THE ICEBREAKER LIFE MISSION TO MARS: A SEARCH FOR BIOMOLECULAR EVIDENCE OF RECENT LIFE.

B. J. Glass[1], J. L. Heldmann[1], C. P. McKay[1], D. Bergman[2], A. Dave[1], A. Davila[1], J. Eigenbrode[3], V. Parro[4], R. Quinn[1], C. R. Stoker[1], R. Warwick[5], K. Zacny[2], and the Icebreaker Team, [1]NASA Ames Research Center, Moffett Field, CA, [2]Honeybee Robotics, Altadena, CA, [3]NASA Goddard Space Flight Center, Greenbelt, MD, [4] Centro de Astrobiologia (INTA-CSIC), Torrejon de Ardoz, Spain, [5]Lockheed Martin Space Systems Company, Littleton, CO.

Introduction: The Icebreaker mission is the first mission to search for life signatures on Mars using biomolecular methods. Icebreaker lands in the ice-rich mid-latitudes of Mars and collects samples down to at least 1 m depth to 1) search for molecular signatures of life and 2) assess the habitability of the icy regolith in the context of recent orbital cycles (Figure 1). Icebreaker is a NASA Discovery-class mission.

Science Investigations: Icebreaker addresses multiple high priority science questions and seeks to answer one of humanity's greatest questions: Is there life beyond Earth? To address this fundamental question, Icebreaker investigates icy regolith in the mid-latitudes of Mars, a region with high potential for habitability in the recent past. The mission samples icy regolith down to at least 1 m depth and measures five well-defined molecular qualities to distinguish organics produced by life and those produced abiotically. The Icebreaker organic analyses complement and expand on past and current missions, and are informed by the successful detection of organic matter by previous Mars landed missions. Icebreaker also chemically characterizes the icy regolith to provide context for interpretation of potential life signatures.

Figure 1. Artist's concept of the Mars Icebreaker lander, with drill deployed.

Science Relevance: Icebreaker addresses high-priority scientific questions within NASA's Planetary Science program and as outlined within the National Academies' Decadal Survey on Planetary Science and Astrobiology 2022-2023 [1]. Icebreaker addresses the science goals of the Decadal Survey-prioritized Mars Life Explorer (MLE) mission concept, which would search for signatures of life and understand habitability of near-surface ice".

Mission Design: The Icebreaker lander, a low risk, natural evolution of the Mars Phoenix and Mars Insight landers, delivers a carefully selected payload to the Martian surface with twice-proven EDL (Entry, Descent, and Landing) technology [2]. Once on the surface, Icebreaker's Sample Acquisition System [3] collects samples of icy regolith down to 1 meter depth and distributes them to the science instruments while preventing contamination by foreign materials. Icebreaker's analytical instruments search in the samples for molecular signatures of life in amino acids and fatty acids, two types of organic compounds universally found in life on Earth, and expected to be present in life elsewhere.

Instruments: Icebreaker relies on high heritage and high TRL (Technology Readiness Level) payload elements. The Chirality and Refractory Organic Molecule Analyzer (ChROMA), an ultrasensitive mass spectrometer with heritage from the Sample Analysis at Mars (SAM) instrument on MSL (Mars Science Laboratory)[4] and the Mars Organic Molecular Analyzer (MOMA) instrument on ExoMars [5], measures the relative abundance and enantiomeric excess in amino acids, as well as the relative abundance and molecular structure of fatty acids. The Signs Of Life Detector (SOLID) [6], a molecular recognition microarray-based optical sensor, performs an additional test for the presence of amino acid polymers. Each one of these five molecular qualities is a potential fingerprint of life. Collectively, these measurements provide a robust framework to establish whether organic matter in sampled materials formed through biological processes. Figure 2 shows an overview of the Icebreaker payloads deployed.

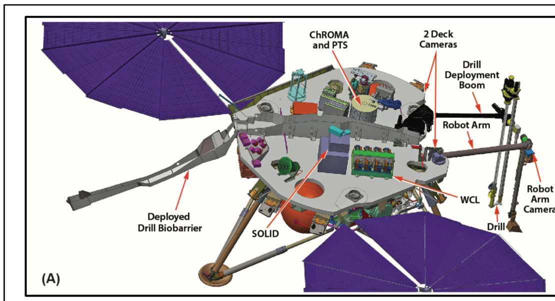

Figure 2. Payload deck overview, showing instruments and the deployed drill and sampling arm (right) after biobarrier removal (on left).

Icebreaker also performs a thorough habitability assessment based on multiple physicochemical parameters in order to place amino acid and fatty acid analyses in the proper environmental context. The Wet Chemistry Laboratory (WCL), an improved version of the successful instrument flown on the Mars Phoenix mission [7], characterizes the chemistry of icy regolith, and searches for elements and energy sources that are essential for life. The Icebreaker Imaging System (IIS) provides geologic context and documents sample acquisition and handling. The broad range of habitability parameters are used to further our understanding of the biological potential of the planet today, in the past, and in the future.

Subsurface access is achieved via the TRIDENT drill, which is being developed for flight in 2023-24 on the NASA PRIME-1 (Polar Resources Ice Mining Experiment-1)[8] and VIPER (Volatiles Investigating Polar Exploration Rover)[9] missions to the Moon. TRIDENT is a rotary percussive drill which can penetrate to depths of at least 1 m and provide cutting samples to the instruments [10]. The Sample Transfer Arm / Active Sample Ejection Device (STA-ASED) is a 4 degrees of freedom robotic manipulator arm with active ejection scoop end effector to transfer samples from the drill to the instruments. STA-ASED benefits from Mars Phoenix, InSight, and Mars Surveyor heritage [11], with an added actuator paddle.

Technology Development: Icebreaker is intentionally designed to address the highest priority science questions with the most advanced, high heritage technologies and operational concepts available for spaceflight. However, we welcome continued advances in several areas of technology development which could further optimize the Icebreaker mission.

Drilling. Continued advances in automated hands-off drilling technologies (software and hardware) which penetrate beyond 1 m into the subsurface on Mars are advantageous to enable measurements of a deeper subsurface stratigraphy and minimize radiation effects on organic molecules closer to the surface.

Planetary Protection. Planetary protection techniques (viz. the biobarrier in Fig. 2) and protocols are critical to ensuring the robustness of the Icebreaker scientific results, and hence technological advances in hardware cleaning protocols, biobarrier development, and contamination tracking would enhance the Icebreaker mission.

Sample Transfer. Icebreaker must deliver subsurface samples (including icy regolith) to the instrument inlets, and thus clean, redundant, and robust sample transfer technologies from the drill to instrument suite are beneficial to ensure optimal sample transfer for sample measurement. Figure 3 shows sample transfer from a TRIDENT drill to the STA-ASED, with a photo of prototypes.

Power Systems. On-board power storage and solar array structures can be optimized to extend the lifetime of the mission beyond the nominal Martian spring / summer months to enable more science measurements and a more thorough characterization of the landing site.

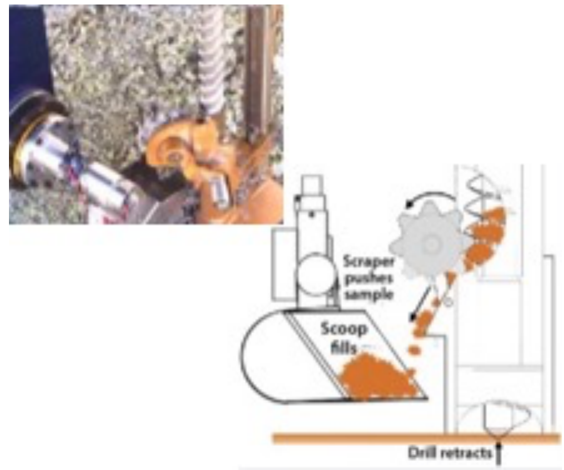

Figure 3. Sample transfer from the TRIDENT auger into the STA-ASED scoop, prior to transfer to instruments.

Operations. We welcome further optimization of science operations, including modern planning and scheduling tools for mission operations. We will benefit from VIPER's experience, as well as ongoing Mars rover missions, and are open to further improvements in scientific productivity and resource efficiency.

References: [1] Natl. Academies Press, 2022. [2] McKay, C.P., et al., *Astrobiology* 13(4):334-353, 2013. [3] Glass, B. et al., *J. Field Robotics*, 31(1):192-205, 2014. [4] Mahaffy, P.R. et al., *Space Sci Rev* 170:401–478, 2012. [5] Brinckerhoff, W., et al., *IEEE Aerospace Conference*, doi: 10.1109/AERO.2013.6496942, 2013. [6] Parro, V., et al., *Astrobiology* 11, DOI: 10.1089/ast.2010.0501, 2011. [7] Hecht, M., et al. *Science* 325(5936):64-67, July 2009. [8] www.nasa.gov/directorates/spacetech/game_changing_development/projects/PRIME-1, 1 Nov 2022. [9] Colaprete, A., et al., *AGU Fall Meeting*, #P34B-03, 2019. [10] Zacny, K., et al., *52nd LPSC*, #2400, 2021. [11] Bonitz, R. G., et al., *J. Geophys. Res.* 113:E00A01, 2009.