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Space Architecture: Habitats, Habitability, and Bases (1)

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HYBRID-MODULE DESIGN FOR HUMAN LUNAR COLONIZATION

Abstract

Establishing a permanent human presence on the Moon is a crucial step towards becoming an interplanetary species and enabling further exploration of the Solar System. This paper presents a comprehensive design approach for the initial modules that will form the foundation of a lunar colony at the South Pole, accommodating the first crew of four astronauts. Our multidisciplinary team conducted an extensive study of historical literature and state-of-the-art human habitat designs to develop an innovative proposal tailored for lunar colonization. The proposed outpost is designed to evolve through distinct phases, utilizing four different module types: a Vertical Surface Habitat for the living environment, two distinct Horizontal Modules serving various functions such as laboratories, storage, and greenhouse, and an evolvable Node module that facilitates grid expansion and connection of additional modules. Leveraging 3D modeling tools, architectural design principles, and immersive virtual reality simulations, we consolidated our final design for the layout, structure, and interior configurations of these modules. The paper emphasizes the importance of incorporating hybrid modules from the outset of lunar colonization efforts. This hybrid approach, combining rigid and inflatable components, offers remarkable gains in terms of mass and volume optimization, which are critical factors for the initial human settlement on the Moon's surface. Through digital evaluation systems and trade studies, we demonstrate the significance of standardization and reconfigurability of internal usable volume within the modules. The hybrid design allows for efficient utilization of space while accommodating the evolving needs of the colony as it grows and expands over time. This work underscores the importance of hybrid module design for lunar colonization following the Artemis missions. Future research should focus on further optimizing the mass of these modules through advanced materials and construction techniques, as well as exploring additional configuration possibilities for the interiors of the horizontal modules to support a wider range of activities. The design presented in this paper is the result of a collaborative effort with the Sasakawa International Centre for Space Architecture (SICSA), the Universities of Houston and Texas, USA. Embracing hybrid module architecture is a crucial step towards achieving sustainable, resilient, and scalable lunar habitats, paving the way for humanity's permanent presence on the Moon and serving as a stepping stone for eventual crewed missions to Mars and beyond.