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RESPONSIVE SPACE STRUCTURES: MODULAR, RE-CONFIGURABLE TILES FOR MICROGRAVITY SELF-ASSEMBLY

Abstract

The future of human habitation in outer space lies in “living structures”: self-assembling and adaptive, following principles of re-configurability to scale cost-effectively from common module units to larger mega-structures. To achieve this, we propose a technology development roadmap where responsive sensing augments the physical shell material of modular space structures to guide autonomous actuation and assembly. This facilitates space structure construction independent of astronaut EVAs (extra-vehicular activities) and robust to single part failure via a decentralized system of RF-enabled “smart assembly nodes.”

This paper will describe the TESSERAE platform (Tessellated Electromagnetic Space Structures for the Exploration of Reconfigurable, Adaptive Environments)—a complementary set of self-assembling hexagonal and pentagonal panels, outfitted with an array of configuration, inertial, and proximity sensors to diagnose and actuate bonding via controllable electro-permanent magnets at their interface surfaces. Tiles are released to circulate and assemble quasi-stochastically in microgravity environments, facilitating autonomous construction of space structures.

The TESSERAE assembly and in-orbit deployment plan uniquely combine several existing aerospace technologies and bio-mimetic principles of self-assembly. We build on [1], [2] for demonstrating feasibility of magnetic docking approaches, and electromagnetic formation flight [3], [4]. We note prior work in macro and meso scale self-assembly [5], where the geometry of each sub-part is tuned to induce accretion into the desired whole, such as lock and key physical joints or magnet bonding pairs [6].

We will present microgravity test results of the TESSERAE prototype system from a 2019 Parabolic Flight and 2019 Suborbital Launch with Blue Origin. The paper will discuss in detail the technical architecture across subsystems (mechanical, electrical, communications, GNC, etc). This research project serves as a technology demonstration mission for self-aware self-assembly in orbit.

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[3] Kong, Edmund Mun Choong. ”Spacecraft formation flight exploiting potential fields.” PhD diss., MIT, 2002.

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[6] Tibbits, Skylar, and Kenny Cheung. ”Programmable materials for architectural assembly and automation.” Assembly Automation 32, no. 3 (2012): 216-225.