The Scientific Rationale and Technical Challenges of Drilling on the Moon and Mars C. R. Stoker, NASA Ames Research Center, M.S. 245-3, Moffett Field, CA 94035, carol.r.stoker@nasa.gov

Introduction: Drilling is a key science activity for both robotic precursor missions and human missions on both the moon and Mars. Drilling is needed to explore the third dimension to understand global processes on both bodies, and to answer many key questions. Furthermore, to get samples that are stratigraphically preserved, date from an epoch of interest, or are unaltered by surface weathering processes requires access to the subsurface.

Science Objectives: Science Objectives for the Moon that require drilling have been recently outlined [1] and include the study of regolith formation processes, sample a variety of basalts, study impact processes, characterize the lunar polar volatiles, and search for a record of the Hadean Earth. Life originated during this period and may have had multiple origin and extinction episodes.

Drilling and core sample analysis is also very important for addressing the key science questions on Mars. The highest level goal of the Mars exploration program is the search for life. The surface of Mars is hostile to the preservation of life signatures so the subsurface is most likely to hold the preserved record of biological activity on Mars. Should life survive on Mars to the present epoch, it might experience growth spurts during periods when orbital forcing increases the solar flux in the Northern plains regions resulting in ice in the near surface sediments melting to provide a liquid water niche for modern life. By drilling 5 m in the Mars Northern plains, a record of 10 M years of cycles of freezing and thawing may be accessed [2]. The growing evidence that liquid water occurs in the Martian subsurface, in some locations at relatively modest depths (100-500 m) [3], suggests searching for current life in Martain aquifers. This liquid water would also be readily accessible as a resource since it could be extracted by pumping.

Technical Capabilities: Modular, reconfigurable, autonomous and human-tended drilling systems are needed for use initially on Lunar and Mars robotic missions and ultimately by crewed missions. On the moon, the thickness of the regolith varies from ~5 to 15m so obtaining regolith samples through full depth is achievable with a 10-20 m drill, and such a system could also obtain bedrock samples and be used to emplace heat flow measurements. Similar depth of drilling on Mars could assess the preservation of biosignatures in sedimentary rocks and could assess whether liquid water occurs episodically in the Northern Plains. Automated fluidless drilling systems capable of supporting these objectives in robotic missions have been developed with NASA support for the Moon [4] and for Mars [5]. These systems use augering to bring cuttings to the surface, and depth is achieved by attaching segmented drill strings. Deep drilling (> 10s of meters) will require massive equipment if the same approach is used. An alternative low mass system is under development by my group for use in Mars ice-cemented material that uses side wall expansion anchors for downhole support and a drill head tethered to the surface so that additional depth of penetration requires only adding more cable.

A fluidless, low power, highly autonomous coring drill, capable of autonomous core ejection into a core clamp, and instruments for inspecting and documenting the core, subsampling, crushing, and performing in situ analysis for biosignatures was developed for the MARTE project and field tested to 6 m depth in a simulation of a Mars life search mission [5]. A drill system of this design could be landed on the moon or carried on a capable Lunar rover, although a relatively large mass drilling system is needed for this approach (50-100 kg, depending on depth).

Borehole logging tools have also been developed that can deteremine the presence and concentration of hydrogen, organic compounds, and biomarkers down hole, alleviating the need for sample retrieval to the surface.

Design issues to be addressed for a deep drill include operational simplicity, bit development and change-out strategies to respond to bit wear, 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, and ensuring hole stability in unconsolidated regolith. While a fully automated or Earth-supervised shallow drill is feasible, deep drilling would benefit greatly by human tending the drill at crucial junctures. Astronaut field surveys are also needed to determine where to drill.

[1] Nat. Res. Council Scientific Context for exploration of the Moon, interim report, 2006. [2] McKay, C.P. et al., 38th LPSC 2007. [3] Heldmann, J. and M. Mellon, Icarus 168, 2004. [4] www.honeybeerobotics.com/crux.html. [5]Stoker,C. et. al Astrobiology, Aug. 2008.