POTENTIAL OF PROBING THE LUNAR REGOLITH USING ROVER-MOUNTED GROUND PENETRATING RADAR: MOSES LAKE DUNE FIELD ANALOG STUDY,

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Introduction: Probing radars have been widely recognized by the science community to be an efficient tool to explore lunar subsurface providing a unique capability to address several scientific and operational issues. A wide-band (200 to 1200 MHz) Ground Penetrating Radar (GPR) mounted on a surface rover can provide high vertical resolution and probing depth from few tens of centimeters to few tens of meters depending on the sounding frequency and the ground conductivity. This in term can provide a better understand regolith thickness, elemental iron concentration (including ilmenite), volatile presence, structural anomalies and fracturing. All those objectives are of important significance for understanding the local geology and potential sustainable resources for future landing sites in particular exploring the thickness, structural heterogeneity and potential volatiles presence in the lunar regolith.

While the operation and data collection of GPR is a straightforward case for most terrestrial surveys, it is a challenging task for remote planetary study especially on robotic platforms due to the complexity of remote operation in rough terrains and the data collection constrains imposed by the mechanical motion of the rover and limitation in data transfer. Nevertheless, Rover mounted GPR can be of great support to perform systematic subsurface surveys for a given landing site as it can provide scientific and operational support in exploring subsurface resources and sample collections which can increase the efficiency of the EVA activities for potential human crews as part of the NASA Constellation Program.

In this study we attempt to explore the operational challenges and their impact on the EVA scientific return for operating a rover mounted GPR in support of potential human activity on the moon. In this first field study, we mainly focused on the ability of GPR to support subsurface sample collection and explore shallow subsurface volatiles.

Survey & robotic setup: The ground penetrating radar is a non-invasive technique for probing terrestrial and planetary subsurfaces using electromagnetic radio waves that can reaches different depths and resolutions depending on the sounding frequency and the soil geoelectrical properties. GPR measures changes in signals induced by the dielectrical properties and structural heterogeneity. In our survey a pulse repetition GPR has been mounted on two platforms: K-10B (top of Fig. 1, built by NASA/AMES) and JSC-Chariot (bottom of Fig.1, built by NASA/JSC) each operating at two different frequencies. In the first configuration soundings were performed from 600 to 1200 MHz using two shielded bi-static antennas, with frequency swapping and four polarimetric modes: HH, HV, VH and VV (H: Horizontal and V: Vertical). This provided penetration depth of 0.5 to 3 m and vertical resolution of 0.05 to 0.12 m in Moses lake Aeolian deposits. The constrained penetration is mainly results of the moisture content (average of 28% of samples mass) that increase the radar signal attenuation losses in the subsurface. The antennas were mounted on the bottom section of the rover with a 30 cm separation from the surface. The second configuration is a mono-static 400 MHz antenna that operate in the frequency band from 200 to 600 MHz. The transmission unit and the antenna were both fixed in the back-dock of the JSC-Chariot platform with the main lobe of the antenna oriented downward. The GPR system was covered with radar shielding materials to avoid any interferences with the onboard electronic and communication systems.

Fig 1: On the top in the front plan, K10 Black rover (NASA/AMES), performing subsurface reconnaissance in support of crew EVA (in the back plan). On the Bottom, the GPR mounted on the back-dock of the Chariot platform (NASA/JSC).

Site description [1]**:** The Moses Lake dune field is located in the southern Quincy Basin of central Washington state, at the south west of Moses Lake. The Basin is a structurally controlled depression formed within the Tertiary Yakima Basalt Subgroup of the Columbia River Basalt Group. Much of the basaltic dune sand is suggested to have been reworked from sediment deposited in the Quincy Basin during the multiple flood events that swept across eastern Washington and the underlying Columbia Basalts between 17,000 and 12,000 years. Late Pleistocene and Holocene winds have driven the Moses Lake sands east-northeast-ward. Currently, much of the Moses Lake dune field occurs above the gravels and cobbles of the central and eastern portions of the distal Ephrata Fan, which in turn lies above a scabland of eroded Wanapum Basalt units. The dunes are formed with basaltic Aeolian sand generally consist of more than 55% basalt lithic fragments; lighter-toned grains comprising most of the remaining bulk were interpreted as quartz. Other lithic fragments cover a range of compositions including small pieces of schists transported first by glaciers then by Missoula Floods. The radar transacts where performed in two areas: (1) across 4 small (less then 4 m height) sand dunes, (2) in a crater-like terrain, with a diameter approaching 200m.

Results: While the exposed surface geology of Moses Lake dune field suggested a dry and homogenous environment, the radargram obtained using both radar frequencies suggested the presence of successive layers of moist soils with several fine layering that results potentially from the different Aeolian and fluvial deposits that occurred in the site. Figure 2, shows an example of the 400 MHz GPR data mounted on Chariot during the June 2008 tests.

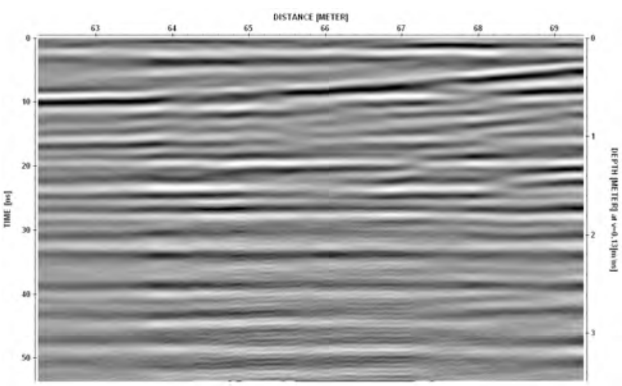

Fig. 2: An 8m-long section of the 400 MHz radargram transact in Moses Lake (penetration 3.2 m) showing the layering corresponding to different moisture level in the Aeolian deposits.

Figure 3 shows the 900 MHz radargram acquired with K10B in the internal zone of the crater-like area. Two distinct reflections can be clearly observed, the first occurring roughly at 1 m and the second at 2 m toward the end of the transact. Those interfaces corresponding to two high dielectric contrasts are though to be representative of depths with higher concentrations of moisture in the subsurface. A suggestion that has been validated by a trench performed on the first investigated site in the dune area where similar layering has been observed. Figure 3, also shows several fine layering that is observable in the first meter of the subsurface, those have been found to correlate with the succession of dark and lighter-toned sands layering in the shallow subsurface. The dark ones being richer in iron they shows higher dielectric constant then the lighter-toned ones that are richer in silica for similar moisture content. Hence we were able to distinguish both moisture and iron-concentration variation in the subsurface. At the time of the conference more radargrams at 400 and 900 MHz will be presented supporting the identification of the two above-mentioned features.

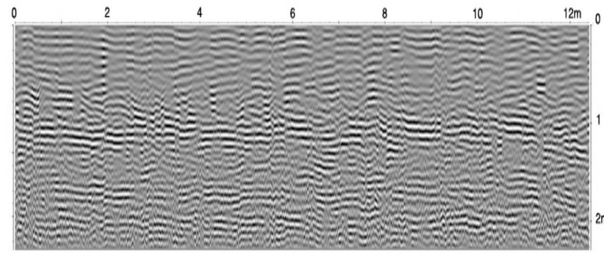

Fig. 3: A 13m-long transact at 900 MHz in the Moses Lake Crater-like area showing the fine and coarse layering corresponding respectively to Aeolian and fluvial deposition mechanisms as observed in the first 2 m of the subsurface.

Implications for science and operation on future human exploration: This survey comes as a part of a series of field tests being carried by NASA AMES and JSC to better understand the robotic support for future human return on the moon [2]. Our approach was to use the GPR in this simulated operation test in order to evaluate its relevance to support future EVA activity on the moon as part of the NASA Constellation Program especially for potential sustainable resource exploration. The use of GPR on a robotic platform has shown to be efficient in surveying extended area simultaneously or preceding EVA activities. Several technical challenges are yet to be resolved to allow a real-time data for EVA crew that can be used for locating buried samples or exploring volatiles rich zone. More analog study on sites that has stronger geophysical and geological lunar relevance will help us get a better understanding of the expected scientific results from having a GPR on a lunar rover platform. In a first step, our survey at the Moses Lake helped us define the operational challenges and their impact on the science organization and operation, which is in itself of a great benefit to support the development of innovative and realistic shallow subsurface exploration methods for the Lunar regolith.

References: [1] Banfield et al., (2002), JGR-Planets, *107*(E11), 5092 [2] Fong et al., (2008), NLSI Lunar Science Conference, NASA Ames Research Center, Moffett Field, California, abstract no. 2141.

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