PRIME: Phobos Reconnaissance & International Mars Exploration

A Canadian-led International Mission to Explore Mars's Small Inner Satellite

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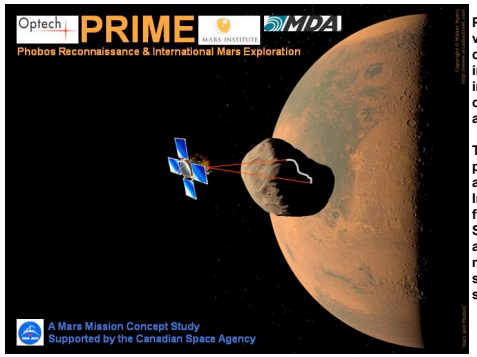

PRIME will rendez-vous with Phobos to conduct in-situ investigations using imaging, lidar and compositional analysis instruments.

The present concept, proposed by Optech and the Mars Institute with support from the Canadian Space Agency, is of an international mission with substantial private sector engagement.

INTRODUCTION: The Canadian Space Agency (CSA) has recently selected the ***PRIME*** **(*P*hobos *R*econnaissance and *I*nternational *M*ars *E*xploration)** Mars mission concepts study for funding. The acronym PRIME conveys a) the inherent *top* science and exploration value presented by missions to Mars's inner moon Phobos, and b) the *preparatory role* that such missions could play as *early* steps before more complex Mars and other small bodies exploration are undertaken. Initial PRIME mission concepts were developed in a joint partnership between the Mars Institute and Optech Inc.. Optech now serves as overall lead and industrial prime for the CSA-supported concepts study. Mars Institute serves as lead institution for science. MDA Space Missions and Simon Fraser University in Canada, and Johns Hopkins University's Applied Physics Lab (APL) in the USA, are industrial partners. The PRIME Science Team is international and includes participants from Canada, USA, Europe, Russia, and Japan. PRIME Principal Investigator is Dr. Pascal Lee (Mars Institute). PRIME Deputy Principal Investigator is Dr. Alan Hildebrand (University of Calgary). Dr. Robert Richards (Optech) is PRIME Mission Concepts Study Lead and Project Manager.

WHY PHOBOS? Ever since their discovery in 1877, the two small satellites of Mars, Phobos and Deimos, have been a source of puzzlement. Spectra acquired from the Earth and from spacecraft suggest ambiguous and conflicting links with different types of asteroids (C, D, P, T), while imaging data from the *Mariner 9, Viking Orbiters 1 and 2, Phobos 2, Mars Global Surveyor*, and *Mars Express* missions reveal irregular shaped, heavily cratered, and regolith-covered bodies. In spite of the repeated flybys and the global imaging coverage available for both objects (down to ~ 2 to 50 m/pixel), several fundamental questions remain unanswered: 1) What is the origin of Phobos and Deimos? 2) How did they evolve through time? 3) What are they like today in detail? The investigation of Phobos and Deimos bears directly on Mars science and the future exploration of Mars, and on studies of other solar system bodies as well. Although they are the two stable-orbit planetary bodies most economically accessible from low-Earth orbit (LEO) in terms of Δv requirements, Phobos and Deimos remain largely unexplored.

Regarding the origin of the two moons of Mars, two competing hypotheses still stand unresolved: A) they are captured asteroids; B) they were formed in circum-martian orbit (*e.g.,* Burns 1992). Regarding their evolution through time, a wide range of questions remain unanswered (*e.g.,* Thomas 1993). For instance, how have impacts modified their sizes, shapes, and landscapes? How did Phobos acquire its grooves? Regarding their status at present, major questions include: What processes might still be actively modifying these objects? What is their internal structure? Does their regolith contain martian meteoritic signatures? Is there any H (or H_2O) in their regolith at present? Does dust levitate? (Lee 1996, 1997).

Between Phobos and Deimos, the study of Phobos may be considered of higher priority because: i) Phobos orbits significantly closer to Mars (a = 2.76RM, R_M = radius of Mars) than Deimos (a = 6.90R_M); its exploration offers a stronger connection to Mars, for instance as a closer-positioned platform for Mars remote sensing and monitoring, as a more likely potential repository of martian meteoritic materials or signatures, and as a more likely hub in future human Mars exploration (Lee *et al.* 2005); ii) Phobos (13.5 x 10.7 x 9.6 km) is significantly larger than Deimos (7.5 x 6.0 x 5.5 km) and offers *a priori* greater opportunities for scientific enquiry and discovery; iii) Phobos's surface appears to have less regolith mantling and a higher abundance of boulders, and thus may offer more ready access to coherent rock outcrops, and iv) has a system of linear grooves of unknown origin whereas Deimos shows none.

PRIME CONCEPT STUDY: The PRIME mission will substantially advance our understanding of: a) the nature and origin of Phobos, b) the evolution of Phobos through time, c) the current state of Phobos. *Two separate* mission concepts of particularly strong merit in consideration of their anticipated science return, relative simplicity, and estimated relatively low cost are under investigation: 1) ***PRIME Orbiter***, and 2) ***PRIME Lander***.

PRIME ORBITER: PRIME Orbiter is an Orbiter of Mars that will explore Phobos by co-orbiting Mars with Phobos for up to 90 days. The payload is baselined with four instruments (Table 1). The mission will provide new and definitive data on Phobos's mass, volume, density, internal structure, bulk composition, surface composition, near-surface H content, surface features, and terrain textures. CAMELOT, to be built by Optech, will establish Phobos's volume to within 1 km^3. MSI and NIS will achieve spatial resolutions of 2 m/pixel and 65 m/spot from a 20 km range, respectively. NDO will be almost identical to the HEND instrument on Mars Odyssey. The spacecraft will also carry an ultrastable oscillator for radio science.

TABLE 1: PRIME ORBITER: Instruments, Heritage, and Science Objectives

Instrument	Heritage	Science Objectives
CAMELOT (*Canadian Mars Exploration Lidar for Orbital Topometry*)	Phoenix	Shape, Topography, Structure, Textures
MSI (*MultiSpectral Imager*)	NEAR	Surface Features, Composition, Textures
NIS (*Near-Infrared Spectrometer*)	NEAR	Composition
NDO (*Neutron Detector – Orbiter*)	Mars Odyssey	Composition. Hydrogen? H_2O?

PRIME LANDER: PRIME Lander is a fixed Lander that will soft-land on Phobos and examine its surroundings for up to 1 martian year. The payload is baselined with four instruments (Table 2). Two are body-mounted: *PASCAL* and *NDL*. Two are arm-mounted: *CHAMP* and *APXS*. The mission will provide new and definitive data on the surface of Phobos, the nature of its features and the composition of its materials. PASCAL, to be built by Optech, will support hazard avoidance during landing and terrain studies and positioning after landing. CHAMP will image Phobos's surface in color at global and microscopic scales (3 microns/pixel), and will monitor Mars over time. APXS will assess elemental abundances in the regolith, including carbon content. NDL will measure H abundances within the topmost 1 m of the regolith.

TABLE 2: PRIME LANDER: Instruments, Heritage, and Science Objectives

Instrument	Heritage	Science Objectives
PASCAL (*Phobos Altimetry & Surface Characterization Azimuthal Lidar*)	Optech XXS-11	Topography, Textures, Positioning. Dust Levitation?
CHAMP (*Camera, Hand lens, And Microscope Probe*)	JPL	Surface Features, Composition, Textures. Meteoritic signature? Mars Monitoring.
APXS (*Alpha-Proton X-ray Spectrometer*)	Pathfinder, MER	Composition (including C). Meteoritic signature?
NDL (*Neutron Detector – Lander*)	Mars Odyssey, MSL	Composition. Hydrogen? H_2O?

VALUE TO CANADA: The PRIME missions focus on an important "niche" in Mars exploration (the exploration of Mars's moons), are relatively modest in cost, and draw on a wide range of key scientific and technological expertise already existing in Canada. Implementation of PRIME with Canada as a lead or strategic contributor would position Canada as a leading space partner not only in global Mars exploration efforts, but also in the exploration of small bodies, in particular of Near-Earth Objects (NEOs). Canadian taxpayers would benefit from the knowledge gained and shared excitement in the exploration of a little known world offering alien landscapes and grand views of Mars. Cost estimates, schedules, and requirements details will be provided in the future as a result of the ongoing study. Synergies between PRIME and upcoming international efforts to explore Mars and Phobos (*e.g.,* Phobos-Grunt; see Zakharov *et al.* 2006) will be sought and developed throughout the PRIME mission concepts study.

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