DEPLOYING GROUND PENETRATING RADAR IN PLANETARY ANALOG SITES TO EVALUATE POTENTIAL INSTRUMENT CAPABILITIES ON FUTURE MARS MISSIONS.

K. K. Williams[1], J. A. Grant[1], A. E. Schutz[2], and C. J. Leuschen[3]. [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC, 20013, williamsk@nasm.si.edu, [2]Geophysical Survey Systems, Inc., 13 Klein Drive, North Salem, NH, 03073, [3]The Johns Hopkins University Applied Physics Lab, 11100 Johns Hopkins Road, Laurel, MD, 20723.

Introduction: Over the past 30 years, the number of applications for ground penetrating radar (GPR) has increased dramatically, leading to GPR being an invaluable tool for efficient, non-intrusive investigation of subsurface structure and properties [1-3]. GPR has been used on Earth to address a variety of geological, archaeological, and engineering problems. Typical GPR operation involves pulling an antenna across the ground, sending a radar signal into the subsurface, and collecting the returned signal to reveal information about the dielectric properties and structure of subsurface materials and interfaces.

Terrestrial GPRs operate over a large frequency range from less than 2 MHz to ~1.5 GHz, depending on the desired depth of penetration and resolution where lower frequencies penetrate deeper at lesser resolution. Penetration depth also depends on material properties, but GPRs operating between 100 and 1000 MHz can often penetrate up to 10-20 m. This frequency range is between the lower frequencies of airborne and orbital radar sounders [4-6] and the higher frequencies of airborne and orbital imaging radars [7,8] and is effective in constraining near surface geologic structure and setting. The ability to reveal subsurface structure remotely without drilling or excavating has proven economical and even invaluable in some applications on Earth and would add a new dimension to rover-based investigations on Mars, the Moon, or other solar system bodies.

Field Operations: In recognition of the potential benefits of a GPR on future rovers and landed missions, fieldwork has been conducted and is underway in Mars analog terrains to demonstrate the mission relevant abilities of GPR. Other studies [e.g., 9-11] have used GPR to study Mars analog sites in Egypt and other arid areas and have shown the remarkable ability of GPR to provide data about the subsurface that can be used to constrain the local geologic setting and history. Recognition of the potential for a GPR onboard the 2009 Mars Science Laboratory (MSL) rover [12] has motivated collection of additional GPR data using a prototype instrument being designed for Mars.

Arizona Fieldwork. Several volcanic, cratered, and fluvially modified sites in northern Arizona were selected for GPR deployment and included Sunset Crater, Meteor Crater, and the 2002 FIDO test site near Cameron, respectively. At each site, GPR data were collected using commercial antennas at 400 MHz, 500 MHz, and 1.5 GHz, as well as a 600 MHz prototype Mars impulse GPR antenna. The commercial antennas were dragged on the ground, whereas the prototype antenna was above the ground off the back of a metal wagon that was used to simulate a rover (Figure 1).

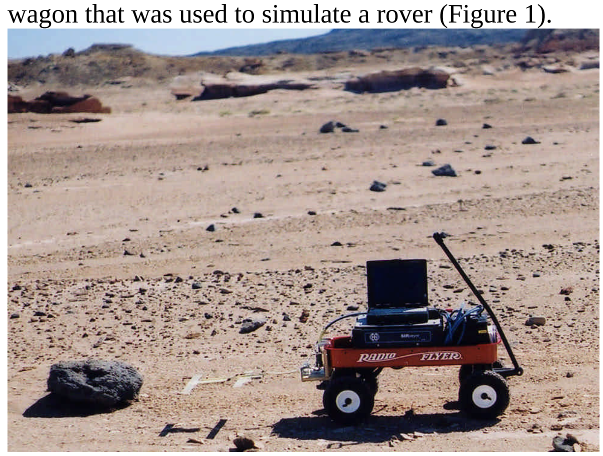

Fig. 1. Prototype Mars GPR antenna attached to the 'rover' carrying the battery and electronics. Antenna is ~20 cm above the ground. Image is from the 2002 FIDO site.

Results: GPR data collected at the Arizona sites reveal subsurface interfaces that help determine the geologic setting of each site. At Sunset Crater (Fig. 2 and 3), several episodes of volcanic cinder deposition have buried a pre-existing lava flow that crops out at the end of the data track. There has also been aeolian reworking of cinders that results in filling of low areas.

At Meteor Crater, data were collected where the top of the ejecta blanket dips below fine-grained alluvium. Even though the dielectric constant of the alluvium is relatively high ($\varepsilon = 5$), the buried top of the ejecta is evident in GPR data to a depth of ~2.5m. By contrast, data from the FIDO site revealed the absence of a buried eroded channel, highlighting the stripped nature of the setting.

Our results demonstrate the ability to distinguish a variety of units in each of these locales and suggest that a rover operating in the same settings on Mars could employ GPR to determine drilling depths to obscured lava flow or other material for in situ sampling.

Fig. 2. Data track (yellow) from the base of a volcanic cone to an outcrop of the underlying basalt flow (foreground). Geologist at base of the cone for scale.

Future Fieldwork*:* Planning is underway for data collection in areas of permafrost and buried ground ice in early March. Work will be carried out in the MacKenzie Delta, Northwest Territories, Canada. Previous and ongoing research by Canadian researchers [13] focuses on understanding the distribution of massive ground ice and the effects of climate. The current work will target several types of near-surface ground ice that could potentially exist on Mars [14,15], including buried massive ice, ice wedges, pingos, and ice-rich soil. Analysis of GPR data of these features will help determine their distribution laterally and with depth, and data collected with the prototype Mars GPR will demonstrate capabilities for mapping the distribution of subsurface ice on Mars.

Summary: Results of this and other geologic GPR studies show that information about the shallow subsurface at a landing site can illuminate a new dimension of rover-based Mars science. A rover-deployed GPR on Mars could enable 3-D mapping of local stratigraphy and has the potential to penetrate aeolian material or snow masking layered or ice-rich units or gullies [16-18]. GPR data would also be useful for defining the stratigraphy of polar layered deposits [19], determining the distribution of high latitude ground ice [20,21], and defining the degree of weathering on a surface or subsurface. Lastly, GPR can provide the geologic context of a landing site necessary to guide other rover instruments and can detect hazards such as voids or dust-filled cracks prior to their engagement.

Given these potential capabilities, a rover-deployed impulse GPR on Mars could result in measurements relevant to a range of NASA Mars Exploration Program goals. In particular, a GPR would be a timely addition to the 2009 MSL mission, which would likely have a nominal mission of two Earth years. Because MSL would travel much farther and over more varying terrain than the MER rovers, GPR could provide subsurface information needed to fully and efficiently understand the changing geologic setting.

References: [1] Ulriksen, C.P.F. (1982) *Applications of Impulse Radar to Civil Engineering*: Ph.D. Thesis, Sweden. [2] Grant, J.A. et al. (2003) *JGR*, *108*. [3] Leuschen, C. et al. (2003) *JGR*, *108*. [4] Holt, J.W. et al. (2003) *EOS Trans. AGU*, *84*(46), Abstract P31B-1058. [5] Safaeinili, A. et al. (2001).*Geophys. Detection of Subsurf. Water on Mars*, Abstract #7032. [6] Seu, R. et al. (2003) *Sixth Mars*, Abstract #3079. [7] Lou, Y. et al. (2001) *IEEE IGARSS '01*, 2046. [8] Jordan, R.L et al. (1995) *IEEE Trans. Geosci. Remote Sens*., *33*, 829. [9] Maxwell, T.A. et al. (2002) *GSA*, *34*, 174. [10] Paillou, P. et al. (2001) *GRL*, *28*, 911. [11] Grant, J.A. et al. (2004) *JGR* (submitted). [12] Arvidson, R.E. et al. (2001) *NASA MEP 2007 Smart Lander Mission Science Definition Team Report*, Washington, DC. [13] Calvert, H.T. et al. (2001) *Geophys. Detection of Subsurf. Water on Mars*, Abstract #7041. [14] Carr, M.H. and Schaber, G.G. (1977) *JGR*, *82*, 4039. [15] Leverington, L.W. (2003) *Mars Polar Conf*., Abstract #8013. [16] Christensen. P.R. (2986) *JGR*, *91*, 3533. [17] Ruff, S.W. and Christensen. P.R. (2001) *1st MER Landing Site Workshop*, A.R.C., CA. [18] Christensen, P.R. (2003) *Nature*, *422*, 45. [19] Malin, M.C. and Edgett, K.S. (2001) *JGR*, *106*, 23429. [20] Boynton, W.V. et al. (2002) *Science*, *297*, 81. [21] Feldman, W.C. et al. (2002) *Science*, *297*, 75.

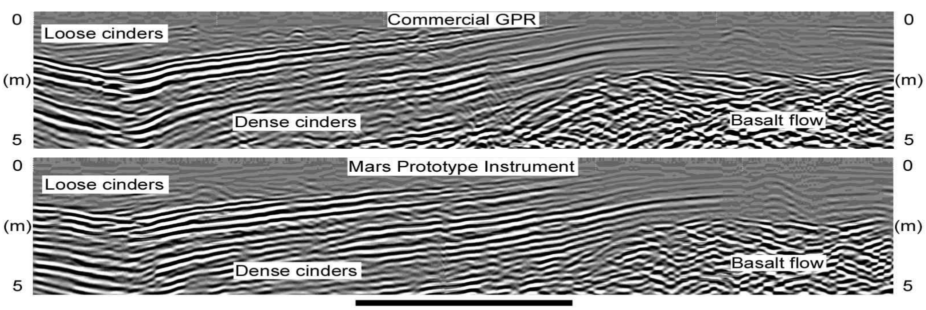

Fig. 3. Portion of data track at Sunset Crater. Left side is at the base of the cone. Data collected with a 400 MHz commercial antenna (top) show layered cinders overlaying a lava flow. Data collected with the prototype Mars antenna (bottom) match extremely well.