NASA SBIR 2015 Phase I Solicitation

Z1 Advanced Power and Energy Storage Systems for Cross-Cutting Space Applications

Lead Center: LaRC

The Advanced Space Power and Energy Storage Systems topic area will focus on technologies that generate power and/or store energy within the space environment. Functional areas, sub-topics, of interest include:Â

Â

Solid State Power GenerationÂ

Â

Thermoelectric and thermionic component materials will be investigated for the creation of electricity from thermal energy in space applications. There is particular interest in high Z materials and materials with low work functions applicable to thermionic energy conversion. The focus of the topic area will be to generate working devices by the end of an SBIR Phase II. Material performance and testing may be the focus of the Phase I activity as long as explicit discussion of eventual working device is included in the Phase I proposal and the intent of the effort is to use Phase II follow on effort to build and test the working system.Â

Â

Modeling and Simulation / Modeling and Measurements

Â

Innovative model development to will provide insight into design decisions and trade-offs for advanced propulsion and power systems are sought. The focus is on improving the correlation between experiments and predictions by developing and validating multi-scale physics-based models. The goal is to reduce the development time of future systems needed for space exploration.Â Â

Subtopics

Z1.01 Modeling and Measurements for Propulsion and Power

Lead Center: GRC

Participating Center(s): ARC, JPL, MSFC

To reduce the development time of advanced future systems needed for space exploration, physics-based modeling tools are sought for:Â

- Electrochemical systems such as batteries, fuel cells and electrolyzers.
- Nuclear power and nuclear power based propulsion systems.
- Microfluidic electrospray propulsion systems.

In each case, the emphasis is on determining performance-limiting features and identifying potential means to overcome limitations. Models should focus on aspects of the system where interactions of sub-systems or components is poorly understood and where development frequently relies on heuristics or iterative build and test cycles to settle on designs. Electro-chemistry models are sought that predict the rates of reaction, or side products of a reaction, predicated upon the thermodynamic or kinetic properties of electrode and electrolyte materials are needed. Nuclear systems models are required that model the fission reaction, heat transport, latent radiation, etc. in sufficient detail to predict design efficacy, evaluate engineering solutions, and reduce testing requirements. Creating interfaces between reactor models and engine system models, including radiation effects, and modeling nuclear thermal propulsion ground test engine exhaust filtering and containment are areas of particular interest. Physics based models are sought to predict flow properties of liquid metal or ionic liquids for microfluidic electrospray propulsion systems. Of particular interest are models that describe capillary flow forces as a function of micro-geometry, the characterization of end-to-end velocity profiles in a feed system, viscosity and velocity characterization as a function of thermal gradients, the boundary between flow characteristics determined by micro-fluidic capillary forces and flow characteristics determined by formation and operation of Taylor cones, and fluid properties under steady state and pulsed electric operation at the boundary of Taylor cones. Model validation will also be required; improved measurement techniques needed for validation are also of interest provided they are coupled with a modeling activity outlined above. Tools that exclusively model proprietary systems will not be considered for award.Â Â

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