National Aeronautics and Space Administration

Dynamic Radioisotope Power Systems Development and Potential First Mission Utilization

S. Oriti, S. Wilson, M. Hickman, J. Zakrejsek | Salvatore.M.Oriti@nasa.gov | (216) 433-2066 | NASA Glenn Research Center, Cleveland, OH 44135

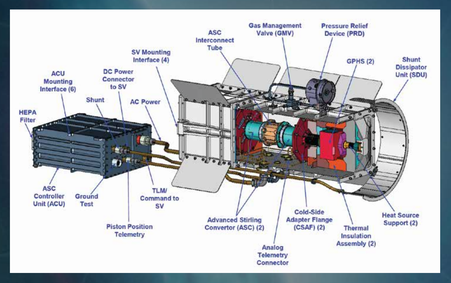
ABSTRACT

Dynamic power conversion offers the potential to significantly enhance Radioisotope Power System (RPS) performance. Potential improvements include higher conversion efficiency (more power per kg of Pu-238 fuel and less waste heat), low or zero degradation beyond fuel decay, and thus higher end-of-mission power. Degradation-free life of Stirling-cycle conversion has been demonstrated on the time scales required by several missions.

DYNAMIC POWER CONVERSION

- Stirling, Brayton, Rankine, Ericsson are suitable for space applications
- Conversion efficiencies demonstrated up to 40%
- Non-contacting bearings and seals (enables long-life continuous operation)
- Zero degradation via elimination of wear mechanisms
- Macroscopic engineering challenges (high-temp materials, high-cycle fatigue)

ADVANCED STIRLING RADIOISOTOPE GENERATOR (ASRG)	
Development Timeframe	2006-2013
Heat Source	2 GPHS
Power	140 W_e (DC)
Efficiency	28%
Conversion Technology	Free-piston Stirling
Specific Power	4.4 W_e/kg



CONVERTOR PERFORMANCE GOALS

- Derived from Surrogate Mission Team input
- Encompasses wide range of potential Planetary Science Missions

CATEGORY	GOAL
Design Life	20 years
Efficiency	>24% at T_{cold}>100°C
Specific Power	≥20 W_e/kg
Partial Power	Enables conversion-redundant generators
Size	Enables 200-500 W_e generator
Degradation	<0.5%/year
Hot-end Temp	<1000°C
Cold-end Temp	20-175°C
Random Vibe	Launch qual (14.6 g_{rms})
Static Acceleration	20g for 1 minute, 5g for 5 days
Radiation	300 krad
Robustness	Ample margins, tolerant of user error

PATH TO FLIGHT DEVELOPMENT

PHASE	DURATION	WORK FOCUS	TRL
1	6 months	Design	4
Decision Gate 1			
2	18 months	Prototype Fabrication Performance Demonstration	4, 6
3	12-24 months	IV&V Test Support	6
Decision Gate 2			

GOAL: Begin Flight Development 2021

RECENT CONVERTOR DESIGNS

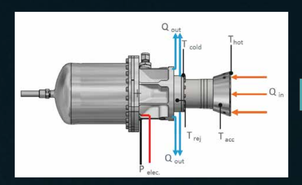
FLEXURE ISOTOPE STIRLING CONVERTOR (FISC) American Superconductor, Inc.	
Power	70 W_e
Efficiency	31%
Hot-end	650°C
Specific Power	21 W_e/kg

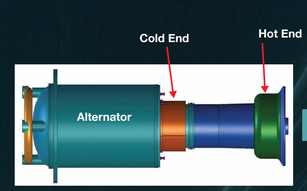
TURBO-BRAYTON CONVERTOR (TBC) Creare, LLC	
Power	355 W_e
Efficiency	26%
Hot-end	730°C
Specific Power	22 W_e/kg

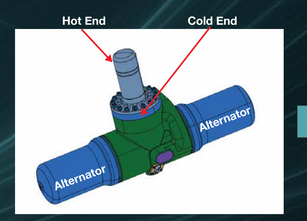
SUNPOWER ROBUST STIRLING CONVERTOR (SRSC) Sunpower, Inc.	
Power	65 W_e
Efficiency	29%
Hot-end	720°C
Specific Power	33 W_e/kg

THERMO-ACOUSTIC POWER CONVERTOR (TAPC) Northrup Grumman Aerospace Systems	
Power	110 W_e
Efficiency	26%
Hot-end	700°C
Specific Power	19 W_e/kg

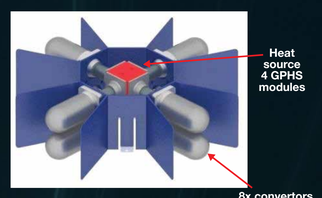
CONVERTORS

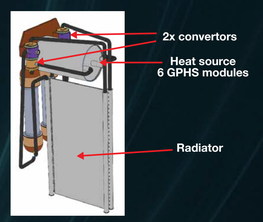


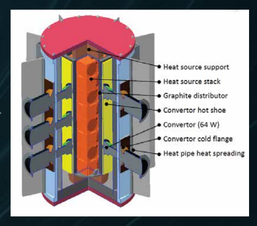




NOTIONAL GENERATOR DESIGNS







MISSION POTENTIAL

- Dynamic power conversion has never been flown in space
- Analogous cryocoolers have operated for up to 20 years in space
- First mission could be much shorter than outer planets (3 yrs vs 20 yrs)
- Lunar mission as flight demo is viable
  - Short cruise time, several destinations that require RPS, short mission duration
- For short missions, life with margin has been demonstrated at flight-prototype level
- For long missions (>15 years), demonstrating 2x life is unrealistic
- First mission must accept some amount of risk, which can be burned down
- Flightlike Stirling convertors have operated in lab setting for over 12 years (at full temp and power)
- NASA GRC test article holds all-time world record for heat-engine runtime (>110,000 hrs)

Flexure-bearing Stirling convertor continuous operation test article

Date	2010	2016
TDC #13	65.4 W	65.4 W
TDC #14	64.5 W	64.5 W

Example performance data of flexure-bearing convertors showing degration-free life

Test Article	Years of Operation
TDC #13	12.6
TDC #14	12.1
TDC #15	11.6
TDC #16	11.6

Test Article	Years of Operation
ASC-0 #3	8.3
ASC-E3 #4	3.1
ASC-E3 #6	2.4
ASC-E3 #9	1.6
ASC-E3 #8	1.9
ASC-L	4.0

Example cumulative runtimes on flight-relevant Stirling convertors at NASA GRC