NASA SBIR 2021 Phase I Solicitation

A1.07 Electric Power Generation Via Thermionic Conversion for Hypersonic Applications

Lead Center: LaRC

Participating Center(s): GRC

Scope Title:

Thermionic Energy Harvesting

Scope Description:

When employing a nonrotating propulsive device (engine), conventional generators for electrical power are not generally a viable design option; therefore, an alternative option is to utilize direct thermal-to-electric power conversion methods. One such technique is thermionic energy extraction applied to the primary flow path. Thermionic devices have been shown to be efficient in exploiting extreme temperature differentials, like those that typically characterize hypersonic flight environments, and also have a higher/larger energy density than that of standard batteries. The applications of thermionic devices in hypersonic vehicles are numerous, and broaden the design space, since 10 to 100 kW/m$^2$ of electrical power are compatible with realistic hardware implementation strategies. Significant, prior efforts in the 1960s, by both the U.S. and Soviet Union, were explored for space applications, but hypersonic atmospheric applications have not been extensively investigated.

For hypersonic atmospheric applications, the operational environments, relevant to the thermionic conversion process, are characterized by free-stream flight trajectories having dynamic pressures bounded by 750 to 3,500 (lb/ft)/ft, and internal-flow path, peak static temperatures associated with adiabatic-flame temperatures (of a combusting hydrocarbon/air stoichiometric mixture). Additionally, volumetric and weight constraints of a novel thermionic device need to be competitive, and/or exceed, existing state-of-the-art battery technology in order to create viable design alternatives for system-design exploration. Although U.S. governmental restrictions typically apply to hypersonic-flight systems, this is not deemed to be a limiting factor in this Phase I activity, due to the low TRL; however, this issue will need to be further addressed during a Phase II award cycle, via coordination with appropriate U.S. governmental and industrial entities.

Expected TRL or TRL Range at completion of the Project: 1 to 3

Primary Technology Taxonomy:
Level 1: TX 03 Aerospace Power and Energy Storage
Level 2: TX 03.X Other Aerospace Power and Energy Storage

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
Prototype

**Desired Deliverables Description:**

Phase I - Design of a testable prototype, capable of generating a few W/cm².

Phase II - Generation of experimental data in a relevant test environment with a thermionic device to quantify basic performance parameters and initiate scaling study.

**State of the Art and Critical Gaps:**

The specifics of designing a device with acceptable work functions for both emitter and collector surfaces is a significant technical issue. Additionally, manufacturing a volumetrically efficient device is not codified.

**Relevance / Science Traceability:**

The applications of power generator in harsh environments is relevant to atmospheric flight and numerous other commercial applications associated with energy conversion needs.

**References:**


(4) SECOND INTERNATIONAL CONFERENCE ON THERMIONIC ELECTRICAL POWER GENERATION, Stresa, Italy - May 27-31, 1968.