LUNAR/MARS IN-SITU PROPELLANT PRODUCTION (ISPP)TECHNOLOGY: DEVELOPMENT ROADMAP.

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Utilizing resources on the Moon, Mars, and other potential sites of human exploration for mission enhancement or for the benefit of Earth has been considered and studied for years. In-Situ Resource Utilization (ISRU) concepts range from making oxygen and fuel for propulsion, power generation, and life support; to making solar arrays from minerals extracted from lunar soil; to running fusion power plants on Earth with lunar supplied Helium-3. Over the years, research has been performed on a number of interesting concepts and chemical processes, and study after study has shown that use of in-situ resources can reduce the cost and risk of human exploration by decreasing Earth launch and logistics requirements while providing life support, propellants, power, and manufacturing capabilities to become more self-sufficient. Over the last few years, ISRU has been viewed more and more as an "enabling technology" for the human exploration and exploitation of our solar system.

Since most of the technologies for ISRU are immature, the mission benefits of using ISRU are based on the research to date as well as estimates of ISRU concept complexity, power demand, and chemical conversion or extraction efficiency. Most of the research being performed by NASA, universities, and industry has been at the concept or experimental proof-of-concept stage with limited component or breadboard development. Also, the research to date has been mostly uncoordinated and unfocused since a clear strategy or mission plan to explore the Moon and Mars in the 21st Century has not been available.

Over the past year, a group within NASA has been attempting to coordinate and focus the development of ISRU technologies in the area of In-Situ Propellant Production (ISPP) to support both robotic and human exploration initiatives to the Moon and Mars. The roadmap currently includes the following:

1) a rationale and benefits section on using ISRU for exploration
2) an overview of the most promising ISPP concepts for both Lunar and Mars exploration
3) an overview of current ISPP development participants and technology activities
4) the technology areas and issues that require development for each promising concept
5) development schedule with flight demonstrations to support human Moon and Mars exploration
6) a preliminary funding profile to develop robotic and human ISPP

The mission strategy used in the ISPP Roadmap for human exploration in the 21st Century is still very preliminary, but covers human exploration of both the Moon and Mars. The mission strategy for lunar exploration begins with a simple, short term lunar surface stay in 2003. The first mission would last only a few days and consist primarily of existing technology; however, long duration landers and habitats, and nuclear transfer stages would be demonstrated on other missions. For missions to Mars, human exploration would begin with the launch of an unmanned habitat and return stage in 2009 to support the first human mission to Mars in 2011. The 2009 return lander would include an ISPP plant to produce the propellant needed for ascent from the Mars surface before the first human crew left Earth in 2011. Robotic orbiters and landers to help define the environment and surface conditions as well as perform engineering demonstrations of key technologies are also an integral part of these mission strategies.

Demonstrating the production of oxygen using lunar resources is a major element of the first human mission to the Moon. Depending on the availability of water on the Moon, the oxygen production demonstration may use either lunar water or regolith. The Lunar Prospector, to be launch this year, will help determine the availability of water on the lunar surface. Should water be found in large quantities at the south pole, a lunar polar explorer could be launched in 2001 to deploy an ISPP demonstration based on lunar water. The first oxygen production demonstration most likely will be constrained by available power and mass, but it is hoped that the oxygen produced could be used to supplement crew life support to extend the first mission by a few days. Once ISPP has been demonstrated, an automated oxygen production pilot plant would be launched in 2005 to refuel small landers for reuse as human or cargo return vehicles. To meet these launch dates, a lunar ISPP chemical process must be selected by 2000 at the latest. Currently, there are five lunar regolith chemical processes being considered: hydrogen reduction, sulfuric acid reduction, methane reduction, molten electrolysis, and vapor phase pyrolysis.

The roadmap for Mars ISPP is centered around making a Go/No Go decision in 2003 or 2004 to support the human exploration of Mars in 2009 and 2011. Four major criteria must be completed to support this Go/No Go decision date: 1) ISPP technologies to be used must be greater than Technology Readiness Level 5 [component prototype demonstrated]; 2)

The ISPP chemical process to be used must be selected; 3) an autonomous, long-term system demonstration of the process to be used must be performed; 4) the Mars surface environment and how it impacts ISPP must be characterized. To meet these criteria, the ISPP chemical process to be used in the 2009 mission must be selected in 2000. Also, to meet criteria #4, an ISPP demonstration, called the Mars ISPP Precursor (MIP), is currently under development as a potential payload on the 2001 Surveyor lander. Even though it is not one of the Go/No Go criteria, it is highly desirable to perform an end-to-end demonstration of the ISPP system to be used in 2009 as a verification of the system's performance. Due to Earth/Mars launch opportunity limitations and mission durations, there are only two launch opportunities to perform this type of demonstration and still impact the design of the 2009 vehicle; in 2003 and in 2005. At this time, a Mars sample return mission using ISPP is tentatively planned for launch in 2005 to fulfill this desire.