ISRU-derived water purification and Hydrogen Oxygen Production (IHOP) Component Development. Philipp Tewes, Jordan Holquist, Chad Bower and Laura Kelsey, Paragon Space Development Corporation, 3481 E Michigan Street, Tucson, AZ 85714 USA, ptewes@paragonsdc.com

Introduction: NASA has identified a critical need for the design, fabrication, and testing of in-situ resource utilization (ISRU) components to produce purified water, oxygen, and hydrogen on the Moon and/or Mars from regolith-based resources. Extended stays on the Lunar or Martian surface will require a readily available source of purified water. Once the water is purified, it can be used as a source of oxygen, (both as breathable air for habitat crew and as propellant oxidizer), and hydrogen as propellant fuel. Transporting large quantities of any of these resources to the surface of the Moon or Mars is difficult and expensive, necessitating the use of in-situ resources to generate propellants and life support consumables. NASA has specifically identified the need for development and testing of critical components for the extraction and purification of water from ice that exists at the lunar poles in permanently, or near-permanently, shadowed regions (PSRs) on the Moon. The lunar water can be used to produce hydrogen and oxygen propellant for lunar transportation vehicles (ascent and landers), reusable cis-lunar transports, and eventually, human missions to Mars and beyond. Propellant production requirements of 14 to 50 metric tons of H_2/O_2 per mission are anticipated. Purification and electrolysis of in-situ lunar water has never been done before. It presents unique challenges related to the hazardous, toxic, and flammable gases present with the lunar water and the lunar polar environment; as well as the typical constraints of system launched to the lunar surface (mass, volume, power, autonomy, robustness, reliability, and lifetime). This technology development is vital to allow humans to achieve a sustainable presence on the Moon. Using the technology to support such an effort will also certify the hardware for use on Mars, a destination where independence from Earth is even more critical for crew survival.

System Content: Paragon Space Development Corporation (Paragon) and our partner Giner, Inc. (Giner) are pursuing development and testing of key components in the ISRU-derived water purification and Hydrogen Oxygen Production (IHOP) subsystem (see Figure 1) as well as advancement of the subsystem architecture. IHOP purifies ISR-derived raw water from sources on the Moon or Mars and will initially be optimized to process lunar ISR-derived water [1, 2]. Paragon is developing an innovative, contaminant robust subsystem that removes acidic and water soluble contaminants found within ISR-derived water on the Moon and Mars that could corrode systems, degrade electrolyzer (or other downstream system) performance, or present serious toxicity issues to humans.

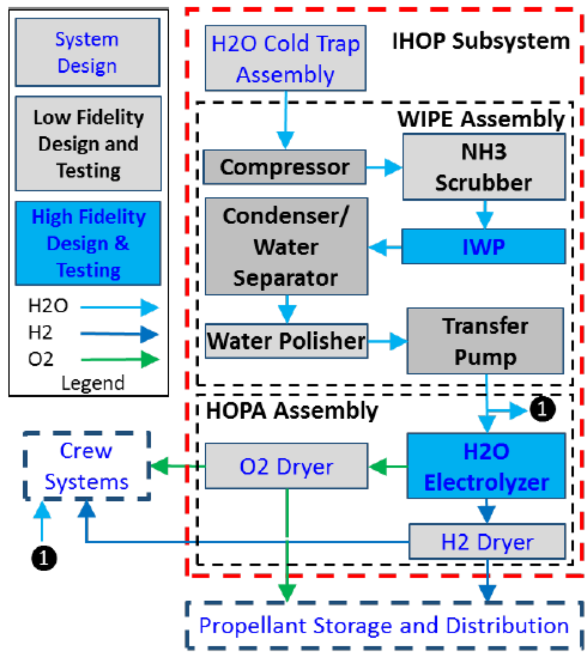

Figure 1. The IHOP concept with Water, ISRU-derived, Purification Equipment (WIPE) and Hydrogen Oxygen Production Assembly (HOPA).

A Cold Trap and Paragon's Nafion-based Ionomer-membrane Water Purification (IWP) technology provide the IHOP subsystem with broadband contaminant filtration, while an ammonia (NH_3) scrubber and water polisher are optimized for a specific contaminant and final trace contaminant removal, respectively. The purified water is then electrolyzed using a static feed water electrolyzer to produce H_2 and O_2 propellant. IHOP has very few moving parts, and is projected to require no regeneration or resupply while producing up to 47 metric tons of hydrogen and oxygen propellant per year for two years. A customized IWP module is shown in Figure 2.

This closely-coupled architecture of water purification and propellant production allows NASA maximum flexibility to adapt IHOP to a variety of upstream and downstream ISRU subsystems for applications on either the Moon or Mars. Our technical solution builds on both prior executed contracts as well as internal research and development.

Figure 2. Customized Ionomer-membrane Water Processing (IWP) Module

Technical Goals and Objectives: Current work focuses on the design, fabrication, and testing of critical components in a relevant environment and whose operation within an ISRU system requires unique design considerations not included in state-of-the-art hardware such as that found on the ISS. This work utilizes technologies and processes that leverage and support space or terrestrial commercial activities. Paragon and Giner will advance the technology readiness level of two key ISRU water and propellant production components from 4 to 5.

The WIPE (water purification) and the HOPA (hydrogen/oxygen production) components will undergo a thorough maturation and development effort. Testing of the components under relevant conditions (realistic, raw ISRU-derived water ersatz) will be performed to demonstrate functionality and performance. In addition, a preliminary design of the IHOP subsystem will be completed, which integrates the two key technologies (WIPE and HOPA) with the balance of plant required. This will be followed by integrated testing of the two components under relevant conditions (realistic, raw ISRU-derived water ersatz) for an extended duration to demonstrate performance and validate the close coupling of these fundamental ISRU processes.

Acknowledgments: This work has been supported by NASA under a NextSTEP-2 BAA contract.

References:

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[2] Holquist, J., Pasadilla, P., Bower, C., Tewes, P., Kelsey, L., "Analysis of a Cold Trap as a Purification Step for Lunar Water Processing," *Accepted for 50th International Conference on Environmental Systems*, 2020.