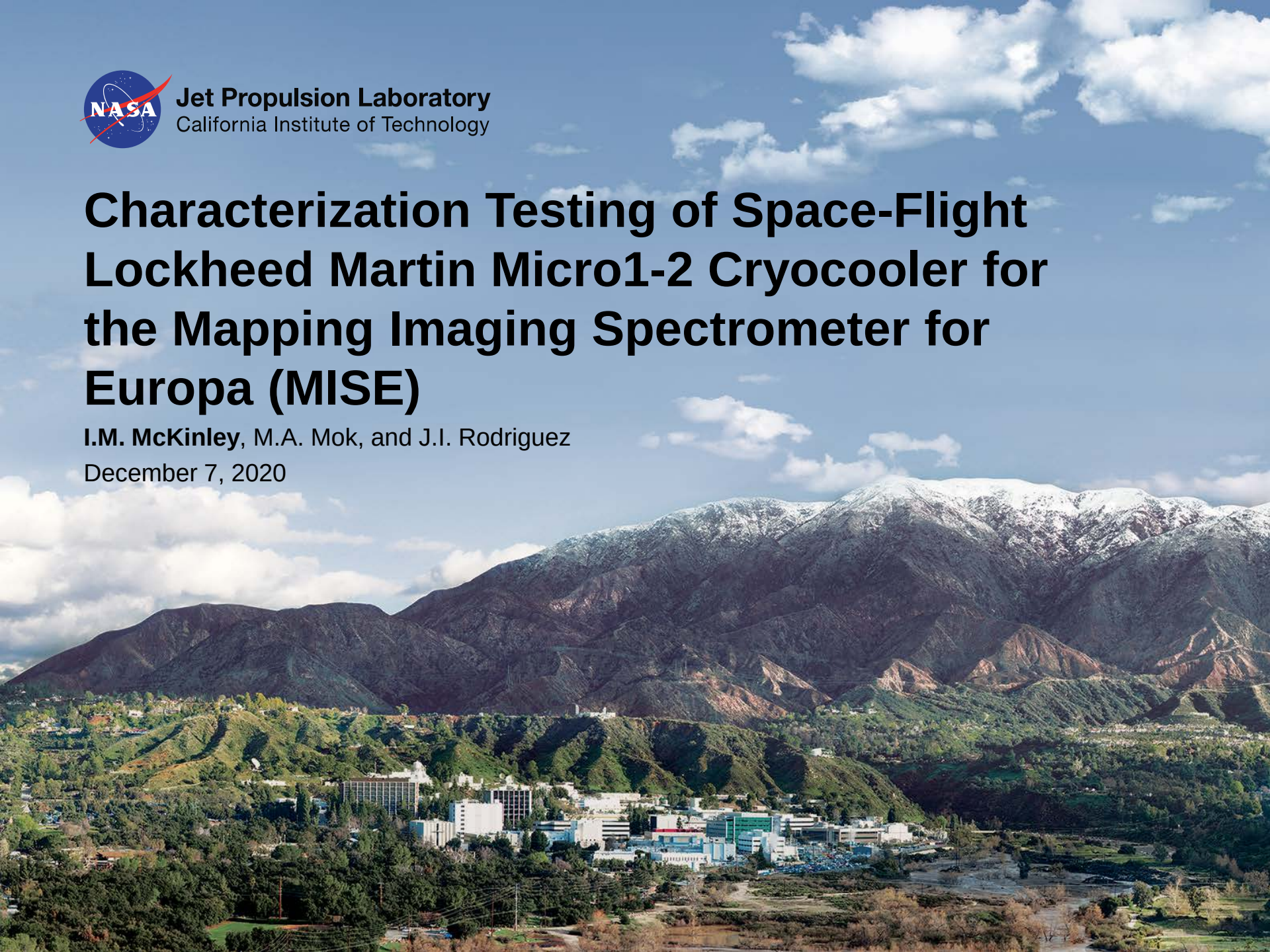

Jet Propulsion Laboratory
California Institute of Technology

Characterization Testing of Space-Flight Lockheed Martin Micro1-2 Cryocooler for the Mapping Imaging Spectrometer for Europa (MISE)

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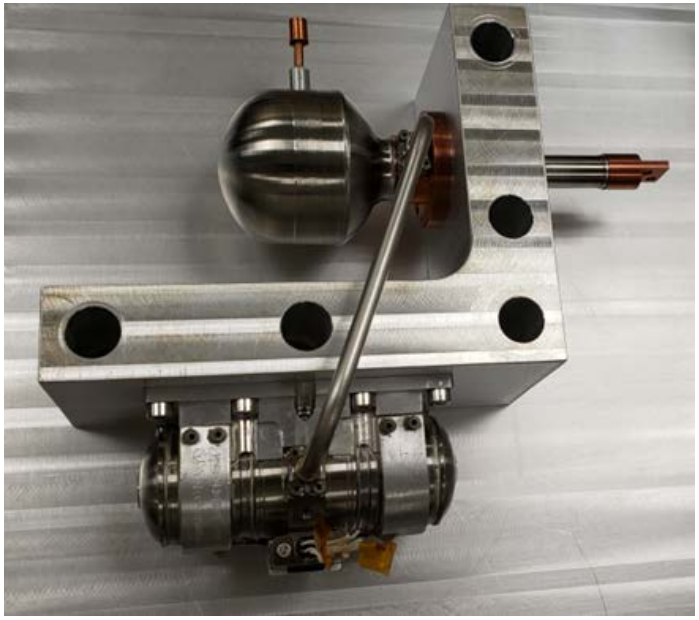
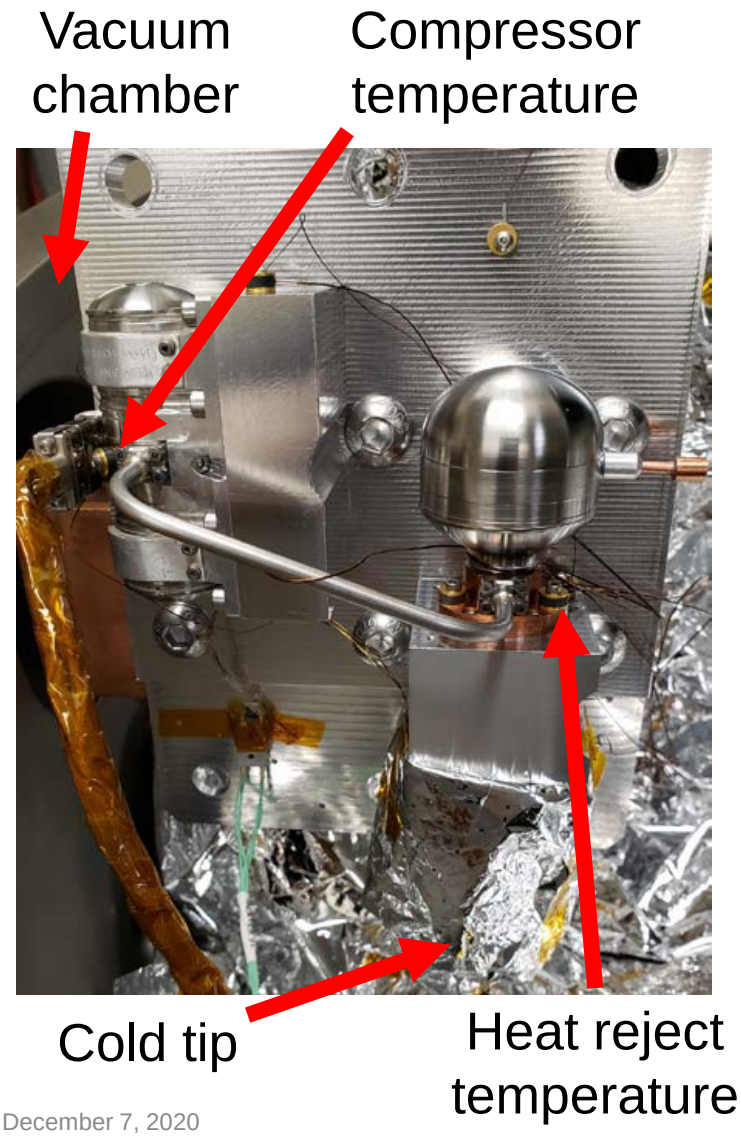
Lockheed Martin Micro1-2 MISE Flight Cryocooler

- The Jet Propulsion Laboratory procured a flight model for the Mapping Imaging Spectrometer for Europa (MISE) Instrument on the Europa Clipper
- Characterization tests were performed to assess the cooler's compatibility with the environmental requirements of the Europa Clipper as well as assess its performance in the expected thermal environment



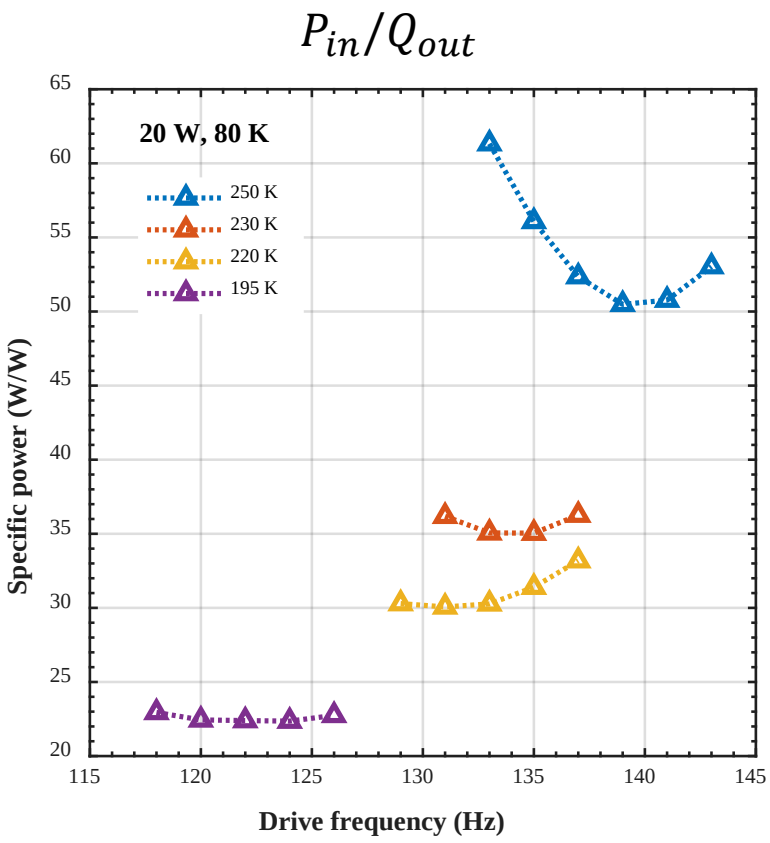
- Pulse tube type
- Flexure bearings
- Maturity level: TRL 6 for Earth and Europa
- Mass: 480 grams
- Compressor: 92 mm long
- 60 W maximum input power
- 725 psi He fill pressure
- Optimized for:
  - 80 K cold tip
  - 135 Hz drive frequency
  - 220 K heat rejection temperature

Thermal Vacuum Performance Testing



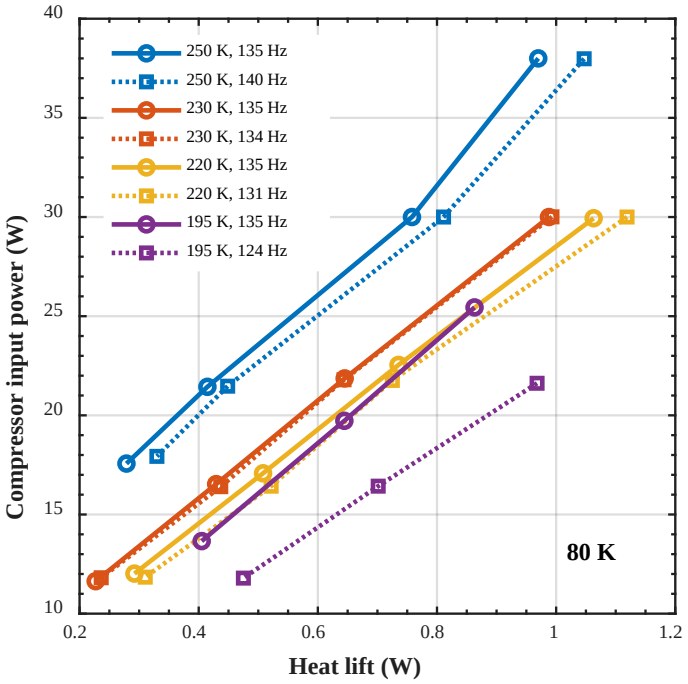
- Parametric study:
  - Frequency: 118 Hz to 143 Hz
  - Heat rejection temperature: 195 K to 250 K
  - Input power: 10 to 40 W
  - Heat lift: 0 W to 1.2 W
- Not shown:
  - Cold tip
  - MLI surrounding cooler
- Compressor temperature was <20 K higher than expander temperature
  - Performance previously shown to be independent of compressor temperature
- Cooler driven with Chroma 61602 AC power supply

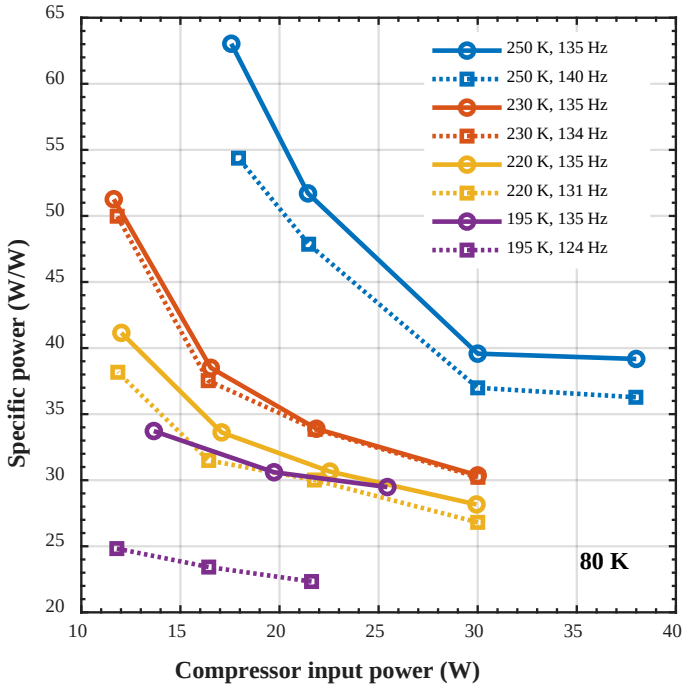
Effect of Drive Frequency



- Optimal drive frequency corresponds to a minimum in specific power
- Optimal frequency decreased with decreasing reject temperature
- Specific power decreased with decreasing frequency
  - Higher thermodynamic efficiency at lower reject temperatures
- Specific power less dependent on frequency as reject temperature decreased
- Frequency sweeps performed by Lockheed Martin at 30 W at 80 K
  - Cooler optimal frequency independent of input power between 20 W and 30 W

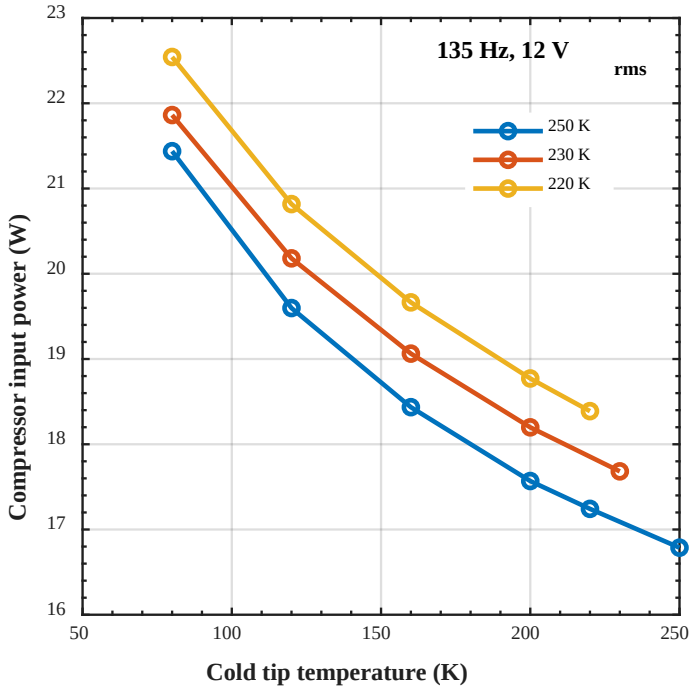
Performance at 80 K Cold Tip

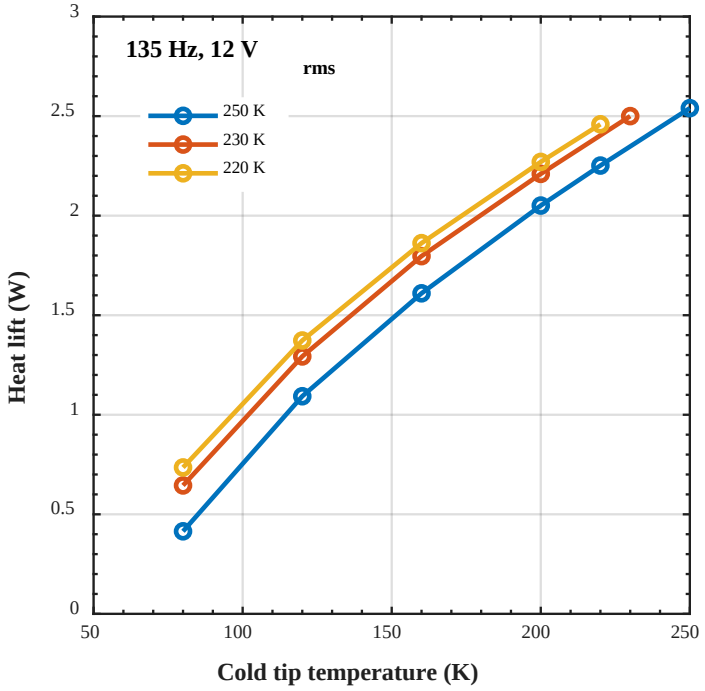




- At optimal drive frequency, the performance increased with decreasing temperature
- At 135 Hz, the performance was roughly the same between 195 K and 220 K heat reject temperature
- Specific power decreased with increasing input power
  - Dependence on input power decreased with decreasing heat reject temperature

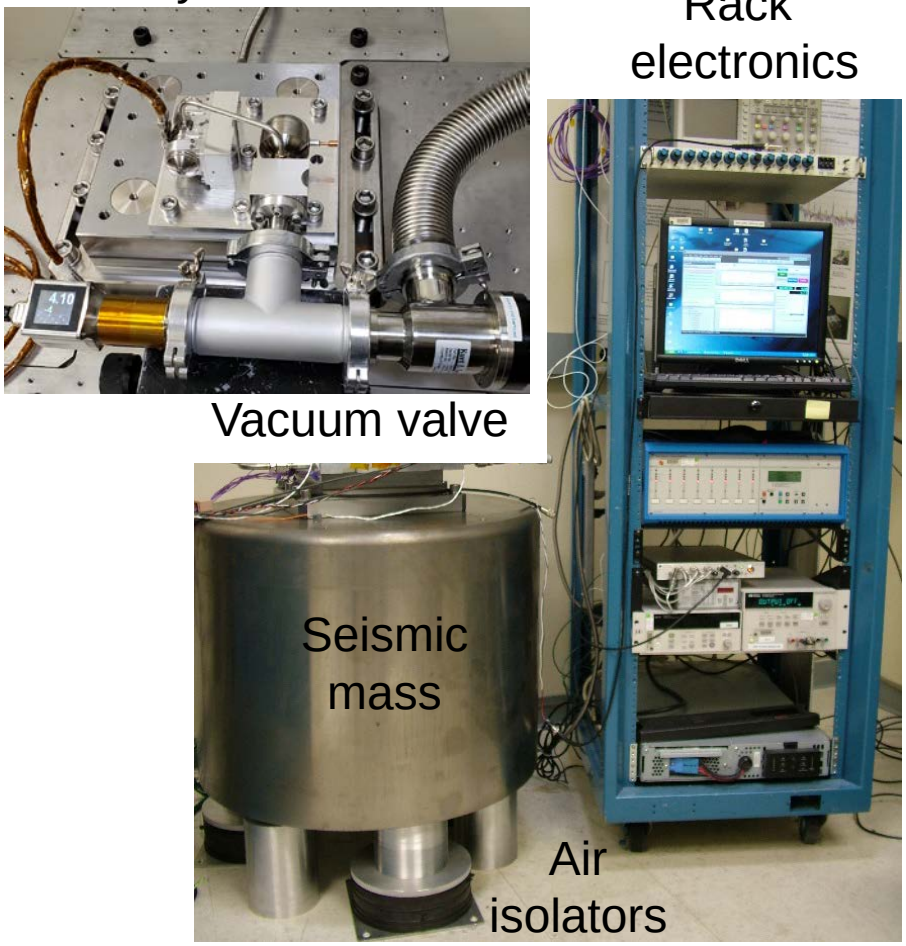
Performance at 12 V_{rms}





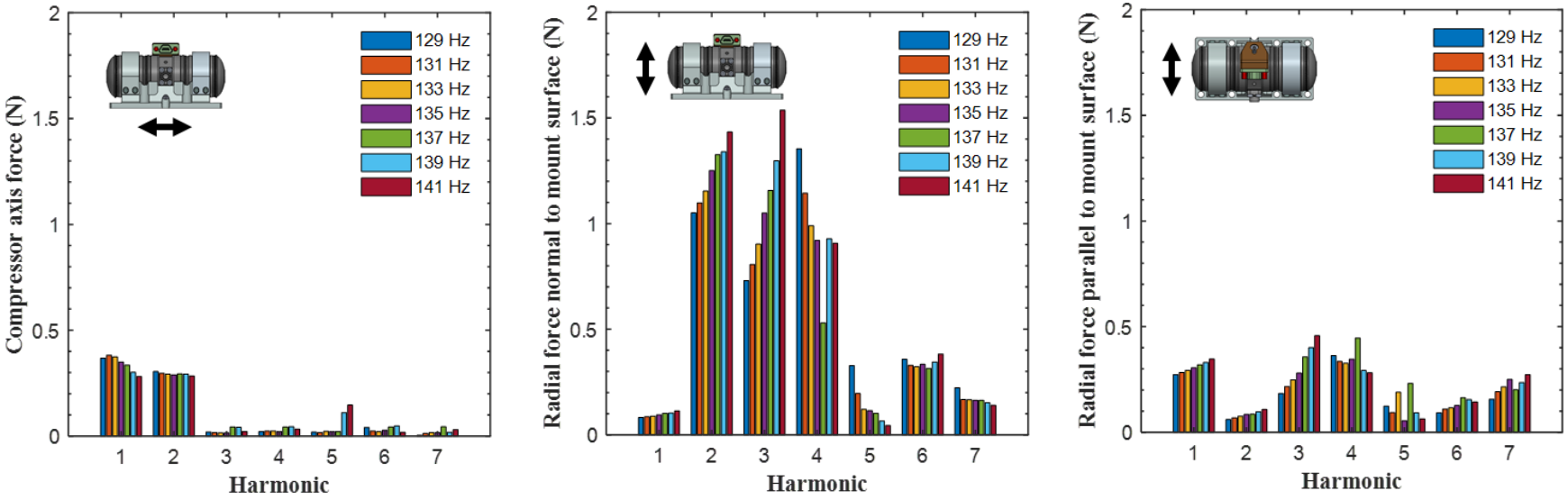
- Compressor input power increased with decreasing cold tip temperature and decreasing heat reject temperature
- Heat lift decreased with decreasing cold tip temperature and increasing heat rejection temperature

Measurement of Exported Forces and Torques



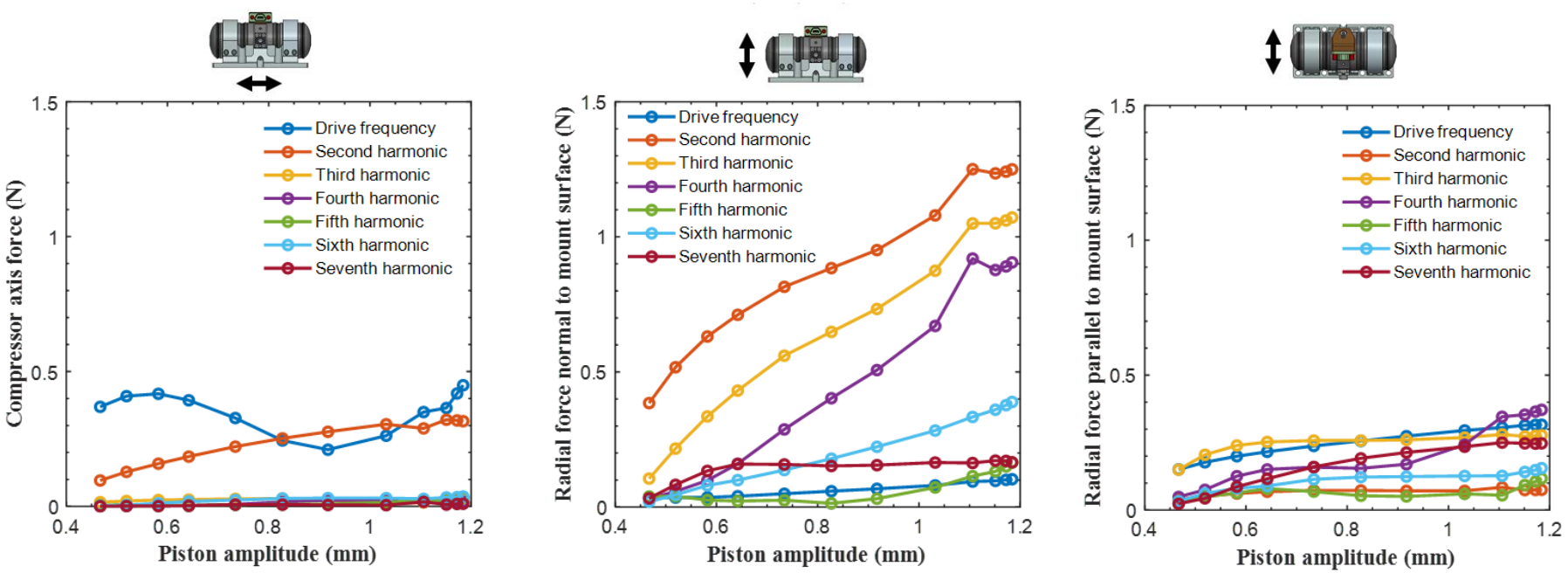
- Parametric study:
  - Drive frequency
  - Input power
- Cold tip under vacuum
- Room temperature heat reject
- Rigid mounting
- Cooler driven with Chroma 61602 AC supply

Effect of Drive Frequency on Exported Forces



- 47 W compressor input power or ~1 mm piston amplitude
  - Cooler running off-resonance
- Radial force normal to the mount surface was highest
- Forces also measured with 30 W input power (~1 mm piston amplitude) between 152 Hz and 160 Hz running near resonance
  - Radial forces normal and parallel to mounting surfaces as high as 13 N and 7 N, respectively
  - Previously shown a radial mode at 480 Hz with 1 mm piston amplitude

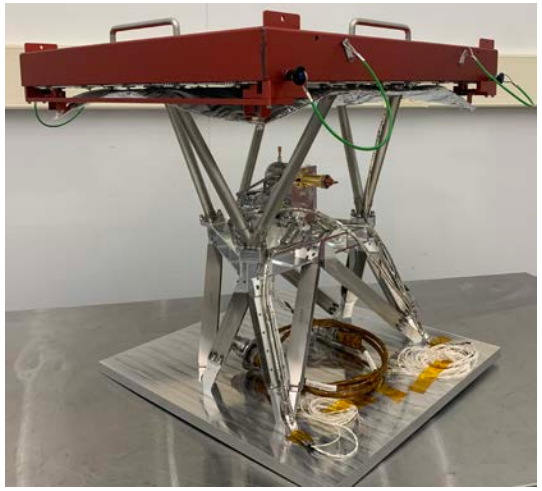
Effect of Piston Amplitude on Exported Forces

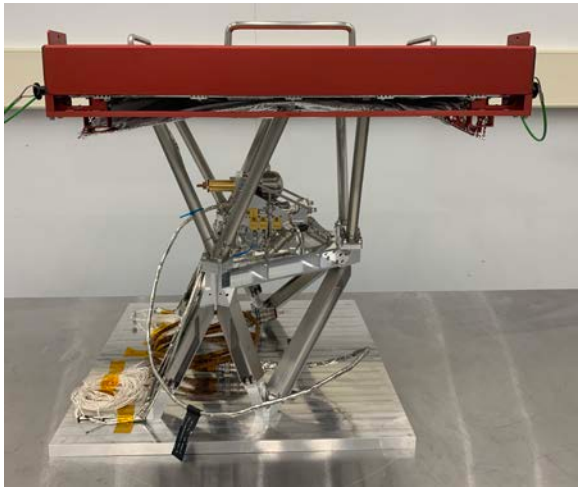


- Cooler running off-resonance at 300 K
  - Optimal drive frequency: 151 Hz at 300 K
- Compressor axis and radial parallel to mounting axes nearly independent of piston amplitude
- Radial higher harmonics increase linearly with increasing amplitude

Conclusions and Future Work

- Thermal performance was as expected
- Exported forces were comparable to past Lockheed Martin microcoolers
- Met the requirements and needs of the MISE instrument
- Has proceeded to integration at the next level





Thank you for your attention

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Questions?