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Some Challenges for Automotive Embedded Systems

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Carmeq GmbH

Overview

Carmeq

Model-Based Development

Requirements Specification

Product-Lines / Reuse of Development Artifacts

Mission

Our mission is technical consulting and engineering services focused on software-driven systems for the automotive industry.

We improve quality and reduce costs through customer-oriented use of advanced technologies, efficient development processes and modern architecture.

Carmeq - Past and Present

04 June 2002

Decision to found Carmeq by the group's board of directors

30 July 2002

Carmeq GmbH founded as a 100% subsidiary of the Volkswagen Group

01 January 2003

Business commences with 16 employees

Today (September 2008)

Approx. 220 employees

Sites

Berlin (head office)

Wolfsburg

Ingolstadt

Berlin

Wolfsburg

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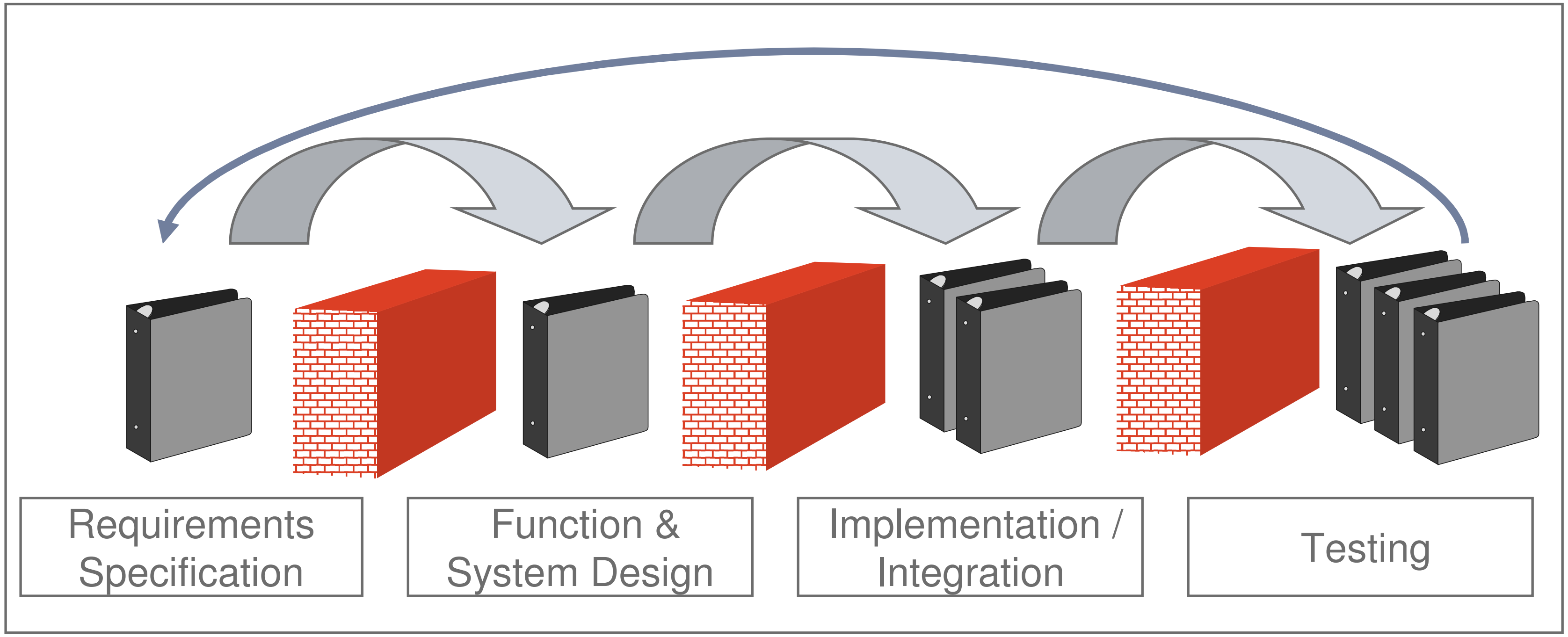
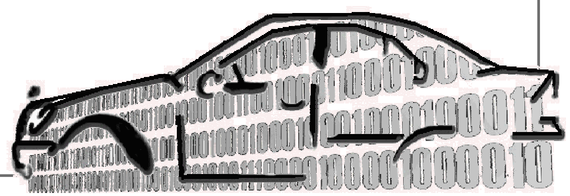
Basics of Model-Based Development

Traditional Approach

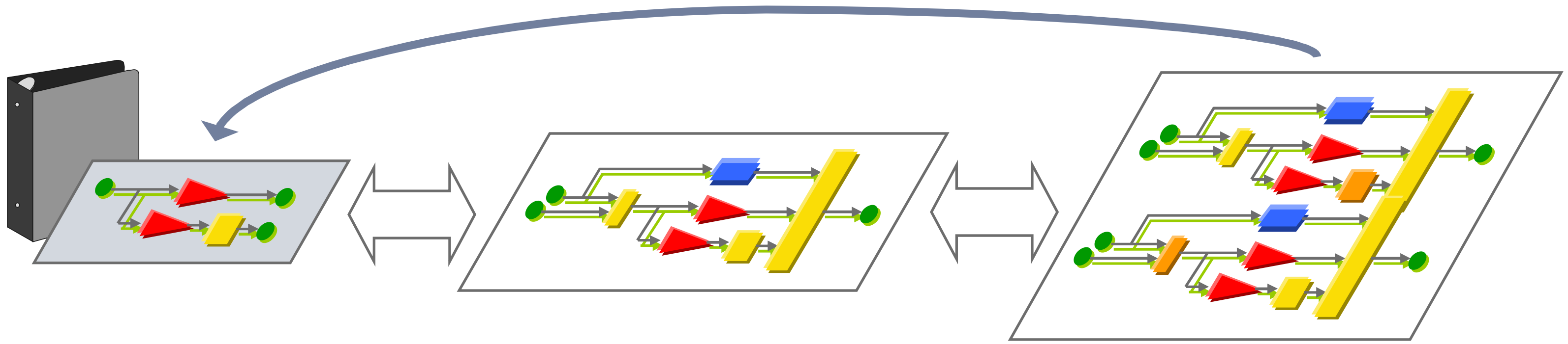


Traditional development process based on documents

- Textual specification of functions
- Manual Implementation of (simulation) prototypes or production code
- Late Testing



Model-Based Approach



Requirements Specification

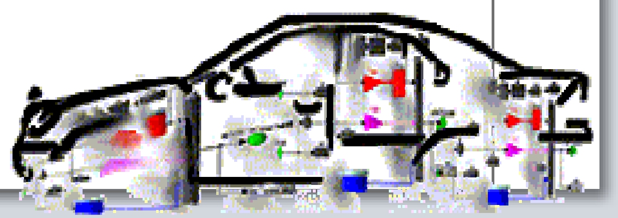
Function & System Design

Implementation / Integration

Testing

Model-based development process

- (almost) continuous presence of executable functional models
- (almost) comtinuous validation and testing
- Possibility of automatic compilation into C-Code



The Challenge

Product Related Challenges

Functionality increase

Complexity increase

Increased Safety-criticality

Quality concerns

Challenges Related to Development Process

Supplier-OEM relationship

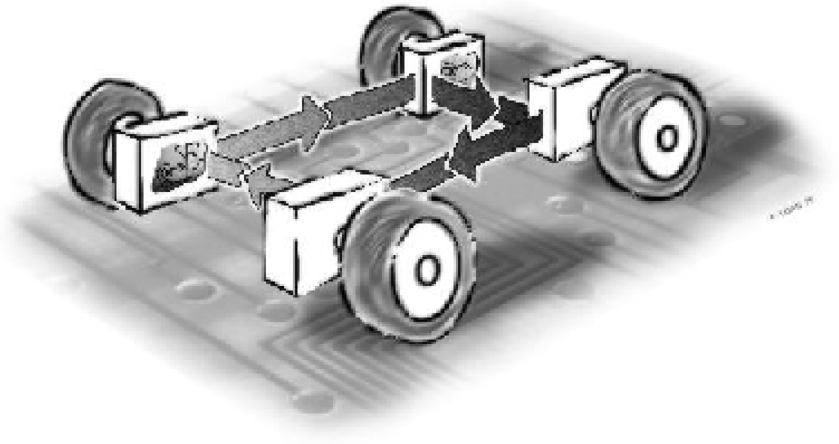
Multiple sites & departments

Product families

Componentization

Separation of application from infrastructure

Safety Requirements, ISO 26262



Which Models should be used?

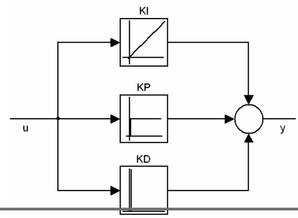
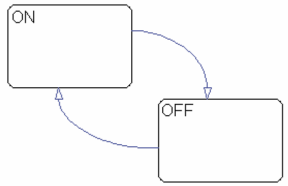
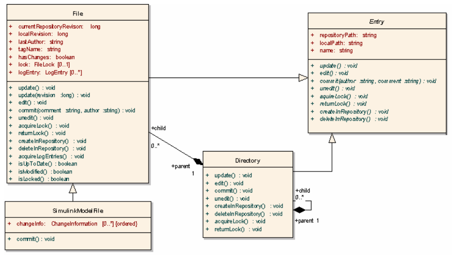
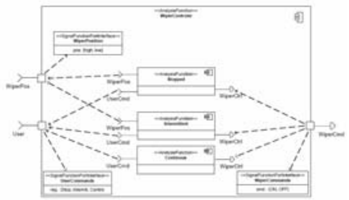
- The use of modeling languages or notations has become standard practice in almost all engineering disciplines.

- In the automotive domain, electronics (control systems) and computer science (software) have grown to dominating importance.

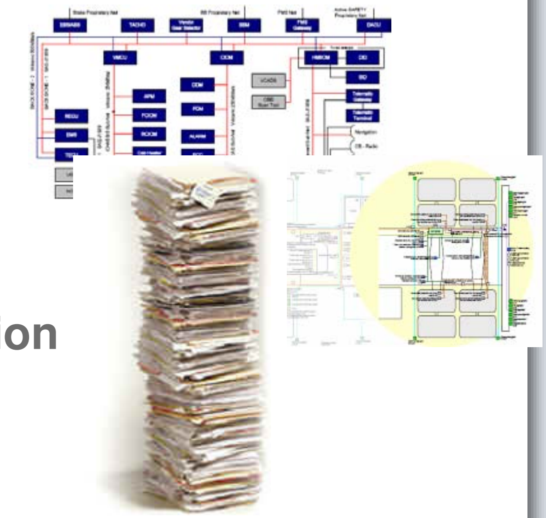
- There is a desire to use a single modeling language in order to avoid semantic ruptures or even inconsistencies.

- Preconditions:
  - The modeling language is sufficiently powerful to model all relevant aspects and to provide adequate views
  - The modeling language is understood by all stakeholders, at least in those parts relevant for the respective stakeholder
  - There are appropriate methods and tools available for modeling (and simulation)

Examples of Modeling Languages

Sprache	Beispiel
Block Diagrams	
State automata (including Harel‘s extensions)	
UML/SYSML	
Domain specific Architectural languages EAST ADL, Autosar	

The Response - EAST-ADL2



Architecture Description Language **for Handling all engineering information required to sustain the evolution of vehicle electronics**

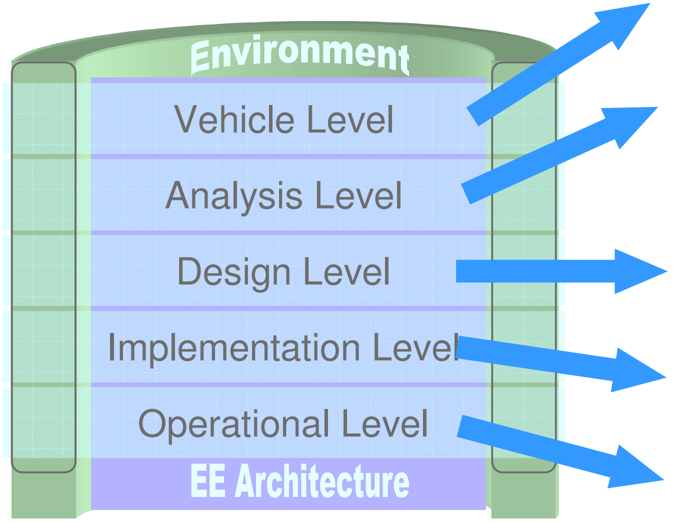
EAST-ADL2

A System Modeling Approach that

Is a template for how engineering information is organized and represented

Provides separation of concerns

Embrace the de-facto representation of automotive software – AUTOSAR



Feature content

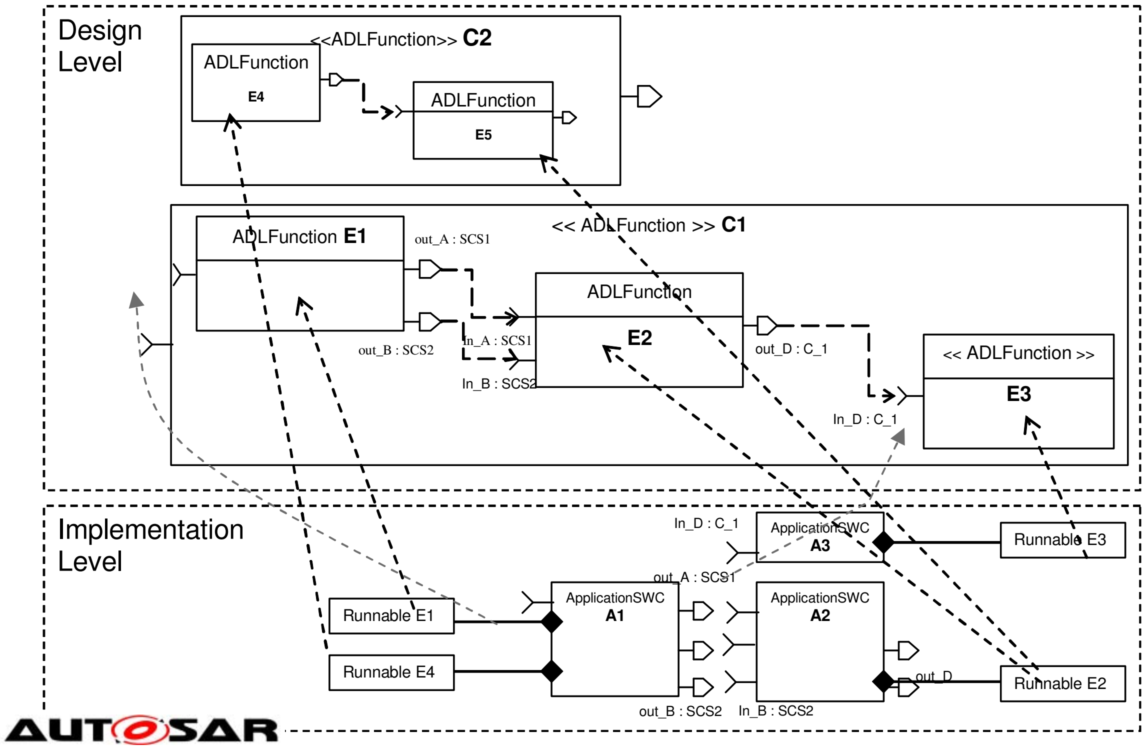
Abstract functional architecture

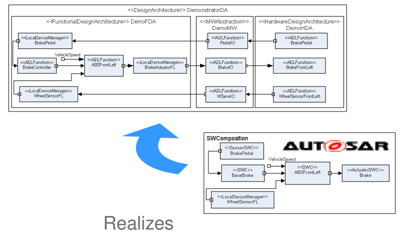
Functional architecture, HW architecture, platform abstractions

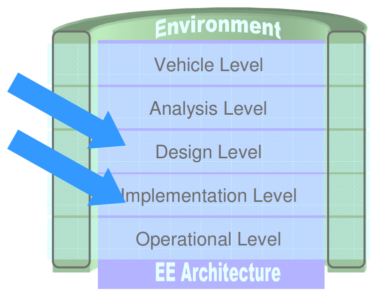
AUTOSAR Software architecture

Embedded system in produced vehicle

EAST-ADL2 – AUTOSAR Mapping

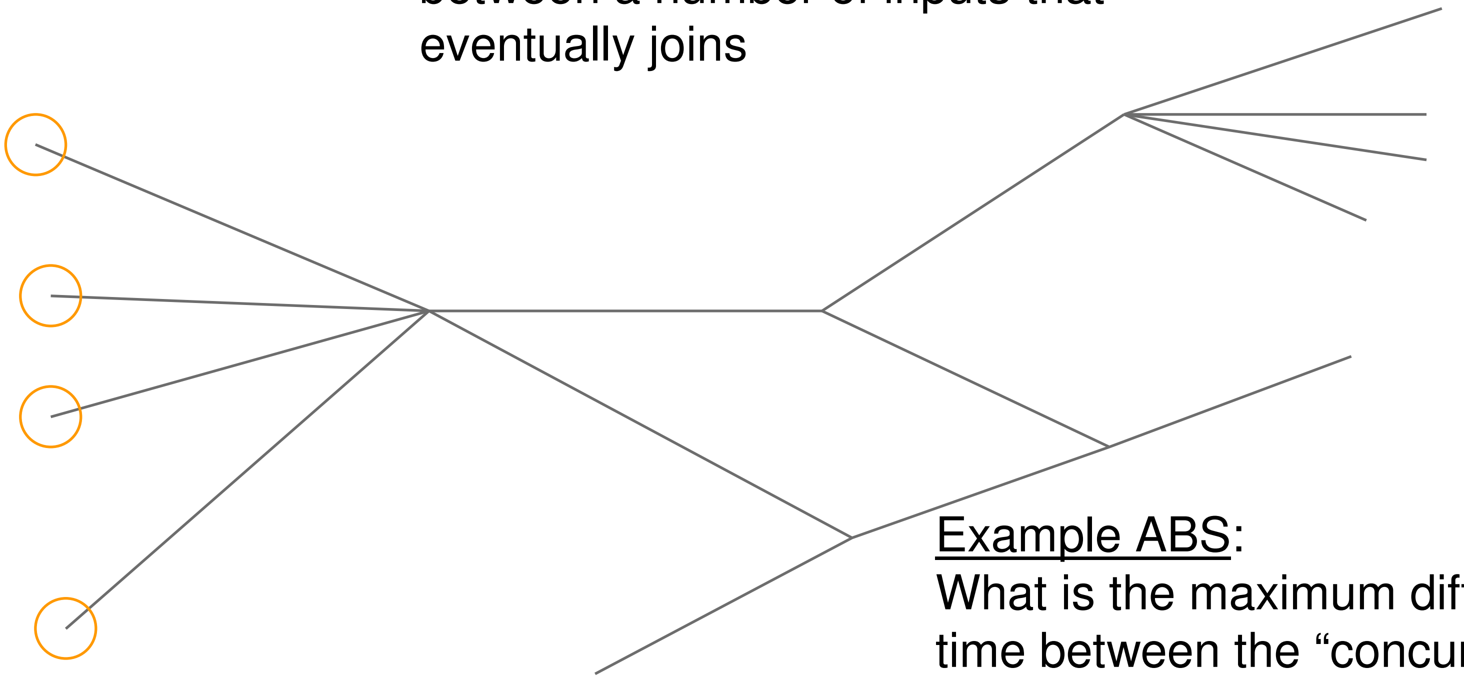






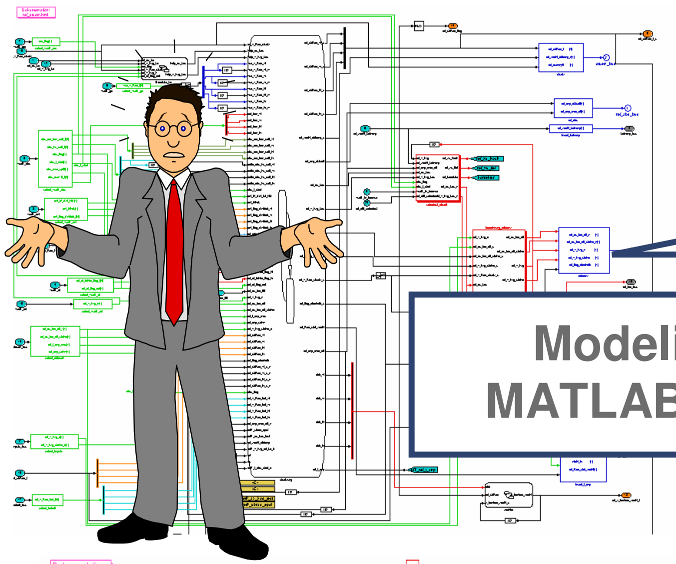
Timing Measures

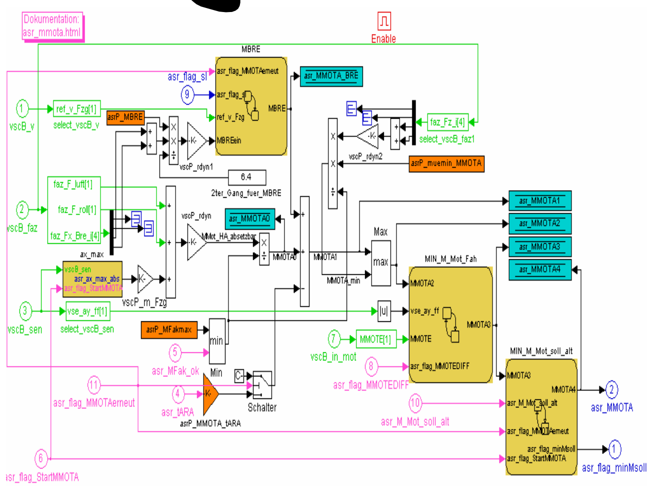
Input
Synchronization: What is the difference in time between a number of inputs that eventually joins

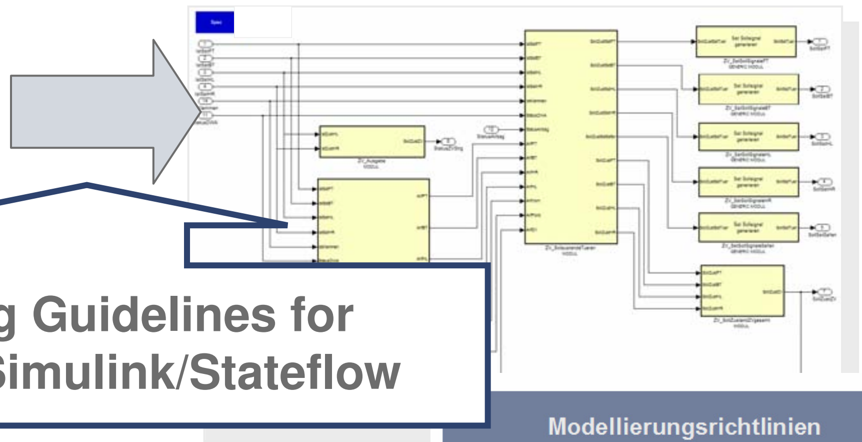


<u>Example ABS</u>:
What is the maximum difference in time between the “concurrent” samples of the four wheel sensors.

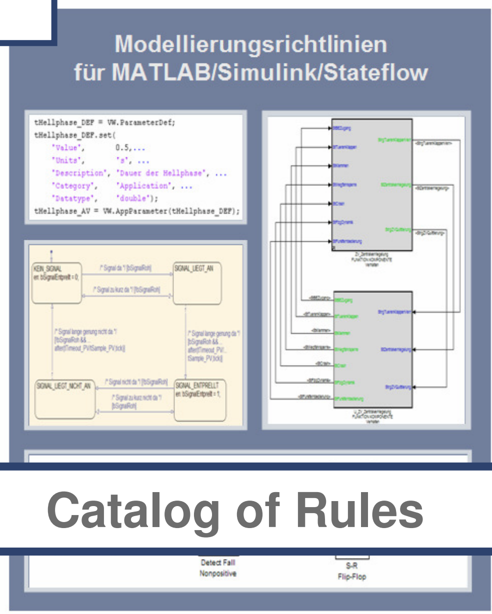
Necessity of Modeling Guidelines





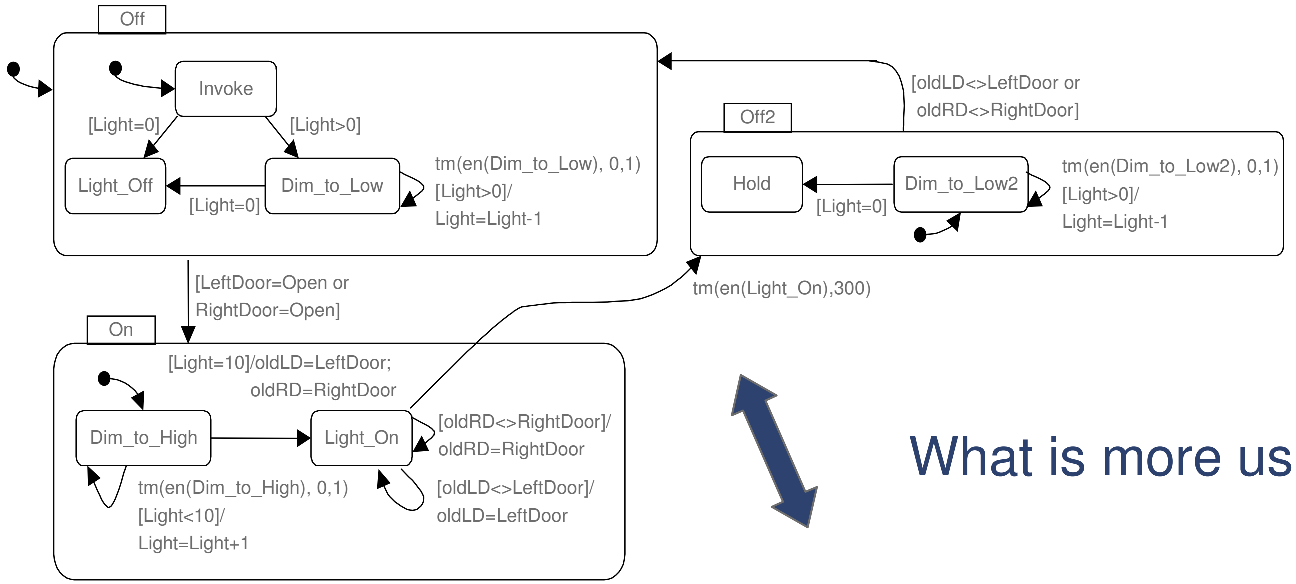


Modeling Guidelines for
MATLAB/Simulink/Stateflow



Catalog of Rules

Modeling is not a panacea

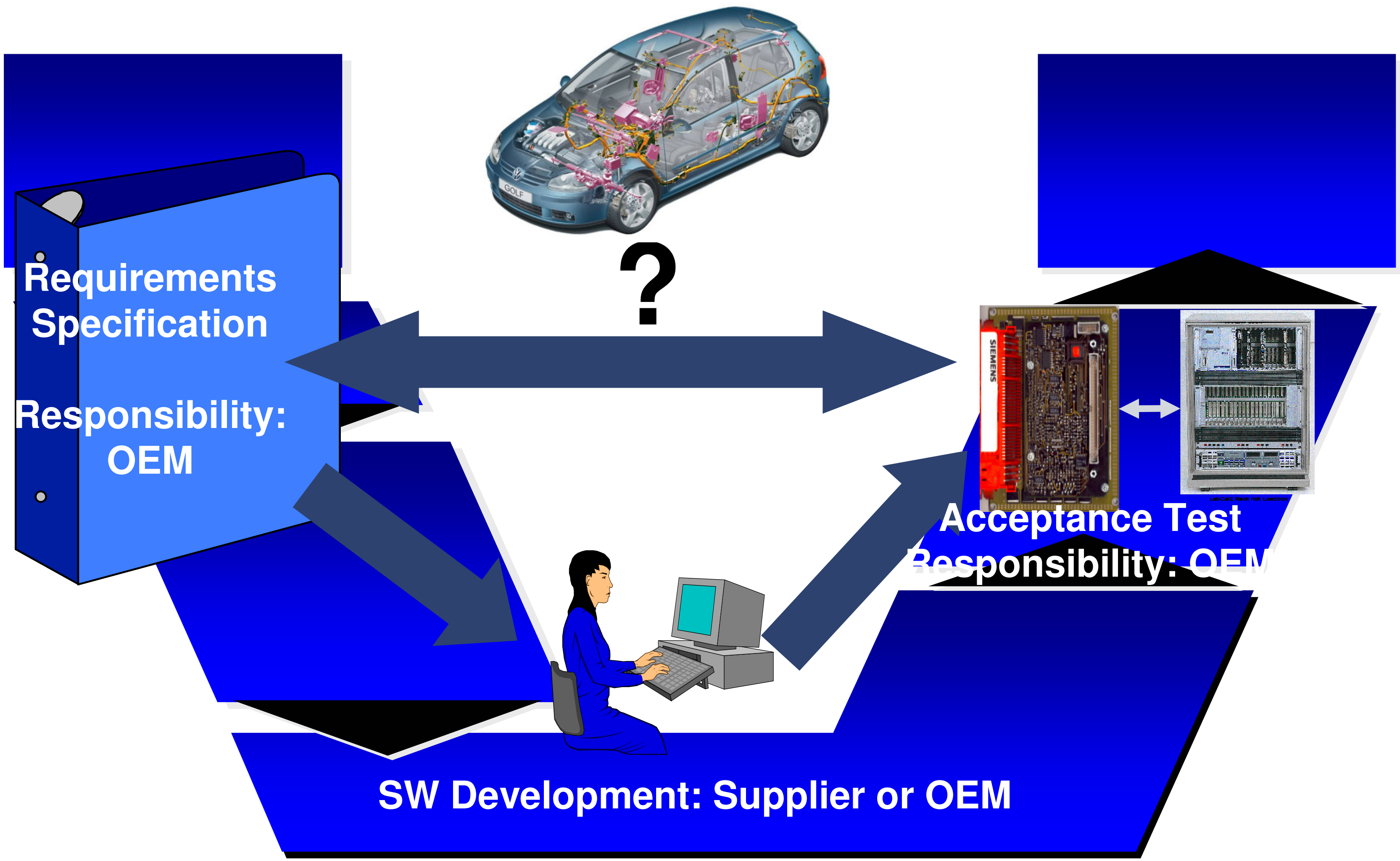


What is more useful?

- After invocation (power-on), the interior light shall be off.
- Opening one or both doors invokes the light, which dims up within 1 second in 10 steps.
- If both doors are closed, the light shall dim to off (1 second, 10 steps).
- If the light is on for 5 minutes without any driver action (i.e. opening or closing a door), the light shall dim down (for power-saving reasons).

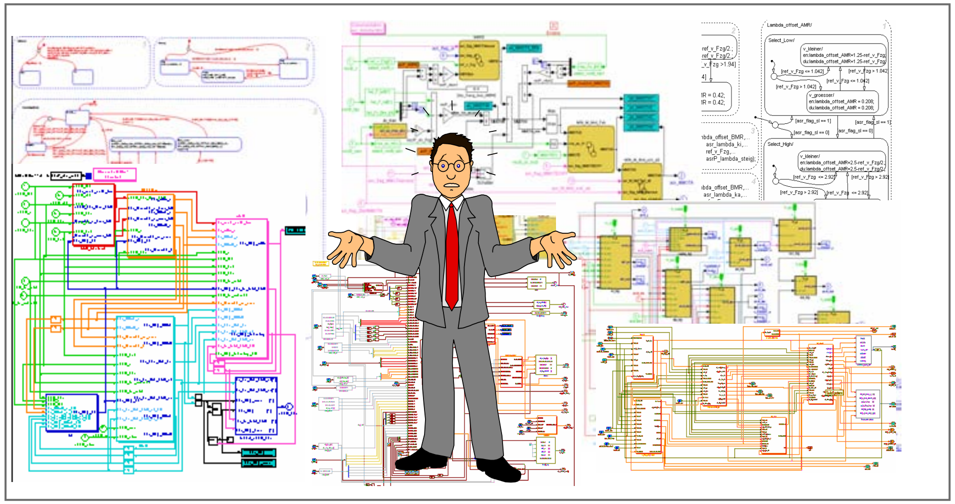
Requirements Specification

Requirements Specification: OEM-Supplier Contract



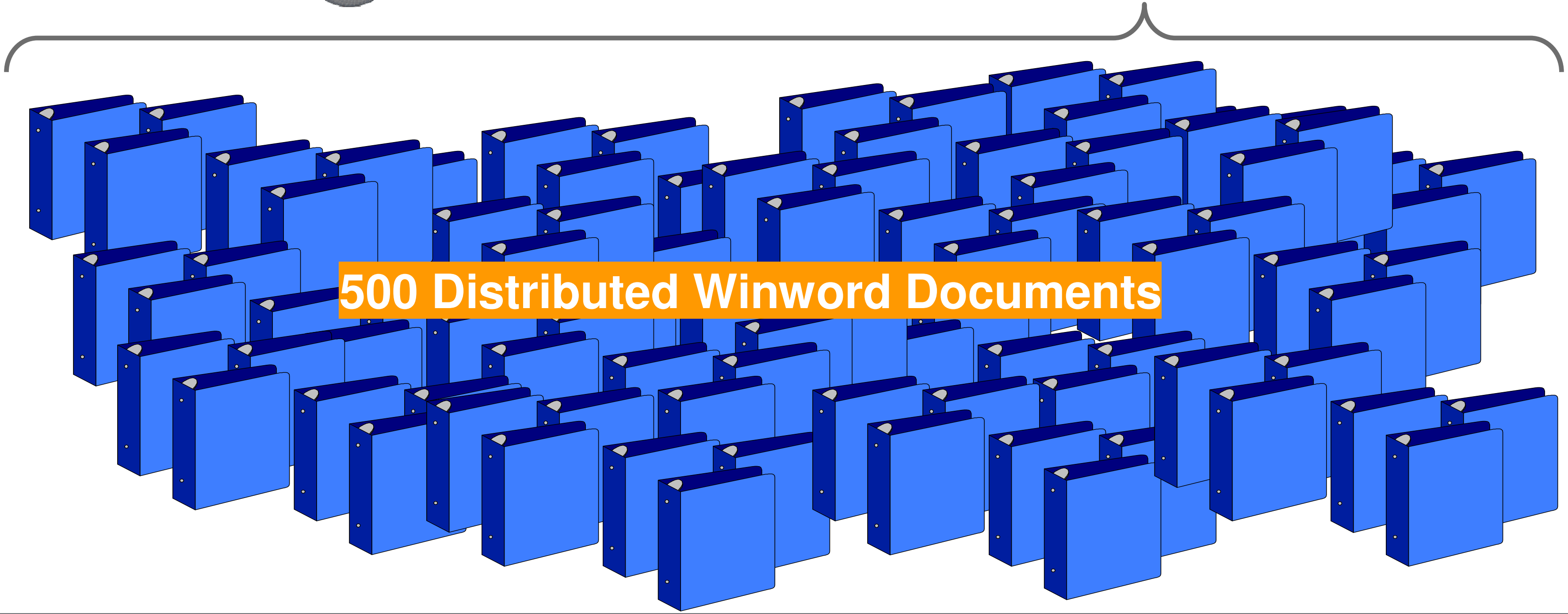
Model-Based Development
Textual Requirements are indispensable

- **Executable models focus on constructive aspects, i.e. important information cannot be modeled adequately**
  - High-level Requirements
  - Non-functional requirements,
  - System properties
  - Rationale for requirements
  - …



- **Further documentation is indispensable**
  - However: system requirements ≠ model documentation
- **Requirements from standards (e.g. SPICE)**:
  - Separate requirements phase
  - Requirements tracing across all development phases

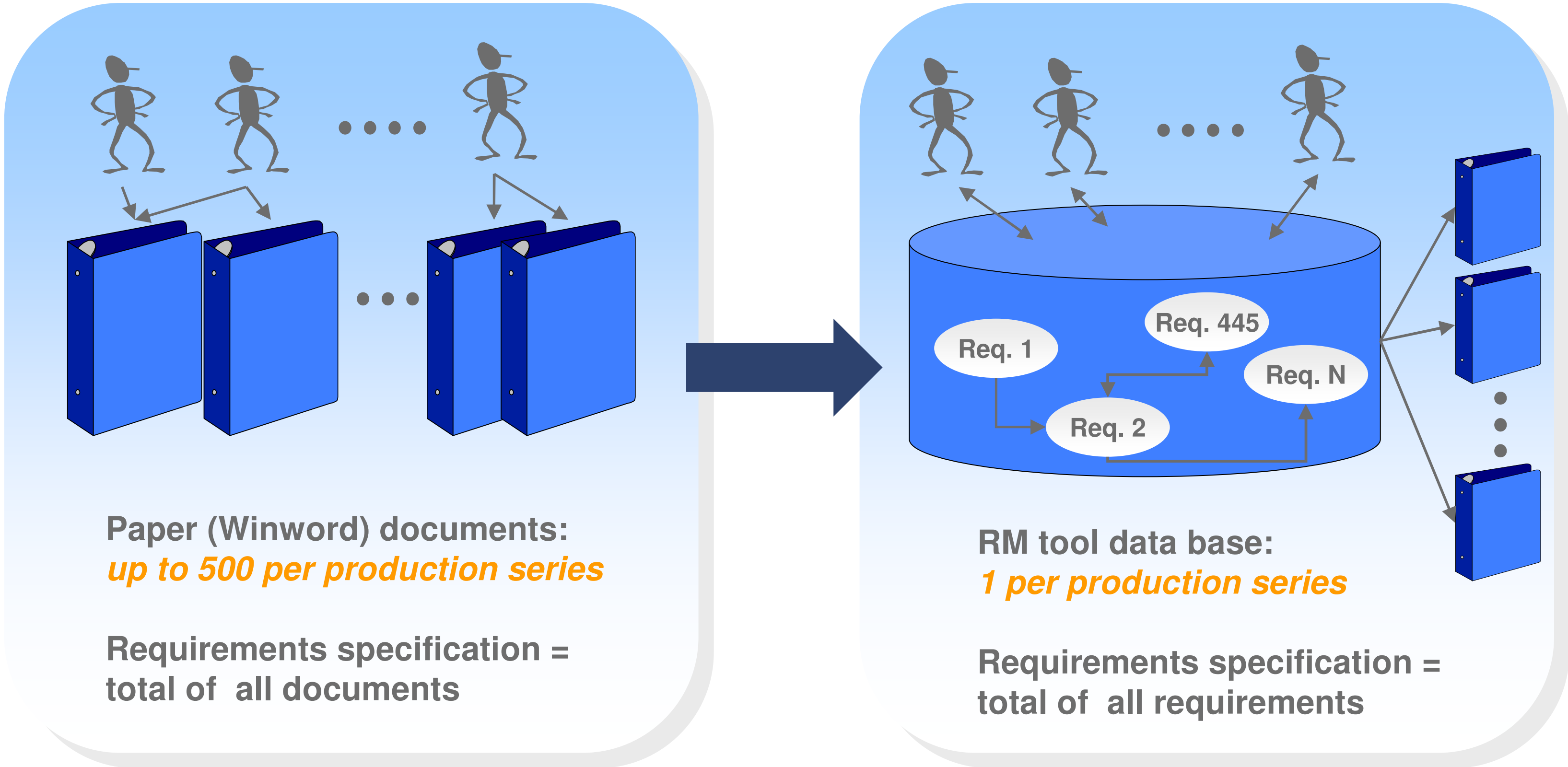
EE Specification Volume - Mercedes S-Class (W220)



Typical Questions in a Project Context

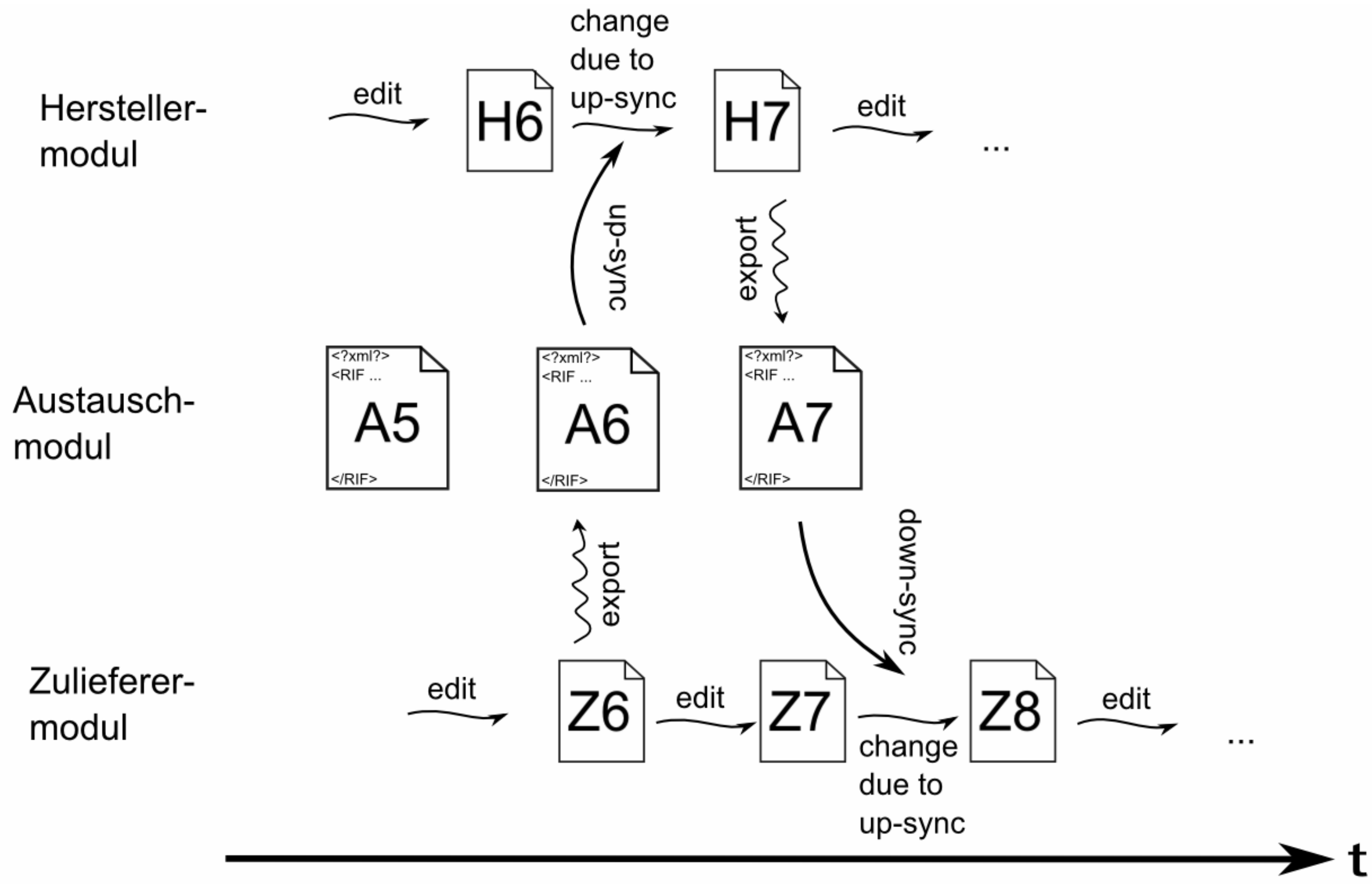
- Where is the latest version of requirement X.
- Have the requirements for function X been reviewed by the supplier?
- Which requirements are implemented by ECU X.
- Which ECU-sample should realize which requirements? Have the suppliers agreed to it?
- What has been changed for function X since the last review? Who did these changes?
  - ➔ What kind of impact do these changes have on the tests?
  - ➔ What are the costs for these changes?
- Which requirements have been deleted? Which have been postponed until later versions?

Requirements Management: Documents versus Data Base



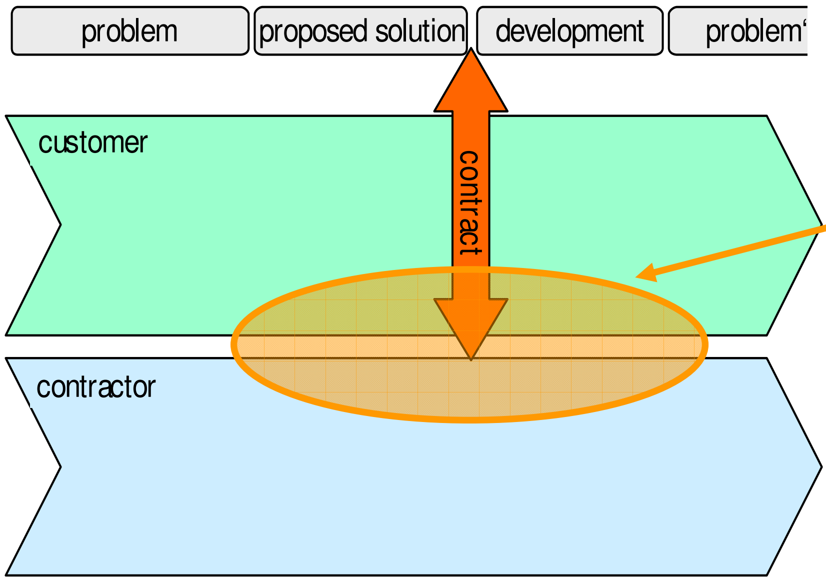
- ➔ ***RM tool manages text modules as individual requirements (objects)***
- ➔ ***Documents are created as extracts from the database***

Exchange of Specifications



Austausch-Zyklen allgemein/gemischt (mit Update)

There is no clear boundary between manufacturer requirements specification and supplier system specification!



Customer also has to specify significant parts of the solution

Customer demands and contractors duties in automotive development

Relation between Model and Requirements – Ideal World

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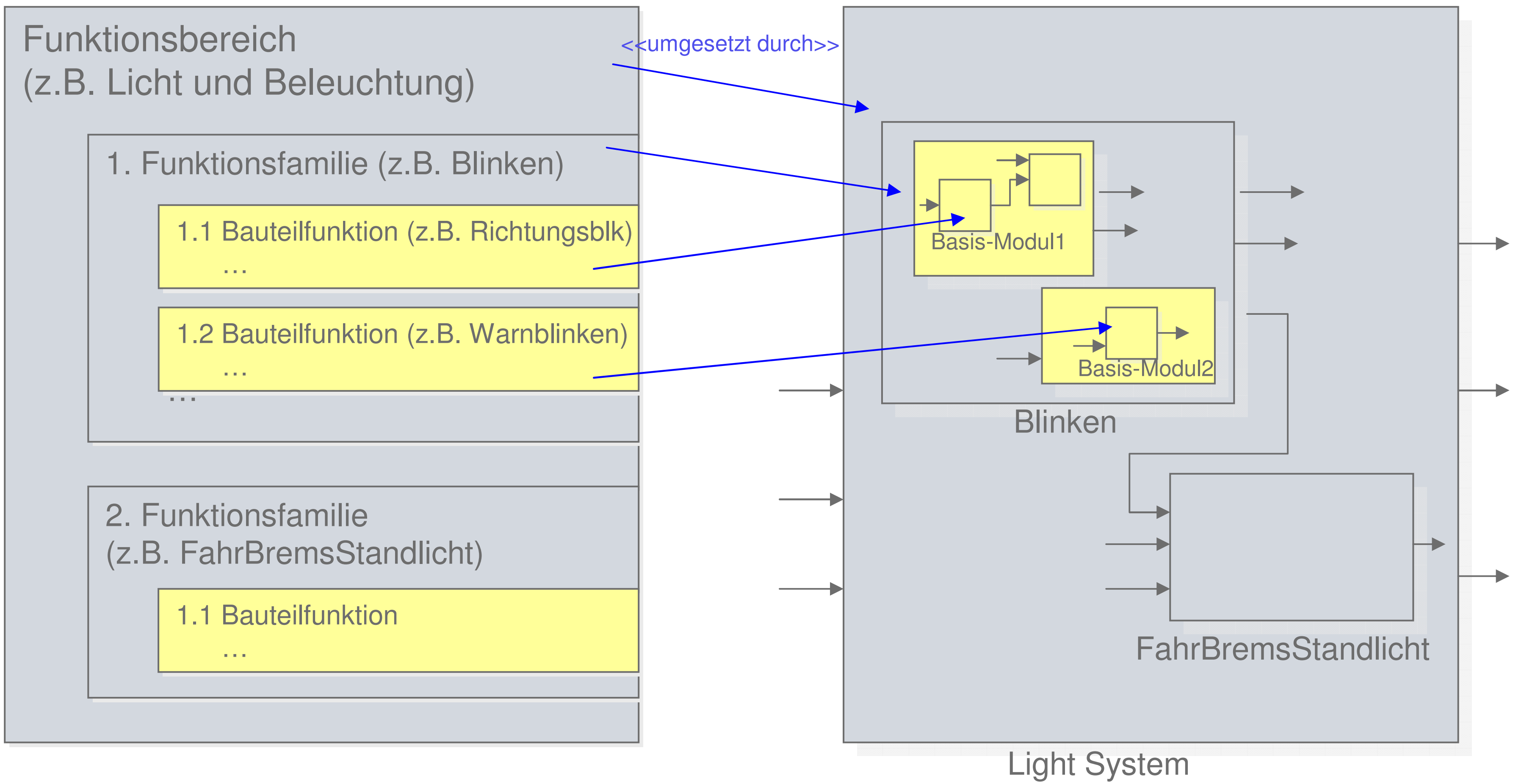
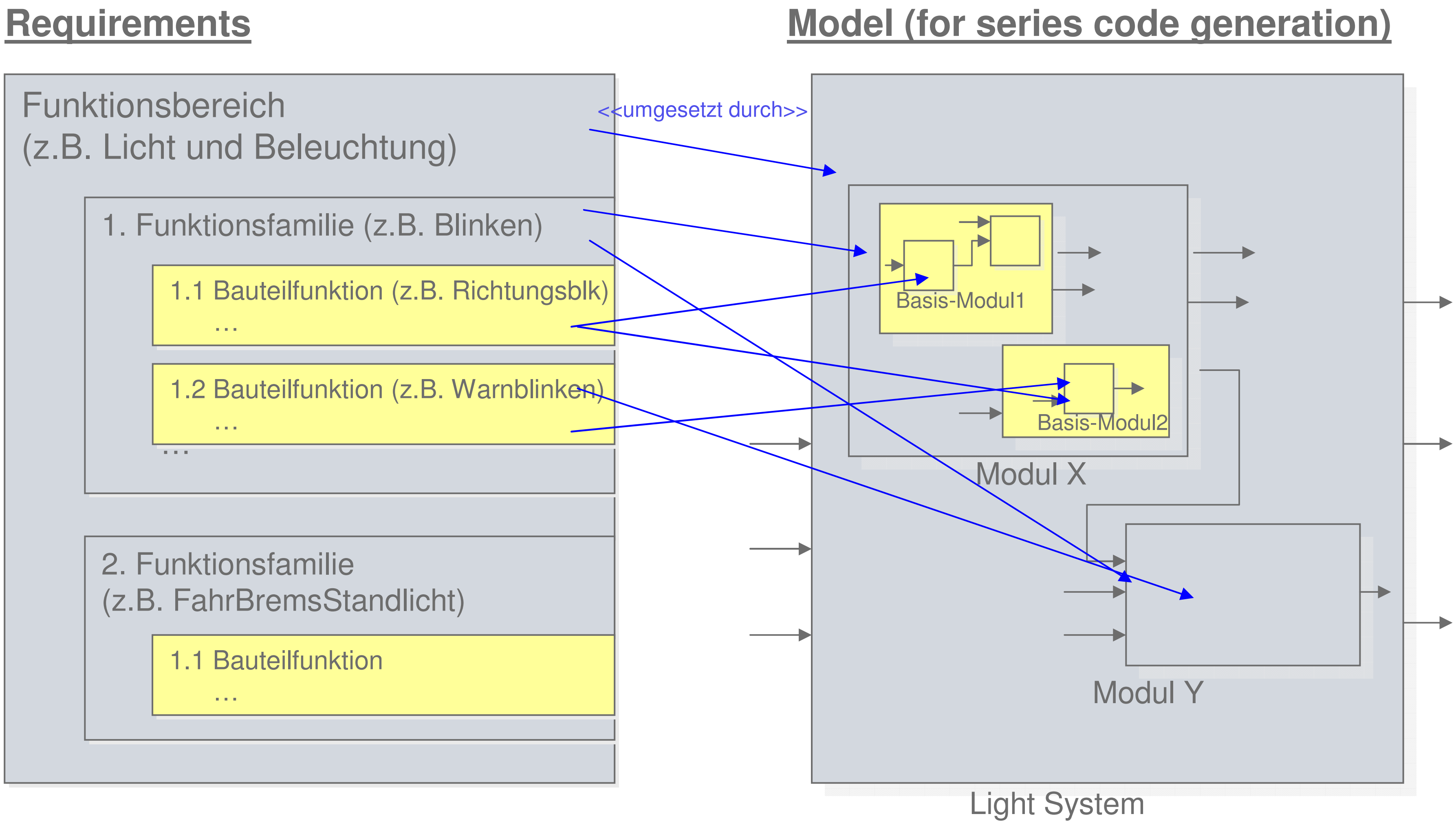
Requirements **model**

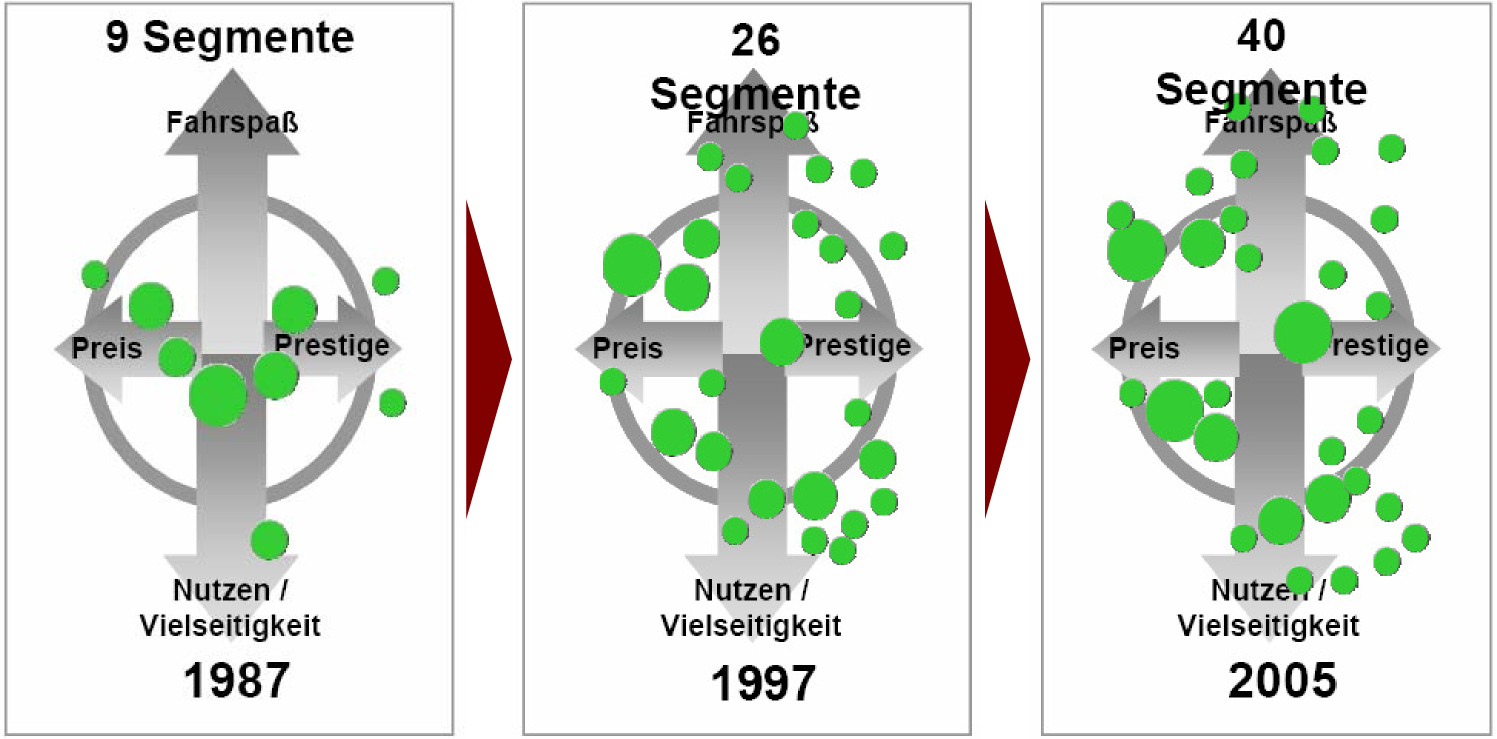


Relation between Model and Requirements – Real World



Product Lines / Reuse of Development Artifacts

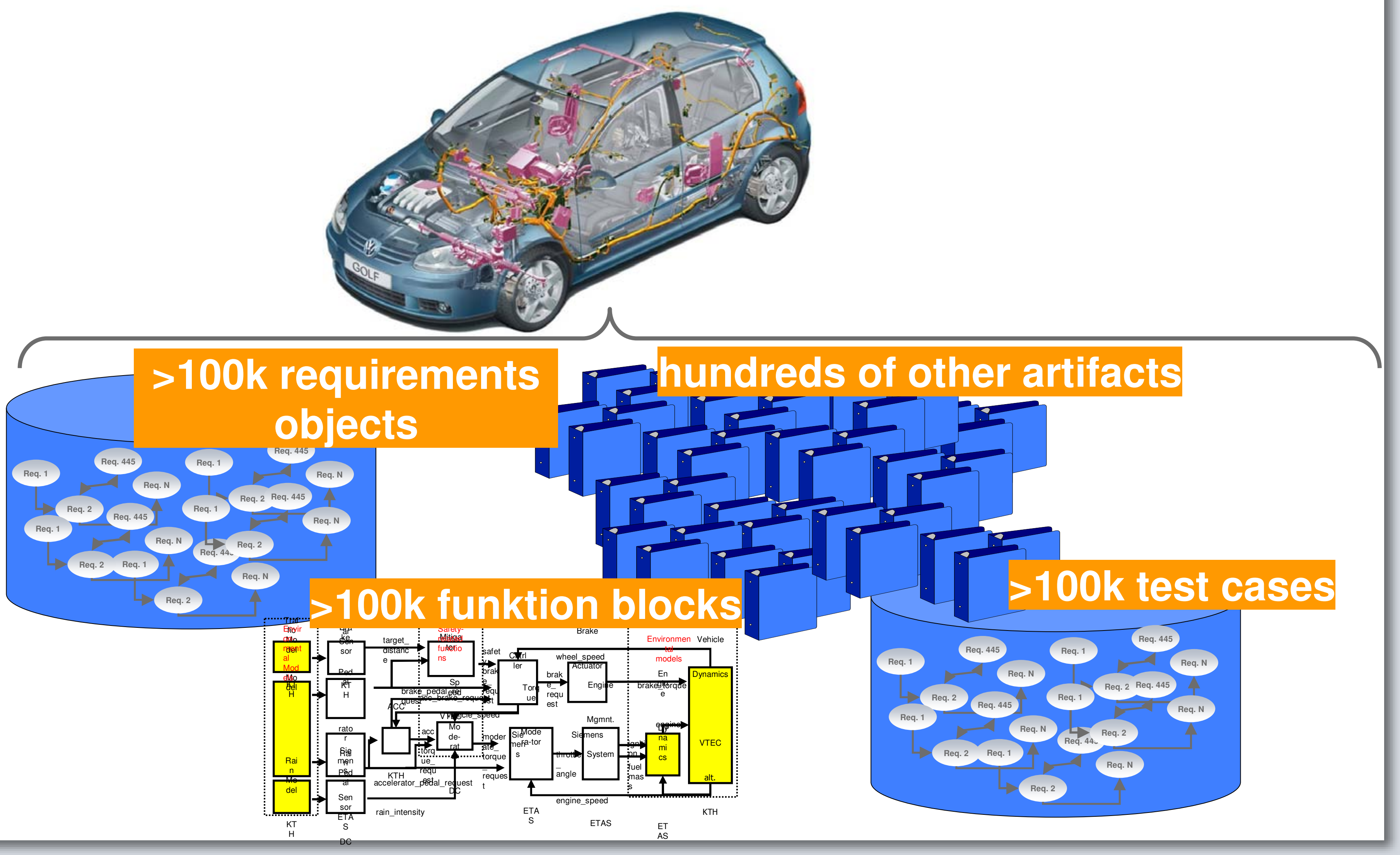
Market Segmentation



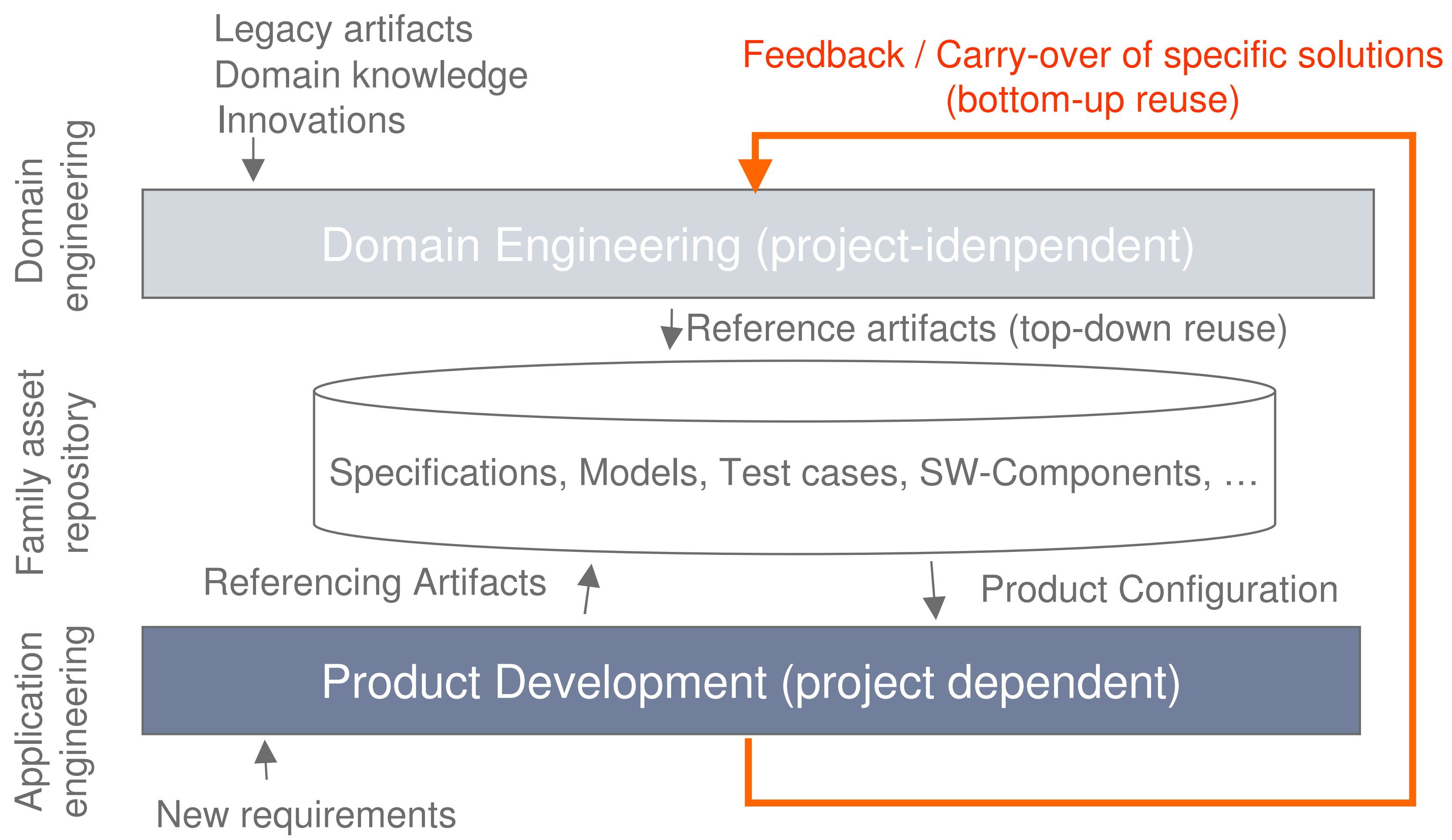
- Number of segments is increasing; size is decreasing.
- The significance of individual models is decreasing – product families are of growing importance.

„Leohold: Herausforderung zwischen Funktionsintegration und Komplexitätsmanagement"
(Automobil Elektronik 9. Internationaler Fachkongress 2005, Ludwigsburg)

Development Artifacts of an Automotive Electronic System

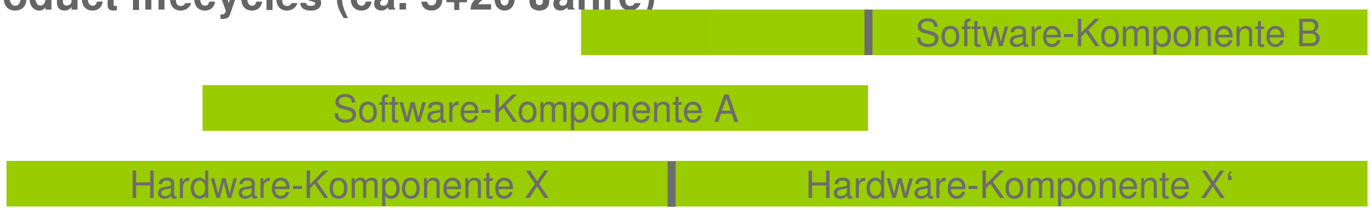


Product lines for Specifications / Models / Tests / Code etc. „Real World“



Reuse in the automotive domain

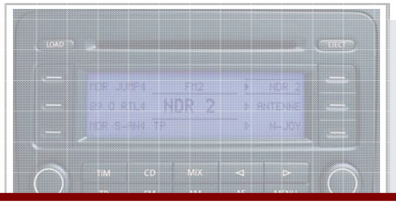
- **High Degree of Variability**
  - Car Platforms
  - Markets
  - Variant and Optional Functionality
  - Different Laws and Regulations (geoprahical, temporal)
  - Different Availability of Parts (geograpical, temporal)
  - Technology changes
  - Cost pressure
- **Heterogenity of run-time environment (Hardware & Software)**
- **Long product lifecycles (ca. 5+20 Jahre)**

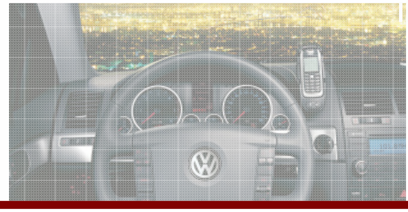


- **Diverging lifecycles (e.g. infotainment vs. safety-relevant functions)**

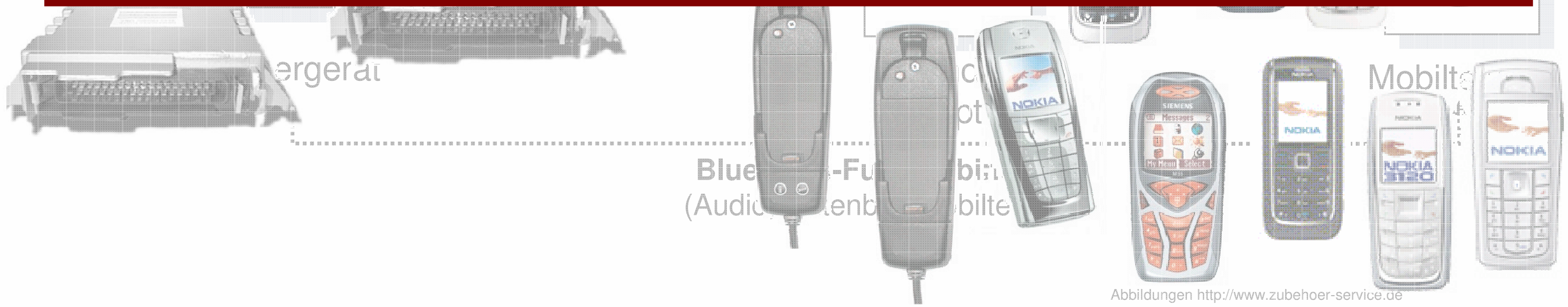
- → ***<u>Reuse is very difficult but indispensable</u>***

Herausforderungen für Volkswagen.
Beispiel Freisprecheinrichtung.





- **Different ECU Variants**
- **Different HMI concepts**
- **Different Cell-Phones**
- **Different Cell-Phone Adapters**
- **Different Software-Platforms**
- **Short Development Cycles in the Cell-Phone market with sharp rising functionality**



Abbildungen http://www.zubehoer-service.de

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Problem Areas.

Module Strategy

Lack of precision of module concept wrt. module variability and configuration

No clear identification of causes of variability

Insufficient basis of variability-related decisions

Development

Ad-hoc reuse of development artifacts leads to massive increase in variants

Rising variability after SOP base on technical changes and new parts

insufficient backward compatibility

Challenges Variant-Management in Automotive Electronics

Production

Configuration complexity in production keeps growing ⇒existing production logistics becomes insufficient.

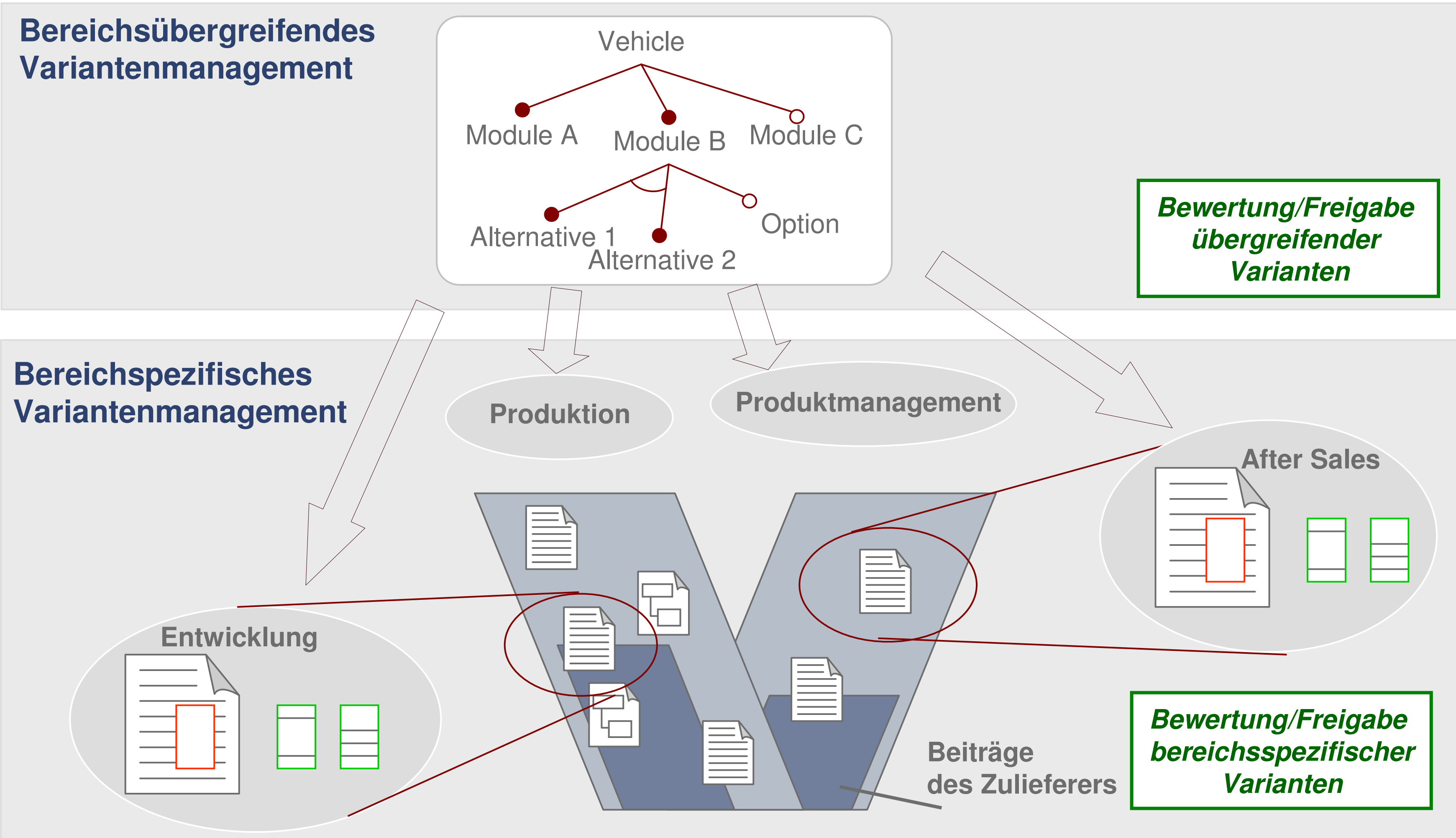
Specifics of production, such as use of left-over parts lead to many new variants in the field.

After-Sales

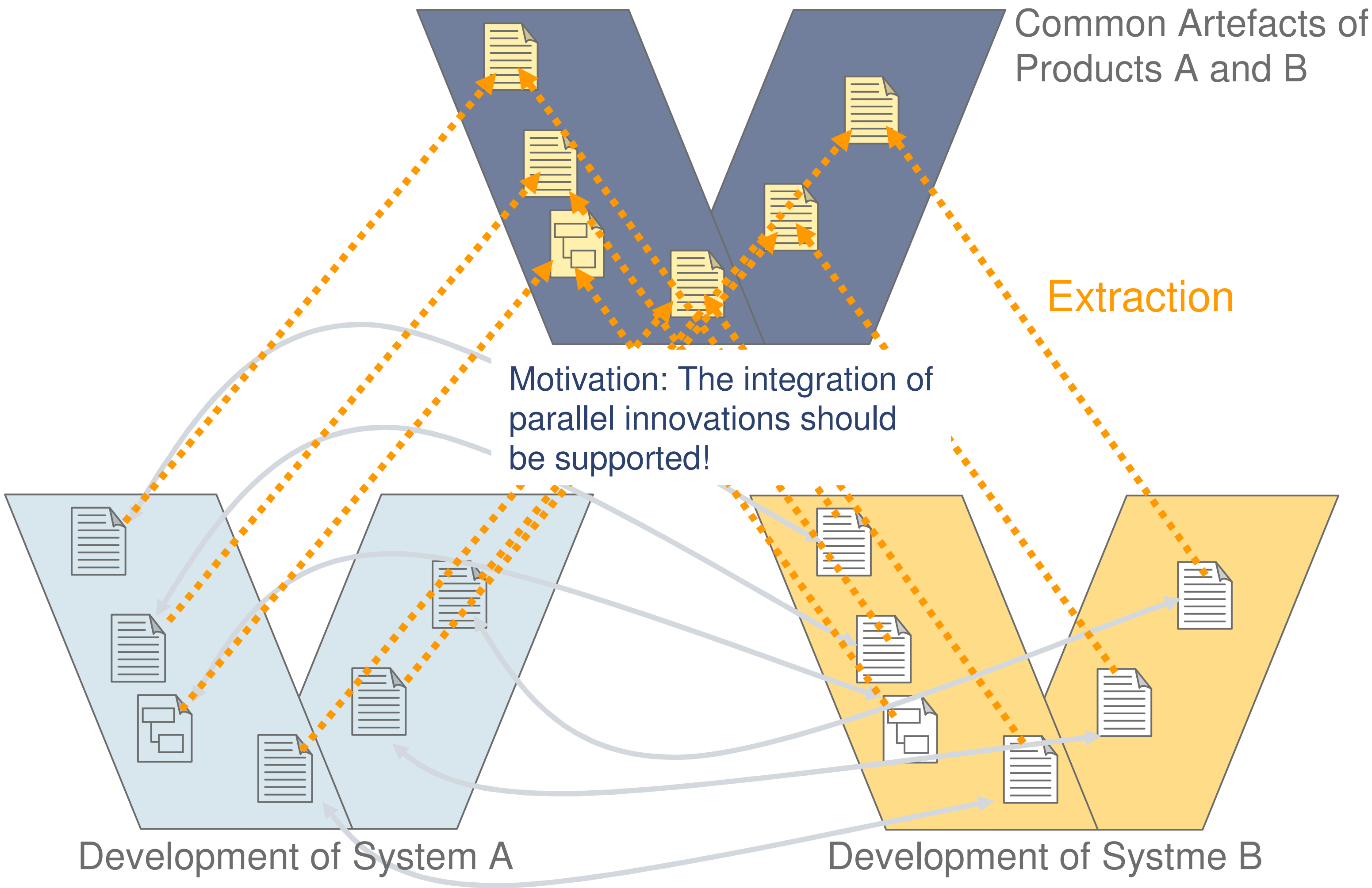
Variant-Complexity leads to increased storage costs to meet after-sales requirements

Rising number of variations in car-fleet based on flashware and parameterisations

Abstimmung Variantenmanagement@EE.



Integration of parallel Innovations / Introduction of product line development



Further Challenges

- Timing behaviour
- Error modeling

Thank You

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Backup - EAST-ADL2

Outline

- **Example usageof EAST-ADL2**
- Model Structure
- Example Model
- AUTOSAR Relation
- Areas covered by EAST-ADL2
- Conclusion

Some Typical Scenarios

The Vehicle Manufacturer decides what to include in the next product

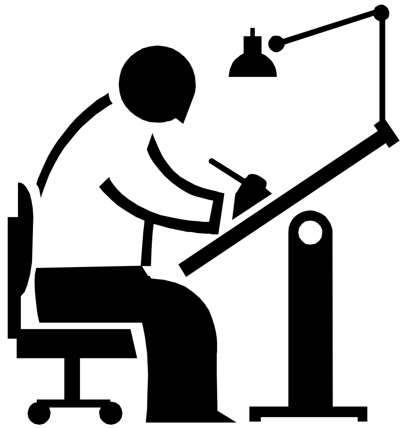
A Chassis engineer analyses a novel control algorithm

Application expert defines detailed design

Software engineer defines software architecture

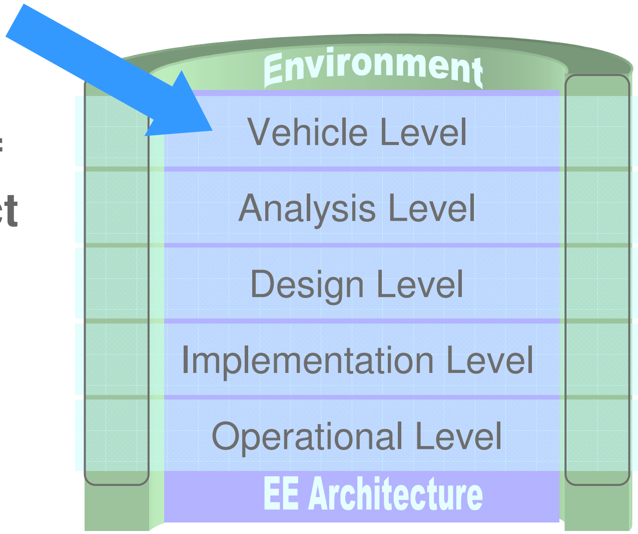
Packaging and allocation, Integration on ECU

Early phase validation and verification



Product Planners decide what to put in the next product

- Features represent the properties/functionality/traits *(Brake, Wiper, CollisionWarning, …)*
- Vehicle Feature Model organize Features for the vehicle
- Variability mechanism supports the definition of rules for inclusion in different vehicles – Product Line Architecture



A Chassis engineer analyses a novel control algorithm

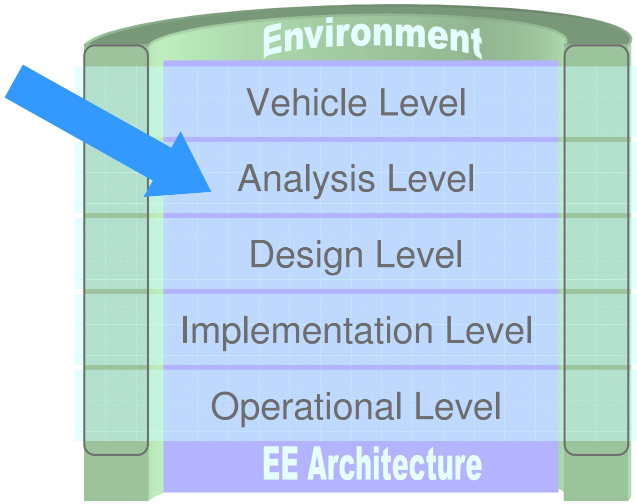
Control algorithm is defined as a ADLFunction connected to a plant ADLFunction in the Environment model

EAST-ADL2 defines structure, legacy tools can be used for behavior definition, simulation, etc.

Realization details are omitted:

Functional validation and verification can be done with respect to key aspects

Understanding of key aspects is possible

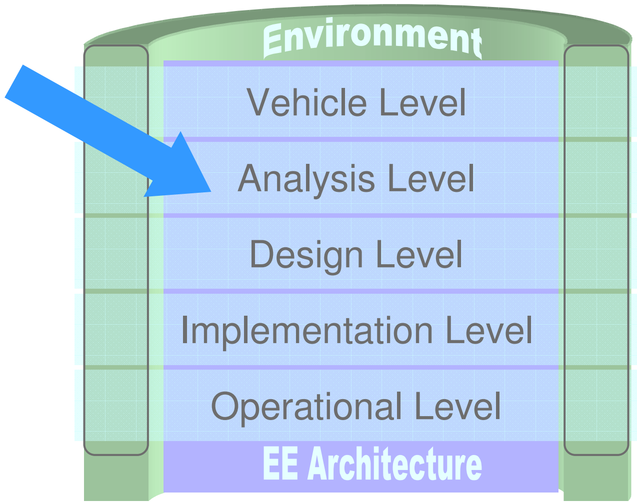


An OEM and Supplier agree on specification

A model of the supplied system provides a clear and effective information exchange

Functions can be integrated and validated before SW and HW exists

Interfaces and interaction is clear, avoiding common specification bugs

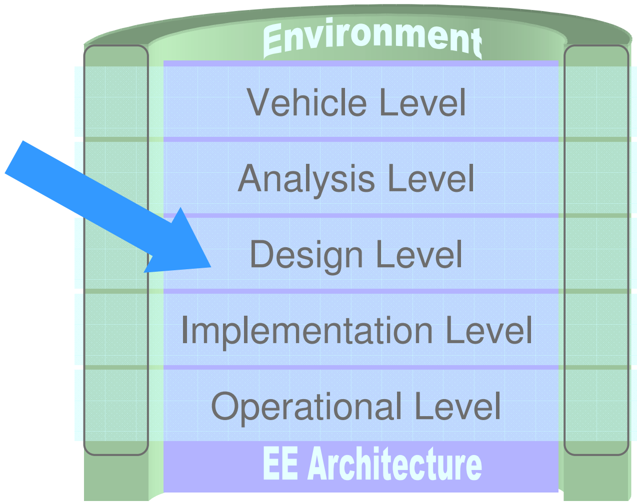


Application expert defines detailed design

A detailed functional architecture is defined, addressing e.g.

- Hardware architecture
- Allocation
- Fault tolerance
- Implementation concerns
- Sensor, actuator constraints

Focus is behavior and interaction of functions



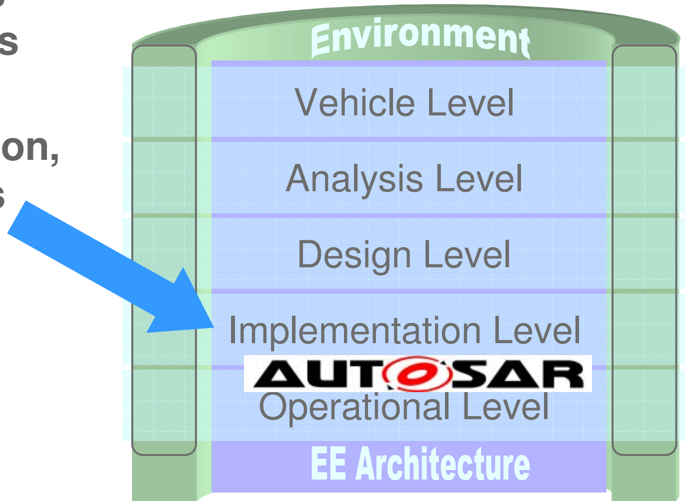
Software engineer defines SW Architecture

AUTOSAR Application SW Components are defined

The set of SW components together realizes the Functional Architecture

Software organization and functional organization is decoupled and optimization of the SW architecture is possible.

Legacy, sourcing, allocation, performance, verification, responsibility, re-use, etc. influence which functions are realized by each SW component



Outline

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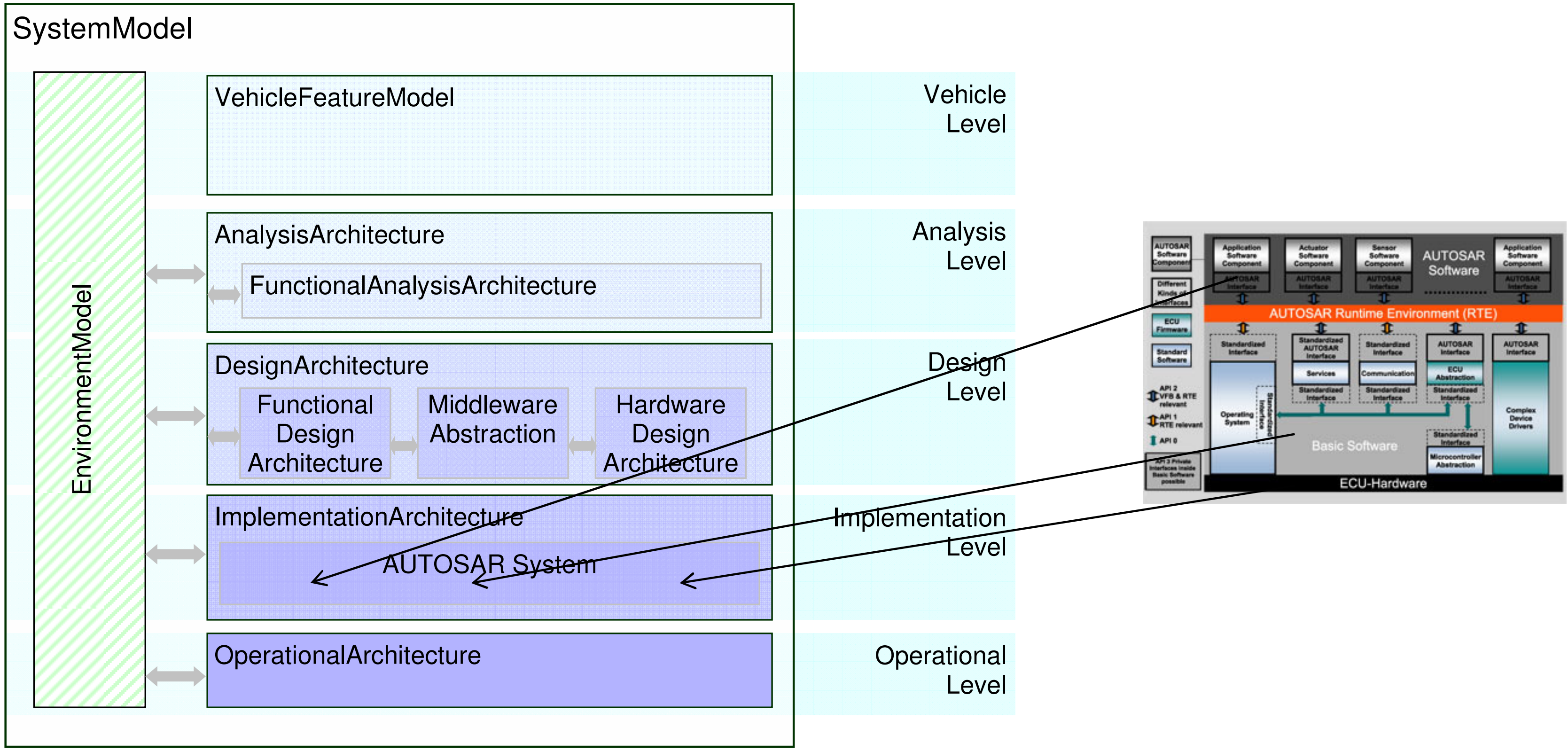
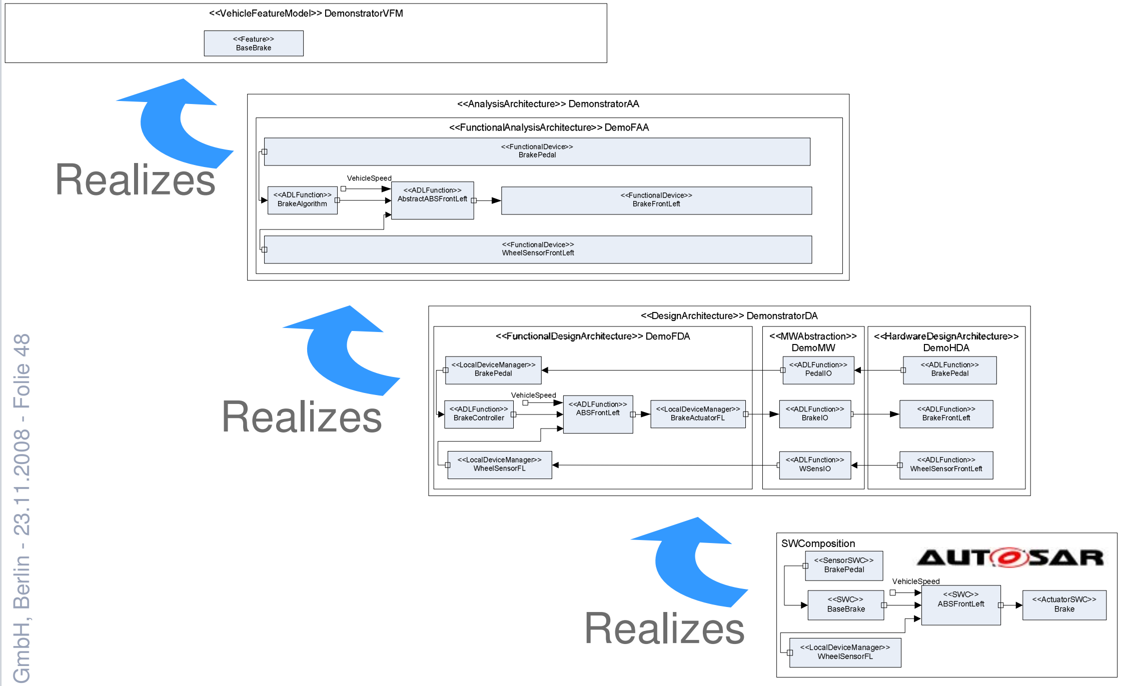
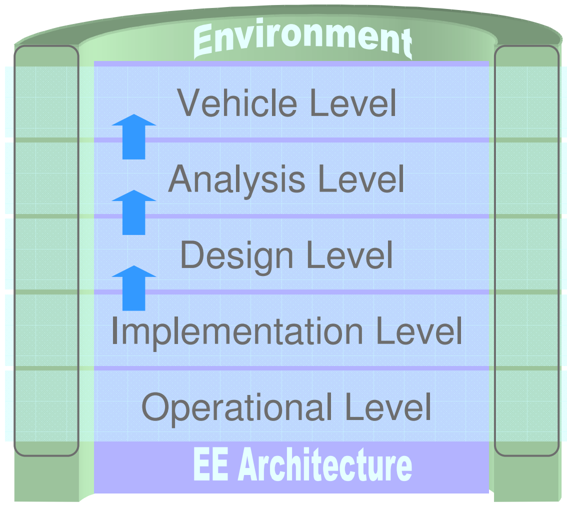
EAST-ADL2 System Model



Principle of Realization

- Entities on lower abstraction level realizes Entities on higher abstraction level





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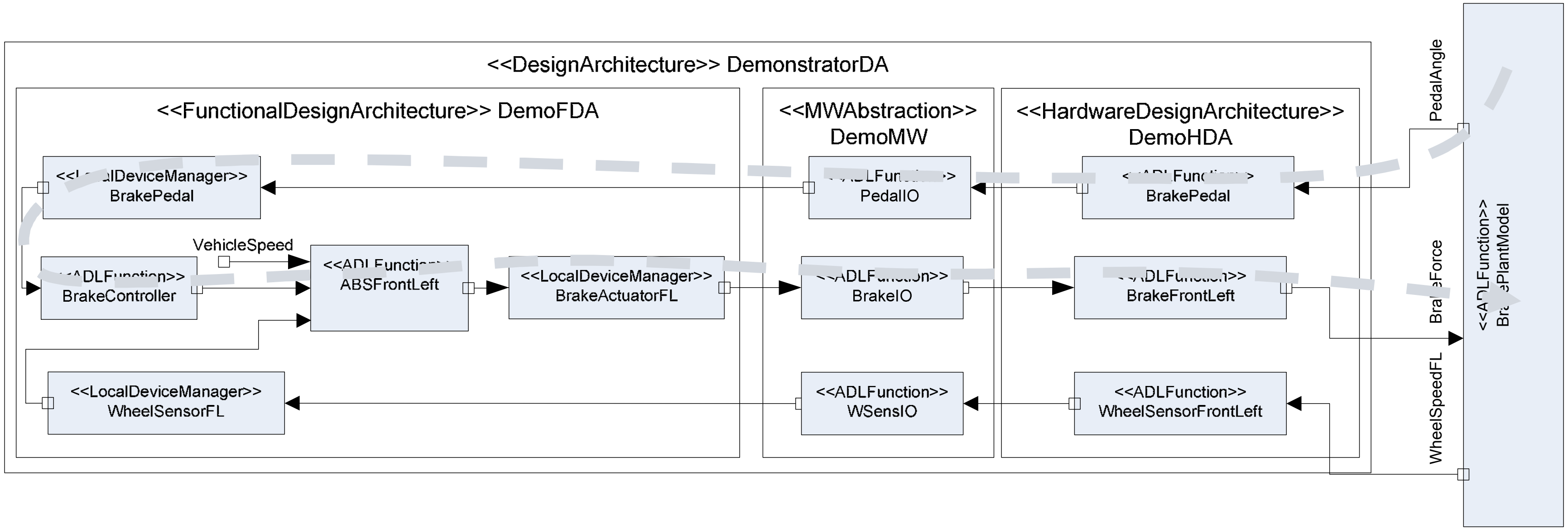
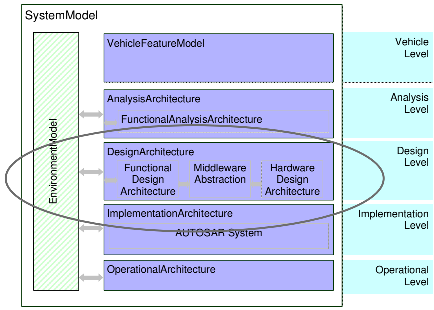
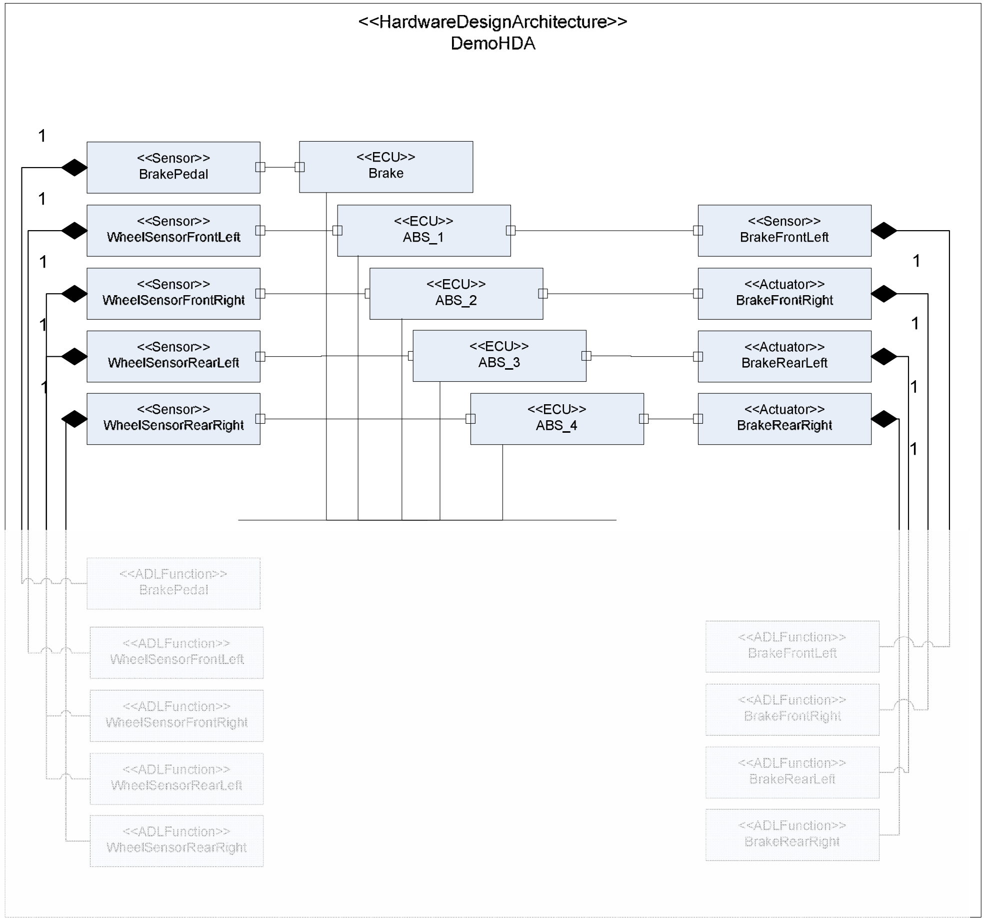
Function interactions – end-to-end



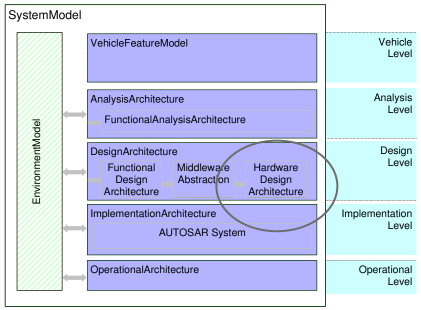
▪Model structure supports interaction with the environment and end-to-end functional definitions



Hardware Design Architecture



- Hardware architecture to allow hardware design and functional allocation
- Behavior of HW entites can be defined for analysis of end-to-end function



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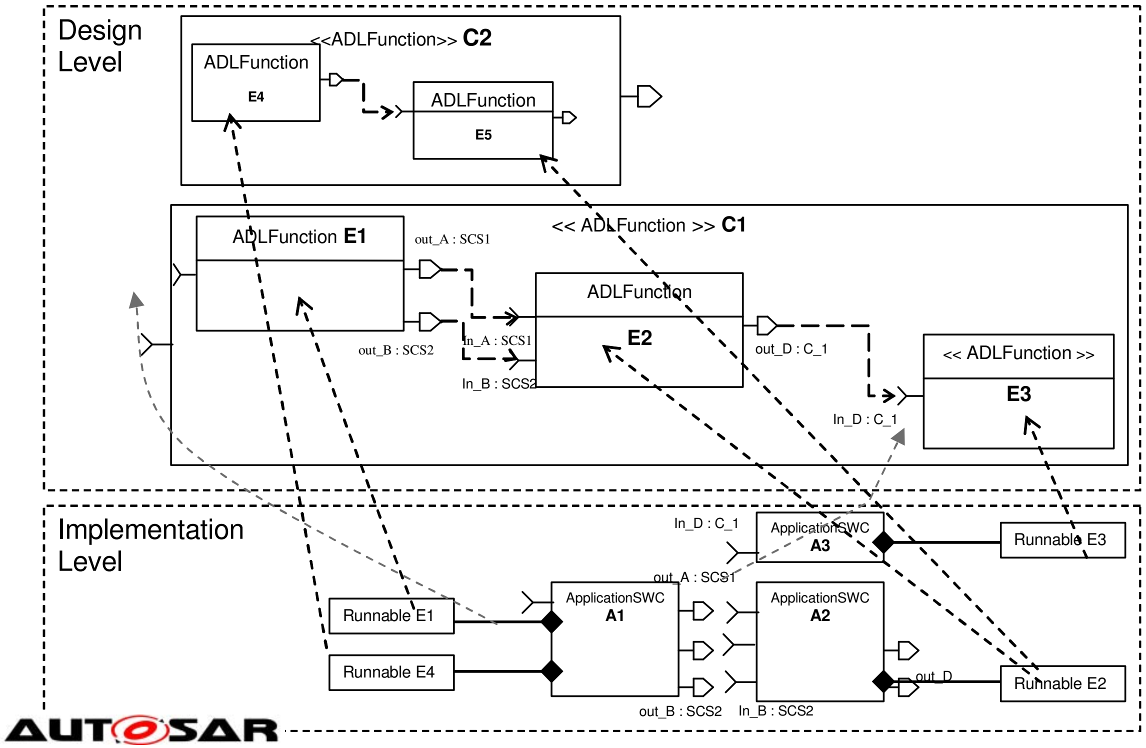
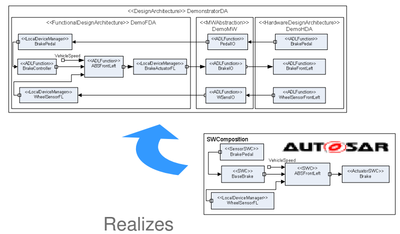
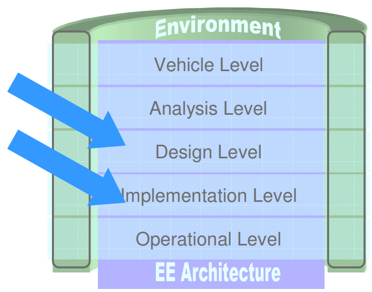
EAST-ADL2 Complements AUTOSAR

- **EAST-ADL2 is an information structure including aspects beyond the Software Architecture**
  - Requirements, traceability, feature content, variability, safety, etc.
- **Provides means to define what the software does**
  - An AUTOSAR specification defines the software architecture and information required for SW integration - but is neutral to its functionality
- **Provides means to model strategic properties**
  - Key vehicle aspects is captured independently of the software architecture
- **Supports modelling of error behavior and the representation of safety-related information and requirements**

EAST-ADL2 – AUTOSAR Mapping





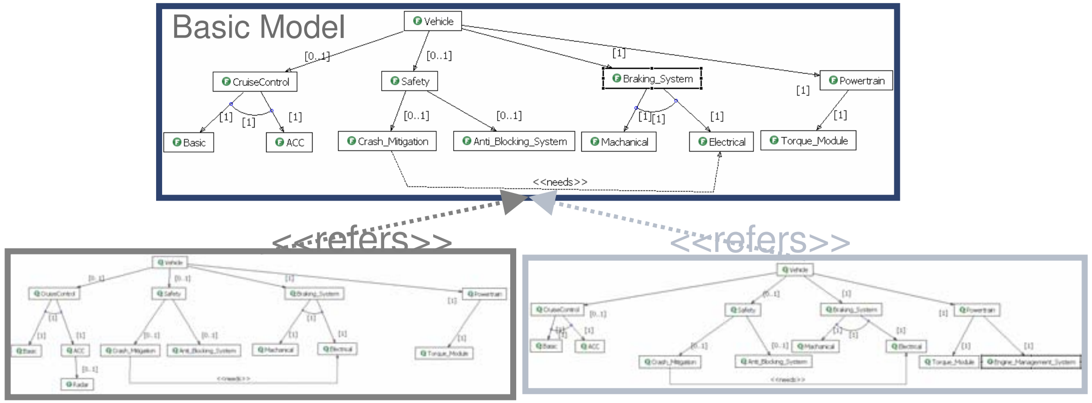


Outline

- Example usage of EAST-ADL2
- Model Structure
- Example Model
- AUTOSAR Relation
- **Areas covered by EAST-ADL2**
- Conclusion

Variability

- **Definition of Feature Content of Vehicle using Feature Trees**
  - Definition of Product Line in terms of mandatory and optional features for each vehicle category
- **Definition of Variability rules for realization**
  - Optional/mandatory functions and components
  - Definition on how to resolve variability based on feature content

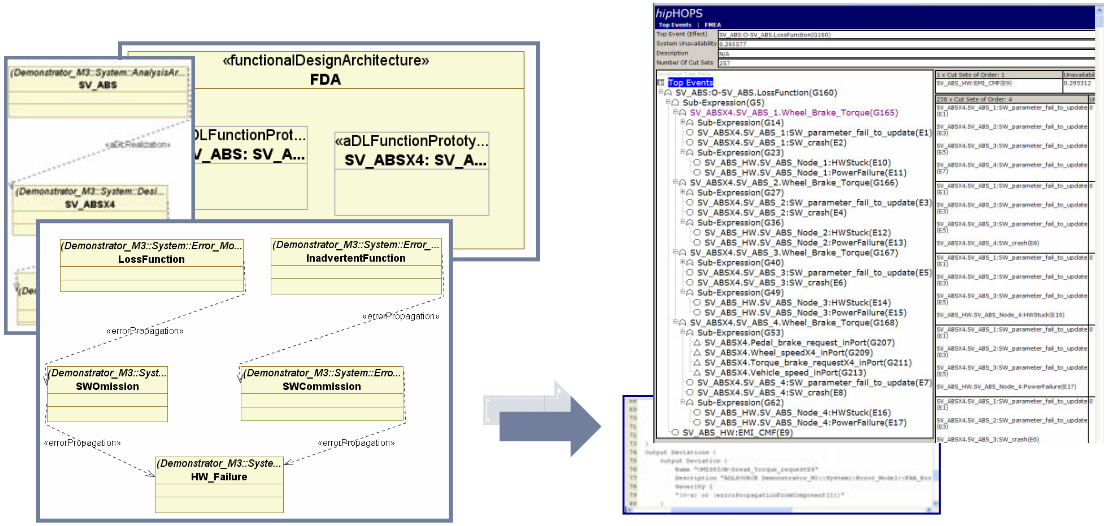


Requirements and V&V

- **Definition of Requirement modelling framework based on SysML**
  - Concepts for capturing requirements and components in same model
  - Traceability between requirements, components and V&V
- **V&V constructs to capture test case, test outcome, etc.**
- **Integration of RIF concepts (Requirement Interchange Format)**

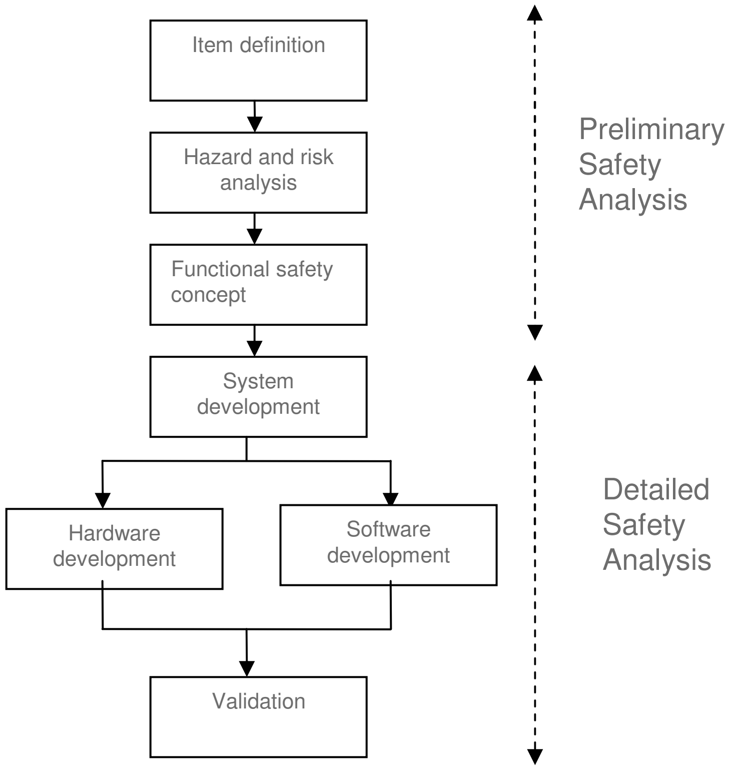
Error modelling & failure analysis

- Modelling Concepts for Hazards and Error Propagation
- Basis for Hazard Analysis and Fault Tree and Failure Modes and Effects Analysis
- Tool Interface for Automatic FTA/FMEA



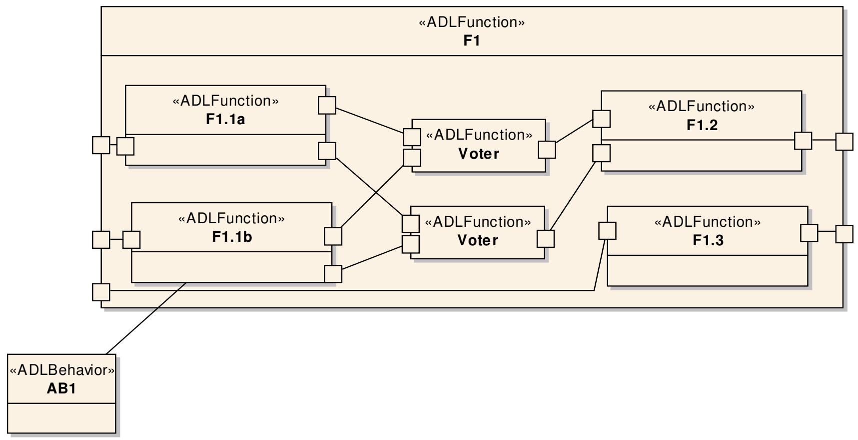
Safety Aspects & ISO 26262

- ASIL Categorization through requirements
- Support for Safety Case – Use of model entities to argue safety
- Organization of informationin line with ISO 26262
- Support for methods required by ISO26262



Behavior

- Definition of Behavioral semantics to allow legacy tool integration
  - Ascet, Simulink, legacy code, etc.
- "Native" EAST-ADL2 definition of Behavioral semantics
- Definition of relation to AUTOSAR behavior
- Behavioral Semantics for Environment model (Plant)



Outline

- Example usage of EAST-ADL2
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Conclusion

- **EAST-ADL2 provides an information structure for design of automotive embedded systems**
  - Architecture Description Language
- **Use of abstraction levels is a fundamental concept**
  - entities on lower levels *realize* entities on higher levels
- **EAST-ADL2 is a fully aligned complement to AUTOSAR**
  - AUTOSAR is the SW architecture definition enabling SW component integration on ECU
  - EAST-ADL2 supports the successful integration of AUTOSAR components
  - EAST-ADL2 Supports additional engineering steps including

    feature definition, requirements engineering, V&V , safety analysis, functional modeling/integration, product line engineering