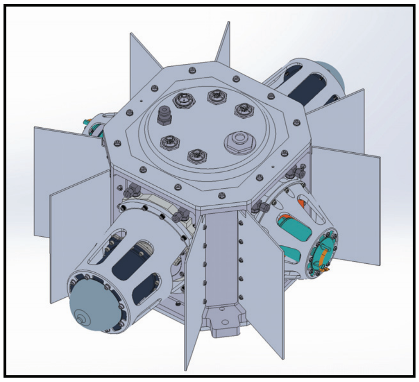
to cause a flow of electrons within a wire is a property of physics known as Faraday's Law). The addition of an internal regenerator heat exchanger greatly improves the efficiency of the cycle, by storing and releasing heat as the gas moves between the hot end to the cold end.



A 3D model of an upcoming DRPS testbed: NASA GRC

A Brayton-cycle convertor works in a different way. The thermal energy from the radioisotope fuel heats a gas that flows through a turbine, causing it to turn more than 160,000 revolutions per minute. The gas transfers some of its thermal energy into rotational kinetic energy of the turbine. Waste heat is then rejected through radiator panels. This cooler gas is then flowed through a compressor that is on the same rotational shaft as the turbine, which increases the pressure and temperature of the gas. The gas is then flowed past the RPS heat source to further increase its energy, and back to the inlet of the turbine to repeat the cycle.

This continual movement of the working gas in the Brayton convertor provides constant rotational energy on the shaft that connects the turbine and compressor. At the center of the shaft an installed magnet spins at high speed within a coil of wire. Faraday's law is used again here to generate alternating current. For both the Stirling and Brayton options, the alternating current needs to be converted into direct current by a controller unit, which provides power to support spacecraft operations and scientific observations.

Stirling and Brayton convertors are under development for potential future use in space applications. A Brayton-cycle prototype was recently development for NASA by Creare, LLC based on the cryogenic cooler flown in the NICMOS (Near Infrared Camera and Multi-Object Spectrometer) instrument installed in the Hubble Space Telescope. Brayton-cycle machines use hydrodynamic journal bearings to keep the turbine and compressor shaft aligned and free from friction, also eliminating wear and enabling a long mission life.

Stirling-cycle convertors have been in development for space mission applications since the early 2000's. Two companies, Sunpower Inc. and American Superconductor

DRPS Generator Goals

Design lifetime: At least 14 years in space

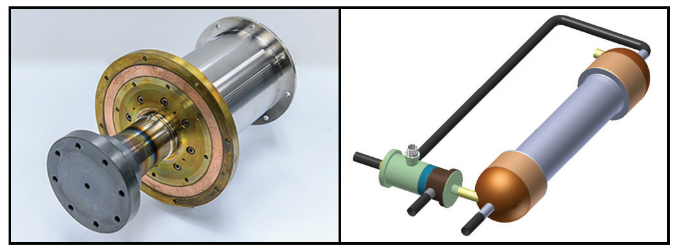
Electrical power output: 300 to 400 Watts

RPS thermal to electric efficiency: > 20%

Fuel: Plutonium dioxide in General Purpose Heat Source (GPHS) modules

Capability: On the lunar surface, in the vacuum of deep space, in the atmospheres of planets such as Mars and Titan, and on distant icy moons such as Enceladus

(AMSC), have recently developed the latest iteration of their free-piston Stirling convertors. Each uses a different non-contacting piston bearing technique. Sunpower's design uses gas bearings to prevent the moving piston from rubbing, thus eliminating wear that could shorten the lifetime of the convertor. AMSC's design uses a thin metallic planar spring called a flexure that prevents side motion and rubbing of the piston.



Sunpower Robust Stirling Convertor (SRSC): Sunpower, Inc. (left)
Turbo-Brayton Convertor: Creare, LLC (right)

Earlier Stirling designs using both bearing techniques have successfully demonstrated performance and life in the laboratory and have the potential to allow a DRPS generator to last for at least 17 years, the amount of time typically necessary for long transit times to the outer planets and their moons. While Stirling convertors have yet to be flown in space, Stirling cryocoolers paired with similar supporting technologies have been used very successfully on many space missions, including the 16-year-long RHESSI solar flare observatory. AMSC and Sunpower have provided prototype convertors to NASA Glenn, with several having completed more than 4,000 hours of operations and testing. The units will undergo environmental testing to demonstrate robustness to the harsh conditions anticipated during space missions.

The DOE's Idaho National Laboratory, with Aerojet Rocketdyne as its industrial partner, is working in collaboration with NASA's Glenn Research Center to design a flight-quality DRPS. The goal of this technology development activity is to provide a DRPS flight unit by the end of this decade toward a demonstration mission on the Moon as part of NASA's Artemis program.

For more information about radioisotope power systems, visit **rps.nasa.gov** or write to **NASA-RPS@mail.nasa.gov**.

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