



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

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Mathworks EXPO – Ghent – June 21th

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

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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:

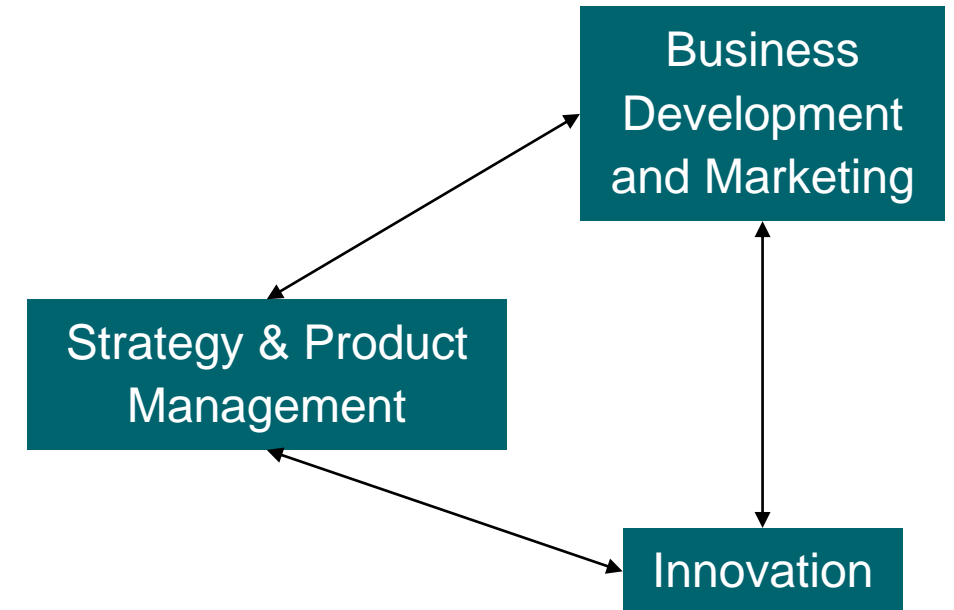
- 2009 - Master of Science in Mechatronics (Univeristy of Ghent)
- 2009-2014: Controls engineering for light vehicle and heavy duty applications
- 2014- now: multiple roles within SISW related to controls and software engineering

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Industry challenges

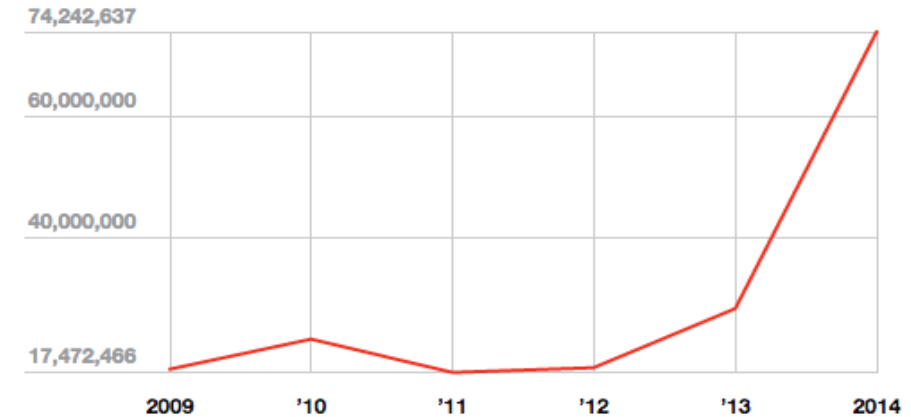
The automotive industry struggles to solve these challenges...



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

Vehicle recalls in the U.S.A.

The National Highway Traffic Safety Administration marked a record year in 2014, with the highest number of vehicle recalls due to NHTSA investigations and enforcement efforts in more than three decades.



... and the cost increased accordingly

Automotive News

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

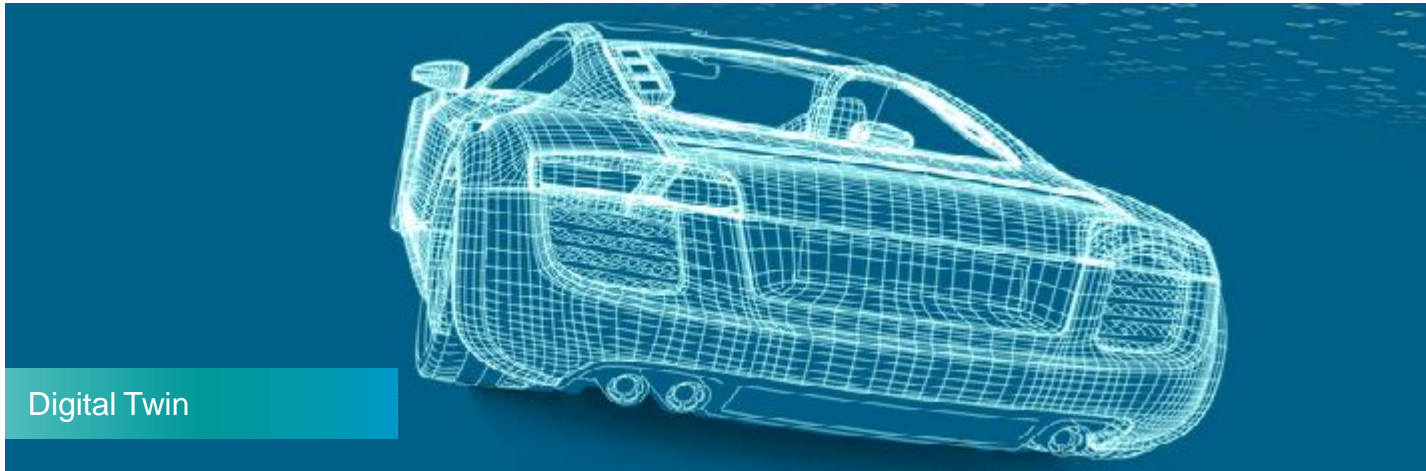
January 30, 2018 @ 6:15 pm

Industry challenges



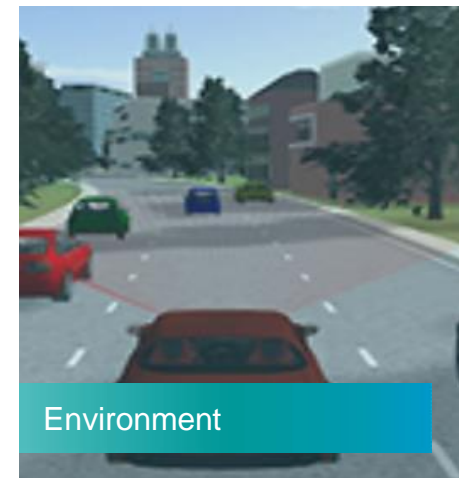
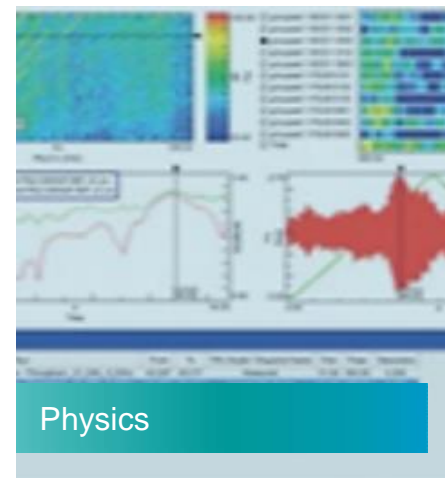
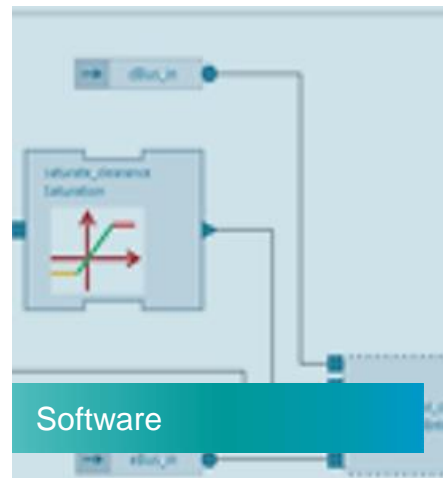
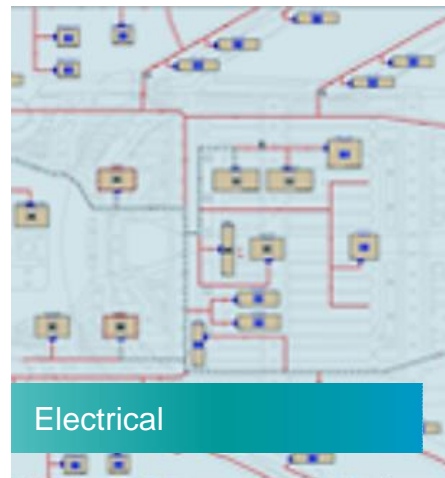
How can we save his life?

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

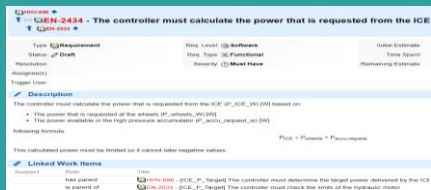
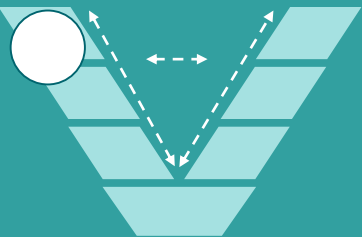
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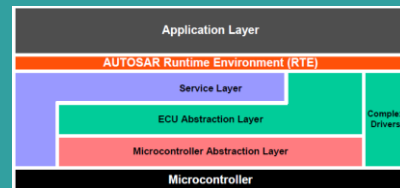
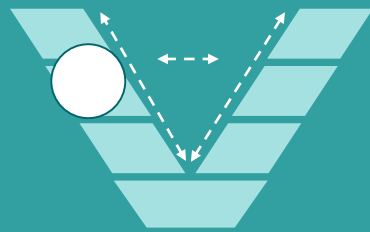
Why are we here?

- 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

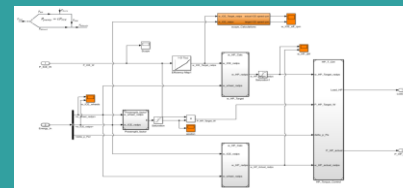
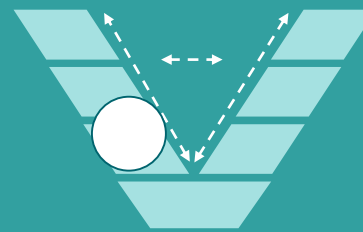
Engineering Process Optimization



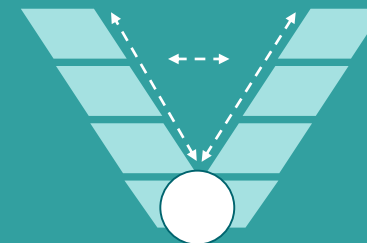
AUTOSAR Architecture



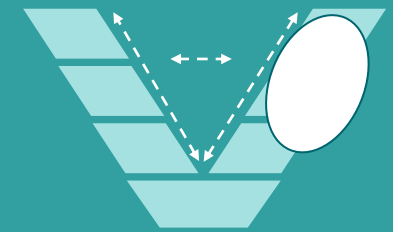
Controls Design

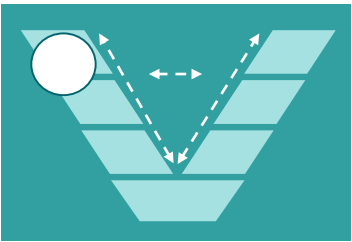


Software Development



Framework for V&V and Certification





Why is MathWorks instrumental for Siemens? Engineering Process Optimization



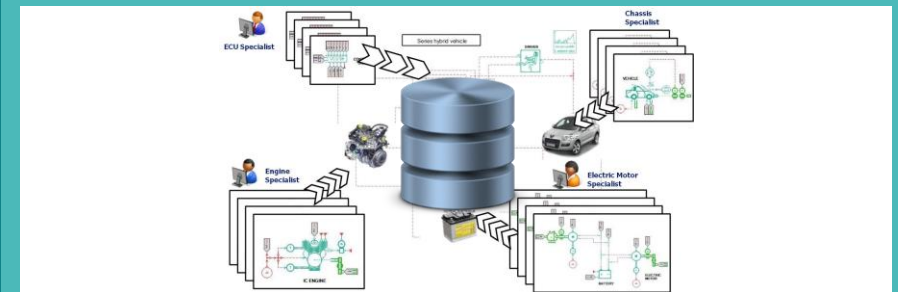
Provide multiple tool integrations that allow to optimize the MBSE process

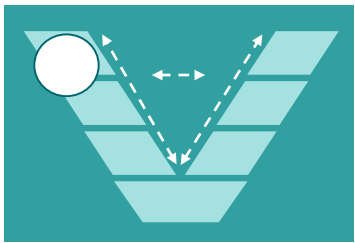
- Integration with scalable ALM solutions to manage the entire lifecycle of the E/E and software activities and deliverables from requirement, over implementation, to test case evaluation
- Report generation to close the testing loop
- Integration with model management platform and version control systems like GIT, SVN,...

ALM process integration



Version control and model management





Engineering Process Optimization

Simulink integration with ALM



Ensure bidirectional traceability

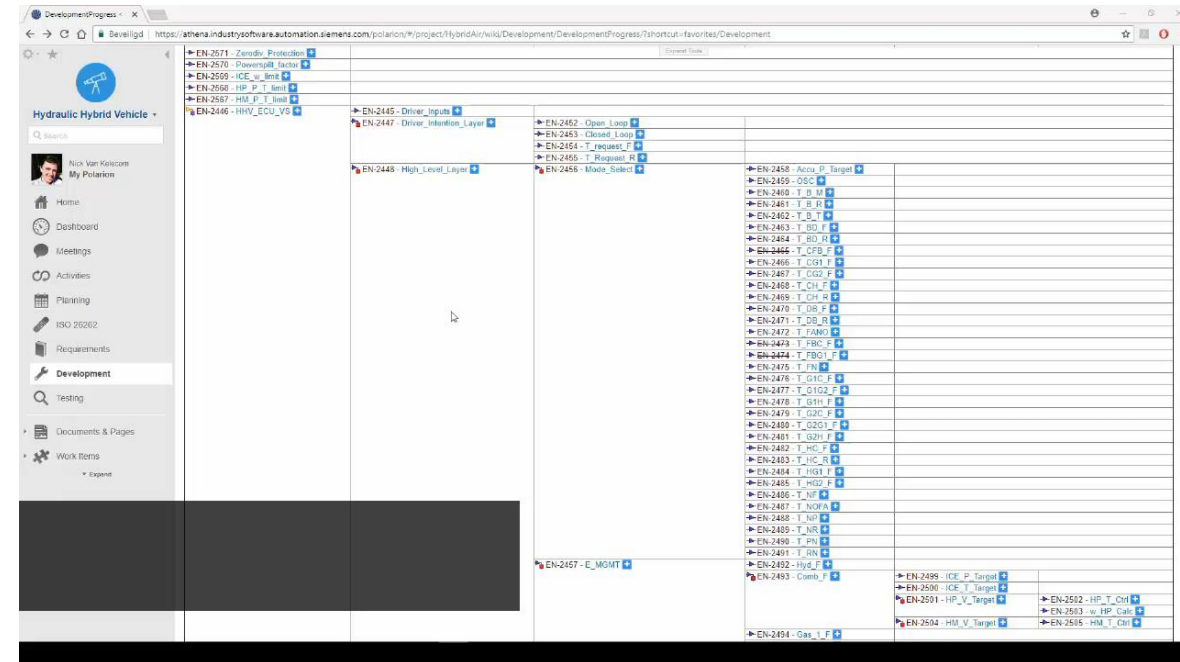
Linking of models to their corresponding requirement

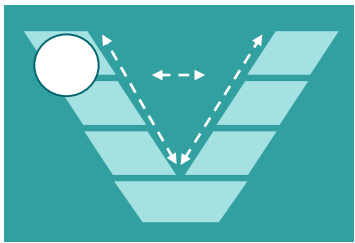
- Fast and easy to use
- Include screenshot of the model for convenient visual review
- Open linked model from ALM tool to quickly find it in large model structure if it has been added to MATLAB path

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

- **Simulink Verification and Validation (R2016b)**
- **Polarion ALM**





Engineering Process Optimization

Result reports closing the loop



Generate various result reports

- Simulink Verification and Validation (R2016b)
- Simulink Report Generator
- Simulation Data Inspector
- Polarion ALM

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

EN-2456 +
 EN-2479 - T_G2C_F

Model Properties

Type: Atomic Model
 *Status: Under Development
 Author: Sam Silverans (Admin)

*SLX Model: T_G2C_F.slx
 Requirements Document: Requirements / T_G2C_F
 Testing Document: Testing / T_G2C_F Test Cases

Research Project: Enpower
 Resolution:

Linked Work Items

Suspect	Role	Title
	has parent	EN-2456 - Mode_Select

Traceability

Project
t

General

Compile Check: **SUCCESS**

Compile Error Message:

Model Block Count: **12**

Cyclomatic Complexity: **2**

Model Analysis results

linkedreq: **HHV-642**

General Passed: **63**

General Warning: **9**

General Failed: **0**

ISO 26262 Passed: **9**

ISO 26262 Warning: **0**

ISO 26262 Failed: **0**

Code Coverage results

MDCD Coverage (%): **100**

Decision Coverage (%): **100**

Condition Coverage (%): **100**

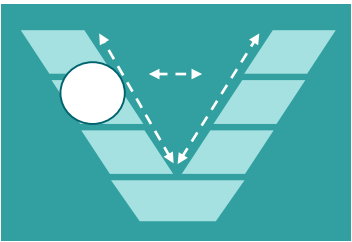
Execution Coverage (%): **100**

Performance tests

Functionality Error Pass: **1 2 3**

Functionality Error Fail:

Test Results



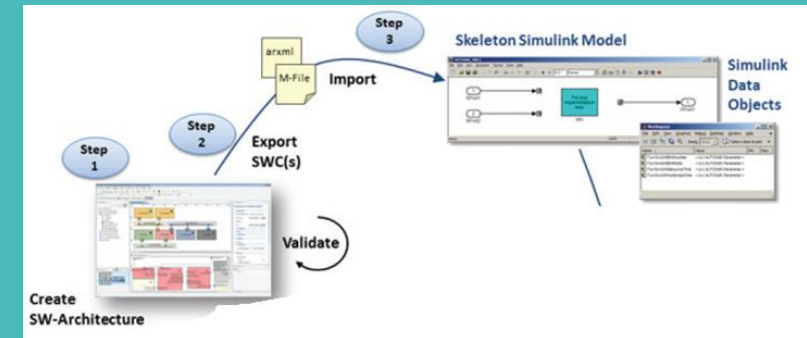
Why is MathWorks instrumental for Siemens? AUTOSAR Architecture



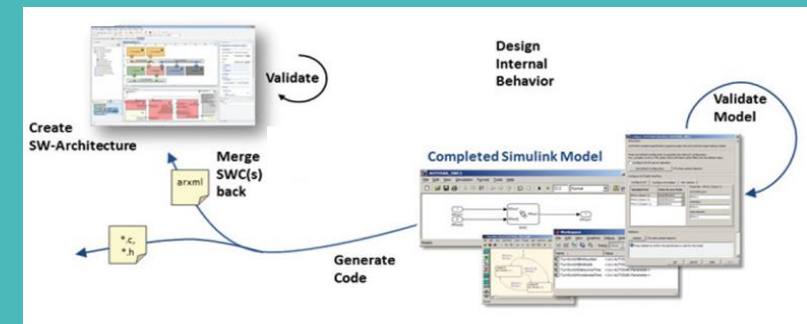
Design AUTOSAR-compliant software

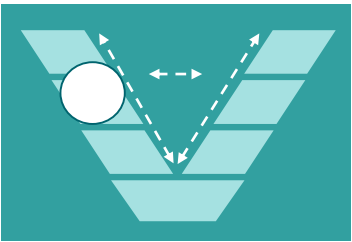
- Top-Down approach: **Import ARXML files** containing the empty architecture shells designed in the authoring tool and enrich them with a Simulink implementation
- Bottom-Up approach: **Configure** AUTOSAR software components from existing Simulink implementations and **export** them to the **AUTOSAR authoring tool**
- **Frontload** the simulation with **BSW Services** (such as a NVRAM manager etc)

ARXML Import



Export to authoring tool





AUTOSAR Architecture

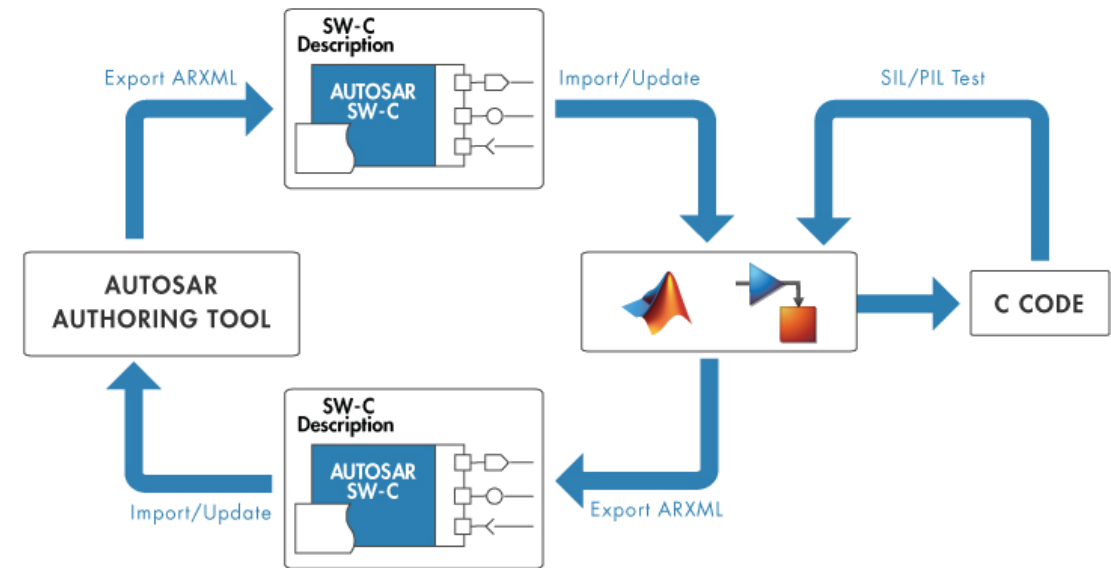
AUTOSAR support

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)



- **Embedded Coder**
- **Embedded Coder Support Package for AUTOSAR Standard**





Why is MathWorks instrumental for Siemens? Controls Design

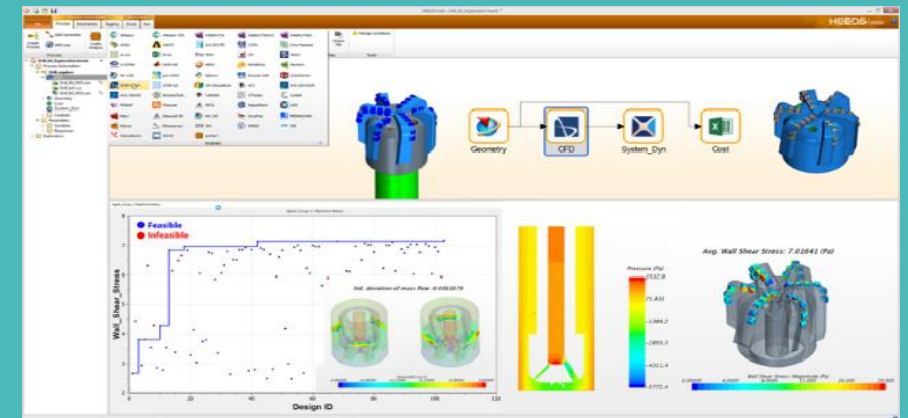
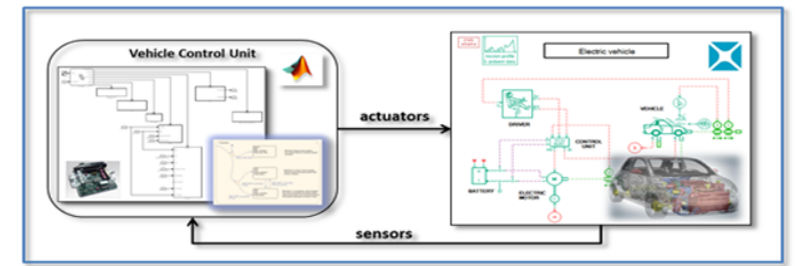
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Design high-quality controls in the least possible time

- 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

Vehicle Control Unit

Baseline Vehicle Controller Application for Electric Vehicles

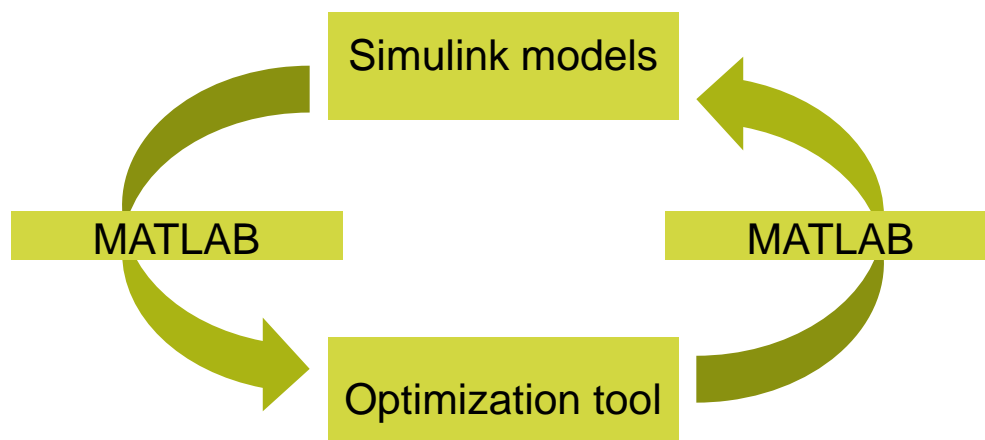




Controls Design Design Optimization

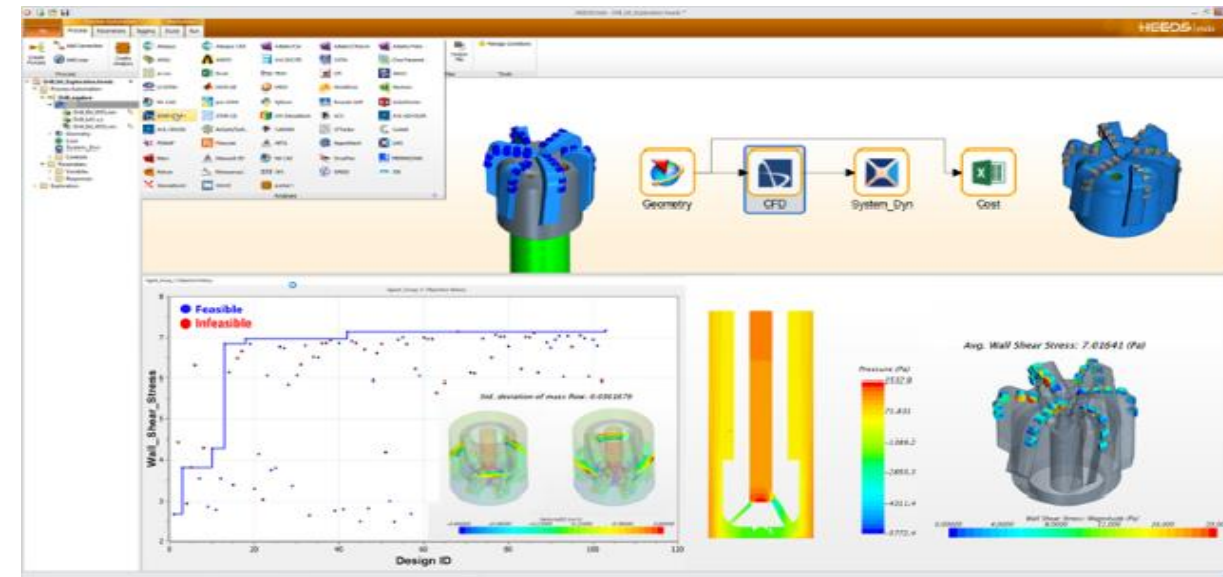
Fine-tune your control models by integration with optimization tool

- 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



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- **MATLAB**
- **Simcenter HEEDS**



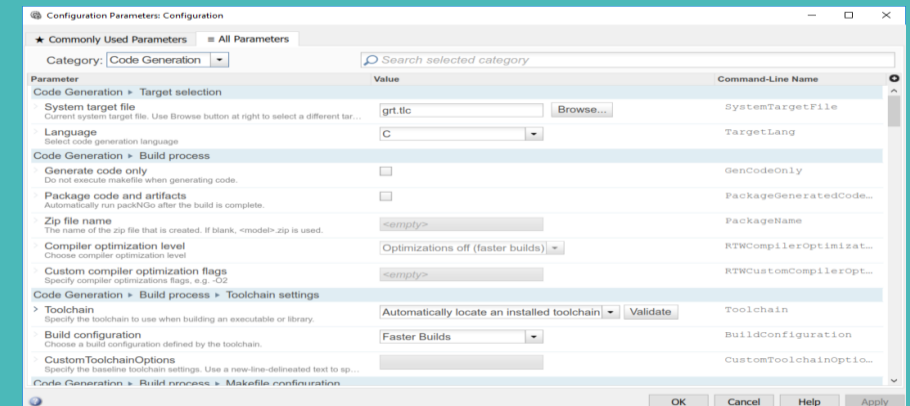
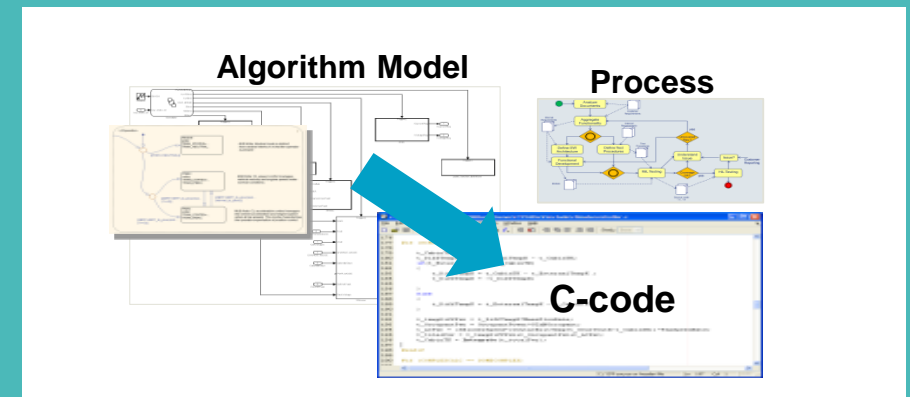


Why is MathWorks instrumental for Siemens? Software Development

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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





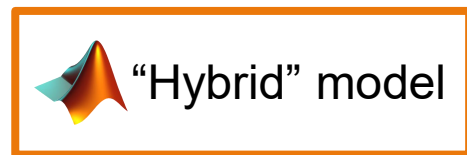
Software Development

Code Import and Generation



Convert hybrid model to
deployable code

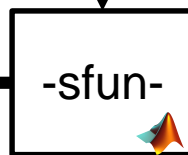
- Embedded Coder
- Simcenter Embedded Software Designer



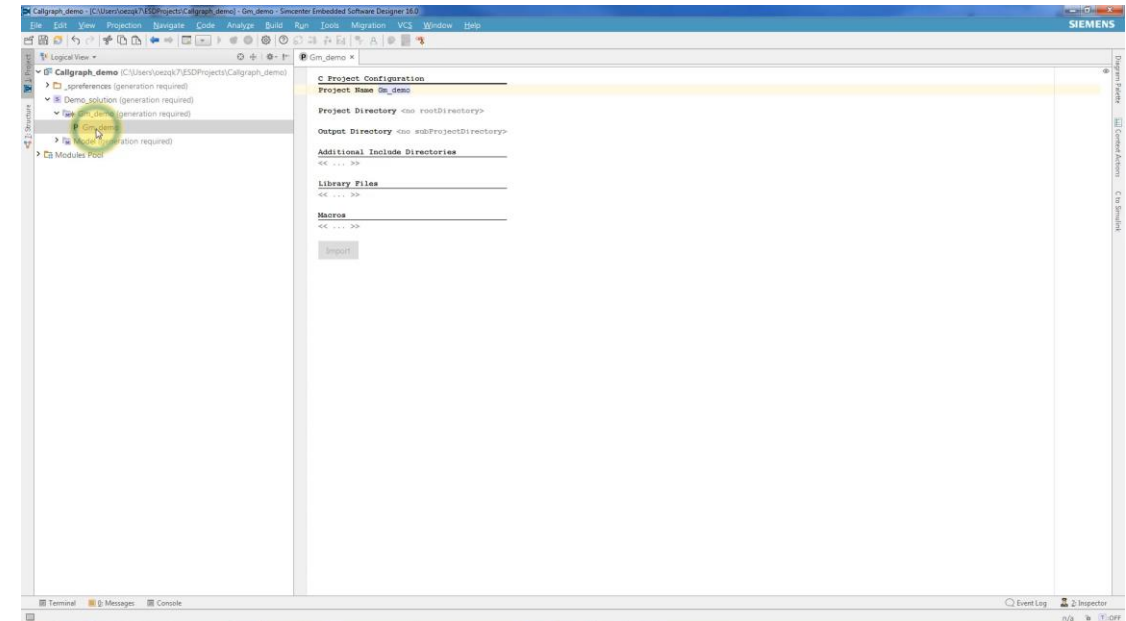
"Hybrid" model

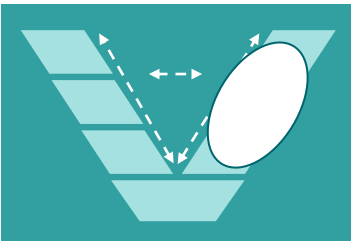
- Modify configuration to your specific needs
- Trace code to original model and vice versa

Legacy code



Seamless integration
of your legacy code
into new production
project





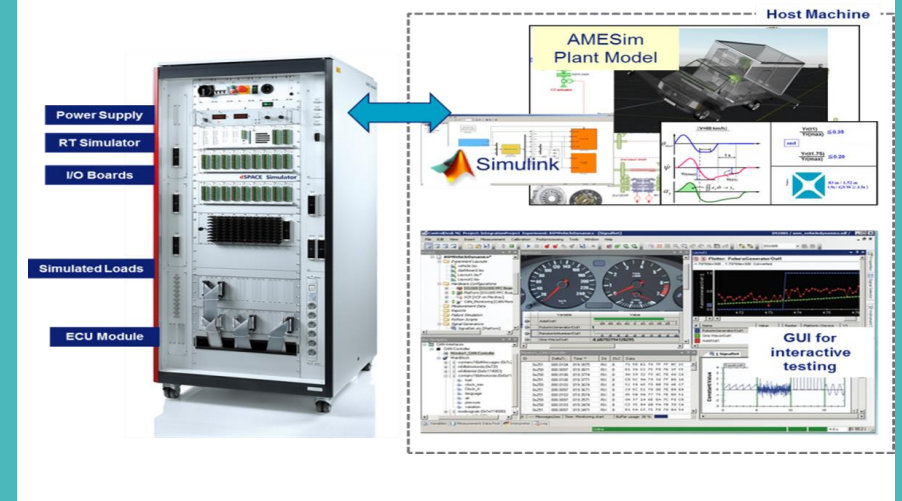
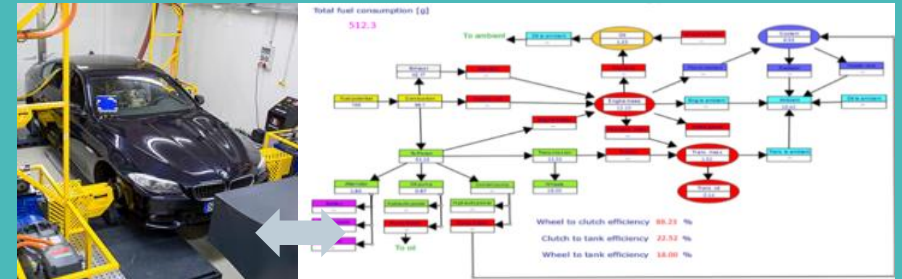
Why is MathWorks instrumental for Siemens?

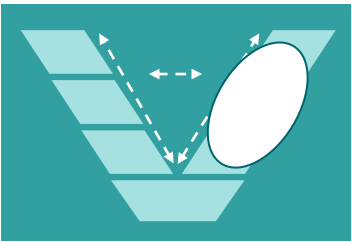
Framework for V&V and Certification



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





Framework for V&V and Certification

Integrated test framework

Set up test framework to automate repetitive jobs

Generation of test harnesses

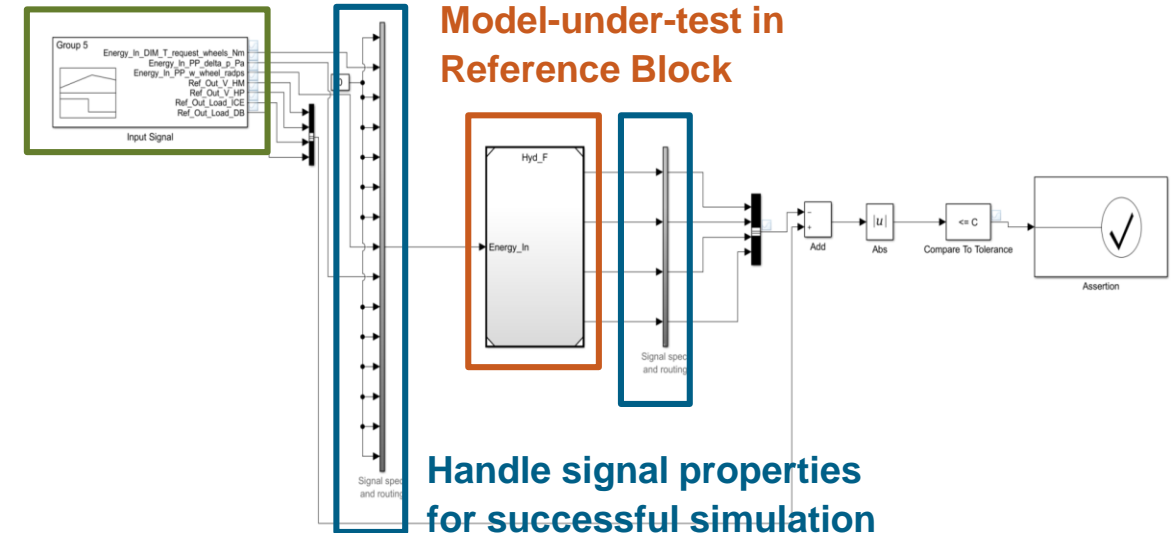
- Consistent layout of test harnesses
- Easy handling of test case inputs

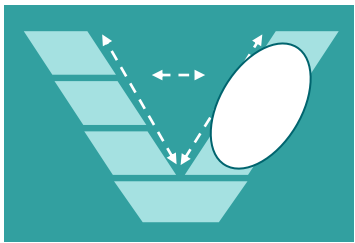
Record coverage results

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

- **Simulink Test**
- **Simulink Verification and Validation (R2016b)**
- **Simulink Design Verifier**

Test cases in Signal Builder





Framework for V&V and Certification

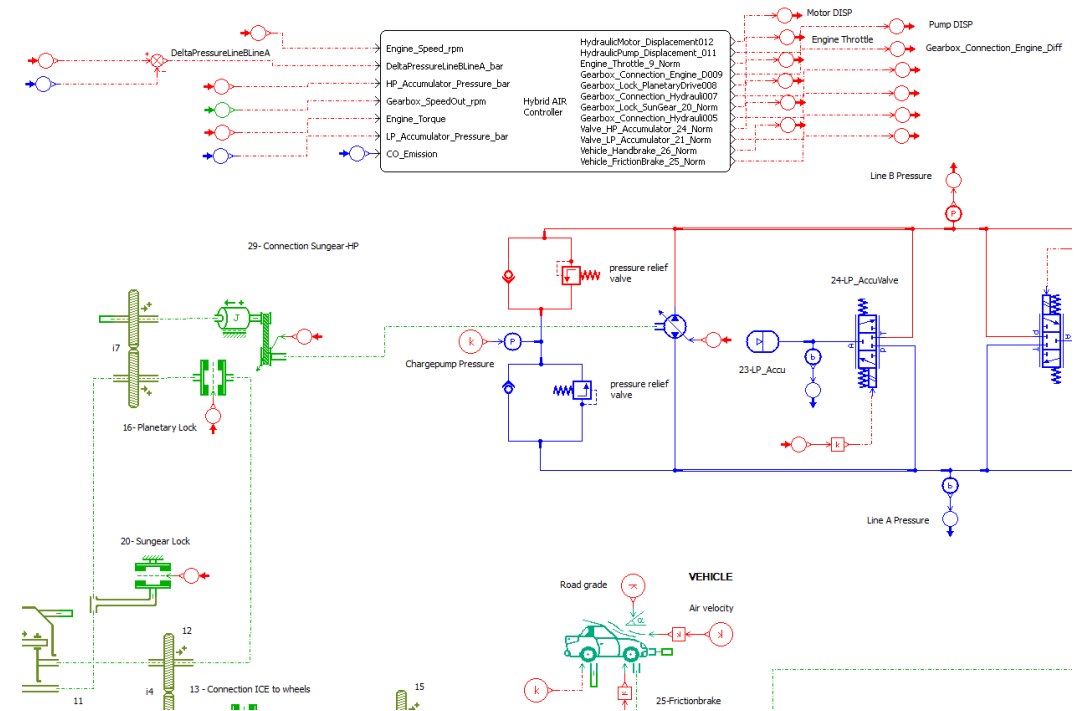
Integration with plant models and FMI Support



Frontload validation with off-the-shelf verified plant models

- **Simulink**
- **Simcenter Amesim**
- **TASS Prescan**

- 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



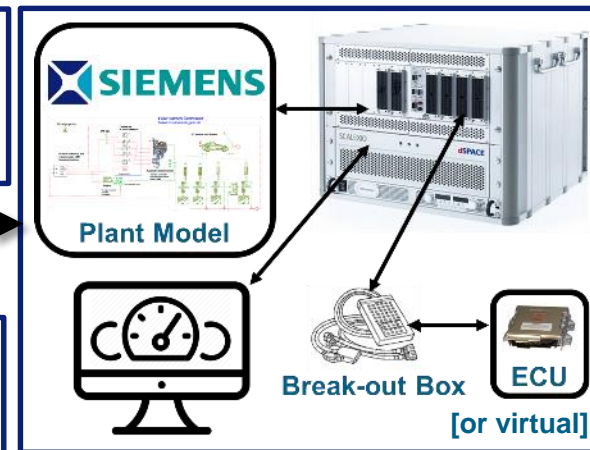
Conclusion: The Digital Twin approach

Support in development and testing for control and software systems

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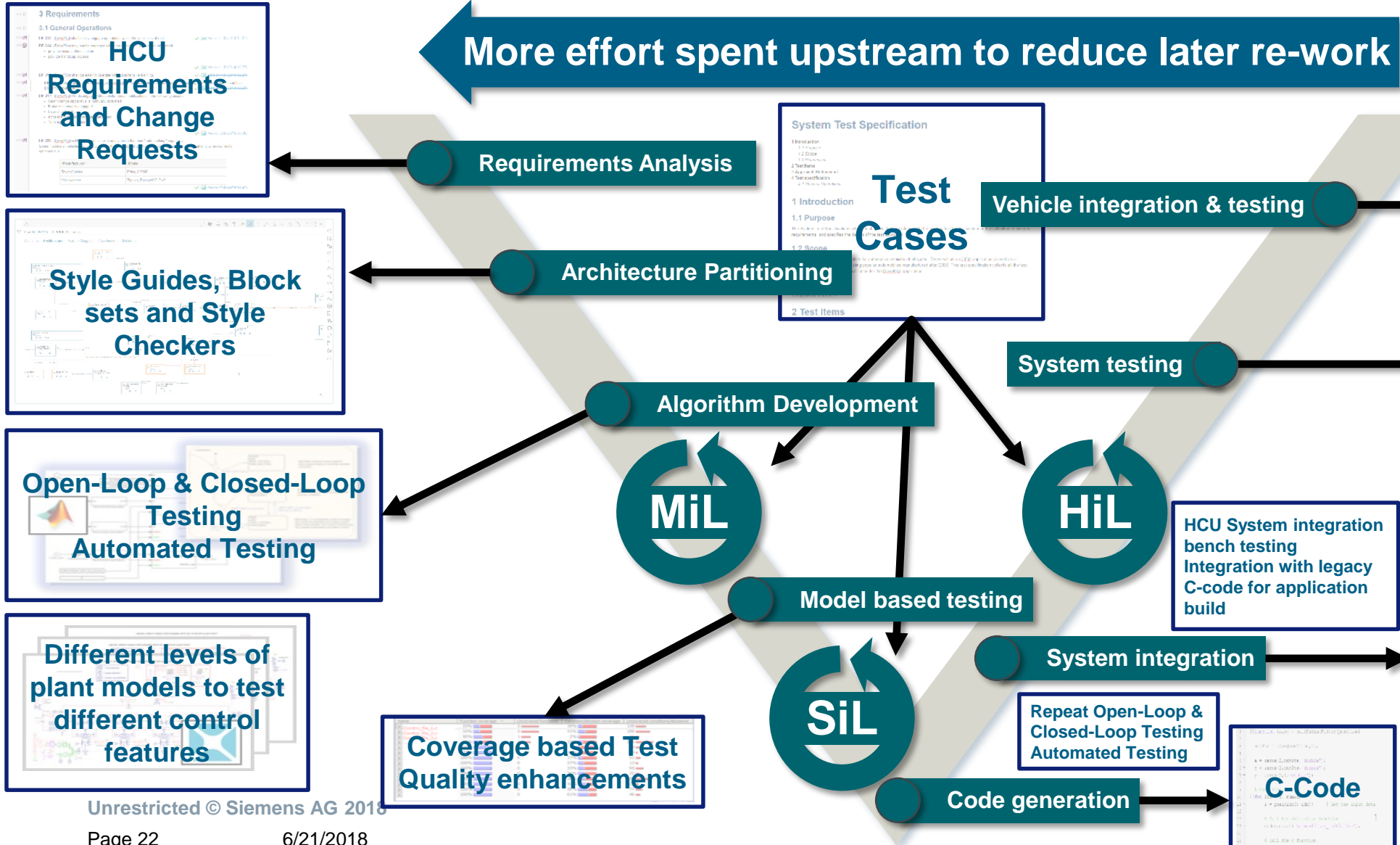
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More effort spent upstream to reduce later re-work



```

C-Code
// Example C-Code snippet
int main() {
    // ...
}
    
```

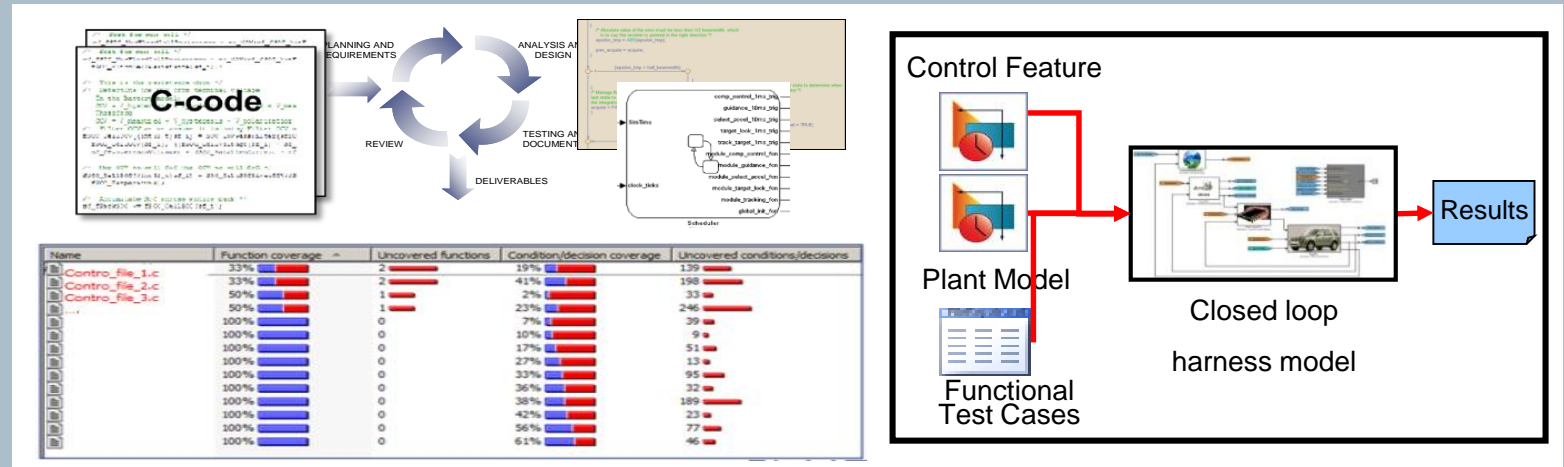


Customer Case

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



- Uniform efficient development process deployment
- Many bugs/issues identified early in the design
- Customer gets over 300% ROI using LMS services

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

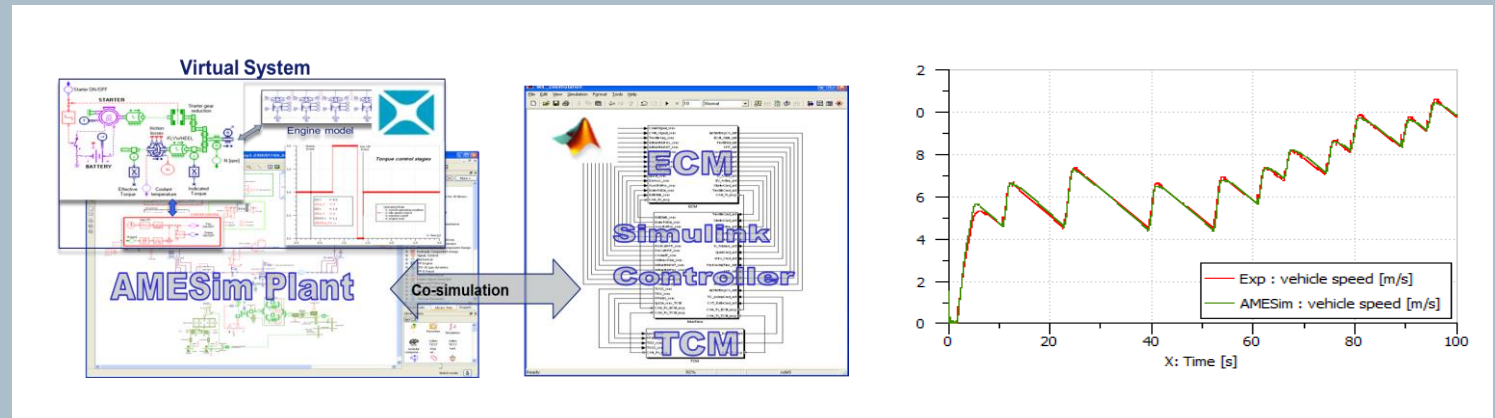
Customer Case

Scalable system simulation platform for new engine controller design



- 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

OEM applies the digital twin concept to optimize engine controller 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

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





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