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Moon Exploration – Part 3 (2C)

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DESIGN AND IMPLEMENTATION OF THERMAL CONTROL STRATEGY FOR MICRO-SIZE LUNAR EXPLORATION ROVER HAKUTO

Abstract

In recent years, space missions led by private ventures have been increasing. The currently ongoing Google Lunar X Prize (GLXP) is a competition made to incentivize development of low cost access to the lunar surface with minimal aid from government funds. As of 2018, Team Hakuto was selected as one of the five finalists and has successfully completed the development of a lunar micro rover Flight Model (FM). Team Hakuto has developed a unique thermal control system in order to use these hardware, designed for use in Earth Orbit, in the thermal environment of the Moon within the severe weight range under 4kg. The topic of this research is the thermal interface design of the Hakuto Rover FM and insights acqruired from results of the final thermal vacuum experiment. In previous research, thermal vacuum experiments were conducted on a Pre-Flight Model (PFM) prototype of the lunar rover to verify the thermal performance of structural materials and thermal interface design in preparation for FM development. Based on the experimental results, we were able to identify needed improvements to keep critical components, (CPU, battery, etc), within operational temperature in the expected thermal environment. A thermal design approach introduced by E.W. Hammond is used as guideline to keep the design tradeoffs clear and concise. As an initial step, a thermal model is developed, where the rover is broken into six different radiating surfaces. Based on the rover's orientation in reference to the solar radiative flux, the rover's surface temperature is determined. Other thermal inputs such as lunar radiation, solar albedo, and conduction from lunar regolith are also accounted for. By using such heat conditions, feasible mounting location for the avionics and the solar panel is determined to optimize the rover's thermal performance while keeping the small (4kg) size of the rover. Once the avionics placement is fixed, thermal isolation concept is studied to separate both radiative surface (avionics side) and heat absorbing surfaces (solar panel side). After the preliminary thermal analysis is completed, computational simulation is performed to verify the thermal response of the Hakuto Rover FM design in the expected lunar environment conditions. Thermal parameters such as specific heat and thermal conductivity from the PFM phase rover's thermal testing is used to tune the rover's parameters. This research culminates in the system design for the Hakuto lunar micro-rover FM thermal interface, with insights from construction process and integrated thermal vacuum testing.