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The Stepped Frequency GPR: A Proposal to investigate the Lunar Subsurface

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Past lunar exploration has consisted of numerous missions that gathered information about the surface of the Moon. However, long-term exploration as well as the intended permanent human presence would benefit from more information about the structure and the properties of the lunar subsurface. Research questions in particular are the thickness of the lunar regolith, the existence, extent, shape, and depth of lunar volcanic caves and lava tubes, as well as the layering frequency, thickness, and extent of lunar maria and pyroclastic deposits. Other relevant objectives are the determination of depth, shape, and extent of important resources such as subsurface water ice in the Permanently Shadowed Regions of the lunar poles. These questions cannot be answered using orbital radar instruments alone, such as carried by the Lunar Reconnaissance Orbiter. However, surface-based results could be used to help calibrate orbital observations, in turn.

The Stepped Frequency GPR (SF-GPR) is proposed as payload for a mobile ground asset, such as a small wheeled rover. It will be either carried or dragged by the rover, while performing measurements as the host platform is traversing the lunar surface. The SF-GPR's electronic unit's dimensions range from 0.2 x 0.2 x 0.2 m to 0.1 x 0.1 x 0.1 m, depending on the available volume, while the antenna and electronic system mass is less than 2 kg. The main advantage of the Stepped Frequency Radar is its flexibility that allows the payload to adapt to a specific geomorphological situation or to a specific desired application, enabling the mission desiginers to maximize the scientific value of observation by reusing hardware design. To leverage this aspect, the antenna design will be adaptable to suit the required frequency, ranging from 400 to 100 MHz. The antennas will be installed in box-shaped volumes on each side of the rover, with 0.4 x 0.4 x 0.14 m dimensions. The stepped frequency radar scheme allows low overall power consumption and compatible electrical interface to fit many upcoming surface missions to the Moon. In addition, a full-wave tomography approach will be applied to the collected radar data to recover more information from the subsurface using advanced inverse mathematics.

With the proposed frequency range and antenna setup, the SF-GPR is expected to be able to resolve subsurface interfaces and features with penetration depths of tens to hundreds of meters and a depth resolution of meters to centimeters. Thus, penetration depth and resolution would be sufficient to examine the proposed science questions, i.e. to detect and map lunar subsurface volcanic cavities, interfaces in maria and pyroclastic deposits, distribution of potential resources, as well as regolith thickness. Any new data of lunar subsurface features are of vital importance to scientific inquiry and the future of long-term lunar exploration.

This proposal was sent as a response to a Request For Information (RFI) by the European Space Agency for Missions of Opportunity and HERACLES: Lunar Exploration Campaign: Science and Technology Payloads.