LRO/CRaTER
Technical Interchange Meeting

LRO Mechanical Systems

Giulio Rosanova / 543
301-286-5907 / Giulio.G.Rosanova@nasa.gov
LRO Baseline (Deployed on Orbit)

- Solar Array
- Optical Bench / Radiator
- Instrument Module
- Avionics Module
- Propulsion Module
- High Gain Antenna
- X (Thrust)
- Y
- Z (NADIR)
LRO Baseline (Stowed)
LRO Coordinate System Definition

Coordinate Axis Origin
Located at center of L/V Separation Plane

- ZENITH (-Z)
- THRUST DIRECTION (+X)
- NADIR (+Z)
- RHR (+Y)
- Velocity Vector +/- X axis
Mechanical Baseline Design

82 in. (2.1 m)
79 in. (2.0 m)
110 in. (2.8 m)
LRO Launch Vehicle Interface

DELTA-II 3-Stage
9.5 ft. P/L Envelope

100” DIA. (2.54m)
Mechanical System Requirements

- Mechanically Accommodate LRO Instrument Suite
  - Provide Mechanically Stable Instrument Bench for Pointing Requirements
  - Meet Instrument FOV Requirements
  - Provide Thermal Radiator Area for Instruments
  - Provide Orbiter Purge System for Instruments

- Compatibility with DELTA-II Class Launch Vehicle
  - Instruments shall comply with “LRO Structural Loads and Mechanical Environments Specification” (430-SPEC-000022)
  - Fairing Doors for Instrument Access on Launch Pad
  - T-0 Purge Available
Mechanical System Requirements

- Comply with LRO Alignment, Pointing Jitter Budget
  - Instrument Pointing/Alignment Errors
  - Thermal Distortion after Off-Pointing and/or Eclipse, G-Sag
  - High Frequency Jitter
    - Deployed Structures First deployed Frequency: ≥1 Hz

- Verify all Mechanical / Structural Designs and Functionality
  - Qualification by Test

- Use Simulators to Verify Interfaces
  - Provide Orbiter Wiring Mock-Up
  - Instrumenters to provide Hi-Fi Mass simulators for complex Designs
    - Used for LRO Orbiter Structural Qualification Testing
<table>
<thead>
<tr>
<th>INSTRUMENT</th>
<th>MASS</th>
<th>FOV(R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRaTER</td>
<td>5.60 kg</td>
<td>60° Full Angle Nadir &amp; Zenith</td>
</tr>
<tr>
<td>Diviner</td>
<td>9.98 kg</td>
<td>160° Full Angle Nadir Centered</td>
</tr>
<tr>
<td>LAMP</td>
<td>5.00 kg</td>
<td>40° Full Angle Nadir Centered</td>
</tr>
<tr>
<td>LEND</td>
<td>23.20 kg</td>
<td>20° Full Angle Nadir Centered (4)</td>
</tr>
<tr>
<td>LOLA</td>
<td>10.60 kg</td>
<td>&lt;&lt;1° Nadir Centered (2)</td>
</tr>
<tr>
<td>LROC</td>
<td>14.40 kg</td>
<td>NAC (2)- 60° Full Angle WAC- 120° ct X 30° dt</td>
</tr>
</tbody>
</table>
LRO Fields of View
CRaTER Fields of View
CRaTER Fields of View
CRaTER Fields of View
CRaTER 30ºZ-80ºN Fields of View
CRaTER 30°Z-80°N Fields of View
Instrument Design Requirements

- Design Limit Load: 12 g’s any axis
- Minimum Factors of Safety

<table>
<thead>
<tr>
<th>Type of Hardware</th>
<th>Design Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield</td>
</tr>
<tr>
<td>Tested Flight Structure – metallic</td>
<td>1.25</td>
</tr>
<tr>
<td>Tested Flight Structure – beryllium</td>
<td>1.4</td>
</tr>
<tr>
<td>Tested Flight Structure – composite*</td>
<td>N/A</td>
</tr>
<tr>
<td>Pressure Loaded Structure</td>
<td>1.25</td>
</tr>
<tr>
<td>Pressure Lines and Fittings</td>
<td>1.25</td>
</tr>
<tr>
<td>Untested Flight Structure – metallic only</td>
<td>2.0</td>
</tr>
<tr>
<td>Ground Support Equipment</td>
<td>3.0</td>
</tr>
<tr>
<td>Transportation Dolly/Shipping Container</td>
<td>2.0</td>
</tr>
</tbody>
</table>

- Minimum Frequency Requirement: 35 Hz (50 Hz Recommended)
- Overall acoustic environment: 149.6 dB qual, 146.6 dB acceptance
- Random Vibration Environment for Instruments and Components

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Protoflight/Qual Level</th>
<th>Acceptance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.026 g$^2$/Hz</td>
<td>0.013 g$^2$/Hz</td>
</tr>
<tr>
<td>50</td>
<td>0.160 g$^2$/Hz</td>
<td>0.080 g$^2$/Hz</td>
</tr>
<tr>
<td>800</td>
<td>0.160 g$^2$/Hz</td>
<td>0.080 g$^2$/Hz</td>
</tr>
<tr>
<td>2000</td>
<td>0.026 g$^2$/Hz</td>
<td>0.013 g$^2$/Hz</td>
</tr>
<tr>
<td>Over All</td>
<td>14.1 grms</td>
<td>10.0 grms</td>
</tr>
</tbody>
</table>
LRO FEM: Configuration F

**Total Mass: 2490 lbm (1129 kg)**

**CG (Origin at center of clampband IF)**

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>43.246</td>
<td>0.716</td>
<td>0.570</td>
</tr>
<tr>
<td>Y</td>
<td>1.0984</td>
<td>0.0182</td>
<td>0.0145</td>
</tr>
</tbody>
</table>

**Mass Moments of Inertia**

<table>
<thead>
<tr>
<th>Inertias about I/F (lbm*in²)</th>
<th>Inertias about I/F (kg*m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lxx 951379.60 lxy 120558.70</td>
<td>lxx 278.413 lxy 35.281</td>
</tr>
<tr>
<td>lyy 6625327.00 lyz 1614.27</td>
<td>lyy 1938.847 lyz 0.472</td>
</tr>
<tr>
<td>lzz 6650097.00 lzx 159823.80</td>
<td>lzz 1946.096 lzx 46.771</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inertias about C.G. (lbm*in²)</th>
<th>Inertias about C.G. (kg*m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lxx 949295.00 lxy 43445.97</td>
<td>lxx 277.803 lxy 12.714</td>
</tr>
<tr>
<td>lyy 1968112.00 lyz 598.73</td>
<td>lyy 575.952 lyz 0.175</td>
</tr>
<tr>
<td>lzz 1992413.00 lzx 98500.76</td>
<td>lzz 583.063 lzx 28.825</td>
</tr>
</tbody>
</table>
Fundamental Mode: Lateral Direction

**Mass scaled to launch vehicle capability (1480 kg)

\[ f_n = 19.6 \text{ Hz} \]

\[ f_n = 19.9 \text{ Hz} \]
Fundamental Mode: IM

\[ f_n = 46 \text{ Hz} \]
Mechanical Topics for TIM

- CAD Models: (PRO-Engineer), (SOLID-WORKS), (IDEAS)
- Identify CRaTER Orientation wrt LRO Coordinate System
- Identify Access zones to support testing do you Require?
  - (i.e., sources required for calibration, etc)
- Identify Connector Locations and Access/Stay-Out Zones Required?
- Identify Optical Reference Surfaces (as required)?
  - Alignment cube/reference mirror surfaces: size, and location?
- Identify GSE Handling Points
- Will Aperture Doors or Shutter be Considered?
- FEA Models: (FEMAP), (NASTRAN)
Mechanical Topics for TIM

- Identify your Design Heritage? (have some MLA info)
  - What were the design limit loads?
  - What factors of safety were used?
  - What was the random vibration environment?
  - What was the instrument’s first frequency?
  - What Analysis Documentation Exists?
  - What Verification Test Reports Exist?
  - Is the instrument sensitive to shock or acoustics?
- Do you require Access while on the Launch Pad?
- Do you require T-0 Purge at Launch?
- Mechanical Mass Simulator Required
  - Simple Designs over 50 Hertz (i.e. LAMP, CRaTER) mass and CG only.
    - Mass Simulator must be Qualified before Orbiter Structural Testing.
LRO Mechanical System Development Flow

MECHANICAL Design & Analysis

MECHANICAL Fabrication

CDR

MECHANICAL Design & Analysis

PROP. Module (PTyp) Build

S/C Bus (PFlt) Build

Inst. Module (PFlt) Build

Deployables (PFlt) Build & Test

Mechanical System Assy. Functional

Mechanical Qualification Testing

Spacecraft I&T

Orbiter I&T

Orbiter Environmental Testing

Launch Activities

PROP. Module (FLT) Build & Proof

PM Pluming Assy.

LRO S/C Subsystems / Components

INSTRUMENTS

INSTRUMENT MASS SIMS.

12/06

1/07

2/08

7/08

10/07