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# Science from the Lunar Permanently Shadowed Regions

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## Abstract

Understanding of the volatile contents in lunar Permanently Shadowed Regions (PSR) has advanced significantly over the last decade. We present potential science objectives for a potential mission to lunar permanently shadowed regions.

## 1. Introduction

One decade ago, an Atlas V rocket launched from Ken-nedy Space Center in Canaveral, FL carrying Lunar Crater Observation and Sensing Satellite (LCROSS) and Lunar Reconnaissance Orbiter (LRO) to the Moon. Within a few months, astounding new results from Chandrayaan-1, Deep Impact, and Cassini revealed at spectral signature of OH on illuminated regions of the Moon [1-3]. Then, the planned impact of LCROSS into the permanently shadowed region (PSR) Cabeus revealed that plentiful volatiles, including H2O, CO2, CO, Hg, and Na, are stored in at least some locations in PSRs [4-8]. Soon thereafter, the National Research Council conducted the Planetary Science Decadal Sur-vey [9]. The Lunar Polar Volatiles Explorer concept [10] was studied for consideration in prioritization for potential NASA missions. That study resulted in a rover that would explore a PSR on the Moon to de-termine the lateral and vertical distribution, chemical composition and variability, isotopic composition, physical form, and rate of change of volatiles.

In the intervening years, significant progress con-tinues on understanding volatiles on airless bodies. For the next decadal survey, it is important to use the evolution of our understanding of volatiles to formu-late potential NASA missions. Here, we consider the potential scientific objectives of a mission to the lunar PSRs.

## 2. Discussion

We will examine a mission to a lunar PSR if our pro-posal to the NASA Planetary Mission Concept Study is selected. Here we present some of the compelling science that can be achieved in such a mission.

### 2.1 Ground-truthing

The significant database of remote sensing observations has been interpreted regarding lunar volatiles abundance, distribution, composition, and physical form. However, these are expected to vary on spatial scales smaller than the resolution of the remote sensing data. Therefore, in situ measurements provide the crucial ground-truth to our existing data sets.

### 2.2 Processes modulating distribution

The distribution and abundance are somewhat known, although there is more work to be done. The most compelling questions that remain are those surrounding the processes that modulate these quantities. Potential factors include the age of the deposits, the thermal environment, exposure to space, impact processes, and gas-surface interactions.

### 2.3 Activity and Transport

Processes that are ongoing today have the potential to be significant influences of PSR volatiles. Even minor sources or losses can ac-cumulate to be a significant process compared to more rare occurrences. Measuring the present-day rate of mass loss or addition and the physical mechanism for it enables tracking the present contents of PSRs back in history.

### 2.4 Composition and Chemistry

The original source(s) of PSR volatiles provided the initial composition of PSR volatiles. However, these have been modified over time based on relative volatility, interaction with surfaces, potential reactions spurred on by cosmic ray and impacts. Thus, the present-day composition, how it varies, and the isotopic make up of PSR volatiles is an important measurement to understand the sources and processes affecting PSRs.

### 2.5 Thermophysical and Geotechnical Properties of PSRs

In addition to being a reservoir for volatiles, lunar PSRs are interesting as an extremely cold, low pressure environment. The thermal and geotechnical prop-erties of the regolith are not well understood. In addi-tion to revealing how materials behave in this extreme environment, knowing the geotechnical properties is crucial for any future development of lunar volatiles as a resource.

## 3. Conclusions

Volatiles remain an important scientific endeavor for understanding the evolution of planetary bodies, the formation of the solar system, and processes ongoing on airless bodies immersed in a hostile space environment. Many significant results await future orbiters, landers, rovers, penetrators, and sample return missions to reveal them.

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