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SHIFTING THE PARADIGM OF COPING WITH NYX ON THE MOON - A GROUND-PENETRATING RADAR CASE -

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Radar has played a key role in characterizing the properties and geology of the Moon, from ground-based [1] to bi-static [2], sounders [3] and a ground-penetrating radar [4]. Currently, a higher level of fidelity in data is needed to fully characterize and interpret the lunar geologic and to be able to exploit its resources. Radar will continue to be a key tool in this effort, and this belief is supported by the needs outlined in the Lunar Exploration Road Map and the Lunar Knowledge Gaps document.

Detection and mapping of polar volatiles, of pyroclastic deposits and regolith stratigraphy, and of lunar lava tubes are among the primary science cases for ground-penetrating radar instruments. Aside from the ice deposits expected in and around the permanently shaded areas near the poles, primary science targets are distributed around the Moon in the equatorial and tropical latitudinal bands.

MARGE

The DASHER concept at JPL, currently being developed for ice sheet subsurface mapping, combines ground penetrating radar with the Puffer mobility technology [5] and navigational autonomy in a compact solar-powered rover platform or agent. The concept entails multiple agents, from a pair up to a heard, which are intended to map the subsurface. Each agent traverses cooperatively with other agents in order to allow different types GPR soundings: quasi monostatic (transmitter and receiver adjacent), to bistatic and multi-static (Figure 1). This distributed, multi-agent autonomous deployment provides great benefit from traditional GPR implementations in that it allows for rapid and efficient 3D mapping of the subsurface stratigraphy and signal velocity structure.

We are currently adapting the DASHER prototype instrument for lunar use. The Multi-static Autonomous Roving Ground-penetrating-radar Explorer (MARGE) concept is driven by the size of the GPR antenna, which is approximately 50×50 cm and capable of transmitting and receiving an ultra-wide frequency band from 120 MHz to 2 GHz. A lighter, 30×20 cm Mini-MARGE conceptual configuration has frequency and bandwidth of 900 MHz and a smaller antenna, and it could be adopted for more restricted payload mass/volume requirements or a different set of science or exploration goals (Figure 2).

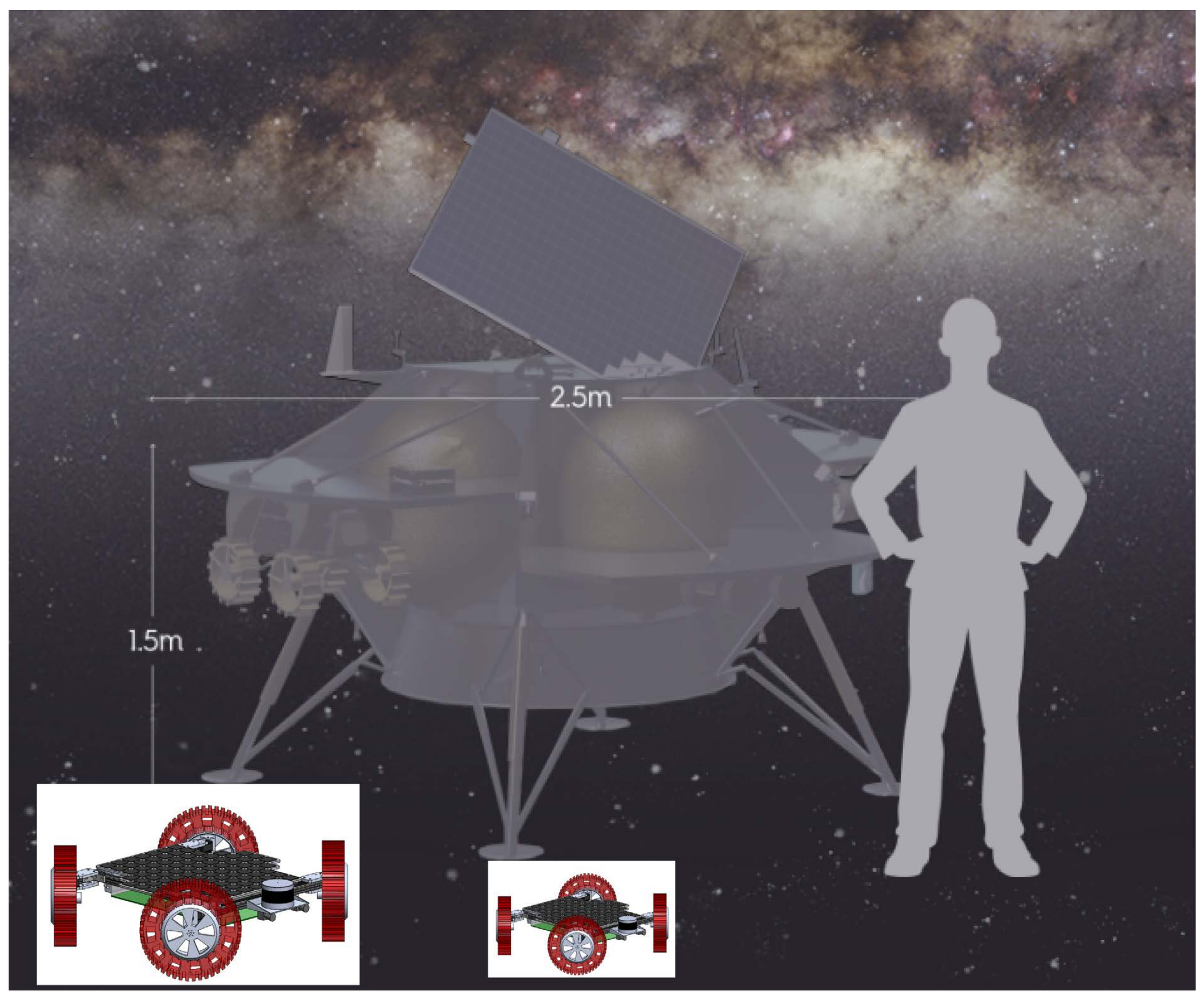
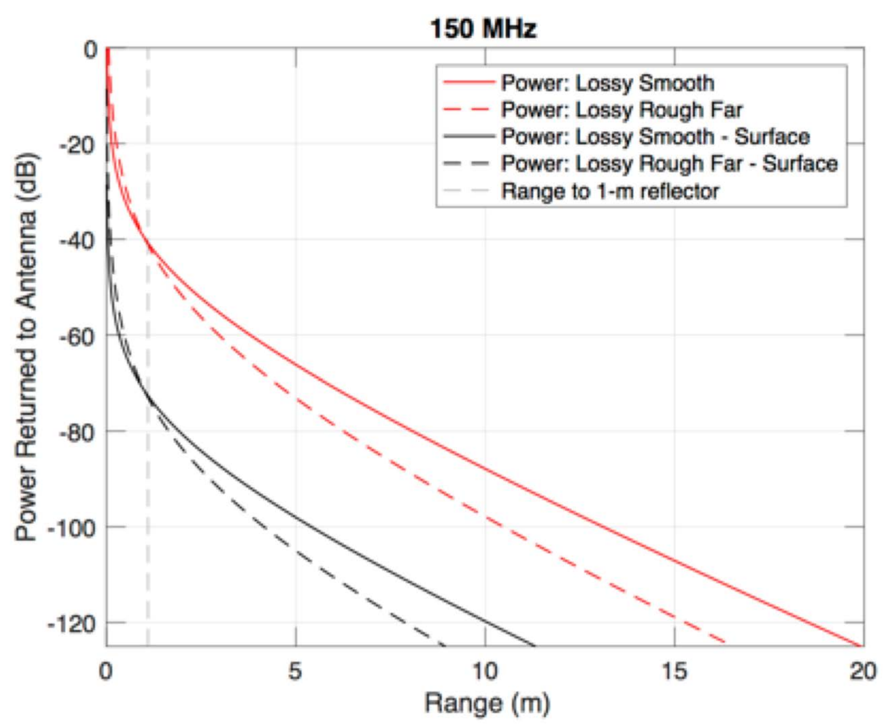


Figure 2– MARGE and Mini-MARGE concepts next to a drawing of Astrobotic's Peregrine Lunar Lander



Link analysis for a reflection arising from a regolith/rock dielectric interface for increasing depth (range).

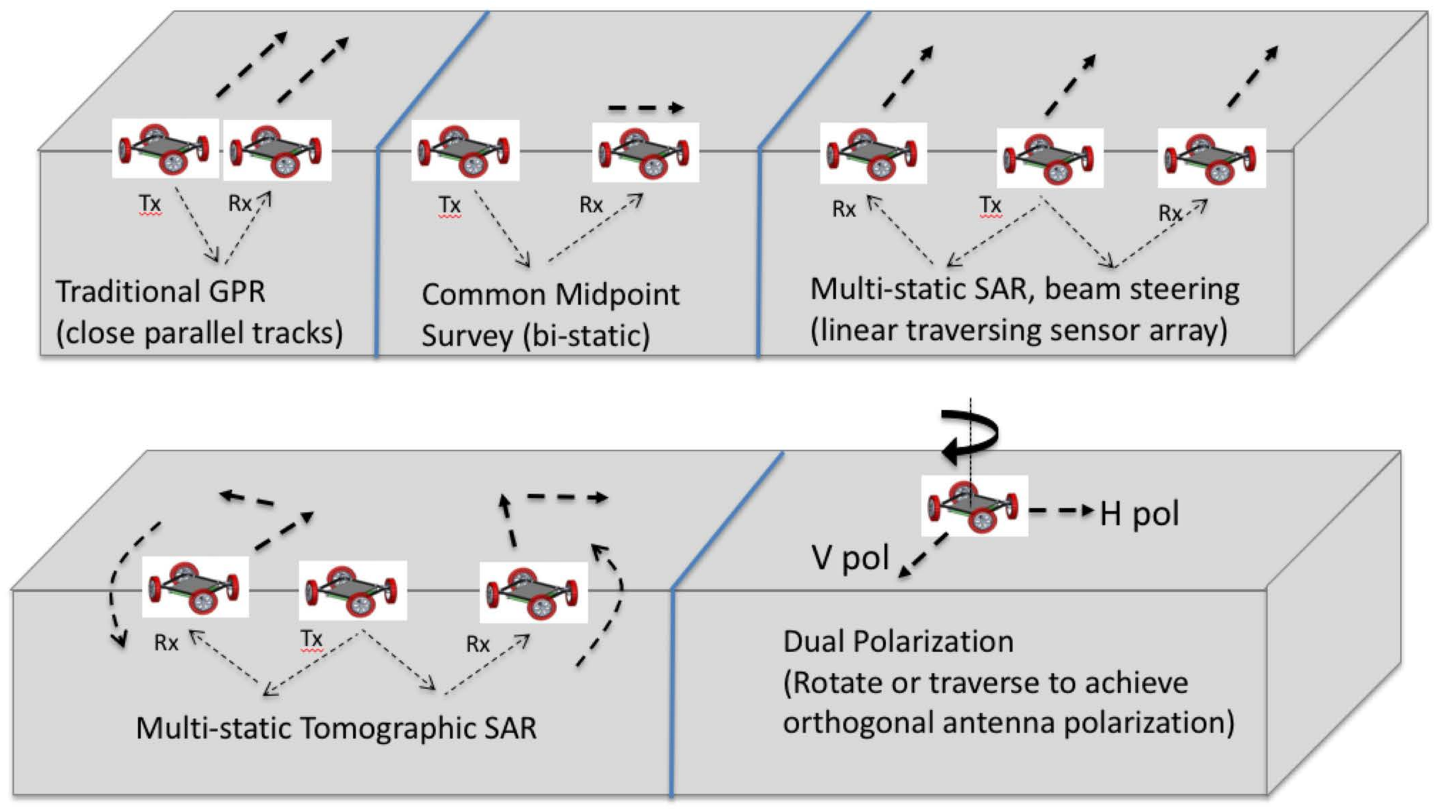


Figure 1 – Survey configurations for conceptual DASHER and MARGE agents.

Common strategies: Since Sojourner, survivability has depended on active and passive thermal management, through a combination of battery-powered heaters, small radioisotope power systems and heat sources and thermal insulation like aerogel [6]. These have worked reasonably well in the past. The long dark period on the moon makes heating a power hungry option. Commercial landers may not wish to use radioisotope heating units at least in the beginning. Our heritage solutions for Mars or the past lunar missions may not always apply to this new opportunity.

New Strategy: To survive the relatively long lunar night we propose to shift the strategy from one of full dependence on thermal management to one of increasing thermal tolerance. For example, special components and electrical traces that are tolerant to variations on the order of 300°C can be used. This comes down to material and alloy selection and architecture. Specific power storage solutions tailored to survival of freeze/thaw cycles and the heat of the lunar day as well as concepts of operations that allow for opportunistic operation between thermal extremes are needed. We will present some possible solutions to these challenges based off our current effort on MARGE.

REFERENCES: [1] Hagfors, T. (1970), *Radio Sci., 5*(2), 189-227. **[2]** Nozette, S. et al. (1996), *Science, 274*(5292), 1495. 10.1126/science.274.5292.1495. **[3]** Phillips, R. J. et al. (1973),*LPSC Proceedings*, Houston, TX. **[4]** Fa, W. et al. (2015), *GRL 42*(23), 10,179-110,187. [5] Karras, J. T. et al. (2017), *IEEE International Conference on Robotics and Automation (ICRA)*.