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AUTONOMOUS FAULT MANAGEMENT IN ATTITUDE DETERMINATION AND CONTROL SUBSYSTEMS: HARDWARE AND PROCESSOR IN THE LOOP TESTING

Abstract

This paper introduces an autonomous fault management architecture, integrated with the Attitude Determination and Control Subsystem (ADCS) for small satellites. The proposed approach is intended to be executed in on-board processors with limited computing resources, while guaranteeing a good reliability of the platform ensuring robustness to failures and anomalies. In fact, despite the great advances in small spacecraft maturity, their components still suffer frequent breakups that may lead to loss of controllability and, in the worst cases, to the loss of the entire mission.

The fault management functions are directly connected to sensors and actuators data, which are continuously processed to estimate and detect anomalies in the hardware behaviour. Spikes, erratic trends, drifts, step biases, data losses, hardware stuck, thermal and power anomalies can be detected with low computing and memory resources. Then, the failure detection event triggers an isolation routine that immediately excludes the anomalous component from the subsequent ADCS processing. This process runs in parallel with the determination and control tasks, with allocated timing budget to avoid delays and interruptions in pointing control. The isolation functions are designed to recover the anomaly in the component while minimizing the false positive in failure detection. The entire fault detection, isolation and recovery process is transparent for the ADCS, since the excluded component is seamlessly substituted with a redundant hardware element or with an alternative software processing. Indeed, in the proposed fault tolerant ADCS, the fundamental pointing modes can be achieved with multiple software alternatives associated to different hardware components. In case several failures have occurred, and no resource is left, the fault management functions ask for a transition to a simpler available determination and control mode.

The seamless fusion of the ADCS blocks with fault management functions provides a holistic solution to the challenges posed by the determination and control subsystem. The integrated architecture is designed to autonomously recalibrate and reconfigure after encountering failures, showcasing fault tolerance at both the determination and control levels. In addition to theoretical discussions, the study presents test results, validating the performance of the integrated system at hardware-level. The validation and verification of the proposed method is achieved through real-time flat-sat testing, ensuring the fused architecture not only meets stringent design requirements but also performs reliably in representative hardware, with real sensor and actuators telemetries.