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A HIERARCHICAL MODE CONCEPT TO ENABLE AUTONOMY FOR SMALL SPACECRAFT

Abstract

Spacecraft on orbit are exposed to radiation and frequent temperature fluctuations. Small satellites commonly implement commercial off-the-shelf hardware that is inherently less reliable than space-grade components and is additionally more affected by the space environment. Consequently, (transient) hardware faults are to be expected in the course of such missions. A common fault handling approach for satellites is a transition into safe mode, where all non-essential hardware is switched off. In order to limit the complexity of the spacecraft, fault isolation and recovery often requires intervention from the ground, which may in turn significantly reduce the satellite's availability. Consequently, autonomous fault isolation and recovery can increase the mission availability on the one hand, while it reduces the ground operations efforts on the other.

Following this, at Technische Universität Berlin we developed a hierarchical mode concept that targets at minimizing the complexity involved in enabling autonomy in both, nominal operations and fault handling. The system is based on the realization that every satellite is built in a hierarchical manner. Multiple components, e.g. reaction wheels, can be combined to form a device. Multiple devices, e.g. a set of attitude sensors and reaction wheels, form the (attitude control) subsystem. Finally, multiple subsystems form the system layer, i.e. the entire spacecraft. Depending on the current task of the spacecraft each of these layers must be in a well-defined state, called a mode. Only system modes are being directly commanded while all lower layers are autonomously set to their respective mode. As the expected state of each layer is always known, deviations caused by hardware faults may be easily detected. On the layer in question it may then be decided whether operating according to the requirements is still feasible or if escalating to the next higher layer is necessary. This layer may then again evaluate the situation and attempt to resolve the problem. In this manner, only faults that are passed through to the system level without being resolved may activate the safe mode.

TechnoSat, the first satellite that implements the presented concept, was launched in 2017. TechnoSat is a 20 kg technology demonstration microsatellite that is based on our modular TUBiX20 platform. This paper outlines the implementation of the mode concept based on experiences gained while operating TechnoSat and describes how we successfully applied the concept post-launch through software updates. Finally, we will elaborate on how TechnoSat and its successor TUBIN – an Earth observation mission set to launch in 2020 – benefit from the implemented concept.