

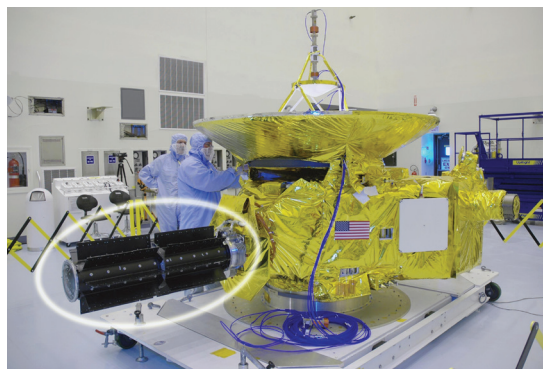


# Safety of Radioisotope Power Systems

One fundamental requirement for a space mission is a reliable source of sufficient electrical power. Planetary exploration spacecraft and their electrical power sources must be built to withstand extremes in temperature, radiation, pressure and dust that would quickly disable or destroy most hardware and software on Earth. In addition, these spacecraft often must function continuously in such environments, sometimes for many years, to accomplish their goals.

100 times per second to generate an electrical current via a linear alternator.

Regardless of the power source, mission success is the driving force behind all of NASA's engineering decisions. At every stage, this drive for success is grounded in planning for the safety of the general public and project personnel, which guides NASA's use of RPS from start to finish.



*The New Horizons spacecraft, with its radioisotope power system attached (circled), is prepared for its January 2006 launch to explore Pluto and the Kuiper Belt, starting in 2015.*

For certain missions to the moon and destinations beyond that offer sufficient sunlight and natural heat, solar power is an excellent choice. However, several proposed NASA missions given top priority by the scientific community would visit some of the harshest, darkest, and coldest locations in the solar system; many of these missions would not be possible or would be extremely limited without the use of Radioisotope Power Systems (RPS).

Produced through a partnership between NASA and the Department of Energy (DOE), RPS use the heat produced from the natural decay of the radioisotope plutonium-238 to generate electricity for powering spacecraft. RPS can also be used to provide heat to keep spacecraft components and systems warm. In a traditional Radioisotope Thermoelectric Generator (such as the Multi Mission Radioisotope Thermoelectric Generator [MMRTG] in use by the Curiosity Mars rover), a temperature difference across the junction of two different metals generates the electricity. In a new design of RPS under development called an Advanced Stirling Radioisotope Generator, the radioisotope heat is used to drive a piston that moves back and forth more than

## Materials Science With a Purpose

The natural nuclear decay process of plutonium-238 causes it to emit alpha particles, a type of ionizing radiation. These alpha particles, emitted in the form of helium nuclei, travel only about three inches in the air, and can be blocked by clothing, skin or even a sheet of paper. The radioisotope fuel can be a health hazard only when it is broken into particles small enough to be inhaled or ingested and then retained in the body.

To greatly reduce this hazard, the plutonium-238 used in a RPS is manufactured in a ceramic form, known as plutonium dioxide. This form has material properties similar to a coffee cup: it tends to fracture in large, non-inhalable chunks and it is highly insoluble; this means that it does not easily mix or become easily transportable in water, nor does it react easily with other chemicals.

## Rugged Layers of Protection

Each marshmallow-sized pellet of plutonium dioxide used in an RPS is encased in iridium—a strong, ductile metal that resists corrosion and does not react chemically with the radioisotope fuel. In the unlikely event of an accident involving an impact, the iridium cladding is designed to deform yet contain the nuclear fuel.

Moving outward, a pair of these iridium-clad fuel pellets are inserted inside a cylindrical casing of heat- and impact-resistant material made of a hard carbon-carbon fiber (similar to what is used in the nosecone of a missile); this cylinder is then covered in an insulating sleeve made of graphite. Two of these carbon-carbon cylinders are then enclosed inside a box-shaped casing of yet more rugged carbon-carbon fiber to form the basic building block of an RPS, known as a General Purpose Heat Source (GPHS).

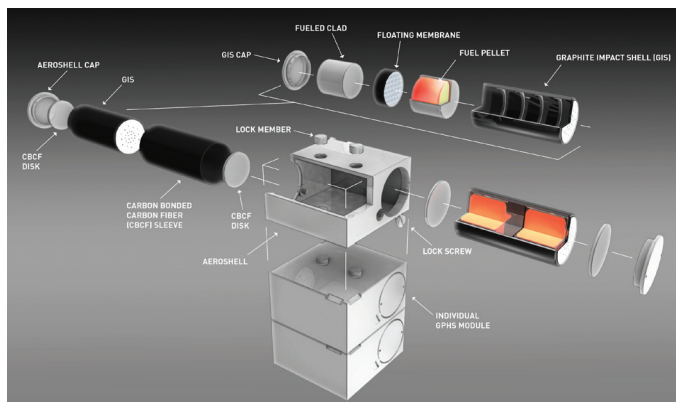
Each rugged modular heat source produces about 250 watts of heat that can then be converted into

NASAfacts

electricity; the current RPS used by NASA contain between two and eight of these heat source modules, producing about 110-130 watts of electricity. The existing enhanced heat source module is an evolution of a design that has worked with extreme reliability for the past three decades; to provide even greater protection, the broad face of the module and the face between the two shells are 20 percent thicker than the modules used in RPS previous to the MMRTG.

Small, pencil eraser-sized pieces of plutonium dioxide are sometimes used inside spacecraft and planetary rovers to keep their systems warm in frigid environments. Known as Radioisotope Heater Units (RHUs), these lightweight units are similarly encapsulated by a protective alloy of platinum and rhodium, and strong carbon-carbon fiber.

## Extensive Testing & Analysis



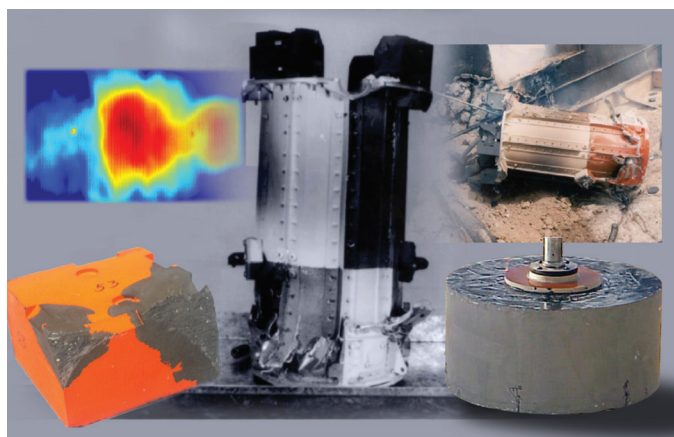
A cutaway view showing the nested layers of protective materials that are built up to form a General Purpose Heat Source module.

Thanks in large part to the care taken in the design and construction of each heat source module, an RPS is designed to contain its plutonium dioxide in a wide range of potentially severe accident conditions, including launch failure and atmospheric re-entry scenarios. Extensive computer modeling and rigorous physical testing, which check and reinforce each other, have been conducted on RPS over the past five decades.

The battery of safety tests that the modules and related components have undergone include fires (both solid propellant and liquid fuel), blasts similar to launch vehicle explosions, the intense thermal effects of friction from atmospheric re-entry, and submersion in water, plus a range of impacts designed to simulate pieces of metal shrapnel, large rocket booster fragments, or the hard surfaces of the Earth.

Computer modeling is accomplished with state-of-the-art three-dimensional modeling using some of the nation's most advanced supercomputers.

Even if the multi-layer system of containment in an RPS is breached, this does not mean that the plutonium dioxide would be widely dispersed. The system is designed to minimize this release as much as possible, based on the ceramic form of the plutonium dioxide and the ductility of its iridium shell, which greatly limit the potential mobility of the material in the local environment.



Images credit: Department of Energy

A sample of the results of the many types of destructive physical tests conducted to test the ruggedness of radioisotope power systems and their components over the past five decades, including blast damage, heating effects and ground impacts.

## Launch Review, Approval and Support

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

To ensure the safety of the public and launch personnel in the event of a launch accident, expert teams of emergency response specialists are in place in advance of any launch carrying an RPS, and are highly integrated with the local, state and federal agencies responsible for public safety in the surrounding community.

## A Long Record of Success

The United States has used RPS for the civilian exploration of space for more than 40 years.

NASA has an outstanding record of safety in launching spacecraft carrying nuclear power systems, with 17 successful launches and no failures over the past three decades. Prior to 1971, three missions using radioisotope power systems were subject to mechanical failures or human errors unrelated to the power system that resulted in early aborts of the mission. In every instance, the radioisotope power system performed as it was designed.

No member of the public has ever been injured in a NASA launch, and the RPS team at NASA and the DOE works every day with the strict intent to maintain and extend this important record of safety and success.

For more information about radioisotope power systems, visit [rps.nasa.gov](http://rps.nasa.gov)