PHOBOS FIRST! –THE RIGHT FOCUS FOR NASA'S VISION. T. H. Sweetser, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109; ted.sweetser@jpl.nasa.gov .

Introduction: The architecture of the Mars Exploration Program needs to change.

We all agree that Mars is the goal, and learning about life on Mars is what the Mars Exploration Program is primarily about. More specifically, NASA's vision has been directed toward human exploration of Mars. "Only a human presence in Mars mission surface operations activities could facilitate and achieve the ambitious scientific goals and objectives of MEPAG." [1] But if we concentrate directly on achieving actual human presence on the surface of Mars there are too many unknowns to allow us to do realistic planning and costing. We need to focus our vision on an intermediate goal—virtual human presence.

The right focus for the Mars Exploration Program is telerobotic exploration of Mars from a permanently-occupied base in Phobos. It's not quite as romantic as "boots on Mars," but in every other way—scientifically, technically, politically, economically, organizationally, with respect to time, and for public involvement—Phobos First! has significant advantages as the immediate focus for human exploration. Many of the most problematic unknowns about Mars expeditions are deferred and the scope of the challenge becomes manageable. Moreover, it would most likely enable a human expedition to Mars's surface sooner than if we did not use Phobos first.

Phobos Basecamp: The use of a base on a Mars moon as a waystation for Mars exploration, or even as a base for teleoperations, has been suggested before [2], [3], [4], [5], [6]. But it is time to view it as a destination in its own right which would enable rapid advancement in our knowledge of Mars.

A base for long-term habitation at Phobos would be very similar in scale to the ISS. The habitable modules would be dug into the surface of Phobos on the side facing Mars so that Phobos and Mars would shield the inhabitants from radiation. Solar arrays and antennae for communications would be deployed on the surface of Phobos.

At any time about one-fourth of the Martian surface would be within line of sight from the basecamp (assuming an elevation mask of 10 degrees at any site on the Martian surface). The maximum round-trip light time of 55 milliseconds between the basecamp and Mars's surface enables real-time teleoperations, even for probes as operationally demanding as small airplanes. Sites along the equator would have direct line-of-sight for 3.7 hours twice per day (every 11.1 hours actually, which is the synodic period between Phobos's orbital rate and Mars's rotation rate). The same frequency of communication passes applies at all latitudes, but the duration of each pass decreases as the latitude increases, falling to 2.75 hours at 45 degrees and zero at 60 degrees north or south.

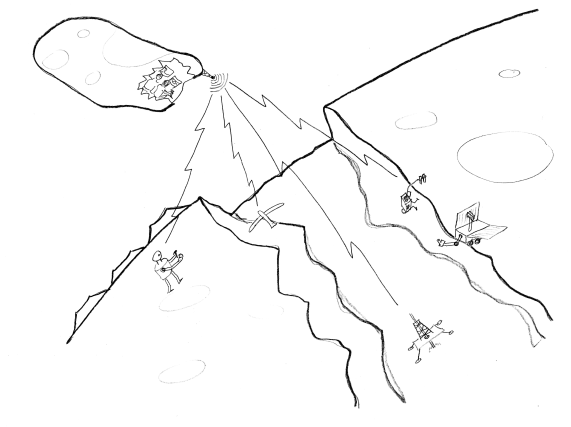

Figure 1. A basecamp in Phobos would allow real-time operation of multiple probes on Mars's surface.

Teleoperations from the basecamp could be console-driven, or full telepresence on the Martian surface could be achieved using a walker on Mars and a resisitive suit which takes advantage of the near-zero gravity in the basecamp. Adjusting the suit to provide motion resistance consistent with Earth gravity would minimize the adjustment needed to virtually walk on Mars; astronauts would then get needed exercise at the same time as they explore Mars (this was suggested to me by Damon Landau at JPL).

Advantages of Phobos First!: Establishment of a Phobos basecamp would speed up exploration of Mars a hundredfold over the current pace of robotic exploration—each telerobotic mission could be ten times as productive as a robotic surface mission commanded from Earth, and a basecamp could deploy probes from Phobos to Mars ten times as often as Earth can launch spacecraft. Because of the efficiencies inherent to direct interaction with Mars through telerobotics, a small crew at Phobos could operate a multitude of surface probes deployed at a variety of sites around Mars.

Such probes could be deployed in quick and direct response to bring different instruments or functional capabilities to bear on unexpected discoveries. These probes could be part of the equipment brought from Earth, or assembled from parts and subsystems similarly brought to Phobos, or perhaps Phobos basecamp could take advantage of 3D printing technology to quickly tailor probes in function and instrumentation to respond to new discoveries on Mars.

Another possibility is multiple sample returns from the surface of Mars to Phobos basecamp. Instead of having an Earth-return vehicle rendezvous with a sample launched into low Mars orbit as in the usual Mars Sample Return architecture, a smaller and simpler orbit transfer vehicle could be teleoperated to retrieve such orbiting samples and bring them back to the basecamp. Analytic capabilities which are greatly enhanced over what can be provided even by telerobotic surface probes could be available in a laboratory module in Phobos basecamp.

Perhaps the single strongest reason for Phobos First! is that working telerobotically from Phobos would minimize human impact on Mars and minimize the risk of interference with life studies on Mars that are the primary objective of the whole program. Conversely, the Phobos First! approach reduces the risk to human health and safety because the mass of Phobos provides radiation shielding and an anchor for mechanical simulation of gravity.

Programmatically, a Phobos basecamp doesn't have the yet-unsolved technical challenges of landing humans on the surface of Mars and then launching them for return to Earth; thus it can be planned and costed with some hope of validity. Phobos First! strengthens programmatic justification for both human lunar orbit missions doing teleoperations on the lunar surface and human NEO missions. An installation that is dug in to Phobos would also maximize heritage of the ISS and indeed would require near-term use of the ISS for both technology development and as a rehearsal hall for operations specific to Phobos basecamp. Besides its technical aspects, the ISS heritage includes a proven framework for extending international cooperation in space to Mars.

The value of the Phobos basecamp would extend beyond the initial telerobotics campaign. First of all, the rapid increase in scientific understanding of Mars enabled by teleoperations would enable a thorough assessment of potential landing sites for actual human presence. Then Phobos basecamp itself would serve as a staging area and safe haven for human expeditions to the surface, and provide operational oversight and coordination for surface activities.

Phobos First! would also offer strong and immediate benefits here on Earth. Investment in telerobotics technology would have direct relevance to exploration and operations in hazardous environments such as sea bottoms and disaster areas. And the mission itself would allow us at home to be virtual partners in exploration—consider how exciting it has been for people to follow the rovers on Mars even at the slow pace required by commanding from Earth, and how much more exciting a delayed, real-time, virtual presence on the surface would be.

Furthermore, telerobotic exploration of Mars from Phobos would unite the robotic and human exploration sides of NASA in a common objective and take advantage of their respective expertise.

Conclusion—Near-term Implications: Adoption of a new exploration architecture that embraces Phobos First! has immediate consequences for current technology development and program planning. NASA investment in telerobotics and teleoperations technologies could speed up development in that area and is needed to extend this field to the zero-g environment, which itself offers potentially significant advantages—for one thing, it may be possible for a teleoperator in zero-g to be more fully immersed in the virtual world than a teleoperator tied to the surface of Earth.

This proposed programmatic direction would also raise the importance of and add new objectives to a future Phobos sample return mission. Besides the scientific return which already justifies such a mission, we would need to learn about Phobos's suitability as an environment for habitation both from a health and safety perspective and from a mechanical engineering perspective.

Beyond a robotic Phobos mission, NASA should begin formulating human precursor missions to support Phobos First! One opportunity for such missions is the use of teleoperations on the lunar surface from lunar orbit to bring that technology to operational readiness while doing scientific work that is valuable in its own right. Another is human expeditions to near-Earth objects, which would offer the opportunity to experiment with construction techniques at bodies with negligible gravity.

References: [1] MEPAG HEM-SAG (2008). Planning for the Scientific Exploration of Mars by Humans, p. 5, posted March 2008. [2] Landis G. A. (1995) JBIS 48 367–342. [3] Singer S. F. (2000) To Mars by Way of Its Moons, *Scientific American,* March 2000, pp. 56-57. [4] Clark B. C. (2003) Mars Waystation: Architectural Optimization For Human Safety And Robotic Efficiency. Presented at IAF 2003. [5] Lee P. (2007) Phobos-Deimos Asap: A Case For The Human Exploration Of The Moons Of Mars, presented at the Workshop on the Exploration of Phobos and Deimos (2007). [6] Landis G. A. (2004) Robots And Humans: Synergy In Planetary Exploration. *Acta Astronautica* 55 (2004) 985 – 990, doi:10.1016/j.actaastro.2004.05.072.