National Aeronautics and Space Administration

Magnetometer Technology Development for the ARTEMIS Initiative

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Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Architecture for Thermal Enclosure of Moon Instrument Suites - Strategic Initiative Leader: Ying Lin

Objectives:

The overarching goal of the ARTEMIS-M task was to design and validate an implementation strategy to perform long-term magnetic field measurements on the lunar surface to measure internal structure. This involved several distinct objectives: 1) to assess the readiness and suitability of competing magnetometer types to meet the measurement requirements; 2) to test design modifications to the optical subsystem of JPL's Vector Helium Magnetometer to make it more robust to the lunar environment; 3) to develop the interface with, and integrate the optically-pumped VHM into a nested, dual-thermally switched prototype thermal enclosure developed in the ARTEMIS-T task; 4) to test the integrated ARTEMIS-T/M system in a thermal vacuum (TVAC) chamber that simulates conditions on the lunar surface over six day/night cycles in order to demonstrate the ability to satisfy the magnetic field measurement requirements for a long-lived lunar surface magnetic field investigation. Task completion ensures that the LMTE/VHM system will be ready to propose as a stand-alone lunar instrument.

Background:

Magnetometer measurements are required to address several key lunar science goals including: (1) magnetic sounding to determine the moon's internal electrical conductivity profile; (2) understanding the effects of solar wind and Earth's magnetotail plasma on surface composition; (3) determining if the OH depletion observed in lunar swirls is the result of strong magnetic field anomalies shielding the surface from solar wind; and (4) determining the origin and history of the lunar crustal magnetic field, likely arising from a now extinct dynamo. Probing the internal conductivity and structure of the moon drives requirements, as continual monitoring for > one year is needed, with a magnetometer accuracy of <100 pT at a cadence of 1 Hz. In addition, to ensure an accuracy of <100 pT in the presence of other noise sources, the stability of the magnetometer is required to be < 25 pT. These requirements drive the need for a thermally-regulated enclosure to host a highly stable magnetometer. The JPL VHM integrated into the ARTEMIS-T enclosure (Figure 1) mounted on a boom is capable of meeting these requirements; the work done within this strategic initiative demonstrates its robust operation in the lunar environment.

Approach and Results:

The ARTEMIS-M task involved several sub-tasks: 1) identify requirements on magnetometer measurements for lunar science; 2) perform design updates to improve robustness and reduce accommodation challenges for lunar deployment, and validate by lab testing; 3) testing to demonstrate performance over the lunar diurnal temperature cycle. Results are shown in the figures at right.

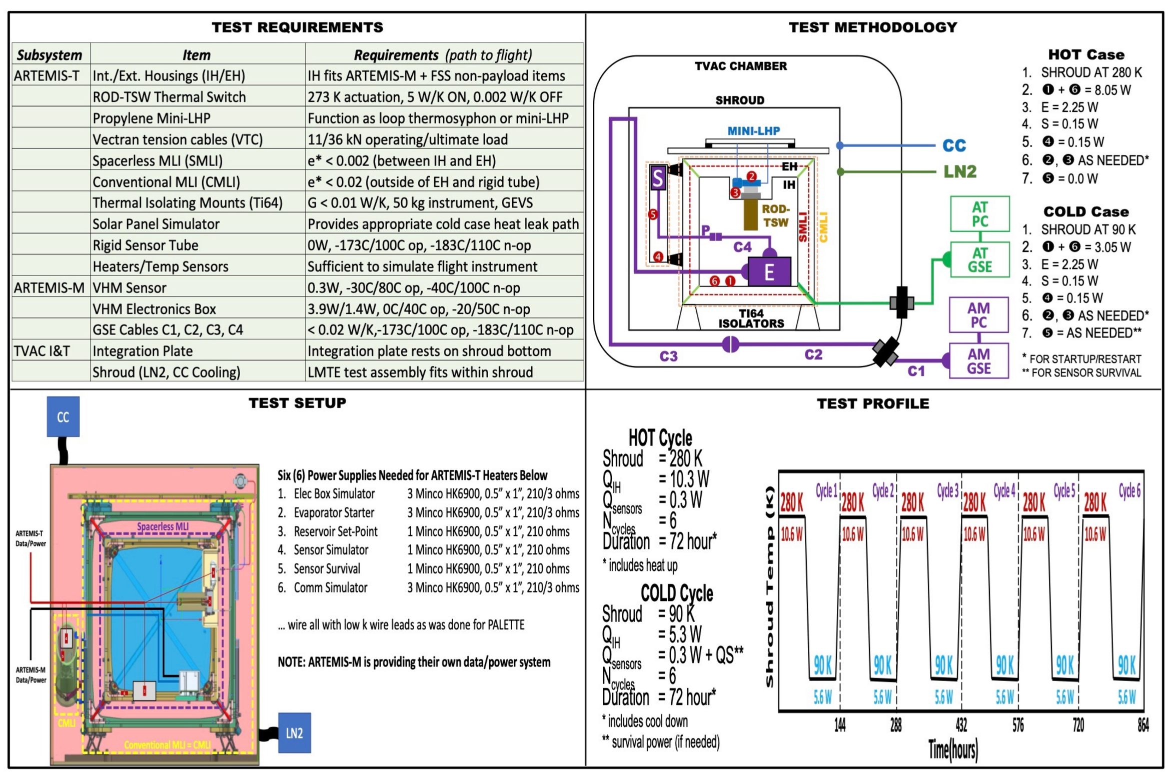

Figure 1. *Lunar Magnetic Thermal Enclosure (LMTE)/VHM Test Article Requirements/Test Plan*

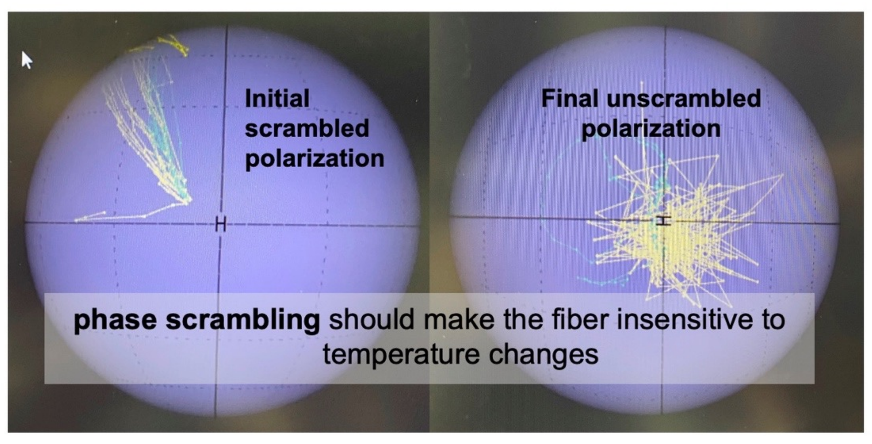

Figure 2. *A delay loop in the optical fiber to scramble the polarization was tested to confirm that it would eliminate polarization jumps that introduce noise into the magnetic field data. The stability of the laser signal during the test showed that the technique works as expected.*

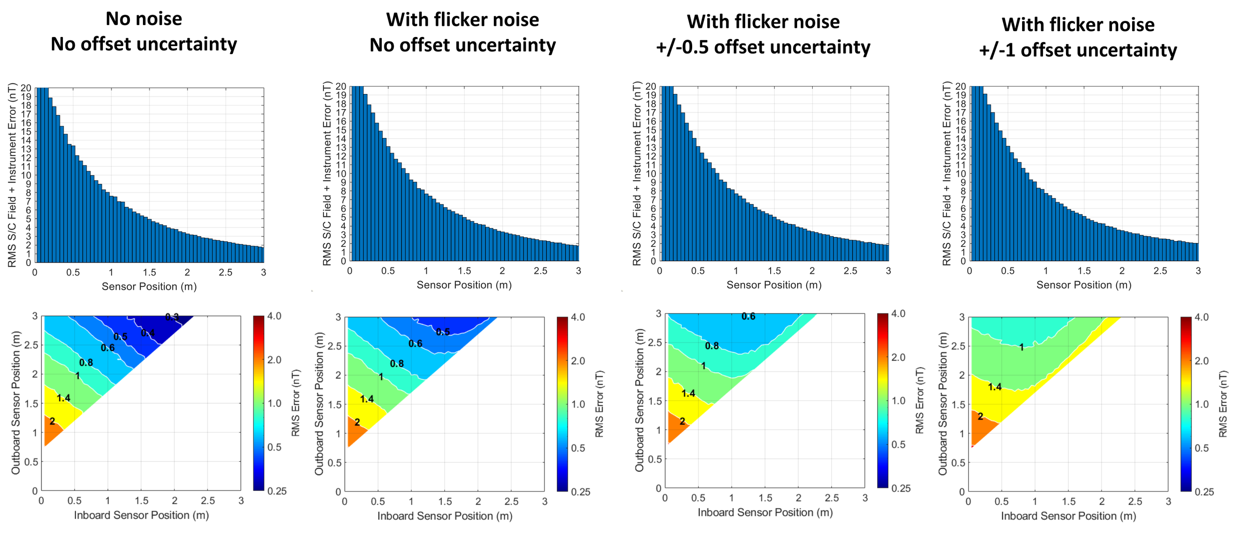

Figure 3. *Modeling was performed to determine expected accuracy as a function of boom length and sensor placement. Two sensor gradiometry on a 3 m boom can meet requirements.*

Significance/Benefits to JPL and NASA

This work provides JPL with a competitive advantage in responding to upcoming NASA Announcements of Opportunity for Payloads and Research Investigations on the Surface of the Moon (PRISM) via demonstration of a new approach to maintain stability of a commercial fiber optic cable and operation over the diurnal lunar temperature range that can achieve the requisite magnetometer sensitivity.

Figure 4. *Test sensor (copper housing) shown mounted in a G10 tube in the LMTE TVAC configuration (left).*

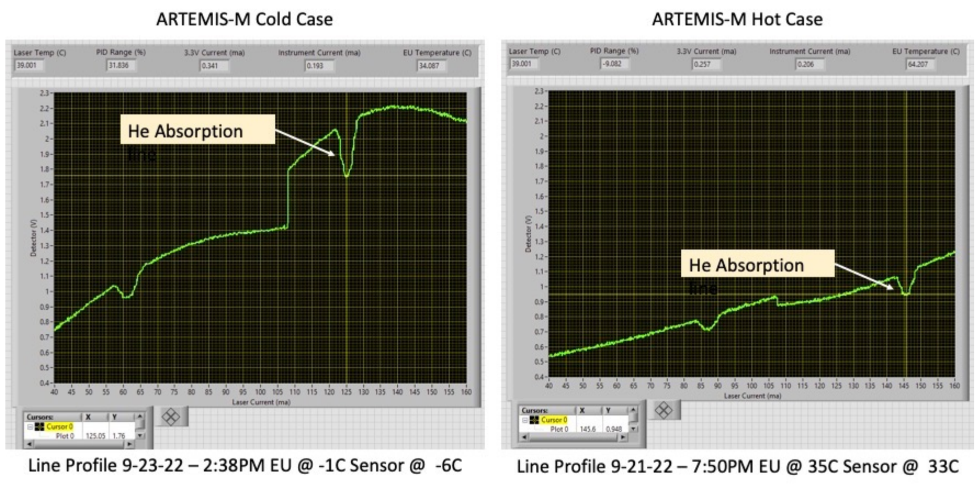

Figure 5. *The wavelength of the laser diode is invariant to ambient temperature as shown by the detections of He 1083nm absorption in both the cold and hot cases. The test indicated that adding an automatic gain control circuit would improve the stability and further reduce noise in the hot case.*

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www.nasa.gov

Clearance Number: CL#
Poster Number: RPC#

Publications:

Carol A. Raymond, C. J. Cochrane, N. Murphy, B.P. Weiss, K.K. Khurana and V. Angelopoulos, "Investigating the Lunar Interior Using Long-Lived Surface Magnetometers", *Lunar Surface Science Workshop (Virtual), LPI Contrib. No. 2241,* 2020.

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