ARE THERE ELECTRICAL HAZARDS ASSOCIATED WITH OPERATIONS IN THE LUNAR POLAR REGION?
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Motivation: Under the new realignment, robotic and human systems are anticipated to visit the Moon, near-Earth objects, and the moons of Mars. Each of these near-airless rocky bodies has a common element: They are each directly exposed to the harsh space environment that includes large and small impactors, solar photonic radiation, solar wind plasma, solar storm generated energetic particles and galactic cosmic radiation.

For the Moon, the permanently shadowed regions at the poles are considered especially-harsh but resource rich environments. Due to the extreme cold, these regions will trap migrating volatiles like water. Other resources are anticipated to lie within these craters. As such, these regions remain highly desirable robotic targets. We suggest herein that lunar polar regions also possess electrically complex special environments [1-3] which can pose a challenge to any landed system. Specifically, the lunar regolith is a semi-conductor and in extreme cold becomes an insulator (see Figure 9.48 of [4]). As such, landed systems are electrically grounded to the passing solar wind plasma – like any spacecraft in the solar wind. However, recent analysis of solar wind flow at polar craters [5] indicates that plasma currents become vastly reduced within (i.e., crater floors) due to the obstruction of the flow by surrounding topographic features. As such, human or robotic systems run a risk of becoming electrically isolated – to effectively have an electrical reference that 'floats' relative to surrounding features and objects.

The Equivalent Electrical Circuit of a Roving System: Figure 1 shows a simple electrical model of a roving system in the lunar environment. As the system moves over the regolith, it will collect charge via tribo-charging (contact electrification) between the object and surface. In essence, the system is a capacitor storing this tribo-charge. The system is electrically connected to both the regolith and the plasma (shown on the figure). However, in cold polar regions, the regolith is a very poor conductor (R_g large). As such, the pathway to 'bleed off' the capacitor tribo-charge build up is via plasma currents. In essence, the human system is 'grounded' to the plasma reference.

Polar Electrical Environment: However, recent studies of solar wind current flow into polar craters suggest that the plasma flow is obstructed directly behind the obstacle. Plasma expansion models applied to topographic maps of Shoemaker crater [5] indicate that environmental current flow is reduced from near 100 nA/m^2 at topside regions to below 0.1 nA/m^2 along the leeward edges of the crater floor. As such, the ambient plasma currents (I_{amb} in Figure 1) are also no longer effective pathways for dissipating tribo-charge buildup. Hence, in lunar polar craters, both major electrical dissipation pathways for the system (i.e., the capacitor) become effectively 'disconnected'.

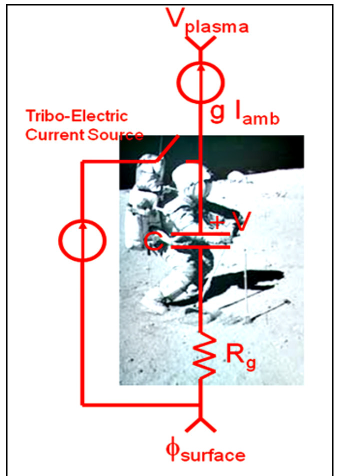

Fig 1 – Equivalent circuit for a human or robotic system.

Implications for Disconnection: An obvious issue to consider is the dissipation time for a charged object and the nature in which excess charge buildup is ultimately removed. Calculations suggest that dissipation times for a charged system can exceed 100s within polar craters (compared to milliseconds in dayside regions). Such times challenge the ability for fast roving where tribo-charge buildup times can exceed the time for dissipation. Digging and drilling operations would also have to contend with the challenges of charge buildup (and possibly excessive dust cling that acts to remediate the charge). In essence, in PSRs, there is a lack of a large charge reservoir which provides an electrical reference or 'ground'; this possibly creating environmental ESD hazards that should be considered in engineering approaches to visiting robotic and human systems. Such 'grounding' considerations are also relevant to landed mission to any rocky body (NEO, moons of Mars).

References: [1] Stubbs, T. J., et al. (2006), *Adv. Space Res., 37*, 59. [2] Farrell, W. M., et al. (2008) *Geophys. Res. Lett., 35*, L19104. [3] Halekas, J. S., et al. (2010), Planet. Space Sci., submitted. [4] Carrier, W. D., et al., (1991), in *The Lunar Sourcebook*, edited by G. H. Heikenet al., pp. 475–594, Cambridge Univ. Press, Cambridge, U. K.. [5] Farrell, W. M., et al. (2010) , *J. Geophys. Res., 115*, E03004.