Lunar Flashlight:
Illuminating the Moon's South Pole

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Motivation

Recent reflectance data from LRO instruments suggest water ice and other volatiles may be present on the surface in lunar permanently shadowed regions, though the detection is not yet definitive [1, 2, 3]. Understanding the composition, quantity, distribution, and form of water and other volatiles associated with lunar permanently shadowed regions (PSRs) is identified as a NASA Strategic Knowledge Gap (SKG) for Human Exploration. These polar volatile deposits are also scientifically interesting, having the potential to reveal important information about the delivery of water to the Earth-Moon system.

Lunar Flashlight Mission

The Lunar Flashlight (LF) mission is a 6U CubeSat, to be launched as a secondary payload on the first test flight (EM-1) of the Space Launch System (SLS), currently scheduled for 2018. **The goal of LF is to determine the presence or absence of exposed water ice and map its concentration at the 1-2 kilometer scale** (Fig. 1). After being ejected in cislunar space by SLS, Lunar Flashlight maneuvers into a low-energy transfer to lunar orbit and then an elliptical polar orbit, spiraling down to a perilune of 10-30 km above the south pole (Fig. 2).

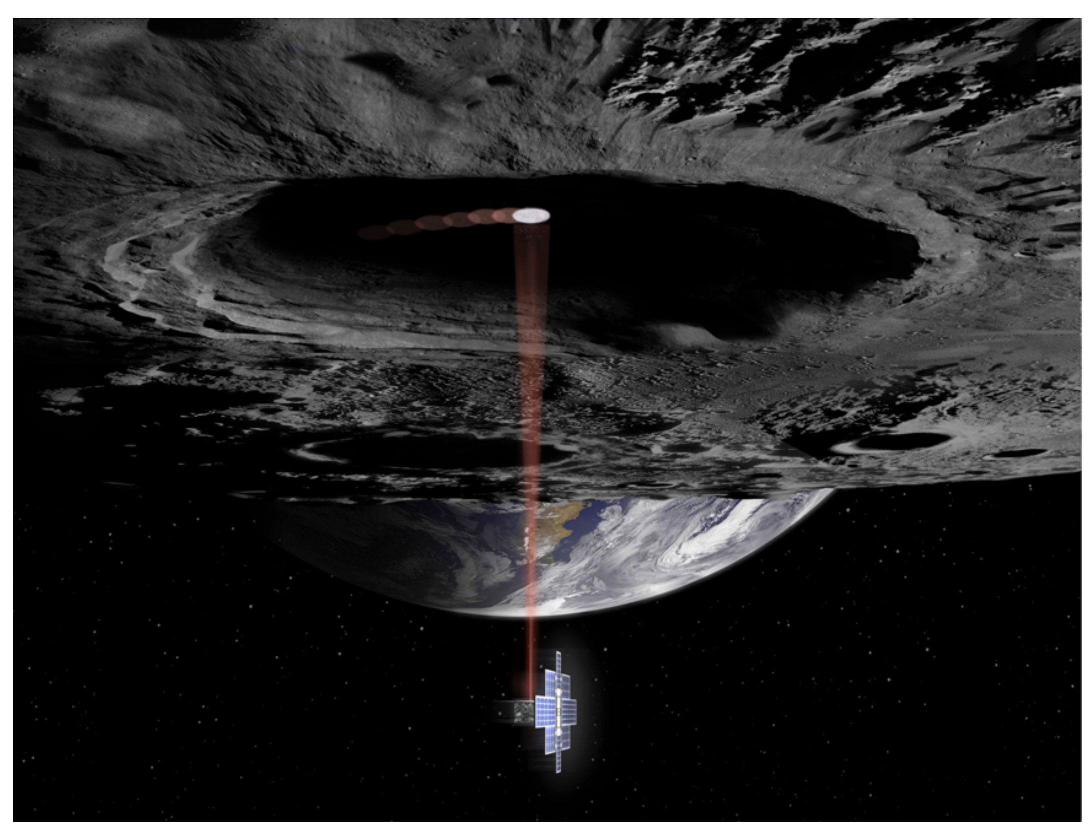


Figure 1: View of a permanently shadowed crater near the lunar south pole, probed by Lunar Flashlight's laser beam. For the first time, these shadowed regions will be illuminated in four near-infrared spectral bands to determine the abundance of H_2O ice and map its distribution in the Moon's south polar region.

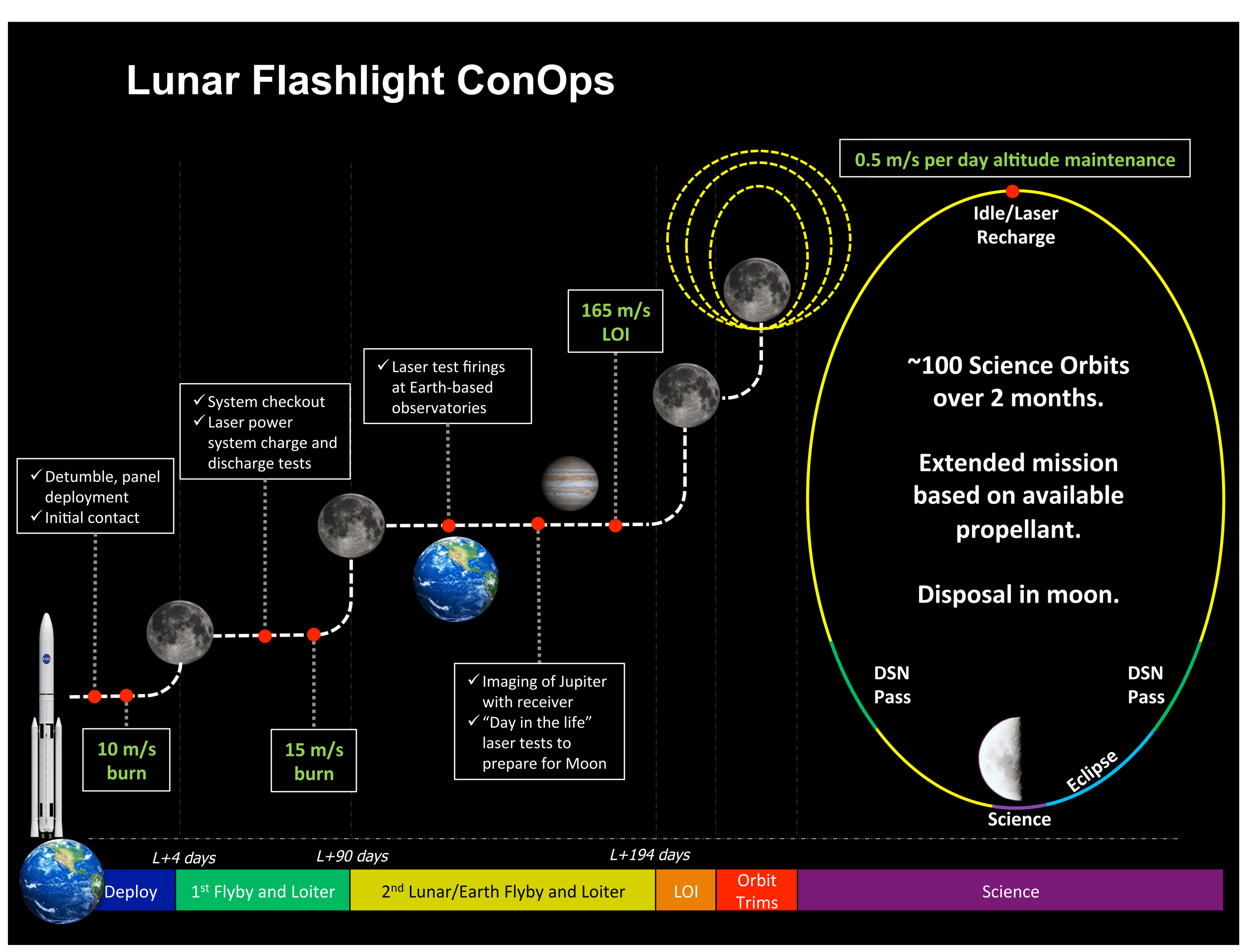


Figure 2: Concept of Operations for Lunar Flashlight Mission. After lunar orbit insertion (LOI), the spacecraft spirals down to its science orbit, with ~10-30 km perilune over the south polar region.

Measurement Approach

Lunar Flashlight's four-channel laser projector will illuminate permanently shadowed regions, measuring surface reflectance at wavelengths near 1.4, 1.5, 1.84, and 2.0 µm. Water ice will be distinguished from dry regolith in two ways: 1) spatial variations in albedo, and 2) reflectance ratios between absorption and continuum channels. Water ice band depths will be mapped in order to distinguish the composition of the PSRs from that of the sunlit terrain. These data will be highly complementary to other lunar datasets, including LRO.

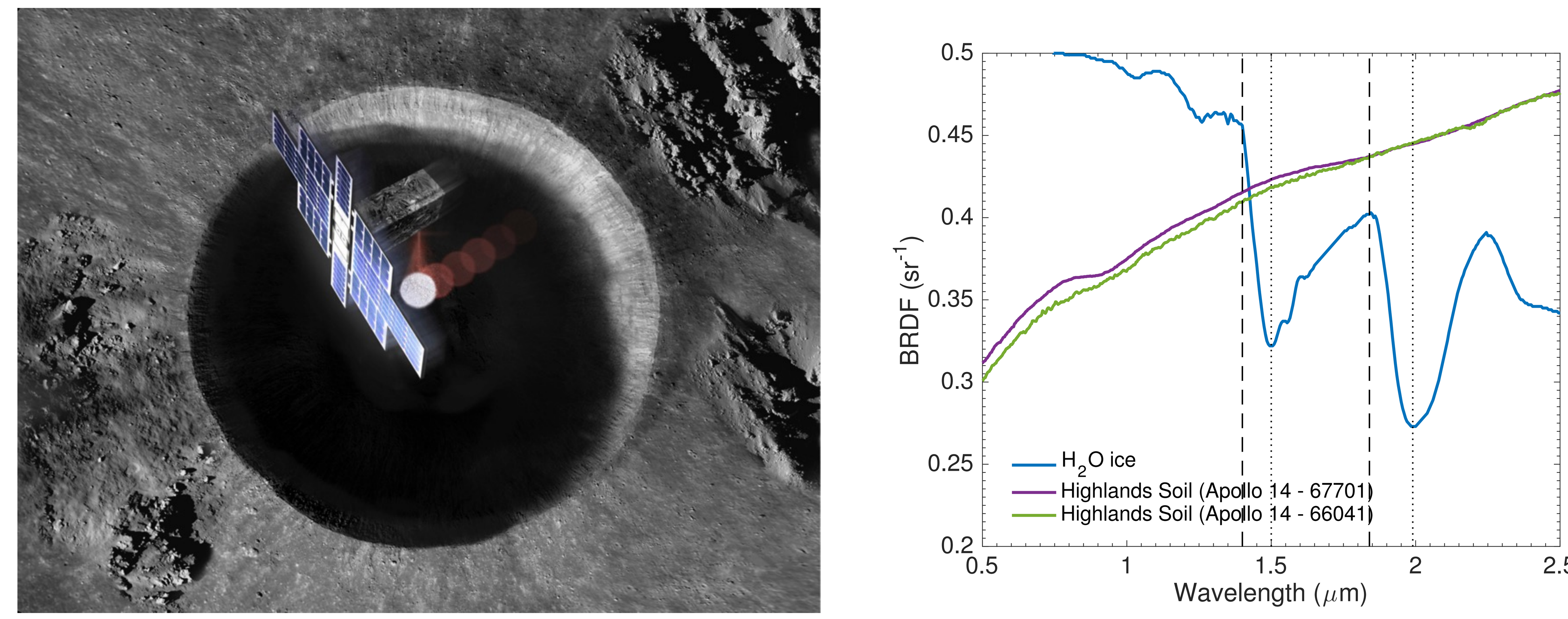


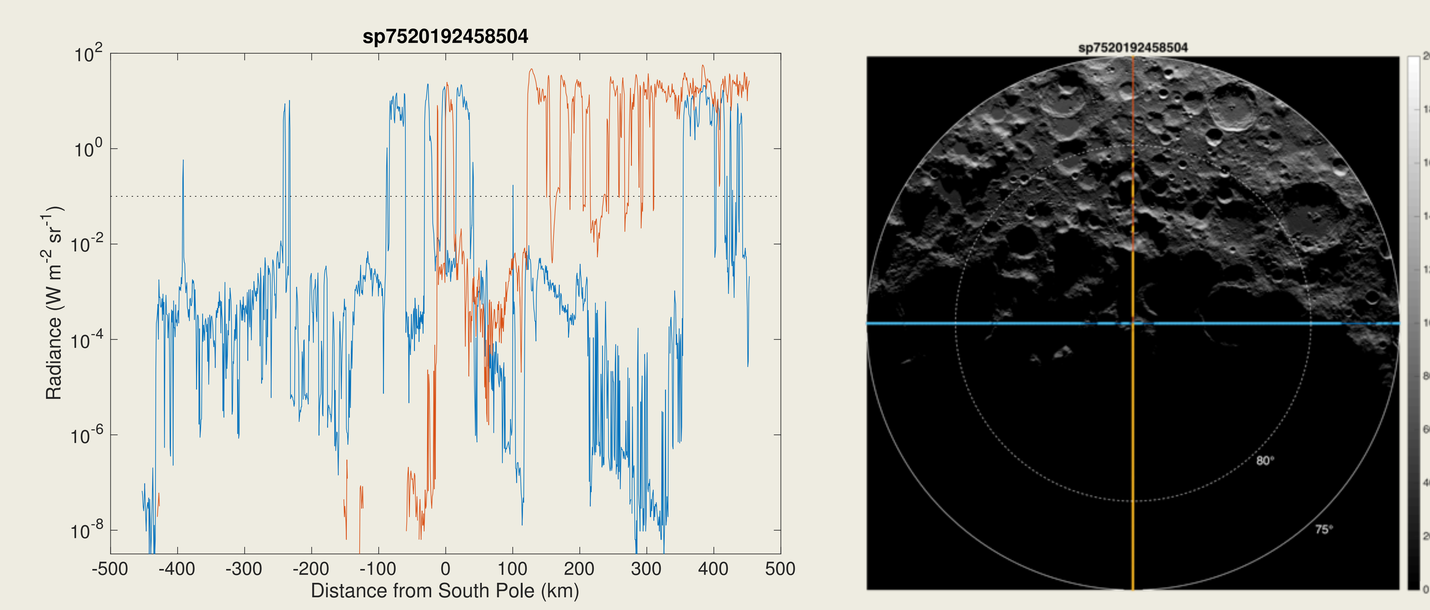
Figure 3: Carefully selected spectral bands in the near-infrared can be used to distinguish water frost at small concentrations (< 1 wt%) from dry regolith. The spectra on the right are examples, derived from water ice optical constants [4] and measured reflectance spectra of two Apollo highlands soils [5].

Current Status and Milestones

Currently in Phase B, Lunar Flashlight has completed several important milestones relevant to science and the mission payload:

- Developed an end-to-end instrument performance model to evaluate uncertainty in [H_2O] ice detected under a range of concentrations, particle sizes, and regolith composition (Fig. 3). This model includes radiative transfer [6] for calculating bidirectional reflectance for the given composition and illumination/viewing geometry, and stray light contributions (Fig. 4).

Figure 4: Stray light analysis for Lunar Flashlight, using a 3-d ray-tracing model [7] to calculate background radiance (left) from modeled fluxes (right). Model includes direct and indirect solar, infrared, and earthshine.



- Utilized performance model to select optimal wavelengths for custom fabrication by laser vendor (DILAS)
- Designed and fabricated laboratory chamber and testbed for detector testing (Fig. 5)

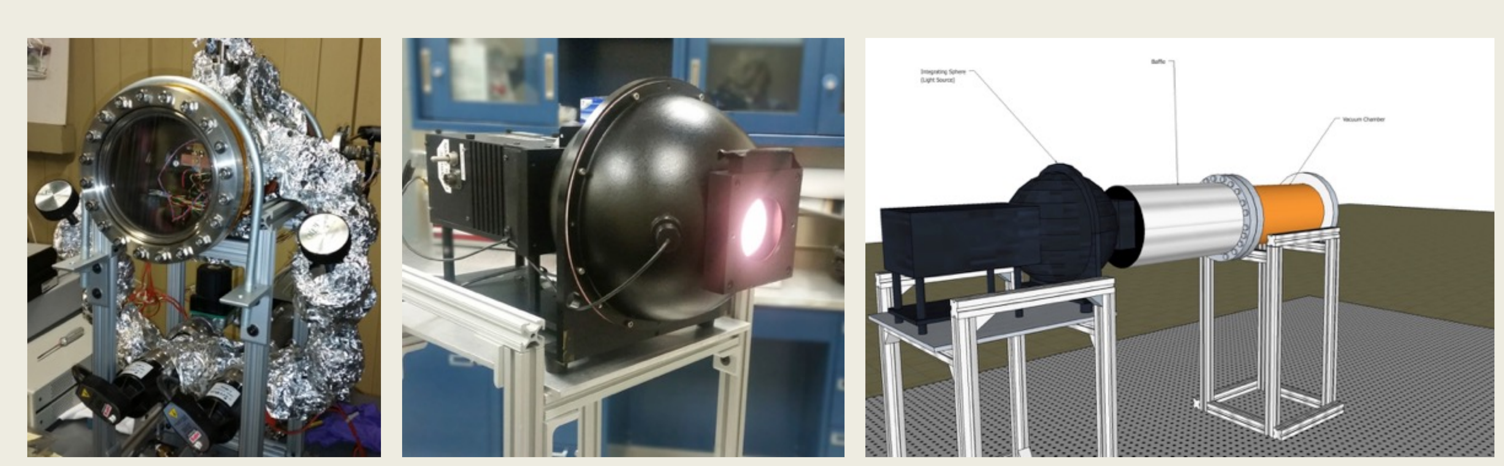


Figure 5: Components of Lunar Flashlight payload testbed (left to right): Cryogenic vacuum chamber for detector testing; integrating sphere light source; rendering of detector testing setup

References:

[1] Gladstone, G. R., et al. (2012) *JGR 117*, CiteID E00H04. [2] Zuber, M. T., et al. (2012) *Nature*, 486, 378-381. [3] Hayne, P. O., et al. (2015) *Icarus 255*, 58-59. [4] Warren, S. G. and Brandt, R. E. (2008), *JGR 113*, D14. [5] Adams, J. B. and T. B. McCord (1971), *Science 171*, 567-571, 1971[6] Hapke, B. (1981), *JGR 86*, B4. [7] Paige, D. A., et al. (2010), *Science 330*, 479-482.

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