Frontload the design, V&V and certification of software-intensive mechatronic systems by adopting the Digital Twin approach

Mathieu Dutré – Business Development & Innovation Manager, MBSE
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What to remember of this presentation?

- Siemens supports engineering teams in delivering **high-quality mechatronic systems** by adopting the “Digital Twin” approach.

- Mathworks supplies us and customers with the necessary tooling to **optimize development time**.

- Due to the tight integration of **Siemens Simcenter** products and **MATLAB/Simulink**, the customer is able to:
  - Optimize the engineering process and workflow
  - Balance multi-attributes like performance, fuel economy and comfort using physical models
  - Significantly reduce the development time and cost by frontloading V&V and calibration
Who am I?

Role:
• Senior Business Owner, MBSE portfolio
  Simulation and Testing solutions Division within Siemens PLM

Location:
SISW NV – Leuven - Belgium

Job content:
• Strategy and product roadmap for the Simcenter portfolio targeting controls and embedded software departments
• Business development & Go-To-Market for Simcenter products and services
• Innovation by defining and managing of funded national or EU Research projects

Career and Education:
• 2009 - Master of Science in Mechatronics (Univeristy of Ghent)
• 2009-2014: Controls engineering for light vehicle and heavy duty applications
• 2014- now: multiple roles within SISW related to controls and software engineering

Contacts:
Mobile: +32472409225
Email: Mathieu.Dutre@siemens.com
Industry challenges

A modern car realizes 100’s of vehicle functions…
…with increased algorithm complexity…
…Programmed in million lines of software code.

Each function needs to be validated and calibrated…
…at reduced development time and cost…
…and needs to be certified before going in production!
Industry challenges
The automotive industry struggles to solve these challenges...

... as the number of recalls increased exponentially...

Automotive News
Auto recall bill grew 26% to $22 billion in 2016, study says

January 30, 2018 @ 6:15 pm
Industry challenges

How can we save his life?
The Digital Twin for software-intensive mechatronic systems Vertical know-how for solutions tailored to individual domain

Why?

- Enable a concurrent mechanical, software and E/E hardware design process
- Replace expensive and time-consuming physical tests with early virtual evaluation and validation
The Digital Twin for software-intensive mechatronic systems

Why are we here?

• Siemens Engineering teams help controls and software engineering departments to develop and validate best-in-class mechatronic systems by learning them how to apply the “Digital Twin” engineering approach

• MathWorks is a key partner for Siemens as it provides us with state of the art tooling applicable in all steps of the V-cycle allowing us to optimize the execution time of our products
Provide multiple tool integrations that allow to optimize the MBSE process

• **Integration with scalable ALM solutions** to manage the entire lifecycle of the E/E and software activities and deliverables from requirement, over implementation, to test case evaluation

• **Report generation** to close the testing loop

• **Integration with model management platform and version control systems** like GIT, SVN,…

**Why is MathWorks instrumental for Siemens?**

**Engineering Process Optimization**

**ALM process integration**

**Version control and model management**
Ensure bidirectional traceability

Linking of models to their corresponding requirement
- Fast and easy to use
- Include screenshot of the model for convenient visual review
- Open linked model from ALM tool to quickly find it in large model structure if it has been added to MATLAB path

Track model development status with identity card
- Visual overview of model status, test results,…
- Close the testing loop by importing results and displaying them in visual overview
Generate various result reports

Close the testing loop by bringing test results back to ALM tool

- Gradually complete the model identity card with information about
  - Model compilation
  - Compliancy to guidelines
  - Complexity metrics
  - Test results
  - Test coverage

- Inspect failed tests after execution in Simulation Data Inspector

- Simulink Verification and Validation (R2016b)
- Simulink Report Generator
- Simulation Data Inspector
- Polarion ALM
Design AUTOSAR-compliant software

- Top-Down approach: **Import ARXML files** containing the empty architecture shells designed in the authoring tool and enrich them with a Simulink implementation.

- Bottom-Up approach: **Configure** AUTOSAR software components from existing Simulink implementations and **export** them to the **AUTOSAR authoring tool**.

- **Frontload** the simulation with **BSW Services** (such as a NVRAM manager etc).

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**Why is MathWorks instrumental for Siemens?**

AUTOSAR Architecture

**ARXML Import**

1. Import ARXML files
2. Create Simulink Model
3. Import SW Data Objects
4. Export SWEC

**Export to authoring tool**

1. Create SW Architecture
2. Validate
3. Design Internal Behavior
4. Generate Code
5. Validate Model
Support for multiple AUTOSAR integration workflows

- AUTOSAR Support package from Embedded Coder available for download (since R2014b)
- Import AUTOSAR Composition from arxml File to Simulink is a huge improvement (since R2017b)
- Enhanced frontloading through capability of simulating AUTOSAR Basic Software Services and Run Time Environment (since 2017b)
- Support for multiple third party AUTOSAR authoring tools like Mentor Graphics Volcano Vehicle System Architect (MathWorks connection partner)
Design high-quality controls in the least possible time

- Increase readability for every team member and accelerate development by support for many different modeling patterns
- Refine your models with the integration of a design optimization tool
- Support to ensure compliancy with industry standards like ISO 26262, DO178B and MISRA-C
Controls Design
Modeling Patterns and Model Checking

Ensure consistency and compliance throughout all models

Support for different modeling patterns
- Busses
- Data Dictionaries
- Model Reference blocks
- Configuration Sets
- ...

Perform model checks for discovering design errors and for compliance to many different standards

- Simulink Verification and Validation (R2016b)
- Simulink Report Generator
Fine-tune your control models by integration with optimization tool

- Integrate with a design optimization tool to make the models meet preset objectives
- Run a set of simulations to find the optimal solution
- Directly import optimal solution in the design
Efficiently convert your model to standard-compliant c-code

- Integrated code generator supplying the means to develop fast software code
- Optimize code generation by large set of configuration possibilities
- Keep original model as single source of truth through traceability matrix from model to code
- Reuse legacy code throughout different projects
- Support to ensure compliancy with industry standards like ISO 26262, DO178B and MISRA-C
Software Development
Code Import and Generation

Convert hybrid model to deployable code

- Modify configuration to your specific needs
- Trace code to original model and vice versa

-embedded Coder
- Simcenter Embedded Software Designer

• Embed “Hybrid” model
• -sfun-

Legacy code

Seamless integration of your legacy code into new production project
Reduce costs with virtual V&V and calibration

• Verify and validate control systems early against desired functional requirements without having to wait for the availability of ECU hardware using virtual desktop and real-time capable plant models in MiL, SiL, HiL and Driver-in-the-Loop testing integration scenarios

• Get guidance and engineering support in the roll out of automated frameworks for V&V and early calibration
Generation of test harnesses
- Consistent layout of test harnesses
- Easy handling of test case inputs

Record coverage results
- Assess completeness of test cases
- Automatically generate additional test cases for missing coverage

Set up test framework to automate repetitive jobs

Test cases in Signal Builder
- Model-under-test in Reference Block
- Handle signal properties for successful simulation

Framework for V&V and Certification
Integrated test framework

- Simulink Test
- Simulink Verification and Validation (R2016b)
- Simulink Design Verifier
Framework for V&V and Certification
Integration with plant models and FMI Support

Frontload validation with off-the-shelf verified plant models

- Virtually analyze complex system behavior and support the design of controlled systems from early specification to subsystem and full vehicle testing replacing expensive and time-consuming physical tests
- Run co-simulation scenarios due to the integration of generic co-simulation capability and the functional mock-up interface (FMI) into the product portfolio
- Virtually test autonomous systems behavior through real-life environment modeling capabilities

- Simulink
- Simcenter Amesim
- TASS Prescan
Conclusion: The Digital Twin approach
Support in development and testing for control and software systems

More effort spent upstream to reduce later re-work

Requirements and Change Requests

Style Guides, Block sets and Style Checkers

Open-Loop & Closed-Loop Testing Automated Testing

Different levels of plant models to test different control features

HCU Requirements and Change Requests

Requirements Analysis

Architecture Partitioning

Test Cases

Algorithm Development

MiL

Model based testing

HiL

System integration

SiL

Coverage based Test Quality enhancements

Code generation

System testing

Repeat Open-Loop & Closed-Loop Testing Automated Testing

C-Code

HCU System integration bench testing Integration with legacy C-code for application build

Plant Model

Break-out Box ECU [or virtual]
Customer Case
Controller development support for a Dual Clutch Transmission

Legacy code migration and knowledge transfer on model based controls development and testing to improve the code quality for an automotive OEM

1. Translated Control Logic Software to Stateflow models in a short time. Guaranteed equivalence between legacy C-code and Stateflow Models.
2. Setup open-loop and closed-loop test harness to test Control Logic Model and Feature Software.
3. Developed Test Cases to evaluate new design changes.
4. Applied Coverage Metric to improve testing quality
Customer Case
Scalable system simulation platform for new engine controller design

OEM applies the digital twin concept to optimize engine controller design

- The closed-loop test results are used to improve engine control design as replacement for test rigs
- Platform can be used to do impact studies on control feature allocations between different embedded processors on the vehicle
- Predefined plant models can be setup for V&V at different stages of design

- Developed baseline engine control features in MATLAB/Simulink and tested them in closed-loop
- Developed multiple resolution engine, drivetrain and vehicle models in Simcenter Amesim for testing engine control strategy in MiL and SiL
- Implemented models of the CAN communication layer using SimEvents and modeled the interface between engine and transmission controller
- Studied the robustness of the control strategy to physical system disturbances and communication delays using various performance scenarios in closed-loop

Figure 1: Vehicle speed in m/s

Figure 2: Engine speed in rpm
Conclusion: We’re in love

MathWorks is a strategic partner for Siemens in adopting the Digital Twin approach at their customer base as it allows us and our customers to:

- Optimize the engineering process and workflow
- Develop AUTOSAR-compliant software architectures
- Design high-quality smart controls, embedded software and E/E networks in the least possible time
- Balance multi-attributes like performance, fuel economy and comfort using physical models
- Significantly reduce the development time and cost by frontloading V&V and calibration