Mars Deep Drill Prototype Development and Test

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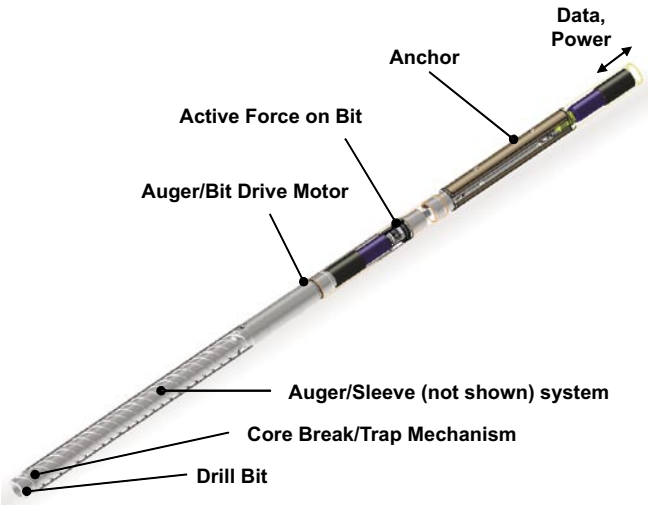
The Exploration Systems Engineering Office at Johnson Space Center (JSC) is working to develop a deep coring drill that promises significant gains in reducing mass and power requirements for subsurface planetary exploration. The purpose of this task is to explore the subsurface of Mars for both scientific and human exploration purposes. In addition to the search for resources such as water that could help enable human missions, drilling also promises to aid our understanding of the geologic and climate history of the planet and may shed light on the question of whether there may have been past life on Mars. This capability is a key component of NASA's strategic vision for exploration and of the Mars Exploration Program.

To carry out this vision, the office is developing a deep-drilling capability that we can deploy on early robotic precursor missions. In 2004, we built and tested a second-generation prototype at JSC and in the high Canadian Arctic. The drill development is a partnership between the flight expertise of JSC and the real-world drilling expertise of Baker Hughes Incorporated, a Space Act partner on this task. Key collaborators include Ames Research Center, the University of Texas at Austin, and the University of California at Berkeley.

A drill bound for Mars as part of a robotic mission will bear only a passing resemblance to drills used on Earth for geoscience drilling. We will measure the mass available for a drilling instrument in mere tens of kilograms, precluding the use of drilling fluids for removing cuttings and for cooling the bit. Severe limits also exist on the use of conventional casing, which also consumes large quantities of mass and volume. The current use of solar cell arrays on Mars also limits the amount of power available to carry out a drilling mission much less then that of the massive diesel generators used on Earth. Although power may be less of an issue if newly available nuclear power sources can be used, bit temperature considerations such as sample alteration and bit wear will likely prevent more than a few tens of watts of electrical power to be used. Given these constraints, robotic drilling on Mars will be a slow, but overall feasible, process.

To meet these challenges of robotic drilling on Mars, we developed and tested the drill system to explore low-mass, low-power drilling. The bottom hole unit is attached to a wireline, or cable, so that the depth to which the wireline can penetrate is not constrained by the mass and complexity of a drill string composed of individually joined rods, as is the case in conventional drilling on Earth. This wire could contain power and data transmission paths, as well as a mechanical connection to the drill. The bottom hole unit anchors itself to the sides of the hole being drilled, and weight on bit is provided by an internal mechanism to allow the tool to drill down.

The coring bit comminutes only the minimum amount of material needed to capture 2.5-cm diameter core. The cuttings are carried upward by an auger and deposited in a "basket" sitting on top of the core receptacle. When sufficient core has been captured, the basket is snapped off, and the entire unit is winched to the surface where the cuttings are disposed of and the core extracted. Drilling rates in sandstone of about 8 to 15 cm/hour have been demonstrated in the laboratory while expending 60 W of electrical power (~20 W mechanical). Drilling in the laboratory has reached depths up to 2.2 m in rock.

We built and tested a second-generation concept of the drill to incorporate lessons learned from the initial prototype and to add enhanced robustness and operational performance. This new drill has been field tested at a Mars analog location in the high Canadian Arctic in frozen rock and pure ice.