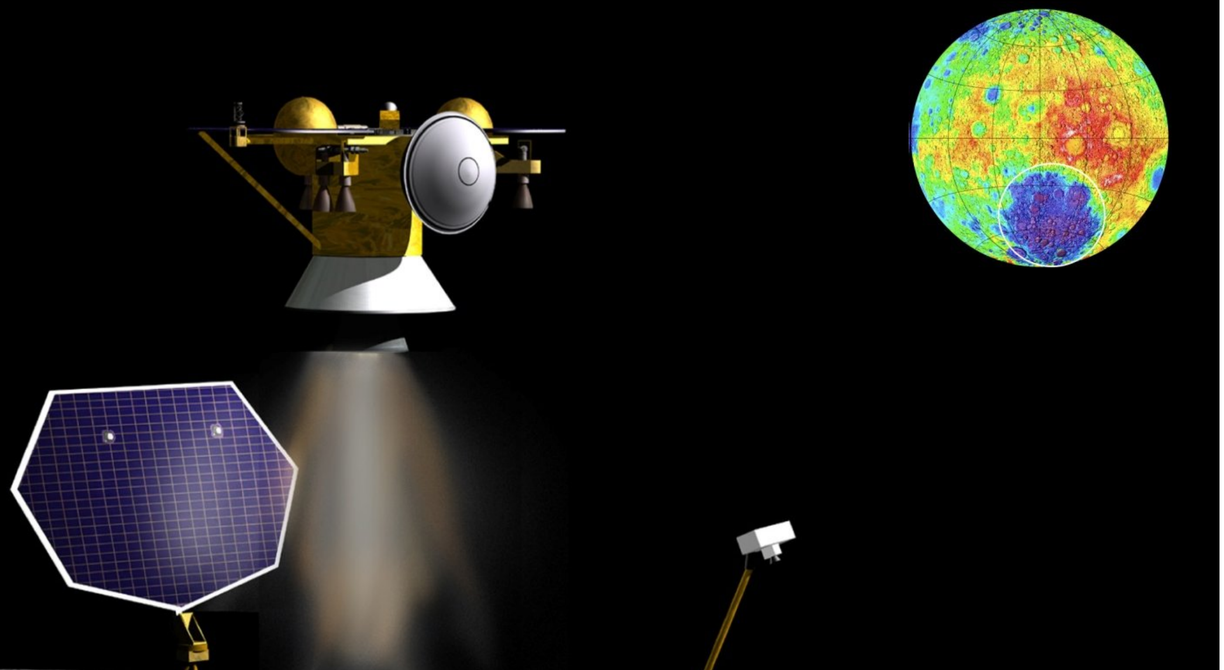
MoonRise:

Sample Return from the South Pole – Aitken Basin



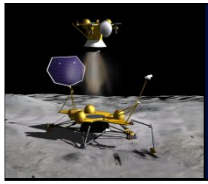
Leon Alkalai, JPL
Brad Jolliff, WUSTL
Dimitri Papanastassiou
JPL

International Planetary Probe Workshop, 2010
Barcelona, Spain

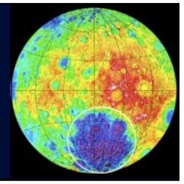
June 17, 2010

JPL   LOCKHEED MARTIN   Washington University in St. Louis   DLR   Malin Space Science Systems

NASA   Ames Research Center
Langley Research Center   Canadian Space Agency   Agence Spatiale Canadienne



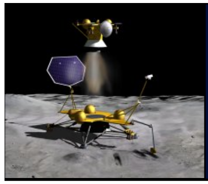
Recent News, Press Releases, Publications



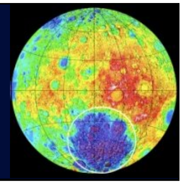
For more information: http://moonrise.jpl.nasa.gov

- ✓ Global Lunar Utilization Conference (GLUC), Beijing, China, May 29 – June 4th 2010, Brad Jolliff, Dimitri Papanastassiou, Leon Alkalai.
- ✓ Goldschmidt Conference, Knoxville, TN, June 13-17, 2010, B. Jolliff .
- ✓ International Planetary Probe Workshop, Barcelona, Spain, June 14-18, 2010

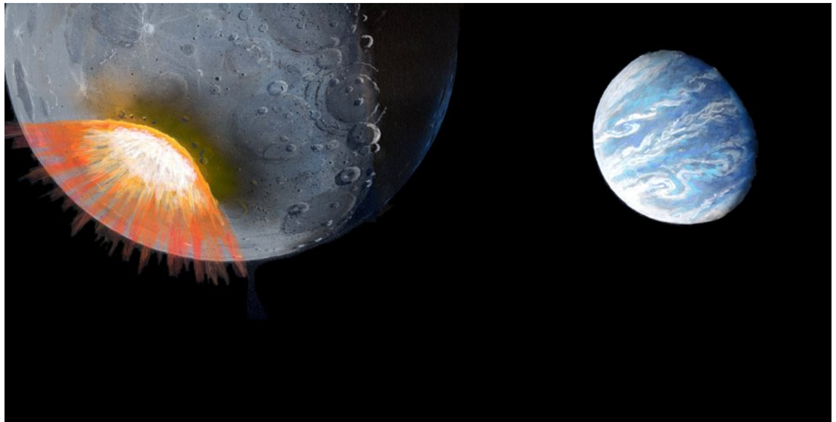
- ➢ NLSI Meeting at Ames Research Center, July 19-22, 2010
- ➢ LEAG meeting, September 14-17, 2010 in Washington DC
- ➢ European Planetary Science Congress, Vienna, Sept. 27, 2010



MoonRise:
Window into deep Solar System History



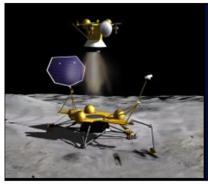
- **Determines the age of a key event in Solar System history.**
  - Tests the Cataclysm hypothesis for early bombardment of Earth-Moon System
  - Tests hypotheses for early orbital dynamics of gas giant planets
- **MoonRise tests these hypotheses by determining the age of the oldest impact melts and thus the age of the South Pole - Aitken Basin formation.**



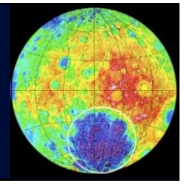
Artist’s concept of formation of the South Pole-Aitken Basin

William K. Hartman

MoonRise would profoundly affect our understanding of the origins and early years of life on Earth.



MoonRise:
addresses key Solar-System science

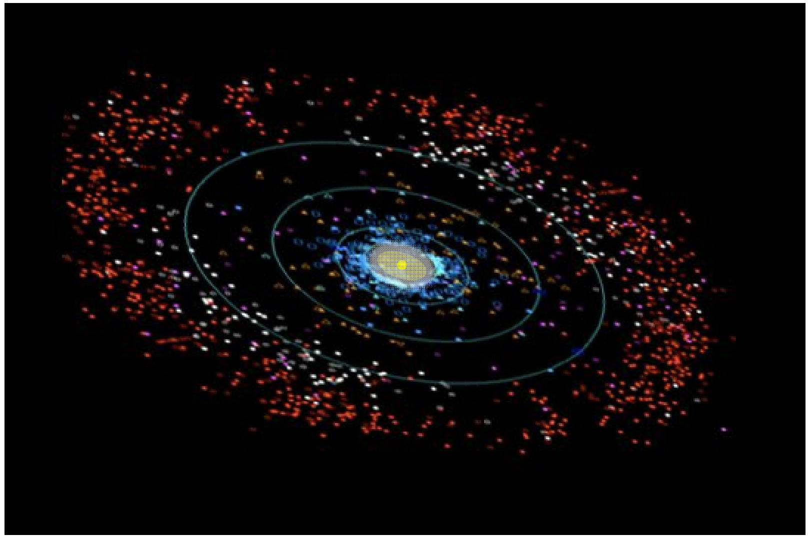


- **Apollo samples show that Moon and Earth experienced a late, heavy bombardment or "Terminal Cataclysm"**

  ~ 3.8 to 4.0 billion years ago

- **Current dynamical models indicate that a shift in orbits of the gas giants could have caused the injection of asteroids and comets into the inner Solar System at about 500 m.y. following planetary accretion.**

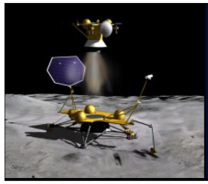
- **Materials of the SPA Basin hold the key to the impact Cataclysm and thus what happened on the Earth and Moon in their first ~500 million years.**



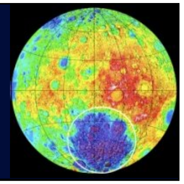
Artistic rendering of objects in the Solar System including gas giant orbits (green) and objects of the inner Kuiper Belt (red).

Solar System relevance:

- **Test models of orbital dynamics in the early Solar System**
- **What caused the release of small orbiting bodies to the Inner Solar System?**
- **What were the effects on the development of habitable environments and life on Earth?**



MoonRise: Basis for High Priority

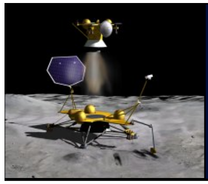


- **New Frontiers in the Solar System, an Integrated Exploration Strategy. *US National Academy of Science Decadal Survey, Solar System Exploration*, National Research Council, 2003.**

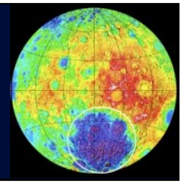
- **Report on The Scientific Context for Exploration of the Moon (SCEM), NRC, 2007**

- **New Opportunities for Solar System Exploration (NOSSE), NRC, March 2008**

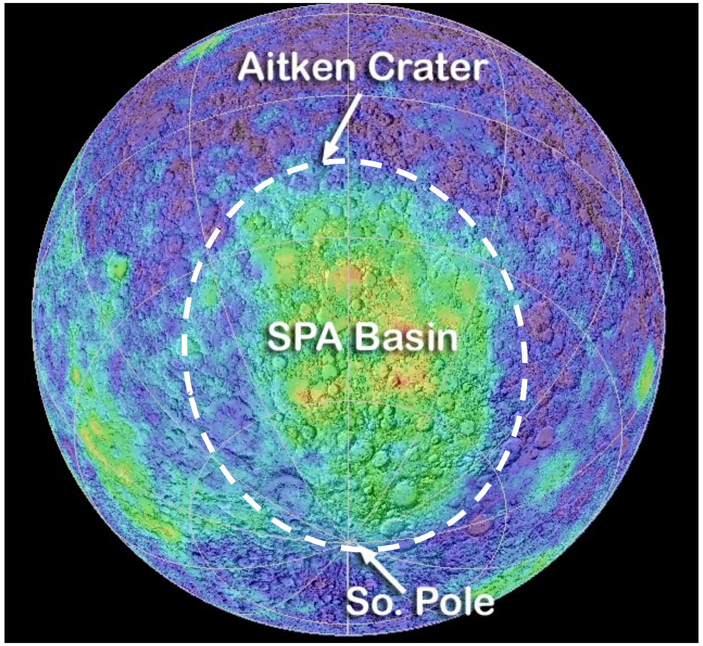
Sample return from South Pole-Aitken Basin is a well established high priority for Solar System Science



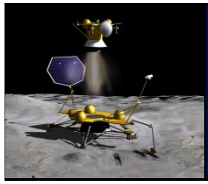
MoonRise Goals: address 3 broad Planetary Science Issues



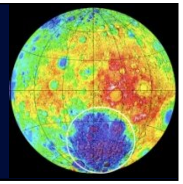
1) **Impact history of inner Solar System**
   - Test Cataclysm Hypothesis
   - Illuminate first 500 million years of Solar System history
2) **Large basin impact events and effects**
   - Understand basin formation processes
   - What is their role in the evolution of planetary bodies?
3) **Interior differentiation of planetary bodies**
   - Learn how planetary crusts and mantles formed



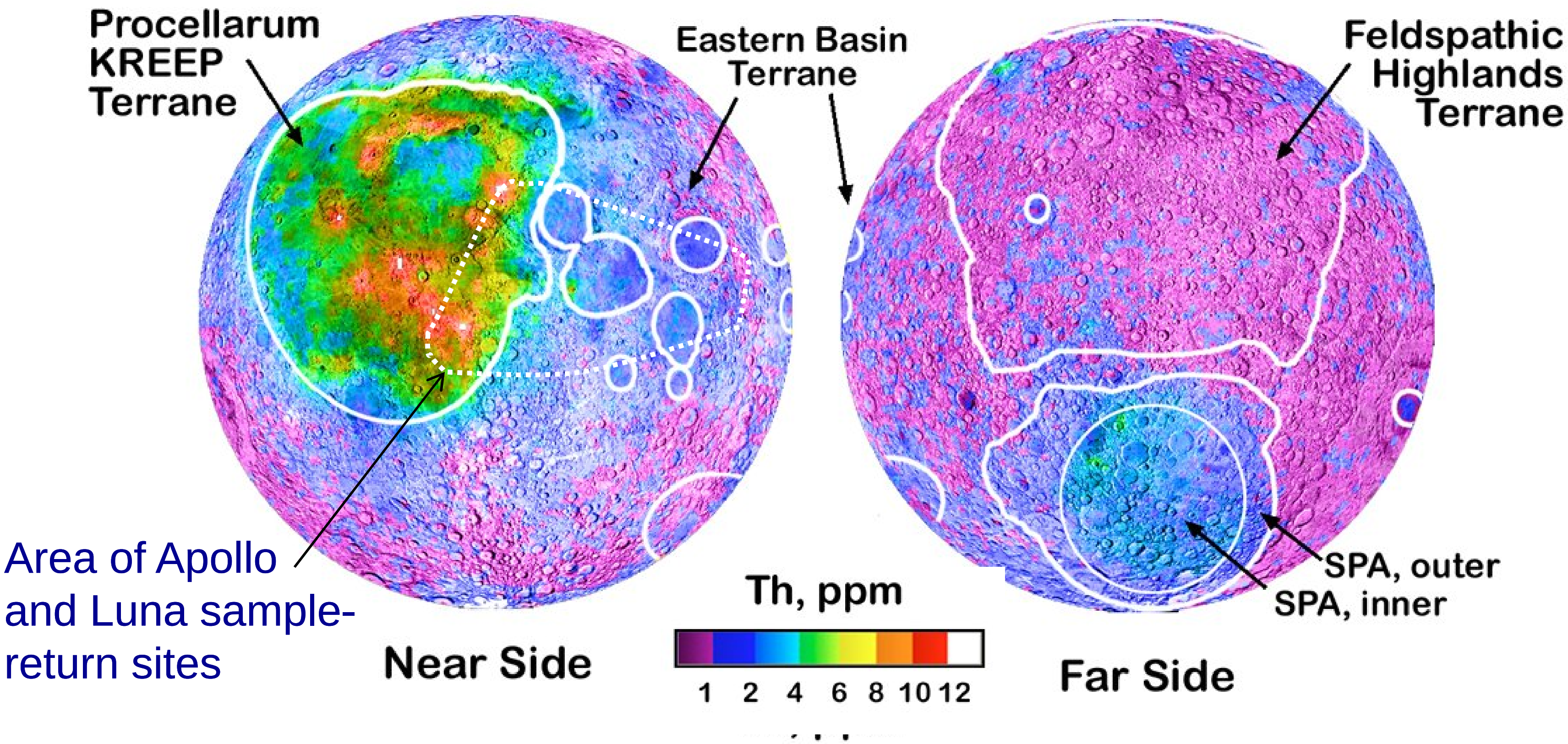
Moon uniquely preserves a record of these events in its rocks and regolith.



MoonRise to provide: Ground Truth for Orbital Observations



- **First surface mission to far side of the Moon**
  - Provides <u>sampling and ground truth</u> far from the Earth-facing-side landing locations of the Apollo missions – greatly expanding knowledge of Moon's differentiation and diversity of materials.



Slide 7

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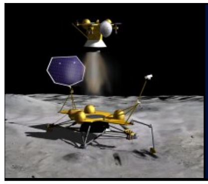
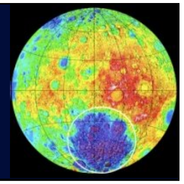
Janis Graham, 08/06/2010

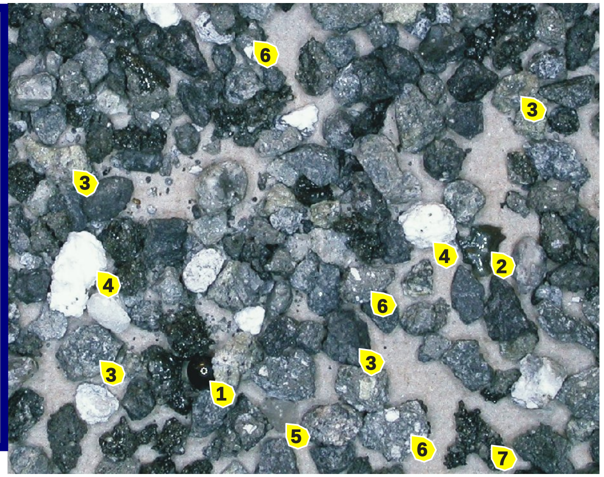


Sieve to concentrate rock fragments and collect unsieved regolith for context



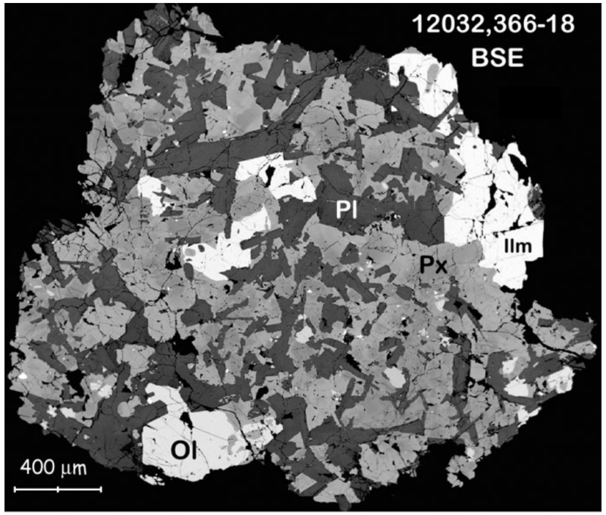
Rock fragments carry unique, individual histories of igneous, impact, and volcanic events.

Rock fragments (2–10% by mass of regolith)
- **– represent local and distant events**
- **– rock types are diverse because of impact mixing.**



Sampling requirements:

- Sieve regolith to increase number of rocks, thus science potential 10–50x
- Unsieved regolith for comparison with orbital data
- 900 g sieved;
- > 50 g unsieved



JPL-JG8

Slide 8

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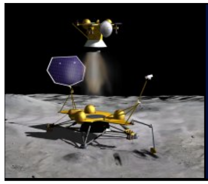
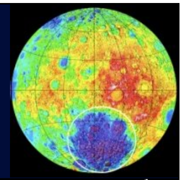
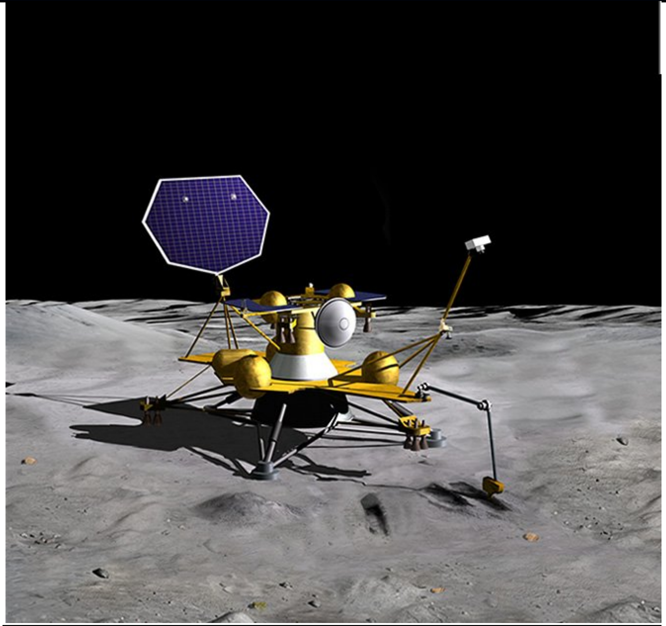
Janis Graham, 08/06/2010



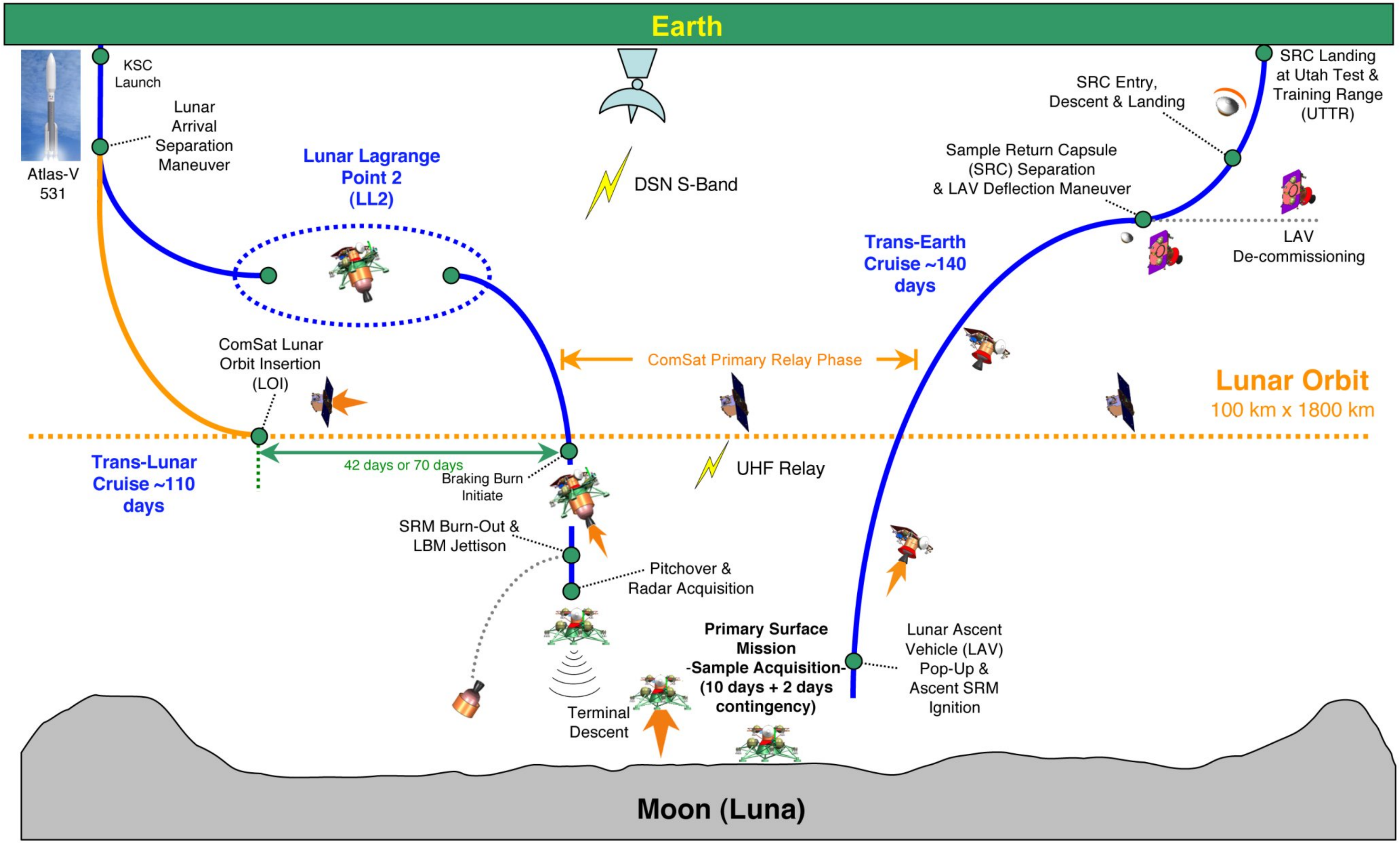
MoonRise: Baseline Mission Overview

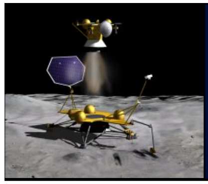


- Launch ~ late 2016.
- Lander descends into the interior of the SPA B
- A dedicated ComSat provides relay coverage
- Scoop, sieve & collect rock fragments: ~ 1 kg.
- Transfer samples to capsule (SRC) on Lunar Ascent Vehicle (LAV).
- Launch LAV and return SRC to Earth where it is recovered and transported to the JSC Curatorial Facility.
- Samples would be made available to the science community for many years to come.

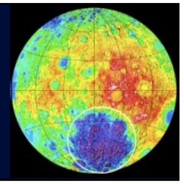


Mission Overview: Technical Description

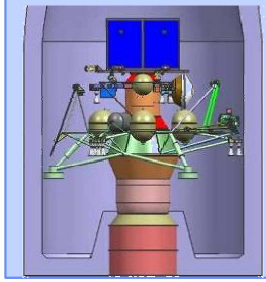




MoonRise Mission Overview - Implementation

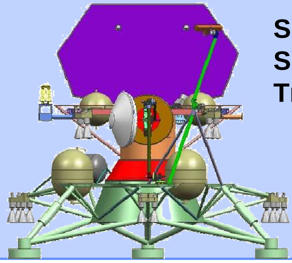


Launch



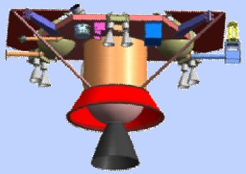
Atlas V 531
TLC: low energy
ComSat relay

Surface Operations



Scoop,
Sieve,
Transfer

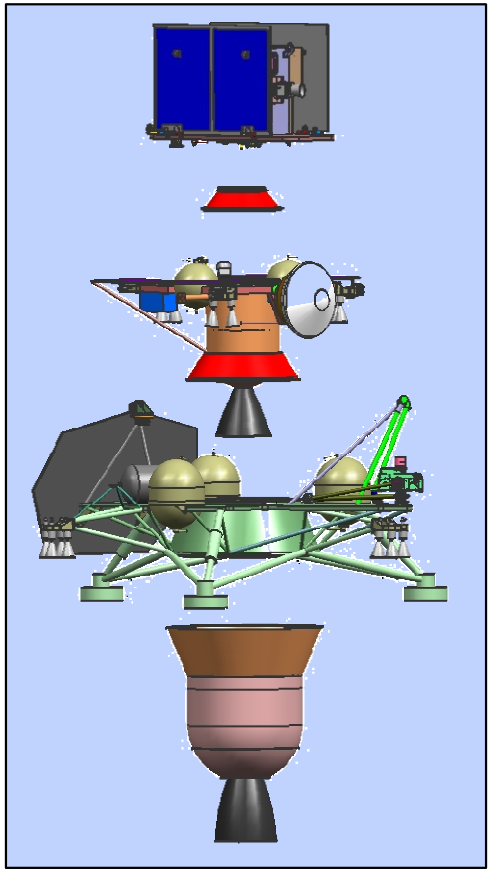
Ascent



TEC: low energy

Landing at UTTR

Curatorial services at JSC for PE



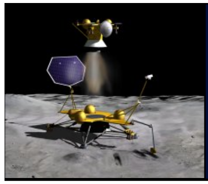
Flight System Elements:

1. **ComSat**:

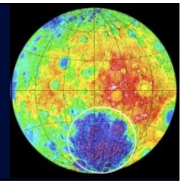
2. **LAV**:
3. **SRC**:

4. **LSM**:

5. **LBM**

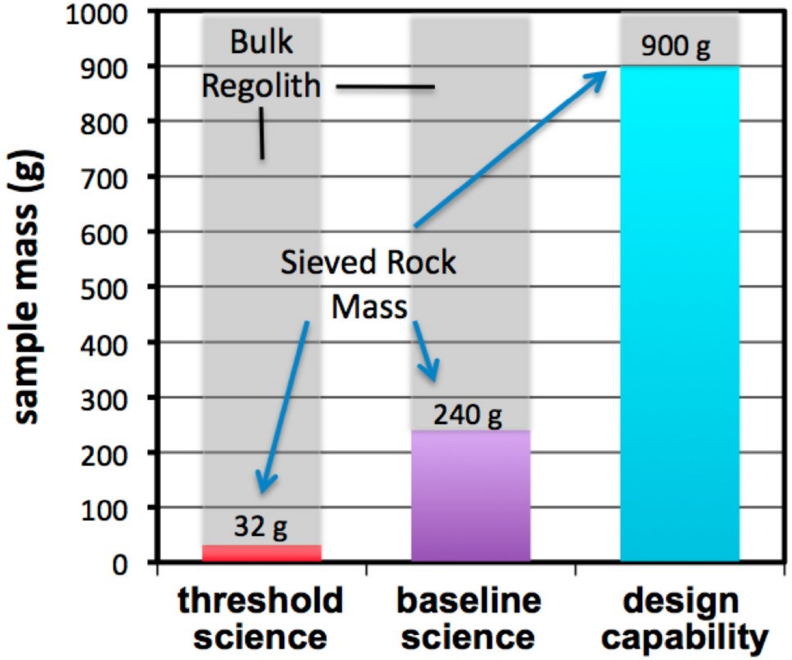


MoonRise Overview - Science



Science Goals:

1. Impact history of inner Solar System
2. Large basin impact events and effects
3. Interior differentiation of planets

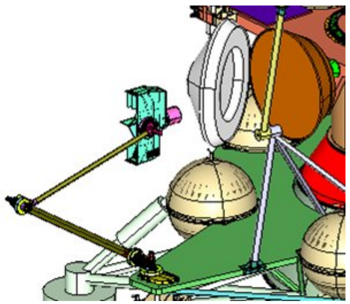


Science Objectives:

1. Determine SPA basin impact chronology
2. Understand giant basin processes
3. Investigate crust-mantle transition
4. Thorium distribution and thermal evolution
5. Basalts as probes of far-side mantle

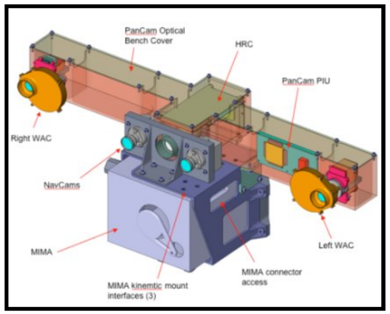
MoonRise Payload

Robotic Arm & End Effector



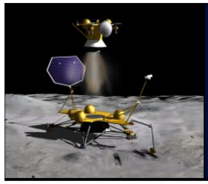
Descent Imager

Context Imager

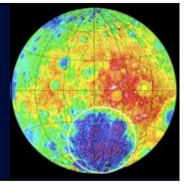


Arm Camera

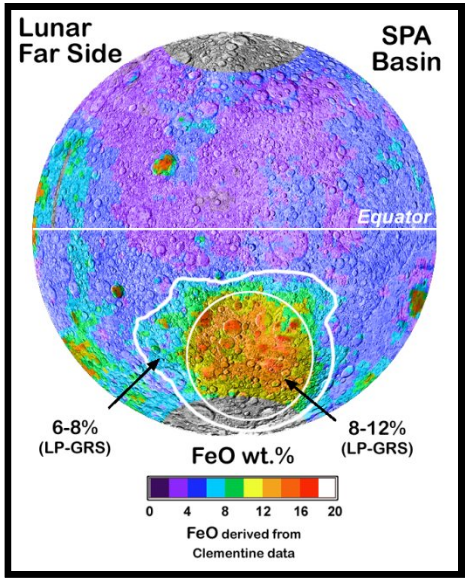
Site selection and Certification

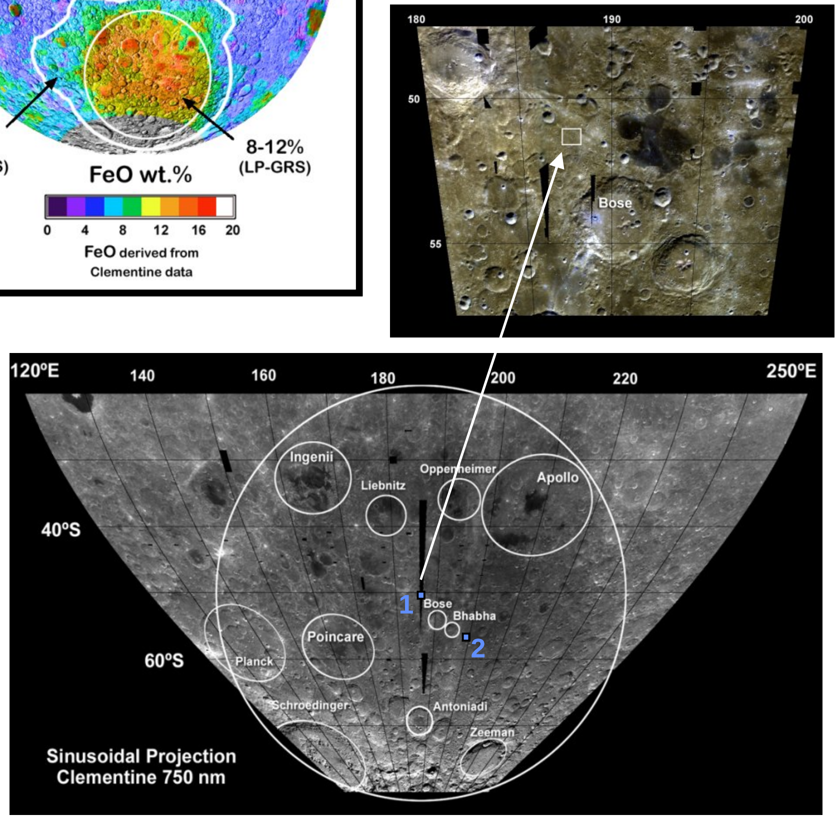


We know where to sample; exact sample location not critical to Science



- **Science Criteria**
  - Near center of basin
    - Broad geochemical anomaly guides selection
    - Mineralogy (high res) nice to have but not critical
  - Large Impact processes
    - Concentrate original SPA materials toward center of basin.
    - Distribute deeper ejecta from basin rim back toward center where impact-melted SPA substrate is concentrated.
  - Post-SPA impacts (25-100 km) penetrate "megaregolith" and mix fresh SPA substrate into deposits.
- **Result: Best location in deposits of small to intermediate craters near center of SPA basin**
  - E.g., Bose (91 km) and Bhabha (64 km)





JPL-JG2

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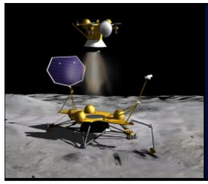
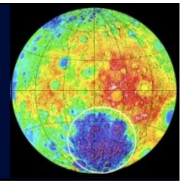
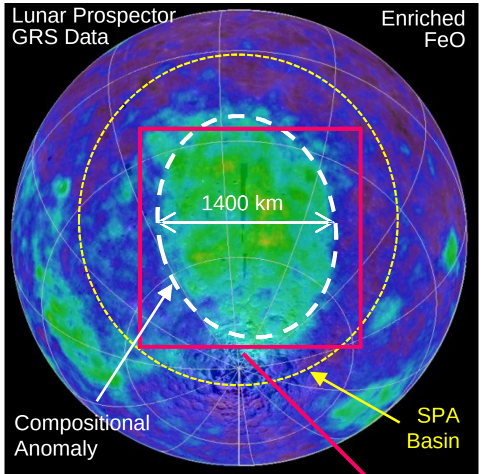
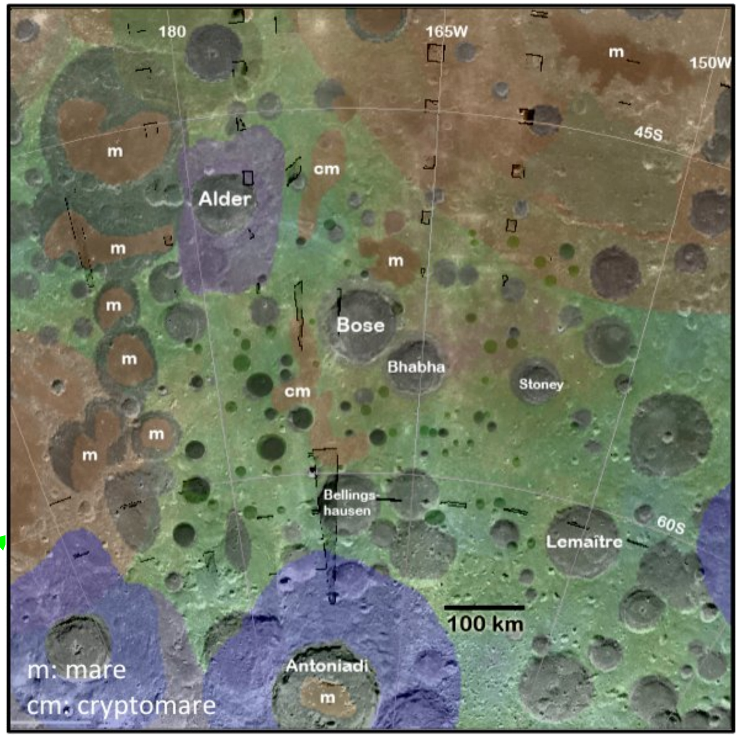


Defining Science Regions in SPA Basin

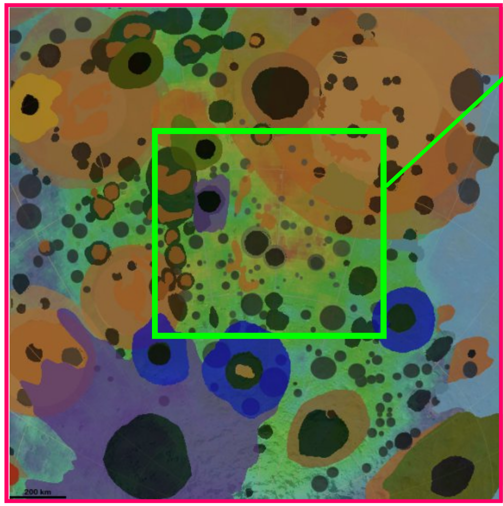




1. The enriched FeO signature of the SPA Basin interior reflects the major compositional region that is targeted for the MoonRise mission.



2. Shaded areas mark keepout sites based on science criteria and proximity to obvious landing hazards (craters, rough topography). Remaining areas (green) meet science criteria.



3. Large regions of the SPA Basin interior meet the science criteria and can provide a safe MoonRise landing site.

Candidate landing sites to be selected with wide community input.

JPL-JG3

Slide 14

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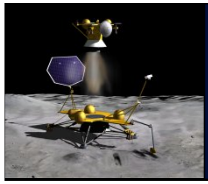
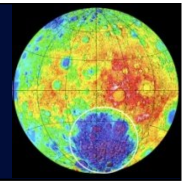
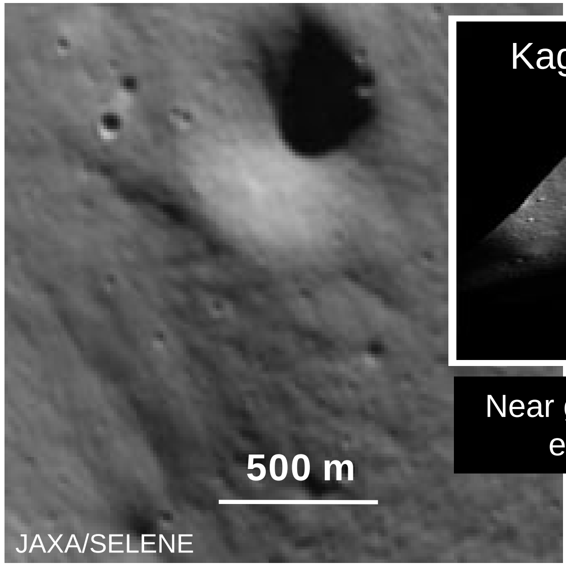
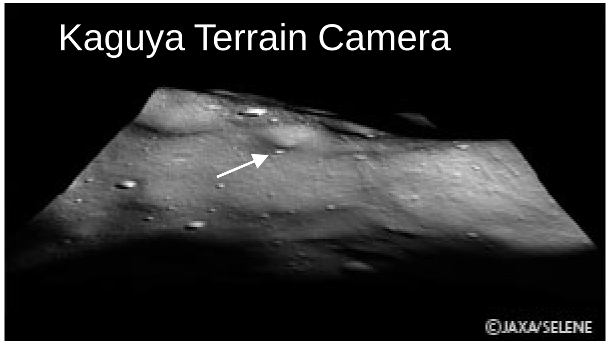


MoonRise leverages new lunar orbital datasets with US and International Partners

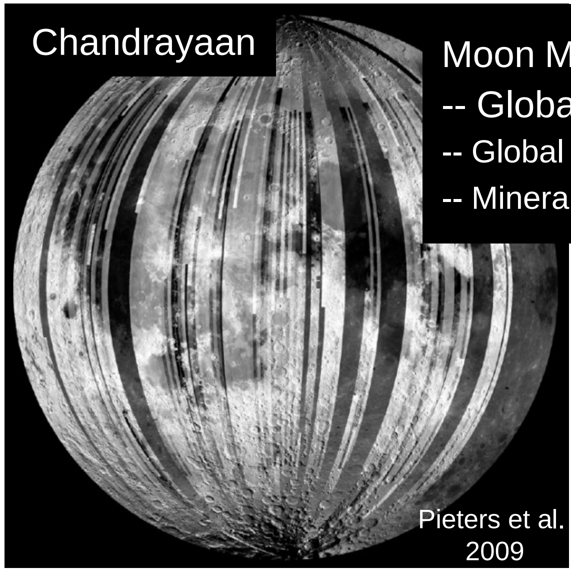




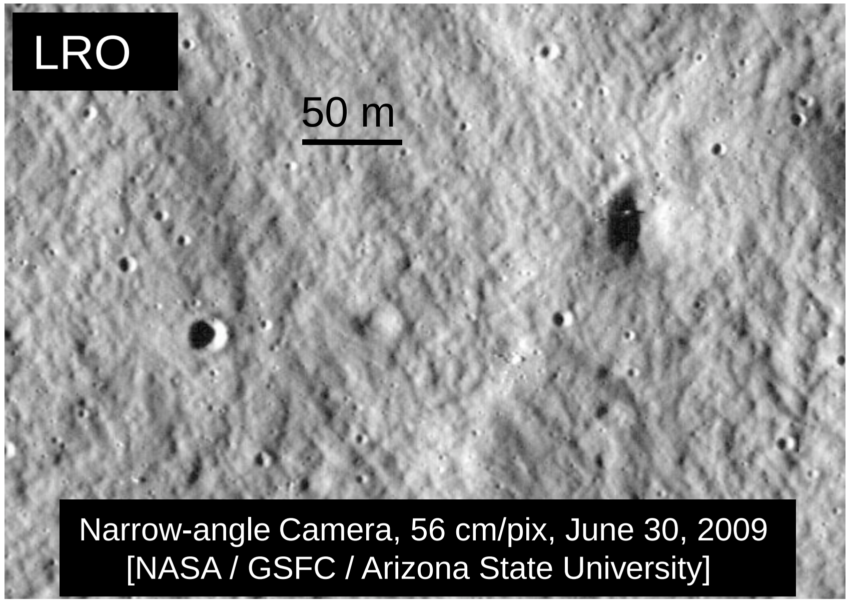


Near global coverage obtained prior to end of mission June 11, 2009

MoonRise is a logical next step in exploration now that recent orbital missions have provided imaging and compositional data to support selection of sites that are optimal for science and safe for landing.



Moon Mineralogy Mapper
- -- Global Coverage
- -- Global mode 140 m/pix
- -- Mineralogy of SPA Basin



Narrow-angle Camera, 56 cm/pix, June 30, 2009 [NASA / GSFC / Arizona State University]

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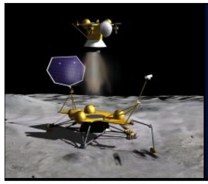
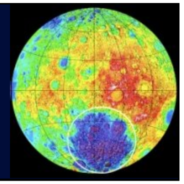
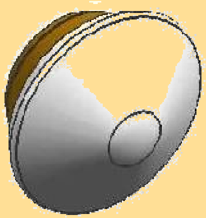


Returning the samples to Earth …



SAMPLE RETURN

Sample Return Capsule



Sample Curation and Preliminary Examination

SAMPLE ANALYSIS

Mineralogy / Petrology
Petrographic Microscopy,
Electron Microprobe Analysis

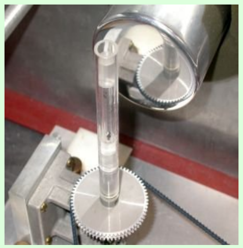
Chemistry
Inductively-Coupled Plasma
Mass Spectrometry (ICP-MS)

Geochronology
Thermal Ionization Mass
Spectrometry (TIMS)

Geochronology
$^{40}Ar/^{39}Ar$ Analysis
Noble Gas Mass
Spectrometry

Optical Spectroscopy
UV-VIS-IR Reflectance
Spectroscopy

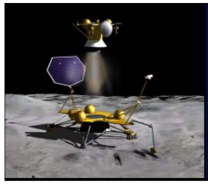
Mineral Trace Elements
Ion Microprobe



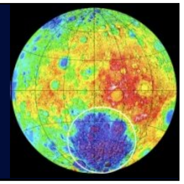
Rock Trace-Element Geochemistry
Neutron Activation Analysis Gamma Ray
Spectrometry

JPL-JG5

JPL-JG5 Need Predecisional footer showing on this slide
Janis Graham, 08/06/2010



MoonRise Team and Partners



Science Team Institutions

Washington University, St. Louis, MO
Brown University, Providence, RI
College of Charleston, Charleston, SC
Harvard University, Cambridge, MA
Jet Propulsion Lab, Pasadena, CA
Purdue University, Lafayette, IN
University of Arizona, Tucson, AZ
University of California, Los Angeles, CA
University of Hawaii, Honolulu, HI
University of New Mexico, Albuquerque, NM
Johnson Space Center, Houston, TX
Lawrence Livermore Nat'l Lab, Livermore, CA
Lunar Geotechnical Institute, Lakeland, FL
Marshall Space Flight Center, Huntsville, AL
US Geological Survey, Flagstaff, AZ
Australian National University, Canberra
Institut de Physique du Globe de Paris
University of Muenster, Germany
DLR, Institute of Planetary Research, Berlin
University of W. Ontario, London, Ont.

Spacecraft Development Team

Jet Propulsion Laboratory, Pasadena, CA

- Project management, systems engineering, mission design, and navigation and operations

Lockheed Martin Space Systems Co., Littleton, CO

- Implementation of the flight system

Malin Space Science Systems, San Diego, CA

- Descent camera system

Deutsches Zentrum für Luft und Raumfahrt (DLR), Berlin, and Mullard Space Science Laboratory, University College, London

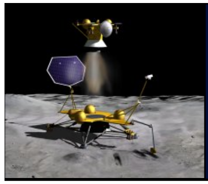
- Surface multispectral imager

Canadian Space Agency, MDA

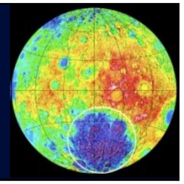
- Robotic Arm

Collaborators

JAXA Kaguya Imaging/Mineralogy Team

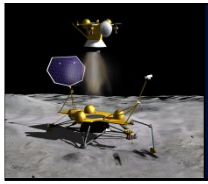


MoonRise, Science Summary

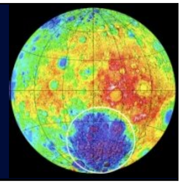


- **The Moon bears witness to 4½ billion years of Solar System history.**
- **Among the events it records is the timing of the intense bombardment of Earth and Moon 3.8-4.0 billion years ago.**
- **This was a critical period in Earth history:**
  - Life beginning to gain a foothold
  - Formative years of Earth’s continents
- **The heavy bombardment at that time as recorded on the Moon was one of the most important events in Solar System history and affected all the terrestrial planets.**
- **MoonRise would test the Cataclysm hypothesis by determining the age of the oldest and largest impact basin on the Moon.**

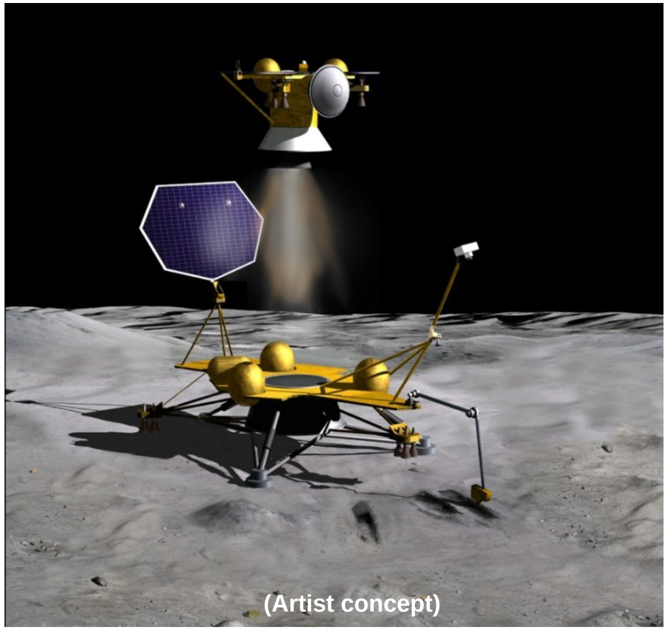
Through MoonRise, we would gain a better understanding of the effects of impact bombardment on surface environments, including habitability of planets in the inner Solar System.



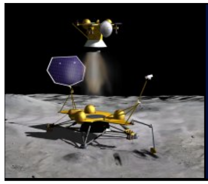
MoonRise Feeds Forward



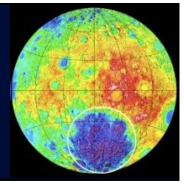
- **MoonRise would be the first US robotic sample-return mission from the surface of another planetary body and first surface mission to the far side of the Moon.**
- **MoonRise would demonstrate sample-return capabilities applicable to future Mars sample return missions.**
- **MoonRise would demonstrate a state-of-the art lunar lander that could deliver ~ 900 - 1000 kg of payload to the surface of the Moon for future in-situ space exploration missions.**
- **In-situ sample acquisition and transfer would demonstrate surface robotic operational capabilities applicable to future human and robotic lunar exploration missions.**



(Artist concept)



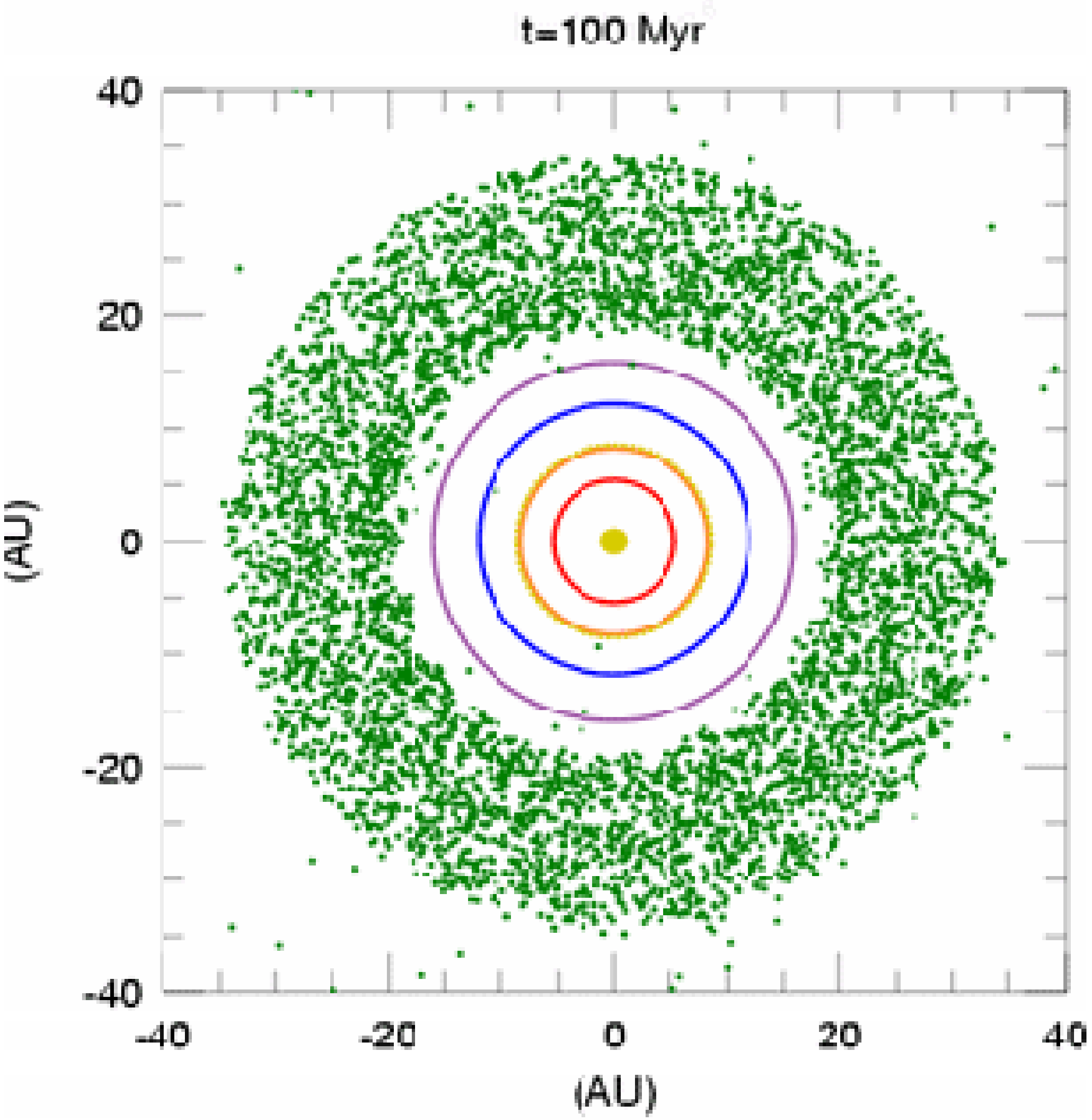
MoonRise Concluding Points



- **MoonRise addresses key Solar System Science Objectives as stated in the 2003 NRC Decadal Survey for Solar System Exploration and re-validated in NRC 2007 “NOSSE” report.**
- **MoonRise addresses key objectives for lunar exploration as stated in 2007 NRC study on Scientific Context for Exploration of the Moon.**
- **MoonRise is a pathfinder for automated sample return from planets and moons in the Solar System.**
- **MoonRise utilizes a medium-size lunar lander that can deliver a large scientific payload (~ 1000 kg) to the lunar surface for potential future NASA lunar robotic missions.**
- **MoonRise’s in-situ mission represents a key milestone in the international scientific exploration of the Moon.**

MoonRise addresses key NASA objectives for Planetary Science: to advance scientific knowledge of the history and processes of the Solar System, with implications for the history of early Earth at a pivotal time in development of habitable environments. MoonRise addresess questions of how the Solar System evolved to current diverse state, and how events in the Solar System led to the origin of life.

From: "*Testing the Lunar Cataclysm with a SPA-B Sample Return Mission*" Timothy Swindle, Univ. Arizona



(From Gomes, *et al.*, 2005, *Nature*, v. 435, p. 466-469.)