**PREPARING MARS-C FOR FLIGHT: ELECTROCHEMICAL ISRU TESTING FOR PARTIAL GRAVITY ENVIRONMENTS.** K. Supak[1] and S. Sankarasubramanian[2], [1]Southwest Research Institute, 6220 Culebra Rd., San Antonio, TX 78023, kevin.supak@swri.org, [2]University of Texas San Antonio, One UTSA Circle, San Antonio, TX 78249, shrihari.sankarasubramanian@utsa.edu.

**Introduction:** To establish a sustained human presence on the Moon and Mars and meet NASA's In-Situ Resource Utilization (ISRU) goals, a deeper understanding of electrochemical processes and associated multiphase flow in reduced gravity is required. University of Texas San Antonio (UTSA) and Southwest Research Institute (SwRI) have been awarded a NASA Techleap Prize to investigate the performance of an electrochemical ISRU technology called Mars Atmospheric Reactor for Synthesis of Consumables (MARS-C) under Lunar (1/6g) and Martian (1/3g) aboard a parabolic aircraft. MARS-C is designed to produce oxygen, hydrogen, and C1 and C2 hydrocarbons directly from atmospheric CO2 and brine under Martian-relevant average temperatures (-36°C) without an intermediate hydrogen step [1][2][3]. The electrochemical cell design and choice of electrode materials primarily produces ethanol during CO2 reduction. Ethanol is a valuable feedstock that exists as a liquid at typical Martian conditions. It can be used both as a fuel in combustion or electrochemical (fuel cell) systems and as a feedstock for further downstream processing into valuable chemicals such as polyethylene.

Fig 1. MARS-C Prototype Operating in Earth Gravity

Laboratory testing has demonstrated MARS-C's potential to significantly reduce size, weight, and power (SWaP) requirements compared to existing systems. However, electrochemical performance under reduced gravity remains uncharacterized, particularly with respect to gas bubble behavior at the electrode surfaces as shown in Fig 1. As production proceeds, changes in electrolyte viscosity and density, along with buoyancy-altered bubble detachment and contact angles, may significantly impact system efficiency necessitating performance testing in reduced gravity.

**Methods:** The flight test payload is designed to incorporate six electrochemical cells that are operated in parallel to study the effects of reduced buoyancy, temperature, electrode material and surface properties. A photograph of the flight payload structure can be seen in Fig 2.

Fig 2. Electrochemical Cells Mounted in the Flight Payload

The cells utilize transparent materials to enable direct imaging of bubble growth, contact angle evolution, and detachment behavior using both conventional and high-speed cameras. Potentiostats are used to monitor real-time electrode potentials and cell currents throughout the flight and post-flight liquid samples are analyzed using nuclear magnetic resonance (NMR) spectroscopy to quantify the production of oxygen, hydrogen, and C1 and C2 hydrocarbons as a function of gravitational level.

Most of the development of MARS-C to date has been conducted in ground-based laboratory studies where controlling cell temperature can be easily achieved by placing the cells in dry ice baths. Therefore, a key requirement for adapting the lab-scale prototype to operate in a flight test was to incorporate electrolyte temperature control within a containment box that could provide potential spill control during the parabolas. To achieve lower temperatures, the electrochemical cell was coupled to a Peltier cooler attached to a convectively-cooled heat pipe that can transfer heat to the ambient air within the aircraft. This arrangement has demonstrated electrolyte temperature between -15°C and -10°C. A photograph of the electrochemical cell and containment box is shown in Fig 3. The electrochemical cell is loaded with a simulated Martian brine composed of a 2.8 Molar magnesium perchlorate solution saturated with CO2. The cell is operated with a voltage potential between one and two volts across the electrodes yielding a circuit current of about 200 mA.

The cells are designed to operate only during the partial gravity experienced during the parabolas to

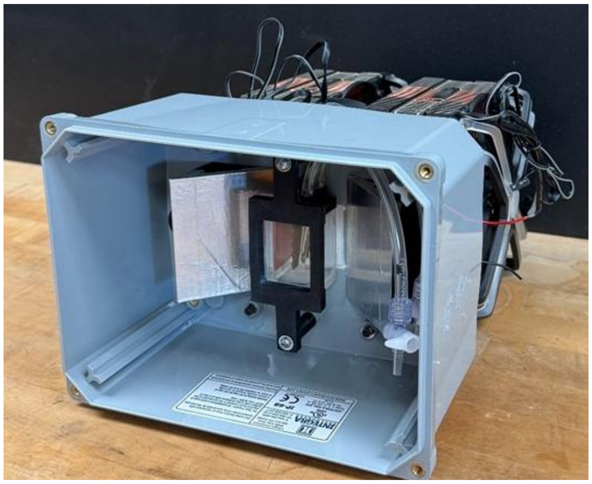

Fig 3. Flight-ready electrochemical cell within the containment box

isolate the effect that reduced buoyancy has on product formation. Ground-based tests have been conducted to validate payload operations during the flight and measure product formation during simulated parabola lengths and timing and determine transient effects of cell operation.

**Results & Discussion:** Fig. 4 shows the cell potential and current density from the ground testing. The potentiostat was programmed to only operate during

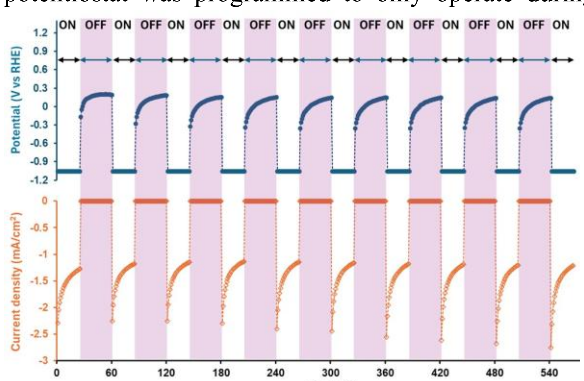


Fig 4. Ground testing cell potential and current density profiles

the 20 second parabolas. The current density varied, as expected, between about 1 and 2 mA/cm$^2$. The liquid product samples showed a measurable ethanol content during the limited time (~200 total seconds) that each cell will experience in reduced gravity. Fig 5 shows the NMR output peak at around 1 PPM. The two other spikes in the NMR are from the deuterated water and dimethyl sulfoxide (DMSO) added to the solution as reference chemicals. It is important to note that the electrode materials used in the ground test campaign were selected based on previous steady-state laboratory testing. Additional electrode materials are being considered to enhance the product formation rates during the shorter, non-steady durations of cell operations encountered during parabolic flight.

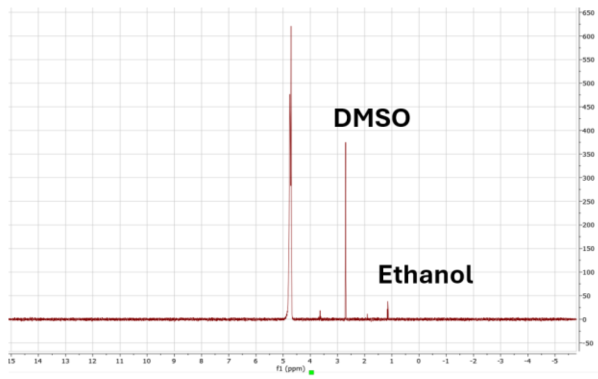


Fig 5. NMR spectroscopy results from ground testing MARS-C

**Future Work:** The flight test for this NASA Techleap award is expected to occur in the second half of 2026. This flight test will raise MARS-C to TRL 5 and generate key insights to guide the design and optimization of ISRU systems for long-term use in partial gravity environments like Mars and the Moon.

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**References:** [1] Gayen P., Sankarasubramanian S., and Ramani V. K. (2020) PNAS, 117, 31685–31689. [2] Shahid M. et al. (2023) AIChE J., 69, e18010. [3] Munera L. et al. (2025) AIAA SciTech, 2025–1478.