The PRIME (Phobos Reconnaissance and International Mars Exploration) Mission and Mars Sample Return. Pascal Lee[1], Robert Richards[2], Alan Hildebrand[3], and the PRIME Mission Team. [1]Mars Institute, SETI Institute & NASA Ames Research Center, pascal.lee@marsinstitute.net, [2]Optech Inc., [3]University of Calgary.

Introduction: PRIME is an international robotic lander mission concept to explore Mars's inner moon Phobos to address the outstanding question of its origin. The mission could also play a significant role as a milestone in Mars Sample Return efforts. PRIME was proposed jointly by the Mars Institute, Optech Inc., and MDA Space Systems, and was selected for conceptual study in 2007 by the Canadian Space Agency [1,2,3].

Background: As reiterated during the *First International Conference on the Exploration of Phobos and Deimos* held at NASA Ames on Nov 5-7, 2007, the single most important science objective in the exploration of Phobos is to determine its origin. Resolving this issue will not only address the nature of Mars's inner satellite, but also answer fundamental questions about planet and satellite formation, small body evolution, impact cratering frequency and dynamics, Mars surface evolution, and the role Phobos might play in future Mars exploration, from Mars Sample Return to human missions [3,4].

Competing hypotheses concerning Phobos's origin fall into two categories [5]: 1) *Circum-Mars Formation*: Phobos is a circum-Mars formed body or the collisional remnant of a once larger body formed around Mars; 2) *Capture*: Phobos is a captured small body (asteroid or comet) or the collisional remnant of a once larger object that was captured. In each of these cases, Deimos might be genetically related to Phobos, or not.

The PRIME Lander Mars mission concept was developed with the central scientific goal of determining the nature and origin of Phobos. Important but secondary scientific goals are to understand better Phobos's evolution through time and to assess the object's current state, including the processes that affect it.

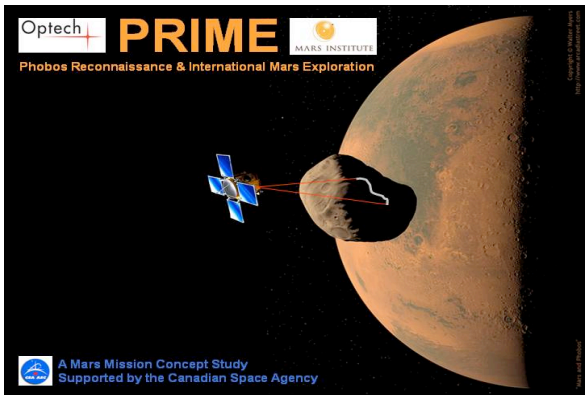

Figure 1: The PRIME Lander will survey Phobos during a pre-landing orbital phase (Mars Institute art).

Mission Objectives: The primary objectives of the proposed PRIME Lander mission are to substantially advance our understanding of:

- the Nature and Origin of Phobos.
- the Evolution of Phobos through time.
- the Current state of Phobos.

The single most reliable measurement that can be made to answer the question of Phobos's origin is to determine the martian moon's bulk composition. While remote sensing studies may help constrain the bulk composition of Phobos, they characterize strictly only the composition of Phobos's surface regolith, which might not be representative of Phobos's bulk. Determining the bulk composition of Phobos can be done unambiguously only by determining the composition of a *representative sample of Phobos's bulk*. This is most economically done via *in situ* petrographic and mineralogic examination of a representative piece of Phobos's bulk *and* by analysis of its elemental composition. Access to a representative sample of Phobos's bulk for the proposed investigation can only be done reliably by contacting Phobos's surface and by examining within an arm's length fresh, dust-free lithic material, an outcrop or boulder. A lander capable of precision landing is required.

PRIME Lander and its "Rock Dock" Capability: The PRIME Lander is a fixed lander that will first characterize potential landing sites from orbit - actually pseudo-orbits about Phobos -, then soft land on Phobos using a short-range lidar (CAMELOT-2), then conduct in situ measurements. The PRIME Lander's performance floor science payload will examine the landing site's immediate surroundings using a body-mounted gamma-ray spectrometer/neutron detector (GRS/NDL) and two arm-mounted instruments, a combination panoramic/microscopic color imager (CHAMP) and an alpha particle x-ray spectrometer (APXS). Additional baseline instruments include a surface scanning lidar (PASCAL) to map the local topography and a magnetic susceptibility measurement experiment (MAG), the latter also an arm-mounted instrument. The Lander would also be equipped with an ultrastable oscillator capable of supporting Radio Science during the initial pre-landing orbital phase.

The PRIME Lander's CAMELOT-2 lidar, designed by Optech, will allow a precision soft touchdown of the spacecraft within an arm's reach (< 0.5 m) of a selected block or outcrop exposed on Phobos's surface. This "rock dock" capability is unique to the PRIME Lander mission and represents the key enabling tech-

nology that will allow reliable access to a representative sample of Phobos's bulk and resolution of the mystery of Phobos's origin. A PRIME Lander in situ analysis mission incorporating the "rock dock" capability, while inherently more complex than a strictly orbital mission, will more likely allow definitive resolution of the question of Phobos's bulk composition and therefore its origin.

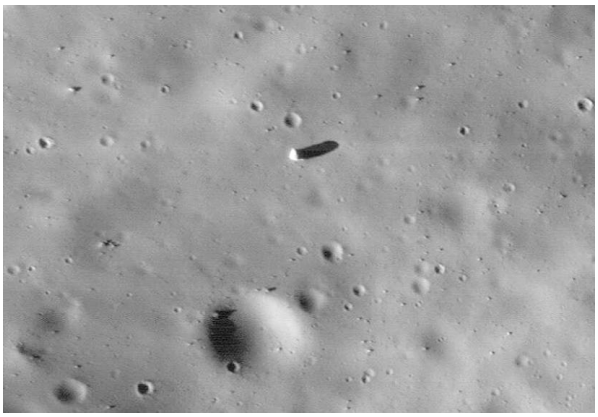

Figure 2: Mars Global Surveyor MOC image of a 90 m wide discrete positive relief feature (DPRF) near Crater Stickney on Phobos (NASA/JPL/MSSS).

Large (1-100m scale) discrete positive relief features or DPRFs on Phobos are considered likely samples of Phobos's bulk, as opposed to accreted meteorite fragments (B. Gladman, *pers. comm*.). The PRIME Team selected the boulder shown in figure 2 as a candidate landing site to illustrate the PRIME mission's unique targeting capabilities. With its "Rock-Dock" capability, the PRIME Lander will be able to land within an arm's length (1m) of this feature, expose fresh lithic material using an abrasion tool, and conduct in situ compositional analysis.

From PRIME Lander to Mars Sample Return: In addition to providing an opportunity to address the question of Phobos's origin, the PRIME Lander mission involves mastery of key technologies and strategies of direct relevance for an eventual Mars Sample Return (MSR) mission, namely: 1) Orbital rendez-vous in Mars orbit, 2) Landing hazard avoidance, and 3) High precision landing (rock dock maneuver). In this respect, the PRIME Lander mission would serve as a useful precursor to MSR.

The PRIME Team is currently examining an enhanced Phobos Sample Return (PSR) version of the PRIME mission or PRIME PSR which could also serve as a more complete precursor to MSR. In addition to the technologies deployed on the PRIME Lander mission concept, PRIME PSR would provide an opportunity to test Mars sample return procedures while minimizing planetary protection risks.

Table 1: PRIME Mission Science Team

Pascal Lee (PI)	Mars Institute, NASA Ames
Alan Hildebrand (DPI)	Univ. of Calgary
Bob Richards (PM)	Optech
Stephen Braham	Mars Institute & SFU
Peter Brown	Univ. of Western Ontario
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Ed Cloutis	Univ. of Winnipeg
Ralf Gellert	Univ. of Guelph
Nadeem Ghafoor	MDA Space Systems
Brett Gladman	Univ. of British Columbia
Brian Glass	NASA Ames
John Hahn	Optech
Jun Kawaguchi	JAXA (Japan)
Penny King	Univ. of New Mexico
Igor Mitrofanov	IKI (Russia)
John Parnell	Univ. of Aberdeen (UK)
Phil Stooke	Univ. of Western Ontario
Seiji Sugita	Univ. of Tokyo (Japan)
Peter Thomas	Cornell Univ.
Joseph Veverka	Cornell Univ.
Paul Wiegert	Univ. of Western Ontario

Table 2: PRIME Mission Support Team

Marc Boucher	Mars Institute
Kieran Carroll	Consultant
Camille Desportes	Mars Institute
Daven Maharaj	Optech
Sam Ng	MDA Space Systems
Michael West	Mars Institute
Nicholas Wilkinson	Mars Institute

References: [1] Lee P. et al. 2006. PRIME: A small body mission at Mars, *Canadian Space Astronomy Workshop, Nov 23-24, 2006.* [2] Lee P. et al. 2006. PRIME Mission. *Exploration Canada 2006 Workshop, Oct 17-18, 2006*. [3] Richards, R., et al. 2007. *First Int'l. Conf. on the Exploration of Phobos and Deimos, LPI Contrib. #1377,* 32. [4] Lee, P. 2007. *First Int'l. Conf. on the Exploration of Phobos and Deimos, LPI Contrib. #1377*, 25. [5] Burns, J. 1992. Mars, Univ of Arizona Press, 1283-1301.

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