Function Modeling and Validation at Mercedes-Benz: Success Factors, Roadmap, and Future Challenges

MAC
20th October 2022

Christian Dziobek
Dr. Thomas Ringler
Dr. Florian Wohlgemuth

Mercedes-Benz

Overview

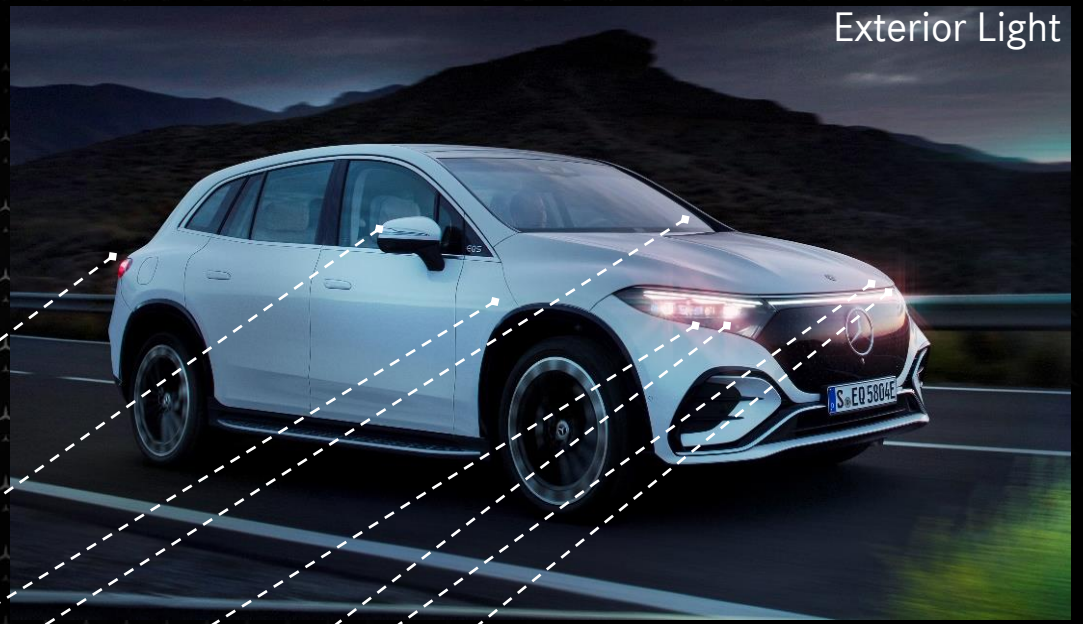
Body&Comfort Domain at Mercedes-Benz

Model-based Development of distributed Body&Comfort E/E-Systems in a distributed organisation

Future Challenges and Roadmap for Virtual integration of distributed systems

Success Factors, Questions and Challenges, Conclusion

Body&Comfort Domain at Mercedes-Benz



E/E architecture

ECU: Electronic Control Unit

Highly distributed E/E-functions integrated into a lot of different ECUs provided by various different suppliers
Globally distributed workshare - internally and by tier1s

Overview

Body&Comfort Domain at Mercedes-Benz

Model-based Development of distributed Body&Comfort E/E-Systems in a distributed organisation

Future Challenges and Roadmap for Virtual integration of distributed systems

Success Factors, Questions and Challenges, Conclusion

Where we started in the 2000th with Model-Based Design

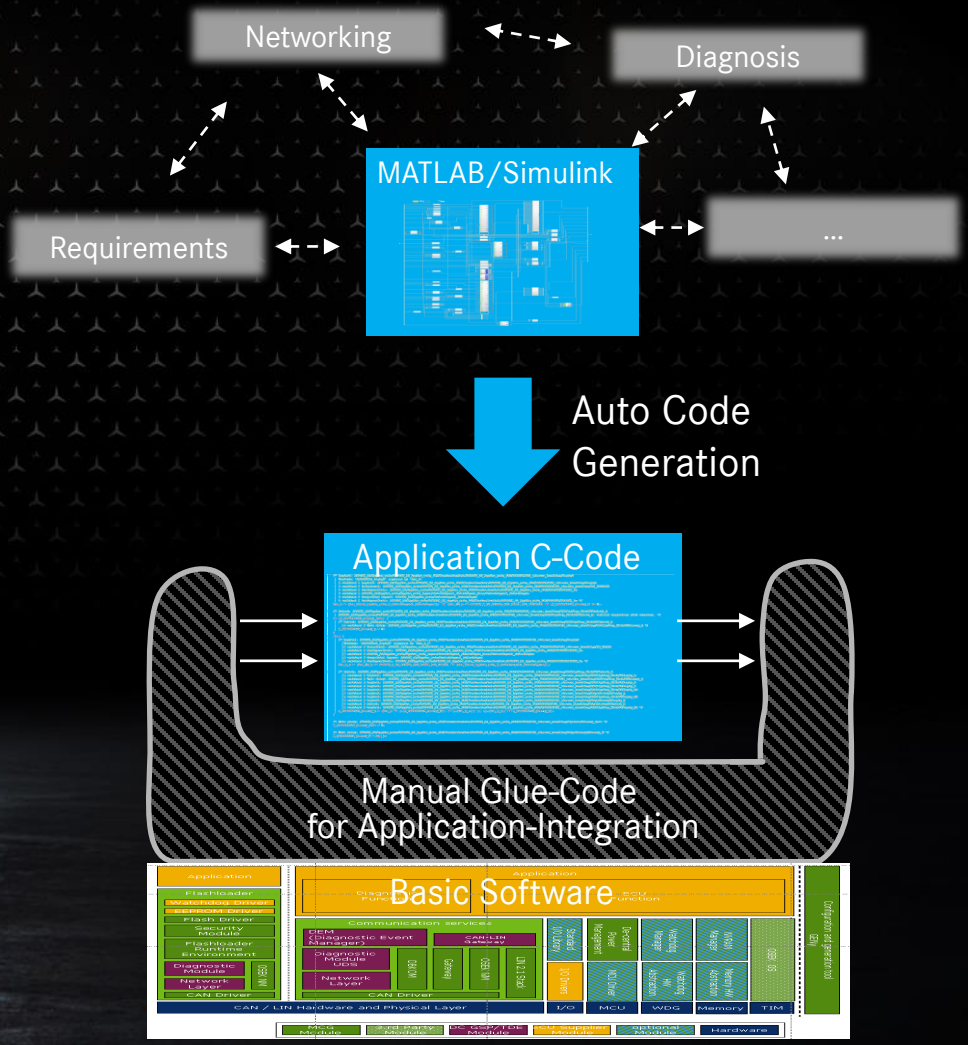
Development of individual functions

- Mainly body and comfort control-functions, were some make use of mechatronic environmental models

=> Already good support for the individual function development and automatic code generation

However: poor infrastructure & environment

- A lot of different tools with manual data transfer from one to another tool
- Different software-architectures at different ECU integrators
- Manual SW integration into different SW stacks
- Almost no reuse of SW functions between different product-lines



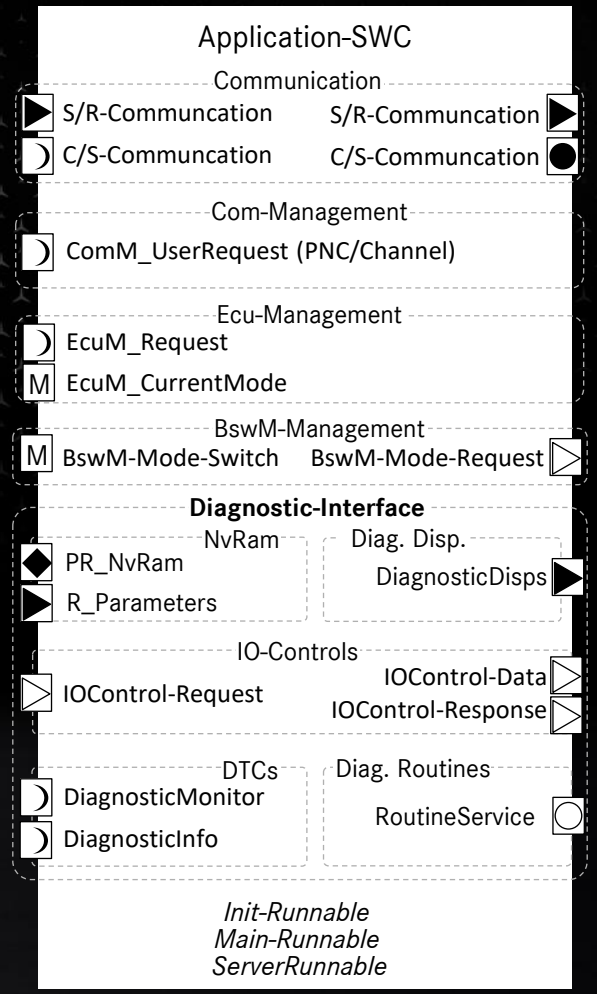
Long-Term Mission & Vision

Provide a distributed integrated development environment for the development of distributed body and comfort functions

Requirement		Addressed Solution
Standardized methodology & SW pattern for the overall domain including Tier1	1	Engagement in AUTOSAR Software Standard
Seamless tool-environment / toolchain	2	Engagement in AUTOSAR Meta-Model, tooling, standardised exchange format as basis for the tool-chain
Support fast and efficient model-based function development	3	Engagement in enhancement of Simulink as software development environment
Facilitate fast feedback-loops by validation by simulation	4	Virtual validation environment (MIL, SIL, PIL)

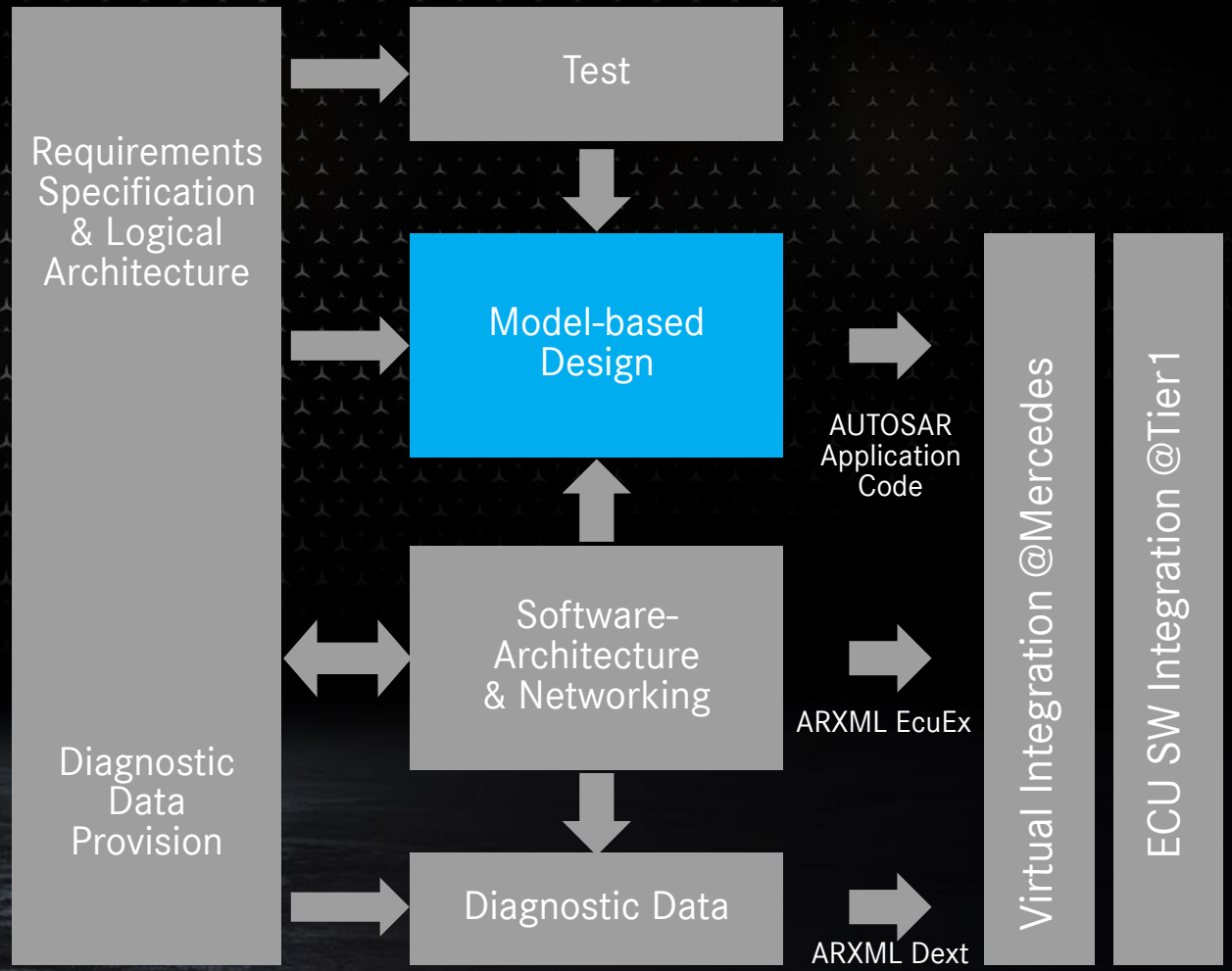
1 AUTOSAR Software Standard as Foundation

- Common, standardized software architecture among all ECUs
- Same application interfaces for all SWCs on a ECUs: A clearly defined application pattern based on a proven subset of the AUTOSAR standard
  - S/R an C/S Communication including transmission monitoring & E2E
  - Managers
    - Com-Management (PNCs, Channels)
    - Ecu-Management
    - BswM-Management
  - Diagnostics
    - NvRam
    - Diag.-Displayables
    - I/O-Controls
    - DTCs (Diagnostic Trouble Code)
    - Diag.-Routines
- Defined set of Event-Types & Runnables (C-functions of SWC)



2 Seamless Toolchain based on AUTOSAR

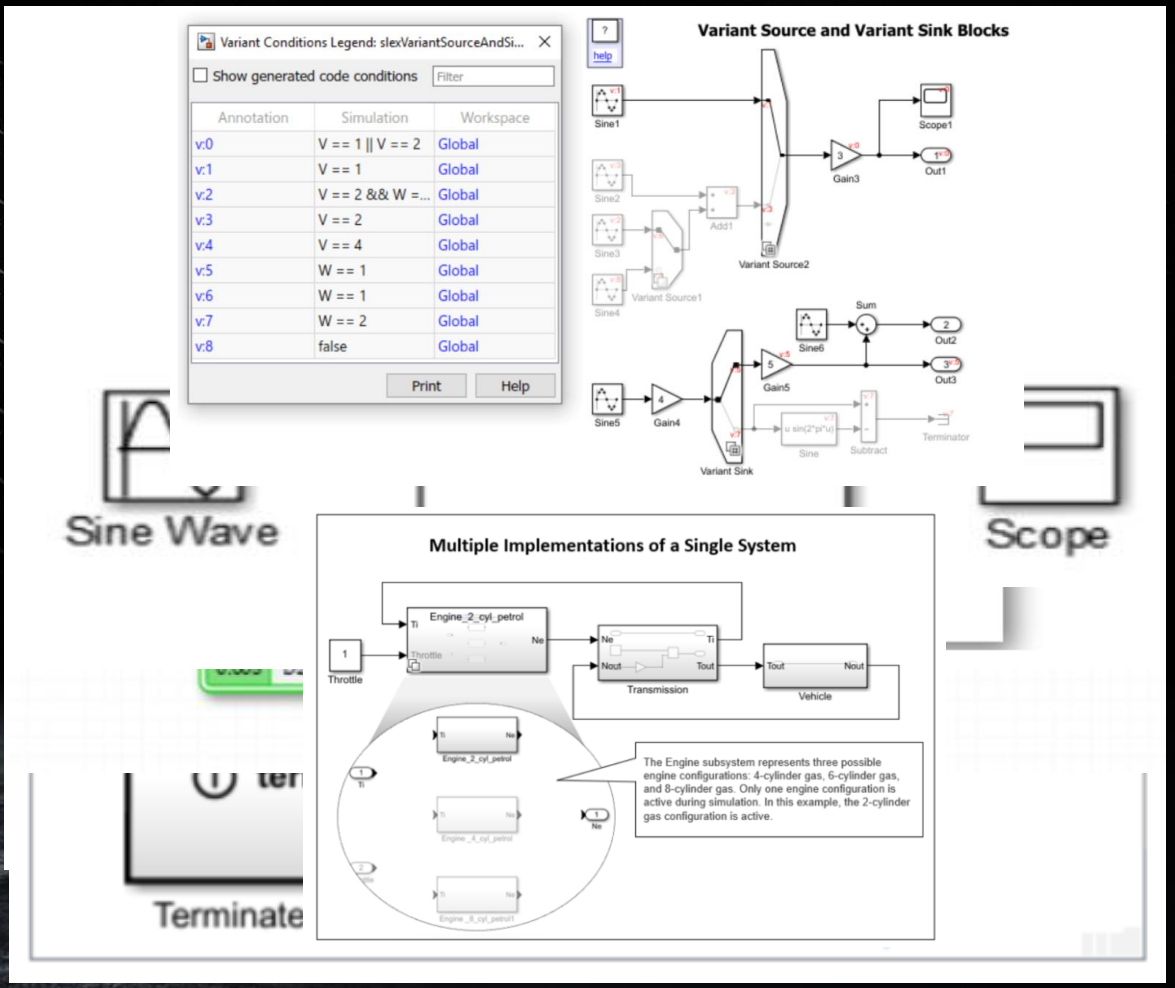
- Requirements specification
- System/SW-architecture design
- Networking/System-architecture
- Modelling environment
  - AR-Import and Model frame generation
  - Application Block Library & guidelines
  - Refactoring and block diagram Layouting
  - Integrated environment for SW-component validation through simulation
  - Traceability with respect to requirements and test
  - Static model analysis
  - Generation AUTOSAR-compilation Code
  - Code-Analyse
- Seamless diagnostic data provision process
- Consistent Delivery of all Artefacts incl. C-Code
- Virtual integration tooling



3 Simulink as Software Development Environment

Enhancements

- Enhancement of the semantics of the graphical language of Simulink and Stateflow
- Modularisation
  - Referenced-Subsystem/Model
  - Libraries
- Event Functions (Power-up/Down, Reset)
- Scheduling/Events
- SimEvents
- Software Pattern & AUTOSAR-Semantic like
  - Client/Server: Simulink Functions
  - S/R: Simulink Messages
- Variants

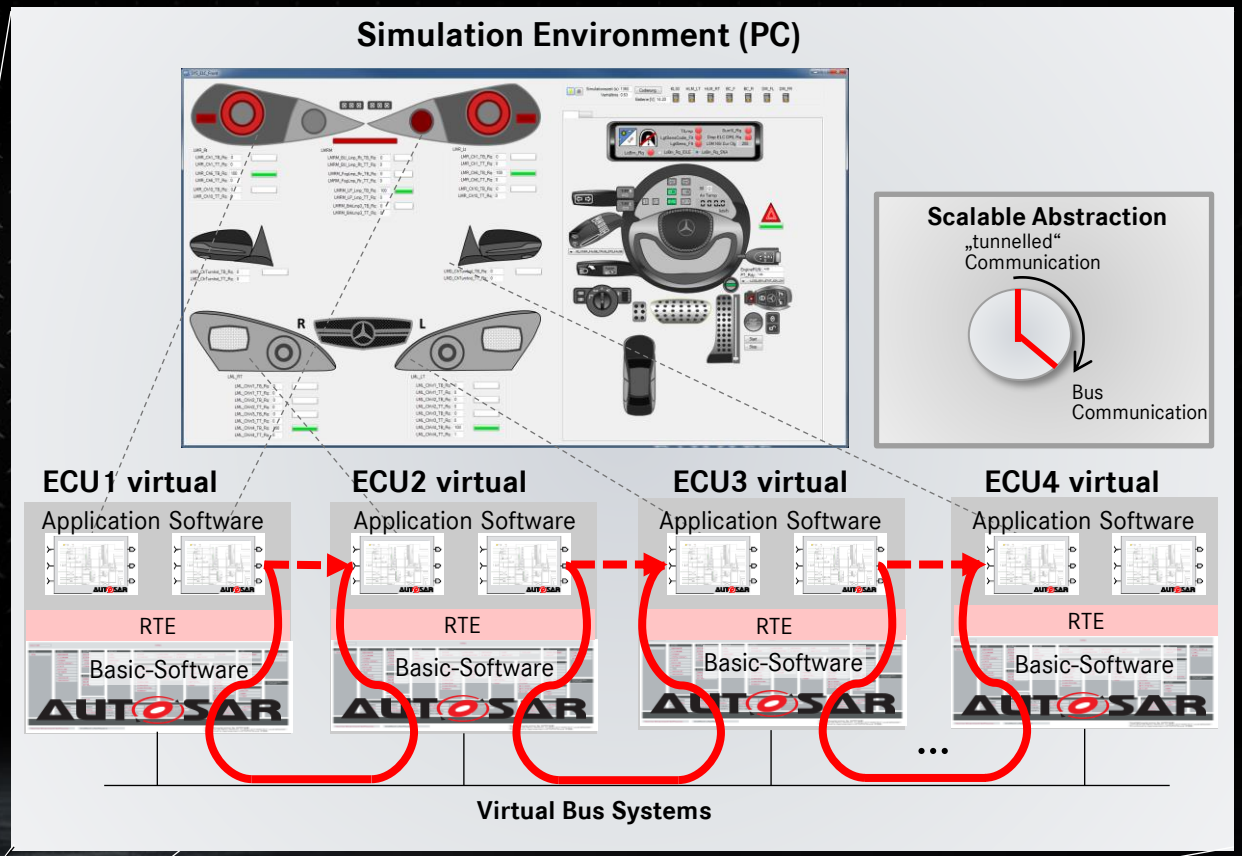


4 Virtual Validation Environment

- PC based validation of a distributed system prior model/code delivery to the different ECU-integrators

- Adjustable level of abstraction and accuracy
  - Pure function using virtual function bus
  - Function including middleware & Network Communication

=> Goal: Focus on
  - System integration tests
  - Fast iteration test with short feedback loops (Build a little, Test a little approach)



Long-Term Mission & Vision ... Resume

Provide a distributed integrated development environment for the development of distributed body and comfort functions

Requirement		Addressed Solution
Standardized methodology & SW-pattern for the overall domain including Tier1	1	Engagement in AUTOSAR Software Standard
Seamless tool-environment / toolchain	2	Engagement in AUTOSAR Meta-Model, tooling, standardised exchange format as basis for the tool-chain
Support fast and efficient model-based function development	3	Engagement in enhancement of Simulink as software development environment
Facilitate fast feedback-loops by validation by simulation	4	Virtual validation environment (MIL, SIL, PIL)

Overview

Body&Comfort Domain at Mercedes-Benz

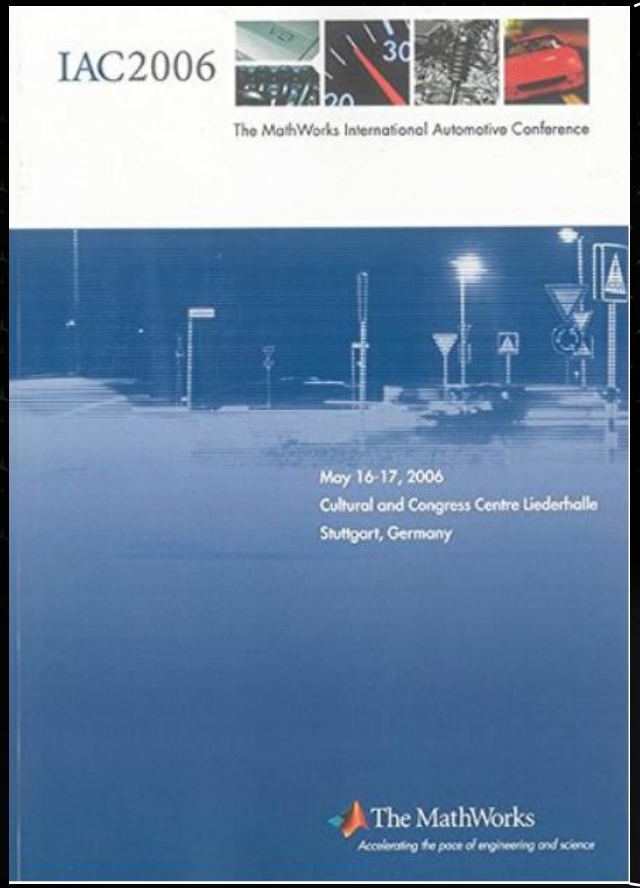
Model-based Development of distributed Body&Comfort E/E-Systems in a distributed organisation

Future Challenges and Roadmap for Virtual integration of distributed systems

Success Factors, Questions and Challenges, Conclusion

4 Virtual Validation Environment

Goal: validation of the model-based developed distributed system in a seamless environment
Requirements from 2006 are still valid...



Modeling and Simulation of Distributed Automotive Systems with Simulink

DAIMLERCHRYSLER

Challenges for Modeling Distributed Systems

Current State: Modeling independent functions	Use-Case 1: Modeling function-compound located on an ECU	Use-Case 2: Modeling distributed functions (e.g. Light Control)
Functional Aspects		
▪ Validation of interfaces and functional behavior ➢ Init. and shutdown	▪ Validation of interrelationship of ECU-functions ➢ ECU related Power-Up/-Down	▪ Validation of interrelationship of distributed functions ➢ Global vehicle states
Temporal Aspects		
➢ Abstracted execution models	➢ Temporal interrelationship of functions and basic software	➢ Temporal behavior of communication systems

↳ State of the art

↳ Additional requirements towards modeling-tools

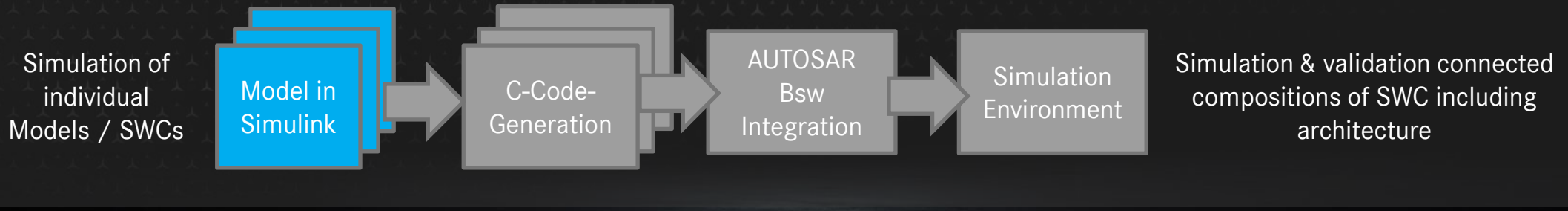
MathWorks IAC 2006
Stuttgart
May 16th 2006

Dr. Thomas Ringler

4 Virtual Validation Environment

State of the Art

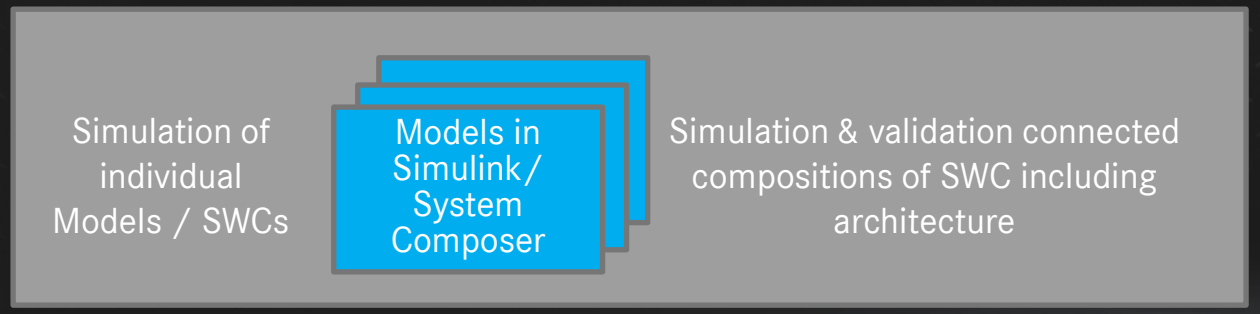
- Model based development and validation of individual SWC → is possible within Simulink
- Model based development and validation of connected compositions of SWC
  → dedicated additional environment outside Simulink on C-code level needed
  → requires external additional tools outside Simulink respect to
  – Architecture design
  – Whole virtual system validation
  => Different skills, longer turnaround times, complex refactorings, …



4 Virtual Validation Environment

State of the Art

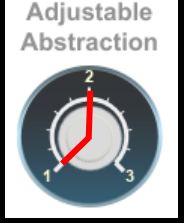
- Model based development and validation of individual SWC → is possible within Simulink
- Model based development and validation of connected compositions of SWC
  → dedicated additional environment outside Simulink on C-code level needed
  → requires external additional tools outside Simulink respect to
    – Architecture design
    – Whole virtual system validation
    => Different skills, longer turnaround times, complex refactorings, …



Vision

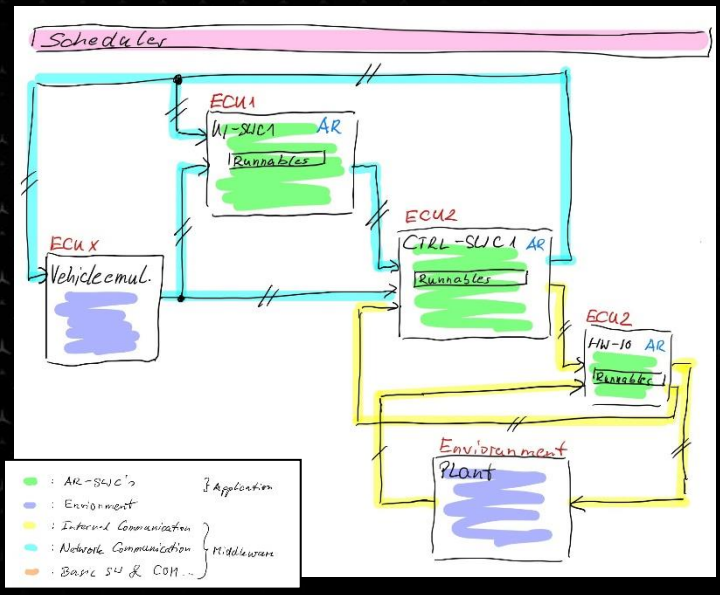
- Integrated virtual system development in one tool environment for architecture/interfaces and behaviour modelling and implementation
- Specify the distributed SW architecture
- Early validation of distributed system, within Simulink and System Composer

4 Required / Expected System Composer Roadmap



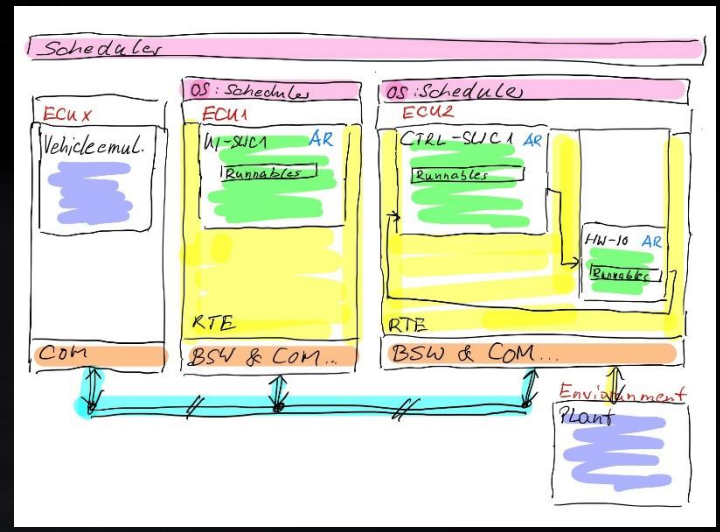
Step 1: Modelling&Validation a Composition of 1…n SWC's within one ECU

1. System Composer authoring decomposition of AUTOSAR SWC
   → Requires S/R and C/S-AUTOSAR-Support incl. RTE Status API
2. Modelling and Virtual Function Buss Validation through Simulation
3. Validation through Simulation including the AUTOSAR Middleware
   → Requires ability to implement/configure the AUTOSAR Middleware within the System Composer



Step 2: Modelling&Validation a Composition of 1…n SWC's in 1…m ECU's

1. System Composer authoring the decomposition of distributed AUTOSAR System
   → Requires full AUTOSAR Support incl. com.-network design and ECU-partitioning
2. Validation through simulation including a AUTOSAR middleware
   → Requires the ability to implement/configure the AUTOSAR middleware within the System Composer

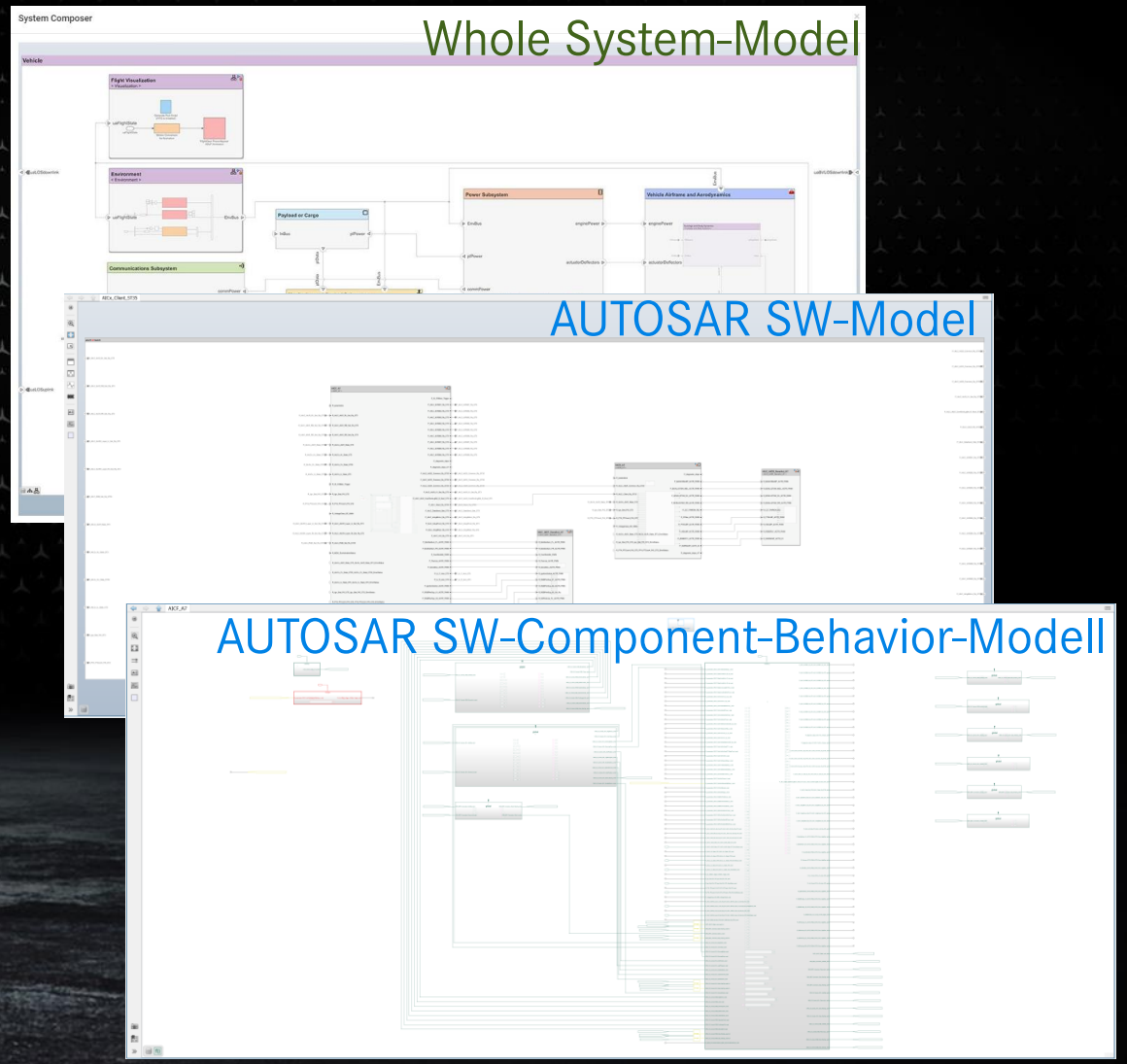


4 From native Simulink to System Composer

Transition from a control design tool to
→ System – design tool
→ SW – design tool

What is still missing
- Additional semantic to connect to Simulink behaviour models
- Methods/Services
- Full featured Middleware (RTE, BSW, COM, Diagnostics …)
- Out of the box modelling of various kinds of communication busses
- Enhanced Data types
  - Invalid values
  - Split Scalings (Scaled & Enum)
  - Bitfields

→ Full AUTOSAR support



Overview

Body&Comfort Domain at Mercedes-Benz

Model-based Development of distributed Body&Comfort E/E-Systems in a distributed organisation

Future Challenges and Roadmap for Virtual integration of distributed systems

Success Factors, Questions and Challenges, Conclusion

Success Factors

- Incremental approach
- Long term strategic activity
- Common AUTOSAR based integrated development environment for distributed body application functions
  - Joint centralized database for communication and SW-Components
  - Well defined SWC AUTOSAR pattern which is intuitive applicable by the SL – graphical language
- Active and continues activity to close gap's and shortcomings in the AUTOSAR standard
- Close and trusting cooperation with all tool suppliers
- Close and trusting cooperation with 'The Mathworks' to close identified shortcomings and gap's
- Toolkit to develop standardized and reusable AUTOSAR compliant application function libraries

This Enables

- Simplified and seamless validation using 'virtual integration' in conjunction with the AUTOSAR middleware as early as possible in the development process
- Simplified and automatic bug free integration on all body ECU's
- Shorter development times

Open Questions and Challenges

- What is the typical definition domain of application functions to be developed using Simulink?
  - Mechatronic Control – functions including plant models
  - AI – applications
  - Data – driven applications
  - … ?
- Were are gaps?
  - Data management (Object lists, run-time databases)
  - Real-time video synthetization in the area of head-light and ambient-light
  - … ?
- How does Simulink cooperate / compete with pure source code development environment‘s?

Conclusion

- AUTOSAR is an enabler to provide standardized and reusable body and comfort functions at Mercedes-Benz!

- Continuous and early **virtual validation through simulation** increases maturity of our functions and is an enabler to reduce ‘time to market’ for new innovative body and comfort features and **must be possible** within the function modeling phase **at any time with adjustable accuracy**!

- Switching tools in the area of architecture design and model based function must be removed in order to speed up and simplify the application development process further!