ICE DRAGON: A MISSION TO ADDRESS SCIENCE AND HUMAN EXPLORATION OBJECTIVES ON MARS

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Summary: We present a mission concept where a SpaceX Dragon capsule lands a payload on Mars that samples ground ice to search for evidence of life, assess hazards to future human missions, and demonstrate use of Martian resources.

Introduction: The search for life on Mars is a priority for NASA's Science Mission Directorate, a pivotal question of the Astrobiology Program and the ultimate goal of the Mars Exploration Program (MEPAG 2010). Assessing the presence or absence of life on Mars is a pre-requisite for human exploration to identify potential threats to planetary protection. Human exploration will also be enabled by the characterization of water resources, such as ground ice, that provide the basis for sustained human presence. Finally, a future human Mars exploration program requires clear demonstration that humans can land and safely operate on the surface of Mars.

***Mission and Systems Concept*:** The Ice Dragon mission uses landing system called "Red Dragon"[1] that is based on a SpaceX Dragon crew capsule to land on Mars. Launched by a Falcon Heavy, this spacecraft is capable of delivering more than 1000 kg of analytical and engineering payload to the surface of Mars at low cost. The large interior volume allows a variety of possibly payloads to be delivered.

The Ice Dragon mission concept focuses on three key questions: (1) Is there life on Mars? (2) Are there viable and accessible resources for humans? (3) Is it safe to land humans on Mars?

These are logically addressed by studying martian ground ice. 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. Furthermore, water on Mars, in the form of ground ice and hydrated minerals may provide a valuable resource to enable long-term human exploration. Water can provide the raw materials for rocket propropellant, other fuels, and life support consumables for future human Mars missions.

Ground ice is expected to be fairly common in mid to high latitudes on Mars based on Gamma Ray Spectrometer data, geomorphology, and numerical modeling. Subsurface ice has been directly observed in two locations: the Phoenix landing site (68^{o}N) and Amazonis Plantia (~45^{o}N) [2].

Mission objectives and payload elements of Ice Dragon include:

Objective 1—Determine if life ever arose on Mars. Ice Dragon will search for evidence of life using two different strategies: 1) searching for complex biomolecules that constitute definite evidence of biological activity (*proof of life*), accomplished using SOLID2 [3], a TRL-5 immunoassay instrument capable of detecting a broad range of biologically produced compounds. 2) search for simple organic molecules that might be linked to biological (or nonbiological) processes (*indicators of life*). The TRL-9 TEGA instrument used on Phoenix performed organic analysis [4] but could not uniquely detect organics in perchlorate-rich Mars soil. An alternative candidate instrument, currently at TRL-4, uses Laser Desorption Mass Spectrascopy.

Objective 2—Assess subsurface habitability. The habitability of ground ice is assessed by evaluating the availability of water, energy, and nutrients to support life. Payload elements that can achieve this objective are TRL-9 and include the Wet Chemistry Laboratory flown on Phoenix [5] and APXS flown on Mars Exploration Rovers [6] to identify the presence of nutrient elements and ions important for life.

Objective 3—Establish the origin, vertical distribution and composition of ground ice. Ice Dragon will sample ground ice and determine whether liquid water processes were involved in its implacement or diagenesis by imaging the ice within the borehole, determining the water content of drilled samples, and measuring mechanical properties while drilling the ice.

Objective 4— Assess potential human hazards in dust, regolith and ground ice, and cosmic radiation. Biological and chemical hazards to humans are assessed using the same instruments that addresses objectives 1 and 2. A candidate instrument to characterize the radiation environment on the martian surface is the TRL-9 CRaTER instrument flown on Lunar Reconnaissance Orbiter [7].

Objective 5— Demonstrate ISRU for propellant production on Mars. Systems can be carried to demonstrate the collection of carbon dioxide from the Mars atmosphere and subsequent catalytic processing into methane and water. Atmospheric collection will also allow for incorporation of a dust measurement instrument (size and count rate). The demonstration uses existing TRL 4/5 hardware as a starting point. In addition to atmospheric ISRU, utilizing water from hydrated material and/or near surface ice could be game-changing. Determining soil properties, water/ice quantity, contaminants and other volatiles in the soil, and evaluating cleaning techniques, are required to utilize these resources in future missions. Payload elements that can demonstrate water extraction are currently TRL-5.

Objective 6—Conduct human relevant EDL demonstration. Ice 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 has not previously been demonstrated in flight.

Payload implementation: Samples are obtained using a rotary percussive drill [8] capable of retrieving cuttings from up to 2 meters depth in ice-cemented ground. The 2 m depth allows access to materials that have not been sterilized by ionizing cosmic radiation over geologic timescales [9], and will allow ice to be sampled at midlatitude sites where it may be covered by up to 1 m of dry soil. The drill is a larger and deeper version of the Icebreaker drill that has been tested to TRL-6. Figure 1 illustrates a concept for implementing the drill and instruments in a Dragon capsule. Icy regions on Mars are protected from contamination by terrestrial microbes by steralizing all elements that touch samples and keeping them within a sterile chamber housed in the capsule center. Instrument sample acceptance ports penetrate this chamber but the instruments and support hardware remain outside of it. The height of the capsule allows a single drill string capable of 2 m depth to fit vertically within it. The single drill string approach is simpler and lower risk than an approach requiring multiple drill strings to achieve depth. Openings in the capsule base allow allow drill use inside the capsule. Cuttings samples from the drill are provided to the instruments aseptically.

Conclusions: The payload and landing system we identify for Ice Dragon addresses high priority scientific and human exploration goals. The mission seeks to bridge the gap between science and human exploration, at low cost, by targeting key Strategic Knowledge Gaps. The mission can be scaled up in cost from Discovery-class to New Frontiers-class, and is easily adjustable to budget limitations. However for each class Red Dragon can deliver to Mars more science and technology than previous landing systems. Based on preliminary studies Ice Dragon could become a high pay-off mission as early as the 2018 launch opportunity.

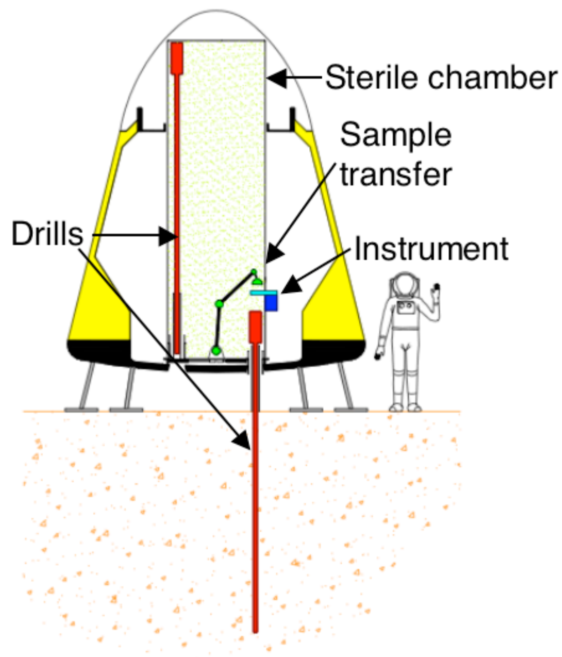

Figure 1: Schematic illustrating payload accommodation within the SpaceX Dragon capsule. Two drills (one deployed to depth, one stowed, shown in red) are housed within a sterile chamber. Instruments are mounted around the circumference of the chamber with sample ports extending inside. A sample transfer system (green) moves cuttings from the drill to the instrument ports. A human is shown for scale.

References:

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