MISSION CONCEPT TO ENABLE SCIENCE AND IN SITU RESOURCE UTILIZATION OF MID-LATITUDE ICE ON MARS

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Summary: Human exploration of Mars will ultimately merge SMD (Science Mission Directorate) and HEOMD (Human Exploration Operations Mission Directorate) goals and objectives. Mid-latitude ice represents an accessible in situ resource to enable long duration human exploration and is also a scientifically rich target for study. Here we outline a mission concept to address both science and exploration goals and discuss a candidate site within the ice-rich plains of Amazonis Planitia.

Science goals: Within SMD, the guiding philosophy of the Mars Exploration Program has been to "Follow the Water" in order to understand recent climate, geology, and to assess the potential for habitability and life on Mars. Given the successful missions of the previous decade, the exploration of Mars is increasingly focused on understanding habitability and the search for life. For several reasons outlined below, arguably the best place to search for extant life on Mars is within the ice-rich subsurface. For example, the subsurface environment provides protection from radiation to shield organic and biologic compounds from destruction. The ice-rich substrate is also ideal for preserving organic and biologic molecules and provides a source of H_2O for any biologic activity. Examination of martian ground ice can test the hypotheses of whether ground ice supports habitable conditions, that ground ice can preserve and accumulate organic compounds, and that ice contains biomolecules that show past or present biological activity on Mars.

In addition to the search for life, studies of ground ice also enable studies of local geology, past habitability, and recent climate change. For example, fieldwork at the nominal Amazonis site will allow the study of local geology and stratigraphy. The Amazonis Site is located on deposits of early to middle Amazonian age flows emanating from Olympus Mons [1, 2]. In situ stratigraphy mapping would allow detailed studies of the geology, structure, and timing of the Olympus flow. The nature of past habitability can also be assessed. Mid latitude ground ice has high potential for past habitability given the presence of a water source and protection from surface radiation. The cryoprotective properties of water ice in the terrestrial cryolithosphere are well documented [3, 4] as the frozen (solid) water and subfreezing temperatures preserve biologic structures. Subsurface profiles of soil ice content and cryostratigraphy will also yield insights into the ice depositional history and past climate of the site.

Exploration goals: In situ investigation of water ice deposits on Mars is of high priority for human exploration. For HEOMD, water may be a valuable resource for in situ resource utilization (ISRU) to enable long duration human exploration. To assess the feasibility of ice-based ISRU and to facilitate the design of ISRU systems, an improved understanding of the nature of the subsurface ice is required. The Amazonis plains are expected to be underlain by ice and vertical profiles of ice content plus physical and chemical properties are needed from precursor measurements.

The presence of water is also important in terms of planetary protection and crew safety. Liquid water habitats have the highest potential for harboring life on Mars and thus the search for extant life on Mars focuses on regions where liquid water may exist to support martian biota. The possibility of indigenous martian life must be addressed prior to sending humans to Mars in order to understand any potential biologic threats to the crew. Characterizing the ice, the most likely location for extant life, as well as the globally circulating dust which will undoubtedly come in contact with crew within the habitat, is required from a planetary protection perspective prior to the first human mission.

Presence of ground ice: Ground ice is expected to be fairly common in mid to high latitudes on Mars given a variety of indirect measurements such as Gamma Ray Spectrometer (GRS) analysis [5], geomorphology [6, 7, 8], and numerical modeling [9]. However, there are only two regions on Mars where subsurface ground ice has been directly observed: 1)

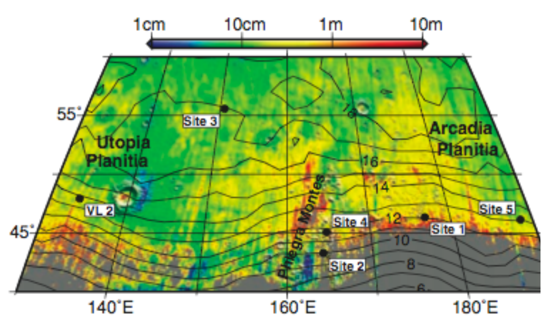

Figure 1. Map showing location of Viking Lander 2 (VL2) and five sites of recent impact craters excavating subsurface ice. From Byrne et al. 2009.

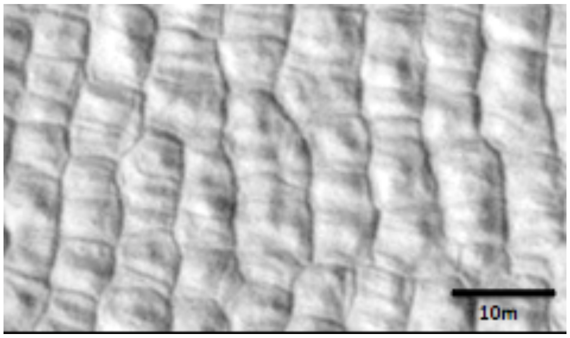

Figure 2. Polygonal terrain located within the Amazonis Site. HiRISE image ESP_011494_2265. Image credit: NASA/JPL/University of Arizona.

the Phoenix lander site and 2) Amazonis Plantia (near the boundary of Utopia and Arcadia). The Phoenix lander dug into the subsurface in the martian Arctic to confirm the presence of subsurface ice. In Amazonis Planitia five recent impact craters have exposed subsurface ice within the upper meter [1]. These new craters excavated ice within the upper meter (often 10s of cm) of the surface (Figure 1) [1]. These sites span from Utopia into Arcadia and Amazonis Planitias. Direct observation from HiRISE showing bright material that then faded over time as the ice sublimated away and CRISM spectral measurements confirmed that the bright material was ice.

The Phoenix site is not amenable to human settlement given the seasonal accumulation of CO2 surface frost. A more ideal candidate landing site is within Amazonis Planitia given the unequivocal presence of ground ice at mid-latitude [1]. A detailed study of the fresh icy craters within the vicinity of Utopia – Arcadia – Amazonis Planitias revealed an optimal landing site near 188.51ºE, 46.16ºN (Figure 2).

Candidate mission concept: Both science and exploration objectives can be achieved through a landed mission in an ice-rich mid-latitude site such as Amazonis. Of key importance for ISRU is to access and characterize the nature of the subsurface ice. An ice-penetrating drill applicable to Mars has been developed and tested in the Mars-analog environment of the Antarctic [10]. A Mars drill is capable of collecting ice samples from up to 1 m depth. Engineering data is used to characterize the physical properties of the ice during drilling activities. A sample handling mechanism then delivers these samples to the instrument payload. The instrument payload is tuned to address both science and exploration objectives. For example, samples of the ice-rich subsurface would be appropriate for an ISRU demonstration. Samples are also analyzed for signs of life using an immunoassay microchip to search for organics and biomolecules [11] and a laser desorption mass spectrometer. A derivative of the Phoenix Wet Chemistry Laboratory is used to determine the solution chemistry and an Alpha Proton X-Ray Spectrometer to identifies elemental composition. A camera system nominally based on the Phoenix Surface Stereo Imager provides context images of the local terrain and drill operations. All mission operations are consistent with current planetary protection policy. Investigation of an ice-rich mid-latitude site enables both science and human exploration objectives on a sustainable path for continued Mars exploration.

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