The enhanced MMRTG – eMMRTG – Boosting MMRTG Power Output

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The MSL Curiosity Rover on Mars is powered by the Pu238 fueled Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). This generator is based on a design and technology heritage that dates to the highly successful Pioneer and Viking missions of the 1970's. It has no moving parts and its performance is very stable under all loads and environmental conditions. It is capable of meeting mission requirements from planetary surface operation with high temperatures and a variety of atmospheres, to deep space and orbital missions with high radiation fields or a need to detect weak electromagnetic fields. It is also mechanically robust for a range of launch vehicles, orientations and mission maneuvers. This flight proven system is now the only radioisotope power system available for near term NASA missions.

New thermoelectric (TE) materials have been developed in recent years that offer significant improvements over the materials used in the MMRTG. Among the most interesting are those developed at the Jet Propulsion Lab (JPL) because of both their demonstrated performance and repeatable and documented fabrication process. The maturity of the materials and the MMRTG design flexibility enable a low risk system upgrade that can substantially improve MMRTG performance. System design trade studies now in progress are looking at changing the TE materials and increasing the hot side temperature to find the best combination of improved performance and program cost.

Key to this upgrade is the compression loaded TE modules in the MMRTG design that can easily accept other TE materials and the hot side design margin of the system. Preliminary studies indicate that the short term, low risk upgrade/enhancement is to use the skutterudite (SKD) materials developed at JPL. Simply replacing the PbTe/TAGS TE elements in the TE modules with SKD elements and making a few low risk modifications to the MMRTG design potentially provides approximately 25% increase in power output at beginning of life (BOL). This would increase nominal BOL power output at 32 vdc load from 117 watts to 145 watts. This 145 watt power output level is predicted with a thermal inventory of 1920 watts of Pu238 fuel, which is lower than the 2016 watts of fuel in the MSL MMRTG. More important than the BOL power output increase is the End Of Mission (EOM) power output increase. With the anticipated lower degradation rate of the SKD materials, it is anticipated that the EOM power output will be as much as 50% higher than the current technology MMRTG. This enhanced efficiency eMMRTG will enable future missions such as a Europa mission to be performed using only 4 eMMRTG units instead of 5 MMRTGs, which indicates the great savings in the range of 20% to 33% in costly Pu238 fuel.

The key differences from the MMRTG design are: 1) the use of the SKD materials and aerogel insulation in the thermoelectric module, 2) an increase in the thermoelectric hot junction temperature from about 512°C to 600°C at BOL on load, 3) the addition of a high emissivity coating inside the liner and, perhaps, 4) special treatment to the end insulation heat source support system.

It is important to note that these are very low risk modifications. Increasing the hot junction temperature another 50°C to 650°C would yield a 33% power increase to 156 watts. However, the design modifications become slightly higher risk and leave less room for temperature excursion margin without some MMRTG hot side material design changes. These options have not been explored fully yet, but represent either additional potential for the first upgrade or for a second evolutionary step in the eMMRTG program.

A number of parametric studies were performed for the JPL in 2013 under a subcontract entitled eMMRTG Studies. Results of these studies will be presented. Other efforts are planned which will focus on a number of details such as; specific mission profiles, optimizing the design to reduce temperature gradients and enable greater margin/higher temperatures and more detailed thermal and structural models.