



NASA SBIR 2021 Phase I Solicitation

S3.03 Energy Storage for Extreme Environments

Lead Center: GRC

Participating Center(s): JPL

Scope Title:

Energy Storage for Extreme Environments

Scope Description:

NASA's Planetary Science Division is working to implement a balanced portfolio within the available budget and based on a decadal survey that will continue to make exciting scientific discoveries about our solar system. This balanced suite of missions shows the need for low mass/volume energy storage that can effectively operate in extreme environments for future NASA Science Missions.

Future science missions will require advanced primary and secondary battery systems capable of operating at temperature extremes from $-200\text{ }^{\circ}\text{C}$ for outer planet missions to $400\text{ to }500\text{ }^{\circ}\text{C}$ for Venus missions, and a span of $-230\text{ }^{\circ}\text{C}$ to $+120\text{ }^{\circ}\text{C}$ for missions to the lunar surface. Operational durations of 30 to 60 days for Venus; 30 to 60 days for deep-space environments such as Europa, Enceladus, and Titan; and 14-day eclipses for lunar night survival and operations on the Moon are of interest. Advancements to battery energy storage capabilities that address operation for one of the listed missions (Venus, deep space, or lunar) combined with high specific energy and energy density ($>250\text{ Wh/kg}$ and $>500\text{ Wh/L}$ for rechargeable or $>800\text{ Wh/kg}$ and $>1000\text{ Wh/L}$ for nonrechargeable at the cell level) are of interest in this solicitation. Novel battery-pack-level designs and technologies that enhance battery reliability and safety and support improved thermal management are also of interest. Combinations of cell-level improvements and/or battery-system-level improvement for enhanced temperature capability will be considered.

Furthermore, missions that incorporate nonrechargeable (primary) batteries will benefit from instrumentation or modeling that can effectively determine state of charge to a high degree of accuracy and/or state of health, particularly those missions that use cell chemistries with discharge voltage profiles that are a weak function of state of charge or state of health such as lithium carbon monofluoride (Li-CFx) cells. Technologies of interest include: radiation-hardened (to 1 Mrad total ionizing dose) coulomb integration application-specific integrated circuits (ASIC) or hybrid circuits, with $>1\%$ accuracy over 1 to 20 A, operating over 24 to 36 V; computational models that can predict state of charge/state of health for primary cells; nondestructive instrumentation that can detect state of charge/state of health for primary and secondary cells.

Expected TRL or TRL Range at completion of the Project: 3 to 5

Primary Technology Taxonomy:

Level 1: TX 03 Aerospace Power and Energy Storage

Level 2: TX 03.2 Energy Storage

Desired Deliverables of Phase I and Phase II:

- Prototype

Desired Deliverables Description:

Research should be conducted to demonstrate technical feasibility in a final report for Phase I and show a path toward a Phase II, and when possible, deliver a demonstration unit for NASA testing at the completion of the Phase II contract. Phase II emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into science-worthy systems.

State of the Art and Critical Gaps:

State-of-the-art primary and rechargeable cells are limited in both capacity and temperature range. Typical primary Li-SO₂ and Li-SOCl₂ operate within a maximum temperature range of -40 to 80 °C but suffer from capacity loss, especially at low temperatures. At -40 °C, the cells will provide roughly half the capacity available at room temperature. Similarly, rechargeable Li-ion cells operate within a narrow temperature range of -20 to 40 °C and also suffer from capacity loss at lower temperatures. The lower limit of temperature range of rechargeable cells can be extended through the use of low-temperature electrolytes, but with limited rate capability and concerns over lithium plating on charge. There is currently a gap that exists for high-temperature batteries, primary and rechargeable, that can operate at Venus atmospheric temperatures. In addition, there is a gap in the ability to accurately predict or measure the amount of usable capacity of primary battery cells, particularly after a long mission cruise with exposure to varying temperatures and ionizing radiation dose. This solicitation is aimed at the development of cells that can maintain performance at extreme temperatures to minimize or eliminate the need for strict thermal management of the batteries (which adds complexity and mass to the spacecraft) as well as instrumentation or modeling to predict state of charge/state of health of primary batteries for deep-space missions.

Relevance / Science Traceability:

These batteries are applicable over a broad range of science missions. Low-temperature batteries are needed for potential NASA decadal missions to ocean worlds (Europa, Enceladus, and Titan) and the icy giants (Neptune, Uranus). These batteries are also needed for science missions on the lunar surface. Low-temperature batteries developed under this subtopic would enhance these missions and could be potentially enabling if the missions are mass or volume limited. There is also significant interest in a Venus surface mission that will require primary and/or rechargeable batteries that can operate for 60+ days on the surface of Venus. A high-temperature battery that can meet these requirements is enabling for this class of missions.

References:

NASA Science: <https://science.nasa.gov/>

Solar Electric Propulsion: <https://www1.grc.nasa.gov/space/sep/>