The purpose of In-Situ Resource Utilization (ISRU) is to harness and utilize resources at the site of exploration to create products and services, which can enable and significantly reduce the mass, cost, and risk of near-term and long-term space exploration. The ability to make propellants, life support consumables, fuel cell reagents, and radiation shielding can significantly reduce the cost, mass, and risk of sustained human activities beyond Earth. The ability to modify the landscape for safer landing and transfer of payloads, creation of habitat and power infrastructure, and extraction of resources for construction, power, and in-situ manufacturing can also enable long-term, sustainable exploration of the solar system. Since ISRU can be performed wherever resources may exist, both natural and discarded, ISRU systems will need to operate in a variety of environments and gravitations. Also, because ISRU systems and operations have never been demonstrated before in missions, it is important that ISRU concepts and technologies be evaluated under relevant conditions (gravity, environment, and vacuum) as well as anchored through modeling to regolith/soil and environmental conditions. While the discipline of ISRU can encompass a large variety of different concept areas, resources, and products, the ISRU Topic has been divided into two subtopics dealing with the fundamental difference in technologies associated with solid in-situ material handling and processing versus gaseous and gaseous/solid processing. An attempt was made to minimize the potential overlap in technologies and processes between the two subtopics.

### Subtopics

**X1.01 Regolith/Soil Transfer, Handling, & Processing of Extraterrestrial Material**

**Lead Center:** JSC  
**Participating Center(s):** GRC, KSC, MSFC

**Regolith/Soil Transfer and Handling**

- Long-life, light-weight, and minimum consumable technologies to move feedstock material from the surface or a collection hopper to processing reactors (at least 3m); High separation efficiency gas/solid particle separation techniques and regenerable particle filters
- Granular materials mixing and size separation for reactor feedstock conditioning: remove material > 0.5 cm diameter before dumping into storage bin during excavation operation for oxygen extraction from regolith
- Granular flow computer models, devices, and instruments to evaluate material flow and manipulation under
low and micro-gravity flight and ground vacuum experimental conditions

- Mineral beneficiation concepts to separate iron oxide-bearing material from bulk regolith; up to 20 kg/hr based on hydrogen reduction

**Regolith/Soil Processing To Extract Resources and Products of Interest**

- Regolith/soil valve/seal concepts for processing systems with no gas leakage after 1000’s of operating cycles with material. For processes that require elevated temperatures, thermal isolation or minimum heat loss is required
- Regolith/soil processing reactor concepts for extracting volatiles and water/ice
- Regolith/soil processing reactor concepts for extracting metals through electrolysis and/or metal/waste/salt removal and separation techniques.
- High temperature (=1000 C), high efficiency insulation for regolith/soil processing reactors
- High temperature (=1000 C) pressure sensors and instruments for process control and performance assessment
- Alternative thermal, chemical, and/or biological processing concepts for oxygen (and potentially metal) extraction from regolith/soil besides

**Hydrogen Reduction and Carbothermal Reduction Processes**

- Light-weight, deployable solar concentrator concepts and solar energy transfer methods into regolith/soil processing reactors
- Low energy loss methods for redirecting solar energy from concentrators and fiber optic cables to allow multiple users in series

**Regolith/Soil Processing for Protection, Construction, and Energy**

- Thermal energy storage and utilization using bulk or processed regolith
- Techniques for hardening or modifying in-situ materials so that landing pads and roads can be constructed to prevent landing plume debris damage and wear on surface mobility platforms

---

**X1.02 Gas, Liquid, and Solid Processing to Produce Oxygen and Fuels from In-Situ Resources**

*Lead Center: JSC*

*Participating Center(s): ARC, GRC, KSC*
Solid/Gas Processing to Support Oxygen and Fuel Production

- Gas Separators for lunar oxygen extraction from regolith that provide low pressure drop separation of the system and product gas streams from impurities (e.g. HCl, HF, H₂S, SO₂); the process should be regenerable and the output contaminant concentration should be less than 50 ppb

- Hydrogen gas pumps with rates (up to 6 scfm) for recirculation and pneumatic transport

- Carbon dioxide collection and separation from Mars atmosphere

- High efficiency carbon dioxide/carbon monoxide separation concepts with high quality carbon dioxide produced

- Long-life carbon dioxide electrolysis/dissociation into carbon monoxide and oxygen concepts with high conversion efficiency at pressures greater than or equal to 1 bar

Water Processing

- Water/gas separators that use the space environment for water condensation/separation with minimal energy usage; concepts that can operate in both low-gravity (1/6-g and 3/8-g) and micro-gravity are of greatest interest

- Removal of dissolved ions in water by methods other than de-ionization resins to meet water electrolysis purity requirements (minimum resistivity of 1M-Ohms-cm). Ions of interest are dissolved metal ions (Fe, Cr, Co, Ni, Zn) at concentration of 0.01% and dissolved anions (Cl, F, S) at concentrations of 0.01%-2%. The process should be regenerable, minimize consumables, and minimize water loss.

- Contaminate resistant, high temperature water electrolysis concepts

Trash/Waste Processing for Fuel Production

- Processing concepts for production of carbon monoxide, carbon dioxide, water, and methane from plastic trash and dried crew solid waste. Proposals must define use of solar or electrical energy during processing, and any reagents/consumables; recycling schemes for reactants/reagents used in the processing should be evaluated

- Methods for waste/trash transfer and handling before and after processing