NASA SBIR 2020 Phase I Solicitation

S3.02 Dynamic Power Conversion

Lead Center: GRC

Technology Area: TA3 Space Power and Energy Storage

Scope Description

NASA is developing Dynamic Radioisotope Power Systems (DRPS) for unmanned robotic missions to the moon, and other solar system bodies of interest. This technology directly aligns with the Science Mission Directorate (SMD) strategic technology investment plan for space power and energy storage and could be infused into a highly efficient RPS for missions to dark, dusty, or distant destinations where solar power is not practical. Current work in dynamic radioisotope power systems is focused on novel Stirling, Brayton, or Rankine convertors that would be integrated with one or more 250 watt-thermal General Purpose Heat Source (GPHS) modules or 1 watt-thermal Light Weight Radioisotope heater Unit (RHU) to provide high thermal-to-electric efficiency, low mass, long life, and high reliability for planetary spacecraft, landers, and rovers. Heat is transferred from the radioisotope heat source assembly to the power convertor hot end using conductive or radiative coupling. Power convertor hot end temperatures would generally range from 300-500 °C for RHU applications and 500-800 °C for GPHS applications. Waste heat is removed from the cold end of the power convertor at temperatures ranging from 20-175 °C, depending on the application, using conductive coupling to radiator panels. The NASA projects target power systems able to produce a range of electrical power output levels based on the available form factors of space rated fuel sources. These include a very low range of 0.5-2.0 watt-electric that would utilize one or more RHU, a moderately range of 40-70 watt-electric that would utilize a single GPHS Step-2 module, and a high range of 100-500 watt-electric that would utilize multiple GPHS Step-2 modules. For these power ranges, one or more power convertors could be used to improve overall system reliability. The current solicitation is focused on innovations that enable efficient and robust power conversion systems. Areas of interest include:

1. Robust, efficient, highly reliable, and long-life thermal-to-electric power convertors that would be used to populate a generator of a prescribed electric power output range.
2. Electronic controllers applicable to Stirling, Brayton, or Rankine power convertors.
3. Multi-Layered Metal Insulation (MLMI) for minimizing environmental heat losses and maximizing heat transfer from the radioisotope heat source assembly to the power convertor.
4. Advanced dynamic power conversion components and RPS integration components, including efficient alternators able to survive extended exposure to 200 °C, robust high-temperature tolerant Stirling regenerators, robust highly effective recuperators, integrated heat pipes, and radiators that improve system performance, and improving the margin, reliability, and fault tolerance for existing components.

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 will vary depending on the particular service provider and mission characteristics. Additional information on the CLPS program and providers can be found at this link: https://www.nasa.gov/content/commercial-lunar-payload-services.

CLPS missions will typically carry multiple payloads for multiple customers. Smaller, simpler, and more self-sufficient payloads are more easily accommodated and would be more likely to be considered for a NASA-sponsored flight opportunity. 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 larger and more complex payloads will be accommodated. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

References

Radioisotope Power Systems (RPS): https://rps.nasa.gov/about-rps/overview/

Oriti, Salvatore, "Dynamic Power Convertor Development for Radioisotope Power Systems at NASA Glenn Research Center," AIAA Propulsion and Energy (P&E) 2018, AIAA 2018-4498.

Wilson, Scott D., "NASA Low Power Stirling Convertor for Small Landers, Probes, and Rovers Operating in Darkness," AIAA P&E 2018, AIAA 2018-4499.

Wong, Wayne, "Advanced Stirling Convertor (ASC) Technology Maturation," AIAA P&E 2015, AIAA 2015-3806.

Expected TRL or TRL range at completion of the project: 3 to 5

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Research

Desired Deliverables Description

The desired deliverables include prototype hardware that has demonstrated basic functionality in a laboratory environment and the appropriate research and analysis used to develop the hardware. Deliverables also include maturation options for flight designs.

State of the Art and Critical Gaps

Radioisotope Power Systems are critical for long duration NASA missions in dark, dusty, or harsh environments. Thermoelectric systems have been used on the very successful RPS flown in the past, but are limited in efficiency. Dynamic thermal energy conversion provides significantly higher efficiency and through proper engineering of the non-contact moving components, can eliminate wear mechanisms and provide long life. While high efficiency performance of dynamic power convertors has been proven, reliable and robust systems tolerant of off-nominal operation is needed. In addition to convertors appropriate for General Purpose Heat Source (GPHS) RPS, advances in much smaller and lower power dynamic power conversion systems are sought that can utilize Radioisotope Heater Units (RHU) for applications such as distributed sensor systems, small spacecraft, and other systems that take advantage of lower power electronics for the exploration of surface phenomenon on icy moons and other bodies of interest. While the power convertor advances are essential, to develop reliable and robust systems for future flight, advances in convertor components as well as RPS integration components are also needed. These would include efficient alternators able to survive 200 C, robust high-temperature tolerant regenerators, robust high efficiency recuperators, heat pipes, radiators, and controllers applicable to Stirling flexure-bearing, Stirling gas-bearing, or Brayton convertors. Similar scope and content was previously included as part of the broader S3.01 subtopic last year. This nomination is for dynamic power conversion as a stand-alone subtopic under S3.

Relevance / Science Traceability

This technology directly aligns with the Science Mission Directorate - Planetary Science Division for space power and energy storage. Investments in more mature technologies through the Radioisotope Power System Program is ongoing. This SBIR subtopic scope provides a lower TRL technology pipeline for advances in this important power capability that improves performance, reliability, and robustness.