The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance

Brian L. Markham, NASA/Goddard Space Flight Center, Edward J. Knight, Brent Canova, Eric Donley, Geir Kvaran, and Kenton Lee
Ball Aerospace & Technologies Corp.
OLI Presentations

- The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance Characterization --- Brian Markham—NASA Goddard Space Flight Center; Edward Knight, Brent Canova, Eric Donley, Geir Kvaran, Kenton Lee — Ball Aerospace & Technologies Corp.

- Operational Land Imager: Radiometric Calibration Overview --- Geir Kvaran — Ball Aerospace & Technologies Corp.

- Reflectance Factor Measurements of the OLI Flight Diffusers --- Stuart Biggar, Nikolaus Anderson—University of Arizona; Linda Fulton, Geir Kvaran, Harlan Kortmeyer—Ball Aerospace & Technologies Corp.

- The OLI Radiometric Scale Realization Round Robin Measurement Campaign -- Hansford Cutlip, Jerold Cole—Ball Aerospace & Technologies Corp.; B. Carol Johnson, Stephen Maxwell—NIST; Milton Hom, Brian Markham, Lawrence Ong—NASA Goddard Space Flight Center; Stuart Biggar—University of Arizona, College of Optical Sciences
Outline

- Instrument Description Overview
- Summary of Testing
- Summary of Test Results
The Operational Land Imager (OLI) represents a generational change in Landsat technology.

- Whiskbroom imager
- Obscured telescope
- 1020 cm² aperture
- 8 bits transmitted to ground
- VIS/SWIR and IR

- Pushbroom Imager
- Unobscured telescope
- 143 cm² aperture
- 12 bits transmitted to ground
- OLI is VIS/SWIR only (TIRS does IR)
OLI Maintains Landsat Legacy

- **Landsat Continuity Mission demands**
  - Accurate spectral and spatial information
  - Frequent synoptic earth views
  - NIST calibrated over time
  - Precise geo-referenced data

- **Key instrument parameters**
  - Cross-track FOV: 185 km
  - S/C altitude: 705 km
  - Geodetic accuracy*
    - Absolute: 65 m
    - Relative: 25 m
  - Geometric accuracy**
    - Absolute: 12 m

Coastal/Aerosol and Cirrus bands are new; NIR and Pan are narrower; bandpasses of others equivalent

<table>
<thead>
<tr>
<th>Band Name</th>
<th>CW (nm)</th>
<th>Bandwidth (nm)</th>
<th>GSD (m)</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal/Aerosol</td>
<td>443</td>
<td>20</td>
<td>30</td>
<td>130</td>
</tr>
<tr>
<td>Blue</td>
<td>482</td>
<td>65</td>
<td>30</td>
<td>130</td>
</tr>
<tr>
<td>Green</td>
<td>562</td>
<td>75</td>
<td>30</td>
<td>100</td>
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<tr>
<td>Red</td>
<td>655</td>
<td>50</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>NIR</td>
<td>865</td>
<td>40</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>SWIR 1</td>
<td>1610</td>
<td>100</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>SWIR 2</td>
<td>2200</td>
<td>200</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>PAN</td>
<td>590</td>
<td>180</td>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>Cirrus</td>
<td>1375</td>
<td>30</td>
<td>30</td>
<td>50</td>
</tr>
</tbody>
</table>

Note: Geometric reqts are tighter for OLI
OLI is a fairly simple instrument

- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- On-board calibration with both lamps and full aperture diffusers
OLI Focal Plane

- **Focal Plane Array**
  - Consists of 14 modules to cover the 15-degree field of view
  - 6919 detectors per multi-spectral band (13832 for Pan band)

- **Focal Plane Module (FPM)**
  - 494-detector array for each multi-spectral band (988 for Pan band)
  - Silicon PIN detectors for VNIR bands, HgCdTe detectors for SWIR bands
  - Butcher-block filter assemblies cover the detector arrays
OLI Is Complete*
Radiometric and Spectral Tests Completed with traditional spheres and monochromators

Aligning “Death Star” Calibration Sphere

Inspecting heliostat alignment

Large aperture linear polarizer

Spectral Measurement Assembly
Heliostat Calibration provides transfer of calibration to orbit

Heliostat steers sunlight into T/V chamber

Atmospheric transmittance characterized by University of Arizona

Measuring Heliostat Transmission

Sun illuminating heliostat
Extensive Spatial Characterization

- Conducted stray light characterizations in state of art facility
- Other Spatial Characterizations with BATC’s Horizontal Collimator Assembly (HCA)
  - Collimator and instrument in Vacuum
  - Various spatial targets used to conduct characterizations of edge response, ghosting, bright target recovery, pointing

Spatial targets used for testing

OLI being lowered into chamber for spatial testing
Spectral Performance - In band

- Relative Spectral Responses have desired sharp bandpasses
Spectral Performance – Out-of-band

- Out-of-band response
  - Measured at Focal Plane Module (Detectors + filters) level; focal plane fully illuminated; optics contribution (mirrors + window) analytically added
  - Typically $10^{-4}$ or better (approximate stray light level in test set up)
  - Some SWIR band crosstalk – most likely within detector material—within requirements
Polarization Performance

- Polarization
  - Polarization Sensitivity well below 2%
  - Will not alter measured signal from highly polarized scenes such as canopies and water
Radiometric Performance

- **SNR**
  - SNR significantly exceeds requirements and heritage

- **Calibration**
  - Radiance uncertainty ~3.5%
    - Extensive round robin for NIST traceability
    - Transfer-to-Orbit uncertainties measured
  - Reflectance uncertainty ~2.5%
  - To be discussed in upcoming presentations
Radiometric Performance - Stability

- Stability over 16 days (time between Solar Diffuser Cals) is excellent
  - <0.54% 2σ for all but Cirrus Band which is <1.19%
Spatial Performance

- **Spatial Performance**
  - Want sharp edges for change detection
  - Measured spatial response has:
    - Steep slope (exceeding reqts)
    - Low extended edge (good half edge extent)
    - No ripple/overshoot

- **Geolocation**
  - Want good pointing knowledge, again for change detection
  - Performance depends on both instrument and spacecraft; final measurements made during initial on-orbit checkout
  - Pre-launch instrument measurements mapped line of sight of all detectors to reference pixel/boresight to ~1/10th of a pixel
  - On target to have absolute geometric accuracy of <1/2 pixel
OLI Stray Light Testing Complete

- Tests using BATC state-of-the-art stray light facility; had tremendous results
  - Background light from facility undetectable (detector noise dominated)
  - Reference point: 9 orders of magnitude is difference between 10:30 am sun and ¼ moonlight

![Comparison of Azimuth Scans for Three Filters](image)

Stray Light Ninjas
Summary

- OLI represents a generational change from ETM+, but must preserve data continuity and therefore maintain solid calibration.
- Instrument design focuses on simplicity
  - Pushbroom vs. whiskbroom instrument
- Thorough pre-launch calibration and characterization complete
  - With unique BATC calibration facilities
- Performance meeting user needs
Landsat Data Continuity Mission (LDCM) Overview

Mission Objectives
• Provide continuity in the multi-decadal Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics
  • Land cover/use change
  • Human settlement and population
  • Ecosystem dynamics
  • Landscape scale carbon stocks
  • Resource management/societal needs

LDCM Data Needed to Address NASA Earth Science Focus Areas, Questions, and Applications

<table>
<thead>
<tr>
<th>Focus Areas</th>
<th>Science Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Carbon Cycle, Ecosystems, &amp; Biogeochemistry</td>
<td>- What are the changes in global land cover and land use, and what are their causes?</td>
</tr>
<tr>
<td>• Water &amp; Energy Cycle</td>
<td>- How do ecosystems, land cover &amp; biogeochemical cycle respond to and affect environmental change?</td>
</tr>
<tr>
<td>• Earth Surface &amp; Interior</td>
<td>- What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?</td>
</tr>
<tr>
<td></td>
<td>- What are the consequences of increased human activities on coastal regions?</td>
</tr>
</tbody>
</table>

Instruments
• Operational Land Imager – BATC
• Thermal Infrared Sensor – GSFC

Spacecraft
• Orbital

Mission Team
• NASA Goddard Space Flight Center
• Dept. of Interior’s United States Geological Survey (USGS)
• NASA Kennedy Space Center

Launch Readiness Date – December 2012

Landsat 7 data used to aid Indonesian government with tsunami relief efforts (David Skole, Michigan State University)
LDCM Mission Overview

- **Mission Description**
  - 1 satellite
  - 5 year mission
    - 10 years of propellant
  - After declaration of operational readiness, responsibility for LDCM transitions to USGS

- **Orbit**
  - 705 km at equator
  - 98.2° Inclination Sun-Synchronous
  - 16-day ground repeat
  - 10am mean local time (descending node)

- **Spacecraft**
  - 3-axis stabilized
  - Instrument Accommodation
    - OLI
    - TIRS

- **Launch**
  - Launch Vehicle - Atlas V 401
  - Date: December 12, 2012
# Landsat and LDCM Spectral and Spatial Requirements

<table>
<thead>
<tr>
<th>Landsat-5/7 TM/ETM+ Bands (µm)</th>
<th>LDCM Band Requirements (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 m Coastal/Aerosol 0.433 - 0.453</td>
</tr>
<tr>
<td>Band 1</td>
<td>30 m Blue 0.450 - 0.515</td>
</tr>
<tr>
<td>Band 2</td>
<td>30 m Green 0.525 - 0.605</td>
</tr>
<tr>
<td>Band 3</td>
<td>30 m Red 0.630 - 0.690</td>
</tr>
<tr>
<td>Band 4</td>
<td>30 m Near-IR 0.775 - 0.900</td>
</tr>
<tr>
<td>Band 5</td>
<td>30 m SWIR-1 1.550 - 1.750</td>
</tr>
<tr>
<td>Band 6</td>
<td>60/120m* LWIR 10.40 - 12.50</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Band 7</td>
<td>30 m SWIR-2 2.090 - 2.350</td>
</tr>
<tr>
<td>Band 8**</td>
<td>15 m Pan 0.520 - 0.900</td>
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Spotlight Session—LDCM

Preflight Calibration for the Thermal Infrared Sensor on the Landsat Data Continuity Mission
Kurtis Thome, Dennis Reuter, Ramsey Smith—NASA/Goddard Space Flight Center; Allen Lunsford—Catholic University of America; Matthew Montanaro, Brian Wenny—Sigma Space Corporation; Zelalem Tesfaye—Bastion Technologies, Inc.

The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance Characterization
Brian Markham—NASA Goddard Space Flight Center; Edward Knight, Brent Canova, Eric Donley, Geir Kvaran, Kenton Lee—Ball Aerospace & Technologies Corporation

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Reflectance Factor Measurements of the OLI Flight Diffusers
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Landsat Data Continuity Mission On-orbit Calibration and Validation Development
Ron Morfitt, Esad Micijevic—Stinger Ghaffarian Technologies, Inc.; Brian Markham—NASA Goddard Space Flight Center

Calibration of Satellite Imagery, Recalibration of the Past, Through the Present, and into the Future Using Invariant Sites
David Aaron, Larry Leigh—South Dakota State University; Nathan Leisso, Jeffrey Czapla-Myers—University of Arizona