Overview of Proposed ISRU Technology Development.

D. L. Linne[1], G. B. Sanders[2], S. O. Starr[3], and N. H. Suzuki[4], [1]NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, OH 44135, MS 86-8, diane.l.linne@nasa.gov, [2]NASA Johnson Space Center, Houston, TX 77058, MC EP3, gerald.b.sanders@nasa.gov, [3]NASA Kennedy Space Center, Kennedy Space Center, FL 32899, MS UB-R3, stanley.o.starr@nasa.gov, [4]NASA Headquarters, Washington, DC 20546, MS 7074, nantel.h.suzuki@nasa.gov.

Introduction: In-situ resource utilization (ISRU) involves any hardware or operation that harnesses and utilizes 'in-situ' resources, both natural and discarded, to create products and services for robotic and human space exploration. By collecting and converting local resources into products such as propellants and life support consumables, ISRU can greatly reduce mass, cost, and/or risk of space exploration and lead to Earth independence. ISRU, therefore, is a disruptive capability in that it enables more affordable exploration than today's paradigm and allows for more sustainable system architectures to be developed. Although past work has demonstrated the feasibility of many facets of ISRU, significant work is needed to mature these technologies. Specifically, work is still needed for:

- development and testing closer to full-scale and for longer operational durations,
- testing in relevant environments,
- integration of the many components and subsystems into system prototypes, and
- realization of the synergy between ISRU and other system technologies.

A focused ISRU project is needed to answer the technology questions and retire the risks so that we can inject credible performance information into the exploration systems architecture trades, understand the ripple effects in the other Exploration systems, and provide confidence in the maturity and performance of ISRU capabilities before decisions are made in other Exploration elements that may reduce or preclude the benefits that ISRU can provide.

Objectives: NASA's Advanced Exploration Systems in the Human Exploration and Operations Mission Directorate is assessing options for ISRU technology and system maturation focused on volatiles resource acquisition, including water extraction from regolith, and volatiles and atmospheric processing into propellants and other consumable products. Production rates and hardware scale needed for robotic precursors and human missions are described in reference 1. Critical challenges include defining what is the best set of components and subsystems to enable production of mission consumables from either regolith or atmospheric resources at a variety of destinations, what is the performance and life that can be expected from the ISRU system in the actual environment, and how does the ISRU system integrate and interact with other exploration systems. One overall goal would be to achieve system-level TRL 6 to support future Pathfinder missions.

Approach: The envisioned technology maturation approach includes progression from components to subsystems to integrated systems, with parallel paths for regolith-based ISRU and for atmosphere-based ISRU. Technology development in these parallel paths would be applicable to multiple locations (e.g., Moon, Mars, asteroids, moons of Mars) and applications (e.g., propulsion, life support, regenerative power, manufacturing). The two paths would periodically be combined in both models and hardware to demonstrate ISRU capabilities such as oxygen production alone from Mars atmosphere, water production alone from regolith, and oxygen/methane production from both atmosphere and regolith.

Initially, focus would be on closing critical technology gaps such as icy/hard regolith excavation, water extraction from regolith microchannel reactors, solid oxide stack performance and life, and gas and water cleanup and separation. Emphasis would be on component testing in relevant environment for better control of test conditions and to provide parametric data to validate and improve analytical models.

The component technology development phase would lead into ISRU subsystem tests in a relevant environment. These subsystem testbeds would be used to understand interactions between components and to evaluate multiple technology options before downselect. The subsystem testbeds would then continue to be used to evaluate new component technologies and for long-duration testing.

The final goal of a ground-based technology maturation effort would be to bring the two parallel paths together to build and test end-to-end ISRU systems in a relevant environment. For example, the regolith-based development path would provide the system that excavates and delivers icy or hydrated regolith, processes the regolith to extract water, and cleans, purifies, and stores the water for life support or further processing. The atmosphere-based development path would provide the system that gathers the Mars atmosphere, processes it into oxygen only or oxygen/methane, and liquefies and stores the product in vehicle tanks. It is anticipated that a final integrated, ISRU/Exploration systems demonstration would then follow that integrates the ISRU systems with other Exploration systems such as power, thermal rejection, autonomous control, interfaces to life support and the ascent vehicle, etc.

Successful execution of such a technology development effort would continually provide the Exploration Architecture Teams with validated, high-fidelity answers for mass, power, volume, and concept of operations of ISRU systems and enable the development of exploration architectures that truly open up the potential of Space Exploration.

References:

[1] Linne, D. L., Sanders, G.B., and Taminger, K. M. (2015) AIAA 2015-1650.