Cost-effective Avionics Test Benches to support fast and iterative GNC Systems Design and Validation

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ABSTRACT

Nowadays the space missions are becoming more and more demanding (particularly to what refer the GNC/AOCS systems) while design, development and verification/validation (DDVV) phases are becoming shorter in order to reduce costs and to avoid that some of the elements of the mission become obsolete even before of the flight (but without possibility of replacing them because of impact on mission cost and schedule).

In this context, every piece of the mission, and particularly every piece of the GNC system DDVV (the core of this paper) shall be adjusted to the required situation in an optimum manner. Avionics test benches are a key part of the GNC DDVV cycle as they are the conductive and connecting threat between the algorithms and the flying on-board SW:

- While the first analysis of the functional performances of the GNC algorithms are perfomed in dedicated engineering tools/simulators (e.g. Functional Engineering Simulators, FES, in Matlab/Simulink), the Avionics Test Benches (ATB) shall support the first analysis of the suitability of the GNC algorithms to be flown (compatibility in terms of needed resources and provided performances with the on-board avionics).
- High demanding GNC missions will require from several iterations to be performed in the design (at algorithm level) and implementation (at SW level) during the mission lifecycle. Thus, the related Avionics Test Benches shall allow fast iterations between the algorithms and the SW levels.
- ATB shall support the ultimate verification and validation of the GNC system (before integration in the spacecraft) by either providing the required test bench framework or by being re-used/tailored/extended/evolved into the required complete test bench framework (i.e. mission level test bench).

In the case of using autocoding techniques (if not, the same approach is still applicable but in a less automated manner), a cost effective approach for GNC systems DDVV approach can be based on the following integrated chain: FES➔Autocoding➔Avionics T/B➔HIL T/B, where:

- The Functional Engineering Simulator (FES) includes reference models of the selected algorithms (GNC-ALG) and solutions for the GNC (and associated AMM and FDIR if needed) system/s. This is the main conductive design supporting tool and verification at algorithm level (Model in the Loop, MIL) all along the GNC work. It is fundamental to define modelling rules/guidelines for later autocoding. The FES simulator supports the full V-cycle for the GNC-ALG (Simulink algorithms).
- Autocoding techniques (e.g. TargetLink from dSpace) can be used to translate the FES-validated On-Board Part (GNC, AMM, FDIR) into C code and start the SW V&V process. A SW in the Loop (SIL) verification step by integrating the produced GNC-SW in the FES simulator can be envisaged as intermediate V&V step (SIL V&V level is achieved).
- The Avionics (Processor In the Loop, PIL) test benches, non real-time (optional depending of the GNC design case and the eventual provided added value) and real-time, will integrate the GNC-SW. The PIL test bench/es will allow testing the GNC-SW in flight realistic conditions regarding the avionics (representative processor/s of the mission platform flight models).
- The dynamic HIL/Sensors test bench is logical extension of the PIL test benches (ideally, it shall include the PIL T/B as an integral part). This test bench is the last step on the on-ground GNC validation and verification chain and provides real dynamic conditions reproduction that stimulates real HW sensors with air-to-air signals so as to achieve the maximum ground testing level (HIL level, TRL 5-6) regarding the achieved representativity of the flight conditions.

This chain can provide (as demonstrated during several ESA activities) invaluable support during the Design and Development phases and possibility to test V&V requirements already at early and intermediate design phases, allowing fast design iterations.

Following Figure 1 presents a diagram with the cost-effective GNC DDVV approach.

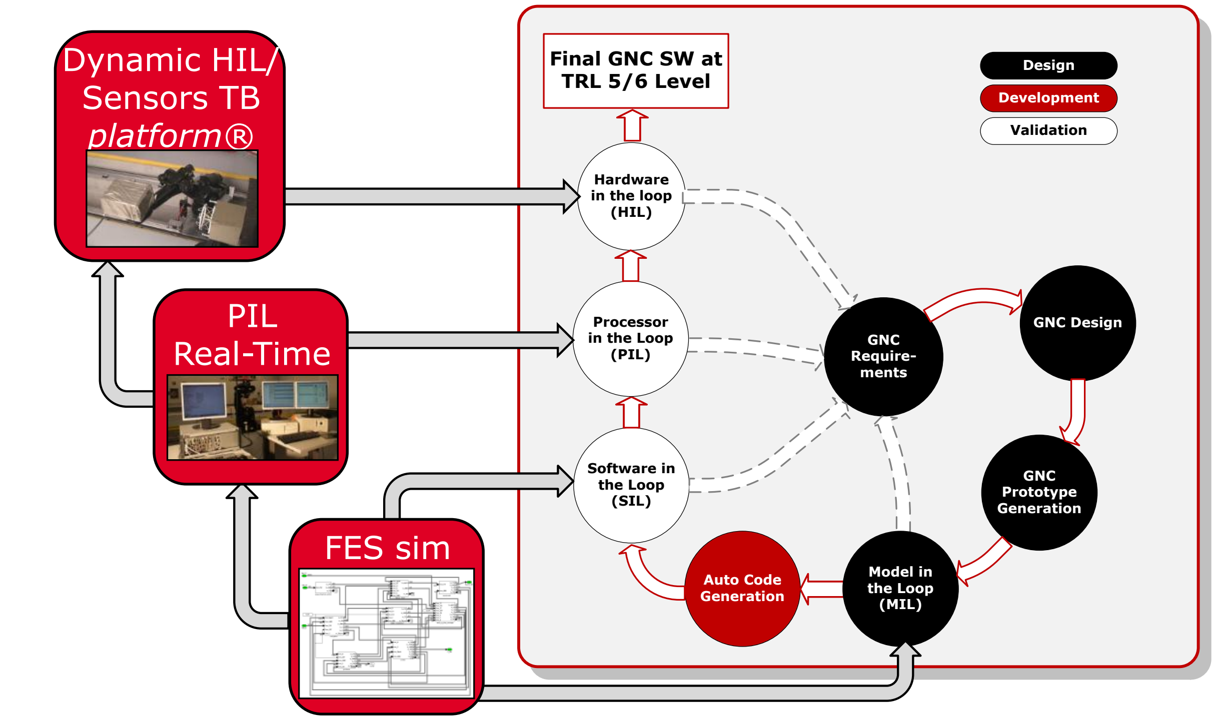

Figure 1. Coherent, incremental, highly automated GNC Design, Development, Verification and Validation (DDVV) Approach.

This paper describes in detail the GMV perception about the required Avionics test benches (mainly from a GNC viewpoint) and the main characteristics and functionalities they shall provide to effectively provide the required conductive and connecting threat between the algorithms and the OBSW levels in a flexible, efficient and fast iterative-permissive approach.