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GENERALIZED MAGNETIC ATTITUDE CONTROL OF SPACECRAFT WITH APPLICATION TO
A 0.5U CUBESAT PLATFORM**Abstract**

Since 1999, The Aerospace Corporation has launched 16 small satellites and 4 reentry breakup recorders. Over the course of the Aerospace picosatellite program, the growing demands of picosatellite applications has driven the development of increasingly sophisticated small-satellite hardware and software and the implementation of systems-engineering techniques that facilitate turnover of approximately one mission per year.

The three CubeSats of the AeroCube-4 series built by The Aerospace Corporation were launched aboard an Atlas V launch vehicle from Vandenberg Air Force Base on 13 September 2012. These three 1U CubeSats were secondary payloads with eight other CubeSats, deployed from the OUTSat module. All CubeSats were delivered to a roughly 480 x 780 km altitude orbit inclined at 65 deg. The mass of each satellite is approximately 1.2 kg.

The mission of the AeroCube-4 series required sophisticated attitude knowledge and control for precise pointing of the AeroCubes and ground-based facilities, a challenge that demanded high-precision knowledge of the satellites' state in space. High-precision orbit determination (OD) was made possible by a GPS receiver installed on each satellite that collected fixes on a regular basis and delivered measurements of the satellites' position and velocity.

In addition to the standard 10-cm cube-shaped bus, all three AeroCube-4 satellites are equipped with extendable wings (9 x 10 cm). Deployment or retraction of the pair of wings on command alters the cross-sectional area of each AeroCube by up to a factor of three. During the course of the mission, the operations team successfully deployed and retracted the wings on all three CubeSats.

This paper reports on the operations activities for the AeroCube-4 program, including the successful utilization of the on-board GPS receiver, high-precision orbit determination for GPS validation and mission operations, detection of deliberate ballistic-coefficient variation, and formation control.

The AeroCube-4 series of three satellites have provided a wealth of experience in the operation of a CubeSat constellation that will be invaluable for future missions that require sophisticated formation flying with multiple small spacecraft. With the aid of an on-board GPS receiver, the AeroCube-4 series

of three satellites has successfully demonstrated the ability to produce high-precision ephemerides for a CubeSat with meter-level uncertainty.