ADVANCED STIRLING RADIOISOTOPE GENERATOR FLIGHT DEVELOPMENT.

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Introduction: Radioisotope-based generators have powered missions to collect planetary science data since the launch of an astronaut-deployed generator on the moon's surface during Apollo 12 in 1969. From the earliest days of radioisotope power systems (RPS) deployed beyond the farthest reaches of the solar system, the method of energy conversion has been that provided by passive thermoelectric elements. While many NASA missions have become comfortable launching spacecraft containing mechanisms and other moving parts, there has been no dynamic-energy conversion RPS flown to date. Both NASA and the Department of Energy are actively developing what offers to be the first such power system. This paper provides an overview status of the Advanced Stirling Radioisotope Generator flight development and relates it to potential flight opportunities for the science community.

System Configuration: The Advanced Stirling Radioisotope Generator (ASRG) is a power system using a typical Pu-238 fuel configuration, being based on the General Purpose Heat Source (GPHS) module as its building block. The ASRG system design and configuration is based on program requirements developed and baselined in 2010.

The ASRG produces electrical power from the heat output of radioisotope fuel contained within the GPHS. An ASRG utilizes Stirling engines to generate alternating current electrical power from the heat of two GPHS modules. The Advanced Stirling Convertors (ASCs) are each paired with a GPHS module that provides the convertor with its heat input. Each ASC operates at a nominal frequency of around 100 Hz and the resulting AC power from a linear alternator is fed into the ASRG Control Unit (ACU). The ACU then converts the AC power to a nominal 28 VDC spacecraft bus and also synchronizes the operation of the ASCs to minimize vibration inputs to the spacecraft. The ASRG power conversion efficiency is on the order of 30 percent and as a result utilizes less plutonium-238 to produce a given power level compared to thermoelectric energy conversion that is around 7 percent efficient. A cutaway drawing of the ASRG appears in Fig. 1.

The RPS Program is working in partnership with the DOE and their system integrator, Lockheed Martin, to develop the flight units. The Stirling converters themselves have been designed and built by Sunpower Inc. with input from NASA Glenn.

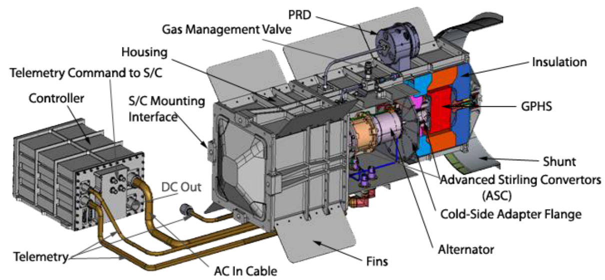

Figure 1. Cutaway drawing of an Advanced Stirling Radioisotope Generator

Development Status: The ASRG Project continues to pursue its flight design configuration baseline, finalizing component and subsystem configurations and interfaces. The project's system-level Final Design Review (FDR), conducted in mid-2011, resulted in additional questions from reviewers and led to two closeout reviews being scheduled for early 2012. The ASC design finalization has led to a more robust manufacturable design, adding confidence to the system life predictions that strive to meet a 17-year maintenance-free operational lifetime. The ACU design finalization, having lagged in its timeline in response to the ASC configuration improvements, has also matured to provide a demonstrated system that both maintains control of the dual-opposed convertor operation as well as providing conditioned power to the spacecraft power bus interface.

Potential Mission Applications: In parallel, two mission concepts have been selected for study from the 2010 Discovery Program announcement of opportunity whose missions are enabled by the use of two flight ASRGs.

The two RPS-enabled mission concepts are the Titan Mare Explorer, a mission to Saturn's moon Titan that would land a floating platform on Titan's *Ligeia Mare* methane-ethane polar sea and the Comet Hopper mission that would rendezvous and land repeatedly at comet Wirtanen during the comet's orbit. Both these missions, along with the third non-RPS mission concept, have been selected to complete concept phase or preliminary design studies toward a down selection, leading to a single potential launch in the year 2016.

Next Steps:

Once the ASRG FDR closeout reviews are completed, the project will proceed to build serial hardware for a fully fueled and fight tested qualification unit, and two flight systems. The baseline schedule provides for the two flight systems to be deliverable to the Kennedy Space Center for mission integration in the late summer of 2015.

Summary:

The design and development preparations of an ASRG represents a paradigm shift from traditional space-based RPS with the addition of moving parts and active control electronics to assure proper operation of the convertors and stable power conversion and transfer to the spacecraft power bus. The ASRG Project team is well on its way to fulfilling its design requirements, and seeing its capabilities aligned to two potential planetary science missions whose phenomenal science would not be possible without the project's efforts. The project looks forward to providing a robust power system for use in its first planetary science mission application.