SOTERIA: Searching for Organisms Through Equipment Recovery at Impact Areas
A proposal to assess microbial forward contamination through a mission to recover lunar spacecraft debris from recent impact sites near the South Pole.

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All spacecraft sent to the Moon have carried viable microorganisms with them. Because the Moon's surface environment is sterilizing to life and the Moon itself is not considered to house indigenous life forms, NASA policy has not required the elimination or even the measurement of microbial contamination on lunar space equipment prior to launch [1, 2]. Yet multiple exposure studies have demonstrated that microorganisms can likely survive high-velocity impacts [3] and exposure to space stresses for some time [4, 5]. Does any of the Earth biomass residing on lunar hardware remain viable? The Artemis program offers a chance to take advantage of this natural experiment, through a mission that is feasible and that promises to generate unprecedented data on microbial survival.

We propose a two-phased mission in which imaging would be conducted to obtain data on previously crashed spacecraft near the Lunar South Pole, then astronauts would recover spacecraft debris to return to Earth for analysis of viable life and biosignatures. We propose the name **SOTERIA** for this planetary protection mission, for the Greek goddess of safety and delivery from harm.

The Lunar Microbial Survival model predicts there may be surviving microbiota on recently delivered spacecraft debris located near the Lunar South Pole.
Using current knowledge on microbial survival of both high-velocity impact forces and lunar biocidal conditions such as UV exposure, temperature extremes, and low pressure, Schuerger and colleagues built a Lunar Microbial Survival (LMS) model to predict the abundance of viable microbial life that might still be present on debris from 54 lunar missions since 1959 [2]. Although many are predicted to have no remaining life, the LMS model predicts that the 10 most recent spacecraft might still carry viable microorganisms, with the highest bioburdens on the deep internal surfaces of spacecraft near the Lunar South Pole [2].

India's Chandrayaan-1 Moon Impact Probe (MIP) is a promising target.
Recent, high-resolution polar mosaics produced by Lunar Reconnaissance Orbiter Narrow Angle Camera images have enabled us to map the location of the descent images generated by the MIP, and therefore estimate its impact site more accurately than has been previously reported (Fig. 1). The impact apparently occurred at 89.44° +/- 0.01° S, 229.7° +/- 4.0° E. This location is on the Earth-facing flank of the Connecting Ridge, one of the most illuminated points on the Moon and one considered for an early NASA Artemis Program landing. In addition to the Chandrayaan-1 MIP, we have identified three other high-priority target locations near the South Pole: the NASA Lunar Prospector orbiter (87.5° S/42.3° E), the NASA LCROSS shepherding spacecraft and Centaur upper stage (84.7° S/311° E), and the ISRO Chandrayaan-2 Vikram lander (70.9 °S/ 22.8°E). These sites might serve as alternatives or complements to the MIP site.

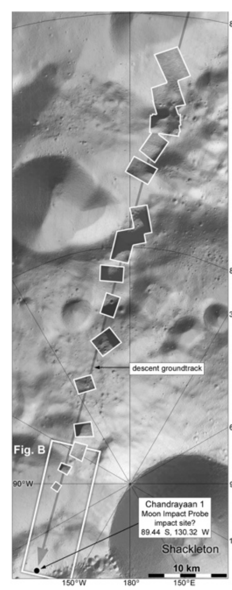

Figure 1. MIP descent images and estimated landing site.

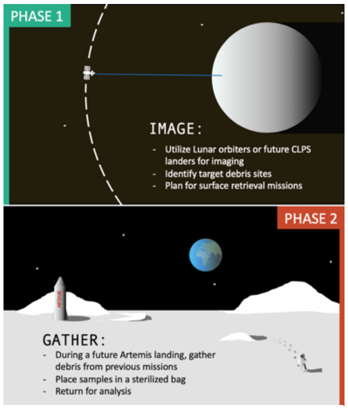

Figure 2. Mission architecture.

SOTERIA mission architecture (Fig. 2)

Phase 1 - Image: A precursor imaging mission, involving lunar orbiters with high-resolution cameras and/or Commercial Lunar Payload Services landers, would map out the impact sites mentioned above.

Phase 2 - Gather: Astronauts would collect debris from the impact site into sterile containers and return it to Earth, under COSPAR Category V "unrestricted Earth return" [6, 7]. Only a few kilograms of material would be required, and the required crew training would be minimal: an untrained eye could likely identify metallic spacecraft debris easily amongst lunar rocks/regolith. Samples would undergo a suite of assays on Earth. We propose not only enumeration of culturable organisms using standard NASA procedures [8], but also detection of non-culturable viable organisms using viability PCR and sequencing [9, 10], and analysis of biosignatures that would pose a contamination risk to detection of novel life on other planets. Biosignature analysis could include deep UV resonance Raman and fluorescence spectrometry (as carried out by SHERLOC) and classical laboratory organic extraction with GC-MS analysis [11].

Recovery and analysis of space hardware has been carried out before, and should be repeated. During the Apollo 12 mission, astronauts retrieved a portion of the Surveyor III's camera during a surface EVA in November 1969 [12]. Back on Earth, Mitchell and Ellis (1971) recovered a culture of *Streptomyces mitis* from the hardware, suggesting that the bacteria had survived launch, space travel, and 2.5 years of the harsh lunar environment [13]. However, doubt has been raised about the sterility of the procedure [14]. SOTERIA would offer a chance to revisit the question using more modern methods, and to obtain information about the survival not only of viable life but also of biosignatures.

Even a negative result would be valuable.

Recovering live microorganisms is not the goal of this mission concept; a negative result, in which even the most sensitive microbiological assays fail to detect viable cells, would be just as useful. NASA's effort to understand the conditions required for life requires sending spacecraft to Mars and other planetary bodies without contaminating them with terrestrial life, and assessing with certainty the provenance of any detected biosignatures. SOTERIA addresses these goals by 1) providing data on the survival of spacecraft-associated organisms in extraterrestrial conditions, directly informing questions of forward contamination; 2) assessing the survival of non-viable organic matter that could influence planning for life detection investigations [15]; and 3) serving as a trial opportunity to perform sample collection and analysis in real planetary field conditions under the high levels of sterility and contamination control that will be required at other targets in the search for extraterrestrial life. SOTERIA will contribute to Space Biology and Astrobiology, and verify Planetary Protection procedures with data derived from another world, for the first time in the history of spaceflight.

References

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