MITIGATING INADVERTENT CONTAMINATION IN SUBSURFACE DRILLING. B. Glass[1], G. Paulsen[2], K. Zacny[2], A. Dave[1]. [1]NASA Ames Research Center, Moffett Field, CA 94305, USA, Email: brian.glass@nasa.gov, [2]Honeybee Robotics, Pasadena, CA, 91103, USA.

Introduction: The issue of drill bits or other sampling mechanisms penetrating a subsurface Special Region is a current sampling technology gap in planetary protection. Our concept is to develop and test a new method of subsystem sterilization (bit sterilization) compatible with sample retrieval and transfer to in-situ spacecraft instruments or for sample return caching. With the drill bit's internal-heater self-sterilizing capability, this concept also tackles how we could recover during a mission if an accidental contamination does occur.

With this advance in planetary protection technologies and practices, the accidental contamination of a drill during sample transfer (or wind-blown particles off a spacecraft deck, or other vectors) would not necessarily mean a difficult choice between end-of-mission or else introducing potential contaminants into a Special Region.

Background: Our team have also participated in a Discovery-class mission proposal, called "Icebreaker", (Figure 1) which is a Phoenix-derived Mars polar lander with life and organics detection instruments and a 1 m sampling drill (McKay 2013). As a solar system exploration mission, the Icebreaker mission must comply with the Planetary Protection requirements established by NASA policy NPD 8020.7G and detailed in NPR 8020.12D, "Planetary Protection Provisions for Robotic Extraterrestrial Missions."[1].

The Phoenix mission to Mars was considered a Category IVc mission because the arm on the lander accessed a Special Region – the subsurface ice. As a result the arm was sterilized to the IVc requirements [2,3] and the rest of the spacecraft was cleaned to IVa requirements. To ensure that the arm remained sterilized the arm was encased in a biobarrier cocoon [2] during assembly and deployed from the cocoon (with some difficulty) on Mars.

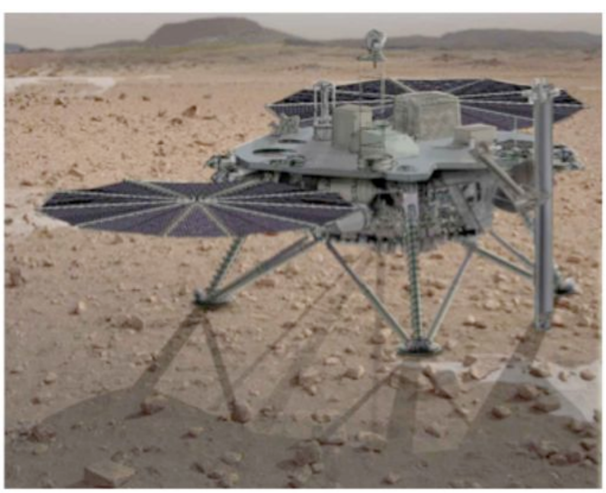
Figure 1. Concept of "Icebreaker" Phoenix-derived polar drilling lander

Mars polar drilling and sampling missions (like Icebreaker) will access the subsurface ice. If this ice is still considered a Special Region, the planetary protection requirements for Icebreaker will be the same as for Phoenix.

1. The main part of the spacecraft will need to satisfy Category IVa cleanliness.
2. The drill and any portions of the spacecraft that could come in contact with the ice in the subsurface will need to satisfy Category IVc requirements.
   - *sterilization*
   - *biobarrier containment*
   - *non-contact with unsterilized lander components during operations*

Current practice for sterilization for Planetary Protection purposes uses dry heat microbial reduction (DHMR). This is a NASA certified process [4, 1] which involves temperatures in the range of 104 to 125ºC with controlled absolute humidity, for durations that depend on the temperature. Barengoltz [5] points out that DHMR may be used without any assay and with the surface spore burden density specifications, or with a prior assay to establish a lower pretreatment density. Biobarrier containment was a significant challenge for the Phoenix arm [2] and will be a challenge for the Icebreaker drill. Any sample handling subsystem that is in contact with the drill will also have to be included within a biobarrier. On Mars, the drill assembly will have to emerge from the biobarrier to commence operations.

Approach: Automated sample delivery while breaking the chain of contact (maintaining sterile/nonsterile separations from a drill) is an unresolved technology gap that must be addressed before astrobiology missions can penetrate Category IVc (Special Region) areas. Our drilling planetary protection concept proposes to develop prototypes and test two aspects of planetary protection of the subsurface: a robotic system for retrieving and conveying drill or scoop samples to instruments, without drill contact; and a new planetary-protection technology: an embedded heat-sterilization inductive heating loop inside the drill bit, capable of re-sterilizing the drill in case of unplanned or inadvertent contact with the sample handling system (or other sources of contaminants). Of interest for study are the microbial counts before and after sterilization protocols, allowing for iterative improving of protocols and designs based on the contaminant reduction performance of these two approaches.

Our conceptual approach is to reduce spore counts by heating the drill in-situ. While a few minutes of high surface temperatures is not equivalent to Viking-standard long-duration/modest-temperature baking (~120°C x 24-48 hours), it will still reduce and alleviate spore counts blown over or from inadvertent contact with a "dirty" spacecraft.

In terrestrial exploratory drilling where bio-cross-contamination is an issue, current practice after sample acquisition is to clean and then reduce the bio-load of the drill end before re-insertion into a borehole. Under field conditions on Earth, this is typically done to exploration drills by using strong solvents and/or by dousing the drill string in alcohol and setting it on fire briefly. Heating would occur outside the borehole, and the drill string would then be expected to loiter after a heat-disinfection cycle sufficient to return to surface ambient temperatures prior to reinsertion.

As a side benefit, in an emergency an embedded bit heater could reduce mission-loss risks significantly -- by providing a means of freeing a drill string frozen stuck in an ice layer. And the bit-end temperature sensor could also be used for downhole heat-flow measurements. Starting with just an initial concept here, it would be possible to demonstrate the effectiveness of an embedded heater in a drill bit by integrating commercial off the shelf (COTS) components with existing (Icebreaker) or new drill hardware. In the design example shown in Figure 2, a 28.6 mm (1.125 inch) diameter COTS drill bit is shown with a 200 W and 871°C (1600°F) capable COTS Cartridge Heater with internal type K thermocouple. The COTS drill bit and heater/thermocouple combo are shown integrated with an existing auger design.

While there is a significant spacecraft power draw for a bit heater, it would be only about 2-3 times the load of normal drilling operation levels (70-100 W), and heated periods are expected to be much shorter than the time spent drilling. This fits within expected spacecraft drilling power budgets. If it proves to be an effective in situ sterilization approach, it could conceivably reduce or eliminate the need for DMHR/biobarrier for the bit assembly.

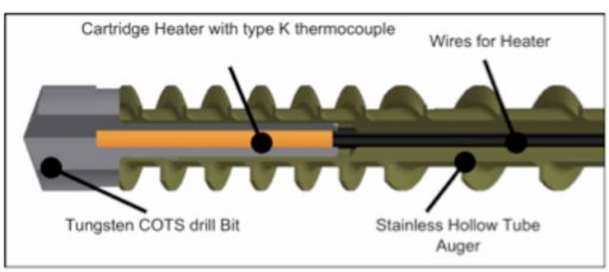

Figure 2. Location of Cartridge Heater in Icebreaker-Compatible Drill Bit.

Technology Objectives and Maturity Goals: Two key goals of this project will be to (1) assess the effectiveness of the heated drill bit to sterilize the exterior surface of the drill prior to penetrating the subsurface, and (2) to characterize the extent that drill cuttings and subsurface dusts might contaminate the drill rig, payloads, and local terrain. The 1st goal is to prevent the forward contamination of the subsurface, and the 2nd goal is to prevent the back contamination of the drill rig and terrain. We will seek to improve the readiness of planetary protection and contamination management technologies, demonstrated in both Mars chamber environments and analog-site field tests. Field tests are necessary to provide confidence in robustness, force system stand-alone integration, and to discover any unanticipated design flaws that were masked by the constraints of small test chamber sample targets.

Conclusion: A new sample acquisition planetary protection concept offers promise through the development and testing of a new method of subsystem sterilization (embedded bit heater) compatible with subsurface sample acquisition and transfer.

References: [1] NASA Procedural Directive 8020.12D (2011). [2] Salinas et al. (2007) *IEEE Aerospace Conf.* [3] Bonitz et al. (2008) *J. Geophys Res.,*113. [4] J. Barengoltz and J. Witte (2008) *Advances in Space Research,* **42.** [5] J. Barengoltz (2005) *IEEE Aerospace Conf.*