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# EVOLVABLE SPACE HABITATION ARCHITECTING WITH EMBEDDED FLEXIBILITY

**Abstract**

Early-phase concept studies for space habitation systems – the payloads subject to some of the highest gear-ratios of a crewed mission – provide the greatest opportunity to identify system architectures and technological investments that provide maximum scientific, economic, and aspirational value over many decades. Current methods of habitat concept exploration fail to adequately acknowledge the uncertainties in human spaceflight objectives and constraints as well as inter-program coupling, leaving decision-makers to choose between point-designs which may not be robust to changing circumstances. This paper presents a method for rapid system architecture generation, evaluation, and optimization based on real options analysis (ROA) of systems with embedded flexibility. The method is supported by 1) a taxonomy of evolvable habitation system enablers including modularity, reusability, reconfigurability, and commonality 2) parametric sizing of subsystems to ensure system closure, 3) quantification of initial development, architectural switching, and recurring costs, and 4) forecasts of future human spaceflight scenarios across multiple missions and campaigns. The paper provides a review of historical habitat trades and past applications of ROA to terrestrial and space systems. The method and all assumptions are presented with a case study for an evolvable habitat architecture for a potential cis-lunar station, lunar and Martian surface systems, and a Mars transit habitat, with results identifying areas in which architects can provide effective and efficient options in and on the system. Sensitivities to both architectural decisions, objectives, and assumed parameters are provided followed by a description of future improvements to the model. This new capability will give concept development teams the tools required to analyze a broad tradespace and inform stakeholders about the expected value of their investments in habitat assets over time as we prepare for our next steps beyond low Earth orbit.