GNC software production process

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FFIORD Seminar – March 7th, 2012

Context

- SSC has developed a significant experience in code generation process using Mathworks tools ➔ GNC software was auto coded for the SMART-1 mission (lunar probe)
- Process reused for PRISMA to develop GNC software and numerous components of the flight software (including I/O)
- Matlab / Simulink is the only environment to perform GNC algorithm integration and validation ➔ 2 possibilities for delivering software contributions:
  - traditional source code (C, C++) encapsulated within a special Simulink block (S_function)
  - Simulink based design
- Design rules and recommendations are given by SSC to partners using Simulink for code development (Model Based On Board Software)

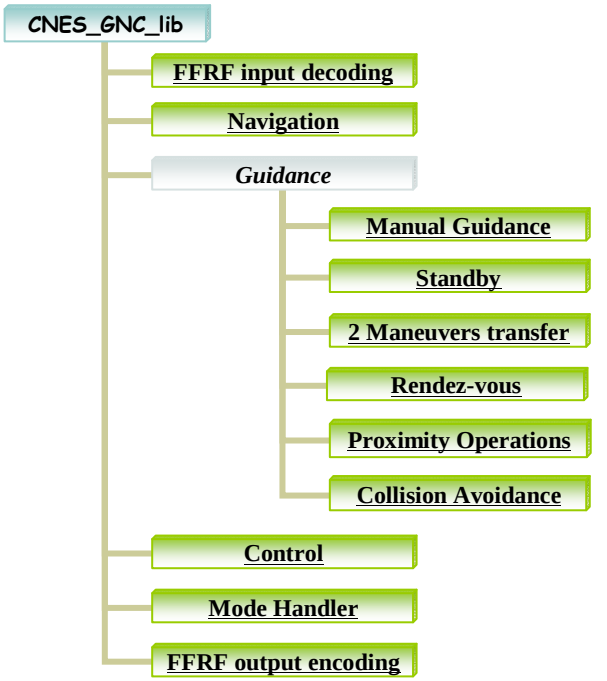
Besides the technical interest, CNES choice of the second option was driven by the short development timeframe

Development approach

- Internal development performed by the GNC team
  - CNES DCT/SB/PS et DCT/SB/MO
  - Partnership with Astrium and TAS for 2 guidance functions

- 11 functions integrated in a Simulink library:
  - Simulink = model oriented approach that simplifies the development of complex algorithms and simulators
  - From initial prototyping, to simulator for studies, until flight software
  - Direct interface with Matlab

→ CNES_GNC_lib = Simulink library delivered to SSC



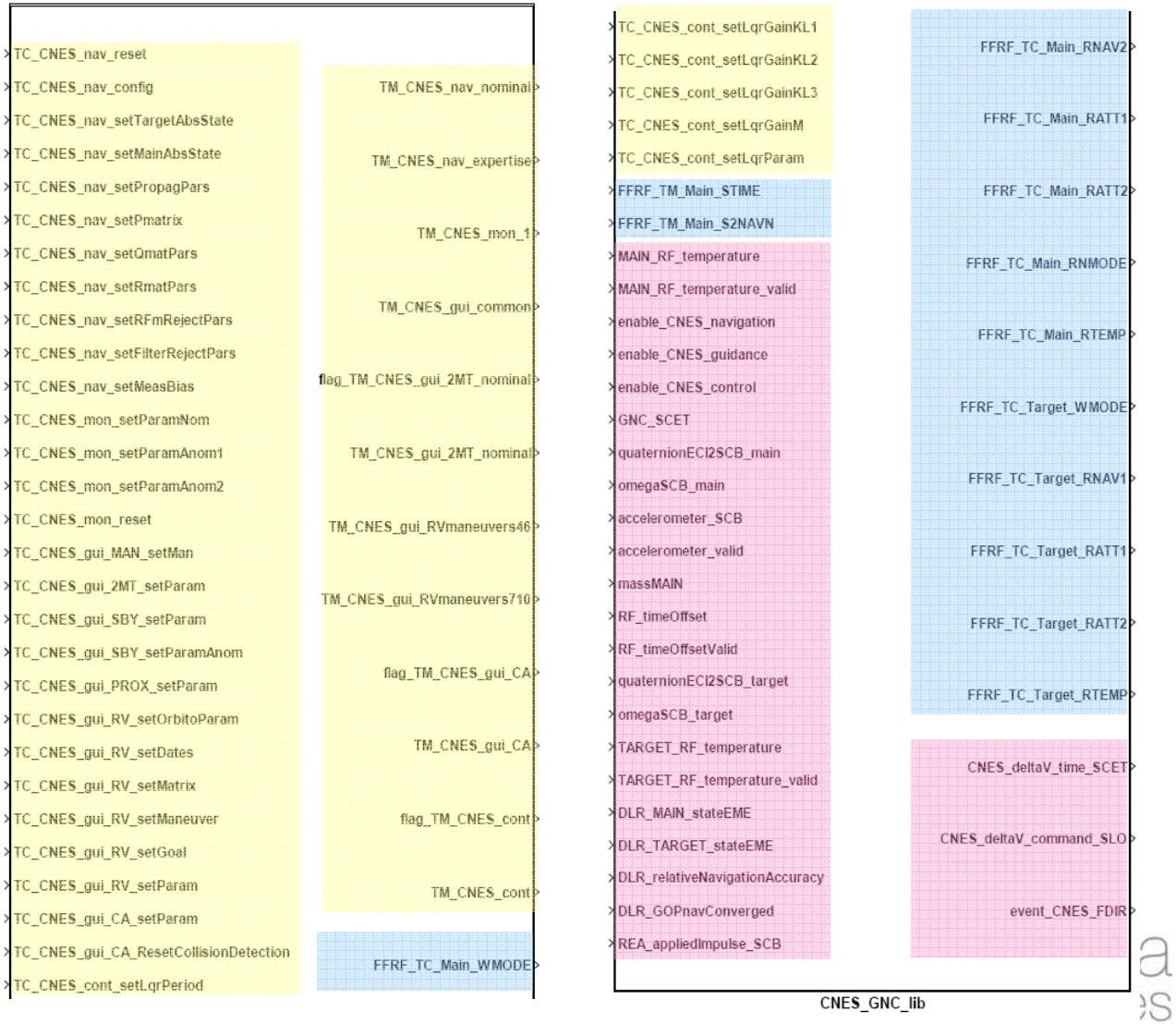
- Quick development :
  - Start nominal mission = 2006
  - First integration in Prisma flight software = january 2008
  - Flight version = march 2009

➔ Even faster for the extended mission activities

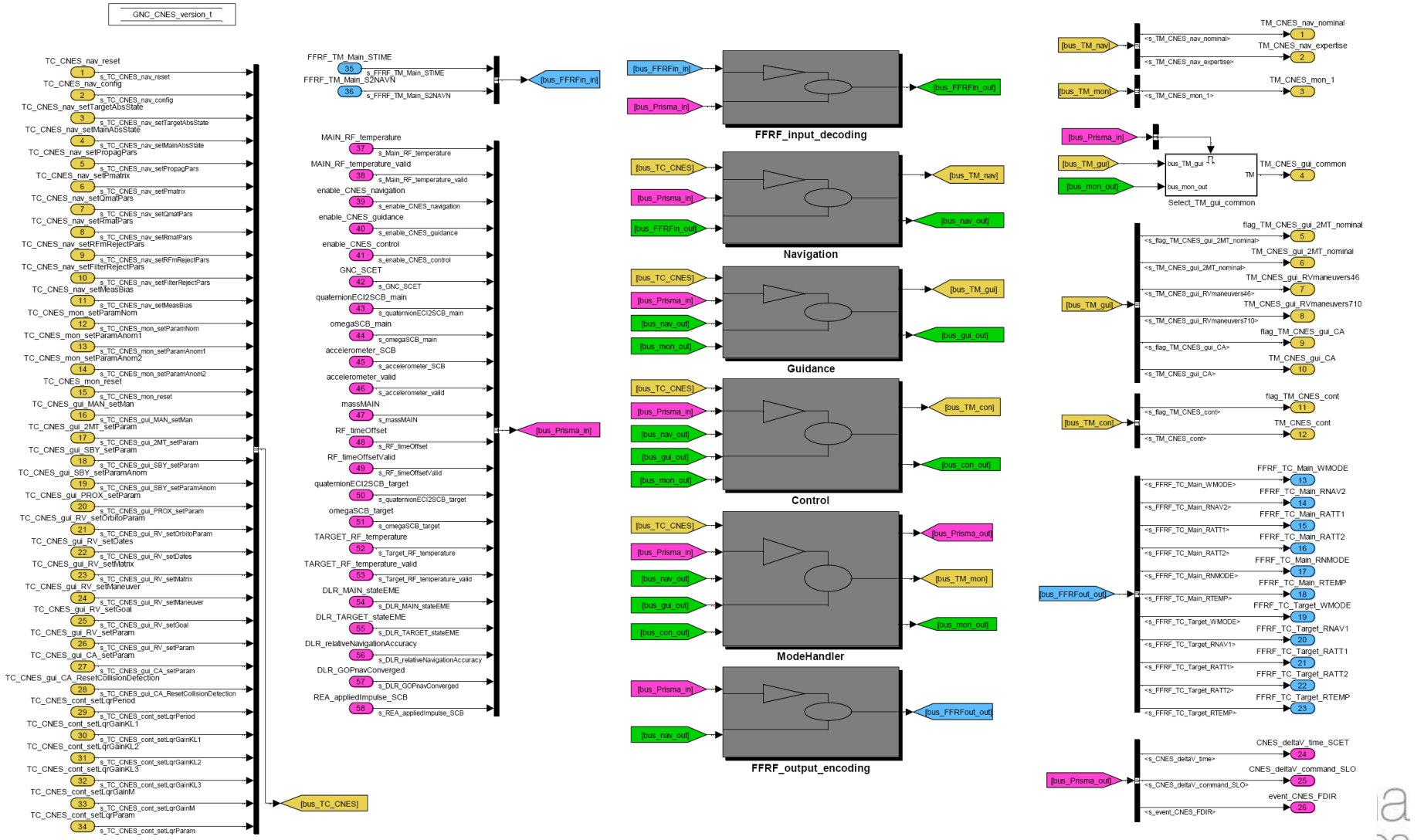
Matlab/Simulink/RTW used by SSC to develop:
- flight software
- numeric satellite simulator (Satsim)

Simulink development

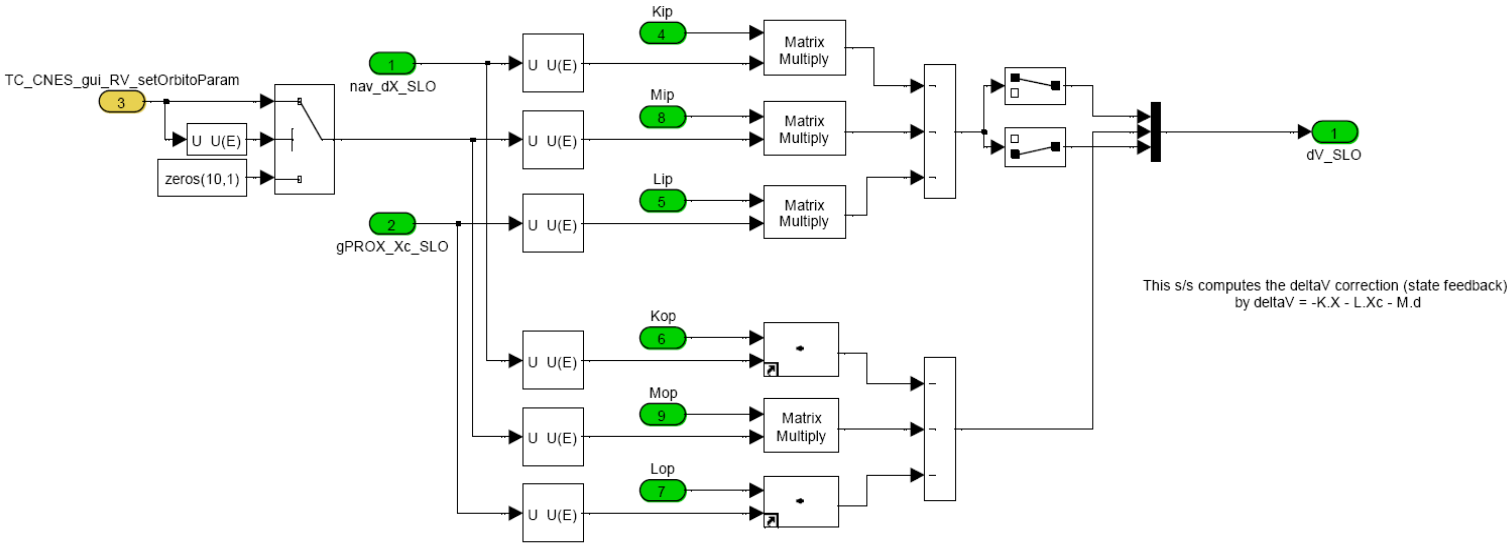
- Utilisation intensive de Simulink
  - 58 entrées (524 éléments), 27 sorties (566 éléments), 35 paramètres modèles
  - 11 librairies internes pour 11 fonctions dédiées
  - 679 sous-systèmes, 11553 blocks Simulink
  - 3 s-functions codées en C (Navigation + FFRF_IF)



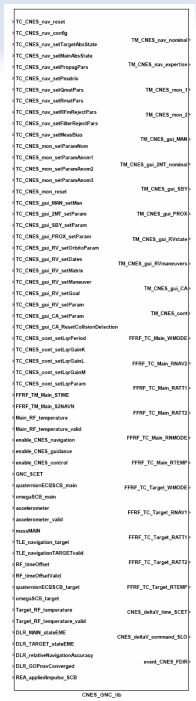
Simulink development
Software high level architecture



Simulink development

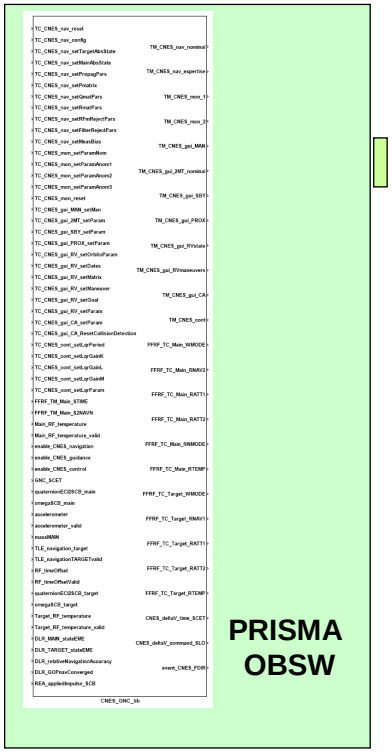


Integration and code generation (option 1)



CNES_GNC_lib

Delivery to SSC



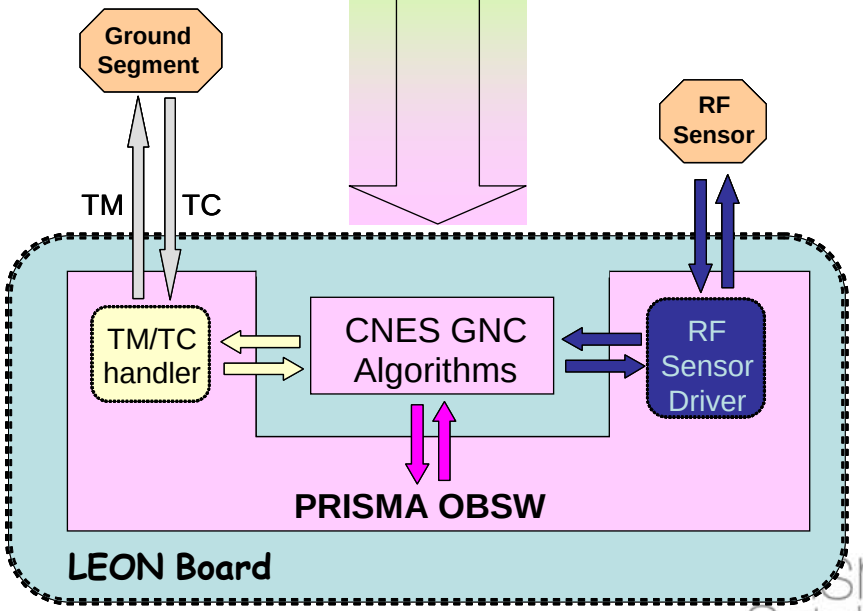
PRISMA OBSW

Integration of CNES_GNC_lib into PRISMA OBSW in Matlab/Simulink

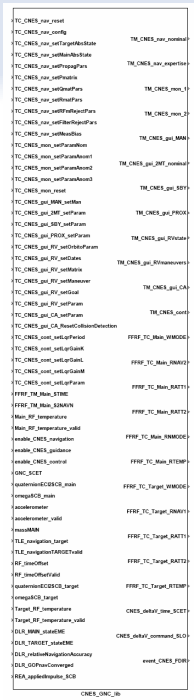
Real Time Workshop

C Code OBSW

Compilation on the Target



Integration and code generation (option 2)



CNES_GNC_lib

Delivery to SSC

CNES

Real time workshop

C Code

C Code

PRISMA OBSW

Integration of CNES_GNC_lib s_function

SSC

Real time workshop

C Code OBSW

Compilation on the Target

Ground Segment

TM

TC

RF Sensor

TM/TC handler

CNES GNC Algorithms

RF Sensor Driver

PRISMA OBSW

LEON Board

Validation approach

CNES has chosen an hybrid approach:

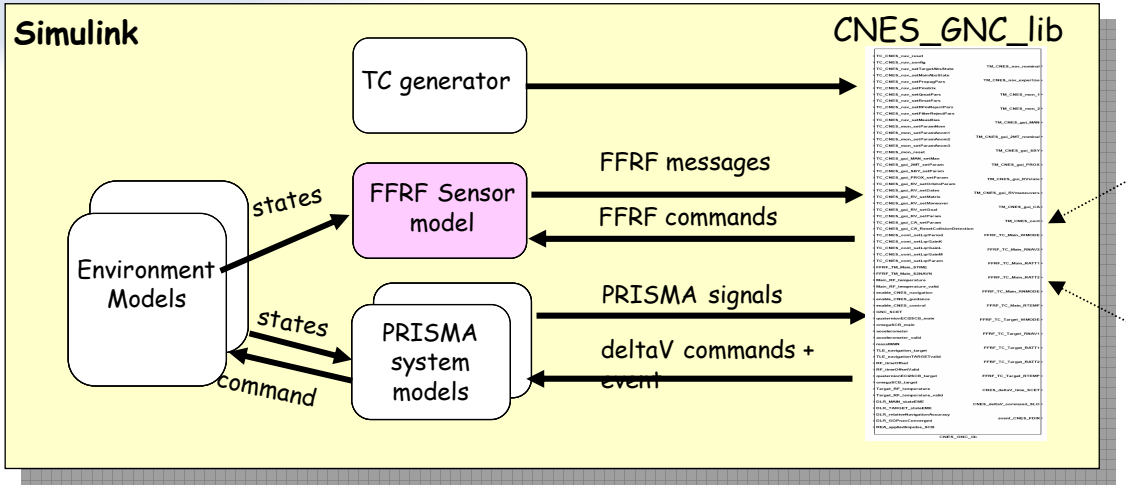
- **Deliver the software to SSC according to option 1**
  - ➔ To limit the validation risk and complexity given the tight developement schedule (with a new software production process)
- **Perform code generation in CNES to validate independently the code generation process at CNES_GNC_lib level**
  - ➔ To reduce the number of iterations and cross validate in case of anomaly

Validation of generated code in 2 steps

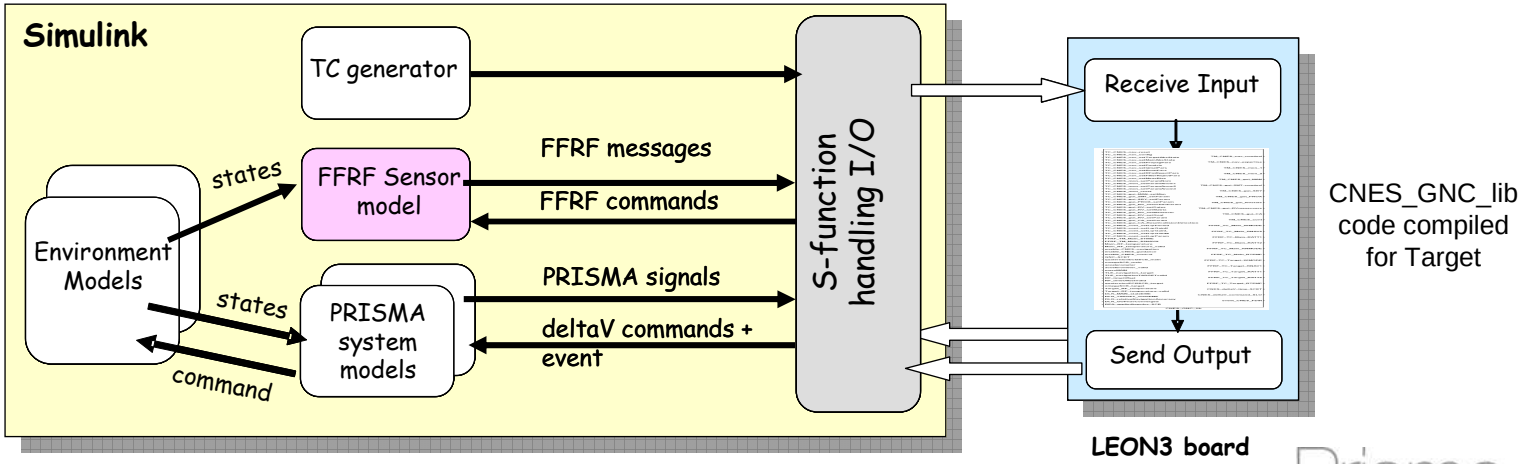
1. validation in Simulink environment
2. validation on the real target (LEON processor)

GNC validation at CNES

Step 1 All Simulink



Step 1 Hybrid simulation

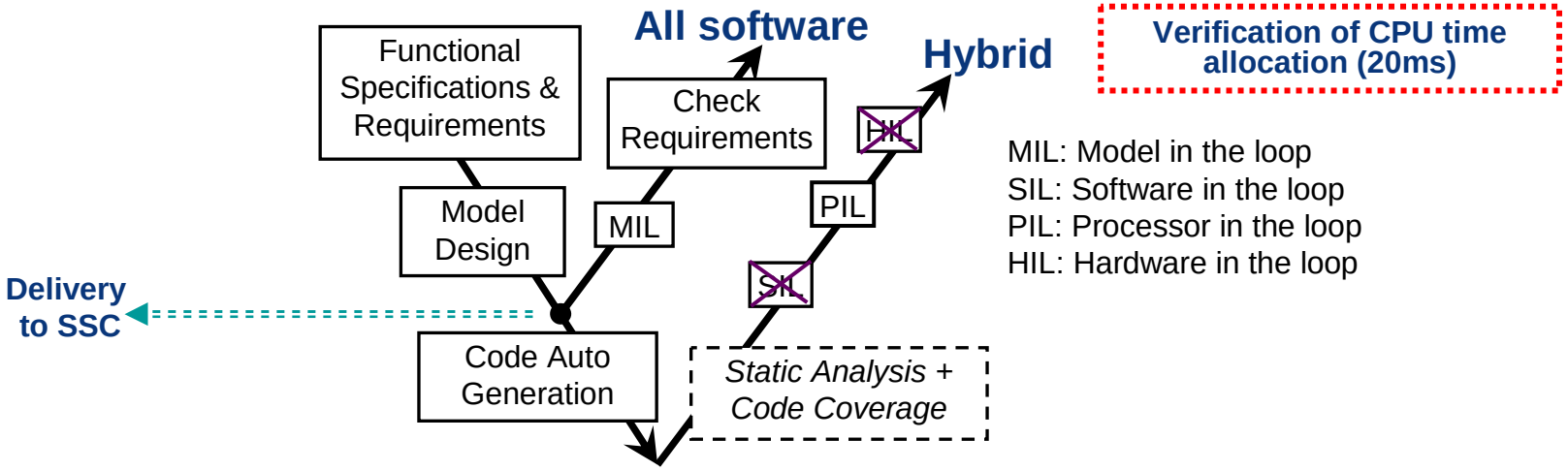


Software requirements

- To be validated (SSC point of view)
  - Library interface (list of I/O ports with dimensions and types)
  - CPU load (20 ms for a CNES_GNC_lib cycle @1Hz)
  - Coding rules (mostly guidelines)
  - Safety: generates no exceptions

- To be validated (CNES point of view)
  - SSC requirements +
  - GNC functional behavior
  - GNC performance behaviour

GNC validation at CNES



GNC validation at SSC

Incremental CNES_GNC_lib validation with SSC testbenches

SFPT-2 **Satellite Test Bench**	**April 2009**	System and Functional Test Bench: ➔ Software validation
System tests **OPSIM**	**October 2009**	System tests campaign: ➔ verification of procedures and end to end validation (all scenario processing to telemetry delivery).
System tests **GNCViewer**	**October 2009**	System tests campaign: ➔ Validation of scenarii
Patch Validation **GNCViewer + OPSIM**	**March 2010**	Flight operations / extended mission ➔ Validation of software patches

- **Satellite Test Bench: AIT with FFRF emulator in the loop**
- **OPSIM: Operational Simulator – real time operational testbench with FFRF emulator**
- **GNCViewer: all Simulink tool including the Prisma GNC software and capable to run operational procedures and mission scenarii (20x real time). Includes a FFRF sensor model.**

GNC validation at SSC

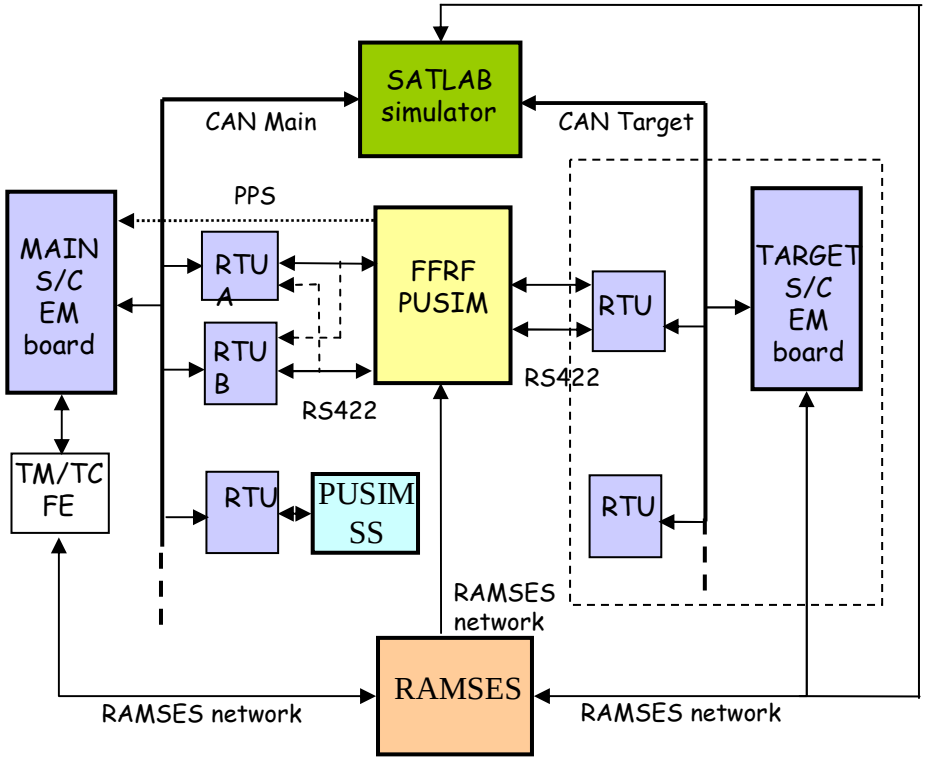
OPSIM testbench

Main Characteristics

- Most of the avionics FM components are integrated in the satellites (emulators replace instruments that cannot be stimulated)
- Complete TM/TC chain
- FFRF PUSIM connected to both S/C

Test objectives

- GNC software validation (closed loop tests)
- Procedure / program validation



All validations were performed without any hardware dynamic simulator !!

GNC validation at SSC

Simplified process for extended mission:

➔ The new software was regarded as a patch

GNCViewer	**September 2011**	Functional and performance validation → cross-check of results on specific mission programs
OPSIM	**September 2011**	Code validation -> including real time allocation, TM processing

Relevant process → No anomaly was detected in flight !

Code generation + pragmatic validation approach

➔ from new GNC design to software upload: 4 months