GNC/AOCS DEVELOPMENT SYSTEM FOR RENDEZ-VOUS AND DOCKING MISSIONS AT SENER, AND ASSOCIATED TEST FACILITIES

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INTRODUCTION

• The involvement of SENER in Rendez-Vous and Docking activities has been recently focused in three missions:

  • ASVIS (Automatic Servicing Vehicle for ISS Surveying)

  • Automatic Rendezvous and Docking Demonstration Mission

  • ConeXpress

• Generic AOCS Test Bench development → GATB
ASVIS: DESCRIPTION

• ASVIS (Automatic Servicing Vehicle for ISS Surveying) is an operative system for providing ISS services like inspection at different ranges, both periodical and on-demand and support to EVA

• The GNC validation has been performed in two steps:
  • First, a simulator called ASMIS developed in the Matlab/Simulink environment that demonstrates the validity of the GNC concept.
  • The second step of the validation process is the migration of the Simulink simulator to the EuroSim/Linux environment. GNC algorithms are implemented in a Minicraddle platform based on ERC32, which is controlled and operated from a laptop.
ASVIS: ASMIS

- Simulator architecture:
  - On board processor and Failure Detection and Isolation functions
  - Dynamic, Kinematic and Environment
  - Sensors and actuators models
  - Communications coverage with ISS
  - ISS sensors
  - Rest of ASVIS Subsystems block
  - Guidance block
  - Introduction of off-nominal conditions.
ASVIS: TEST BENCH & VISUALIZATION TOOL

- Test Bench elements:
  - PC: Environment Code running on Eurosim under Linux.
  - Miniforce: Simulated On Board GNC Software running on the flight representative TARSYS mother board with ERC32 architecture.
  - Interface Boards: Between both stations.

- All the models were developed with Matlab/Simulink.

- OBSW code in Matlab/Simulink format is transformed into C code using the Real Time Workshop. Then, it is cross-compiled into ERC32 executable file. And finally, it is downloaded into the TARSYS board.

- Visualization Tool architecture is based on Eurosim and 3D visualization tool.
The main goals of this mission, denoted the “Rendezvous and Docking Demonstration Mission (RVDM) are:

- Technology demonstration such as the electromagnetic capture and soft docking function of the IBDM (International Berthing and Docking Mechanism).
- Risk mitigation for future applications of automatic rendezvous
- Docking without the use of absolute or relative GPS (in circular and elliptical orbit).

The baseline of the mission is thus, a Target (PROBA) and a Chaser (SMART-1) spacecraft launched jointly into a circular LEO, carrying the IBDM and the Radio Frequency Far Field sensor (from Darwin Mission) and LIDAR (upgraded ATV sensor)

A software-based simulator (MISSIM) has been developed in order to demonstrate the mission feasibility and assess the pointing and position error and fuel budget of the concept.
RENDEZVOUS AND DOCKING DEMONSTRATION MISSION: MISSIM

• The simulator is based on the Generic AOCS, which is an on-going internal development of simulation and analysis tools in Matlab/Simulink. It contains a large set of libraries including dynamics/environmental models, actuators, sensors, GNC blocks. A special variant for rendez-vous & docking is available, which is used as the basis for the simulation environment in this project.

• The software simulator contains three main subprograms:
  - Mission Analysis GUI
  - MISSIM simulator
  - Visualization GUI
RENNDEZVOUS AND DOCKING DEMONSTRATION MISSION: MISSION ANALYSIS GUI

- Mission Analysis GUI: allows the user to introduce all the orbital data as well as the mission profile required for the mission and provide display of ideal results
- The following manoeuvres can be implemented:
  - HOMING/CLOSING
  - STATION KEEPING
  - FORCED (Linear) APPROACH
  - FLY AROUND
  - FREE FLIGHT
  - DOCKING / UNDOCKING
- Different Attitude predefined profiles
RENDEZVOUS AND DOCKING DEMONSTRATION MISSION: MISSIM

- MISSIM simulator: main core of the MISSIM software performing S/C simulations in a highly realistic environment. The simulator takes into account effects such as:
  - Errors in the absolute and relative sensors
  - Errors in the actuators
  - External disturbances
- MISSIM allows the computation of the propellant required for the different manoeuvres, and the accuracy obtained at the contact instant.
- Visualization GUI: provides high quality visualization of both S/C’s position, attitude, fuel consumption, battery charge, coverage flags of the mission ground stations (Kiruna, Redu, Villafranca)
CONEXPRESS: DESCRIPTION

- ConeXpress is a general platform based on the use of an Ariane 5 cone adaptor. The ConeXpress Orbital Life Extension Vehicle (CX-OLEV) mission services GEO telecommunication satellites that are almost finishing their mission lifetime while the payload is still in a good shape. CX-OLEV, once docked to the Client S/C, will extend its lifetime for several years.

- GNC SW simulations have been performed to test the performance and functionality of the GNC design. GNC SW simulator, developed by SENER, was integrated as one of the elements of a System simulator for the ConeXpress S/C called DSF (Design Simulation Facility), responsibility of Dutch Space.
**CONEXPRESS**

- Simulation SW has been focused in future autocoding
- Model a philosophy based in three principles:
  - Simplicity
  - Modularity
  - Portability
- Docking phase has been subject to additional analysis in order to test the contact dynamics between ConeXpress and the Client S/C at the instant of docking. The dynamics of both S/C (including GNC) and the forces exchanged in case of contact allowed to check the success of the docking strategy.
GATB: DESCRIPTION

- Generic AOCS Test Bench (GATB) is an adaptable and scalable system test bench to validate and verify GNC/AOCS subsystems.

- The GATB staggered approach offers to the AOCS supplier the opportunity to verify and validate the subsystem, starting from communication principles running in real time, up to open and close loop tests that may include both the On Board Computer and/or the Unit Models –Sensors and Actuators– in the loop.

- GATB for RVD

- The main four elements of the GATB architecture are:
  - Matlab/LabVIEW host
  - SCOS 2000 host
  - PXI rack
  - VME rack
GATB: Offered Testing Staggered Approach

Step A. The AOCS SW and the Simulation Software run together in real time in the processor of the PXI Controller.

- Step B. The AOCS SW runs in real time in a flight representative on board processor –ERC32 or LEON–, whilst the Simulation Software runs also in real time in the PXI rack.

- Step C. The AOCS SW runs in real time in the On Board Computer, while the Simulation Software runs in real time in the PXI rack. Interface between both devices is performed via the I/O boards plus the data bus boards.

- Step D. Same as Step C but additional flight hardware –Sensors and/or Actuators– may be included in the loop.
GATB: Offered Testing Staggered Approach – Step D
GATB: APPLICATION IN CONEXPRESS FRAME

- The levels of testing and the corresponding use of GATB with steps proposed are hereafter listed:

  - Software Validation with two possibilities
    - Use of GATB Step B
    - Use of CX EM ERC32 board

  - Hardware In the Loop Testing
    - Focused in DHU (GATB steps C/D)
    - Focused in DPCU (GATB steps C/D)
    - Overall EGSE (GATB steps C/D)
    - Docking Payload Test in EPOS (GATB steps C/D)

  - Spacecraft Simulator for Operations: proposed approach is to use the overall ConeXpress Test Bench configuration with Engineering Models units in the loop
Software Validation

• The software is validated in real time close loop tests running in an ERC32 processor. Two alternatives: GATB Step B and using CX EM ERC32 board. The latest would be preferred since real interfaces are tested (CAN bus).
HIL Testing – DHU Focused
HIL Testing – DPCU Focused
HIL Testing – Overall EGSE
HIL Testing – Docking Payload Testing in EPOS

- Feasibility of the proposed test must be carefully considered gathering the test bench capabilities together with the EPOS performances.
CONCLUSIONS

• The involvement of SENER in RVD missions has led into development of tools that enhance SENER capabilities in order to perform GNC design, verification and validation for RVD missions.

• The tools developed cover a wide set of functionalities:
  
  • MISSIM allows designing and testing the performance of Rendez-Vous a Docking strategies.
  
  • GNC design for both ASVIS and ConeXpress has been tested (functionality and performance) by dedicated simulators based on Simulink developing environments.
  
  • GATB→HIL verification systems are available at SENER including target computer in the loop, capability for all front-end simulation, and integration of HIL sensors and actuators.