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Comparison of Standard RPS Systems for NASA Missions

Garry Burdick
Jet Propulsion Laboratory

This information is pre-decisional and for discussion purposes only.

MMRTG Assessment

Pros

- Extensive database of performance data exists for PbTe-TAGS thermoelectrics.
- Significant heritage - Design based on existing and previously flown RTGs.
- Generates no vibration.
- Generates no AC magnetic fields.
- Built-In redundancy via series-parallel wiring of the thermoelectrics.
- Failure modes are well characterized and result in graceful degradation.
- Radiation tolerant to 1 MRad with existing parts, and potentially good to several MRad with minimal or no modifications.
- Can withstand the vibration environment of the Delta IV-H as designed.
- Generates more heat that can be used to warm spacecraft subsystems.

Cons

- Lower specific power than the SRG on a unit basis.
- Lower power conversion efficiency, resulting in more plutonium required for a given power level relative to SRG.
- Generates more heat which could complicate the S/C thermal design.
- Higher estimated unit cost that SRG due to higher plutonium usage.

SRG Assessment

Pros

- Lower unit mass than MMRTG.
- Higher power conversion efficiency, resulting in less required plutonium relative to MMRTG.
- Higher specific power than the MMRTG on a per unit basis.
- Generates less heat that MMRTG, which could simplify S/C thermal design (aeroshell missions).
- Lower expected unit cost than MMRTG due to reduced plutonium usage.

Cons

- Unproven long term reliability. Require a redundant unit to fly on missions, adding mass.
- Degradation modes are not fully characterized, and are not all graceful.
- Failure of one Stirling Convertor Assembly (SCA) would likely require the second SCA to be shutdown in order to prevent vibration damage to the spacecraft.
- Lower radiation tolerance (controller ~50 krad) would require the use of a significant amount of shielding for a Europa orbiter / lander mission.
- Lower random vibration tolerance (0.2 g2/Hz), makes the SRG incompatible with a stock Delta IV-H launch vehicle.
- AC fields generated by the SRG could overlap the range of interest for certain science instruments (i.e., plasma wave).
- Generates less heat than MMRTG, which may require more electric heaters to warm S/C systems.

General RPS Preferences

The MMRTG could be the preferred choice for:

- Long duration missions where demonstrated long-term RPS reliability is required.
- Missions requiring the use of the Delta IV-H - which the SRG currently can not support from a vibration standpoint.
- Missions expected to receive high radiation doses (i.e., Europa)
- Missions with high AC EMI cleanliness requirements (e.g., plasma wave experiments, etc.)
- Missions with sensitive vibration requirements.

The SRG could be the preferred choice for:

- Shorter duration missions such as those on the Moon where long term RPS reliability is not as great an issue.
- Mission where plutonium availability was major constraint (e.g., high power missions, etc.)
- Missions where the SRG's reduced heat generation could simplify the thermal control system and result in a lighter spacecraft (i.e., aerocapture missions)

Backup

NASA Missions Potentially Requiring RPSs

Missions	Potential Power Sources
Europa Geophysical Observer (Orbiter)	MMRTG or SRG
Titan Explorer (Long Duration Aerobot)	MMRTG or SRG
Europa Astrobiology (Long Duration Lander)	MMRTG or SRG
Neptune Orbiter with Probes (Orbiter)	MMRTG or SRG
Mars Science Laboratory (Rover)	MMRTG* or SRG
Mars Astrobiology Field Laboratory	MMRTG or SRG
Solar Probe	MMRTG* or SRG
Lunar Applications (Robotic or Crewed Rovers, etc.)	MMRTG, SRG, or Solar + Batts
New Horizons (Pluto Flyby)	GPHS RTG (Baselined)
Venus Surface Explorer (Long Duration Rover)	Stirling + Cryocooler
Long Lived Mars Net Lander	Small RPS or solar + Batts?

* - *Note: MMRTG is the current baseline for the MSL and Solar Probe missions.*

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RPS Performance Comparison

Parameter	GPHS RTG	MMRTG Generation 1	SRG Generation 1
Power per Unit (BOM)[1], We	~285	125	116
Mass per Unit (NTE), kg	55.9	45	34[2]
#GPHS Modules per Unit	18	8	2
Thermal Power (BOM), Wt	4500	2000	500
Unit Specific Power, We/kg	5.2	2.8	3.4
Conversion Efficiency	6.6%	6.3%	23.4%
Technical Readiness Level	9	5	3
Redundancy	Built In	Built In	Req. min of one additional SRG.
Permissible LVs	Not designed for stock Delta IV-H.	All	Not designed for stock Delta IV-H.
Availability	Production stopped. Limited to F5 and possibly a 2nd unit using spare parts.	2009 for MSL, with additional units available on a yearly basis.	Potentially available to support missions in 2011.

Notes
1. Power level for a deep space environment. Operation in a Mars environment yields slightly lower power levels.
2. SRG mass without cooling tubes (~1.2 kg per unit) and adapter plate (~2.6 kg per unit).

Comparison of Gen 1 and Gen 2 RPSs

Parameter	GPHS RTG	MMRTG Generation 1	Advanced MMRTG[1] Generation 2	SRG Generation 1	Upgraded SRG[2] Generation 2
Power per Unit (BOM)[3], We	~285	125	170	116	126
Mass per Unit (NTE), kg	55.9	45	34	34[4]	26.7[4]
#GPHS Modules per Unit	18	8	8	2	2
Thermal Power (BOM), Wt	4500	2000	2000	500	500
Unit Specific Power, We/kg	5.2	2.8	5	3.4	4.7
Conversion Efficiency	6.6%	6.3%	8.0%	23.4%	25.2%
Technical Readiness Level	9	5	3	3	3
Redundancy	Built In	Built In	Built In	Req. min of one additional SRG.	Req. min of one additional SRG.
Permissable LVs	Not designed for stock Delta IV-H.	All	All	Not designed for stock Delta IV-H.	Not designed for stock Delta IV-H.
Availability	Production stopped. Limited to F5 and possibly a 2nd unit using spare parts.	≥2009 (MSL would be First User)	≥2014 (TBD)	≥2011 (TBD).	≥2011 (TBD).

Notes
1. Advanced MMRTG based on using skutterudites thermoelectrics.
2. Upgraded SRG based on using a smaller, lighter weight linear alternator.
3. Power levels assessed in a deep space environment.
4. SRG masses do not include masses of cooling tubes (1.2 kg per unit) and adapter plate (2.6 kg).

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