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HUMAN EXPLORATION OF THE MOON AND MARS SYMPOSIUM (A5)
Near Term Strategies for Lunar Surface Infrastructure (1)

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A STRUCTURED METHOD FOR CALCULATING HABITABLE VOLUME FOR IN-SPACE AND SURFACE HABITATS

Abstract

Habitable volume is the volume remaining in a spacecraft after accounting for the losses caused by deployed equipment, stowage, and structural inefficiencies ("nooks and crannies") that decrease the functionally usable volume. This volume has become a major driver for sizing spacecraft, especially for missions featuring longer durations, hazardous environments, or remote and isolated destinations for which habitability is critical. Current literature on habitable volume primarily discusses methods to estimate how much habitation space is required for a specified mission. These methods include regressions based upon historical spacecraft and Earth-based analogs, confinement studies, and task analyses. There is little documentation on methods to actually calculate this volume for a designed vehicle's interior layout and on methods to quantify the structural inefficiencies resulting from a specific interior layout. In historical spacecraft studies, volume estimation methods are often unclear, they lack standardization, and they are inconsistent across studies. There is also little documentation describing how to estimate functionally usable volume for spacecraft designed for planetary or lunar surfaces that have a gravity orientation. In order to properly compare habitable volumes of historical spacecraft and current and future habitat designs, consistent methods of estimating habitable volumes are required.

This paper presents structured, automatically calculable methods for determining the habitable volume for in-space and surface habitats. A summary of the requirements documents for the habitable volume metric are provided, followed by a description of the proposed methods. These methods combine anthropometric and biomechanics data with geometric parameters defined by the interior layout to identify the functionally usable and accessible space. Examples of methods presented include (1) a method that sums the lengths of concave edges within an interior space to quantify structural inefficiencies and (2) a method that fills an interior with small unit volumes having anthropometric significance (such as the width of a hand or length of an arm). These methods are validated by calculating habitable volumes using conceptual-level layouts of existing spacecraft. In addition, this paper characterizes how habitable volume should be measured for habitats with gravity orientations and directly applies this to lunar surface concepts currently being designed. Historical spacecraft and Earth-based analogs are then evaluated to determine how the reported habitable volumes were calculated, to ensure accurate comparison of the concepts. Finally, habitable volume requirements and how they may be used for the design of in-space and surface habitat is discussed.