THERMAL MANAGEMENT FOR LUNAR LANDERS AND ROVERS. William G. Anderson[1], Jeffrey Diebold[2], Michael C. Ellis[2], Kuan-Lin Lee[2], Ion Nicolaescu[2], Nathan Van Velson[2], and Quang Truong[2], [1]Advanced Cooling Technologies, Inc., (ACT) 1046 New Holland Ave., Lancaster PA 17601, Bill.Anderson@1-act.com, [2]ACT, 1046 New Holland Ave., Lancaster PA 17601

Introduction: The Lunar night poses a significant thermal challenge to small, low power payloads, rovers and landers. Due to the slow rotation of the lunar surface relative to the sun, the environmental temperature drops to below 100K for approximately 14 earth days. In order to enable long duration science missions on the lunar surface it is necessary to maintain the electronics above survival temperature during the lunar night. The Apollo astronauts went to the moon during early Lunar morning, which is a relatively benign thermal environment. In contrast, Lunar Landers and Rovers must be able to survive and function over multiple Lunar Day/Night cycles. It has been estimated that for every watt of power supplied by batteries during lunar night an additional 5kg of battery mass is required. Surviving multiple lunar cycles without the use of active power sources for heating and cooling requires advanced thermal management techniques that serve as variable thermal links, allowing waste heat to be rejected during the Lunar day, while passively shutting down during the Lunar night. It should be noted that there is no current system that can meet these requirements.

Thermal Toolbox: The principal objective of the program is to develop high technology readiness level (TRL) thermal "toolbox" elements, and develop complete thermal control systems, consisting of passive elements for (1) Heat Acquisition, collecting heat from electronics, (2) Heat Transport, (3) Heat Rejection, and (4) Heat Storage.

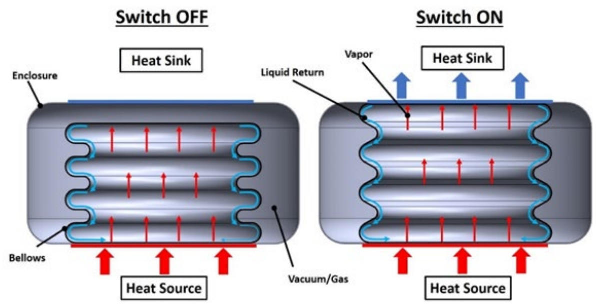

Figure 1. Two Phase Thermal Switch.

These tool box elements, can be combined in a number of different ways, depending on particular design/mission needs and constraints. The program is currently developing the two thermal elements with the lowest Technology Readiness (TRL): 1. Two Phase Thermal Switch, and 2. Thermal Control Valves (TCVs) for Loop Heat Pipes (LHPs)

Two-Phase Thermal Switch: Mechanical thermal switches are designed to minimize heat transport below a certain temperature, with a typical capacity of a few Watts. A two-phase thermal switch [1]; shown in Figure 1, can carry up to 100W, which is required for the larger Lunar landers and rovers. The presentation will present our work on thermal switches to date.

LHPs with TCVs: Thermal Control Valves for LHPs are also being developed. LHPs can carry up to 1kW of power, but require a TCV to passively shut down during the Lunar night [2]. Preliminary Results show that the TCV will allow the LHP evaporator to maintain its temperature with a very cold condenser; see Figure 2. The presentation will also present our work on thermal switches to date.

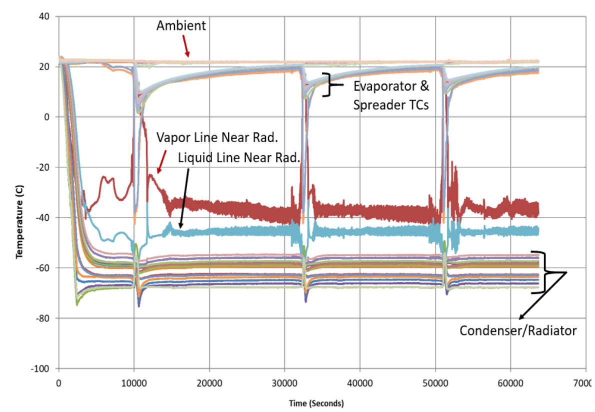

Figure 2. LHP 16.5 Hour Survival Demonstration (in ambient)

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References: [1] Nathan Van Velson et al. (2015) Two-Phase Thermal Switch for Spacecraft Passive Thermal Management, ICES. [2] Sean Hoenig E. F. et al. (1997) Development of a Passive Thermal Control Valve for 3D-Printed Loop Heat Pipes, ICES.