Radioisotope Power Systems Program

NASA’S RADIOISOTOPE POWER SYSTEMS PLANNING AND POTENTIAL FUTURE SYSTEMS OVERVIEW

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• Summary
To make RPS ready and available to support the exploration of the solar system in environments where the use of conventional solar or chemical power generation is impractical or impossible to meet the needs of the missions.
RPS Program Purpose

• Strategic leadership
• Acquires flight hardware, through DOE, to supports missions
• Maintains a robust technology development portfolio
• Works to reduces National Environmental Policy Act (NEPA) and launch safety approval schedule risk
• Maximizes utilization of the available Pu-238 supply in the development of RPS for science missions;
• Provides insight to DOE implementation of RPS-related production infrastructure operations;
• Provides insight to DOE implementation of the Plutonium-238 Supply Project.
Systems Formulation & Mission Integration
(aka Program Planning and Assessment)

- Customer / User engagement
  - Missions – Mars 2020, NF
  - Assessment Groups (OPAG, SBAG, etc.)
  - Developing User’s Guide for MMRTG – See LPSC peripheral session & RPS website
- Develops requirements and sustainment strategy
  - eMMRTG: Improves EODL power by > 50% compared to MMRTG
  - Stirling/Dynamic RG: Higher power, robust, reliable
- Assesses State of Art for RPS technologies
  - RFI for Stirling
- Mission Studies to inform system needs to support planetary science: NPAS
- Developing life performance prediction models
  - MMRTG LPPM
  - Stirling Risk Informed Life Models and Prediction Models
- Performs as the Surrogate Mission
  - Cross Flight Center with DOE Mission Team
Systems Formulation & Mission Integration
(aka Program Planning and Assessment)

SF&MI
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Dave Woerner, Deputy Manager (JPL)
Assessment Lead,
Jason Labay (GRC)

DOE
Dirk Cairns-Gallimore

Mission Analysis
Young Lee (JPL)

RTG Integration
Dave Woerner (JPL)

SRG Integration
Ken Hibbard (APL)
Systems Formulation & Mission Integration
(aka Program Planning and Assessment)

RTG/SRG Integration
Dave Woerner (JPL) RI Manager
Ken Hibbard (APL) SI Manager

Models and Testing
- LLPM
- RILT

Flight Project Support
- Mars 2020
- New Frontiers
- MMRTG Info Release

Generator
- eMM*
- Concepts
- Requirements
RPS Sustainment

- Program Requirement driven
  - The RPS Program shall sustain current and future RPS capabilities and the necessary support functions to provide for future missions as required

- RPS Program Sustainability Definition:
  - Long term investment to maintain critical or key Government and Contractor competencies, skills, and facilities. Investment means to strategically (content and timing) and economically balance these critical and key assets across the RPS Program Portfolio to meet NASA needs.

- Sustainability Process
  - Identify current critical and key RPS capabilities
  - Identify RPS critical and key capabilities that can be supported by funded in-line work
  - Identify risk of losing a RPS capability
  - Develop sustainment recommendations

Cost Prohibitive To Reestablish RPS Capabilities
4 RPS Capability Sustainment Areas

• Thermoelectric principles, materials, and couple development, modeling, testing, and production, and supporting laboratories
• Stirling principles, convertor development, modeling and testing, and supporting laboratories
• Nuclear risk analysis, probabilistic risk assessment, accident scenario modeling and analysis, risk communications, radiological contingency planning, and compliance engineering and planning.
• DOE facilities used to integrate and fuel RPS
  – Qualified staff
  – Key facilities in an operational mode
  – Base level of safety and technical analysis capabilities
  – Nuclear materials and systems transportation and storage
  – Procurement of necessary
MMRTG

Heat Source Liner

Thermal Insulation

Cooling Tubes

Heat Distribution Block

Housing

8 GPHS Module Stack

Thermoelectric Modules

Fin

Mounting Interface

Thermal Insulation
# MMRTG Nominal Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MMRTG</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>Power, electrical (BOM</em>)</em>*</td>
<td>110 We</td>
</tr>
<tr>
<td><em><em>Power, thermal (BOM</em>)</em>*</td>
<td>2,000 Wₜh</td>
</tr>
<tr>
<td><strong>Design Lifetime</strong></td>
<td>17 yrs (14 yrs operational)</td>
</tr>
<tr>
<td><strong>Diameter, fin-tip to fin-tip</strong></td>
<td>64 cm (25 in)</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>66 cm (26 in)</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>45 kg (94 lbs)</td>
</tr>
<tr>
<td><strong>Voltage Range</strong></td>
<td>23-36 V dc</td>
</tr>
<tr>
<td><strong>Max Fin Root Temperature</strong></td>
<td>200 C</td>
</tr>
<tr>
<td><strong>Random Vibration Qual Limit</strong></td>
<td>0.2 g²/Hz</td>
</tr>
<tr>
<td><strong>Pyrotechnic Shock Qual Limit</strong></td>
<td>6,000 g</td>
</tr>
</tbody>
</table>
SKD Technology Potential

TAGS/PbSnTe “P” Leg
PbTe “N” Leg

Hot Shoe
Cold Shoe

“N” Type SKD
“P” Type SKD

MMRTG
Thermoelectric Couple
eMMRTG
Thermoelectric Couple
Technology Maturation Process - eMMRTG Specific

Technology Decision Gate 1
- Assess:
  - Manufacturing readiness and initial performance of skutterudite (SKD) materials, elements, and couples
  - Initial adequacy of sublimation suppression and thermal insulation options
  - Progress in developing a validated lifetime performance prediction
  - Readiness to proceed to 2nd iteration couples and 12-couple modules
  - Technical development and schedule risks on getting to Gates 2 and 3

Technology Decision Gate 2 (Couple Down-Select)
- Assess:
  - Readiness to proceed to flight-like couple iteration
  - Adequacy of sublimation suppression and thermal insulation options
  - Progress in developing a validated lifetime performance prediction
  - Technical development and schedule risks on getting to Gate 3

Technology Decision Gate 3
- Assess:
  - 48-couple module manufacturability and performance
  - Lifetime performance prediction and initial validation
  - Readiness to proceed to eMMRTG development

Phase A
- eMMRTG System engineering (JPL/TESI/AR)
- ATEC Tech Transfer (NASA/JPL)
- Industry knowledge and expertise (TESI/AR)

Phase B

Phase C
- eMMRTG flight development (DOE)

NASA Lead: JPL
Industry Lead: Teledyne
Collaborators: DOE

DOE Guidance and Review
eMMRTG

- Enhancements under consideration
- Known enhancements

Engineering: emissivity change to liner, substitute insulation

Changes needed to MMRTG

New Technology: Substitute SKD thermoelectric couples

Diagram labels:
- BiMetal Ring
- Min-K Insulation
- T/E Getter Assembly
- Cooling Tube
- General Purpose Heat Source
- Microtherm Insulation
- Power Out Receptacle
- Module Bar
- Thermoelectric Couple Assembly
- Heat Distribution Block
- Isolation Bellows
- Isolation liner Assembly
- Seal Weld Cover
### eMMRTG Projected Nominal Performance

<table>
<thead>
<tr>
<th>Parameter</th>
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<tr>
<td>Power, electrical (BOM*)</td>
<td>141</td>
</tr>
<tr>
<td>Power, thermal (BOM*)</td>
<td>$2,000 \ W_{th}$</td>
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<td>Design Lifetime</td>
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<td>Mass</td>
<td>43 kg (94 lbs)</td>
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<tr>
<td>Voltage Range</td>
<td>23-34 V dc</td>
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<tr>
<td>Max Fin Root Temperature</td>
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Summary

• Make RPS ready and available to support the exploration of the solar system in environments where the use of conventional solar or chemical power generation is impractical or impossible to meet the needs of the missions

• RPS Program works closely with the Department of Energy to implement a process by which potential RPS systems and missions are studied and assessed to inform optimal investments

• Process is being applied today in both thermoelectric and Stirling/Dynamic applications of radioisotope power
  – Supporting Mars 2020
  – Support New Frontiers
  – Develop eMMRTG Technologies and potential eMMRTG
    » ~50% more power at end of mission