PHOENIX LANDER IMPLICATIONS ON *IN SITU* RESOURCE UTILIZATION FOR ROBOTIC EXPLORATION OF MARS.

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Introduction: Sample return and manned Mars missions benefit greatly from *in situ* resource utilization (ISRU) by substituting hardware for consumables mass, thereby reducing initial Earth launch requirements [1,2]. It has been 30 years since a Sabatier/electrolysis ISRU system was first proposed for near-term Mars missions and the current Mars orbiters, surface rovers and the Phoenix Lander are generating data that, when coupled with the remarkable advances in computational and unmanned vehicle systems technology, justify a re-examination of Mars mission planning and ISRU development priorities. This paper will put forth logic for establishing a robotic base of operations at Mars that can enable mission planning *from* Mars rather than the serial missions *to* Mars being employed currently.

Following the Water: If water ice exists at some locations just beneath Mars' surface, it is possible to commit to a permanent operational base that exploits access to water. However, in doing so it will be necessary to assume that water ice contains organic molecules and other evidence of extent or fossilized biological activity, impacting its use as a feedstock. Furthermore, if a commitment is made to an operational base, reduced access to other future sites must be overcome.

This paper will discuss the engineering challenges associated with manipulating permafrost and other surface materials in a 3/8g, environment whose average surface temperatures is 210 ^oK, along with discussing how Mars' low ambient pressures can enable an "archeological approach" for water feedstock extraction.

Breaking the Serial Mars Mission Development Cycle: Since 1976, the typical time interval between committing to a Mars follow-on mission and an actual arrival at Mars have varied between 7 and 10 years. Only about half of the executed Mars missions to date can be considered successful. In addition, the opportunities for low-energy flights between Earth and Mars are constrained by the 779.86-day synodic period, making it very difficult to explore a 1.4441 x 10^8 km^2 surface area.

Establishment of high data-rate communication links between Mars and Earth is a continuing need and electric power levels approaching 100 kW will be needed for any sort of extended human presence. Early development of an orbiting satellite network that can provide persistently high communication rates while serving as a precision navigation platform can be exploited during the robotic exploration phase. A 10-kWe electric power generation capability can be used to demonstrate nuclear fission power generation or solar derived alternatives such as a very large solar array with energy storage or an orbiting solar power satellite with microwave transmission. Furthermore, that capability can be exploited to enhance system reliability and to demonstrate realistic methane and oxygen production and storage rates while providing the thermal energy required for archeological water extraction. At that point, it is possible for much of the Mars exploration mission planning and execution to start from the Martian surface.

This paper will discuss propulsion systems utilizing liquid methane and oxygen for powering reusable airplanes and hoppers from the Martian surface. The planned *Sky Crane* for the 2009 Mars Science Laboratory mission could have used methane-LOX as its primary propellant enabling its reuse for future exploration missions. Subsequently, fleets of unmanned exploration vehicles can be fueled and deployed on relatively short cycle round-trip surface sortie missions to virtually any location on the Martian surface via ISRU.

Compressed carbon dioxide as an auxiliary propellant: In addition to exploiting water as a feedstock, this paper will report on work by undergraduate students at Old Dominion University that has focused on condensing solid dry ice out of the Martian atmosphere utilizing a Peltier refrigerator and subsequently reversing the polarity of the device to act as a heat pump, producing supercritical carbon dioxide fluid at very high pressures for rocket propulsion and compressed gas tool operation. By using small solar arrays to generate the electrical power, these systems can be used for emergencies and as a local energy source away from the main base.

References:

[1] Ash, R.L., Dowler, W.L., and Varsi, J. (1978) *Acta Astronautica*, 5, 705-724. [2] Hoffman, S.J. and Kaplan, D.I. (1997) *NASA Special Publication 6170*.