Thermal Design and TVAC Test Correlation of a Lunar Rover Prototype

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# ABSTRACT

The lunar surface thermal environment is particularly harsh amongst planetary bodies in the solar system. Lunar nights last over 14 Earth days, and without a radioactive heat source (RHU or RTG), all components must survive with limited heater power. During the equally long lunar days, constant solar radiation bakes the surface regolith, and the need for solar cells limits real estate for radiators, further constraining the thermal design.

To further develop the thermal design of rovers and other assets destined for the moon, Canadensys Aerospace and Maya HTT partnered with the Canadian Space Agency to carry out the Mobility & Environmental Rover Integrated Technology (MERIT) program. This work included the development and test of a Thermally Regulated Electronics Enclosure (TREE) in a thermal vacuum environment.

To survive this environment, the TREE uses thermally-insulated modules within the rover body. Four thermostatically-controlled loop heat pipes (LHP) developed by Allatherm SIA evacuate the heat during the day, and isolate the modules during the extended nights. Each LHP is equipped with a Bi-metallic Valve Thermostatic Switch (BVTS), a totally passive element which provides system temperature control to switch off the LHPs below a setpoint temperature. Additional insulation is provided by MLI and thermal standoffs.

The TREE assembly was TVAC tested at the CSA’s David Florida Laboratory. The lunar environment was simulated by flooding the TVAC shroud with liquid nitrogen, driving it down to -190°C. Test results showed a better than expected thermal performance during lunar night and that the equipment would well survive. Results from the hot daytime operations provided valuable data for the future development of the loop heat pipe systems, and underscored the challenges of modelling loop heat pipe behavior especially in transient conditions.

Test results were used to correlate the thermal model. The correlation of the lunar night proved to be challenging, with minimal dissipations, high thermal resistances and a cryogenic environment in which the temperatures had not settled after several days. Some imponderables, such as the heat brought in by test harnesses, could not be ignored. Furthermore, the temperature-dependency of the thermal standoffs had to be factored in. The test results were correlated with adequate accuracy, and a lunar night transient simulation provided reliable estimates for the temperatures and power consumption.