DRILLING TO EXTRACT LIQUID WATER ON MARS: FEASIBLE AND WORTH THE INVESTMENT

C. Stoker, (carol.r.stoker@nasa.gov), MS 245-3, NASA Ames Research Center, Moffett Field, CA

A critical application for the success of the Exploration Mission is developing cost effective means to extract resources from the Moon and Mars needed to support human exploration. Water is the most important resource in this regard, providing a critical life support consumable, the starting product of energy rich propellants, energy storage media (e.g. fuel cells), and a reagent used in virtually all manufacturing processes. Water is adsorbed and chemically bound in Mars soils, ice is present near the Martian surface at high latitudes, and water vapor is a minor atmospheric constituent, but extracting meaningful quantities requires large complex mechanical systems, massive feedstock handling, and large energy inputs. Liquid water aquifers are almost certain to be found at a depth of several kilometers on Mars based on our understanding of the average subsurface thermal gradient, and geological evidence from recent Mars missions suggests liquid water may be present much closer to the surface at some locations. The discovery of hundreds of recent water-carved gullies on Mars indicates liquid water can be found at depths of 200-500 meters in many locations. Drilling to obtain liquid water via pumping is therefore feasible and could lower the cost and improve the return of Mars exploration more than any other ISRU technology on the horizon. On the Moon, water ice may be found in quantity in permanently shadowed regions near the poles.

A system of modular, reconfigurable, autonomous and human-tended deep drilling technologies should be developed for use initially on Mars precursor missions and later for subsequent crewed missions that are less mass and power constrained. For the Mars application, the drilling technology will be focused on obtaining liquid water via pumping for resource utilization purposes. Early testing on the Moon could be used to establish viability of this technology so that it can be a cornerstone architecture element of Mars exploration, as well as a tool for resource exploration and science.

The required technologies for the Moon and Mars have much in common but there are important differences. On the Moon, directional drilling is likely to call for the use of a conventional drill string (similar to one under development for robotic Mars application) and a steerable down-hole unit. Hole stability in the lunar regolith will require the use of casing or of microwave sintering. Exploitation of lunar resources identified by drilling will subsequently be a mining and processing operation. On Mars the main task will be deep penetration to gain access to liquid water. Penetration to depths of kilometers would require massive equipment if a drill string is used but could be implemented using a wire-line device (one that anchors itself to the bottom of the hole and exerts force on bit from there rather than from the surface) where additional depth penetration requires only the addition of more cable. Its advantages include lightweight and convenience in automating its control since digital data can be more easily communicated. Mars ISRU goals will involve gaining controlled access to liquid water that can be pumped to the surface. Because of the stabilizing effect of ground ice, much of a Martian drill hole may not need stabilization. Preventing bit freeze up may require controlling bit temperature, and cuttings removal may require use of low temperature drilling fluids, such as liquid CO_2 derived from Mars air. It may also be necessary to line the hole with an insulating material to ensure that water does not freeze on its ascent to the surface.

Drills developed for robotic Mars mission applications have been field tested to 10 m depth. Deeper depths suggest a wire line drill string (downhole motor driving the bit) suspended on a cable and an elevator bailer to remove cuttings. Design issues to be addressed for a deep drill include operational simplicity and low mass, bit development and change-out strategies to respond to bit wear and the need to cut a range of materials, cuttings removal approach, systems for anchoring the drill string in the hole and providing weight on bit, casing for hole stability and capping to prevent destructive effects of pressure differentials.

While NASA Code S has recently invested in technology development for robotic drills for Mars exploration (and useful progress has been made) the investment is not consistent in scope with the new Space Exploration vision.