U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Energy University Programs (NEUP) Fiscal Year (FY) 2017 Annual Planning Webinar

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

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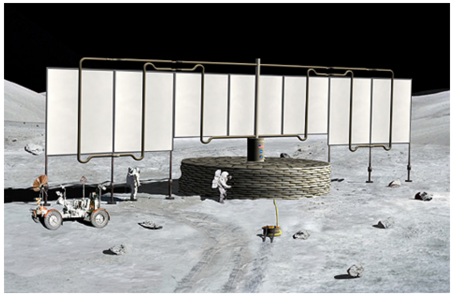
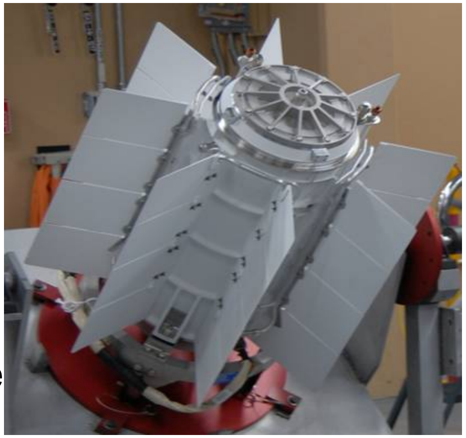
August 2016

Space and Defense Power Systems Program

- **Space and Defense 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



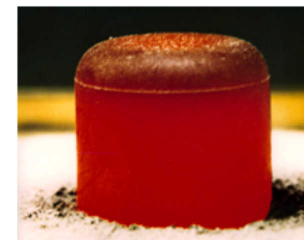
- **Benefits**
  - Enable customer missions in locations and environments where other power systems such as chemical batteries and solar power systems do not work
  - Directly support NASA missions to explore the moon, Mars, outer planets and beyond

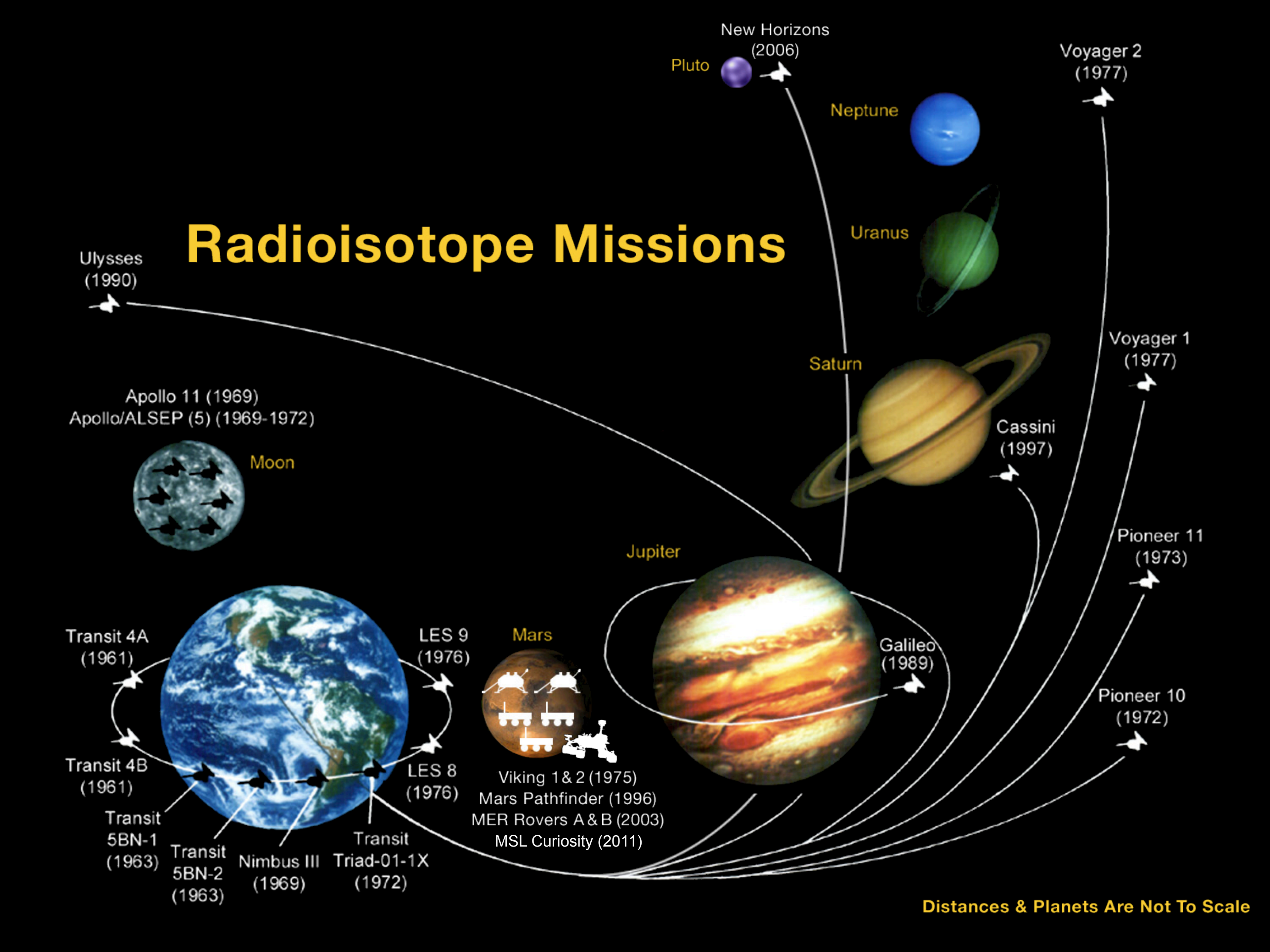


- **Key R&D Areas:**
  - Develop materials for use in the extreme environments required for space applications

Space and Defense Power Systems Program Overview

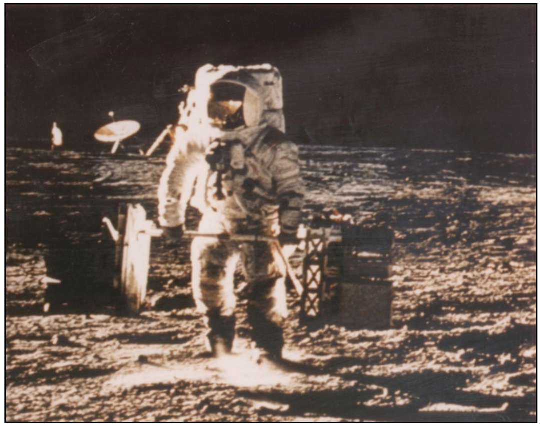
- Provides nuclear power sources for space science and exploration missions and national security applications for which solar energy or other power sources are not practical
- Maintains the capabilities to produce and deliver plutonium-238 fueled radioisotope power systems
- Reports to the Deputy Assistant Secretary for Nuclear Reactor Technologies within the Office of Nuclear Energy
- Works with NASA to provide radioisotope power systems for use in space
- Works for NASA to maintain ongoing capabilities and facilities at several national laboratories and awards private sector contracts for design, fabrication and delivery of specific power systems



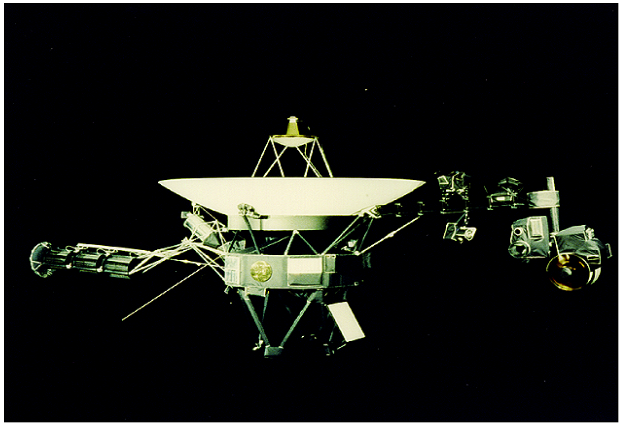


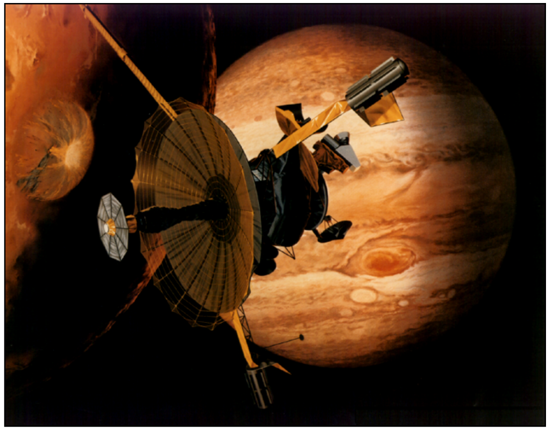
Radioisotope Missions
New Horizons (2006)
Pluto
Voyager 2 (1977)
Neptune
Uranus
Ulysses (1990)
Saturn
Voyager 1 (1977)
Apollo 11 (1969)
Apollo/ALSEP (5) (1969-1972)
Moon
Cassini (1997)
Jupiter
Pioneer 11 (1973)
Transit 4A (1961)
LES 9 (1976)
Mars
Galileo (1989)
Pioneer 10 (1972)
Transit 4B (1961)
LES 8 (1976)
Viking 1 & 2 (1975)
Mars Pathfinder (1996)
MER Rovers A & B (2003)
MSL Curiosity (2011)
Transit 5BN-1 (1963)
Transit 5BN-2 (1963)
Nimbus III (1969)
Transit Triad-01-1X (1972)
Distances & Planets Are Not To Scale

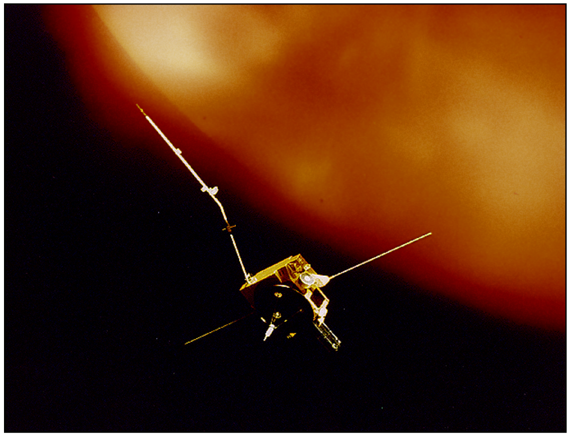
Successful Missions

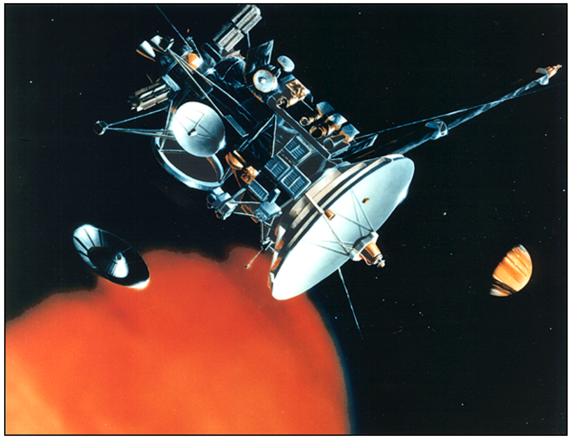

Apollo (1969 - 1972)


Pioneer 10 (1972)

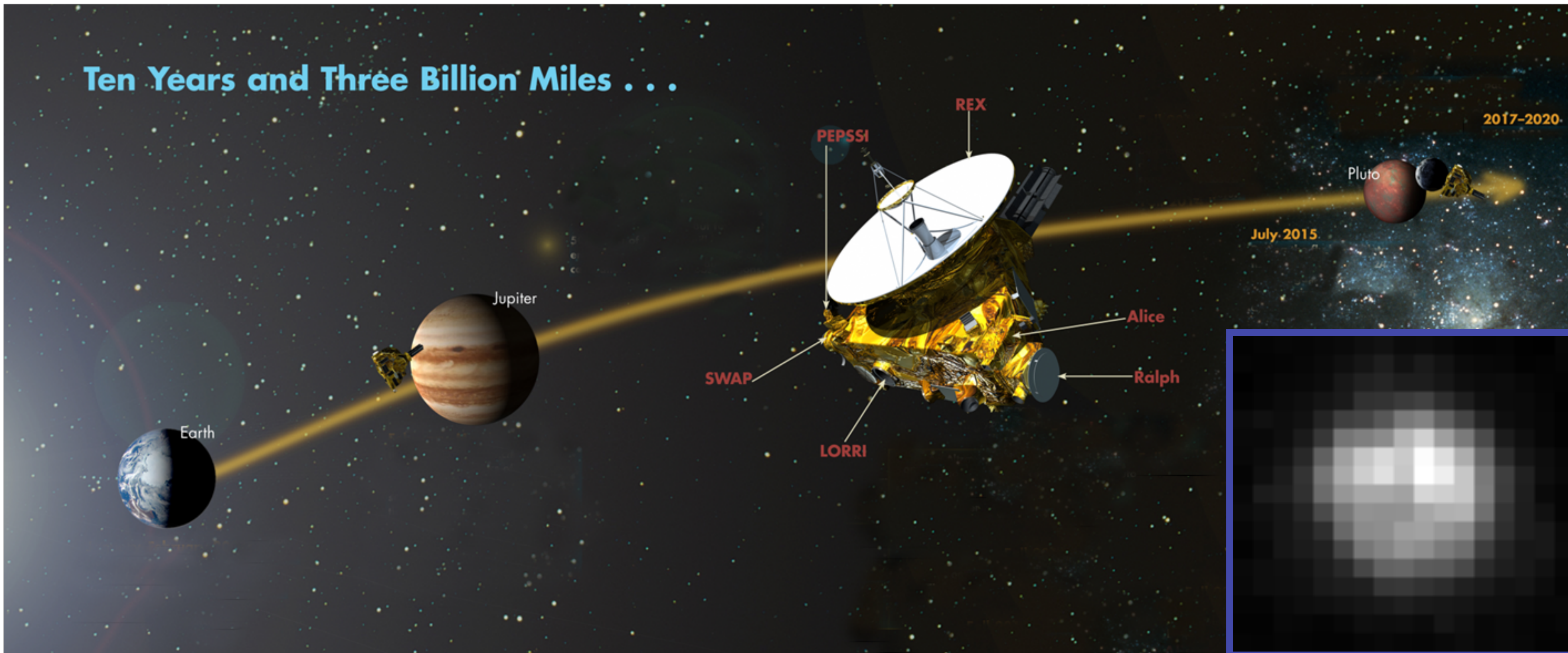

Voyager (1977)


Galileo (1989)


Ulysses (1990)

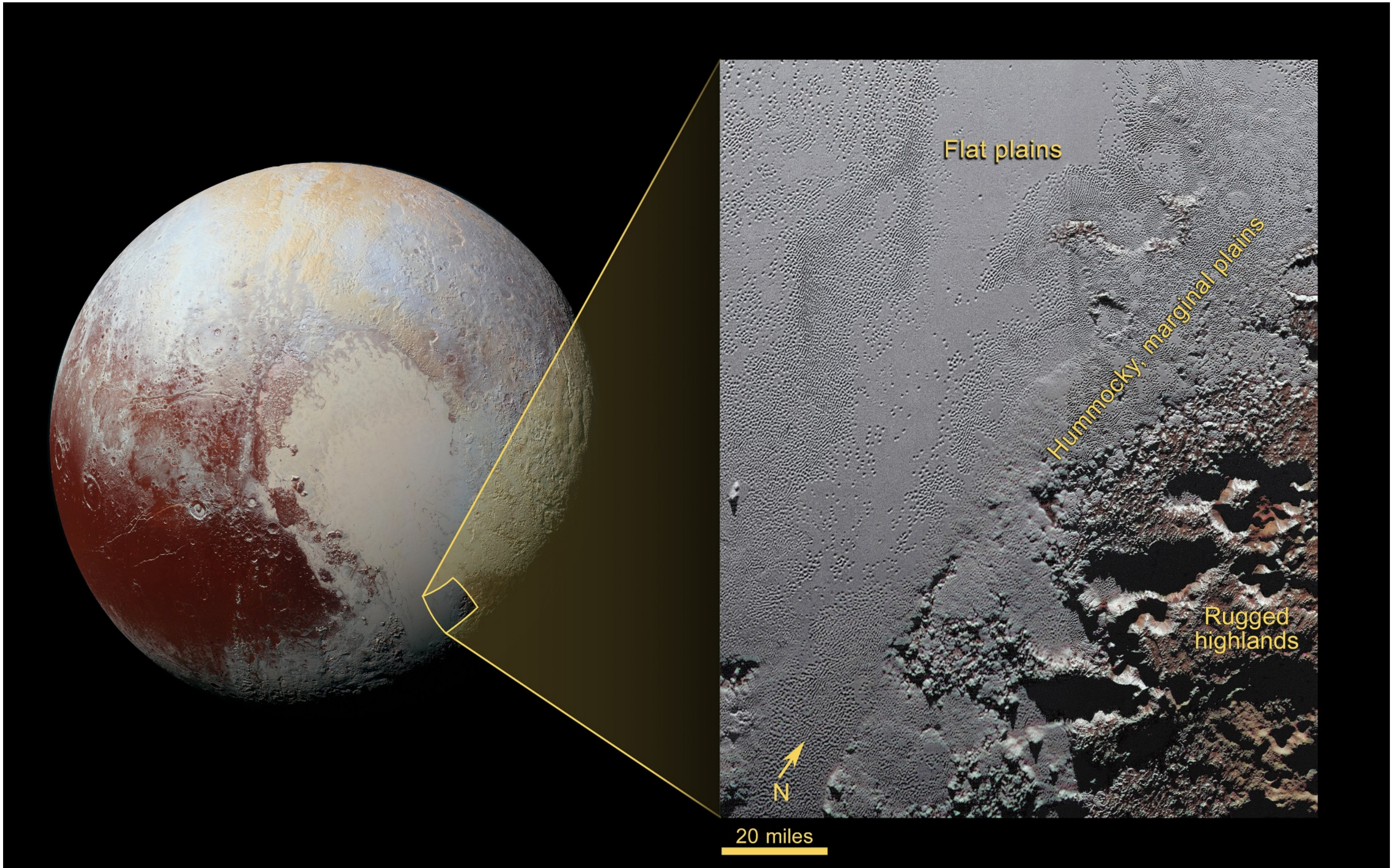

Cassini (1997)

New Horizons – Pluto

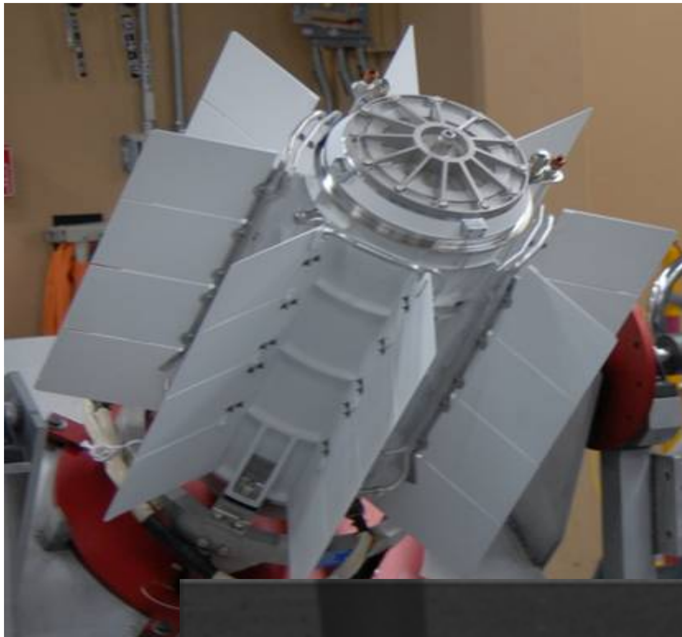


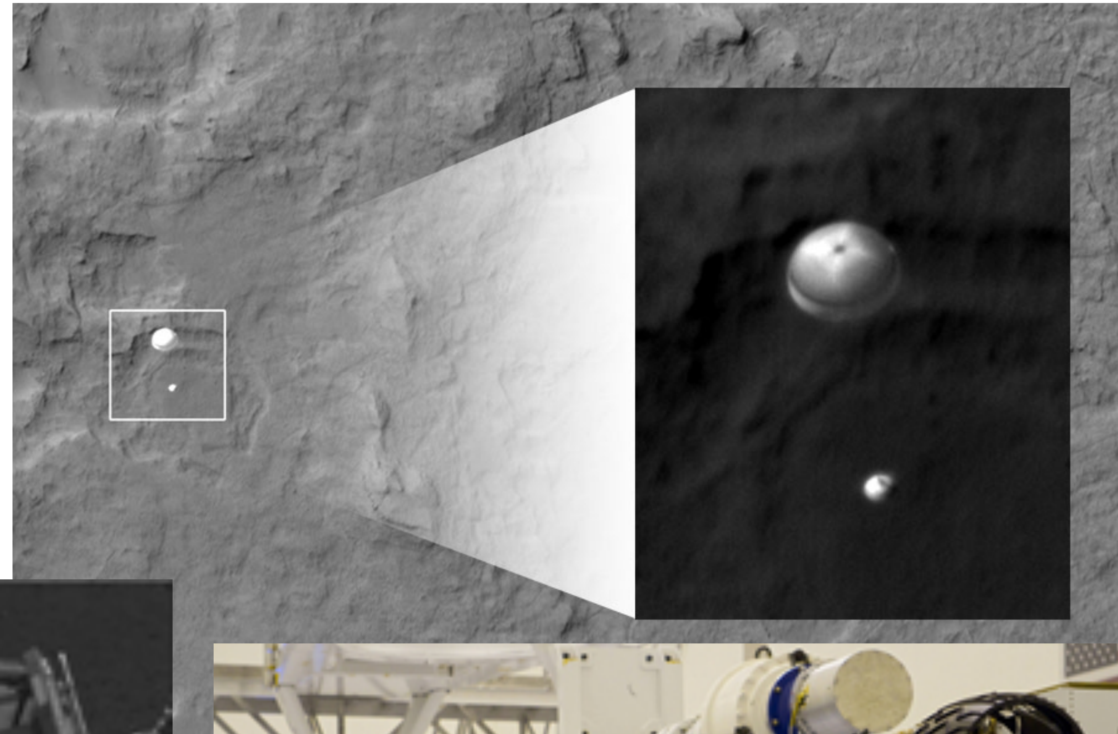
Pluto at best Hubble resolution at time of launch

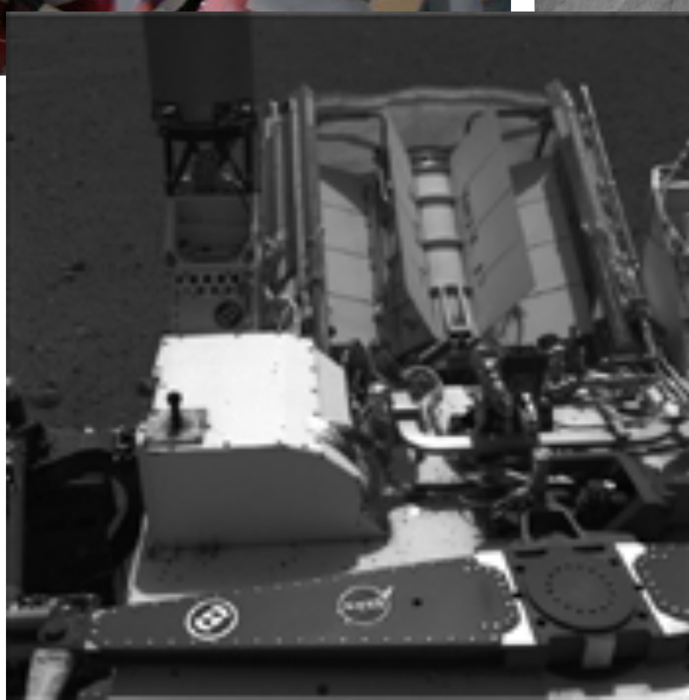
New Details of Pluto



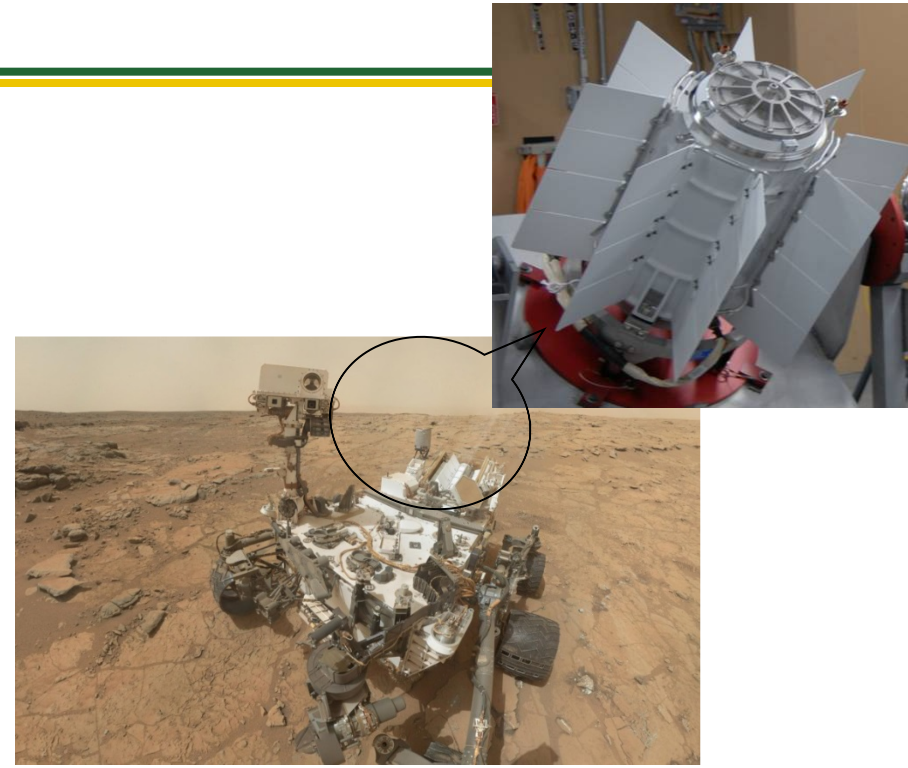
Mars Science Laboratory – Landed August 6, 2012







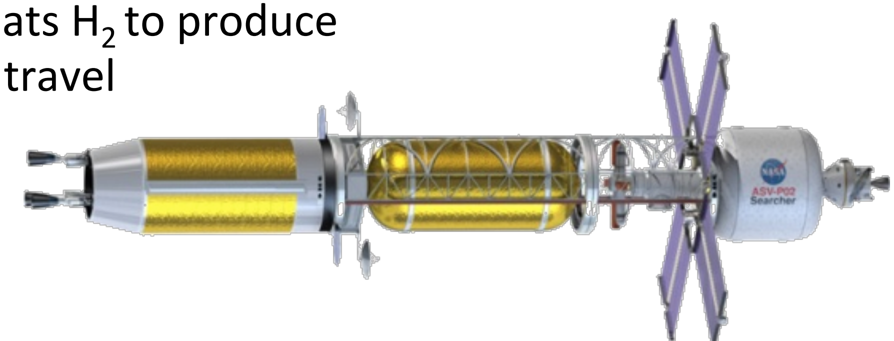
Space Nuclear Power System Projects



- **Multi-Mission Thermoelectric Generator (MMRTG)**
  - Fueled with $^{238}PuO_2$
  - 110 W electricity
  - Launched in 2011 on the Mars Science Laboratory rover Curiosity
  - Will power upcoming MARS 2020 mission

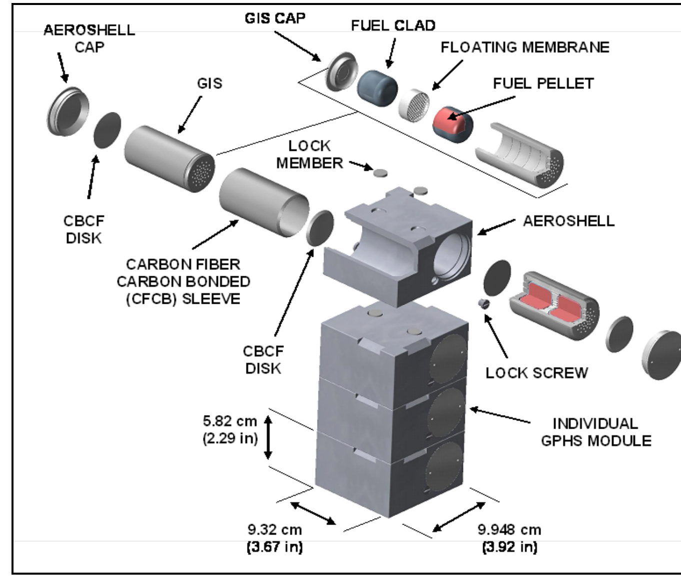
Nuclear Thermal Propulsion

Nuclear fission reactor heats H_2 to produce thrust for inter-planetary travel

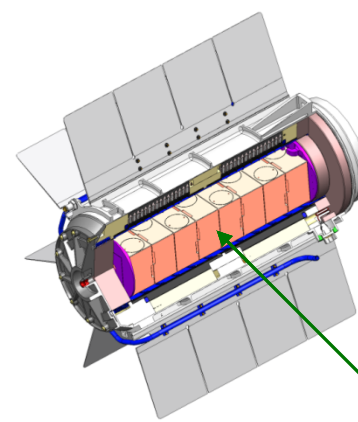


Key Components and Safety Features

- **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)**
- **Radiator (rejects excess heat)**



General Purpose Heat Source Module



Multi-Mission Radioisotope Thermoelectric Generator

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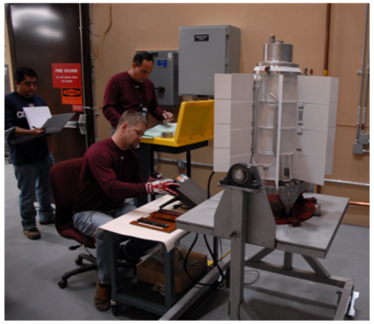
Grand Challenges

- **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



Transformative Research Needs – Space Reactor Power Systems R&D

- **Space Reactor and Fuels Development**
  - Effort toward developing a conceptual design for a reactor and fuel that covers a range of power outputs from 2-3 KWe to 40 KWe. Designs that could benefit both NASA and national security users are sought. Simplicity of design and manufacturability are important as well as minimizing total system mass.
- **RD&D Goals:**
  - Innovative design concepts that leverage existing fuel experience with focus on high reliability power conversion and reactor operations. Novel power conversion systems that improve on the current state of the art are encouraged.

Workscope Description

Nuclear Thermal Propulsion System

- Proposals are sought for development of a nuclear thermal propulsion system design that would use NERVA-derived composite fuels. Performance goals are for a 25,000-30,000 lb thrust with a specific impulse of 900 seconds.
- Attempt to leverage existing NERVA fuel and reactor designs to optimize proposed propulsion system designs.

Workscope Description

Portable Compact Reactor Designs

- Proposals are sought for portable compact reactor designs that can be deployed for terrestrial applications. The proposed design should focus on reliability, low maintenance and be compact to allow rapid transport, deployment, and removal. Applications are sought for 100kW to 1 MW electric power output.

- Self-contained systems with compact features will enable the transport and deployment.