NASA SBIR/STTR
Small Business Innovation Research / Small Business Technology Transfer

NASA SBIR 2021 Phase I Solicitation

Z1.07 Dynamic Energy Conversion for Space Nuclear Power and Propulsion

Lead Center: GRC

Participating Center(s): MSFC

Scope Title:

Megawatt-Class Nuclear Power System

Scope Description:

Recent Mars transportation assessments identify megawatt-class nuclear electric propulsion (NEP) systems as a reasonable approach for use in a crewed mission to Mars. A critical subcomponent of the reference NEP concept is a dynamic thermal-to-electric power convertor. Dynamic power convertors are needed that address the following technical challenges:

- Robust, efficient, high-reliability, long-life thermal-to-electric power conversion and controller technology in the minimum range of 100 to 500 kWe. Brayton, Rankine, and Stirling convertors are of primary interest. Multiple parallel/redundant convertors may be used to achieve the megawatt-class power level.
    - Includes subcomponents such as efficient turbomachinery, bearings, alternators, recuperators, and heat exchangers.
- Convertors must be capable of interfacing with pumped liquid-metal loops:Â one for thermal energy input and one for heat rejection.

In addition, liquid metal pumps that address the following technical challenges are also needed:

- Can operate for long periods of time (years) at relevant in-space (in vacuum and zero g) reactor/power generation temperatures.
- Can withstand liquid metal freeze-thaw transition during initial reactor startup in zero g.
- Low mass and high efficiency at fluid throughputs that are relevant for in-space nuclear power generation.
- Wetted surfaces of the pump composed of materials that are compatible with liquid

metals under consideration for in-space nuclear power generation (NaK, Li, etc.).

The desired deliverables are primarily prototype hardware, research, and analysis to demonstrate concept feasibility and a Technology Readiness Level (TRL) range of 3 to 5. There is a strong desire for hardware that can operate or has a clear path for operation in the relevant space environment. The specified higher power levels are of priority, but demonstrations at lower power levels may be considered as long as the scaling to higher power levels is straightforward and does not require significant new technology or configuration change. The prototype hardware may include one (or more) of the following:

- Power convertor (hot-end temperature = 850 Âº C, cold-end temperature = 100 to 200 Âº C).
- Controller electronics.
- Convertor subcomponent(s).
- Liquid metal pump and/or subcomponent(s).

Expected TRL or TRL Range at completion of the Project: Â 3 to 5Â
Primary Technology Taxonomy:Â
Level 1: TX 03 Aerospace Power and Energy StorageÂ
Level 2: TX 03.1 Power Generation and Energy ConservationÂ
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

The desired deliverablesÂ for Phase I includeÂ monthly progress reports and a comprehensive final report.

For Phase II, the primary interest is component and/or breadboard hardware that demonstrates concept feasibility in a laboratory or relevant environment. The appropriate research and analysis required to develop the hardware are also desired. The Phase II deliverables should include hardware, monthly progress reports, and a comprehensive final report.

State of the Art and Critical Gaps:

Multikilowatt electric propulsion systems are well developed and have been used on commercial and military satellites for several years. Higher power electric propulsion systems are currently being considered to support crewed missions to near-Earth asteroids and as cargo transport for sustained lunar or Mars exploration, and for very high power crewed missions to Mars and the outer planets. One of the key technologies required in a NEP system is the power convertor. A recent Mars Transportation Assessment Study was completed that included Brayton, Stirling, Rankine, thermoelectric, and thermionic technologies in the trade space. The study identified HeXe Brayton as the baseline dynamic power convertor in the reference NEP concept, with supercritical CO_2Â Brayton and K-Rankine as the primary options. Current state-of-the-art Brayton technology has been demonstrated in a relevant space environment (ground test) in the 10s of kWe range.Â Convertor scaleup to the 100s of kWe per unit is required.

Relevance / Science Traceability:

This technology directly aligns with the Space Technology Mission Directorate (STMD) roadmap for space power and energy storage.

References:

Mason, Lee S., â€œDynamic Energy Conversion: Vital Technology for Space Nuclear Power,â€ Journal of Aerospace Engineering, April 2013.

https://www.researchgate.net/publication/275186601_Dynamic_Energy_Conversion_Vital_Technology_for_Space_Nuclear_Power

Gilland, James H., LaPointe, Michael R., et al., â€œMW-Class Electric Propulsion System Designs for Mars Cargo Transport,â€ AIAA 2011-7253, September 2011.Â

https://arc.aiaa.org/doi/abs/10.2514/6.2011-7253