.634</td>
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<td>1Q13</td>
<td>32.158</td>
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<td>47.287</td>
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<td>32.393</td>
<td>13.142</td>
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<td>1Q14</td>
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<td>16.036</td>
<td>50.260</td>
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<td>2Q14</td>
<td>19.670</td>
<td>-1.513</td>
<td>51.610</td>
<td>56.232</td>
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<td>3Q14</td>
<td>5.943</td>
<td>-19.739</td>
<td>68.194</td>
<td>55.001</td>
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</tbody>
</table>
L7 Geodetic Accuracy Characterization

L7 Geodetic Mean Accuracy (3Q11 - Present)

- MEAN_PREFIT_ALONG
- MEAN_PREFIT_ACROSS

Meters

L7 Band to Band Characterization

- All bands within spec as of July 2014

Band Average RMS Registration Error Since Launch
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
L7 Bumper Mode Mirror Calibration

L7 ETM+ Bumper Mode Mirror Scan Velocity

Radians per Second

- L7 ETM+ Forward Scan Velocity
- L7 ETM+ Reverse Scan Velocity
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

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 NiH₂ battery
- Unregulated 22 V - 36 V power bus
- Two power distribution boxes

THERMAL CONTROL
- Passive with heaters
- Constant conductance heat pipes

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

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
Landsat 8 Scenes Acquired per day

- OLI & TIRS
- OLI
- TIRS
- Daily min
L8 OLI TIRS processed scenes

L8 OLI and TIRS Processed Scenes
DOY 13101 through DOY 14261

April 11, 2013 through September 18, 2014
303,721 L8 OLI and TIRS Scenes
887 OLI Scenes
1,216 TIRS Scenes
301,618 OLI_TIRS Scenes
17,637 Unique L8 OLI and TIRS Scenes

USGS
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)

From USGS Tom Cecere Introduction, 9/30/14
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

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

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

Volcano
p175r73, 2013, day 304

Fire
p188r34, 2013, day 299

OLI Bands 4,3,2 (RGB)

Band 10 (Thermal)

OLI Bands 4,3,2 (RGB)

Band 10 (Thermal)

Band 7 (SWIR2)

Band 6 (SWIR1)

Band 7 (SWIR2)

Band 6 (SWIR1)
L8 Geometric Performance Summary

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

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

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

USGS, Jim Storey and Mike Choate, 8/4/14
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 On-Orbit Spatial Performance Estimates

Band 8 values are divided by 2 to put them on the same scale.

- XT_ES
- AT_ES
- Edge Slope Spec Limit
- Aliasing Limit

USGS, Jim Storey and Mike Choate, 8/4/14
Bahrain and China Bridge Targets

King Fahd Causeway

West Section

Center Section

East Section

Qingdao Bridge

Panchromatic Band Images

Single Span Bridges

USGS, Jim Storey and Mike Choate, 8/4/14
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
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
• 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
Initial Stray Light Correction

[Images of maps and horizontal profiles]
Initial Stray Light Correction
Red
Near InfraRed

OLI NIR Band 5 Trends: Band Average

Response Relative to Mission Day 75

Time Since Launch [years]

Symbols:
- stim lamp (working)
- stim lamp (backup)
- stim lamp (pristine)
- solar (working)
- solar panel (pristine)
- lunar
Short Wave InfraRed 1

OLI SWIR1 Band 6 Trends: Band Average

Response Relative to Mission Day 75

Time Since Launch [years]

- stim lamp (working)
- stim lamp (backup)
- stim lamp (pristine)
- solar (working)
- solar panel (pristine)
- lunar
Short Wave InfraRed 2

OLI SWIR2 Band 7 Trends: Band Average

Response Relative to Mission Day 75

Time Since Launch [years]

- stim lamp (working)
- stim lamp (backup)
- stim lamp (pristine)
- solar (working)
- solar panel (pristine)
- Lunar
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

Map showing the distribution of ground stations around the world with categorizations for completed agreements, in-progress agreements, and the LGN network.
## Landsat 8 Agreement Overview

### Signed (22 ground stations):

<table>
<thead>
<tr>
<th></th>
<th>Country</th>
<th>Location(s)</th>
<th>Date</th>
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<tbody>
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<td>China (RADI)</td>
<td>BJC, KHC</td>
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<td>Indonesia (LAPAN)</td>
<td>DKI, RPI</td>
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<td>LBG</td>
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<td>Argentina (CONAE)</td>
<td>COA</td>
<td>15 February 2013</td>
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<td>7.</td>
<td>Canada (CCMEO)</td>
<td>PAC</td>
<td>22 March 2013</td>
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<td>8.</td>
<td>Norway (NSC / KSAT)</td>
<td>SGS</td>
<td>22 March 2013</td>
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<td>Saudi Arabia (KACST)</td>
<td>RSA</td>
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<td>JSA</td>
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<td>12.</td>
<td>Japan (AIST)</td>
<td>KUJ</td>
<td>21 November 2013</td>
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<td>13.</td>
<td>Brazil (INPE)</td>
<td>CUB</td>
<td>TBD</td>
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# Landsat 8 Ground Station Certification

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<td>2. Japan (AIST-GSJ)</td>
<td>Kumamoto (KUJ)</td>
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<tr>
<td>3. China (RADI)</td>
<td>Miyun / Beijing (BJC)</td>
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<tr>
<td>4. Australia (GA)</td>
<td>Alice Springs (ASA)</td>
</tr>
<tr>
<td>5. Indonesia (LAPAN)</td>
<td>Parepare (DKI)</td>
</tr>
<tr>
<td>6. Canada (CCMEO)</td>
<td>Prince Albert (PAC)</td>
</tr>
<tr>
<td>7. Argentina (CONAE)</td>
<td>Córdoba (COA)</td>
</tr>
<tr>
<td>8. Europe (ESA)</td>
<td>Matera (MTI)</td>
</tr>
<tr>
<td>9. South Africa (SANSA)</td>
<td>Hartebeesthoek (JSA)</td>
</tr>
<tr>
<td>10. Indonesia (LAPAN)</td>
<td>Rumpin (RPI)</td>
</tr>
<tr>
<td>11. Europe (ESA)</td>
<td>Kiruna (KIS)</td>
</tr>
<tr>
<td>12. Thailand (GISTDA)</td>
<td>Bangkok (BKT) – Backup</td>
</tr>
<tr>
<td>13. Thailand (GISTDA)</td>
<td>Si Racha (SRT)</td>
</tr>
</tbody>
</table>
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 defined in the National Strategy for Earth Observations
  - 3 key areas – Earth Observations Requirements Capabilities and Analysis – tied together via an information evaluation system
Joint Approach USGS in Partnership with NOAA: Two Complementary Components

System Development
Joint Unified Architecture

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

Requirements Elicitation
Customizable to Agency Needs

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

Joint development with NOAA/TPIO And USGS/LRS

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

<table>
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<th>USGS RCA-EO</th>
<th>Earth Observation Requirement Evaluation System (EORES)</th>
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<tr>
<td>USGEO EOA II</td>
<td>Planning</td>
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<tr>
<td>SBA Value Tree Development</td>
<td>NOAA Missions (Oceans, Weather, Space Weather, Transportation, Disasters, Climate, etc.)</td>
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<tr>
<td>OSTP STPI Elicitations (cover what not covered by USGS and NOAA)</td>
<td>USGS Missions (Elicitations)</td>
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<tr>
<td>National EO Assessment /Plan</td>
<td>2013</td>
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<tr>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td>EORES O&amp;M</td>
<td>Add / Refine EOA-2 requirements</td>
</tr>
<tr>
<td>USGS Missions (Elicitations)</td>
<td>2013</td>
</tr>
<tr>
<td>USDA Missions (Ag and Forestry), DOI Missions (Water, Ecosystems, Climate, Disasters, Energy &amp; Minerals, etc.), EPA Mission (Health, Water, etc.), DOE Missions (Energy, Climate, etc.), NIH Missions (Health, etc.), NSF Missions (Oceans, Climate, Ecosystems, Biodiversity, etc.), more …</td>
<td></td>
</tr>
</tbody>
</table>
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
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.

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<tr>
<th>Observation System (Ranked Order)</th>
<th>Agency</th>
<th>Ag&amp;Fst</th>
<th>BioDiv</th>
<th>Climate</th>
<th>Disasters</th>
<th>Ecosys</th>
<th>Energy</th>
<th>HumanHlth</th>
<th>Oc&amp;Gel</th>
<th>Space Wx</th>
<th>Trans</th>
<th>Water Res</th>
<th>Wx</th>
<th>Ref Meas</th>
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<tr>
<td>1. Global Positioning System (GPS) satellites</td>
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<tr>
<td>2. Next Generation Weather Radar (NEXRAD)</td>
<td>DOC/NOAA</td>
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<td>3. Landsat satellite</td>
<td>DOI/USGS, NASA</td>
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<tr>
<td>4. Geostationary Operational Environmental Satellite System (GOES-NOP)</td>
<td>DOC/NOAA</td>
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<tr>
<td>5. National Agriculture Imagery Program (NAIP)</td>
<td>USDA/FSA</td>
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<tr>
<td>6. Airborne LIDAR</td>
<td>DOC/NOAA, DOD/USACE, DOI/USGS, NSF</td>
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<tr>
<td>7. Forest Inventory and Analysis (FIA)</td>
<td>USDA/USFS</td>
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</table>

Impact:
- *: Contributes
- Moderate
- High
- Very High
- Highest
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

From USGS Tom Cecere Introduction, 9/30/14
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 NNG14G5837Q 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/
- Supports RCA-EO Requirements vs System Solutions
- The Number of satellites is growing fast!
- Nearly 200 EO satellites to be launched in 2014!
Many More Planned

<table>
<thead>
<tr>
<th>Agency</th>
<th>Website</th>
<th># Missions</th>
<th># Instruments</th>
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<td><strong>Totals</strong></td>
<td></td>
<td><strong>393</strong></td>
<td><strong>532</strong></td>
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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
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/
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

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
  – 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