PENETRATION TESTING OF THE OPRA REGOLITH PENETRATOR

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Introduction: The Optical Probe for Regolith Analysis (OPRA) is under development at the University of Arkansas. It will consist of a spike-shaped surface probe delivered to a planet, asteroid, or cometary body by a lander and/or rover. As shown in Figure 1, the probe will have a series of optical windows along its length, each having two fiber optics running out of the top of the probe to an FTIR unit in the spacecraft's body. Once inserted into the surface, the FTIR will address each window one at a time, using one fiber to illuminate and the other to return the reflected signal. This then provides reflectance IR spectroscopy as a function of depth beneath the surface. The wavelength range will likely be 0.8 – 5 microns with 1 cm diameter windows spaced about every 2 cm.

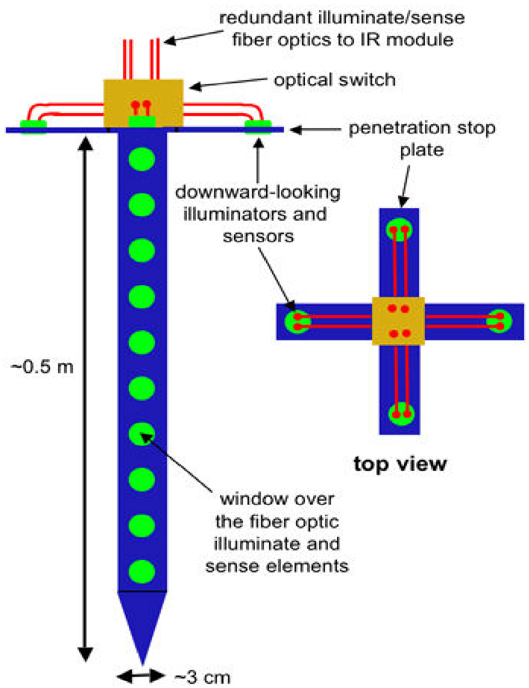

Figure 1. The Optical Probe for Regolith Analysis.

The purpose of this project is to measure the force required to insert and withdraw such a probe in simulated Martian regolith with regard to its length, shape, thickness and taper. A separate project is addressing the optical design of the windows, fiber optic coupling and sample illumination issues and is being presented at this conference as "Optical Design of OPRA" [1]. The results of both projects will determine the final shape and size of the probe.

Design Envelope: The current baselines for the mechanical design are: length = 0.2 - 0.5 m, diameter = 1 - 4 cm, tip length = 3 - 10 cm, and cross sectional shape = circular, square, or triangular. A circular cross section will be investigated since it is a nominal shape, but the final probe probably will have at least one flat face to more easily accommodate the windows.

Experimental Methods and Equipment: A probe for testing is machined from bar stock in the shape, diameter and tip length desired. Two soil simulants are used: (1) *JSC Mars-1* which contains feldspar, Ti-magnetite, minor olivine, pyroxene and glass. It has a close spectral match to the bright regions on Mars. (2) *JPL Mars Simulant:* 45% clay, 45% basalt, 10% iron oxide.

Penetration testing is performed in constant velocity mode at a rate of 7 mm/sec. The test system, shown in Figure 2, consists of a constant-speed motor driving a linear actuator screw that pushes the probe down and pulls it back out. The probe does not rotate during testing. A load cell is mounted between the force actuator and the probe for force measurement, both in and out. The electric actuator pushes the probe down to a designated depth and stops there while continuously measuring the force required.

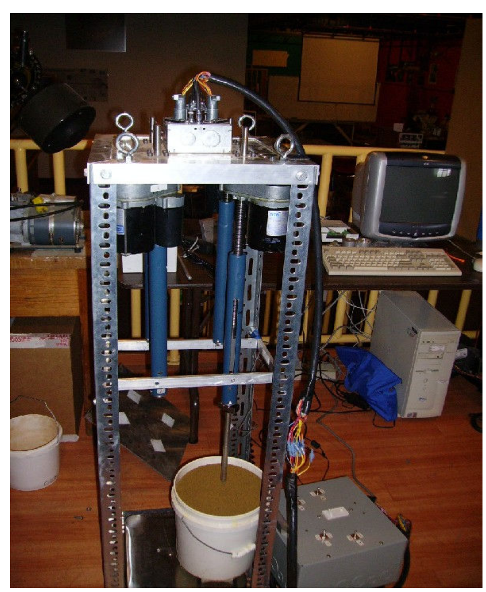

Figure 2. Constant velocity penetration test apparatus.

Effects of Diameter: Two probes with different diameters (12.7 and 19.1 mm) were fabricated with a 60° tip angle and pushed into JSC Mars-1 to a depth of 15.2 cm. The larger probe had a diameter 50% larger than the smaller amounting to an area ratio of 2.3 and required about three times the force to achieve any depth (Figure 3). To reach the full depth of 15.2 cm, the forces were 212 N and 79 N. For this experiment, the difference in required force is close to the area ratio.

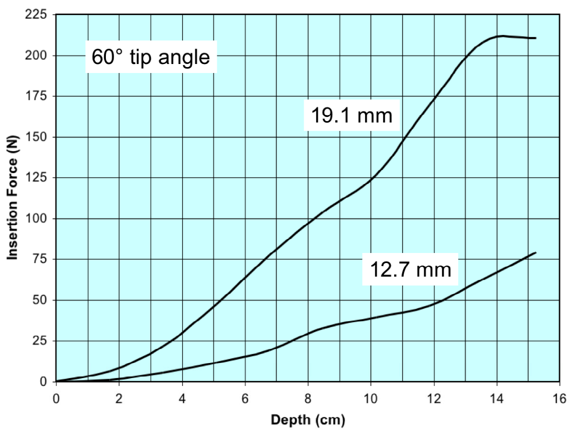

Figure 3. Force required to insert a 12.7 mm and 19.1 mm probes into JSC Mars-1. Both had 60° tip angles.

Withdrawal forces were much less than insertion forces for both. It took 6 N to remove 19.1 mm spike and 3 N to remove the 12.7 mm spike from a total depth of 15.2 cm.

Effects of Regolith Texture: Inserting identical spikes into both regolith simulants showed that the required forces for the JPL Mars simulant was about 1/10 that required for the coarser-grained JSC Mars-1 material.

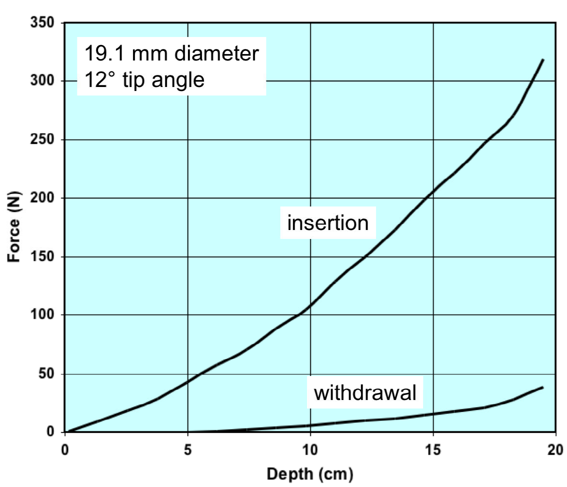

Figure 4. 19.1 mm diameter cylindrical spike with 12° tip angles in JPL Mars stimulant

Effects of Tip Angle: Two 19.1 mm probes were tested with 12° and 19° tip angles. The insertion and withdrawal forces for these two spikes are very close as shown in Figures 4 and 5. Since the tips alone were 9.1 cm long for the 12° model and 5.7 cm for 19°, this is the minimum insertion distance to get the first window to the surface. Therefore, 98 N was required with the 12° tip to get the first window down to the surface, but only 56 N for the shorter 19° tip. Withdrawal forces were in all cases much lower than insertion forces.

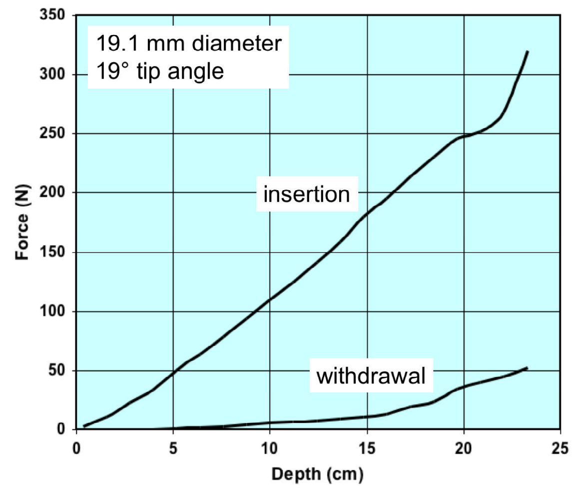

Figure 5. 19.1 mm diameter cylindrical spike with 19° tip angles in JPL Mars stimulant

Conclusions – The NASA Phoenix Mars lander has a weight on Mars of about 1530 N while Spirit and Opportunity weigh 690 N. Even these relatively light structures can provide an anchor force well in excess of what's required for the penetrators tested to date. Future landers such as MSL will exceed 3000 N.

We can conclude that sufficient anchoring force will be available for the penetrators we are currently investigating and that withdrawal forces will be considerably less than the forces required to insert them, an important consideration to mission safety.

In future work we will continue testing a variety of probe sizes and shapes. Towards the end of Spring 2008, these results will be combined with those from the optical testing program to finalize a probe configuration.

References: [1] Pilgrim et al., Optical Design of OPRA, submitted to the 39th Lunar and Planetary Science Conference.