How Have Results from Recent Lunar Missions Changed Our View of the Moon?

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The Johns Hopkins University / Applied Physics Laboratory
Laurel MD

2010 Annual LEAG Meeting
Washington DC
September 14-16, 2010

Where are we now?

Samples: Apollo, Luna, lunar meteorites

Human exploration: 1969-1972: Apollo

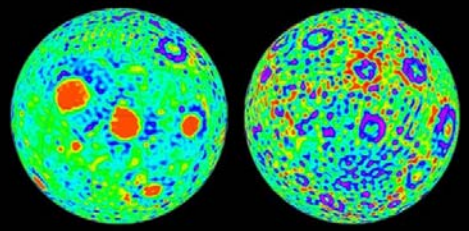
Robotic spacecraft: 1959-Present: Lunar Reconnaissance Orbiter, Chandrayaan-1, Kaguya, Chang'e, SMART-1, Lunar Prospector, Clementine, Apollo, Luna, Lunokhod, Surveyor, Ranger, Zond

Earth-based observation: 1609 (Thomas Harriott) - present

Summaries:

- New Views of the Moon
- The Lunar Source Book – A User's Guide to the Moon
- 40+ years LSC/LPSC

Kaguya



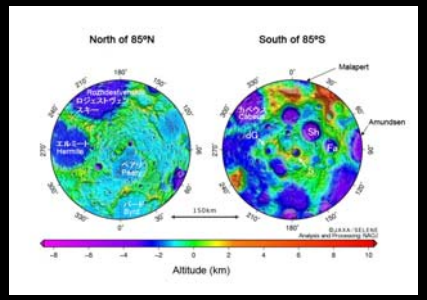
(C)JAXA/SELENE
Analysis and Processing: Kyushu University, NAOJ

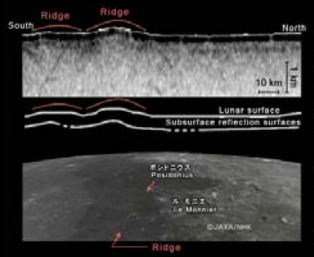
Launch: September 14, 2007

EOM: June 10, 2009

Payload:

- Terrain Camera
- CCD HDTV
- X-Ray Fluorescence Spectrometer
- Gamma-Ray Spectrometer
- Magnetometer
- Spectral Profiler
- Laser Altimeter
- Radar Sounder
- Charged Particle Spectrometer
- Plasma Analyzer
- Upper Atmosphere / Plasma Imager
- Radio Science
- Subsatellites for far-side gravity





LRS observation data of Mare Serenitatis. The red arcs indicate the location of ridges.

Lunar surface and sub-surface reflection surfaces of Mare Serenitatis

(C)JAXA/SELENE
Analysis: Tohoku University, Nagoya University, Kyoto University

KAGUYA HDTV image

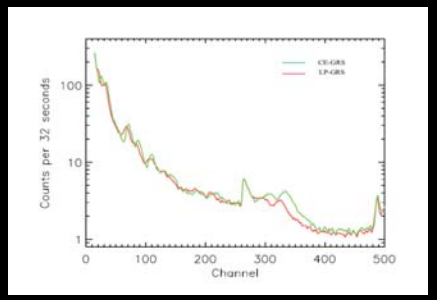
Chang'e - 1

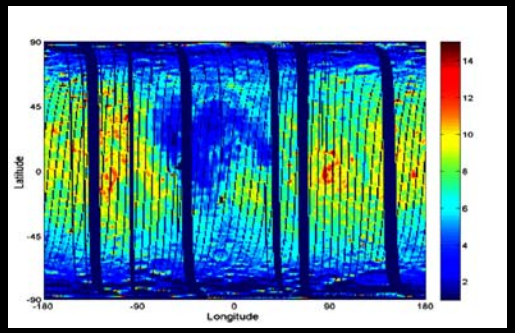
Launch: October 24, 2007

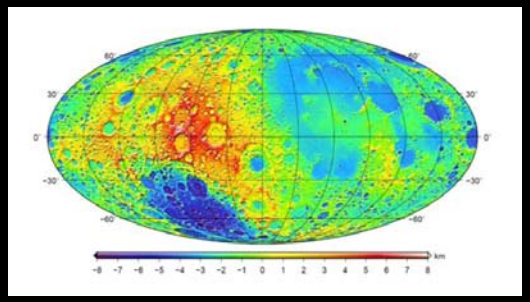
EOM: March 1, 2009

Payload:

- Stereo Imaging
- VNIR Spectrometer
- Microwave Radiometer
- Laser Altimeter
- X-Ray Spectrometer
- Gamma-Ray Spectrometer
- High Energy Particle Detector
- Solar Wind Detector







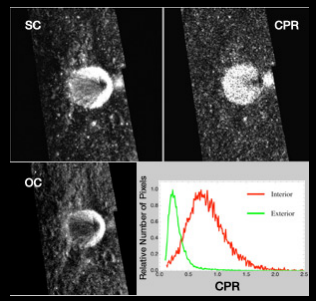
Chandrayaan - 1

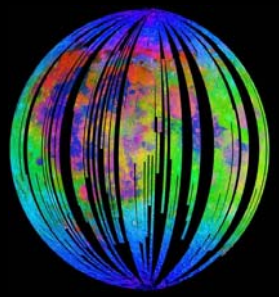
Launch: October 22, 2008

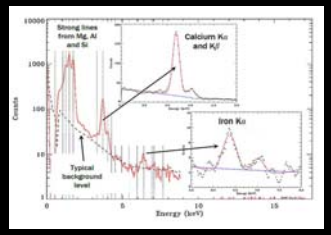
EOM: August 29, 2009

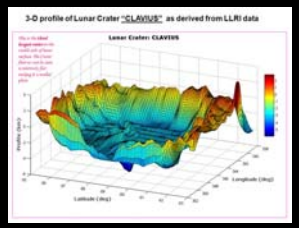
Payload:

- Terrain Mapping Camera
- Hyper Spectral Imager
- Gamma / X-Ray Spectrometer
- Laser Altimeter
- Impact Probe
- X-Ray Fluorescence Spectrometer
- Atom Reflecting Analyzer
- Mineralogic Mapper
- Near Infrared Spectrometer
- Mini-SAR
- Radiation Dose Monitor

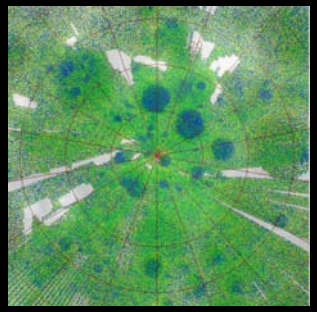








Lunar Reconnaissance Orbiter

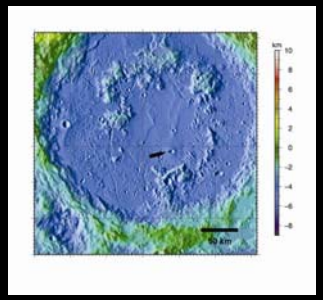


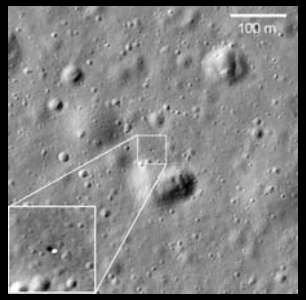
Launch: June 18, 2009

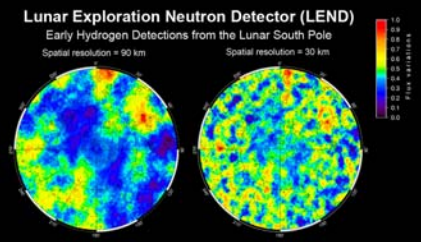
EOM: ….

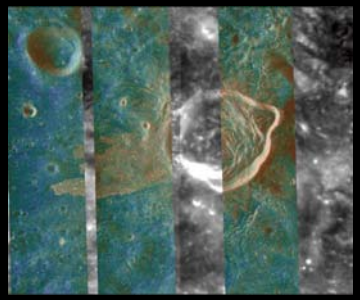
Payload:

- Laser Altimeter
- Narrow- / Wide-Angle Imager
- Neutron Spectrometer
- Thermal Radiometer
- UV Mapping Spectrometer
- Cosmic Radiation Telescope
- Imaging Radar



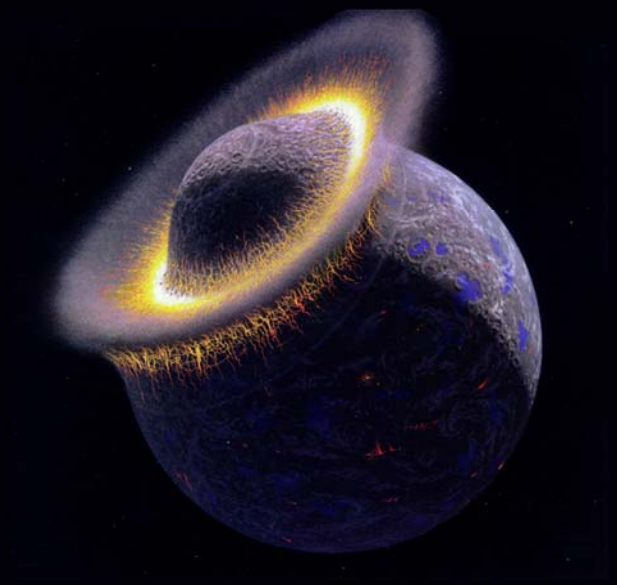




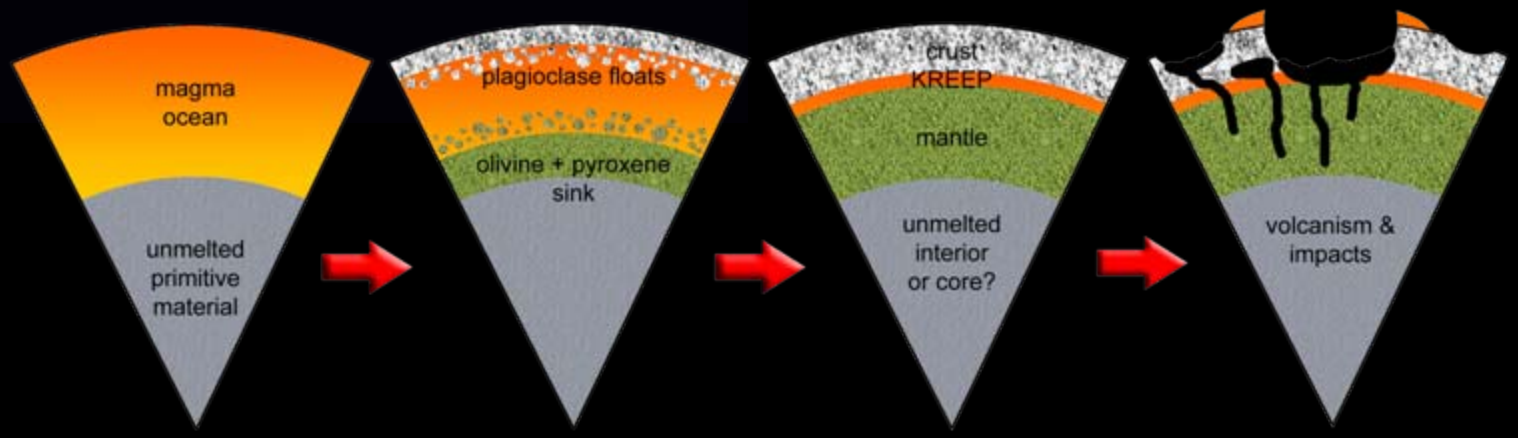


Overarching Themes

Giant Impact Hypothesis



Magma Ocean Hypothesis



Geology of the Moon

Near Side

Far Side

Don’t We Already Know Everything About the Moon?

ELEPHANTS

Larger than the moon

Don’t We Already Know Everything About the Moon?

Scientific Context for Exploration of the Moon: Final Report

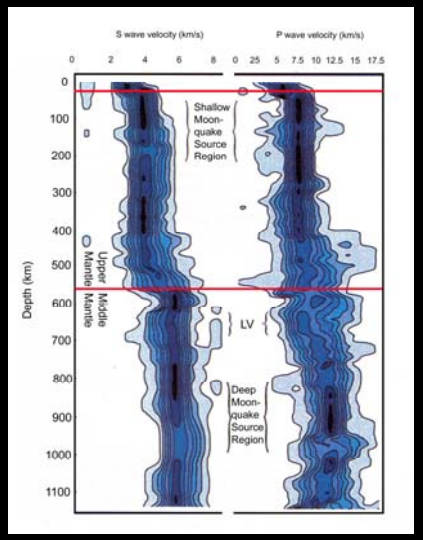
- Bombardment history of the inner solar system uniquely revealed on the Moon.
- Structure and composition of the lunar interior provide fundamental information on the evolution of a differentiated body.
- Key planetary processes are manifested in diversity of lunar crustal rocks.
- The lunar poles are special environments that may bear witness to the volatile flux over the latter part of solar system history.
- Lunar volcanism provides a window into the thermal and compositional evolution of the Moon.
- The Moon is an accessible laboratory for studying the impact process on planetary scales.
- The Moon is a natural laboratory for regolith processes and weathering on anhydrous airless bodies.
- Processes involved with the atmosphere and dust environment of the Moon are accessible for scientific study while the environment remains in a pristine state.

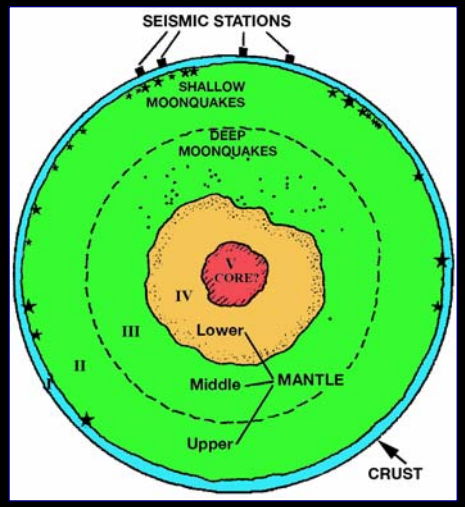
Interior Structure - Mantle - Core

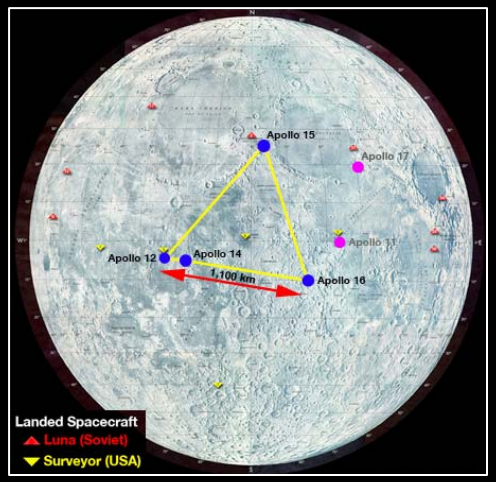
Characterize chemical/physical stratification of mantle, particularly nature of the putative 500 km discontinuity and composition of lower mantle.

Estimated at <460 km radius, metallic Fe with some Ni, S, And C, but could also be molten Ti-rich silicate magma.

Determine the size, composition and state (solid/liquid) of the core of the Moon.







Bombardment History

Flux considerably greater early time.

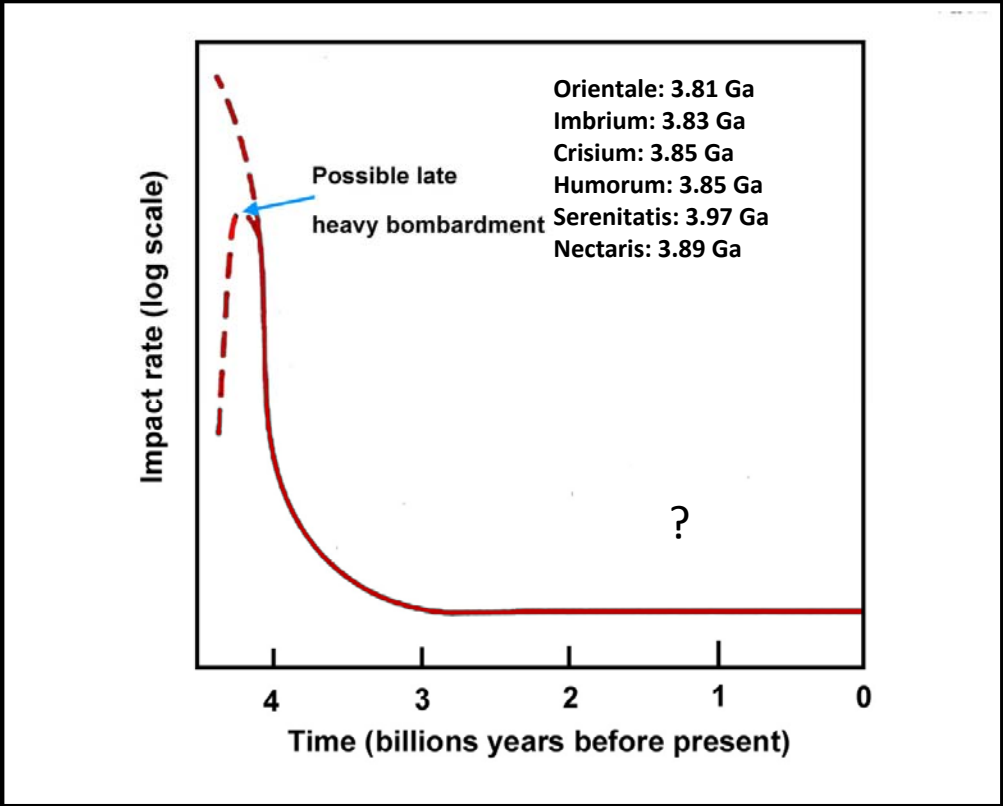
Several basins have similar ages.

Question of biased sampling – all the samples saw the same small set of events.

Bombardment history of the inner solar system.

Early cataclysm?

Episodic variations over the last 0-3 Ga?



Regolith Formation / Evolution

Regolith develops due to meteoroid bombardment (macro to micro).

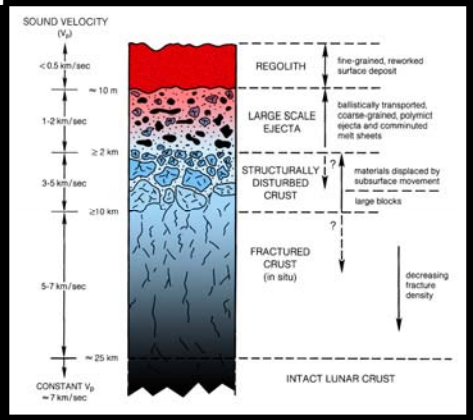
Regolith / megaregolith

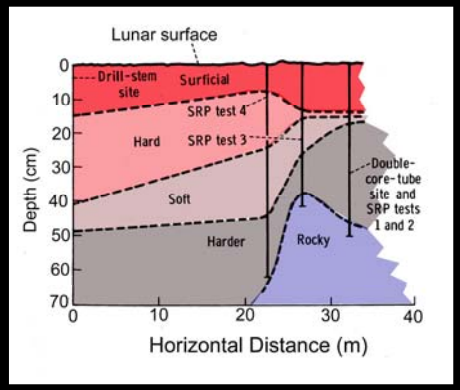
Older the surface – thicker the regolith and the more mature.

Lateral variations, complex layered medium.

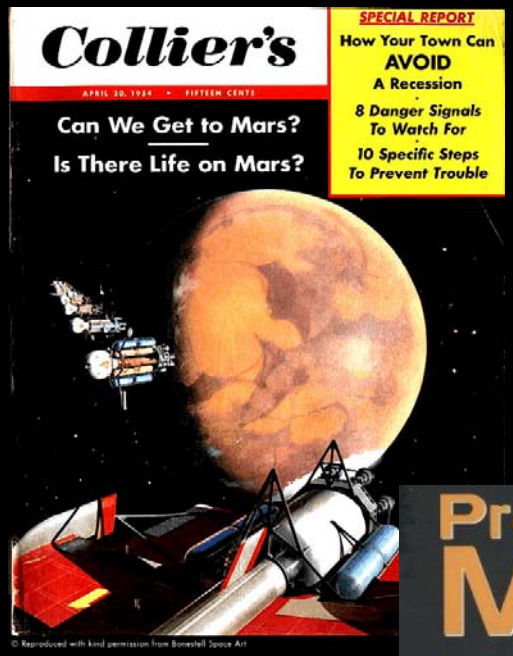
The Moon is a natural laboratory for regolith processes and weathering on anhydrous airless bodies.

AS15-89-12115





Who Cares?


Collier's
APRIL 30, 1954 • FIFTEEN CENTS
SPECIAL REPORT
How Your Town Can
AVOID
A Recession
8 Danger Signals
To Watch For
10 Specific Steps
To Prevent Trouble
Can We Get to Mars?
Is There Life on Mars?
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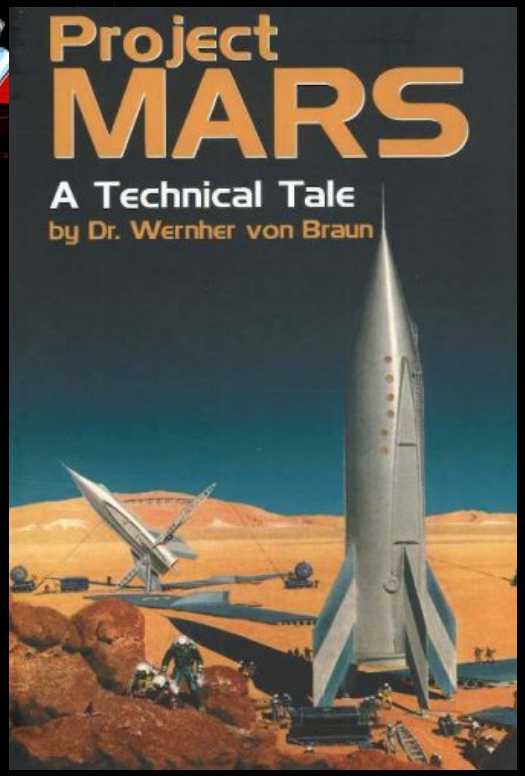
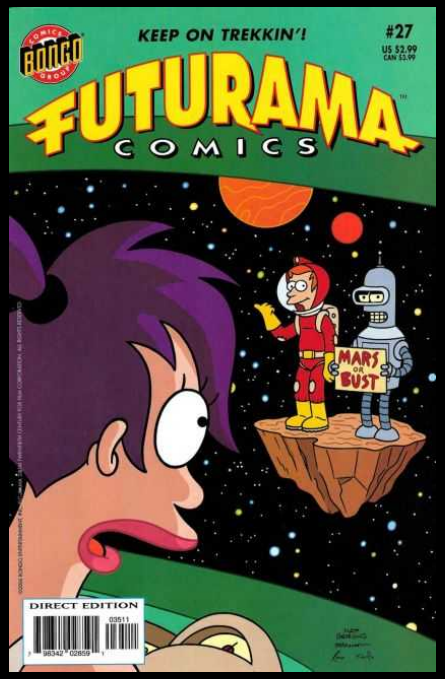

Project
MARS
A Technical Tale
by Dr. Wernher von Braun


KEEP ON TREKKIN'!
#27
FUTURAMA
COMICS
MARS OR BUST
DIRECT EDITION


Mars
or bust

Who Cares?

Moon – Terrestrial planet with a complex and long-lived geologic history in its own right.

Moon – Rosetta Stone of Solar System

Records history of solar system events and processes

- Impact history
- Solar history
- Volatile flux

Space weathering on planets without atmosphere

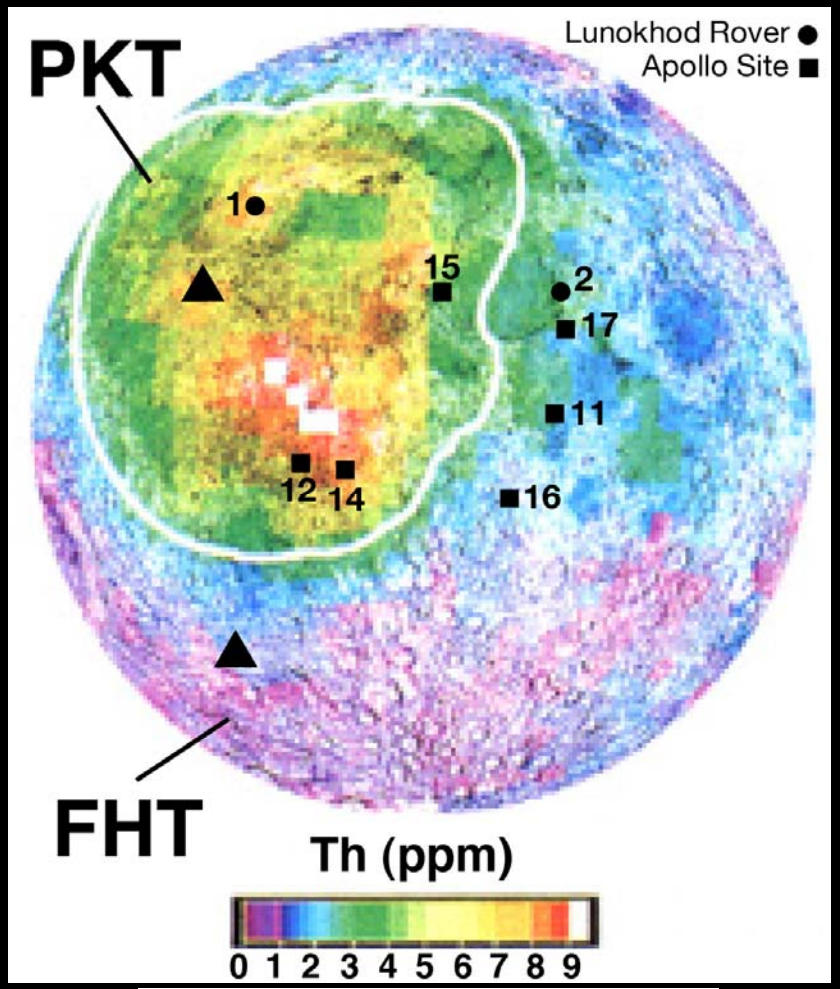
Exosphere formation and evolution

Formation and evolution of planetary regoliths

Cryogenic processes – volatiles

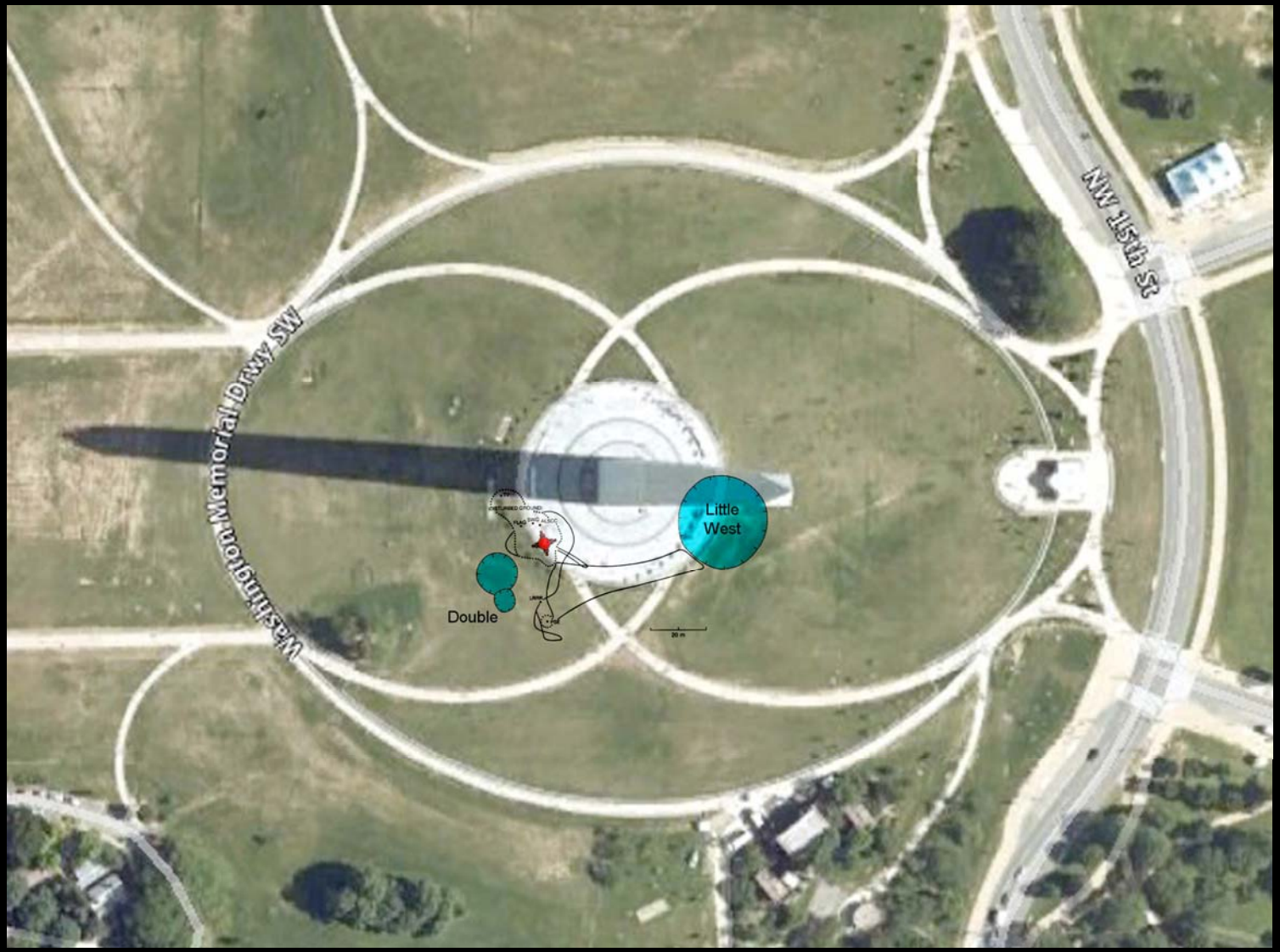
Planetary evolution

Haven't We Been Everywhere?

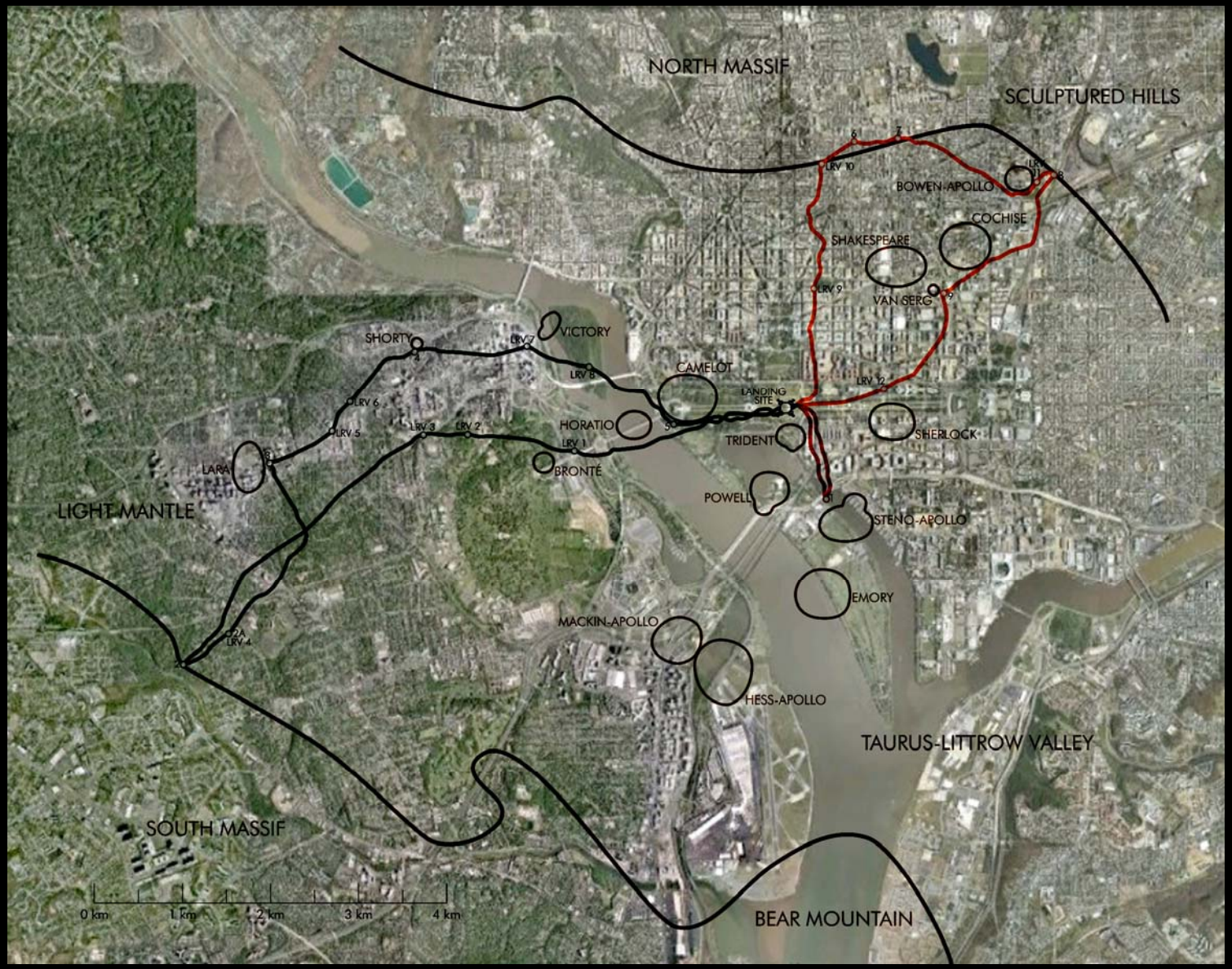


Jolliff et al. (2000) JGR 105, 4197

Haven’t We Been Everywhere?



Haven't We Been Everywhere?



What's Next?

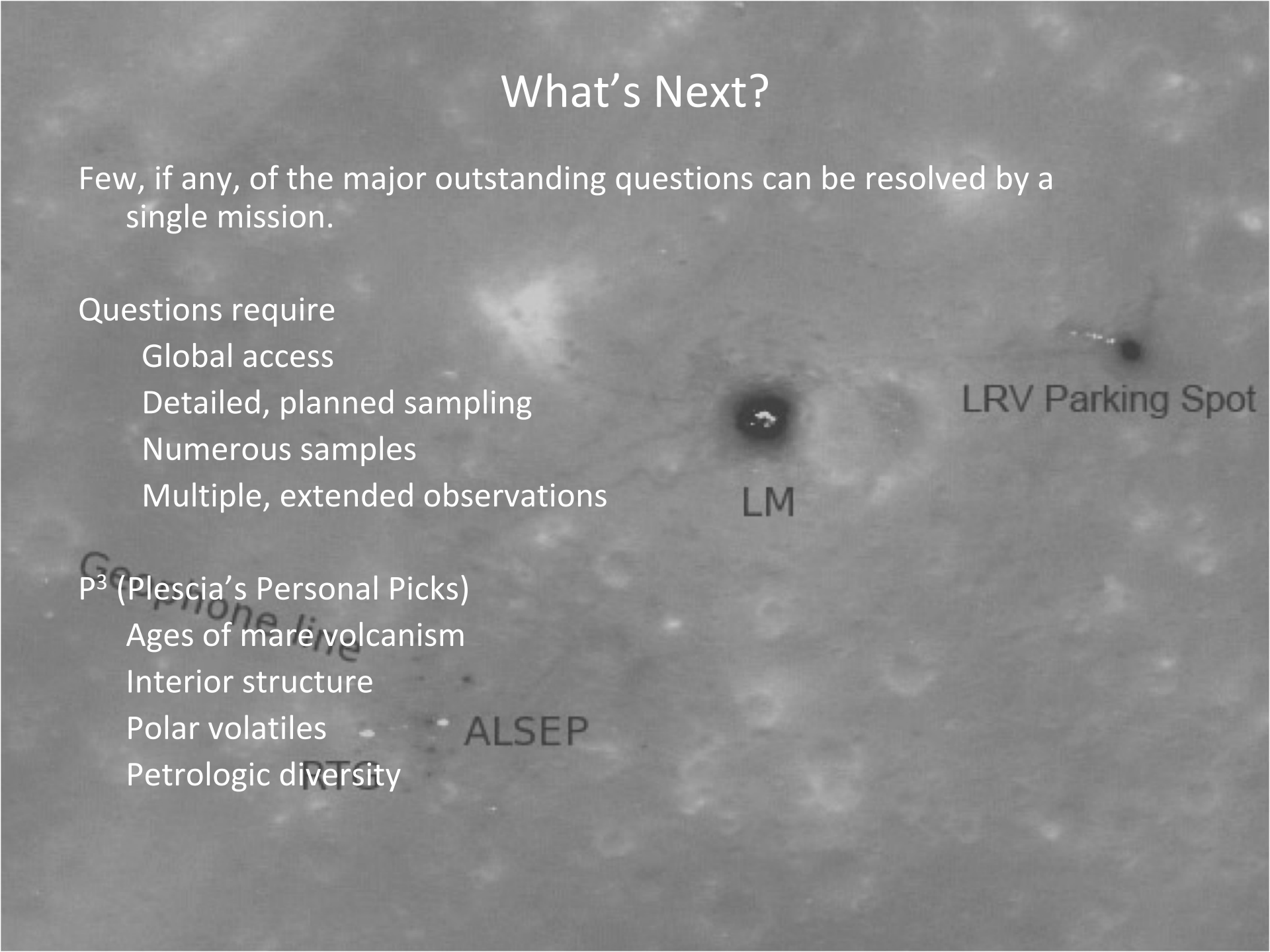
Few, if any, of the major outstanding questions can be resolved by a single mission.

Questions require

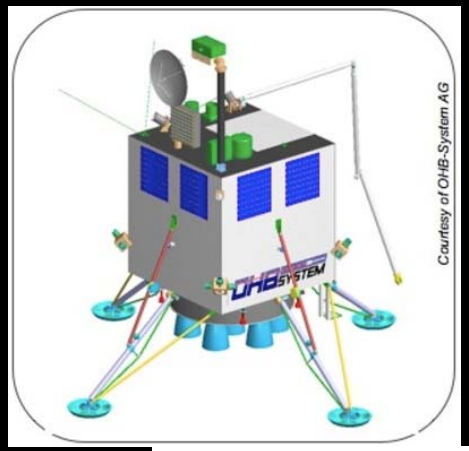
- Global access
- Detailed, planned sampling
- Numerous samples
- Multiple, extended observations

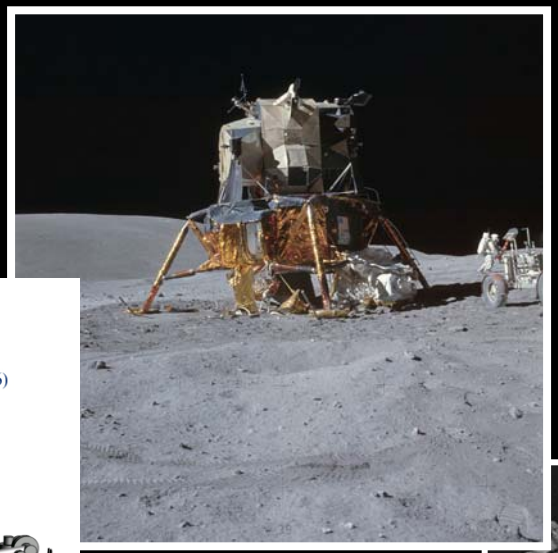
P^3 (Plescia's Personal Picks)

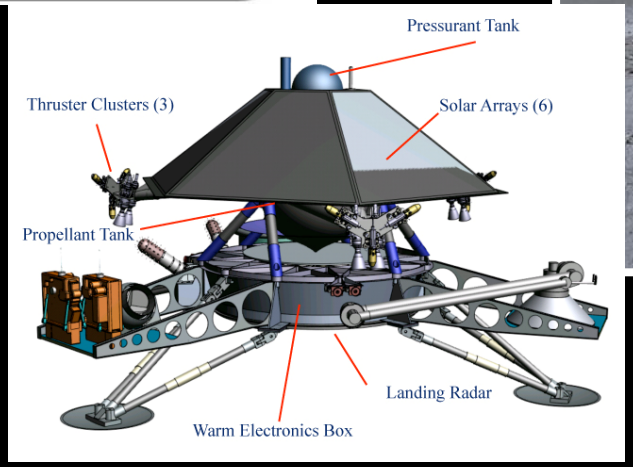
- Ages of mare volcanism
- Interior structure
- Polar volatiles
- Petrologic diversity

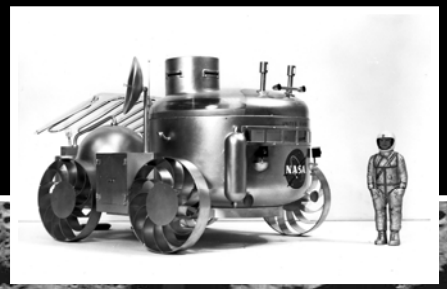


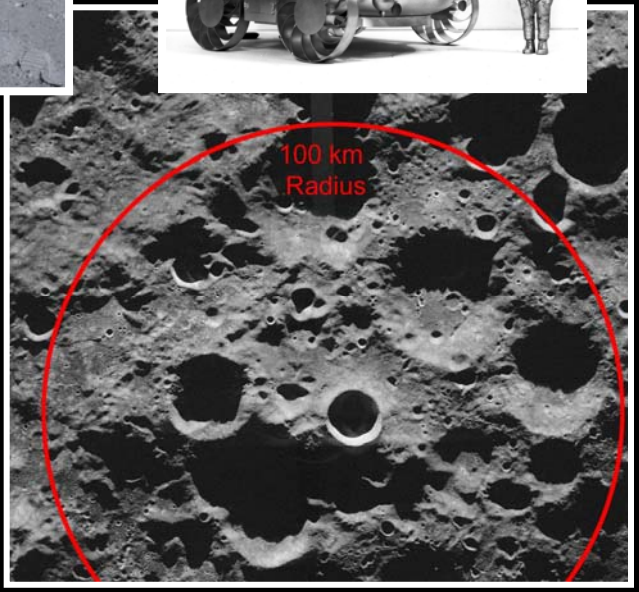
What's Next?


OHB SYSTEM
Courtesy of OHB-System AG




Pressurant Tank
Thruster Clusters (3)
Solar Arrays (6)
Propellant Tank
Landing Radar
Warm Electronics Box


NASA


100 km
Radius

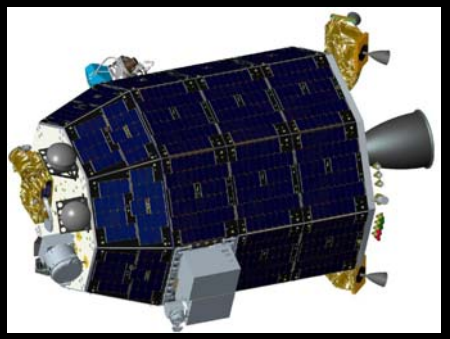
Lunar Atmosphere and Dust Environment Explorer - LADEE

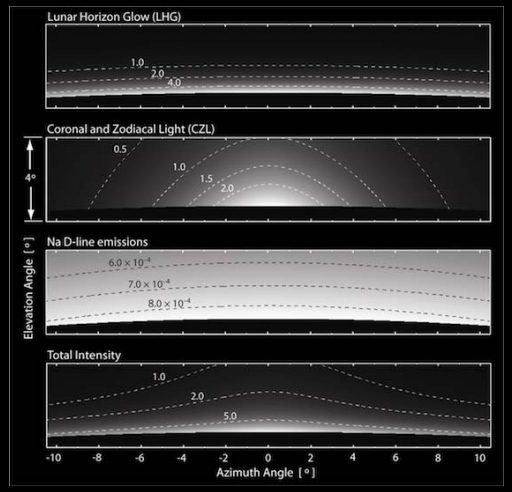
Launch: May 2012

Mission Length: 100 days

Payload

- Neutron Mass Spectrometer
- Dust Counter
- UV Spectrometer
- Laser Communications





GRAIL

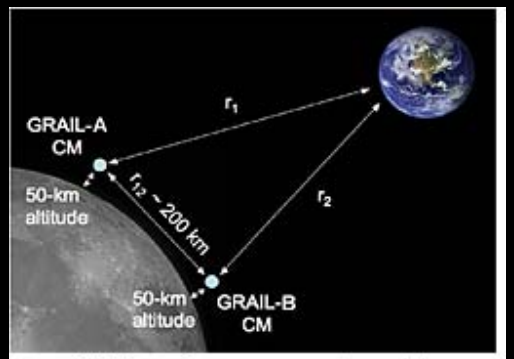
Gravity Recovery and Interior Laboratory - GRAIL

Launch: September 2011

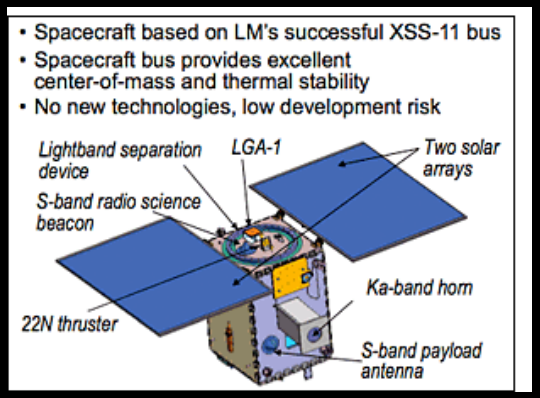
Mission Length: 90 days

Payload:

- Ka Band
- Imaging



GRAIL gravity measurement model



Summary

Many major scientific questions remaining.

- Environment, surface and interior

Pure science – applied science

Few questions can be addressed with a single mission, none with a single sample or measurement.

Any mission will make some progress on some subset of the questions.

Any location can add to understanding about many questions.

Global access and samples are key.

Lunar science doesn’t end. Questions are addressed, understanding matures, new problems are discovered, new techniques are developed, new samples are acquired, analysis continues.