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INTERIOR VOLUMETRIC SENSITIVITY ANALYSES FOR LONG DURATION HABITATS

Abstract

Crewed long-duration spaceflight habitats are necessary elements within human deep space exploration architectures. Since before the first Mercury missions, flight medicine, human factors, and system design experts have been concerned with how the design of the working and living spaces can potentially impact system performance and mission success. Specifically, "habitable volume" or "free volume" has been, and still is, used as a proxy for volumetric variables of interior design and layout of a habitat which would be acceptable for long duration occupation.

Current early-phase conceptual design of future long-duration habitats attempt to generate and evaluate systems against metrics of mass, power, and size in an effort to inform the direction of human exploration endeavors. When conducting habitat trades, emphasis is focused on variables which provide highest value in terms of these system metrics within the constraints of the mission architecture. Many recommendations of minimum habitable volume – that which will not degrade crew performance for a given duration – have been published by NASA and others for use in habitat design trades.

Unfortunately, the use of minimum habitable volume thresholds by habitat system designers focused on mass, power, and size inevitably results in designs with minimum interior volumes. Years of additional human testing is required to develop relationships between net habitable volume, crew psychological and physiological health, and crew performance, a task which the human research community is actively working on.

System designers can work from the other direction, in parallel, by understanding marginal costs of changing volume away from this threshold. This paper presents a series of sensitivity analyses of future long-duration habitat concepts with respect to habitable volume. Multiple methods, including physics-based modeling, subsystem scaling, and geometric arguments will be used to assess the cost of habitable volume on system metrics of mass, power. Analysis cases span variables of duration, crew size, and aspect ratios and geometries of the pressure shell.

Results indicate that the costs of habitable volume is inversely proportional to both duration and crew size. Model caveats and assumptions used in the analyses are also presented. The understanding and acceptance of these sensitivities by system designers and human habitability researchers are essential to making objective, informed decisions about the future exploration habitat design and the relative value of human factors and habitability research efforts. The paper closes with a discussion of the practical applicability of the results and future work.