Conference: IEEE Aerospace Conference, Big Sky, Montana, March 2016

Target Session: **Session 8.01: Human Exploration beyond Low-Earth Orbit**

Session Summary: This session seeks papers addressing the broader aspects of human exploration including planning, development, system concepts, and execution of missions beyond low-Earth orbit. Sample topics include systems architecture studies of human missions to the Moon, asteroids, and Mars, design reference mission analyses, strategic concepts, and broader trade study and systems engineering analyses for any aspect of human space exploration systems beyond low-Earth orbit. New approaches and unique applications of systems concepts are sought.

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Title: Human and Robotic Exploration Missions to Phobos prior to Crewed Mars Surface Missions

Phobos is a scientifically significant destination that would facilitate the development and operation of the human Mars transportation infrastructure, unmanned cargo delivery systems and other Mars surface systems. In addition to developing systems relevant to Mars surface missions, Phobos offers engineering, operational, and public engagement opportunities that could enhance subsequent Mars surface operations. These opportunities include the use of low latency teleoperations to control Mars surface assets associated with exploration science, human landing-site selection and infrastructure development which may include in situ resource utilization (ISRU) to provide liquid oxygen for the Mars Ascent Vehicle (MAV).

A human mission to Mars' moons would be preceded by a cargo predeploy of a surface habitat and a pressurized excursion vehicle (PEV) to Mars orbit. Once in Mars orbit, the habitat and PEV would spiral to Phobos using solar electric propulsion based systems, with the habitat descending to the surface and the PEV remaining in orbit. When a crewed mission is launched to Phobos, it would include the remaining systems to support the crew during the Earth-Mars transit and to reach Phobos after insertion in to Mars orbit. The crew would taxi from Mars orbit to Phobos to join with the predeployed systems in a spacecraft that is based on a MAV, dock with and transfer to the PEV in Phobos orbit, and descend in the PEV to the surface habitat.

A static Phobos surface habitat was chosen as a baseline architecture, in combination with the PEV that was used to descend from orbit as the main exploration vehicle. The habitat would, however, have limited capability to relocate on the surface to shorten excursion distances required by the PEV during exploration and to provide rescue capability should the PEV become disabled. To supplement exploration capabilities of the PEV, the surface habitat would utilize deployable EVA support structures that allow astronauts to work from portable foot restraints

or body restrain tethers in the vicinity of the habitat. Prototype structures were tested as part of NEEMO 20.

PEVs would contain closed loop guidance and provide life support and consumables for two crew for 2 weeks plus reserves. The PEV has a cabin that uses the exploration atmosphere of 8.2 psi with 34% oxygen, enabling use of suit ports for rapid EVA with minimal oxygen prebreathe as well as dust control by keeping the suits outside the pressurized volume. When equipped with outriggers and control moment gyros, the PEV enables EVA tasks of up to 8 pounds of force application without the need to anchor. Tasks with higher force requirements can be performed with PEV propulsion providing the necessary thrust to react forces.

Exploration of Phobos builds heavily from the developments of the cis-lunar proving ground, and significantly reduces Mars surface risk by facilitating the development and testing of habitats, MAVs, and pressurized rover cabins that are all Mars surface forward. A robotic precursor mission to Phobos and Deimos is also under consideration and would need to launch in 2022 to support a 2031 human Phobos mission.