PHOBOS-DEIMOS ASAP: A CASE FOR THE HUMAN EXPLORATION OF THE MOONS OF MARS.
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Introduction: A human mission to Phobos and/or Deimos presents the following key attractive attributes: 1) technically, it is achievable in the relative near-term, i.e. within the context of the current Constellation Program using the Ares V, CEV, LSAM, and lunar EVA suit systems; 2) scientifically, it will provide important new knowledge about Mars, its system, small bodies, and the formation and evolution of the solar system; 3) programmatically, it will likely help reach the more difficult and longer term goal of landing humans on Mars sooner, and at the same time advance the human exploration of NEOs, 4) programmatically as well, it offers an ideal solution to addressing planetary protection concerns regarding Mars exploration; 5) outreach-wise, it will be a new, exciting, tangible, and meaningful near-term step beyond the Moon and towards Mars.

Technical Feasibility: Much of the technical challenge and cost of human missions to Mars lies in reaching the actual surface of Mars: entry, descent and landing (EDL), safe and productive surface ops, and reliable return to low-Mars orbit. Creating and maturing the systems for humans to reach, survive, operate on, and return from, the martian surface will likely impose a large time gap between near-term human return to the Moon and the first human landing on Mars. A human mission to Phobos, however, is achievable with the systems already under development for Constellation. The Ares V, CEV, and LSAM space systems, combined with a low-thrust propulsion system to preposition cargo, offer a range of attractive options for low total ΔV early human missions to the moons of Mars, assuming aerobraking at Mars. EVAs on Phobos or Deimos could be supported using lunar EVA suit systems with few modifications. Significant challenges do exist, mainly i) long-duration (~2.5 yrs) exposure to space radiation and continuous microgravity, ii) achieving adequate autonomy and reliability for all spacecraft systems on that timescale; and iii) mastering (man-rating) aerobraking at Mars. But these challenges are also the first obstacles that need to be overcome before human landed missions on Mars.

Science Value: Phobos and Deimos are of significant scientific value not only as small bodies, but as records of Mars's formation and evolution. Solving the mystery of their origin will shed light on their nature and the history of the martian system, including Mars itself. Three hypotheses dominate discussions of the origin of Phobos and Deimos: a) they are captured primitive asteroids – if so, this would imply Mars likely had an extensive early atmosphere; b) they formed in circum-martian orbit – if so, they would be the last surviving building blocks of Mars; c) they resulted from the break-up of a larger moon, which itself would: c-i) have resulted from an earlier capture by Mars, or c-ii) have formed in circum-Mars orbit. Separate from these unresolved links to Mars, Phobos (and to a lesser extent Deimos) might serve as repositories of martian meteoritic signatures. Although impact ejecta from Mars typically hits Phobos at 1-2 $km.s^{-1}$ (Gladman, *pers. comm..)*, survival of martian meteoritic signatures cannot be ruled out. In an optimal scenario, such a record would be a *Library of Alexandria of Mars*: a global sampling of martian crustal materials collected throughout Phobos's history around Mars, possibly better preserved on Phobos than on Mars.

Programmatic Value: Human missions to Phobos and Deimos, being technically and fiscally achievable earlier than full-up human missions to Mars, and scientifically compelling in their own right, will help get and keep the *Humans to Mars ball* rolling earlier than otherwise possible. In addition to providing a tangible near-term milestone for the long term goal of landing humans on Mars, such missions would simultaneously advance the human exploration of NEOs. Moreover, planetary protection issues associated with human Mars exploration can be addressed via an initial Phobos mini-outpost phase, with Phobos serving as an platform in LMO for humans to teleoperate robotic explorers asceptically on Mars *and* to stage (for initial analysis, sorting, and curation) robotically-returned martian samples in a quarantine environment prior to their forwarding to Earth. A mini-outpost on Phobos could serve other important functions in support of human Mars exploration, including as a Mars remote-sensing base and communications relay, both requiring only solar power for sustained long-term operation.

Outreach Value: A human mission to Phobos or Deimos would be a new, exciting, tangible, and meaningful step beyond the Moon and towards Mars.

Conclusion: Human missions to Phobos and Deimos are possible in the relative short term and uniquely valuable. Their explicit inclusion for study *asap* in current Mars exploration architecture design efforts is recommended.