

# Assessment of Plutonium-238 Production Alternatives

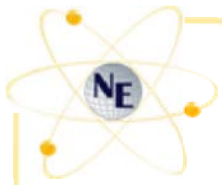
Briefing for  
Nuclear Energy Advisory Committee

April 21, 2008

Dennis Miotla

Deputy Assistant Secretary for  
Nuclear Power Deployment





# Statement of Work

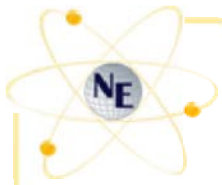
Independently evaluate the Pu-238 heat source requirements for NASA's mission projections and assess Pu-238 production assumptions, strategy and alternatives for meeting those requirements

- Desired end state:
  - Reliable, sustainable, affordable supply of Pu-238 suitable for NASA applications
- Assumptions:
  - NASA obtains funding for planned missions
  - Russia is out of material to sell to US
  - DOE maintains balance of radioisotope power source infrastructure during period of depleted supply



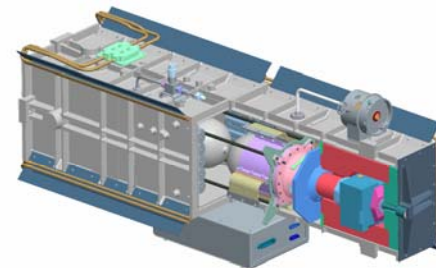
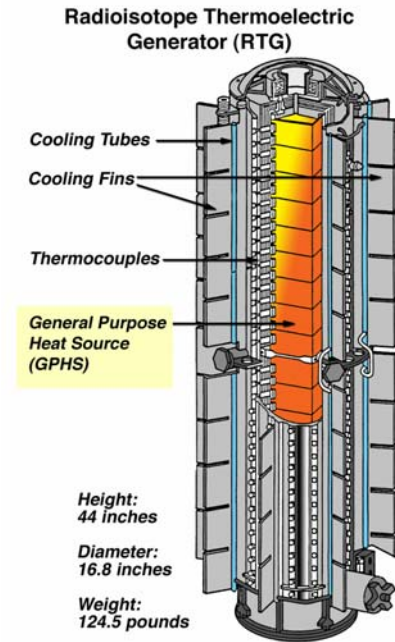
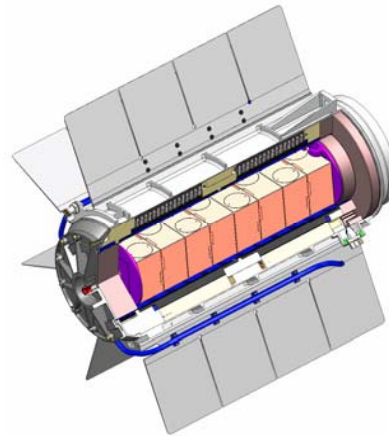
# Why Pu-238 as a Heat Source?

- Long half-life- 87.7 years
- High power density/specific power ~ 0.57 watts/gram
- Low radiation levels – primarily an alpha emitter
  - limit radiation exposures of operating personnel during production, fabrication, testing and delivery
  - low-mass configurations for space applications offer very little self shielding
  - compatibility with sensitive instrumentation for space exploration
- High thermal stability – oxide form with high melting point
- Low solubility rate in the human body and environment
- Producibility in sufficient quantities and schedule to meet mission needs
- Other isotopes considered and dismissed over the years
  - investigated several times in response to concerns over supply



# RPS Designs - Current and Under Development

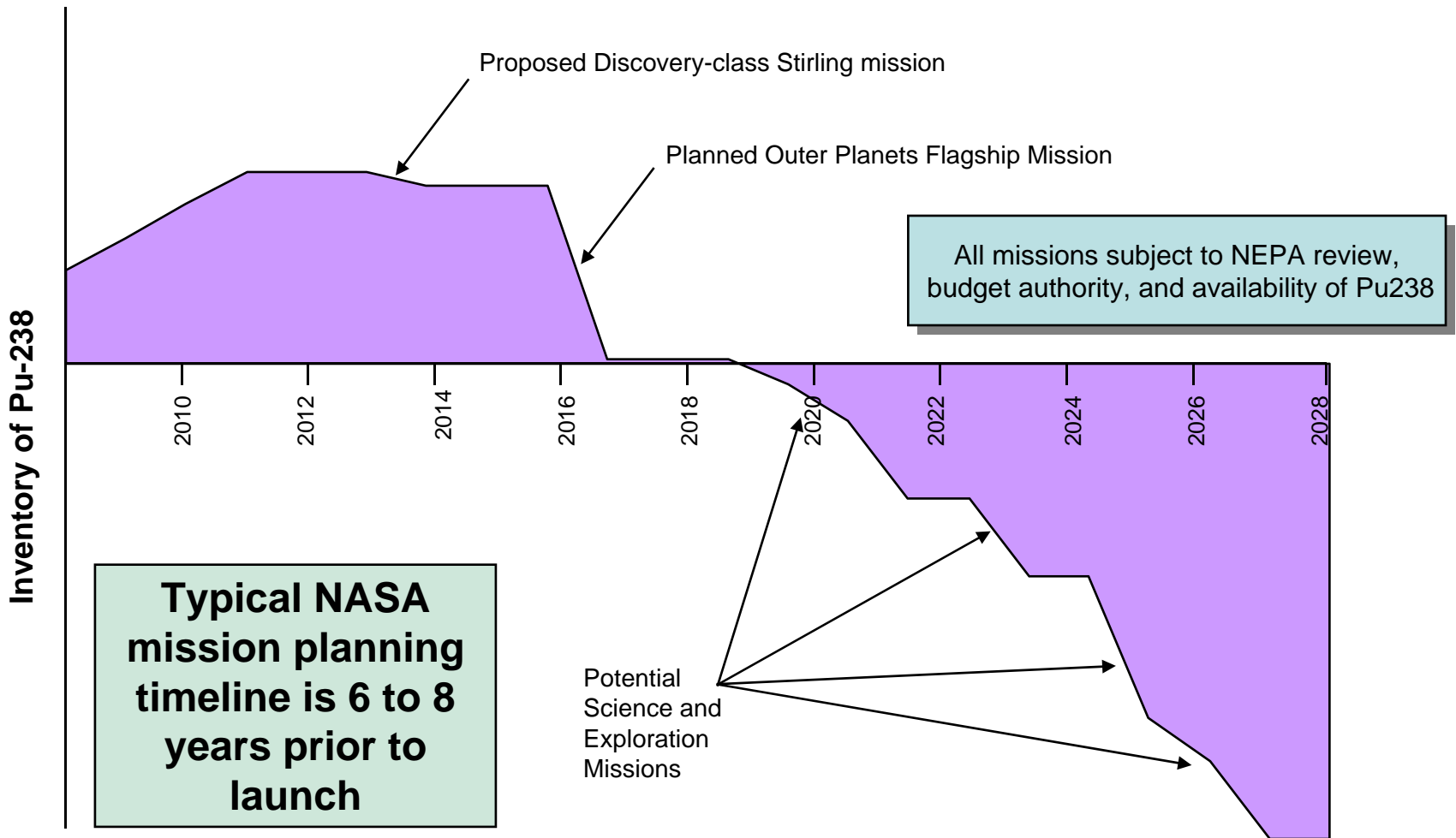
- **GPHS Radioisotope Thermoelectric Generator (RTG)**
  - 18 GPHS modules,  $\sim 7.9 \text{ kg}_{\text{Pu-238}}$
  - electric power  $\sim 210 \text{ watts}$  beginning of mission (BOM)
  - Galileo, Ulysses, Cassini and New Horizons missions (no longer available for future missions)
- **Multi-mission RTG (MMRTG)**
  - 8 GPHS modules,  $\sim 3.5 \text{ kg}_{\text{Pu-238}}$
  - $\sim 120 \text{ W}_e$  BOM
  - Mars Science Laboratory (to be launched Sep 2009)
- **Advanced Stirling Radioisotope Generator (ASRG) – dynamic system, under development**
  - 2 GPHS modules,  $\sim 0.88 \text{ kg}_{\text{Pu-238}}$
  - $\sim 140 \text{ W}_e$  BOM





# The Problem

**Next two budgeted NASA RPS missions will exhaust remaining inventory (including planned Russian purchases)**





# The Plan for Production

---

- FY 2008 – CD-0 Approve Mission Need
- FY 2009 – CD-1 Approve Alternative Selection
  - Issue university grants to develop alternatives
  - Promising concepts would be considered in CD-1 alternatives analysis
- Timing for CD-2, CD-3 and CD-4 will depend on alternative



# Considerations for Candidate Alternatives

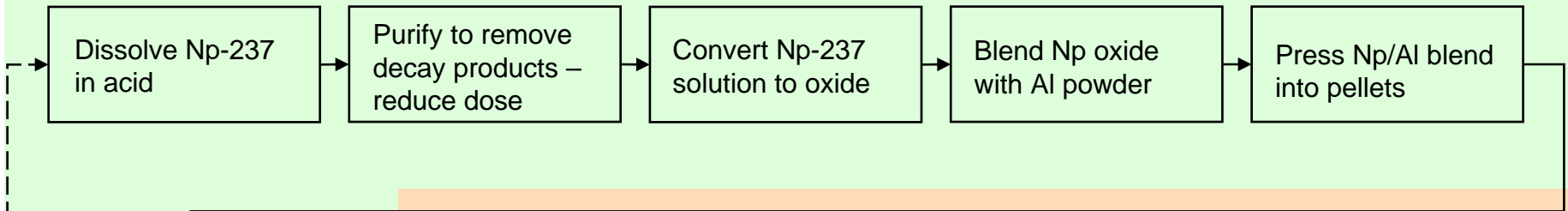
---

- Product must be suitable as feed to current fuel fabrication process
- Thermal power density of product must be consistent with current radioisotope power system designs
- Process must have the potential to offer significant advantages in cost, schedule or technical risk relative to historic production process, taking into account:
  - safety, licensing
  - security
  - technology development and demonstration
- Process must be scalable to produce 5 kg Pu-238 per year

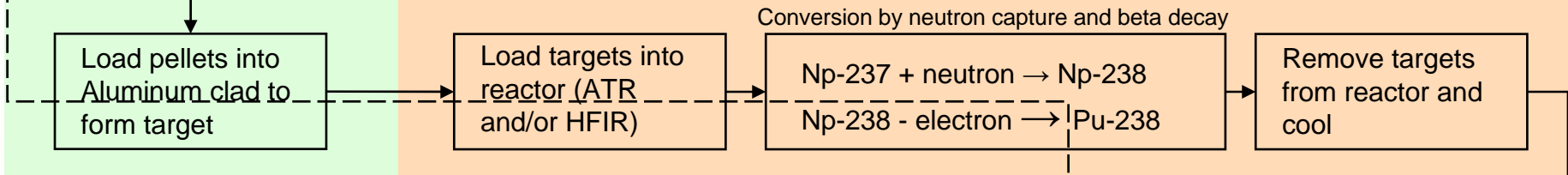


# Historic Process Flow for Pu-238 Production and Recovery

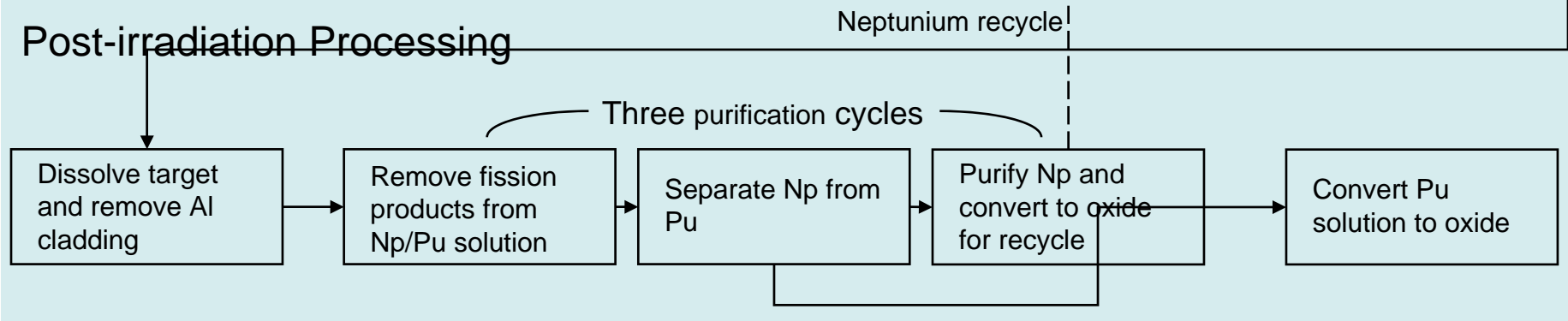
## Target Fabrication



## Target Irradiation



## Post-irradiation Processing



**Product is plutonium dioxide powder with an isotopic content of Pu-238 greater than 80%. Each production cycle converts 10-15% Np-237 to Pu-238 with remainder of Np recycled.**





# Examples of Candidate Alternatives

---

- Alternate target fabrication approaches
- Alternate irradiation approaches
- Alternate post-irradiation processing approaches

# Back-up Charts

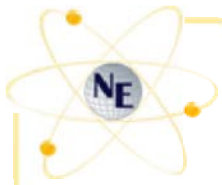




# Motivation for Study

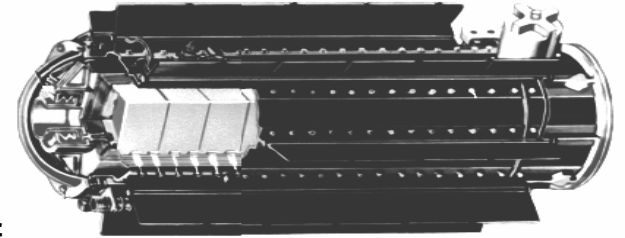
---

- The United States has not produced Pu-238 since shut down of K Reactor at SRS in late 1980's
- Procurement of Pu-238 from Russia commenced in early 1990's and will conclude in 2010
  - Approximate quantity purchased from Russia by that time will be 30-40 kg
  - Russia also lost its capability to produce new Pu238
  - By agreement, Pu-238 from Russia can not be used for national security applications
- Preliminary cost estimates indicate that re-establishment cost for infrastructure to support domestic production of Pu-238 will be several hundreds of millions of dollars

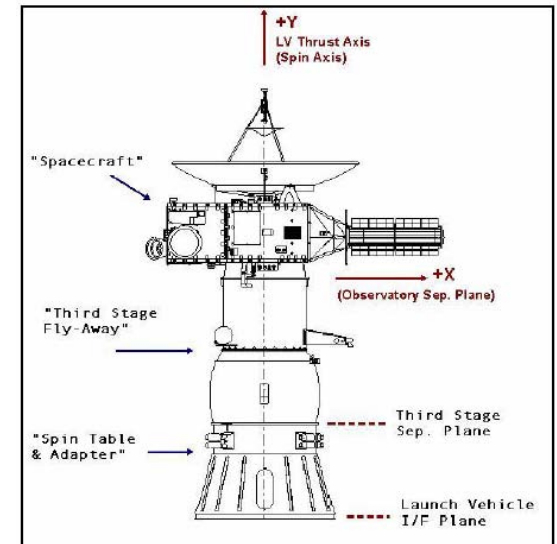


# Radioisotope Power for Space Missions

- Radioisotope Power Sources (RPS)
  - Converts heat from radioactive decay of plutonium-238 to usable electrical power
  - 2 major components: General Purpose Heat Source and electric converter
  - Technology is culmination of over 40 years of design evolution
- Long history of RPS use in space
  - First launched in 1961
  - Used safely and reliably in missions for 40 years
    - » 5 on the Moon (1960s - 1970s)
    - » 8 in Earth orbit (1960s - 1970s)
    - » 2 on Mars (1970s & 2 heater units 1996, 2003)
    - » 8 to outer planets and the Sun (1970s - 2006)



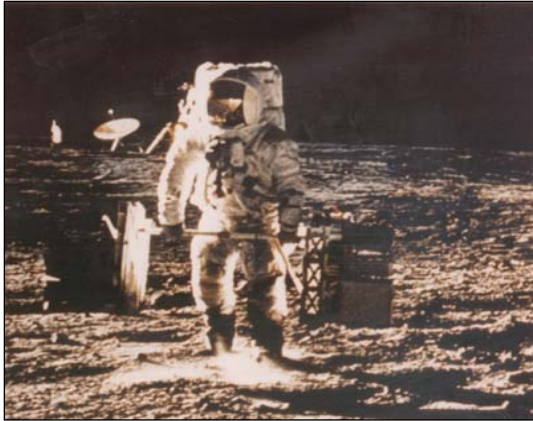
Radioisotope Thermoelectric Generator



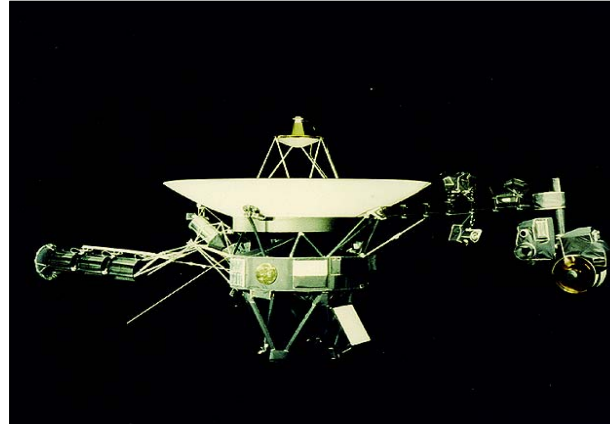
New Horizons



# Examples of Space RPS Missions



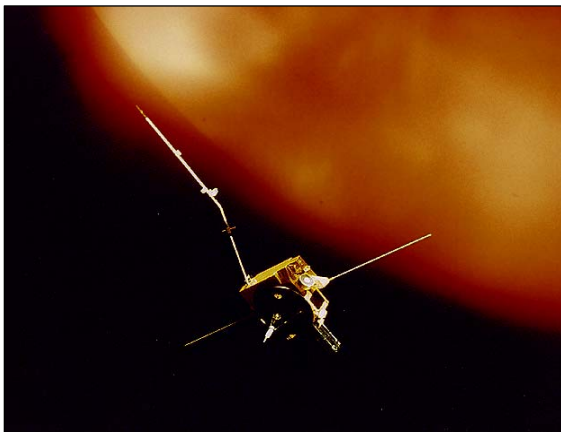
Apollo (1969 - 1972)



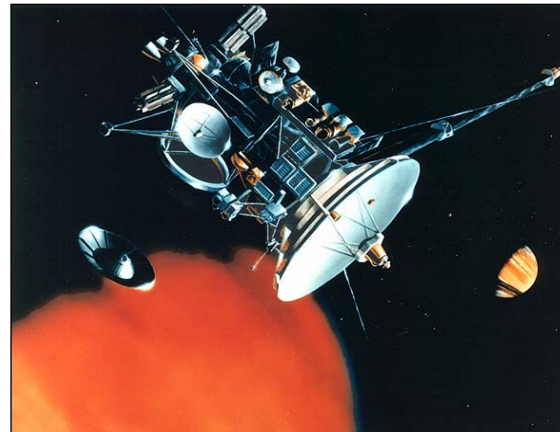
Voyager (1977)



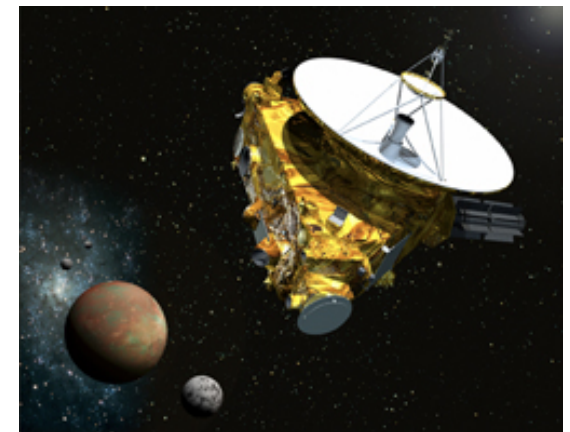
Galileo (1989)



Ulysses (1990)



Cassini (1997)

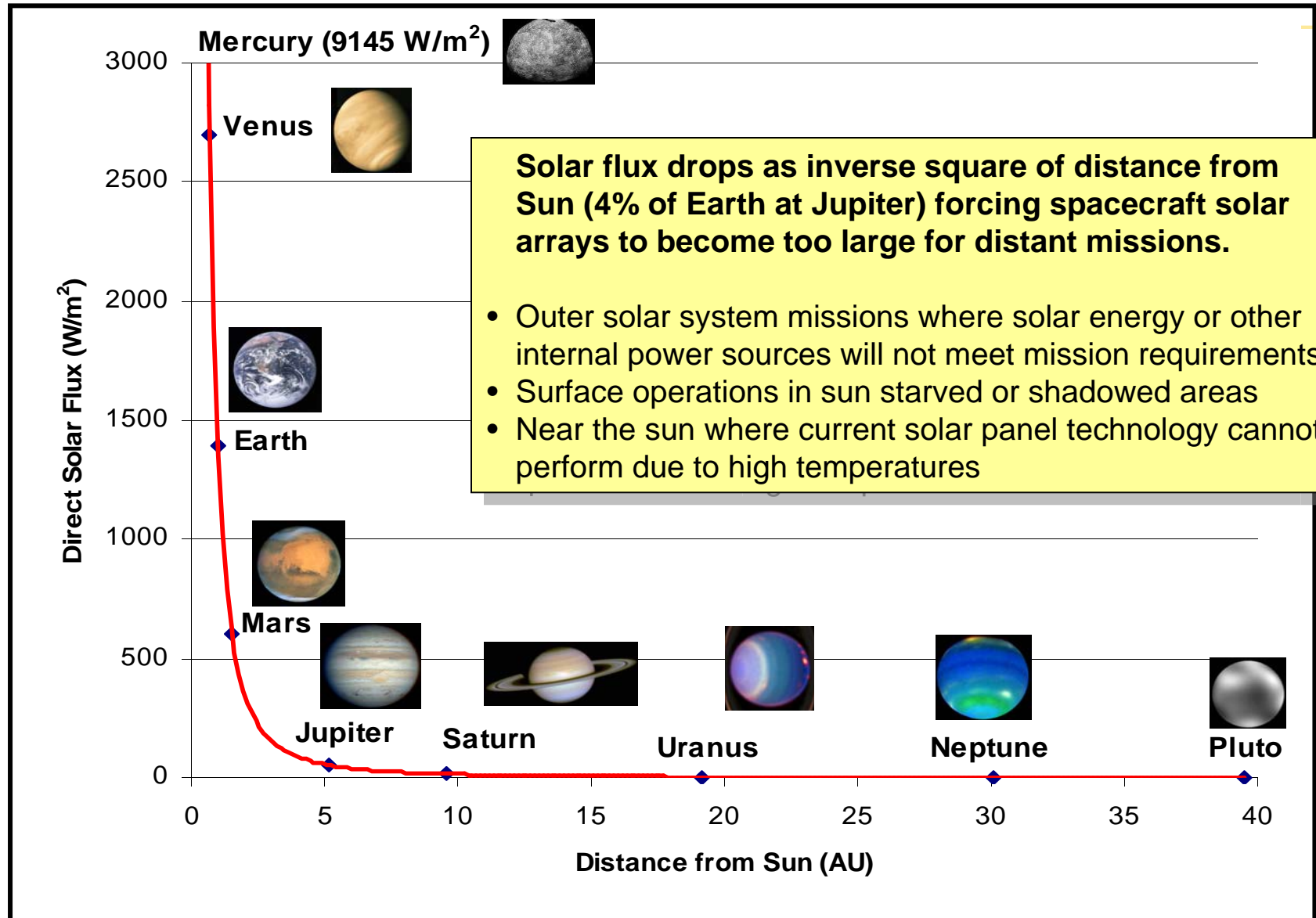


New Horizons (2006)

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



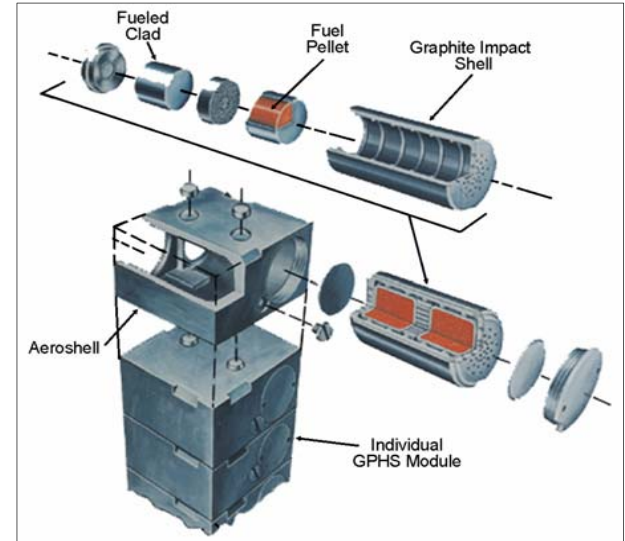
# Radioisotope Power Enables Missions



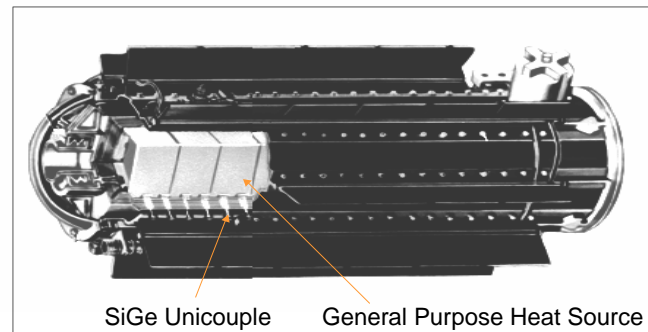


# Key Safety Features of Space Radioisotope Power Sources

- Ceramic Pu-238 fuel (generates decay heat)
  - Robust to high temperatures (low vaporization rate)
  - Fractures into largely non-respirable chunks upon impact
  - Highly insoluble
- Cladding (encases the fuel)
  - Provides protection against impact and high temperatures
- Graphite components (protects fuel & cladding)
  - Impact shell provides impact protection
  - Aeroshell protects against heat of re-entry
- Generator housing design
  - Designed to release individual aeroshell modules in cases of inadvertent re-entry (minimizes terminal velocity)



General Purpose Heat Source Module



Radioisotope Thermoelectric Generator



# Safety Analysis Process

- Accident Scenarios and Probabilities
- Accident Environments
- Nuclear Hardware Response Modeling
  - Mechanical Impact Environments
  - Liquid and Solid Propellant Fire Environments
  - Reentry Environments
- Source Terms
- Radiological Consequence Analysis (Dose, Health Effects, Risk and Land Contamination)
  - Atmospheric Transport and Dispersion Modeling
  - Low Altitude Releases
  - High Altitude Releases (Particulate)
  - High Altitude Releases (Small Particles)
- Exposure Pathway Modeling
  - Inhalation, ingestion and external
- Radiological Consequences
  - contamination, doses and health effects

**Accuracy of source term estimates depends on thorough understanding of hardware response to accident environments**





# DOE Safety Tests

- Testing Purposes
  - Validate Design
  - Calibrate Deformation Models
  - Develop Source Term Models
- Explosion Overpressure
- Propellant Fires
- Fragment Impacts
- Reentry Ablation
- Surface Impact
  - RPS Converter
  - GPHS Module
  - Fueled Clad



**Safety tests address complex environments of potential launch and reentry accidents**