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

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SPACE HABITAT RECONFIGURABILITY: TESSERAE PLATFORM FOR SELF-AWARE ASSEMBLY

Abstract

As we prepare to venture into deep space, from NASA's priorities for a lunar-orbiting gateway station [1] to private industry prospective Mars missions, we face an inflection point for self-aware, autonomous control of space structures. Can we free space architecture from static, single-use module design and instead enable dynamic, modular, self-aware space structures?

This paper presents the TESSERAE platform (Tessellated Electromagnetic Space Structures for the Exploration of Reconfigurable Adaptive Environments), a set of self-assembling, multi-functional structural tiles with natively embedded sensing and quasi-stochastic GNC. The TESSERAE research area aims to enable a new class of rapidly reconfigurable, adaptive space architecture that can: pack flat in a payload fairing; dynamically self-assemble in microgravity contexts; disassemble, re-configure, and re-assemble with LEGO-like interchangeability; successfully achieve steady-state pressurization and ECLSS-function robustness; be repurposed for reinforcing surface settlement habitats on the lunar or martian surface.

Beyond the research focus on the TESSERAE tiles as aerospace structures base units, this model of self-assembly in orbit will rely on a temporary, flexible membrane to encapsulate structural elements and maintain proximity for feasibility of magnet-attractive bonding action (building on various previously explored concepts for balloon inflation in aerospace contexts [2]). We also consider relevant principles from joint reversibility and hierarchical assembly of spacecraft [3]. Our modular approach yields the additional benefit of reconfigurability at the shell level, which inflatable concepts such as BEAM (Bigelow Expandable Activity Module [4]) do not.

This paper will a) present the latest TESSERAE habitat mission architecture and b) discuss prototype evolution across early TRL levels and four classes of completed testbed demonstrations (from parabolic flight tests in 2017 and 2019, a 2019 Blue Origin suborbital test, 2019 miniaturized ISS internal deployment, and on-ground testing and fabrication at human scale). While initial research efforts have focused on closed-topology habitat concepts, this paper will also briefly show extensibility to a wider range of space structure construction needs.

[1] "NASA Strategic Plan 2018." NASA. [Online] Accessed 11 November 2018. Available: https://www.nasa.gov/sites/d

[2]Bekey, Ivan. Advanced space system concepts and technologies: 2010-2030+. p.32, AIAA, 2003.

[3] Jenett, Benjamin, Christine Gregg, Daniel Cellucci, and Kenneth Cheung. "Design of multifunctional hierarchical space structures." In 2017 IEEE Aerospace Conference, pp. 1-10. IEEE, 2017.

[4] "Bigelow Expandable Activities Module (BEAM)," Bigelow Aerospace and NASA, [Online] Accessed 10 October 2018. Available: https://www.nasa.gov/content/ bigelow-expandable-activity-module.