

TFAWS Abstract

Interdisciplinary

Development of the Lunar Environment Monitoring Station Thermal Control Subsystem Design

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The Lunar Environment Monitoring Station (LEMS), funded by NASA's Development and Advancement of Lunar Instrumentation (DALI) program, aims to operate instrumentation delivered to the surface of the moon by a Commercial Lunar Payload Services (CLPS) lander for 24 lunar days, or 2 Earth years, at a mass of 35 kg. The current LEMS TRL-6 development at the Goddard Spaceflight Center effort baselines a mass spectrometer and seismometer for scientific instrumentation but the LEMS has been designed to accommodate a variety of scientific payloads. The design of the LEMS Thermal Control Subsystem (TCS) addresses the extremes of the lunar thermal environment with a novel solution.

Despite its proximity as Earth's nearest neighbor, the lunar surface is one of the most extreme thermal environments in the solar system. With the moon tidally locked to Earth, surface spacecraft must contend with a day of 354 hours and eclipse of 354 hours. Long solar days and regolith optical properties result in surface temperatures from -160°C to 80°C at a latitude of 45°, the current baseline for CLPS landers. Electronic components typically have operational temperature limits from -35°C to 60°C. Daytime regolith temperatures and electronics heat dissipations necessitate heat rejection through radiating surfaces but extended sun exposure at a variety of angles due to the sun transiting the sky throughout the day limit radiator effectiveness to mitigate high temperatures. Additionally, the extended eclipse duration makes the mass of the power subsystem sensitive to small milliwatt changes in continuous power consumption like from heaters.

Long term Apollo instrumentation relied on radioisotope materials to generate power and maintain temperature limits. However, use within a compact system like the LEMS creates a positive design loop where increasing radioisotope heat to survive eclipse necessitates a larger radiator to dissipate that heat during the day which requires further heat during eclipse and so on. The result is a system design that exceeds thermal switch mechanical limits, instrument field of view requirements, and mass limits. Additionally, political hurdles and dwindling supply have limited the attainability of radioisotope heaters and generators.

The LEMS TCS addresses these challenges by mitigating electronic heat loads, incorporating recent developments in thermal control technology, and detailed modeling of all parasitic heat leaks. Scientific operations for high power instrumentation like the mass spectrometer and communications transponder are limited to short windows while all other command and data handling are kept to the bare minimum to mitigate heat loads. Environmental heat loads have been minimized through the use of Integrated MLI with an e^* of 0.0020 developed by the QUEST Thermal Group that provides lower heat flux and mass than traditional MLI, helping meet critical thermal and mass goals. IMLI is a robust structural insulation, able to span open spaces and supported on an external frame. New solutions reduce edge and seam heat leaks, and provide lightweight grounding. Surviving launch loads requires a strong mechanical connection to the lander which would result in heat leaks beyond the capability of the TCS so a pyrotechnic mechanism to decouple the launch legs is under development that will reduce the heat leak 4 to 6 times compared to a non-mechanistic solution. Heat transfer through the radiator is

controlled by a variable conduction heat switch with an on/off conductance ratio of 100, sold by the Sierra Nevada Corporation. Finally, a trade study has been conducted to select harnessing materials to minimize heat leaks from externally mounted components like the solar arrays. The resulting design is a spacecraft that is able survive surface temperatures through the lunar day and eclipse with the use of 0 to 2 radioisotope heaters units, totaling 0 to 1.6 Watts, depending on scientific payload.