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Author: Dr. Chinmayee Govinda Raj
NASA Ames Research Center, United States

Mr. Stephen Lantin
University of Florida, United States
Dr. Diana Gentry
NASA Ames Research Center, United States
Dr. Sergio Santa Maria
NASA Ames Research Center, United States
Mrs. Kayla Bryant
National Aeronautics and Space Administration (NASA), Ames Research Center /Blue Marble Space Institute of Science, United States

ADVANCING LUNAR BIOLOGY: TESTING AND INTEGRATING A MICROBIAL VESSEL FOR ENHANCED ELECTROCHEMICAL AND OPTICAL MEASUREMENTS IN SPACE EXPLORATION

Abstract

The Lunar Explorer Instrument for Space Biology Applications (LEIA) is slated for a 2026 Moon launch, carrying yeast to study its responses to lunar radiation and gravity through optical measurements. Like the earlier BioSentinel (Artemis 1), with which it shares a biofluidics architecture, LEIA relies on a specialized ground-support equipment (GSE) sensor-enabled culture system to accurately map flightlike optical data onto a broader array of electrochemical parameters, thereby enhancing the mission's scientific outcomes. This GSE system has evolved from a two-parameter optical-only setup to the current Microbial Vessel for Impedance Spectroscopy and Electrochemistry (MVISE) prototype. MVISE simultaneously measures six parameters of a microbial liquid culture, including optical density at multiple wavelengths, colorimetric oxidation-reduction potential (ORP), pH, directly sensed ORP, electrical conductivity (EC), dissolved oxygen (dO2), headspace CO2, and contactless dielectric spectrometer (CDS). These added parameters enable monitoring the culture's electrochemical state, offering valuable biological status information. All sensors except the custom optical density and CDS probes are commercial off-the-shelf components.

The MVISE is designed to be compatible with both subtractive and additive manufacturing. For subtractive manufacturing, polycarbonate will be used owing to its ease of manufacturing, durability, and biocompatibility. Additive manufacturing, which allows for more rapid design iteration and single-use implementation, will be using stereolithography 3D printing. Multiple COTS resins were tested for biocompatibility with yeast, relying on both absorbance readings and agar plate growth measurements. Medical grade resin (similar to that used for dental fixtures) was found to be the most biocompatible and used for 3D printing the current MVISE prototype. Both designs include detachable contactless OD measurement modules. These modules are only constructed from polycarbonate and undergo vapor polishing to achieve a smooth surface finish. This smooth surface finish is essential to prevent biofilm formation as well as staining from colorimetric indicators in the culture media.

The MVISE has undergone rigorous testing to confirm its dimensions, air- and water-tightness, sterilizability, and long-term durability. Biology tests on the 3D-printed MVISE will commence shortly, immediately followed by the correlation of both contactless and immersion optical density readings with

electrochemical parameters. In the long term, the mapping of CDS readings to optical readings will also be conducted.

Beyond elevating the scientific outcomes of the LEIA mission, MVISE has broader implications. It supports studies on microbial adaptation to conditions resembling space mission environments, providing a controlled but dynamic simulated microenvironment. This positions MVISE as a valuable tool for upcoming space biology missions.