AFFORDABLE PRECURSOR MISSIONS TO SEARCH FOR LIFE AND PAVE THE WAY FOR HUMAN EXPLORATION OF MARS

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Introduction: Humans on Mars in 2033. So reads is the headline of USA today (Nov. 5 2016) accompanying a National Geographic Special that dramatizes NASA's current plans for landing humans on Mars in that timeframe. To achieve this goal, a critical precursor program must occur in the 2020's to identify landing sites that are safe and have the necessary resources to sustain a human presence. A key precursor requirement prior to human landing is to understand whether there is extant life on Mars that could pose a risk not only to Mars crews but to Earth when the crew returns. This risk must be evaluated even if no life is currently metabolically active on Mars, because extant martian life may be presently dormant but grow when exposed to humid conditions within crew habitats or once returned to Earth. Recent discoveries related to periodic habitable conditions occurring in near surface ground ice associated with changes in orbital forcing [1], Recurring Slope Linnea [2] features that flow seasonally in association with warm temperatures, and salt deposits that can host life by concentrating atmospheric water vapor [3] suggest that Mars may host environments with habitable conditions in modern times. The possibility that life persists on Mars in near surface environments can't be ignored. Furthermore, once humans land on Mars, it will be contaminated with Earth life and a search for indigenous Martian life will be confounded. So it is important to characterize whether life exists on modern Mars prior to human landing. This paper describes mission concepts studied by the author and colleagues that provide crucial precursor information about the possibility of extant life on Mars, as well as characterizing near surface ground ice as a resource for human exploration.

Icebreaker Life Mission: The Icebreaker Life mission [4] (Figure 1) proposed to Discovery in 2015, places a small stationary lander near the high N. latitude site characterized by the Phoenix mission. Ground ice there hosts habitable conditions for life periodically, most recently during high obliquity, 0.5 to 10 M yr ago. Habitable conditions include 1) pressure above the triple point of liquid water; 2) ice near the surface as a source of liquid water; 3) high summer insolation at orbital tilts >35^{o} which recur periodically and are equivalent to levels of summer sunlight in Earth's polar regions at the present time. Terrestrial permafrost communities are examples of possible life in the ground ice. Studies in permafrost have shown that microorganisms can function in ice-soil mixtures at temperatures as low as -20°C, living in thin films of interfacial water. In addition, it is well established that ground ice preserves living cells, biological material, and organic compounds for long periods of time, and living microorganisms have been preserved under frozen conditions for thousands and sometimes millions of years. During high obliquity, which has occurred in the last 10 MY, the ground ice experiences habitable conditions down to depths of 75 cm. If inhabited and metabolically active at high obliquity, biomolecular evidence of life could have accumulated in the ice-rich regolith on Mars. The Icebreaker payload includes a 1-m drill that brings cuttings samples to the surface where they are analyzed by instruments to search for definitive biosignatures (proof) of life, as well as broad spectrum organic analysis and habitability assessment. By drilling to 1m, the history of habitable conditions in the modern epoch can be studied, and the search for life advanced.

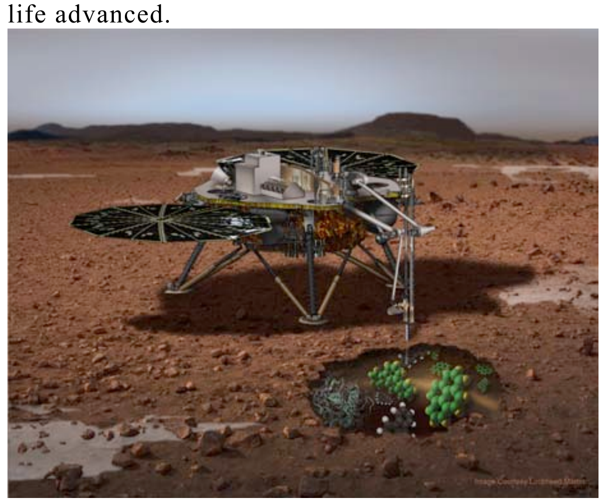

Figure 1. Icebreaker lander to search for life on Mars.

IceDragon: A human precursor mission to characterize midlatitude ground ice. Geomorphological evidence suggests ground ice is widespread on Mars north of 40^{o} latitude. Recent impacts have exposed near surface ground ice at less than 1 m depth [5] which can provide an important and easily accessible resource for human exploration. The IceDragon mission [6] has a 2m drill and payload instruments within a Red Dragon Mars lander (Fig. 2), in development by SpaceX Corp. The large interior volume of Red Dragon allows delivery of a variety of engineering and analytical payload to the surface of Mars, and payload masses in excess of a metric ton can be delivered. Mission objectives for a midlatitude ice lander include: 1) *Search for Life and assess subsurface habitability using methods proposed for Icebreaker Life, 2) Establish the origin, vertical distribution and composition of ground ice, and 3) Demonstrate ISRU for propellant production on Mars.* Furthermore, Red Dragon enters and lands on Mars using an EDL system that is relevant to spacecraft that may land humans on Mars in future missions, but have not previously been demonstrated in flight.

Figure 2. Red Dragon mars lander can host a variety of payloads including a deep drill to search for life and a return rocket to bring samples from Mars to Earth.

Mars Sample Return from potential human landing site: Previous studies have concluded that sample return from the site of future human landings would provide the best information on site characteristics and materials, including resources, and the most unambiguous way to evaluate risks to human crews. A study of Mars Sample Return using the SpaceX Dragon to land the sample return hardware [7] showed that a single landed Dragon capsule could collect samples from a potential human landing site and launch them all the way back to Earth Orbit. A rendezvous with the sample capsule in Earth orbit brings the samples to Earth while completely breaking the chain of contact with Mars, thereby addressing Planetary Protection requirements for return samples. By using the large payload capacity of Red Dragon to host both the sample collection and return rocket capabilities, Mars sample return can be achieved affordably, providing essential precursor information to prepare for human landing on Mars.

References: [1] Stoker, C.R. et al. *J.G.R.* DOI:10.1029/2009JE003421, 2010. [2] McEwen et al. *Science DOI:* 10.1126/science.1204816, 2011. [3] Davilla et al. *Astrobiolog*y DOI:10.1089/ast.2009.0421, 2010. [4] McKay, C.P. et al. *Astrobiogy* 13 (4) 334-353, 2013. [5] Byrne, S. et al. *Science* 325 (1674) 2009. [6] Stoker, C.R. et al. Concepts for Mars Exploration Houston TX June 12-14, 2012. [7] Gonzales, A. and Stoker, C.R. *Acta Astronautica* 123, 16-25, 2016.