

Science exploration architecture for Phobos and Deimos: Are the moons of Mars in the critical pathway of human exploration of Mars?

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Abstract. As NASA plans to send humans to Mars in the 2030's, it is vital to gain a further understanding of the role of the martian moons. Phobos and Deimos may facilitate later exploration of Mars through exploitation of in-situ resources, through incremental development of technologies tested in the martian system, or by providing radiation protection. It is crucial to develop a mission architecture to serve as a roadmap for the exploration of Mars' moons focusing on the questions: What is the origin of Phobos/Deimos? Are Phobos/Deimos in the critical pathway for human exploration of Mars?

Mission Framework. We developed a framework of scientific questions to assess prior to sending humans to the moons of Mars. In order to determine if Phobos/Deimos are in the critical pathway for human exploration of Mars, their near-surface physical and chemical characteristics must be understood. To gain an understanding of these properties, the key question that initially drives this framework is: What is the origin of Phobos/Deimos? Several formation models have been proposed: co-accretion with Mars¹, ejecta from an impact with Mars², and capture of a foreign body, potentially sourced from the asteroid belt³. Each formation model has distinct implications for the utility of Phobos/Deimos in the human exploration of Mars.

We recommend an initial orbital + landed mission to address our key question, prior to investing resources in the development of technologies for humans to operate in low-gravity environments. This mission (Stages I–II) investigates the physical and compositional characteristics of both moons to determine how they formed. If the formation cannot be resolved with this initial orbital + landed mission and an additional lander could determine the origin, we send another lander. If the results of these missions indicate that Phobos/Deimos have utility for human exploration, our program continues with subsequent missions to determine the role of Phobos/Deimos in human exploration of Mars (Stage III). These missions ultimately determine whether humans can successfully operate on the surface of the moons^{4,5}. We outline a suite of objectives that human explorers can accomplish on the moons of Mars (Stage IV).

¹ P. Rosenblatt, C. Charnoz, *Icarus* 221, 806–815 (2012).

² R. I. Citron, et al., *Icarus* 252, 334–338 (2015).

³ M. Pajola, et al., *Astrophys. J.* 777, 2 (2013). ¹ P. Rosenblatt, C. Charnoz, *Icarus* 221, 806–815 (2012).

⁴ S. L. Murchie, et al., *PSS* 102, 176–182 (2014).

⁵ C. M. Pieters, et al., *LPS* 28, 1113 (1997).