Landsat Data Continuity Mission

presented at
The 15th Annual LCLUC Science Team Meeting
March 29, 2011
UMUC Marriott, Adelphi, Maryland
by
Jim Irons
NASA LDCM Project Scientist
NASA Goddard Space Flight Center
Greenbelt, MD
The Landsat Data Continuity Mission (LDCM) is under development for a December, 2012 launch

- Developed as a NASA / USGS partnership
- LDCM conducted a successful critical design review (CDR) May 25 – 27, 2010

Courtesy of Orbital
Mission Life Cycle Status

• LDCM is a NASA Category 1 Mission
  – LDCM receives the highest level of visibility in NASA
    • Same as Hubble Space Telescope, Space Shuttle, Space Station, etc.
  – LDCM requires approval of the Agency Program Management Council to initiate each phase of the project lifecycle
  – An independent Standing Review Board evaluates the mission periodically (all mission level reviews) and makes recommendations to the Agency Program Management Council (both technical and programmatic)
Top Level Mission Ops Concept - Continuity

- Fly LDCM observatory in legacy orbit (716 km, near-polar, sun-synchronous)
  - Ground tracks maintained along heritage WRS-2 paths with 10:00 a.m. equatorial crossing time
- Collect image data for multiple spectral bands (Vis/NIR/SWIR/TIR) across 185 km swath along each path
  - Provide coverage of global land mass each season by scheduling the collection of 400 WRS-2 scenes per day
  - Maintain rigorous calibration
- Archive data and distribute data products
  - Provide nondiscriminatory access to general public, generate Level 1 data products, distribute data products at no cost upon request
- Direct broadcast of data to network of international ground stations having memoranda-of-understanding with USGS
LDCM Overview

Category 1, Risk Class B Mission  
(TIRS Risk Class C Instrument)  
Category 3 L/V

LDCM Orbit  
705 km circular  
sun sync, 10am DNLT  
185km swath, 16-day repeat

Alaska Ground Station  
Gilmore, AK

Atlas V  
VAFB

Launch Readiness Date Dec. 2012  
5yrs. of Operations  
(excluding TIRS) with 10 years of fuel

LDCM Observatory  
(OLI, TIRS)

Representative IC  
Canada

Landsat Ground Station  
Sioux Falls, SD

Svalbard Ground Station  
Svalbard, Norway

TDRSS

X-band RT Broadcast  
384 Mbps

X-band Stored Science  
RT+PB or 2 PB @ 384 Mbps

NASA GN  
Wallops Island, VA
NASA/USGS Partnership

• NASA Responsibilities
  – Space Segment, Launch Segment, and Mission Operations Element (MOE)
  – Lead mission development as system integrator and lead missions systems engineering for all mission segments throughout development, on-orbit check-out, and acceptance
  – Lead Mission Operations through completion of on-orbit checkout period
  – Accountable for mission success through on-orbit check-out and acceptance across all mission segments

• USGS Responsibilities
  – Development of Ground System
    • Excluding the MOE
  – Lead, fund, and manage the Landsat Science Team
  – Lead LDCM mission operations, after the completion of the on-orbit checkout period
  – Accept and execute all responsibilities associated with the transfer of the LDCM Operational Land Imager (OLI) instrument, spacecraft bus, Mission Operations Element, and NSC/KSAT contracts from NASA following on-orbit acceptance of the LDCM system including assuming contract management
Operational Land Imager (OLI)

- OLI Provides
  - Accurate spectral and spatial information
  - Precise calibrated, geo-referenced data

- OLI Contains
  - Pushbroom VIS/NIR/SWIR detectors
  - Focal plane consisting of 14 Sensor Chip Assemblies (SCA) – 6,000 detectors per SCA for a total of 84,000 detectors
    - Visible and Short Wave Infrared Sensors
  - Four-mirror telescope
  - On-board calibration with both diffusers and lamps

- OLI is being built by Ball Aerospace and Technology Corp. of Boulder, CO
  - Contract awarded in July 2007
  - Critical design review held October, 2008
### OLI Spectral Bands

#### L7 ETM+ Bands

<table>
<thead>
<tr>
<th>L8 ETM+ Bands</th>
<th>LDCM OLI Band Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>30 m Coastal/Aerosol 0.433 - 0.453</td>
</tr>
<tr>
<td>Band 2</td>
<td>30 m Blue 0.450 - 0.515</td>
</tr>
<tr>
<td>Band 3</td>
<td>30 m Green 0.525 - 0.600</td>
</tr>
<tr>
<td>Band 4</td>
<td>30 m Red 0.630 - 0.680</td>
</tr>
<tr>
<td>Band 5</td>
<td>30 m Near-IR 0.775 - 0.900</td>
</tr>
<tr>
<td>Band 6</td>
<td>30 m SWIR-1 1.550 - 1.750</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>
</tr>
<tr>
<td></td>
<td>30 m Cirrus 1.360 - 1.390</td>
</tr>
</tbody>
</table>

#### Explanation of Differences

1. **Cirrus Band added in 2001 to detect cirrus contamination in other channels**
2. **Coastal Band added in 2001 at request of ocean color investigators requiring higher resolution of coastal waters relative to MODIS and SEAWifs**
3. **LWIR data to be collected by Thermal InfraRed Sensor (TIRS)**
4. **Bandwidth refinements made in all bands to avoid atmospheric absorption features**
   1. Enabled by higher SNR which is, in turn, enabled by push-broom instrument architecture
OLI Status

- Flight instrument integration completed
  - Focal Plane System
  - Calibration Subsystem
  - Electronics Boxes
  - Baseplate

- Flight OLI completed performance testing
  - Spatial, spectral, and radiometric testing complete

- Sensor integrated to baseplate
Near Term Milestones (Next 6 months)

- Complete environmental testing
  - EMI/EMC
  - Vibration
  - Thermal vacuum/thermal balance

- OLI Pre-Ship Review will be held ~2 weeks prior to shipment

- Ship OLI to the spacecraft vendor – June 2011

- Integrate OLI to Spacecraft
Pre-Launch OLI Signal-to-Noise Performance

OLI Signal-to-Noise Performance at Ltypical

- OLI SNR Requirement (median at Ltyp)
- OLI SNR Performance (12-bit median at Ltyp)
Pre-Launch OLI Signal-to-Noise Performance

OLI Signal-to-Noise Performance at \( L_{\text{high}} \)

- **SNR**
  - **1**: OLI SNR Requirement (median at \( L_{\text{high}} \))
  - **2**: OLI SNR Performance (12-bit median at \( L_{\text{high}} \))
Completed OLI Instrument

 Courtesy of Ball Aerospace & Technologies Corp.
TIRS Overview

- 2 channel (10.8 and 12 um) thermal imaging instrument
- Quantum Well Infrared Photodiodes (QWIP) / FPA built in-house at Goddard
- 100 m Ground Sample Distance
- 185 km ground swath (15° field of view)
- Pushbroom design with a precision scene select mirror to select between calibration sources
- Two full aperture calibration sources: onboard variable temp black body and space view
- Passively cooled telescope assembly operating at 180K
- Actively cooled (cryocooler) FPA operating at 43K
- 3 Year Design Life, Class C Instrument
- TIRS is being built in-house at NASA/GSFC
  - TIRS was officially added to the scope of the mission in December 2009
- Critical Design Review (CDR) completed - April 2010
### TIRS and ETM+ Spectral Bands

<table>
<thead>
<tr>
<th>L7 ETM+ Thermal Band</th>
<th>LDCM TIRS Band Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 6</td>
<td>100 m LWIR</td>
</tr>
<tr>
<td>60 m LWIR 10.00 - 12.50</td>
<td>10.30 – 11.30</td>
</tr>
<tr>
<td>100 m LWIR 11.50 – 12.50</td>
<td>Band 11</td>
</tr>
</tbody>
</table>

- 120 m resolution TIRS requirement deemed sufficient to resolve most center-pivot irrigation fields in U.S. West - typically 400 to 800 m in diameter – TIRS design provides for 100 m resolution
- Landsat 4 & 5 TM’s provided 120 m thermal images for a single thermal band
- Landsat 7 ETM+ provided 60 m thermal images for a single thermal band
- A two band instrument will enable atmospheric correction so that more accurate surface temperatures can be derived.
Focal Plane Array, Focal Plane Electronics, and telescope assembled and currently in flight calibration testing. Preliminary results are within specification.
TIRS Primary Structure completed all qualification testing including thermal vacuum, vibration, acoustics, and cold Earthshield deployment.
TIRS Status

Flight Cryocooler with Electronics:
All environmental testing has been completed Pre-Ship review scheduled for March 30th.

Flight Scene Select Mechanism:
Completed vibration testing and is currently in Thermal Vacuum. T/V is the last of the qualification tests prior to delivery to I&T.

MEB Test Bed tested with no issues found. Flight boards have been assembled and are in testing. MEB delivery to I&T expected the end of May.
Near Term Milestones

• Pre-Environmental Review (PER), August 2011

• Deliver TIRS to spacecraft vendor in November 2011 for integration
Spacecraft
Spacecraft

- **Spacecraft**
  - Accommodates two instruments (OLI, TIRS)
  - Provides pointing, power, data capacity, etc. to support LDCM operations

- **Contract awarded to General Dynamics Advanced Information Systems (GDAIS) in April 08**
  - GDAIS sold to Orbital Sciences Corporation in April 2010

- **Spacecraft Integration Readiness Review completed – August 2010**
TIRS & OLI on LDCM Spacecraft

Deployable Earth Shield (Stowed)

Sensor Unit Connector Bulkhead

Cryocooler Electronics

MEB

OLI
Spacecraft Bus Making Progress

Oven Controlled Crystal Oscillators (OCXO) Flight
S-Band Transceivers 1 & 2

Integrated Electronics Module (IEM)

Components in Italic Red are Engineering Models
S-Band Antenna Brackets
SIRU Bracket
Star Tracker Bracket

Reaction Wheels 1&2
Reaction Wheels 3&4
Reaction Wheels 5&6

Solar Array Brackets (Stowed)

Load Control Unit (LCU)
1553 Coupler
Electromagnetic Torque Rods (ETR)
Spacecraft BusMaking Progress

Components in Italic Red are Engineering Models

- Electromagnetic Torque Rods (ETR) X & Z
- Solar Array Mounts (Stowed)
- Reaction Wheels 5&6
- Three-Axis Magnetometers 1&2 TAM
- Star Tracker Bracket
- Charge Control Unit (CCU)
- Load Control Unit (LCU)
- I&T Battery With Cooling Plate

- Solar Array Mounts (Stowed)
- Reaction Wheels 3&4
- Reacttion Wheels 1&2
- SIRU Bracket
- Spacecraft Single Point Ground
Completed Propulsion Subsystem
Ground System Architecture
# Ground System Development Approach

<table>
<thead>
<tr>
<th>Element</th>
<th>Capability</th>
<th>Agency / Developer</th>
<th>Approach</th>
</tr>
</thead>
</table>
| Mission Ops Center and Backup Mission Ops Center | • Serves as control center for mission operations performed by the FOT  
• Hosts the MOE, CAPE, and other operations tools | NASA / MOMS | Minor mods to HSM MOC, GSFC B3/14 and B32 (bMOC) |
| Mission Ops Element | • Performs command encryption and commanding, RT telemetry monitoring, mission planning and scheduling, monitoring and analysis, flight dynamics, and onboard memory management and mission data accounting | NASA / The Hammers Co., Inc. | COTS customization |
| Collection Activity Planning Element | • Generates instrument image collection schedules based on science priorities | USGS / TSSC | GOTS customization |
| Ground Network Element | • Performs S-band communication for S/C commanding and HK telemetry receipt  
• Receives S/C mission data via X-band  
• Routes HK telemetry to MOC and mission data to the DPAS | USGS / TSSC, NOAA, KSAT | Modification of existing stations |
| Data Processing and Archive System | • Performs mission data ingest, product generation, and image assessment  
• Provides storage and archive services  
• Provides web interface for data discovery, product selection and ordering, and product distribution | USGS / TSSC | Customization of heritage systems |
| NASA institutional services (SN, NEN, NISN, FDF) | • Performs S-band communication for S/C commanding and HK telemetry receipt  
• Provides network connectivity across GS  
• Supports post-launch FD | NASA | Existing systems and services acquired through PSLA |
Ground System performance is monitored through a set of technical performance metrics (TPMs)

- To support management of the development process between milestone reviews
- Design is not static

TPMs are monitored on a regular basis

<table>
<thead>
<tr>
<th>TPM</th>
<th>Requirement</th>
<th>Performance</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGN Contact Time (with SvalSat)</td>
<td>98 min/day</td>
<td>133 min/day</td>
<td>+36%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>248 min/day</td>
<td>+153%</td>
</tr>
<tr>
<td>Ingest and Processing Throughput</td>
<td>400 scenes/day</td>
<td>890 scenes/day</td>
<td>+123%</td>
</tr>
<tr>
<td>Distribution Capacity Years 1-2</td>
<td>1250 scenes/day</td>
<td>4,700 scenes/day</td>
<td>+276%</td>
</tr>
<tr>
<td>Distribution Capacity Years 3-5</td>
<td>3500 scenes/day</td>
<td>4,725 scenes/day</td>
<td>+35%</td>
</tr>
<tr>
<td>End to End Latency</td>
<td>85% in 48 hrs</td>
<td>85% in 12 hrs</td>
<td>+75%</td>
</tr>
<tr>
<td>Receiver Implementation Loss</td>
<td>3 dB</td>
<td>2.3 dB</td>
<td>+23%</td>
</tr>
</tbody>
</table>
LGN Design Approach

• LDCM Ground Network (LGN)
  – Partnerships to use existing stations currently supporting Landsat
  – NOAA Interagency Agreement (IA) to use Gilmore Creek Station (GLC) near Fairbanks, AK
  – Landsat Ground Station (LGS) at USGS/EROS near Sioux Falls, SD
  – NASA contract with KSAT for Svalbard; options for operational use by USGS
  – Provides ≥ 200 minutes of Contact Time

• Common Avtec Programmable Demods
  – LDPC Forward Error Correction and CCSDS/CFDP Processing and Data Capture

• Landsat Scalable Integrated Multi-mission Simulator System (LSIMSS)
  – Used for T&C Processing at LGN Stations
  – Transfer of Station Status to MOE
  – Used for MOE and S/C testing
Standard LDCM Data Products

- LDCM standard Level-1T data products will be consistent with heritage Landsat product specifications – backward compatibility
  - OLI and TIRS data will distributed as a combined product. Pixel size: 15m/30m/30m
  - Quality Assurance (QA) “band” will be included
  - Media type: Electronic
  - Product type: Level-1T (precision, terrain correction)
  - Output format: GeoTIFF
  - Map projection: UTM (Polar Stereographic for Antarctica)
  - Orientation: North up
  - Resampling: Cubic convolution
First L1T Out of DPAS
Launch Vehicle

• Launch from Vandenberg Air Force Base on an Atlas V

• Interactions between Project, KSC, United Launch Alliance (ULA), and Orbital have begun
Conclusion

• Continuity with previous Landsat missions is fulfilled by LDCM
  – LDCM data will be comparable to data from previous Landsat satellites
  – Data collection along heritage orbital paths with identical 185 km swath width
  – Ensure global coverage of land mass on seasonal basis
  – LDCM data will be backward compatible with data from previous Landsat sensors
    • Supports long term retrospective studies to trend change over time

• Capabilities are advanced
  – Two new reflective bands, refined band widths avoid atmospheric absorption features, two thermal bands facilitate atmospheric correction
  – Improved performance
  – More data – 400 scenes per day lead to improved global coverage

• USGS will distribute LDCM data free to the general public
  – Capabilities to process and analyze large volumes of Landsat data are advancing rapidly for long term and broad area studies

• On Schedule for a December 2012 launch
Landsat Science Team

- Ninth Science Team meeting held March 01 – 03 in Mesa, AZ
  - Included visits to Orbital to view spacecraft

- Final Science Team meeting scheduled for April 16 – 18 in Sioux Falls, SD
  - 2011 is the fifth and final year of the initial Science Team contracts

- USGS plans to re-compete Science Team membership with a solicitation for proposals expected this summer
  - Five year contracts will be awarded