National Aeronautics and Space Administration

NASA**facts**

Advanced Stirling Radioisotope Generator (ASRG)

Radioisotope power systems (RPS) have been a steady source of electricity and heat for a wide variety of U.S. space missions for more than five decades. All previous versions of these highly dependable power sources have been based on the principle of applying a large difference in temperature across a carefully constructed junction of two different metals. The large temperature difference creates a natural flow of electricity through the junctions.

The heat for this thermoelectric process comes from the decay of the radioisotope plutonium-238 (Pu-238). Although NASA and the Department of Energy (DOE) are working to restart production of Pu-238 for U.S. civil space exploration, the supply of this special nuclear fuel could limit the ability of NASA to consider flying missions that would benefit from an RPS. One way to extend this fuel supply is to build a more efficient RPS.

NASA, DOE and several partners in industry are developing a new, much more efficient type of RPS that combines modern engineering materials and technologies with the Stirling engine heat cycle, invented nearly two centuries ago during the Industrial Revolution. Known as the Advanced Stirling Radioisotope Generator (ASRG), this new system should be four times more efficient than the past thermoelectric systems.

How does an ASRG work?

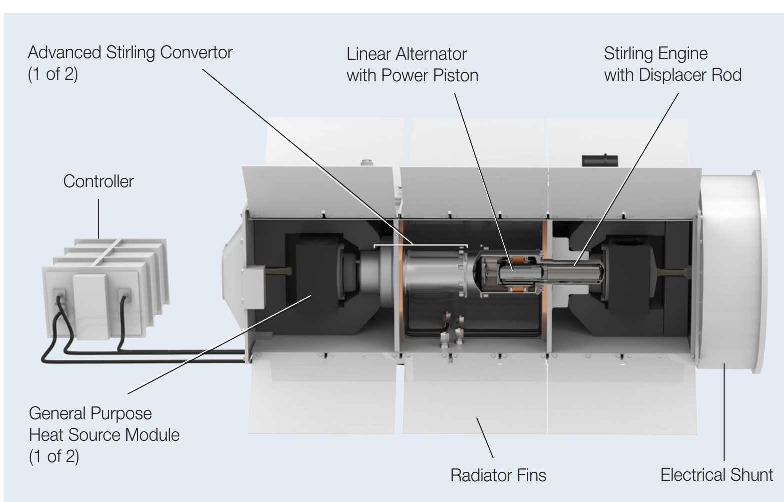
An ASRG produces electricity by a triple energy transformation: it first turns the thermal energy from the hot radioisotope fuel into the high-speed kinetic motion of a small piston and its companion displacer. In turn, this magnetized piston oscillates back and forth through a coil of wire, thereby generating a flow of electrical energy (using a property of physics known as Faraday's Law).

Inside the ASRG, the oscillating piston and its companion displacer are sealed inside a closed cylinder, suspended in helium gas. The displacer moves in sync with the piston, rapidly forcing the helium gas back and forth between the "hot side" heated by the radioisotope fuel at one end, and a passive cooler at the other end. The steady alternating expansion and contraction of gas within this Stirling heat cycle drives the magnetized piston through the coil of wire more than 100 times per second, thus creating an alternating current of electricity.

Each ASRG contains two sets of pistons and displacers—each set known together as an Advanced Stirling Convertor. The two convertors are aligned end-to-end in the middle of the generator; this configuration helps to cancel out the small linear vibrations produced by the pistons when their motion is synchronized. The helium gas sealed inside each converter also functions as a "hydrostatic" bearing, keeping the displacer and the piston from rubbing the walls of the cylinder and eliminating almost all physical wear. This enables the ASRG to be designed for a long operating lifetime of 17 years.

A controller connected by electrical cables to the ASRG synchronizes the two pistons, provides data about the status of the ASRG to the spacecraft carrying it, and transforms the alternating current (AC power) produced by the generator into about 130 watts of direct current (DC power) at a voltage that a spacecraft can use.

The far end of each convertor is connected to a General Purpose Heat Source (GPHS) that contains the radioisotope fuel heat source. The ASRG uses two of the identical GPHS modules, the same type used in the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) that powers the Curiosity Mars rover. The GPHS contains



Each ASRG contains two Advanced Stirling Convertors.

the power source's nuclear fuel within several layers of rugged and heat resistant carbon-carbon material, graphite and iridium metal.

These tough layers help ensure the safety of the power source in the unlikely event of an accident during launch of an RPS-powered mission or in an accidental atmospheric reentry during an Earth-swingby maneuver. In addition, the nuclear radioisotope fuel in an RPS (plutonium dioxide) is used in a ceramic form that would break primarily into large, non-inhalable and non-soluble pieces, rather than fine particles that could be harmful to human health or the environment.

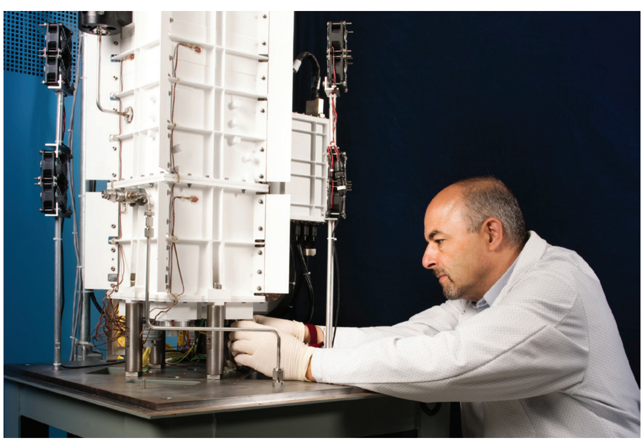
Why does NASA need an ASRG?

The energy conversion process used by an ASRG allows it to use about one quarter of the plutonium-238 used in previous radioisotope systems to produce a similar amount of power. This greater efficiency helps extend the limited U.S. supply of this special material.

Like the MMRTG, the ASRG is designed to work in the atmosphere of planets like Mars, as well as in the vacuum of deep space. Both the ASRG and MMRTG could be used alone or in different multiples, depending on a proposed mission's scientific and operational needs. For example, the ASRG will be lighter than an MMRTG, while the MMRTG can supply more heat for mission systems that may benefit from it.

About the size of a carry-on suitcase, the ASRG converts its total input heat of 500 thermal watts into about 130 electrical watts available to power spacecraft systems and instruments. The remaining 75 percent of the input heat could be used for keeping those systems and instruments at their proper operating temperatures.

Unused heat is emitted through a rectangular outer housing on the ASRG featuring large radiator fins, and any excess electricity is shed through a set of electrical resistors called a shunt.



An engineer works on an engineering test unit of the ASRG. Such test units (with non-nuclear heat sources) have operated for a total of more than 33,000 hours in the laboratory over more than a decade of increasingly integrated development work.

What types of NASA missions might use an ASRG?

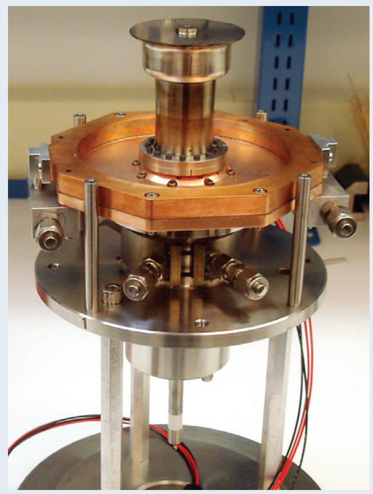
NASA and the scientific community are studying a wide variety of missions that might require an ASRG, from orbiters, landers and rovers to balloons and planetary boats. Possible destinations for future missions that would carry an ASRG include Mars, Saturn's moon Titan, Jupiter's moon Europa, or the outer planets Uranus and Neptune.

The RPS Program is developing the first pair of flight-quality ASRGs to be ready to be fueled as early as 2017. Mission candidates could emerge through NASA's Discovery and New Frontiers programs.

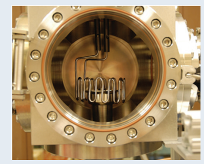
It may be possible to build a small Stirling-powered RPS that would use only one GPHS module, to power smaller spacecraft, highly mobile missions, or those that might require a network of small stations.

Who is building the ASRG?

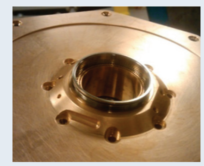
The U.S. Department of Energy is building the ASRG for NASA, with key contributions from NASA's Glenn Research Center, Cleveland, OH, Lockheed Martin, Valley Forge, PA, and Sunpower Inc., Athens, OH.



Advanced Stirling Converter (ASC) – E3 #2 preparation for initial operation

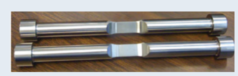


High-temperature heater head leak test rig



First E3 production cold side adapter flange (CSAF) press

Completed ASC–E3 heater head



Materials sample

ASC–E2 #7 and #8 in Lockheed Martin Coherent Technologies controller testing

Flight-quality hardware for the first ASRGs is being produced, assembled, and tested in a variety of locations across the country.

ASRG Facts

Power Output: 130 Watts (beginning of mission)
Efficiency: 26 percent
Total Mass: 70 pounds (32 kilograms)
Fuel: 2.7 pounds (1.2 kilograms) of plutonium dioxide protected in two General Purpose Heat Source Modules
Dimensions: 2.5 feet long (76 centimeters); 1.5 feet by 1.3 feet wide (46 by 39 centimeters)
Design Lifetime: At least 17 years

For more information about NASA's use of radioisotope power systems for space exploration, see:
rps.nasa.gov