Model-Based Avionics Verification & Validation

H. Bratulic , F. Maingam
Thales Alenia Space

In the frame of the Observations & Sciences and Telecommunication Spacecraft programs, THALES ALENIA SPACE France is in charge of the Avionics Validation.
Like any complex real-time system, a spacecraft is submitted to Verification and Validation tests, in order to verify its proper behaviour (on-board software and hardware) under flight representative conditions. A comprehensive sequence of validation is usually conducted on the flight software, in a real hardware and software models environment. Simulation models are used in a large range of facilities:

- High Fidelity Simulator: equivalent to a Functional Engineering Simulator,
- Software Verification Facility (SVF),
- Platform Simulator (SimPF): equivalent to a Functional Validation Test bench,
- Avionic Test Bench (ATB and eATB): equivalent to a Spacecraft AIV Simulator,
- Dynamics Spacecraft Simulator (DSS): equivalent to a Training, Operation and Maintenance Simulator.

The position papers are intended to give the point of view of THALES ALENIA SPACE
France onto the following topics:

- Model-types involved in the avionics verification and validation ?
- Impact on validation plans by the formal introduction of models ? Traceability of
- different models and their relations throughout the verification process ?
- Which system properties (data) required for the avionics V&V process ?
- How are the models validated with respect to a domain of applicability and maintained throughout the avionics lifecycle?

Astrium Satellites generic functional avionics Verification and Validation approach

M. Janvier
Astrium Satellites

The benefit of advancing system test activities though the use of software models on test benches is recognised to provide solutions regarding schedule adherence. Astrium has developed over the last years a generic Avionics Verification and Validation approach, now applied on most of his programs from the various prime sites, which takes benefit of standardised benches and simulation use cases to implement his V&V activities.

The intended presentation aims at summarising this approach, addressing the relationship between the used bench types and the Verification or Validation objectives applicable during along the overall Avionics V&V process. The key associated underlying assumptions, such as bench & models continuity along the Avionics V&V activities are developed, and a particular zoom is done on:

- The assets of using an integrated database solution along this process
- The use of OBC model solution along this process.

Modular and Incremental Framework for GNC Subsystem Validation and Verification

Daniele Gherardi, Víctor Marco, Antonio Ayuso, Guillermo Rodriguez

SENER Ingeniería y Sistemas S.A., Severo Ochoa, 4, 28760 Tres Cantos, Madrid, Spain.

Telf: +34918078609, Fax: + +34 918077208, daniele.gherardi@sener.es

ABSTRACT

This abstract presents SENER position in the use of Model-Based Validation and Verification logic that is being followed by the Guidance, Navigation and Control (GNC) and Attitude and Orbit Control (AOCS) subsystems development.

SENER's heritage is based in the design, development and verification of the GNC/AOCS subsystem in Herschel-Planck, Smart-OLEV, IXV, Proba-3 and Minisat, together with direct experience on verification tools development such us SENERIC, GATB and TEF.

Based on this experience, a modular and incremental framework has been developed focusing on the overall GNC/AOCS Validation and Verification process and in particular in the role of the Simulator Model libraries. The main objective of this framework is to guarantee a short development cycle allowing early prototyping with generic pre-validated models, an effective validation of the GNC/AOCS application software and early verification with incremental development of the hardware-in-the-loop (HITL) facility.

The GNC and AOCS subsystem validation and verification is split-up in four main steps:

1. The design on the basis of rapid prototyping is developed within an Algorithm Design Environment which allows definition of the AOCS prototype and their tuning based in generic pre-validated models.
2. Design validation to be carried out by analysis and simulation of a prototype integrated with the Functional Engineering Simulator (FES), which has been fully tailored to the specific project needs and has gone through a dedicated validation process. A retro-fit of the developed GNC/AOCS application software can be done within this same facility.
3. The design qualification is performed in an avionics test bench, which has a representative set of avionics electrical system and in particular of the GNC/AOCS electrical subsystem. An incremental approach will use simulation models to replace missing units and test harness to provide hybrid hardware configurations.
4. System Verification, once the actual hardware and software components are integrated and tested together on the proto-flight model, final verification of the control system will be performed for those aspects that cannot be verified at subsystem level.

The aforementioned steps will exploit the parallel development of the Simulators Model-Based Library which is an integrated part of SENER simulator and functional verification facilities development:

- The first two steps are based in the existing in-house development environment framework called SENERIC. It consists on a suite of high fidelity tools for the generic mission analysis design, development and validation of a GNC/AOCS.
- The last two steps are associated with the Generic AOCS Test Bench (GATB) developed by SENER, allowing hardware-in-the-loop verification, which has also been the basis for the Test Environment Facility (TEF) to be used in IXV for the GNC Subsystem verification.

The usability of this library as a core element of the progressive development of the subsystem and of the simulators facility is oriented to comply with requirement of real-time performance and high fidelity models. The High Fidelity Models initially developed and used in the Design Validation stage are then used for HITL test to allow preparation of the performance tests with the full GNC/AOCS hardware chain. Finally a gradual and incremental integration of the GNC/AOCS subsystem will allow easier isolation of problem and incompatibility behaviour.

WHAT MODEL-TYPES ARE INVOLVED IN THE AVIONICS VERIFICATION AND VALIDATION?

There are two classification criteria of these model types; the first is related to its usage within the design, validation and verification process; while the second is associated to function of the item modelled.

The development of these Simulators model library shall be based on the domain of applicability which is linked to the development stage:

1. In principle, the design phase will use a generic set of simulator models which are tailored to be representative of the system architecture, but are not necessarily a high fidelity model of the plant. At this stage, the goal is to define a set of robust algorithms which will be tuned later on when mission specific high fidelity models are available.
2. The design validation will be based on a mission specific facility, which is implementing representative of real units' performance. These models will also have to take into account hardware chain latency, jitter and on-board software scheduling. A key feature of these models is its validation, which has to be performed against real unit or mission specific high-fidelity simulated data.
3. The Model-Based verification will need high fidelity models, which have to cope with direct interface to the Application Software and/or Processor in the loop facility.
4. The re-usage of these high-fidelity models within the HITL will request to enhance the simulator with the ability to monitor actuator commands as inputs to the dynamic simulation, which close the loop by propagating the spacecraft dynamics and evaluating the stimuli levels to be applied to the sensor electronics. Hence modularity and real-time performance will be key requirements for these models' library development.

The major Simulator models types, with respect to the item function, are listed as follow:

- Sensors and Actuators
- On-board computer
- Subsystem Models
- Dynamics, Kinematics and Environment Models (including Flexible dynamics)
- Mass, Centring and Inertia Models
- Ground segment model

WHAT IS THE IMPACT ON VALIDATION PLANS BY THE FORMAL INTRODUCTION OF MODELS? HOW IS THE TRACEABILITY OF DIFFERENT MODELS AND THEIR RELATIONS THROUGHOUT THE VERIFICATION PROCESS ENSURED TODAY?

The four domain applicable types of model identified above have different validation needs, re-usability and impact in the system or subsystem validation as detailed in the table below.

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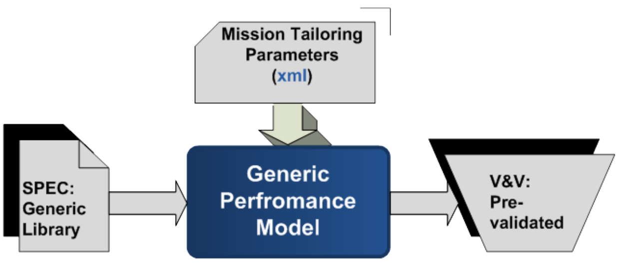
<td>
</td>
<td>Generic Performance model are:
• re-used of generic libraries,
• pre-validated,
• tailored by means of mission tailoring parameters.
Scope of these models is oriented to preliminary design and analysis.</td>
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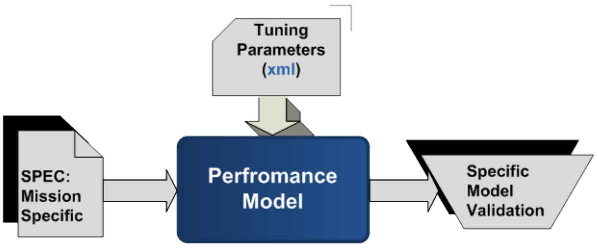
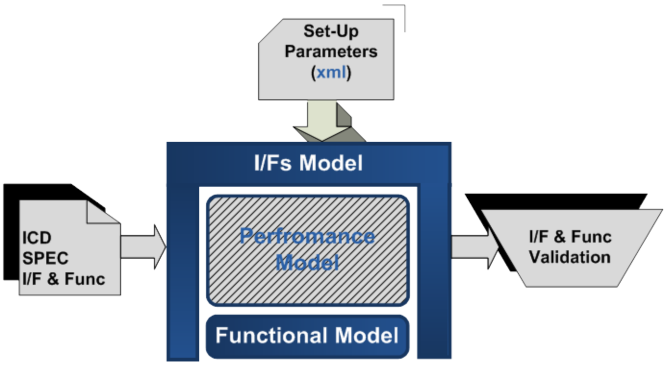


Mission specific performance model is specified and dedicated validation is performed.

A set of Tuning parameters allows to keep the model up to date with latest performance estimation throughout the system lifecycle. These parameters are maintained in an xml standard format to be re-usable in the different steps of the development.

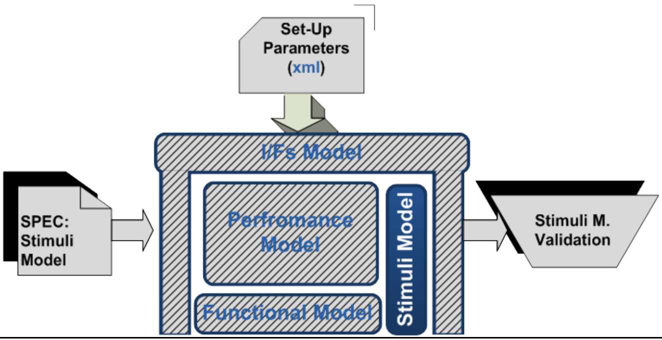
Scope of these models is the detailed design validation at CDR level, as well as its re-usability in the verification as a core of the High Fidelity Models.



The high fidelity model (HFM) are re-using the performance model as the model's core and are enhanced with interfaces and functional model to allow a Mode-Based Verification.

The Set-up parameters allow to maintain both functional and performance features up to date.

The scope of these models is to fulfil the part of the system/subsystem qualification when no further stage is possible or to advance and prepare the avionics qualification with HITL.



The HFM are enhanced to allow hardware stimulation of sensors and actuators.

The scope of the HITL is to confirm that electrical interfaces and real units interaction is not affecting functional and performance behaviour of the system.

WHICH SYSTEM PROPERTIES (DATA) ARE REQUIRED FOR THE AVIONICS V&V PROCESS AND WHAT FUNCTION DO THEY HAVE? HOW IS THIS HANDLED TODAY?

The following table identify the most relevant systems properties required in each stage of the V&V process and their function in the applicable domain.

System Properties	*Design*	*Design Validation*	*Model-Based Verification*	*HITL Verification*
Mass, Centring and Inertia data	X	X	X	X
Control Mode Architecture	X	X	X	X
Equipment Matrix	X	X(*)	X(*)	X(*)
Functional System Properties	X	X	X	X

Mounting data		X(*)	X(*)	X(*)
Software parameters		X	X	X
Mission specific performance model data		X	X(**)	X(**)
Calibration data			X(**)	X(**)
TM/TC database			X	X
Electrical ICDs				X

(*) Equipment Matrix data are partially replace by Mounting data.

(**) Mission specific performance model data are mostly replace by Calibration data.

HOW ARE THE MODELS VALIDATED WITH RESPECT TO A DOMAIN OF APPLICABILITY AND MAINTAINED THROUGHOUT THE AVIONICS LIFECYCLE?

The four domain applicable types of model identified above have the following validation needs throughout the system and subsystem design, validation and verification process.

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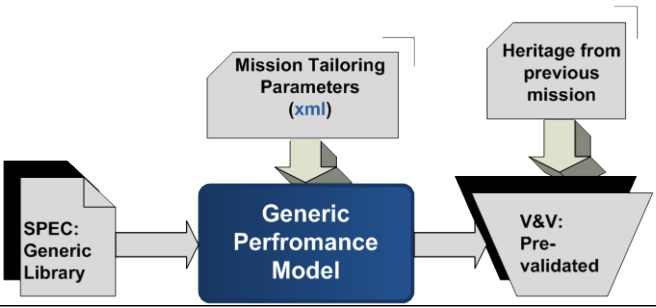

</td>
<td>There are not specific needs of validation as they have been pre-validated within the frame of a generic library derived on in-house heritage from previous missions.</td>
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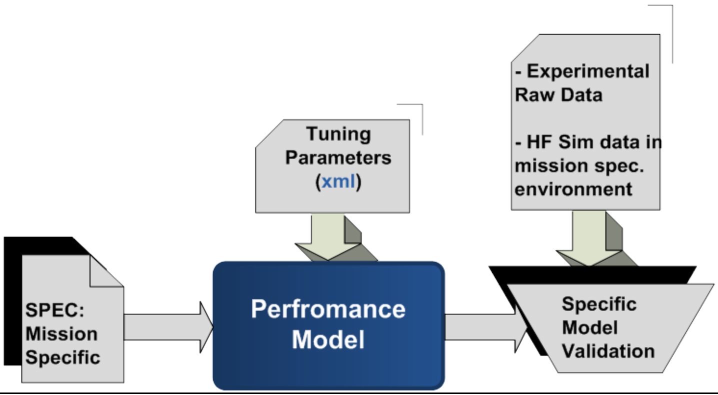

</td>
<td>The models performance validation is achieved on the basis of experimental raw data provided by units' supplier or high fidelity simulation data applicable to the specific mission environment.</td>
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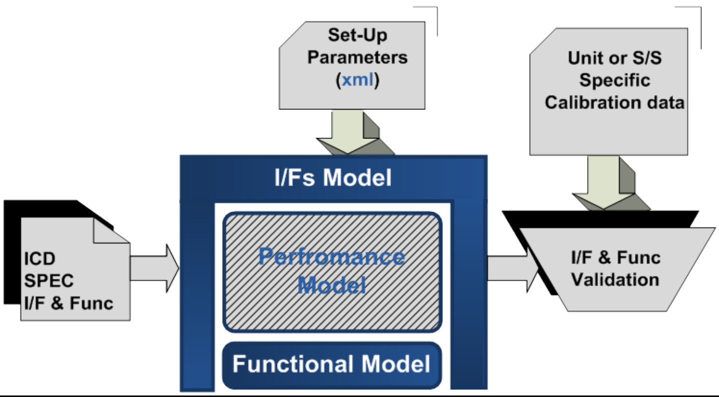

</td>
<td>The high fidelity models validation needs to be performed against specific calibration data obtained on dedicated test campaign or measurement performed at system, subsystem and units level on mission dedicated hardware.</td>
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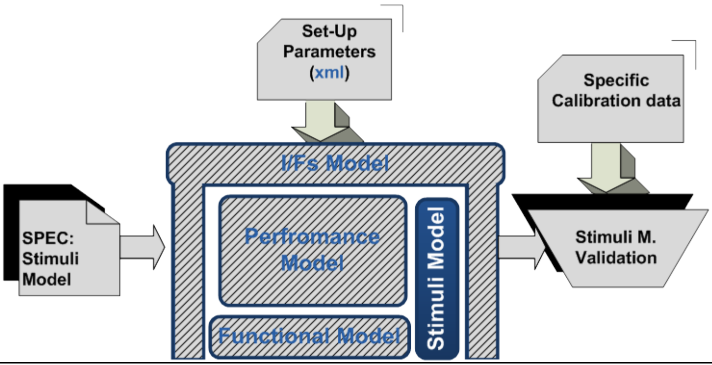	Specific calibration data and reference cases are used to validate the Stimuli model used in simulator implemented for HITL verification.