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DEVELOPMENT AND TESTING OF NANOSATELLITE FORMATION CONTROL ALGORITHMS

Abstract

Constellations or formations of nanosatellites can be used for the realization of complex missions, for example for telecommunications or Earth observation. Zentrum für Telematik e.V. (ZfT), located in Würzburg (Germany), contributes to this development with several nanosatellite formation missions, e.g. TOM (Telematics Earth Observation Mission), CloudCT and TAMARIW (TeilAutonome Montage/Aufbau und Rekonfiguration im Weltraum). One of the challenges that have to be solved for satellite formation flying is the development and implementation of control approaches for acquisition, maintenance and reconfiguration of the formation structure.

This paper will provide insight in development and testing of some of the formation control algorithms at ZfT, namely a Distributed Robust Control (DRC) approach and a Constrained Low Thrust (CLT) control approach. DRC combines robust control and distributed control using the consensus approach, and adapts it to low-thrust nanosatellite formation flying. As part of the DRC framework, the proof for a stability condition for force-free satellite formations will be given. CLT control features a guidance and control strategy consisting of a reference governor in Relative Orbital Elements (ROE) state space and a controller based on Lyapunov theory. The next part of the paper will describe how the formation control software is tested during the development and implementation process. For the simulation of satellite orbits and formations, a modular satellite formation simulation framework is currently developed at (ZfT). This simulation framework is using the space dynamics library Orekit for orbit calculations and is written in the Java programming language, while the flight software for the satellites is written in the C programming language. To be able to test and verify the control algorithms without the necessity of re-implementing them in Java code in the process, the possibility for Java-C interoperability has been included in ZfT's simulation framework. This enables Software-in-the-loop (SiL) tests. Next, the setup of Hardware-in-the-Loop (HiL) tests will be described, which allows testing the formation control software as part of the whole Attitude and Orbit Control System (AOCS) on the real flight hardware. Guidance and navigation data for the HiL tests is provided by the simulation framework and fed into the AOCS running on the flight hardware by using the capabilities of the Compass protocol. Finally, an outlook on further developments for ZfT's satellite formation simulation framework will be given in the paper.