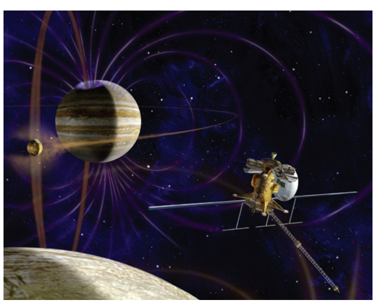
National Aeronautics and Space Administration

Radioisotope Power Systems for Space Exploration

NASA is exploring ideas for future missions to send robotic spacecraft to harsh and distant places that hold great promise for major new discoveries. Landers, rovers, orbiters and flyby craft could be sent on pioneering missions to some of the coldest, hottest, and darkest environments imaginable beyond Earth.

The questions that drive these visions for future exploration largely revolve around the origin and evolution of life. While the solar system presents a variety of hostile environments not favorable to life on first glance, scientists have found lifeforms on Earth thriving in incredibly extreme conditions, such as the areas surrounding deep, dark, hot water vents on the ocean floor. Such observations on Earth and our human curiosity lead us to ask whether life could exist, or may have existed, in other exotic places in our solar system.

If life arose elsewhere in the solar system, how did it start? How might it be similar or different than life on Earth? These profound questions are within our scientific reach for the first time.



NASA is studying a concept for a future mission to orbit Jupiter's icy moon Europa.

Scientists could find clues for answering these and other questions about life's origins in the ice-covered seas that may exist on Jupiter's icy moon, Europa, or in water deposits hidden beneath the frigid surface of Mars. Evidence of the building blocks of life, or chemical environments similar to the early Earth, might be found in the atmospheres, surfaces or sub-surfaces of various planets and moons, or within the intriguing small bodies of the solar system, comets and asteroids.

Choosing the Right Electrical Power Supply

Creating robotic spacecraft that could thrive in these extreme environments demands technical innovation. One of the most important components for such missions is their electrical power supply. For most space exploration missions where sunlight is abundant, solar power has been the preferred choice. But as the environments at chosen destinations grow harsher, and missions evolve to be more demanding, it becomes more likely that effective power and heating for a spacecraft would require a Radioisotope Power System (RPS).

An RPS converts the heat generated by the natural decay of the radioactive isotope plutonium-238 into electricity; this material is not used in weapons and cannot explode like a bomb. A portion of this decay heat often has an important secondary use in helping to keep spacecraft subsystems warm in cold environments.

An RPS offers the key advantage of operating continuously, independent of unavoidable variations in sunlight. Such systems could provide power for long periods of time (significantly longer than chemical batteries), and at vast distances from the Sun. Additionally, an RPS has little sensitivity to temperature, radiation or other space environmental effects. They are ideally suited for missions involving autonomous, long-duration operations in the most extreme environments in space and on planetary surfaces.

Developing and Improving RPS Technology

Seven generations of RPS have been flown in space by the United States since 1961, powering 26 missions that have enabled world-renowned scientific exploration of the Moon, the Sun, Venus, Mars, Jupiter, Saturn, Uranus, Neptune, and—soon—Pluto. All of the RPS on these historic solar system exploration missions have worked beyond their design lifetimes. An eighth RPS configuration, called the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), has recently been qualified for flight. It is planned for use on the Mars Science Laboratory rover, Curiosity.

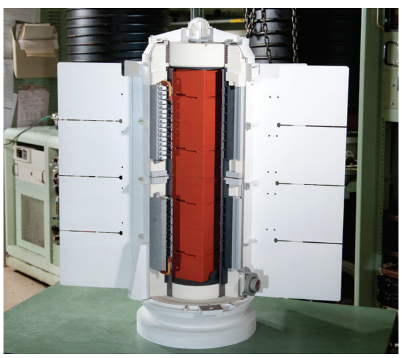
Artist's concept of the Mars Science Laboratory rover Curiosity on Mars.

NASAfacts

The overall science goal of Curiosity is to enable scientists to determine the past and present potential of Mars to support microbial life at an intriguing location on the Red Planet. The MMRTG will provide the electrical power and onboard heat required for the mission to accomplish its ambitious goals over one Martian year (or about two Earth years), including the capability to explore latitudes that are too high for the rover to efficiently use solar power.

The MMRTG is based on the proven RPS design used to provide electrical power for NASA's two earlier Viking landers, which operated on the surface of Mars for 40 months and more than six years, respectively. Other missions in NASA's heritage of safe and successful use of such generators for solar system exploration over the past 40 years include Voyager 1 and 2. The Voyagers continue to operate more than three decades after their launches, seeking the boundary of true interstellar space more than nine billion miles from the Sun.

As part of an ongoing partnership with the U.S. Department of Energy (DOE), NASA is conducting a mission-driven RPS Program whose purpose is to develop the next generation of reliable radioisotope power systems, enabling a broad range of science missions that could operate more widely and efficiently than their predecessors. This program is developing and validating two basic RPS units: the MMRTG and the Advanced Stirling Radioisotope Generator (ASRG).



A cutaway model of a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). The vertical red blocks in the center are individual heat source modules and the white fins on either side are radiators.

The MMRTG passively converts the heat generated by the natural decay of its nuclear fuel into about 110 watts of electricity through simple thermocouples, which have no moving parts. Each MMRTG carries eight individually shielded general purpose heat source modules, compared to 18 modules in the previous RPS generation. Unlike some of these previous generations of RPS, the MMRTG can operate in the atmosphere of a planet as well as in space.

Now that the MMRTG is ready for use in flight, the RPS Program is turning much of its focus to the ASRG. This new unit also employs plutonium-238 as its heat source (producing about 130-140 watts of electricity), but would use this heat to drive a moving piston. This system can generate electrical current over four times more efficiently than an MMRTG, thus preserving a limited resource of fuel.

Both the MMRTG and the ASRG are modular, meaning that more than one generator could be used when higher power levels would be needed.

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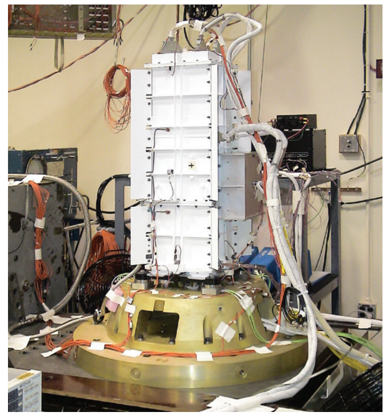
In addition, NASA and DOE are developing improved power conversion technologies that aim to increase the efficiency and capability of key RPS subsystems, thus increasing the watts produced per unit of fuel. These advanced technologies could also help produce an RPS device with lower mass (thus increasing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



Lockheed Martin

An Advanced Stirling Radioisotope Generator (ASRG) being prepared for vibration testing.

Possible Future Missions

Any NASA mission that proposes to use an RPS undergoes a comprehensive multi-agency environmental review, including public meetings and open comment periods during the mission planning and decision-making process, as part of NASA's compliance with the National Environmental Policy Act. Additionally, any such mission proposed by NASA would not launch until formal approval for the mission's nuclear launch safety is received from the Office of the President.

Radioisotope power systems are used when they enable or significantly enhance missions to destinations where inadequate sunlight, harsh environmental conditions, or operational requirements make other electrical power systems infeasible.

Beyond Jupiter's fascinating moon Europa, Saturn's moon Titan is often discussed as a highly desirable destination for science. Titan features a thick atmosphere of organic chemicals and a scientifically interesting surface where liquid hydrocarbons have carved lakes and streambeds. Ideas for future missions to Titan include an orbiter, a lander, various mobile rovers, or robots that could traverse the atmosphere or float in a lake.

Other recent mission studies include probes to study the Sun, missions to various asteroids and comets, and an orbiter for Neptune or its large, active moon Triton. Because an RPS is designed to work steadily in environmental extremes, it could also be considered for a surface rover to a permanently shadowed crater on Mercury or the Moon, or an aerobot to explore the atmosphere of Venus, cruising high above its lava-covered surface.

For more information on the development of radioisotope power systems for space exploration, see: *http://www.ne.doe.gov*

For descriptions of possible future missions and their power requirements, see: *http://solarsystem.nasa.gov/missions/index.cfm*