U.S. DEPARTMENT OF ENERGY | Nuclear Energy

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

Space and Defense Power Systems
RC-7: Radioisotope Power Systems Applied R&D

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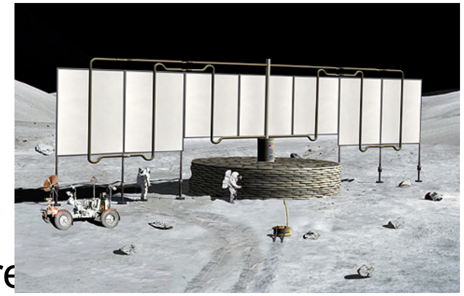
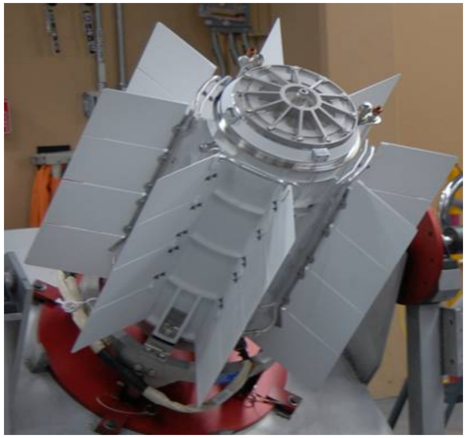
Space and Defense Power Systems Program

- **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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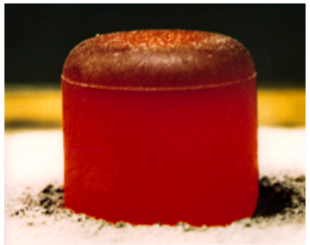
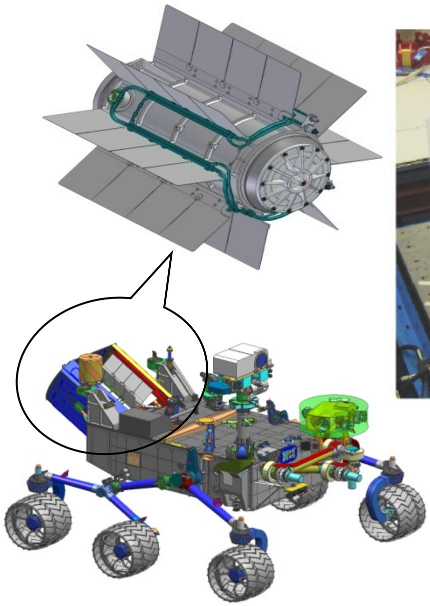
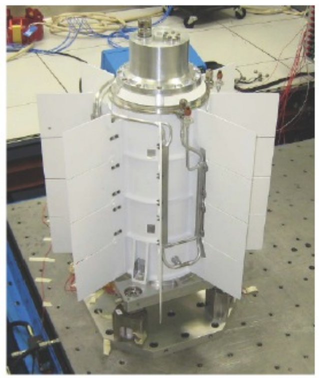
Space and Defense Power Systems Program Overview

- 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



Current Projects

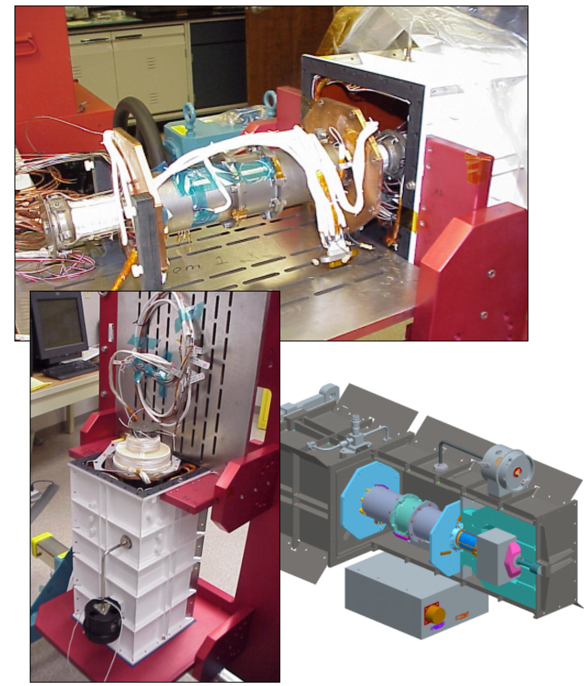




Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) for NASA

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

Mars Science Laboratory



Advanced Stirling Radioisotope Generator (ASRG) for NASA

high efficiency (25-30%) under development

Nuclear Thermal Propulsion Technology for NASA

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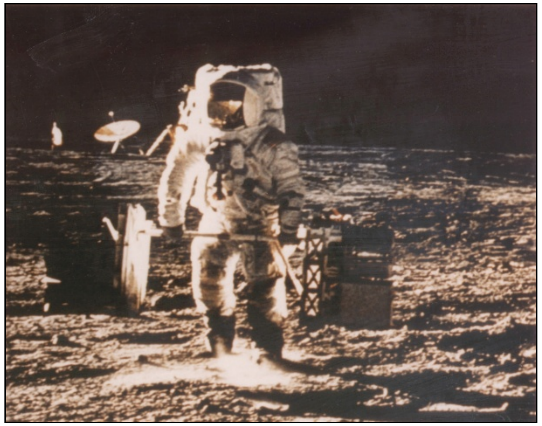
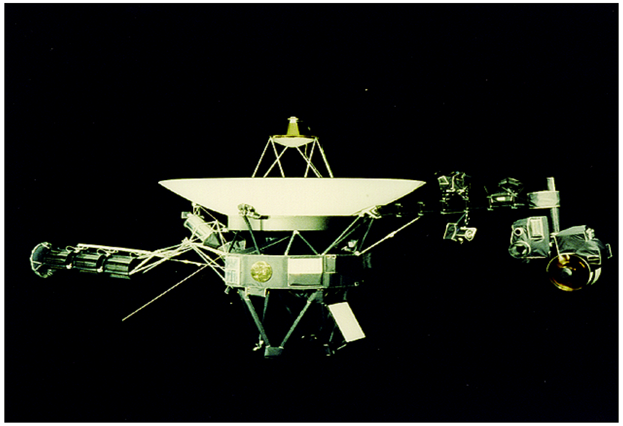
Successful Missions

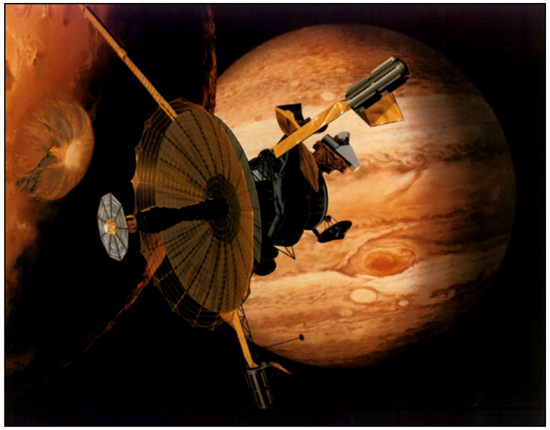


Apollo (1969 - 1972)

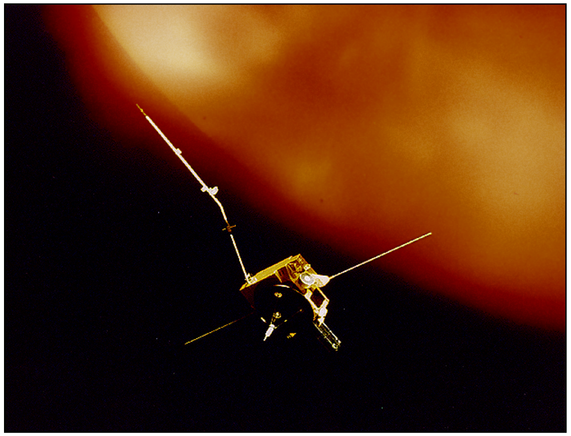
Pioneer 10 (1972)



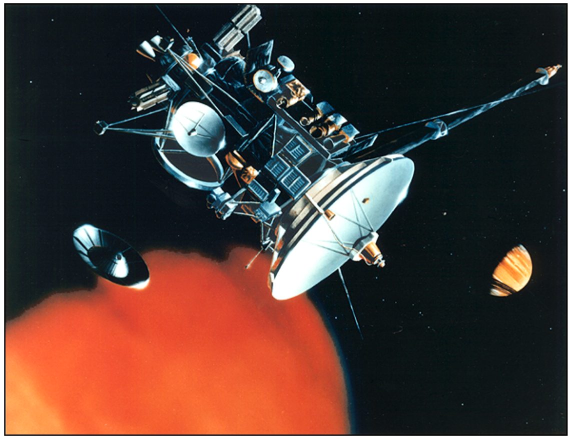
Voyager (1977)



Galileo (1989)

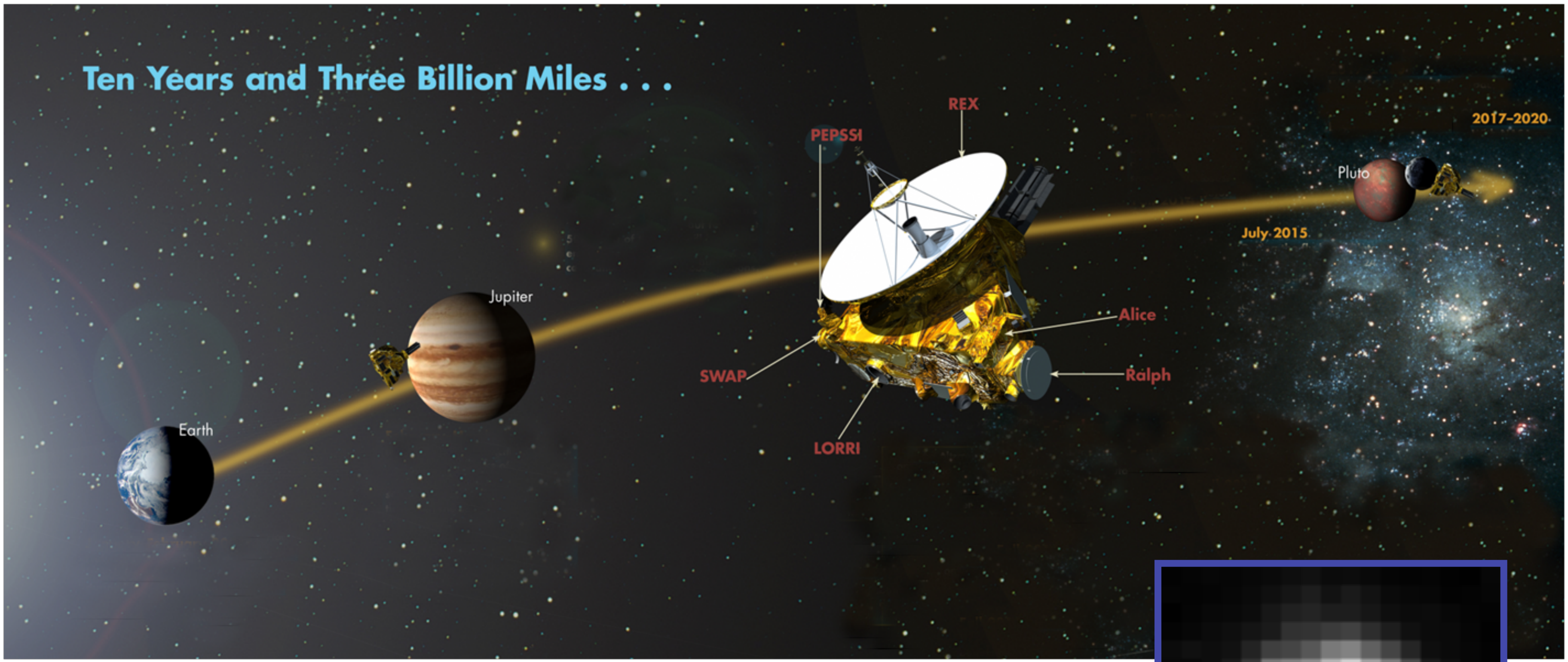


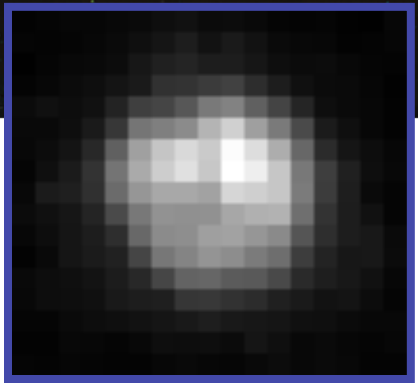
Ulysses (1990)



Cassini (1997)

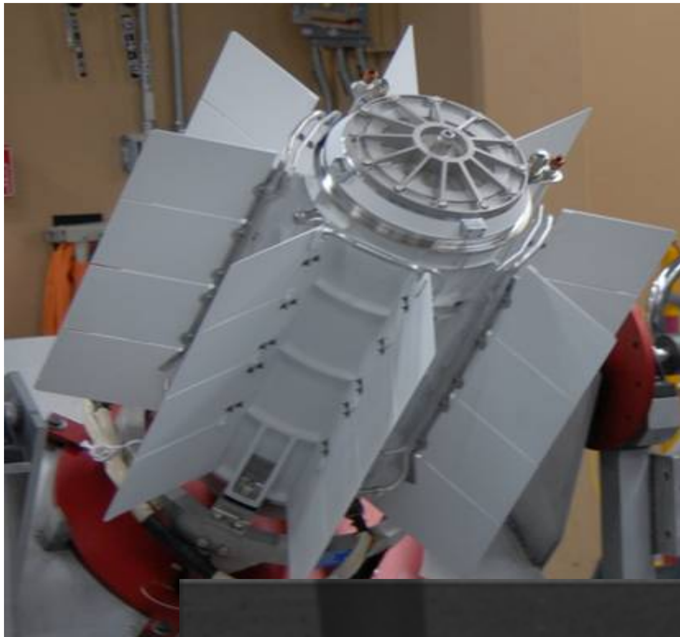
New Horizons – Pluto

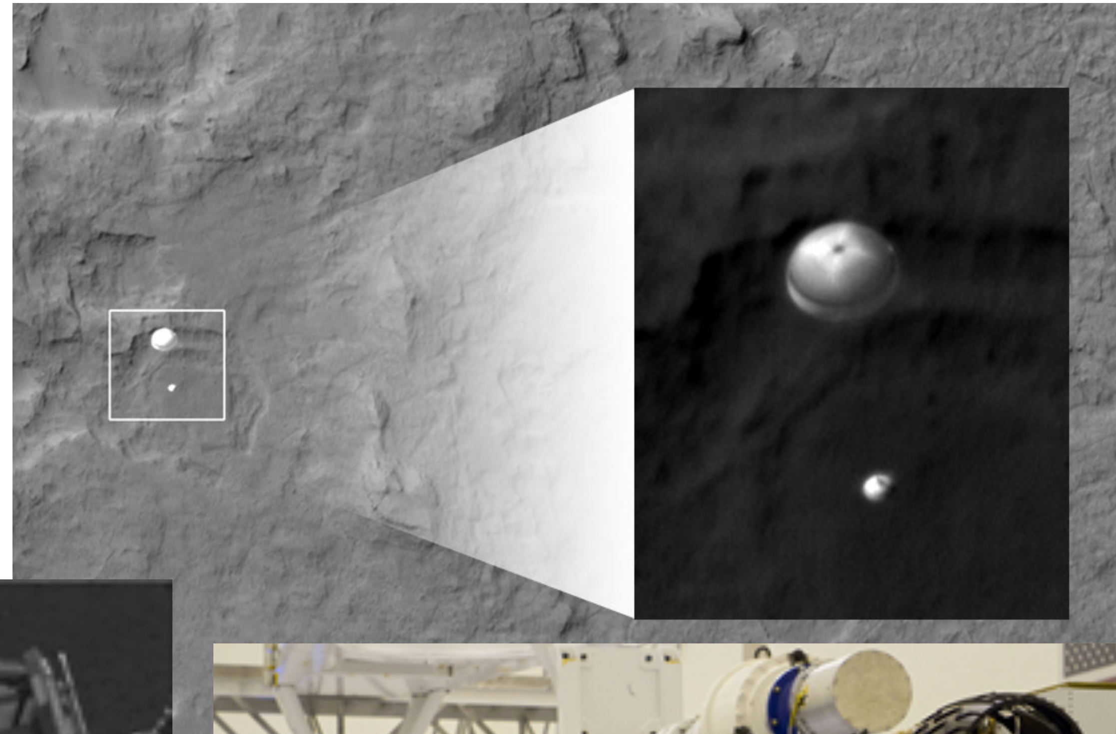


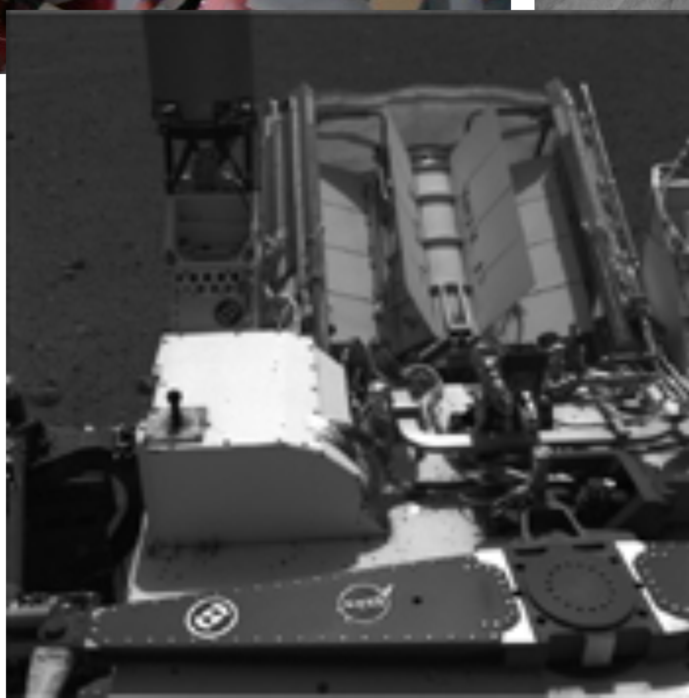


Pluto at best Hubble resolution at time of launch

Mars Science Laboratory – Landed August 6!!

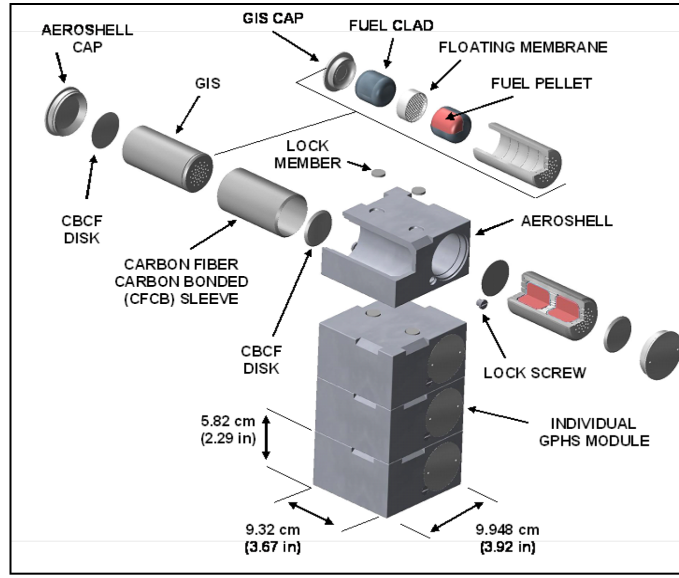




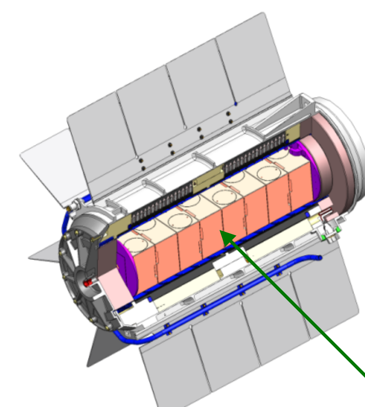


Key Components and Safety Features

- **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)**



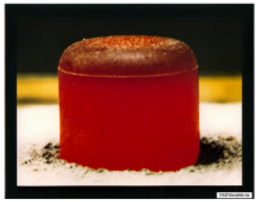
General Purpose Heat Source Module



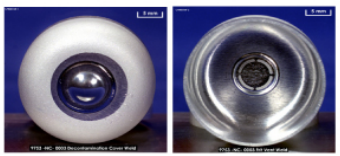
Multi-Mission Radioisotope Thermoelectric Generator

RPS Process Flow and Responsibilities

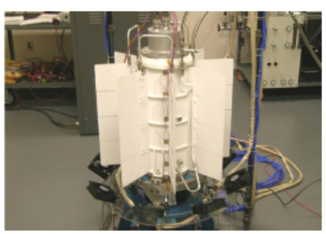
Plutonium Oxide (PuO_2) Fuel Pellet Production
LANL



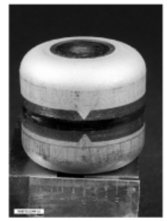
Iridium Component Fabrication
ORNL



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



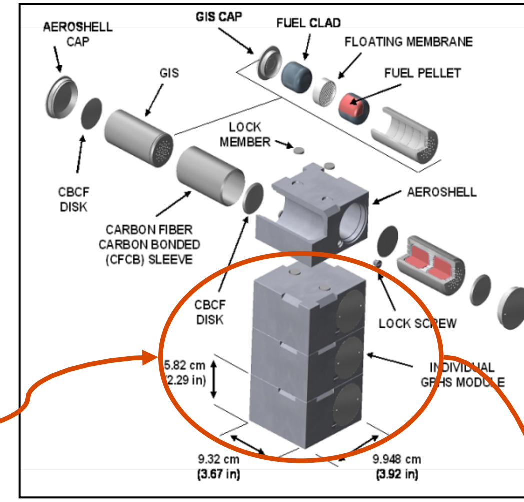
Fuel Pellet Encapsulation
LANL



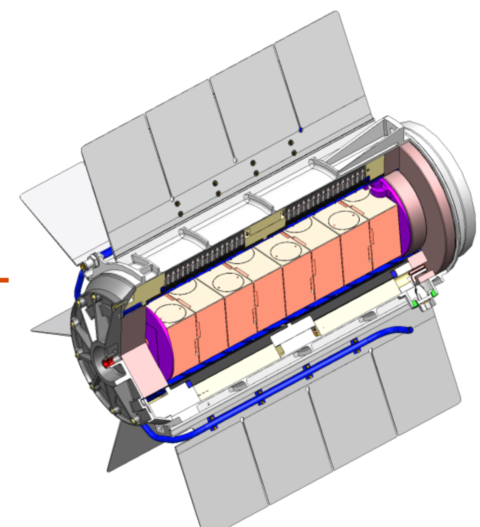
General Purpose Heat Source Module Assembly
INL

RPS Assembly and Testing
INL

RPS Shipment to KSC
INL



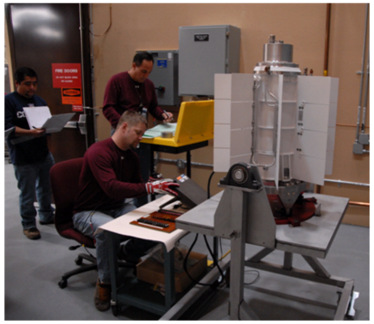
General Purpose Heat Source Module



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



Applied Research Needs

Innovative Heat Source Fuel Forms

- **Providing ceramic plutonium-238 oxide heat source that meets specifications on time while assuring personnel safety**
  - Pu-238 purification and encapsulation process provides a radiation dose to laboratory workers that is tightly controlled
  - Current ceramic heat source production method dates back over decades and results in relatively large (>20%) failure rate of the green and sintered ceramic fuel source during the production processing
- **Seeking improvements to manufacturability and to material properties that could lead to:**
  - Improved safety performance of product
  - Improved production efficiency
  - Enhanced personnel safety

Workscope Description

- **Proposals are sought for innovative methods of manufacturing ceramic Pu-238 heat sources**
- **Devise a new method of preparation of the materials to be used for forming the ceramic plutonium oxide fuel which will lead to fuel that exhibits more robust mechanical properties**
- **Ceramic product should:**
  - Conform to existing geometry and heat output of current designs and lead to enhanced safety performance
  - Be compatible with the current iridium alloy used in the encapsulation process
- **Emphasis on reliable processing parameters and enhanced personnel safety**
- **Process should be cognizant of the existing safety verification testing basis**