Testing of the Advanced Stirling Radioisotope Generator Engineering Unit at NASA Glenn Research Center

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Purpose

- Advanced Stirling Radioisotope Generator (ASRG) engineering unit (EU) has been on test at NASA GRC for almost 4 years and has accumulated over 27,000 hours of operation
- How has the ASRG EU been operated and tested?
- What have we learned?
- Future plans
Outline

• Advanced Stirling Radioisotope Generator Engineering Unit (ASRG EU) Background
• Test facility
• ASRG EU and ASRG Flight Unit
• Overview of ASRG EU testing
• How the ASRG EU was controlled
• Tests conducted under AC bus control
• Tests conducted under ASC Controller Unit (ACU) control
• Test data
• Conclusion
ASRG EU Background

- ASRG system integration contractor Lockheed Martin, under contract to the Department of Energy, designed and built the ASRG EU

- ASRG Engineering Unit (EU) designed and fabricated by LM, then underwent system-level tests to qualification level
  
  Thermal balance - thermal model validation
  
  Thermal performance - in thermal vacuum chamber, tested beyond allowable flight temperatures
  
  Sine transient – verify ASRG response to 5 to 80 Hz range to qualification level in two axes
  
  Random vibration – to qualification level in three axes
  
  Simulated pyrotechnic shock – to qualification level in two planes
  
  Electromagnetic interference (EMI) – conducted and radiated emissions and susceptibility

- Delivered to NASA Glenn Research Center on August 28, 2008 to begin extended operation

ASRG Flight Unit, courtesy of Lockheed Martin
The ASRG EU Test Facility

- Mounted vertically
- Two control options: AC bus control and ASC Controller Unit (ACU)
- Heat rejection through forced convection
- Full data set recorded every 2 seconds
- Data includes:
  - Temperatures
  - Heater power
  - Alternator voltage, current, power
  - DC bus voltage, current, power
  - Piston amplitude
  - Interface force and acceleration
  - ACU telemetry
  - Other parameters
The ASRG EU and the ASRG Flight Unit

Differences between the ASRG EU and ASRG Flight Unit

- Flight controller remotely mounted
- Longer flight radiator fins
- Increased flight convertor hot-end temperature
- Flight generator operating temperature range increased
- Flight convertor alternator voltage increased
- Electrical shunts moved from inside the generator to outboard end of the flight generator
Summary Overview of ASRG EU Testing

- Over 27,000 hours total operation
- 15,378 hours of operation on EDU 1 ACU
How the ASRG EU was Controlled

ASRG EU under AC bus control

ASRG EU under EDU 1 ACU control
Tests Conducted under AC Bus Control

- AC bus voltage variation
- Heat input variation
- Cold-end and pressure vessel temperature variation
Tests Conducted under EDU 1 ACU Control

Controller level tests
- ASC stability under ACU control
- ACU stability and drift
- ASC voltage setpoint command resolution
- Operating frequency command resolution
- Performance under different control modes
  - Voltage control
  - Piston amplitude control
  - Temperature control

System Characterization Tests
- ASC voltage setpoint variation
- DC bus voltage variation
- Heat input variation
- Core loss test
Convertor Output Power

- Setpoint adjustment
- 1st set of rack improvements
- 2nd set of rack improvements
- Begin ACU control
- Begin heat input effect test
- Resume AC bus control
- 32 hours of EDU 2 ACU control
- Removed J2 connector saver
- 24 hours operation on cards 1 & 2
- Recalibration
- Begin natural convection test
- End natural convection test
- Resume operation on cards 1 & 2
- Recalibration
- Resume AC bus control

**Graph Details**

- **Y-axis**: Power (W)
- **X-axis**: Time (hrs)
- **Legend**:
  - ASC A - ASC-E #2
  - ASC B - ASC-E #3
Heat Rejection Temperatures

- Windows replaced; add more auxiliary fans
- Natural convection test: 13,128-13,636 hrs
Conclusion

**ASRG EU performed an important role in the ASRG development**

- Integrated Stirling convertors with an electronic controller in a housing suited for radioisotope fuel
- Pathfinder for many of the manufacturing processes, assembly procedures, and tests
- Tests provided insight into characteristics and nuances of the ASRG relevant to mission
- EDU 1 controller proved the viability of the PWM-based control approach and paved the way for later generations of the controller (EDU 2, EDU 3, to be followed by the flight-like EDU 4)
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