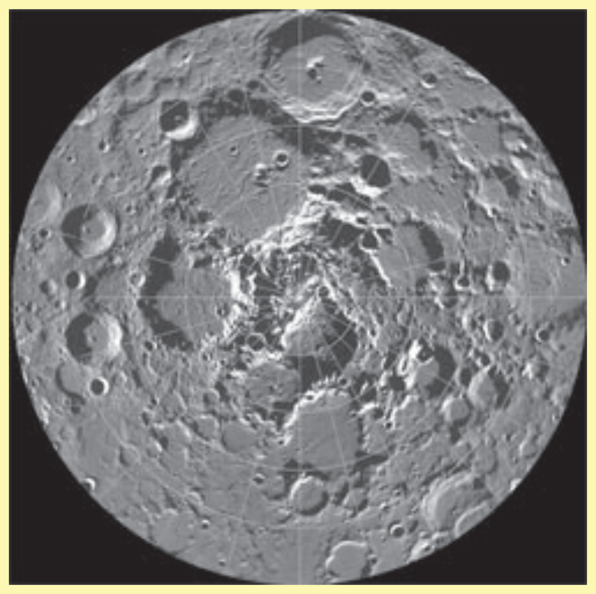
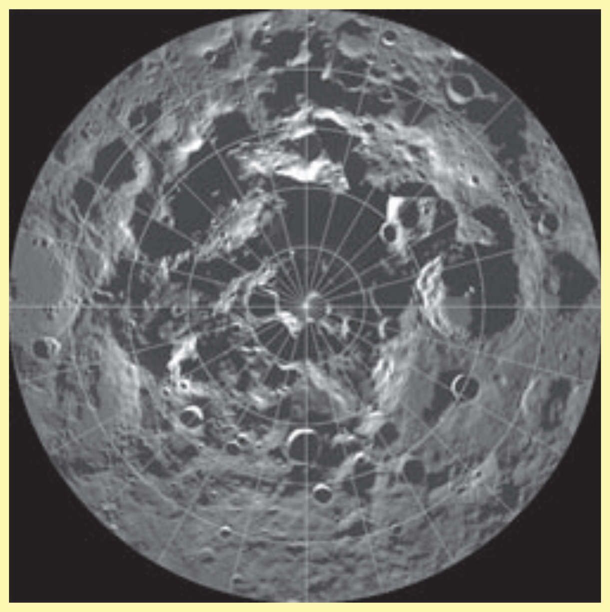
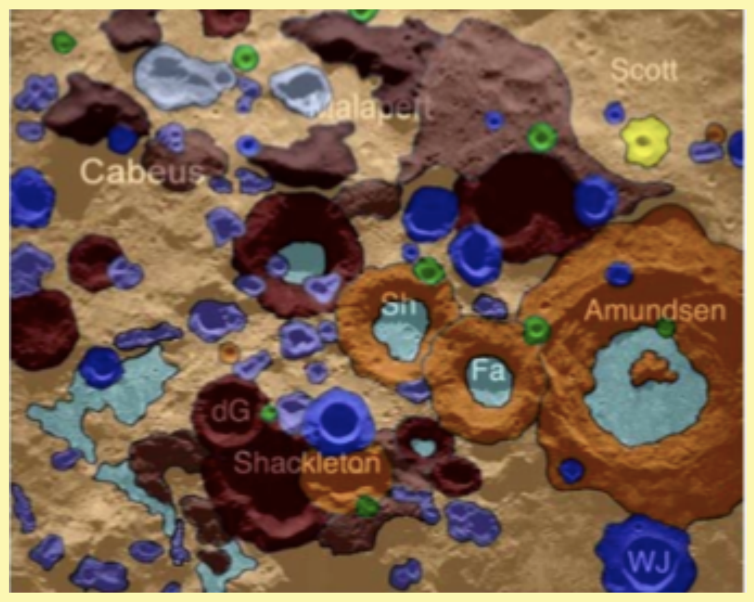
SCIENTIFIC AND EXPLORATION POTENTIAL OF THE LUNAR POLES



Background: The lunar polar regions are important for both scientific and exploration reasons. They have great scientific potential because they preserve a record of the early history of the Solar System and the volatile record over the last few billion years within their permanently shaded regions. The lunar poles also have significant exploration potential as the preferred human settlement outpost site. Our team is undertaking a comprehensive, coordinated study that is advancing our understanding of the lunar polar regions, by employing a diverse group of experienced researchers. Our work is divided into three topics: (1) Lunar Polar Environment, (2) Surface Characterization, and (3) Surface Science, Instrumentation, and Operations. These topics address basic, fundamental science questions and examine how the polar regions could be explored and exploited by robots and humans. By design, there is substantial overlap across topics, which providing information to the others to facilitate a deeper, more thorough understanding of the questions that are posed.



Lunar Polar Environment: Our goal is to shift our understanding of the poles into the category of "Luna cognita." The four tasks associated with this topic will map the geology, characterize the lighting and thermal conditions, and study the potential distribution of volatiles, especially inside the permanently shadowed craters.



Polar Geology: We are reexamining the geology of the north and south polar regions, using the latest data sets, to place it in the context of the geologic history of the Moon. We are studying the bedrock geology, including the role of impact basins in the early evolution of the lunar crust. Geologic mapping will be complemented by integration of other data to provide a geologic, petrological, and geochemical setting for the polar regions.

Illumination Studies: The lunar polar regions experience unusual illumination conditions that make them attractive candidates sites for future exploration, both robotic and human. We are using Kaguya & LRO topography data to fully characterize the illumination conditions at both poles. We have identified sites that are continuously illuminated for several months around mid-summer, as well as mapping areas that are permanently shadowed.

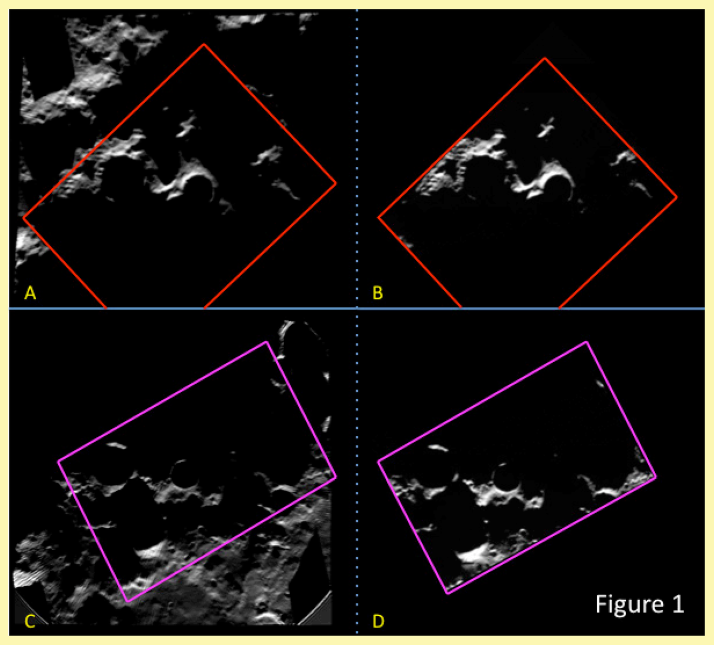
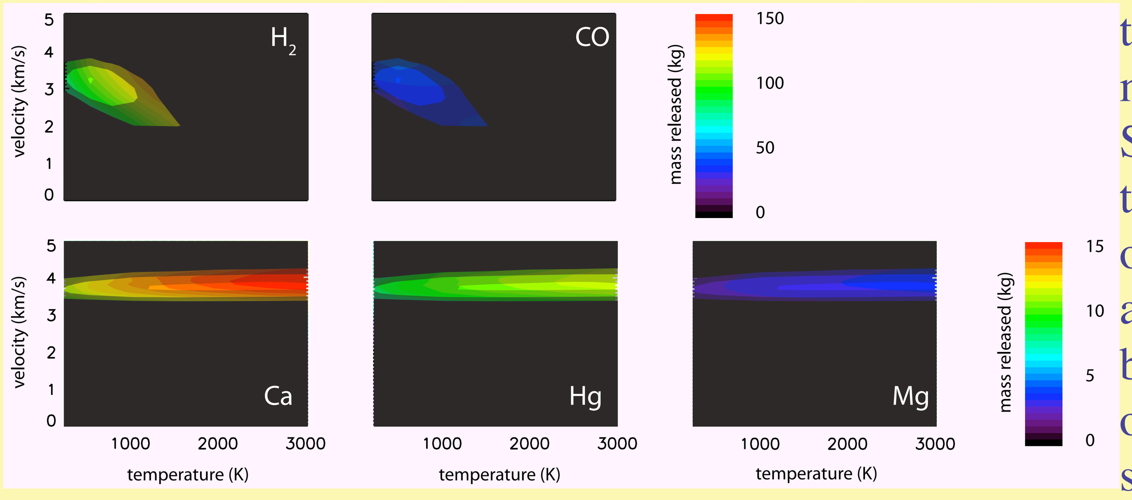
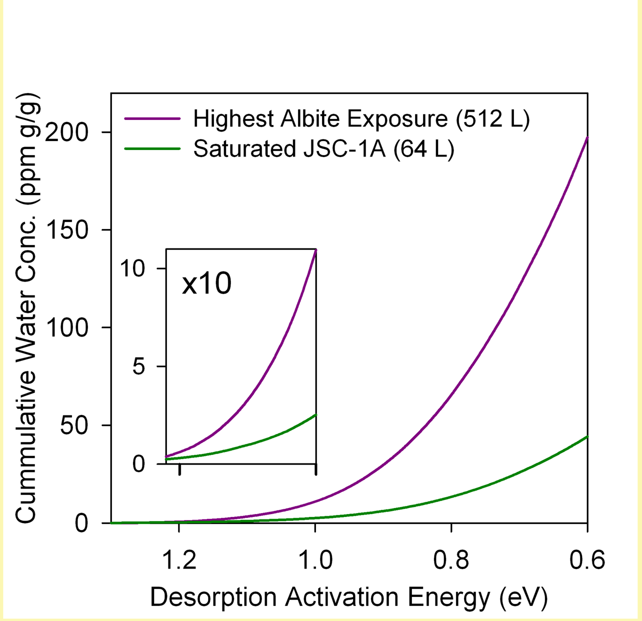


Figure 1

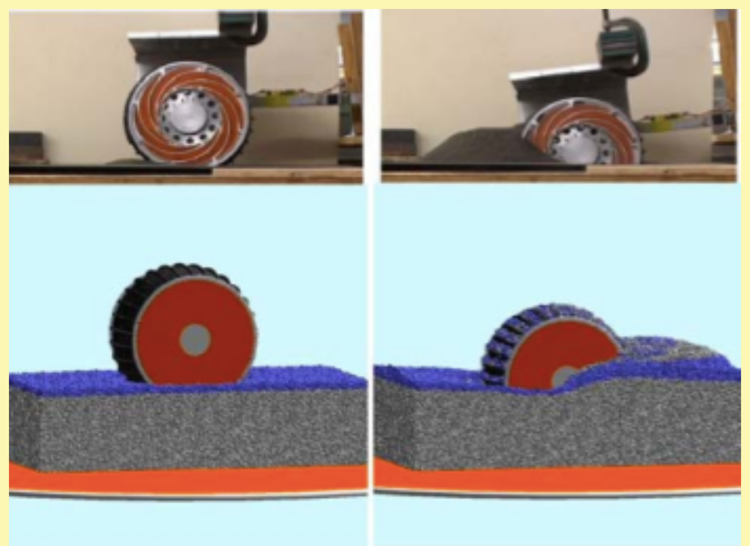
Volatile Transport Modeling: Since the NLSI was established, volatiles in lunar polar regions have been definitively detected. The polar volatiles group studies both data regarding volatiles on the Moon and does modeling to support interpretation of the data. This work includes atmospheric modeling to consider volatile transport and space weathering modeling to follow volatile retention. For example, the impact of the Lunar Crater Observation and Sensing Satellite (LCROSS) into the crater Cabeus released water and other volatiles into the atmosphere, where they were observed by LRO, LCROSS, HST, and ground-based telescopes. We modeled the propagation of the vapor release and compared to the observed light-curves for H2O, OH, H, O, Na, H2, CO, Mg, Ca, and Hg. For selected species, we determined the timing, temperature, bulk velocity, mass, and regolith abundance of the species. Work is ongoing to incorporate other relevant data to unravel the important sources and losses to volatile reservoirs in lunar polar regions.



Volatile_Regolith Laboratory Studies: We are using laboratory experiments to obtain stability, optical, and mechanical information about volatile-regolith mixtures. The possibility being explored is that polar volatiles will not exist as bulk ices but as thin layers of molecules adsorbed onto the hydroscopic lunar grains, stable against desorption because of the extremely low temperatures that maintain the thermal energies of the adsorbate lower than their desorption en- ergies. We are measuring the energies of desorption of cryosorbed molecules of water and other major (>1% abundance relative to water) cometary gases (e.g., CO2, methanol, methane) as evi- dence exists that cryosorption occurs on other airless bodies at temperatures even greater than the permanently shadowed regions on the Moon

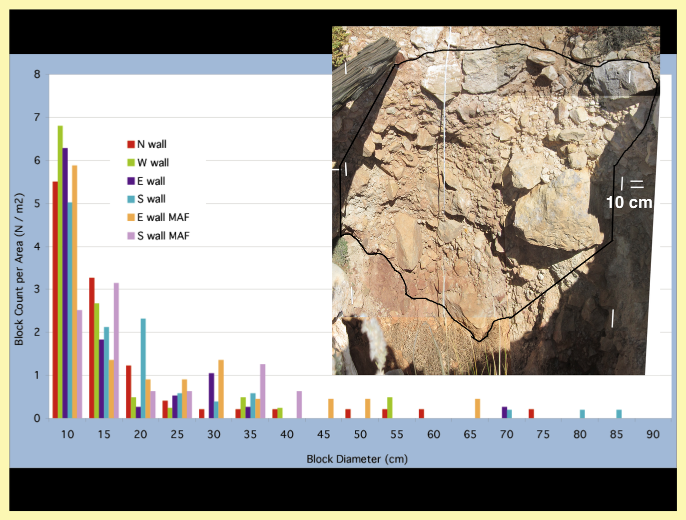


Surface Science, Instrumentation & Operations: Future robotic and human lunar missions will provide an opportunity to deploy instruments and equipment that will enable us to further our understanding of the Moon, the Earth, and other astronomical bodies. Our team is examining a set of instrument and surface operations tasks that range from applied engineering to basic science. While the objectives are diverse, the common thread is that they either uniquely use the lunar poles and/or are uniquely enabled by a lunar polar location.

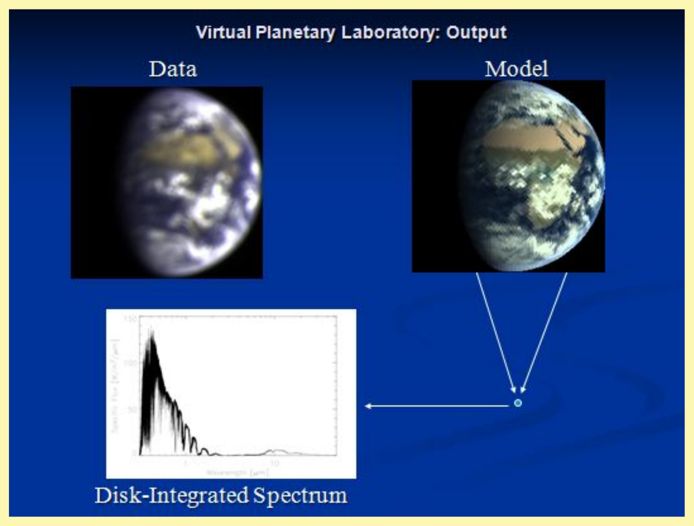


Excavation & Mobility Modeling: Experiments and modeling are being used to investigate how the geotechnical properties of polar and non-polar regolith affect excavation and mobility as these activities will be important to the success of landed robotic or human missions. The study of regolith geotechnical properties related to excavation and mobility activities will be used to validate a physical discrete element model that can then be used to simulate more complex regolith mechanical behavior processes at the particle scale.

Ground Penetrating Radar: GPR data from terrestrial analogs for deposits on the Moon can help define the near-surface properties at the meter to sub-meter scale required for designing and implementing in-situ geologic and engineering studies. Terrestrial analog sites include: impact ejecta at Meteor Crater, AZ, volcanic flow and ash materials at Sunset and SP cones, AZ; and basaltic flows on the Columbia Plateau, WA.

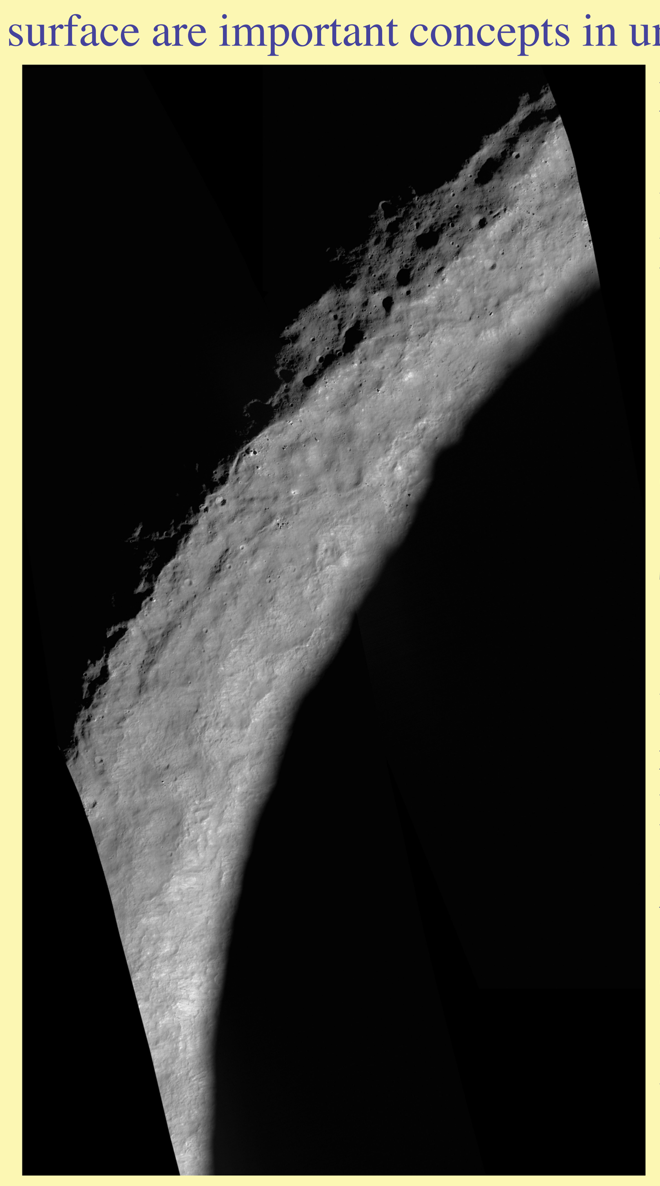


Neutron Spectrometer: This task is studying the technical feasibility and operational aspects of two complementary, surface-based neutron detection techniques. The first uses low resource neutron sensors to obtain information within a 0.5–1 m3 volume. A second technique will assess neutron imaging to obtain spatially resolved hydrogen measurements over distances of 10–1000 m.



Earth Observation: The Camera for Lunar Observations of the Variable Earth (CLOVE) is a concept for a Moon-based instrument to characterize the remotely detectable physical and biological signatures of Earth over time. The lunar polar surface deployment enables these data to be obtained continuously over long timescales and this unique vantage point makes it possible to track Earth's ever-changing photometric, spectral and polarimetric signatures in a manner analogous to future observations of extrasolar terrestrial planets.

Surface Characterization: The nature of the impact-generated regolith and the characteristics of the surface are important concepts in understanding how the surface evolved and how small-scale geologic processes have operated on it. This knowledge is also a benficial in designing future landing and surface systems. The objectives of this topic are to provide information on the surface properties of the Moon as they relate to understanding the geology of the polar regions and to provide constraints on the ability to excavate the regolith and assess hazards associated with landing and surface operations. This work considers the population of surface and subsurface rocks and craters, regolith thicknesses, slopes, and geotechnical properties.



The pair of NAC frames shown on the left covers a portion of the rim of Shackleton at the south pole, about 2800 m along the rim. The Earth is toward the top of the frame and the sunlight is coming from the lower right part of the frame. The upper inner crater wall is illuminated. Numerous small craters dot the surface, the largest of which are about 60 m across, all of which are fairly degraded. Small clusters of boulders are scattered across the region ranging in size from the limit of resolution to 10-15 m across. Much of the area is smooth perhaps indicative of impact melt coating the crater rim and walls; alternatively the smooth texture may be due to creep of the regolith down the slope.

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