DESIGN AND MODELING OF AN ELECTROCHEMICAL DEVICE PRODUCING METHANE, OXYGEN AND POLYETHYLENE FROM IN-SITU RESOURCES ON MARS. J. B. Greenblatt[1], [1]Emerging Futures, LLC, 2726 Eighth St., Berkeley, CA 94710, jeff@emerging-futures.com.

Introduction: Emerging Futures, LLC developed preliminary engineering designs for two devices that would work in tandem with an electrochemical (EC) device developed by Opus 12, Inc. producing methane (CH_4), ethylene (C_2H_4) and oxygen (O_2) from Martian CO_2 and water. Other reduced products such as hydrogen (H_2), carbon monoxide (CO), etc. are also synthesized in the device. This work was conducted on behalf of Opus 12, Inc. as part of a Phase II NASA SBIR titled "In-Situ Ethylene and Methane Production from CO_2 as Plastic Precursors." The two devices provide important enabling technologies that can add considerable capabilities to both robotic and human missions.

Propellant production: The first device would use the output from the Opus 12 device and separate CH_4 and C_2H_4 from other fuel products and unreacted CO_2 and water. O_2 is produced in a separate chamber from the fuels and only needs to have water vapor removed. The design includes a water-gas shift system to convert CO into H_2, membrane separation stages, gas drying, and an integrated heat management system to reject waste heat to the Martian atmosphere. See Fig. 1. The resulting CH_4/C_2H_4 mixture can be used in a suitably-modified CH_4/O_2 rocket engine (the specific impulse of such an engine is virtually identical to that of a pure CH_4/O_2 engine). Balance of system mass and energy budgets were developed, along with exploration of parameter sensitivities. The system is sized to supply sufficient propellant to refuel a 2009 Design Reference Architecture Mars Ascent Vehicle (MAV) (7 mt CH_4 and 23 mt O_2) over 480 days, with ample O_2 available for other uses (life support, etc.). The baseline system mass is 412 kg including 265 kg for radiators; the device draws 30 kW, rejecting 13 kW.

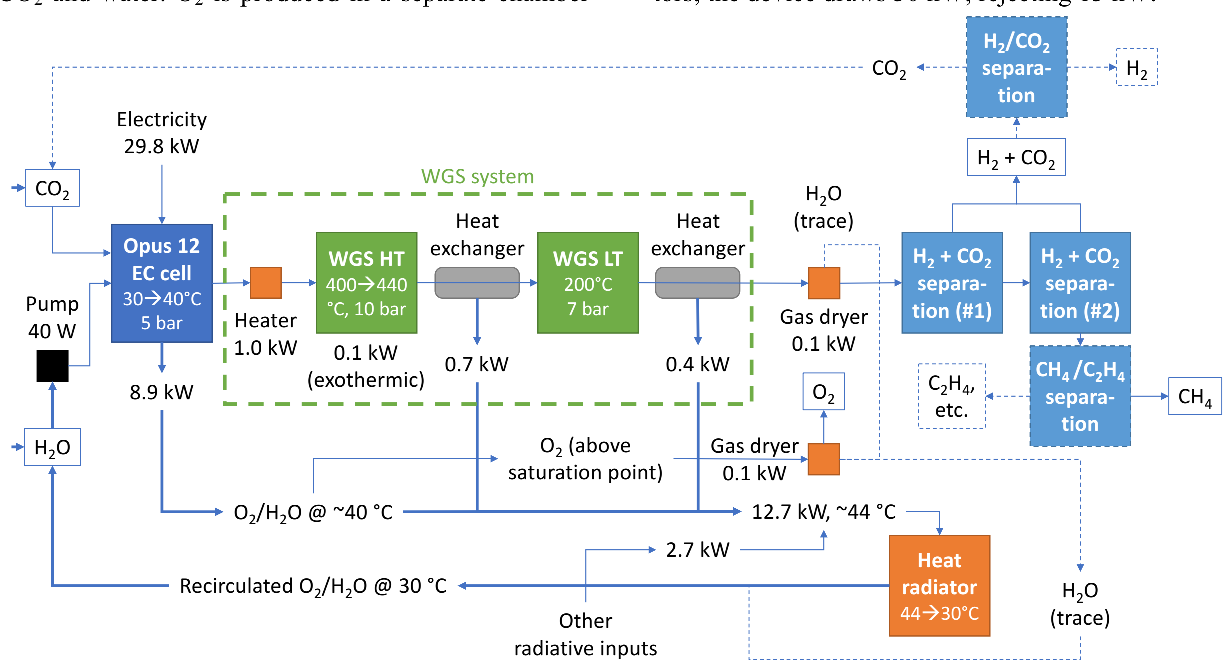

Fig. 1. Major components of the CO_2-to-propellant reactor design

Fig. 2 shows the physical system layout, including heat radiators required to reject waste heat generated by the system. The fully-stowed device including radiator panels is 0.66 × 0.66 × 0.60 m^3. There are four symmetrically folded panels against the sides of the central "device core" containing a water pump, EC cells, water-gas shift (WGS) reactor that converts co-produced CO into H_2 (for easier gas separation), gas dryers, and multiple separation stages. The fully-extended radiator panel area is 26.9 m^2 (double-sided). Heat is removed using water circulated through the anode side of the device. Schedule 5 aluminum pipe is used for the radiator panel tubing due to its low mass, yet has a maximum burst pressure of ~400 bar, many times higher than the expected maximum pressure of 10 bar.

Polyethylene production: The second device feeds the CH_4/C_2H_4 mixture into a polymerization reactor to produce high-density polyethylene, a versatile, food-compatible plastic with high strength, and good resistance to fatigue, wear and organic solvents. A small amount of H_2, readily available as a separated byproduct from the first device, is also required to quench the reaction, along with a catalyst that must eventually be replenished (140 kg provides a five-year supply). See Fig. 3. CH_4 remains unreacted and emerges at 97 percent purity, potentially suitable for use in an unmodified CH_4/O_2 engine. The device has a mass of 36 kg and consumes 750 W, producing 9 kg/day of polyethylene.

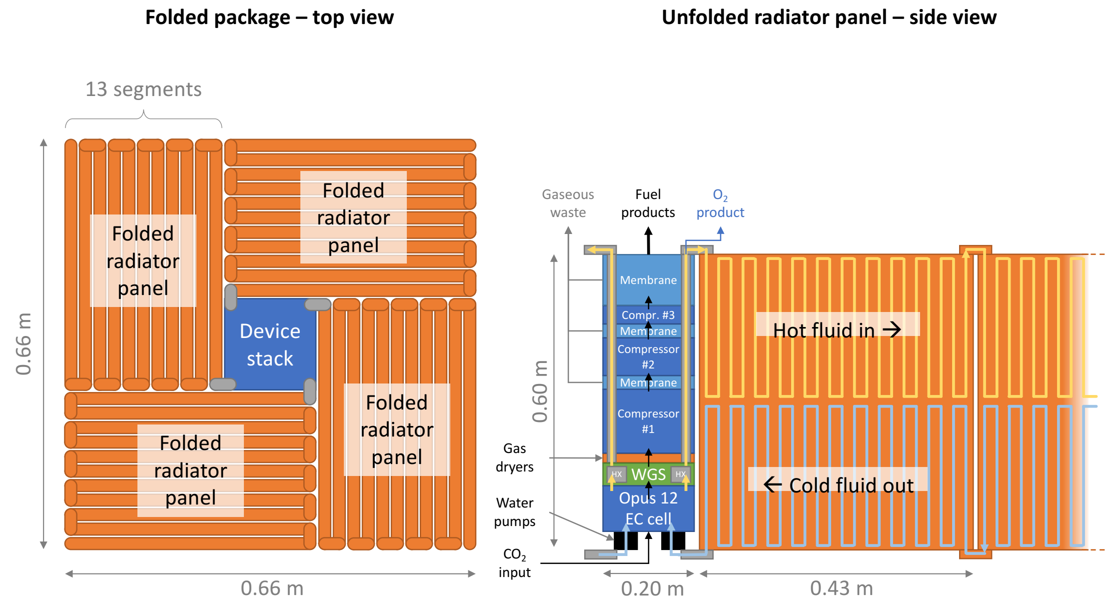

Fig. 2. Overall device physical layout

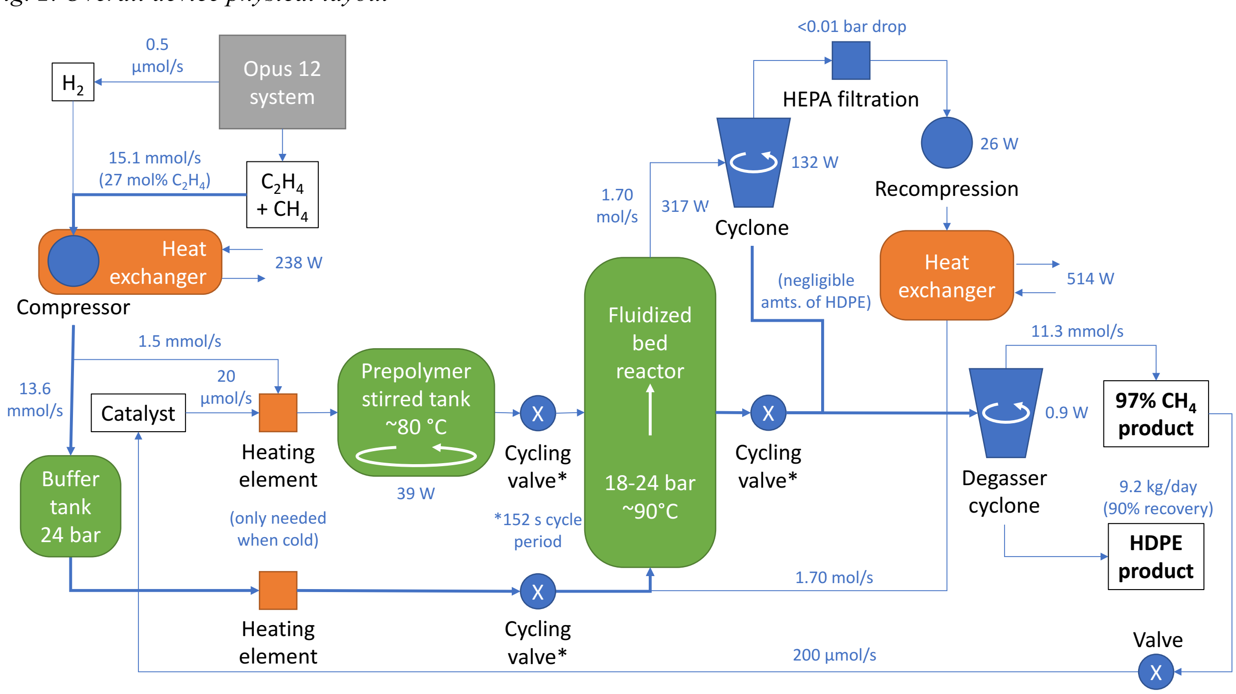

Fig. 3. Diagram of CO_2-to-plastics reaction design

Conclusion: We have developed a preliminary device design that can produce 14.6 kg/day of CH_4 and 58.6 kg/day of O_2 from Martian resources, sufficient to refuel the MAV, with 9.7 kg/day C_2H_4 that can be used to make ~9 kg/day of polyethylene, plus 0.77 kg/day H_2 and 66.6 kg/day of additional O_2. If a CH_4/C_2H_4 mixture can be used in the MAV, a lower total device mass of 249 kg is possible in principle.