Human Mars Mission Operations from a Phobos Base Camp: Transfer Stage and Lander Propulsion and Technology Implications

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Phobos, the innermost of Mars' moons, is closer to its planet than any other moon in the solar system; Phobos always has once side facing Mars and orbits several times in 1 Mars day (1 SOL), making it a very interesting place from which to observe and explore Mars. Phobos' low gravity level would preclude the need for a separate Phobos lander to establish a base camp for Mars exploration, as the Phobos transfer stage/spacecraft (PTSS) would fly to within a very short distance of the moon and deploy a tethered penetrator or other mechanism to anchor itself. The PTSS would deploy inflatable habitation and other modules on Phobos for crew habitation. An initial mission to Mars via a Phobos stopover would provide a validation of all transfer, power, mobility and telecommunication systems necessary to a sustainable Human Mars program. Once the initial Phobos base camp is completed and operational, additional crews arrive with Mars landers, these crews (and their landing craft, based at Phobos) conduct sorties to the Mars surface and return to the Phobos base camp and to the PTSS vehicles that are stationed there (that will eventually return them to Earth). The Phobos camp serves as the way station for crews and acts as a depot and service base for Mars landers and transfer stages. Subsequent missions to Mars rendezvous with Phobos, resupply the base and the landers with the necessary propellant, supplies and spare parts necessary for the next surface sortie. Landers are spared the difficult, high dV ascents necessary to reach high Mars orbits (i.e. 1 SOL orbits) and thus could be much smaller in size and require significantly less propellant if based at Phobos' low, easy to reach altitude. Descents from Phobos' low altitude would reduce the deceleration loads and entry requirements on the lander descent aeroshell. Phobos first serves as a tele-operation base for extensive exploration of the surface of Mars with a variety of rover types and pilot technologies, such as in-situ propellant plants (ISPP). These are operated real time and valuable experience is gained in the Mars environment to allow for the next step – Manned surface exploration. The tools, processes and communication equipment necessary to the crews survival and success will have been proven at Mars via the Phobos base camp.

This architecture will need space propulsion and power systems to support it. *Propulsion* for Trans-Mars, Trans-Earth and Phobos-to-Mars descent/ascent stages; *Propellant transfer* for lander refueling; *Power* (including fission surface sys) for Phobos crew habitation and science, and *In-situ resources* utilization (ISRU). Each of these technologies must be mass efficient, long lived, sustainable and extensible to later more ambitious Mars surface activities.

This characterization and description of the Phobos base camp architecture and its transfer stage systems may serve to help define those technology requirements necessary to Mars exploration; specifically by allowing technologists' to focus of the three separate phases of the mission/architecture;

1) the Earth-Mars/Phobos transfer stages and their technologies, which include high Isp, electric propulsion (Solar or Nuclear), Nuclear thermal propulsion, and chemical propulsion (which may involve the utilization of Oxygen derived from the Mars atmosphere or water derived from the surface).

2) Phobos-Mars landers and their technologies, which may include O2/Methane propulsion to take advantage of CO2 in the Mars atmosphere (ISRU), or other advanced propulsion, and

3) power systems that facilitate ISRU and make long duration crew habitation possible.

In this range arise opportunities for advanced space propulsion and power system technologies that might significantly increase the science return and other exploration potentials of the mission, and/or greatly decrease the cost and size of transfer and lander systems, making an extended Human Mars campaign more economical and sustainable in the long term. Advanced propulsion technologies validated at Phobos can then be extended to the Mars surface in a logical way.