STRATEGIC PLANNING FOR EXPLORATION OF THE MARTIAN SUBSURFACE. D.W. Beaty[1] and G. Briggs[2], S. M. Clifford[3], [1]David.Beaty@jpl.nasa.gov, JPL, 4800 Oak Grove Dr., M/S 264-426, Pasadena, CA 91109, [2]gbriggs@mail.arc.nasa.gov, NASA Ames Research Center, Code 239-20, Moffett Field, CA 94035, [3]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, clifford@lpi.usra.edu.

Introduction: Exploration of the upper 2-5 km of the martian crust (i.e. the portion that we can realistically envision physically accessing) is a tantalizing prospect. This may provide our best opportunity to advance the three current objectives of the Mars exploration program: Life, Climate, and Resources, with a common theme of water.

Objectives: Mars subsurface exploration has three objectives: the search for life, acquisition of water as an in-situ resource to support future human and robotic exploration, and understanding the planet's subsurface geology and hydrology (which in turn may provide critical clues regarding its hydrologic and climatic evolution).

The search for life can be advanced at several different scales. First of all, it would be useful to make measurements of the organic carbon content of material collected below the zone influenced by martian surface oxidants. This may be as shallow as a few meters or as great as a kilometer in depth. Second, water-lain sediments -- and perhaps even the frozen relic of an early ocean -- may be present beneath surficial deposits of dust and volcanics present in the northern plains [1]. Such materials, which may exist at depths ranging from several meters to several hundreds of meters, may hold the best chance of preserving a record of extinct life. Third, drilling to access subpermafrost ground water (which may reside from 2-5 km beneath the surface) offers one of the best chances of discovering extant life.

Geophysics: Geophysical investigations are critical to exploring the subsurface for two reasons. First, orbiting sounders have the potential to provide planet-wide information about gross crustal structure, lateral heterogeneity, and perhaps even the depth to liquid water. Since Mars has no rainfall (at least today), the top of the groundwater may approximate a planet-wide surface of constant geopotential [2]. However, this expected distribution may be complicated by local processes, such as low- and high-temperature hydrothermal convection, compaction and tectonic displacement. If zones of shallower water could be discovered, it would be of high value in targeting a drilling mission.

Second, landed geophysical investigations have the potential for assessing the distribution of subsurface volatiles directly. Present models of the subsurface distribution of water and ice on Mars are poorly constrained, and additional data are sorely needed. In addition, landed geophysics can also provide important information about the structure, lithology, and physical properties of the intervening crust. Such data can make a significant difference in the choice of penetration technique, cuttings removal procedures, casing techniques, and drilling strategies. Indeed, terrestrial experience has demonstrated that, without this kind of information, a drilling investigation's likelihood of success is greatly diminished. ESA's NetLanders (a local array of seismometers) may be expected to provide the first useful seismic data set.

We plan to begin planet-scale mapping of Mars with ESA's 2003 Mars Express mission which has an Italian-US ground-penetrating radar experiment. We should, however, be cautious in expecting that Mars will cooperate and that these soundings will penetrate sufficiently deeply and be reliably interpretable. A second-generation ground-penetrating radar system is already being developed in concept (one that utilizes dual-receviers and operates at greater power) that can be expected to identify an ice/brine boundary to depths of five kilometers or more [3]. A global data set from such an orbital mapping mission will provide the information needed to select a short list of optimal sites for a drilling experiment intended to reach the top of the putative hydrosphere.

Drilling: The needed drilling technology for direct subsurface exploration is clearly not available within NASA or its aerospace contractors and is, in fact, significantly different from the technology in daily use within the petroleum and gas industries. Work has been underway for the last several years to develop the necessary competency with the help of other government laboratories, industry and academia [4].

Several types of drilling approaches have been proposed. Key differences include the depth of access, the mechanics of the bit and the means of clearing the hole, and casing strategies. Some of these designs can be supported by downhole data collection, others cannot.

We expect that ongoing systems studies will lead in the next year or so to the identification of the two or three most promising lightweight, autonomous drilling systems for martian application. Such systems will have to be capable of operating initially on solar powered spacecraft and will create what would be termed micro-boreholes on Earth -- holes 2 or 3 cm in diameter from which pristine cores a cm in diameter can be extracted. Before application on Mars these systems will have to prove themselves in various Mars-analog environments on Earth, most likely including Arctic and Antarctic sites. Given the poorly explored nature of the subterranean biosphere we may expect these terrestrial demonstrations to yield significant science results.

Post- or Syn-drilling data acquisition: There are two basic strategies for interpreting the subsurface lithology. First, an appropriate set of downhole measurements, which can be collected either during or after drilling, can provide powerful information. Such downhole data collection is possible with certain drilling designs, and not possible with others. Second, samples can be returned to the martian surface, either for analysis there, or for sample return and analysis at Earth. The astrobiology-related subsurface objectives require detailed sample analysis, rather than down-hole logging.

Water production: One of the goals of subsurface exploration is to deliver liquid water to the martian surface. If a deep (2-5 km) drill hole intersects the martian water table, it may be a formidable challenge to lift water from there to the surface. In addition, it is expected that there will be significant issues regarding wellbore stability and casing perforation.

An alternative strategy is to target water in the form of ground ice (which can be melted), which may exist in the form of massive lenses or simply within the pores of volcanic and sedimentary rock. The benefit of this approach is that such targets are likely to be present at much shallower depths. The chief disadvantages are that ground ice may yield more limited quantities of water, since it won't flow towards the wellbore unless melted (an operation that requires a significant amount of energy and whose maximum volumetric influence is limited by conduction). Finally, a third way to deliver water to the surface is to produce water vapor from the unsaturated zone that may lie between the base of the cryosphere and the water table at many locations. This has the dual advantage of requiring a low level of energy at the surface, and a flowing system (potential for high volumes, but very low rates). The water produced in this way would have no value to life detection experiments.

References: [1] Clifford, S. M. and T. J. Parker, Icarus, in press; [2] Clifford, S.M., JGR 98, 10973, 1993; [3] Clifford, S. M., J. A. George,