Lunar Reconnaissance Orbiter OVERVIEW

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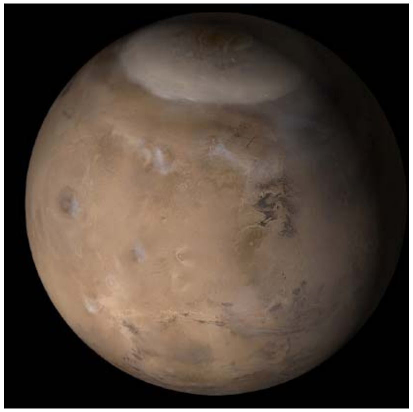
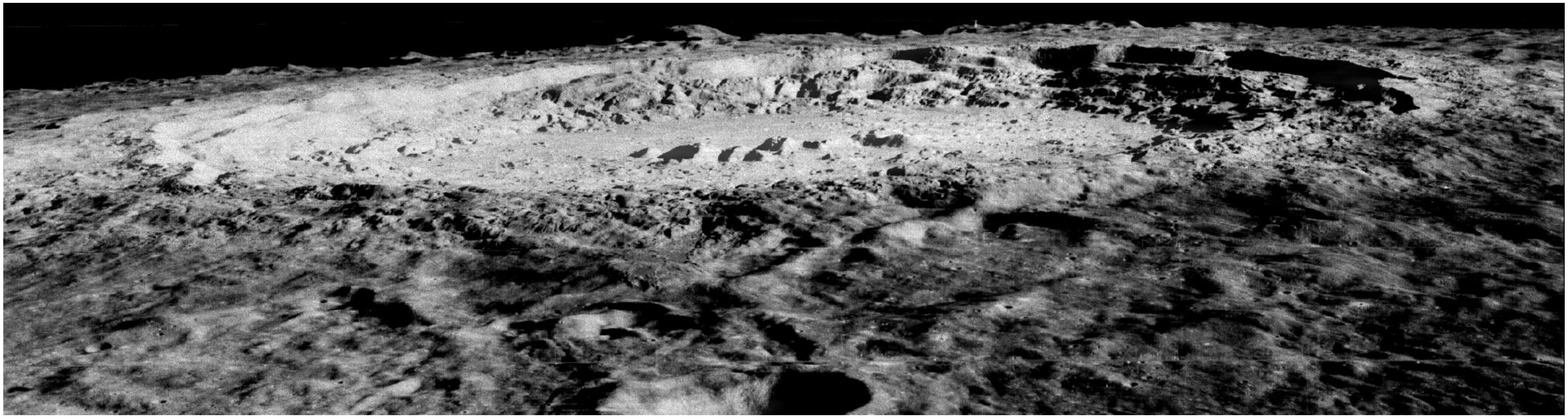
LRO Identified in Exploration Vision



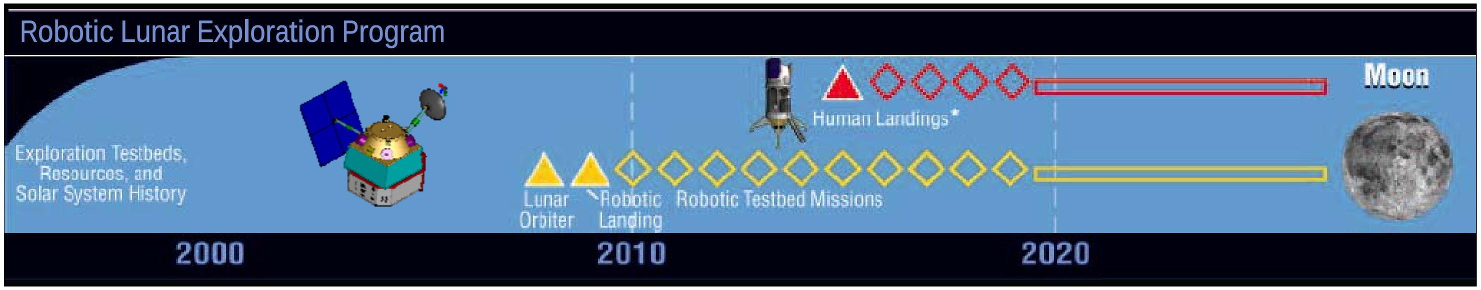
"Starting no later than 2008, initiate a series of robotic missions to the Moon to prepare for and support future human exploration activities"
- *Space Exploration Policy Directive (NPSD31), January 2004*

Rationale

- Environmental characterization for safe access
- Global topography and targeted mapping for site selection and safety
- Resource prospecting and assessment of In-Situ Resource Utilization (ISRU) possibilities
- Technology "proving ground" to enable human exploration



2008 Lunar Reconnaissance Orbiter (LRO)
First Step in the Robotic Lunar Exploration Program



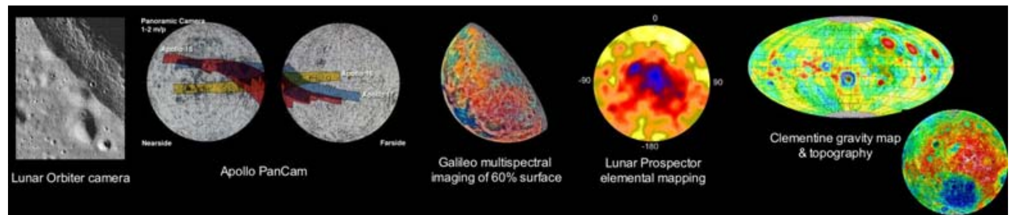
LRO Objectives

• **Characterization of the lunar radiation environment, biological impacts, and potential mitigation. Key aspects of this objective include determining the global radiation environment, investigating the capabilities of potential shielding materials, and validating deep space radiation prototype hardware and software.**

• **Develop a high resolution global, three dimensional geodetic grid of the Moon and provide the topography necessary for selecting future landing sites.**

• **Assess in detail the resources and environments of the Moon's polar regions.**

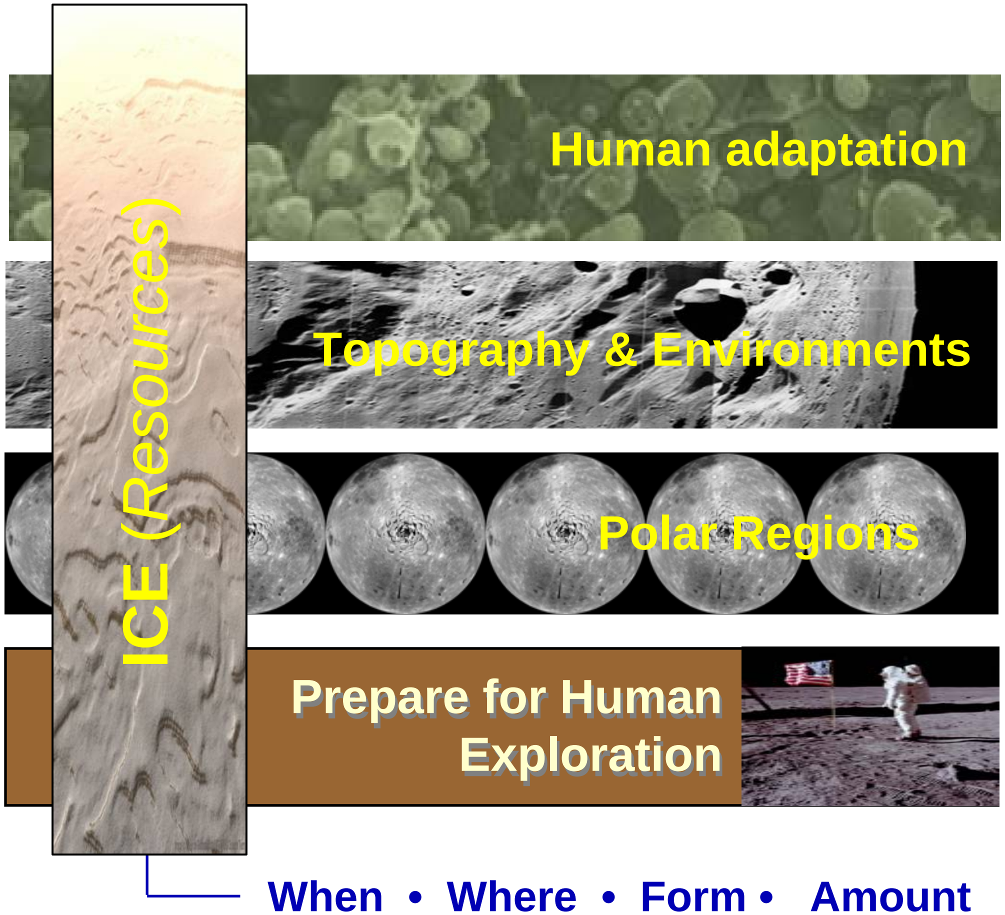
• **High spatial resolution assessment of the Moon's surface addressing elemental composition, mineralogy, and Regolith characteristics**



Objective: The Lunar Reconnaissance Orbiter (LRO) mission objective is to conduct investigations that will be specifically targeted to prepare for and support future human exploration of the Moon.

LRO Mission Overview

Science and Exploration Objectives



Biological adaptation to lunar environment ***(radiation, gravitation, dust...)***

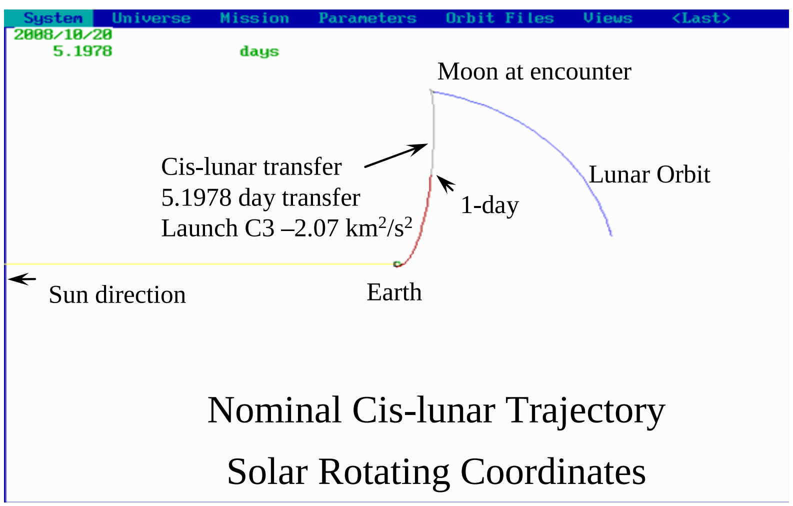
Understand the current state and evolution of the volatiles (ice) and other resources in context

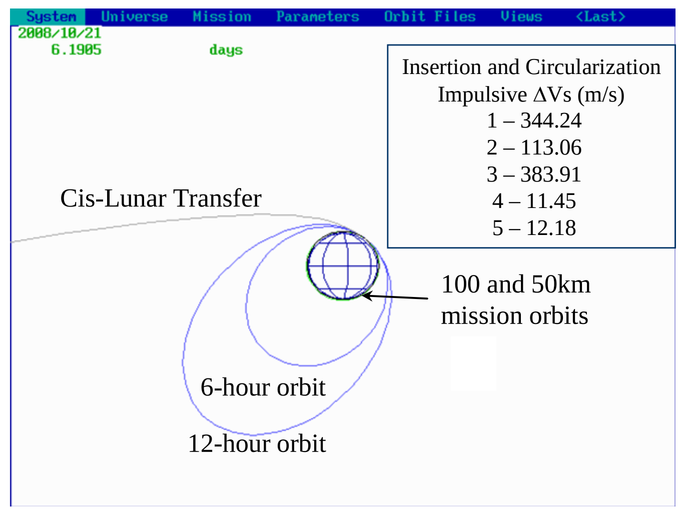
Develop an understanding of the Moon in support of human exploration ***(hazards, topography, navigation, environs)***

LRO Mission Overview

Flight Plan – Direct using 3-Stage ELV

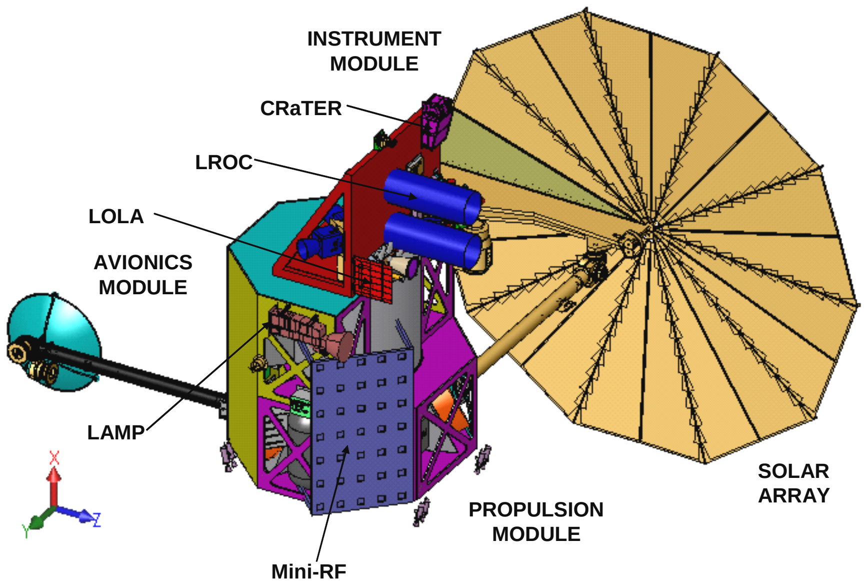
- Launch on a Delta II rocket into a direct insertion trajectory to the moon.
- On-board propulsion system used to capture at the moon, insert into and maintain 50 km altitude circular polar reconnaissance orbit.
- 1 year mission
- Orbiter is a 3-axis stabilized, nadir pointed spacecraft designed to operate continuously during the primary mission.



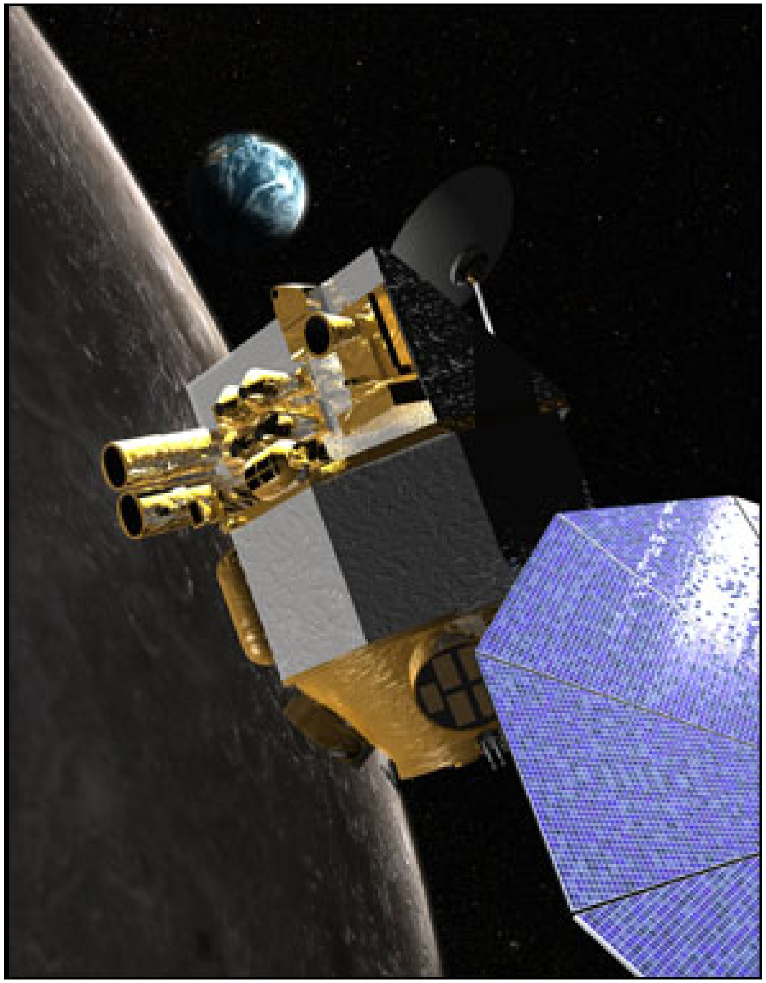


LRO Mission Overview

Orbiter - Initial Configuration



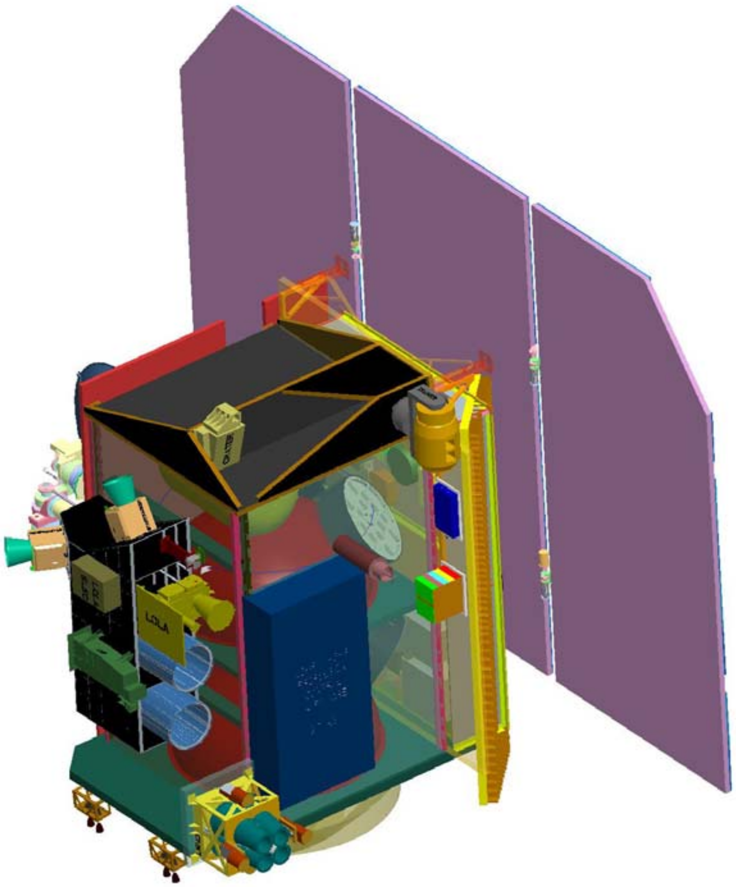
Preliminary LRO Characteristics	
Mass	1317 kg
Power (bus orbit ave.)	745 W
Measurement Data Volume	575 Gb/day



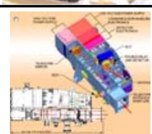
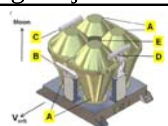
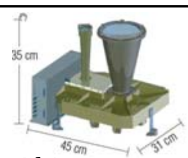
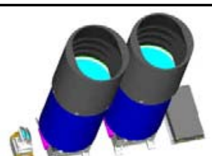
LRO Preliminary Design

LRO Mission Overview

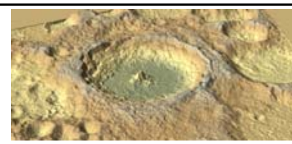
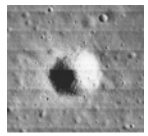
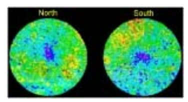
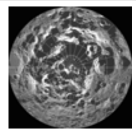
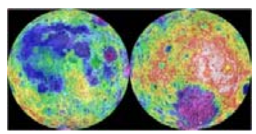
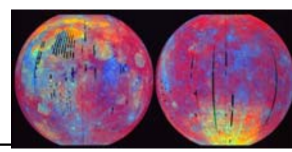
Orbiter - Latest Configuration 1/06



LRO Instruments Provide Broad Benefits

INSTRUMENT	Measurement	Exploration Benefit	Science Benefit
CRaTER  (BU+MIT) Cosmic Ray Telescope for the Effects of Radiation	***Tissue equivalent response to radiation***	***Safe, lighter weight space vehicles that protect humans***	***Radiation conditions that influence life beyond Earth***
Diviner  (UCLA)	***300m scale maps of Temperature, surface ice, rocks***	***Determines conditions for systems operability and water-ice location***	***Improved understanding of volatiles in the solar system - source, history, migration and deposition***
LAMP  (SWRI) Lyman-Alpha Mapping Project	***Maps of frosts in permanently shadowed areas, etc.***	***Locate potential water-ice (as frosts) on the surface***	
LEND  (Russia) Lunar Exploration Neutron Detector	***Hydrogen content in and neutron radiation maps from upper 1m of Moon at 5km scales, Rad > 10 MeV***	***Locate potential water-ice in lunar soil and enhanced crew safety***	
LOLA  (GSFC) Lunar Orbiter Laser Altimeter	***~50m scale polar topography at < 1m vertical, roughness***	***Safe landing site selection, and enhanced surface navigation (3D)***	***Geological evolution of the solar system by geodetic topography***
LROC  (NWU+MSSS) Lunar Recon Orbiter Camera	***1000's of 50cm/pixel images (125km^2), and entire Moon at 100m in UV, Visible***	***Safe landing sites through hazard identification; some resource identification***	***Resource evaluation, impact flux and crustal evolution***

National Academy of Sciences *NRC Decadal (2002*) lists priorities for the MOON *(all mission classes thru 2013)*

NRC Priority Investigation		NRC approach	LRO measurements
Geodetic Topography (*crustal evolution*)		**Altimetry from orbit (with precision orbits)**	***Global geodetic topography at ~100m scales (< 1 m rms)***
Local Geologic Studies In 3D (*geol. Evolution*)	 	**Imaging, topography (at m scales)**	***Sub-meter scale imaging with derived local topography***
Polar Volatile Inventory	  	**Spectroscopy and mapping from orbit**	***Neutron and IR spectroscopy in 3D context + UV (frosts)***
Geophysical Network (*interior evolution*)	 	***In situ* landed stations with seismometers**	***Crustal structure to optimize siting and landing safety***
Global Mineralogical Mapping (*crustal evolution*)		**Orbital hyperspectral mapping**	***100m scale multispectral and 5km scale H mapping***
Targeted Studies to Calibrate Impact Flux (*chronology*)	 	**Imaging and in situ geochronology**	***Sub-meter imaging of Apollo sites for flux validation and siting***

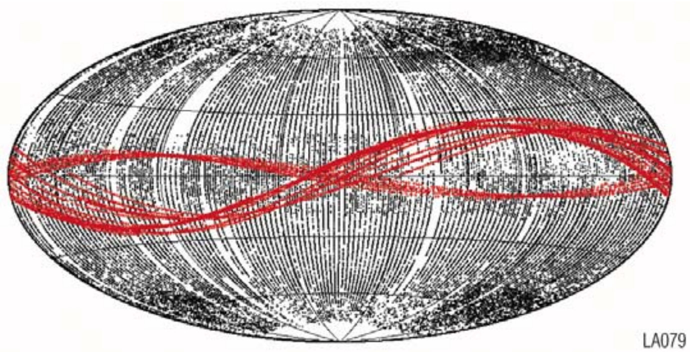
Comparison to International Systems Demonstrate LRO Uniqueness and Value

Reqt's for LRO *(from NASA ORDT, and ESMD RLEP Reqt's 9/04; NRC Decadal, 2002)*	*2008 NASA LRO* [50km orbit, 1 yr+] Competed Payload	SELENE (JAXA orbiter ~ 2007) [100km orbit, 1 yr]	SMART-1 (ESA lunar 2005 orbiter) [250km periapsis]	Chandrayaan (ISRO 2007-2008 launch) [100+ km orbit]
Radiation Environment	Global assessment including neutrons, GCR (imaging NS, Rad Sensor)	Highly limited overlap in some narrow energy ranges	Limited to some energy ranges	TBD
Biological Adaptation	Biological responses to radiation (Rad Sensor)	Not addressed	Not addressed	Not addressed
Shielding materials (test-beds)	Shielding expt's with TEP (Rad Sensor)	Not addressed	Not addressed	Not addressed
Geodetic topography (global)	10's m x,y, with < 1m vertical precision, attn to poles (Lidar)	1.6 km x, y at > 20 m vertical precision (RMS) [not meet LRO goals]	Not addressed	Not addressed
H mapping to assess ice	Landform scale at 100 ppm (~5 km scale at poles) (imaging NS)	160km scale via GRS (does not meet LRO goals)	Limited to 100's of km scale (H) [does not meet LRO goals]	Some potential, but depends on contributed sensors
T mapping cold traps (polar)	Landform scale at 3-5K (40-300K): ~300m scale (IR mapper)	Not addressed	Not addressed	TBD
Putative ice deposits at poles	~25-400m scales in shadows (Imager, Lidar, NS, IR, UV)	Not addressed in this mission (cf. GRS)	Not addressed	TBD *(contributed S-band SAR and Mineral mapping from US?)*
Sub-meter imaging for landing site assessment	Targeted, meter-scale feature detection, hazards (Imager, Lidar)	Not addressed: best imaging is ~10m/pixel stereo, MS imaging (10+ VISNIR bands)	Not addressed (best imaging is 10-100 m/pixel)	Not addressed, but imaging (MS) will be included (10's m/pixel)
Polar illumination	High time-rate polar imaging (Imagers)	Partially addressed, but frequency TBD?	Limited	TBD
OTHER	Far UV imaging for frosts and lunar atmosphere (farside gravity from lidar)	Particles and Fields, Farside gravity, elemental chemistry	Particles and Fields, etc.	Likely *(contributed mineralogy mapping?)*

LRO Measurement Objectives Addressed by LOLA

- Determine the global geodetic grid for the Moon in three dimensions with high spatial resolution:
  - (a) global topography,
  - **(b) characterization of landing sites**

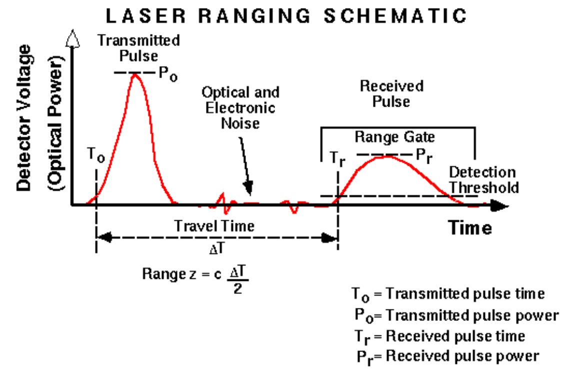
Present altimeter coverage:
- Apollo (red)
- Clementine (black)

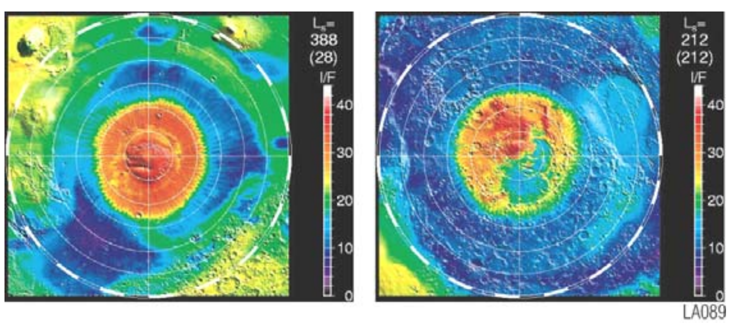


- Assess the resources in the Moon's polar regions (and associated landing site safety evaluation), including characterization of permanently shadowed regions and evaluation of any water ice deposits.

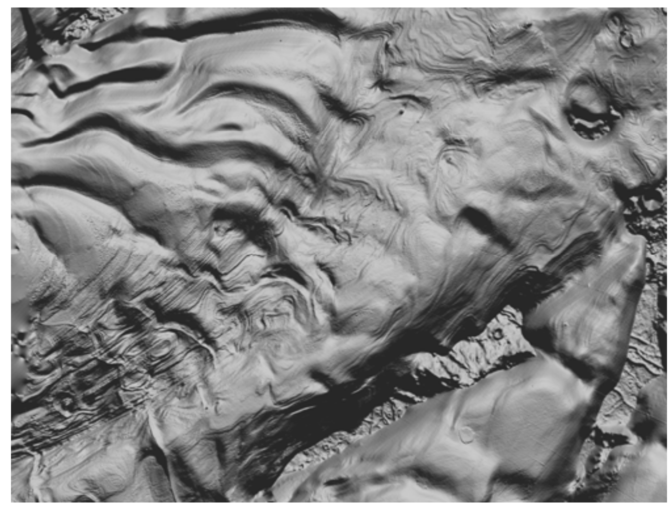
Lunar Orbiter Laser Altimeter (LOLA) Measurements

- **Range to the surface**
  - shape & topography
- **Slope of the surface in 2 orthogonal directions**
  - Landing site characterization
- **Roughness of the surface**
  - height of the rocks
- **Reflectance of the surface**
  - locations of possible surface ice





South pole of Mars: Reflectance Map

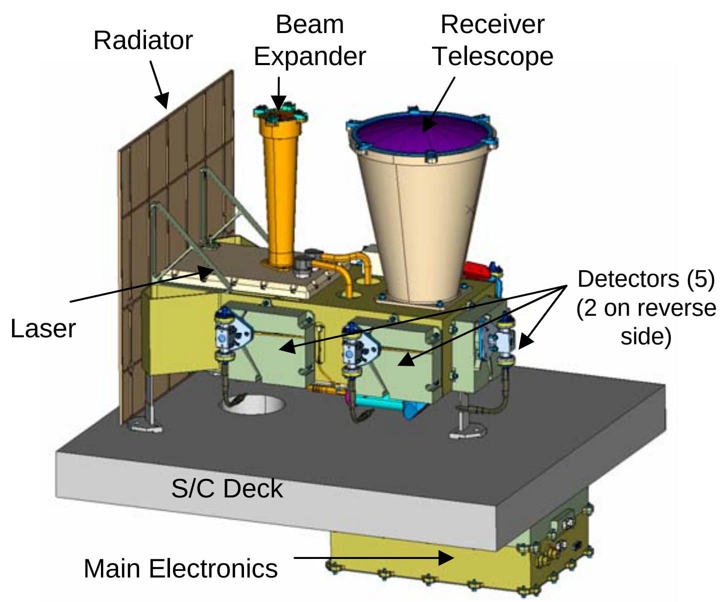


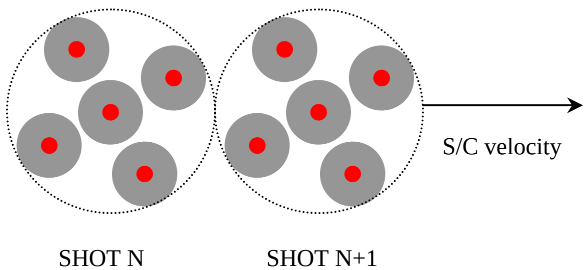
South pole of Mars: Topography image
(made solely from pulse time-of-flight data, NOT a camera image

South pole of Mars: MOLA Data

LOLA Instrument Overview

- LOLA measures:
  - Range to the lunar surface (pulse time-of-flight)
  - Reflectance of the lunar surface (Received Energy/Transmitted Energy)
- LOLA operates continuously during LRO mapping mission
- LRO provides time, attitude and orbit position
- LOLA Science Operations Center ingests LOLA & LRO data and produces:
  - Digital Elevation Model (DEM) products, lunar gravity model

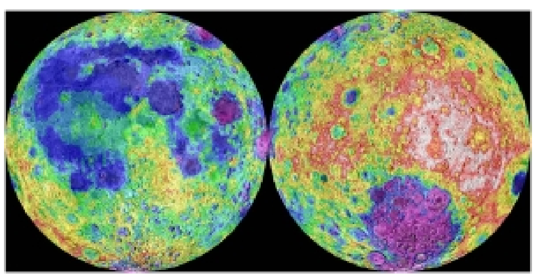


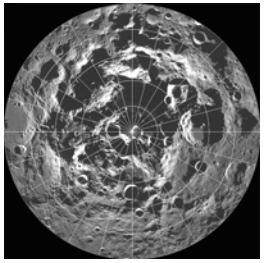


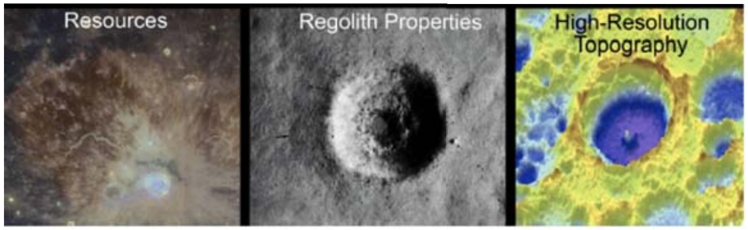
LOLA sample pattern on lunar surface

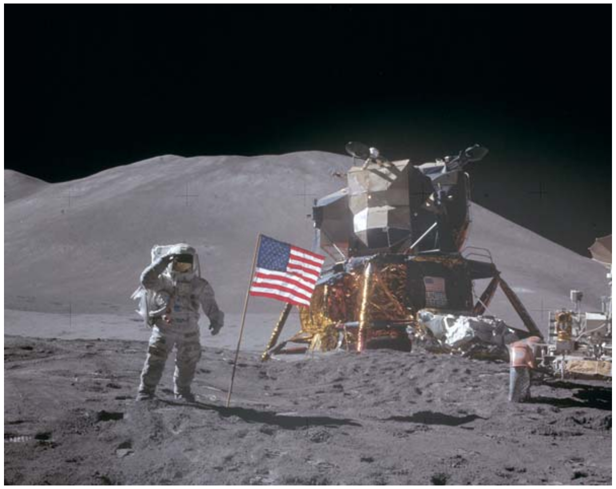
LRO : Science and Exploration

- LRO will fill in critical knowledge gaps of the Moon
  - Returning to the Moon without LRO would confine any future landing to equatorial sites where we have existing, but incomplete reconnaissance with known risk
  - Reduces risks and cost of all future landed missions (robotic and human)
- LRO completely addresses the majority of the National Academy of Sciences (NRC, 2002) scientific priorities for the Moon *(from orbit)*
  - LRO measurement sets will resolve key unknowns about the lunar crust (3D), sources and sinks of polar volatiles (i.e, the lunar “water” cycle”), and history of its earliest crust
  - LRO will enable scientific discoveries about the “other Moon” (polar regions) not explored with Apollo (i.e., localization and inventory of water ice)
  - LRO will put the Moon in a more complete context with respect to Earth and Mars









Apollo 15 set down on the rim of a small crater, damaging the engine bell and tilting at ~10°

Slide Credits

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