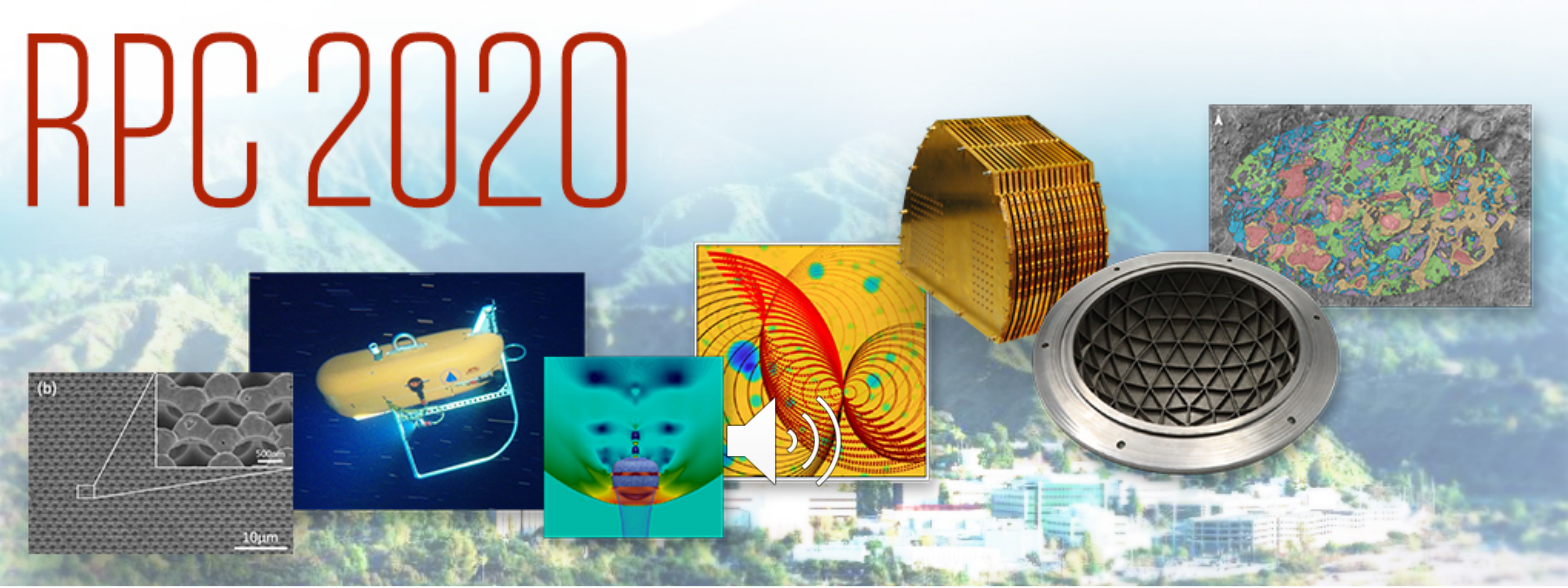

Virtual Research Presentation Conference

Magnetometer Technology Development for the ARTEMIS Initiative

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Program: Strategic Initiative

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Tutorial Introduction

Abstract

The dynamic magnetic field of the Moon provides key constraints on its origin and evolution, and its interactions with the solar wind. Highly sensitive field measurements are needed to answer current outstanding questions in lunar science. JPL helium magnetometers (in particular the Vector Helium Magnetometer, VHM) are well suited to perform long-term, highly accurate surface measurements, owing to their superior stability. To prepare for future opportunities to propose such experiments under NASA's PRISM call, we are executing a program to reduce implementation risk for lunar day/night operations by testing and validating a novel approach to reduce the temperature sensitivity of the optical fiber that couples the He cell to the laser diode. The project is also working with the companion thermal task to integrate the VHM into a novel thermally-switched enclosure to allow efficient thermal management and reduce resource use for day/night operation. Lastly, we assess the potential of new solid state/atomic technologies for very small, low-power magnetometers, to develop an investment strategy that further strengthens JPL's leadership in magnetometer development, especially for low-temperature operation.

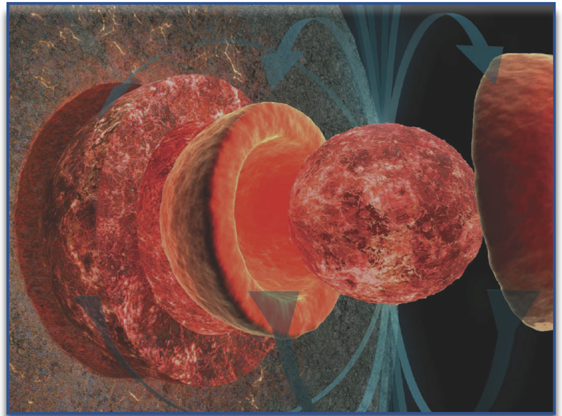

Image credit: B.P. Weiss, Science, 346, 1246753, 2014.

Problem Description (1 of 2)

The ARTEMIS Initiative comprises two linked tasks: Thermal Technology Development for the ARTEMIS Initiative (ARTEMIS-T) to develop a passive, no-radioisotope thermal architecture and this task (ARTEMIS-M) to develop a TRL6 helium magnetometer capable of operating over the lunar diurnal cycle. The task (ARTEMIS-M) matures the existing JPL helium magnetometer for the challenges of lunar surface operations, preparing us to develop a competitive proposal to the future NASA call for *Payloads and Research Investigations on the Surface of the Moon* (PRISM). To achieve the magnetic field goals at the Moon requires long-term accurate measurements.

No flight magnetometers that have been demonstrated to survive and operate in an environment comparable to the lunar nighttime. The most commonly flown fluxgate magnetometers (FGMs) are very precise at high frequencies, but noisy at low frequencies and they cannot meet the required accuracy. Additionally, FGMs suffer from fluctuating offsets (zero-levels) that are temperature sensitive which can be calibrated on spinning spacecraft, but interfere with maintaining stability on fixed platforms. Helium magnetometers are very stable at low frequency and thus are ideally suited for long-term lunar surface measurements

Problem Description (2 of 2)

By combining lunar magnetometer technology development and thermal architecture development, the initiative addresses key goals in the *JPL Strategic Implementation Plan (Solar System)* and in the *2017 NASA Strategic Technology Investment Plan* that relate to lunar/planetary surface exploration and extended operations. The work will:

- Strengthen JPL's competitiveness in future lunar payload solicitations (e.g. PRISM) that result from NASA's new focus on the Moon. In-situ lunar missions are expected on an annual cadence over the next decade.
- Provide maturation, risk reduction, and improvement of existing helium magnetometer technology, and plan for investments in new solid state/atomic technologies to further strengthen JPL's leadership in magnetometer development, especially for low-temperature operation.
- Enable long-duration lunar science missions (e.g., New Frontiers Lunar Geophysical Network) that require day/night monitoring of magnetic and seismic activity, surface chemistry, and other phenomena.

Methodology

Our approach to address the goals previously outlined, and specific implementation approaches are to:

- Define environmental requirements for long-term operation on the lunar surface, and for integration into the ARTEMIS-T enclosure
  - Component power and volume, total number of cables (including optical fiber requirements), and need for external boom
  - Thermal requirements pending outcome of lab-testin
- Demonstrate robustness of the VHM to lunar surface operations by assessing laser and magnetometer performance using commercial fiber-optic cable(s) at low temperature
  - Measure the noise level of magnetometer and characterize laser output (power draw, wavelength, polarization, with and without polarization scrambling), using three configurations of the coupling between the laser diode and the helium cell:
    - Using standard commercial fiber-optic cables
    - Using a hollow-core photonic crystal fiber
    - Using a free-space coupled configuration
- Assess current magnetometers' capabilities and develop roadmap for future opportunities to guide investments

Results (1 of 2)

Accomplishments for FY20

- Developed test plans and procured test articles and equipment to demonstrate laser and magnetometer performance using commercial fiber-optic cable(s). Test setup partially complete in the JPL magnetically-shielded test facility. Testing was delayed to FY21 due to COVID-related delays.
- Provided environmental requirements to the ARTEMIS-I team for use in designing the thermal enclosure
- Submitted abstract to Lunar Surface Science Workshop
- Submitted PRISM RFI response for Lander VHM
- Compiled draft White Paper on Magnetometer Capabilities and Roadmap

Results (2 of 2)

Significance

The work has advanced the maturity of the JPL VHM for lunar science applications through planning for, and setting up for system performance testing using various configurations of commercial fibers. Preliminary work on the interface with the ARTEMIS-T thermal enclosure has made progress toward ensuring operation through the lunar night. Our assessment of the current state and future trends in the field of spaceborne magnetometry provides the basis to understand JPL's competitive position and what investments will yield the highest payoffs.

Next Steps

In FY21 we will complete testing and expect to respond to the impending PRISM call for lunar lander payloads.

Publications and References

Raymond, C.A., 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, LPI Contrib. No. 2241,* 2020.