

## SESP 2010

Session: Session: Avionics TestBenches (20)  
 Type: Concurrent Session  
 Date: Thursday, September 30, 2010  
 Time: 11:00 - 13:00  
 Room: Newton  
 Chair:  
 Co-chair:  
 Remarks:

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Seq	Time	Title	Abs No
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1	11:00	Integrated Test Bench for Rapid GNC Design, Verification and Validation	
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Rodriguez, E.; Ayuso, A.; Vicente, C.J.; Gherardi, D.; Sánchez, R.;  
 Lyautey, B.; Barrios, I.  
 SENER Ingeniería y Sistemas, S.A., SPAIN

The design process of a Guidance Navigation and Control subsystem of a spacecraft must keep an eye on the later verification of its requirements. In order to meet the tight schedule that is usual in recent missions, the GNC and its Special Checkout Equipment are built in parallel. The GNC-SCOE will be used for the design of the GNC, and also during its Assembly Integration and Verification campaign.

The GNC is integrated in a test bench with the GNC-SCOE for verification and validation. The GNC-SCOE is based on the simulation models of all GNC sensors and actuators, and has also a model for the Dynamic and Kinematic Environment. A modular architecture allows replacing simulation models by real hardware models.

The GNC-SCOE can also be integrated with the rest of the Electrical Ground Support Equipment for system verification and for Telemetry/Telecommand handling.

SENER is developing and integrating a Test Bench for rapid GNC design, verification and validation. This Test Bench is the result of the combination of several SENER's tools and procedures developed in previous projects and improved during last years.

SENER's GNC Development is supported by a large MATLAB/Simulink models library called "Generico" which includes very detailed models of dynamics, kinematics, environment, sensors, actuators and GNC functions. "Generico" has been developed incrementally during several years with projects specific models/algorithms. Furthermore, a continuously development was done to enlarge this library. MATLAB/Simulink autocoding and hardware implementation is based on the SENER's expertise gained in the project GATB "Generic AOCS Test Bench". The project consisted in the development of a test bench for the validation and verification of an AOCS in several phases: from a Simulink Simulator, to a Real Time platform and finally to the highest level of the implementation of a Hardware In the Loop (HIL) facility. This test bench was validated against Herschel/Planck Functional Model during the satellites test campaign in SENER.

Recently, SENER, taking advantage of previous developments, has established a new set of procedures in the validation and verification phases integrating the available tools and expertise. Starting with the

"Generico" library, AOCS engineers develop the GNC algorithms in Simulink. Design simulators, specific for this first phase, support the first AOCS versions. In parallel, a realistic full environmental close loop simulator is needed to validate and verify the GNC algorithms. Simulator phase is called DSF-Design Simulator Facility and is used to run parametric and Monte-Carlo simulation aimed to verify and validate the AOCS models in Simulink.

Next step is to move this Simulink environment to a hardware real time one. To do this, some modifications are automatically generated to adapt the DSF to be used in another environment. This new product is called SO-SIM (from SMART-OLEV SIMulator where it was developed). The environment chosen is LabVIEW where interfaces development is done to communicate the inputs/outputs of SO-SIM with the processor (Flight/functional computer) and the operation system SCOS2000. This facility is called Processor In the Loop (PIL) and can be used for GNC performance verification, for Operations preparation/simulation and for spacecraft developments test (Data base, Test Benches and Software).

Finally, last test bench stage involves Hardware In the Loop (HIL). HILs include final software versions and dedicated interfaces development to communicate with the Hardware included in the tests. HIL bench has multiple applications. The first one is the open-loop test for independent units, and also for OBC interfaces. Once the units are checked, closed loop tests can also be performed, even mixing simulated and hardware units. For hardware in the loop sensors, some stimuli should be applied. This stimuli is either provided by the UCE or by the SCOE. For sensors, some actuation transducer must be used, to introduce the data into the DKE and close the loop.

2 11:30 Validation Facilities for Vision Based Rendezvous GNC in Elliptical Orbits

Bastante, J.<sup>1</sup>; Gómez, S.<sup>2</sup>; Fernández, V.<sup>2</sup>; Monteiro, J.<sup>1</sup>; Hagenfeldt, M.<sup>2</sup>; Dinis, J.<sup>3</sup>; Rebordão, J.<sup>3</sup>

<sup>1</sup>DEIMOS Engenharia, PORTUGAL;

<sup>2</sup>DEIMOS Space, SPAIN;

<sup>3</sup>Faculdade de Ciências da Universidade de Lisboa, PORTUGAL

The proposed paper presents the objectives and a description of the employed simulators architectures, for its various configurations, in the frame of ESA automated vision based rendezvous projects. In specific, the consortium has been collaborating in a strategic programmatic line of ESA projects, namely GNCO ("Development of GNC algorithms for Rendezvous and Formation Flying in Non-Circular Orbits"), GNCOMAT ("GNC Maturation and Validation for Rendezvous in Elliptical Orbits") and PROBA-3 Rendezvous Experiment projects. The nature of this technology also allows future use in other missions, such as MSR ("Mars Sample Return"). The objectives of the GNCOMAT project are the increase up to TRL 4-5 of Vision Based Rendezvous GNC in elliptical orbits and, for PROBA-3 experiment, further increase to TRL 8/9. The efficient and reliable philosophy used along these projects is the reuse of simulation infrastructures and consideration of previous lessons learnt.

The simulation infrastructure consists on two implementations: a non real-time Functional Engineering Simulator (FES) and a Real-Time Test Bench (RTTB). The last is subdivided in a Processor in-the-loop (PIL) configuration and Hardware in-the-loop (HIL) configuration based on an image processing (IP) laboratory mock-up.

The objective of the FES is to provide support for functional validation of GNC/IP algorithms.

The IP laboratory is used to achieve HIL objectives. Proper evaluation

of IP performance in realistic conditions is of paramount importance because IP is a slave subsystem to GNC that provides information on the chaser/target relative positions, i.e. provides optical navigation observables used in the closed-loop chain. The specific objectives of the IP laboratory are:

- Test IP methods with real images taken on a spherical canister;
- Test specific IP modes or states sequences;
- Work with real camera parameters. The RTTB (PIL+HIL) objectives can be enumerated as:
  - Evaluation of the GNC algorithms real-time performance in a target environment (LEON3);
  - The GNC real-time and algorithmic performance evaluation;
  - Assessment of FES architecture suitability;
  - Evaluate the integration and performance of the entire GNC and IP chain;
- Test the algorithmic and real-time performance of IP routines.

The relationship between these implementations/configurations is a large contributor for efficient and reliable evolution of the infrastructure complexity. The PIL configuration is based as much as possible on the FES architecture (by porting it to a real-time implementation). The difference is that the real-time implementation runs the "Real World" and GNC algorithms in dedicated machines (dSPACE® and LEON3, respectively), which provide real-time performance and representativity of the target environment in which GNC/IP software will run. Then, the PIL architecture and IP laboratory serve as a basis for the HIL configuration, in the sense that the HIL configuration is an enhancement of the PIL configuration and includes a representative of a navigation camera, acquiring images in realistic/expected conditions that are inherent to the mission characteristics. Thus, as a basis it includes the "Real World" models ported from FES and PIL configurations with exception of the part that generates the navigation observables for relative motion (i.e., camera ones), now obtained directly from an image acquisition-processing chain with HW in the loop that is representative for future space applications.

In the laboratory mock-up, the camera and attached lens are supported by a pan and tilt unit. The lens is placed at a fixed distance (2.5m) of a small ball (40mm diameter), painted with an appropriate texture. The centre of the ball is aligned with the lens optical axis (without any camera pan/tilt). The ball is fixed at the top of a small rod, which is attached to the axis of a motor (ball motor). This motor is overlapped by a rotary table (horizontal table) that supports a second rotary table (vertical table), placed vertically, and connected at a right angle. In turn, the vertical rotary table is connected to the light source by another right angle. The light source can be rotated around the ball for every latitude and longitude, with the exception of a small region around the ball support. Obviously, it is also not possible to illuminate the ball by the optical axis direction; it would obstruct the image acquisition. The ball can rotate without restrictions by the vertical axis in order to simulate the free -not controlled- rotational motion of the canister, and the effect on image processing algorithms of a set of moving -snapshot to snapshot- retro-reflectors

The GNC and validation facilities development cycles are driven in parallel, so that GNC/IP algorithms can be validated in the applicable environment, i.e. the respective implementation and configuration.

3      12:00      End-to-End Simulation Environment: From GOCE to Exomars and NGGM  
De Sanctis, S; Parisch, M.  
 Thales Alenia Space Italia, ITALY

In the frame of GOCE program, TAS-I has developed an End-to-End simulator able to assess the overall mission performance and to support the evolution of the design. The concept of this End to End simulator has been upgraded and it is now the base of the new performance simulators developed in TAS-I. The main improvements cover the following areas:

- Formation flying simulation (NGGM): the migration from C language to C++ allows the multiple instantiation of objects and then easy the set-up of a multiple satellite simulator
- EDL simulator (Exomars): apart from the model library enrichment with specific models for Mars environment and EDL models (i.e. parachute), a multi-phase simulation capability has been implemented. The new SW simulation framework (NUMES) is then the basic environment that can be used to build-up high fidelity performance simulators and to integrate simulators supporting the spacecraft GNC life cycle, from the check of the design up to the validation. This simulation environment relay on the TAS-I long experience in the dynamics simulation field, merging the products developed for the multi-body dynamics simulation (i.e. DCAP) with the simulation products developed for supporting the GNC validation activities. It is constituted by different components: model repository, libraries, utilities functions, procedures, mission manager and schedulers. Mission Manager and Schedulers are customised to obtain the different instantiations of the simulator. The fidelity level of the simulator depends on the scheduled models (all belonging to the models repository). The models library collects all the models set-up during the different simulator development (GOCE, NGGM, EXM and other minor studies); it includes dynamics, gravity models (Earth and Mars), environmental models (Earth and Mars), sensors and actuators generic models (customisable through input file), sensor and actuators specific models (relevant to a specific unit) and parachutes models. The libraries provide function for I/O management, classical mathematical operation (vector, matrix, and quaternion), specific orbital functions (orbital parameters conversion, ephemeris computation, reference frames conversions). New models externally developed can be interfaced through a suitable wrapper, even if written in other language, i.e. Fortran, or automatically generated using an autocode tool (i.e. from Simulink).

Objective of the NGGM study is to establish a mission architecture concept aimed at the optimal recovery of the Earth time variable gravity field. The mission is based on a Satellite to Satellite laser Tracking (SST) observation technique and includes the analysis of a variable number of pairs of satellites with different orbits and inclinations. The NGGM E2E is able to simulate the identified mission scenarios including a multi-satellite dynamics, the defined control systems, the model of the various payload and sensor/actuator elements and, in particular, is interfaced with the timevariable Earth gravity field model. The NGGM E2E consists of two separate modules: a "forward module" developed by the industrial team, generating the satellite observable (i.e., inter-satellite distance variation and the non-gravitational acceleration measurements) starting from the signal produced by the variable gravity field at the satellite level, and a "backward module" developed by the scientific team, recovering the variable gravity field from the satellite observables. The recovered gravity field models is post-processed and exploited to estimate parameters of target geophysical signals, in concert with the pre-defined scientific requirements. This way allows estimating the mission performances till to the early stage of the project. The development of the Exomars EDL E2E simulator started in phase B2. A preliminary version of the EDL simulator, named DPS simulator, was based on Matlab/Simulink, interfacing directly the GNC algorithms developed in Simulink. After the EDM mission redesign (phase B2X), the DPS simulator has been abandoned and a preliminary version of Functional End To End simulator (FE2E) has been instantiated for supporting the B2X, B2X2 activities. This version includes simplified performance

models for the parachute and GNC equipment and a C-language version of the GNC algorithms generated using Matlab/Simulink Embedded Real Time coder. The main advantages of this simulator with respect to the DPS simulator are: reduced simulation time, more flexibility in the multi-phase management and models scheduling, user familiarisation with the tool to be used in the next phases of the program development.

4 12:30 Evolutive Infrastructure for Avionics Verification and Validation Activities

Pace, F.<sup>1</sup>; Barrena, V.<sup>1</sup>; Wijnands, Q.<sup>2</sup>; Lindman, N.<sup>3</sup>

<sup>1</sup>GMV, SPAIN;

<sup>2</sup>ESA, NETHERLANDS;

<sup>3</sup>ESA, SWEDEN

The verification and validation of a component, algorithm, technology or related standards is a key process in the lifecycle of the space applications and products. An infrastructure capable of performing verification and validation of avionics for space missions at all phases level (starting from phase 0 up to the final product delivery) is an ambitious and complex use for a validation infrastructure. In the context of the ATB-RAC project the concept of evolutive infrastructure architecture has been defined for an End to End Avionics System TestBench (E2E ATB) infrastructure. This infrastructure is meant as the evolution of the Avionics Test Bench developed over the past years at ESTEC laboratory. For the definition and design of an evolutive infrastructure (like E2E ATB) a clear definition of the potential use cases and users were defined at the beginning of the ATB-RAC activity. This initial process has identified the verification and validation activities expected to be performed with this kind of infrastructure. Based on the use cases definition, a set of system and software requirements has been defined for driving the architectural design of the infrastructure capable of being configured in 4 different configurations (verification facilities):

1-The Functional Engineering Simulator (FES) allowing the verification of critical elements of a baseline system design (such as Data Handling and AOCS/GNC algorithms) and to support the analysis of system performance.

2-The Functional Validation Test-bench (FVT) allowing the simulation of a system running under real-time environment, with a focus on the identified critical and prototyped/bread-boarded elements.

3-The Software Validation Facility (SVF) allowing the validation of the on-board software, which needs to be performed in a context that is representative of the spacecraft system in space and with ground interfaces. The SVF contains a fully functional and performance representative simulation model of the spacecraft hardware (e.g. On-Board Processor emulator) where the on-board software is validated.

4-The Real-Time Test Bench (RTB) allowing the validation activities that involve HW in the loop configurations (for at least the OBC to provide full representative real time conditions) with full real interfaces for TM/TC and commanding (EGSE). The configuration management of this kind of infrastructure offers the user the possibility to easily configure and adapt the validation infrastructure (through a dedicated configurator tool) to a specific mission and configuration. In this way, the mission "context" is used for the verification and validation processes identified by the mission needs that otherwise would be difficult to assess, predict or estimate without simulation.

The ATB concept includes modularity, configurability and maintainability as a major ATB design driver. This modularity, configurability and maintainability refer to the different ATB configurations (FES). Another important aspect of the ATB infrastructure is the portability/re-use of simulation models from the FES configuration to the real-time configurations by conversion to SMP2 standards through automatic autocoding techniques from

Matlab/Simulink® models.

Additionally, the requirements and the architectural design of the E2E ATB have been customized and tailored for four reference missions:

1-Exploration Mission: one or more fixed crafts (lander and/or rover) on the Mars surface, one or more Mars data relay spacecrafts, one or more Earth data relay spacecrafts and one or more Earth based ground stations.

2-Formation Flying Mission: at least two spacecrafts in formation where the GNC algorithms are capable of centralized constellation control.

3-GEO Mission: a geostationary telecom satellite.

4-Earth Observation Mission: an Earth observation satellite.

The corresponding paper will describe the results of the ATB-RAC activity:

- E2E-ATB Use cases definition
- E2E-ATB System and Software requirements specification
- E2E-ATB Architectural design

With particular emphasis on the following drivers:

- Maximization of the synergy between the configurations in terms of software reuse and configurations
- Configurability of the infrastructure
- Modularity and maintainability
- Use and migration of the simulation models to the SMP2 specification
- Automatic testing capabilities