

# Solid-State Thermionic Nuclear Power For Megawatt Propulsion, Planetary Surface And Commercial Power Project

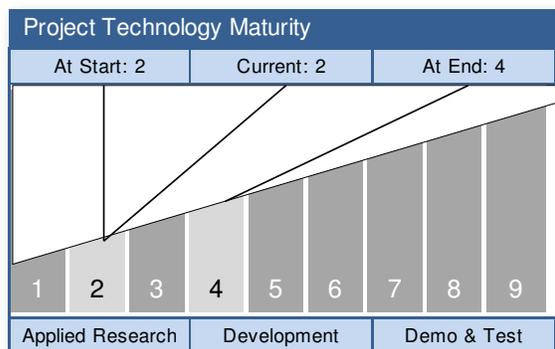
Center Innovation Fund: JSC CIF (Also Includes JSC IRAD) Program  
 Space Technology Mission Directorate ( STMD )



NASA/JSC Propulsion and Power Division

## ABSTRACT

Thermionic (TI) power conversion is a promising technology first investigated for power conversion in the 1960's, and of renewed interest due to modern advances in nanotechnology, MEMS, materials and manufacturing. Benefits include high conversion efficiency (20%), static operation with no moving parts and potential for high reliability, greatly reduced plant complexity, and the potential for reduced development costs. Thermionic emission, credited to Edison in 1880, forms the basis of vacuum tubes and much of 20th century electronics. Heat can be converted into electricity when electrons emitted from a hot surface are collected across a small gap....**Read more on the last page.**



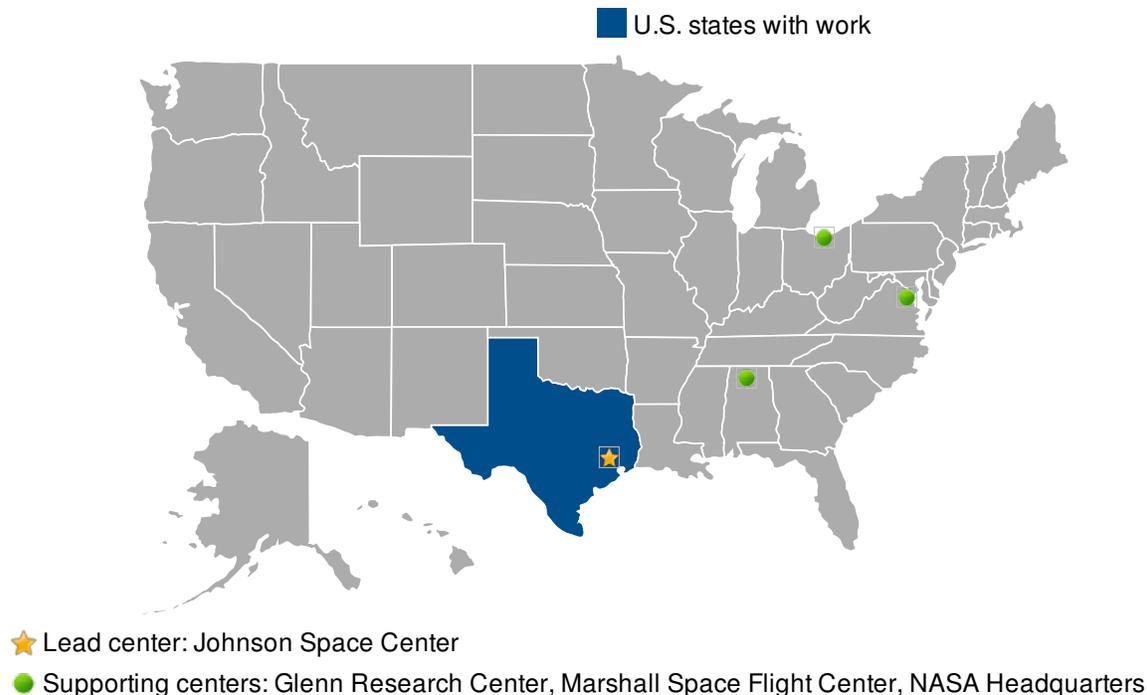
Technology Area: Space Power & Energy Storage TA03 (Primary)  
 In-Space Propulsion Technologies TA02 (Secondary)

## ANTICIPATED BENEFITS

### To NASA unfunded & planned missions:

This project targets one the most critical barriers to human deep space exploration – the means to efficiently power and rapidly propel human missions to Mars and beyond. The project will explore the implementation of a high efficiency “Solid-State” Thermionic-based nuclear fission power systems to serve Electric Propulsion systems such as Q-thrusters, VASIMR, Hall, or other approaches. A Solid-State approach centered around advanced Thermionic power converters would combine the high efficiency of traditional dynamic power conversion (Rankine, Brayton, Stirling) with the simplicity of a static converter with no moving parts. The resulting system...

Read more on the last page.



## DETAILED DESCRIPTION

Thermionic (TI) power conversion is a promising technology first investigated for power conversion in the 1960's, and of renewed interest due to modern advances in nanotechnology, MEMS, materials and manufacturing. Benefits include high conversion efficiency (20%), static operation with no moving parts and potential for high reliability, greatly reduced plant complexity, and the potential for low Design, Development, Test and Evaluation (DDT&E) costs. Thermionic emission, credited to Edison in 1880, forms the basis of vacuum tubes and much of 20th century electronics. Heat can be converted into electricity when electrons emitted from a hot surface are collected across a small gap. For example, two "small" (6 kWe) Thermionic Space Reactors were flown by the USSR in 1987-88 for ocean radar reconnaissance. Higher powered Nuclear-Thermionic power systems driving Electric Propulsion (Q-thruster, VASIMR, etc.) may offer the breakthrough necessary for human Mars missions of < 1 yr round trip.

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### MANAGEMENT

**Program Executive:**  
John Falker

**Program Manager:**  
Ronald G Clayton

**Project Manager:**  
Jeffrey George

## DETAILED DESCRIPTION (CONT'D)

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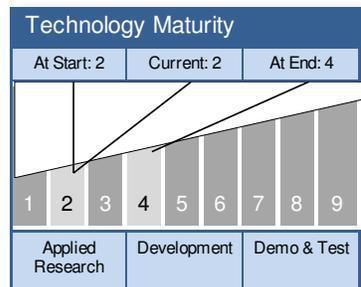
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This project provides the initial foundation and confidence for high efficiency solid-state power converters, and early definition of enabled human exploration systems and missions (ex. Megawatt Electric Propulsion, Moon/Mars Surface Power). Subsequent converter development will improve readiness and lifetime, leading to “flight ready” articles. An intermediate NASA infusion step would demonstrate kilowatt-class nuclear power systems applicable to Moon or Mars surface. Human vehicle system development would then integrate these converters with DOE nuclear reactor technology, NASA balance of plant (ex. radiators, PMAD), and electric propulsion (ex. Q-thrusters, VASIMR, Hall thrusters) to develop an “ultimate” NASA application of a Human Mars Megawatt-class Nuclear Electric Propulsion vehicle and mission. Terrestrial applications would be informed/infused resulting in high efficiency power systems with greatly reduced complexity and cost.



## TECHNOLOGY DETAILS

Solid-State Thermionic Nuclear Power for Megawatt Propulsion, Planetary Surface and Commercial Power



- Project Development Phases (3 Years)
  - Year One: Concepts, Missions, Nanomaterials Emission, Lab Converter Demo.
    - Multi-Megawatt NEP system & Mars mission concepts, models and analysis.
    - Research & design of practical Thermionic Converters.
    - Fabricate nanostructured thermionic emitters of various surface size & features.
    - Test & characterize thermionic emission for various nanomaterials.  
Examples: Tungsten, BaO coated, aligned carbon nanotubes, nanocrystalline diamond
    - Demonstrate thermionic power conversion in a laboratory configuration.
    - Assess “modern” potential to increase efficiency, reduce operational emission temperature, increase power density.
    - Explore applicability to smaller power systems for deep space or Moon/Mars surface, as well as potential for simpler, more cost effective terrestrial nuclear power plants.
  - Year Two: Breadboard Converter DDT&E.
  - Year Three: Brassboard Converter DDT&E

- This technology is categorized as a hardware system for manned spaceflight
- Technology Area
  - TA03 Space Power & Energy...

Performance Metrics		
Metric	Unit	Quantity
Power Conversion Efficiency (at Maturity)	%	20

## TECHNOLOGY DETAILS

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### TECHNOLOGY DESCRIPTION (CONT'D)

Storage (Primary)

- TA02 In-Space Propulsion Technologies (Secondary)

### CAPABILITIES PROVIDED

Thermionic converters have a very high potential for Dual Use. Commercial power plants, nuclear or otherwise, would benefit from high efficiency power conversion with reduced plant complexity, maintenance and capital costs. A nuclear plant based upon Thermionic conversion may be well suited to meeting Department of Energy (DOE) goals for its next-generation Small Modular Reactor program. At smaller scales, successful lowering of the electron emission threshold would also allow Thermionic converters to perform power scavenging or bottoming from otherwise "waste heat". Thermionics would double the efficiency and recovery of Thermoelectric "tailpipe" converters being developed to harness automotive exhaust energy, replacing electrical alternators and eliminating their parasitic drag on the engine.

### POTENTIAL APPLICATIONS

1. Space Nuclear Power Systems
2. Space Solar Power Systems
3. Terrestrial Commercial Nuclear Power Plants
4. Terrestrial Commercial Fossil Fuel Power Plants
5. Terrestrial Solar Power Plants
6. Automobile Waste Heat "Scavenging"



## IMAGE GALLERY

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## ABSTRACT (CONTINUED FROM PAGE 1)

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For example, two "small" (6 kWe) Thermionic Space Reactors were flown by the USSR in 1987-88 for ocean radar reconnaissance. Higher powered Nuclear-Thermionic power systems driving Electric Propulsion (Q-thruster, VASIMR, etc.) may offer the breakthrough necessary for human Mars missions of < 1 yr round trip. Power generation on Earth could benefit from simpler, more economical nuclear plants, and "topping" of more fuel and emission efficient fossil-fuel plants.



## ANTICIPATED BENEFITS

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### **To NASA unfunded & planned missions: (CONT'D)**

could enable Human Mars missions of < 1 year round trip by affording a system of megawatt power, low specific mass (<10 kg/kWe), greatly reduced plant complexity, and associated savings in development cost.

Advanced Nuclear-Thermionic power systems driving Electric Propulsion (Q-thruster, VASIMR, Hall, Ion, MPD, etc.) may offer the breakthrough necessary for human Mars missions of < 1 year round trip, resulting in significant improvement to crew health and safety, large reductions in consumables mass, mass of spares and redundancy, and reduced "window" for catastrophic hardware failure or solar flare events.

### **To other government agencies:**

The Department of Energy (DOE) Small Modular Reactor (SMR) Program may benefit from this work in the area of efficient and economical commercial nuclear power plants with fewer parts, fluid loops, and waste products.

### **To the nation:**

Terrestrial applications would be informed and infused resulting in high efficiency power systems with greatly reduced complexity and cost. Benefits include high conversion efficiency (20%), static operation with no moving parts and potential for high reliability, greatly reduced plant complexity, and potential for lower Design, Development, Test and Evaluation (DDT&E) costs. This could lead to more efficient and economical nuclear power plants, or alternatively serve as a "topping" cycle in fossil fuel plants to reduce fuel consumption, emissions and cost. Solar power plants may become a more competitive option. Automobiles and buses may consume less fuel and produce less waste gas by scavenging waste heat from engine blocks and exhaust.

