X5.01 Oxygen Production from Lunar Regolith

Lead Center: JSC

Participating Center(s): GRC, KSC, MSFC

Oxygen production from lunar regolith processing consists of receiving regolith from the excavation subsystem into a hopper, transferring that regolith into a reactor where it is reduced using chemical or an electrochemical process, potentially intermediate reactions to reach oxygen, purification of the oxygen, and transfer of the oxygen to the liquefaction and storage subsystem. After oxygen has been extracted from the regolith, the spent regolith must be removed from the reactor and returned to the excavation subsystem for disposal. Depending on the process used, the reactor may contain reduced metals that can be extracted in their pure form for use as a manufacturing feedstock.

To maximize the benefits of In Situ Resource Utilization (ISRU) for the Lunar Exploration Architecture, oxygen production systems must minimize the mass and power consumption of ISRU systems. ISRU systems must be able to produce many times their own mass in oxygen and other products to provide a benefit to the architecture. ISRU systems must be able to autonomously operate in a harsh environment that has wide temperature swings, high radiation and abrasive dust. Depending on the outpost location, the systems must be able to sustain many startup and shutdown sequences when solar power is not available. Some of these shutdown periods may exceed several hundred hours.

The next phase of ISRU research and development will focus on the design and testing of a regolith reduction system that can produce roughly 1000 kilograms of oxygen in a year. The operation assumption is that the production plant will operate off of solar power which is estimated to be available about 70% of the time and will operate at a lunar pole with highlands soils. The current oxygen production approaches being developed into prototypes are: Hydrogen Reduction, Carbothermal and Molten Oxide Electrolysis. The basic description of these approaches can be found in the NASA funded report by Eagle Engineering, entitled "Conceptual Design of a Lunar Oxygen Pilot Plant (1988)". The report can be found on the web at http://www.isruinfo.com/index.php.

NASA is seeking subsystem component technologies rather than full system proposals. We would like to
encourage the development of subsystem components that could be inserted into our Exploration Technology Development Program funded oxygen production systems to improve the mass, power and efficiency of the system. Technology areas of particular interest are:

- Heat exchangers to recover energy from heated regolith;
- Low/No maintenance system filtration technologies for removing dust from gas lines;
- Water condensers that would use the cooling potential of the space environment to water condensation with minimal energy usage;
- Solar Concentrators that are lightweight and able to deliver concentrated solar thermal energy to reactors generating regolith temperatures from 900°C up to 1600°C;
- Gas Separators that provide low pressure drop separation of the system and product gas streams from impurities (e.g., H₂S, SO₂);
- Microchannel methanation reactors that convert a mixture of carbon monoxide, carbon dioxide, and hydrogen to methane and water vapor with carbon monoxide and carbon dioxide consumed to the maximum extent possible;
- O₂ Purification technologies that perform the removal (and reclamation) of all contaminants prior to liquefaction of the oxygen;
- Feed systems to introduce regolith to the reactors and remove the regolith, slag or molten products from the reactor post processing. The systems must minimize the possibility of dust contaminating the reactor seals;
- Reactor Seals: The sealing of reactors includes sealing gas interfaces from the reactor to the remainder of the system and also the regolith feed/exit to the reactor. Valves proposed for use for gas interfaces must be capable of 1000s of operations and able to operate when lunar dust is present in the gas stream. Reactor regolith feed/exit seals proposed for use must either be kept clean, can be automatically cleaned, or seal even with a coating of lunar dust. Interested companies should keep in mind that each reactor system operates at significantly different temperatures so the gas and regolith sealing methods could see a wide range of thermal conditions.