CubeSat-Sized Space Microcryocooler

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Motivation

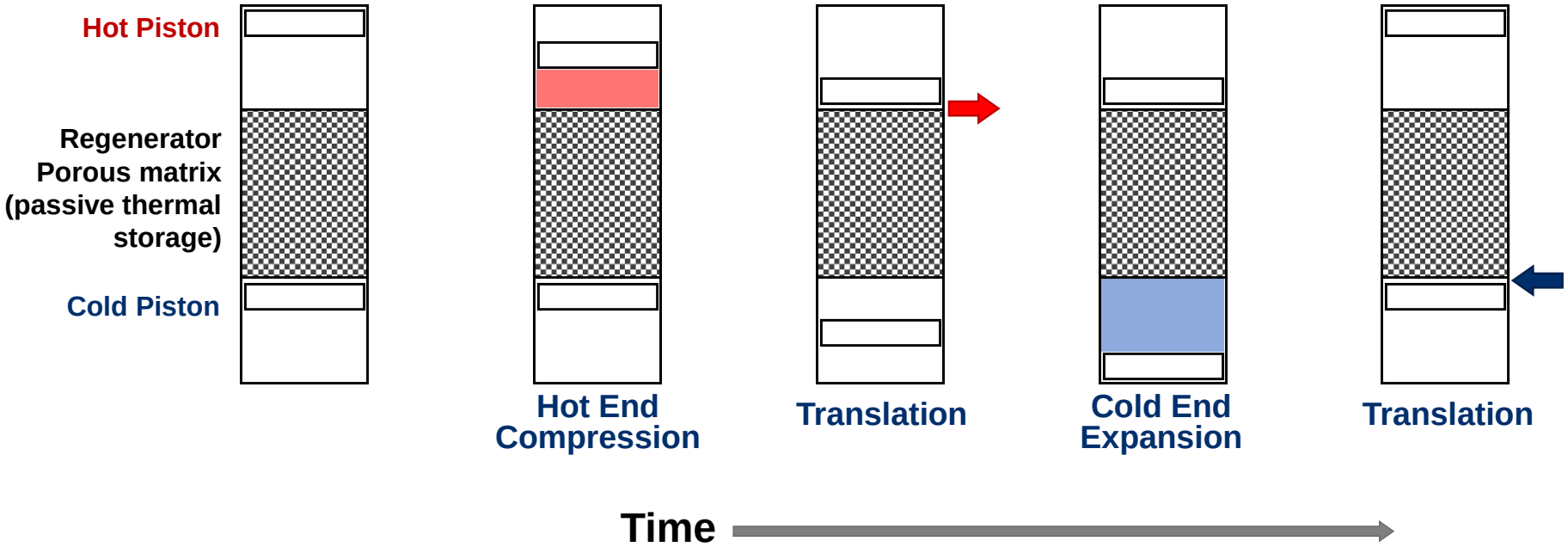
Cryogenic instruments on small satellites and deep space missions require compact, low-mass cryocoolers

Many missions require operational lifetime of several years or more

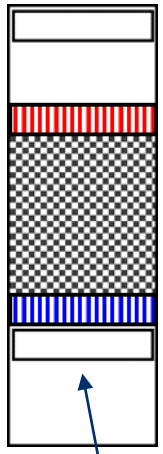
Some missions have very challenging environmental conditions

The trend toward smaller satellites is creating a need for smaller space-quality cryocoolers

Description of Stirling Cryocooler



Space Cryocooler Configuration



Hot Piston: Power input

Hot Heat Exchanger: Heat rejection

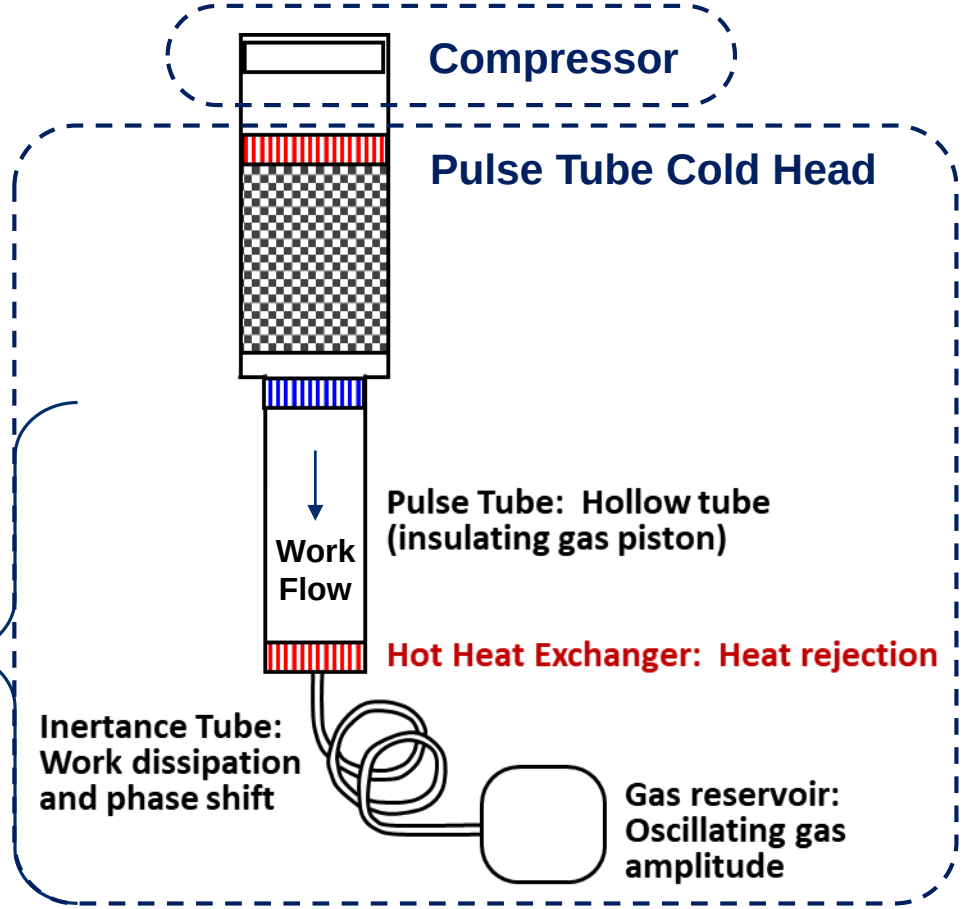
Regenerator

Cold Heat Exchanger: Cooling Power

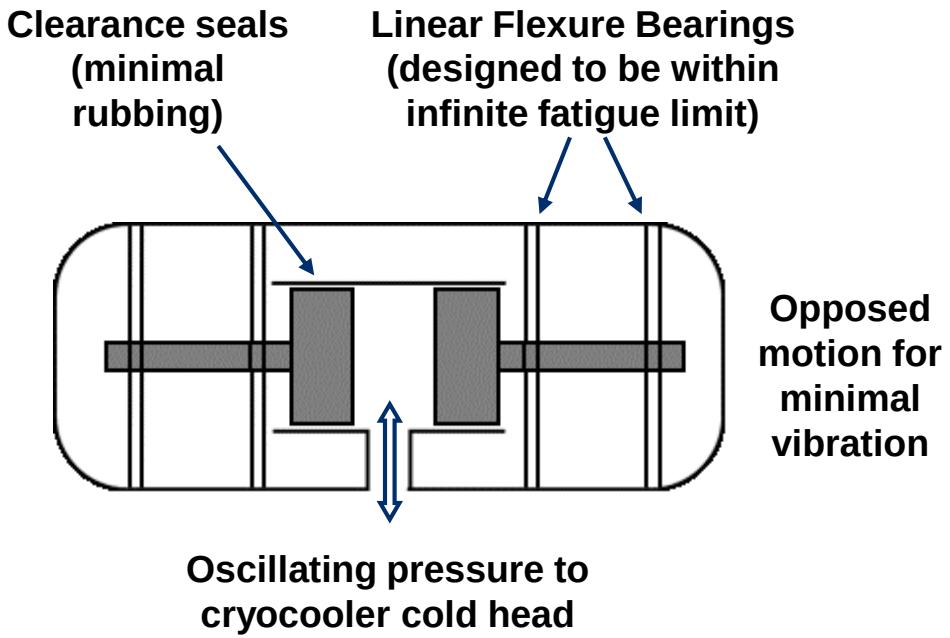
Cold Piston: Work extraction

Moving cold part is one of the primary causes of failure in a Stirling cryocooler

Replace moving cold part with passive components



Long Life Compressor Features

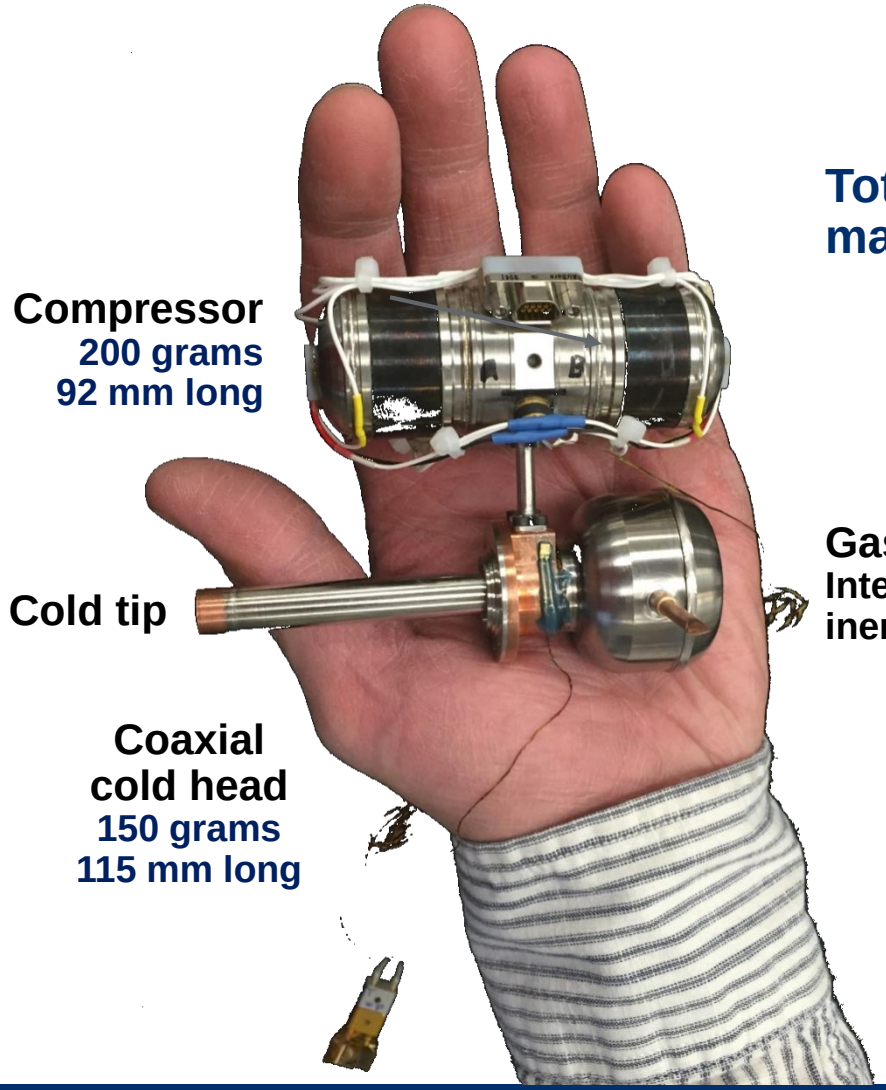


Long-life space configuration developed in 1990s at Oxford University

Lockheed Martin compressors have external motor coils (no electrical penetrations into pressure vessel

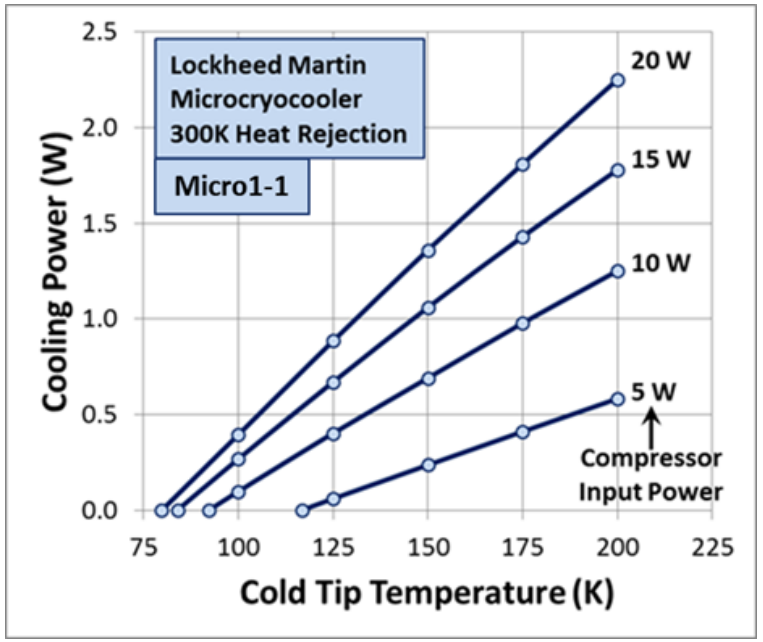
There has never been an on-orbit failure of a pulse tube cryocooler with an Oxford-style compressor in over 200 years of operational time

Lockheed Martin Micro1-1 Microcryocooler



Total cryocooler mass <375 grams

Gas reservoir
Internal inertance tube

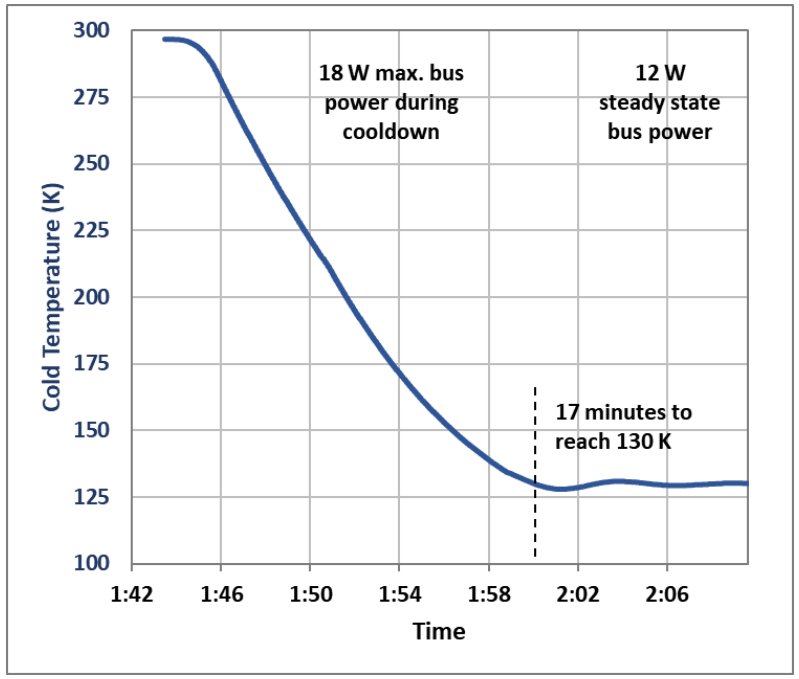


Smallest and lightest long-life cryocooler available

Can be packaged in ½ U

Lockheed Martin LunIR CubeSat

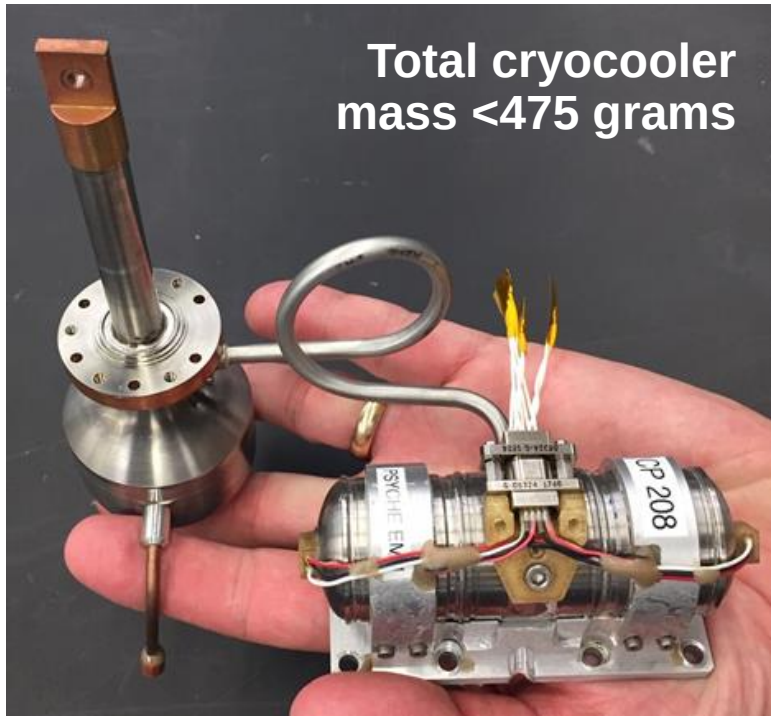
- Lockheed Martin and Tyvak Nanosatellite developed the LunIR 6U CubeSat, which includes a LM Micro1-1 microcryocooler
- Cryocooler was integrated and tested with the LunIR instrument (LM-developed compact IR Sensor) in 2018
- LunIR will perform a lunar flyby and return IR images of the moon and cryocooler performance data
- Mission CONOPS requires the cryocooler to cool the IR camera to 130 K in less than 30 minutes
- Scheduled to launch as a ride-along on the first SLS launch with Orion EM-1 as a participant in NASA's NextSTEP program



First LM microcryocooler launch scheduled for 2021

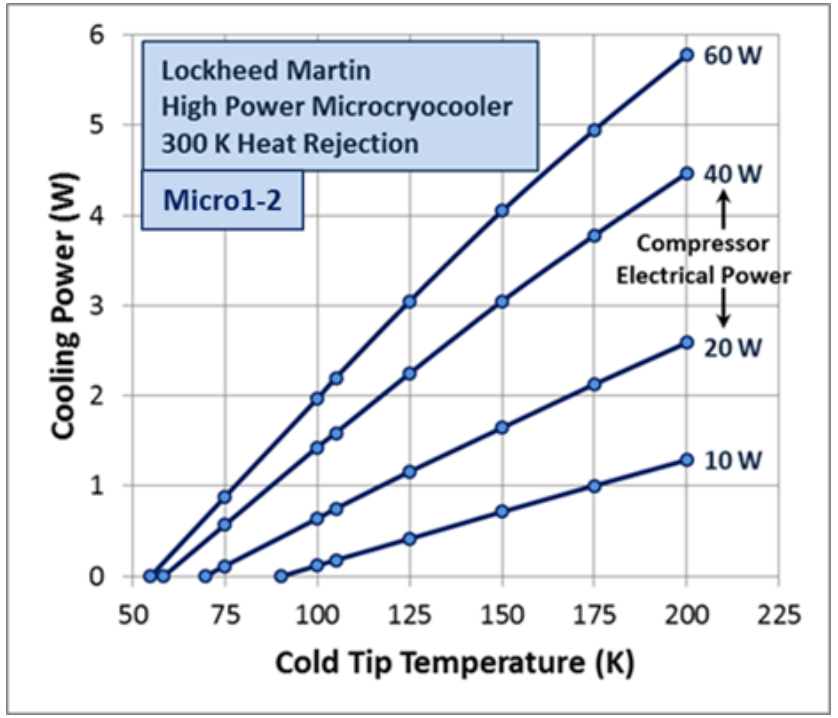
Lockheed Martin Micro1-2 Microcryocooler

Cold tip



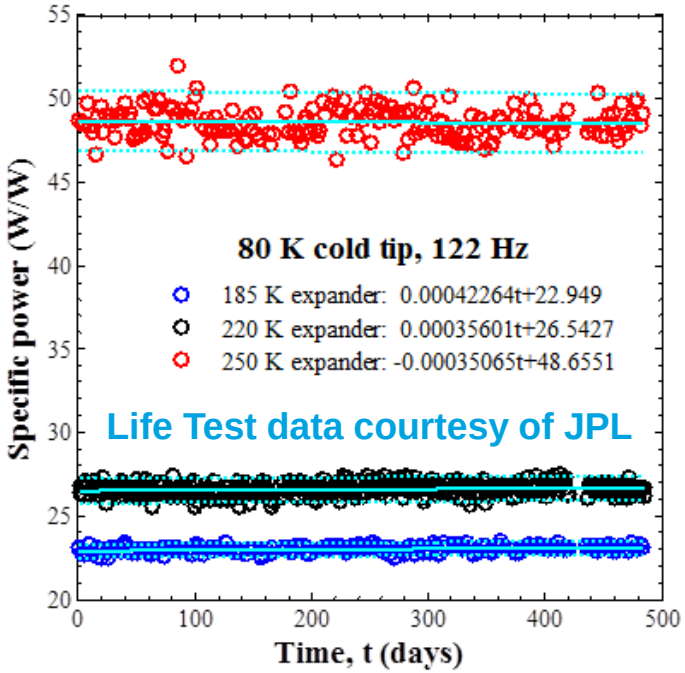
Cold head: slightly heavier with larger heat exchangers

Compressor: larger pedestal, added heat straps



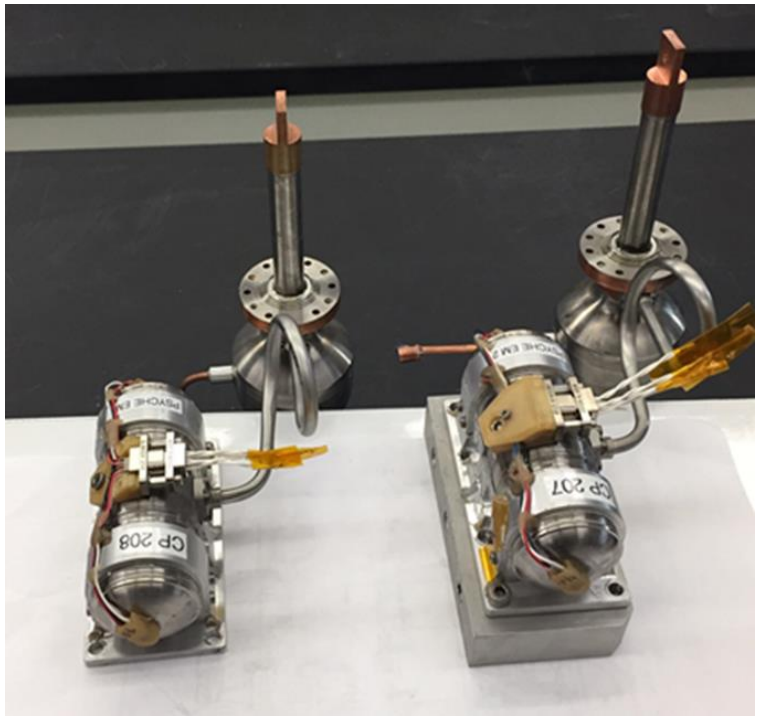
Mapping Imaging Spectrometer for Europa (MISE)

- MISE is being built by JPL for the Europa Clipper
- MISE is a Class B instrument on a Class A mission
- Cryocooler cools an IR spectrometer to 80 K
- Jupiter is a challenging environment, and MISE is not in the protective vault:
  - 220 K nominal cooler ambient temperature
  - Numerous non-operational cold soaks below 150 K in between flybys of Europa
  - 250 kRad radiation exposure
- Flight cooler program began late 2018, scheduled to deliver December 2019
- Europa Clipper scheduled to launch in 2023



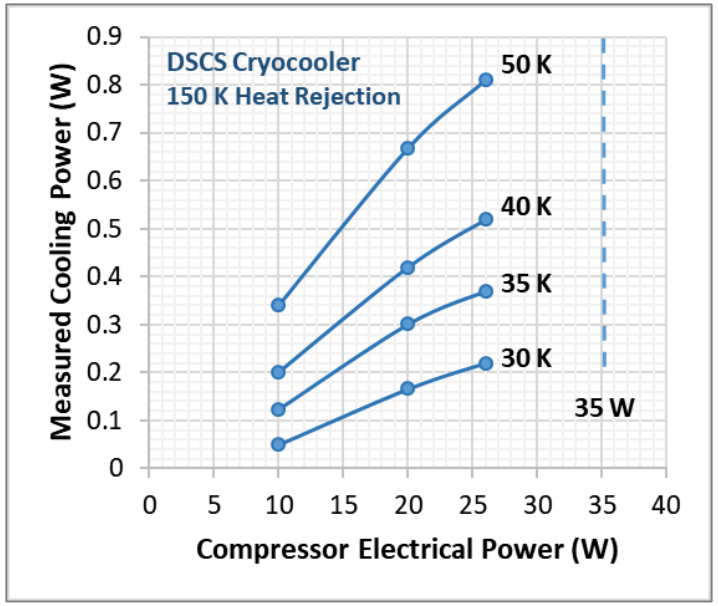
Psyche Gamma Ray and Neutron Spectrometer (GRNS)

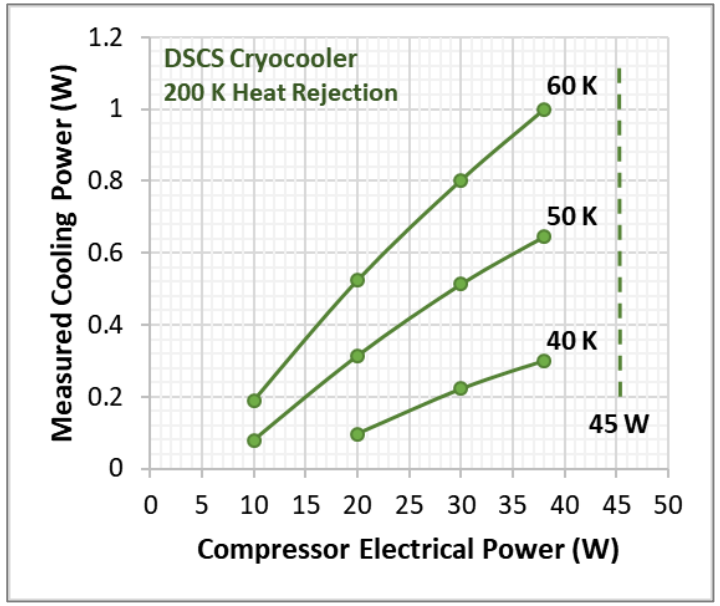
- GRNS is being built by Johns Hopkins University Applied Physics Laboratory (JHU/APL) for the Psyche asteroid mission
- Psyche is a Category 2, Risk Class B mission
- Cryocooler cools the gamma ray spectrometer's germanium crystal to < 90 K
- Mission has several challenges:
  - Minimizing the mass of some specific elements in the cryocooler (such as nickel) is important to avoid masking the signatures from 16 Psyche
  - Cryocooler cold tip must be capable of surviving many anneal cycles where the germanium crystal is warmed to 398 K (125°C)
- Flight cooler program began April 2019, scheduled to deliver two FM coolers in 2020
- Psyche mission scheduled to launch in 2022

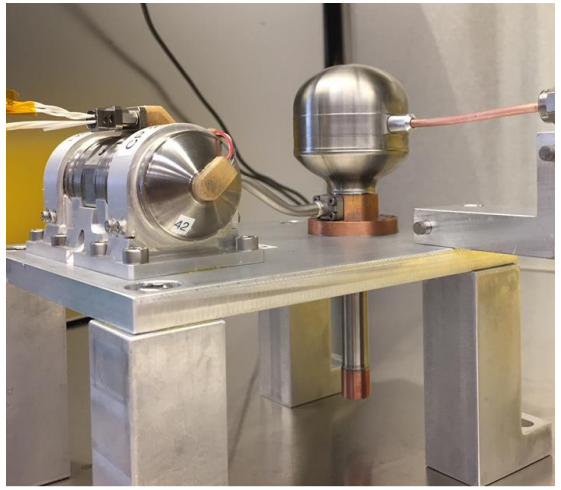


Deep Space Cryocooler System (DSCS)

- DSCS is a recently-completed Phase II SBIR led by Iris Technology
- SBIR program developed a low-mass miniature cryocooler and electronics for deep space missions:
  - 150 K cryocooler heat rejection temperature, 35 K cold tip temperature







The Deep Space Cryocooler System is waiting for the right mission

Acknowledgements

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- LunIR spacecraft design, integration, and mission operations is performed by Tyvak Nanosatellite
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