National Aeronautics and Space Administration

NASAfacts

Radioisotope Power Systems: The Power to Explore

Radioisotope power systems (RPS) generate reliable electrical power and valuable heat energy for long-duration space missions, working dependably in harsh environments where solar panels or batteries would be ineffective or impossible to use.

RPS have been used on more than two-dozen U.S. space missions over five decades, and counting. RPS-powered missions include the Voyager 1 and 2 probes to the outer planets and interstellar space (both still operating after more than 35 years), the Cassini mission to Saturn, and the Curiosity Mars rover. Many exciting missions envisioned for future exploration of the planets, their moons, and the icy bodies beyond them could be enabled or significantly enhanced by using RPS.

NASA and the Department of Energy (DOE) work together to sustain and improve radioisotope power technology so that RPS can continue to be a viable option when considering future missions to many of the darkest, coldest, and most extreme environments known beyond Earth.

Choosing the Right Electrical Power Supply

One of the most fundamental components for challenging robotic space missions that operate in extreme conditions is their electrical power supply.

For most space exploration missions where sunlight is abundant, solar power has been the preferred choice. But as the natural environments at chosen destinations grow harsher, and missions evolve to be more demanding in their duration, duties, and distance from the Sun, it becomes more likely that the most effective power and heating for a spacecraft could be provided by RPS.

RPS produce enough power to operate a spacecraft by converting the heat generated by the natural radioactive decay of plutonium-238 (in the form of plutonium dioxide) into electricity. A portion of this heat of decay often has an important secondary use in keeping temperature-sensitive spacecraft subsystems (such as electronics and motors) warm enough to function in frigid environments.

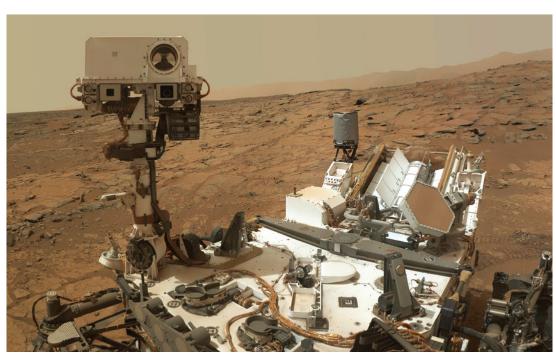
RPS offer the key advantages of operating continuously and with very slow degradation over the years, independent of unavoidable variations in sunlight. Such systems can provide power for more than a decade (significantly longer than regular chemical batteries), and can do so billions of miles from the Sun. RPS have been designed to have little or no sensitivity to temperature, radiation or other potentially damaging effects of the space environment. They are ideally suited for missions involving autonomous, long-duration operations, both in the vacuum of space and within planetary atmospheres such as Mars.

Decades of Evolutionary Development

Research on ways to harness radioisotope power for use in space began in earnest in the mid 1950s. The United States has flown eight basic RPS configurations since their first launch in 1961 as a technology demonstration payload on a U.S. Navy navigation satellite. RPS have powered 27 missions that have enabled trailblazing scientific exploration of the Moon (including experiments deployed by the Apollo astronauts), the Sun, Mars, Jupiter, Saturn, Uranus, Neptune, and—in 2015—icy Pluto and its moons.

The most recent RPS configuration, called the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), has demonstrated excellent performance since landing with the Curiosity Mars rover in August 2012. The MMRTG is based on the proven RPS design (SNAP-19) used to provide electrical power for NASA's two earlier Viking landers, which operated on the surface of Mars for more than three years and more than six years, respectively.

With no moving parts, the MMRTG converts the heat generated by the natural decay of its nuclear fuel into about 110 watts of electricity (at the beginning of a mission), using a property of physics called the Seebeck effect. In this process, a large temperature difference is imposed across carefully manufactured metal junctions, called thermocouples, which produces a flow of electrical current.



A self portrait by the Curiosity rover on Mars, with its MMRTG power system visible (center right) as the white cylinder with large radiator fins.

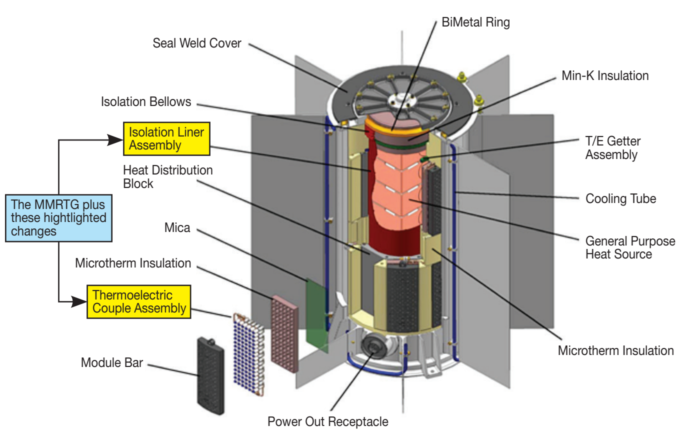
In an MMRTG, the 'hot side' of this temperature difference originates from 2,000 Watts of heat emitted by ceramic pellets of plutonium dioxide. The nuclear fuel is contained within individually shielded protective aeroshells called General Purpose Heat Source (GPHS) modules. An MMRTG uses eight GPHS modules, compared to the previous generation GHPS-RTG, which used 18 modules to produce about 300 watts of electricity. The GPHS-RTG was used to power the ongoing Cassini mission at Saturn and Pluto-New Horizons, as well as Galileo to Jupiter and Ulysses to the Sun's poles.

Meeting the Needs of Future Missions

The RPS Program is working on two major fronts to develop the next generation of RPS technology for the needs of future space missions: an MMRTG that could be enhanced with new advanced materials for its electricity-generating thermocouples, and continued maturation of Stirling engine technology for a new generation of RPS that would offer greater efficiency and higher power levels.

A potential enhanced MMRTG (eMMRTG) could use a new generation of more efficient thermoelectric materials—known as skutterudites—that could be "retrofitted" in the current MMRTG thermocouples with minimal changes to the overall system. These new semiconducting materials are made from cobalt arsenide with variable amounts of nickel and iron.

Using these skutterudite materials could allow an enhanced MMRTG to produce 30 percent more power at the beginning of a mission, and because performance degradation is less, as much as 50 percent more power than the current MMRTG by the end of a typical 14-year mission. To the further benefit of spacecraft mission designers, the overall dimensions and mass of an eMMRTG would remain about the same as an MMRTG.



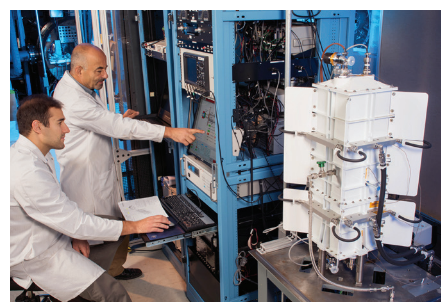
This artist's concept shows the internal structure of an enhanced MMRTG, which would feature new thermoelectric materials that could significantly improve the generator's performance.

Stirling Space Power

RPS concepts using Stirling engine technology would also employ GPHS modules with plutonium dioxide fuel as their heat source, but would use this heat to drive a moving piston back and forth inside a sealed container. This "closed-loop" process can generate electricity about 3-4 times more efficiently than even advanced thermoelectric systems. Stirling systems could also be sized up to produce higher total mission power levels than current RPS can do easily (toward a kilowatt or more).

NASA and its partners in industry have operated non-nuclear Stirling systems, and their associated computerized control units, for more than 600,000 hours in the laboratory. Stirling systems with similar technology, used as cryocoolers, have flown in space frequently, operating successfully for a decade or more. The RPS Program and its partners are continuing to work on manufacturing techniques and long-term reliability assurance for Stirling radioisotope systems, with the intent to develop them for flight as the next generation of RPS.

In addition, NASA continues to explore the development of improved power conversion technologies that aim to increase the efficiency and capability of key RPS subsystems, thus increasing the watts produced per unit of fuel. These advanced technologies could also help produce an RPS device with lower mass (thus increasing its specific power, or power per unit mass), longer lifetimes, and greater system flexibility in a wider range of environments.



Technologists at NASA's Glenn Research Center work with an electrically heated engineering unit of an advanced Stirling generator. Such systems could quadruple the efficiency of future radioisotope power systems for space exploration.

Making Every Launch Count

Shaped by on-going input from the scientific community, the aerospace industry, and U.S. national leadership, a variety of future NASA missions in the coming decades could benefit from RPS. Destinations could range from robotic missions to the outer planets and their icy moons, to the intense thermal environments of the surface of Venus and perpetually shaded craters on Mercury or the Moon, to human outposts beyond Earth.

A NASA mission that proposes to use an RPS undergoes an environmental review as part of NASA's compliance with the National Environmental Policy Act (NEPA). The NASA NEPA process typically includes opportunities for public engagement and review of NASA NEPA documents. Additionally, a mission powered by RPS would not launch until after a multi-agency review of the mission's nuclear safety is conducted and formal approval is received from the Office of the President. NASA and DOE, and their partners, work cooperatively to make these NEPA and launch approval processes effective and efficient.

To enable and enhance potential future science missions, NASA and DOE make strategic investments in RPS technology development and nuclear safety assessments. Meanwhile, NASA is funding DOE to resume production of a steady supply of new plutonium dioxide fuel.

Collectively, these efforts help ensure that RPS will continue to be a valuable option in the constant quest for sufficient power to explore.

For more information on the development of radioisotope power systems for space exploration, visit: ***rps.nasa.gov***