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Strategies & Architectures as the Framework for Future Building Blocks in Space Exploration and Development (1)

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EXTENSIBLE, TRANSFORMATIVE SPACECRAFT USING CUBESATS AS MODULAR BUILDING BLOCKS

Abstract

Certain classes of reconfigurable modular robotics systems are intended to function like social insects or multicellular animals, where millions of cells work together to ensure the survival of the whole. While each cell is simple, has a short life span, and is limited, they work together to create a robust system more capable than the sum of its parts. As a result, these methods can outperform traditional design and control methods. However, the more pressing challenge is, putting this promise into practice.

Developing simple, robust, and reliable assembly methods to endure intense external pressures and disturbances in the field and coordination and control are the two critical obstacles in making such reconfigurable systems viable. Even though reconfigurable modular robots are theoretically superior to conventional robots because they allow parallelism and optimal task-specific configurations to solve complex tasks, these challenges have prevented practical field use of these systems. However, modular robotic constructions in space are getting closer to becoming a reality, thanks to recent advancements in the field of small spacecraft docking and proximity operations, in a process called on-orbit or in-space assembly. Conventional spacecraft used for applications such as Earth Observation, Space Observation and Exploration are massive, often weighing a few tonnes. They are assembled in specialized cleanroom facilities, tested for vibration, thermal, and other relevant space conditions in specialized test facilities, and launched atop an expensive launch vehicle. We believe that we can eliminate the complexity of sending large spacecraft from Earth by assembling comparable, large spacecraft out modular small spacecraft on-orbit.

In this paper, we explore the concept of reconfigurable, modular, autonomous, robotic spacecraft using CubeSats as building blocks. The CubeSats use Visible Light Communication (VLC) techniques to communicate and coordinate using Active Lighting Cues and Modified Cone and Probe Docking Adapters to perform alignment, latching, and soft capture. We identify and make the case of such transformative spacecraft for use cases such as an extensible Robotic Space Station, or a spacecraft refueling station. We plan to use 3D Physics simulations and analytical calculations to perform trade studies between our architecture and conventional large spacecraft to achieve a specific task in terms of cost, logistics, complexity, versatility, and expendability, among others. Finally, we propose a CubeSat mission concept based on the trade study results that will deploy and demonstrate the technology on-orbit.