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MISSION OPERATIONS OF THE YAOKI LUNAR MICRO-ROVER ON INTUITIVE MACHINES MISSION 2: DEVELOPMENT, SURFACE OPERATIONS AND LESSONS LEARNED

Abstract

In February 2025, Intuitive Machines launched the IM2 mission on a SpaceX Falcon 9. Seven days later, the Athena lander reached the Moon but struck a crater, damaging its legs and toppling it. Lacking sufficient solar power, its battery rapidly depleted, forcing onboard NASA and commercial payloads—including the Yaoki rover—to race against time to conduct surface operations and maximize data collection. In this paper, we focus on the mission operations of the Yaoki lunar micro-rover. Designed and built by Dymon, the 500gram rover is the smallest privately funded lunar rover. Its small size and the harsh lunar South Pole environment create unique operational challenges. Key mission partner JAOPS designed, implemented, and controlled the mission operations. We first present the mission control system development, then describe the five phases of surface operations, and finally share the rover's results and data, which are made publicly available.

The Mission Control System for the Yaoki mission uses the opensource Yamcs framework. This modular system, with 15 years of heritage supporting Earth-orbit missions as well as lunar landers and rovers, is customizable for both large and small missions. The telecommand and telemetry database defines all received data and sent commands. We implemented camera image streaming: decoding, assembly, and display of each image packet is done in realtime to boost operational efficiency. All raw and processed engineering data are stored for secure archiving and efficient access. The user interface was developed with Yamcs Studio and Grafana (see UI screenshots from lunar surface operations). A 3D simulation of the lunar surface, Athena lander, and Yaoki rover was developed to aid operational design and operator training. The paper shows renderings of the mission in nominal condition and in its reconstructed toppled state, demonstrating the value of simulation for situational awareness and mission operations.

We detail five phases of surface operations: situational awareness after landing, first contact and initial procedure, deployment and troubleshooting, maximizing technology demonstration and data downlink, and data archiving. For each phase we discuss the main processes and commands executed with a focus on the human factor. Finally, we present the key results of this first microrover mission to the lunar South Pole. Data is available via a publicly accessible Yamcs archive and can be visualized with Grafana on a cloudbased server hosted by JAOPS. We analyze operational results, including telecommands sent,

images received, sensor and housekeeping telemetry, and the cadence achieved under nonnominal landing conditions.