We Must Search for Extant Life on Mars Prior to Human Exploration

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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]. Consequently 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.

Article 9 of the Outer Space Treaty will likely prevent return of samples from Mars, or things exposed to the Mars environment including Astronauts, without the due diligence of a prior search for extant life on Mars. This treaty informs planetary protection protocols that have been followed for decades and has the force of law for all US entities including private space companies. The Mars 2020/Perseverance sample collection was not optimized for finding extant life because the collection site, 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, very late to impact planning and mission design for human exploration. It is important to perform a search for extant life on Mars prior to humans landing and to build that strategy into mission planning at the start. 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. The widespread presence of perchlorate salts on Mars may allow brines to form daily over a large part of the Martian surface due to deliquescence [6]. On present Mars conditions for liquid perchlorate brines occur at night when temperatures are below the metabolic limits of known terrestrial organisms but daytime surface temperatures in those same locations are much higher. The potential habitability of recurring deliquescent perchlorate brines needs careful study.

Ice Rich Terrains: These are important locations to search for extant Martian life. They are also highly desirable as a source of abundant water for *in situ* resource utilization. They are currently considered 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. Consequently, many locations on the Martian near subsurface experience ice rich conditions periodically [9], and therefore may harbor extant life persisting in a frozen or desiccated state that could possibly rebound if exposed to the right conditions.

Sampling near surface soils, salts and ground ice to search for life can be accomplished with a robotic lander carrying a 1-2 m drilling system [10,11] but rover-based drilling would be preferable to search for life in mid-latitudes where the ice presence and depth is variable. Any dormant life is likely to be heterogeneously distributed so a stationary lander approach risks missing the evidence. Two rover missions with representative drilling and payload capability are in development: the lunar Volatiles Investigating Polar Exploration Rover (VIPER) [12] and the ExoMars rover [13]. Flight prototype life detection instruments fed with a 1 meter drill like that on VIPER successfully identified biosignatures in Mars analog hyper arid Atacama Desert samples that were collected and analyzed during Mars mission simulations [14] demonstrating this life detection mission concept in one of the most biologically sparse locations on Earth.

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 [15]. 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 indicating 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 [16]. 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 [17].

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. 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 mission to detect extant life will be low mass and low cost compared to human support systems. Therefor it should be deployed to the candidate human landing site as a precursor mission. Once the possible presence (or lack) of extant Mars life is better understood, human exploration can proceed with greater confidence and further search for a record of life on Mars can be a compelling science objective of missions involving human crews.

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