

## Stirling Power Conversion for Lunar Applications

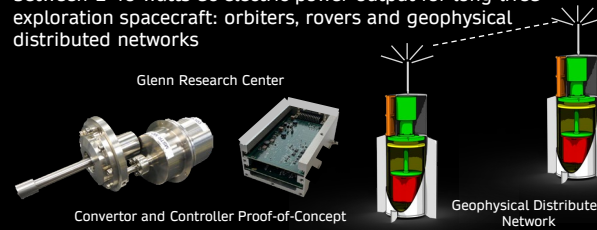
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### Free-Piston Stirling Engine Advantages

- Thermal-to-electric conversion efficiency demonstrated up to 40%
- Non-contacting bearings and seals enables long-life continuous operation
- Zero degradation via elimination of wear mechanisms and accounting for life limiting design aspects (high-temp creep, high-cycle fatigue)
- Long-life, maintenance-free capability demonstrated in NASA's Stirling Research Laboratory
  - 1,284,935 hours (146 years) accumulated in total
  - 139,515 hours (16.0 years) accumulated on single machine
- V&V testing used to demonstrate robustness in relevant environments, including random vibration testing to simulate rocket launch, static acceleration testing in a centrifuge to simulate launch and landing loads, and thermal cycling

### Low Power Applications using Isotope Heat Source

- Developing a scalable Stirling Radioisotope Power Systems architecture for isotope-fueled space capable power systems between 1-40 watts dc electric power output for long-lived exploration spacecraft: orbiters, rovers and geophysical distributed networks

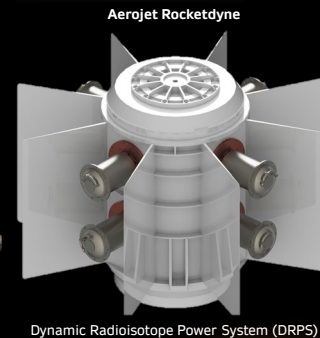
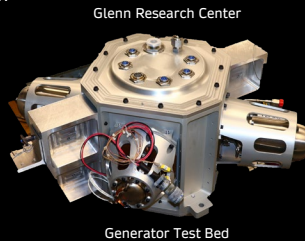
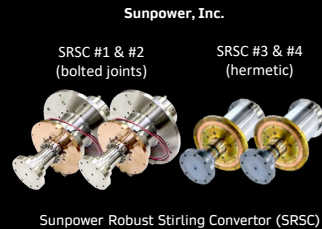
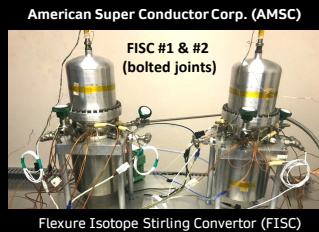


Small Stirling Technology Exploration Power (SmallSTEP)

Performance Parameter	Value
System Power Output	1-40 W <sub>e</sub>
System Design Life	10 years
System Efficiency	>16%
Heat Source	Isotope fuel source (St-90, Am-241, Pu-238)
Converter Power Output	Scalable from 2 We to 40 We for heat input
Converter Efficiency	28 %

### Radioisotope Power Systems

- SRG110 (200-2006) 16 prototypes and 2 engineering units (all flexure-bearing units)
- ASRG (2007-2013) 17 prototypes and 20 engineering units (all hydrostatic gas-bearing units)
- DRPS (2017-2022) 6 prototypes (2 flexure-bearing and 4 hydrostatic gas-bearing units)
- Aerojet Rocketdyne generator design good for lunar PSD or full sun mission

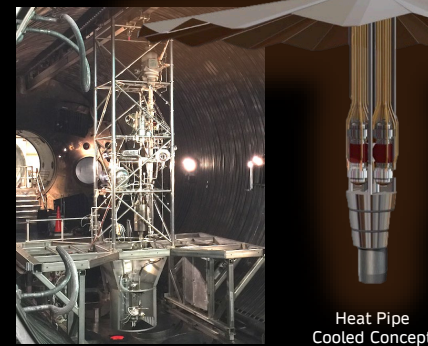
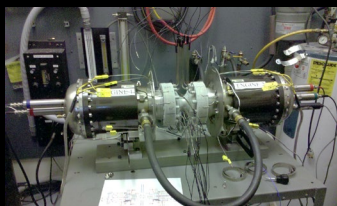


Dynamic Radioisotope Power System (DRPS)

Performance Parameter	Value
Electrical Power at Launch (We) (assumes 3 yrs after fueling)	284 We
Mass	110 kg
Design Life (includes 3 yrs of storage)	17 years
Number of GPHS	6
Fault Tolerance	Double fault tolerant
Converter Power Output	60 We
Converter Efficiency	26%
Converter Mass	3.6 kg

### Fission Power Systems

- 1.3 kWe gas-bearing Stirling converters were used to demonstrate small-scale pumped liquid sodium (NaK) loop for transferring heat from simulated reactor to converters (2010)
- 6.3 kWe gas-bearing Stirling converters demonstrated 40 kWe Test Demonstration Unit (TDU) at full-scale and 1/4 power output. Electromagnetic pumped NaK loop cooled the electrically-heated reactor simulator and Ti/H<sub>2</sub>O heat pipes cooled the Stirling converters (2015)



40 kWe Test Demonstration Unit (TDU)

Performance Parameter	Value
System Power Output	40 kW <sub>e</sub>
Design Life	10 years
Reactor Cooling	Liquid metal cooled or heat pipe cooled
Fault Tolerance	Single fault tolerant
Converter Power Output	12 kWe
Converter Efficiency	25%
Converter Mass	220 kg

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NASA/CR—2010-216750, TM-2019-219935