Considerations Related to Planning for the Exploration of the Martian Subsurface

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The Martian subsurface is of enormous interest for astrobiology, geochemistry, climatology, and In Situ Resource Utilization (ISRU) objectives, which cannot be addressed with surface missions alone. Specifically, subsurface data are needed to continue the search for extinct of extant life started by the Viking landers more than forty years ago and to prepare for human exploration. If Mars ever had life, whether it emerged on or below the surface, then as the atmosphere thinned and global temperatures dropped [1], life may have followed the groundwater table to progressively greater depths where stable liquid water could persist. At such depths, life could have been sustained by hydrothermal activity and rock-water reactions. Hence, the subsurface likely represents the longest-lived habitable environment on Mars. Moreover, while the preservation of ancient molecular biosignatures on Mars is debated, the consensus is that detection at depths greater than a few meters is favored because of the shielding from harmful radiation [e.g., 2, 3] and the possibility to preserve water/ice resources.

On one hand, if Mars hosts extant life, then the most likely place to find evidence of it may well be at depths of a few hundred meters to many kilometers, where groundwater may persist depending on local geothermal gradient [e.g., 4, 5]. On the other hand, we also face today the need to determine the presence and accessibility of resources for potential use (ISRU) and hazards to human health within the Martian subsurface, as part of the process of planning future human missions to the Red Planet.

The need to explore the Martian subsurface for astrobiology/science and resource purposes, with the support of national space agencies, academia, and the commercial sector has motivated a Keck Institute of Space Studies workshop titled "*MarsX: Mars Subsurface Exploration for Life and Resources*", held Feb. 12-16, 2018 in Pasadena, CA, with participants from NASA, JPL, ESA, SpaceX, Schlumberger, Honeybee Robotics, and various universities and research institutes.

The goal of the workshop team was to identify astrobiologically and resource-related (a) scientific measurements, instruments, and technologies, and (b) mission concepts and strategies that enable chemical characterization, mapping, and ground-truthing of subsurface volatiles, focusing on H_2O, and the overburden across multiple spatial scales, from meters to multiple kilometers.

Here, we report the outcome of this workshop, focusing on key subsurface measurements and regions of interest, the feasibility of needed exploration technologies (drilling, sounding, analytic tools, and others), and goal-oriented mission ideas to chart a roadmap for Mars subsurface access as it applies to the search for life and resources.

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