Self-Contained Propellant Production Plant for Mars Sample Return.

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Introduction: Human exploration of Mars will require many tons of consumables like propellants, water and breathing air.[1] The logistics train to bring all of these commodities to Mars would greatly increase the mission cost. Utilizing resources available on Mars would enable a sustainable presence and reduce overall mission cost. In order to insure functionality for eventual human missions, a series of validation missions will be needed for these consumable production technologies.

This presentation describes a precursor system that will generate propellant for a sample return class mission in a self-contained package that that allows for an independent mission or a secondary payload. This Self-Contained Propellant Production Plant (SCPPP) includes all of the equipment to collect and process Mars resources.[2],[3],[4],[5] While the primary product of this system is propellants for a sample return vehicle, the products from this plane also represent many of the consumables required to support human exploration while also providing a strong science return. Figure 1 shows a similar self-contained concept developed to extract oxygen from lunar soil. Known as the Precursor In-situ Lunar Oxygen Testbed (PILOT), the system demonstrated many aspects of resource collection and processing that can directly relate to Mars resources. The entire system was mounted on a lander frame that is the same size as the Mars Phoenix lander to demonstrate single launch mission capability.

SCPPP Overview: The SCPPP will include all the elements to collect resources and produce methane, water and oxygen. These specific features represent notional characteristics based on earlier work and could be changed after further research and analysis. One example used for a starting point is a concept developed to demonstrate propellant production in Mars, the Propulsion Utilization of Mars Produced Propellants (PUMPP) (Figure 2). The PUMPP experiment was intended to demonstrate production of methane and oxygen for a thruster firing. This system used many of the technologies envisioned for the SCPPP including frozen CO_2 collection and compression, Sabatier reactor for methane production and water electrolysis to separate the oxygen and recycle the hydrogen. The PUMPP demo showed many of the self-contained, highly integrated aspects including thermal integration and a shared cryocooler.

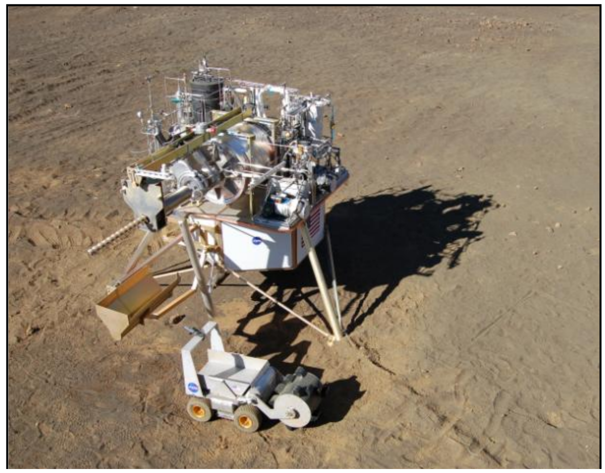

Figure 1 – Precursor In-Situ Lunar Oxygen Testbed represents a self-contained approach developed for lunar resources.

The SCPPP takes this a step further by collecting water from the Mars soil for use in the propellant production. With recent scientific evidence of abundant water near the Mars surface many latitudes on Mars have readily available water resources. The SCPPP will carry a soil collection rover that gets deployed upon arrival. The excavator rover would use thermal energy from a radioisotope power source to separate water from the soil while performing a series of scientific analyses on various soil samples. Elements of the SCPPP are listed below.

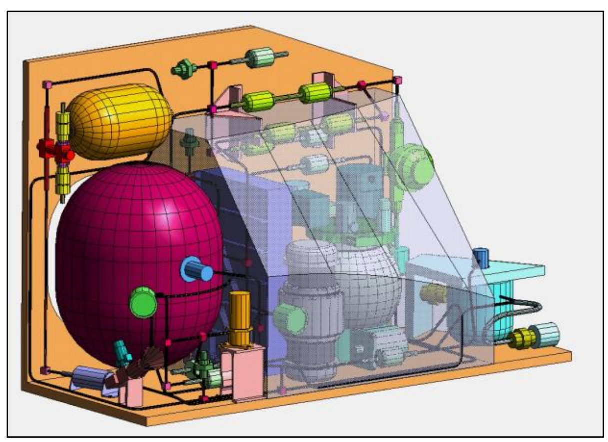

Figure 2 - Early propellant production concept called the Propulsion Utilization of Martian Produced Propellants (PUMPP) shows highly integrated system.

Excavator: The SCPPP will carry a rover that collects water from Mars soil using a bucket drum excavating device. This device uses a rotating collection drum with a series of small cutting teeth that will cut through a wide variety of soils including frozen ice. The excavator will use a radioisotope power system to provide electrical power as well as thermal energy for the water extraction process.

Water Recovery: Water will be recovered from the soil using a rotating extraction vessel heated from the radioisotope power supply. The water will be collected using a cold surface to generate diffusion pumping. Since any number of volatiles could also be released, the addition of a gas analyzer could provide wide ranging scientific data.

Atmosphere Collection: Carbon dioxide will be collected from the atmosphere using a cryocooler to freeze CO_2 to a cold surface inside a pressure vessel. When the vessel is closed on the cooling stopped, the CO_2 will melt, leaving a high pressure liquid for transfer to the processing element.

Water Electrolysis: An electrolyzer will be employed to separate the hydrogen and oxygen from the collected and water produced in the Sabatier reactor. The electrolyzer can generate high pressures that can be used to drive equipment and reduce liquefaction requirements.

Sabatier Reactor: Methane will be produced in a Sabatier reactor where hydrogen and carbon dioxide are combined to produce methane and water. The methane is separated and sent to storage while the water is condensed and sent to the electrolyzer. The Sabatier reaction is exothermic and highly favorable making it self sustaining with complete conversion using efficient catalysts.

Propellant Storage: This concept proposes that the methane and oxygen propellants be stored directly in the tanks of the ascent vehicle. These tanks can be efficiently nested in each other using a common bulkhead (Figure 3). There is a wide range of temperatures where both methane and oxygen can exist as a liquid. The common bulkhead tank can utilize a cryocooler more efficiently since a single cooler can refrigerate both fluids simultaneously.

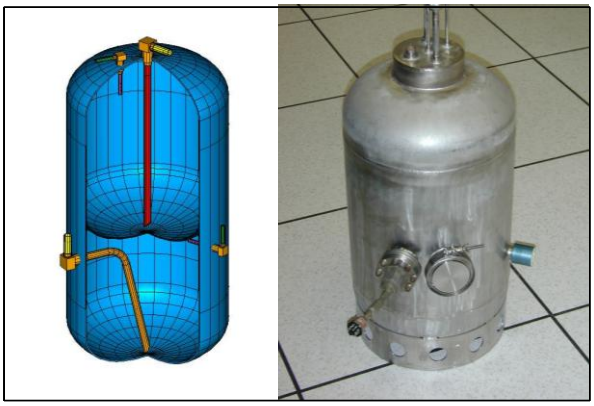

Figure 3 – Common bulkhead tank envisioned for ascent vehicle keeps propellants at same temperature until launch.

References:

[1] Hoffman S. J. and Kaplan D. I. (1997) NASA Special Publication 6107, *The Reference Mission of the NASA Mars Exploration Study Team*. [2] D. L. Clark, *et al.*, *In-Situ Propellant Production Demonstration* Final Report JPL Contract 960247. [3] D. L. Clark, *In-Situ Propellant Production on Mars: A Sabatier/ Electrolysis Demonstration Plant* AIAA 97-2764 33rd Joint Propulsion Conf. [4] D. L. Clark et al., *Report on the Construction and Operation of a Mars In-Situ Propellant Production Plant*, AIAA-94-2844, 30th AIAA Joint Propulsion Conference. [5] Simon T. M., R. S. Baird, J. R. Trevathan, and D. L. Clark. 2002. *An Advanced In-Situ Resource Utilization (ISRU) Production Plant Design for Robotic and Human Mars Missions.* In 53rd International Astronautical Congress, The World Space Congress, Houston, TX.