MINIATURE CONE PENETROMETER FOR *IN SITU* CHARACTERIZATION AND SAMPLING OF THE MARTIAN SUBSURFACE. J. W. Haas and J. D. Shinn, Applied Research Associates, 415 Waterman Rd., S. Royalton, VT 05068 (jhaas@ara.com).

Over the past decade, cone penetrometer technology (CPT) has emerged as one of the most useful and efficient instruments for characterizing, both physically and chemically, the terrestrial subsurface. The penetrometer consists of a cylindrical rod string, terminated in a solid conical tip that can be dynamically or quasi-statically driven into the ground to depths of up to 200 feet. It is a nearly ideal platform for *in situ* sensor deployment and has been widely employed by geologists and engineers to study the geophysical properties of soils in support of construction projects. The technique is also used in hazardous waste site investigations to determine soil properties and stratigraphy, as well as delineate subsurface chemical contaminant plumes and collect soil samples.

In the course of its development, CPT has demonstrated many distinct cost and technical advantages over competing methodologies. For example, CPT provides a **continuous, *in situ* profile** of subsurface parameters vs. depth during a penetration. Integrating *in situ* analyzers into rotating, cutting drills and augers is exceedingly difficult. It can also collect soil cores with minimal sample disturbance as well as to emplace long-term monitoring sensors (e.g., seismic accelerometers) and sampling tubes (wells) into the subsurface - all of which have been proposed as part of future missions to Mars.

A logical extension of CPT is to exploration below the Martian surface. We believe subsurface investigation is an important next step in exploring Mars because, as on earth, most of the “keys to the past” are likely to be found underground, protected from surface weathering. Furthermore, understanding subsurface geophysical properties will also be important to successful landing of larger spacecraft, travel and construction during later human missions to the planet. Application of CPT to Mars exploration would be relatively low-risk, taking practical advantage of considerable previous investment in state-of-the-art deployment, sampling and sensing technologies. For example, nearly every one of the dozens of sensors already developed for terrestrial CPT would find a similar use on Mars. A representative list of CPT sensors and their potential application to Mars exploration is presented in Table 1. It is notable that many of these sensors have already been employed or are proposed for Martian surface investigations.

Terrestrial CPT systems are large and heavy. The keys to adapting CPT for near-term planetary exploration are to downsize the equipment, develop an alternative to the hydraulic "push" system, and reduce overall power requirements. Under a first project funded by NASA, we have established feasibility in each of these areas and designed a miniature CPT system for planetary exploration. The mini-CPT consists of small-diameter sampling and characterization probes and a unique static-impact probe deployment system that requires < 10 W electrical power and < 2.5 kg impact mass. A characterization probe that can view and measure subsurface soil particles, collect soil gases, measure temperature, classify soil type (sand, clay, etc.), and measure soil moisture (ice) content in real-time has also been designed. The miniature CPT is a versatile platform that will enable new sensor and sampling probes to be quickly integrated and deployed in support of specific Mars exploration objectives as they evolve over the next 15 years.

Table 1. Some CPT Sensors Applicable to the Exploration of Mars

Sensor	Description
Tip & sleeve load	Tip and sleeve loads are measured with strain gauges. Tip-to-sleeve stress ratio is used to classify soil type and strength.
Soil moisture-resistivity	Detects electrical contrast between geologic materials. Can be used to locate mineral deposits, organic strata and water (ice).
Seismic	Used to determine soil damping characteristics, natural seismic activity, etc.
Temperature	Provides equilibrium soil temperatures.
Redox	Measures subsurface oxidation-reduction potential in support of geochemical investigations.
Luminescence	Detects aromatic hydrocarbons and other organic/inorganic luminophores through a sapphire window.
Raman spectroscopy	Performs *in situ* mineralogical analysis with a fiber optic probe. Also identifies high concentration organics in soil.
Video	Video camera provides a real-time view of subsurface soil. Soil color as well as particle size, shape, angularity, and texture can be determined.
XRF, LIBS	Measure soil elemental composition using Sojourner-type XRF or laser induced plasma emission spectroscopy.
Fast GC	A mini-GC detects vapors generated by a unique heated soil vapor sampler.