Miniature Ground Penetrating Radar (GPR) for Martian Exploration: Interrogating the shallow subsurface of Mars from the surface. Soon Sam Kim[1] Steven R. Carnes[1] and Christopher T.Ulmer[2], [1]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Dr., Pasadena, CA 91109, e-mail: Soonsam.Kim@jpl.nasa.gov Steven.R.Carnes@jpl.nasa.gov), [2]Ulmer Systems, Inc. (Los Angeles, CA 90017, e-mail: chrisulmer@ymail.com).

Introduction: Through previous NASA miniature instrument development programs including, PIDDP, MIDP and Lunar and Planetary Surface Operations (LPSO, ESR&T) program, we have developed a miniature ground penetrating radar (GPR) for mapping subsurface stratigraphy from a rover platform for Mars and other planetary applications. The GPR instrument has been field tested extensively, and currently at TRL 4-5 [1].

We would further develop the Mars GPR to TRL 6 and beyond, optimized for the Mars prospecting applications. The GPR would be an essential part of NASA's prospecting needs for Martian exploration.

For the Martian subsurface characterization, there have been two orbitor based GPR survey as listed in Table 1. However, for prospecting purposes, one needs local subsurface stratigraphy with higher resolution. Thus, the JPL developed Rover GPR would satisfy NASA's need for SMD, HEOMD and OCT objectives.

Table 1. Comparison of orbital GPR vs. rover GPR.

Instrument	MARSIS (2003)	SHARAD (2005)	JPL Rover GPR
Space Craft	Mars Express	MRO	
Frequency (MHz)	1.4 – 5.5	15-25	80/800
Penetration Depth (m)	~ 5000	500 ~ 1000	50/5
Resolution (Depth)	50-100 m	15 m	1.5m/15 cm
Resolution (Horizontal)	5-10 km	0.3-3 km	<0.5 m

Martian Prospecting Applicability: Possible causes of stratigraphy are ice layers, regolith/bedrock interfaces and contrasts in sediment porosity and mineralogy (feldspars vs. mafic minerals).

By characterization of subsurface stratigraphy, GPR data will provide critical guidance for a trench-based sampling, e.g., for the ISRU:

(a) GPR would discover shallow subsurface features not exposed to surface by penetrating through an overburden (Fig. 1). Under a slanting stratigraphy, GPR could guide a rover to positions where the layer is close to the surface for easy sampling. It would also show the extent of the homogeneity of the layer, thus the utility of sampling depth.

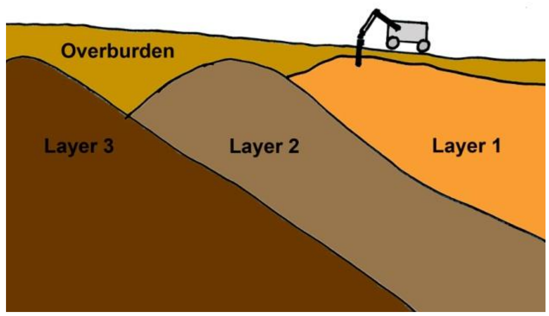

Fig. 1. Guidance of sampling sites by a rover based GPR.

(b) GPR data would show relative dielectric constant contrasts and the phase of the reflected wavelets from each layer. One could obtain constraints on subsurface materials of the layer, including presence of water-ice to a depth of 50/5 m, depending on the antenna length (80 MHz, 2m/800 MHz, 1m). For the detection of hydrogen (water), Mars Odyssey (2001) Neutron Spectrometer showed the distribution, however, unlike GPR, the penetration depth is limited up to 1 m.

In summary, GPR data would give the extent of homogeneity along the same stratigraphy, and guide the next sampling sites in search for different subsurface layers. GPR data would be used to interpret stratigraphic dips, thicknesses and layer homogeneities. In addition, the data would establish constraints on subsurface materials and help identify potential sampling for ISRU, as well as building sites for manned posts.

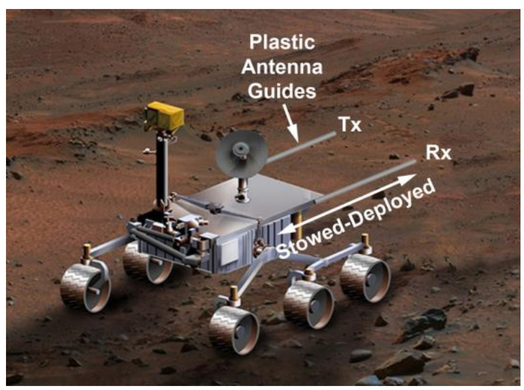

Fig. 2. Deployment concept for JPL miniature GPR on MER or MSL sized rover. The wire antennas (Tx/Rx, resistively loaded dipole, 1m – 2m length) would be deployed through 2 plastic tubings as guides, and stowed by retraction.

Deployment concept of the GPR is shown in Fig. 2. The GPR electronics would be housed inside a rover warm electronics box, and the antennas would be placed on a light weight plastic platform (just enough to support two wire antennas) that could be stowed and deployed at the backside of a rover.

GPR Instrumentation: The GPR is a short-pulse system (impulse GPR), which detects stratigraphic interfaces between materials of differing dielectric permittivity. The operation of GPR is simple, radio frequency (RF) pulses are radiated into the ground through a transmit antenna (Tx) and the RF reflections back from the interfaces are detected through a receive antenna (Rx), amplified and compiled as signal. A block diagram and fabricated JPL GPR electronics board are shown in Fig. 3. The prototype GPR has miniaturized radar electronics (2 boards of 5 x 10 x 2 cm, 1W power, 45g), with a power source (9 VDC) and two resistively loaded dipole antennas (Tx and Rx). It has two antenna configurations: 2 m length for deeper penetration (80 MHz center frequency) up to 50 m depth into the Martian subsurface at moderate resolution (1.5 m) for a geological characterization; and 1 m length for shallow penetration (800 MHz center frequency) up to 5 m depth to give a finer resolution of 15 cm. The GPR has been extensively field tested.

Field Testing at Mars Analog Site: The GPR was tested along the Kilauea Southwest Rift, in Hawaii Volcano's National Park [2]. This site is ideal due to the exposed layers that can be compared with stratigraphy obtained by GPR (Fig. 4). Overall, GPR variations in unit thickness and contours are confirmed by exposed rift stratigraphy.

The material making up the layers is ash derived from numerous eruptions of Halema'uma'u. The mineralogy of the ash is characteristically basaltic, including pyroxene, plagioclase, olivine, magnetite, and hematite. The material is indurated by hydrated opaline silica, which has the appearance of a white coating. The ash particles are angular and poorly sorted, ranging in size from very fine to coarse, with frequent cobble-sized ejecta.

References: [1] Kim, S. S., Carnes, S.R. Haldemann, A.F., Ulmer, C.T., Ng, E. and Arcone, S.A. "Miniature Ground Penetrating Radar, CRUX GPR," Paper No. 1365, 2006 IEEE Aerospace Conference, Big Sky, Montana, March 4-11, 2006. [2] Easton, R.M. (1987), Volcanism in Hawaii, edited by R.W. Decker, T.L. Wright, and P.H. Stauffler, 243–260.

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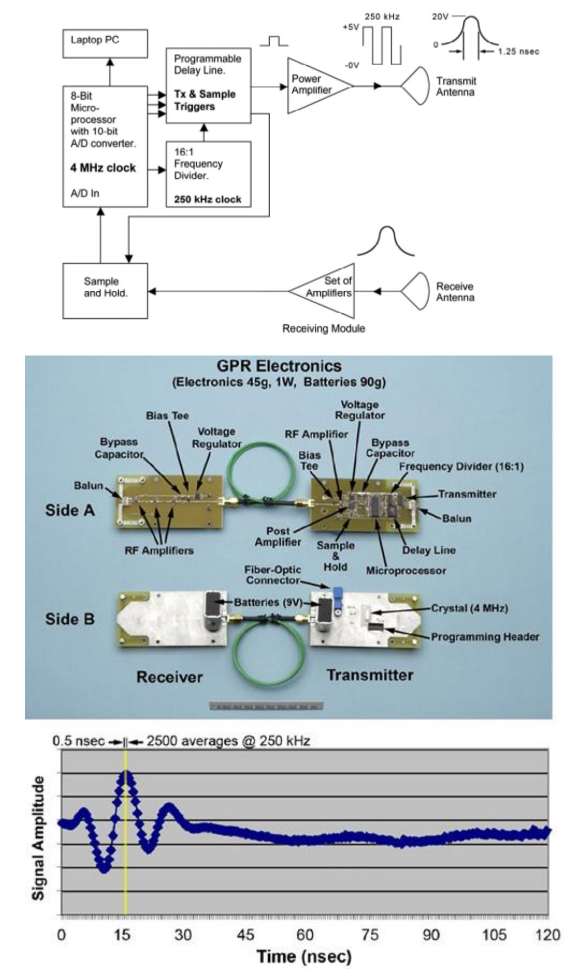

Fig.3. Top, JPL GPR Block diagram; middle, GPR Electronics board; bottom, "box-car" sampling mode.

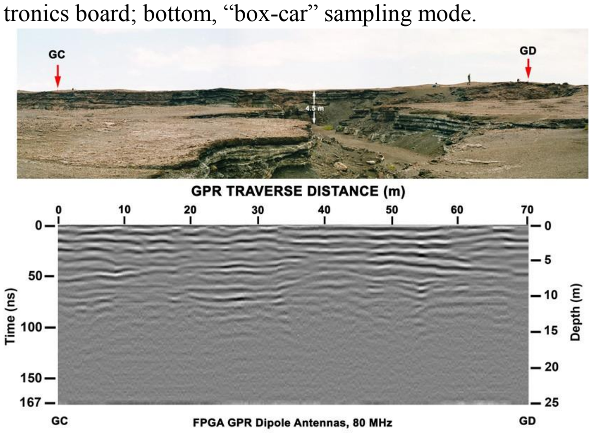

Fig. 4. Kilauea Southwest Rift, Hawaii. Top, GPR traverse was made along the rift, from GD to GC. Bottom, GPR trace with resistively loaded dipole antennas. GPR traces show variations in unit thickness and contours that can be confirmed by exposed rift stratigraphy along the rift. The depth was calculated with dielectric constant, ε' = 4.