# The Importance of Sample Return Missions and Analyses

D. A. Papanastassiou, B. L. Jolliff,
C. K. Shearer, L. Alkalai, and L. E. Borg

March 5, 2011, The Woodlands, TX

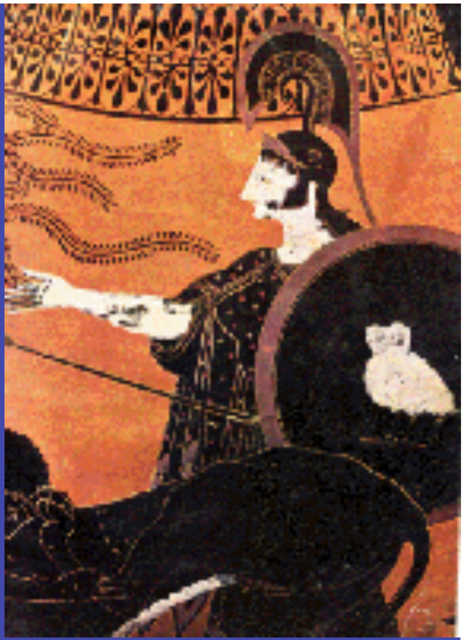
# Outline

- Observations from Earth, Flybys, Orbiters, Landers (in situ), Landers (sample return)
- There is excitement with every type of mission, at different stages of knowledge
- The explosion in understanding comes with sample return (meteorites, Apollo, Stardust, Genesis)
- Sample return also serves as the ground-truth for the design of follow-up orbiter and lander (in situ analyses) instrumentation

# Examples of Need for Iteration and Complementarity

- Spectroscopy of the lunar surface: once Apollo 11 and subsequent samples were returned, all prior observations required recalibration and reinterpretation
  - The presence in the soils of glass, agglutinates, and nanophase Fe (solar wind-reduced Fe) had been totally unexpected
- All crater chronology and inferred lunar evolution had to be drastically and irrevocably changed, based on ages determined on returned samples
- Chemistry provided by Surveyor (α-back-scattering) allowed preparation (on Earth) for the Apollo returned samples
  - However, only one isotope lab was adequately prepared for Rb-Sr on basalts, and almost none for U-Pb on basalts
- Sample return was essential for understanding and interpreting (and re-interpreting) prior observations and dispelling myths

# Preaching to the Choir?



- Coals to Newcastle?
- Owls to Athens?

Not quite!

- There are those who would persevere with more orbiters and landers, avoiding sample return, due to perceived complexity and cost
- We also need to agree that ground truth based on returned samples results in paradigm shifts: the prime Apollo lesson

# Believe It or Not: Past Frequent Fliers

- Ranger 1  August 1961
- Ranger 2  November 1961
- Ranger 3  January 1962
- Ranger 4  April 1962
- Ranger 5  October 1962
- Ranger 6  January 1964
- Ranger 7  July 1964
- Ranger 8  February 1965
- Ranger 9  March 1965

- Surveyor 1  May 1966
- Surveyor 2  September 1966
- Surveyor 3  April 1967
- Surveyor 4  July 1967
- Surveyor 5  September 1967
- Surveyor 6  November 1967
- Surveyor 7  January 1968

- Luna missions (flybys, orbiters, landers, robotic sample return)
- Luna 9  Jan 1966; first soft lander
- Luna 16 (Sep 70), 20, 24 sample returns

- Learning curve with Ranger; lessons applied quickly to Surveyor Program;
- Quantum leap in understanding of the Moon came with Apollo lunar samples

- ***If, now, we can not fly as frequently, we should  avoid lingering with just  orbiters and landers, simply because that fits in our comfort zone***

# The Apollo Legacy

- Creation of a multidisciplinary community of scientists
- The excitement of discovery (and funding) attracted a generation of then young scientists
- A key contributor to the birth of planetary science with contributions from physicists, chemists, geologists, biologists, astronomers, material scientists
- The development of new instrumentation and new analytical techniques [next slide]
- A completely new way of doing science by focusing multiple approaches on specific science questions
- Adequate funding (larger teams) for a few years
- The Apollo experience allowed the development of modern geochemistry and of environmental science

The beginning of the recognition of the importance of environmental science!

# Analytical Capabilities FOR Apollo

- Electron microprobes standardized and used
- SEMs available but not ubiquitous
- Ongoing developments of organic mass spectrometry
- High precision solid source mass spectrometry (Rb-Sr dating): only one instrument with sufficient precision
- Application of the then new technique of stepwise heating for $^{40}Ar$-$^{39}Ar$ plateau age determinations
- Inadequate U-Pb measurements, given extremely low non-radiogenic Pb and high U/Pb in the returned lunar samples
- Rare earth element and siderophile element analysis mostly by neutron activation (low sensitivity)
- New chemistry and mass spectrometry for Gd, Sm for determining secondary neutron fluence on the Moon (maximum at  depth of ~1.5m) and soil gardening on the lunar surface
  - Taking advantage of large thermal and epithermal neutron cross sections

# Analytical Capabilities (Isotopes) AFTER Apollo

- TIMS - high precision commercially available (late 70s)
- SIMS - Ion microprobes developed for planetary materials, isotopes
- Sm-Nd dating technique developed, using lunar Gd and Sm methods
- U-Pb low contamination chemistry developed, leading, *inter alia,* to the recognition of and proposal for a Terminal Lunar Cataclysm
- NTIMS -- Re-Os dating and siderophile element determinations through negative ion TIMS, at greatly increased sensitivity ($x10^5$)
- These techniques have revolutionized both cosmochemistry and geochemistry
- Microanalysis through MegaSIMS, Nanoprobe, SARISA/RIMS, Synchrotron XRF, new STEM
  - all with significant investment by the community and by NASA through SRLIDAP and the LARS Program, in connection with the GENESIS and STARDUST Discovery Program missions

**All this shows the persistent value of returned samples as analytical capabilities improve**

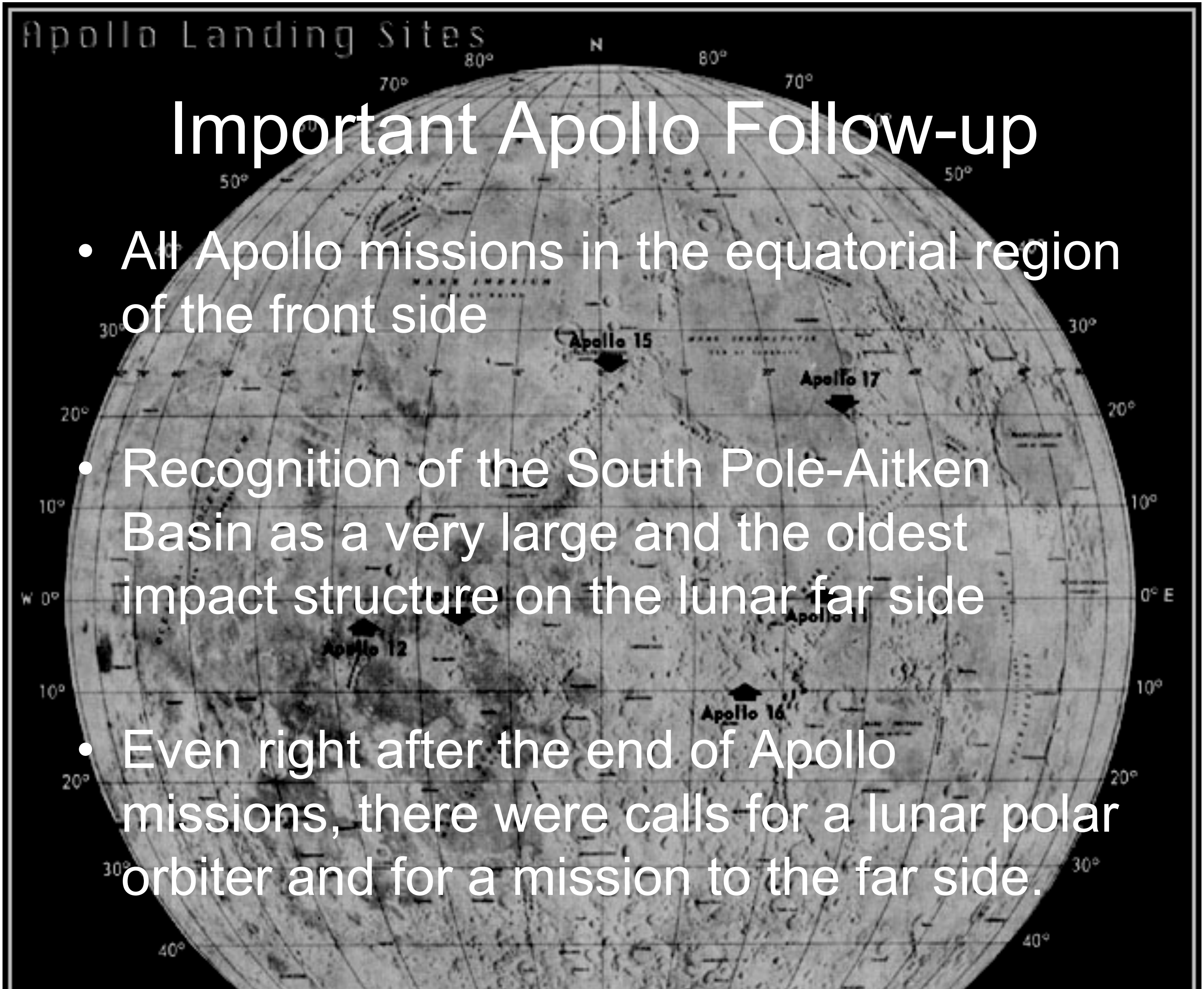
UCLA MegaSIMS

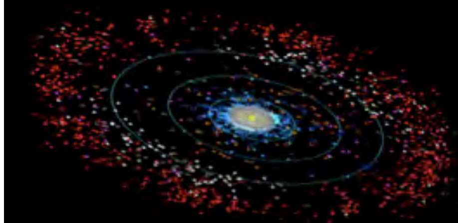
# Important Apollo Fallout

- Science approach applied in full to the study of the Allende meteorite
  - Major attention to Allende (Fall, Feb 8, 1969) delayed until the end of Apollo missions
  - Full benefit of new tools developed for Apollo
- Geochemistry paradigm shift: Sm-Nd
  - Major importance of the Sm-Nd system as a means to address terrestrial mantle evolution (recognized by a couple of Crafoord Prizes)
  - Traceable directly to the analytical techniques for Gd and Sm for neutron effects on the Moon

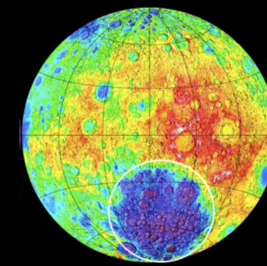
# Important Apollo Follow-up

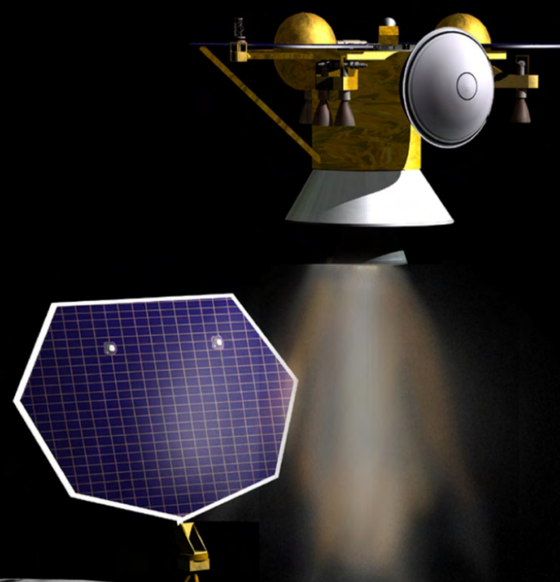
- All Apollo missions in the equatorial region of the front side
- Recognition of the South Pole-Aitken Basin as a very large and the oldest impact structure on the lunar far side
- Even right after the end of Apollo missions, there were calls for a lunar polar orbiter and for a mission to the far side.





*A window into Planetary and Solar System History*

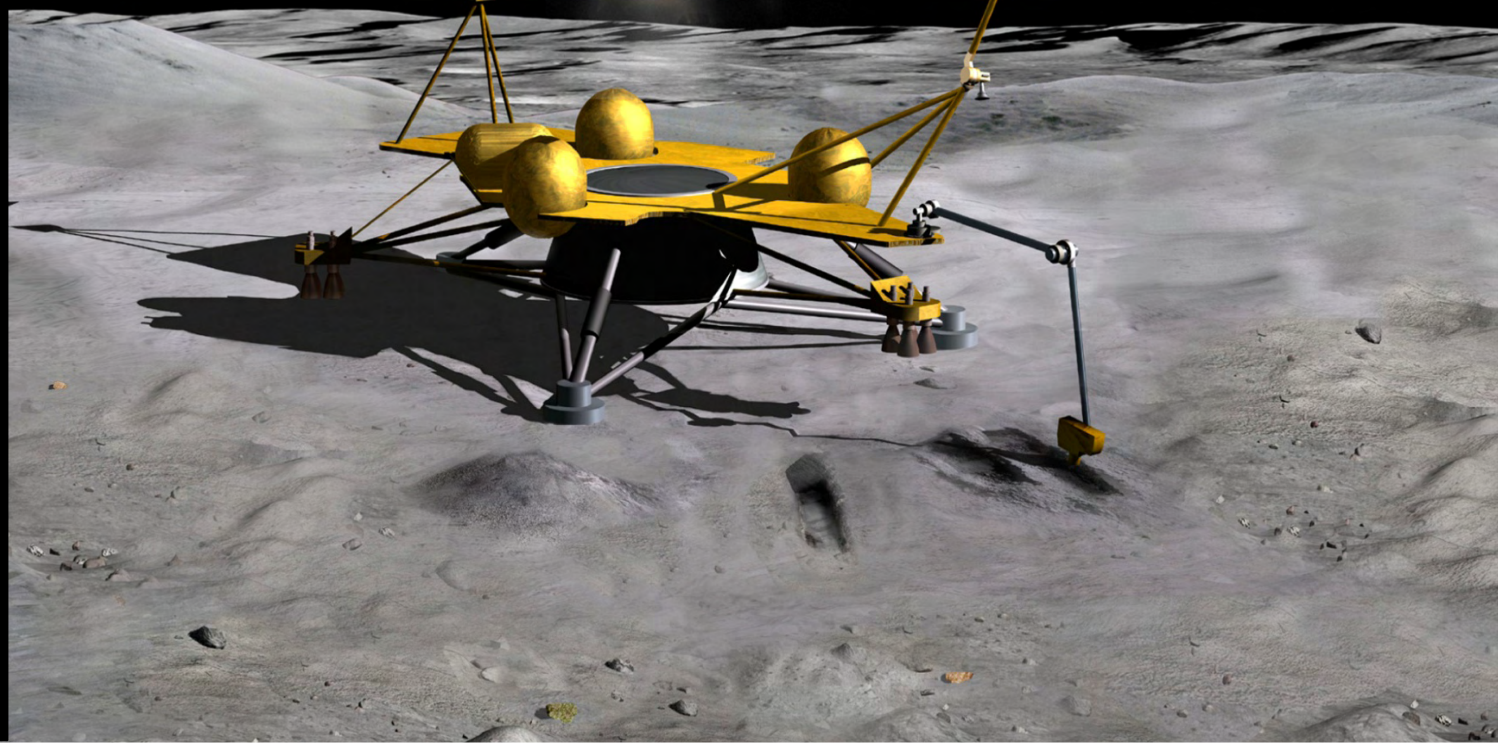


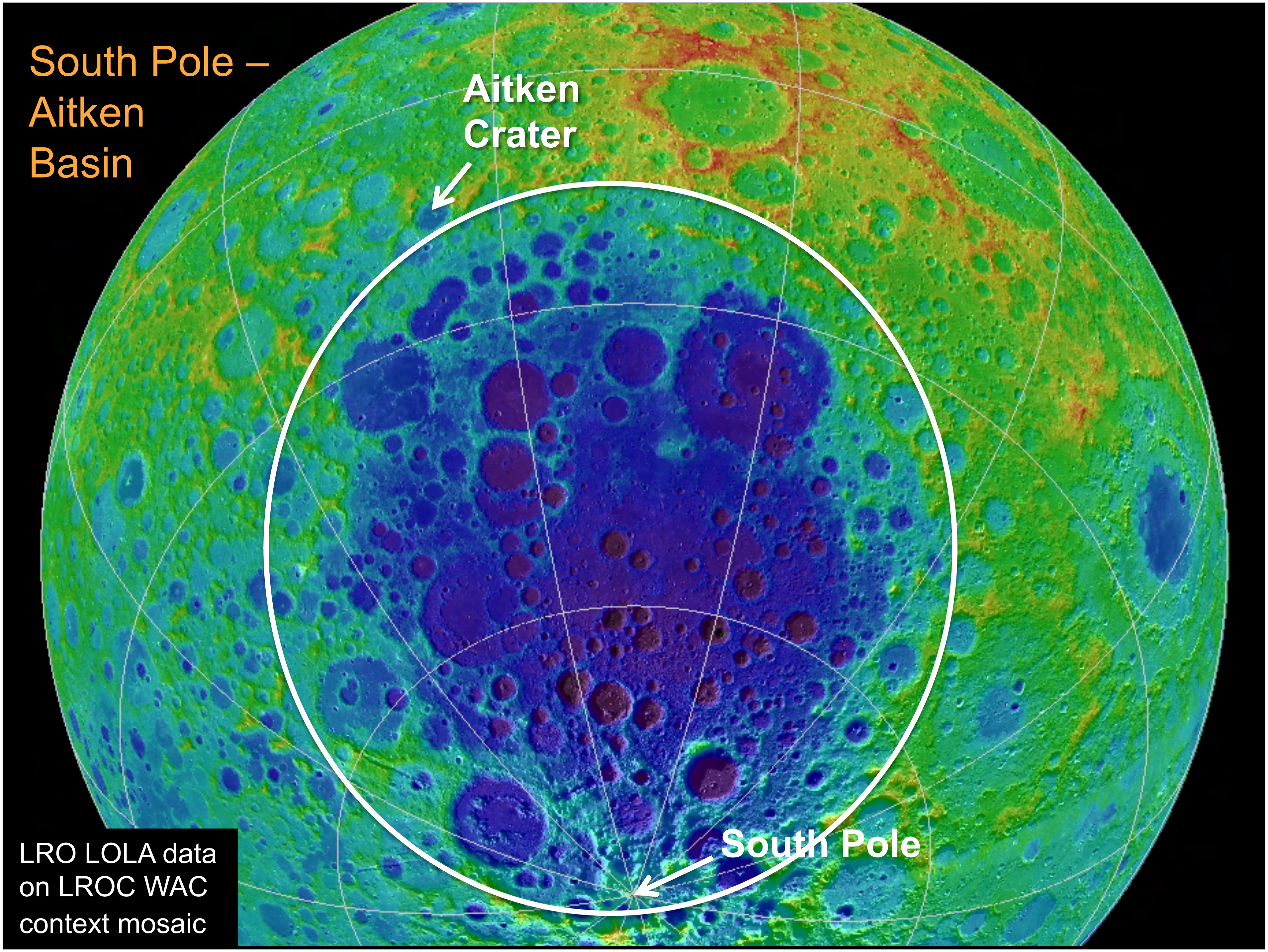


# *MoonRise*

**A NASA New Frontiers Mission Proposal**

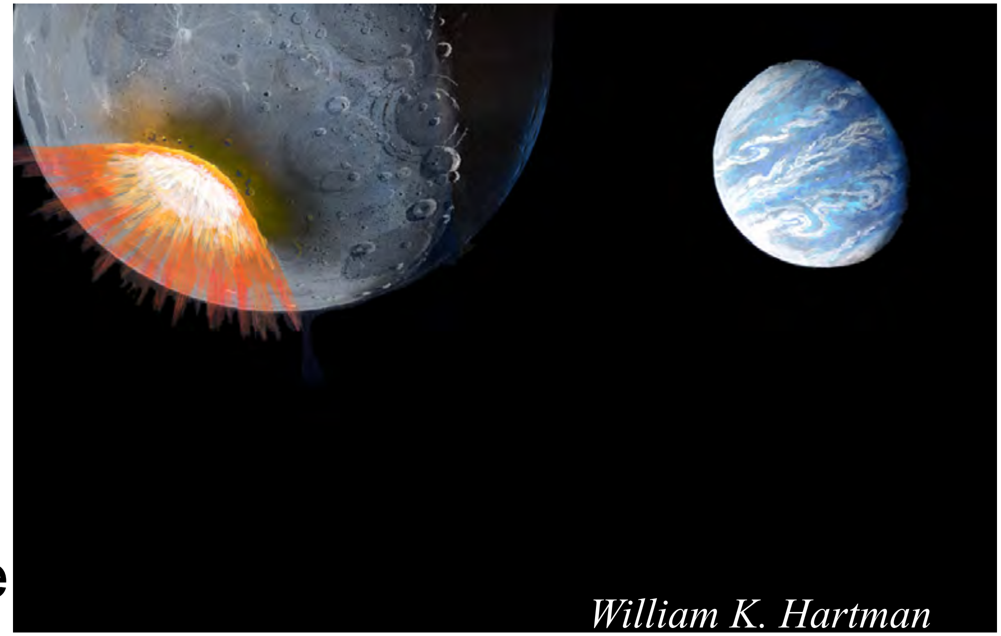
A South Pole-Aitken Basin Sample Return




South Pole – Aitken Basin
Aitken Crater
South Pole
LRO LOLA data on LROC WAC context mosaic

# Why MoonRise?

- Understand the late Inner Solar System bombardment
  - Significant for early Earth
  - Significant for Solar System
  - Understand orbital dynamics of Giant Planets




- Major question and puzzle identified by Apollo lunar sample analyses
- Timing of a key event in Solar System history
  - Will permit a unique understanding of how the Solar System evolved
  - This was the key reason why this was highly rated as a New Frontiers mission, by the NRC (2003)

# Why MoonRise Now?

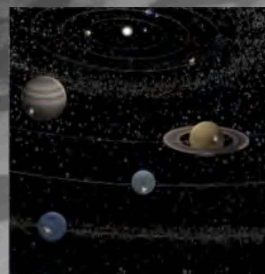
- The main science objective addresses understanding a key event in the Solar System
- Based on several recent high resolution orbiter missions (Kaguya, LRO) and extensive data analyses, we can land safely on the Moon (and as we could with Surveyor)
- We have an excellent understanding of the lunar regolith and of how to sample the lunar surface and to obtain many thousands of small rocks (~5,000, 3-20 mm diameter) for analysis and age dating
- Experience with Stardust provides confidence for a safe landing on Earth (at UTTR)
- High sensitivity and high precision state-of-the-art analytical techniques would be used by MoonRise science team members and by the general sample analysis community

# MoonRise sample return addresses key Solar System Science

***Addresses key objectives for Planetary Science!***

***Advances scientific knowledge of Solar System history and processes.***

*How the Solar System evolved to its current diverse state.*

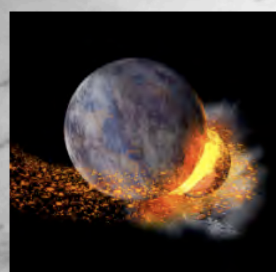


Dynamics of the Outer Solar System

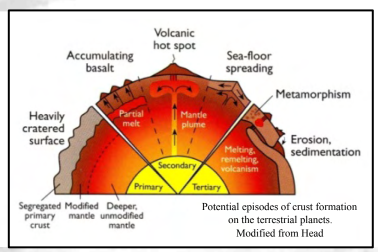
Impact Cataclysm

Effects of Giant Impacts on Planetary Evolution

MoonRise Science (SPA Samples)



Origin of the Earth-Moon system




Differentiation and Thermal History of the Terrestrial Planets

Planetary Environments for the Origin and Evolution of Life

*Implications for the history of Earth at a pivotal time in the development of its habitable environments and the origin and survival of Earth's early life.*