CHARIOT TO THE MOONS OF MARS. D.A. Minton[1], D. Spencer[1], B. Horgan[1], Z. Putnam[2], J. Puig-Suari[3], and P. Christensen[4], [1]Purdue University, West Lafayette, IN 47907, USA, (daminton@purdue.edu), [2]University of Illinois Urbana-Champaign, Urbana Illinois 61801, [3]Tyvak Corporation, Irvine, CA 92618, [4]Arizona State University, Tempe, AZ 85281.

Introduction: The origin of the two moons of Mars, Phobos and Deimos, remains a major unsolved mystery in our understanding of planet and satellite formation. Existing observations of Phobos and Deimos are insufficient to determine which of the many proposed models for their origin and modification history is correct. Proposed origin models include capture of asteroids, contemporaneous formation with Mars, and formation from an impact-generated debris disk. The lack of a definitive origin model also has major implications for human exploration, as the amount of extractable resources needed to aid in human exploration of Mars is tied to the moons' formation and evolution. Therefore, the potential for resource exploitation of the moons of Mars is highly uncertain. Phobos and Deimos lack key observations because there has not yet been a successful mission dedicated to the study them. However, smallsats provide a new opportunity to conduct focused investigations to address high priority science objectives that cannot be obtained from primary Mars missions, and thus are ideal for a mission to Phobos and Deimos.

Science Target and Rationale: Existing observations of Phobos and Deimos are insufficient to effectively constrain models for their origin. Visible/near-infrared reflectance spectra of Phobos and Deimos most closely resemble carbonaceous asteroids [1-5]. This observation has led to the Intact Capture Hypothesis, which proposes that the satellites are captured carbonaceous asteroids [2, 6]. However, the Intact Capture Hypothesis cannot adequately account for the orbits of these satellites, because their circular, prograde co-planar orbits deep within the gravity well of Mars are highly implausible outcomes for any proposed capture scenario [7, 8].

An alternative origin model is the *Protosatellite Disk Hypothesis* [7]. Scenarios proposed based on this hypothesis include in-situ formation alongside Mars [9], formation from giant impact ejecta [10-13], and debris-disk formation with a cyclic breakup and reformation of Phobos [14]. However, the strong spectral resemblance of the two satellites to carbonaceous asteroids and the weak resemblance to martian material is difficult to reconcile with any proposed Protosatellite Disk Hypothesis [7, 15]. Thus, the origin of Phobos and Deimos remains a major unsolved mystery in our understanding of planet and satellite formation.

The primary limitation in our current knowledge of the origin of the martian moons Phobos and Deimos is that previous observations of Phobos have insufficient spatial resolution and coverage to tie observed spectral variability to specific surface features and geologic processes [15]. In addition, Deimos is virtually unstudied. A major distinguishing feature of the different origin models for Phobos and Deimos is in the relationship between the two bodies. At one extreme, the Intact Capture model holds that the satellites are wholly unrelated to each other, while Protosatellite Disk Hypothesis models suggest varying degrees of commonality in the starting material and post-formation processing of satellites. To address this major knowledge gap, the Chariot mission will conduct a high-resolution observing campaign of both satellites to determine their bulk and surface mineralogy and thereby constrain the origin of the martian satellite system.

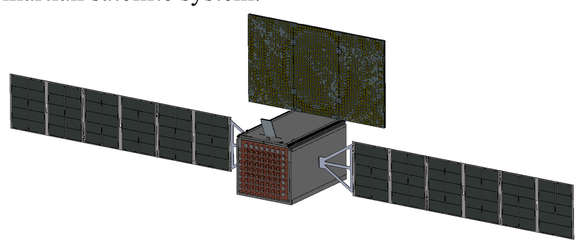

Figure 1. 12U Chariot CubeSat in deployed configuration

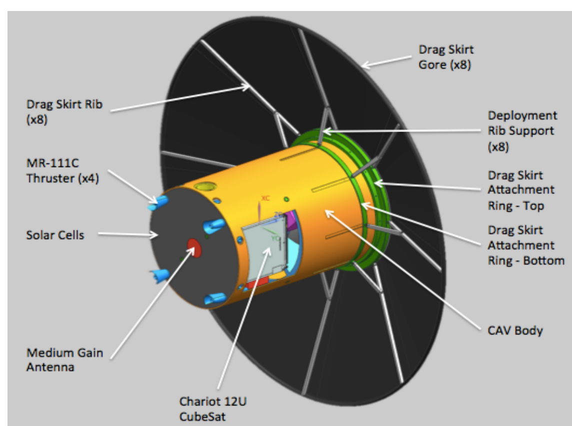

Figure 2. CAV with the drag skirt fully deployed.

Preliminary Instrument Complement: The primary goal of the Chariot mission is to characterize the composition and variability of the surface of both satellites. Previous investigations have demonstrated that Phobos exhibits spectral diversity at both visible/near-infrared (VNIR; 300-1100 nm) and thermal-infrared

(TIR; 5-25 μm) wavelengths, but the specific mineralogy leading to this diversity and the origin of the differences in mineralogy is poorly understood. Whether or not Deimos exhibits these variations is not known. In addition, the anti-Mars sides of Phobos and Deimos are not well characterized at these wavelengths.

Thus, to build on these previous observations, Chariot will map the spectral properties of the entirety of both Phobos and Deimos at VNIR and TIR wavelengths. VNIR wavelengths are primarily sensitive to iron and other transitions metals in both alteration and primary mafic minerals. Water bands due to strongly hydrated phases can also be observed at VNIR wavelengths. However, VNIR wavelengths are not sensitive to the strong fundamental absorptions of silicate minerals, and VNIR photons mix non-linearly, making quantitative mineral determination from VNIR spectra challenging. In addition, VNIR spectra are strongly influenced by space weathering, which can be a useful indicator of exposure to space, but also severely diminishes the spectral contrast of diagnostic mineral absorption bands. In contrast, TIR wavelengths are sensitive to the fundamental absorptions in primary and secondary silicates, and linear unmixing of TIR spectra can be used to extract quantitative abundance estimates. TIR spectra also provide additional information on the temperature and thus thermal properties of the surface. Thus, using these two complementary methods together provides the most information about the composition of the surface.

Spacecraft Concept: Six possible mission architectures were considered during the course of the Chariot to the Moons of Mars concept study. These concepts include free-flier mission architectures utilizing a cruise/aerocapture vehicle (CAV) to accomplish the Earth-to-Mars transfer and aerocapture into Mars orbit. Each of the free-flier mission concepts are initiated with deployment from the launch vehicle upper stage using the ESPA interface. The sixth concept is a ride-along mission, where the CubeSat is deployed into a near-equatorial Mars orbit by a primary orbiter.

The Chariot 12U CubeSat design is solar-powered and three-axis stabilized, with cold gas propulsion and active thermal control. The CubeSat in deployed configuration is shown in Figure 1. The Iris-2 radio, reflect array, and patch antenna are used for X- and Ka-band communication. Two deployable, single-axis gimballed solar arrays, each consisting of six panels, provide 122 W of power at beginning of life. The JPL Sphinx avionics board provides command and data handling capability, and science data storage. The multi-spectral thermal infrared imager, near-IR point spectrometer, and visible camera, are accommodated by the spacecraft structure and are all co-aligned for nadir-pointed observations. Heaters, thermal blanketing, and a radiator are used for thermal control.

The Cruise-Aerocapture Vehicle (CAV) is a cylindrical-shaped spacecraft with a drag skirt mounted on its forward face. As shown in Figure 2, the drag skirt is made up of eight individual gores in addition to a forebody heat shield. The aft face of the CAV contains the medium gain antenna for communication, four MR-111C thrusters for trajectory and attitude maneuvers, and circular body-mounted solar cells for power generation.

The Chariot aerocapture system enables exploration of the moons of Mars on a rideshare with any future host Mars mission. The aerocapture system provides a non-propulsive orbital insertion capability that results in a lower-mass vehicle that is capable of using an ESPA-class secondary payload slot. Orbit insertion is achieved by using drag generated during a single high-speed atmospheric pass. An ablative heatshield and drag skirt are used to protect the spacecraft from the severe aerothermal environment and target the proper transfer orbit energy.

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