# A tool for nano-satellite functional verification: comparison between different inthe-loop simulation configurations

# A tool for nano-satellite functional verification: comparison between different *in-the-loop* simulation configurations

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This paper describes the simulator technology and the verification campaign for the e-st@r CubeSats family, developed at Politecnico di Torino. The satellites' behavior has been investigated using a Model and Simulation Based Approach. One of the critical issue in the verification and validation of any space vehicle is the impossibility to fully test some features due to the particular and often un-reproducible environment in which it will operate. Simulations result as one of the best means for testing space system capabilities as it may help to overcome the abovementioned problem.

In order to perform different simulation configurations for e-st@r CubeSats, an in-house simulator (named StarSim) has been developed. It is a unique infrastructure, modular and versatile, capable of supporting any desired configuration of the system under test, ranging from full algorithm in the loop simulations (AIL), and gradually inserting satellite hardware, until a complete hardware in the loop (HIL) simulation is performed.

When a verification campaign is led on a real object, pure AIL computer based simulations (in which all the equipment and mission conditions are reproduced by virtual models) are not sufficient to test the actual software and hardware to a high degree of confidence since real systems can exhibit random and unpredictable dynamics difficult to be perfectly modeled (i.e. communication delays, uncertainties, and so on). For these reasons, Software In The Loop (SIL), Controller In The Loop (CIL) and HIL simulations were planned. SIL simulations foresee that algorithms are written in the final programming language and executed on ground hardware. In CIL simulations, the software runs on the flight processor while other system's element are still kept virtual. In HIL simulation, the real hardware (i.e. sensors, actuators, and power sources) are included in the loop.

In this paper, after the details of the simulator architecture and its characteristics are described, an exhaustive comparison between AIL and HIL simulations is presented, highlighting main differences and singularities: similar trends of the sensible system's variables are reached but not identical performances (i.e. absolute and average pointing error and stability, attitude determination accuracy, battery charging and discharging duration) arose analyzing the values. Moreover, it is demonstrated how the technology here presented can effectively support and improve the verification and validation activities for a nano-satellite, by increasing the confidence level on the mission objectives achievement.