MMRTG – Power for the Mars Science Laboratory

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The Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) is providing the electrical power for the Mars Science Laboratory (MSL) Rover, aptly named "Curiosity." The MMRTG is fueled with the Department of Energy's General Purpose Heat Source (GPHS) modules containing the Pu238 fuel that provides a reliable, long life source of heat. The generator design and technology is based on the highly successful Pioneer and Viking systems dating back to the 1970's. The system has no moving parts and its performance is stable under the full range of loads and environmental conditions expected for the MSL mission. This includes all mission phases from integration; launch; cruise; Entry, Descent, and Landing (EDL); to surface operations. This flight proven system is currently the only radioisotope power system available for near term NASA missions.

The MMRTG program was inititated in June 2003 with a goal of developing a generator with multimission capability and that could be ready for flight by 2009. The engineering development phase, including fabrication and testing of a high fidelity engineering unit generator, was completed in September of 2006 culminating in a Final Design Review. The fabrication of the flight generator commenced shortly thereafter. The assembly of the MSL MMRTG (F1) was completed in June 2008. A series of electrically heated tests were performed prior to delivering the unit to the Idaho National Laboratory (INL) for fueling in August 2008 [1]. The fueling of the F1 was completed in early November 2008, leading up to the flight acceptance test program. The generator acceptance included vibration testing, magnetic testing, thermal vacuum testing and mass properties testing. The acceptance test program was completed in May 2009. In December 2008, the launch of the MSL mission was slipped by two years to provide time to address issues with rover systems, so the F1 unit was placed into storage for two years. During storage, the temperature was reduced to minimize thermoelectric degradation and creep of load bearing preloaded elements. The F1 unit was taken out of storage and transported to Kennedy Space Center (KSC) in June 2011. While at KSC, mechanical and electrical integration checks were performed at the Payload Hazardous Servicing Facility (PHSF). In preparation for launch, the F1 MMRTG was transported to the Verticle Integration Facility (VIF) for final integration with the rover and cruise stage. The MSL was launched on Nov 26, 2011.

The performance of the F1 MMRTG has been monitored from before launch to current Martian surface operations [2]. The launch transient included the transition from the fairing environment on the pad to the vacuum environment once the fairings were ejected. During the cruise to Mars, the F1 MMRTG was cooled by the cruise stage heat rejection system, with coolant flowing through the cooling tubes of the MMRTG. As the spacecraft approached Mars, preparations for the EDL were made. EDL presented some of the most challenging requirements for the MMRTG. Initially, the cooling system was vented and the cruise stage was separated from the entry vehicle. The temperature of the MMRTG increased during the period following cooling system venting as it remained packaged within the entry vehicle with radiation cooling only. The MMRTG withstood all of the entry loads as the entry vehicle was slowed, including the parachute loads. After the rover touchdown on Mars, surface operations thermal control was established via heat rejection fins and the nominal diurnal Mars surface operations began. The F1 system is providing both electrical power and heat to the rover during the Mars surface operations. The unit is perfoming well for the Mars surface operations including the changing diurnal and seasonal conditions [3]. The system has now operated for more than 540 Sols on Mars. The F1 power system has now been fueled and operational for more than five years.

This paper summizes the MMRTG program including the timeline for design, fabrication, integration and testing of the F1 for the MSL. The performance of the F1 is summarized for launch, cruise, EDL and Martian surface operations.

References:

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