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Author: Dr. John Walker
ispace Technologies, Inc., Japan

FLIGHT-SYSTEM ARCHITECTURE OF HAKUTO'S LUNAR MICROROVER FOR THE GOOGLE LUNAR XPRIZE

Abstract

Hakuto is a Google Lunar XPRIZE (GLXP) team, operated by ispace, Technologies Inc. of Japan. Over several years, it has iterated the design of its lunar microrovers. Through extensive environmental and operational testing, most subsystems of a 7.5 kg four-wheeled microrover were qualified for flight-readiness, to the satisfaction of judges in an interim part of the competition called the "Terrestrial Milestone Prize" (TMP). In this phase of the project, the microrover used a 360 degree, single camera system with a conventional (for space use) FPGA-based main controller and and off-the-shelf, ARM-based controller used as an imaging controller.

Based on these results, in which the imaging controller performed beyond expectations, especially in radiation testing, the rover's design was updated in three major phases. First, the electronics were updated to a candidate architecture for flight, using two ARM controllers instead of a conventional, radiation-hardened FPGA; and four cameras comprising a 360 degree view instead of a single 360 degree camera system. This architecture was designed for low power consumption. Second, the architecture was qualified once again in environmental and operational testing, with particular focus on radiation tolerance. Third, the structure, power generation and thermal design was updated in order to minimise mass, considering lowered power consumption.

The final flight-system architecture is presented as a four-wheeled microrover with just 4 kg mass, including test results showing mobility performance maintained compared to previous 10 kg and 7.5 kg versions. Adequate thermal performance (i.e.: components within their temperature ranges) is shown using thermal-vacuum test results and simulations, for Hakuto's lunar target of Lacus Mortis at 45 degrees latitude. For this mission, justification for a target distance traveled of 10 km in one lunar day is given. This surpasses the performance of any rover mission to date.

The architecture, having two CPUs, four cameras and four motors, is modular and scalable. The 4 kg design is shown to be capable of a mission in the region of -60 to 60 degrees latitude, with varying constraints on operation depending on latitude. The potential for scaling the architecture down to a 1.7 kg, two-wheeled, one-CPU, two-camera design with reduced reliability and capability is shown using simulations. While 4 kg is planned for the ispace's first mission, successful results in that mission will justify lowering the of mass a single rover by removing redundancy, while maintaining reliability and increasing scientific value by increasing the number of rovers sent in the next mission.