SPACE PROPULSION SYMPOSIUM (C4)
Propulsion System (2) (2)

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BENEFITS OF A HYBRID PROPULSION SYSTEM UTILIZING IN SITU PRODUCED OXIDIZER FOR A MARS ASCENT VEHICLE

Abstract

In Situ Propellant Production (ISPP) makes hybrid propulsion especially attractive for a Mars Ascent Vehicle (MAV) as part of a Mars Sample Return (MSR) Campaign. Gaseous oxygen can be produced from the Martian atmosphere. Therefore, only the dense, hybrid fuel needs to make the trip from Earth. The paraffin/oxygen hybrid design presented here optimizes in performance at a fuel to oxidizer ratio of about 2.5/1. This translates into a 70% propellant mass savings for the MAV. Additionally hybrids have systems benefits over traditional (solid propulsion) Mars Ascent Vehicle designs. The thermal "igloo" typically required can be minimized with this design because paraffin enjoys a particularly low glass transition temperature. A hybrid MAV can also be throttled, enabling more accurate Mars orbit insertion to ease the requirements on the rest of the campaign.

The ISPP process is completed in three relatively simple steps. A low power cryocooler is used to freeze carbon dioxide out of the Martian atmosphere. Of all the constituents in the Martian atmosphere, CO2 has the highest freezing point (about 150K at Martian surface pressure), meaning it will freeze first. The relatively pure CO2 is then allowed to warm up in a small, holding volume, where it increases in pressure. The pressurized CO2 is then passed through a solid oxide electrolysis (SOXE) unit. The SOXE unit converts the CO2 to O2 with approximately 67% conversion efficiency. Unconverted CO2 can be passed through the SOXE again or vented into the atmosphere. The rate of production depends on the power input into the SOXE. Roughly 50 grams per hour can be produced at 250 W. The ISPP oxidizer can then be transferred to the MAV as high pressure gaseous oxygen.

The merits of the two stage, hybrid system design will be presented in comparison with a two stage solid MAV. The entire system will be evaluated as part of the design, including the rocket itself, the hardware required for the in situ propellant production and the thermal insulation of the system. The representative solid system is presented by scaling previous designs using CTPB-based (low temperature, Mars qualified) propellant. Residual challenges for the hybrid MAV will be discussed. As will, potential complementary benefits, such as the demonstration of oxygen production at Mars, which is the first step in human exploration to the red planet. The mass savings enabled by the ISPP, hybrid MAV could enable or substantially augment the MSR campaign.