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APPLICATION OF GAUSS' VARIATIONAL EQUATIONS TO RELATIVE ORBIT PHASING AND ACQUISITION – A CASE STUDY

Abstract

Canadian Advanced Nanospace eXperiments 4 and 5 (CanX-4 CanX-5) are a pair of identical formation flying nanosatellites that demonstrated autonomous sub-metre formation control, with relative position knowledge of better than 10 cm and control accuracy of less than one metre at ranges of 50 to 1,000 metres. This level of performance has never before been seen on nanosatellite class spacecraft to the author's knowledge. This capability is crucial to the future use of coordinated small satellites in applications such as sparse aperture sensing, interferometry, ground moving target indication, on-orbit servicing or inspection of other spacecraft, and gravitational and magnetic field science. Groups of small, relatively simple spacecraft can also replace a single large and complex one, reducing risk through distribution of smaller instruments, and saving money by leveraging non-recurring engineering costs.

As a precursor to the autonomous formation flight mission, a campaign of relative orbit phasing was undertaken to bring the spacecraft to within a few kilometres of each other from a maximum separation of over 2,300 km. Given each spacecraft's small form factor, and future mission requirements, it was a requirement that this be performed in a fuel-efficient manner. Therefore, a system to calculate optimal recovery trajectories was required. As the relative distances were quite large, the Hill-Clohessy-Wiltshire equations were not suitable for the task. Therefore, a relative dynamics model based on Gauss' Variational Equations was successfully employed.

In this paper, the design of the orbit phasing and acquisition controller is detailed, and validated using on-orbit results. A commercial orbit propagator is used to compare these results to other control methods.