Electromagnetic Simulations of Ground-Penetrating Radar Propagation near Lunar Pits and Lava Tubes.
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Introduction: Placing an Orion capsule at the Earth-Moon L2 point (EML2) would potentially enable telerobotic operation of a rover on the lunar surface [1]. The Human Exploration Virtual Institute (HEVI) [2] is proposing that rover operations be carried out near one of the recently discovered [3] lunar pits, which may provide radiation shielding for long-duration human stays as well as a cross-disciplinary, science-rich target for nearer-term telerobotic exploration. Ground penetrating radar (GPR) instrumentation included onboard a rover has the potential to reveal many details of underground geologic structures near a pit, as well as characteristics of the pit itself. In the present work we employ the full-wave electromagnetic code MEEP [4] to simulate such GPR reflections from a lunar pit and other subsurface features including “lava tubes”. These simulations will feed forward to mission concepts requiring knowledge of “where to hide” from harmful radiation and other environmental hazards such as plama charging and extreme diurnal temperatures.

Results: A number of idealized scenarios are investigated, such as those shown in Fig. 1 (below). In Fig. 2 a 30 MHz wave is launched at the surface, coarsely resolving a cylindrical tunnel buried tens of meters underground (e.g., the scenario of Fig. 1a). Fig. 3 shows that the same source wave produces a more complex return near a lunar pit (e.g., the scenario of Fig. 1b) where “clutter” reflections from various interfaces occur. Using simulations and theory as a guide we will discuss how different environmental factors are likely affect the strength and character of GPR returns, including temperature-dependent electrical conductivity of the surface, radar frequency, and scale, complexity, and depth of subsurface features of interest as well as other scatterers.

References: [1] Burns et al. (2012) ASR, submitted. [2] Farrell et al. (2013) LPSC abstract. [3] Robinson, M. S., et al. (2012), Planetary and Space Sci., 69, 18-27. [4] Oskooi et al. (2010) Comp. Phys. Comm.

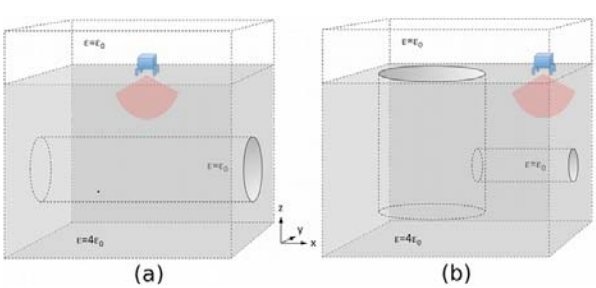

Figure 1 (bottom left column): Idealized scenarios for simulating GPR returns near a lunar pit. (a) Rover investigates an underground lunar tunnel. (b) Rover investigates a tunnel attached to a lunar pit.

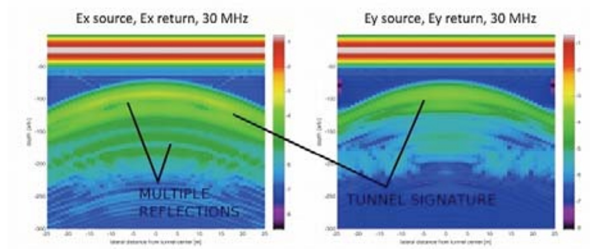

Figure 2: Simulated GPR returns from scenario (a) of Fig. 1, with a 10-m diameter hollow cylindrical tunnel placed 20-m underground. The wave source is a Gaussian pulse with central frequency 30 MHz (wavelength 10 m) and temporal width about 5 wave periods. The x-axis represents lateral distance of the rover from the central axis of the tunnel, the y-axis effectively shows time of signal return, and the color scheme shows log of wave power received. The source and return wave polarizations are denoted respectively as E_x or E_y parallel or perpendicular to the tunnel axis.

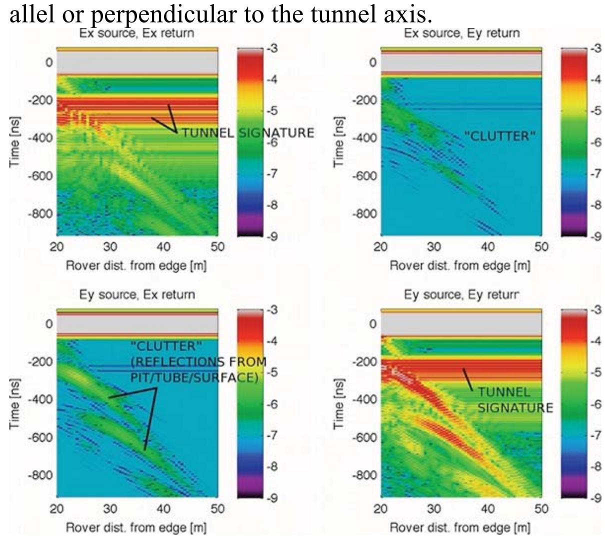

Figure 3: Simulated GPR returns from scenario (b) of Fig. 1, with a 10-m diameter, 20-m depth hollow cylindrical tunnel attached to a lunar pit 100-m in diameter and 30-m deep. The x-axis shows distance away from the edge of the pit (above and along the axis of the tunnel), while the y-axis, color scheme, and wave source are as in Fig. 2. The reddish, horizontal bands are the primary GPR return from the tunnel, while the sloping signatures are reflections of the source wave from the tunnel, pit, and overhead lunar surface interfaces.