Understanding the Impact of The Deep Space and Lunar Environment on Humans and Biology.

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Introduction: As the Artemis mission advances to the Moon, women and men will be venturing into dangerous environments and facing unique hazards. In addition to living in closed environments, with microgravity, the deep space environment adds high levels of radiation, the absence of Earth's magnetic field, and altered gravity for lunar missions. These elements present new challenges to long duration space flight that need to be overcome. To meet these challenges we have to understand:

1. What is the biological effect of living in a small closed system for an extended period of time?
2. What is the biological effect of living in microgravity for an extended period of time?
3. What is the impact of deep space radiation on organisms within the habitat module over an extended period of time?
4. Is a magnetic field a requirement for long term health of people or other organisms?
5. Is lunar gravity sufficient for most or any organisms?
6. Are there interaction effects from any or all of the factors above?

NASA understands living [1] in confined spaces can be a problem for astronauts. These challenges are likely to increase on smaller volume vehicles operating at or on the Moon for longer periods of time in far more isolated environments. For long duration missions we need to understand how to maintain and grow key nutrients or foods in closed environments. This is made harder by the deep space radiation environment that may have played a role in the Apollo astronauts experiencing four times the risk of heart disease of other astronauts despite being in space for much shorter missions than ISS crews [2]. High energy radiation damages DNA and may ultimately reduce or eliminate any organisms ability to survive or reproduce. Another factor is that many organisms growth responses may be impacted by very weak (Lunar or deep space level) magnetic fields [3]. Microgravity studies, including the famous "twins study" on Mark and Scott Kelly have shown massive alterations in gene expression, protein levels, enzyme functions, cell stress levels, etc. It is possible that many of these alterations could be affected or enhanced by the altered magnetic and radiation environment of deep space. Studies on partial gravity effects on organisms are limited because the durations of the Apollo missions were brief in comparison to the planned Artemis missions. Nonetheless, a review on the effects on Apollo astronauts shows that there are effects, and suggests that Lunar gravity was insufficient for maintaining muscle and bone strength. [4]. We need to understand these effects more completely for humans, their microbiome, and other organisms (e.g. plants) that are being considered for supporting long duration, deep space missions.

Artemis provides unique opportunities to conduct important biological science investigations expanding both the fundamental knowledge base and providing operational knowledge needed for exploration. The moon provides a stable and consistent one sixth "g" condition which is superior to all other locations. The long term performance of biological systems under this "g" level is unknown. Will the response be more similar to micro gravity or earth gravity? The Lunar surface has significantly higher radiation levels of a different spectrum than orbiting vehicles due to secondary radiation from the Moon's surface. This is not easily simulated on Earth. Understanding the interaction of the low magnetic field, partial gravity, and radiation environment on different model organisms (including humans) is essential to NASA's long term exploration mission.

If an organism's response is similar to performance on Earth, the pathway for missions to the Martian surface is much simpler. However, if the effects are more similar to microgravity, a new round of testing will be needed to simulate the three eighth gravity of the Martian surface. The Lunar surface is a very good location for this additional testing of the "g" effect between its 1/6 "g" and the Martian 3/8 "g" and the establishment of consistent baseline performance characteristics.

Understanding of the biological effects of long duration lunar habitation will enable successful long term Lunar occupancy and provide necessary data for eventual Mars expeditions.

Proposed Testing: In ideal experiments, all variables are controlled except for one, producing a unique dependent variable. Conducting experiments in same equipment in different environmental conditions would provide data to address the fundamental questions. Identical test equipment should be used in each location to remove equipment driven effects.

- Test set 1: Closed system testing should be conduct in chambers on Earth under a prescribed set of environmental conditions (Test set 2) providing the closed system effect.

- Test set 2; Chamber on Earth could be configured with equipment where magnetic fields are eliminated and testing under the same environmental conditions of Test set 3 would provide data revealing the magnetic field effect
- Test set 3: The APH chamber on ISS could be configured to provide the same environmental conditions as Test 4 and testing the organism in this micro "g" environment would revealed microgravity effect when compared to Test 1.
- Test set 4: Testing at the Gateway within the habitat module under its measured environmental conditions will reveal the effects of Space Radiation on various organisms when the effect seen in Test 2 and Test 3 are removed. The measured environmental conditions will enable proper test setups in Test 1, 2, and 3.
- Test set 5: Testing on the Lunar surface within the habitat module under its measured environmental conditions will reveal the effects of 1/6 "g" when radiation and closed environment without magnetic field effect are removed, removing the effects seen in Test 2 and Test 4. The measured environmental conditions will enable proper test setups in Test 1, 2, and 3.

Test Equipment: will be dependent on the mission. Extremely valuable scientific data on radiation effects can be gained by simply flying packets of seeds, bacteria, worms, insects, or human cells in stasis to and from Lunar vicinity, Gateway, and the Moon. If the samples can be returned to earth, these early experiments could require volumes under 100 mL, no power, no crew time, and have masses less than 100 grams. More advanced experimental designs can be considered for later missions where small amounts of power, or crew time and larger volumes can be spared. Something similar to the BRIC-LED may be a good example for size and power requirements. Again, for early flights to Lunar vicinity and back, or Gateway and back, a single BRIC can return highly valuable science regarding the impact of the radiation, magnetic and microgravity environments on the growth of cells or small organisms. Later experimental designs can be scaled according to mission and hardware maturity.

Similar to early transit and Gateway missions, packets of organisms in stasis could be placed on CLPS landers that are slated to be visited by later Artemis missions and collected for return. If they were trapped between an insulating blanket and the lunar surface some types of organisms would be able to endure the long lunar days and nights until they were collected. Precedence for this comes from culturing of *Streptococcus mitis* from Surveyor 3 after 31 months on the Moon. Careful sequencing of returned organisms would provide information about DNA damage, while culturing or growth can provide information about long term viability. As knowledge is gained, more substantial investigations will provide better answers and demonstrate needed performance. Maximum tele-science, based on imaging and sample analysis systems currently used on ISS will be considered first due to sample return constraints.

Long duration missions to lunar surface will require stable environment to support crew needs and healthy sustainment. This environment will provide an ideal environment for microbial growth and biofilm formation. Much can be learned by monitoring this activity overtime in the unique conditions present on the lunar surface. Capability to monitor the microbial ecology of the habitat both during occupancy and dormant periods is needed. Biofilm formation in piping systems and water supply tanks needs to be in-place as soon as the system is opened to operational usage. Some of this can be done using simple swabs and solutions like RNAlater®. Kits would be less than 100 grams.

Understanding how biology is impacted by Lunar gravity, magnetic fields, radiation and closed ecosystems is critical to survival and meeting NASA's deep space goals.

References:

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