U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Energy University Programs (NEUP) Fiscal Year (FY) 2013 Annual Planning Webinar

Space and Defense Power Systems
MS-RC-2: Radioisotope Power Systems RD&D

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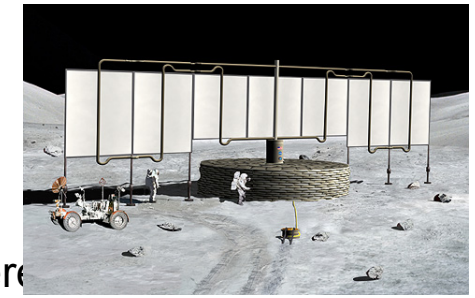
Space and Defense Power Systems Program

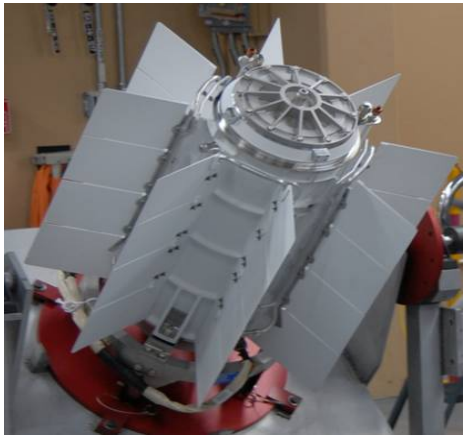
Space Nuclear Power Systems Program Goals

- Design, develop, build and deliver radioisotope power systems for space exploration and national security applications
- Support research, development and design of fission power systems for space exploration and national security needs



Benefits

- Enable customer missions in locations and environments where other power systems such as chemical batteries and solar power systems do not work
- Directly support NASA missions to explore the moon, mars, outer plants and beyond



Key R&D Areas:

- Develop materials for use in the extreme environments of space applications
- Improve the efficiency of thermoelectric couples

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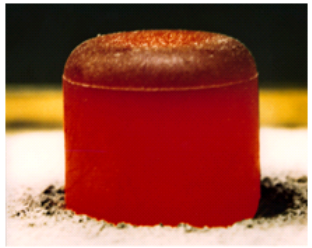
Space and Defense Power Systems Program Overview

- Provides nuclear power sources for space science and exploration missions and national security applications for which solar energy or other power sources are inadequate
- Maintains the capabilities to produce and deliver plutonium-238 fueled radioisotope power systems
- Reports to the Deputy Assistant Secretary for Nuclear Reactor Technologies within the Office of Nuclear Energy
- Works cooperatively with NASA to provide radioisotope power systems for use in space
- The infrastructure is comprised of capabilities and facilities at several national laboratories. DOE awards system integrator contracts to the private sector for specific power systems



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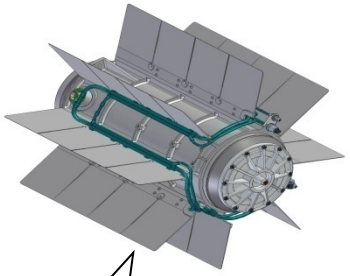
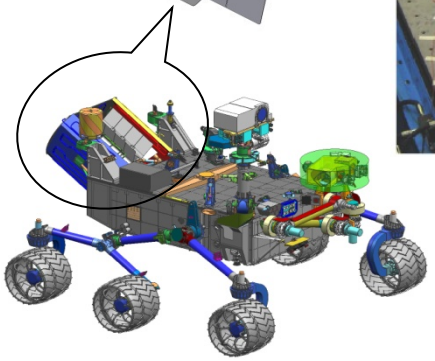
Current Projects

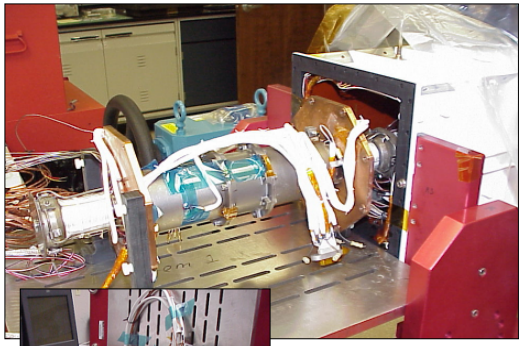


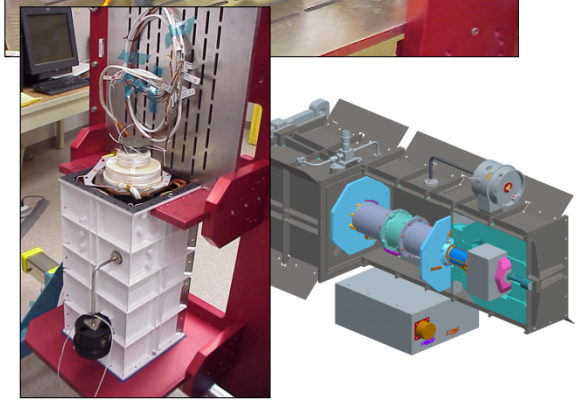


Mars Science Laboratory

Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) for NASA

proven performance, but low conversion efficiency (5-7%)





Advanced Stirling Radioisotope Generator (ASRG) for NASA

high efficiency (25-30%) under development

Nuclear Thermal Propulsion Technology for NASA

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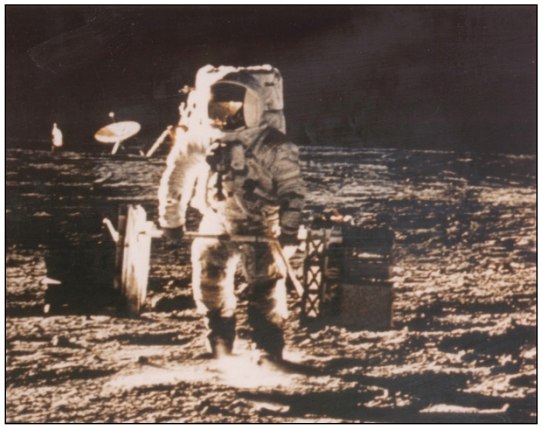
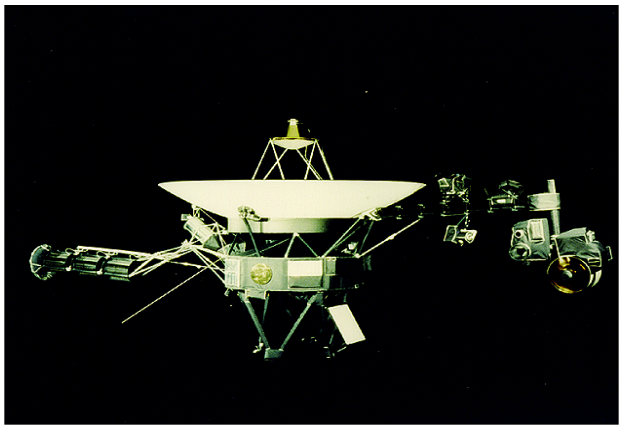
Successful Missions

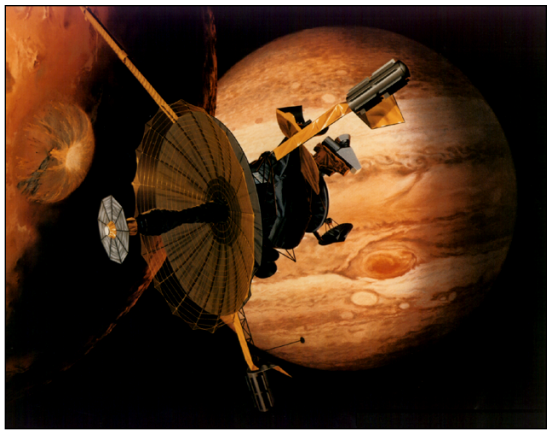


Apollo (1969 - 1972)

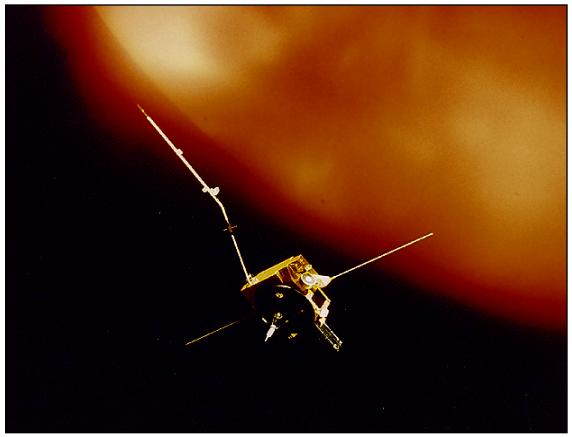
Pioneer 10 (1972)



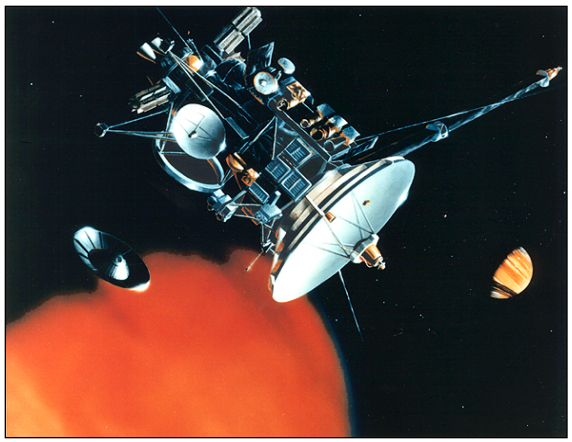
Voyager (1977)



Galileo (1989)

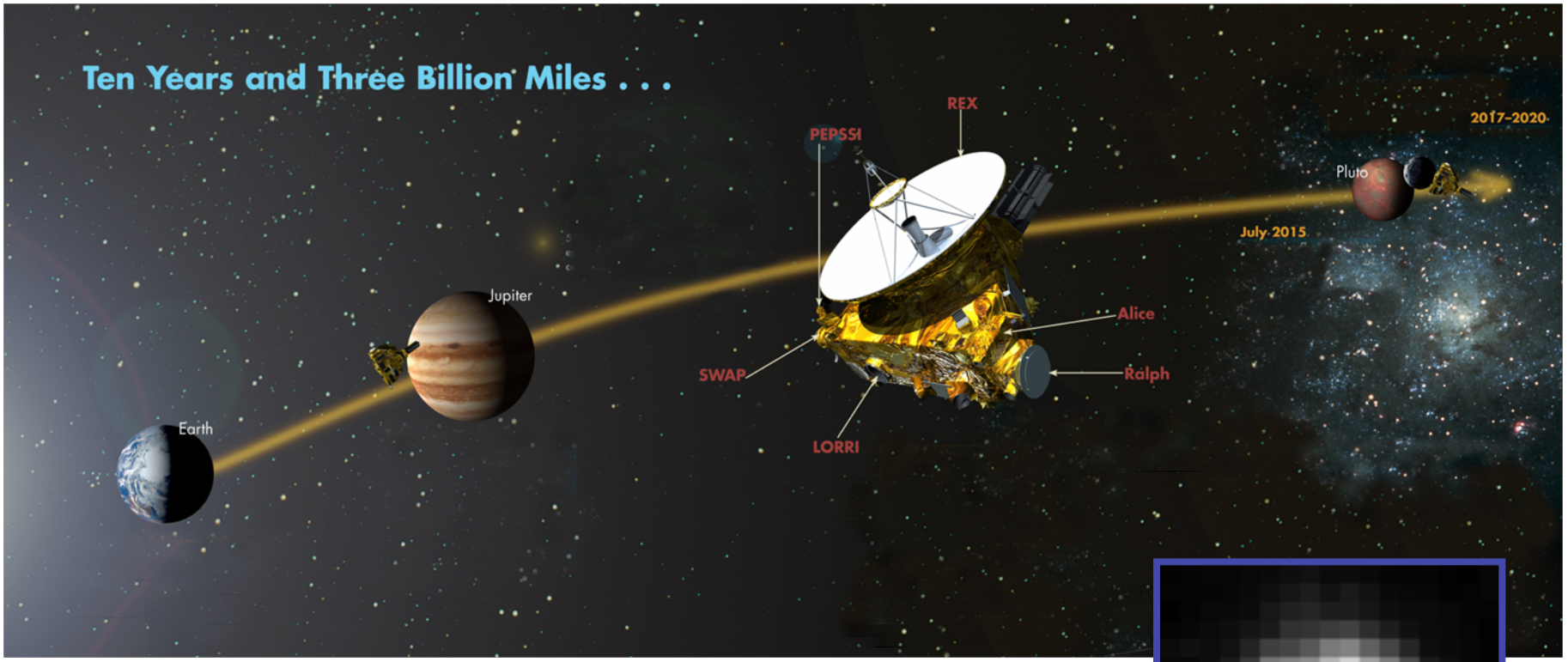


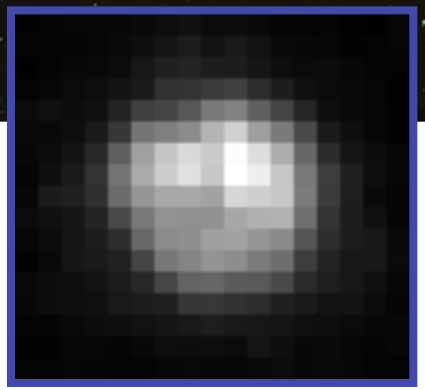
Ulysses (1990)



Cassini (1997)

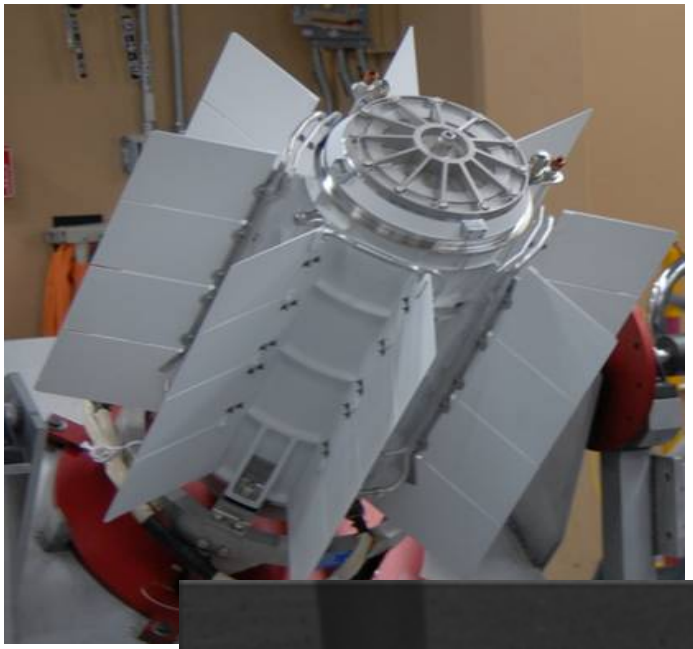
New Horizons – Pluto

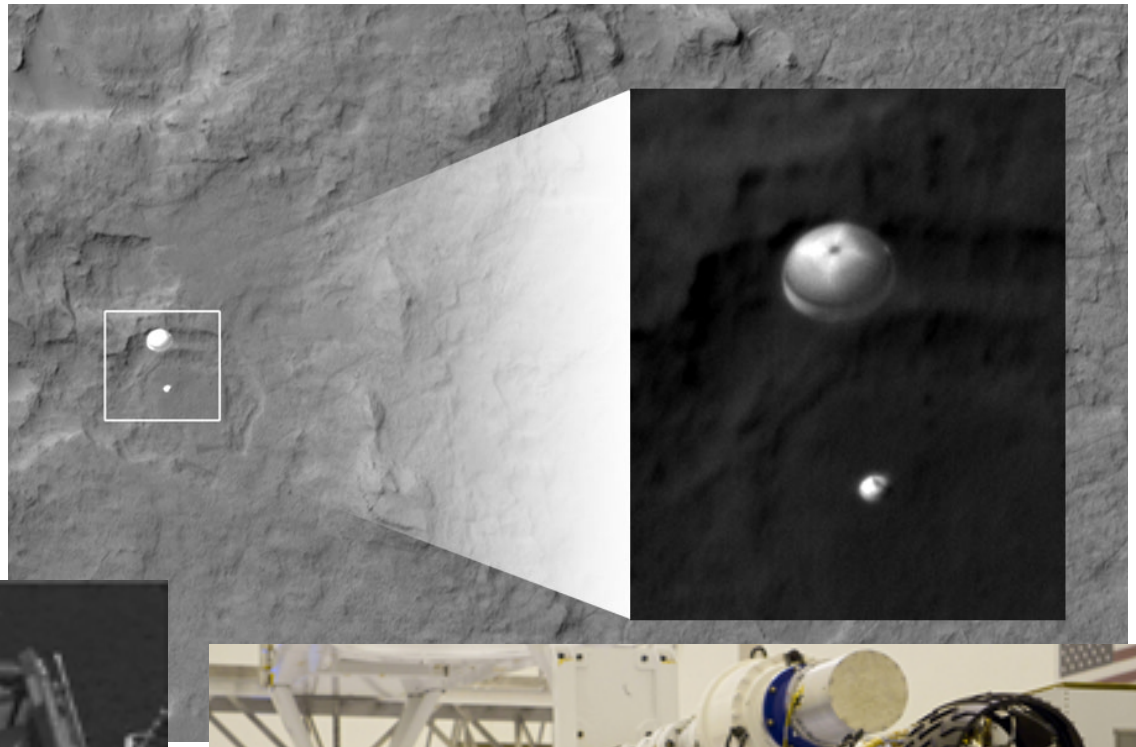




Pluto at best Hubble resolution at time of launch

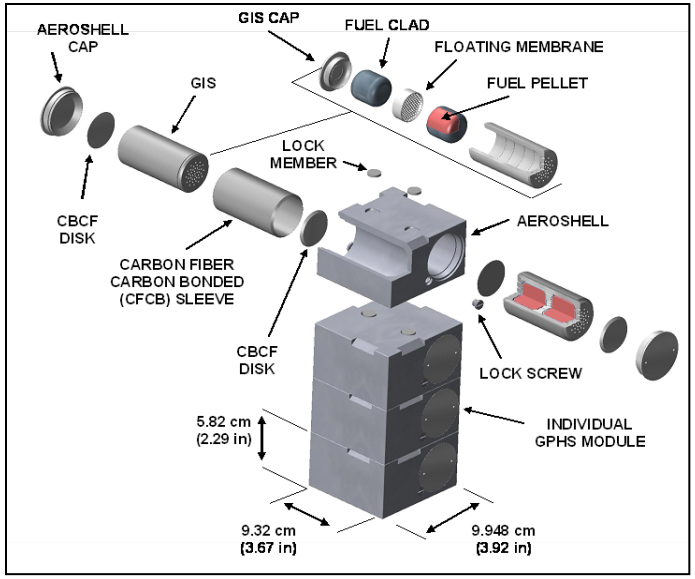
Mars Science Laboratory – Landed August 6!!



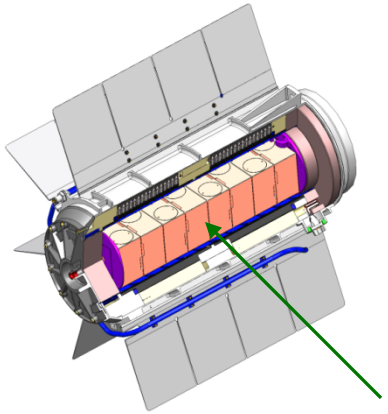


Key Components and Safety Features

- **Pu-238 fuel (generates decay heat)**
  - Alpha-emitter, 87-year half life
  - High melting temperature (2,400°C / 4,352°F)
  - Fractures into largely non-respirable chunks upon impact
  - Highly insoluble in water
- **Cladding (encases the fuel)**
  - Fuel containment (normal operations or accidents)
  - High melting point -- thermal protection (2,454°C / 4,450°F)
  - Ductile -- impact protection
- **Graphite heat source (protects fuel & cladding)**
  - Impact shell -- impact protection
  - Insulator -- protect clad during reentry
  - Aeroshell -- prevent burnup during reentry
- **Converter (converts heat to electricity)**
  - Designed to release individual aeroshell modules in cases of inadvertent reentry (minimizes terminal velocity)
- **Radiator (rejects excess heat)**



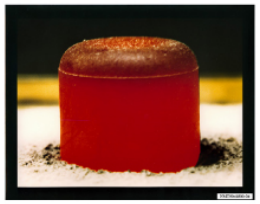
General Purpose Heat Source Module



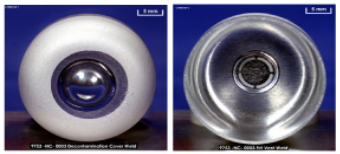
Multi-Mission Radioisotope Thermoelectric Generator

RPS Process Flow and Responsibilities

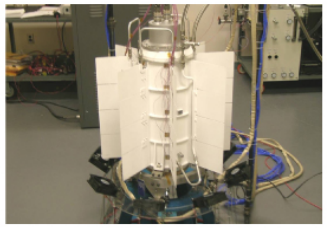
Plutonium Oxide (PuO_2) Fuel Pellet Production
LANL



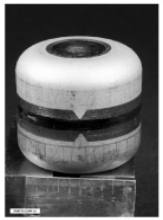
Iridium Component Fabrication
ORNL



Generator
Design Architect/System Integration Contractor (DA/SIC)



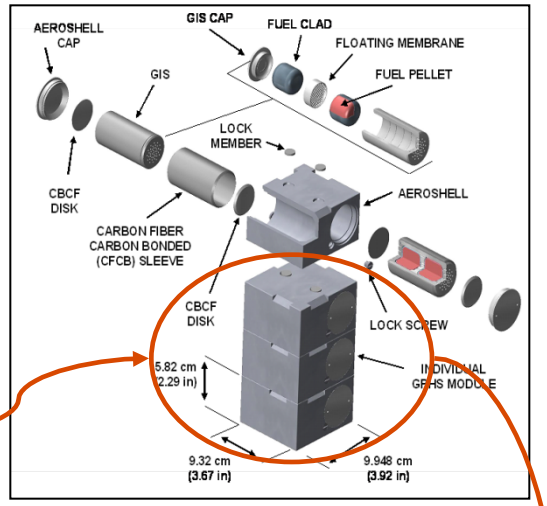
Fuel Pellet Encapsulation
LANL



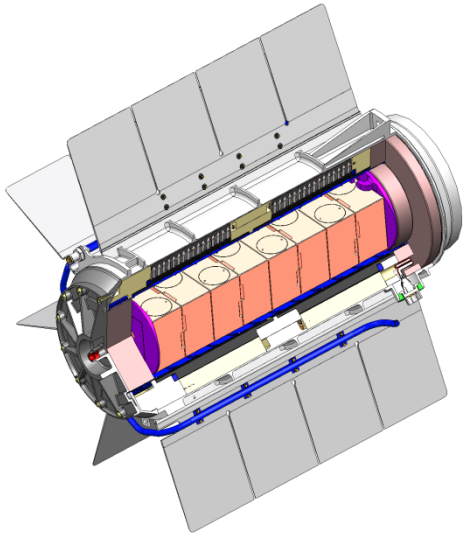
General Purpose Heat Source Module Assembly
INL

RPS Assembly and Testing
INL

RPS Shipment to KSC
INL



General Purpose Heat Source Module



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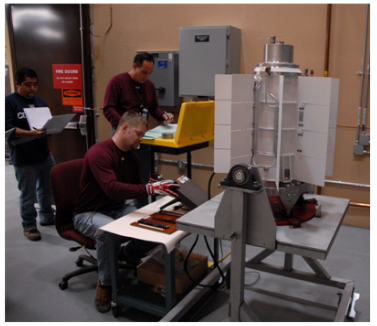
Grand Challenges

- **Enhanced safety performance – contain nuclear materials under accident conditions**
  - Materials selection – ceramic fuel, cladding, aeroshell, system structural components
  - Product and component characteristics
- **Improved system performance**
  - Power output and efficiency - power conversion, mass
  - Reliability – mission duration, operating environments
  - Other design goals – flexibility to meet variety of mission needs
- **Manufacturing processes**
  - Enhanced worker safety
  - Fewer defects
  - Reduced waste generation



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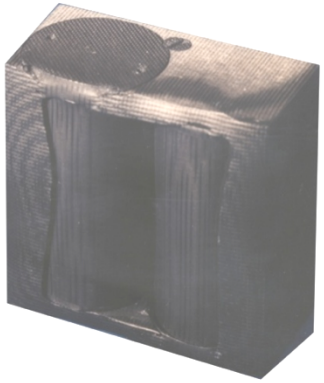
Transformative Research Needs - Specialized Replacement Materials

Replacement Materials

- Current materials for aeroshell module that protects radioisotope power system fuel during potential atmospheric reentry events perform well but are difficult to manufacture.
- Nation's manufacturing base has moved on. Vendors for currently qualified materials are reluctant to continue limited production.

- **RD&D Goals:**
  - Identify replacement materials that meet minimum performance requirements



Workscope Description

Replacement Materials

- Proposals are sought for the development of alternate materials for the aeroshell module that protects radioisotope power system fuel during potential atmospheric reentry events
- The material will need ablation resistance, thermal conductivity, and structural strength (compressive and tensile) that meet minimum performance requirements

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Transformative Research Needs - High Efficiency Thermoelectrics

Thermoelectric couples

- Thermoelectric couples that have been used on all radioisotope thermal generators to date have been extremely reliable
- However they are highly inefficient. Improvements in efficiency have been at best incremental

RD&D goals:

- Ultra high efficiency thermoelectric couples with demonstrated efficiency between 20-30% and a minimum operable life of 10 years.

Workscope Description

Ultra high efficiency thermoelectric couples

- Proposals are sought for development of high efficiency thermoelectric couples (N and P legs) with a hot side temperature of 1000 C
- Couple should demonstrate a minimum efficiency between 20-30% with stable properties providing for a minimum operable life of 10 years.