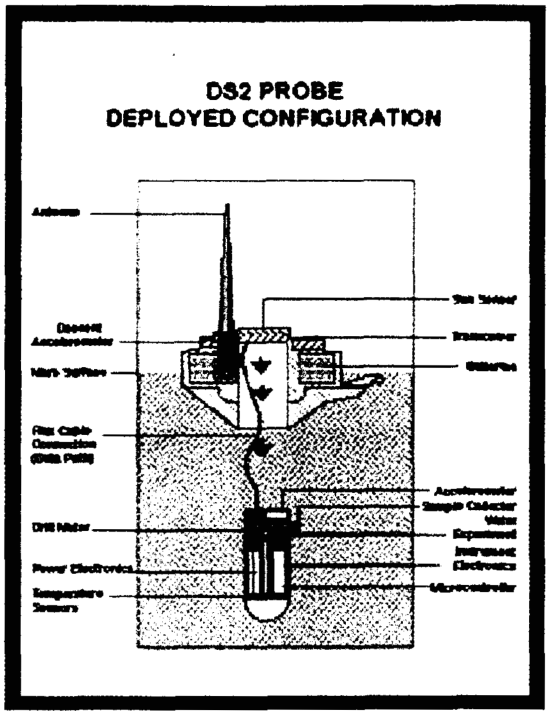
SUBSURFACE SCIENCE FROM A PENETRATOR. A. S. Yen, Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Drive, MS 183-501, Pasadena, CA 91109; Albert.Yen@jpl.nasa.gov).

Introduction ("WHY?"): Much of what we know about the geologic history and present state of Mars is based upon interpretations of data collected from the immediate surface. Unweathered soil samples covered by dust and sand sized particles may provide clues about the role of water and the biological history of the planet. The use of drills and scoops to obtain such samples for lander-based instruments implies the development of relatively large, sophisticated platforms. Small (several kilograms), scientifically focussed penetrators can carry instruments to the subsurface and should be included in the Mars exploration strategy.

Penetrator Platform ("HOW?"): One of the primary objectives of the Deep Space 2 (DS2) Microprobes was to demonstrate the ability to collect and analyze a subsurface sample. Unfortunately, neither of the probes returned data after impact with the martian surface on December 3, 1999. Options for validating the DS2 technologies by retesting aspects of the system are currently being explored. Thus, it is reasonable to expect sufficient testing heritage to conduct a penetrator-based scientific investigation for launch in 2005.

Regardless of the lander or orbiter platforms selected for upcoming launch opportunities, a small penetrator is an ideal piggyback payload and can significantly enhance the scientific return of the mission. The DS2 system consisted of a single stage entry system (~1.2 kg), an aftbody that remained on the surface to provide the telecommunications link (~1.8 kg), a forebody to conduct the subsurface science (~0.7 kg), and the interface hardware to the cruise ring (~2.9 kg). In this design, a subsurface sample is collected by a small drill, sealed by a pyrotechnic actuator, resistively heated, and analyzed for water content by thermal and spectroscopic techniques. An accelerometer was included to provide information on the actual depth of penetration. Thermal conductivity and atmospheric structure measurements were also intended.

Scientific Investigations ("WHAT?"): Here, I present two specific subsurface investigations relevant to water and biology that are compatible with a DS2-like penetrator. These investigation concepts are based upon existing technologies and could be launched as early as 2005 ("WHEN?").



History of water. Images of canyons, valley networks, and outflow channels indicate that liquid water played a significant role in developing the martian geomorphology. However, geochemical evidence in support of a sustained presence of liquid water at the surface is absent. Perhaps the strongest evidence against aqueous weathering of the exposed martian surface is the detection of extensive deposits of unaltered pyroxenes by the MGS thermal emission spectrometer [1]. In a water-rich environment, pyroxene surfaces would be rapidly converted to secondary mineral phases such as clays. Based upon terrestrial weathering rates [2], a 100 micron layer of alteration products would develop on pyroxene surfaces in less than 10^4 years. The apparent absence of clay minerals, carbonates, and hydrated mineral phases challenges the possibility of a "warm and wet" past. Where are the mineralogical markers associated with the putative aqueous history? Is it possible that they are preserved beneath the immediate surface?

A penetrator could provide access to subsurface samples and allow a direct search for indications of past aqueous episodes. The DS2 system provided a method for collecting, heating, and analyzing samples from a depth of approximately 0.5 meters, and minor modifications to this design could be applied to achieve higher temperatures and deeper penetration. Endothermic phase changes and water loss from the soil sample which are diagnostic of hydrated mineral phases can be recorded with temperature sensors and a laser spectrometer similar to DS2. Gypsum, for example, dehydrates at approximately 65°C and 100°C, interlayer water can be released from clays between 150°C and 250°C, lepidocrocite dehydrates near 300°C, goethite evolves water between 350°C and 400°C, and certain clays such as nontronite can dehydroxylate at temperatures as low as 450°C. Thus, a penetrator with thermal and evolved gas instrumentation could be sent to suspected lacustrine or evaporite units to analyze subsurface samples for the presence of hydrated mineral phases. A positive detection would obviously provide valuable information on the history of water on Mars.

Biocompatibility. The biology experiments onboard the Viking Landers did not detect evidence of life in the soil. In fact, the data revealed an unexpectedly reactive surface environment where organic molecules are actively destroyed by one or more unidentified oxidants in the soil [3]. An understanding of the composition and reactive nature of these chemical species would help guide the search for biological molecules and would allow implementation of appropriate countermeasures for minimizing the risk to humans on Mars. Are these oxidants contained in a shallow (<25 cm) surface layer, or do they extend to depths of multiple meters? How deep do we need to go to have a good chance of finding primitive biomarkers on Mars?

A penetrator providing access to the subsurface would be ideal for determining the vertical extent and variability of the oxidizing species. A sensor technique based on thin-film, metallic chemiresistors is well suited for measuring small changes in oxidizing potential. These chemical sensors are good conductors when unreacted and excellent insulators when oxidized to any of the stable oxides. Thin layers (~100 Å) of metal rapidly exhibit dramatic resistance changes when small fractions of a monolayer of metal are converted to metal oxide [4]. An array of chemiresistors in the forebody sample cup can be compared to a similar set in the aftbody to characterize the reactivity changes with depth. In addition to this gradient information, the rate of oxidation of the different thin-films in the array can provide constraints on the composition of the oxidizing species. Characterizing the vertical distribution and the composition of the reactive component in the soil is essential for understanding the biocompatibility of the surface.

Summary: A variety of scientific investigations including the search for water and unoxidized biomarkers are enabled by access to subsurface samples. A penetrator with minimal resource requirements can be carried to Mars as a piggyback payload to pursue these high-priority questions and can significantly enhance the scientific return of the primary mission.

References: [1] Bandfield, J. L. et al. (2000) *Science, 287,* 1626-1630. [2] Brantley, S. L. and Y. Chen (1995) in *Reviews in Mineralogy (v. 31).* [3] Biemann, K. et al. (1977) *J. Geophys. Res., 82,* 4641-4658. [4] Yen, A. S. (1998) Caltech Ph.D. Thesis.