Controller Development for Dynamic Radioisotope Power System

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This document contains no ITAR or EAR controlled technical information

Agenda

- MMRTG to DRPS

- Stirling Fundamentals

- AR's Universal-Engine Controller

- DRPS Multi-Engine Controller

- Redundancy

- Vibration Transmission

- Conclusion

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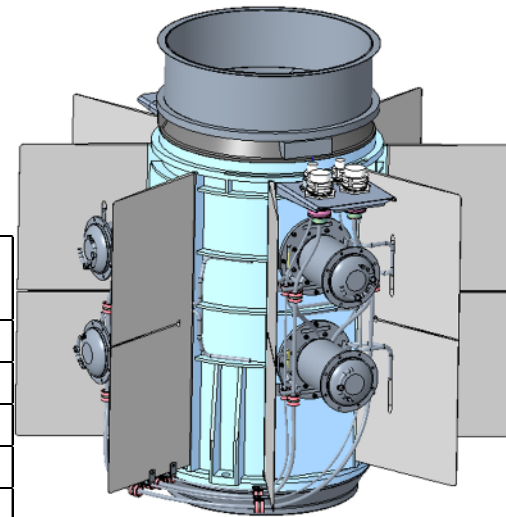# Radioisotope Thermoelectric/Dynamic Generator

AEROJET ROCKETDYNE

Radioisotope Thermoelectric Generator

General Purpose Heat Source (GPHS)
Pu-238 Provide 250Wt

Radioisotope Thermodynamic Generator

	MMRTG BOL	MMRTG EOL	Stirling BOL	Stirling EOL	Units
# of GPHS	8	8	6	6	nu
Thermal Input	2000	2000	1500	1500	Watt
DC Power	124	70	294	242.4	Watt
Mass	45	45	126	126	kg
Efficiency	6.2%	3.5%	19.6%	16.2%	Percent
GPHS Utilization	15.5	8.75	48.9	40.4	We/GPHS

Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) mounted on Mars Science Laboratory (MSL)

Dynamic Radioisotope Power System (DRPS) Conceptual Design with:
6 GPHS,
8 Stirling Convertors

DRPS will generate over 3 times the electrical power from each GPHS

How does a Stirling Engine Work?

Flexures

Stator Coils

Pwr_out

Q_out

Q_in

"Sink" HX Cooler

Regenerator

"Source" HX Heater

Flexures

Heat Shields

Stator Magnets

Alternator Stator Laminations

Alternator "Mover" Laminations

"Power" Piston
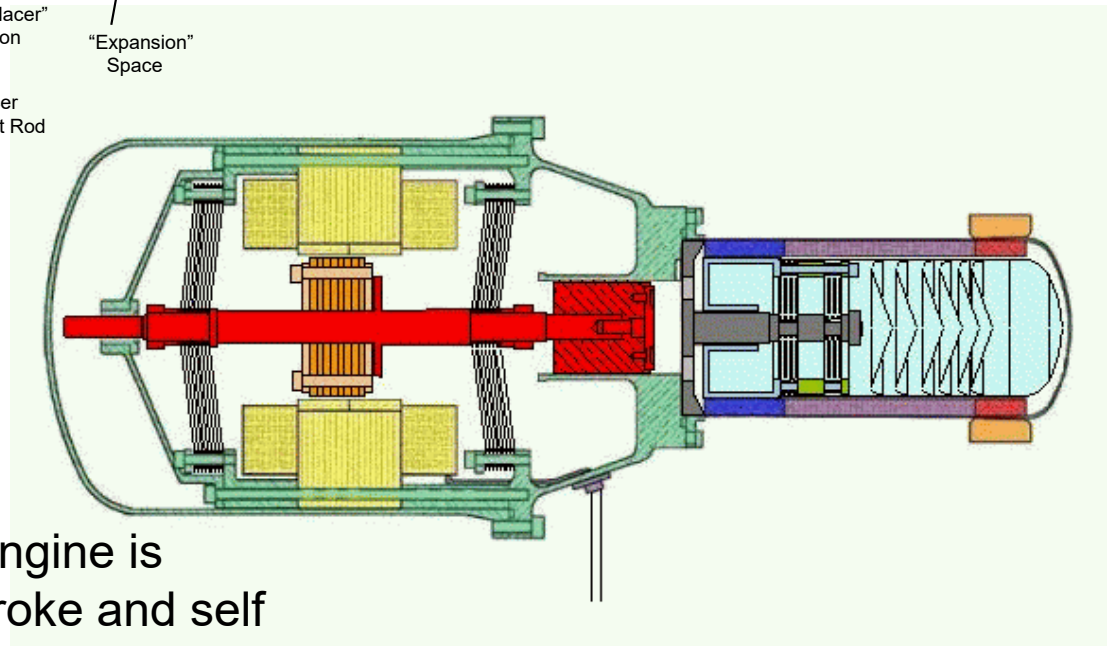
"Compression" Space

Displacer Support Rod

"Displacer" Piston

"Expansion" Space
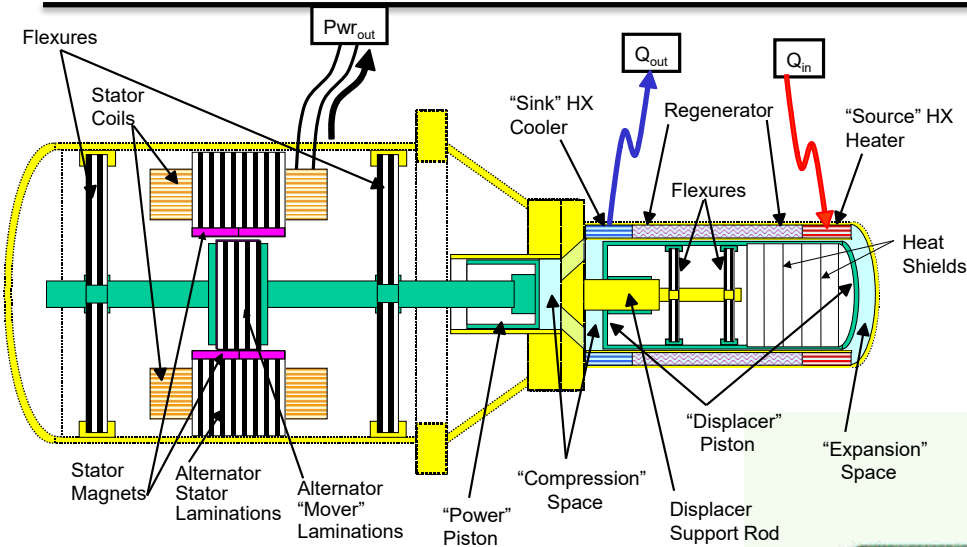
Heat input: causes displacer head to oscillate with appropriate delta T

If you couple a displacer to an alternator you can generate electricity.

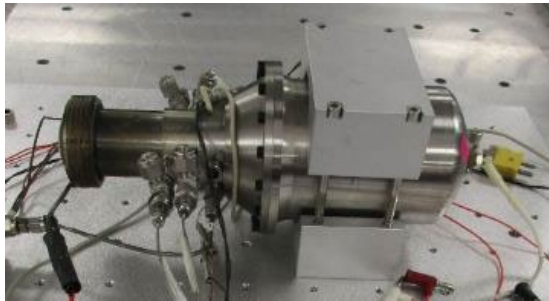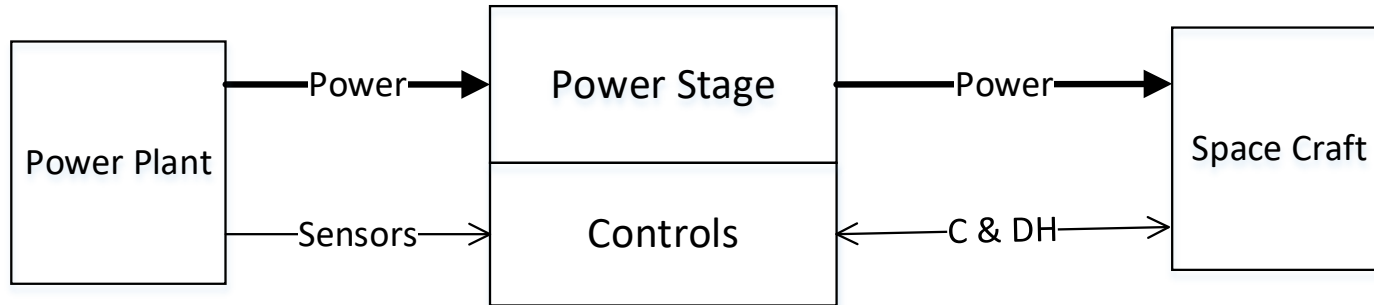Without a proper electrical load engine is unstable and may stall or over-stroke and self destruct.

How do you make a system stable?

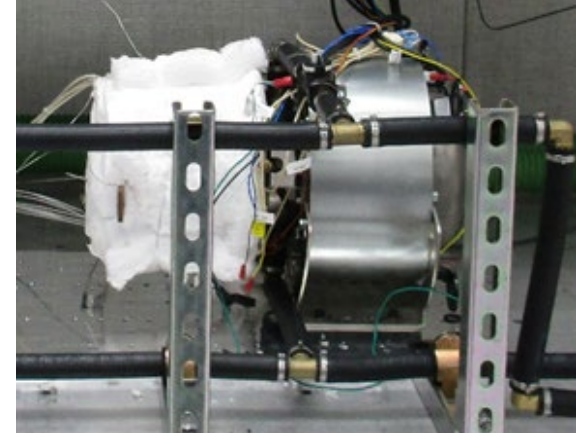With a Controller

Multi-Engine Controller Architecture

Stirling Controller Block Diagram

Power Plant → Power → Power Stage → Power → Space Craft

Power Plant → Sensors → Controls ← C & DH → Space Craft
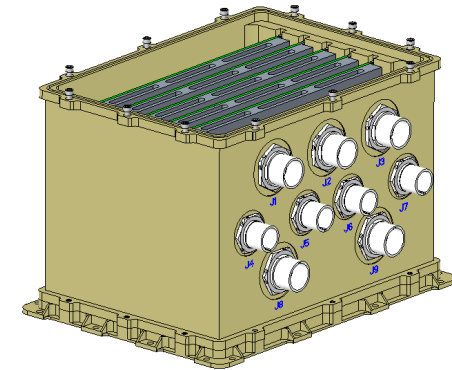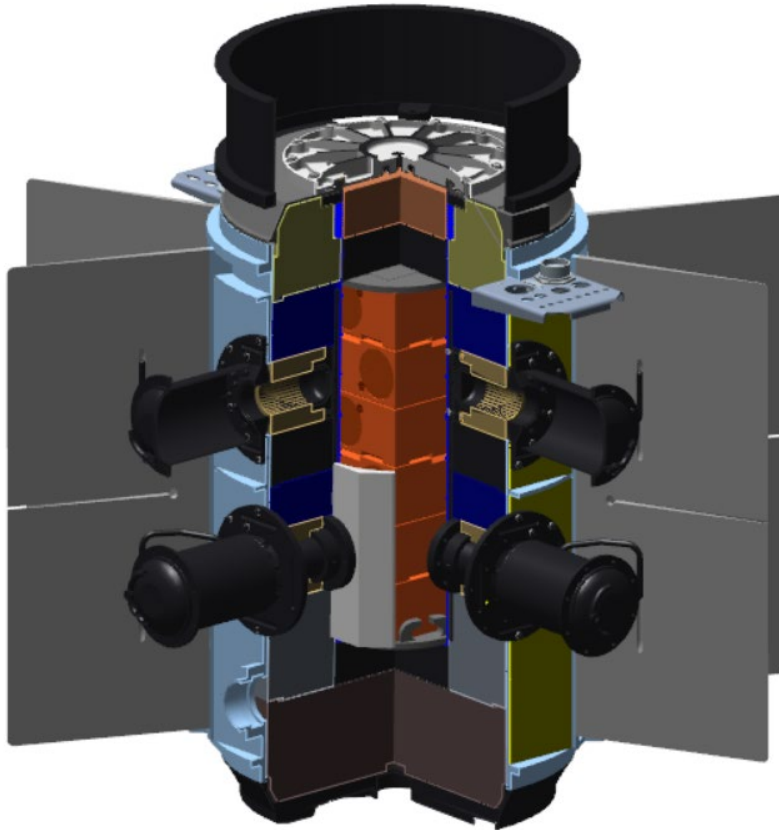
AMSC
55We TDC
180Vrms, 80Hz

Sunpower
80We ASC
20Vrms, 100Hz

Microgen
1kWe
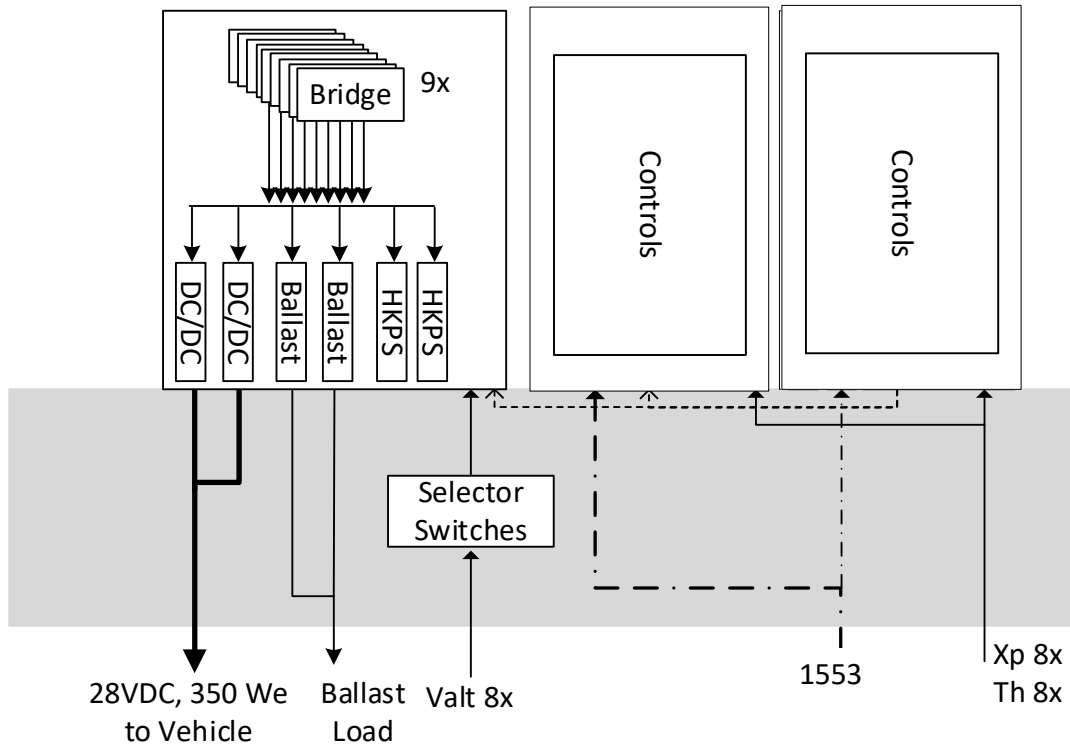240Vrms, 60Hz

DRPS Conceptual Design

Controller Conceptual Packaging

- Controller regulate the vibration and power of each the eight engines ensuring each engine stays with in it acceptable operating ranges.

6

- Only six engines are required to maintain system performance requirements

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Spare Engines Provide Redundancy

AEROJET ROCKETDYNE

- Redundant Control Cards

- Redundant Power Processing Cards

Bridge 9x

DC/DC · DC/DC · Ballast · Ballast · HKPS · HKPS

Controls

Controls

Selector Switches

28VDC, 350 We to Vehicle · Ballast Load · Valt 8x

1553

Xp 8x Th 8x

Redundancy Provides Failure Tolerance

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Vibration Control Minimizes Structural Effect

- Net Transmitted forces must be <= 10N.

- Each convertors has an individual force of > 250N

- Controller must synchronize and cancel all forces accounting for performance deltas if each engine

- Various phase combinations were analyzed to identify configuration with the optimal results.
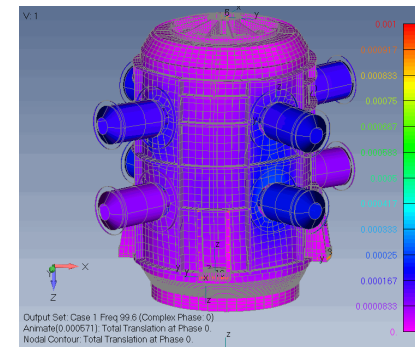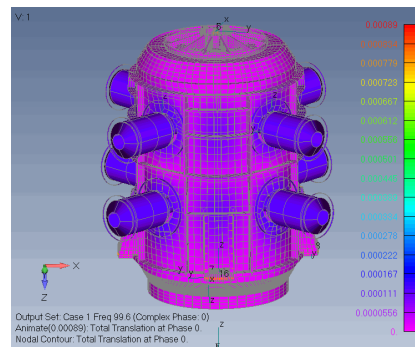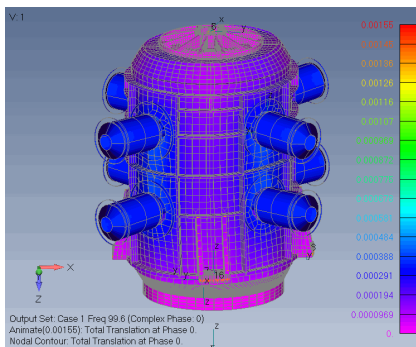
Control Modes Meet Vibration Requirements

Conclusion

- AR's Controller will Enable

    - Enable 3 to 4x increase in power over traditional RTG's

    - DRPS requires sophisticated Controller to manage the health and life of the Stirling Convertors and vibration influence on external system.

    - Health monitoring and control of key parameters for a long life mission

- AR's controls approach is applicable to a wide range of Stirling Convertors.