Radioisotope Power Systems for NASA

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

The questions that drive these visions for future explorations largely revolve around life and its origins. While the solar system presents a variety of harsh environments not favorable to life, we have examples of extreme environments on Earth that harbor life, such as deep, hot water vents on the ocean floor. Such observations on Earth lead us to ask if life could exist, or have ever existed, in other places in our solar system. We seek to understand the building blocks of life and the conditions that are necessary for life to gain a foothold in these harsh environments. We want to explore all of the aspects that could influence the formation of life and the environments in which life might survive, or even thrive, beyond Earth. If life arose elsewhere in the solar system, how did it get its start, and how might it be the same or different than life on Earth?

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

Choosing the Right Electrical Power Supply

Much technical innovation goes into creating robotic spacecraft that can survive in these extreme environments – places that are harsher and more remote than humans have ever explored. One of the most important components for such missions is the electrical power supply. For most space exploration missions where sunlight is abundant, solar power has been the preferred choice. But the harsher the environment and more demanding the mission in terms of duration and distance from the Sun, the more likely it is that power and heating of the spacecraft would require a radioisotope power system radioisotope power system. Such systems convert the heat generated by the decay of radioactive isotopes (such as plutonium-238) into electricity that is then used to power the spacecraft. A portion of this decay heat can even be used to warm spacecraft subsystems in the frigid environment of space.

Radioisotope power systems were first flown on U.S. space vehicles more than 40 years ago, and offer the key advantage of operating continuously, independent of sunlight. They can operate for long periods of time (longer than regular chemical batteries) and at vast distances from the Sun. Additionally, they have little or no sensitivity to cold, radiation or other space environmental effects. They are ideally suited for missions involving autonomous operations in the extreme environments of space and on planetary surfaces. Radioisotope power systems have enabled exploration of the Sun, Mars, Jupiter, Saturn, Uranus and Neptune, and soon, Pluto.

NASA and the Department of Energy are developing a new generation of long-lived, reliable nuclear power systems that would enable a broader range of important science missions. These next-generation space power systesms are the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), and the Stirling Radioisotope Generator (SRG). Both would be capable of producing about 110 watts of electricity at the beginning of a mission, and would have enhanced multi-mission capabilities, i.e., the ability to operate in vacuum of deep space as well as in planetary atmospheres, beyond existing radioisotope power systems.

Both the MMRTG and SRG would be modular, meaning that more than one generator could be used when higher power levels are needed. The MMRTG would be an enhanced capability version of the Radioisotope Thermoelectric Generators (RTGs) that have provided power for many of NASA's most productive scientific explorations, including two landers on Mars, a mission to the Sun's poles, and all missions to the outer planets, including the New Horizons mission to Pluto launched in January 2006. The MMRTG would passively convert the heat generated by the nuclear fuel, as it radioactively decays, into electricity through simple thermocouples. It would have no moving parts. The SRG also would have plutonium as its heat source, but would use the decay heat to drive an active free piston engine to create electricity.

NASA is also developing advanced power conversion technologies to increase thermal-to-electricity conversion efficiencies beyond that of MMRTG and SRG systems. This would increase the watts produced per unit of fuel in radioisotope power systems.

Possible future missions for radioisotope power systems
The Mars Science Laboratory project would set a large rover on Mars to look for areas hospitable to martian life, and currently is in planning for a 2009 launch. An MMRTG is the planned electrical power source, providing day and night operations and the capability to explore latitudes that are too

high for the rover to efficiently use of solar power Radioisotope power systems would be required for the exploration of numerous other high-priority science destinations in the solar system. Scientists and engineers are exploring ideas for missions that might one day send different kinds of spacecraft to these places. Jupiter's fascinating moon, Europa, where a saltwater ocean could exist beneath a global ice crust, currently tops the scientific community's list of bodies rich in potential for major discoveries. A Europa orbiter and lander are often discussed as two highly desired missions.

The Saturn system offers several interesting potential opportunities for discovery. One of Saturn's moons, Titan, is high on the list of desirable places to explore, with its thick atmosphere of organic chemicals and a bizarre surface where liquid hydrocarbons have carved canyons and streambeds. Mission ideas for Titan include an orbiter, lander, rover or an aerobot that would float in the atmosphere. Saturn's rings are another potential destination. The way that rings form, evolve and dissipate provides an excellent model for studying how other disk structures, such as planet systems around stars, form throughout our galaxy.

Radioisotope power systems could be considered for other possible missions to destinations where inadequate sunlight, harsh environmental conditions or mission operation requirements may make other electrical power systems infeasible. Some recent studies include probes to study the Sun, missions to various asteroids, and an orbiter and probe for Neptune and its large, active moon, Triton. Because a radioisotope power system is designed to withstand environmental extremes, it could be considered for a surface probe for Venus, where temperatures are hot enough to melt lead. Such systems could also help make possible an interstellar probe – one that that would travel far from the Sun and beyond the planets toward other stars.

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/scitech/display.cfm?ST_ID=705** .

For information on small radioisotope power sources and possible missions that might use them, see **http://solarsystem.nasa.gov/scitech/display.cfm?ST_ID=665** .

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

4-06