THE MARS ENABLING TECHNOLOGY SYSTEM Robert Zubrin, Mark Berggren, and Heather Rose, Pioneer Astronautics, 11111 W. 8th Ave. unit A, Lakewood, CO 80215, zubrin@aol.com

Introduction The Mars Enabling Technology System (METS) is a system for producing methane, oxygen, and water on Mars in unlimited quantities, using regolith water and atmospheric carbon dioxide as raw materials. In the METS water is acquired by placing soil in a closed chamber and then using a stream of heated CO_2 to outgas its water content and sweep it to a condenser. The CO_2 is then pumped back to the heater where it is reheated and recirculated back to the soil vessel to remove more water. The water so acquired is then sent to an electrolysis unit to be separated into oxygen, which is liquefied and stored, and hydrogen, which is sent to a Sabatier reactor where it is reacted with CO_2 obtained from the Martian atmosphere to produce methane and water. The methane is liquefied and stored, while to water is sent to the electrolysis unit to produce further oxygen and hydrogen.

System Design The Mars Enabling Technology System (METS, Fig. 1) comprises two principle subsystems. There are the Water Extraction Thermal System (WETS) and the Methane/Oxygen Producer (MOP). We discuss each of these in turn.

The Water Extraction Thermal System (WETS) The WETS addresses the question of acquiring water from the Martian soil in a simple and direct fashion. The system, as shown on the left of Fig. 1, works as follows. Concentrated solar energy or waste heat from a nuclear reactor or radioisotope device is used to warm CO_2 gas to about 300 C. This gas is then piped to a vessel which has been loaded with fresh Mars soil. Passing through the vessel, the CO_2 heats the soil and causes its water content to vaporize, which vapor is then swept along with the CO_2 gas stream to a condenser, which is cooled by exposure to the cold Martian environment. Its temperature dropped to near 0 C, the water content in the gas stream drops out to be collected in the condenser vessel in the liquid phase. The CO_2 gas, however continues onward. A heat exchanger is included to exchange heat between the gas streams entering and exiting the condenser, as by so doing both the heat load on the condenser and the heat loss imposed on the CO_2 gas stream are minimized. Upon its exit from the heat exchanger, the gas stream encounters a pump, which drives its recirculation back to the heating area. As shown in fig. 1, there is also a gas bypass system to allow free circulation without the gas entering the condenser at all. This is to avoid unnecessary heat loss during startup, when the goal is to get the soil up to temperature so its starts outgassing water. The soil is fed into the container in batch fashion, and dumped out after it has been dried. A prototype water extraction system designed along these lines was recently successfully demonstrated by Pioneer Astronautics.[1]

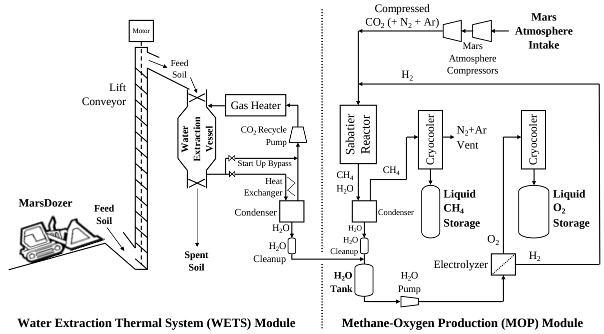

Fig. 1 Mars Enabling Technology System (METS)

The Methane Oxygen Producer

The Methane Oxygen Producer (MOP) uses the Sabatier/Electrolysis cycle first proposed by Ash, Dowler and Varsi in 1976 and demonstrated by Zubrin at Martin Marietta in 1993, and then further developed by Clark, Zubrin, and their colleagues at Lockheed Martin and Pioneer Astronautics in the period from 1994 through the present.[2,3,4] In the METS, this concept will be implemented using a two stage pump system to acquire CO_2 from the Martian atmosphere and feed it into a reactor containing ruthenium on alumna catalyst. In the reactor, the CO_2 is reacted with hydrogen to produce methane, which is liquefied (along with trace argon and nitrogen) using a small Stirling cycle cryocooler and stored, and water. The water is condensed, and along with water acquired by the WETS is sent to an electrolyzer to be separated into hydrogen and oxygen. The oxygen is liquefied using a small Stirling cycle cryocooler, while the hydrogen is sent to the reactor to produce more methane and water.

Mass and Power Requirements of the METS

Based on previous work, we estimate the following for the mass and power requirements of a METS system capable of producing 1 kg of methane/oxygen bipropellent per day.

Subsystem	Mass	Average Power
WETS	30 kg	$60\ W_e + 50\ W_t$
Marsdozer	10 kg	Trivial
MOP	50 kg	$440\ W_e$
Total	90 kg	$500\ W_e + 50\ W_t$

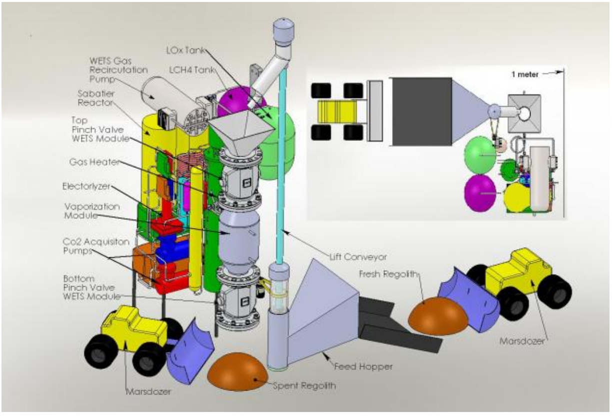

Fig. 2. The METS. The Water Extraction Thermal System (WETS) is on the right, the Methane Oxygen Producer (MOP) is on the left. Waste heat radiators have been omitted for clarity. The lift conveyor is 2.0 meters high.

Impact The net product of the METS is an unlimited supply of liquid methane and oxygen, as well as water, all produced on Mars, without the need to transport any consumables for the process from Earth. Methane and oxygen can be burned in a roc ket engine at an oxidizer/fuel ratio of 3.5:1 by weight to yield a specific impulse of 375 s, an Isp performance among in-space manufacturable propellant combinations second only to hydrogen/oxygen, but far more practical, as it is much denser and much more storable. Using such propellant, both robotic and human Mars missions involving ascents to rendezvous in highly elliptic Mars orbits, or direct return to Earth from the Martian surface become practical, with great reductions in overall mission mass, complexity, and cost. [5]

As a result of the reduction in launch mass enabled by the METS, both the number and/or the size of the launch vehicles required to conduct a Mars mission will be reduced, and the need for on orbit assembly and orbital infrastructure can be reduced or eliminated. As a result of the reduction of the landed mass, the requirements for mass delivery of the entry descent and landing system can be reduced, thereby reducing program development cost and risk further. As a result of the METS ability to make propellants on Mars without need for any feedstocks from Earth, direct return mission architectures become possible, eliminating the costs and risks associated with development and launch of an orbital vehicle, as well as the costs and risks associated with developing and implementing an autonomous rendezvous and dock on the return leg of either a robotic sample return or human Mars mission. In addition, the METS can further reduce the cost and risk and increase the exploratory capability of a human Mars mission by producing unlimited amounts of fuel, oxygen, and water for use by the crew while they are on the surface. By allowing the transformation of energy from a base nuclear reactor into portable chemical form, the METS will give Mars exploration crews mobile power, enabling both long distance mobility and the ability to use high power, for example for such science-critical applications as drilling, at sites far away from their base. The METS could also be used to greatly enhance the capability of the robotic Mars exploration program by enabling rocket powered hopping vehicles with global mobility, thereby allowing a single exploratory spacecraft launched from Earth to visit dozens of widely separated surface sites. Such self-refueling small rocket hopper craft could increase the cost-effectiveness of the robotic Mars exploration by orders of magnitude, and provide human explorers with an extremely valuable auxiliary capability as well. Ultimately, larger self-refueling rocket hoppers enabled by METS technology could give human crews themselves global mobility, allowing a single expedition to visit and explore numerous widely separated places of interest on the Red Planet

References

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