

Jet Propulsion Laboratory
California Institute of Technology

Characterization Testing of Lockheed Martin High-Power Micro Pulse Tube Cryocooler

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Lockheed Martin High-power Microcooler (Micro 1-2)

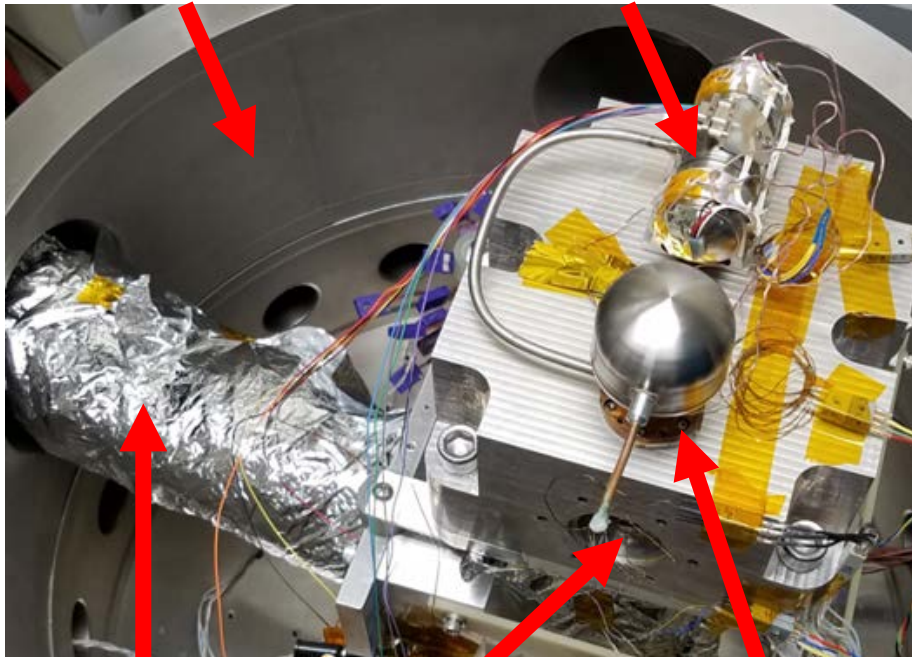


- Pulse tube type
 - Flexure bearings
 - Maturity level: TRL 6 for Earth orbit
 - Mass: 450 grams
 - Compressor: 92 mm long
 - Coldfinger: 160 mm long
 - Optimized for 105 K cold tip
 - 60 W maximum input power
 - Operates at <180 K heat reject
 - 7,700 hour life-test at LM
-
- The Jet Propulsion Laboratory has baselined this cooler for the Mapping Imaging Spectrometer for Europa (MISE) instrument on the planned Europa Clipper
 - Characterization tests were performed to better understand the cooler's behavior in Europa environment

Thermal Vacuum Performance Testing

Vacuum chamber

Compressor temperature



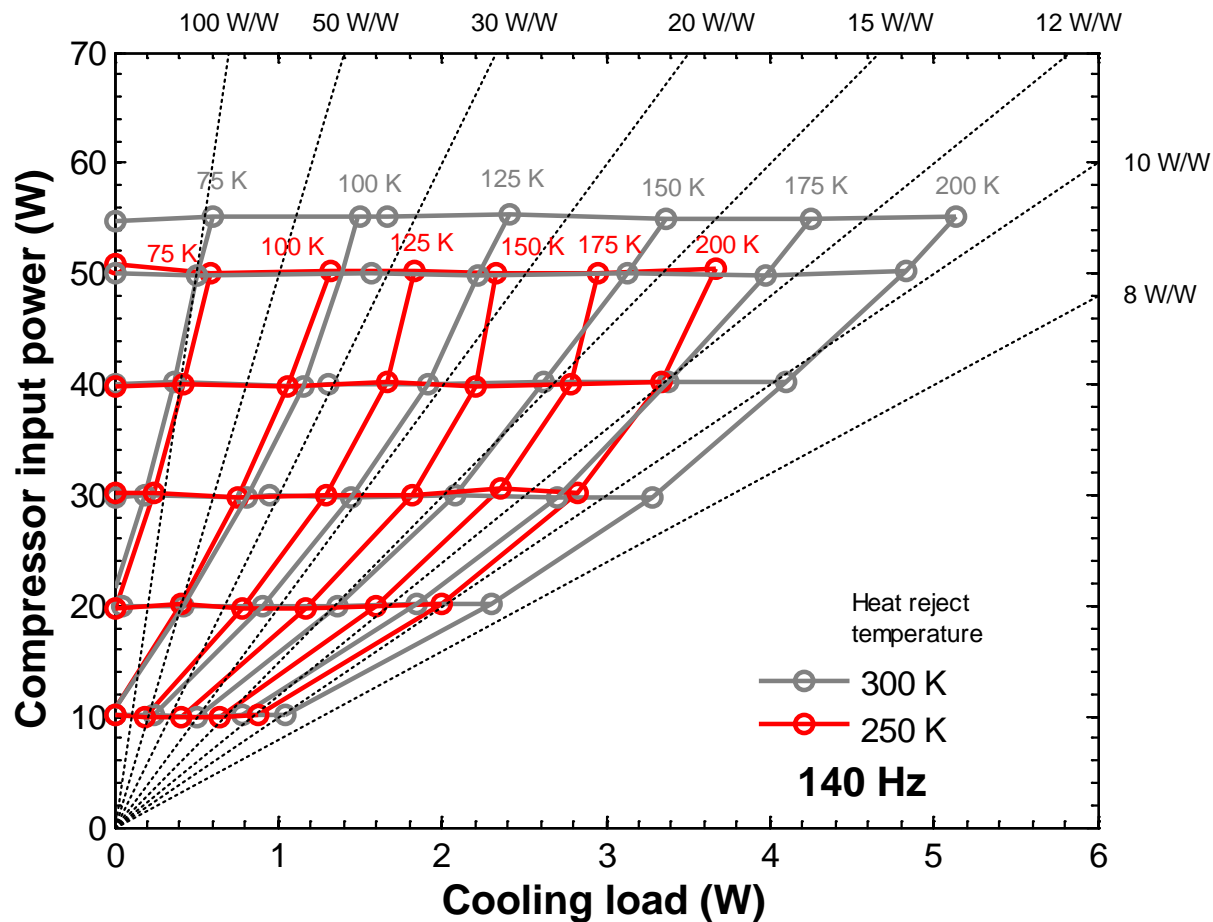
CTI 1050 coldhead

Cold tip

Heat reject temperature

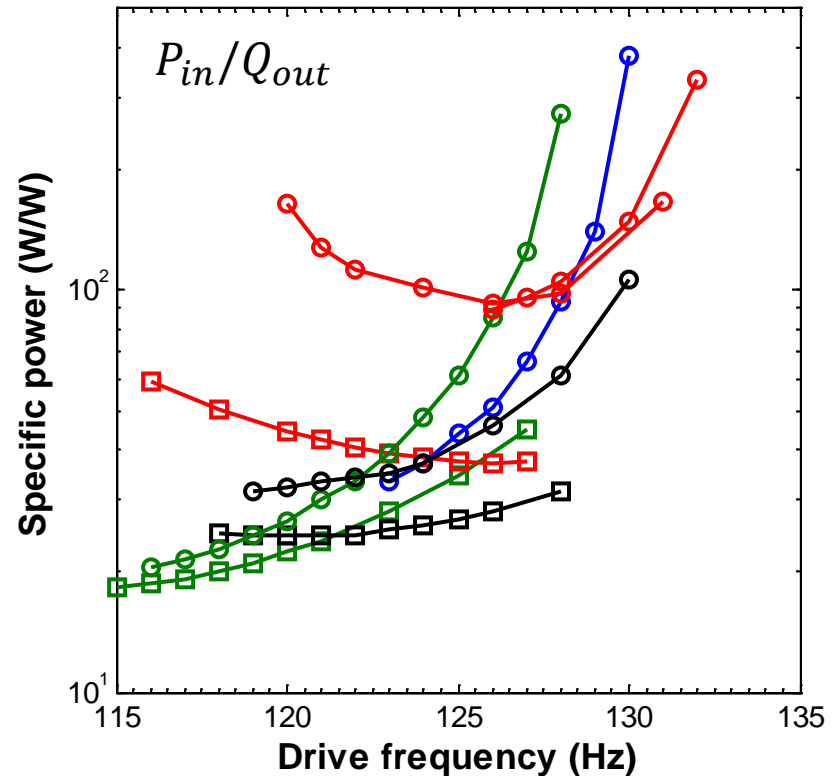
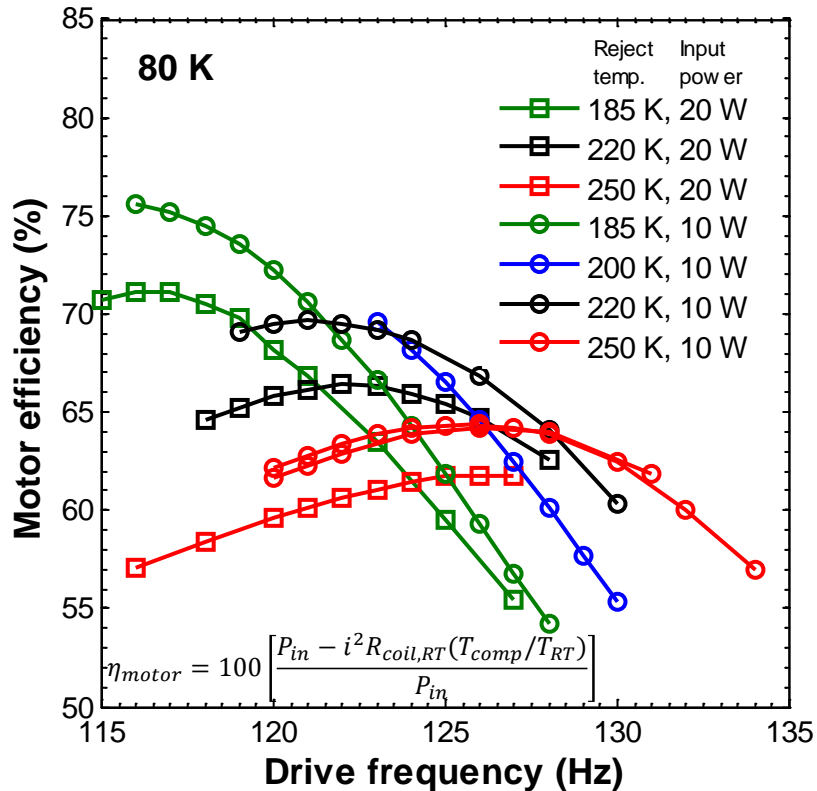
- Parametric study:
 - Frequency: 115 Hz to 140 Hz
 - Heat rejection temperature: 185 K to 300 K
 - Input power: 5 to 55 W
 - Heat lift: 0 W to 5 W
- Not shown:
 - Cold tip: MLI, telemetry
 - MLI surrounding cooler
- Compressor temperature was 2 K to 10 K higher than expander temperature
- Cooler driven with Chroma 61602 AC power supply

Performance Plot at 140 Hz



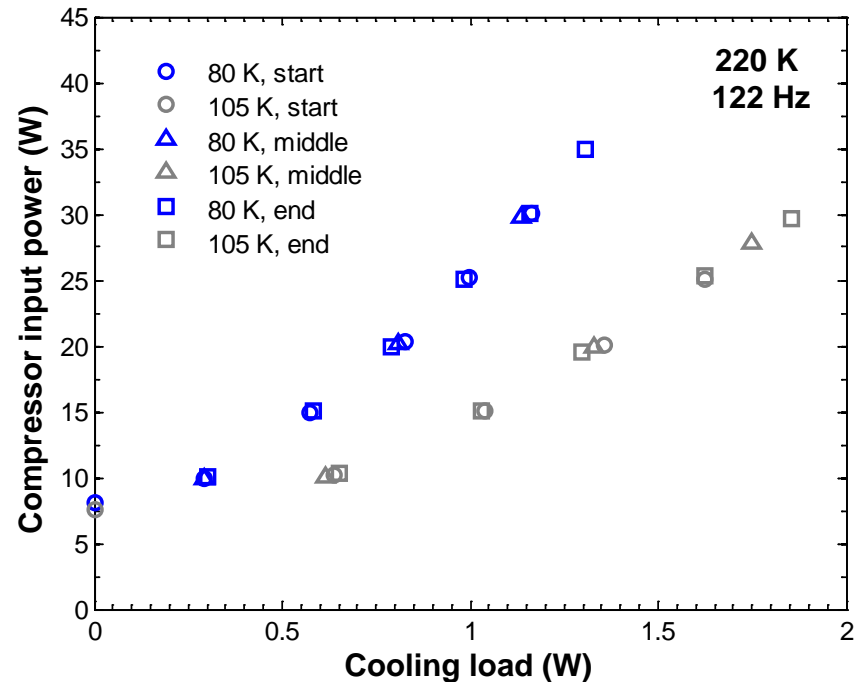
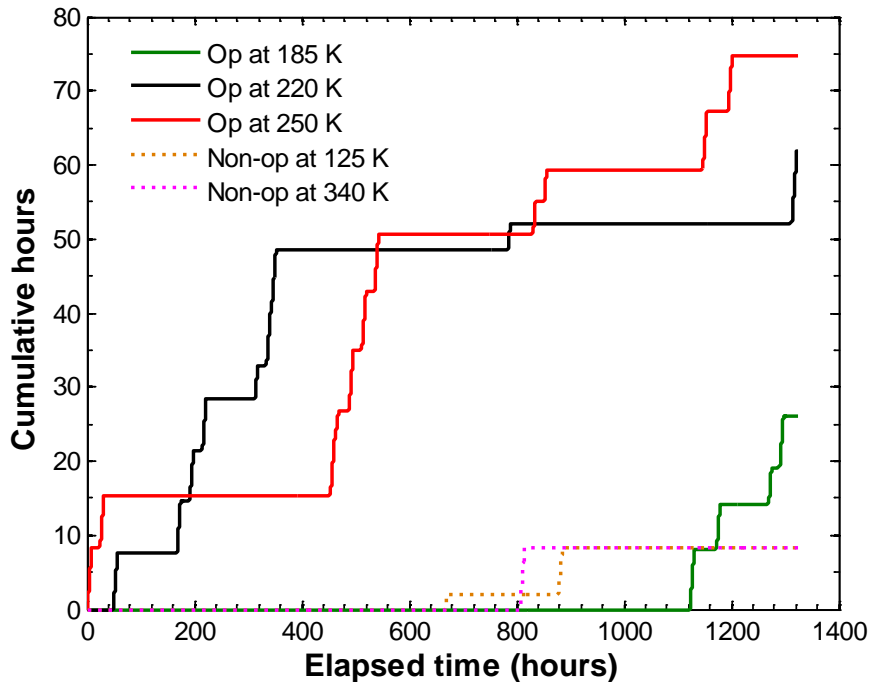
- Cooling power decreased with decreasing heat reject temperature
- Optimal drive frequency highly dependent on reject temperature

Effect of Drive Frequency on Performance



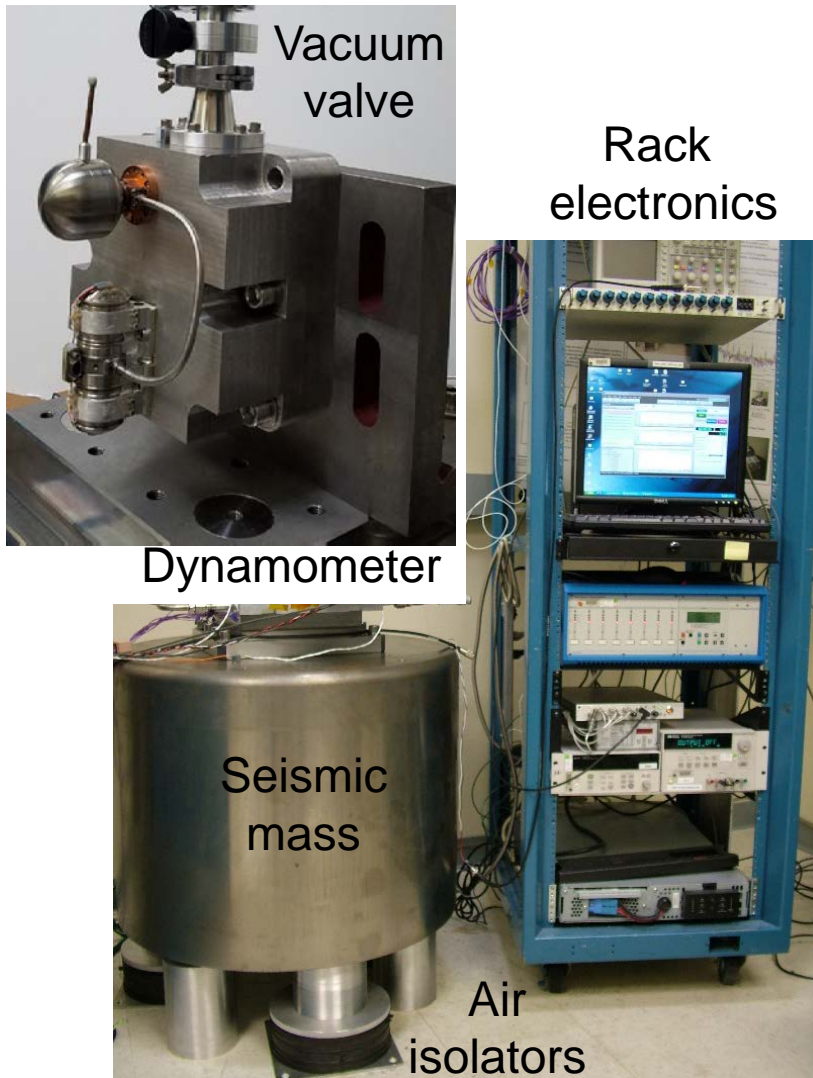
- Optimal frequency dependent on heat reject temperature and compressor input power
- For a given set of conditions, minimum specific power and maximum motor efficiency occur at nearly the same frequency

Temperature Cycling



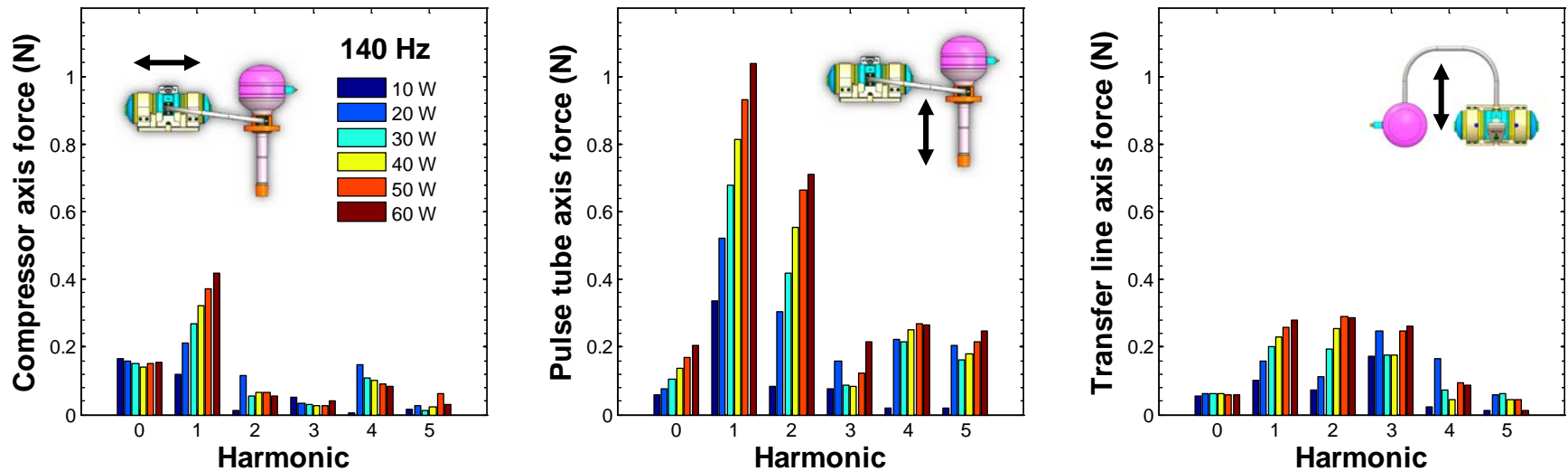
- 8 hr non-op soak: 125 K and 340 K
- Op: 26 hrs at 185 K, 62 hrs at 220 K (nominal), 75 hrs at 250 K
- 80 K and 105 K isotherms measured at beginning, middle, and end
 - Cooler performance unchanged throughout thermal cycling

Measurement of Microphonics



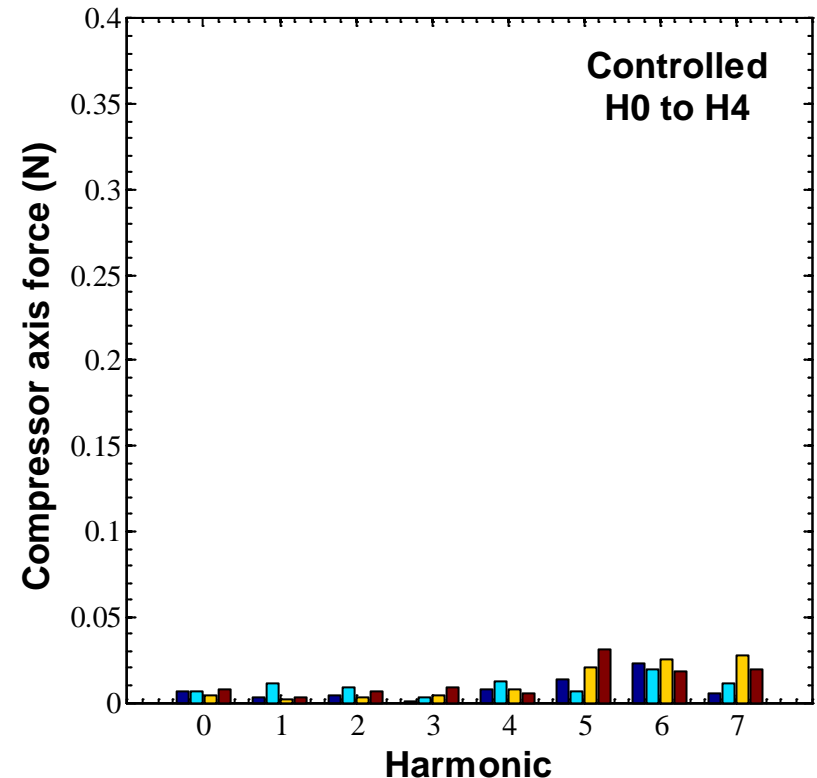
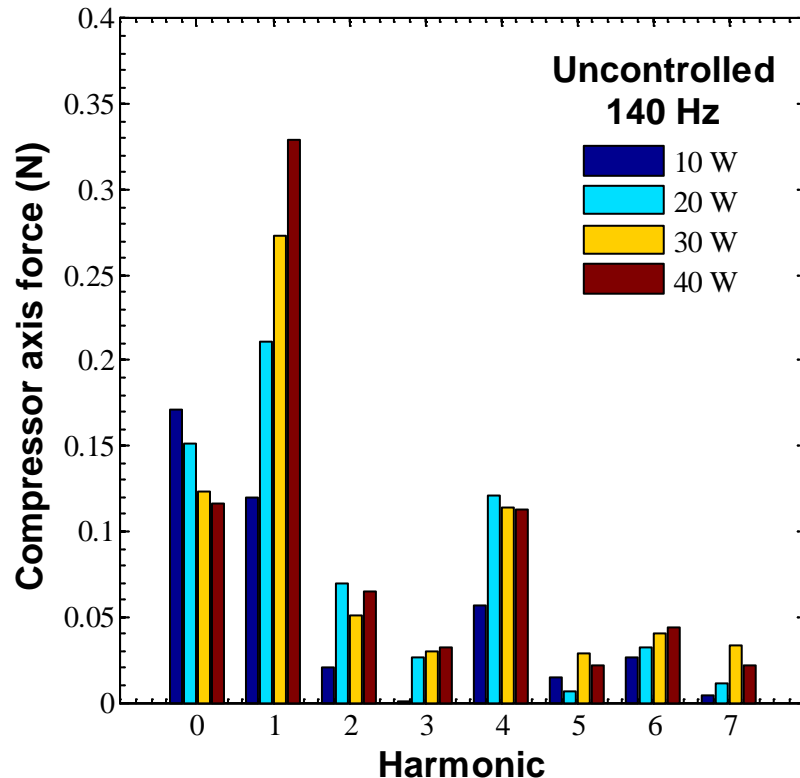
- Parametric study:
 - Drive frequency
 - Input power
 - Drive electronics
 - Mounting angle
- Cold tip under vacuum
- Room temperature heat reject
- Rigid mounting
- Cooler driven with:
 - Chroma 61602 AC supply
 - Iris Technologies LCCE-2
 - Iris Technologies HP-LCCE
 - Vibration feedback tested
 - Force signal in compressor axis used as feedback

Effect of Input Power on Exported Forces



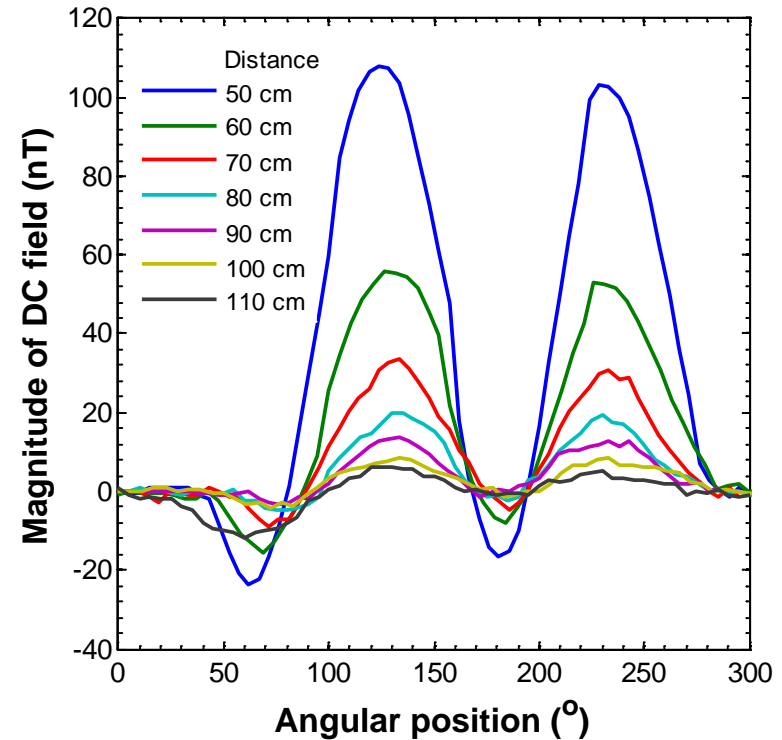
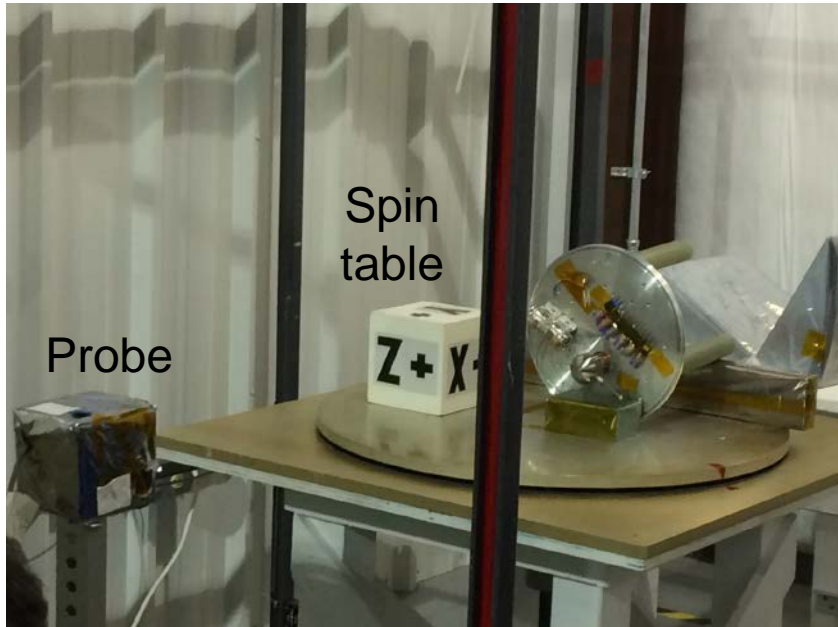
- Cooler at room temperature driven with Iris Technologies LCCE-2
 - Similar forces when driven by HP-LCCE and Chroma 61602 AC supply
- Force increased with increasing input power
- Forces largest in pulse tube axis
- Forces independent of pulse tube axis angle relative to gravity
- Forces nearly independent of drive frequency from 135 Hz to 145 Hz

Effect of Vibration Feedback Control



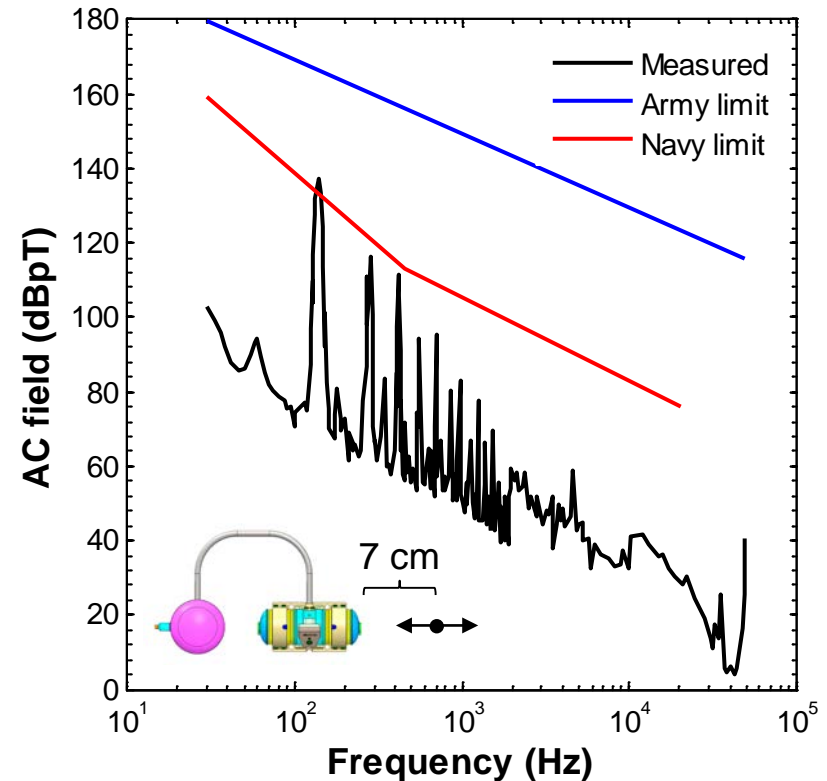
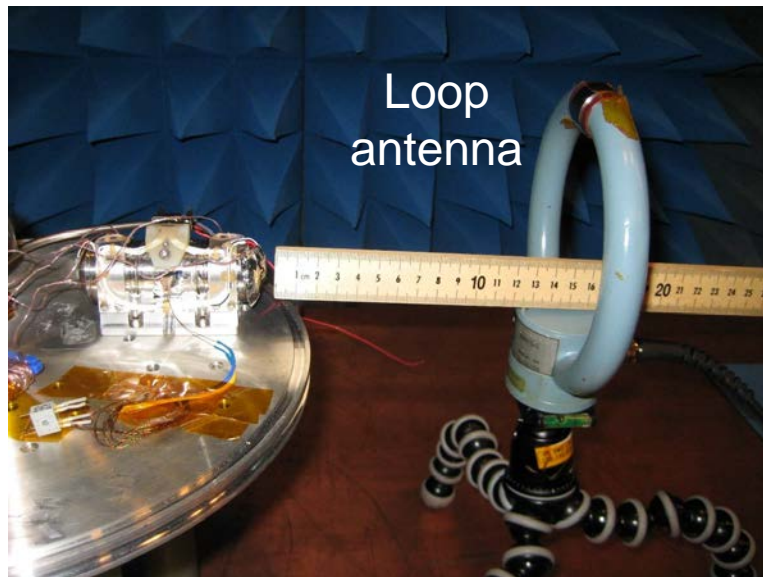
- Cooler driven with Iris Technologies HP-LCCE
- Control reduced the forces of harmonics 0 to 4 to below 15 mN 0-pk
- Control did not affect the forces in the compressor lateral directions

DC Electromagnetic Interference



- Probe fixed, cooler rotates not operating in all three axes
- Maximum radial 0-pk field strength of 10.41 nT at 1 meter
- Total dipole moment of 10.33 mA-m²

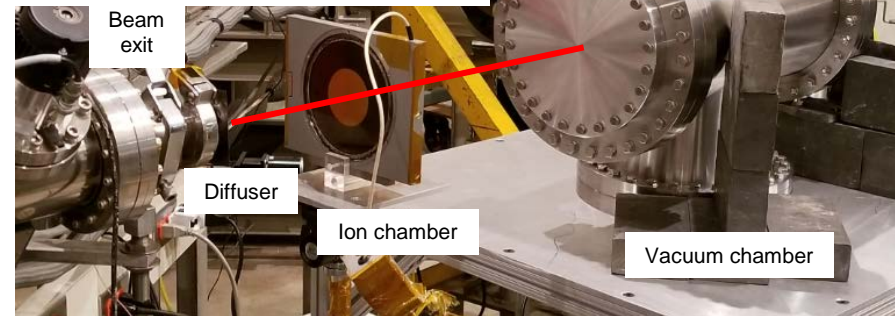
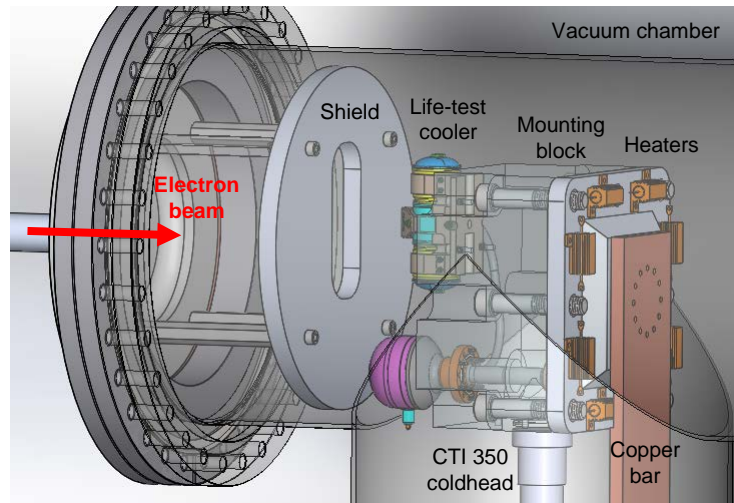
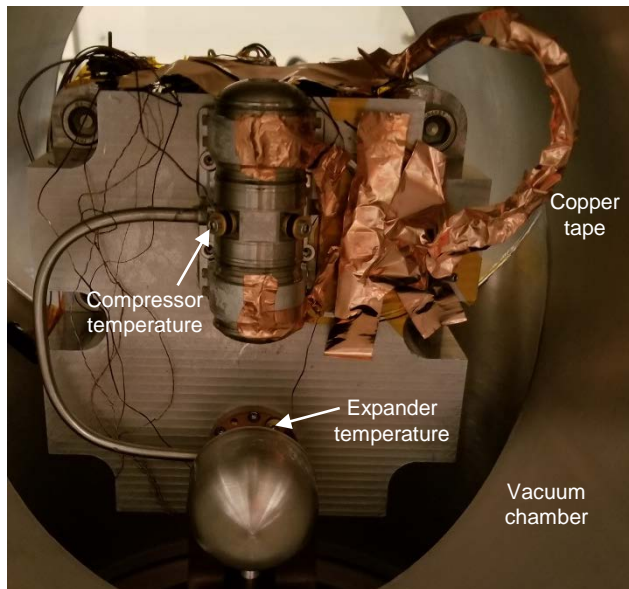
AC Electromagnetic Interference



- At 50 W, the RE101 limit specified in MIL-STD-461G exceeded
- AC field decreased with decreasing input power for a given location

Electron Radiation Testing

NIST in Gaithersburg, Maryland

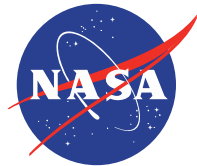


- Subjected to 500 krad with a 25 MeV electron beam at 0.065 nA/cm^2 over 12 hours while operating in vacuum at 222 K reject temperature, 29 W input, 80 K cold tip
- Cooling load was monitored throughout the dose and did not change
- Isotherms and helium leak rate measured before and after test were similar

Conclusions and Future Work

- The optimal drive frequency of the cooler depends heavily on input power and heat rejection temperature
- The exported forces in the compressor axis were successfully suppressed to below 15 mN
- The AC and DC magnetic interference were thoroughly measured
- The cooler survived a 500 krad dose of electron radiation without degradation
- The cooler remains the baseline for the MISE instrument
- Future work:
 - Life-test of 467 days (2x life) with power cycles at nominal op/non-op temperatures of 125 K and 220 K

Thank you for your attention



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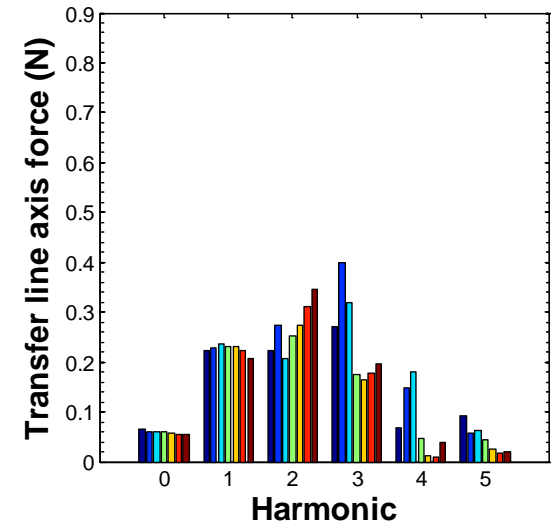
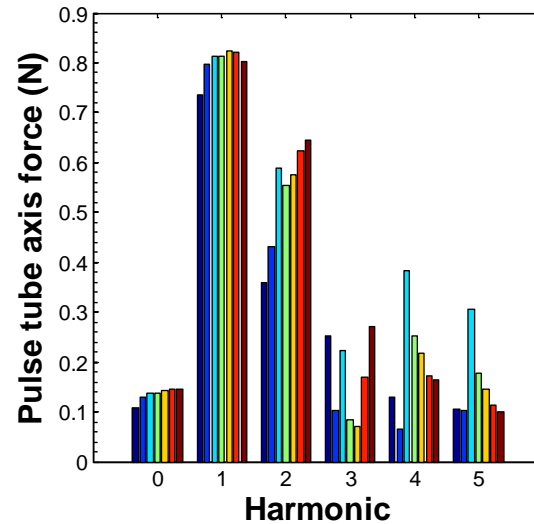
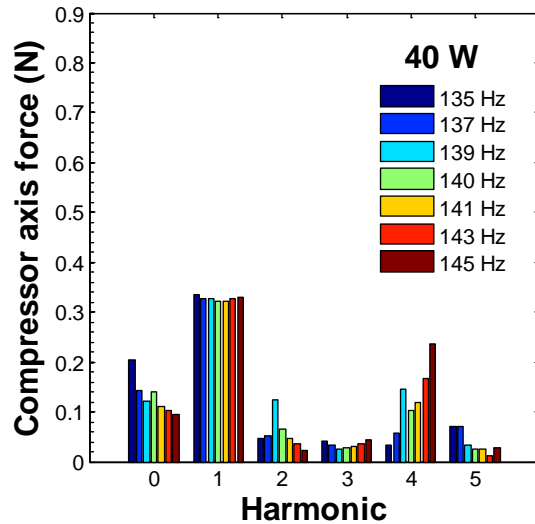
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Questions?

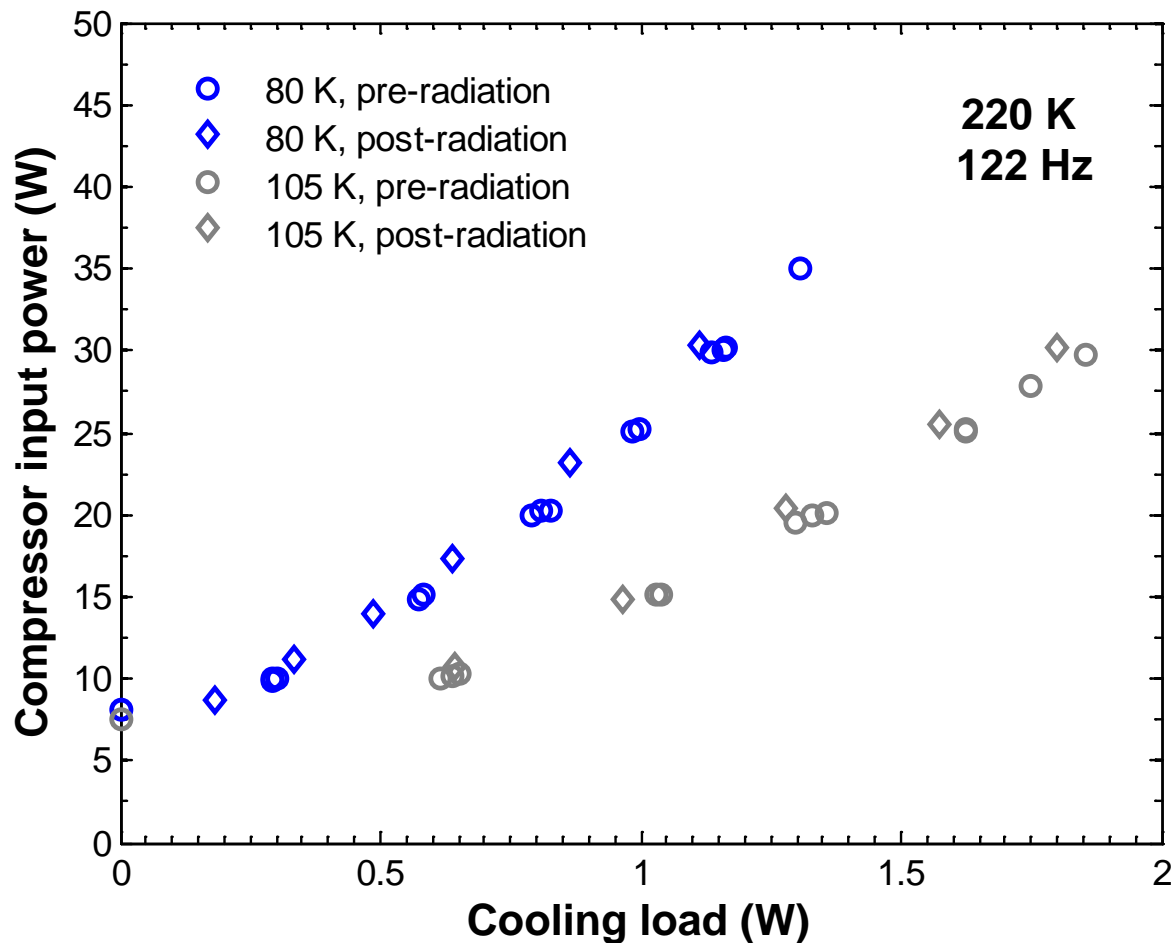
Extra Slides

Effect of Drive Frequency on Exported Forces



- Force nearly independent of drive frequency

Effect of Radiation Dose on Performance



- For a given input power, cooling load changed by less than 6.5%