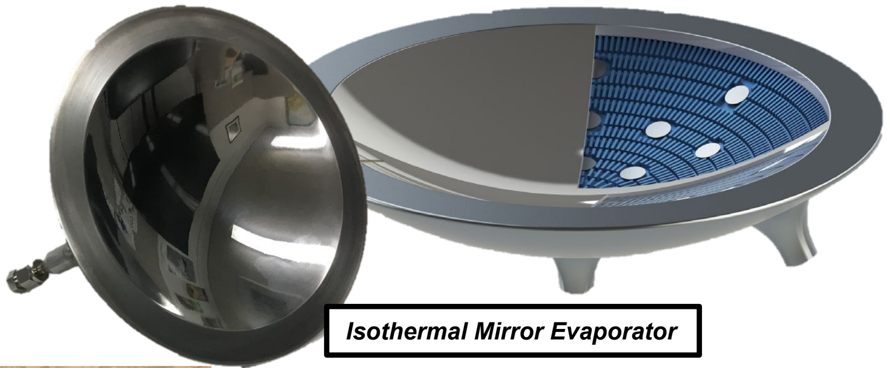
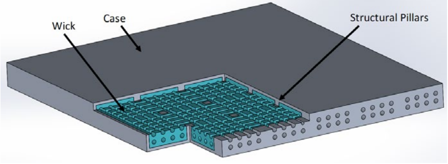
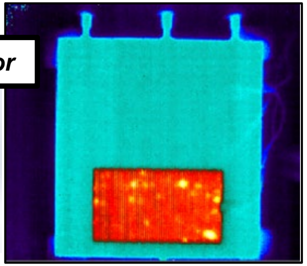


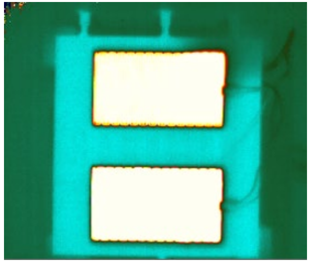
Isothermal Mirror Evaporator

Isothermal Planar Evaporator

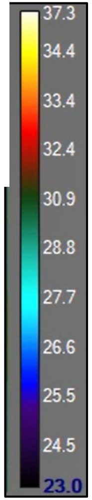




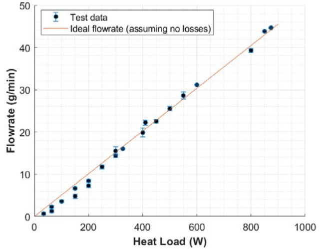
30 W

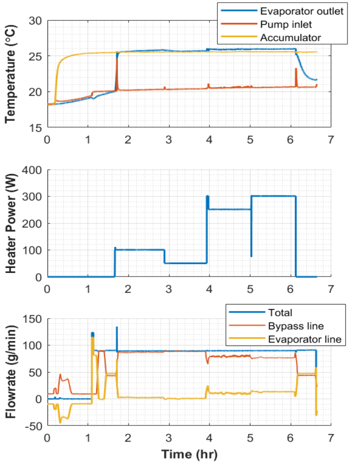


325 W



Two-Phase Fluid Loop Data





Virtual Research Presentation Conference

Two-Phase Thermal Control Technology for Small Spacecraft Exploration

Principal Investigator: Eric Sunada (353)
Co-Is: Ben Furst (353), Scott Roberts (357), Stefano Cappucci (353), Takuro Daimaru (353), Weibo Chen (382), Massoud Kaviany (Univ. of Michigan), Vijay Dhir (UCLA

Program: Strategic Initiative

Jet Propulsion Laboratory
California Institute of Technology

Assigned Presentation #: RPC-268

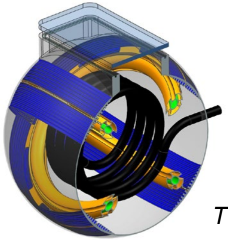
Introduction – The Two-Phase MPFL

Abstract

This task is focused on the development of a superior thermal control system for spacecraft: A two-phase mechanically pumped fluid loop (MPFL) with freezable radiators. The system is capable of providing unsurpassed system level thermal control with minimal mass and power requirements. The high performance capability of this system coupled with its low resource usage make it ideally suited for enabling and enhancing ambitious small sat missions that may not otherwise be possible. The key capabilities of this system are:

1. Accommodates high heat flux (up to 15 W/cm^2) and high power density systems such as SAR
2. Provides milli-kelvin temperature stability for sensitive instruments (0.05 ^oC/hr temporal and 2 ^oC/meter spatial without active heating)
3. Reclaims waste heat from electronics to heat other spacecraft components (e.g. propellant tanks)
4. Ability to turn off radiators to minimize heater survival power in cold environments (e.g. outer planets missions, lunar night) with a 500:1 turndown ratio

Problem Description



Two-Phase Accumulator Rendering

Context (Why this problem and why now)

Small spacecraft planetary space science missions require development of subsystems with high performance, low mass and power, long life, and low cost. The state-of-the-practice (SoP) large spacecraft subsystems are not suitable for small spacecraft applications as they are heavy, power hungry, and costly. The SoP CubeSat technologies are also not suitable for future small spacecraft planetary science missions due to their limited performance capabilities, limited reliability and life. The two-phase mechanically pumped fluid loop (MPFL) presented here directly addresses the need for a superior thermal control system.

SOA (Comparison or advancement over current state-of-the-art)

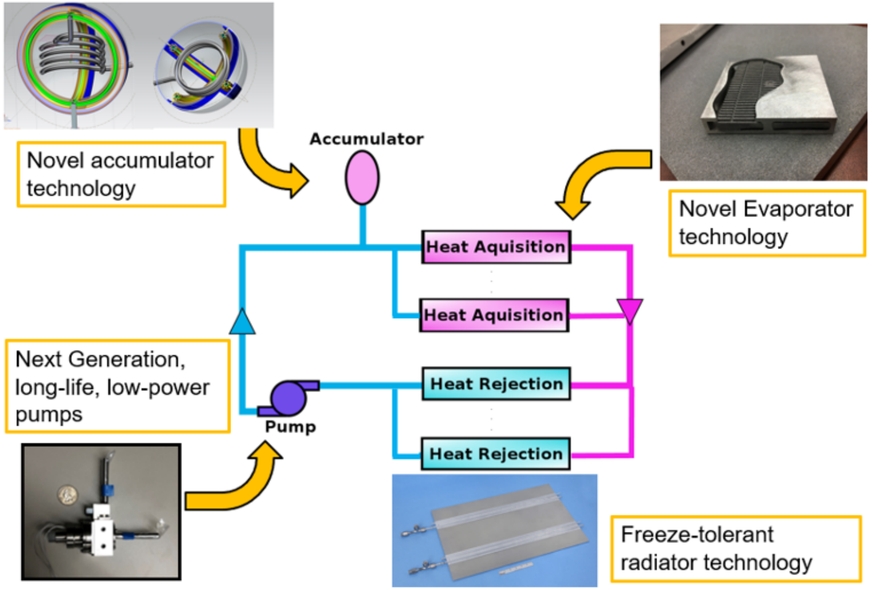
The SoP at JPL is single phase MPFLs. Single phase MPFLs have heat transfer coefficients that are two orders of magnitude less, cannot achieve high spatial and temporal stability, or accommodate high heat fluxes. In addition they require up to 10X more power and 50% more mass. Radiator turn-down is only 75:1 for the Europa Clipper mission which uses a single phase MPFL.

Relevance to NASA and JPL (Impact on current or future programs)

The two-phase MPFL will be developed to TRL 5 by the end of FY21. This will make it mature enough for integration into SIMPLEx mission concepts. Previous studies have shown the system to be enabling for small sat outer planet mission concepts as well us concepts requiring a versatile universal thermal bus that can accommodate a wide range of thermal requirements(e.g. JPL NEXT Cricket).

Methodology

System Operation

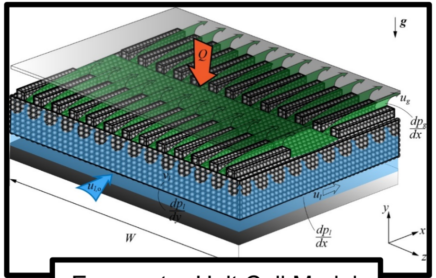


1. **Fluid is circulated by a mechanical pump**
2. **Heat is absorbed isothermally by a phase change of the liquid to a vapor**
3. **Heat rejected by the vapor condensing into a liquid in the radiator**

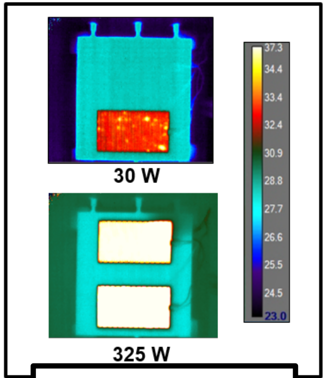
Innovation and Advancement

The two-phase MPFL combines the best elements of several advanced thermal control technologies. It has the versatility, flexibility and robustness of a single phase MPFL, the high thermal performance of two phase systems such as Loop Heat Pipes (LHPs), and the capabilities of traditional systems that use heaters and louvers.

Results



Evaporator Unit Cell Model



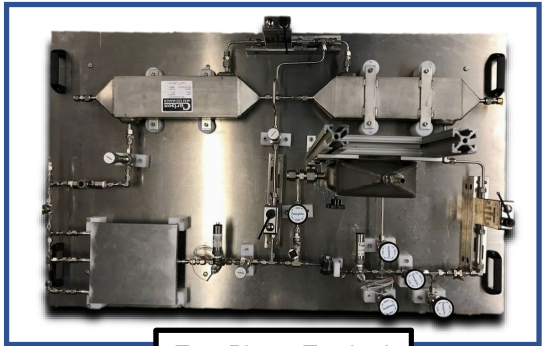
Evaporator IR Image

Accomplishments

- System has been advanced to TRL 4
  - Brass board testbed has demonstrated two-phase mechanically pumped fluid loop operation
  - Computational modelling has been developed to predict system performance
    - Physics based models developed for the evaporator and system

Next steps

- Advance the system to TRL 5
  - Conduct environmental testing
  - Correlate computational models to testbed to develop fully predictive models



Two-Phase Testbed

Publications and References

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1. NTR filed for Evaporator (NTR #50151)
2. NTR filed for Variable Porosity Heat Transfer Device (NTR #50225)
3. Roberts, Scott N., et al. "Multi-Phase Thermal Control Apparatus, Evaporators and Methods of Manufacture Thereof." U.S. Patent No. 10,746,475

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1. Sunada, Eric, et al. "A two-phase mechanically pumped fluid loop for thermal control of deep space science missions." 46th International Conference on Environmental Systems, 2016.
2. Furst, Benjamin, et al. "A Comparison of System Architectures for a Mechanically Pumped Two-Phase Thermal Control System." 47th International Conference on Environmental Systems, 2017.
3. Cappucci, Stefano, et al. "Working Fluid Trade Study for a Two-Phase Mechanically Pumped Loop Thermal Control System." 48th International Conference on Environmental Systems, 2018.
4. Furst, Benjamin, et al. "An Additively Manufactured Evaporator with Integrated Porous Structures for Two-Phase Thermal Control." 48th International Conference on Environmental Systems, 2018.
5. Daimaru, Takuro, et al. "Development of an Evaporator Using Porous Wick Structure for a Two-Phase Mechanically Pumped Fluid Loop." 49th International Conference on Environmental Systems, 2019.
6. Furst, Benjamin, et al. "A Mechanically Pumped Two-Phase Fluid Loop for Thermal Control Based on the Capillary Pumped Loop." 49th International Conference on Environmental Systems, 2019.