How to Access and Sample the Deep Subsurface of Mars. J. Blacic, D. Dreesen, T. Mockler[1] and G. Briggs [2]
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We are developing a technology roadmap to support a series of Mars lander missions aimed at successively deeper and more comprehensive explorations of the Martian subsurface. The proposed mission sequence is outlined in the table below. Key to this approach is development of a drilling and sampling technology robust and flexible enough to successfully penetrate the presently unknown subsurface geology and structure. Martian environmental conditions, mission constraints of power and mass and a requirement for a high degree of automation all limit applicability of many proven terrestrial drilling technologies. Planetary protection and bioscience objectives further complicate selection of candidate systems. Nevertheless, recent advances in drilling technologies for the oil & gas, mining, underground utility and other specialty drilling industries convinces us that it will be possible to meet science and operational objectives of Mars subsurface exploration.

Building on results from three workshops that have examined the objectives and context of deep subsurface sampling on Mars, we are currently performing a preliminary engineering systems analysis of technologies for

Mission	Science Objectives	Operational Objectives
Near-Surface Recon Explorer **(1-5m depth)**	• characterize near-surface materials (cuttings samples - min/pet, geochem) • geophysical sensing of subsurface (seismic array, GPR, gravity)	• explore multiple landing sites -~1km-range rover, long-duration instruments - build geophys. network • demo return to base for sample analysis and vehicle recharge • remote control & mobility demo
Shallow Subsurface Explorer **(200m depth)**	• characterization of shallow subsurface (core samples, 1st look for organics) • expanded geophysical sensing (heat flow array)	• point landing at one of surface sites • demo partial autonomous drilling • demo hole stabilization • demo core sample handling • demo instrumented completion
Deep Subsurface Hydrosphere Explorer **(4000m depth)**	• sample deep hydrosphere • search for biosphere • expanded core analysis • expanded geophysical sensing • validate geophysical models with samples	• point landing at shallow site • demo autonomous deep sampling • demo well pressure control
Water Production **(4000m depth)**	• produce water & other resources (heat, methane, salts)	• demonstrate production well completion & operation (5cm diameter) • demonstrate resource handling/storage/processing

the ***Shallow Subsurface Explorer*** mission. This proposed mission seeks to penetrate up to 200m to acquire core samples, make geologic and geophysical measurements and function as a technology test bed for the system elements that will be needed for the more difficult deep sampling mission. In the analysis, we have identified 36 distinct drilling technologies that we considered might be applicable to this mission. Working from workshop studies yielding agreed upon constraints of mass and power and the probable shallow subsurface geologic environment, we have eliminated all but ten of these systems on first order considerations. For example, systems requiring hydrous drilling muds were eliminated on the basis of mass, contamination of samples and Mars surface temperature and pressure conditions. On the other hand, systems that can use compressed Martian atmosphere as a drilling fluid for cooling and cuttings conveyance have been retained for further analysis. This reduced list of credible systems will be analyzed in greater detail to select down to a list of 3-5 systems recommended for engineering development, terrestrial field testing and comparison. We expect a best system to emerge out of this phase for flight development.

A follow-on mission is proposed to penetrate 3-5km below Mars surface to intersect a putative hydrosphere, take samples and search for possible extant life. We hope to have learned much, both scientifically and operationally, from previous missions to make this difficult task possible. We expect to encounter additional problems of hole stability and well control related to possible geopressured zones or clathrate horizons. Similar problems are dealt with every day in terrestrial drilling, so we are confident that they can be over come on Mars if sufficient resources are available.