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# HERMES ADCS: FROM SYSTEM DESIGN TO PRE-FLIGHT VERIFICATION AND TESTING

**Abstract**

HERMES is a modular project composed by six nano-satellites: the first three Technology Pathfinder (TP) CubeSats are funded by the Italian Ministry of University and Research (MUR) and the Italian Space Agency (ASI), the second Scientific Pathfinder (SP) triplet is instead funded by the European Union (EU) with an H2020-SPACE grant. The spacecraft will be launched in the first quarter of 2024, and the project is currently in advanced phase D.

The main goal of the HERMES program is the accurate and prompt localization of bright astrophysical transients by means of triangulation. Therefore, to correctly perform scientific observations and to download the data to ground, it is fundamental that each HERMES satellite is capable of accurately estimating and controlling the dynamical states of the spacecraft. This means that the HERMES attitude determination and control subsystem (ADCS) shall estimate the complete attitude and position states, both in sunlight and in eclipse, and it shall provide full control of the spacecraft attitude. In existing nano-satellite missions, the requirements for the ADCS may be loose and relaxed with respect to more complex and larger spacecraft. This is not happening for HERMES ADCS, which needs to be reliable and robust to always guarantee the stringent determination accuracy, as required by the high scientific precision.

In nominal conditions, the ADCS algorithms are executed on the main on-board computer (OBC) according to the definition of a finite state machine (FSM), which instructs the ADCS software to follow the pre-defined mission operations. In parallel, on the same OBC, a dedicated fault detection logic runs to check all the status flags generated by the software algorithms, the actuators, and the sensors. If this logic detects an error, a specific error isolation and recovery procedure is then activated.

This work describes the HERMES ADCS hardware and software architecture, highlighting its performance and presenting its advance with respect to the current state of the art. Moreover, the work presents the testing and verification results divided into three phases: a model-in-the-loop (MIL) phase, a software-in-the-loop (SIL) phase and, lastly, a processor-in-the-loop (PIL) phase. The latter exploits a closed loop real-time simulator with realistic digital twins of actuator and sensor data interfaces. This real-time PIL simulation facility, which has been developed at Politecnico di Milano, is also presented, highlighting its technical characteristics, its calibration procedures and its benefits in terms of verification and testing of nano-satellite ADCS.