
NETS
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NUCLEAR and EMERGING TECHNOLOGIES for SPACE
Update on Stirling Radioisotope Power Systems Development at NASA Glenn Research Center
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American Nuclear Society
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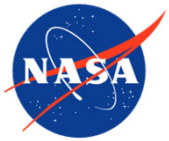

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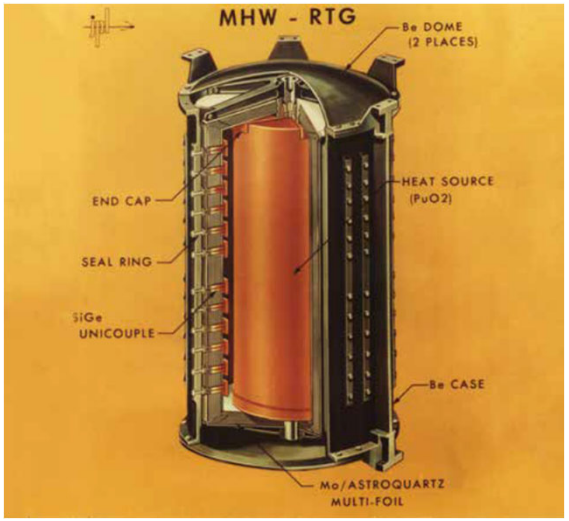
Brief History of Static Radioisotope Power Systems

Radioisotope Thermoelectric Generators (RTGs)

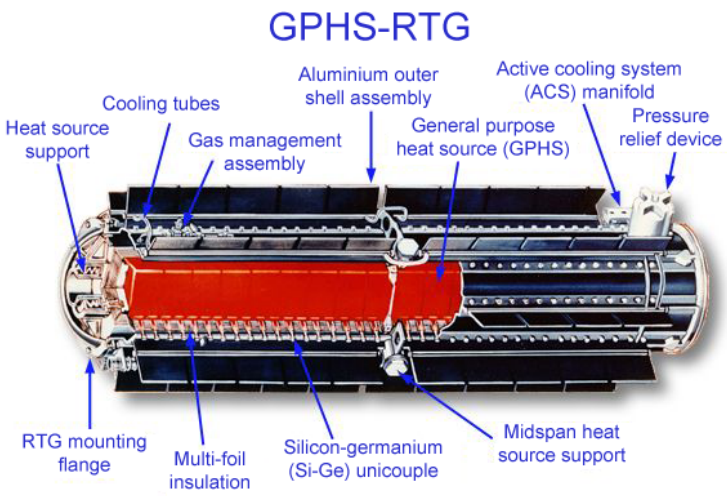
First Mission: 1961
Total Launched = 35 units
Power: 2.7 We – 157 We



Section View of MHW-RTG
(INL RPS Program)

General-Purpose Heat Source (GPHS) RTGs

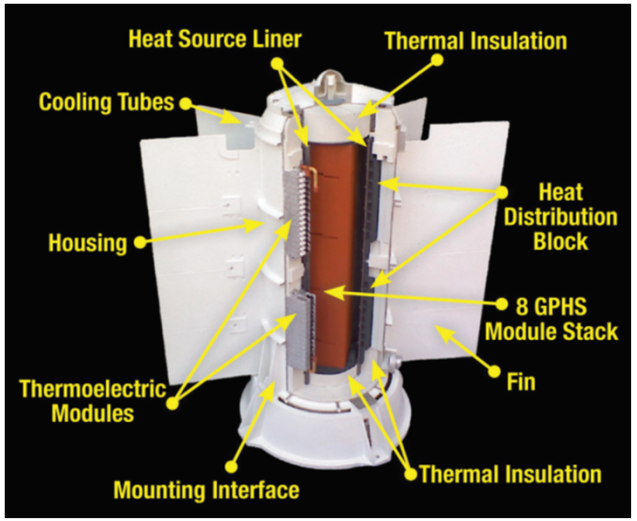
First Mission: 1990
Efficiency: 6.7%
Specific Power BOL: 5.3 We/kg



Section View of a GPHS-RTG
(Galileo/Ulysses model) (DOE/NASA/JPL)

Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs)

First Mission: 2011
Efficiency: 6%
Specific Power BOL: 2.8 We/kg



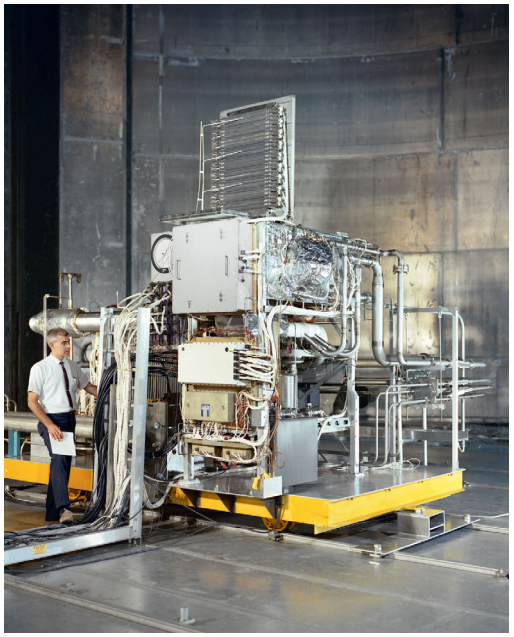
Model of an MMRTG
(NASA)

Introduction of Dynamic Radioisotope Power

Many Missions Demand:

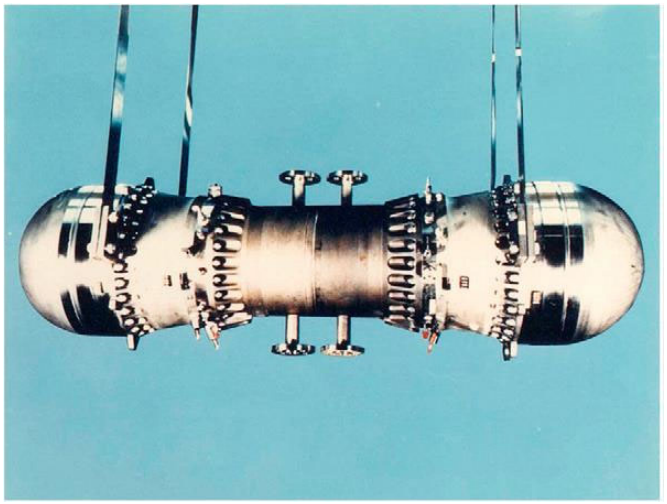
- Increased Overall Efficiencies
- Higher Reliability and Redundancy
- Less Fuel Required
- Flexibility in Many Environments

So, development began in the 1970s and on →



The Space Power Demonstration Convertor (SPDE) – 1987

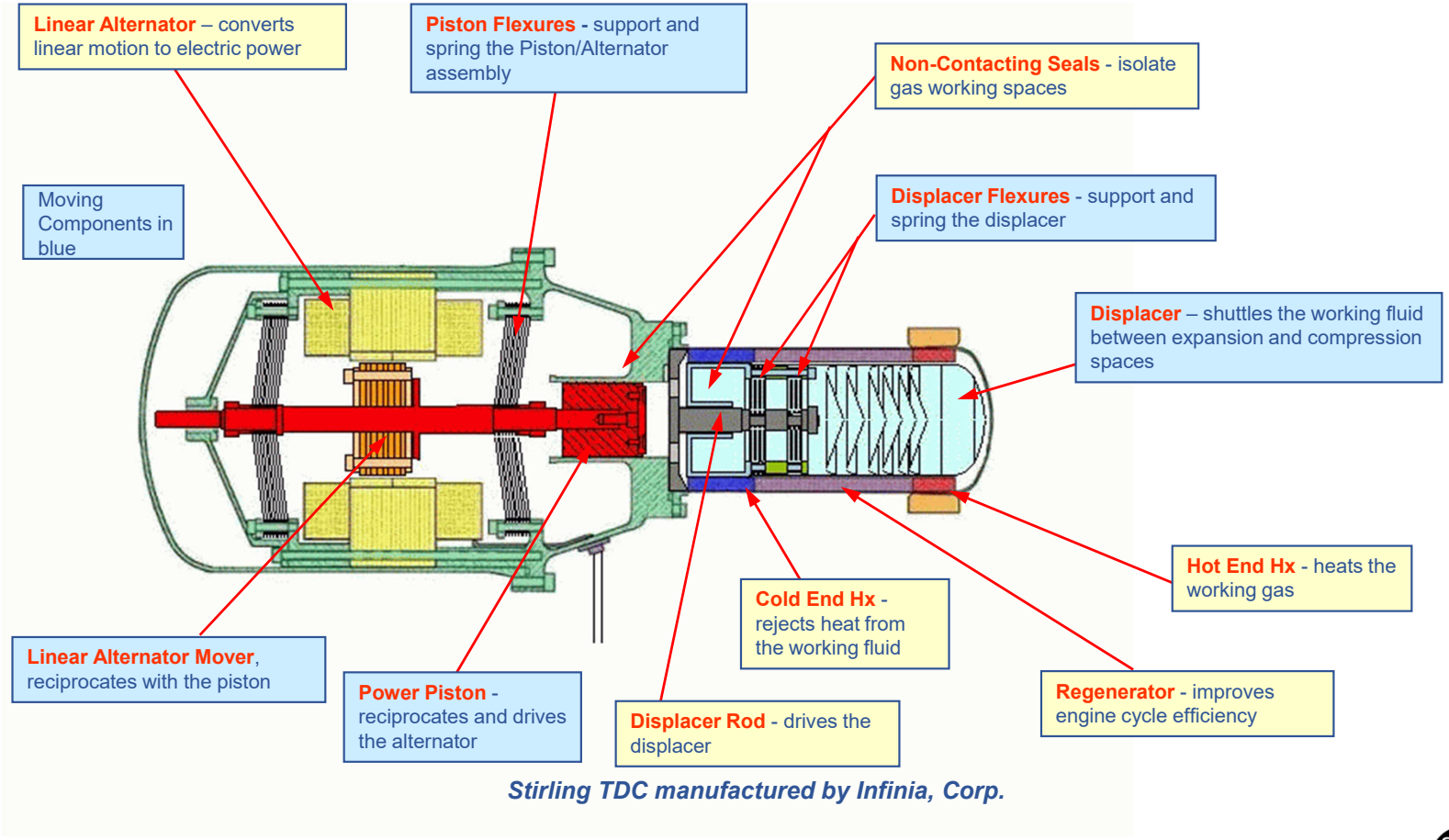
Power Output: 25 kWe



Brayton Rotating Unit (BRU) System Test at ATF – 1972

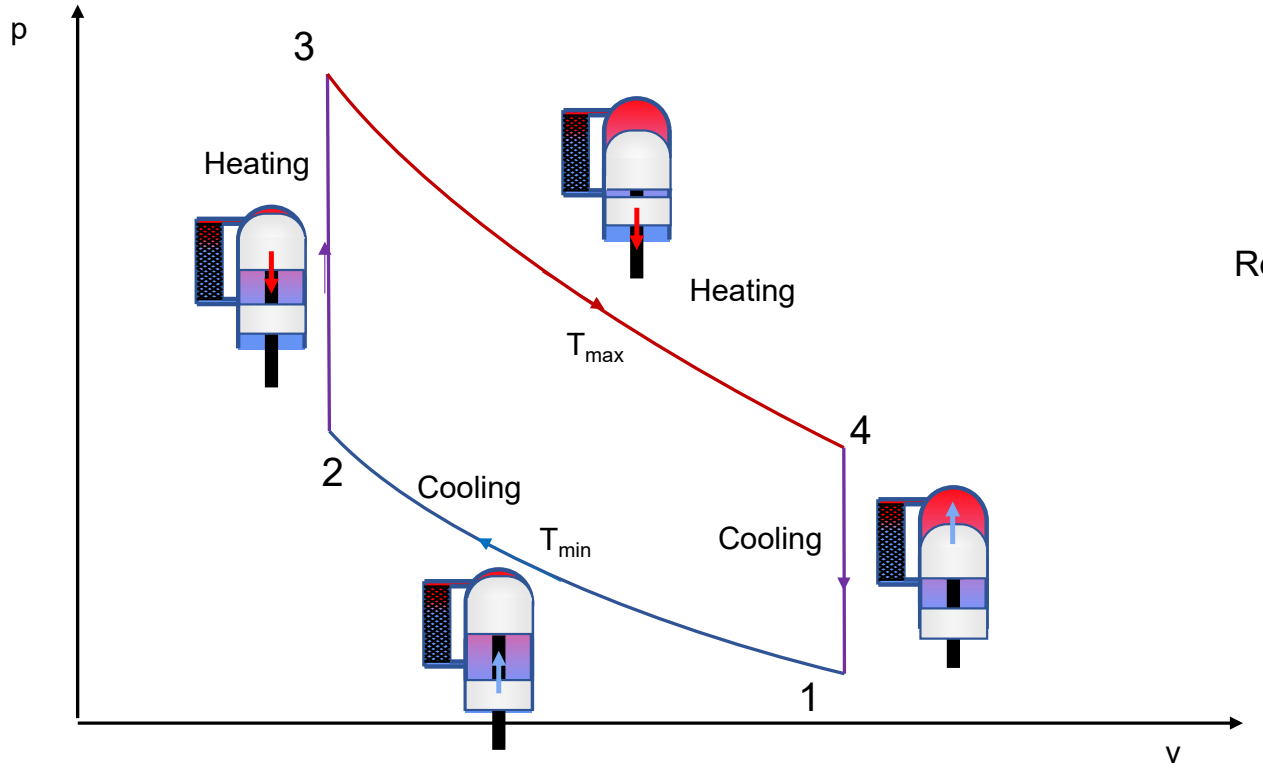
Power Output: 10 kWe

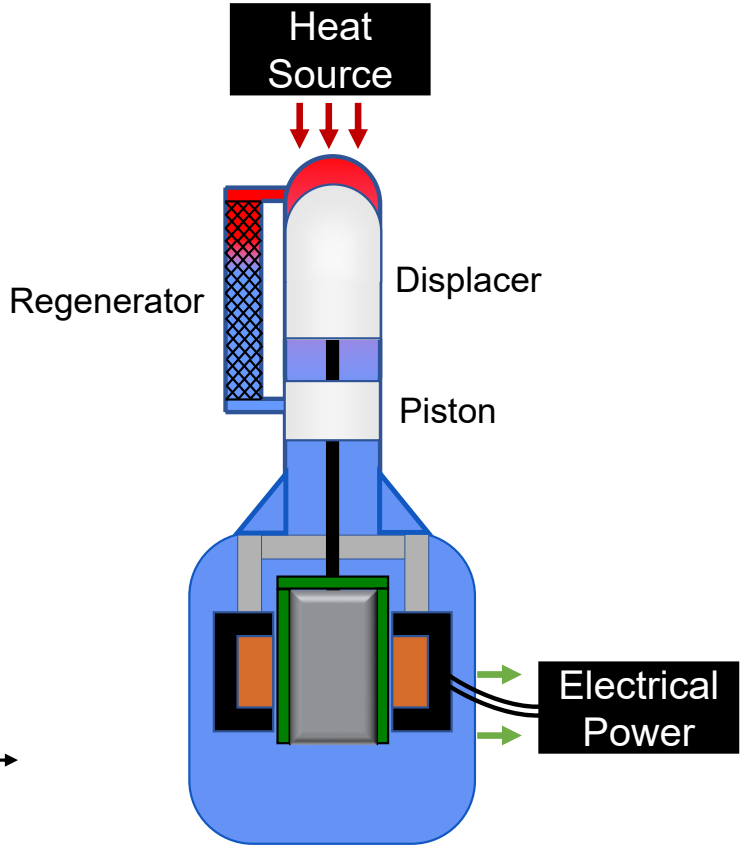
Dynamic Radioisotope Power – Stirling Conversion



Stirling TDC manufactured by Infinia, Corp.

Operation Cycle of Free-Piston Stirling Convertors

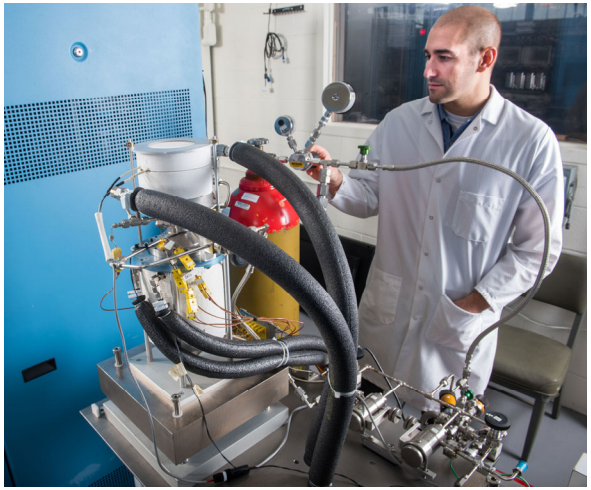




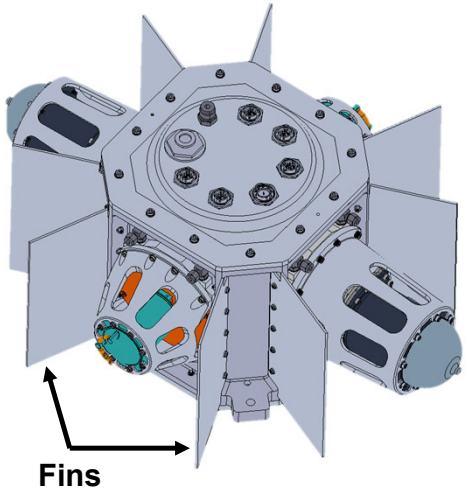
Extended Operation Milestones

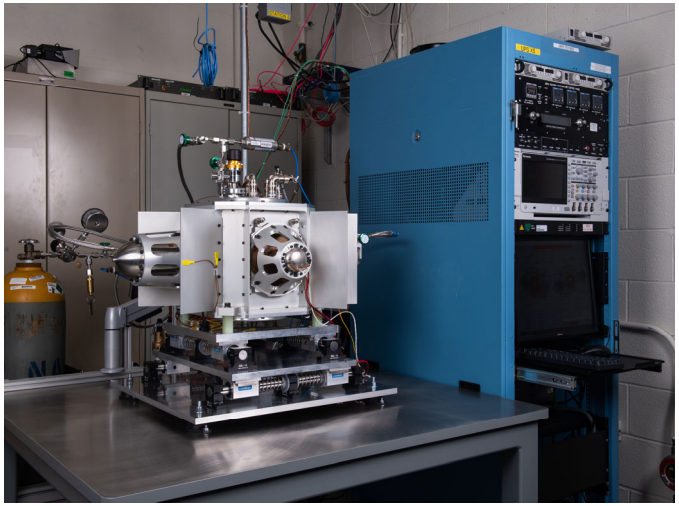
Unit	Hours	Years	Cycles (B)	
TDC #13	154,872	17.7	45.4	Word Record!
TDC #14	105,616	12.1	31.0	
TDC #15	152,573	17.4	44.9	Word Record!
TDC #16	152,573	17.4	44.9	Word Record!
ASC-0 #3	121,978	13.9	45.8	Word Record!
ASC-L	79,541	9.1	29.3	
ASC-E3 #4	59,360	6.8	21.8	
ASC-E3 #9	45,404	5.2	16.7	
SES #2	47,666	5.4	14.0	
SRSC #1	13,903	1.6	5.0	
SRSC #2	20,077	2.3	7.2	
SRSC #3	17,359	2.0	6.2	
SRSC #4	11,278	1.3	4.0	
FISC #1	10,058	1.1	3.0	
FISC #2	13,163	1.5	3.9	

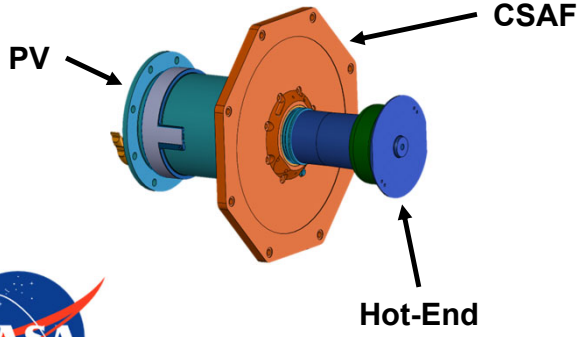
Extended Operation Data as of 10/21/2024

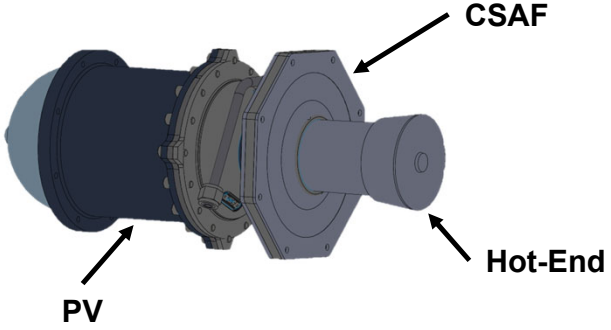


Stirling Generator Testbed







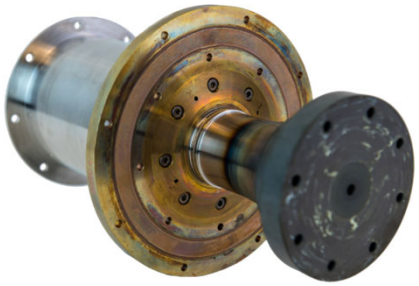


First Operation at Steady-State Baseline Condition

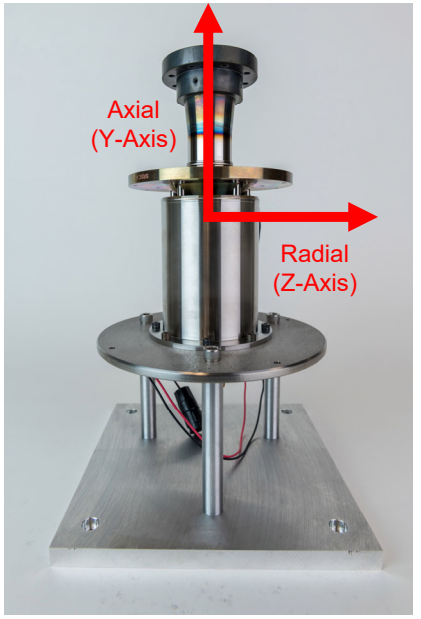
Parameter	1A	1B	2A	2B	Units
Avg. Hot-End Temp.	501.5	497.9	496.4	497.4	°C
Avg. CSAF Temp.	62.0	63.4	69.4	68.0	°C
Avg. PV Temp	57.3	55.9	49.7	47.0	°C
Heat Collector Plate Temp.	545.7	-	-	-	°C
Piston Amplitude	2.8	2.9	3.6	3.6	mm
Alt. Power	22.8	23.3	19.2	19.0	W_e
Charge Pressure	-	-	348.8	347	psia
Frequency	101.3		78.4		Hz
Avg. Fin Root Temp.	54.6				°C
Avg. Fin Tip Temp.	48.3				°C
Ambient Temp.	25.5				°C
Avg. Heat Source Temp.	609.4				°C
Heater Power	500.8				W
Total Power Output	84.3				W_e
Gross Efficiency	16.8				%
Housing Pressure	23.3				psia

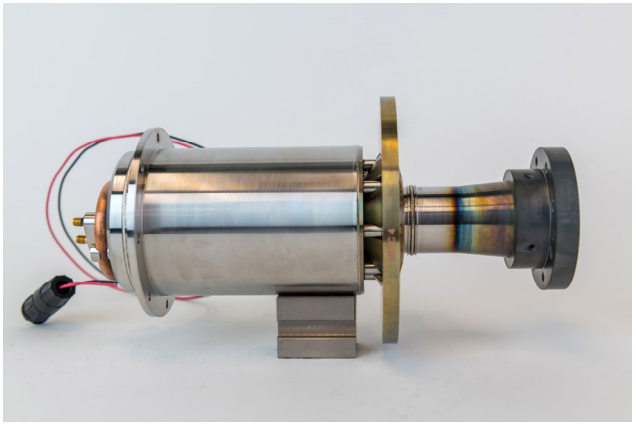
Sunpower Robust Stirling Convertor

SRSC #4 Design Parameters at Nominal Operation		
Mass (no interfaces)	2.0	Kg
Net Heat Input	250	W (Thermal)
Power Output	64	W (Electric)
Conversion Efficiency	26	%
Operating Frequency	99.6	Hz
Max Hot-End Temperature	700	°C
Max PV-Side Temperature	185	°C
Max Cold-End Temperature	175	°C
Design Life	17	Years



SRSC #4

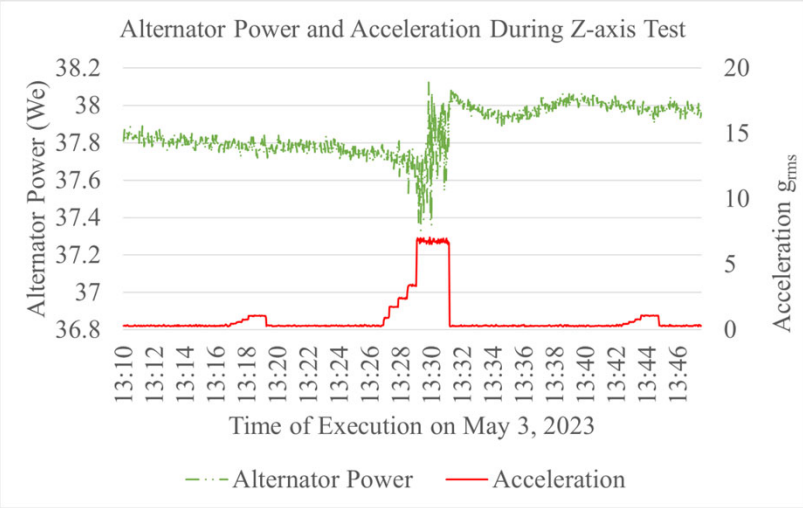


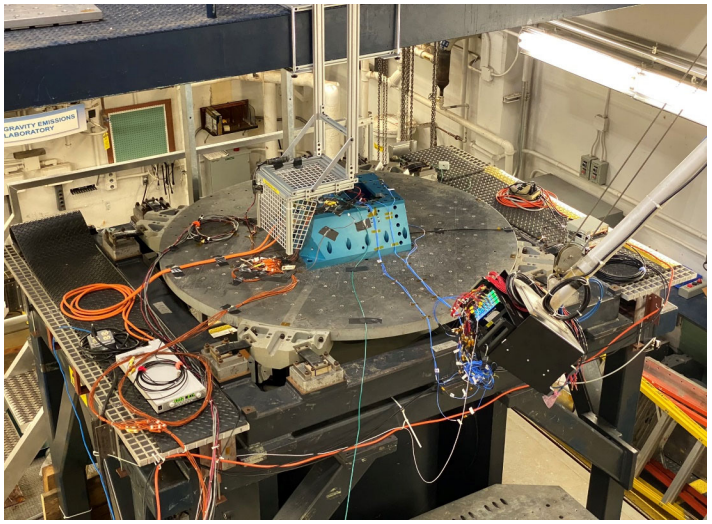


Qualification-Level Random Vibration

Purpose:

- Simulate Launch Sequences at B.O.M.
- Random Vibration of 7.7 grms in 3 axes





Configured for Z-axis testing at the GRC Structural Dynamics Laboratory

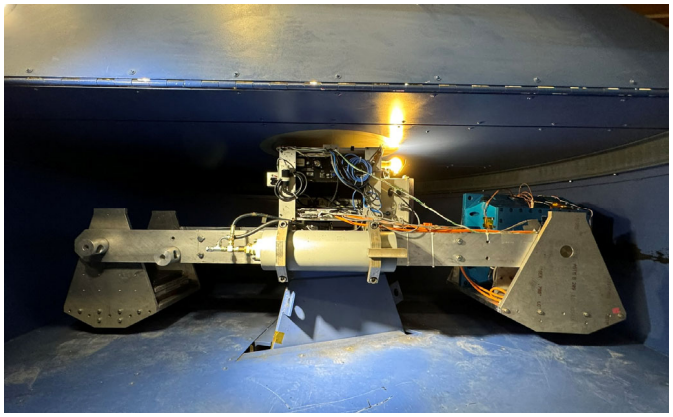
Parameter	Pre-Vibration	Post-Vibration	Difference
SRSC #3 Alternator Power (W)	55.2	55.8	0.6
SRSC #4 Alternator Power (W)	56.3	55.3	-1.0

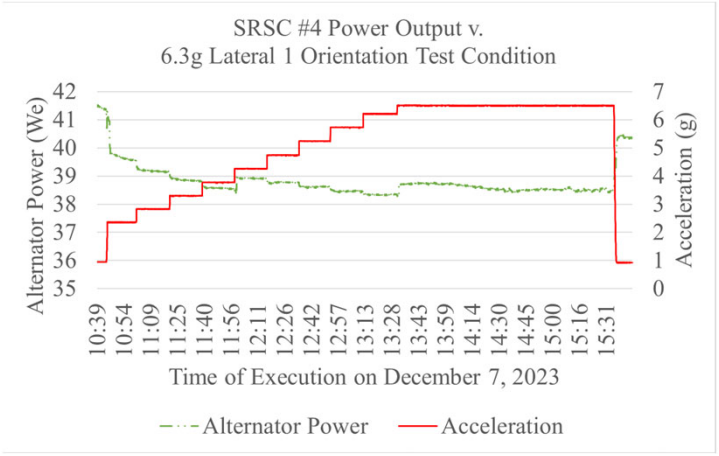
Qualification-Level Static Acceleration Testing

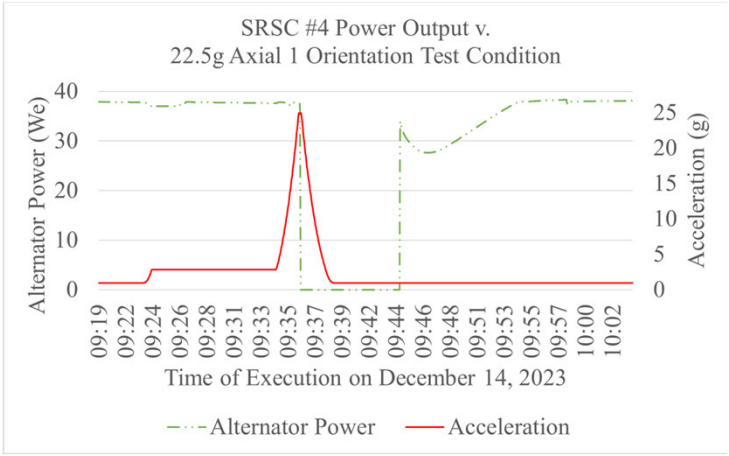
Testing Simulates:

- Launch Loads
- Reentry into Planetary Atmosphere
- Spin Stabilization During Cruise

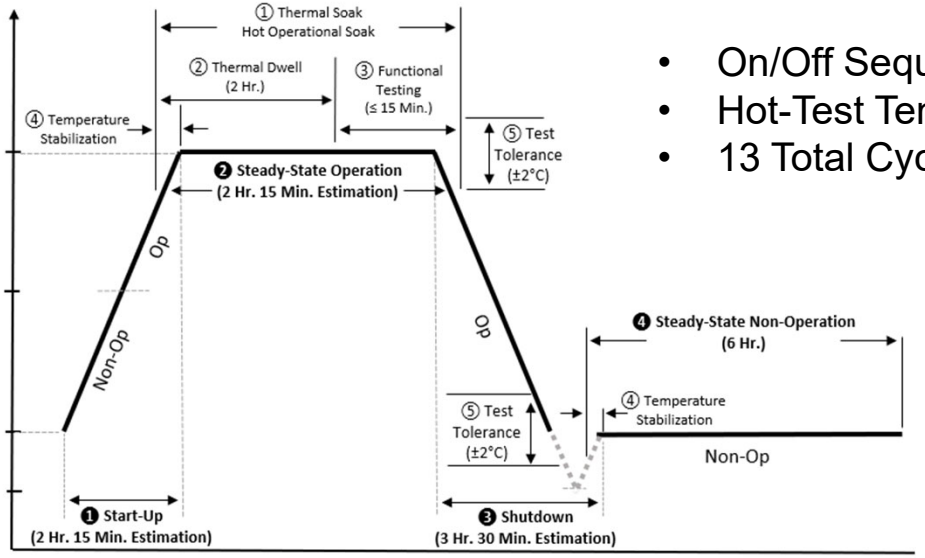
Parameter	Pre-Static Acceration	Post-Static Acceleration	Difference
SRSC #3 Alternator Power (W)	55.5	55.7	0.2
SRSC #4 Alternator Power (W)	55.7	55.3	-0.4







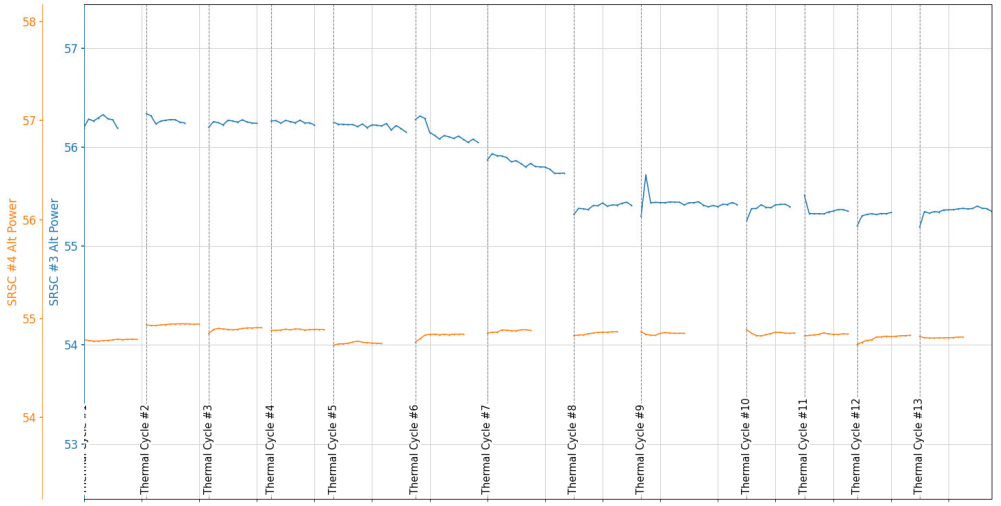
Qualification-Level Thermal Cycling



Purpose:

- On/Off Sequences During Generator Processing
- Hot-Test Temps & Cold-Test Temps
- 13 Total Cycles

Parameter	Pre-Thermal Cycling	Post-Thermal Cycling	Difference
SRSC #3 Alternator Power (W)	55.8	55.9	0.1
SRSC #4 Alternator Power (W)	55.3	55.1	-0.2



(Dr. Tyler Steiner – "RelevantEnvironmentDemonstrationsofSunpowerRobustStirlingConvertorsforRadioisotopePoweredMissions")

Additional Testing

Preliminary Assessment of Measurement Accuracy of SRSC Instrumentation and Data Systems in the SRL

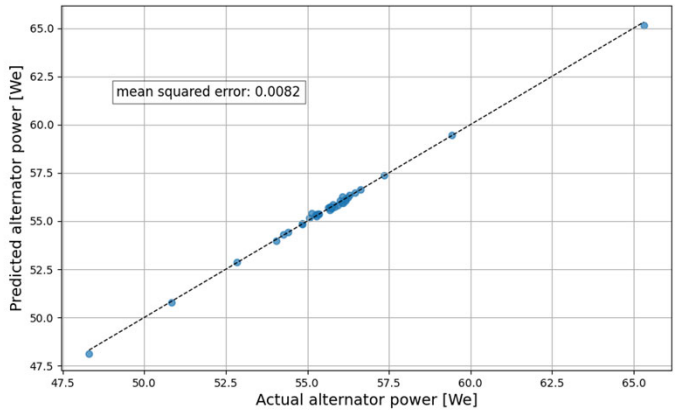
- **Baseline**: SRSC Operating at Extended Operation
- **Purpose**: Determined Sources That Dominate Overall Inaccuracies
- 22 Parameters Measured

Initial Findings	
Thermocouples	+/- 3°C
Heater Voltage	+/- 0.4 V
Heater Current	+/- 0.02 A
Position	+/- 0.04 mm
Charge Pressure	+/- 5 psig
Acceleration	+/- 0.009 g
Convertor Power Output	+/- 2.0 W_e

SRSC Sensitivity Study

- **Baseline**: SRSC Operating at Extended Operation
- **Purpose**: Quantify Response of Parameters to Controlled Perturbations to Then Create a Predictive Equation for Power Output
- 39 Operating Points Measured

- Allows Easy Comparison Between Actual and Theoretical Convertor Power



Conclusions and Ongoing Work

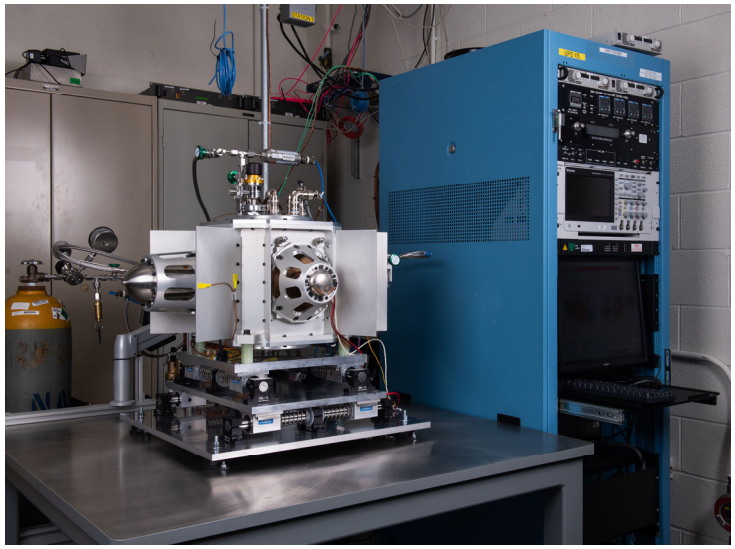
SRL's Mission:

- Furthering the advancement and TRL of:
  - Stirling Convertors
  - Controllers
  - Generators
- Tailored Testing to Component, Subsystem, and Systems Level

Ongoing Work:

- SRSC #5 Beginning V&V Testing
- Stirling Generator Testbed Continued Campaign
- Controller Development

SRSC #5



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