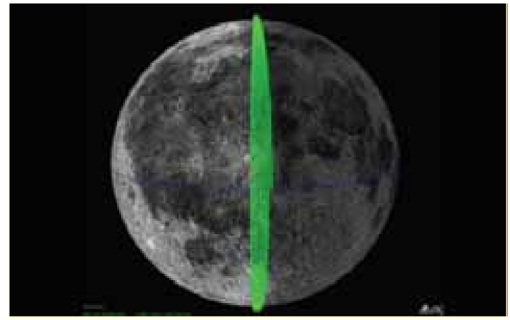
Lunar Reconnaissance Orbiter

LRO Objectives

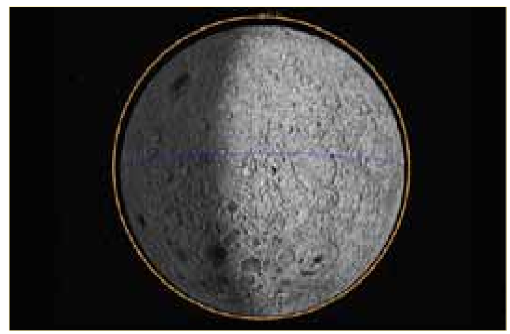
- Safe Landing Sites
  - High resolution imagery
  - Rock abundances
  - Topography
  - Global geodetic grid
- Locate potential resources
  - Water at the lunar poles?
  - Solar illumination as a continual energy source
  - Mineralogy
- Space Environment
  - Energetic particles
  - Neutrons
- New Technology
  - Advanced Radar

LRO Mission Overview

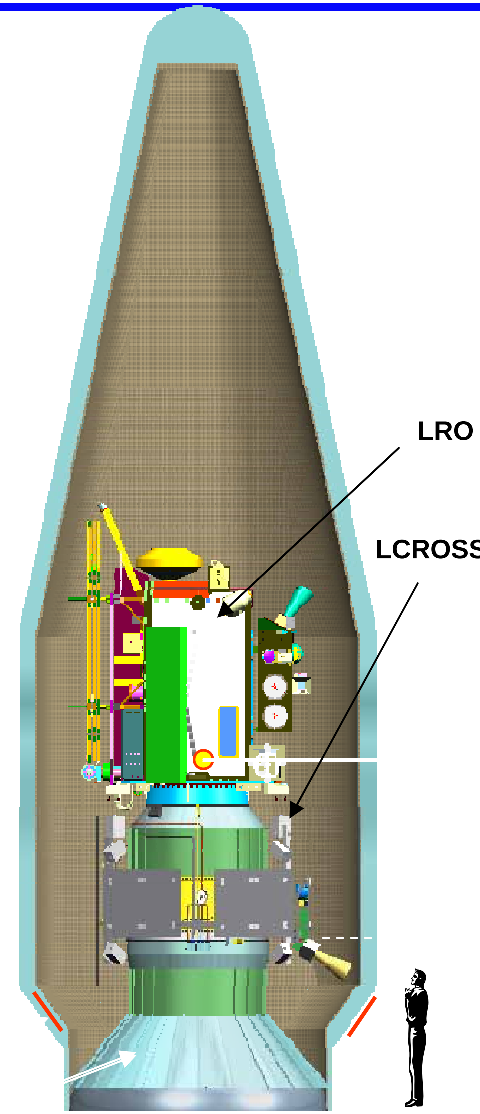
- Launch on an Atlas V into a direct insertion trajectory to the moon. Co-manifested with LCROSS lunar impactor mission.
- On-board propulsion system used to capture at the moon, insert into and maintain 50 km mean altitude circular polar orbit.
- 1 year exploration mission followed by handover to NASA Science Mission Directorate.
- Orbiter is 3-axis stabilized, nadir pointed, operates continuously during the primary mission.
- Data products delivered to Planetary Data Systems (PDS) within 6 months of completion of primary mission.

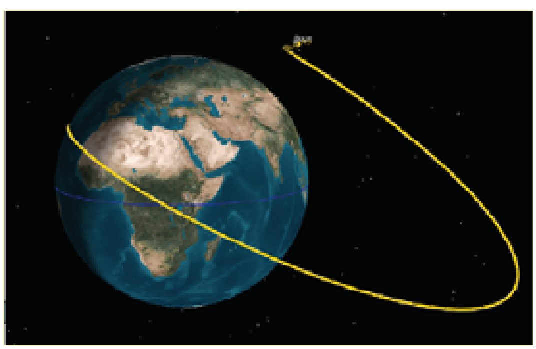


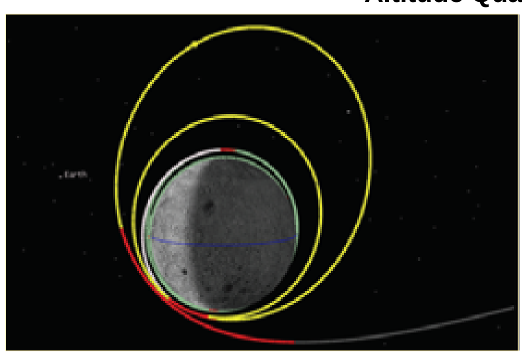
Polar Mapping Phase, 50 km Altitude Circular Orbit, At least 1 Year



Commissioning Phase, 30 x 216 km Altitude Quasi-Frozen Orbit, Up to 60 Days







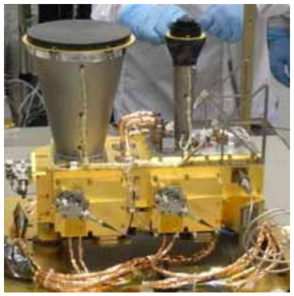
After 1 year of operation to accomplish Exploration objectives, LRO will be operated by NASA's Science Mission Directorate

- SMD mission might be operated in a different orbit (e.g. more complete coverage over the moon's lower latitudes, or in a more stable orbit for prolonged operations)
- SMD will provide funding for the LRO Principal Investigators, as well as for 24 LRO Participating Scientists
- All LRO data products will be delivered to the Planetary Data System within six months for use by the scientific community
- LRO instrument suite has strong planetary science heritage
- Measurement capabilities align with lunar science goals that were identified by the NRC Decadal Survey and SCEM reports

Instrument Overview

LOLA: Lunar Orbiter Laser Altimeter

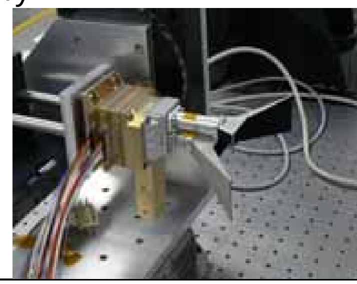
- Topography
- Slopes
- Roughness



Full Orbit
Autonomous

LROC/WAC: Wide-Angle Camera

- Global Imagery
- Lighting
- Resources



Day Side
Autonomous

LROC/NACs: Narrow-Angle Cameras

- Targeted Imagery
- Hazards
- Topography

Day Side
Timeline Driven

LR: Laser Ranging

- Topography
- Gravity

GSFC LOS
Autonomous

DLRE: Diviner Lunar Radiometer Exp.

- Temperature
- Lighting
- Hazards
- Resources

Full Orbit
Autonomous

Mini-RF: Synthetic Aperture Radar

- Tech Demonstration
- Resources
- Topography

Polar Regions
Timeline Driven

CRaTER: Cosmic Ray Telescope…

- Radiation Spectra
- Tissue Effects

Full Orbit
Autonomous

LEND: Lunar Explr. Neutron Detector

- Neutron Albedo
- Hydrogen Maps

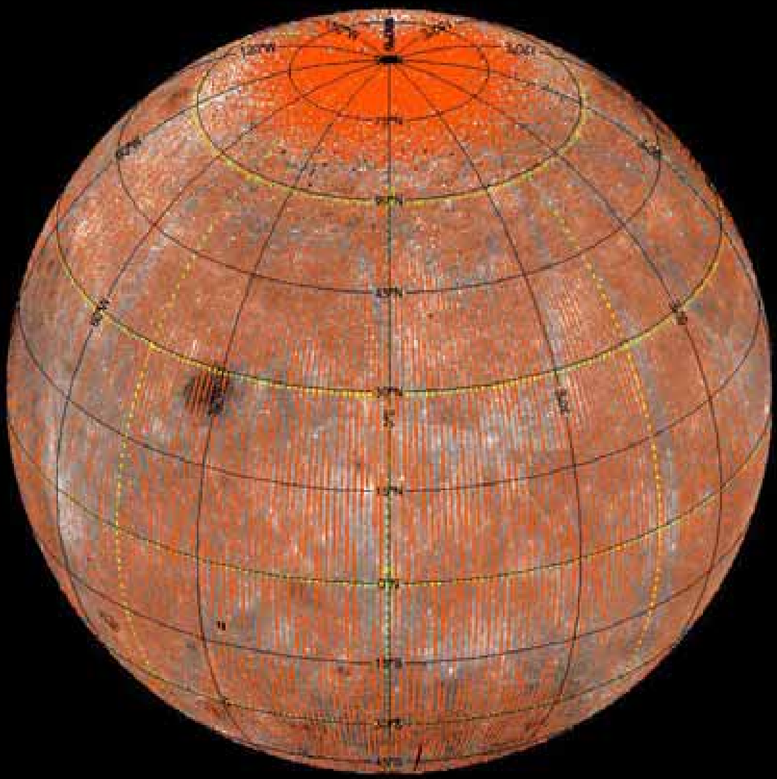
Full Orbit
Autonomous

LAMP: Lyman-Alpha Mapping Project

- Water-Frost
- PSR Maps

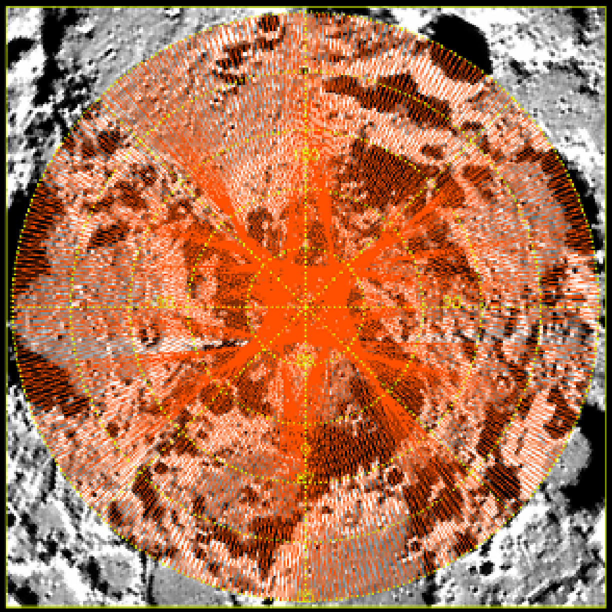
Night Side
Autonomous

LRO Emphasizes the Lunar Poles



27 day orbital ground track prediction

North Pole.

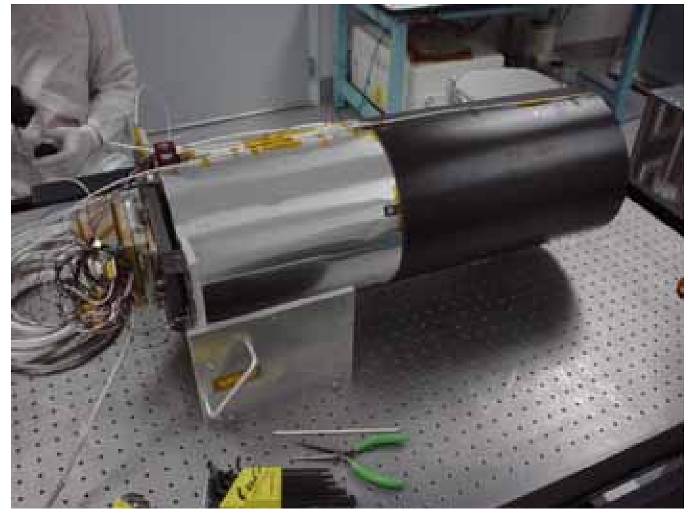


Lunar Reconnaissance Orbiter Camera (LROC)

Mark Robinson PI, ASU

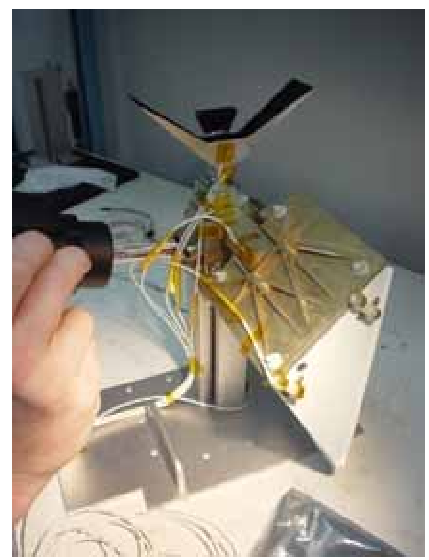
Wide and Narrow Angle Cameras (WAC, NAC)

- WAC Design Parameters
  - Optics (2 lenses) f/5.1 vis., f/8.7 UV
    - Effective FL 6 mm
    - FOV 90º
    - MTF (Nyquist) > 0.5
  - Electronics 4 circuit boards
    - Detector Kodak KAI-1001
    - Pixel format 1024 x 1024
    - Noise 30 e-
- NAC Design Parameters
  - Optics f/3.59 Cassegrain (Ritchey-Chretien)
    - Effective FL 700 mm
    - FOV 2.86º (5.67º for both)
    - MTF (Nyquist) > 0.15
  - Electronics
    - Detector Kodak KLI-5001G
    - Pixel format 1 x 5,000
    - Noise 100 e-
    - A/D Converter AD9842A
    - FPGA Actel RT54SX32-S



NAC

WAC Filters
#1 - 315
#2 - 360 nm
#3 - 415 nm
#4 - 560 nm
#5 - 600 nm
#6 - 640 nm
#7 - 680 nm



WAC

LROC Science/Measurement Summary

- Landing site identification and certification, with unambiguous identification of meter-scale hazards.
- Meter-scale mapping of polar regions with continuous illumination.
- Unambiguous mapping of permanent shadows and sunlit regions including illumination movies of the poles.
- Overlapping observations to enable derivation of meter-scale topography.
- Global multispectral imaging to map ilmenite and other minerals.
- Global morphology base map.

LROC NAC camera will provide 25 x greater resolution than currently available

50 cm pixel dimension from 50 km

Images geodetically tied to LOLA

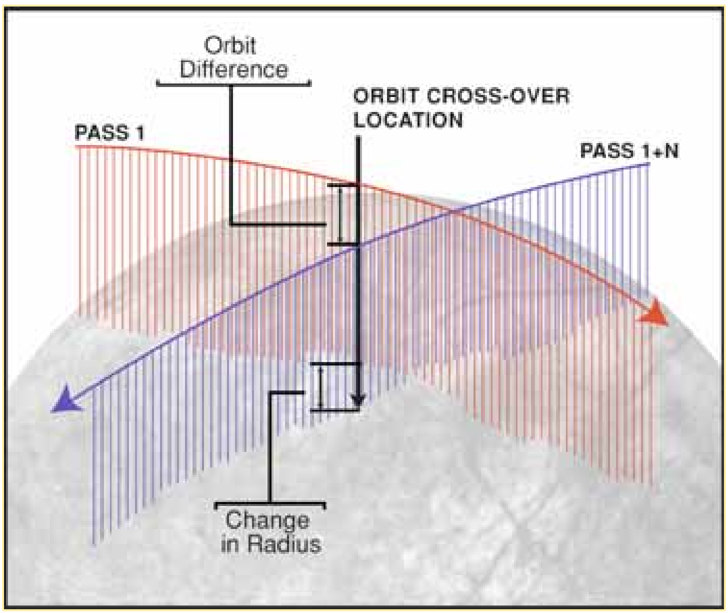
Lunar Orbiter Laser Altimeter (LOLA)

Dave Smith PI, GSFC; Maria Zuber co-PI, MIT

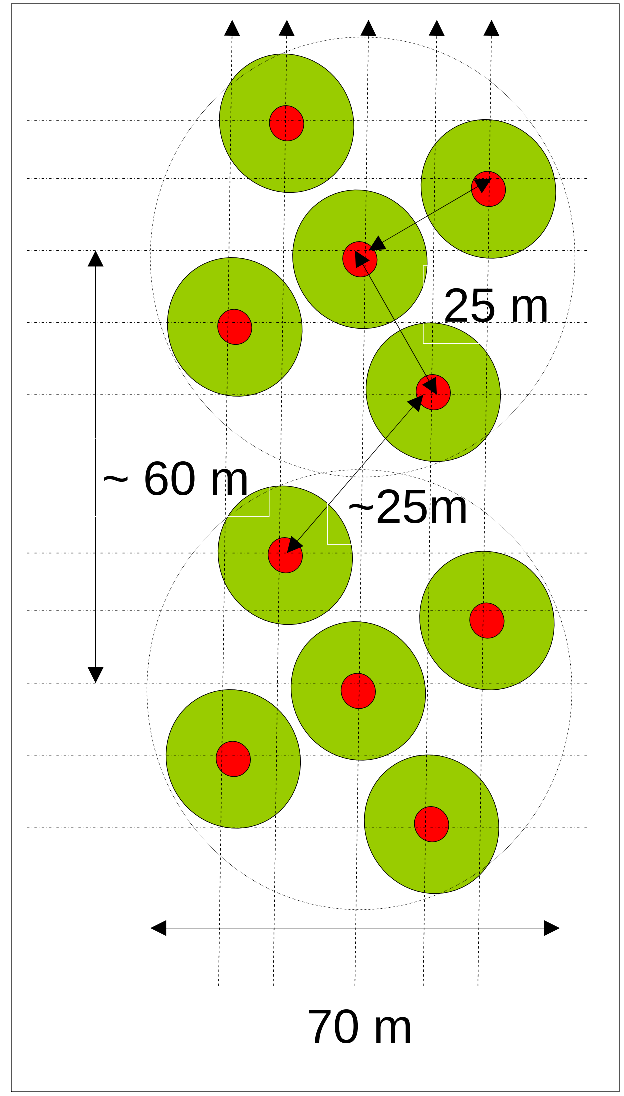
- **LOLA measures:**
  - RANGE to the lunar surface (pulse time-of-flight)
    ±10cm (flat surface)
  - REFLECTANCE of the lunar surface (Rx Energy/Tx Energy)
    ± 5%
  - SURFACE ROUGHNESS (spreading of laser pulse)
    ± 30 cm
- Laser pulse rate 28 Hz, 5 spots => ~ 4 billion measurements in 1 year.

LOLA will Derive an Accurate Global Lunar Reference System

- **LOLA will obtain an accuracy base of ~50 meters horizontal (point-to-point) and 0.5 to 1 meter radial**
  - Current accuracy ~4 km
- **LOLA is a geodetic tool to derive a precise positioning of observed features with a framework (grid) for all LRO Measurements**
  - Measure distance from LRO to the surface globally
  - Laser ranging from ground station to LRO provides precise orbit determination
  - Five laser spots along and across track
  - Measure distribution of elevation within laser footprint
  - Enhanced surface reflectance (possible water ice on surface)

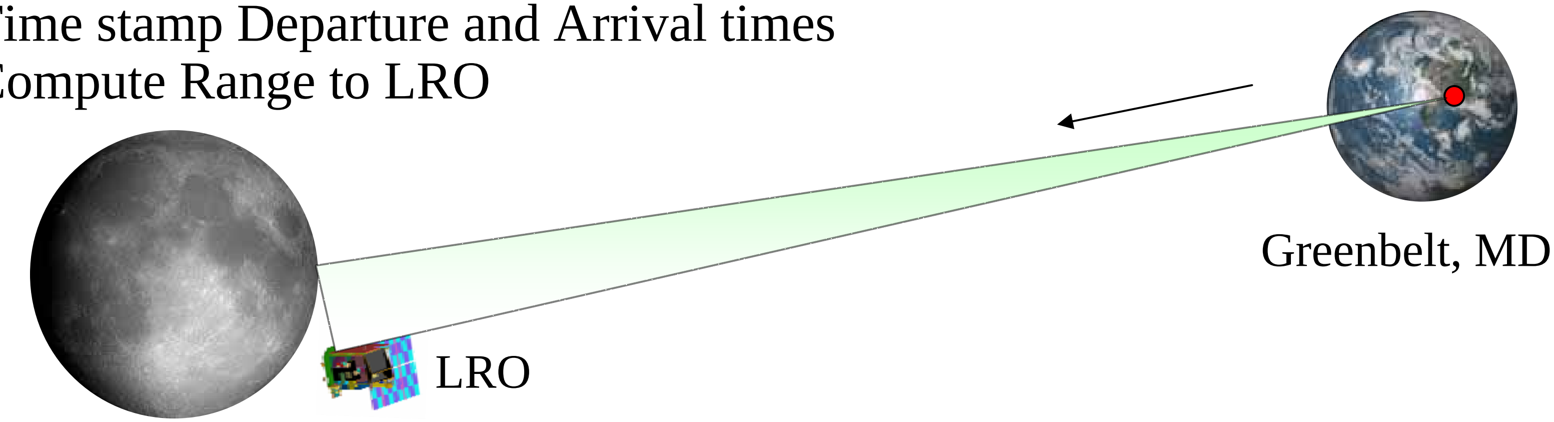


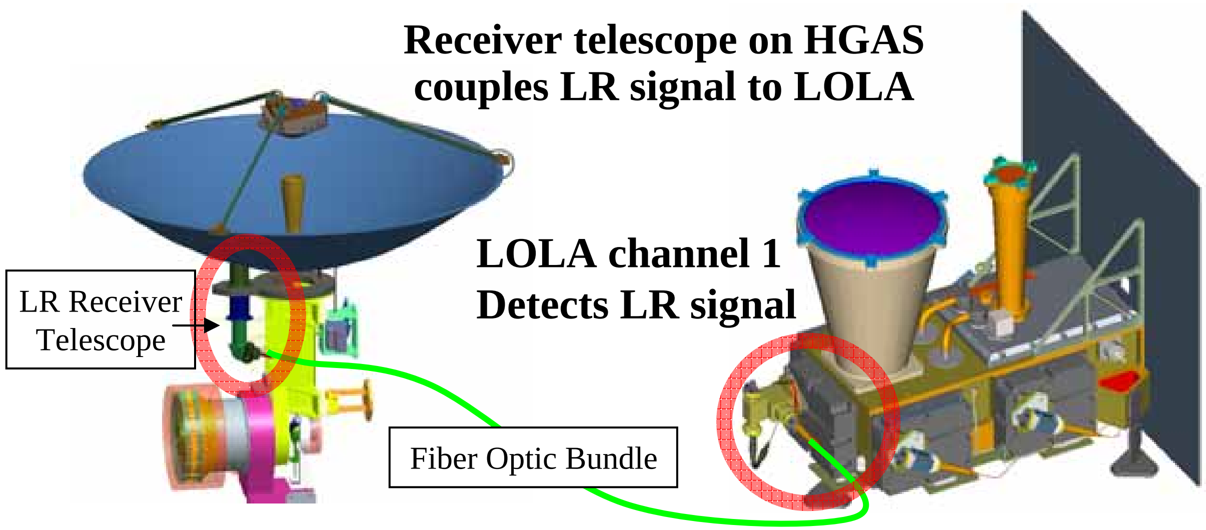
Crossovers occur about every 1 km in longitude and 3 deg in latitude at equator



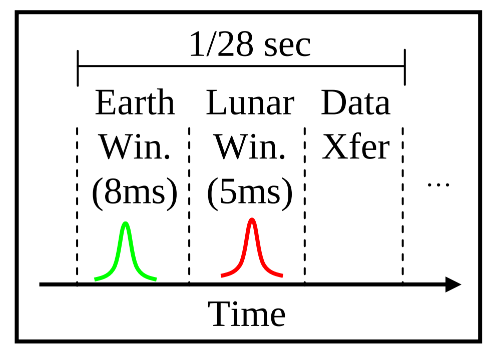
Laser Ranging Overview

- Transmit 532 nm laser pulses at 28 Hz to LRO
- Time stamp Departure and Arrival times
- Compute Range to LRO





LR Timeshares LOLA Detector With Lunar surface returns



Diviner Lunar Radiometer (DLRE)

David Paige PI, UCLA

- Diviner will characterize the moon's surface thermal environment (day and night)
- Surface properties will be mapped
  - Bulk thermal properties (from surface temperature variations)
  - Rock abundance and roughness (from fractional coverage of warm and cold material)
  - Silicate mineralogy (8 micron thermal emission feature)
- The characteristics of the polar cold traps will be determined
  - Map cold-trap locations
  - Determine cold-trap depths
  - Assess feasibility of water ice resources (using data and models)

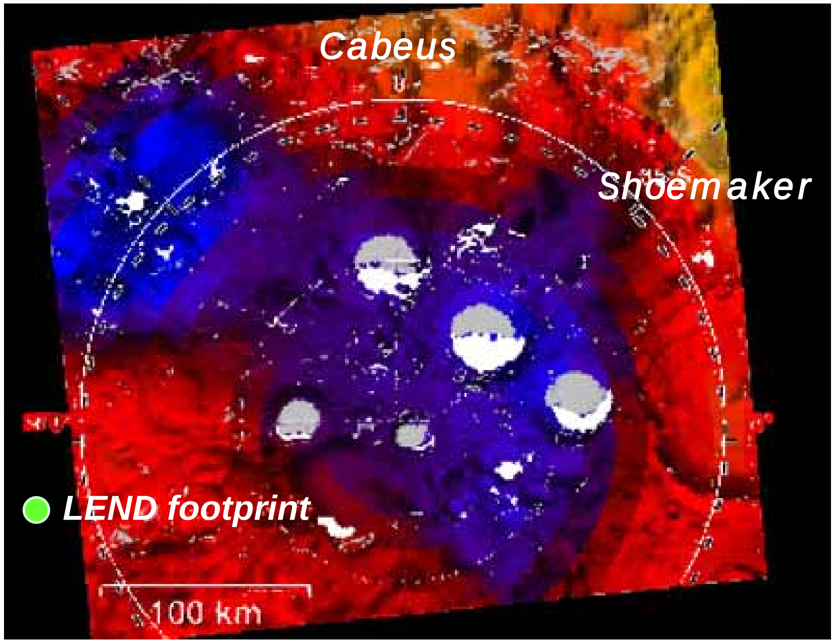
- 9-channel infrared radiometer 40K – 400K temperature range
- 21 pixel continuous pushbroom mapping with ~300 m spatial resolution and 3.15 km swath width at 50 km altitude
- Azimuth and elevation pointing for off-nadir observations and calibration
- Close copy of JPL's Mars Climate Sounder (MCS) Instrument on MRO

Lunar Exploration Neutron Detector (LEND)

Igor Mitrofanov PI, IKI

- LEND is designed to measure lunar thermal, epithermal and energetic neutrons.
- LEND improves spatial resolution for epithermal neutrons from 140km to 10km to locate areas of high hydrogen concentration
- LEND footprint smaller than the Permanently Shadowed Regions
- Improves sensitivity of hydrogen (water) measurements in upper meter of surface in cold spots
- Enables site selection

South Pole



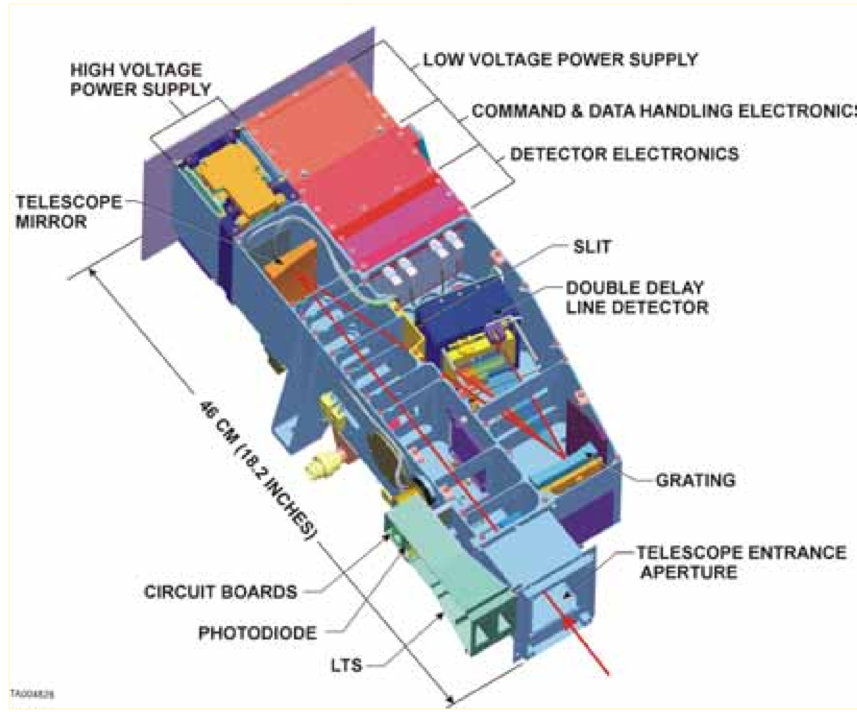
Shackleton

White areas represent permanently shadowed regions as determined from ground based radar and overlaid on Lunar Prospector hydrogen concentrations

Lyman-Alpha Mapping Project (LAMP)

Alan Stern PI, SwRI; Randy Gladstone (SwRI), Acting PI

- LAMP will identify and localize exposed water frost in permanently shadowed regions (PSRs) of the lunar surface PSRs
- LAMP will provide landform mapping (using Lyα albedos) in and around the PSRs
- LAMP will demonstrate the feasibility of using starlight and UV sky-glow for future night time and PSR surface mission applications.
- LAMP will measure the Lunar Atmosphere and Its Variability



<u>LAMP (with LTS):</u>
5.3 kg, 4.6 W
0.2º×6.0º slit
520-1800 Å passband
20 Å point source spectral resolution

Cosmic Ray Telescope for the Effects of Radiation (CRaTER)

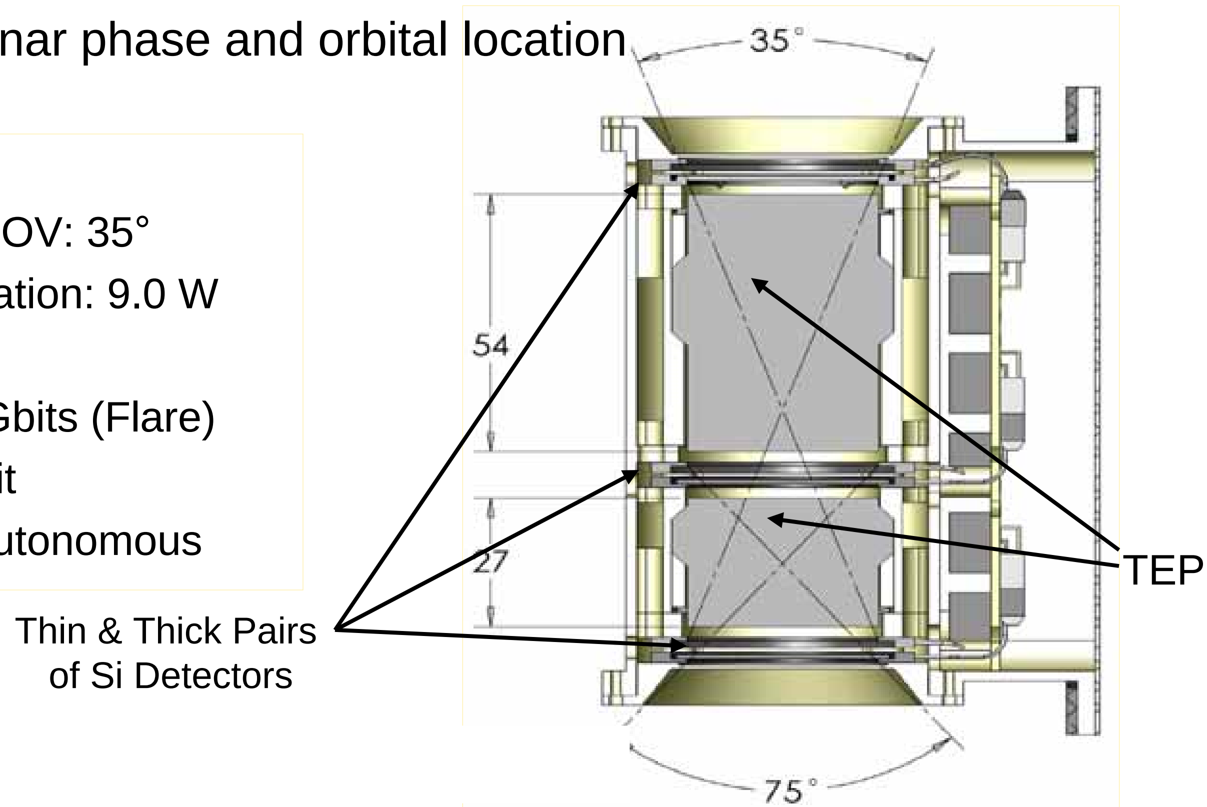
Harlan Spence PI, Boston University

• CRaTER will measure the Linear Energy Transfer (LET) spectra behind tissue equivalent plastic (TEP)

• LET spectra is the missing link connecting Galactic Cosmic Rays and Solar Energetic Particles to potential tissue damage

• Data will be sorted by lunar phase and orbital location

- Nadir FOV: 75°, Zenith FOV: 35°
- Avg. Orbital Power Allocation: 9.0 W
- Mass Allocation: 6.36 kg
- Daily Data Volume: 7.8 Gbits (Flare)
- Data Collection: Full Orbit
- Inst. Daily Operations: Autonomous

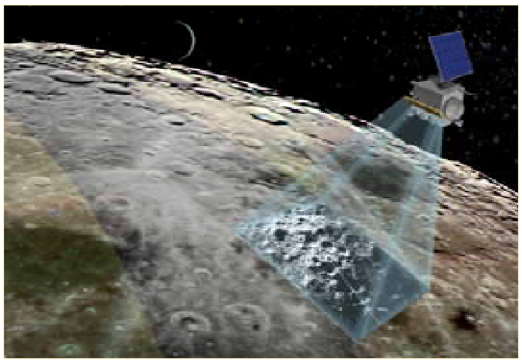


Miniature Radio Frequency Demonstration Project (Mini-RF)

Stewart Nozette PI

Mini-RF Lunar Demonstrations

SAR Imaging (Monostatic and Bistatic)



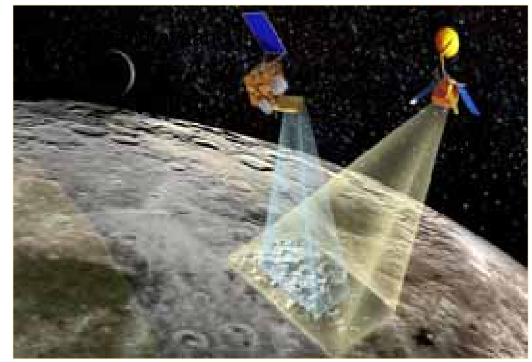
Monostatic imaging in S-band to locate and resolve ice deposits on the Moon.

Communications Demonstrations

Component Qualification

Monostatic imaging in S-band and X-band to validate ice deposits discoveries on the Moon

X-Band Comm Demo

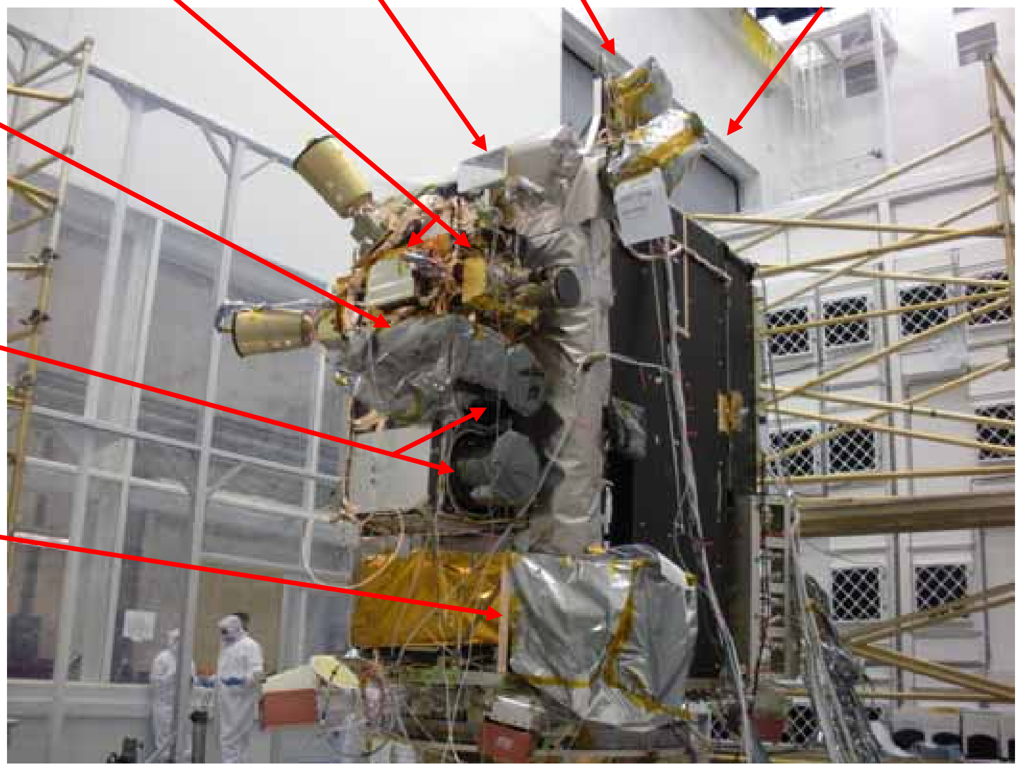


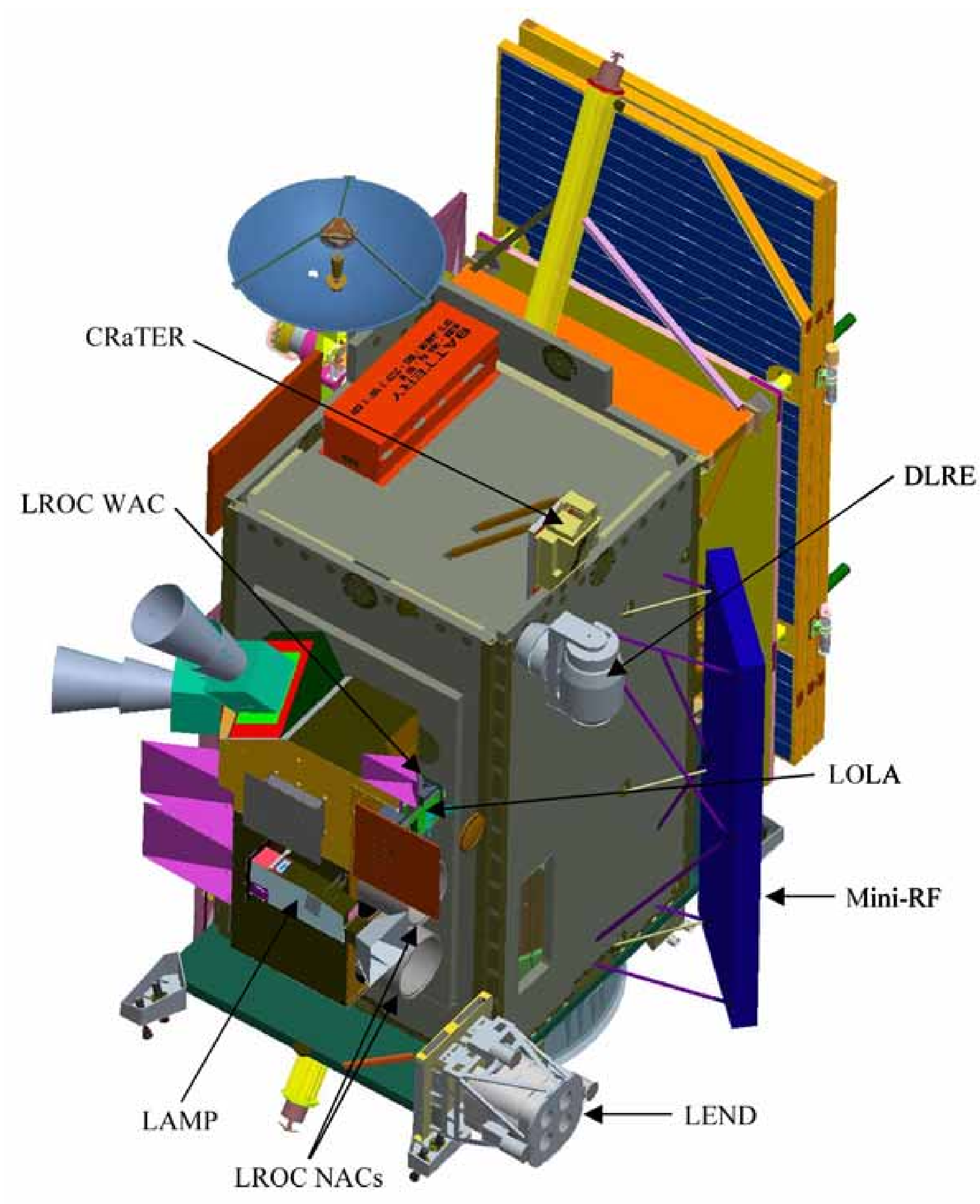
Coordinated, bistatic imaging in S-band, to be compatible with the Chandrayaan-1 and LRO spacecraft, can unambiguously resolve ice deposits on the Moon

Other Coordinated Tech Demos: e.g ranging, rendezvous, gravity

Current Status

- Spacecraft is complete, with all instruments, subsystems, and flight software
- Comprehensive Performance Tests and Mission Rehearsals successfully completed
- Vibration, acoustic, and EMI/EMC testing successfully completed
- Thermal-vacuum testing has begun
- Launch date is April 24, 2009





CRaTER
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