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FLIGHT DEMONSTRATION OF AN ELECTRO-PERMANENT MAGNETORQUER FOR ENERGY-EFFICIENT SMALL SATELLITE ATTITUDE CONTROL

Abstract

Small satellite attitude control remains a critical challenge due to the constraints of Size, Weight and Power (SWaP). Conventional magnetorquers require continuous current to generate a magnetic field, leading to high energy consumption and thermal stress, particularly in power-limited CubeSat missions. To address these limitations, this work presents the Electro-Permanent Magnetorquer (EPM)— a novel attitude control actuator that utilizes solid magnetic materials to retain magnetization after an initial current pulse, significantly reducing energy requirements.

The EPM has been successfully demonstrated in orbit aboard the WaratahSeed-1 satellite, marking the first in-flight validation of this technology. The WaratahSeed-1, Australia's first ride-share satellite mission, is designed by the ARC Training Centre for CubeSats, UAVs and their Applications (CUAVA) to provide a low-cost, rapid-access platform for technology demonstration in space. It hosts multiple payloads from Australian industry and research groups, making it an ideal testbed for validating innovative satellite technologies such as the EPM.

The EPM system was tested pre-launch, demonstrating a dipole moment of 1.287 A·m in pulse mode with an energy consumption of only 0.75 J per pulse. In-orbit experimental results in space confirm that the EPM can detumble a satellite from 27/s to 0/s within 800 seconds, consuming only 82.92 J in total—representing a substantial improvement over conventional magnetorquers. The technology is now being commercialised by Deneb Space, providing a low-power, high-reliability alternative for modular satellite buses and constellation missions.

This paper will present the design, development, and in-orbit performance analysis of the EPM system, including comparisons with existing magnetorquers. The successful demonstration of this technology paves the way for broader adoption in small satellite constellations, offering a low-power, high-reliability alternative to existing attitude control actuators.