JPL

Thermal Control of Small Spacecraft Using Single and Two-Phase Fluid Loops

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OUTLINE

- Background
- Microspacecraft Thermal Management
- JPL Thermal Technology Roadmap
- Two-Phase Mechanically Pumped loop
- Conclusions

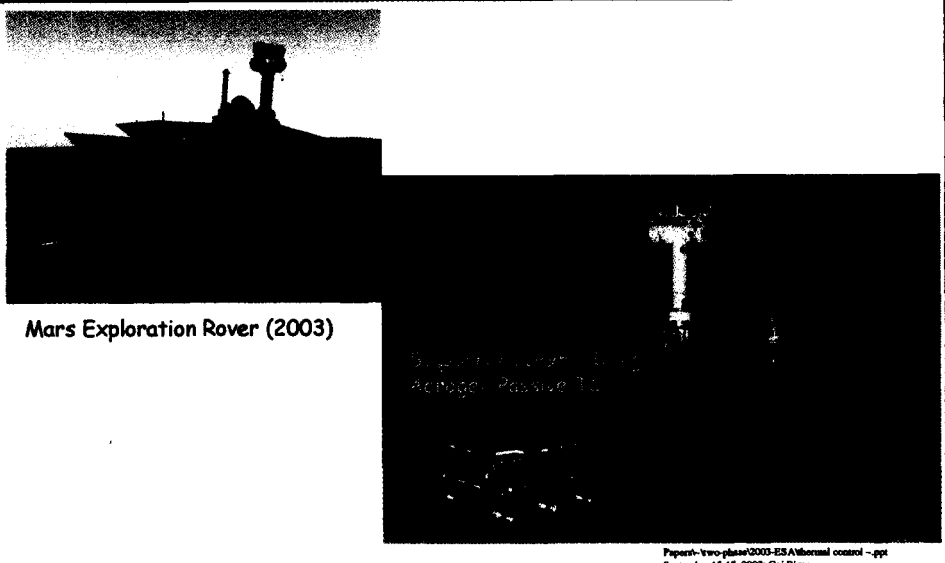
Advanced Thermal Control Technologies

- Small spacecraft of under 100 kg and 100 W are expected to be used for some of the future NASA space science missions
- Thermal control of small spacecraft pose special challenges due to restrictions on volume, mass, and power available for thermal hardware
- These missions will be complex and diverse in terms of thermal environments and requirements; the current thermal control technologies are not adequate to meet the science objectives of these missions
- Advanced thermal technologies and architectures are needed to meet the cost, mass, volume, and capability requirements of small spacecraft used in future
- JPL is developing several advanced thermal control technologies for small spacecraft working with other organizations

Future Space Science Missions at JPL

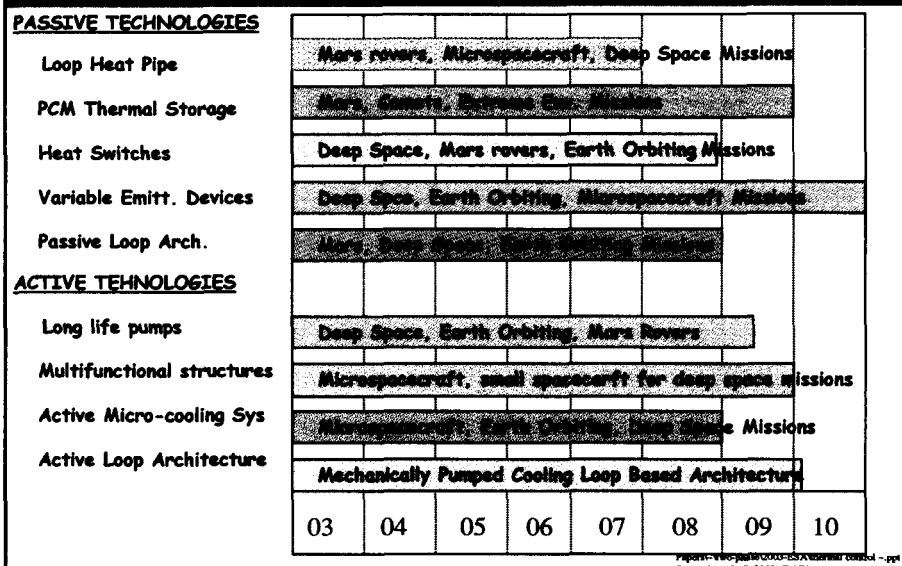
- **Mars Missions**
  - Mars missions - landers, rovers, Mars Micro Missions, MER (2003), Mars Scout (2007) missions
- **Other Deep Space Missions**
  - Missions to other Planets - Europa orbiter/lander, Venus Surface Sample Mission, Jupiter Multiprobe, Titan In-Situ Mission
  - Missions to comets/asteroids - e.g., Comet Nucleus Sample Return, asteroid exploration & sample return
- **Other Missions**
  - Earth orbiting spacecraft/science payload, space telescopes, space interferometer missions, and science instruments

Mars Rovers



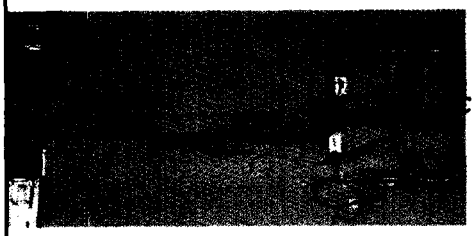
Mars Exploration Rover (2003)

JPL Thermal Control Technology Roadmap



Small Loop Heat Pipe Technology
(Small Size/Capacity LHPs)

Miniature LHP for Mars Thermal Control



Dual Evaporator Miniature LHP

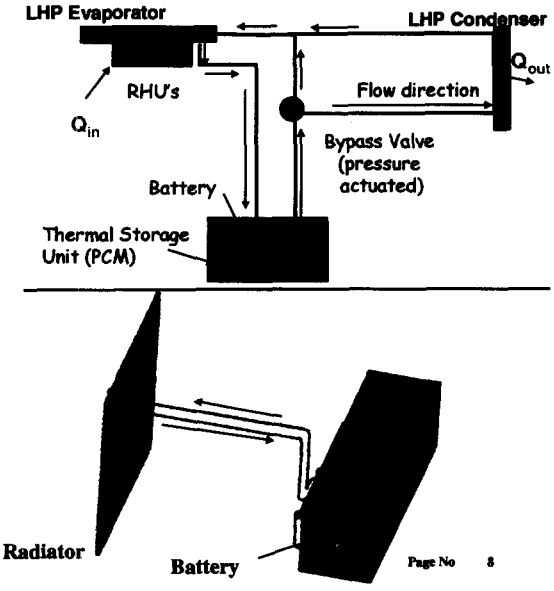
Description:

- A versatile thermal control device: transfers heat, controls temps., and act as a heat switch (all in one)
- Light weight (< 200 gms to transfer 60 W) device compared to other the hardware of same function
- Enormous flexibility in locating heat sources and sinks on the spacecraft

Participants & Facilities:

- JPL is investigating this technology for Mars rover & µS/C applications
- Tests performed at JPL and Goddard during FY00-02 for evaluating miniature multiple evaporator LHP
- Dynatherm Corp (Swales) designed and fabricated a miniature LHP

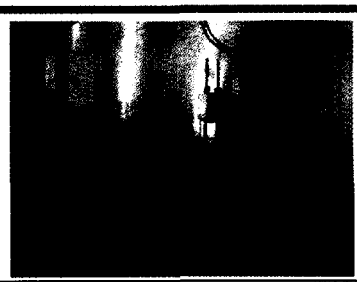
Variable Conductance Loop Heat Pipe

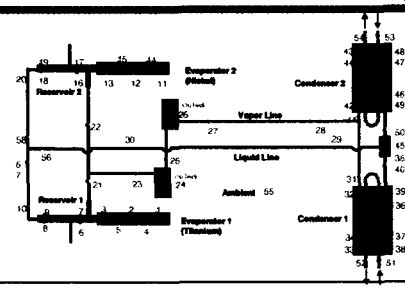


Application

- VCLHP evaluated for Mars battery thermal control
- Backpressure actuated valve is used to bypass the radiator
- Small dia (1/16") tubing allows the condenser to freeze and thaw during Martian diurnal cycles
- Performance and condenser freeze/thaw tests (100 cycles) conducted during late 2000

Dual Miniature Evaporator Mini LHP





Participants & Facilities

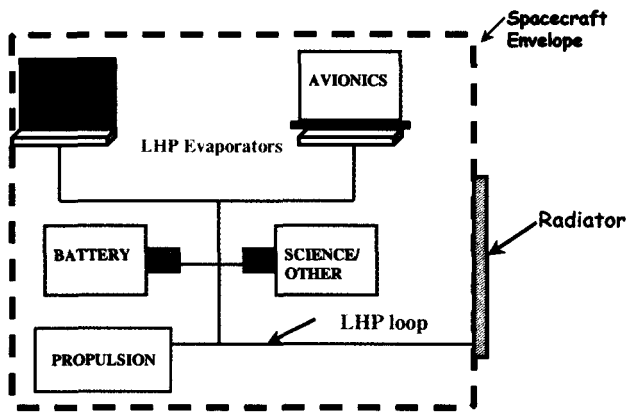
- JPL is investigating this technology for space applications (Mars rover & microspacecraft)
- Tests performed at GSFC during FY00 and more tests at JPL in 2001 for its applications for passive thermal control architecture
- Dynatherm Corporation fabricated the dual evaporator (Ni and Ti wicks) miniature loop heat pipe

Mission Impact & Future Applications

- This technology reduces S/C thermal control mass and provides enormous flexibility
- This is a key technology for enabling Integrated Thermal Energy Management System
- This technology is applicable to small & large S/C and planetary vehicles thermal control

Microspacecraft Thermal Control Architecture

(Based on Passive Two-Phase Fluid Loop)

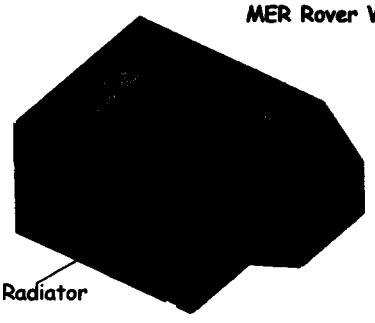


JPL MER Rover Miniature Loop Heat Pipe

Description

- Mini loop heat pipe with 0.5 inch nickel wick and ammonia as working fluid
- Light weight (less than 150 gms (with out the radiator to transfer 50 W)
- Vapor and liquid lines are 1/16 inch dia provides enormous flexibility in locating heat sources and sinks on the spacecraft

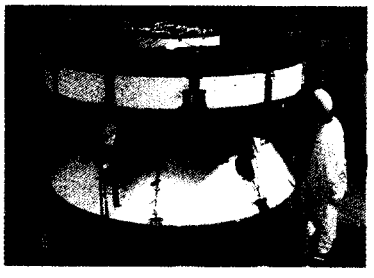
MER Rover WEB



Application

- This LHP removes heat from the MER rover SSPA during the day on Mars, start up heater and CC heater used for control
- Light weight and flexibility allows for easy mechanical integration in the rover
- Small dia tubing allows the condenser to freeze and thaw during Martian diurnal cycles

JPL Mechanically Pumped Cooling Loops



Mars Pathfinder MPL HRS (1996)

Description

- Mechanically pumped single-phase cooling loop used on Mars Pathfinder (1996) and MER (2003) for thermal control
- A pump assembly of 7 kg uses CFC-11 to remove ~160 W from spacecraft electronics to an external radiator

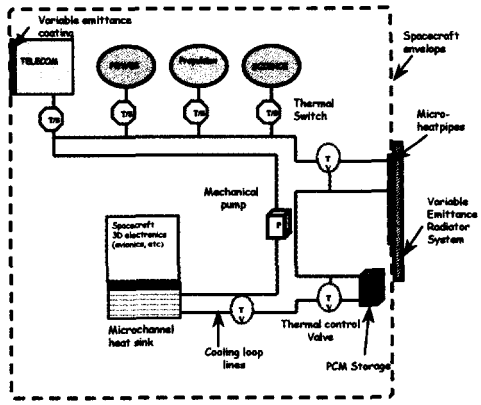
Participants & Facilities

- JPL is investigating this technology for future Mars and deep space missions
- The pump assembly for MER Mission was built by Pacific Design Technology
- An engineering pump unit is under life test at JPL for the last eight months

Microspacecraft Active Thermal Control Architecture

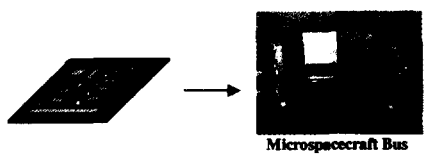
Concept

- JPL is investigating spacecraft thermal control based on a thermal energy management system (ITEMS) for future spacecraft
- Active thermal control with mechanically pumped liquid cooling system
- Potential to transport heat loads from high power density electronics over large distances
- Heat from electronics may be used to warm power, propulsion, and science subsystems
- Features robust and low mass alternatives to passive thermal control hardware



Integrated thermal energy management system architecture

Fluid Loop Based Multi-Functional Structures



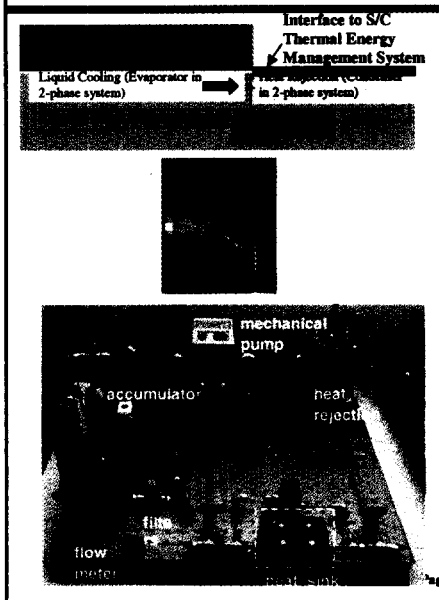
Microspacecraft Bus

MFS panel with fluid channels

Objectives

- Develop Multi-Functional Structure technology incorporating active thermal management, mechanical/electronic packaging, & flex cabling and interconnect functions
- Fabricate and assemble composite MFS panels for avionics, science payload, propulsion, radiator, and fluid system pump assembly
- Integrate MFS panels and demonstrate their performance in microspacecraft testbed

Active Micro-Cooling Systems



Description

- MEMS based liquid pumped cooling system for high density electronics and sensors for future micro/nano Sciencecraft
- Single-phase liquid is circulated in microchannels with a mechanical pump
- Potentially capable of two-phase heat removal

Participants & Facilities

- JPL is investigating this technology for high power density heat removal in microspacecraft and large spacecraft
- A micrcooling test bed used for the evaluation of microchannels and micropumps

Conclusions

- The thermal control challenges posed by small spacecraft for future NASA science missions require advanced thermal control technologies
- Both passive and active thermal control technologies are needed to enable/enhance future missions
- Both near/far term microspacecraft missions require advanced thermal technologies
- JPL is actively working with several organizations in the development of these technologies