Leveraging VIPER Geotechnical and Mobility Insights for Endurance Rover and Traverse Development

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Introduction: A new generation of lunar surface rover exploration is rapidly approaching. This is evidenced by the rise of commercially developed rovers from private companies (e.g., Lunar Outpost's MAPP) and government agencies, like NASA's Volatiles Investigating Polar Exploration Rover (VIPER), the Lunar Terrain Vehicle (LTV), the Endurance/Intrepid rover concepts, and the INSPIRE mission concept [1,2]. The drive distance requirements for off-world vehicles are also rapidly increasing. For example, LTV driving requirements dictate a 20 km range on a single battery charge, with an overall lifetime requirement of 13,000 km over a minimum 10-year service life. Similarly, NASA's Endurance-A mission concept requires a 2000 km vehicle traverse distance, which is nearly 50 times further than the USSR's Lunokhod 2, the longest lunar rover mission to date [3]. Previous planetary surface missions on the Moon and Mars have revealed harsh mobility conditions: aggressive rocky terrains on Mars severely damaged the Curiosity rover's wheels [4], soft lunar regolith caused the Lunokhod 2 rover to sink [3] and NASA's Apollo 15 LRV (Lunar Roving Vehicle) spun out due to poor traction, which required manual correction [5]. This demonstrates that mobility challenges like wheel degradation and soft soil driving performance must be accounted for in a mission's design phase to meet increasingly aggressive mission durations and mobility goals. The success of these long duration missions requires highly reliable and durable mobility platforms in conjunction with a more developed understanding of the geotechnical properties of the lunar surface.

VIPER's Contribution: The VIPER mission is uniquely poised to inform future missions about mobility performance, wheel durability, and lunar surface soil mechanics of sunlit and shadowed regions through use of data streams that already exist for other mission purposes. VIPER's mission to the lunar South Pole will provide a new perspective into off-world mobility challenges including traversal into permanently shadowed regions. Mobility data from VIPER's mission will represent a first glimpse into the surface mobility challenges of the lunar South Pole. Utilization of VIPER's existing capabilities including cameras, inertial measurement unit (IMU) data, motor currents/torque, drill data [6], and the rover's suspension state and kinematics provide the opportunity to determine potentially useful information for future rover and traverse designs, as well as on-Earth testing practices. Data products collected during VIPER's mission could inform design considerations for the Endurance rover much earlier than NASA's standard "lessons learned" approach as VIPER has a highly tactical mission operations structure. This work outlines the specific links between possible data products from the VIPER mission and their potential impact on the Endurance/Intrepid mission concepts in their early design phases. From VIPER, we will also gain insights for future development of onboard mobility software as VIPER is a way-point driven rover which requires more constant human operation on Earth than some other rover missions (non-lunar surface). Primary VIPER data products and insights of interest include wheel sinkage, wheel slip, wheel degradation, surface soil shear strength, and terrain slope estimation. VIPER data products will be made available via the Planetary Data System's Geosciences and Cartography and Imaging Sciences nodes, conforming to the PDS4 standard.

References [1] Colaprete et al., 2019, AGU Fall Meeting [2] NAS, 2022, Origins, Worlds, and Life, Decadal Strategy [3] Basilevsky et al., 2021, Solar System Research 55(4) [4] Rankin et al., 2021, Journal of Field Robotics 38(5) [5] Costes et al., 1972, NASA Technical Report TR R-401. [6] Zacny et al., (2023), TRIDENT Drill for VIPER and PRIME1 Missions to the Moon – 2023 Update, LPSC 2023