AEROJET ROCKETDYNE

Controller Development for Dynamic Radioisotope Power System



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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

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Radioisotope Thermoelectric Generator



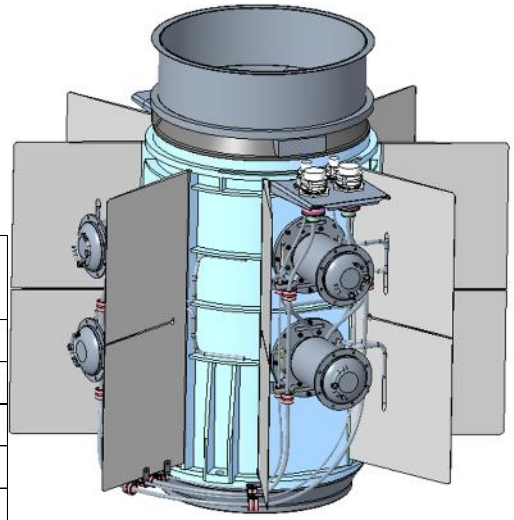
Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) mounted on Mars Science Laboratory (MSL)



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

	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

Radioisotope Thermodynamic Generator

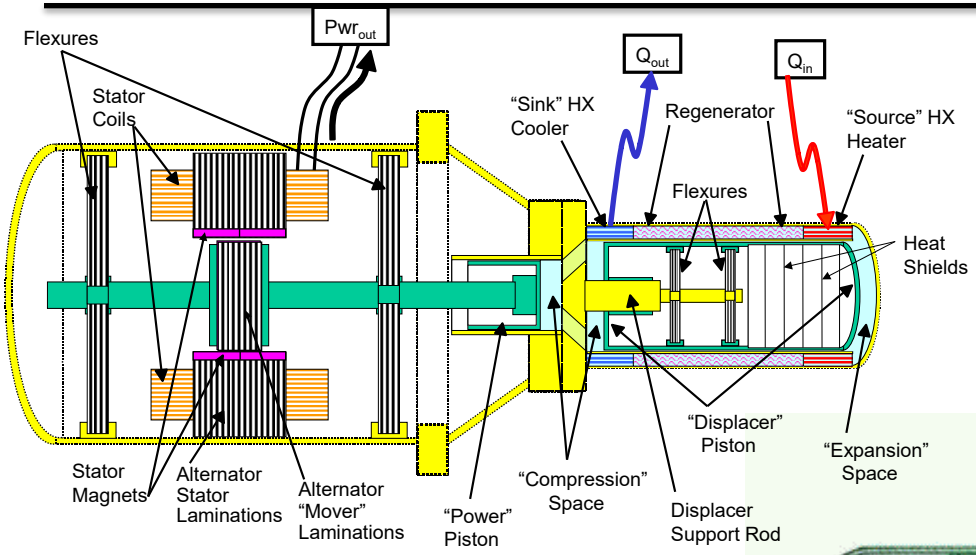


Dynamic Radioisotope Power System (DRPS) Conceptual Design with:
6 GPHS,
8 Stirling Convertors

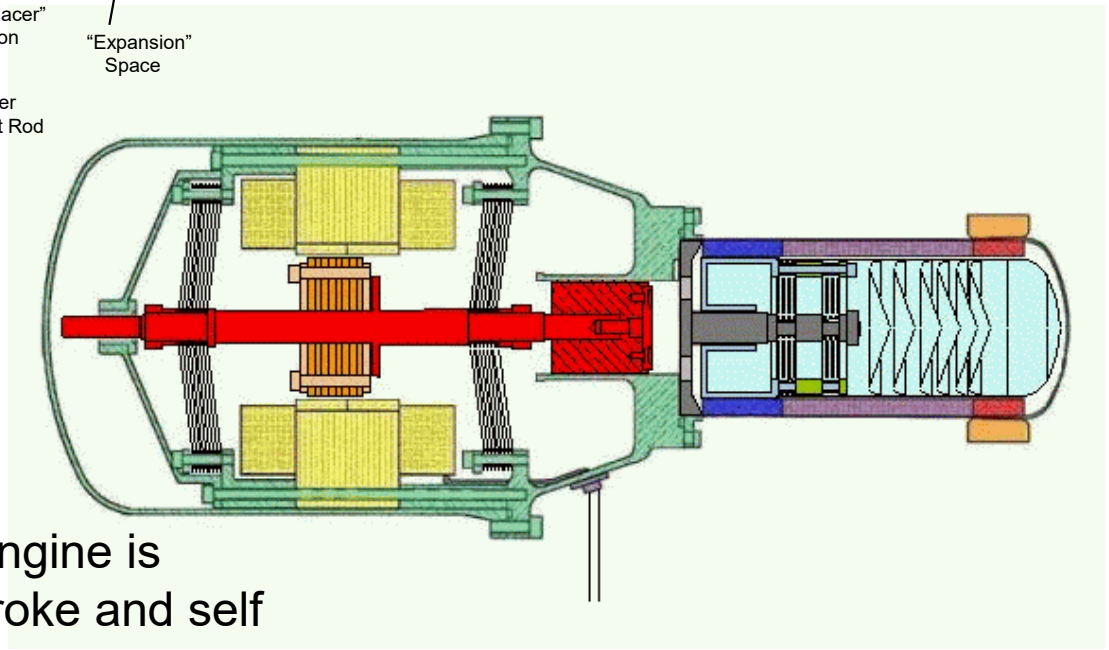
DRPS will generate over 3 times the electrical power from each GPHS

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How does a Stirling Engine Work?



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?

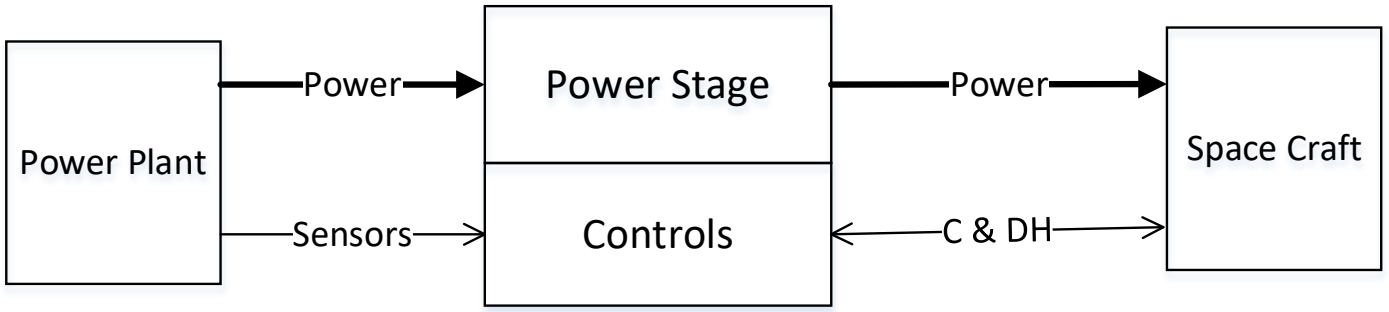
With a Controller

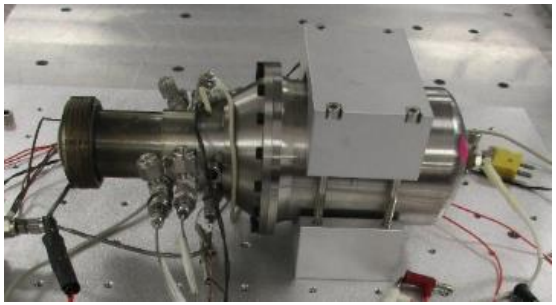
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Multi-Engine Controller Architecture

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Stirling Controller Block Diagram

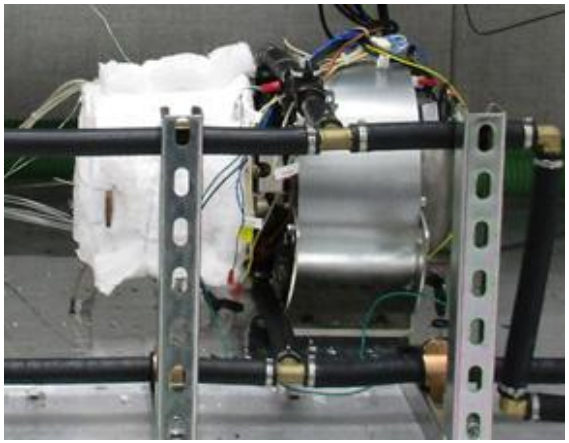




AMSC
55We TDC
180Vrms, 80Hz



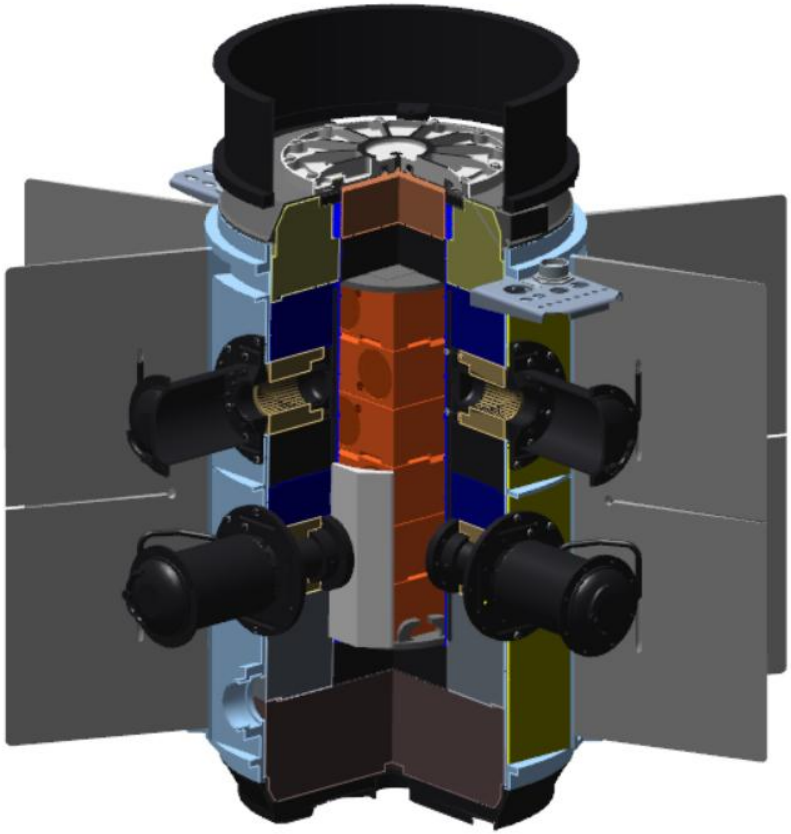
Sunpower
80We ASC
20Vrms, 100Hz

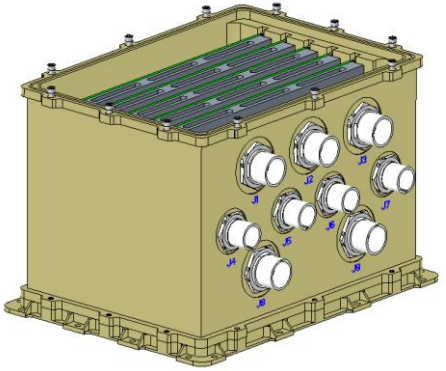


Microgen
1kWe
240Vrms, 60Hz

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DRPS Conceptual Design





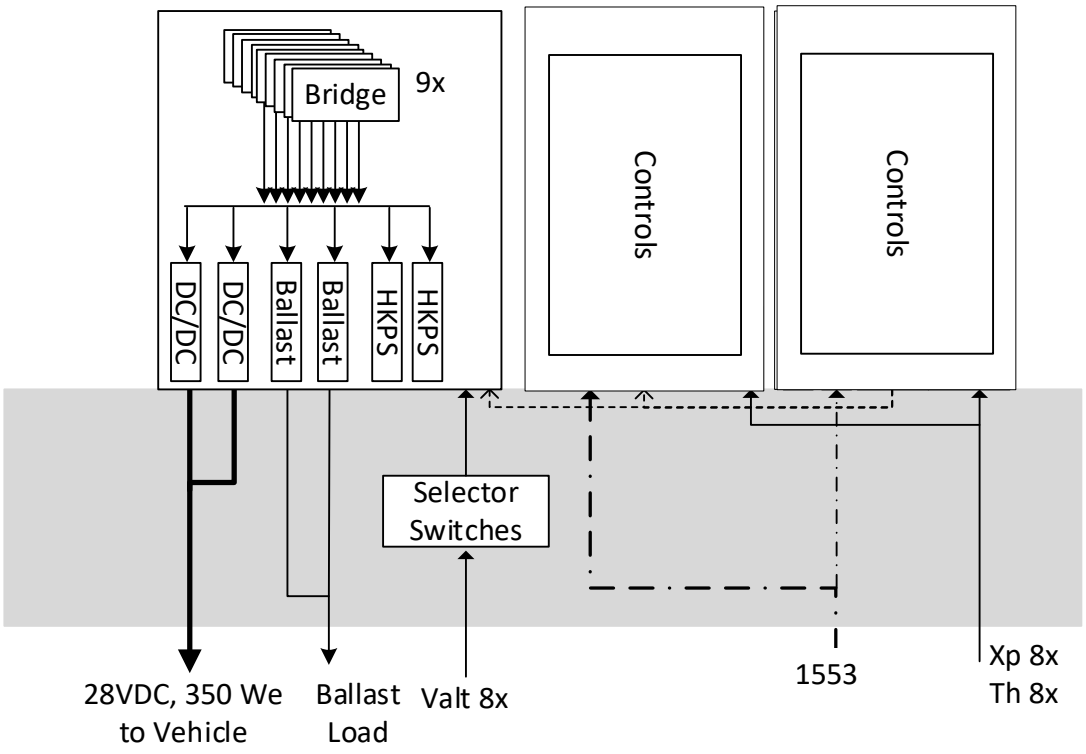
Controller Conceptual Packaging

- Controller regulate the vibration and power of each the eight engines ensuring each engine stays with in it acceptable operating ranges.
- Only six engines are required to maintain system performance requirements

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Spare Engines Provide Redundancy

- Redundant Control Cards
- Redundant Power Processing Cards

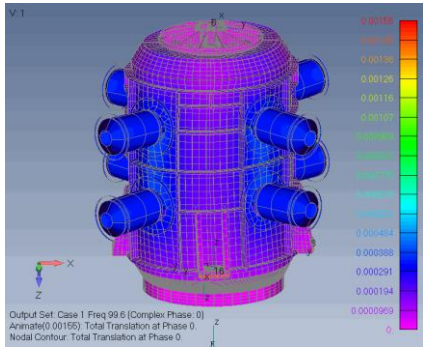


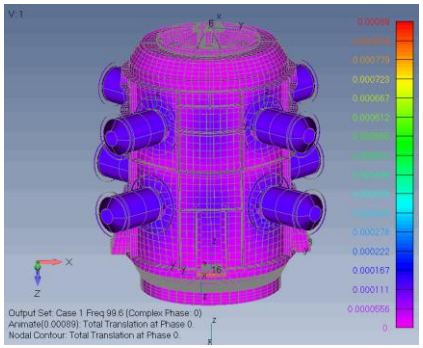
Redundancy Provides Failure Tolerance

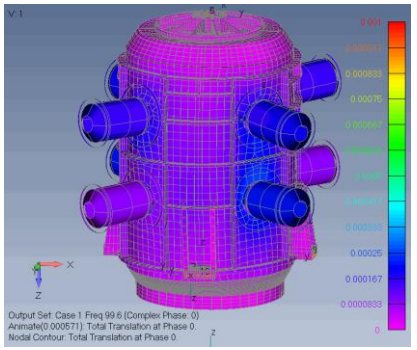
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Vibration Control Minimizes Structural Effect

- 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

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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.

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