In-Orbit Assembly of Modular Space Systems with Non-Contacting, Flux-Pinned Interfaces

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The familiar forces that act between objects at a distance--the Coulomb force, magnetism, and gravity--vary with the inverse square of the distance between objects (i.e. the potential energy varies with the inverse of distance). Technological applications of these forces are limited by Earnshaw's Theorem, which states that no combination of such forces can result in stable separation of objects in all six degrees of freedom. Active control is typically required, as in the case of magnetic bearings. One way around Earnshaw's theorem is to take advantage of the surprising physics of high-temperature flux-pinning superconductors. These materials resist being moved within magnetic fields, resulting in stable relative orientation and position of some number of bodies at finite distances. Furthermore, they do so without power and with no need for active feedback control. The proposed study will evaluate the viability of assembling space structures ranging from small spacecraft to large manned space stations from components that are held in place by flux pinning. This general approach to conjoining mechanical parts without mechanical connection offers the promise of revolutionizing in-orbit construction. The proposed non-contacting interface not only solves a host of technological issues, it also opens up a new way of thinking about modular spacecraft. No longer are we required to distinguish among spacecraft subsystems, individual spacecraft, and constellations of spacecraft. Instead, the proposed concept blurs the distinction between modular spacecraft and formation flying, between spacecraft bus and payload, and to some extent between empty space and solid matter. Articulated payloads, reconfigurable space stations, and adaptable satellite architectures are possible without the mass and power typically associated with maintaining relative position and mechanically rebuilding structures. In 2004-2005 we demonstrated the basic principle; on internal funding, we creating some modular building blocks and showed that they can find each other without active control and remain fixed in rotational and translational degrees of freedom at distances on the order of centimeters. The proposed NIAC Phase I study will base its consideration of possible space-system architectures on this recent result and will proceed through the definition of major issues of feasibility. The primary issues include defining the basin of attraction of these modules and what can be achieved if the technology is advanced, how much mechanical stiffness is appropriate and available, and how the superconductors may be kept below their transition temperature in the space environment.

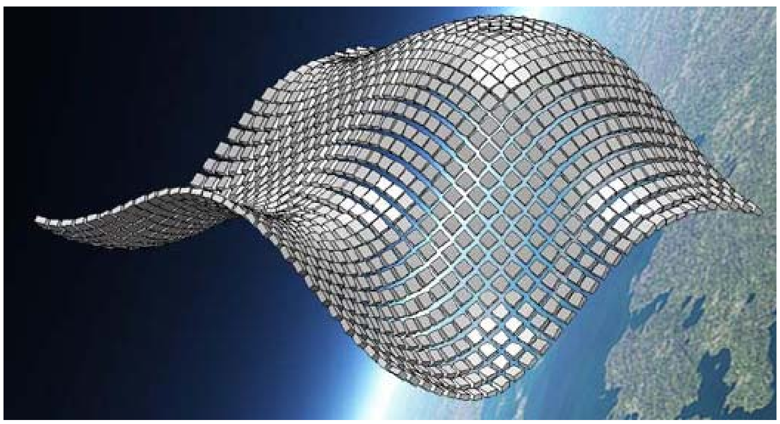

Figure: Articulated Spacecraft with Reconfigurable Structure; Many Payloads and Subsystems in Multiple Simultaneous Orientations