A DUAL ARCHITECTURE FOR SUBSURFACE ACCESS TO MARS VOLATILES DEPOSITS.

B. Glass[1], J. Goordial[2], V. Parro[3], S. Seitz[1], D. Bergman[4], J. Eigenbrode[5], A. Dave[1] and A. Rogg[1], [1]NASA Ames Research Center, Moffett Field, CA 94305, USA (brian.glass@nasa.gov), [2]University of Guelph, Guelph, ON N1G2W1, Canada, [3]Centro de Astrobiología (CSIC-INTA), 28850, Torrejón de Ardoz, Spain, [4]Honeybee Robotics, Altadena, CA 91001, USA, [5]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA.

Introduction: Building upon our increased knowledge and understanding on Mars polar regions, including the structure of volatiles deposits, direct in-situ access and drilling into Mars polar regions in the near surface and subsurface will be necessary to better understand Mars polar environmental processes, climate history, and potential astrobiology. Characterizing surface polar layers while searching for any biomarkers preserved in Mars polar volatiles is the focus of the Icebreaker follow-on to Phoenix, currently proposed to NASA's Discovery program [1]. In mid- and lower-latitude regions with non-polar ice deposits, in situ subsurface exploration also will be desirable for both astrobiology and in the search for accessible resources for further exploration.

Sampling and drilling in situ near-surface volatiles and near-surface stratigraphy and soil composition at the Martian polar and other volatile-bearing regions will allow us to address issues of past climate history, study volatile reservoirs and replenishment, and present-day surface processes. ExoMars in 2020-21 will sample to 2m, but is not designed to drill icy materials and will go to lower latitudes [2]. Phoenix in 2007 attempted to explore the Mars polar near-subsurface, but its arm and scoop were only able to scratch the surface as they were not able to penetrate the harder ice-cemented layers found at 20-30cm depth [3]. The proposed Icebreaker Discovery mission would return to the Phoenix region but would go deeper, with a 1m rotary-percussive drill as well as an arm and scoop for sample transfer and surface studies [4].

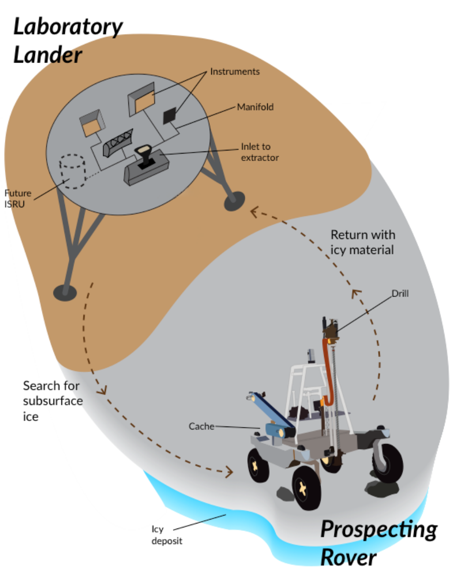

Figure 1. Concept sketch of dual-platform field operations for volatiles exploration.

Past NASA-supported drill technology prototypes have over the past 15 years developed robotic software and hardware capable of hands-off remote drilling and sample acquisition, tested both at terrestrial analog sites and in thermal vacuum chambers, with the Honeybee Trident drill design under current consideration for both Icebreaker and lunar prospecting [5]. This and prior prototypes have been tested within NASA's PSTAR program for in situ drilling and exploration for astrobiology and hence the search for near subsurface biomarkers. The current Atacama Rover Astrobiology Drilling Studies (ARADS) project has demonstrated in Chile a robotic Trident drill and sample transfer arm on a rover, acquiring samples from depths to 1m and transferring these to other instruments onboard the rover [6].

Approach: Practically, however, in recent years we have seen from both Curiosity and from the Mars 2020 Rover designs that, even on a large rover chassis, it is difficult to accommodate and support an array of in-situ instruments with suitable resolution in addition to materials acquisition and processing. And outside Mars polar regions, an immobile Phoenix/InSight or Icebreaker-class lander runs an additional mission-critical risk of landing on a no-ice dry spot, given the patchiness in subsurface ice believed to exist at Mars mid- and lower latitude sites. And constraining all Mars astrobiology or volatile-reservoirs studies to Phoenix (polar) latitudes (viz. Icebreaker) does not provide enough data points from diverse Mars locations, including the lower and mid-latitude regions most likely to host eventual human explorers.

An issue with robotic sample return to Earth is that it requires multiple Mars launch cycle opportunities. In typical terrestrial field science, field samples are gathered and classified in the field, but then brought back to a laboratory facility for detailed analysis. Likewise, resource industries prospecting on Earth typically take borehole samples, but return these to a lab for detailed analysis, rather than cart around a mobile facility.

A recent NASA white paper on accessing subsurface ice [7] addresses these polar science architectural issues regarding studying ices, biomarkers and life detection (both for their own sake and as a precursor to human exploration of Mars) and advocates (in parallel with sample return to Earth) a dual in-situ architecture with a highly-capable in-situ stationary "laboratory lander" platform for sample processing and analysis tended by a mobile, drilling "prospecting rover." The prospecting rover, similar in some respects to the lunar VIPER or Resource Prospector concepts, would locate subsurface ice, drill and capture volatile samples, then return these to the "lab-lander" for handoff for analysis and processing. As shown in **Fig. 1**, this smaller "ice prospecting rover" would locate, sample, image and retrieve ice-bearing samples, bringing them to a stationary base -- a "lab lander" platform where the detailed analysis or processing would be done. Sample transfer from a "fetch" rover to a lander is similarly an issue for Mars Sample Return. Developing mission simulations using both a rover and a static platform allows side-by-side testing to find which operations are optimized by use on which platform.

Proposed Project and Polar Analog Site: The proposed Mars Analog Research Architecture Combining Acquisition, Delivery and Analysis (MARACADA) project would develop an example of this dual rover-lander ice-sampling architecture. This project approach will bring together an existing PHX/InSight lander mockup (**Fig. 2a**) as its "lab lander" together with an existing rover/drill from ARADS (**Fig. 2b**). The "lab lander" will host and integrate current mission-capable instruments to demonstrate the science and exploration architecture.

Figure 2. (a) PHX/InSight lander mockup with Icebreaker drill in June 2017 tests (b) ARADS rover/drill.

These would be deployed and tested at the Haughton impact structure (75.4N, 89.8W), a Mars-analog field site in the Canadian Arctic. Haughton contains continuous permafrost developed on a variety of impact-related outcrops i.e., massive melt breccia deposits, intra-crater paleolacustrine deposits, and fluvioglacial deposits [8]. Haughton Crater's **"**Drill Hill" is located on a 150m-thick deposit of this impact fallback breccia, with evident periglacial structures and intermittent clear subsurface ice layers found typically within 1m of the surface [9]. MARACADA will develop the white paper's dual-platform exploration architecture by doing actual sampling and science operations with the lab-lander and prospecting rover at locations of interest within the Haughton Crater region.

Early Testing: Prior to MARACADA or similar tests at analog sites, the existing ARADS drilling rover together with local in-situ processing was demonstrated in September 2019 during the ARADS field tests in the Atacama Desert. While this was not a polar analog site,

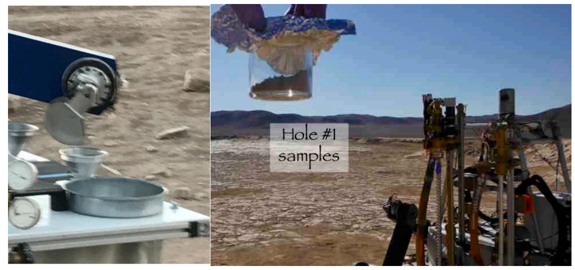

Figure 3. Drilled sample caching for later transfer for off-rover "lander" analysis, in Sept. 2019 Atacama tests.

it allowed for field experimentation with the drilling, acquisition and onboard caching (see **Fig. 3**) of subsurface samples, then used in local in-situ analysis (chromatography and the LDCHIP immunoassay instrument) not on the ARADS rover, as it traversed. Adding sample caching to the nominal onboard instrument sample distribution forced repetitive cleaning after every manual cache transfer from the rover (**Fig. 3**), to avoid contamination of the onboard instruments and drill by humans manually retrieving samples from the rover. Implementation of MARACADA's automated sample cache transfer (rover to lab-lander) would obviate this need in future tests.

Conclusions: A dual robotic architecture for in-situ prospecting and analysis of subsurface samples holds promise for future exploration of polar volatiles and other shallow subsurface deposits on Mars, as well as potentially supporting the study and exploitation of volatile reservoirs at mid-latitude sites. Following a an internal NASA near-surface volatiles exploration study, work has begun to implement and test this dual approach at Mars analogs. Technology development issues (such as autonomous surface docking and robotic cache transfer) developed in support of a dual volatiles-exploration mission architecture will also be relevant to similar issues associated with Mars sample return.

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