PHOBOS AND DEIMOS SAMPLE RETURN: IMPORTANCE, CHALLENGES, AND STRATEGY. Pascal Lee[1,2,3], [1]Mars Institute (NASA Research Park, Bldg 19, Suite 2047, Moffett Field, CA 94035-0006, USA, pascal.lee@marsinstitute.net), [2]SETI Institute, and [3]NASA Ames Research Center.

Summary: The nature and origin of the two moons of Mars, Phobos and Deimos, are still unknown [1, 2]. Selective sample return from both objects is the only assured and practical way to resolve this mystery.

Background: Decades of Earth-based spectroscopy and Mars orbital observations have not been able to establish the composition, nature, and origin of Phobos and Deimos. Are they i) captured asteroids [3,4], ii) remnants of circum-Mars accretionary materials [5], iii) remnants of a once larger moon(s) - itself possibly a captured object or a circum-Mars accretionary body [6]; iv) reaccreted Mars impact ejecta [7]? Phobos and Deimos are at the crossroads of major and outstanding questions in solar system science, bridging topics from planet formation to satellite and small body evolution, impact cratering to interplanetary medium processes, and many more. Their origin is the single most important science question to be answered in their exploration [2]. Phobos presents two major spectral units: a "red" unit, and a "blue" unit (see [8] for a review and latest data). The "red" unit is almost global in extent and matches D-type asteroids. The "blue" unit is associated with fresh-looking material exposed near the rim of Stickney Crater. The "blue" unit is consistent with dehydrated carbonaceous chondrites. Deimos is globally reddish and spectrally similar to the "red" unit on Phobos, although its *streamers* are bluer [8] (Fig.1).

Remote Observations Impasse. Several lines of reasoning suggest that the surface of Phobos and Deimos is not representative of their interior: 1) On Phobos, the "red" unit might be a superficial veneer, and the "blue" unit represents mostly buried materials; 2) Phobos and Deimos's low bulk densities imply that that their interiors are highly porous, possibly H_2O-rich, in contrast to their surface which does not reveal unusually high porosities or high H_2O content [7]; 3) Phobos and Deimos continuously accrete (space-weathered) asteroidal dust [9]; 4) Phobos and Deimos might be coated with martian impact ejecta; although macroscopic fragments of martian ejecta directly accreted onto Phobos or Deimos are likely few [9], impact ejected dust and electromagnetically entrained upper atmospheric dust from Mars might have contributed substantial polluting veneers over time on both Phobos and Deimos, perhaps accounting largely for their reported "Mars-like" spectral features [10].

Efforts to infer the bulk composition of Phobos and Deimos from remote observations have hit an impasse. Phobos and Deimos likely do not look like what they truly are.

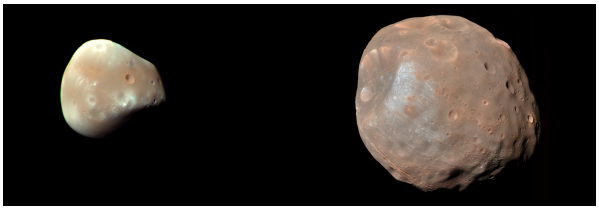

Figure 1: MRO Hi-RISE images of Phobos (right) and Deimos, shown to scale. (NASA/JPL/JHUAPL)

Ejecta Blocks: Phobos and Deimos have large blocks on their surface, the vast majority of which must be impact ejecta blocks [11-13]. These blocks are the only reliable sources of materials representative of Phobos and Deimos's bulk, available at their surface.

***In Situ* Investigations *vs* Sample Return:** Resolving the mystery of Phobos and Deimos's origin requires that *ejecta blocks* materials be examined and analyzed. *In situ* investigations that are able to access/contact ejecta blocks may resolve the origin question *if* Phobos and Deimos are unambiguously identified with known asteroid or meteorite types. However, sample return will be the only assured way of addressing the broader range of possibilities. Sample return will be required for isotopic analyses to determine whether Phobos and Deimos are related to Mars (same original materials), and whether they are related to each other. A Phobos-Deimos SRM would also be a valuable precursor/rehearsal for MSR.

Conclusion. Sample return from *both* Phobos and Deimos is the only assured and practical way of resolving the question of their origin. Samples of *ejecta blocks* (not regolth grab samples) need to be acquired. A New Frontiers class Phobos and Deimos SRM targeting ejecta blocks is under development: *Hall* [14].

References: [1] Veverka, J. & J. Burns 1980. *Ann. Rev. Earth Planet. Sci.*, 8, 527-588. [2] Lee, P. 2010. *Mars Inst. Tech. Pub. 2008-001*, 57 pp. [3] Mazursky, H. *et al.* 1972. *Science* 175, 294-305. [4] Veverka, J. & P. Thomas 1979. In *Asteroids.* U. of Az Press, 628-651. [5] Burns, J. 1992. In *Mars*. U. of Az Press, 1283-1301. [6] Singer, S. F. 2007. *LPI Contrib. 1377*, 36 [#7020]. [7] Giuranna, M. & P. Rosenblatt 2010. Europlanet, Sep 2010. [8] Thomas, N. et al. 2009. *Planet. Space Sci*. *In press*. [9] Gladman, B. 2007. *LPI Contrib. 1377*, 18 [#7049] [10] Lee, P. 2010. *In prep*. [11] Lee, S. et al. 1986. *Icarus*, 68, 77-86. [12] Lee, P. et al. 1996. *Icarus*, 120, 87-105. [13] Thomas, P. 1998. *Icarus*, 131, 78-106. [14] Lee, P. *et al.* 2010. 41st LPSC, LPI, [#1633].

Acknowledgement: This work was supported by NASA under Cooperative Agreement NNX08AO59A.