The Search for Extant Life on Mars: A Human Exploration Objective

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Introduction: A search for evidence of extant life on Mars should be conducted prior to and as part of human exploration missions. Potentially habitable environments for modern life occur on Mars. Despite a vigorous campaign of exploration of the surface over the last 3 decades, no mission has attempted to search for signatures of extant life since the Viking landers in 1976. Finding an example of extant life beyond Earth would be one of the greatest scientific discoveries of all time. This is especially important because (once discovered) the biochemistry and metabolism of the life form can be studied. Earth and Mars exchange materials over geologic time because impacts eject rock and crustal materials into space that are eventually deposited on other planets and moons [1]. Therefore, Earth and Mars could share life with a common origin and similar biochemistry; if this is the case, life on Mars likely experienced billions of years of evolution in isolation from Earth. Alternatively, Mars may host a distinct genesis of life which could be evident from its different biochemistry. Either discovery would change our understanding of life in the solar system and beyond.

The Mars 2020/Perseverance sample collection mission is not optimized for finding extant life because the site for sample collection, Jezero Crater, was chosen for its ancient habitability and likelihood to host fossil evidence of life. Furthermore, the samples collected will not be returned for at least a decade. Within that period, technology development for human exploration will likely be underway and it is possible that humans will land on Mars without an updated knowledge of extant life on Mars, which may pose a risk both to those mission crews and to Earth when they return. Thus, it is important to perform a search for extant life on Mars prior to humans landing at a site where life may persist. Salts and shallow ground ice are particularly important environments to evaluate for extant life prior to human missions because they may be encountered and interacted with by human crews.

Salts and Evaporites: The properties of evaporates and salts make them highly desirable and easily accessible environments in the search for extant life on Mars. On Earth, evaporites and associated brines are inhabited in many places across the globe, supporting a wide diversity of microbial communities including phototrophs, lithotrophs, and heterotrophs [2]. Endolithic phototrophs are found associated with gypsum crusts, and halite-entrapped halophilic archaea and bacteria are commonly observed in enclosed brine fluids, with striking and easily detectable carotenoid pigment biosignatures [3]. Halite and gypsum minerals offer radiation protection by attenuating ultraviolet light and provide protection from long-term desiccation by deliquescence [4]. Finally, dissolved salts also extend the temperature range for maintaining liquid water through freezing point depression and by formation of supercooled liquids, expanding the possibility of life processes at subzero temperatures. Concentrated brines are also common in ice vein networks, due to exclusion of dissolved salts during freezing point depression and ice formation. Because many salts are hygroscopic, liquid brines might form near the surface in locations that receive periodic frosts. Such environments can potentially support microbial growth.

Salts and evaporites are common at the surface and near subsurface of Mars and are readily accessible to mobile platforms. Maps of the Martian surface from Thermal Emission Imaging System (THEMIS) [5] show the distribution of chloride salts on the Martian surface with at least 600 regions identified. Many sites are in local depressions that may have formed from surface runoff, groundwater upwelling, and/or hydrothermal activity. The widespread presence of perchlorate salts on Mars may allow brines to form over a large part of the Martian surface due to deliquescence [6] but currently can form only at temperatures too low for terrestrial metabolism. Still, the potential habitability of such low temperature brines should be carefully studied.

Ice Rich Terrains: These are important locations to search for extant Martian life and are planetary protection "special regions" where higher spacecraft sterilization and cleanliness is required because of their potential habitability. Ground ice is accessible and widespread on Mars at latitudes above 35° N /45° S [7]. On Mars, quasiperiodic climate change results from variations in orbital parameters (obliquity, eccentricity, and season of perihelion) [8] causing the intensity of incident sunlight at a given latitude to change over time along with the locations and timing of habitable conditions in the ice.

Transient liquid water can occur on current Mars from the melting of ice; the stability is enhanced when salts are also present forming brines. Current summer temperatures in ice-rich midlatitude regions are sufficient to support life if melting ice or frost provides transient water. Transient liquid water from melted snow supports microbial life residing below the surface of sandstones in Antarctic dry valleys [9]; analog sites with temperatures comparable to modern midlatitude Mars. It is important to determine if life exists in midlatitude ice prior to human exploration activities that aim to use that resource to prevent both the risk to Earth of inadvertently bringing potentially harmful organisms from Mars, risks to astronaut health, and the complication of recognizing Mars life once terrestrial contamination has occurred.

Sampling ground ice to search for life can be accomplished with landers or rovers carrying 1-2 m drilling systems. McKay *et al.* [10] describes a life search mission hosted on a stationary lander with a drilling system to search for biosignatures of life at the Phoenix Mission landing site. Rover-based drilling would be preferable to search for life in mid-latitudes where the ice depth and heterogeneity below the surface is not well known. Two rover missions with representative drilling capability will be flown soon: the lunar Volatiles Investigating Polar Exploration Rover (VIPER) [11] and the ExoMars rover [12]. Flight prototype life detection instruments fed with a 1m drill like that on VIPER have successfully identified biosignatures in Mars analog hyper arid Atacama Desert samples that were collected and analyzed during Mars mission simulations [13] demonstrating that this life detection mission concept can be successful.

Methods to detect extant life Life on Mars could either stem from a shared ancestry with life on Earth or from a separate genesis, so life detection strategies can be either agnostic, meaning they do not depend upon Martian life similarity with terrestrial life, or can be performed under the assumption that life on Mars would biochemically resemble terrestrial life. A successful search must define features of living systems that should be present in *any* form of life. The use of multiple instruments which can corroborate each other is highly desirable to avoid false positive or negative results. One important instrument that has high heritage from previous missions is Gas Chromatography Mass Spectrometry such as the Sample Analysis on Mars (SAM) instrument on MSL [14]. The instrument should measure organic molecules with sensitivity sufficient to identify patterns of carbon and nitrogen molecules that are distinct from meteoritic and cosmogenic distributions of those molecules and therefor indicate a biological origin. Another relevant measurement technology assays samples for biochemical compounds widely distributed in all terrestrial organisms using Fluorescent Sandwich Immunoassay as the detection method [15]. Another promising life detection technology under development uses Microchip Electrophoresis coupled with LASER Induced Fluorescence to extract and detect amino acids and determine their chirality [16].

The confidence in results indicating life would depend on the ability to distinguish signals from noise and on individual results within the context of the entirety of the results. Future missions would therefore benefit from the development of suites of instruments capable of conclusive *in situ* detection of extant life. Human interaction vastly simplifies sample preparation so many life detection methods can be supported. Spacecraft resources should support enough sample analyses to replicate measurements, and importantly, positive, and negative controls. Contamination control should be coupled with contamination knowledge so that Earth-based material can be eliminated as a possible source of any biological material discovered in Martian samples.

A robotic payload to detect extant life will be low mass compared to human support systems. Therefor it could be deployed at a more habitable site distant from the human landing site in a zone of low biological potential, accompanying short stay human landings as an auxiliary payload. Once the risk of Mars life to human crews is better understood, the search for life on Mars will be a compelling science objectives of long stay missions involving human crews. Crews could operate systems such as deep drills to sample km-deep subsurface aquifers and use flying robots or tethered systems to explore caves for life. These possibilities will be presented at the workshop.

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