Radioisotope Power Systems:

The Quiet Technology

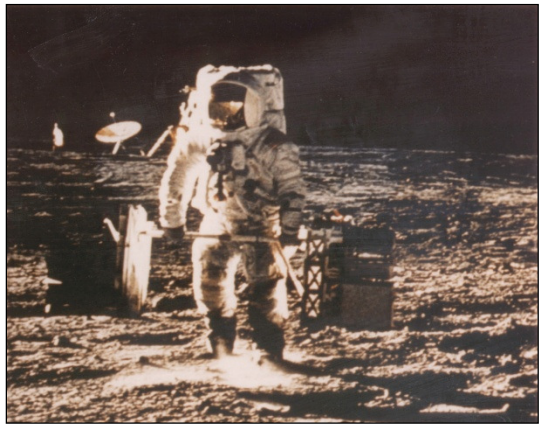
Nuclear and Emerging Technologies for Space (NETS-2011)

Robert Lange, Deputy Assistant Secretary
Office of Nuclear Energy

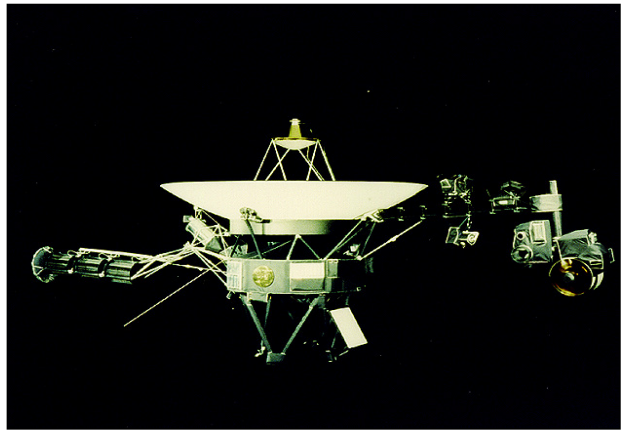
U.S. DEPARTMENT OF ENERGY

Nuclear Energy

RPS Enables Breakthrough Space Science Missions

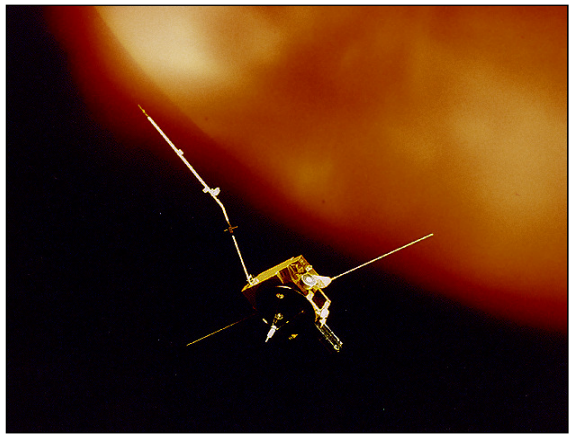


Apollo (1969 - 1972)

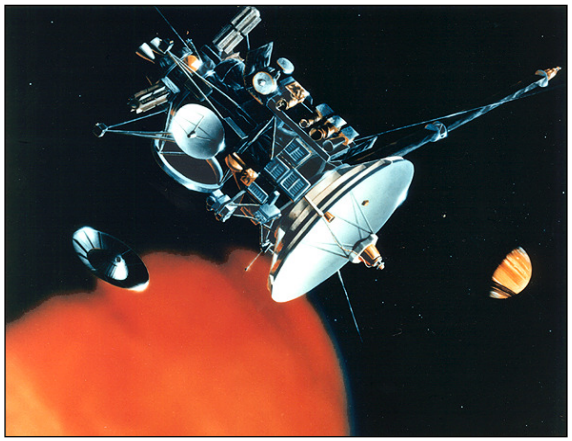


Voyager (1977)

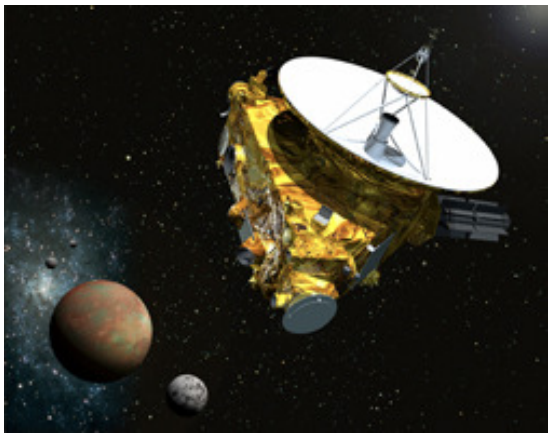
Galileo (1989)



Ulysses (1990)



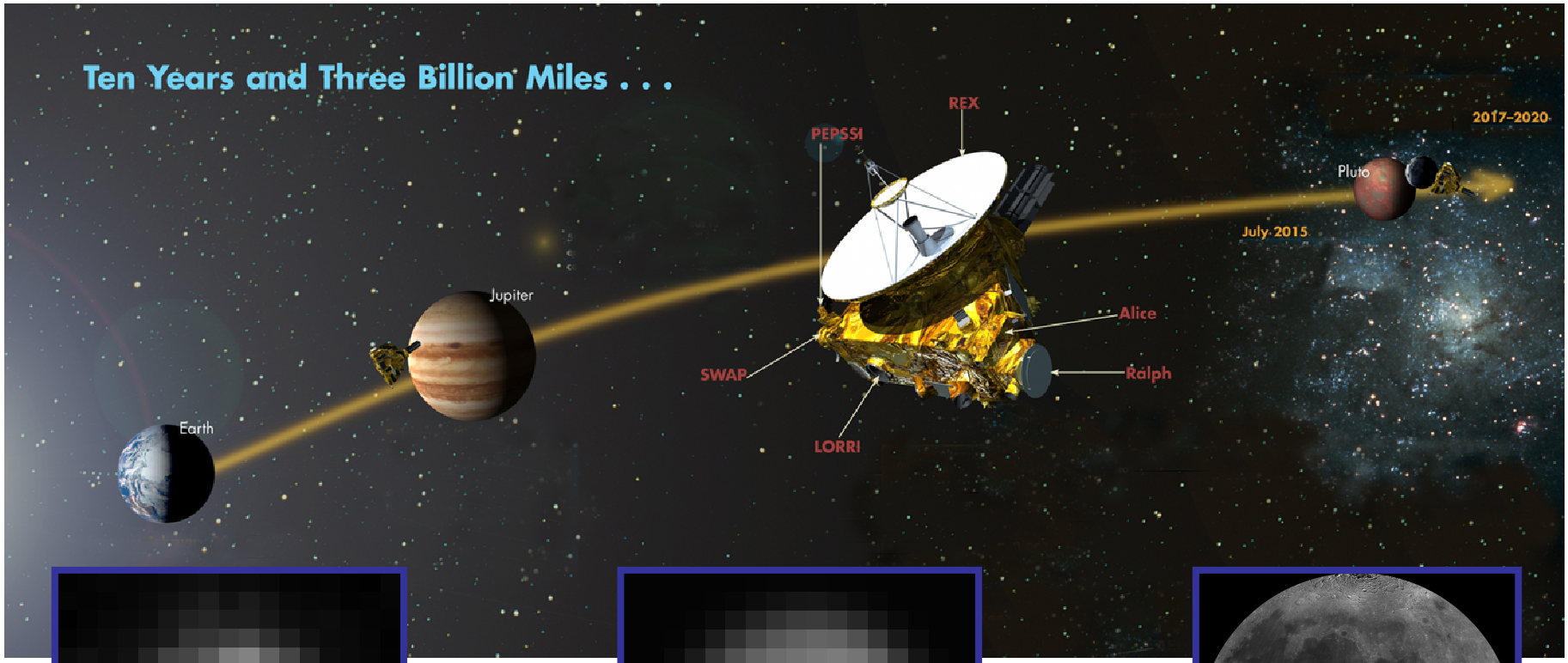
Cassini (1997)

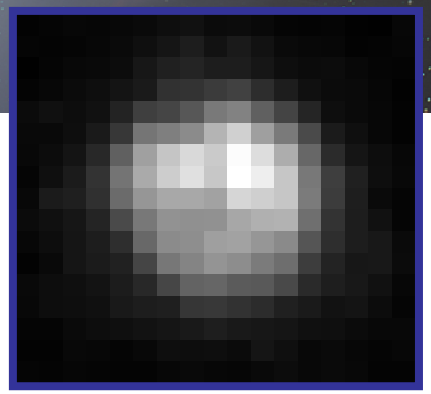


New Horizons (2006)

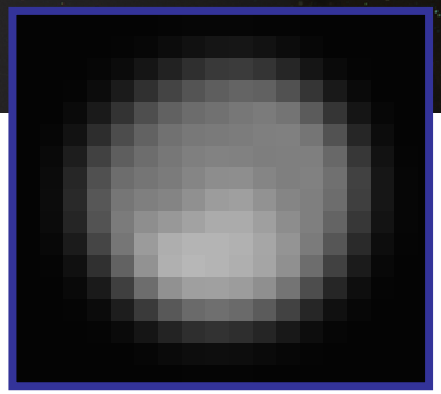
For all prior missions, RPS have continued to operate far beyond their design life

New Horizons – Pluto





Pluto at best
Hubble Resolution



Earth's Moon at the
Same Resolution

Earth's Moon at
5 km per pixel

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DOE Responsibilities and Capabilities

DOE maintains RPS assembly, delivery and analysis infrastructure capability and manages RPS development and system integration contracts

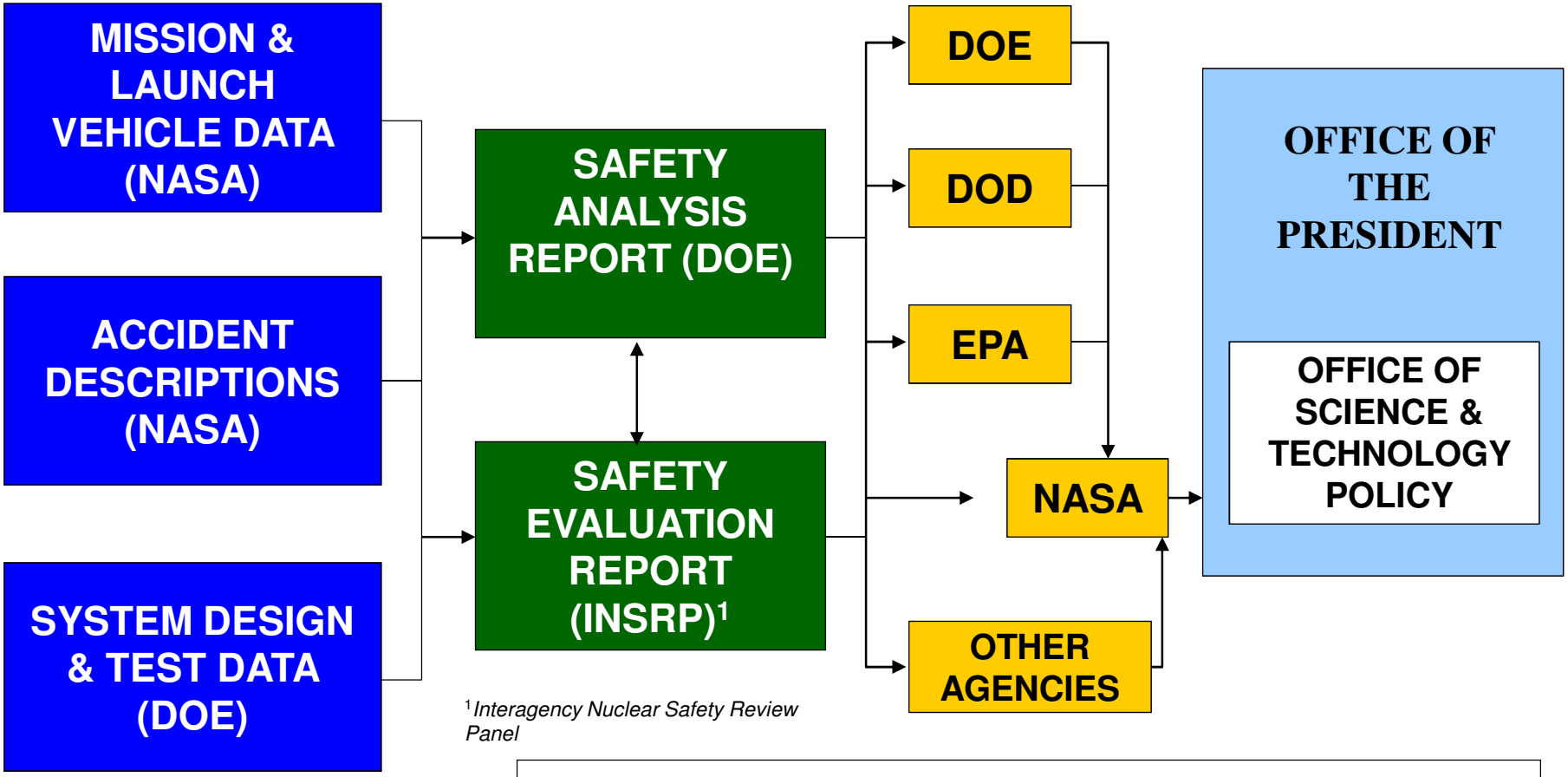
RESPONSIBILITIES

- **Maintain RPS infrastructure and capabilities**
- **Design, manufacture, assemble, test and deliver power systems**
- **Manage customer funded RPS system integration contracts**
- **Manage plutonium-238 supply**
- **Analyze safety and risk of RPS deployment and operations**
- **Provide launch support and emergency response**
- **Provide international leadership on safe use of space nuclear power systems**

CAPABILITIES

- **Knowledge Bases**
  - Safety: in design, production and use for worker safety in production and public safety in application
  - Quality assurance: in production, assembly and testing to assure product quality
  - Program knowledge: the integration of all processes and participant organizations
- **Physical infrastructure**
  - Material processing, handling and storage
  - Fabrication, assembly and testing
  - Safeguards and security
  - Safety
  - Waste management
- **Personnel skills**
  - Professionals and technicians
  - Corporate knowledge
  - Succession

Nuclear Safety Review and Launch Approval Process

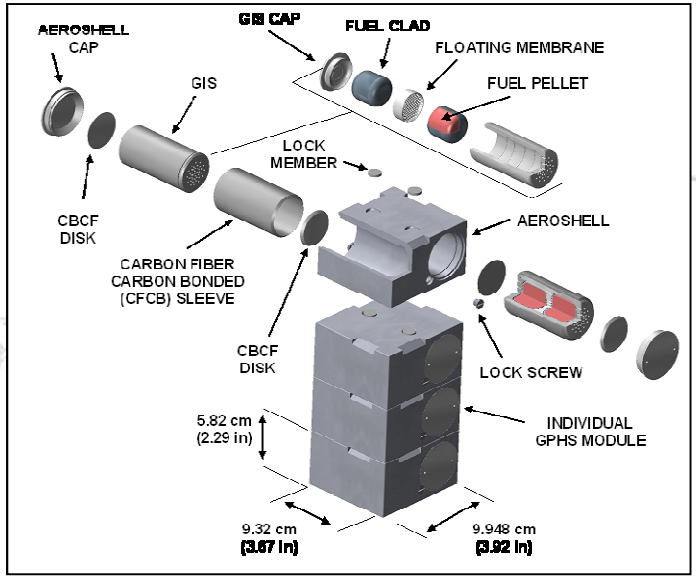


[1] *Interagency Nuclear Safety Review Panel*

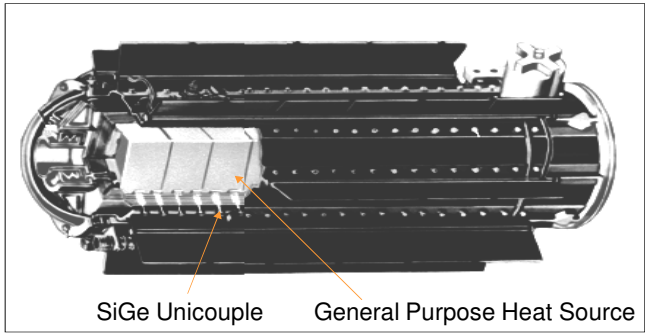
DOE prepares a nuclear risk assessment which will be used by the Office of President to make a decision to authorize a launch using nuclear materials.

Radioisotope Power Systems *Key Components*

- Pu-238 fuel (generates heat)
- Cladding (encases the fuel)
- Graphite heat source (protects fuel & cladding)
- Converter (converts heat to electricity)
  - Thermoelectrics (~6% system efficiency)
  - Stirling (~28% system efficiency)
- Radiator (rejects excess heat)



General Purpose Heat Source Module



Radioisotope Thermoelectric Generator

RPS Evolution

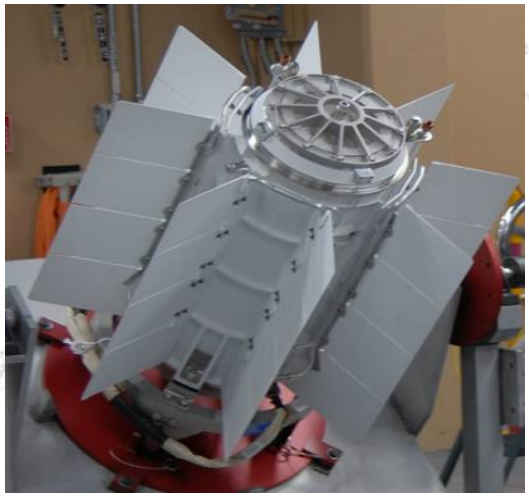
- RPS have allowed the exploration of our solar system and beyond as no other power source could
- DOE has evolved the RPS systems and maintained the unique nuclear facilities and capabilities required to produce them
- RPS systems used in space include SNAP-3, 9A,19, and 27; MHW-RTG, GPHS-RTG; and RHUs

RPS Evolution (cont'd)

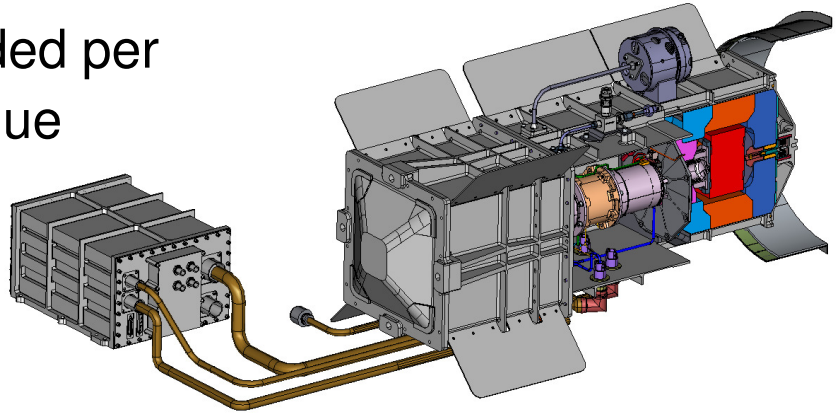
- Though not the first fuel investigated or produced, Pu-238 oxide has been the only fuel used for U.S. space missions.
  - Produces significant amount of heat for a long time
  - Alpha radiation is easily shielded
  - Ceramic form increases safety properties
- The Pu-238 fuel form has evolved to improve its heat source effectiveness and safety properties.
  - the fuel pellets are encapsulated in a strong, ductile iridium cladding, insulated and enclosed in an enhanced aeroshell for a potential reentry

RPS Evolution (cont'd)

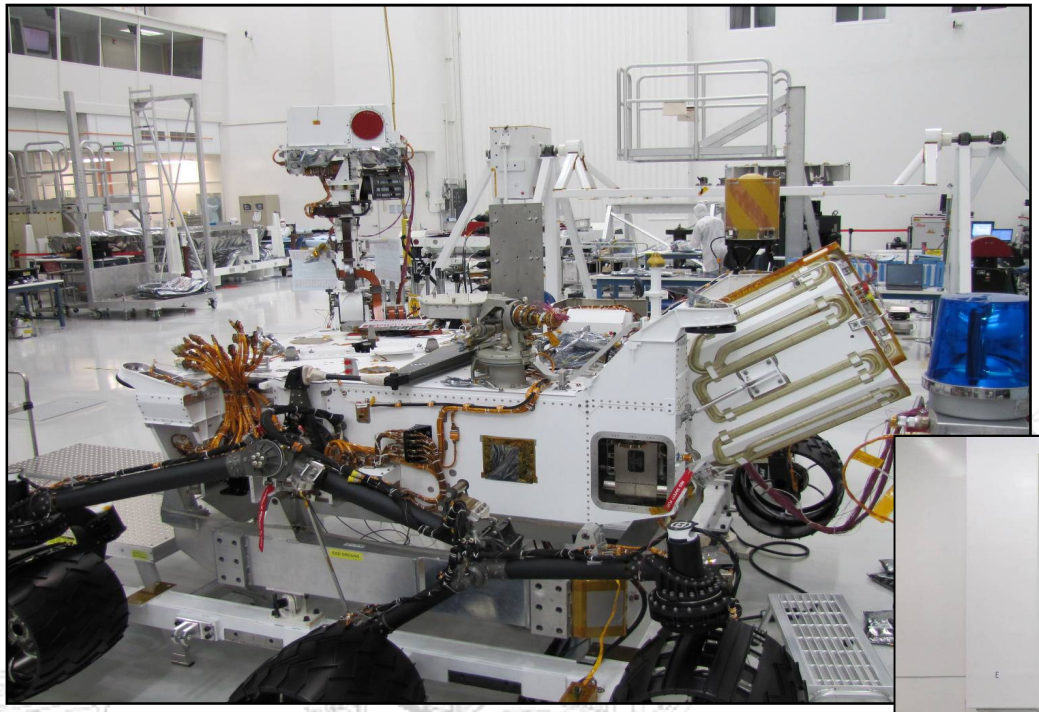
- DOE has developed the Multi-Mission RTG (MMRTG) which will be first used on the Mars Science Laboratory (MSL) mission to be launched Nov.-Dec. 2011



- DOE is also developing the Advanced Stirling Radioisotope Generator (ASRG) using an efficient dynamic power conversion system that promises to reduce the amount of fuel needed per mission, but also presents unique challenges

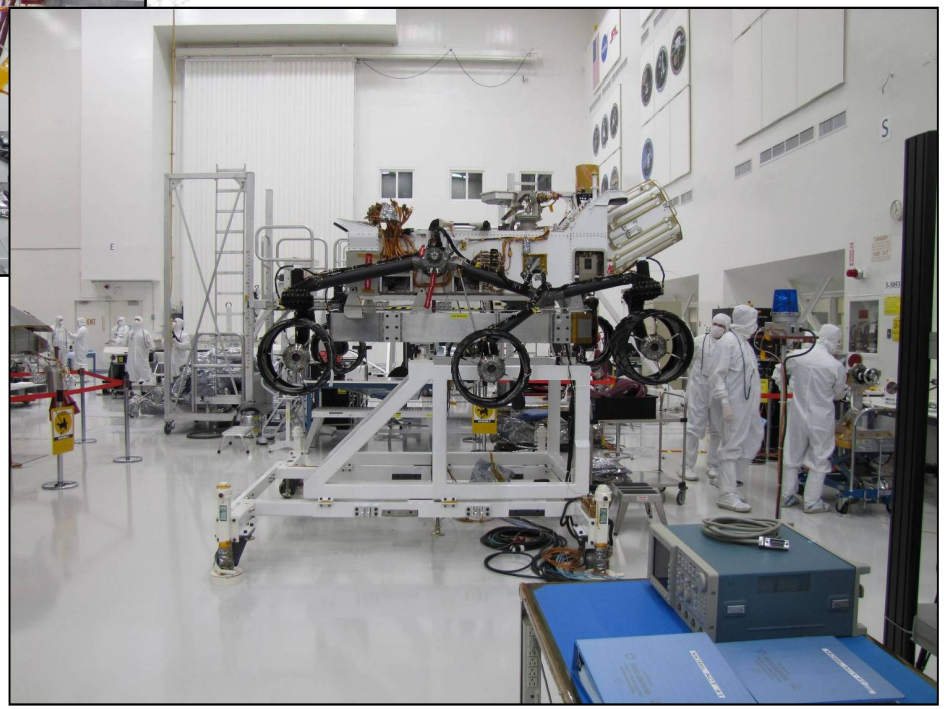


Mars Science Laboratory-Rover



Curiosity at JPL

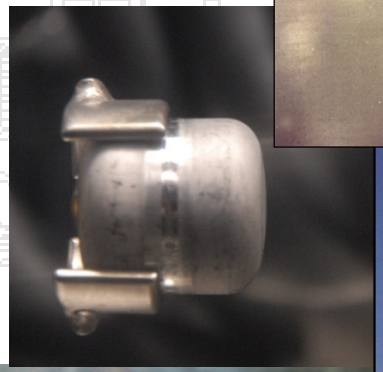
http://mars.jpl.nasa.gov/msl/mission/rover



DOE has completed the Final Safety Analysis Report for MSL and is currently supporting the launch approval process.

DOE Enables RPS Success

- Unique facilities/capabilities
- Isotope supply
  - Pu-238 is the isotope of choice
- Systems integration contractors
- Exotic materials supply, e.g.
  - iridium clads,
  - fine weave pierced fabric,
  - carbon bonded carbon fiber.
- Skilled personnel
- Safety of each launch



Pu-238 Production

- A new supply of Pu-238 is needed to provide assurance that missions beyond the 2020 timeframe can be supported.
- Restarting Pu-238 production will require refurbishing existing facilities to support neptunium-237 target fabrication and extraction of plutonium from irradiated targets.
- The targets would be irradiated in existing reactors – the Advanced Test Reactor (ATR) in Idaho and the High Flux Isotope Reactor (HFIR) in Oak Ridge.

Challenges

- Costs to operate nuclear facilities at national laboratories will continue to escalate.
- Additional Pu-238 is needed for missions beyond 2020.
  - Both DOE and NASA have requested funding in FY 2011 to reestablish a domestic capability.
  - DOE is prepared to move forward with the project when funds are received.
  - DOE is continuing to negotiate with Russia to purchase remaining available Pu-238.

Summary

- DOE-developed RPS have contributed enormously to the scientific understanding of our solar system
- RPS are required to continue this highly successful endeavor
- DOE has the sole government statutory authority to perform work on special nuclear material facilities and systems
- Restarting Pu-238 production is essential to ensure future RPS missions
- RPS missions have changed our understanding of our solar system; to continue this increased understanding requires expanded used of RPS and, in the long term, all space nuclear power systems.