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Red Dragon drill missions to Mars

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ABSTRACT

We present the concept of using a variant of a Space Exploration Technologies Corporation (SpaceX) Dragon space capsule as a low-cost, large-capacity, near-term, Mars lander (dubbed "Red Dragon") for scientific and human precursor missions. SpaceX initially designed the Dragon capsule for flight near Earth, and Dragon has successfully flown many times to low-Earth orbit (LEO) and successfully returned the Dragon spacecraft to Earth. Here we present capsule hardware modifications that are required to enable flight to Mars and operations on the martian surface. We discuss the use of the Dragon system to support NASA Discovery class missions to Mars and focus in particular on Dragon's applications for drilling missions. We find that a Red Dragon platform is well suited for missions capable of drilling deeper on Mars (at least 2 m) than has been accomplished to date due to its ability to land in a powered controlled mode, accommodate a long drill string, and provide payload space for sample processing and analysis. We show that a Red Dragon drill lander could conduct surface missions at three possible targets including the ice-cemented ground at the Phoenix landing site (68 °N), the subsurface ice discovered near the Viking 2 (49 °N) site by fresh impact craters, and the dark sedimentary subsurface material at the Curiosity site (4.5 °S).

1. Introduction

The Red Dragon Mars lander concept provides a new platform for Mars missions. This new platform may be particularly important to NASA Discovery class missions which are moderate cost planetary missions with a cost cap of approximately $425 million including mission design, development, launch vehicle, instruments, spacecraft, launch, operations, and data analysis. Red Dragon presents the possibility of a low-cost, high-capacity option for payload delivery to Mars. Red Dragon has the potential for low cost primarily because it is derived from a routinely flying spacecraft. Low cost is an essential component of a robust Mars program to ensure a reasonable continued cadence of Mars mission opportunities, particularly in the current era of budgetary constraints in NASA's planetary science program.

Red Dragon is an attractive platform concept since it capitalizes on existing Dragon spacecraft capabilities to enable Mars exploration. Dragon is now ferrying cargo to and from the ISS, and a new version of Dragon is being developed for crewed missions to and from the ISS. Unlike other Earth-return vehicles, the crewed Dragon variant has most of the capabilities necessary to land on Mars, including atmospheric entry systems capable of guided lifting entry. In particular, the crewed version of Dragon has a set of high-thrust, throttleable, storable bi-propellant "SuperDraco" engines integrated directly into the capsule which are intended for launch abort and powered landings on Earth. These thrusters provide the possibility of a fully-propulsive, parachute-free deceleration at Mars from supersonic speeds to landing on the surface using Supersonic Retro Propulsion (SRP). Further, a set of landing legs, to eventually be used on Dragon during Earth landings, are also applicable for future Dragon landings on Mars.

Concepts for large, human-relevant landers also often employ SRP [1–5]. Red Dragon's entry, descent, and landing (EDL) approach would scale to those landers as a technology demonstration for future human exploration of Mars. Also, SpaceX's Falcon Heavy rocket which is currently in development will be capable of putting Dragon on a trajectory to Mars. Together, these capabilities point to the possibility of a new platform for Mars surface missions.

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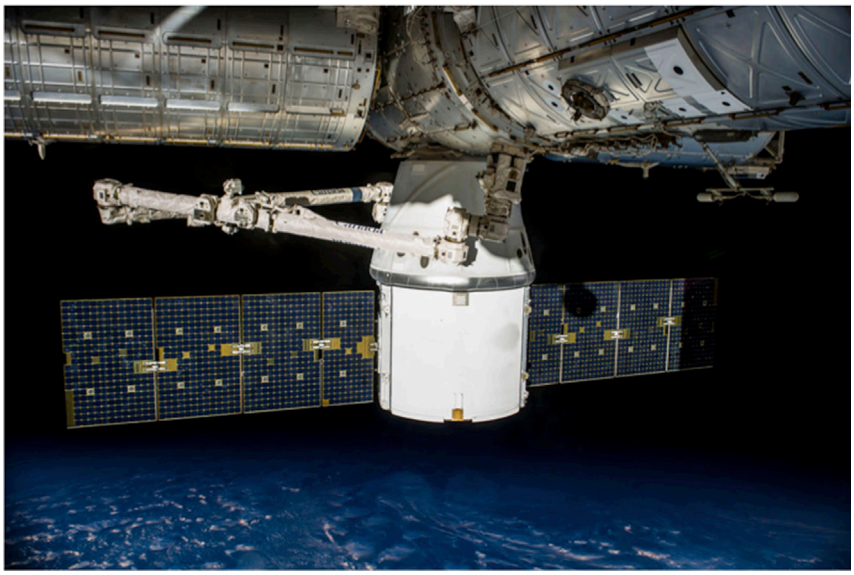

Fig. 1. SpaceX Dragon capsule docked at the International Space Station.

In this paper we consider how Red Dragon can enable NASA Discovery class missions, particularly as a precursor mission to characterize subsurface ice for in situ resource utilization (ISRU). Numerous previous mission concept studies for the identification and characterization of martian in situ resources have considered various spacecraft platforms such as orbiters, single stationary landers, and/or mobile assets such as rovers, hoppers, airplanes, tumbleweed spacecraft, cliffbots, etc. [6]. Here we specifically focus on NASA Discovery-class mission capabilities which precludes mobility-based drill samples. We have increased the robustness of the lander drill approach by assessing landing sites on Mars with high confidence of having subsurface ice. To that end, we first provide an overview of the current SpaceX Dragon capsule including relevant technical aspects and a history of previous demonstration flights to date. We then outline the Red Dragon concept and mission profile as well as discuss Dragon capabilities and modifications required for flight to Mars. We assess whether the Red Dragon platform could support a Discovery class mission to drill to at least 2 m on Mars. We consider three possible targets including 1) the ice-cemented ground at the Phoenix landing site (68 °N), 2) the subsurface ice revealed by fresh impact craters in the area of the Viking 2 (49 °N) site, and 3) the reducing sedimentary rock at the Gale Crater Site (4.5 °S) into which the Mars Curiosity rover was able to drill a few cm. We find that Red Dragon provides a suitable platform for the challenging demands of a drill mission and allows for such ambitious missions at Discovery cost levels.

2. Dragon overview

Dragon is composed of a pressurized capsule and an unpressurized trunk. The Dragon capsule is 4.4 m tall and 3.66 m in diameter with a trunk height of 2.3 m and width of 3.66 m. With the trunk-mounted solar

Fig. 2. Artist concept of the Red Dragon capsule landing on Mars.