MODELING PLASMA INTERACTIONS WITH THE REINER GAMMA MAGNETIC ANOMALY IN ANTICIPATION OF THE ARRIVAL OF *LUNAR VERTEX*.

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Introduction: *Lunar Vertex* is a mission at the intersection of multiple science communities, from planetary geology to space plasma physics. As the first Payloads and Research Investigations on the Surface of the Moon (PRISM1) investigation, scheduled for delivery to the Reiner Gamma (RG) magnetic anomaly in 2024 aboard a commercial lunar lander, *Lunar Vertex* will unravel the nature of the RG anomaly, the connection to and origin of the associated lunar swirl surface feature, and the structure and impact of the "mini-magnetosphere" in this region [1]. *Lunar Vertex* will carry a suite of science-grade and commercial fluxgate magnetometers on the lander (Vector Magnetometer – Lander; VML) and a suite of commercial fluxgate magnetometers on a dedicated rover (Vector Magnetometer – Rover; VMR) that will traverse the lunar surface [2], as well as a low-energy ion and electron analyzer (Magnetic Anomaly Plasma Spectrometer; MAPS) on the lander. The combination of magnetic field measurements taken during cruise and descent by VML and during surface operations by both VML and VMR will characterize the surface magnetic field within a strong lunar magnetic anomaly. These spatially distributed measurements taken from lunar dawn to dusk (spanning ~2 weeks) will constrain the orientation, strength, and depth of the source of the RG magnetic anomaly, and so allow us to infer its most likely origin. The combined magnetic field and plasma measurements from VML and MAPS will provide direct observations of plasma populations reaching the lunar surface and the associated local magnetic field configuration, enabling a more complete understanding of the plasma processes that may be occurring within the RG "mini-magnetosphere". Characterization of the surface strength and structuring of the RG anomaly and influence of external plasma conditions on that structuring is vital for understanding interactions with the surrounding space plasma environment, the dynamics of electromagnetic processes occurring on and near the lunar surface, and the subsequent impacts on surface processes and role in surface evolution unique to lunar magnetic anomalies and associated swirls.

Descent and Surface Profiles for Varying Plasma Conditions: To prepare for *Lunar Vertex* operations during cruise and through the crucial phase of descent to the lunar surface, time series profiles along synthetic trajectories for varying solar wind and magnetosheath conditions are constructed. Additionally, exploring cases of upstream plasma conditions representative of the variable solar wind and interplanetary magnetic field, magnetosheath plasma and magnetic field properties, and the magnetotail populations and magnetic field configuration at lunar distances provides constraints on relative variations of the surface field at the *Lunar Vertex* landing site during the mission. To explore the potential magnetic field profiles during descent and over the course of the lunar day during surface operations, two models are used to construct the RG magnetic field and responses to changing ambient conditions.

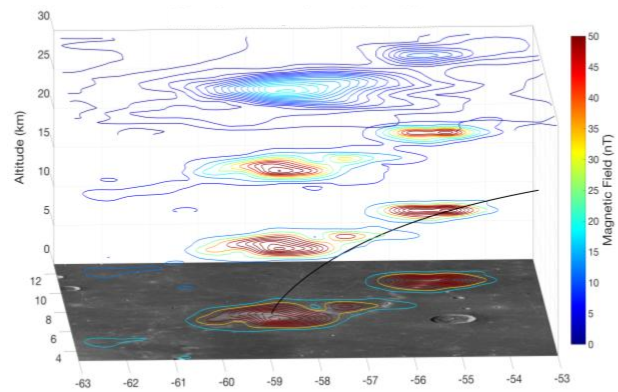

Fig. 1. Modeled volume of the Reiner Gamma magnetic anomaly from [3] with an example descent trajectory of *Lunar Vertex*, overlaid on LROC WAC Mosaic imagery of the associated lunar swirl.

The empirical model of [3] is based on downward continuation of *Lunar Prospector* global magnetic field data from 30 km altitude. Using representative measurements from the THEMIS/ARTEMIS spacecraft in elliptical lunar orbits as input, model runs for different upstream conditions are performed to assess compression of the RG anomaly due to varying dynamic pressure. The Amitis model [4] is also used to further examine the interaction of the plasma environment local to RG, as the hybrid-PIC simulation with inclusion of empirical models for crustal magnetic fields allows for the resolution of ion-scale physics both at RG and globally across the lunar surface [e.g., 5]. Along with construction of temporal profiles of possible magnetic field measurements that may be obtained during descent through the RG magnetic anomaly, temporal variation in the surface field and impinging plasma populations that could potentially be observed by MAPS are also simulated. Input parameters for the external plasma and magnetic field conditions are from representative measurements obtained by ARTEMIS in different regions of the solar wind, magnetosheath, and magnetotail, as well as from limiting cases for possible conditions within those regions. The lunar phase is also incorporated in the Amitis model, allowing for varying conditions appropriate for RG throughout the span of surface operations of *Lunar Vertex*, as well as insights into complex interactions that may arise upon entering into the lunar wake.

Understanding possible effects of the varying external plasma environment over the course of a lunation is critical for assessment of the observations that will be obtained by *Lunar Vertex*. There may likely be higher-order structuring of the magnetic field at/near the surface not fully captured in the models that will be revealed upon the arrival of *Lunar Vertex*. However, these simulations provide a basis for initial interpretation of measurements during descent and on the surface, and, importantly, exemplify the need for surface measurements to untangle the structure and dynamics of RG and other magnetic anomalies. A broader understanding of the local plasma and magnetic field environment also enables a comprehensive view of interactions with magnetic anomalies across the lunar surface, where additional factors like permanently shadowed regions and incidence angles of impinging plasma populations may play an important role in regolith and volatile evolution [e.g., 6].

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