Power and Data Transfer with a Two-Stage CubeSat Docking Adapter

Nicolas Gross, Athip Thirupathi Raj, Jaret Rickel, Jekan Thangavelautham

With the rise in popularity of small satellites, such as CubeSats or nanosatellites, there has been a growing effort to enable small satellite servicing applications. By transitioning past the current communication and technical demonstration role that small satellites currently fill, many opportunities and solutions would become feasible. Example servicing and transfer applications include increasing the limited lifespan of small satellites, given their restricted power capacity, facilitating technology and software upgrades, allowing for the cleaning and removal of space debris, and providing mission flexibility. Power and data transfer specifically support the operation and maintenance of several subsystems, including sensors, instruments, and communication devices. Interplanetary missions could be supported by the maintenance and servicing capabilities offered by small satellite power and data transfer. For example, power could be transferred between a satellite equipped with solar panels, to another satellite that may lack power generation, or has been damaged, and requires supplemental power. If the satellites are large, a small satellite could be transferred between the two, carrying power from one to the other. This would lengthen the duration of the interplanetary mission without needing to send additional satellites that may not be able to travel the long distance in the required time. The development of servicing and transfer capabilities for small satellites is necessary for their future role in the constantly evolving space environment.

We propose a two-stage CubeSat docking adapter with integrated power and data transfer capabilities. For the soft capture stage, the adapters utilize a modified cone and probe geometry designed to correct for rotational and translational misalignment. Shape Memory Alloy (SMA) spring-loaded latches are used for locking and unlocking during and after the hard capture stage. Power and data transfer are facilitated through pogo-pin connectors. These connectors allow for a secure connection regardless of orientation, which is necessary as the adapters allow for docking in four unique orientations. Various connector options were explored, supported by a trade study that identified the optimal connector aligning with the design and mission requirements.

This presentation details the design, analysis, fabrication, and validation involved in creating a two-stage CubeSat docking adapter with integrated power and data transfer capabilities. 3D simulations and analytical calculations were used to develop prototypes for thorough testing in a controlled laboratory environment. Through this testing, limiting conditions are established, considering factors such as misalignment limits and maximum transfer rates. Validation is performed using ground-based systems, including 6-DOF robotic arms emulating spacecraft ADC systems and air tables to replicate the frictionless environment in space. The primary goal is to demonstrate a seamless docking scenario, including power and data transfer between two CubeSats equipped with metal 3D-printed docking adapters. Through this demonstration, the functionality and feasibility of the proposed docking and transfer system are shown.