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SPACE SETTLEMENTS AND THE ULTIMATE HUMAN-MADE ECOSYSTEM: A FOUNDATIONAL FRAMEWORK FOR CLOSED LOOP WASTE MANAGEMENT SYSTEMS FOR FUTURE LUNAR HABITATS

Abstract

This paper develops a framework for minimizing the anthropogenic impact of habitats in the lunar environment through waste management. To determine general guidelines, we analyze existing space habitats–such as the International Space Station (ISS), the analog habitats of Biosphere 2 and BIOS-3, and research stations in Antarctica–and use them as case studies for current strategies and inefficient practices for waste management.

A habitat design depends on the number of individuals and their metabolisms. This is to optimize the productivity of the crew throughout a preliminary three-month period. A framework for human metabolism has been developed using the MIT HabNet database, which is based on a martian habitat. This data is combined with the human metabolism estimates used for the ISS crew. From there we develop a final model of human metabolism for the lunar environment. This data optimization process is further supplemented by a literature review.

The ISS is not a closed system, as it requires resupply shuttles every three months. The Biosphere 2 operated as a closed ecological system without additional food or water input for two years. The ESA MELISSA mission and NASA's Universal Waste Management System are examples of two closed-loop systems designed to reduce the logistical demands of a space habitat. A critical analysis of these systems will be conducted to assess their efficacy in the lunar environment.

The ISS disposes of waste by into cargo ships which burn up upon reentry, while many Antarctic research stations ship waste off the continent for processing. In order to highlight the inefficiencies of these systems for a lunar habitat, a new model will be proposed, based on the human metabolism data, and a critique of ESA's MELISSA closed-loop life support system. The system will also be based on the required activities and scientific objectives of a lunar habitat.

It is critical we examine the viability of a closed-loop space habitat now because 1) sustainability is essential in an environment such as the Moon where monthly resupply deliveries are not possible, and 2) the isolation and supply chain crises resulting from COVID have made obvious the excess of a modern lifestyle. As humans move towards semi-permanent and eventually permanent settlements in the lunar environment, on Mars, and elsewhere, we must adapt not only our technologies but our position as a species within an ecosystem of our own creation.