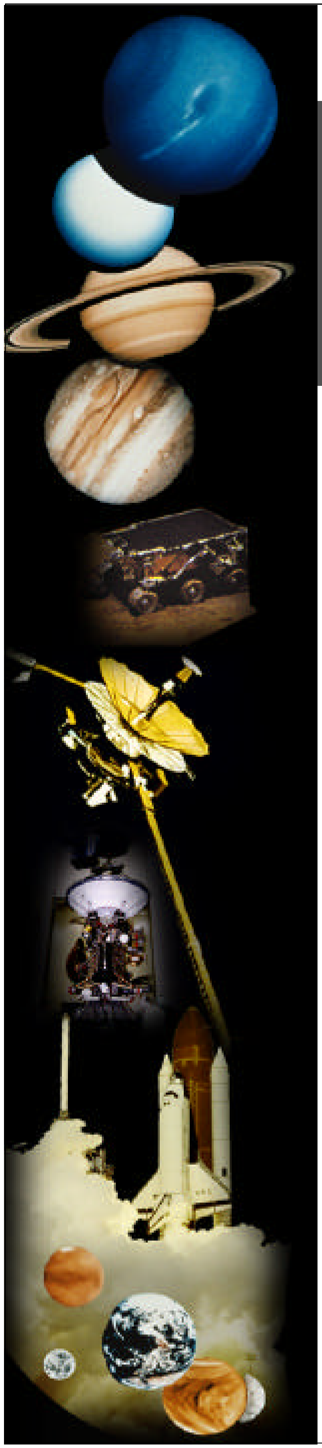


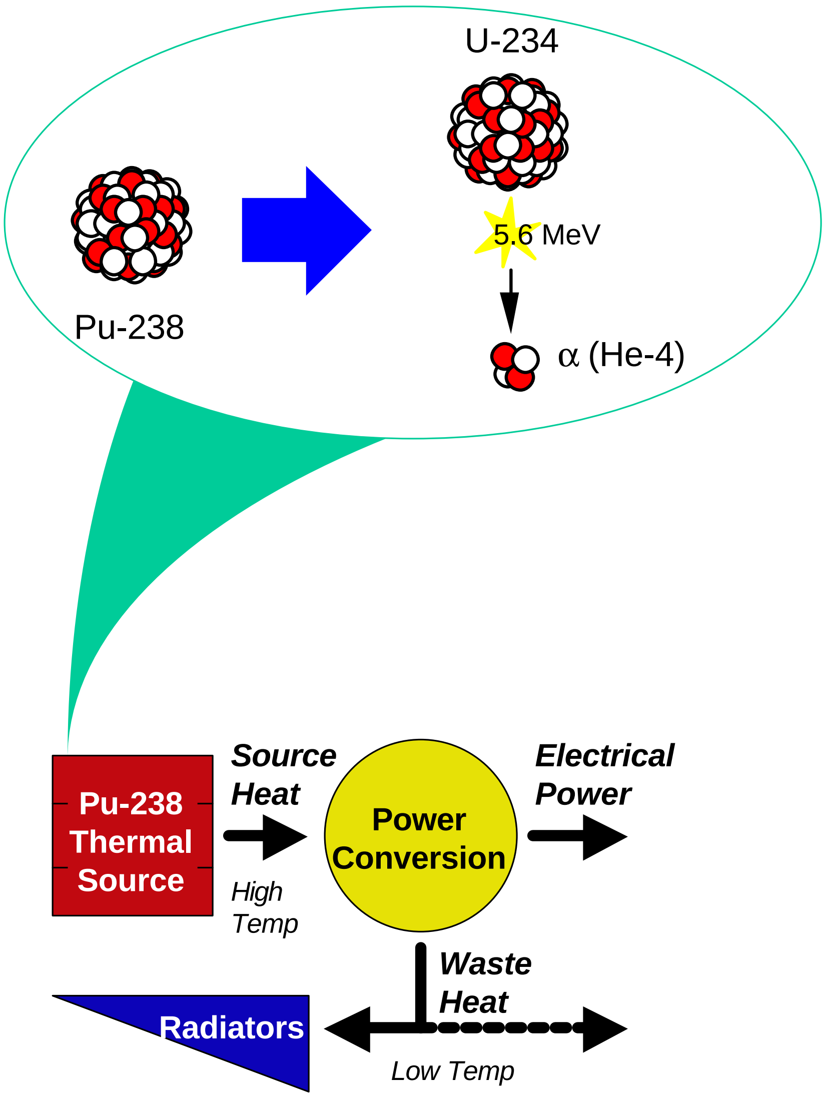
# Radioisotope Power Systems (RPS) for New Frontiers Applications

**Presentation to New Frontiers Program Pre-proposal Conference**

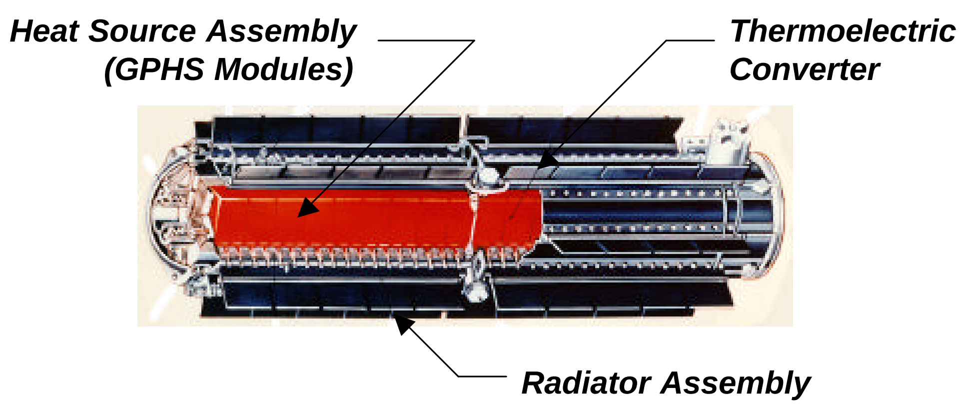
*November 13, 2003*

George Schmidt (NASA Program Executive)
Robert Wiley (DOE MMRTG Program Mgr)
Richard Furlong (DOE SRG Program Mgr)

# Radioisotope Power Systems (RPS)




- **Heat produced from natural alpha (a) particle decay of Plutonium (Pu-238)**
  - 87.7-year half-life
- **Small portion of heat energy (6%-25%) converted to electricity via passive or dynamic processes**
  - Thermoelectric (existing & under development)
  - Stirling (under development)
  - Brayton, TPV, etc. (future candidates)
- **Waste heat rejected through radiators – portion can be used for thermal control of spacecraft subsystems**



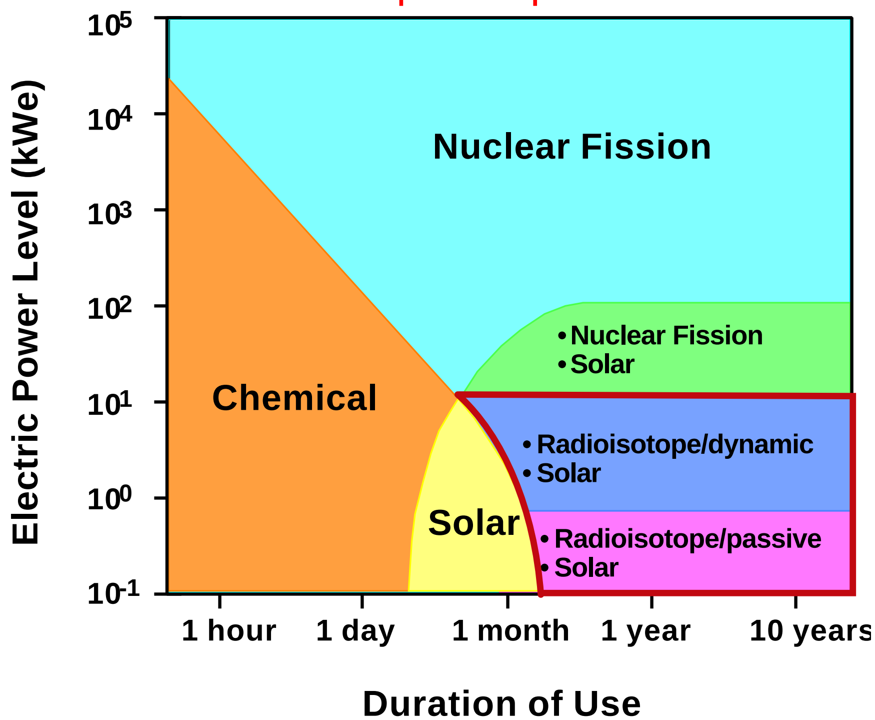

**GPHS-Radioisotope Thermoelectric Generator (RTG)**

# Suitability of RPS

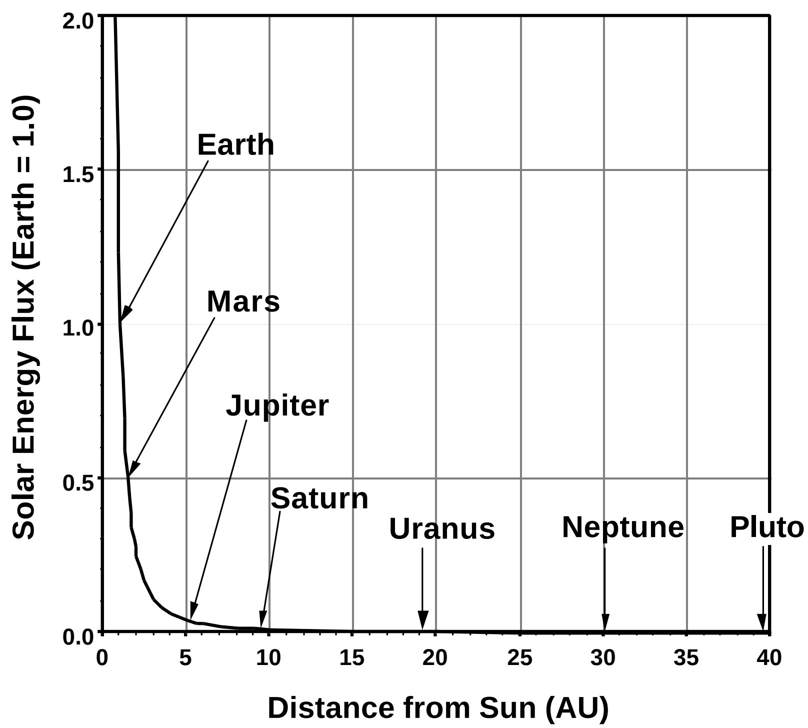
**Radioisotope generators will continue to serve a *critical role* in the scientific exploration of the solar system and deep space**

- Low to moderate power levels (=1-10 kW) for more than several months
- Operations independent of distance and orientation with respect to Sun

Best candidates for maximizing specific power



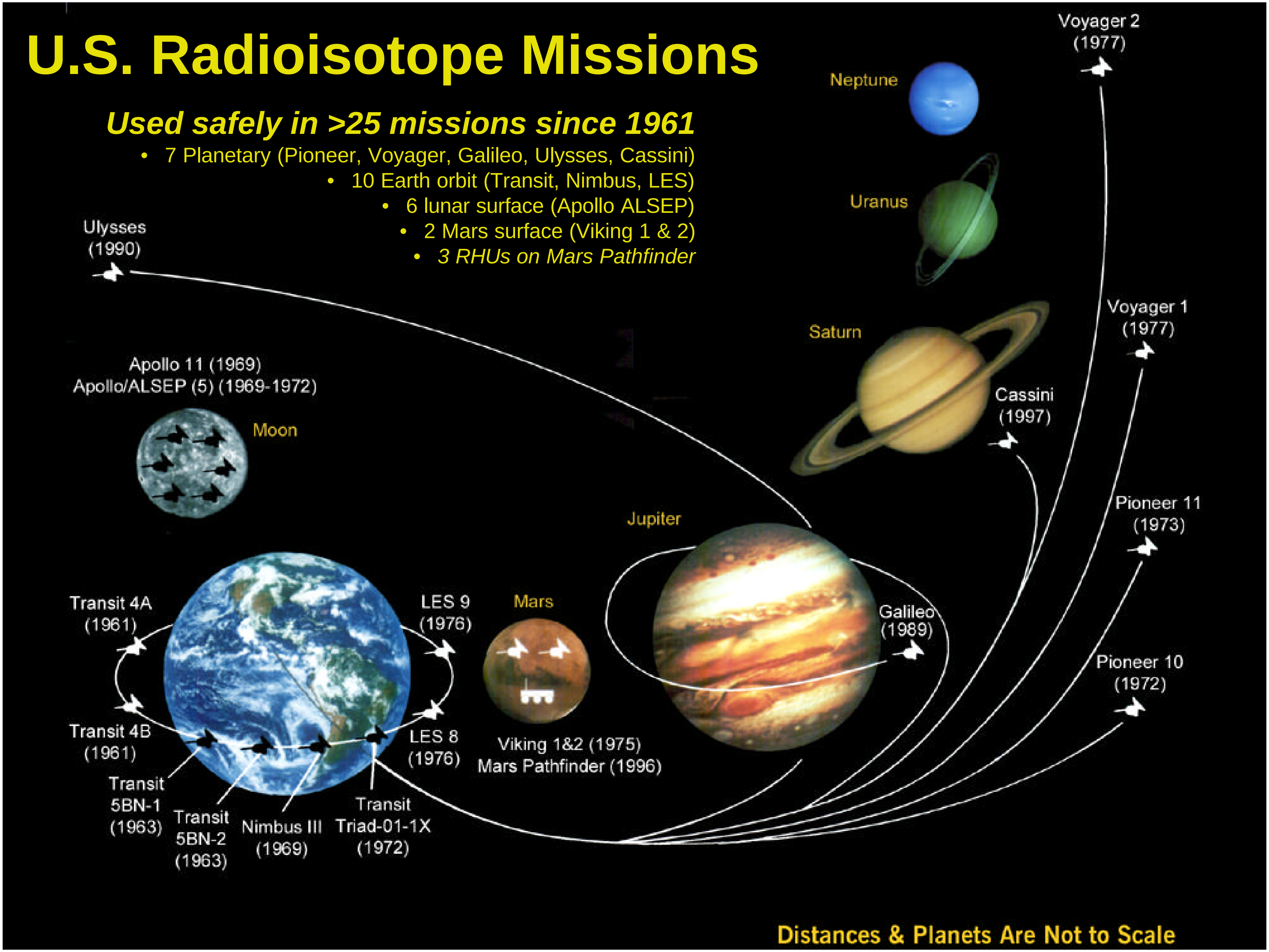

Inherent limitation of solar power



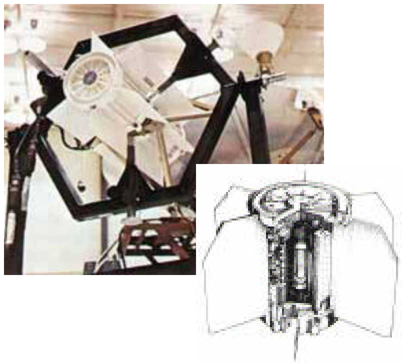
# U.S. Radioisotope Missions

***Used safely in >25 missions since 1961***

- 7 Planetary (Pioneer, Voyager, Galileo, Ulysses, Cassini)
- 10 Earth orbit (Transit, Nimbus, LES)
- 6 lunar surface (Apollo ALSEP)
- 2 Mars surface (Viking 1 & 2)
- *3 RHUs on Mars Pathfinder*



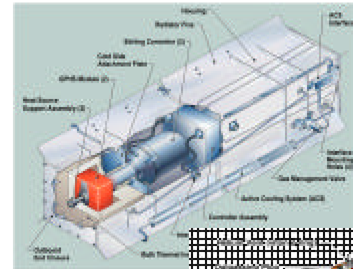
# Recent and Planned RPS Units



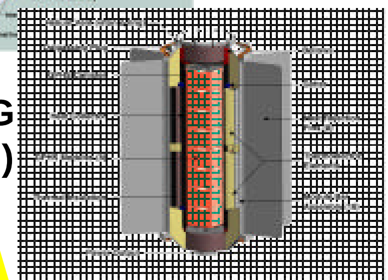
**SNAP-19**
- Pb-Te/TAGS thermoelectrics
- 40.3 Watts (BOM)
- 6.2 % eff;  3 We/kg

- Nimbus B-1/III
- Pioneer 10 & 11
- Viking 1 & 2

**Stirling Radioisotope Generator (SRG)**



**Multi-Mission RTG (MMRTG)**

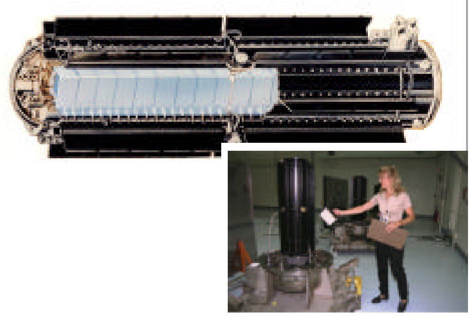


- *Mars Science Lab (MSL)*
- ***New Frontiers 2***
- *Other missions*

1970 1980 1990 2000 2010

**Multi-Hundred Watt (MHW) RTG**
- Si-Ge thermoelectrics
- 158 We (BOM)
- 6.6 % eff;  4.2 We/kg

- LES 8 & 9
- Voyager 1 & 2



**GPHS RTG**
- Si-Ge thermoelectrics
- 292 We (BOM)
- 6.8% eff;  5.2 We/kg

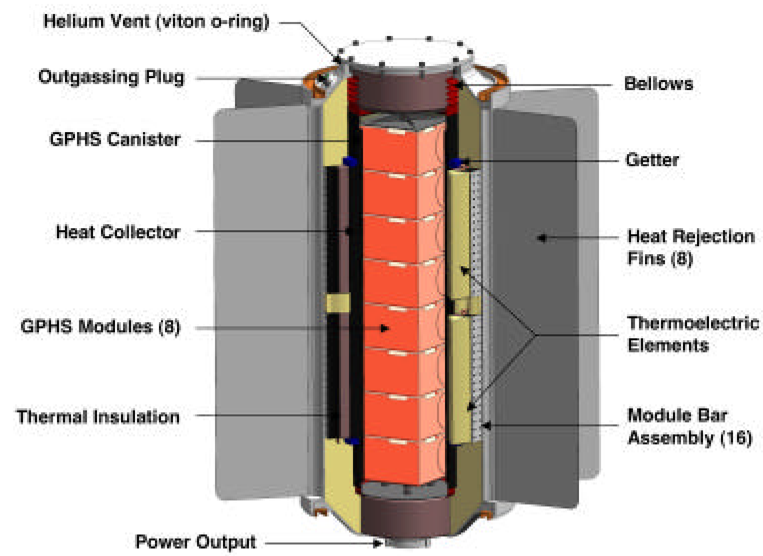
- Galileo
- Ulysses
- Cassini
- *Pluto New Horizons (New Frontiers 1)*

# Multi-Mission RTG (MMRTG)

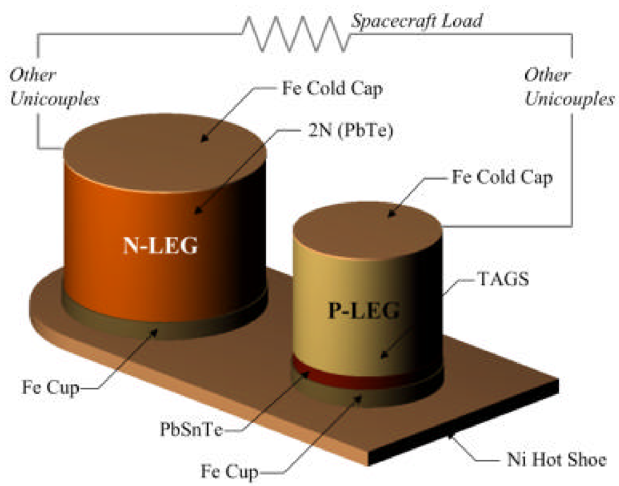
- **State-of-practice, multi-functional RTG designed for potential use on Mars 2009 (MSL) and subsequent RPS-powered missions**

- **Objectives/Requirements:**
  - Minimize development risk through use of flight-demonstrated technology (PbTe/TAGS thermoelectric unicouples)
  - >110 Watts-electric at beginning of mission (BOM)
  - =14 year lifetime
  - Operation in space and on surface of atmosphere-bearing planets and moons

- **Status:**
  - Awarded and initiated development contract in mid-2003 to team of Boeing-Rocketdyne and Teledyne Energy Systems
  - Completed Incremental PDR of unicouple design. Engineering Unit (EU) PDR in January 2004.




**MMRTG Configuration**



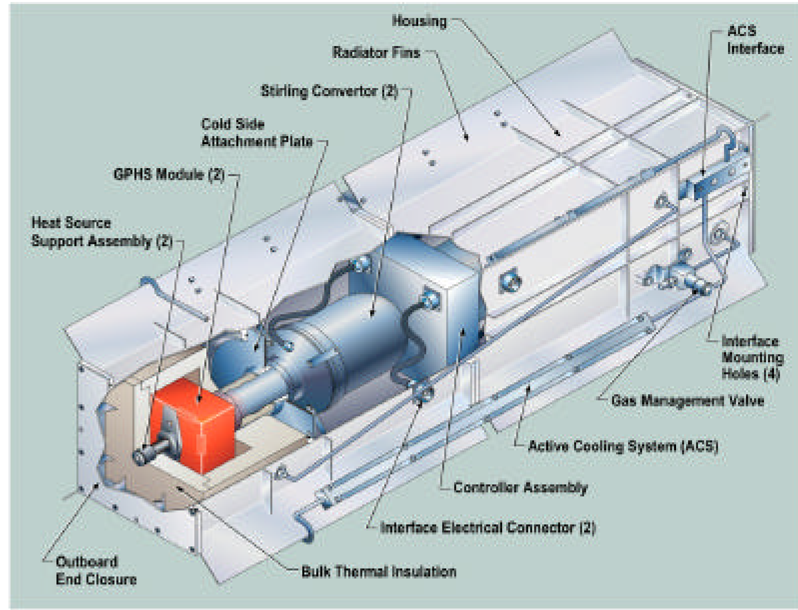

**PbTe/TAGS Unicouple**

# Stirling Radioisotope Generator (SRG)

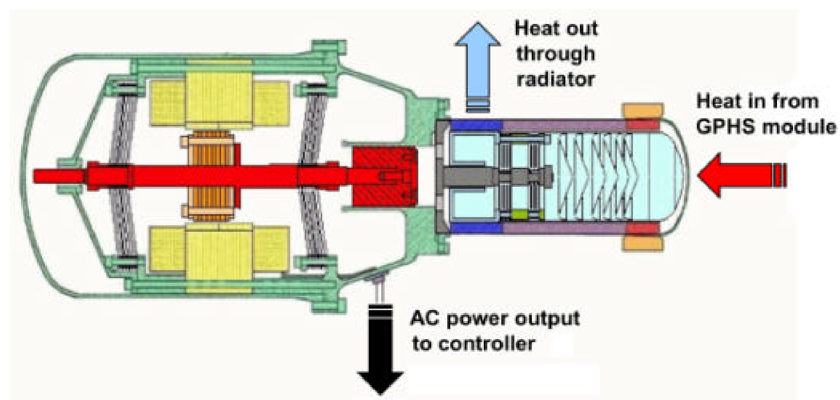
- **High-efficiency RPS for alternate/backup on Mars 2009 (MSL) and potential use on subsequent RPS-powered missions**

- **Objectives/Requirements:**
  - Minimize program risk associated with limited Pu-238 availability (uses x4 less Pu-238 than MMRTG)
  - >110 Watts-electric at beginning of mission (BOM)
  - =14 year lifetime
  - Operation in space and on surface of atmosphere-bearing planets and moons

- **Status:**
  - Awarded and initiated development contract in mid-2002 to Lockheed-Martin – teamed with Stirling Technologies and NASA GRC
  - EU PDR in December 2003.
  - Tests of Stirling convertors at GRC have accumulated =2300 hours of operation.




**SRG Configuration**




**Stirling “Convertor”**

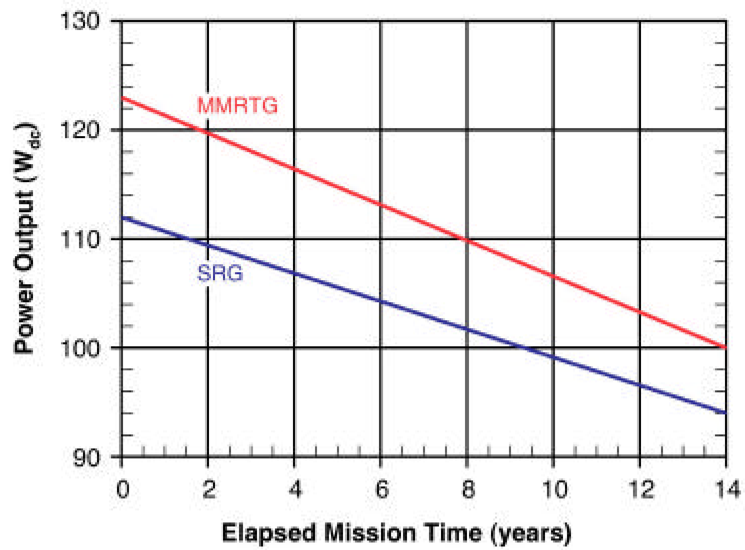
# Proposal Assumptions & Groundrules

- **For these Phase A proposals, use information in “RPS Description” document (New Frontiers Program Library) for aspects associated with RPS accommodation and operation**
  - MMRTG and SRG performance and design requirements
  - Projected availability and acquisition schedules
  - Cost (including launch approval and other activities associated with accommodation of RPS)
- **During Phase A, NASA point of contact (POC) will work with awardees to refine RPS accommodation concepts**
- **From Phase B and on, major RPS elements will be funded by the mission and provided as GFE/GFS (government furnished equipment and services)**
  - RPS hardware
  - NEPA compliance/EIS development
  - Nuclear safety launch approval engineering management
- **Some smaller items may be assigned as responsibility of contract team**
  - Risk communication

# Design and Performance

| Power Source | MMRTG | SRG |
|---|---|---|
| Power (We) | ¥ >110 BOM<br>¥ 123 We @ BOM (nom)<br>¥ ~100 @ 14 yrs | ¥>110 BOM<br>¥ 112 We @ BOM (nom)<br>¥ ~94 @ 14 yrs |
| Mass (kg) | 40 | 34 |
| Envelope (length x fin-fin width) | 65.0 cm x 63.0 cm | 88.9 cm x 26.7 cm |
| Fuel Load | 8 GPHS modules<br>(~4 kg Pu-238) | 2 GPHS modules<br>(~1 kg Pu-238) |
| Voltage (Vdc) | 28 +/- 0.2 | |
| Operational Environments | Space & Atmosphere | |
| Design Lifetime (yrs) | $^{3}$14 | |
| Design Vibration Load ($g^2$/Hz) | 0.2 (example for new ELV) | |
| Design Acceleration Load (g) | 40 (example for new ELV) | |
| EMI/EMC (nT @ 1 meter) | 25 (mission-specific) | |
| Sterilization (Mars only) | NASA 4A or 4B | |

**RPS Power Performance in a Space Environment**



# Availability

## MMRTG

| # MMRTG units used on spacecraft | Date of delivery to KSC |
|---|---|
| 1 unit | July 2009 |
| 2 units | July 2009 |

## SRG

| # SRG units used on spacecraft | Date of delivery to KSC |
|---|---|
| 1 unit | September 2008 |
| 2 units | December 2008 |
| 3 units | March 2009 |
| 4 units | July 2009 |
| 5 units | July 2009 |

- All scenarios include provisioning of spare unit at launch site

# Costs ($M)

## Principal RPS Cost Elements

| Fiscal Year / Activity/Element | FY04 | FY05 | FY06 | FY07 | FY08 | FY09 | TOT |
|---|---|---|---|---|---|---|---|
| NEPA Compliance/EIS | 0.4 | 1.0 | 0.6 | | | | 2.0 |
| Nuclear Launch Safety Approval* | 0.2 | 0.8 | 1.5 | 2.5 | 2.0 | 1.0 | 8.0 |
| Emergency Preparedness | | 0.1 | 0.1 | 0.1 | 0.1 | 1.6 | 2.0 |
| Spacecraft Accommodations, Processing & Integration* | 0.2 | 0.2 | 0.5 | 1.1 | 4.0 | 4.0 | 10.0 |
| Risk Communication | 0.1 | 0.2 | 0.2 | 0.2 | 0.5 | 0.8 | 2.0 |
| Delivered Hardware Costs (for N flight units)** | 0.1¥T | 0.2¥T | 0.3¥T | 0.3¥T | 0.1¥T | | T |

- All costs (except Delivered Hardware) are independent of number of RPS units.

* Does not include NASA KSC costs (e.g., launch vehicle data book, RPS accommodations). See ELV Launch Services Information Summary in NFPL for appropriate cost assumptions.

** Expressed as fraction of total Delivered Hardware Costs (T). $T = C_1 + \ldots + C_N$, where $C_i$ = cost of unit i and N = number of units.

## Hardware Cost for Each Flight Unit ($C_i$)

| Unit Number / Unit Type | 1st | 2nd | 3rd | 4th | Nth |
|---|---|---|---|---|---|
| MMRTG | 20 | 20 | 20 | 20 | 20 |
| SRG | 5 | 5 | 5 | 15 | 15 |