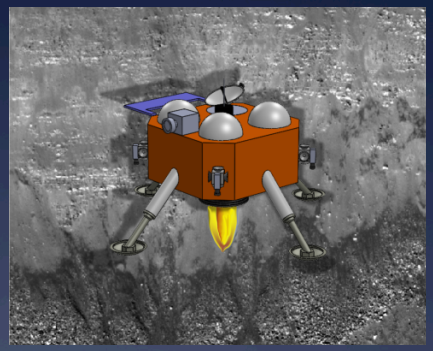
Discoveries from the Lunar Reconnaissance Orbiter and Future Exploration of the Moon

What we must do to prepare for future human exploration and utilization of the Moon



New observations show us where to go and what to do!

Mark Robinson, ASU
SSERVI Exploration Science Forum
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Rationale and Need

The future of the human race lies beyond the Earth-Moon system. The first step in extending our current naive knowledge and capabilities in our transition to a spacefaring species *requires* lunar exploration.

The Moon is in the critical path for Mars and beyond.

We must discover a sustainable architecture for lunar exploration.

We need a series of blue collar landers, rovers and sample return vehicles to investigate key resource, engineering, and science questions to prepare for and support our return to the Moon. The time to start is now, stop studying and start building!

LRO Discovery Highlights

- Shrinking Planet (L)
  - Lobate scarps
- Copernican Volcanism? (L, SR)
  - IMPs
- Silicic volcanism (L, SR)
  - Compton Belkovich (age?)
  - Lassell (age?)
- Pits (L, R)
  - Exploration target
- PSR (L, R, S)
  - Resource target (still enigmatic)
- Composition of pyroclastics (L, SR)
  - Fe content (still enigmatic)
- Photometry (R)
  - Fine scale structure of regolith basis of all remote sensing
  - Engine blast zones
- Ages of Copernican Craters (R, SR)
  - Copernicus, Aristarchus, Tycho, Giordano Bruno, and small very young…
- Stratigraphy, Early chronology (R, SR)
- LRO ERA Impacts (R)
  - CSFD, Engineering
- Exosphere and volatile transport (L)

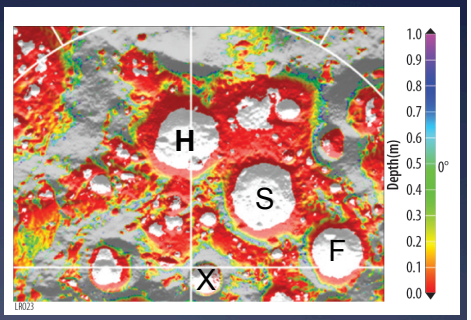
Addressable with: L=lander, SR= sample return, R=Rover

LRO is doing what it was designed to do. Pave the way for human exploration!

Volatiles at the Poles

H, OH, H_2O and more

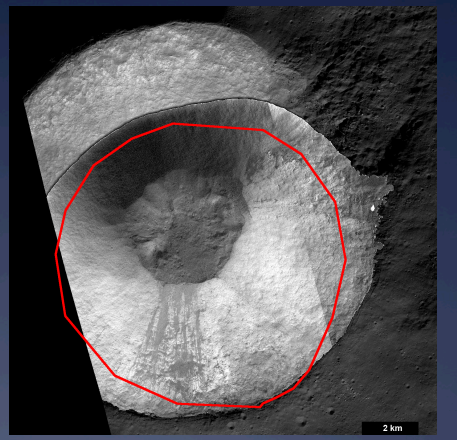
- LCROSS: H_2O +, in one spot
- LEND: H distribution not always in PSRs (S, F, H, X strong to weak)
- Mini-RF: polar "anomalous" craters, bi-static
- LAMP: Frost signature (X, H, F, S strong to weak)
- Diviner: Coldest of the cold (S is warmest)
- LOLA: albedo (S high refl.), depth (S), lighting (S)
- LROC: albedo, morphology, lighting (no sign of volatiles)



Howarth (H), Shoemaker (S), Faustini (F), Shackleton (X) craters -- inconsistent volatile signatures amongst varying measures

Requires Surface Measurements

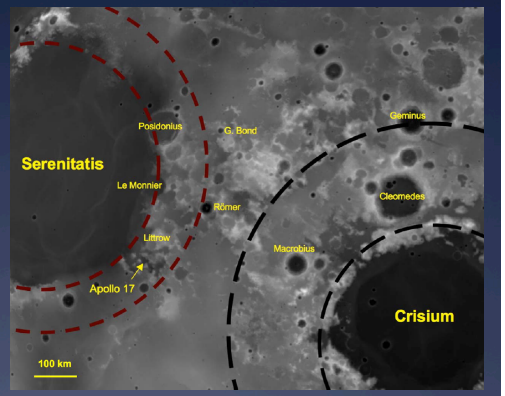
- The lunar poles are tantalizing, vexing!
- Clarity on composition, grade, and extent requires surface assets
- Robotic landers and rovers that can probe the top few meters and return definitive measures of key species
- Why are the mercurian PSRs so different than the lunar examples? Key aspect of sequestration remains unknown!



NAC imaging PSR
Main L (D: 14 km, 81.4°N, 22.8° E)

Solar System Chronology

- Spudis et al basins, LHB or not? Are we correctly interpreting the ages of returned samples?
- Volcanism over time, volumes, mechanisms, compositions, thermal history of the Moon
- Age of young impacts inner Solar System chronology importance of secondaries and auto-secondaries, material properties and small crater morphology

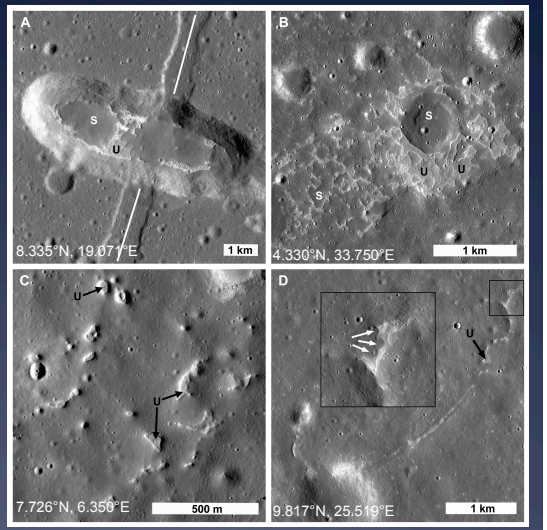


LRO observations consistent with idea that Serenitatis is significantly older than current paradigm …

Sharp, meter-scale morphology, stratigraphy and crater size frequency distributions suggest that IMPs formed *<200 Ma ago*

A) Depression containing an IMP crosscuts a smaller northeast-trending graben
B) Maskelyene F, no significant topographic confinement
C) IMPs in the floor of Hyginus crater
D) IMPs with narrow, discontinuous sections following a curved path

Irregular Mare Patches (IMPs)



Over 70 occurrences discovered so far!

Lunar Pits

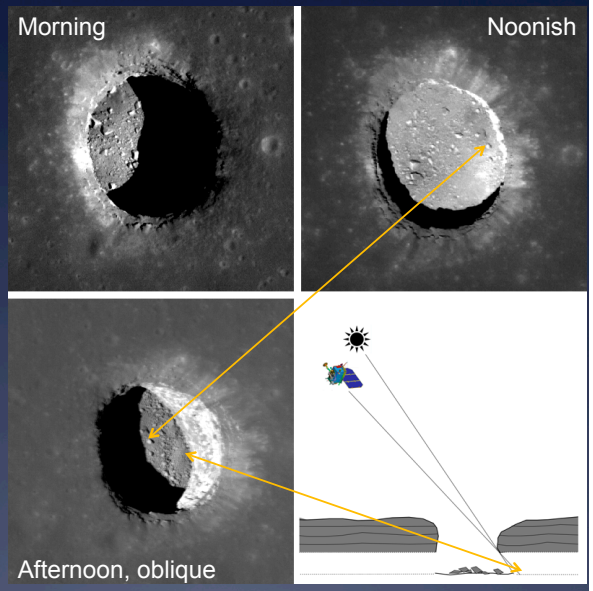
- Mare Tranquillitatis pit →
- 100 m diam, 105 m depth
- Are there extant sublunarean tubes?

- Oblique imaging! Peek under the overhang 20 meters!

- How far does the void extend?

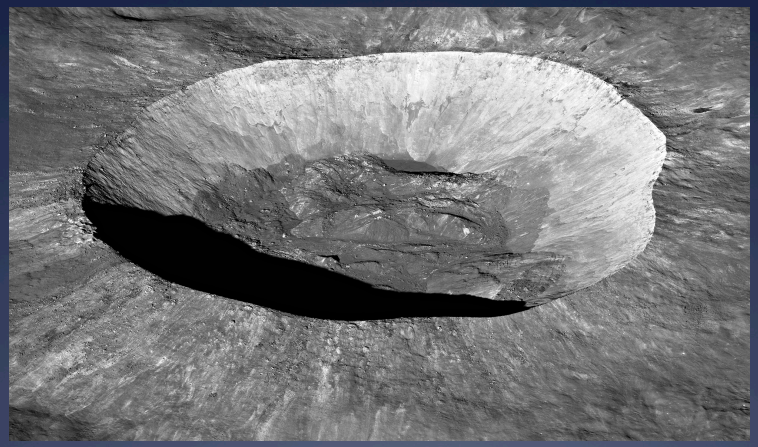
- Subsurface voids (caves) provide shelter from radiation, micro-meteorites and provide constant T (-25°C)

Wagner et al poster: Pit discoveries
Robinson et al poster: Arne – mission to MTP



Over 200 pits discovered in impact melt deposits!

Copernican Impacts

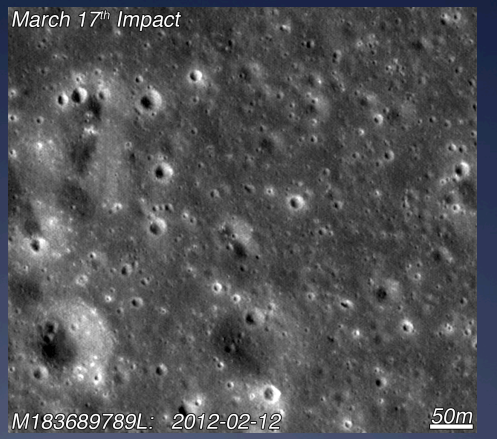


Giordano Bruno (20 km diameter – 10my? 1my? 1000 yrs?)

LROC Temporal Imaging

- Discovered hundreds of impact related changes since start of mission (NAC Before/After pairs)
- Twenty resolved craters!
- Significance
  - Refine flux of >0.5 m bolides inner Solar System
  - Seeing new complex ejecta patterns
  - Secondaries from small craters are extensive
  - Engineering constraints for future long lived assets

Over next two years LROC can collect a definitive set of temporal observations



17 March 2013 impact, 18 m crater, secondaries found >30 km distant

Coherent and Sustainable Exploration Strategy

- Polar landers with mobility (*rover, hopper, other*) to investigate distribution of volatiles
- Simple yet capable long lived *rovers* to measure, sample and scout major geologic terrains (tie remote sensing to the ground). Feed into decision process for human targets, deliver samples from afar to human outpost, wring out engineering.
- Robotic *sample return* missions to answer key science questions and assess potential of large scale pyroclastic deposits (grade, tonnage)
- We need a long range executable and sustainable plan for human and robotic exploration that is robust to political winds