DYNAMIC POWER GENERATION FOR HUMAN AND SCIENTIFIC EXPLORATION OF THE LUNAR SOUTH POLE. J. Mark Hickman[1], Sal M. Oriti[1], Scott D. Wilson,[1] and Eric S. Clarke,[2] [1]NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, OH 44135, [2]DOE Idaho National Laboratory, 1955 N. Fremont Ave. Idaho Falls, ID 83415.

Introduction: Many NASA missions visit some of the harshest, darkest, coldest locations in the solar system and would not be possible, or would be extremely limited, without the use of nuclear power. Radioisotope Power Systems, or RPS, harness the heat of the natural decay of plutonium-238, to produce continuous electric power for operating spacecraft systems and science instruments. Radioisotope power has provided this "Power to Explore" for the past 60 years.

The first two space flights that used RPS were the Navy's Transit 4A and 4B navigational satellites, launched in June and November 1961. A 3-watt Radioisotope Thermoelectric Generator (RTG) was flown on each spacecraft to prove the operational capability of the RTGs in a space environment [1]. Since then, RTGs have flown on such missions as the Viking landers, Pioneer 10 and 11, Voyager 1 and 2, Galileo, Ulysses, Cassini, and New Horizons. The Mars Curiosity rover uses a newer RTG design called the Multi-Mission RTG, or MMRTG. The Perseverance rover that will arrive at Mars in February 2021, is also to be powered by a MMRTG.

While RTGs will continue to power deep space missions, a new RPS design is being developed. This Dynamic RPS, or DRPS, will also use plutonium-238 to create heat, but instead of static thermoelectric power conversion, the heat could be used to create electricity via a Stirling cycle power convertor. The heat created by the decay of the radioisotope is used to create a temperature difference across the reciprocating heat engine. As the moving components oscillate, the piston work is converted to electricity when the moving-magnets move through a stationary copper wire coil and laminations, located in the linear alternator. The moving components maintain running clearances and achieve wear-free long-life operation through the use of flexure or gas bearings. An electronic controller is used to rectify the convertors AC power to DC power, which is then used by the spacecraft [2], [3], [4].

Advantage of DRPS: The advantage of this system is that the power conversion efficiency of DRPS is about four times that of RTGs. Therefore, the system can provide the same power as RTGs for a quarter of the radioisotope fuel or can provide four times the power for the same amount of fuel. DRPS also dissipate around half as much waste heat from the generator surfaces, which could be important depending on mission requirements.

Uses: DRPS are being developed to provide power to deep space science missions lasting as long as 14 years. This would accommodate long cruise times to the outer planets or long duration missions on icy worlds, including powering flyby missions, landers, rovers, and submersibles.

The development of DRPS for space science missions can also benefit Lunar and Mars exploration. Current DRPS development efforts could support a mission in the late 2020's. The first application for DRPS may be for a lunar surface resource exploration rover at the south polar region. Other uses could include electrical and thermal energy for an in-situ resource utilization (ISRU) pilot plant. Prior to large fission reactor deployment, DRPS could be used for auxiliary human habitation support. The design of the DRPS will allow operation of the system in both the extreme temperature differences of the lunar surface and in the atmospheres of Mars, Titan, and here on Earth (during pre-launch operations).

Designs: While designs of the DRPS generator are flexible, the current direction would use six General Purpose Heat Source (GPHS) Step-2 modules to provide the decay heat to an eight-convertor Stirling generator. Full power of 360 W_e at beginning of life would be provided by operating eight convertors at 75% of full capacity. The convertors are paired in dual-opposed alignment to nullify vibration. Operating in this fashion allows for the failure of one opposed pair of convertors while still achieving full power with the remaining six convertors, thus significantly increasing the system reliability through redundancy. Assuming a power degradation of about 0.5% per year over the life of the mission, this design will provide for 300 W_e after a 14-year mission life, plus up to a 3-year ground operation period prior to launch.

Exploration of the Lunar South Pole Region: The benefits of using DRPS at the lunar south pole region are that a DRPS generator can provide continuous power in sunlight or in the permanently shadowed regions (PSRs) where deposits of water ice are likely to exist. A DRPS generator does not need a large area as would a photovoltaic power system. Nor does it need long and heavy high-voltage power cabling to run between a power system and an ISRU oxygen extraction plant. A DRPS is compact, portable, operates during the long 14-day lunar night, and can provide thermal waste heat to help with lunar regolith processing. If peak power requirements are greater than 360 W_e, an energy storage system (battery, fuel cell, etc.) can be added to the power system. The DRPS can charge the energy storage system until the higher-level power is needed.

References:

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