LEVERAGING IN-SITU REGOLITH PROPERTIES FOR NIGHTTIME HEATING. T. M. Powell[1], M. A. Siegler[2], J. L. Molaro[2], D. A. Paige[1], [1]Earth, Planetary, and Spaces Sciences, University of California, Los Angeles CA, 90095, USA (tylerpowell@ucla.edu), [2]Planetary Science Institute based in Tucson AZ, 85719, USA.

Introduction: The Diviner instrument on-board the Lunar Reconnaissance Orbiter [1] is a thermal infrared radiometer that has characterized the lunar surface temperature and thermophysical properties globally. Most of the lunar surface is covered in a highly porous and thermally insulating regolith layer which results in dramatic temperature swings from roughly 400 K at noon to less than 100 K at night at the equator: a challenging environment for a spacecraft. Despite the large fluctuations at the near surface, significant stores of sensible heat might still be accessible by leveraging temperature variations with depth and thermophysical property variations on the surface. Thermally coupling to warm materials already present on the Moon might provide some nighttime heating and reduce the engineering payload necessary for surviving the lunar night.

Subsurface heat: The temperature fluctuation observed at the surface propagates to depth based on the diffusivity of lunar regolith κ and the length of the diurnal period P: $z_s = (\kappa P/\pi)^{0.5}$ where z_s is the skin depth, at which temperature amplitudes decrease to 1/e of the surface value. Typically this is about 4-10 cm. Below about ¼ m depth, the temperature is roughly constant throughout the diurnal cycle at about room temperature, 255 K at the equator (Figure 1).

This high temperature at depth is due to a 'solid state greenhouse effect' from radiative heat transfer within the regolith. The granular nature of regolith and lack of atmosphere cause radiative transfer between grains to be a significant component of regolith conductivity: $K = K_c + BT^3$ where K_c is the phonon conductivity and B is a radiative transfer constant. The temperature dependence of conductivity results in more efficient pumping of heat into the subsurface during the day than out at night, resulting in the diurnal average temperature at 10 cm depth being ~50 K higher than at the near surface.

Rocks and high thermal inertia material: Diviner observations show that high thermal inertia material at the surface like exposed melt or coherent rocks remain warmer throughout the lunar night.

This study uses known lunar thermophysical properties and thermal modeling to determine feasibility of using in-situ materials as nighttime thermal sources.

Methodology: We used COMSOL to model the temperature of a simple lander as a high conductivity box surrounded by an insulating layer. We compare the nighttime temperature of a lander placed on a typical lunar regolith column to a spacecraft thermally coupled to the subsurface and surface rocks. In the subsurface experiment, a conductive rod was added to the lander to a 0.5 m depth

Results: Preliminary results of show that a conductive rod penetrating to a depth of 0.5 m can keep the spacecraft a few 10s of degrees K warmer during the lunar night. This shows that in-situ lunar materials may provide a valuable store of heat that can be utilized for future lander missions.

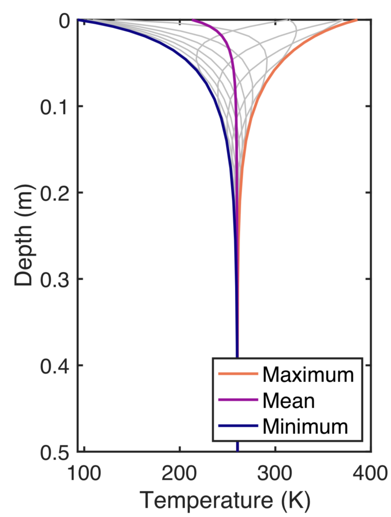

Figure 1. Modeled temperature profile of typical equatorial lunar regolith over a diurnal period. Grey lines show instantaneous profiles every 2 lunar hours.

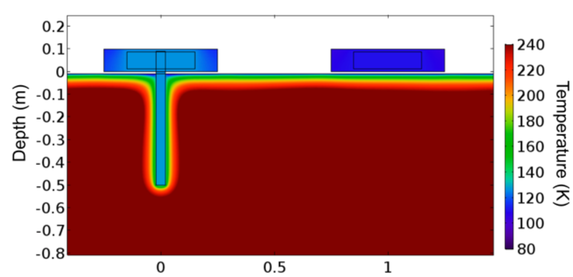

Figure 2. Preliminary model results of thermally coupling to a depth of 0.5 m.

References:

[1] D. A. Paige, *et al.* The Lunar Reconnaissance Orbiter Diviner Lunar Radiometer Experiment. *Space Sci. Rev.,* 150:125-160, 2010.