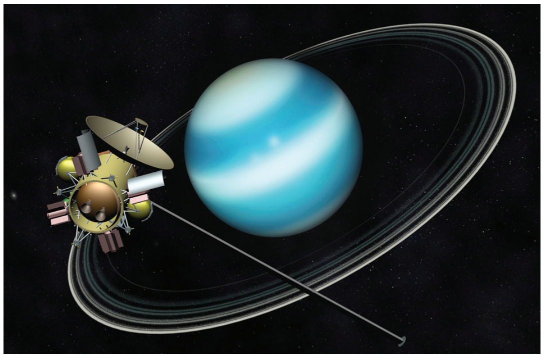
National Aeronautics and Space Administration

NASAfacts

Radioisotope Power Systems: Meeting Mission Needs

Radioisotope Power Systems (RPS) provide spacecraft with reliable electrical power over long durations. Flown on missions across the solar system for over 50 years, RPS are compact, rugged, highly reliable, and resistant to the damaging effects of the space environment. This makes RPS an excellent option to produce steady power (and useful excess heat) for a variety of potential NASA missions to some of the most harsh and extreme destinations in the solar system, and beyond.

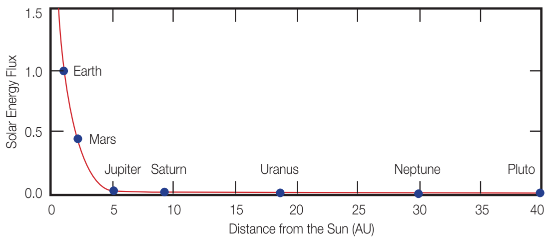
Many concepts for future NASA missions that could be powered by RPS aim to answer profound questions about the origin, evolution and future of life in the solar system—does life exist beyond Earth? If so, how did it start, and how might it compare to life here? Other mission concepts would illuminate our understanding of the earliest days of the solar system, and why planets like Venus and Mars evolved so differently than Earth.



NASA is studying a variety of missions to the Ice Giant planets to help scientists better understand the origins of the solar system, such as this concept for an RPS-powered spacecraft that could orbit Uranus and drop a probe into its turbulent atmosphere.

RPS have powered 27 U.S. space missions, with their next planned use being NASA's Mars 2020 rover. NASA considers using RPS to power a mission when this technology would enable or significantly enhance the capability of the mission to accomplish its scientific or technology development goals, as compared to other power system options such as solar cells or batteries.

Many past uses of RPS for planetary science have been to power spacecraft on deep space missions designed to travel where sunlight drops to a tiny fraction of its intensity at Earth's orbit. Good progress has been made with low-temperature, low-intensity solar cells on spacecraft such as the Juno mission now in orbit around Jupiter. But the natural dimming of the sun's energy as a spacecraft moves outward in the solar system will always present significant limitations.



The energy of sunlight decreases rapidly as distance from the sun increases.

Sunlight may also be too weak to supply enough electrical power for a given mission when it is highly intermittent, or obscured by an opaque or especially dusty planetary atmosphere. Long-duration missions to the high latitudes of the surface of Mars and to the surface of the Moon (which is naturally in darkness for two weeks out of every month) are also considered extremely challenging, if not impossible, for power systems using solar arrays and batteries alone.

For example, the vast distance from the Sun to Saturn means that sunlight received in the neighborhood of the ringed planet is already 100 times less intense than the sunlight that reaches Earth orbit. The thick, hazy atmosphere of organic chemicals on Saturn's moon Titan absorbs another 60 percent of this already faint incoming energy. On Mars, the ever-present red dust has cut the amount of energy produced by the solar panels on the Mars Exploration Rover Opportunity in half, despite several serendipitous cleaning events from local winds and random "dust devils" that can help clean the panels.

RPS are also generally impervious to the physical effects of dust and to the extremes in temperature that can affect almost every mission to space, where swings between intense heat and frigid cold can span 300 degrees Fahrenheit, sometimes in a matter of seconds.

When the destination for a mission is particularly cold, small components called Radioisotope Heater Units (RHUs)—

each of which generates about one watt of heat—can be used to keep the electronics and other internal systems in spacecraft, rovers and landers at proper operational temperature in deep space or in long-duration shadows. More than 300 of these marshmallow-size components have been flown on solar system exploration missions such as the Cassini mission, which orbited Saturn for 13 years, and the Opportunity rover, helping it survive through more than a half-dozen frigid winter seasons on the red planet.

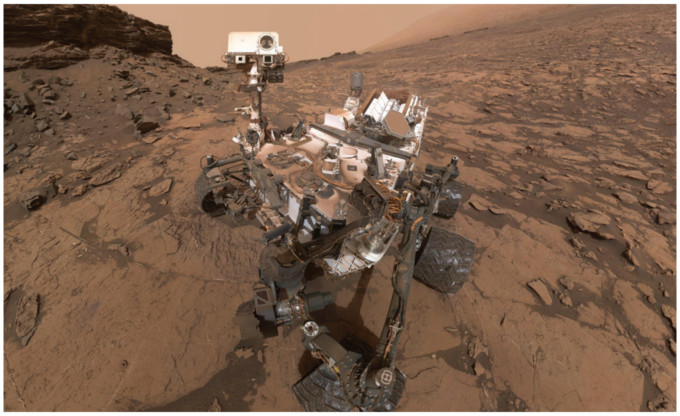
Artist's concept by Tibor Balint/JPL-Caltech/NASA

A concept for an RPS-powered hot-air balloon that could explore the atmosphere of Saturn's moon Titan for several months, and perhaps analyze samples of its methane lakes.

Unlike the sensitive electronic connections in solar panels, the power-producing elements of RPS are not greatly threatened by space radiation, which can be a severe problem in environments such as the Jupiter system. This intense radiation limited the planned primary mission of NASA's Juno spacecraft to one year, even with Juno's efforts to avoid the gas giant planet's damaging radiation belts.

All NASA RPS-powered missions flown so far have used Radioisotope Thermoelectric Generators (RTGs), such as the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) launched in November 2011 aboard the Curiosity Mars rover. Built by the Department of Energy for NASA, RTGs employ thermoelectric power conversion, where a large temperature difference is applied across the junction of two or more different conducting materials to generate the electricity passively, using no moving parts. These thermocouples in an MMRTG are designed for an operating lifetime in space of at least 14 years, although every RTG that has flown in space has far surpassed its design life.

NASA is investing in technology solutions to convert heat from the plutonium dioxide radioisotope fuel to electrical energy significantly more efficiently in the future, using advanced materials for thermoelectric conversion in RTGs and new dynamic designs featuring moving components, known as dynamic RPS. Such systems could produce electricity between 2-4 times more efficiently than existing RPS, meaning they could be lighter or use substantially less radioisotope fuel to generate a comparable amount of power.



NASA/JPL – Caltech/MSSS

NASA's Curiosity Mars rover has roamed the Red Planet conducting scientific measurements since August 2012, powered by an MMRTG. With its bright white radiator fins, the MMRTG is visible at the back of the rover; the excess heat radiated by the MMRTG causes less Mars dust to be deposited on it than on other parts of the rover.

NASA is also studying ideas for smaller or modular RPS, which could provide a range of power from 50 to 500 watts. This range could enable future specialized smallsats and cubesats or distributed missions (such as concepts for networks of landed weather stations across a planet) at the lower end, while allowing larger missions to carry fewer generators or increase the ease of integration with the spacecraft.

Together, this family of RPS technologies serves to support a variety of future mission concepts and designs, enabling NASA engineers to consider a wider range of creative solutions for exploring extreme environments and remote destinations.

Whether it be potential missions to comets and asteroids, distant icy moons like Europa or Enceladus, the still-mysterious ice giant planets Uranus and Neptune, or the vast Kuiper Belt beyond, space scientists have identified a host of amazing destinations that ambitious RPS-powered missions could explore uniquely in the years ahead, in ways that would not be possible with other power systems alone.

For more information about RPS and their power to explore, visit **rps.nasa.gov**