LUNAR LANDING SITES THAT WILL ENHANCE OUR UNDERSTANDING OF REGOLITH MODIFICATION PROCESSES. S.T. Crites[1], S. Quintana[2], A. Przepiórka[3], C. Santiago[4], T. Trabucchi[5], D. A. Kring[6], [1]University of Hawai'i, Honolulu, HI, scrites@higp.hawaii.edu; [2]Brown University, Providence, RI; [3] Space Research Centre of the Polish Academy of Sciences, Warsaw, Poland; [4]University of Texas at El Paso, El Paso, TX, [5]University of New Brunswick, New Brunswick, Canada; [6]Lunar and Planetary Institute, Houston, TX.

Introduction: In 2006, NASA commissioned the National Research Council (NRC) to determine the scientific priorities for future lunar missions. This document, the *Scientific Context for Exploration of the Moon* [1], outlines eight concepts for future robotic and manned missions to the Moon. Concept 7 of the NRC 2007 document states that "the Moon is a natural laboratory to study regolith processes and weathering on anhydrous airless bodies," and outlines four specific science goals within this concept. One of these science goals is to "understand regolith modification processes (including space weathering), particularly deposition of volatile materials." Regolith modification includes large scale impacts as well as small scale processes that together are called space weathering. We conducted a global survey of the Moon to identify possible landing sites where Concept 7 could be studied, with a focus on locations that will enhance our understanding of the suite of processes involved in space weathering.

Importance of space weathering: Space weathering is produced by micrometeorite bombardment, solar wind sputtering and volatile implantation, and irradiation by galactic cosmic rays and solar energetic particles. These processes, known as "maturation," modify the exposed lunar regolith with time. As regolith matures, it accumulates agglutinate particles (aggregates bonded by impact glass), nanometer-size single-domain iron particles (np-Fe^0) in vapor-deposited rims, and implanted solar wind gases. These modifications of the regolith can interfere with remote studies of compositions and ages of surfaces. It is therefore necessary to understand these modification processes to confidently interpret remotely obtained information. In addition, implanted volatiles may someday be an important resource for science and industry on the Moon.

Several factors may influence the consequences of space weathering on the regolith, including exposure time, original composition of the regolith, and presence or absence of a magnetic field [2-5]. We identified four target site requirements that govern where on the Moon future lunar missions can best test the effects these factors have on space weathering of the Moon and other airless bodies.

Landing site requirements:

Locations that allow sampling of mature, intermediate, and immature regolith. Regolith freshly created or exposed in an impact event is considered immature; regolith that has reached steady state with respect to the modification processes of space weathering is considered mature [2]. In order to understand the process of space weathering on regolith as it progresses from immature to fully mature, it is important for missions to sample material of varying maturity. However, the production of small impact craters is a common process on the Moon. Thus, material of varying maturity may be found within a few kilometers of any landing site. We therefore do not consider finding material of different maturities a constraint that limits the selection of landing sites.

Locations that allow examination of the effects of FeO content and opaque mineral content on space weathering. Initial FeO content has been shown to affect the production of np-Fe^0 and locations inferred to have high abundances of opaque titanium-bearing minerals appear anomalously mature using remote sensing data [2,3]. We divide the Moon into high and low FeO regions, and into high, medium, and low titanium regions (Fig. 1). Each of these regions, particularly the moderate titanium regions which were not sampled by Apollo or Luna, should be sampled, adding to the existing sample suite, and enhancing understanding of the compositional controls on the space weathering processes.

Locations with magnetic anomalies. The Moon does not have a global magnetic field, but certain locations of the lunar surface have relatively high magnetic field strength. Many of these locations are associated with lunar swirls (Fig. 1), a type of surface feature that shows anomalous space weathering. Calculations have shown that lunar magnetic anomalies have the potential to deflect solar wind charged particles away from the regolith at those locations [4]. Studying these sites may allow us to deconvolve the effects of the solar wind from other space weathering processes. In addition, though these locations are anomalous on the Moon, they may provide an analog for space weathering on airless bodies that do possess a magnetic field, like Mercury.

Locations where man-made materials have been exposed for a known length of time. Studying space weathering effects on artificial materials exposed on the lunar surface for a known length of time provides a

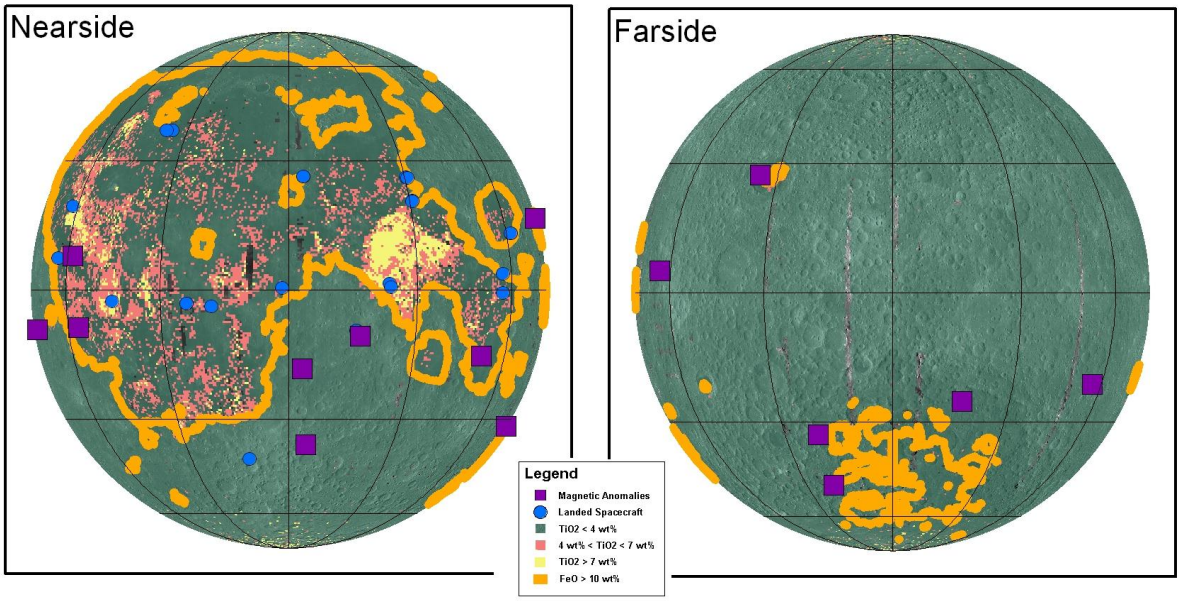

Figure 1: A map of our suggested landing regions. We have prioritized these regions in the following manner: Sampling of regions of varying FeO and TiO_2 are of top priority. Intermediate TiO_2 samples are of higher priority than low or high TiO_2 because of the bimodal appearance of Apollo and Luna samples compared to spectral observations. Next are regions of landed spacecraft because they could potentially be used as a space weathering controlled experiment. Finally regions modified by the presence of a magnetic anomaly should be studied.

controlled experiment that can be used to enhance our understanding of space weathering as it progresses with time. Artificial materials could be brought to the Moon for the purpose of setting up experiments of this type. Alternatively, man-made materials already existing on the Moon in various locations (Fig. 1) from previous landed missions can be used for the same purpose. Knowing how space weathering affects a known material may help calibrate a space weathering chronometer that could assist in remote determination of ages of lunar surfaces.

Discussion and Summary: The regolith and space weathering processes that affect it can be studied, at some level, at any location on the Moon. However, there are local areas where more of the parameters involved in the process can be investigated. The integrated results implied by the landing site requirements described above are shown in Fig. 1, which represent locations that offer the best opportunity to fully characterize the processes of space weathering. The FeO content of the regolith has an important effect on the final space weathering product, so regions of both high and low FeO content should be sampled. Regions with intermediate TiO2 content should be sampled to expand the sample suite to fully reflect the variation of the lunar surface. Magnetic anomalies on the Moon offer important and unique science returns relevant to the Moon and other airless bodies. Locations of man-made materials on the lunar surface provide the opportunity to gain a better understanding of the weathering process with time in a ready-made experiment. At each landing site, effort should be made to sample regolith of widely varying maturity. Areas of enhanced interest occur where several features (or map symbols) are co-located.

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References: [1] Nat'l Research Council (2007), *The Scientific Context for Exploration of the Moon*. [2] Lucey et al. (2000), *J. Geophys. Res.* 105, 20,377-20,386. [3] Noble et al. (2001), *Meteoritics & Plan. Sci.* 36, 31-42. [4] Kramer et al. (2011), *J. Geophys. Res.* 116, E04008, doi:10.1029/2010JE003669. [5] Clark et al. (2002), in *Asteroids II*, Univ. Arizona Press.