LDCM Ground System
Network lesson learned

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NASA LDCM Ground Systems Chief System Engineer
Outline

- Mission overview
- RF design
- Mission RF ETE Test Program
- Lesson learned
The LDCM will continue the acquisition, archiving, and distribution of moderate-resolution multispectral imagery affording global, synoptic, and repetitive coverage of the earth's land surface at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time.

The following are the major mission objectives:

- Define parameters for scheduling and collecting a minimum of 400 OLI and TIRS WRS-2 scenes per day for sunlit areas of the Earth’s landmasses, islands, coral reefs and atolls.
- Optimize data collection based on science and operational priorities as a function of cloud cover, seasonality (vegetation phenology), solar illumination, existing archive quality, and the availability of observatory resources.
- Expedite collection and processing of high priority imaging data to support monitoring of natural disasters or other high interest targets of opportunity.
- Provide the capability for users to request LDCM data collections.
- Provide the capability for International Cooperators to request LDCM data collections.
- Improve upon the success of previous missions based on lessons learned, improved input data, and algorithm refinements.
Driving requirement for the mission is to collect 400 scenes/day.

<table>
<thead>
<tr>
<th>System</th>
<th>Total Size</th>
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<tbody>
<tr>
<td>Daily Volume 400 Scene</td>
<td>390 GB</td>
</tr>
<tr>
<td>C&amp;DH rate</td>
<td>260.92 Mbps</td>
</tr>
<tr>
<td>Downlink Rate</td>
<td>384 Mbps Data/441 Msp Symbol</td>
</tr>
<tr>
<td>LDPC 7/8 rate packet</td>
<td>8160 bits</td>
</tr>
<tr>
<td>Minutes per day (14 contacts)</td>
<td>98 minutes</td>
</tr>
<tr>
<td>5 year archive</td>
<td>~ 400 TB</td>
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Mission Segment Responsibilities

**Space Segment**

- **Operational Land Imager**
  - Multi-Spectral Imaging Instrument
  - Pushbroom VIS/SWIR sensor

- **Thermal Infrared Sensor**
  - 2 thermal channels
  - Pushbroom design

- **Spacecraft**
  - 3-axis stabilized
  - Accommodates OLI & TIRS

**Launch Segment**

- **Atlas V 401**

**Ground System**

- **MOC at GSFC**
  - Collection Activity Planning Element (CAPE)
  - Generates high level imaging mission schedules

- **Mission Operations Element (MOE)**
  - Mission planning & scheduling, command & control, monitoring and analysis, flight dynamics & onboard memory management

- **Ground Network Element (GNE)**:
  - Stations at LGS, GLC & Sval
  - Antenna & associated equipment for X-Band image & S-Band telemetry data downlink reception and generation of S-Band command uplink

- **Data Processing and Archive System (DPAS) at EROS**
  - User Portal Element (UPE)
    - Provides web interface to facilitate: data discovery, product selection & ordering (for Cal/Val), & product distribution

- **Storage and Archive Element (SAE)**
  - Provides storage and services for data processing & archive services for data and archive products

- **Image Processing Element (IPE)**
  - Provides: Ingest, Product Generation, & Image Assessment
Ground Systems

GNE GLC

OS

DPAS & GNE
Ground Network Element

- USGS baseline two ground stations at:
  - EROS – Sioux Falls Landsat Ground station (LGS)
  - Gilmore Creek (GLC) /Alaska: NOAA ground station
- USGS has funded upgrades to these existing stations to support LDCM
- NASA funded KSAT/Svalbard station for LEOP, through commissioning +90 days
- USGS is evaluating additional Ground stations after IOC
  - Use of GN/NENS possible option if ready by 12/12/12
GNE Functional Block Diagram

- GLC LGN (NOAA)
- LGS LGN (USGS/DCPF)

- Exciter
- D/C
- RX/Bit Sync
- LSIMSS
- Demod
- Cache
- DCRSf

- GSFC MOC
- bMOC

- DCRSi
- Cache
- DCRSf
- Cache

- DPAS
- T&C Proc

- RX
- Demod

- NASA SN/NEN (Shown for Completeness)
- T&C Network
- Wideband Data Network

Legend:
- CMD
- TLM
- NISN IOnet T&C Network
GLC – Gilmore Creek, AK
- 10-11 Passes/Day
- Primary data Delivery via Internet 2
  - Defense Research & Engineering Network (DREN) used as backup

LGS – USGS/EROS
- 4-6 Passes/Day
- Local Area Network (LAN) Connection to DPAS

Svalbard – NASA/GSFC
- Contingency passes to ensure sufficient contact time margin
SC to Ground RF design maximizes data portion of RF link:
- High data rate (384 Data Mbps) uses entire X-band (8024 MHz - 8400 MHz) spectrum band allocation to near earth missions.
- Innovative design within X-band infrastructure without using Ka band.
- Low Data Parity Code (LDPC) 7/8 (7136/8160 bits) minimize overhead of error coding correction to data.
  - DSN filter further challenges the spectrum from 400 to 374 Mhz.
- Compression rate 1.55:1.
- $1 \times 10^{-12}$ Bit Error Rate (BER).

Ground receiver / demod key to meeting requirement:
- Gained understating of ETE RF design.
- Tuned demod performance/ programmable parameters.
Avtec HDRM Programmable Demod

- Addresses Key LDCM Requirements
- RF Interface with S/C, OQPSK Demodulation
- Rate-7/8 Low Density Parity Check (LDPC) Forward Error Correction (FEC)
- Fully Configurable CCSDS Processing
  - Frame Synchronization, Virtual Channel Separation, and Packet Processing
  - OLI/TIRS RT, SSR PB, X-Band TLM
- CCSDS File Delivery Protocol (CFDP) class 1
  - Extract mission data files from CFDP wrapper and perform checksum validation on mission data files
  - Error handling of data
- Data capture
  - Write validated data files to internal disk
  - Spool validated data files to DCRSf
- Status and control
  - Return status information to station controller (Includes ACK/NAK messages)
  - Configure, load, enable, and disable stored unit configurations (desktops)
Mission ETE testing RF

- LDPC
- Xmitter
- DSN Filter
- TWTA
- Antenna

- RF-IF chain
- Receiver

- Oct 2009*
- Dec 2009
- Feb 2010
- March 2010
- Jun 2010
- Aug 2011
- Oct 2011
- TBD

- GSFC Code 567 Simulation
- GSFC LDPC Test
- RF test at GD
- Demod FAT at AVTEC
- RF test at GD
- CTV RF Compat at GD
- EMI at GD
- RF Suitcase Testing

* Simulation is updated over time with parameters gleaned from other tests for higher fidelity

Simulated - LOW
Simulated - Better
Similar Unit
Engineering Model
Actual Unit
## RF Test Summary

<table>
<thead>
<tr>
<th>Test</th>
<th>Objective</th>
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<tbody>
<tr>
<td>GSFC Simulation</td>
<td>Independent verification by analysis to show whether the link will work or not, and determine critical design factors, margins, etc. These models are updated as other tests provide refined data and the simulations are repeated to monitor the overall link predicted performance.</td>
</tr>
<tr>
<td>GSFC LDPC Test</td>
<td>Test the Avtec LDPC implementation for compliance against standard (not against spacecraft implementation).</td>
</tr>
<tr>
<td>Demod FAT</td>
<td>Factory Acceptance Test, including test of all protocol layers.</td>
</tr>
<tr>
<td>RF Test at GD (February)</td>
<td>Test performance of link with EM DSN filter for refined overall performance estimate.</td>
</tr>
<tr>
<td>RF Test at GD (April)</td>
<td>Test performance of link with addition of EM TWTA and actual LGN Avtec Demod.</td>
</tr>
<tr>
<td>EMI</td>
<td>I&amp;T testing for interference – represents opportunity to test the entire actual observatory RF chain including antenna.</td>
</tr>
<tr>
<td>CTV RF Compat</td>
<td>Establish observatory compatibility with NEN, SN and LGN stations. Establish LGN Demod compatibility with observatory.</td>
</tr>
<tr>
<td>RF Suitcase</td>
<td>Test compatibility of entire LGN station with observatory. Done at each LGN station. Allows testing of track channels performance and signal optimization.</td>
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Ground Demod Test at GE
PN data was rate 7/8 LDPC encoded, modulated on a 1.2 GHz IF, up converted to 8.2 GHz, filtered to avoid the DSN band, down converted to 1.2 GHz IF, combined with AWGN, input to receiver and decoded.

**Red Line**: Careful measurement with noise source allowed 0.1 dB precision. Measurement repeated with two other commercial receivers resulted in similar curves.

Measured LDCM BER operating point. Less than 2 dB from ideal. Corrected from Es/No to Eb/No.

Allowed LDCM BER operating point 4.3 dB implementation loss allowed.
CFDP – File management

- SSR management and relation to science processing key to flight to ground interface
  - LDCM uses Intervals for science, with SSR managed by files
  - CFDP – Class 1 used to send files to ground, Receiver/Demod converts to files, forwarded to Data Router (DCRS).
  - Deletion of files from recorder done as part of Interval management (off line LCDM tailored process).
- CFDF file size;
  - Needs to be defined: based on data rate (open windows), BER and Seaker recorder buffers multiples
  - LDCM – 1 GByte
- Should have simplified design and use files/CFDP with SC, and build intervals on Ground
  - Use CFDP-2 per Ground station, let protocol handled SSR management
  - Retransmit uncompleted Files on next contact
### Lesson Learned

<table>
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<th>LDCM design</th>
<th>Lesson</th>
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<tr>
<td><strong>LDPC 7/8</strong></td>
<td>Works well, and is a way to optimize spectrum use.</td>
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<tr>
<td>High downlink rate</td>
<td>Design based on maximize use of spectrum and reduce contact time. Downlink rate (384 Mbps) higher than C&amp;DH rate (320 Mbps).</td>
</tr>
<tr>
<td>DSN /Wide band filter</td>
<td>Requires programmable receiver.</td>
</tr>
<tr>
<td>SSR</td>
<td>. tailoring for directories (scenes), requires complicated SSR management.</td>
</tr>
<tr>
<td>CFDP</td>
<td>Class -1.</td>
</tr>
<tr>
<td>File size</td>
<td>1 GByte</td>
</tr>
<tr>
<td>SC interface</td>
<td>Improved interfaces after SC CDR.</td>
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**Lesson:**
- Consider using Real Time rate same as C&DH and increase contact times.
- Testing indicates that programmable receiver corrects most of filter distortion.
- Define multiple data rates in spec (at least one more lower rate).
- Use files /structure supported by SSR vendor.
- Use Class -1 or Class 2 simplified (over one GS).
- No bigger than 1 Gbit, Allow optional smaller file size.
- Work with vendor early/often.
Lesson Learned

- Build good working relation between operations and with RSDO SC vendor
- Availability of high speed internet link key for station capability
  - Equipment is cheap compared to internet
- Allow flexibility in design with optional data rates and file sizes
- Simplify SSR management file/mission data management approach
- LDPC works
  - LDPC 7/8 good option to reduce coding overhead
  - Wide band distortion (DSN filter) are corrected by programmable receiver
Hardware to support design is cheap 140K

Projects are talking...
  - IRIS engaged in discussion with LDCM
  - CLARREO good candidate to use LDCM design features (LDPC, CFDP)
  - Earth mission require compatibility with NOAA, Internationals

NENS to improve interfaces with projects:
  - NPP and LDCM spent money to upgrade KSAT Svalbard
  - No clear road map or commitments (e.g OQPSK)
  - Need single point of contact in 450 (NIMO ?)

NENS viable option for LDCM after IOC if upgrades (Svalbard) available by 12/12/12