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THE ICEBREAKER LIFE MISSION: EXPLORING MARS FOR BIOMOLECULAR EVIDENCE OF RECENT LIFE

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The Icebreaker mission, already proposed in 2015 and 2019 to NASA's Discovery program, would be the first mission to search for life signatures on Mars using biomolecular methods. Icebreaker would land in the ice-rich mid-latitudes of Mars and collect samples down to 2m 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. Icebreaker will address 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 also will address 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".

The Icebreaker lander, based on the Mars Phoenix and Mars Insight landers (Lockheed Martin), will deliver a carefully selected in-situ science payload to the Martian surface with twice-proven EDL (Entry, Descent, and Landing) technology [2]. Once on the surface, Icebreaker's Sample

Acquisition System will drill to collect samples of icy regolith down to 2 meters depth and distribute sample materials with a robotic arm and active scoop to the science instruments (while preventing contamination by foreign materials). Subsurface access will be achieved via the Honeybee Robotics TRIDENT drill, developed for flight in 2024 on the NASA PRIME-1 (Polar Resources Ice Mining Experiment-1) and VIPER (Volatiles Investigating Polar Exploration Rover) missions to the Moon. TRIDENT is a 2m - capable rotary percussive drill, and in 2016-19 Mars-analog field site tests has been demonstrated both to 2m depth and in acquiring drilled-cuttings samples then transferred robotically to Icebreaker-prototype instruments [3].

Icebreaker's analytical instruments will search in these 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. 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. Collectively, these measurements provide a robust framework to establish whether organic matter in sampled materials formed through biological processes.

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], will characterize the chemistry of icy regolith, and search for elements and energy sources that are essential for life. The Icebreaker Imaging System (IIS) will provide geologic context and documents sample acquisition and handling. The broad range of habitability parameters addressed will be used to further our understanding of the biological potential of the planet today, in the past, and in the future.

References: [1] Natl. Academies Press, 2022. [2] McKay, C.P., et al., *Astrobiology* 13(4):334-353, 2013. [3] Glass, B., et al., *Astrobiology* 23(12): 1245-1258, 2023. [4] Mahaffy, P.R. et al., *Space Sci Rev* 170:401–478, 2012. [5] Brinckerhoff, W., et al., *IEEE Aerospace Conference*, 2013. [6] Parro, V., et al., *Astrobiology* 11, 2011. [7] Hecht, M., et al. *Science* 325(5936):64-67, July 2009.