Payload Status

Arlin Bartels
Mary Reden
Joe Cerullo
Leslie Hartz
PAYLOAD SYSTEMS OVERVIEW
Payload has had high degree of continuity since Mission CDR

<table>
<thead>
<tr>
<th>INSTRUMENT</th>
<th>SPONSORSHIP</th>
<th>MEASUREMENT</th>
<th>LVL 1 RQMTS TRACEABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRaTER, Cosmic Ray Telescope</td>
<td>PI: Harlan Spence, BU</td>
<td><em>Tissue equivalent response to radiation</em></td>
<td>M10 - Radiation Environment</td>
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<tr>
<td>for the Effects of Radiation</td>
<td>IM: Tom Heine, BU - joined 5/08</td>
<td>LET energetic particle spectra 200 keV – 1 GeV/nuc</td>
<td>M20 - Radiation on Human equivalent tissue</td>
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<tr>
<td></td>
<td>ISE: Bob Goeke, MIT</td>
<td></td>
<td></td>
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<tr>
<td>DLRE, Diviner Lunar Radiometer</td>
<td>PI: David Paige, UCLA</td>
<td><em>Better than 500m scale maps of temperature,</em></td>
<td>M50 - Surface Temperatures</td>
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<tr>
<td>Experiment</td>
<td>IM: Wayne Hartford, JPL</td>
<td><em>rock abundances,</em> <em>mineralogy</em></td>
<td>M80 - Surface Features and Hazards</td>
</tr>
<tr>
<td></td>
<td>ISE: Marc Foote, JPL</td>
<td><em>LET energetic particle spectra</em></td>
<td>M90 - Polar Illumination</td>
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<tr>
<td>LAMP, Lyman-Alpha Mapping</td>
<td>PI: Randy Gladstone, SwRI</td>
<td><em>UV Albedo maps of the permanently</em></td>
<td>M100 - Regolith Resources</td>
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<tr>
<td>Project</td>
<td>IM: Ron Black, SwRI</td>
<td><em>shadowed areas</em></td>
<td></td>
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<tr>
<td></td>
<td>ISE: Dave Slater, SwRI</td>
<td><em>Maps of frost in permanently</em></td>
<td>M60 – Images ofPSRs</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>shadowed areas, 3km resolution</em></td>
<td>M70 – Subsurface Ice</td>
</tr>
<tr>
<td>Detector</td>
<td>Deputy PI: Roald Sagdeev, UMD</td>
<td><em>at 10km scales</em></td>
<td>M70 – Subsurface Ice</td>
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<tr>
<td></td>
<td>IM: Anton Sanin, IKI</td>
<td><em>Global distribution of neutrons around the Moon</em></td>
<td>M110 – Hydrogen Mapping</td>
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<td>ISE: Maxim Litvak, IKI</td>
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<tr>
<td>LOLA, Lunar Orbiter Laser</td>
<td>PI: David Smith, GSFC</td>
<td>~50m scale polar topography at &lt;10cm vertical,*</td>
<td>M30 - Topography Grid</td>
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<tr>
<td>Altimeter</td>
<td>Co-PI: Maria Zuber, MIT</td>
<td><em>and roughness and slope data</em></td>
<td>M40 - Topography Resolution</td>
</tr>
<tr>
<td></td>
<td>IM: Glenn Jackson, GSFC</td>
<td></td>
<td>M60 - Images ofPSRs</td>
</tr>
<tr>
<td></td>
<td>ISE: John Cavanaugh, GSFC</td>
<td></td>
<td>M80 - Surface Features and Hazards</td>
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<tr>
<td>LROC, Lunar Reconnaissance</td>
<td>PI: Mark Robinson, ASU</td>
<td><em>1000s² of 50cm/pixel images (125km),</em></td>
<td>M90 – Polar Illumination</td>
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<tr>
<td>Orbiter Camera</td>
<td>IM: Scott Brylow, MSSS</td>
<td><em>and entire Moon at 100m visible, 400m UV</em></td>
<td>M100 – Regolith Sources</td>
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<td></td>
<td>ISE: Mike Caplinger, MSSS</td>
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<tr>
<td>Mini-RF Technology Demonstration</td>
<td>PI: Stu Nozette, ACT</td>
<td><em>X&amp;S-band Radar imaging and</em></td>
<td>P160 - Demonstrate new lightweight SAR Technologies</td>
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<tr>
<td></td>
<td>PM: Dean Huebert, NAWC</td>
<td><em>radiometry</em></td>
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<td></td>
<td>DPM: Helene Winters, APL</td>
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LRO MISSION PER - PAYLOAD STATUS
Instrument Accommodations unchanged since Mission CDR

Mission CDR payload layout
Instrument Chronology summary

<table>
<thead>
<tr>
<th>Instrument</th>
<th>PSR Date</th>
<th>GSFC Arrival Date</th>
<th>Orbiter Mechanical Integration Date</th>
<th>Integration Functional Date</th>
<th>CPT Functional Date</th>
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</thead>
<tbody>
<tr>
<td>CRaTER</td>
<td>01/03/08</td>
<td>01/14/08</td>
<td>04/01/08</td>
<td>4/2/08</td>
<td>6/27/08</td>
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<tr>
<td>Diviner</td>
<td>02/06/08</td>
<td>03/01/08</td>
<td>03/26-28/08</td>
<td>5/6/08</td>
<td>6/29/08</td>
</tr>
<tr>
<td>LAMP</td>
<td>02/13/08</td>
<td>02/19/08</td>
<td>03/18/08</td>
<td>4/8/08</td>
<td>6/30/08</td>
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<tr>
<td>LEND</td>
<td>12/20/07</td>
<td>03/25/08</td>
<td>04/15/08</td>
<td>4/17/08</td>
<td>6/27/08</td>
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<tr>
<td>LOLA</td>
<td>06/09/08</td>
<td>04/14/08</td>
<td>04/15-17/08</td>
<td>5/6/08</td>
<td>7/2/08</td>
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<tr>
<td>LROC</td>
<td>05/07/08</td>
<td>05/10/08</td>
<td>05/12/08</td>
<td>5/13/08</td>
<td>6/30/08</td>
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<tr>
<td>Mini-RF</td>
<td>03/12/08</td>
<td>05/03/08</td>
<td>05/05/08</td>
<td>5/19/08</td>
<td>6/29/08</td>
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</tbody>
</table>

The image contains a table summarizing the instrument chronology with dates for various activities such as PSR (Phase Sensitive Referencing) dates, GSFC (Goddard Space Flight Center) arrival dates, mechanical integration dates, and dates for the CPT (Critical Path Time) functional integrations.
Instrument Integration into Orbiter went unusually smoothly

- Mechanical and electrical integration encountered very few problems
- Post-integration processing/closeout also went well
- Post-integration powered testing shows nominal functionality
- Only one Instrument (LOLA) required rework after installation
Integration and Processing sequences similar for entire Payload

- Processing common to entire payload
  - Instrument Post-ship functional prior to integration
  - Mechanical integration to Orbiter
    - Ground straps, purge, harness routing closeout completed
  - Safe-to-mate and electrical integration
    - Official inrush and grounding measurements made
  - Orbiter-level Instrument functional test
    - All Instruments nominal compared to post-ship functional baseline
  - Test thermocouples installed and thermal blankets installed/dressed

- Instrument-specific integration and process steps are complete:
  - Bakeout certification:
    - CRaTER, LEND
  - Optical cube measurement to Spacecraft master cube:
    - DLRE, LAMP, LOLA, LROC, Mini-RF
  - EMI/EMC testing repeated:
    - LEND
  - Functional testing performed with GSFC-supplied radioactive sources to check performance baseline:
    - CRaTER (Co-60)
    - LEND (AmBe)
  - Ambient performance testing to verify end-to-end performance
    - LAMP E-2-E Test
    - LOLA Full CPT
    - Mini-RF Source Horn Test
  - Special alignment verification tests
    - LROC (NAC-NAC coalignment)
    - LOLA laser-to-receiver
  - Special post-delivery processing
    - LAMP Optical Witness Sample removed and verified
    - LEND collimator taped out
    - LEND GBK outer layer installed by LRO thermal

- All Instrument integration and processing necessary to begin environmental test is complete
- No open WOAs are liens on environmental test

LRO MISSION PER - PAYLOAD STATUS 7
## Instrument RFA Status

<table>
<thead>
<tr>
<th>Review</th>
<th>Date</th>
<th>Total # of RFAs</th>
<th>RFAs closed by Review Team</th>
<th>Open RFAs</th>
<th>Comments</th>
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<tbody>
<tr>
<td>LOLA PDR</td>
<td>6/16/2005</td>
<td>50</td>
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<td>LROC PDR</td>
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<td>DLRE PDR</td>
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<td>CRaTER PDR</td>
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<td>CRaTER PER</td>
<td>9/11/07</td>
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<tr>
<td>LOLA PER</td>
<td>11/13/07</td>
<td>29</td>
<td>27</td>
<td>2</td>
<td>One RFA is advisory, several transferred to “residual” status</td>
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<tr>
<td>CRaTER PSR</td>
<td>1/3/08</td>
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<td>RFA is advisory with “Ready to Close” status</td>
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<td>Diviner PSR</td>
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<td>LOLA PSR</td>
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<td>3</td>
<td>5</td>
<td>2 have responses from LOLA</td>
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<td>TOTALS</td>
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<td><strong>389</strong></td>
<td><strong>382</strong></td>
<td><strong>7</strong></td>
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</tr>
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</table>
Instrument Requirements Verification essentially complete

- All L3 (systems spec/ICD) requirements verification complete or waived with approval prior to Orbiter integration with the following exceptions which were deferred to Orbiter level testing:
  - Inrush/grounding
    - Verified during Orbiter electrical integration
  - Acoustics
  - Pyro-shock
    - Exception: LEND performed pyroshock test at Instrument level
  - Self-compatibility at orbiter level (Mini-RF, LOLA)
  - Operating hours (total and failure free)

- All completed Requirements Verification Traceability Matrices (RVTMs) are in LRO CM
  - Exception: LOLA; release imminent

- Some waiver approvals still in process (see next chart)
  - No issues expected during review/signoff
  - None are liens to environmental test

- L2 IRD performance/calibration compliance documentation near final release
  - CRaTER, DLRE, LAMP and LROC reports/matrices essentially complete; need final LRO review
    - LEND, LOLA still completing Instrument-level data analysis
  - Will be presented at Mission PSR by the Instrument teams

- Gold Book waivers/exceptions: NONE
## Instrument Waiver Request Status

<table>
<thead>
<tr>
<th>Instrument</th>
<th>CCR #</th>
<th>CCR Title</th>
<th>Status</th>
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<tbody>
<tr>
<td>CRaTER</td>
<td>451-CCR-000987</td>
<td>CRaTER EMI/EMC Waiver Request</td>
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<tr>
<td>DLRE</td>
<td>451-CCR-001192</td>
<td>DLRE EMI/EMC Waiver Request</td>
<td>In Review</td>
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<td>LAMP</td>
<td>451-CCR-000970</td>
<td>LAMP Mass Allocation Waiver Request</td>
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<td>LAMP</td>
<td>451-CCR-001193</td>
<td>LAMP EMI/EMC Waiver Request</td>
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<td>LEND</td>
<td>451-CCR-001069</td>
<td>LEND Mass Allocation Waiver Request</td>
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<td>LEND</td>
<td>451-CCR-001110</td>
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<td>451-CCR-001155</td>
<td>LEND Electrical Waiver Request</td>
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<td>LEND</td>
<td>451-CCR-001156</td>
<td>LEND Thermal Cycling Waiver Request</td>
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<tr>
<td>LOLA</td>
<td>451-CCR-000381</td>
<td>LOLA Waiver Request Against ESS-209, Harness Splices</td>
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<td>LOLA</td>
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<td>LOLA Optical Receiver Waiver Request against the LRO ESS, Various</td>
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<td>LOLA Waiver Request against ESS-53, Bonding and Mating</td>
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<td>LROC Thermal Testing Waiver (MAR and TSS)</td>
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<td>LROC</td>
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<td>LROC Thermal Testing Waiver (MAR and TSS)</td>
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<td>LROC NAC Primary Mirror Surface/Internal Charging</td>
<td>Closed</td>
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<td>Mini-RF</td>
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<td>Mini-RF</td>
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<td>451-CCR-001177</td>
<td>Mini-RF EMI/EMC Waiver Request</td>
<td>Ready to Close</td>
</tr>
</tbody>
</table>
Individual Instrument Status
CRaTER Instrument Overview

- The primary goal of CRaTER is to characterize the global lunar radiation environment and its biological impacts.
- The investigation hardware consists of a single, integrated sensor and electronics box with simple electronic and mechanical interfaces to the spacecraft.
- The CRaTER telescope consists of six ion-implanted silicon detectors, mounted in pairs and separated by 2 cylinders of tissue-equivalent plastic (TEP).
CRaTER Orbiter Integration went smoothly

Post-Ship Functional in handling fixture

Being craned into position

With thermal blankets dressed for test
Ambient Test Baseline at Orbiter level

- LRO CRaTER Functional Procedure based on merging CRaTER Instrument-level Short Form Functional (SFF) and Long Form Functional (LFF)
  - Orbiter Functional runs the SFF portions
  - Orbiter CPT adds the LFF portion

- Short Form Functional:
  - Command/Telemetry Verification
  - Detector Bias Checks
  - Internal Calibration Signal
  - Detector Noise Threshold

- Long-Form Functional adds:
  - Data sample using Co-60 source (2.9 microrad)
  - Coincidence Mask Test

- Powered-on time at orbiter level as of 7/19:
  - 287 hours (665 total including at Inst level)

Co-60 source in place over telescope for ambient testing
Use of different radiation source at GSFC consistent with prior CRaTER test results

• Long-Form Functional establishes Orbiter-level performance baseline
  – Co-60 source test run pre/post orbiter tvac
    • Different source than one used at MIT, yields slightly different results
  – Internal Calibration Signal pre/post delivery used to show continuity between Inst-level and Orbiter-level performance
    • Run in ambient, tvac, at Cape and on-orbit
    • No radiation source used at launch site

• All results at LRO level comparable to Inst-level performance testing
  – Spectra as expected given slightly stronger strength for GSFC source
  – Cal signal nominal compared to Instrument-level testing
  – Other functional testing all nominal as well
    • Coincidence Mask had to rerun some combinations due to test proc errors
Orbiter-level Environmental Test Plans Baseline

- EMI/EMC test configuration defined and supplied to EMI lead
  - Discriminator settings and cal rates different for “noisy” and “sensitive” modes

- Thermal Vacuum configuration and testing defined
  - Will run SFF as part of Orbiter Functional
  - CRaTER will be part of mission sims in nominal observing modes
  - No radiation source
    - May see some signal from LEND Cf source; no issue from CRaTER side
  - Special targets/fixtures: none
  - Special test heaters: none
PR and Watch List Status

- PRs
  - #0516, CRaTER secondary science packets being dropped on RT link, open
    - Up to 2% of real-time data packets being dropped
      - Real-time only, all data gets archived
    - Issue isolated to ground side, not CRaTER
    - Under investigation, fix expected imminently
    - Not a lien on LRO mechanical testing

- Watch list:
  - Detector channel functionality
    - Residual risk (#CRATER-236) from unverified failure of Amptek PH300 EEE part failure in EM - not seen in either flight or flight spare unit
DLRE
DLRE Instrument Overview

- The objective of Diviner is to measure lunar surface temperatures at scales that provide essential information for future surface operations and exploration.
- Diviner is a multi-channel solar reflectance and infrared filter radiometer.
- The Diviner structure consists of an instrument optics bench assembly, an elevation/azimuth yoke, and an instrument mount.
- The electronics subassemblies control signal processing, instrument operation and articulation, command processing, and data processing and are distributed between the OBA and the yoke.
DLRE Orbiter integration went smoothly
Ambient Test Baseline at Orbiter level

• As infrared radiometer, DLRE detector performance data is qualitative outside of thermal vacuum

• LRO DLRE Functional nearly identical to Instrument-level functional
  – LRO-level functional testing deletes two checks not possible at orbiter level - removal of 1 pps signal and undervoltage threshold test
  – Orbiter Functional runs all other sections of the DLRE functional up to the azimuth and elevation actuator scan table tests
  – Orbiter CPT DLRE Functional adds in the full set of “table walking tests”

• DLRE Functional consists of:
  – All commands/states verified
  – Safing
  – Operational heaters
  – Actuator operation
  – Flight software and memory checks
  – Ability to upload and process scan tables

• Powered-on time at orbiter level through 7/19: 133 hours (702 total)
Orbiter-level Environmental Test Plans Baselined

- EMI/EMC configuration defined and supplied to EMI lead
  - Noisy mode will run the actuators through scan tables, sensitive mode will stare at internal blackbody

- Thermal Vacuum configuration and testing defined
  - Will run DLRE Functional within Orbiter Functional
  - DLRE will be part of mission sims in nominal observing modes
  - Existing thermal vacuum targets/fuxturing will allow quantitative performance measurement:
    - DLRE will slew to view existing LN2 cryopanel in (+X) position relative to DLRE
    - Will also view internal blackbody
  - Special test heaters: none
PR and Watch List status

- **PR Status:**
  - #0389 – DREB to ITP resistance measurement, closed
  - #0397 – Diviner Telemetry was not as expected, closed
  - #0461 – Anomalous HK telemetry, ready for closure, closed
  - #0517 – DLRE-enable command had to be sent twice, currently could-not-duplicate
  - #0518 – Blanket contacting purge enclosure during DLRE motion, closed

- **Watch list items:**
  - PRB#0517, Could not duplicate
    - Currently under investigation
    - Could be STOL-proc timing issue, could be example of dropped command
  - At Instrument level, DLRE known to drop approximately 1 out of 3000 commands
    - Not yet conclusively seen at orbiter level, may be related to PRB-#0517
    - Flight constraint implemented to send the only critical command (/DLSAFE) twice each time safing is executed
    - DLRE Flight Software stress test performed at JPL is intended to be rerun at orbiter level prior to EMI testing
LAMP
LAMP Instrument Overview

- LAMP is an integrated UV spectrograph composed of the following major elements:
  - A 41 x 65 mm off-axis paraboloidal primary telescope mirror.
  - A 50 x 50 mm toroidal holographic diffraction grating.
  - A 2-D imaging photon-counting microchannel plate (MCP) detector assembly with vacuum cover/window assembly.
  - Front entrance aperture with stray-light baffle.
LAMP Orbiter Integration went smoothly

Unpacked for post-ship functional test

On orbiter - straylight baffle cover on

Post-Ship E-2-E test setup

On orbiter - straylight baffle cover off for LTS Functional
Ambient Test Baseline at Orbiter Level

- LRO LAMP Functional nearly identical to Instrument-level functional
  - CPT LAMP Functional runs the entire LAMP Instrument-level functional and Lunar Terminator Sensor (LTS) functional
  - Orbiter Functional deletes the flight software/checksum tests and the redundant-side C&DH commanding tests

- LAMP Functional consists of:
  - Sends all commands/verifies telemetry and does self-test
  - Checks all door commands (only aperture door is actuated)
  - Stimulator/Discriminator test
  - Heater Commands
  - High-speed Data Transfer
  - Lunar Terminator Sensor operation
  - (CPT) Load and check memory
  - (CPT) Redundant C&DH check

- Powered-on time at orbiter level: 170 hours (1024 total)
  - First Instrument to reach 1000 total hours
Performance Baseline verified via E2E test at Orbiter level in ambient conditions

- Due to orientation and setup constraints in thermal vacuum, LAMP E2E test is only performed in ambient conditions at orbiter level
  - Performance in thermal vacuum already demonstrated at Instrument Level
  - Results to be compared to Instrument-level ambient E2E tests
- E2E test checks full “photons-to-output” spectra
- Also checks optical alignments and relative radiometric sensitivity
- D2 lamp & UV collimator attached to airglow aperture
- DDL detector operated at high vacuum
- Aperture Door open; detector & failsafe doors remain closed
Orbiter-level Environmental Test Plans
Baselined

- EMI/EMC test configuration defined and supplied to EMI lead
  - Noisy mode - high rate data and low level HV, perform histogram acquisition; LTS On
  - Sensitive mode: LTS off, HV off, turn on stimulator and run pixel-list
- Thermal Vacuum configuration and testing baselined, one aspect still under discussion:
  - Will run LAMP functional within Orbiter Functional
  - LAMP will be part of mission sims in nominal observing modes
  - Due to orbiter test configuration with nadir-down, LAMP aperture door has negative margin against required torque to fully open.
    - Design is not issue for on-orbit performance, only 1-g ground test issue
    - SwRI proposes that all three LAMP doors remain closed during thermal vacuum
    - LRO and SwRI currently consulting with AETD/544 to discuss whether the failsafe door should be actuated in thermal vac to demonstrate functionality
  - Special targets/fxturing: none
    - High voltage will not be operated and no D2 source will be used inside chamber
    - However, lights inside tvac chamber expected to be used to verify LTS performance
  - Special test heaters: required to reach qualification temps at hot (see thermal section for details)
  - Other considerations: UHP GN2 LAMP purge will be plumbed into chamber and will be used as part of chamber repress
PR and Watch List status

• PR Status
  – #0368 – LAMP internal grounding, closed
  – #0402 – LAMP/C&DH High Speed Data Error, currently could-not-duplicate
  – #0404 – LAMP aperture door failed to fully open, closed
  – #0514 – LAMP heater setpoint not achieved in 240 seconds, closed
  – #0519 – LAMP failed self-test command during powerup, currently could-not-duplicate
  – #0520 – LAMP safing plugs mislabeled, closed
  – #0521 – GSE database incorrect conversion on actuators, closed
  – #0522 – LAMP LAFS task status database error, closed
  – #0560 - Timing issues in LAMP Functional STOL proc, open
    • STOL proc being modified; inconvenient but not showstopper
    • Believed due to fidelity differences between flatsat and flight configurations

• Watch list items:
  – Could Not Duplicates:
    • High Speed Data Error (PRB-402)
      – Initially marked as SpaceWire error
      – Isolated to data frame error at first frame during system test on 4/08
    • Failed self-test command during powerup (PRB-519)
      – Command repeated and was successful
      – Likely STOL proc timing issue
LEND
LEND Instrument Overview

- LEND consists of nine detectors to measure fluxes of thermal, epithermal, and fast neutrons.
LEND Review History and Flight Unit status

- Pre-Ship Review (PSR) held mid-December 2007
  - Note: due to some I&T schedule slips on LEND side combined with visa date inflexibility, official LEND PSR was held during EMI/EMC, prior to vibe and tvac
- During environmental test, the first unit experienced two major hardware failures which led IKI to declare the first unit non-flight:
  - Vibration Failure on SHEN PMT
    - Improper parts selection; had inadvertently used non-ruggedized Hamamatsu PMT
    - Replaced with plug-and-play Hamamatsu ruggedized PMT, subsequent vibration testing successful
  - Front end electronics damaged by facility power line surge
    - Electronics repaired, facility modification performed and surge protection improved
- First unit was repaired and turned into the official Qualification Unit (QU)
  - All environmental tests subsequently completed successfully
- Second unit manufactured became the official Flight Unit
  - Collimator reused from QU, all other hardware new - not part of the two failures
- Flight unit successfully passed all environmental tests
- IRT reviewed LEND flight unit progress over series of telecons in 1st quarter 2008
  - One after each of the QU failures
  - One prior to FU shipment

LEND flight unit configuration: “new” electronics, collimator reused from QU
LEND post-delivery processing and Orbiter Integration went smoothly

Post-ship functional with GSFC AmBe source (circled)
Pictured: Jack Trombka/691 emeritus

EMI/EMC testing in GSFC EMI lab showing ground strap and cable shielding

Mechanical install complete - note collimator taping

Application of GBK blanket layer by GSFC thermal
Ambient Test Baseline at Orbiter Level

- LRO LEND Functional nearly identical to Instrument-level functional
  - Test procedures based on LEND-provided “sequences” converted to run on ITOS/STOL
  - Orbiter Functional runs the LEND Short Form Functional (SFF)
  - CPT LEND Functional runs the LEND Long Form Functional (LFF) with GSFC-provided AmBe source

- Short Form Functional:
  - Telemetry Verification incl power consumption
  - Changing Default Data Collection Time
  - Set to measurement mode (HVPS settings to LOW)
  - Set anticoincidences to all on and do data collect
  - Set discriminator levels on and do data collect
  - Internal 1 pps
  - Heater checkout

- Long Form Functional adds:
  - Repeat SFF with radiation source in place and longer data collects
  - Measurement mode (HVPS settings to HIGH - 1920V)

- Note: as with CRaTER, use of different sources at GSFC modifies performance baseline for subsequent testing
  - AmBe used in ambient
  - Cf used in thermal vacuum

- All tests nominal to date at orbiter level
- Powered-on time at orbiter level: 187 hours (343 total)
Orbiter-level Environmental Test Plans Baselined

- EMI/EMC configuration defined and supplied to EMI lead
  - Same modes as used at GSFC for post-delivery EMI testing
  - Sensitive mode runs HV setting at HIGH
  - Will use AmBe radiation source as before

- Thermal Vacuum configuration and testing defined:
  - Will run LEND short functional within Orbiter Functional
  - LEND will be part of mission sims in nominal observing modes
  - Radiation Source: Cf source will be used in chamber
    - LRO Thermal has accommodated source into fixture design
    - Sam Floyd (691) has built and tested mountbox
    - Radiation Safety (250) has been involved in discussions
  - Special Test Heaters - none
LEND PR and Watch List status

- **PR Status**
  - #0396, Cracks on collimator sealouts, closed
  - #0405, No activity on A-side 1553, closed
  - #0458, Temperature cal curve update, closed

- **Watch list items: none**
LROC
LROC Instrument Overview

• **LROC is an integrated camera suite combining dual high-resolution visible wavelength cameras with a mid-resolution vis/UV camera for context**

• **LROC’s mission is:**
  - Landing site identification and certification, with unambiguous identification of meter-scale hazards
  - Unambiguous mapping of permanent shadows and sunlit regions
  - Meter-scale mapping of polar regions with continuous illumination
  - Overlapping observations to enable derivation of meter-scale topography
  - Global multispectral imaging to map ilmenite and other minerals
  - Global morphology base map
  - Characterize regolith properties
  - Determine current impact hazard by re-imaging 1-2 m/pixel Apollo images

• **LROC Hardware consists of:**
  - **Wide Angle Camera (WAC) subsystem** – dual optics (UV and visible), multi-spectral imager with 100m/pixel visible resolution with a 90° FOV and 400m/pixel UV resolution with a 60° FOV.
  - **Narrow Angle Camera (NAC) subsystem** – two 0.5m/pixel telescopes, co-aligned with a total 5.7° FOV
  - **Sequence and Compressor System (SCS)** – electronics for commanding, receiving data from all cameras, contains power and data (SpaceWire) interfaces with the spacecraft.
LROC Orbiter Integration went smoothly

- Post-ship Functional Testing
- NAC +Z blanket blanket closouts
- NAC1 in handling/installation fixture
- WAC installed on IM pedestal
Ambient Test Baseline at Orbiter level

- NAC telescopes are only in focus in vacuum and after bakeout
  - Reverse-telescope collimator with bar-target used as target for coalignment tests, but results are qualitative
  - Pushbroom imaging: images appear as "stripes"
- WAC is in focus at ambient
  - Pushframe imaging: images appear as roughly 10 pixel-high "blocks"
  - Uses (striped) target when Orbiter configuration permits
- LRO CPT functional and LROC portion of Orbiter functional identical to Instrument-level functional testing:
  - SCS self test
  - NAC and WAC imaging performed
    - Exposure time variable
    - Reset levels variable
    - Companding selectable
    - WAC imaging mode selectable
- Llumalloy aperture covers left in place during functional testing for contamination control
- Orbiter-level image sets nominal compared to post-ship functional testing
- Powered-on time at orbiter level:
  - NACs: 119 hours (919 total)
  - SCS: 120 hours (920 total)
  - WAC: 75 hours (875 total)
Orbiter-level Environmental Test Plans Baseline

- EMI/EMC configuration defined and supplied to EMI lead
  - Noisy and sensitive modes the same - NACs and WACs to be put in continuous imaging loop
- Thermal Vacuum configuration and testing defined
  - Will run LROC Functional within Orbiter Functional
  - LROC will be part of mission sims in nominal observing modes
  - Both NACs will simultaneously view reverse-telescope collimator
    - Verify NAC-NAC coalignment over temperature
    - Verify +X Focus (qualitatively), -X focus (quantitatively)
  - WAC special targets/fuxturing: none - will view cryopanel
  - WAC Survival Heater checkout post-replacement
LROC PR and Watch List Status

• PR Status
  – #0445, Ground S/W update needed to view NAC images, closed
  – #0446, update database for correct calibration curves for thermistors, closed
  – #0449, WAC shroud and bracket interference, closed
  – #0466, WAC to SCS internal harness pulled out of WAC, closed

• Watch list items:
  – none
LRO Proposing To Replace Current WAC with Flight Spare

- **WAC1** (flight unit) meets level 1 science requirements, but has performance concerns
  - Filter performance degraded due to manufacturing issues (tears during mask removal, uneven deposition)
    - Blemishes (560 nm, 650 nm, UV)
    - Out of band leak (560 nm)
  - Scattered light glint off of light shield
- **WAC2** (flight spare) performance superior to WAC1
  - Filter performance much superior (see below)
  - Glint rejection improved
- **WAC2** has passed random vibration, currently in thermal vacuum testing, all testing nominal
  - Current schedule shows WAC2 available for integration to orbiter, 8/4/08
- **LRO** proposes to swap WAC2 for WAC1 after Orbiter mechanical testing
  - Pending successful completion of WAC2 test program and discussion with IRT at WAC2 PSR

Comparison of WAC1 (flight) and WAC2 (flight spare) VIS filters
LOLA Instrument Overview

• LOLA will provide meter-scale models of Lunar topography, surface slopes, surface roughness, surface brightness, and an improved lunar gravity model

• LOLA measures:
  – Range to the lunar surface
    • Single laser pulse measurement, 28 Hz pulse rate
      – Beam split 5 ways. 5 detectors
        Single return per shot per detector
    • Pulse time-of-flight
    • Tx & Rx leading/trailing edge timing
  – Reflectance of the lunar surface
    • Rx energy/Tx energy
LOLA Review Summary

- Review Summary – LOLA PSR June 9, 2008
  - RFA Status (does not include residual RFAs)
    - PSR – 8 assigned, 5 still Open
      - RFA #2 – Verification of Altimeter Ranging Accuracy and Precision (Degnan)
      - RFA #3 – Operation over all operating conditions (Bortz)
      - RFA #9 – Provide test report for thermal testing (Degnan)
      - RFA #10 - LOLA Instrument Performance for a Saturated Detector (Cornwell)
      - RFA #11 - Pulse temporal measurement variation as a function of input energy and detection threshold (Cornwell)
  - PER Nov. 13, 2007 – 29 assigned, 2 still Open
    - RFA #13, advisory – EM laser characterization (Bortz)
    - RFA #25 – Thermal and Optical performance analysis for failure of TEC control circuitry (Kushina)
  - CDR July 14, 2006 – 12 assigned – all Closed
  - ΔPDR Oct. 6, 2005 – 9 assigned – all Closed
  - PDR June 16, 2005 – 50 assigned – all Closed
- Open RFAs relate to indepth performance data analysis which is still ongoing
- Are not liens to LRO mechanical testing
- Data analysis must be complete and RFAs closed prior to Orbiter Thermal Vacuum testing
LOLA Orbiter Integration went smoothly

In handling/installation fixture

MEB after orbiter integration, showing top and bottom “slices”

OTA after orbiter integration in CPT configuration, with laser/beamstop on left and receiver/showerhead on right

Dressed for test
LOLA Rework After Orbiter Integration

• PRB-417
  – During LOLA Electrical Safe-to-mate procedure, the 1553 bus voltages were measured and found to be incorrect
  – Root cause determined to be reversed transformers in MEB DU
    • Fabricated/assembled correctly, error in design
    • Had not been explicitly verified at Instrument level during I&T
  – DU (Top) slice of MEB removed from orbiter and reworked
    • Repair effected and penalty environmental testing performed
    • Lower MEB slice and OTA left in situ on Orbiter
  – DU reintegrated to MEB, 1553 voltages normal and LOLA performance nominal

• PRB-452
  – However, during the DU re-integration to the MEB, LOLA found that one of the thermistors in the DU near one high-power component was no longer reading correctly
  – Since this thermistor is not needed on-orbit LOLA decided to use-as-is
    • Thermal intended for thermal design verification during LOLA thermal balance
    • Thermal balance testing showed no thermal issues associated with component
Ambient Test Baseline at Orbiter Level

- LRO-level LOLA testing essentially identical to Instrument-level CPTs:
  - LRO LOLA-CPT test repeats all 10 LOLA CPT tests + LOLA Functional
  - LOLA Portion of Orbiter Functional consists of LOLA Functional and CPT5

- LOLA CPT tests consist of:
  - LOLA Functional (incl. CPT7)
  - CPT1: Fine Ranging
  - CPT2: Medium Ranging
  - CPT3: Coarse Ranging
  - CPT4: Range Gate Test
  - CPT5: Constant range/variable background
  - CPT6: VGA response/return pulse E
  - CPT7: Noise vs threshold
  - CPT8: Algorithm Test - orbit Sim
  - CPT9: Var Pulse Width - Const Energy
  - CPT10: FSW Maintenance Test

- Laser-receiver optical alignment verified in LOLA Risley test on orbiter
  - Test results nominal (see backup)
  - Will be repeated after LRO Mechanical testing

- Powered-on time at orbiter level: 119 hours (889 total)
Orbiter-level Environmental Test Plans Baseline

• EMI/EMC test configuration defined and supplied to EMI Lead
  – Same as for Instrument level testing
  – Noisy mode - laser is fired
  – Sensitive mode - detector thresholds lowered

• Thermal Vacuum configuration and testing defined
  – Will run LOLA Functional (incl CPT7) and CPT5 as part of Orbiter Functional
  – LOLA will be part of mission sims in nominal observing modes
  – Expect to run entire LOLA CPT sequence at least once hot and cold across the four cycles of tvac
  – Test targets/fixturing:
    • Bench Checkout Equipment (BCE) and fiber-optics required for closed-loop testing will be ported through the chamber
    • Beam Stop Fibers and Showerhead:
      – Removed for thermal balance
      – Installed for thermal vac cycling
      – Installation happens during chamber break
LOLA Verification Status

• L3 (System Spec and ICD) Verification Status
  – Final Verification Matrix pending release
  – Open verifications
    • Approx 5 misc L3/interface requirements still need to be documented
      – No further waivers on L3 requirements anticipated
    • None are liens against LRO environmental test
    • Goal - Release completed RVTM before start of EMI/EMC testing
• L2 (Instrument Performance) Verification Status
  – LOLA assessment is that all L2/IRD performance goals are met, just need to finalize data analysis and release report/matrix
  – Must be complete prior to Orbiter thermal vacuum test
• Gold Book exceptions: none
LOLA PR and Watch List Status

• PR Status
  – #0409, Helicoil replacement, closed
    • Note: helicoil on the IM to which LOLA mounts
  – #0417, 1553 voltage levels below specs, closed
  – #0452, Thermistor temperature incorrect, closed
  – #0474, broken jackscrew, closed
    • Note: broken jackscrew was on spacecraft harness connected to LOLA

• Watch list items:
  – Laser Output Energy: most important performance parameter of a laser altimeter; is trended by LOLA
    • Maps to multiple LRO Project risk items
  – (Risk item #LOLA-256) Detector Operation: looking to maximize LOLA powered-on time (without firing laser) to demonstrate detector reliability
    • Mitigation against latent risk of detector damage from chamber accidental loss of high-vacuum during Instrument-level thermal vacuum test
Mini-RF
Mini-RF Instrument Overview

• Mini-RF will demonstrate new radar technology for future use in planetary resource mapping.
• The Mini-RF antenna mounts directly to the +Z (nadir facing) external surface of the spacecraft at five locations.
• The Mini-RF electronics are divided into 3 separate physically separate assemblies
  – Transmitter and Interconnect Box
  – Control Processor, Digital Receiver and Wave Form Generator
  – Receiver/Exciter.
• The three electronics box assemblies mount directly to the heat pipe headers on the spacecraft isothermal avionics panel.
Mini-RF Orbiter integration went smoothly
Ambient Test Baseline at Orbiter level

- LRO Mini-RF Comprehensive Performance Test (CPT) merges Instrument-level Functional, Limited Performance Test (LPT) and Receiver Performance Test (RPT)
  - Orbiter Functional runs the Mini-RF Instrument-level Functional portion
  - Orbiter CPT adds the LPT and RPT portions via Source Horn Test
- Functional:
  - Command/Telemetry Verification
  - S-band SAR baseline and zoom modes
  - X-band SAR baseline and zoom modes
  - S-band and X-band communications demonstration modes
- Source Horn Test (executed once thus far):
  - Receive path integrity verified
  - Baseline receive parameters established
- Powered-on time at orbiter level: 12 hours
  - Constrained by request to be present at all Mini-RF powered-on activities
Orbiter-level Environmental test plans

- EMI/EMC test configuration defined and supplied to EMI lead
  - Includes free radiating test configuration and test script inputs for the RF self-compatibility tests

- Thermal Vacuum configuration and testing defined
  - Antenna not connected - all tests completed via GSE
  - Will run Mini-RF Functional as part of Orbiter Functional
  - Mini-RF will be part of mission sims in nominal operating modes
  - Special test heaters: none
  - Special targets/fixturing: coax cables through bulkhead to GSE

- Full power transmission test post-TVAC
  - Absorber wall design in process
  - Radiation safety and facilities documentation to be revised
PR and Watch List Status

• PRs
  – #0432, resistance measurement anomaly, closed
  – #0440, secondary power isolation, in-rush, closed
  – #0467, science data not as expected, closed
  – #0511, non-existent permissions for writing in loads directory, open
    • Assigned to ITOS team; Ready to close
  – #0512, peak current safing trip, closed
  – #0513, file store errors during CFDP playback, open
    • Assigned to LRO FSW team; Will be resolved in next FSW release
  – Neither open PR is lien against Orbiter-level mechanical test

• Watch list items:
  – Risk Item Payload-94, Mini-RF Radar Interference with Other Instruments
    • Closure anticipated upon completion of the Orbiter RF Self-Compatibility Test
Waivers Since Delivery

- Waiver Status, 2 waivers approved, 4 waivers in process
  - Approved
    - #1067, ESS-10 (peak current)
    - #1068, TSS-1782 (thermal cycles)
  - In-Process
    - #1161, ESS-33 (polarity reversal protection)
    - #1167, ESS-38 (turn-off transient) & ESS-41 (distributed signal ground)
    - #1174, ESS-27 (operational bus transient)
    - #1177, EMI/EMC Test
Remaining Work

• Close out all open WOAs, PRB reports and Waivers
• Release all L2 and L3 Requirements Verification documentation
• Trending consolidation
  – Trending databases developed by Instrument teams
  – Trend datapoints at orbiter level identified by Instrument teams
  – Orbiter trending procedures developed and becoming routine
  – Orbiter trending database up and running
  – Plan to merge the two databases and begin running routine reports for the Instrument teams by end of mechanical testing
• Improving reliability of dataflow to remote Instrument teams
  – Most Instrument developers get science data from I&T via their SOCs
  – Most are getting real-time housekeeping directly from I&T when powered
  – Routine reliable data connection from I&T to the SOCs/Instrument teams proven more complex than initially thought
  – Plan to have dataflow issues to Instrument teams resolved with routine transfer of science data by end of mechanical testing
Payload is ready to proceed to environmental test

- No liens against LRO Mechanical testing
  - Requirements verification essentially complete
  - Waiver process essentially complete
  - Integration/processing WOAs essentially complete
  - No open RFAs impact mechanical test
  - No open PRB reports impact mechanical test
- All above must be complete before Orbiter thermal vacuum, however
- Ambient functional test baseline established during LRO CPT-1
- Test Instrumentation defined and installed
- Instrument modes/configurations for environmental testing defined
- Targets in thermal vacuum defined and verified
- **Payload is GO to begin environmental test**

+Y view with blankets installed
Backup
LOLA laser-to-receiver boresight alignment verified in Risley setup

Laser 2, Inst X Direction

Laser 1, Inst Y Direction

Laser 2, Inst Y Direction

Laser 2, Inst X Direction
# Surface Cleanliness Budget Status

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Details in contamination control section
# Outgassing Budget Status

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<td>CRaTER</td>
<td>&lt;5.0E-11 g/cm(^2)/sec</td>
<td>Yes</td>
</tr>
<tr>
<td>LEND</td>
<td>Electronics box (ebox) module &lt;5.0E-11</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Doppler Aperture &lt;5.0E-11</td>
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<tr>
<td>LOLA</td>
<td>Laser Bench &lt;5.0 E-13 g/cm(^2)/sec</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Aft Optics Mod &lt;5.0E-13 g/cm(^2)/sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radiator &lt;5.0E-11 g/cm(^2)/sec</td>
<td></td>
</tr>
<tr>
<td>Diviner</td>
<td>&lt;5.0E-11 g/cm(^2)/sec</td>
<td>Yes</td>
</tr>
<tr>
<td>LAMP</td>
<td>&lt;5.0E-11 g/cm(^2)/sec</td>
<td>Yes</td>
</tr>
<tr>
<td>LROC/NAC1</td>
<td>&lt;5.0E-11 g/cm(^2)/sec</td>
<td>Yes</td>
</tr>
<tr>
<td>LROC/NAC2 (same as NAC1)</td>
<td>&lt;5.0E-11 g/cm(^2)/sec</td>
<td>Yes</td>
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<tr>
<td>LROC/WAC</td>
<td>&lt;5.0E-11 g/cm(^2)/sec</td>
<td>Yes</td>
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<tr>
<td>LROC/Radiators</td>
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<td>Yes</td>
</tr>
<tr>
<td>Mini-RF</td>
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<td>Yes</td>
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<tr>
<td>Instrument MLI (all)</td>
<td>&lt;5.0E-11 g/cm(^2)/sec</td>
<td>Yes</td>
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</tbody>
</table>

Details in contamination control section
CRaTER Review Summary

- Pre-Ship Review (PSR) held January 3, 2008
  - RFA Status
    - PSR – 1 assigned, Closed
    - PER Sep 11, 2007 – 8 assigned, all Closed
    - CDR June 28, 2006 – 9 assigned, all Closed
    - PDR Sep. 29, 2005 – 5 assigned, all Closed
DLRE Review Summary

- Pre-Ship Review (PSR) held February 6, 2008
  - RFA Status
    - PSR – 2 advisories assigned, all Closed
    - ETRR Aug. 29, 2007 – 20 advisories assigned, all Closed
    - CDR May 23, 2006 – 14 assigned, all Closed
    - PDR Sep. 14, 2005 – 48 assigned, all Closed
LAMP Review Summary

• Pre-Ship Review (PSR) held February 13, 2008
  – RFA Status
  • PSR – 2 assigned, all Closed
  • PER June 6, 2007 – 16 assigned, all Closed
  • CDR April 13, 2006 – 6 assigned, all Closed
  • PDR Sep. 12, 2005 – 14 assigned, all Closed
LROC Review Summary

- Review Summary – LROC PSR May 7, 2008
  - RFA Status
    - PSR – No RFA’s assigned
    - PER Jan. 30, 2008 – 19 assigned, all Closed
    - CDR June 1, 2006 – 25 assigned, all Closed
    - PDR Sep. 8, 2005 – 18 assigned, all Closed
Mini-RF Review Summary

• Antenna Pre-Ship Review (PSR) held March 12, 2008
• Electronics Acceptance Review (AR) held April 30, 2008
  – RFA Status – No RFA’s from PSR, AR, & PER
    • CDR Feb.22, 2007
      – 38 assigned, all Closed
      – 2 advisories assigned, all Closed
    • Delta PDR Feb.22, 2007
      – 3 assigned, all Closed
    • PDR May 12, 2006
      – 3 assigned, all Closed
      – 29 advisories assigned, all Closed