A LANDED EXPERIMENT PACKAGE FOR INVESTIGATION OF LUNAR MAGNETIC AND ALBEDO ANOMALIES. David T. Blewett¹, George C. Ho², Haje Korth³, Lon L. Hood², Jasper Halekas⁴. ¹Johns Hopkins Univ. Applied Physics Lab, 11100 Johns Hopkins Rd., Laurel, MD 20723 USA (david.blewett@jhuapl.edu); ²Lunar and Planetary Lab, Univ. of Arizona, 1629 E. University Blvd., Tucson, AZ 85721; ³Space Sciences Lab, Univer. of California-Berkeley, 7 Gauss Way, Berkeley, CA 94720.

Introduction: The lunar crust contains magnetic anomalies [1] that are associated with highly unusual bright surficial markings known as lunar swirls [2, 3]. Many of these magnetic/albedo anomalies are found diametrically opposite (antipodal) to the large lunar impact basins such as Imbrium and Orientale [4]. However, the most famous of these features, the Reiner Gamma formation (RGF, Fig. 1) located on the nearside in Oceanus Procellarum, is not antipodal to a major basin. The relationship between the magnetic anomalies and the bright swirl features is uncertain. Magnetized basin ejecta is likely to be the source of some of the magnetic anomalies. One hypothesis states that the magnetic anomaly stands off the solar wind [1], thereby preserving a high albedo by retarding the normal ageing process (soil darkening and reddening, or "space weathering") to which unshielded areas are subjected. The production of nanophase metallic iron (npFe⁰) blebs and coatings on and within soil grains is primarily responsible for the optical effects of space weathering [5, 6]. On the other hand, there is evidence that the solar wind may not play an important role in space weathering, and that micrometeoroid bombardment alone can produce npFe⁰ by impact vapor deposition (summarized by [6]) (a magnetic anomaly would not screen out micrometeoroids). Other workers suggest that a cometary nucleus/coma [3, 7] or meteoroid swarm [8] impact could disturb the surface to produce the bright swirl markings by changing the structure and grain-size distribution of the uppermost regolith. These workers propose that plasma processes within the comet’s coma could amplify and imprint the magnetic signature [3].

A satisfactory explanation for the magnetic anomaly/swirl puzzle has been elusive. Yet the swirls present a natural laboratory for study of at least three major areas in planetary science:

a) Lunar geology: What is the nature and origin of the lunar swirls?


c) Space weathering and remote sensing: The optical effects of exposure to the space environment complicate interpretation of remote sensing observations of the Moon, Mercury and asteroids. The lunar magnetic anomalies potentially allow us to control for one of the key variables, solar wind exposure.

The Role of In-Situ Measurements: A landed instrument package targeted to one of the major magnetic/albedo anomalies, such as the RGF, could help to provide answers to the important questions listed above [10]. We have developed a concept for an instrument suite designed to evaluate the relevant environment at the lunar surface and to measure key properties of the lunar regolith within a magnetic anomaly. Valuable information could be obtained if the package was deployed on a static lander, though the ability to make measurements at multiple locations via roving capability would greatly enhance the science return.

Two key elements of the package, a vector magnetometer and a solar wind spectrometer, assess the space environment on the lunar surface. The orbital magnetic measurements made by Lunar Prospector, Kaguya and other spacecraft represent averages over large areas and must be extrapolated to the surface, so the actual strength of the magnetic field within the anomalies is not well known. Further, magnetometer measurements at the surface within a strong anomaly would help to constrain the depth and thickness of the source region [11]. These constraints are of interest in evaluating the nature of the magnetizing field. For example, was the magnetizing field produced by an ancient core dynamo, by amplification of ambient fields generated during a basin-forming impact, or by a comet impact?

We also note that the surface magnetometer measurements, if combined with simultaneous high-altitude orbital magnetometer measurements, could be applied to electromagnetic sounding of the deep interior [11].

The solar wind spectrometer will directly test if solar wind flux is reaching the surface. The solar wind spectrometer consists of two parts: a sensor for protons and alpha particles (200 eV/q to 20 keV/q), and an electron analyzer (1 ev to 5 keV).

A second group of instruments focuses on characterization of the regolith: an XRF/XRD capable of determining the regolith elemental abundance; a UV-VIS-NIR spectrometer to obtain mineralogy; a Mössbauer spectrometer to measure npFe⁰ content; a high-resolution multispectral imager to assess surface
morphology and composition; and a microscopic imager to determine particle size distribution. In addition to providing data for addressing the questions posed above, this group of instruments would yield important "ground truth" information to aid in the interpretation of remote sensing observations from Earth-based telescopes and spacecraft instruments such as the Clementine, Chang'E, Kaguya and LRO cameras, and the Chandrayaan hyperspectral imager (Moon Mineralogy Mapper).


Figure 1. The Reiner Gamma Formation, the type occurrence of a lunar swirl. The Clementine mosaic is centered at 7.5° N, 302.5° E, with contours of Lunar Prospector total magnetic field strength (nT) at 35.5 km altitude. From [12].