RADIOISOTOPE POWER SYSTEMS & PLANETARY TECHNOLOGIES

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RPS Program Executive

Program Status
VEXAG Meeting

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POWER TO EXPLORE

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Overview

- RPS, Plutonium, and the ASRG Decision
- In-Space Propulsion Technologies
- Broader Planetary Science Technologies
- Science community engagement towards future planetary science technology investment
Advanced Stirling Radioisotope Generator (ASRG)

- ASRG provides increased efficiency (4X current)
- Offered as GFE in Discovery 12
- Highly enabling for science missions
- Conducted Final Design Review in July 2012
- Engineering units in test
- Controller design modified to be more robust to radiation environment
- Qualification unit (QU) build in progress
Status of Stirling Technology

- NASA and DOE will terminate work on Advanced Stirling Radioisotope Generator (ASRG) flight system development
- Non-nuclear hardware being transferred to NASA Glenn Research Center
- Work on technology development and further maturation for flight-ready systems will continue
- Actively considering options for higher-power Stirling systems (500W-1KW)
Why Cancel the ASRG?

- Continuing tight fiscal environment has severely constrained the NASA planetary science budget
  - ASRG experienced significant cost growth since FY 2009
- Several near-term missions that could have used the ASRG have been delayed or deferred
  - Clear need to balance the promising potential of ASRG vs. the potential loss of other mission opportunities
Looking Ahead

- Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) -- working well on Mars -- will be available option for future missions
- Availability of Radioisotope Heater Units (RHUs) also being sustained
- Current U.S. plutonium-238 supply could support Mars 2020 and a Europa mission
- Re-start of Pu-238 production going smoothly, building toward goal of ~ 1kg of isotope/yr

- *It is understood by the program that Stirling technology is critical for operations in the Venusian environment*
Pu-238 Domestic Production Status

• NASA Authorization Act of 2010 authorized NASA to fund DOE efforts in Pu-238 Production under a reimbursable agreement.

• DOE has begun a multi-phase Plutonium-238 Supply Project consistent with the published Start-up Plan to achieve full-scale production late in the decade.

• Phase I efforts to be completed by in 2013.
  – Project planning, NEPA assessment, analysis of project alternatives, cost and schedule estimate for scale-up to full-scale production (average 1 kg isotope/yr)

• Technology demonstration efforts will achieve by the end of 2015:
  – A qualified neptunium-237 target for irradiation in the High Flux Isotope Reactor
  – A qualified process for post-irradiation target processing
  – A qualified Pu-238 product

• PPBE FY15 plan is transfer full funding to NASA
  – PSP plan adjusted to funding limitations in FY13 and FY14 due to Planetary Science Budget
  – Additionally in FY15, NASA expects to begin to fund DOE to maintain the base RPS infrastructure & capabilities
Update from Pu-238 2010 Plan

• The initial cost range of the project is $85M to $125M.
  – This upper bound is higher than in previous reports due to incorporation of knowledge gained during this proof-of-concept stage and the addition of appropriate cost and schedule reserves to the plan.

• The project expects to establish a formal baseline and approval to proceed to project implementation in early fiscal 2016.

• If fully funded, the production capability will be fully operational by Spring 2021
  – The expected full-scale production date has slipped due to budget constraints.

• NASA is pleased with the progress made by the Department of Energy toward a restart of a U.S. production capability for Pu-238.

• Pu-238 remains critical to the needs of NASA robotic space exploration, and the Pu-238 Supply Project is on-track to fulfill this need as we end this decade.
Evolving SMD RPS Mission Planning Set post Decadal Survey

<table>
<thead>
<tr>
<th>Mission</th>
<th>Projected Launch Year</th>
<th>Power Reqmnt ((W_e))</th>
<th>RPS Type (Flight + Spare)</th>
<th>Pu-238 Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars Science Lab</td>
<td>2011</td>
<td>100</td>
<td>1 MMRTG</td>
<td>Operational</td>
</tr>
<tr>
<td>Juno (New Frontiers 2)</td>
<td>2011</td>
<td>No RPS Requirement</td>
<td></td>
<td></td>
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<tr>
<td>Discovery 12 (Not Selected)</td>
<td>2016 - 17</td>
<td>200 - 300</td>
<td>2 ASRG</td>
<td></td>
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<tr>
<td>Osiris-REX (NF3) (In Development)</td>
<td>2016</td>
<td>Directed non-RPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Probe (In Development)</td>
<td>2019</td>
<td>Directed non-RPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discovery 13</td>
<td>2019 - 23</td>
<td>200 - 300</td>
<td>2 MMRTG</td>
<td></td>
</tr>
<tr>
<td>MSM (Mars 2020) (In Planning)</td>
<td>2020</td>
<td>100 - 150</td>
<td>1 MMRTG + Spare</td>
<td></td>
</tr>
<tr>
<td>Europa or Uranus or Other†</td>
<td>2024+</td>
<td>400 - 500</td>
<td>4-5 MMRTG + Spare</td>
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<tr>
<td>New Frontiers 4</td>
<td>TBD</td>
<td>300 - 500</td>
<td>TBD + Spare</td>
<td></td>
</tr>
<tr>
<td>Discovery 14</td>
<td>TBD</td>
<td>200 - 300</td>
<td>TBD</td>
<td></td>
</tr>
<tr>
<td>New Frontiers 5</td>
<td>TBD</td>
<td>300 - 500</td>
<td>TBD + Spare</td>
<td></td>
</tr>
</tbody>
</table>

- 6 year-cadence New Frontier mission opportunities would likely require 500 \(W_e\) RPS
- Every Discovery mission opportunity is proposed to offer an RPS option
- Radioisotope heater units may be required on these and other missions
- Other science, exploration, and demo missions not yet identified may also require RPS

† If funded
- Additional Pu-238 inventory was recently released for NASA set-aside with the promise of new production
- Additional Fine Weave Pierced Fabric for GPHS must be procured for missions beyond Europa

FOR PLANNING PURPOSES.
SUBJECT TO CHANGE.
GRAPHICS ARE NOT PRECISE.

Current NASA Set-Aside Pu²³⁸ Inventory

Existing Pu²³⁸ Inventory

New Pu²³⁸ production of ~1kg/yr starting in 2020
Makes additional material available through blending

Available Fuel for Missions

Fuel in Utilization for Missions

~ 14.3 kg
~ 3.5 kg
~ 7.1 kg
~ 3.5 kg

Pu²³⁸ Outflows


Year
Long-Term Outlook

- NASA GRC will continue work on Stirling technology in FY14
- DOE remains a strong RPS Program partner
- Pu-238 production project will continue, sufficient to support future MMRTG Discovery-class missions every 5-7 years or less frequent New Frontiers/Flagship class
- RPS Program continuing to invest in process improvements for nuclear safety reviews and environmental approvals
- RPS Program continuing to develop energy conversion technologies of promise
**In-Space Propulsion Technology**

- Planetary Science continues to invest in propulsion & transportation technologies
  - Electric propulsion
  - Aerocapture & atmospheric entry systems
  - Advanced chemical propulsion & lightweight tanks
  - Systems & mission analysis tools
- Future funding is challenged as the current investments near maturity for flight systems
- The program is currently developing an integrated plan for continued investment in Hall and Ion Propulsion
- The program will be seeking comment and support for continued investment, goal to complete flight capabilities
  - Objective is to develop support in next years budget cycle
Planetary Science Technologies

• PSD is beginning the process to re-plan and re-structure planetary science technology investments
  – Address current budget realities
  – Provide for better integration and coordination across PSD and the Agency
  – Seeking partnerships and commercial interest
  – Reduce the burden of sustainment

• We will be looking for community input and support
Key Observations:

- End-User Community (industry/proposers) wants to use NASA technologies to support PSD missions
  - Technologies enable missions of interest
- Enabling technologies are not ready (reality & perception)
  - Need to resolve technology readiness issues
  - Development incomplete & Integration support insufficient
  - Proposers perceive SOMA to judge new technologies as high risk
- Current Incentives for technologies are not sufficient

Next Step:

- Follow up discussions to identify/quantify shortfalls, understand technology needs at associated readiness levels
  - Industry (East, West and Central) - Purpose: Gain Community Buy in, Open Dialogue to elaborate responses collected or missing
  - SOMA - Purpose: Discuss SOMA related responses to RFI
  - Assessment Groups – Purpose: Discuss and collect community inputs
Key Messages

- Planetary Science budget realities have forced the re-examination, re-prioritization, and re-structuring of planetary science technology investments
  - The ASRG flight development has been terminated as unaffordable in the near-term, and the ASRG project is being re-structured
  - The agency is re-planning the focus of continued Stirling power investment
  - Beginning in FY12, NASA began covering the cost of the DOE Plutonium Supply Project, and in FY15 NASA expects to begin paying for RPS base infrastructure & capability maintenance
  - The In-Space Propulsion Technology Program is developing an integrated investment plan for Hall and Ion thruster technologies

- We are looking for input and feedback from the Planetary Science Community on their priorities and interests in continued technology investments
NASA is committed to a continuing dialogue with the community on the future of RPS and the missions they would enable or enhance.

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Supplemental Material

- Slides beyond this one are as required
ASRG Forward

- Flight Systems
  - Fueled Qual Unit
  - F1 and F2 Unfueled Units by NLT 10/2016
    - Ready for D-13
    - Ready for NF-4
    - Ready for Mars 2018
  - Other
- “M1” Project
  - Integrate with S/C bus
  - Independent V&V
ORNL Pu-238 Project Concept

• Install new equipment in existing ORNL nuclear facilities
• Neptunium storage remains at INL
• Np shipped to ORNL as needed
• Target fabrication, ORNL laboratories
• Irradiations at HFIR and ATR
• Pu processing, ORNL hot cells
• Pu product shipped to LANL

1.5 kg Pu-238 Average Oxide Production per year
Current Plans for Pu-238 Production

- Pu-238 Supply Project was initiated using NASA funds in FY 2012
- Planned production capacity is an average 1.5 kg oxide/year
- Required production level can be met with existing, operating isotope separations facilities at ORNL
- Target irradiation will be conducted in existing reactors (ATR and HFIR)
- The project has completed NEPA activities and alternatives analysis to select approach
- Tests are underway to finalize the HFIR target design and optimize needed processes
- If fully funded, the production capability will be fully operational by Spring 2021
- Additional Pu-238 inventory was recently released for NASA set-aside with the promise of new production.
- Additional Fine Weave Pierced Fabric for GPHS must be procured for missions beyond Europa.

**Current NASA Set-Aside Pu²³⁸ Inventory**

- Russian Pu²³⁸ Purchase
- Current FWPF Limit

**Existing Pu²³⁸ Inventory Below Spec**

- 123Wₑ (1 MMRTG) MSL
- 260Wₑ (2 ASRG) Discovery 13
- 110 Wₑ (1 MMRTG) Mars 2020

**Usable New Pu²³⁸ Inventory**

- ~1 kg/yr production of ~1kg/yr starting in 2020
  Makes additional material available through blending

**Pu²³⁸ Outflows**

- ~ 1.8 kg
- ~ 3.5 kg
- ~ 1.8 kg
- ~ 3.5 kg

**Available Fuel for Missions**

- Russian Pu²³⁸ Purchase
- Current FWPF Limit

**Existing Pu²³⁸ Inventory**

- ~ 3.5 kg
- ~ 3.5 kg

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