Science Returns Expected from MACIE: Mars Astrobiological Caves and Internal Habitation Explorer (a New Frontiers Mission Concept). C. M. Phillips-Lander, J. J. Wynne, A. Parness, K. Uckert, N. Chanover, T. N. Titus, K. Williams, C. Demirel-Floyd, E. Eshelman, A. Stockton, S. Johnson, D. Wyrick. 1Space Science and Engineering Division, Southwest Research Institute, San Antonio, TX; clander@swri.edu, 2Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ, 3NASA Jet Propulsion Laboratory, Pasadena, CA, 4Department of Astronomy, New Mexico State University, Las Cruces NM, 5Astrogeology Science Center, United States Geological Survey, Flagstaff, AZ, 6School of Geosciences, University of Oklahoma, Norman, OK, 7NASA Ames, Mountain View, CA 8Department of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, GA, 9Department of Biology, Georgetown University, Washington, DC

Introduction: Caves represent one of the best localities for finding evidence of life beyond Earth. These features offer subsurface access without the costs of a deep drilling payload [1] and are ideal locations for potential human habitation. Mars has more than a thousand cave-like features [2], which formed from volcanic processes (e.g. lava tubes), tectonic processes (e.g. atypical pit crater chains), or both. Together, these features represent substantial void space in the subsurface. Numerical heat and mass-transfer modeling of the martian surface indicates equatorial martian caves may not only be shielded from cosmic radiation, but also host favorable conditions to maintain stable water-ice deposits [3]. Both factors would enhance the habitability and astrobiological potential of martian caves relative to surface environments. Therefore, these features represent ideal astrobiological targets on Mars.

Objectives and Relevance: We assessed the potential science returns for a New Frontiers (NF) Mars lava tube (cave) exploration mission. The Mars Astrobiological Caves and Internal Habitability Explorer (MACIE), named after Macie Roberts NASA’s first human computer [4], would address a key recommendation of the 2019 National Academies’ Astrobiology Strategy, “NASA’s programs and missions should reflect a dedicated focus on research and exploration of subsurface habitability in light of recent advances... in our understanding of [the] history and nature of subsurface fluids on Mars...” [5].

MACIE’s Science Goals would address all four goals of the Mars Exploration Program, including (1) Determine whether life ever existed on Mars; (2) Characterize the climate of Mars; (3) Characterize the Geology of Mars; and (4) Prepare for human exploration [6]. MACIE also addresses Strategic Objective 1.1 by “Searching for Life Elsewhere” and Objective 2.2 by “leveraging scientific expertise for human exploration of the Solar System” [7]. If the MACIE did not detect evidence of past or present life, it would still provide significant habitability and geology science returns, and enable us to develop criteria for accessing lava tubes for future use as human astronaut shelters or bases.

Science Goals: MACIE’s primary science goal would be to (1) Assess the astrobiological potential of the subsurface by determining the presence of extant/past life and life-related indicators. MACIE’s other goals, including (2) Assessing habitability of the subsurface, and (3) Determining the geologic history would support interpretation of astrobiological data.

Instrumentation: A number of heritage instruments could be used to satisfy Objectives 1-3 as shown in the STM (Table 1). Payload selection will be driven in part by spacecraft architecture; however, the payload would emphasize instrumentation associated with assessing the astrobiological potential of Mars’ subsurface. A possible strawman payload would include cameras for stereo imaging, a DUV/Vis Raman spectrograph and/or a mass spectrometer, a temperature (T) and relative humidity (T/RH) probe, and a Gamma ray or neutron spectrometer.

Goal 1 Astrobiology: Both Raman and Mass Spectrometry can be used to address Objective 1A (Table 1). However, a mass spectrometer would be required to quantify isotopic ratios (Obj 1A.2) and gas concentrations (Obj 1A.3). A microscope would be required to characterize morphological signatures of life Obj 1B.

Goal 2 Habitability: Objective 2A and part of 2B could be addressed either by mass spectrometry or Raman. Quantifying atmospheric gases would require a mass spectrometer (Obj 2B.2). Cave climate would require an T/RH probe similar to Mars Science Laboratory’s Remote Environmental Monitoring Station and Obj 2C and 3B.1 would require a Gamma ray or neutron spectrometer.

Goal 3 Geology: Cameras required for robotic traverse of the cave can also provide data on the depth, structure, and extent of the cave. In particular stereophotogrammetry may provide a low mass alternative to LiDAR and address Obj 3A.2 and 3B.2. Raman or mass spectrometry can provide insight into Objective 3B.1 and 3B.3.

Spacecraft Architectures: There are three main robotic architectures that could support a NF Mars’ Caves Mission, mainly a rock climbing robot (LEMUR; TRL 6) [8], a two-wheeled axial robot (i.e. similar to Moon Diver) [9], and unmanned aerial systems (SwRI drone; TRL 9 for Earth applications; TRL 4/5 for space). In all cases, the robotic architecture will consist of a surficial
lander for communication, and a mobile unit for communication, and a mobile unit for exploration. Communication repeaters may also be used in the lava tube to enable deep exploration.

**Planetary Protection:** A lava tube cave mission would access an area designated as a “special region” [10] and require compliance with Planetary Protection Category IVc, which addresses special regions [11]. Accordingly, the mission would ensure a total bioburden level of $<1.5 \times 10^{-4}$ spores.

**Discussion:** Advancement of several spacecraft architectures for use in lava tube cave exploration make the search for life in Mars subsurface feasible within the next decade. We recommend exploration of Mars’ subsurface via cave access points for inclusion on the NF list for the upcoming Decadal Survey and recommend that a mission concept study be performed to determine the best payload(s) that could determine whether life existed in Mars’ subsurface with different robotic architecture options.

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**References:**