TASI VIEW ON THE AVIONICS FUNCTIONAL VALIDATION

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FULL FUNCTIONAL TEST

From ECSS-E-ST-10-02C/03C Testing

- The Full Functional Test (FFT), in the perimeter of the Element level testing, is a comprehensive test block that demonstrates the integrity of all functions of the item under test, in all operational modes, including back-up modes and all foreseen transitions.
- FFT tests are usually performed for PFM/FM spacecraft models, after assembly and integration phases, before environmental testing. FFT consists of blocks of open-loop tests related for instance to a payload, an equipment or a functional chain.

FFT approach in TASI

✓ Fully in line with the standard

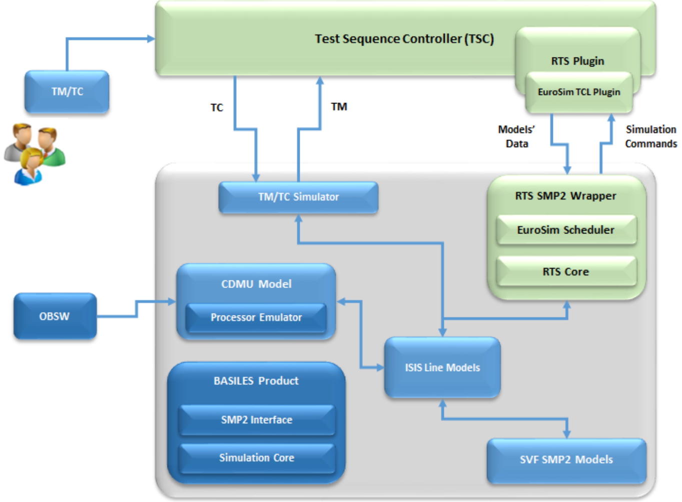
✓ Before running tests on PFM/FM spacecraft models, functional Tests are performed on SVF, STB, ATB, with the objective to anticipate at the maximum extent problem discovery before tests@FM

Model Cat.	Test Bench	Main Purpose	Technology
Virtual Model	AOCS Sim (e.g. E2E)	Support development verify and validate AOCS algorithms and performance, allowing closed loop simulation with either complete AOCS flight SW or single modules of AOCS SW in the loop	Numerical bench
	SVF	Support SW verification and validation	Numerical bench
	SatSim	Support SW-SW integration test and SW system test in open and closed loop set-up, based on a simulated onboard time reference	Numerical bench

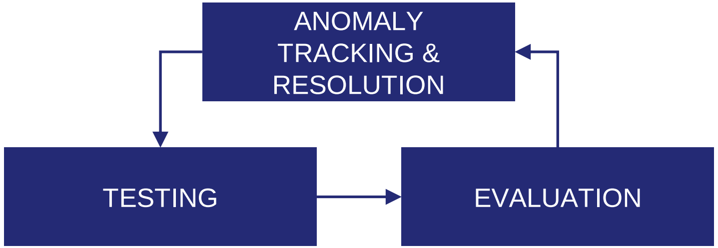
SVF APPROACH

- The S/W verification (against its Technical Specification) tests, are mainly performed on the SVF (Software Validation Facility). The SVF allows the execution of the developed SW on a numerically emulated processing environment.
- It allows performing SW/SW integration and verifying SW behavior in an open or closed loop set-up, based on a simulated on-board time reference.

DETAILED DESIGN + SW Technical Specification + DATASET FOR SW VERIFICATION



SVF



Example of Euclid SVF, implementing closed loop

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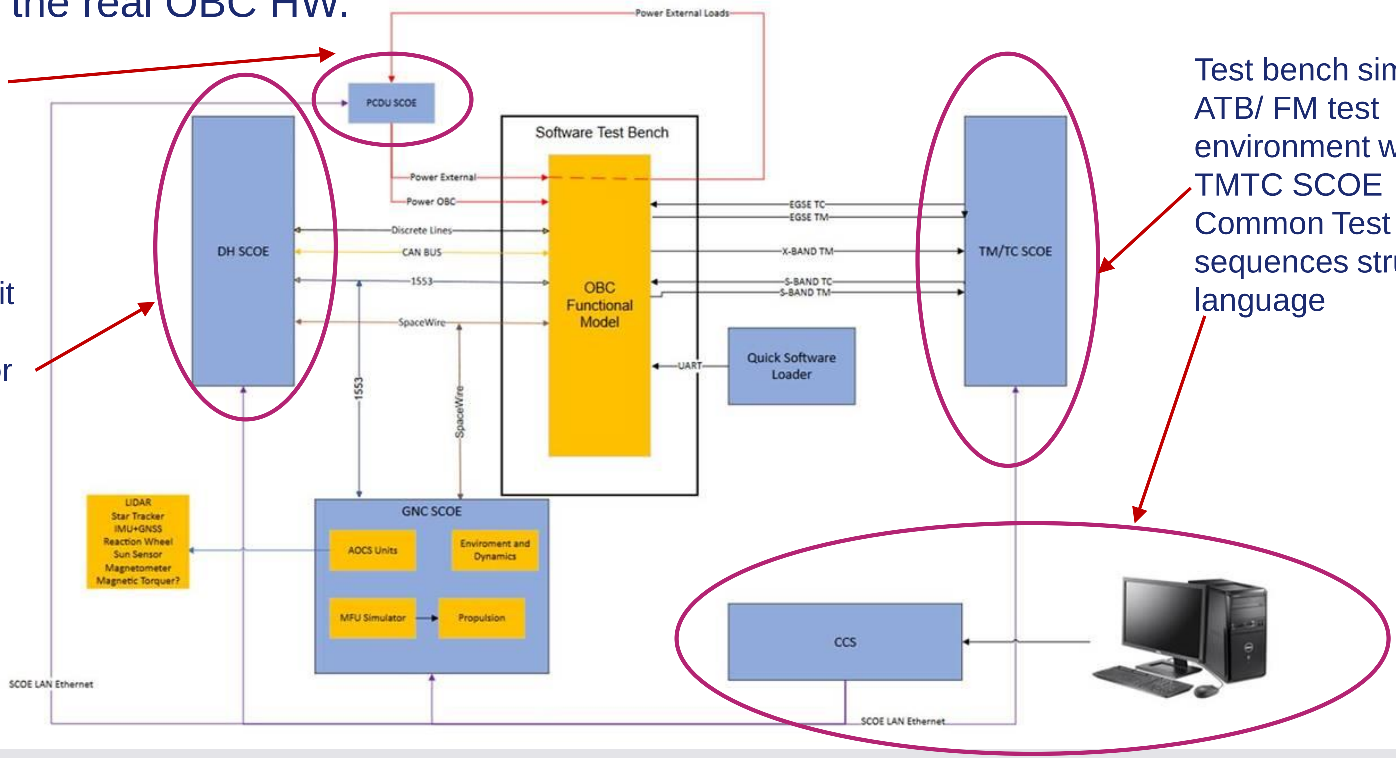
STB APPROACH

SW Test Bench (STB) provide the OBC Functional Model (FuMo) linked to EGSE which simulate the S/C. The SW already validated in SVF will be ported in the FuMo to start integration on the real OBC HW.

Power loads only simulated

In charge to simulate all the unit connected to the OBC. Open loop or close loop functionalities can be implemented

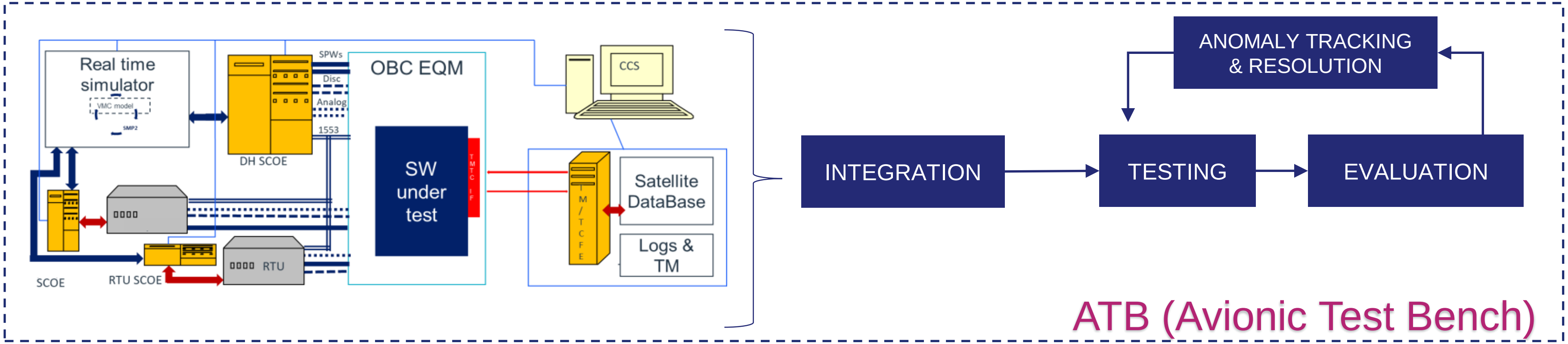


Test bench similar to ATB/ FM test environment with CCS & TMTC SCOE Common Test sequences structure and language

ATB APPROACH

Avionic Test Bench (ATB): the FuMo is replaced by the real OBC (EM or EQM).
It is the test facility allowing executing the Integrated S/S and System tests. Integrated S/S Tests (ISST) shall be used to verify a sub-system functional operation to the maximum extent after all sub-system units have completed I&T activities. Integrated System Tests (IST) shall be used to re-verify assembled Element, functional operation to the maximum extent possible after physical integration of modules has occurred.

DETAILED DESIGN + SW VERIFIED IN SW VERIFICATION FACILITY



QUALIFICATION (REQUIREMENTS CLOSEOUT)

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TAS-I END-TO-END SIMULATOR IN SUPPORT OF GNC

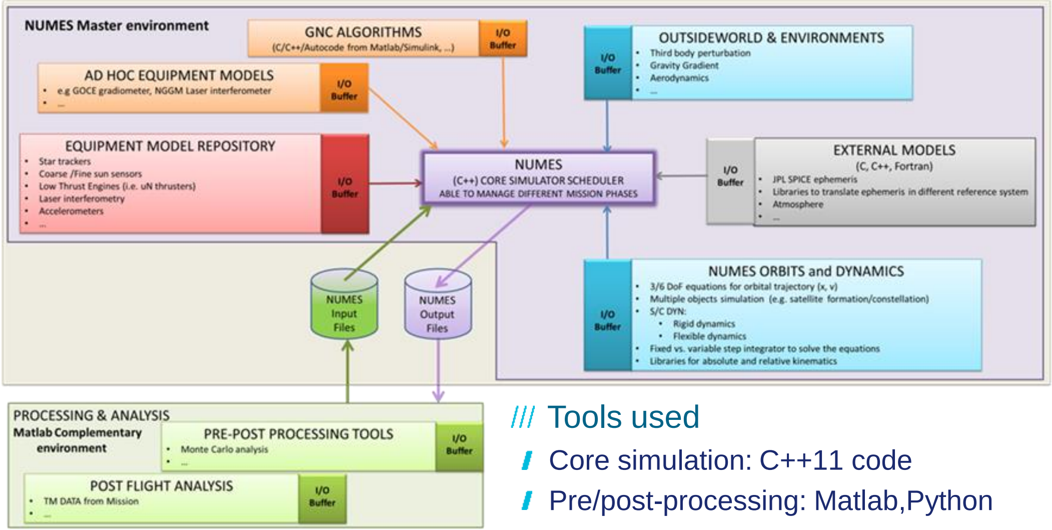
/// GNC has a dedicated Design & Verification environment built around the so called E2E simulator

/// Independent verification of GNC algorithm/implemented ASW using HiFi simulators

In the satellite/probe programs, in which are implemented several autonomous spacecraft functions, TAS-I developed a methodology for GNC algorithms and latter GNC ASW verification based on simulated environment (we call NUMES)

Capabilities:

- E2E simulation
  - Multi body dynamic simulation
  - Sensor/actuator models of increasing complexity/fidelity
    - Start: Preliminary “equivalent noise” models
    - End: Hi-Fi model with manufacturer interaction
- GNC algorithm verification
  - Monte Carlo Analysis
  - Robustness
  - Coverage tool → allows to understand which branches are stressed in Monte Carlo / Robustness case
- System analysis
  - Re-contact analysis
  - Aerodynamic loads
  - Trajectory generation
- Nursing model for GNC-SCOE (EGSE)



/// Tools used

- Core simulation: C++11 code
- Pre/post-processing: Matlab,Python
- Post processing output: Html/JavaScript, interactive browsable results

TEST ENVIRONMENT – SVF CLOSED LOOP

The idea is to ***extend*** SVF approach by interfacing the ***full S/C Simulator in closed loop***, similarly to what performed with E2E simulator for GNC Verification.

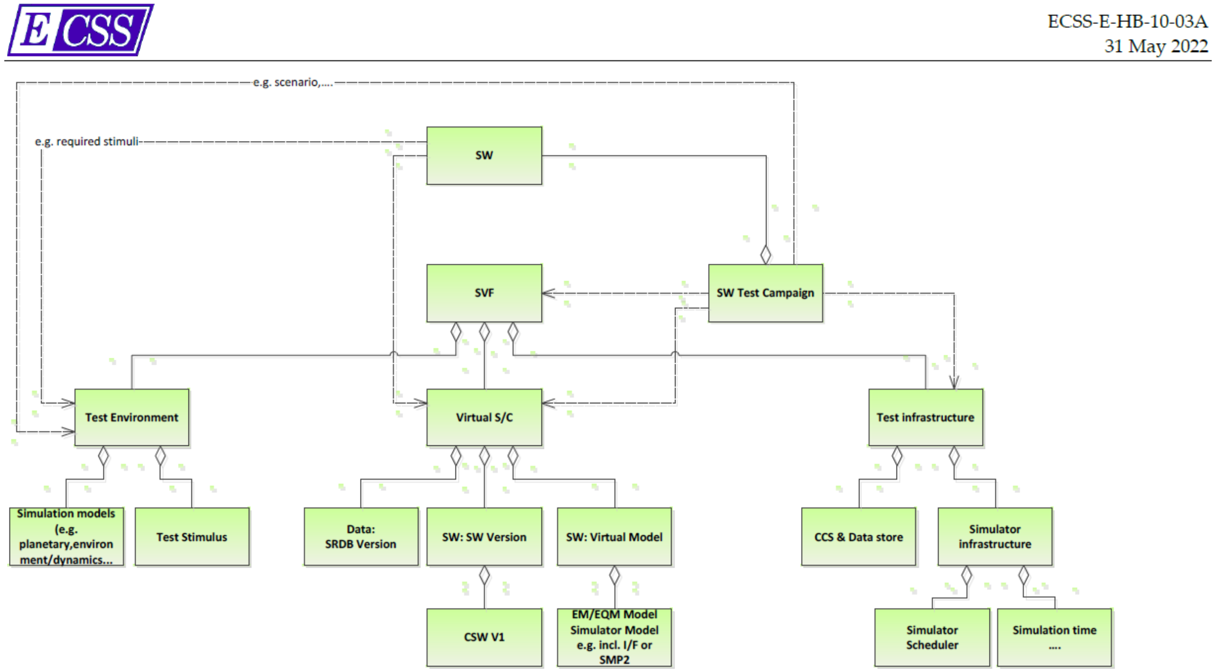


Figure 6-5: Example of an SVF based on the mapping between ECSS-E-ST-10-02C/03C and ECSS-E-TM-10-21A

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DIGITAL TWIN & S/C FUNCTIONAL SIMULATOR

Digital Twin - A virtual representation that serves as the real-time digital counterpart of a physical object, system or process.

- The System Digital Twin challenge is to allows coupling the simulation results with physical data in continuous synch → ***Goal to be reached***
- As part of the System Digital Twin initiative, TASI is focusing to develop a S/C functional simulator able to reproduce at a very accurate level the functional behavior of the satellite → ***Activity started***
- The S/C functional simulator simulates the orbital perturbations affecting the satellite, the attitude dynamics and provides models of the ground stations to allow the exchange of TC/TM with the Satellite Control Center. → ***All parts already available (from E2E, existing benches)***
- The S/C functional simulator can be use din different environment: to support and validate the OBSW but it is also a platform for the Spacecraft Operations development, validation and testing. → ***Used for S/C development and SC operation center***
- It provides a virtual environment that thoroughly reproduces the functional behavior of the satellite and all its subsystems. It is a valuable multi-purpose tool usable also for operational procedures verification and control center validation and training. → ***Link between S/C development and control center***

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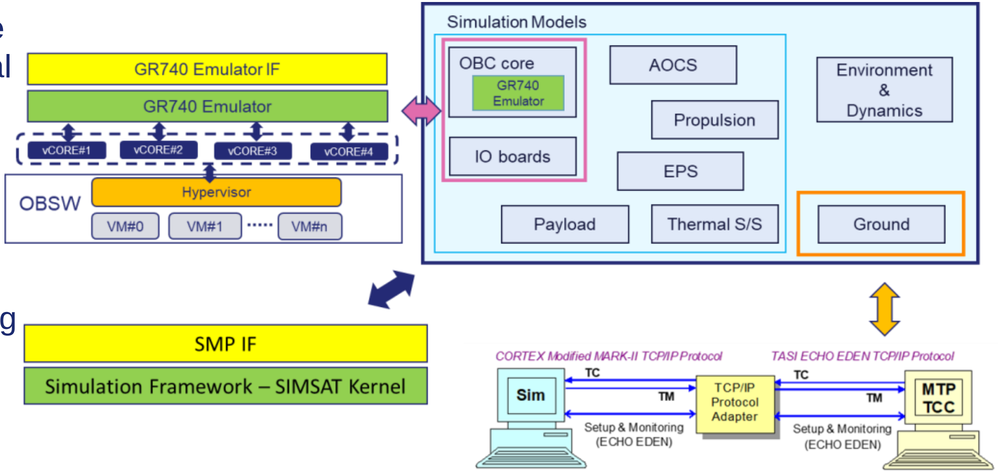
ThalesAlenia Space
a Thales / Leonardo company

S/C FUNCTIONAL SIMULATOR

The S/C Functional Simulator consists of:

- **Simulation infrastructure**: the S/C Functional simulation infrastructure is based on Next Generation (SIMSAT-NG), which is part of ESA/ESOC's SIMULUS suite.
- **On-board models**: simulate the behavior of on-board units and subsystems in terms of TC execution, TM generation, reactions to simulated failures, power budget, bus communication. The real OBSW image runs on the μP emulator of the OBC
- **Models of Environment and Orbital and Attitude Dynamics**: are the models for simulating the spatial environment of the satellite (environmental perturbations), for the orbital propagation and for the attitude dynamics.
- **Models of the ground stations**: are models that allow the Mission Control Center to communicate with the simulator, for the exchange of TC/TM, using the same protocol used to communicate with the real basebands.



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S/C FUNCTIONAL SIMULATOR

The main S/C Functional Simulator objective is to be a ***support tool for***:

- Validation of flight procedures (nominal and contingency).
- Validation of the Control Center.
- Training of operating personnel.
- Satellite database validation.
- Analysis of flight contingencies and definition of recovery actions.
- Validation of the flight software.
- Verification of patches to flight software in the operational phase.
- Verification of satellite performance in scenarios that cannot be reproduced with real HW (for example destructive failure conditions).

The accuracy used in the Simulator to describe the entire satellite in each of its components is such as to reproduce a realistic flow of telemetry from the subsystems on the ground and realistic responses to the telecommands sent on board. In other words, the simulated satellite is able to be commanded and to generate telemetry as in flight.

ANTICIPATE ISSUE IDENTIFICATION – OUR GOAL IN THE V&V PROCESS

- Final objective is to anticipate as much as possible any problem performing the functional verification with a proper environment
- More complex is the environment in which the test is done (e.g. flight model) more difficult is the process for problem identification and solution
- Simpler is the test environment (e.g. SVF) more difficult is to have a model that correctly simulates the system
- Extend close loop testing in the initial verification phases is seen as the way to have benefits in the overall V&V philosophy

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IMPLICATIONS OF CLOSED LOOP TESTING IN THE INITIAL VERIFICATION

- Development high fidelity models. This can be critical if units are new items or have very complex behaviors
- Proper trade off of what must be simulated and what must be checked with real HW leads to an optimize functional testing approach reducing at the minimum benches with real HW
- Benefits is to have a friendly and simple environment with high observability of the system behaviors.
- Different levels of models fidelity can be chosen during the testing phase to optimize the test purposes:
  - Lower fidelity → faster or real time execution for rapid checks or long duration tests
  - Higher fidelity → eventually slower than real time simulation for complex dynamics or simulation requiring verification of specific features

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CONCLUSIONS

- The Functional Validation campaign must be well integrated in the overall development process.
- Simply anticipation of test execution in absence of a proper maturity at models, SW , HW level is not the correct approach to save time and effort
- Digital twin will be the final goal to have a virtual model to be used in all the development and validation phase from S/C manufacturing to Control center validation
- Spacecraft functional simulator is the first step for a more flexible functional validation campaign