TOWARDS A MODELLING FRAMEWORK FOR LUNAR SURFACE GEOPHYSICS

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Introduction: Many lunar and planetary missions are currently planned or already on their way [1]. Most of these missions are of exploratory nature, trying to survey or map or understand lunar and planetary features. One of the main sensor payloads in surface exploration includes surface deployed geophysical sensors, e.g. gravimeters, Ground Penetrating Radar (GPR), magnetometers and EM systems. Surface exploration will mainly be conducted using rovers, with a few being performed by astronauts. The major difference between well established geophysical surveys on Earth and lunar/planetary missions is that the chance to redo a failed survey often does not exist. This constraint requires a much more carefully planned and optimized survey for planetary missions. Several parameters control a successful survey, including but not limited to line spacing, number of measurement stations, accuracy and resolution, total duration and acquisition time per station [2, 3]. In addition, these parameters vary greatly and depend on the assumed target and background geology (regolith or volcanic outcrop) and terrain (slope or surface roughness). In order to model the expected response of the target in a presumed geological setting, forward modeling is employed. A known set of physical parameters is used to predict the geophysical signals at pre-defined locations. From those data, the target signal can be assessed and interpreted or transferred to inversion. Forward modeling is well established for surveys on Earth, but more often than not, the parameters listed above (line spacing, etc.) are not always optimized as most surveys allow for flexibility and adjustments while in the field. Lunar and planetary surveys do not allow for easy adjustments and therefore, we suggest that a more advanced forward/inverse modeling approach is required which takes the variability of the parameters, uncertainties and unknowns into account to optimize a planetary survey in time, number of locations and accuracy to achieve the mission goals.

We will present modeling examples for lunar surface exploration using two geophysical techniques, gravimetry and GPR. The targets include extreme volcanic features and their bulk density estimates from rover gravimetry at the Gruithuisen Domes [4], and the detectability of lava tubes along lunar rilles (e.g. at the Marius Hills region). The approach taken can also be applied to many other geological targets on any planetary surface including asteroids.

Results of this study includes sensitivity maps showing what a specific method could achieve in terms of target resolution and knowledge. These data consequently informs mission planning, landing site evaluation and science objectives.

Figure 1 shows an example of the locations at Gruithuisen Dome Gamma at which a gravity survey using a VEGA space gravimeter [5, 6] with a RMS accuracy of 0.3 mGal would be able to estimate the bulk density difference between the dome volcanics and the surrounding mare volcanics. The colors show the gravity differences in mGal for a 500m long traverse with an estimated density difference between mare and dome volcanics of 400 kg/m^3. For any colored locations, the mission objective could be achieved (considering that the parameter choices for noise, terrain etc. are realistic). For larger density differences, the colored areas would increase, or for a lower gravimeter accuracy, the colored areas would decrease. This type of sensitivity study is able to predict where a particular instrument could resolve planetary features including ice deposits.

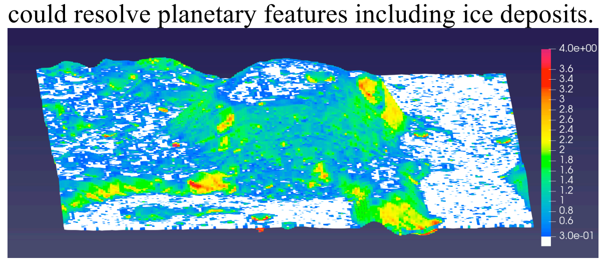

Figure 1: Gravity differences along 500m long gravimetry traverses over Gruithuisen dome Gamma. This models assumes a difference between dome and surrounding mare volcanics of 400 kg/m^3. Colored areas (scale is in mGal with 0-0.3 mGal in white and up to 4 mGal in red) exceed the accuracy of the VEGA gravimeter and would be suitable landing locations to estimate the bulk density of the dome material.

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References: [1] Johnson, K. (2022) *Report CSIS AEROSPACE SECURITY PROJECT*. [2] Saadia et al. (2021), *Github Grasimu project* [3] de Veld et al. (2021), *Can Lunar Conf* [4] Joliff et al. (1991), *Lunar Planetary Sci* [5] Caroll et al. (2019), *Ann Mtg Lunar Exploration Analysis Group* (2019), [6] Caroll, K.A. (2015), *US Patent* No. 10,310,132 (2015) [7] Braun, A. et al. (2022) *LPSC*, Abstract 2831