RPS induced environments

RPS could induce environments that impact science instruments and measurements. To address these concerns, this poster describes existing and potential future RPS designs and their potential radiation, thermal, vibration, electro-magnetic interference (EMI), and magnetic-fields effects on representative science instruments and science measurements. These potential impacts to science instruments must be understood and mitigated where necessary to ensure mission success.

**Power System Induced Environments**

<table>
<thead>
<tr>
<th>Environment</th>
<th>Minimum Level of Impact</th>
<th>Maximum Level of Impact</th>
<th>Environment Impacts on Orbiter Instruments</th>
<th>Mitigation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma Radiation</td>
<td>&lt; 1 krad over 10 years</td>
<td>1.5 krad over 15 years at 1 meter for 18-GPHS RPS</td>
<td>Damage to sensitive components (memory, ADCs, operational amplifiers)</td>
<td>Shielding, separation, error correction codes, use of less sensitive components</td>
</tr>
<tr>
<td>Neutron Radiation</td>
<td>3% n/cm² at 0.5 meters for 2-GPHS SRG</td>
<td>300 n/cm² at 1 meter for 18-GPHS RPS</td>
<td>Single event failures, Detector noise from displacement damage.</td>
<td>Shielding, separation, error correction codes, spike detection and removal, thermal annealing, use of less sensitive components</td>
</tr>
<tr>
<td>Thermal</td>
<td>0.5 kW, for 2-GPHS RPS</td>
<td>4.5 kW, for 18-GPHS RPS</td>
<td>Need to isotope RPS from radiations, thermal images.</td>
<td>Separation, pointing instruments away from RPS, heat shields</td>
</tr>
<tr>
<td>Vibration</td>
<td>0.3 mrad/s² for 2-GPHS SRG</td>
<td>2.0 mrad/s² for 18-GPHS SRG</td>
<td>Need to damp vibration for sensitive images.</td>
<td>Separation, damping</td>
</tr>
<tr>
<td>EMI</td>
<td>Low for TE</td>
<td>Potential Stirling (ASRG = 35 N maximum dynamic force)</td>
<td>Detector and magnetometer noise</td>
<td>Separation</td>
</tr>
<tr>
<td>Magnetic</td>
<td>&lt; 0.1 nT</td>
<td></td>
<td>Magnetometer noise</td>
<td>Separation</td>
</tr>
</tbody>
</table>

**Reference Power Systems**

This assessment focused on four RPS:

- **Multi-Mission Radiosotope Thermoelectric Generator (MMRTG):** 8-GPHS system currently powering Mars Science Laboratory
- **Enhanced MMRTG (eMMRTG):** Upgraded MMRTG currently under development
- **6-GPHS SRG:** Notional future higher-power system.
- **16-GPHS Segmented Modular Radiosotope Thermoelectric Generator (SMRTG):** Notional future higher-power system.

RPS are significant sources of radiation. RPS primarily emit alpha particles, which are easily shielded, but also produce gamma rays and neutrons. The potential effects on payload include:

- Damage to electronics and sensitive surfaces
  - Total Ionizing Dose (TID)
  - Direct Displacement Damage (DDD)
- Increased noise on the sensors
- Complicating measurement of the pristine in situ environment by adding energetic electrons, ions, and neutrons.

Induced radiation is a function of the number of GPHS modules, and distance between the RPS and the payload.

- The relationship with number of GPHS modules is not strictly linear, due to self-shielding effects.
- The relationship with separation distance is roughly 1/r².

The TID from a Galileo style 18-GPHS RTG at 1 meter separation is ~ 1 krad over 10 years.

- This is an order of magnitude lower than the environmental dose rate at Mars, and would have a correspondingly lower contribution to instrument noise and to permanent damage to payload sensors.
- Missions with multiple units could see higher TID.
- RPS with fewer GPHS would lower TID.
- COTS parts can be as soft as 1 krad, and may be impractical for use with RPS.

If configuration issues force < 0.5 meter separation between the RPS and the payload, the TID could be significantly higher.

- Some parts (operational amplifiers, analog to digital converters, and memory) are normally soft at about the 25 krad level, though it is possible to shield them or make them more robust.

**Radiation Impact Mitigation**

- Separation is a very effective strategy as radiation decreases as 1/r², but the design would become challenging when separation distances exceed a few meters.
- Sensitive components could be shielded in a radiation vault or with spot shielding.
  - E.g. Juno used a 180 kg radiation vault to reduce the Jupiter dose to the electronics from ~300 krad to 25 krad. With a RDP of 2, this allowed the mission to use 50 krad capable components.
- SEU-type events could be mitigated with error correction codes, and, for detectors, with spike detection and removal.
- DDD in detectors could be corrected with thermal annealing.
- Instruments could be designed to be more robust, though this can be costly.
  - E.g. Components on Galileo were designed to 150 krad to survive the Jupiter environment.

**Vibration Impacts**

- Separation of RPS and the payload would reduce the effect of vibration.
  - The magnitude of vibration impact is a strong function of the separation distance between the vibration source and the sensitive area, with a less than perfectly stiff structure soaking up much of the vibration.
- Vibration could be damped using isolation adapters or adjusting the spacecraft structure or design.
- Missions using Stirling devices would need to have a contingency plan for a single engine failure – whether that plan is to include accommodations for the increased vibration issues, or to cease operation of the matched pair engine.

**EMI and Magnetic Fields**

- No EMI issues have been identified for RPS that lie beyond normal environmental specifications.
- The electric fields radiation emissions limits from the ASRG ICD are ~20 dBuV/m for sensitive frequencies.
- EMI from TE RPS is low.
- The current trend for payload magnetic requirements is 0.1 nT at the magnetometer.
- ASRGs, operating in balanced mode, are rated to meet this requirement.
- Magnetic fields from TE RPS is low.
- Larger Stirling engines, or SRGs in unbalanced operation might generate more EMI or magnetic fields. Further design maturation and analysis would be needed to quantify these levels.
- Separation is an effective mitigation strategy, as EMI varies with distance as 1/r² and magnetic fields vary with distance as 1/r³.

**Conclusions**

RPS can induce radiation, thermal, vibration, EMI, and magnetic field environments that must be understood to avoid impacting spacecraft payloads and science measurements.

- Given a 1 meter separation distance, radiation from RPS would be lower than the contribution from most space environments, and the same mitigation approaches apply.
- Though a new, higher power RPS could generate more heat per unit than the ASRG and the MMRTG, thermal impact could be mitigated with shading and pointing, if required, by the mission. Alternatively, excess heat could provide benefits in some thermal environments.
- Vibration for new SRGs would be expected to be similar to the ASRG test data, and while this would be expected to be low, it would need to be considered and addressed during spacecraft and instrument design.
- EMI and magnetic fields for new RPS would be expected to be low as for the current RPS, but would need to be considered and addressed if there are sensitive instruments.