Phobos And Deimos & Mars Environment (PADME): A LADEE-Derived Mission to Explore Mars's Moons and the Martian Orbital Environment. Pascal Lee[1,2,3], Michael Bicay[1], Anthony Colaprete[1], Richard Elphic[1], Anthony Genova[1], Butler Hine[1], Mihaly Horanyi[4], Belgacem Jaroux[1], David Korsmeyer[1], Brian S. Lewis[1] and S. Pete Worden[1]. [1]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA, pascal.lee@marsinstitute.net, [2]Mars Institute, [3]SETI Institute, [4]LASP, U. of Colorado.

Summary: PADME is a proposed rapid, low-cost, NASA Mars orbiter mission that will address long-standing unknowns about Mars's two moons and the circum-martian environment. PADME will advance our scientific understanding of A) the origin, composition, surface physics, and internal structure of Phobos and Deimos, and of B) the origin, abundance, composition, and distribution of dust around Mars. In doing so, PADME will help plan future robotic missions to the surface of Phobos and Deimos, and also retire key strategic knowledge gaps in preparation for future human missions to Mars. PADME would launch and reach Mars in 2018.

Introduction: Phobos and Deimos are exciting planetary targets, both as unique small bodies and as the two moons of Mars. After 40 years of solar system exploration by spacecraft, the origin and nature of Mars's satellites, which were discovered by American astronomer Asaph Hall, remain vexingly unknown [1].

Key science questions about Phobos and Deimos are: 1) Which hypothesis about their origin is correct? Are they: a) captured asteroids - including the intriguing possibility that they might be the last *surviving* members of a decimated family of asteroids that once populated a region of the solar system sunwards of the modern main belt (B. Gladman, *pers. comm.*)? b) remnants from Mars's own formation? c) reaccreted impact ejecta from Mars? d) a combination of these hypotheses?; 2) What is their composition?; 3) Is there water in their subsurface, and if so, is there enough to be utilized as a resource for future human exploration? 4) What physical processes act at the surface of Phobos and Deimos to mobilize the regolith, in particular dust? 5) What is their internal structure (esp. given their remarkably low bulk densities)?

In addition to Phobos and Deimos themselves, the circum-Martian environment remains poorly understood. Key science questions about this environment are: 1) Is there significant dust in circum-Martian space? 2) If so, is it concentrated in a torus and a ring, as predicted or hypothesized in many studies [2-17]? Dust is expected to be ejected from both Phobos and Deimos by continual micrometeoroid bombardment and by electrostatic levitation [18]. Considering the production rates and the lifetimes of dust grains, the latest models predict a gossamer *torus* of dust associated with Deimos's orbit, and a gossamer *ring* of dust

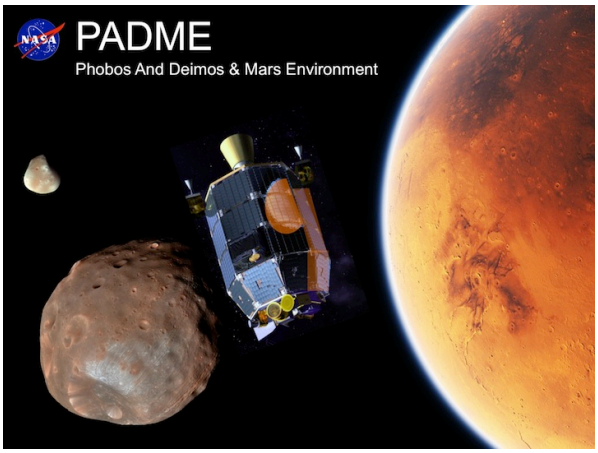

Figure 1: The PADME Mission will explore Phobos, Deimos, and Mars's Orbital Environment. (NASA).

associated with the orbit of Phobos [14,16]. Attempts to image these dust features (e.g., using HST) have so far been unsuccessful, establishing upper limits for their visual optical depths of $\tau < 10^{-7}$ for the Deimos torus, and $\tau < 3 \times 10^{-8}$ for the Phobos ring [15,16]. These dust features are also challenging to detect in situ. One study suggests that the Deimos torus is dominated by 30 μm-sized particles with a peak number density of $\sim 5 \times 10^{-12}$ cm^{-3} [10], close to the detection limit of existing detectors as dust impact velocities are also very low. However, LADEE's LDEX [19] could reliably detect dust in close proximity to its sources (Phobos and Deimos) where densities would be higher.

The PADME Mission. We propose to address this wide range of science and human exploration precursor questions rapidly, reliably, and at low cost, with PADME, a Mars orbiter mission using the proven LADEE-based spacecraft bus. (PADME stands for Phobos And Deimos & Mars Environment).

PADME will launch on a Falcon-9 rocket in May 2018 and reach Mars seven months later, in December 2018. PADME will then begin a series of cyclical flybys of Phobos, followed by a series of flybys of Deimos, with opportunities to investigate the rest of the circum-Martian environment extensively between flybys. To minimize fuel expenditure, PADME will remain on highly elliptical orbits, first in resonance with the orbital period of Phobos for the Phobos flybys, then in resonance with the orbital period of Deimos to conduct the Deimos flybys.

In one scenario, PADME's first close approach to Phobos (at 50-100 km range) occurs on 18 Dec 2018, to be followed by 10 additional flybys of Phobos at 10-day intervals and at ranges decreasing from 10 to 1 km. Phobos flyby velocity will be ~0.85 $km.s^{-1}$. PADME will then transition to Deimos, with flybys beginning in April 2018. A total of approx. 5 flybys of Deimos at 20 day intervals and ranges decreasing from 3 to 1 km, are planned. Deimos flybys will be as slow as ~0.55 $km.s^{-1}$. The PADME mission would end in June 2019.

Instruments: The PADME mission has three science instruments plus a radio communications system doubling as a Radio Science experiment.

Mars Moon Camera System (MMCS): The MMCS is a low mass, low power dual framing camera system with a wide-angle RGB context camera and a narrower angle broad-band high resolution camera. The MMCS will produce *global* color image maps of Phobos and Deimos at a spatial resolution of ~3.5 m/pxl, and *local* panchromatic images of each moon at <0.5 m /pxl, exceeding the highest resolution imaging available to date for both Phobos (3.7 m/pxl) and Deimos (2 m/pxl). MMCS imaging will take place at ranges of order 10 km from each moon. Spacecraft slew will be used to compensate for motion-induced blurring.

Neutron Spectrometer (NS). The NS will count epithermal and thermal neutrons at Phobos and Deimos during close flybys. The cumulative measurements at each moon will provide quantitative estimates of the abundance of hydrogen (H), and by implication water, in the topmost 1 m of Phobos and Deimos's regolith with a sensitivity of 1 wt/% of water-equivalent H buried below 30 cm of dry regolith. PADME's NS instrument will be identical to the *Neutron Spectrometer Subsystem (NSS)* on NASA's upcoming *Resource Prospector Mission (RPM)* to Earth's moon.

Mars Orbit Dust Experiment (MODEX). MODEX is a lightweight impact-ionization type dust detector that will intercept and analyze (by determining the mass, velocity, and direction of travel of) any dust particle encountered around Mars. MODEX will address the long-standing question of whether and where dust occurs in the circum-Martian system. The experiment will in particular quantify dust production functions in close proximity to Phobos and Deimos where dust densities are expected to be relatively high. PADME's MODEX will be identical to LADEE's successful Lunar Dust Experiment (LDEX).

Radio Science System (RSS). PADME will be equipped with a an X-band transceiver radio comms system that will enable high-precision measurements of Doppler shifts during close encounters of PADME with Phobos and Deimos to map their gravity field and internal density distribution.

In addition to RSS, PADME may host a *Mars Laser Communication Demonstration (MLCD)* payload similar to LADEE's LLCD experiment.

Team and Management: The PADME mission will be a PI-led mission, with support from a Deputy PI. The Science Team will also include: i) Instrument Leads; ii) other Instrument Team Members; iii) Interdisplinary Scientists.

NASA Ames Research Center (ARC) will design, develop, build, and test the PADME spacecraft, and manage mission operations. PADME will use the same modular common spacecraft bus (MCSB) as NASA's LADEE. This MCSB, developed at NASA ARC, is an innovative way of transitioning away from custom designs and toward multi-use designs and assembly-line production, thus reducing spacecraft development costs drastically. Additional partnering organizations are expected to have the opportunity to provide and manage science instruments and any technology demonstration payload. NASA KSC is anticipated to be responsible for launch vehicle integration, launch services, and launch range operations. NASA JPL is anticipated to be responsible for Deep Space Network (DSN) support.

Conclusion: By using the proven, streamlined, and low cost approach of LADEE to mission development and implementation, PADME presents an affordable opportunity for NASA to fly an exciting, gap-filling science and human exploration precursor mission to explore Phobos, Deimos and the circum-Martian environment as early as 2018.

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