National Aeronautics and Space Administration

Miniature Efficient Heat Pump for Venus and Lunar Exploration

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Program: FY21 R&TD Topics **Strategic Focus Area: Thermal control systems**

Objectives

- Develop a miniature, efficient heat pump to cool electronics/sensors in hot environments
- High temperature lift: > 50°C
- High heat rejection temperatures: >110°C
- High efficiency: > 2 $W_{cooling}$ / W_e (COP of 2)
- Lightweight: ~ 0.75 kg for 100 W of cooling power
- Low exported vibrations: < 0.3 N

Background

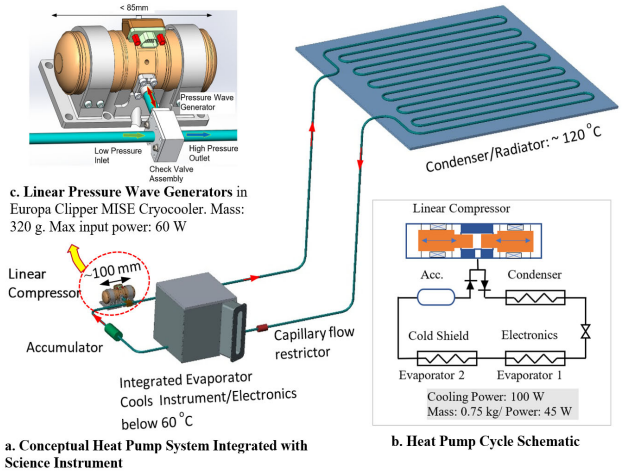
- Environmental temperature can be above 110 °C
  - ❑ Venus balloon flight at altitudes < 45 km
  - ❑ Lunar exploration at low latitude regions
- Existing thermal solutions severely constrain operation and reduce science data return
  - ❑ Thermal storage and passive radiators
- Existing heat pumps cannot meet application needs

Approach

- Reliable linear pressure wave generator (AC flow compressor) developed for space cryocoolers
- Miniature, fast-response check valves to enable efficient, reliable, high pressure ratio operation
  - ❑ Small void volume, low leakage in “OFF” state and low resistance in “ON” state
- Binary refrigerant mixture for efficient dual-temperature cooling

Year I Results

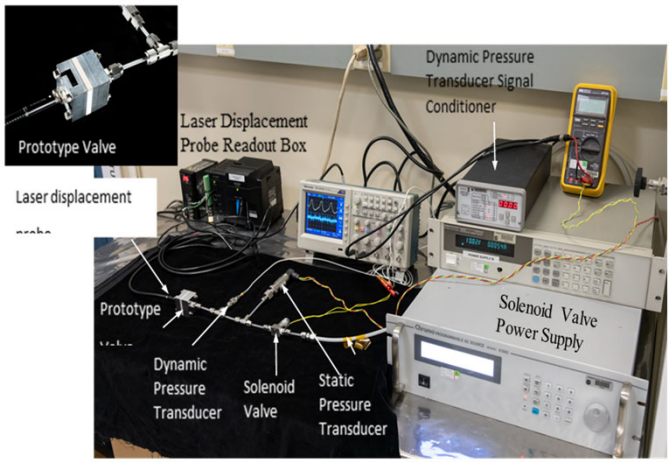
- Developed heat pump and compressor thermodynamic models
- Developed check valve design meeting performance requirements
- Developed valve structural analysis model
- Fabricated and demonstrated a prototype check valve
  - ❑ Measured leak rate is lower than target value
  - ❑ Valve ΔP is consistent with model prediction
  - ❑ Valve response time is shorter than 1.5 ms (limited by test setup)



A Lightweight, Compact Heat Pump to Enable Science Measurement in Extreme Thermal Environments

Significance/Benefits to JPL and NASA

- Cross-cutting thermal management technology for NASA’s future missions
  - ❑ Maintain electronics and sensor operating temperature in hot environments
  - ❑ Provide heat source by lifting heat from low to high temperatures,
  - ❑ Provide cooling for life support systems
- A wide range of terrestrial medical and commercial applications,
  - ❑ Safe transportation of temperature-sensitive medicines, vaccines, and bi0 samples



Year I Prototype Valve Test Setup

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