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

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Abstract

Developing thermal control architecture for small spacecraft poses unique challenges due to the small volume, power, and mass available to accommodate the thermal hardware. Further, the thermal control technologies applicable for small spacecraft are not as advanced as they are for medium and large spacecraft systems. However, during the last five years, there has been a widespread interest in using small and microspacecraft (under 100 kg and 100 W) for diverse space science and engineering missions. These small spacecraft applications include both earth orbiting and deep space missions. Some of the advanced thermal control architectures applicable to small spacecraft and currently being investigated at JPL include: passive loop heat pipe (LHP) based concepts, active pumped fluid loops, and concepts based on advanced technologies such as variable emittance devices and wax actuated thermal switches

In the area of small loop heat pipes, several loop heat pipe configurations have been investigated for Mars rover applications. These include variable conductance loop heat pipe with thermal control valve, a small single evaporator loop heat pipe, and a dual evaporator loop heat pipe. All these loop heat pipes were designed with ½ inch wick with heat carrying capacity of 20 to 100 Watts. The liquid and vapor lines of these LHPs were of 1/16" diameter. The variable conductance LHP was evaluated for its use for the thermal control of the Mars Exploration Rover (MER) battery, whereas the single evaporator LHP was qualified for removing heat from the telecom equipment on (MER). The dual evaporator LHP was investigated for microspcaceraft thermal control application.

Active single-phase pumped fluid loop has been successfully flown on Mars Pathfinder (1996) and is currently flying on MER spacecraft. This loop has a mass of about 15 kg and uses 10W of power to remove about 150 W of electronic heat. Currently, a single-phase mechanically pumped loop concept is being investigated for microspacecraft thermal management. In this concept, a pumped fluid loop is embedded in a structural panel to provide several thermal control functions of heat removal, heat spreading, and heat rejection to space. The current mass and power targets for this fluid loop system are less than 5 kg and 5 Watts to manage up to 100 W of spacecraft power. Two-phase pumped loops are also being investigated for small spacecraft thermal management. In these concepts, a single-phase pump would circulate the fluid while two-phase heat transfer would take place in the evaporator and condenser.

The presentation will include a description of the activities underway at JPL in these areas along with some of the early results from the analytical and experimental studies.