Paper ID: 2777

SPACE PROPULSION SYMPOSIUM (C4)
Joint session on Nuclear Propulsion and Power (7.-C3.5)

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RADIOISOTOPE POWER: A KEY TECHNOLOGY FOR DEEP SPACE EXPLORATION

Abstract

A Radioisotope Power System (RPS) generates power by converting the heat released from the nuclear decay of radioactive isotopes, such as Plutonium-238 (Pu-238), into electricity. First used in space by the U.S. in 1961, these devices have enabled some of the most challenging and exciting space missions in history, including the Pioneer and Voyager probes to the outer solar system; the Apollo lunar surface experiments; the Viking landers; the Ulysses polar orbital mission about the Sun; the Galileo mission to Jupiter; the Cassini mission orbiting Saturn; and the recently launched New Horizons mission to Pluto. Radioisotopes have also served as a versatile heat source for moderating equipment thermal environments on these and many other missions, including the Mars exploration rovers, Spirit and Opportunity.

The key advantage of RPS is its ability to operate continuously, independent of orientation and distance relative to the Sun. Radioisotope systems are long-lived, rugged, compact, highly reliable, and relatively insensitive to radiation and other environmental effects. As such, they are ideally suited for missions involving long-lived, autonomous operations in the extreme conditions of space and other planetary bodies.

A total of 30 U.S. spacecraft have flown radioisotope power systems and heaters. Units on three of these spacecraft (i.e., Transit 5BN-3, Nimbus B-1 and Apollo 13) were never operated due to launch vehicle or spacecraft failure. Four of the 27 successful missions (i.e., Apollo 11, Pathfinder and the two Mars Exploration Rovers) flew radioisotope heater units only. All RPSs have met or exceeded expectations. Many of these, particularly the ones used on the Apollo lunar missions, the Viking Mars landers, and the Pioneer and Voyager planetary probes, produced electrical power well beyond their required lifetimes.

This paper describes the RPS units that the U.S. has flown over the last 50 years, and describes the generators currently under development for future missions. One of these systems, the Advanced Stirling Radioisotope Generator (ASRG), represents a significant departure from traditional RPS, which utilize thermoelectric energy conversion. In contrast, the ASRG employs a higher efficiency dynamic Stirling conversion process, and achieves a four-fold improvement in efficiency and Plutonium-238 fuel utilization. The ASRG also offers the promise of considerably higher specific powers and could greatly expand the application of nuclear-powered missions in the future.