Development of an Active Magnetic Attitude Determination and Control System for Picosatellites on highly inclined circular Low Earth Orbits

A thesis submitted in fulfilment of the requirements for the degree Master of Engineering by Research

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and, any editorial work, paid or unpaid, carried out by a third party is acknowledged.

Jens Gießelmann
03/28/2006
Abstract

Small satellites are becoming increasingly important to the aerospace industry mainly due to their significantly reduced development and launch cost as well as shorter development time frames. In order to meet the requirements imposed by critically limited resources of very small satellites, e.g. picosatellites, innovative approaches have to be taken in the design of effective subsystem technologies. This thesis presents the design of an active attitude determination and control system for flight testing on-board the picosatellite ‘Compass-1’ of the University of Applied Sciences Aachen, Germany. The spacecraft of the CubeSat class with a net spacecraft mass of only 1kg uses magnetic coils as the only means of actuation in order to satisfy operational requirements imposed by its imagery payload placed on a circular and polar Low Earth Orbit. The control system is capable of autonomously dissipating the tumbling rates of the spacecraft after launch interface separation and aligning the boresight of the payload into the desired nadir direction within a pointing error of approximately 10°. This nadir-pointing control is achieved by a full-state feedback Linear Quadratic Regulator which drives the attitude quaternion and their respective rates of change into the desired reference. The state of the spacecraft is determined by a static statistical QUEST attitude estimator processing readings of a three-axis magnetometer and a set of five sun sensors. Linear Floquet theory is applied to quantify the stability of the controller and a non-linear dynamics simulation is used to confirm that the attitude asymptotically converges to the reference in the absence of environmental disturbances. In the presence of disturbances the system under control suffers from fundamental underactuation typical for purely magnetic attitude control but maintains satisfactory alignment accuracies within operational boundaries.

Keywords: CubeSat, Compass-1, picosatellite, active magnetic attitude control, attitude determination, Linear Quadratic Regulator.
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