IAF SPACE EXPLORATION SYMPOSIUM (A3)
Moon Exploration – Part 1 (2A)

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ENABLING EXPLORATION WITH GNSS: RESULTS OF THE LUNAR GNSS RECEIVER EXPERIMENT (LUGRE)

Abstract

The Lunar GNSS Receiver Experiment (LuGRE) is a joint NASA-Italian Space Agency (ASI) payload on the Firefly Blue Ghost Mission 1 (BGM1) awarded as part of the NASA Commercial Lunar Payload Services (CLPS) program. LuGRE was developed with the goal of extending GNSS-based navigation and timing to the Moon, and with three objectives:

OBJECTIVE 1: Receive GNSS signals at the Moon. Return data and characterize the lunar GNSS signal environment. OBJECTIVE 2: Demonstrate navigation and time estimation using GNSS data collected at the Moon. OBJECTIVE 3: Utilize collected data to support development of GNSS receivers specific to lunar use.

The BGM1 spacecraft launched January 15, 2025 and executed three Earth-centered phasing loops before entering lunar orbit on February 14, 2025. The spacecraft spent 16 days in low lunar orbit, then successfully landed on March 2, 2025. It operated from the lunar surface through end-of-mission on March 16, 2025.

The LuGRE payload operated successfully through all phases of the mission. Beginning 6 hours after launch, LuGRE completed 16 one-hour data collection operations in the transit phase, including in lunar orbit, then operated nearly continuously throughout the surface mission. LuGRE acquired, tracked, and performed real-time navigation using GPS and Galileo L1/E1 and L5/E5a signals in all phases of the mission, and additionally collected and downlinked raw L1 and L5 I/Q samples for ground processing.

LuGRE accomplished several previously-unachieved milestones, including the highest altitude known use of GPS and Galileo signals, the highest altitude known GNSS navigation fix, the first use of these signals in lunar orbit, and the first known use of GNSS on the lunar surface. The data collected by LuGRE will enable developers of lunar-specific GNSS receivers and navigation systems to utilize in-situ lunar-vicinity data and applicable lessons learned to benefit their developments, and will enable lunar missions to better assess the potential benefits of GNSS in their navigation design.

This paper discusses the overall payload description and design, the flight experience and activities, the high-level results of the mission, and the key findings and lessons learned. It focuses on the real-time results from the LuGRE payload, including acquisition and tracking performance and real-time navigation results, and captures the status of the defined science investigations performed by the LuGRE team after the completion of operations. Additionally, it discusses the implications of GNSS availability for navigation around the Moon for future robotic exploration.