NASA SBIR 2019 Phase I Solicitation

Z1.04 Long Duration Lunar Energy Storage and Discharge

Lead Center: GRC

Participating Center(s): GRC, JSC

Technology Area: TA3 Space Power and Energy Storage

NASA is seeking innovative solutions for long duration energy storage to support lunar surface operations, including landers, habitats, science platforms, robotic and crewed rovers, and the utilization of in-situ resources. Effective solutions require high-capacity, high-energy density, and long-life energy storage systems with very high reliability. Many of these systems will be required to provide continuous power during a 354-hour lunar night prior to recharge via a solar array during the lunar day. Power levels for these assets range from 500 W to 10 kW. Rovers capable of providing prolonged excursions before returning to the base will also be required. Power requirements for rovers are expected to be in the 1-3 kW range for unpressurized rovers increasing to 7-20 kW for pressurized rovers. It is anticipated that these vehicles will be refueled at the base, possibly directly re-fueled with scavenged propellants, or in-situ produced fuels, or electrically recharged via a solar array or other power technology. Technologies of interest in this solicitation are primary and regenerative fuel cells and rechargeable batteries. Technologies should be lightweight, low cost, and have service lives >5 years to survive multiple crew campaigns. Strong consideration should be given to environmental robustness for surface environments that include day/night thermal cycling, unshielded natural radiation, partial gravity, vacuum, and dust.

Advanced secondary/rechargeable batteries that go beyond lithium-ion and can safely provide >400 Wh/kg at the cell level are of interest for these missions. Secondary batteries that have 4-year shelf life and can provide >1,000 cycles at 70% depth-of-discharge are highly desirable. These secondary batteries are expected to operate safely over a temperature range of -20° C to +70° C with excellent capacity retention, comparable to room temperature operation.

Technological advances are also sought for Primary Fuel Cell (PFC) and Regenerative Fuel Cell (RFC)-based systems and sub-systems that contribute to system simplicity and improved reliability through:

- Innovative, integrated system-level design concepts.
- Passive ancillary components.

An example of these advances at the system level is primary and/or regenerative fuel cell systems that minimize or eliminate reactant re-circulation external to the stacks themselves. Examples at the component level include replacement of pumps and other active, motorized mechanical ancillary components with passive devices that perform the functions of both reactant management and thermal control.

Solutions are sought for PFCs using solid electrolytes in the power classes of 1 to 10 kW. Target specific power for the Lunar applications is >2,000 W/kg with an efficiency of >70% at 1,500 W/kg. PFC nominal current density is >200 mA/cm^2 with peak transients of >750 mA/cm^2. A final operational life of >10,000 hours is desired. Proposers should specify the path to meet this requirement at the system level. Reactant chemistries of interest in this solicitation are H_2/O_2 and CH_4/O_2, as well as other propellants. The ability to operate on scavenged propellants is highly desirable.

RFC systems are also of interest to meet long duration surface power energy storage needs with minimal opportunity for servicing or maintenance. PFC, water electrolyzers, and associated balance-of-plant hardware constitute a RFC system. The most direct approach to achieving mission efficiency, life, and reliability goals is to implement fuel cell, electrolysis, and RFC integrated fluid system functions through passive means and the elimination of as many ancillary and rotating components as possible. The range of energy storage of interest is 36 kW•hr(net) to >350 kW•hr(net) with a system level specific energy of > 600 Wh/kg, Target round trip efficiency is >51% (HHV) at 600 Wh/kg. Discharge power levels are anticipated to be between 100 W and 1 kW for an RFC. The final desired mission operational lifetime for the RFC is >60 cycles @ 680 hours per cycle with a service/maintenance Interval ? 5 years. Proposers should specify the path to meet the life and service requirements at the system level. RFC development should focus exclusively on proton exchange-membrane (PEM) technology utilizing pure hydrogen, oxygen, and water as reactants. Electrolyzer self-pressurization is required to meet round-trip efficiency targets. Any proposal including a full RFC system operation must identify mechanisms to managing high-pressure water quality over the mission duration and de-humidification of gases prior to storage if gases are stored beyond the controlled thermal envelope.

RFC Subsystem Requirements are as follows:

Fuel Cells

- Power Levels: 100 W to 1 kW
- Specific Power: >2,000 W/kg
- Efficiency: >60% at 1,500 W/kg
- Operational Life: >10,000 hours (Specify path to meet this requirement at the system level)
- Nominal Current Density (Peak transient): 150 to 250 mA/cm^2 (>850 mA/cm^2)
- Applicable Chemistries: Solid electrolyte (non-liquid) including polymeric (ionic and anionic) and ceramic
- Reactant Chemistries: pure H_2 and O_2

Electrolyzers

- Production Rates: Generate sufficient reactant to support fuel cell operation with capability of >15% margin
- Efficiency: >70% at 1,500 W/kg
- Operational Pressure: ? 2,000 psig (sustained)
- Pressure Configurations: balanced (anode ? cathode) Preference given to a design that can also operate in an unbalanced mode with a fully pressurized oxygen cavity and ambient pressure (~15 psia) hydrogen cavity.
- Operational Life: >10,000 hours (Specify path to meet this requirement at the system level)
- Applicable Chemistries: Solid electrolyte (non-liquid) including polymeric (ionic and anionic) capable of meeting the pressure requirement Reactant Feed Configurations: Liquid Anode Feed, Vapor cathode feed
- Feedstock Chemistries: H_2O

The energy storage technologies described in this subtopic have applicability over a broad range of mobile and stationary lunar surface systems. It is believed that Space Technology Mission Directorate (STMD) is the relevant directorate to develop and mature this technology given its wide scope of applicability. It is anticipated that these technologies will be required to enable initial lunar exploration and the establishment of a human presence on the moon. After appropriate development and maturation in STMD, the technology would most likely be transitioned to specific programs in Human Exploration and Operations Mission Directorate (HEOMD) and Science Mission Directorate (SMD) responsible for developing the individual assets for lunar exploration. These assets include landers, unpressurized and pressurized rovers, robotic rovers, and various science platforms.

The desired deliverables would be a prototype of the types of technologies described above and/or a lunar payload package of the technology developed which can meet the size and related limitations of the lunar payload statement in the above subtopic description. The goal is to mature technologies from analytical or experimental proof-of-concept (TRL 3) to breadboard demonstration in a relevant environment (TRL 5). Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

NASA has plans to purchase services for delivery of payloads to the Moon through the Commercial Lunar Payload Services (CLPS) contract. Under this subtopic, proposals may include efforts to develop payloads for flight demonstration of relevant technologies in the lunar environment. The CLPS payload accommodations are yet to be precisely defined, however at least for early missions, proposed payloads should not exceed 15 kilograms in mass and not require more than 8 watts of continuous power. Smaller, simpler, and more self-sufficient payloads are more likely to be accommodated. Commercial payload delivery services may begin as early as 2020 and flight opportunities are expected to continue well into the future. In future years it is expected that payloads of higher mass and with higher power requirements might be accommodated. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

References:

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