NASA Lunar Robotics for Science and Exploration

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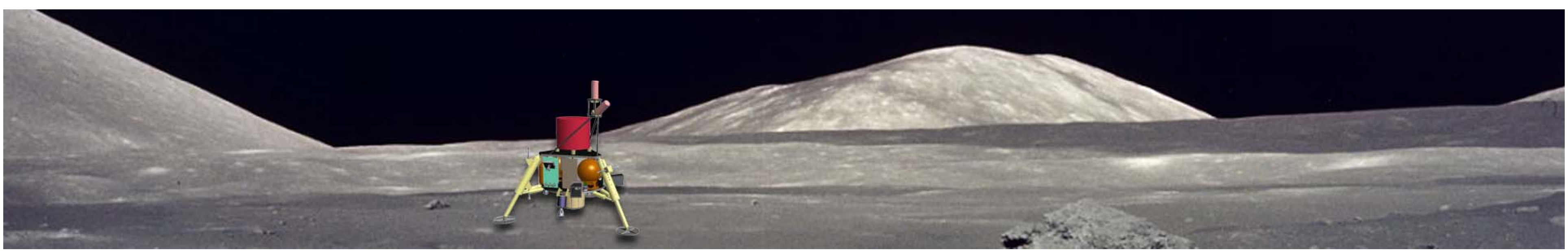
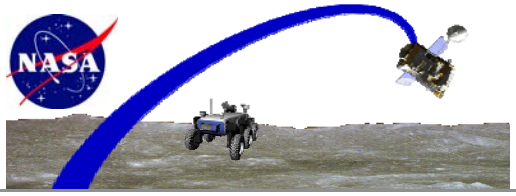
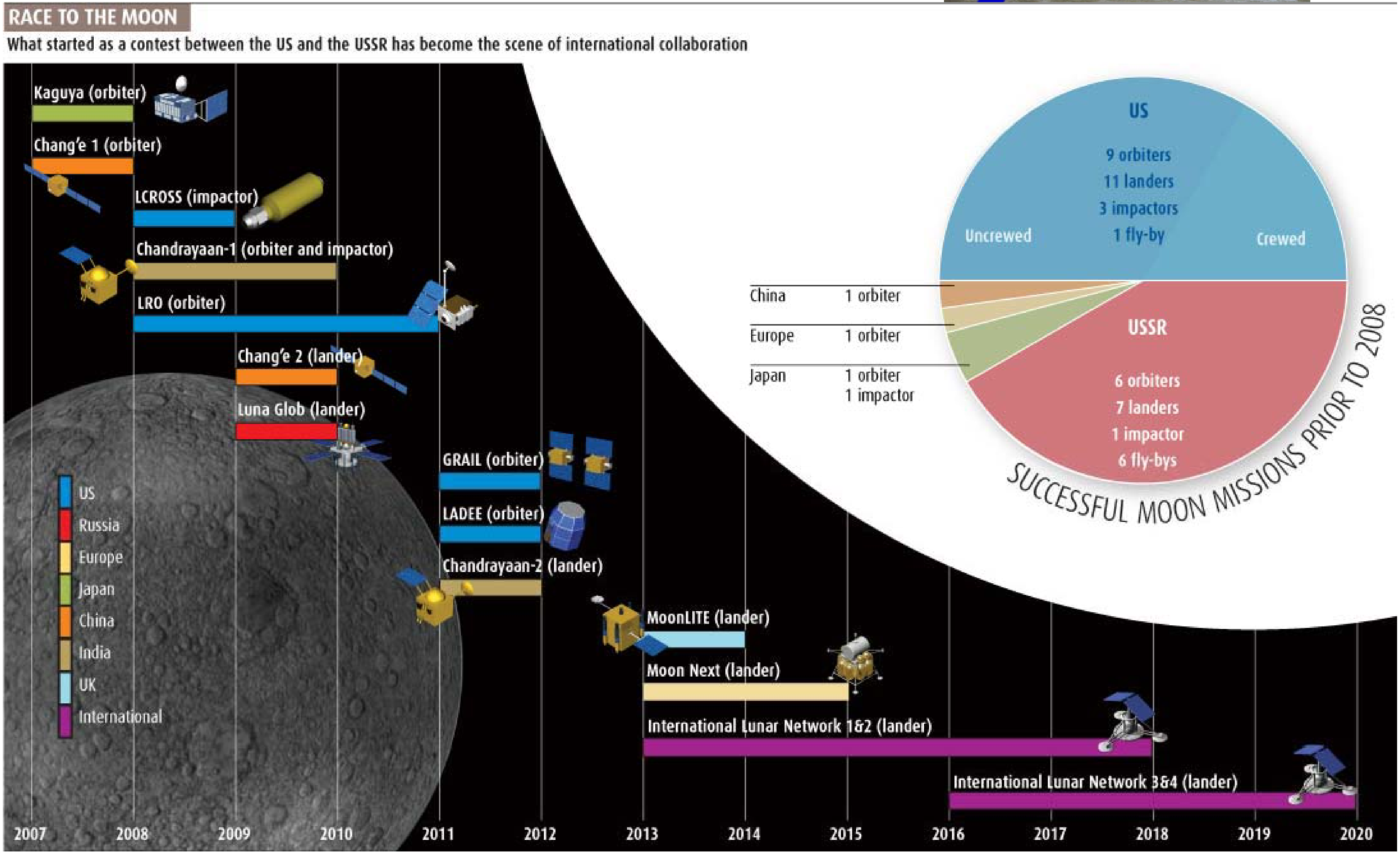


Robotic lunar missions





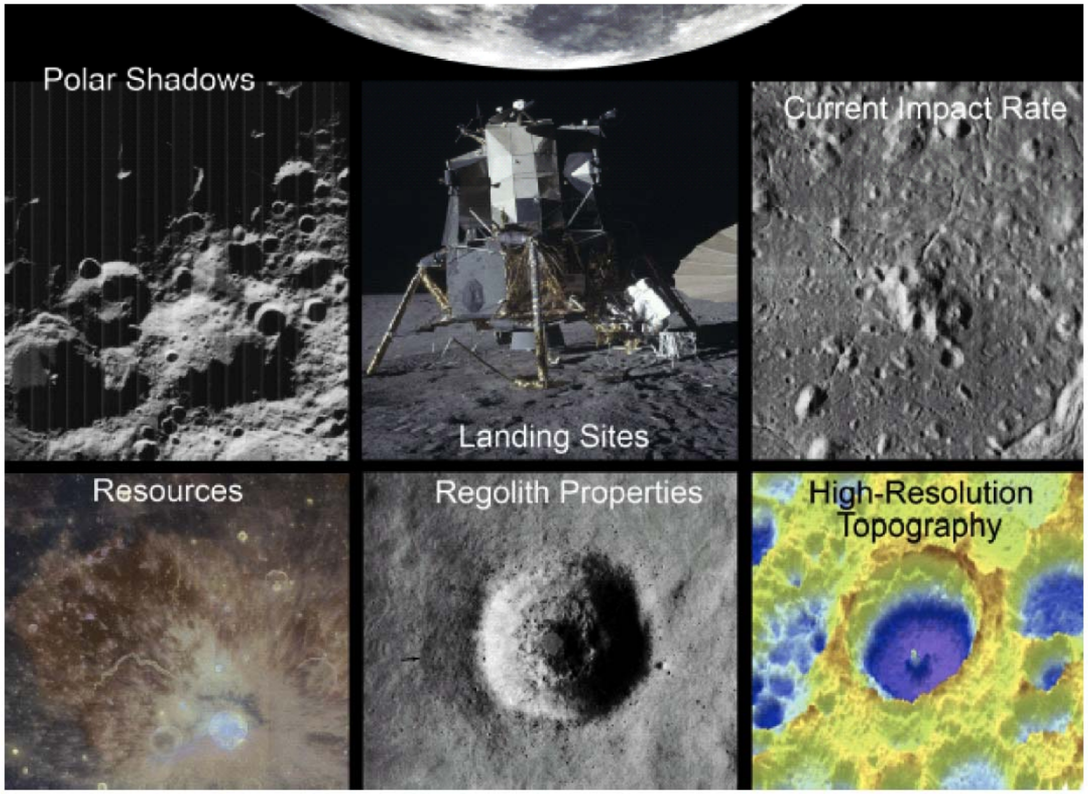
D. Mackenzie, New Scientist, July 11 2008

Robotic lunar missions at MSFC

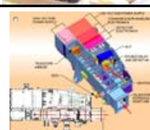
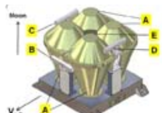
- Lunar Precursor Robotics Program (LPRP)
  - Robotic missions to gather lunar environmental data to advance U.S. exploration objectives earlier and with less cost
  - LRO and LCROSS
- Discovery Program
  - Small PI-led science missions, competed among all science
  - M3 and GRAIL
- Lunar Science Program
  - Robotic missions to accomplish key lunar scientific objectives
  - LRO, which will transition after one year of operations to SMD for a 2-year nominal science mission, LADEE, and two landed payloads as part of the International Lunar Network (ILN)

LRO (2009)

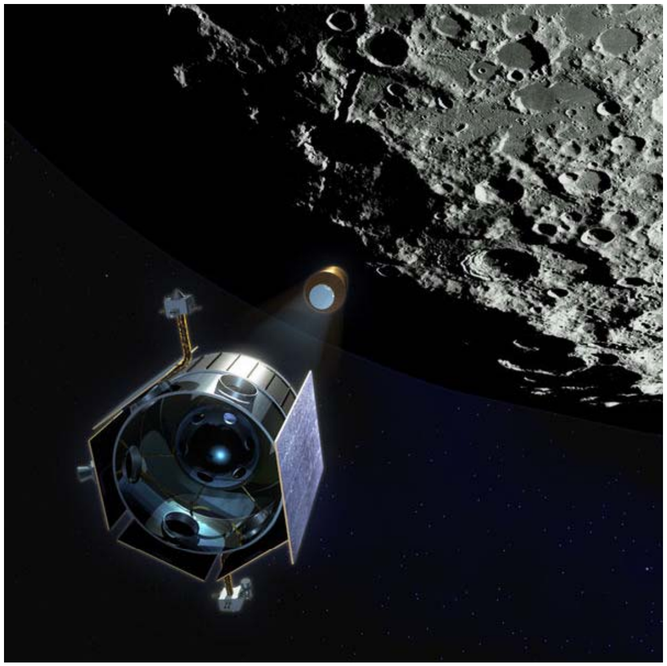
- Lunar Reconnaissance Orbiter (LRO) – initiated in 2004 as the first step back to the Moon in the Vision for Space Exploration
- Exploration Systems Mission Directorate (ESMD) – focus is on datasets to help plan human activities
- Goddard project, managed under LPRP at MSFC
- Objectives:
- Characterization of the lunar radiation environment, biological impacts, and potential mitigation
- High resolution global topography necessary for selecting future landing sites
- Assess resources and environments of lunar polar regions
- High spatial resolution visible imagery

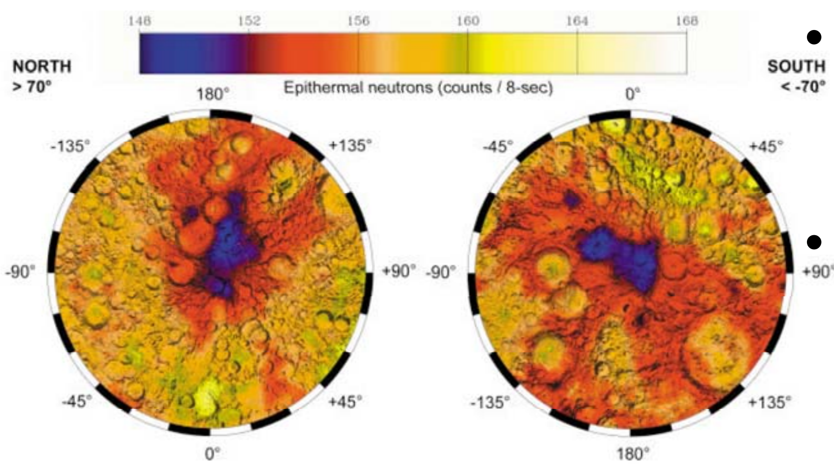


LRO Instruments

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	***1000Õs of 50cm/pixel images (125km²), and entire Moon at 100m in UV, Visible***	***Safe landing sites through hazard identification; some resource identification***	***Resource evaluation, impact flux and crustal evolution***

LCROSS (2009)





- Lunar Crater Observation and Sensing Satellite, chosen as a secondary payload on LRO vehicle
- Ames project under LPRP management
- Objectives: to reveal the presence & nature of water ice on the Moon
- Shepherding S/C directs the Centaur into a permanently-shadowed crater
- The S-S/C observes the ejecta cloud, and then enters the cloud using several instruments looking for water
- Lunar-orbital and Earth-based assets will also be able to study both clouds (LRO, Chandrayaan-1, HST, etc)

LCROSS Instruments

1 Visible Context Camera:
4 color, 6 degree FOV, <0.5 km resolution at T-10 min to S-S/C impact

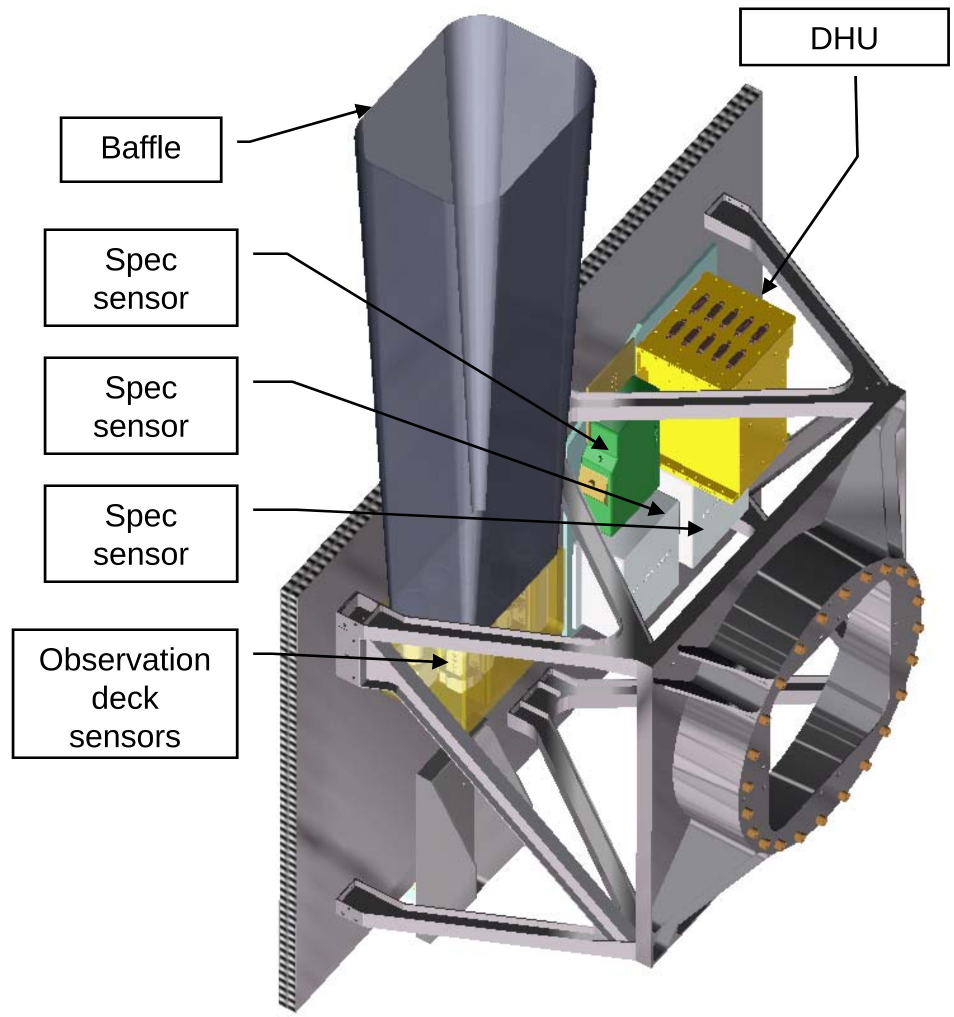
2 NIR Cameras
1.4 μm water ice band depth maps
1 km resolution at T-10 min

2 mid-IR Cameras
7 and 12.3 μm
< 0.5 km resolution

1 Visible Spectrometer
0.25 to 0.8 μm, ~0.002 μm resolution

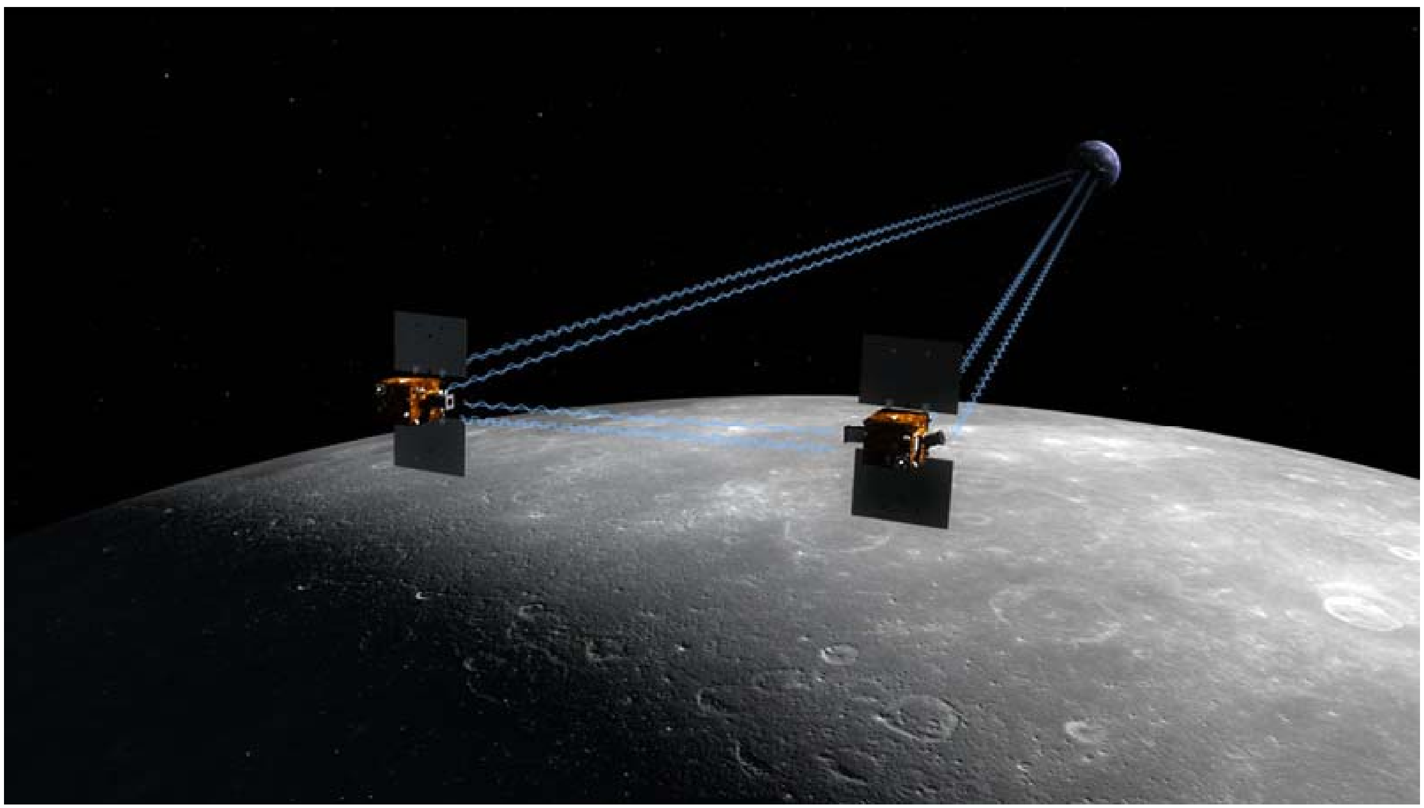
2 NIR Spectrometers
1.35 to 2.45 μm, 0.012 μm resolution

1 Total Visible Luminance Photometer
Broadband from 0.6 – 1.2 μm, sample rate >1000 Hz, < nW NEP @ 1000 Hz



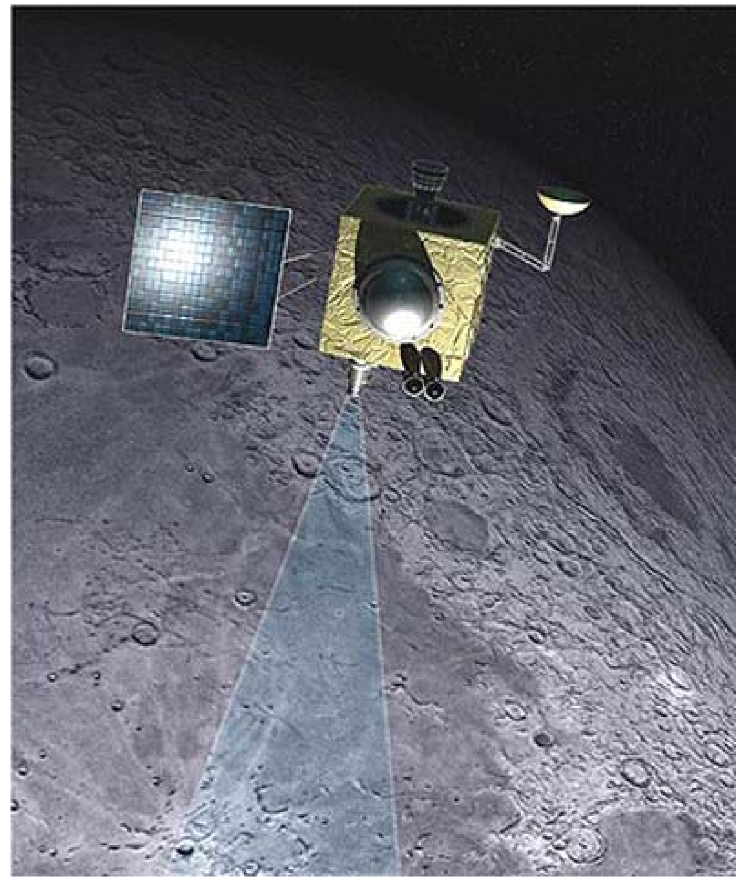
GRAIL (2011)

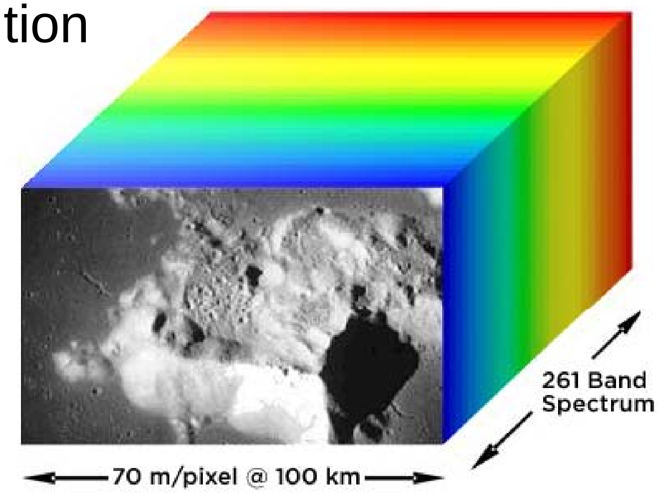
- Gravity Recovery and Interior Laboratory, an SMD PI-led mission by Dr. Maria Zuber at MIT, managed by Discovery program
- Based on GRACE on the Earth - twin spacecraft with mutual microwave ranging to very precisely map the moon's gravity field



Moon Mineralogy Mapper (2008)

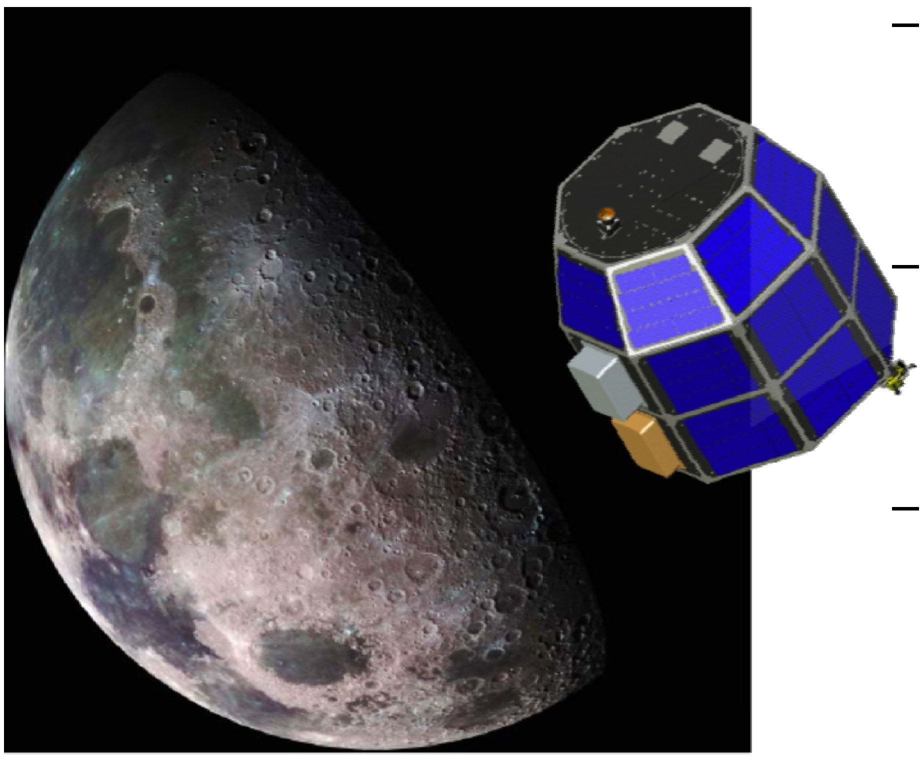
- Discovery PI-led instrument by Carle Pieters at Brown University on Chandrayaan-1
- Imaging spectrometer (VIS-NIR) to map the lunar surface at high spatial and spectral resolution
- Objectives: characterize and map the mineral composition of the lunar surface to gain information about the Moon's geologic evolution





LADEE (2011)

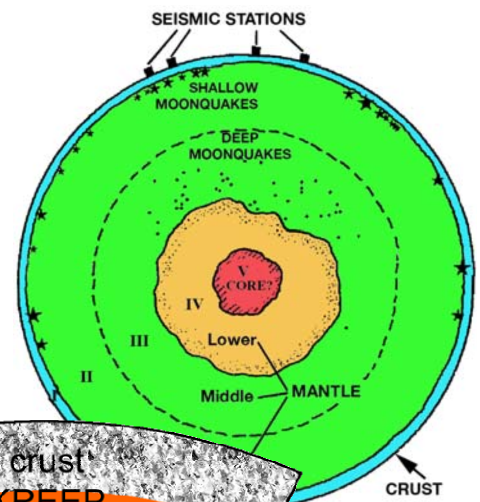
- Lunar Atmosphere, Dust and Environment Explorer, Ames/GSFC project, managed by Lunar Science Program at MSFC
- Instruments: Neutral Mass Spectrometer, UV/VIS spectrometer, Dust counter

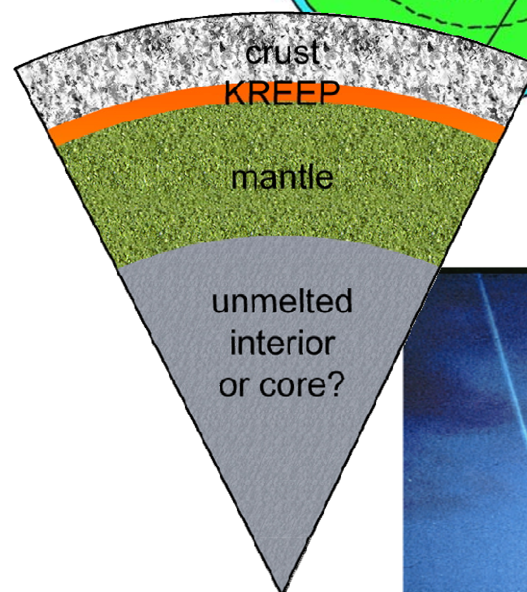


- Goals:
  - Determine the global density, composition, and time variability of the fragile lunar atmosphere before it is perturbed by further human activity
  - Determine if the Apollo astronaut sightings of diffuse emission at 10s of km above the surface were Na glow or dust
  - Document the dust impactor environment (size-frequency) to help guide design engineering for the outpost and also future robotic missions

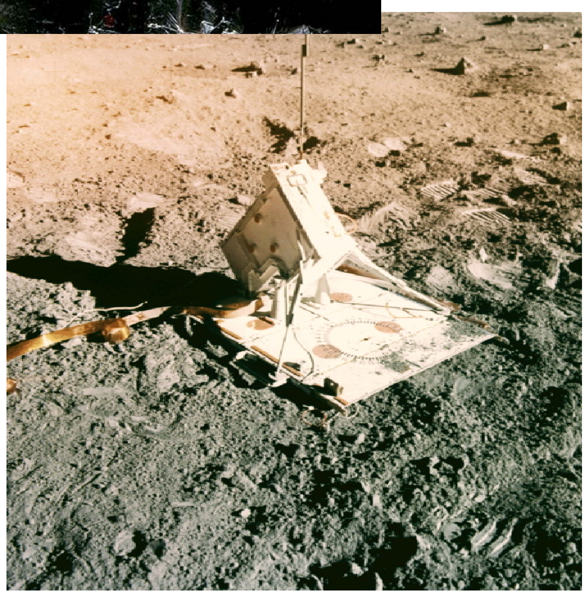
ILN (2014)

- International Lunar Network– a geophysical network to accomplish high priority science, but difficult for any single agency to accomplish on its own
- US and international landed missions, 2-4 US Landers planned, project at MSFC/APL, managed by Lunar Science Program at MSFC
- Goals: understand the interior structure and composition of the moon
  - Determine the thickness of the lunar crust (upper and lower)
  - Characterize the chemical/physical stratification in the mantle
  - Determine the size, composition, and state (solid/liquid) of the core of the moon.
  - Characterize the thermal state of the interior





ILN (2014)



- US Science Definition Team recommended seismometers, heat flow probes, electromagnetic sounding, laser ranging (active or passive)
- International Core Instruments Working Group chartered July 2008 to define core ILN instruments
- International Communications Working Group also chartered July 2008 to coordinate communication and navigation needs to support ILN and beyond, including spectrum, standardized communication protocols standardized data and networking protocols

Summary

- NASA is undertaking a sustainable yet comprehensive approach to robotic investigation of the moon to support science and exploration objectives

- The lunar flight projects being undertaken by NASA provide a *robust robotic lunar flight program* for the next decade, complement lunar R&A initiatives to *rebuild a lunar science community*, and *increase international participation* in NASA's exploration plans