NASA SBIR 2015 Phase I Solicitation

Z1.02 Solid-State Thermal-to-Electric Power Generation

Lead Center: JPL

Participating Center(s): GRC, JSC

Future NASA missions require power generation capabilities beyond what can be easily supported using solar arrays or chemical fuel cells. Thermal-to-Electric materials and systems working in conjunction with nuclear systems have the potential to serve this need and to operate at distances from the Sun well beyond the limit of its useful energy. Existing Thermal-to-Electric materials and systems do not â€œtrade wellâ€ with existing power generation options, e.g., fuel cells, due to poor efficiency and specific power, however their longevity of operation makes them attractive for many other mission spaces. In the last decade extensive research has gone into raising the figure of merit for thermoelectric materials, ZT, both new materials and new fabrication techniques that modify the morphology and atomic lattice of the materials, have been attempted with varying degrees of success. Simultaneously, work has been done on creating â€œcoupledâ€ systems similar to multi-junction solar arrays that produce greater efficiency than single layer systems. Although this research has resulted in significant advances at the basic materials level, these advances have yet to be transitioned to NASA RTGs. In fact the Mars Curiosity MMRTG utilized the same TE materials and reported the same system level performance, i.e., efficiency and specific power, as the SNAP 19 RTG launched in 1972 for Pioneer 10. Thermionic power conversion is a complimentary static approach which could extend power conversion efficiencies beyond thermoelectric limits to as high as 25% or more. Successful thermionic converters would enable power systems with the efficiency of dynamic systems (Rankine, Brayton and Stirling), but with no moving parts and the potential for high reliability. High waste heat rejection temperatures also lead to modest radiator area and mass. Thermionic converters received much attention in the 1960's-90's for solar and nuclear power, and were flown in space by the Russians in the 1990's. At the time, high-temperature low-work-function materials, precise gap maintenance, and space charge buildup proved problematic for the then state-of-art. Since the year 2000, major advances have been made in the highly relevant fields of nanotechnology, nanomaterials, MEMS, micromachining and fabrication, and new converter topologies. Proposals are thus solicited for application of these new ideas towards practical thermionic converters for nuclear and solar space power generation, and terrestrial topping cycles or energy harvesting.Â

This topic seeks to explore emerging capabilities in both Thermoelectric and Thermionic materials with an eye towards improving base system efficiencies and specific power of systems employing thermal to electric concepts. Proposals are solicited that focus on transitioning the improvements in bulk TE materials to system solutions for advanced power-generation and conversion technologies that will enable or enhance the capabilities of future science and human exploration missions. Requirements for these missions are varied and include long life, high reliability, significantly lower mass and volume, higher mass specific power, and improved efficiency over the state of practice for components and systems. Other desired capabilities are high radiation tolerance and the ability to operate in extreme environments (high and low temperatures and over wide temperature ranges). This topic will focus on:Â

- Advanced bulk materials enabling demonstration of high efficiency thermoelectric energy conversion (>15%) when using high grade space-qualified heat sources (> 1000 K).
- Advanced thermoelectric couple and module component technologies that will facilitate integration of new high performance materials into high reliability, high temperature long life systems.
- Advanced high temperature (>1500 K) thermionic materials demonstrating low work function (< 3 eV) and high Richardson coefficient (> 80 Amps/cm^2-K^2) to enable high efficiency (>25%) thermionic converters.
- Advanced thermionic converter designs leveraging modern approaches in nanotechnology, nanomaterials, microfabrication, and/or novel system topologies which demonstrate the potential for high conversion efficiency (> 25%).Â

Phase I products should include materials and proof-of-principle device-level demonstrations, test data, and conceptual system designs that incorporate the components advanced in Phase I and show a path to a successful Phase II project predicated on the criteria below.Â

Phase II should result in a working performance demonstrator at TRL 4 or greater, and should include a technology development plan for potential infusion into a flight system.Â