Dedicated to innovation in aerospace

Connecting MATLAB, EcosimPro and 20-sim to the Simulation Model Portability standard, with a case study on real-time AOCS EGSE.

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Background

National Aerospace Laboratory NLR

- The national knowledge centre for aviation and space technology in the Netherlands
- Research facilities

www.nlr.nl

- **Space Systems Department (ASSP)**
  - Avionics development and qualification
  - Satellite systems and sub-systems
  - Space operations

- **Collaborative Engineering Systems Department (AVCE)**
  - MOSAIC development & distribution
  - EuroSim co-development
  - SMP2 CCB, Model Portability ECSS
  - Application of knowledge in avionics test environments, flight simulators, knowledge based engineering projects

Presentation overview

- **MOSAIC9 project:**
  - Automated model transfer
  - Achievements
  - Approach
  - Validation

- **Case study: Real-time AOCS EGSE**
  - Using MATLAB, MOSAIC9, EuroSim, and SMP2-compliant building blocks
  - OBS development
  - Validation

Automatic model transfer

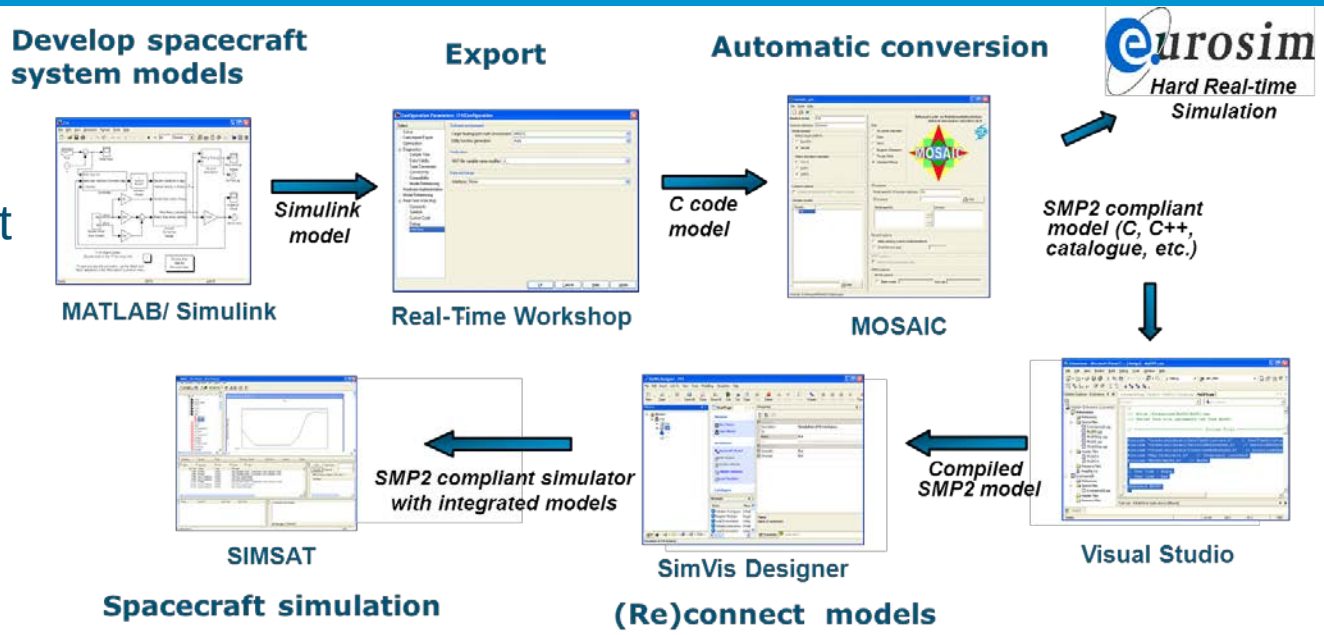
- **Purpose**
  - Re-use of models during a complete project life-cycle to reduce cost, time, effort
- **Approach**
  - Automate model transfer between COTS tools and model standards
- **Product**
  - MOSAIC

Model-Oriented Software Automatic Interface Converter

Modelling tools:
- **MATLAB**
- **EcosimPro**
- **20-sim**
- **Modelica**
- **..**

MOSAIC usage

- **Usage principles**
  - Model adaptation in originating environment
  - MOSAIC treats model as black box
  - Analyses the source code's API and adds interfacing code to it
  - End-to-end support



- **Free-of-charge license in ESA member states**

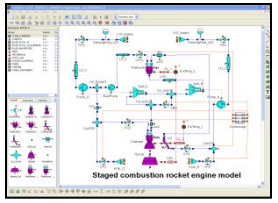
- **Used in European space industry**
  - For more than 10 years
  - In a large number of projects

- **Latest version: MOSAIC 9 (Feb. 2012)**

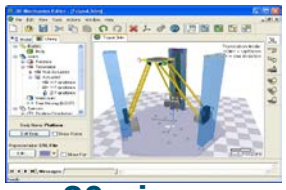
MOSAIC 9 key requirements

- **Enhance tool with support of multiple input formats**
  - MATLAB R2010b (latest version at project start),
  - EcosimPro 4.8 (e.g. simulation of propulsion and power systems)
  - 20-sim 4.1 (e.g. simulation of robot systems or for thermal simulation)
- **Feature usability of tool (+ efficient maintenance of tool)**

Simulink



EcosimPro



20-sim

C code generated by RTW

Exported C++ class

Exported C++ class

MOSAIC

Transfer of Model

Ready-to-use code

SMP2 Standard (SimVis/SIMSAT2, SIMSAT4, Basiles, EuroSim)

Ready-to-use code

eurosim

Hard Real-time Simulation

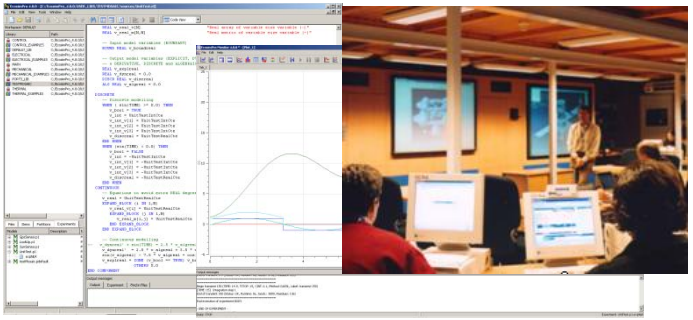
MOSAIC 9: Collaborative project approach (1)

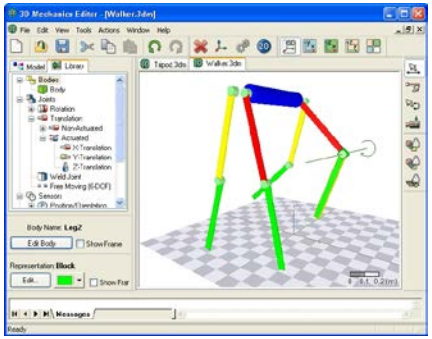
- Feature usability of tool (+ efficient maintenance of tool)
- Involve end-users during MOSAIC 9 development

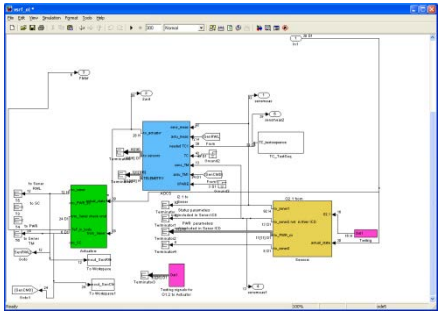
- Involve EcosimPro and 20-sim developers

MOSAIC 9: Collaborative project approach (2)

- **Start with rapid prototyping based on three use cases:**
  - EcosimPro -> SimVis/SIMSAT (CDF)
  - 20-sim -> SIMSAT4 (Robotics Lab)
  - MATLAB -> EuroSim / SMP (VSRF/ATB)







- **Review of prototypes by end-users and EcosimPro / 20-sim developers**

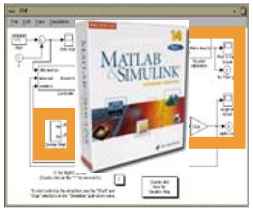
- **Collect and process feedback into MOSAIC 9 integrated version**

MOSAIC 9 results: Transfer combinations

- Modular architecture allows multiple transfer combinations
- Not all combinations are validated yet

MOSAIC 9 results: Transfer combinations (MATLAB input)

- Modular architecture allows multiple transfer combinations
- Not all combinations are validated yet (= validated)



MATLAB R2010b

C code generated by RTW

MOSAIC

Transfer of Model

SMP2 compliant code

SimVis/SIMSAT2

EuroSim

SIMSAT4

Basiles

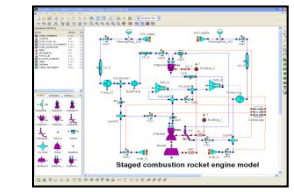
Native format

eurosim

Hard Real-time Simulation

MOSAIC 9 results: Transfer combinations (EcosimPro input)

- Modular architecture allows multiple transfer combinations
- Not all combinations are validated yet (■ = validated, → = not validated, □ = not yet supported)



EcosimPro 4.8

Exported C++ class

MOSAIC

Transfer of Model

SMP2 compliant code

SimVis/SIMSAT2

EuroSim

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eurosim

Hard Real-time Simulation

MOSAIC 9 results: Transfer combinations (20-sim input)

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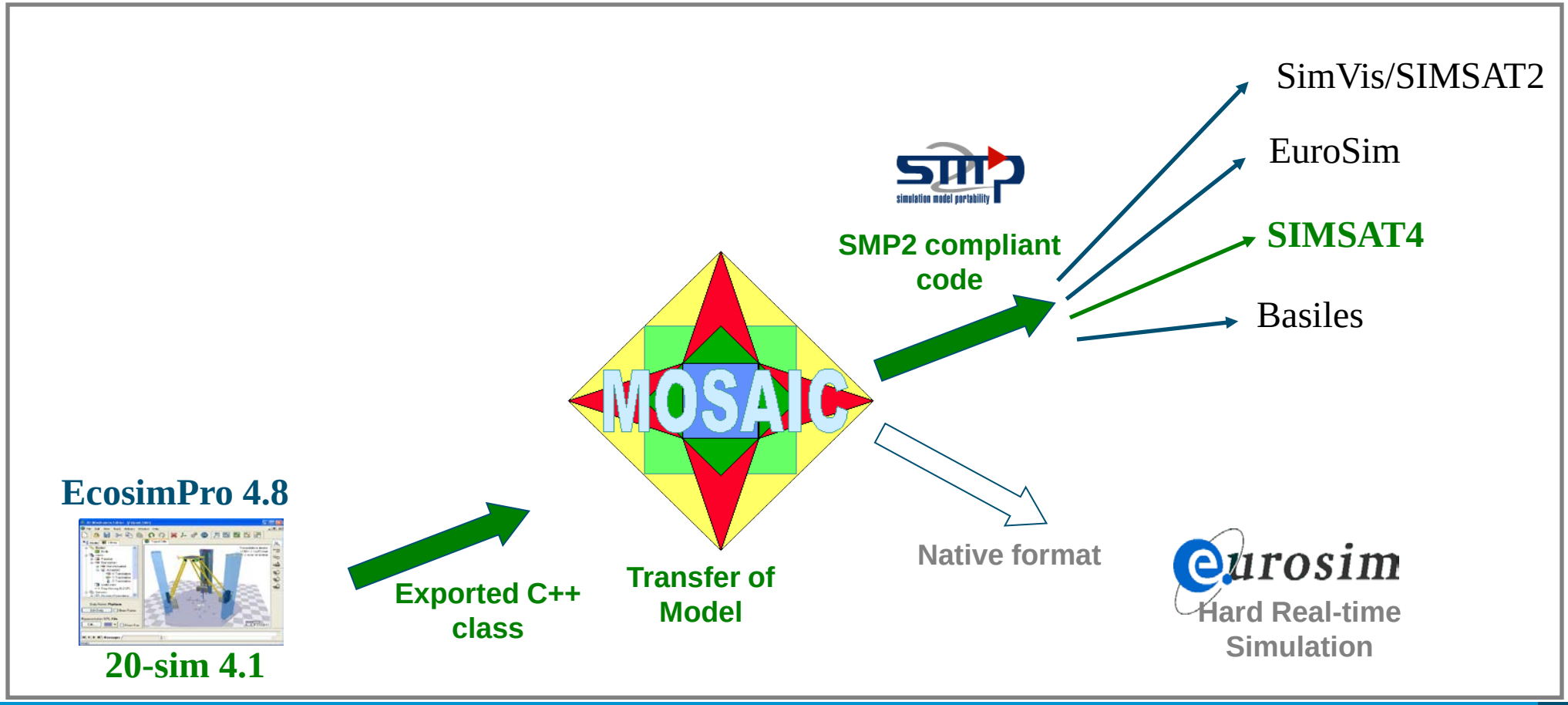
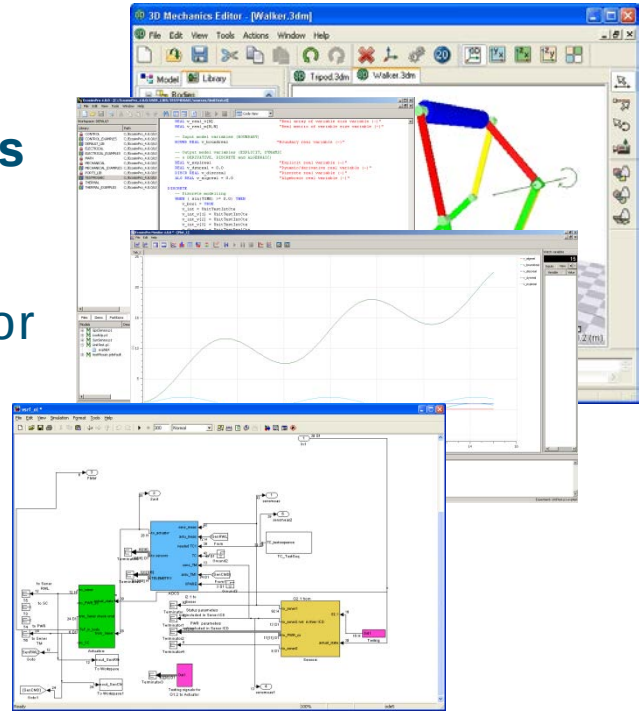


MOSAIC 9 Validation

- **Internal testing at NLR**
- **11 acceptance tests (all passed), based on various use cases:**
  - MATLAB models (VSRF use case)
  - EcosimPro models (VSRF + specific development for SimVis use case)
  - 20-sim models (use case from Robotics Lab)

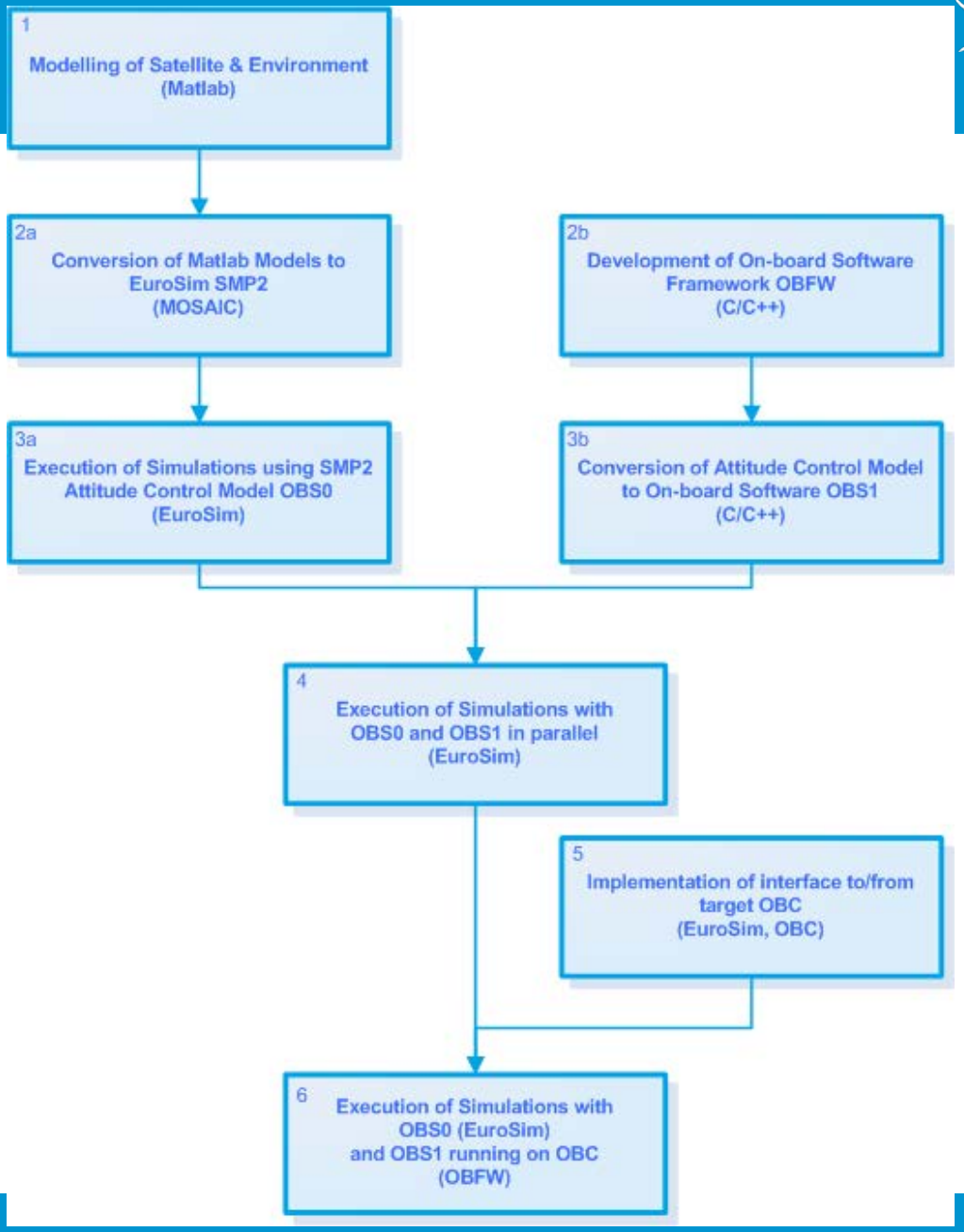
  All acceptance models developed by ESTEC
- **Use of SMP2 Conformance suite, for validation of MOSAIC 9 output SMP2 files**



- **Application in EuroSim 4.4 acceptance and NLR AOCS EGSE case study**
- **User feedback on MOSAIC 9 prototypes (and integrated version)**
  - Processed into MOSAIC 9 software and documentation as much as possible
  - Documented as recommendations for future development

MOSAIC 9 Case Study

- Satellite attitude control development process: from MATLAB simulations to EGSE test bench with hardware-in-the-loop
- Targeting low cost small satellites
- Study impact of SMP2 on process



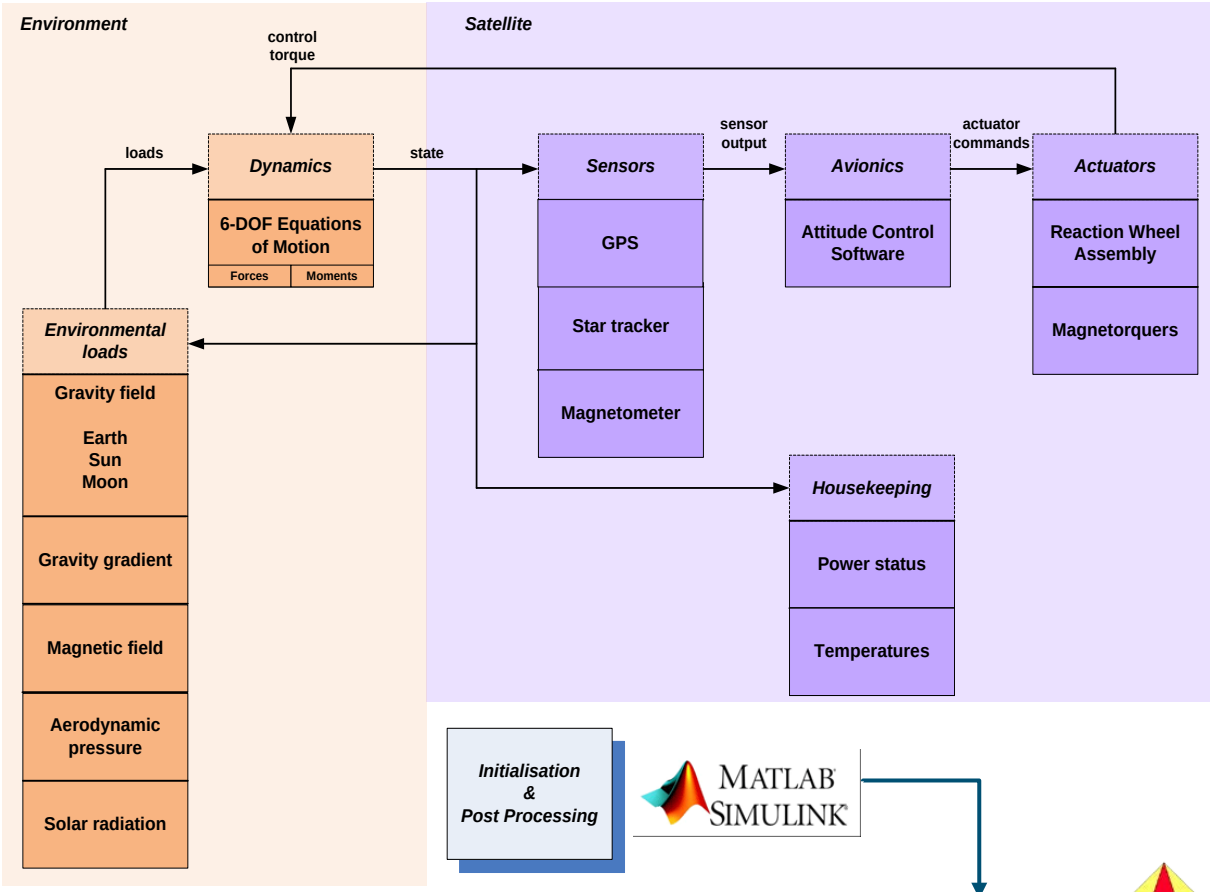
Case Study 1: MATLAB simulator

Environment Model

- GGNCSIM

Satellite Model

- Power subsystem
  - generation
  - storage
  - consumption
- Avionics subsystem
  - sensors
  - actuators
  - attitude control
- Thermal subsystem
  - temperatures
- Payload
- Communication

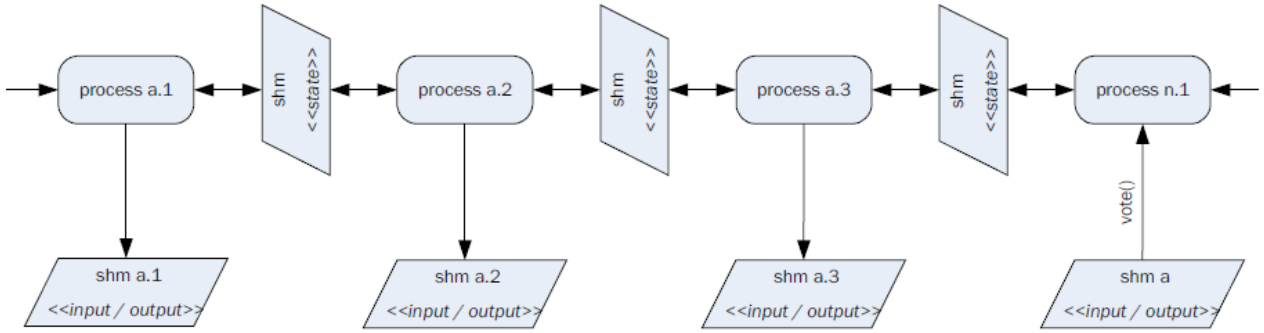


Step 2a: Automatic model transfer to SMP2

Case Study 2b: on-board software framework

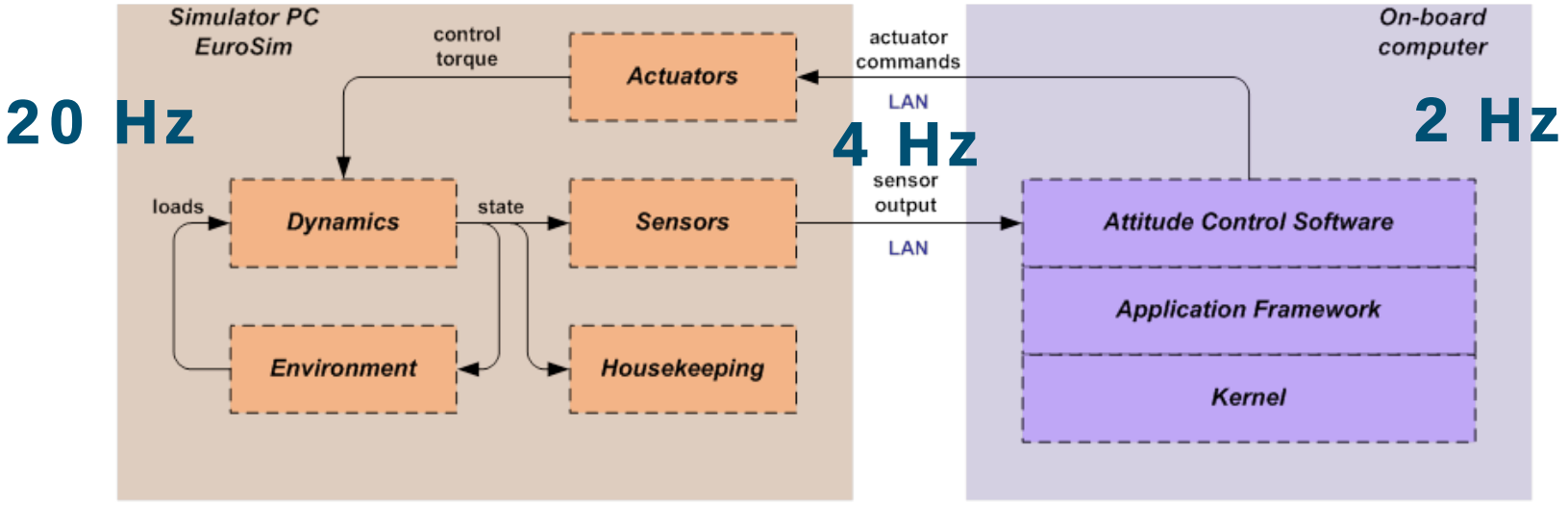
- **Target on-board computer**
  - Cortex-A9 CPU
  - I2C interfaces
  - high data rate interface

- **Software triple modular redundancy (TMR)**
  - keep-alive mechanism to monitor other processes
  - checksum mechanism to check own code integrity
  - redundancy in data (triple data with voting and scrubbing)
  - redundancy in processes (triple processes with voting)

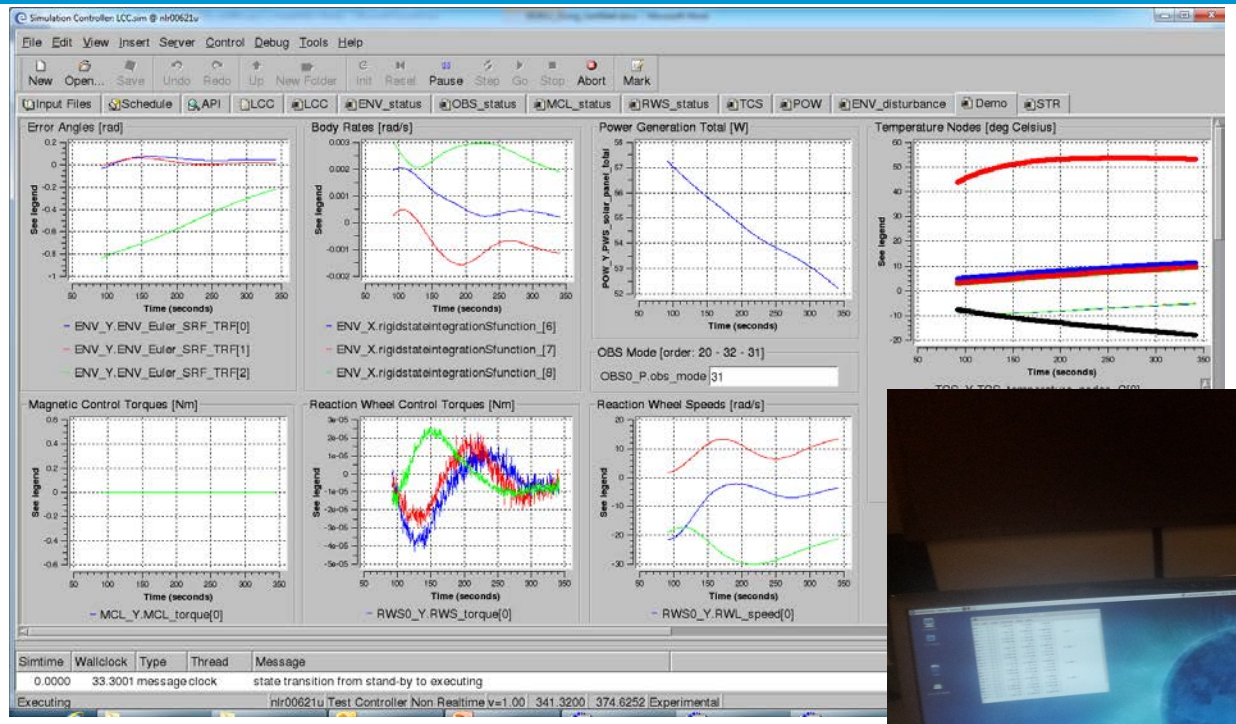


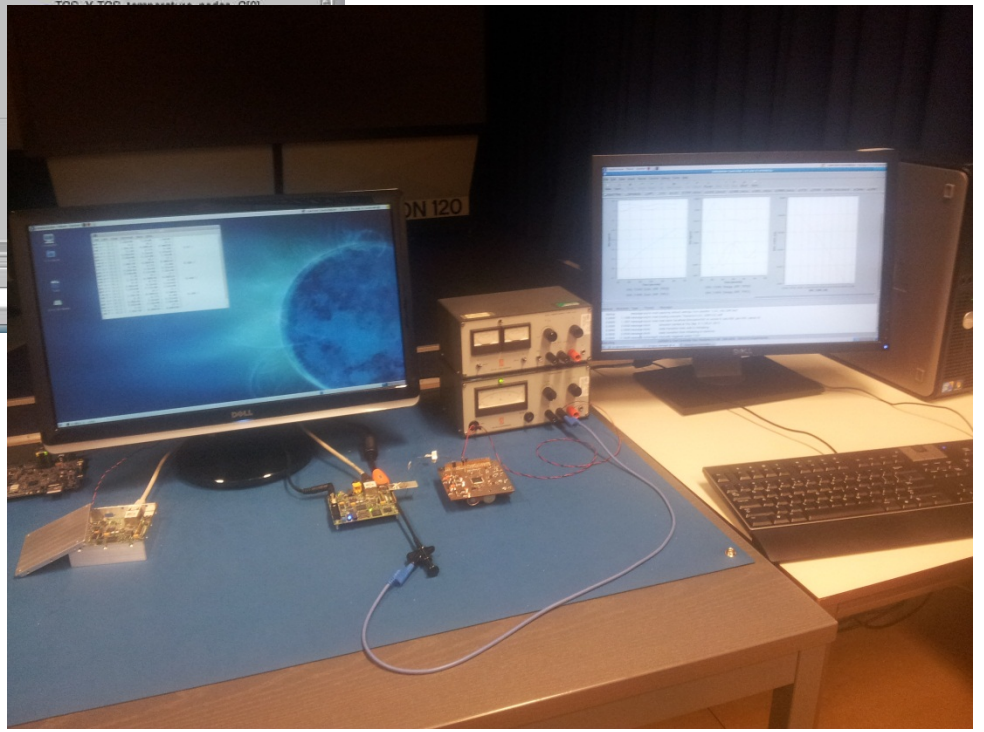
Case Study : test bench

- Conversion of Matlab attitude control software to framework, eg matrix operations for Kalman filter (step 3b)
- Executes on target computer as well as in EuroSim for pre-validation of conversion (step 4)
- Adding LAN interfaces for data exchange (step 5)
- Hardware-in-the-loop with *asynchronous* behavior (step 6)

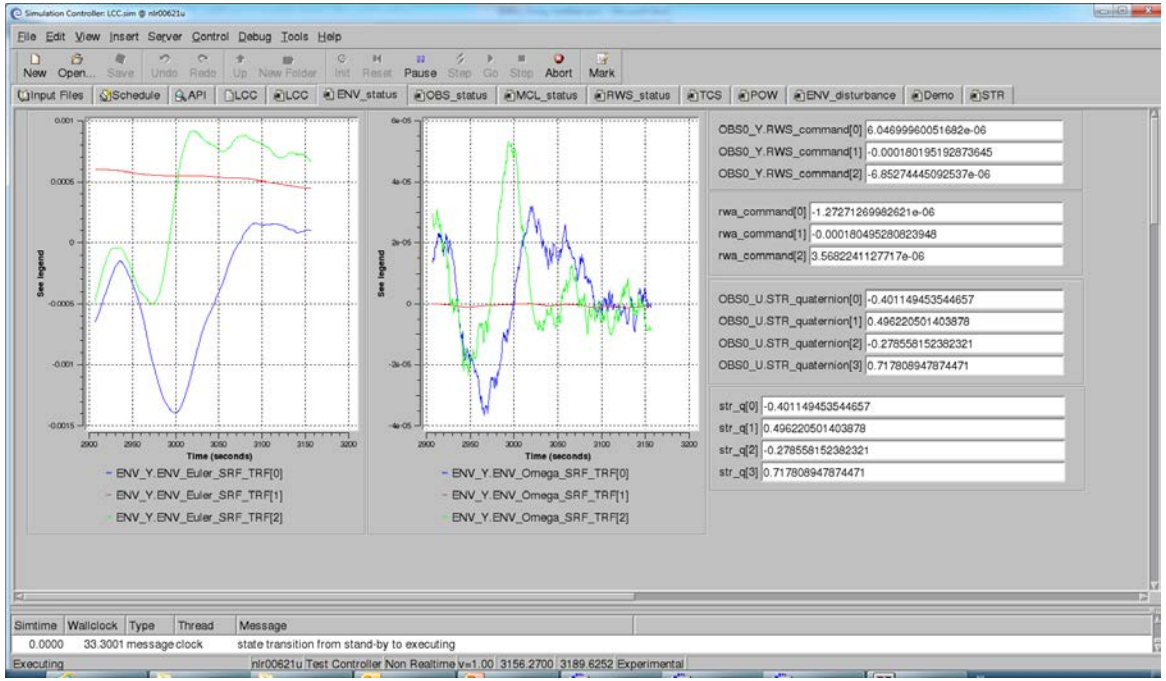


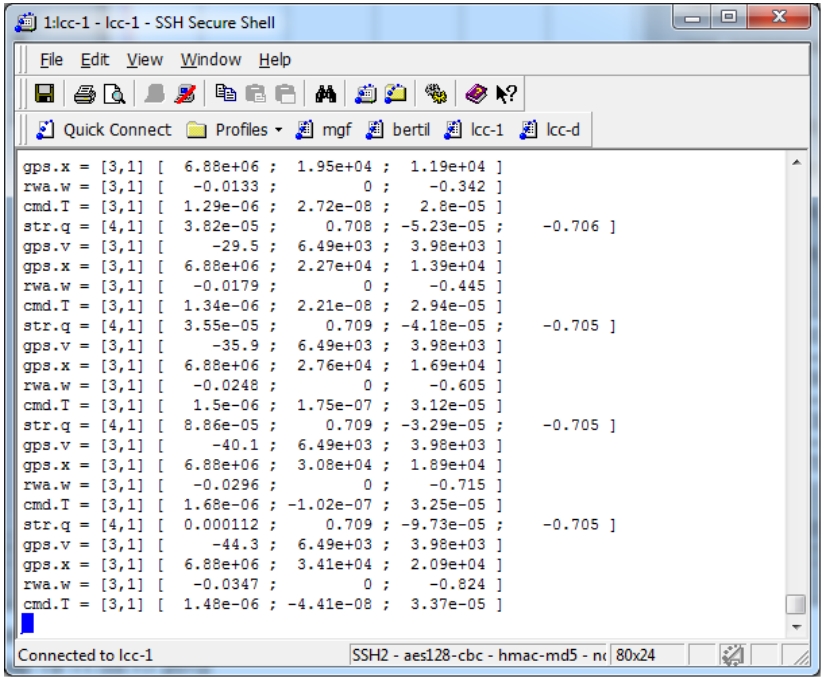
Case study: results (1)





Case study: results (2)





Conclusions

- **MOSAIC AOCS EGSE Case study**
  - Efficient and effective approach of developing attitude control software: small effort, good results
  - Automatically converted SMP2 models used for verification of attitude control software
  - Automatically converted OBS0 SMP2 model used as validation of manually converted OBS1

- **Automated model transfer**
  - Essential in simulation life-cycle
  - Different use cases (new cases supported by MOSAIC9)
  - Success based on continuous interaction between developers and space community (e.g. prototype evaluation)

- **MOSAIC usage**
  - Strategic importance for ESTEC and the space community
  - Free-of-charge in ESA member states (license request: **mosaic@nlr.nl**)

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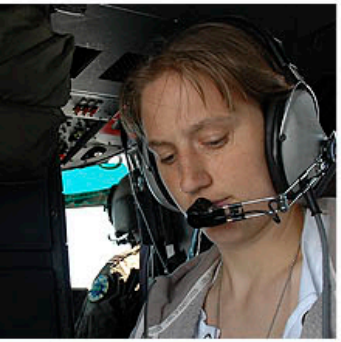



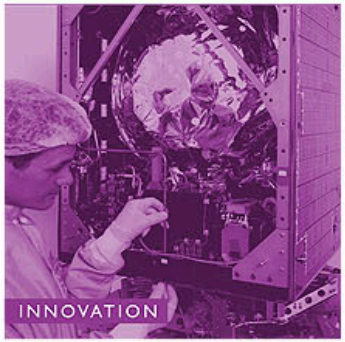


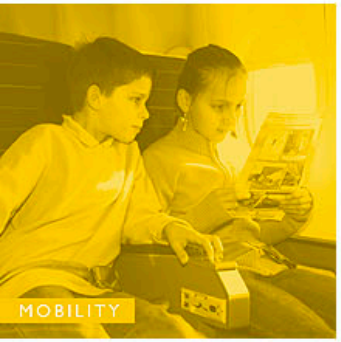

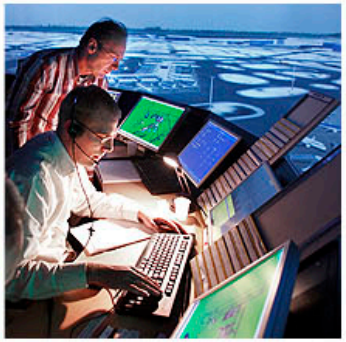


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