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DRAGON: the Deimos Reconnaissance And Geological ObservatioN CubeSat

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Abstract

Phobos and Deimos, the small moons of Mars, are potentially key players in the human settlement of space. Whether that settlement ends up being primarily robotic or human, or robot-assisted and how, and what types of settlements are feasible and on what timescale, and how to begin, depend on variables that we are just beginning to find out.

Towards that goal, we propose the low-cost pathfinder mission DRAGON, the Deimos Reconnaissance And Geologic ObservatioN CubeSat, whose goal is to provide unique data about the most valuable surface locations on Deimos in preparation for the first soft landings there. This mission concept builds upon a two-year student-led effort, with enhancements aimed at obtaining unique, priority reconnaissance data of Martian moons Phobos and Deimos ahead of future landings.

1. Introduction: Phobos or Deimos?

The Martian moons have significant advantages compared to most asteroids when it comes to establishing a long term presence in deep space [1]. Deimos has two small regions at sub-Mars latitudes (60°N, 0°W; 51°S, 7°E) that offer constant line of sight to Earth and the Sun in summer and winter, respectively. Moreover, orbiting just outside Mars geosynchronous radius ~6R_{Mars}, Deimos maintains persistent line of sight with any location on the planet surface for as long as 60 hr on the equator.

Phobos orbits every 8 hr, thus has at most 4 hr persistent communication with a site on Mars. Moreover, Phobos orbit is so close that Mars spans 42.5° in Phobos' sky, meaning that the highest latitudes of Mars are obscured. Lastly, the propulsion requirements for matching orbits with Deimos are ~750 m/s less than for Phobos.

Phobos has been the focus of multiple mission concepts [2, 3], including In-Situ Resource Utilization Missions [4]. While Phobos might hold answers to more profound science questions, and is therefore the more fruitful target in the near-term for science missions such as JAXA's MMX (Mars Moons eXploration) mission [2], Deimos appears to offer the better 'high ground' supporting long term human presence [1].

2. Mission Concept

CubeSats offer the opportunity to perform low-cost, focused science exploration, with rapid turn-around times between multiple missions. We propose development of a 12U, 24 kg interplanetary CubeSat called DRAGON that would perform reconnaissance of Deimos at altitudes of 5 km and less over a 2-year mission.

DRAGON is inspired by JPL's INSPIRE and MarCO CubeSats on the way to Mars. The CubeSats would be dropped-off on an Earth Escape trajectory to Mars much like the MarCO CubeSats (**Fig. 1**) or contain a propulsive ESPA stage that would put it on a flyby trajectory to Mars.

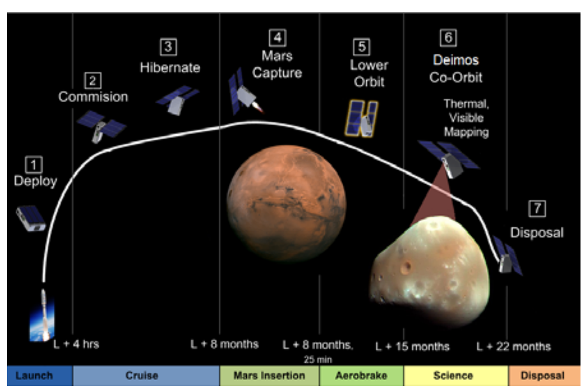

Fig. 1. DRAGON Concept of Operations.

The spacecraft upon reaching Mars may use on-board propulsion to achieve a highly elliptical capture orbit that is then regularized through multiple aero-drag manuevers by passing through the Martian atmosphere. An alternative is a one-shot aero-capture manuever that places the spacecraft in an elliptical co-orbit with Deimos.

3. Spacecraft

The CubeSat, a 12U, 24 kg spacecraft will be developed by Space Dynamics Laboratory (Utah State University). The CubeSat will be equipped with a pair of MMA eHawk+ solar panels providing ~40 watts at Mars and high-gain communications antenna with 40+ dBi gain enabling transmission of high-resolution images and short videos direct to earth. The spacecraft would contain JPL's Iris transceiver for communication and Doppler tracking through the DSN, an on-board high delta-v chemical propulsion system and rad-hardened electronics to withstand a multi-year mission in deep space.

4. Science Instruments

The instrument suite onboard DRAGON are tentatively as follows:

1. Telescopic color imager for highest resolution imaging from a sequence of slow flyovers.

2. Thermal imager for understanding the nature (e.g. particle size) of the upper regolith

3. Point-spectrometer for mineral characterization of selected regions

4. Wide angle b/w imager, for final images prior to the terminal impact.

5. Operations

The DRAGON mission is designed to make a first close-up assessment of these optimal sites on Deimos by making use of breakthroughs in CubeSat propulsion, instrumentation and communications technology to perform a sequence of slow flybys over 2 years followed by a terminal impact. Repeated close encounters with Deimos over a 2-year period will provide sufficient high-resolution images for meeting the mission reconnaissance goals. Spacecraft observations are focused on obtaining data only from these northern and southern hemispheric 'sweet spots', with a goal of minimizing risk for future soft landings.

The proposed mission campaign has three phases:

1. **Close Flyovers.** At least 2 low-velocity (<100 m/s) flyovers, of each N and S target region 100 × 100 m^2, from closest approach distance of <5 km

2. **Descent Imaging**. Take pictures of the predicted crash site, coverage over an area of 3 m × 3 m.

3. **Free Fall.** At a predicted time, the spacecraft fires a reverse thruster to cancel its free-fall velocity, resulting in it hovering above the surface for some minutes until it lands.

6. Mission Finale

The terminal impact will follow a retro-burn that will slow the spacecraft to a few m/s before making a surface impact. Due to Deimos' low gravity, the terminal impact is expected occur over a few minutes allowing for transmission of multiple high resolution images of candidate landing sites.

The highest resolution final images, at better than 1 cm/pixel, are the top level science goal. We do not expect survival of the spacecraft on the surface, although the wide angle camera can continue to transmit if the spacecraft does survive.

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