Integration of systems engineering and simulation based on standards
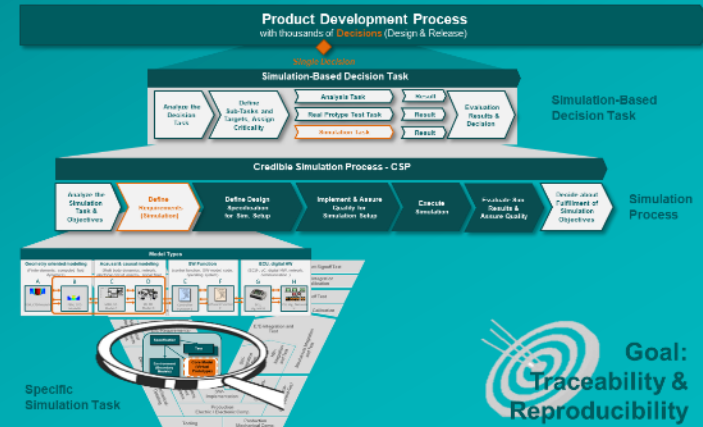
The needs, challenges and solutions from an industrial perspective

Modelica Conference 2025

Daniel Krems (AVL List)
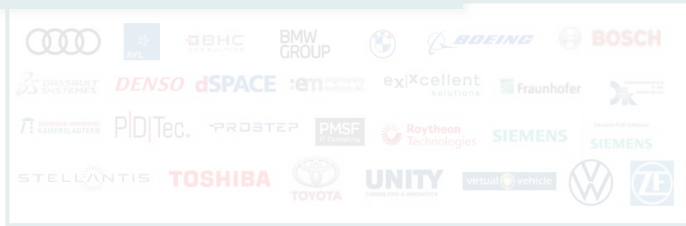Hans-Martin Heinkel (Robert Bosch)
Thomas Schwartzkopff (Robert Bosch)

Smart Systems Engineering - SmartSE
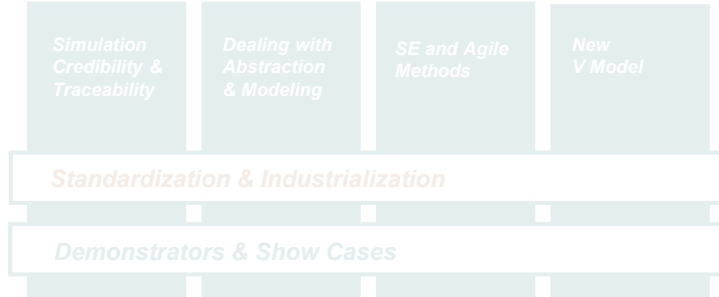## Building Blocks for cross-company simulation-based engineering

**25+ project participants**

Mission Phase 5 (2022-2024)

Enabling collaborative development and validation of complex products by simulation along a multi-tier supply chain.

SmartSE Project Organization

Simulation Credibility & Traceability	Dealing with Abstraction & Modeling	SE and Agile Methods	New V Model

Standardization & Industrialization

Demonstrators & Show Cases

Processes
Structuring, assignment responsibilities

Methods
I.e. Functional Safety Standard, FMEA, Simulation Credibility Standard

Information
Harmonization of metadata, semantics, interfaces

Data Formats
heterogeneous IT environments, collaboration between partners

Blueprint and Building Blocks for a targeted standardization

The initiation, development and industrialization of standards in the field of model-based and cross-company development is an important part of the work of the SmartSE project group.

What is systems engineering?
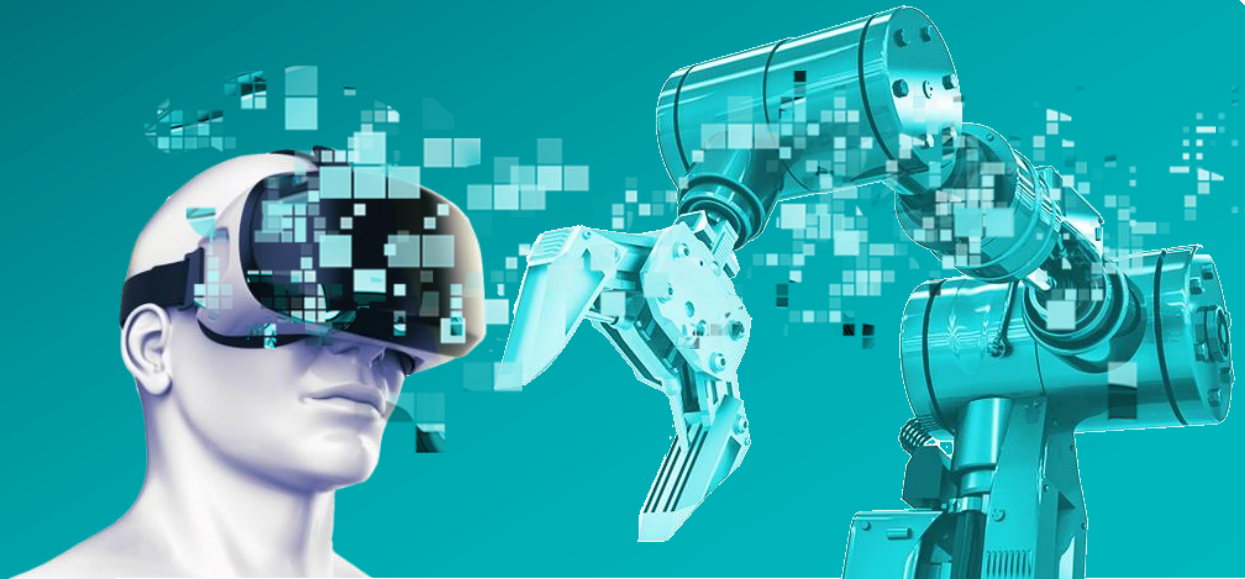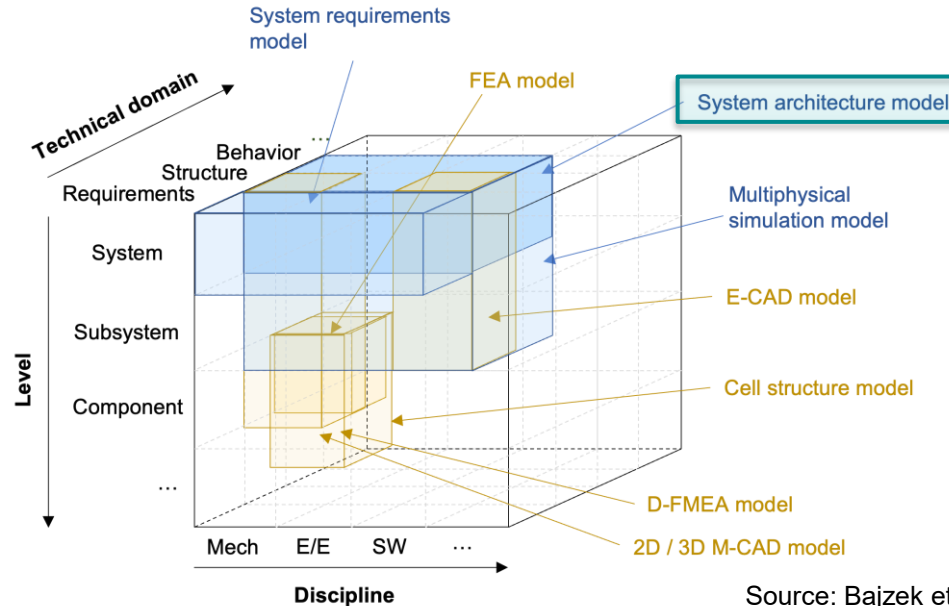
The goal of product development:
Be on time, on spec, on cost, achieve high customer satisfaction

Source: INCOSE & Bosch

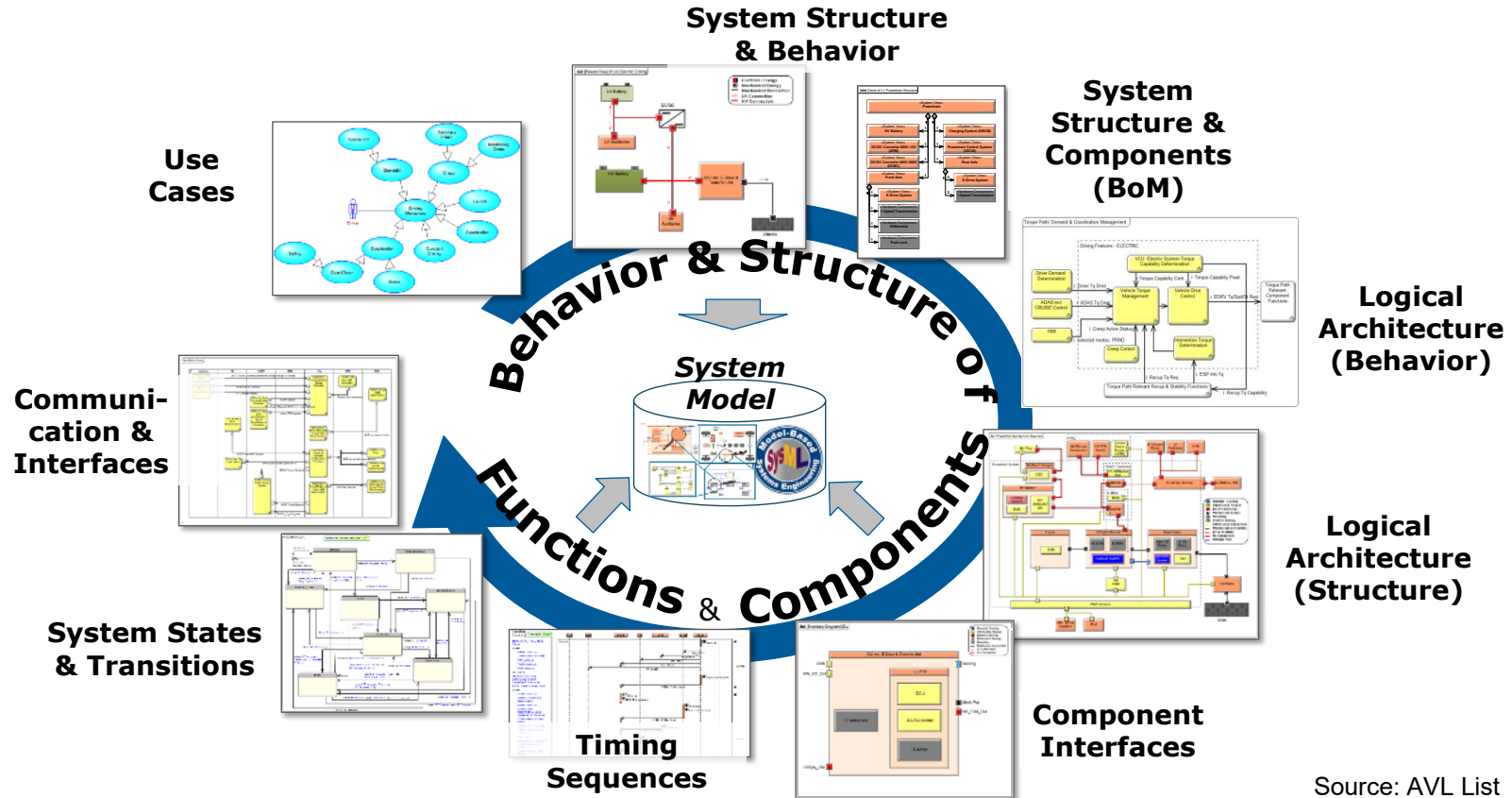# Solution: (Model-based) systems engineering

MBSE: Framework for consistently handling connected & dependent information
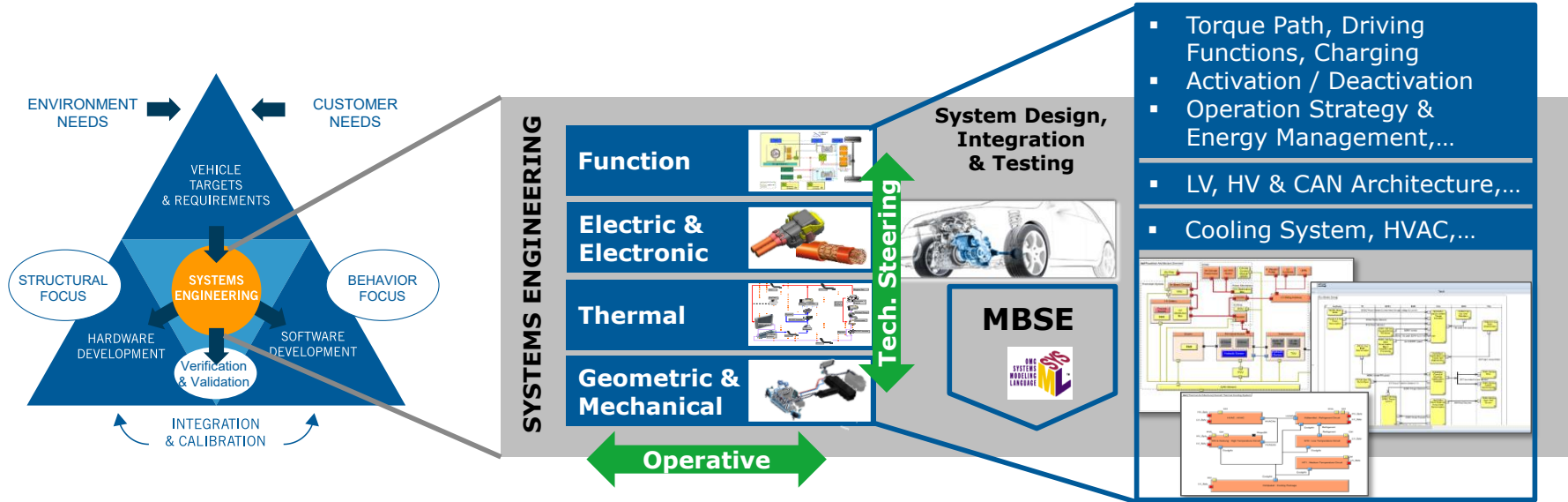

Source: Bajzek et al.

System knowledge is in the system architecture model as single source of truth

Content of a system architecture model

System Structure & Behavior

System Structure & Components (BoM)

Use Cases

Logical Architecture (Behavior)

Communication & Interfaces

Logical Architecture (Structure)

System States & Transitions

Component Interfaces

Timing Sequences

Behavior & Structure of Functions & Components

System Model

Source: AVL List
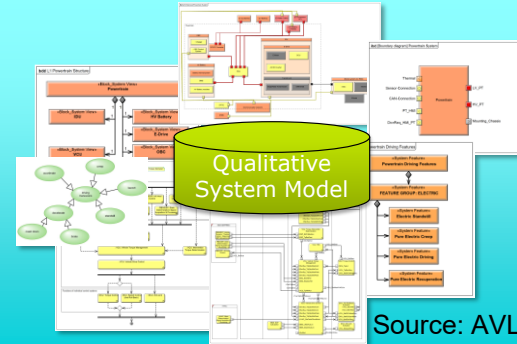
Application of MBSE: Example from AVL List

Source: AVL List

System model vs. system model

System model:
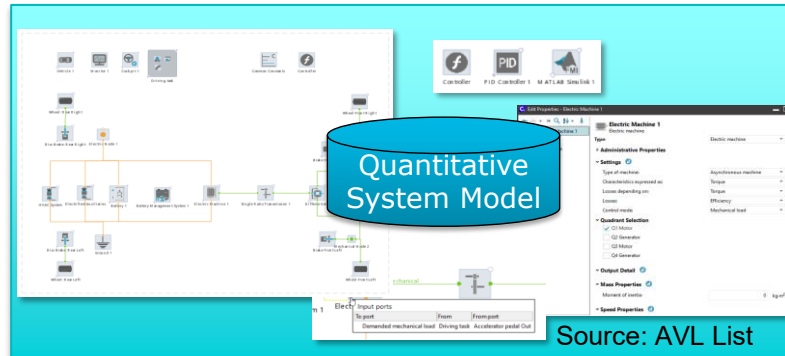- Qualitative & descriptive
- Multi discipline system design
- Structural und behavioral description
- Limited "simulation" capabilities

Qualitative System Model

Source: AVL List

Quantitative System Model
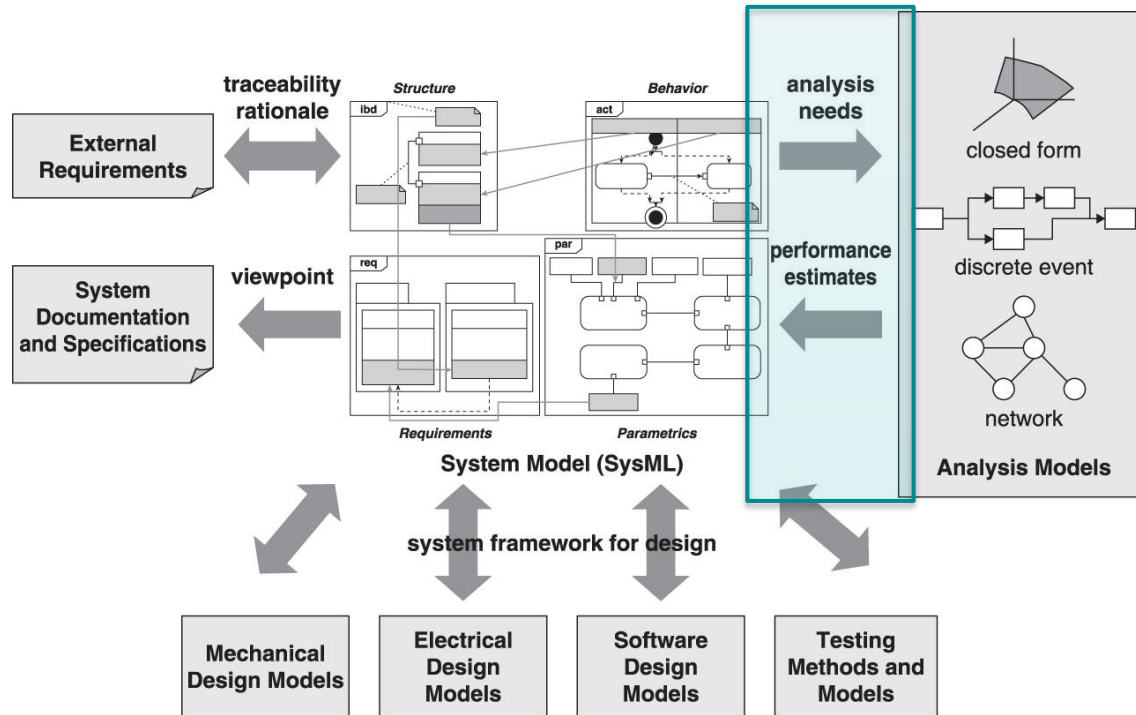
Source: AVL List

System model:
- Quantitative & executable
- Focus on virtual V&V
- Defined by the simulation purpose
- Structural, behavioral, and parameter description required as input
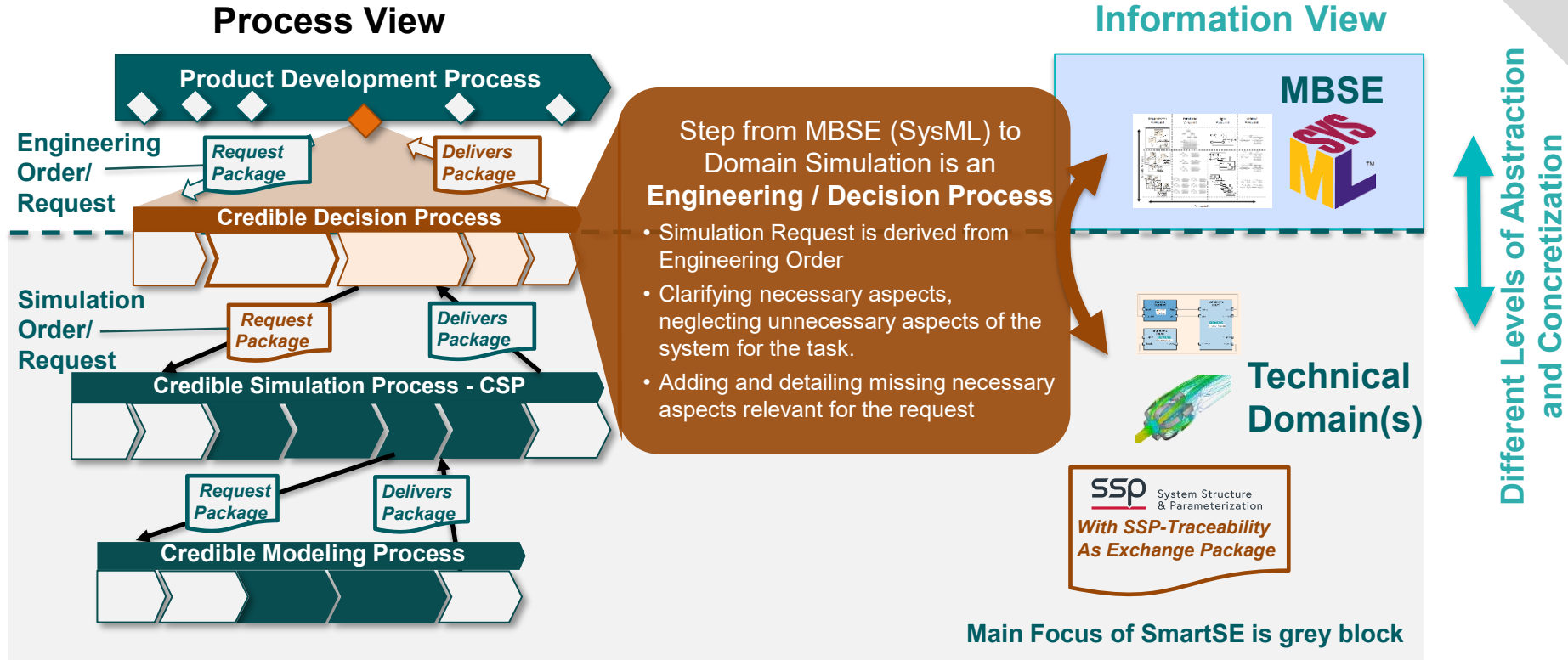
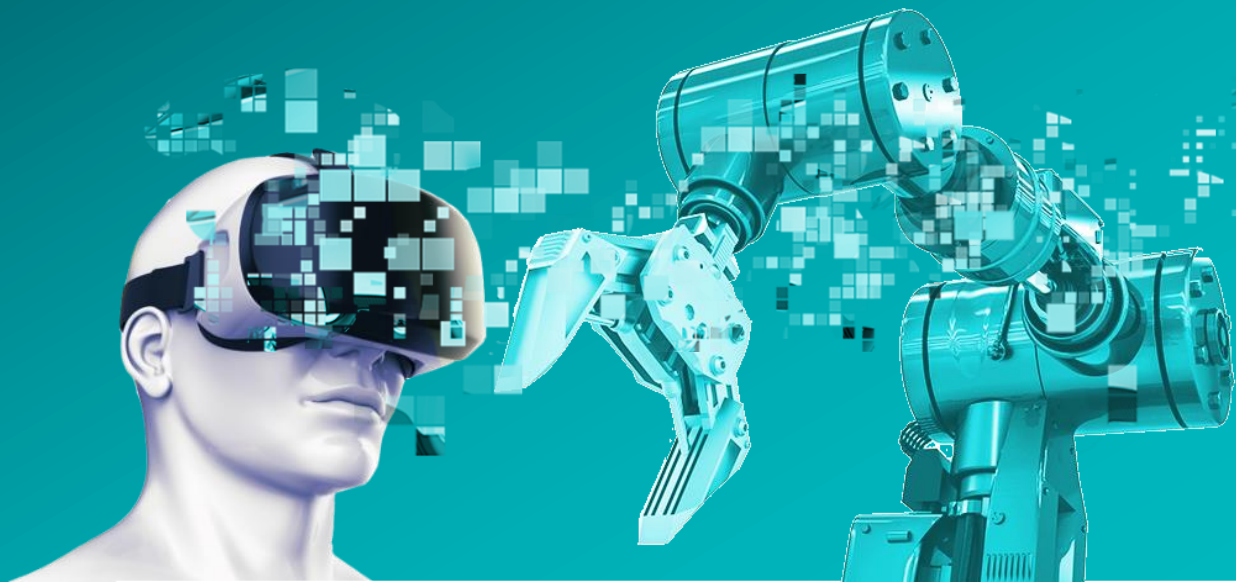# Mission Statement

Our target

Source: Friedenthal

- Bridge the gap between architecture and simulation
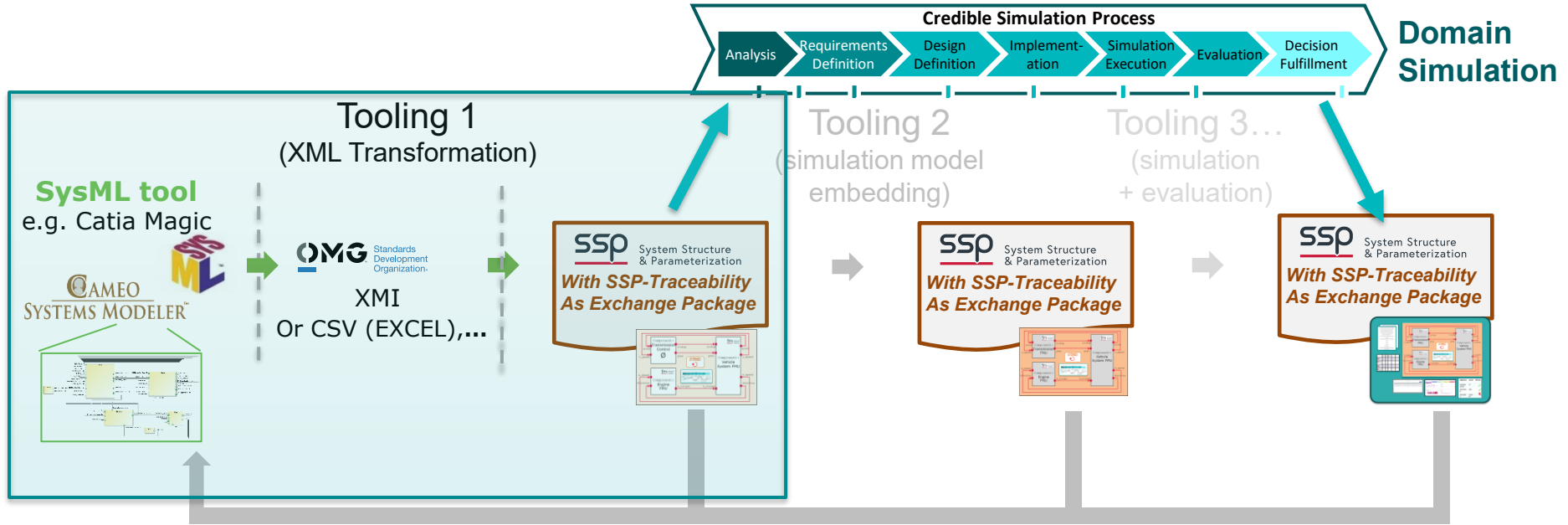- Ensure standards-based & seamless interoperability

Connect SysML with domain simulation based on SSP

Process View

- Product Development Process
- Engineering Order/ Request
- Request Package
- Delivers Package
- Credible Decision Process
- Simulation Order/ Request
- Request Package
- Delivers Package
- Credible Simulation Process - CSP
- Request Package
- Delivers Package
- Credible Modeling Process

Step from MBSE (SysML) to Domain Simulation is an **Engineering / Decision Process**

- Simulation Request is derived from Engineering Order
- Clarifying necessary aspects, neglecting unnecessary aspects of the system for the task.
- Adding and detailing missing necessary aspects relevant for the request

Information View

MBSE

Technical Domain(s)

SSP — System Structure & Parameterization

With SSP-Traceability As Exchange Package

Main Focus of SmartSE is grey block

Different Levels of Abstraction and Concretization

Results

SysML↔SSP toolchain vision

Credible Simulation Process

Analysis | Requirements Definition | Design Definition | Implement-ation | Simulation Execution | Evaluation | Decision Fulfillment

Domain Simulation

Tooling 1
(XML Transformation)

SysML tool
e.g. Catia Magic

CAMEO SYSTEMS MODELER™

OMG Standards Development Organization®

XMI
Or CSV (EXCEL),…

SSP System Structure & Parameterization
With SSP-Traceability As Exchange Package

Tooling 2
(simulation model embedding)

SSP System Structure & Parameterization
With SSP-Traceability As Exchange Package

Tooling 3…
(simulation + evaluation)

SSP System Structure & Parameterization
With SSP-Traceability As Exchange Package

SSP-Traceability standard for exchange package for structuring information

SysML↔SSP demonstrator architecture

SysML↔SSP demonstrator architecture

SysML tool
e.g. CATIA Magic

XMI

Model Transformation

Model Transformer
SysML → SSP

System Structure & Parameterization

Traceability

SSP tool
Model.CONNECT

«SystemRequirement»
Maximal Torque

Id = "3"
isAssumption = false
Text = "The maximal Torque shall be 15Nm"
ValidationStatus = New/Changed

«testCase»
TC StartUptime

attribute
: WiperDirectMotor
: SensorRotationalSpeed
: SensorMomentum
: RotationalBrake
: PowerSupply
: MeasurementSystem

«EngineeringOrder»

Dokumentation = "Verify the the requirement start time with test case 1 for the selected design"
Verify start time

Business value

System under development
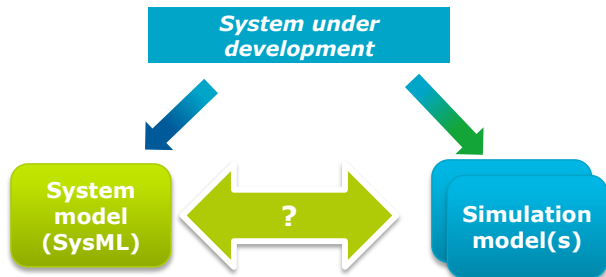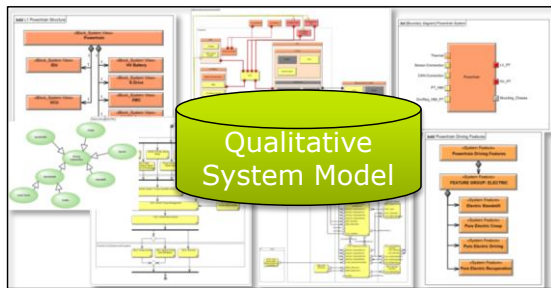
System model (SysML):

- Qualitative & traceable interdependencies
- System structure & behavior
- Holistic views / all disciplines

System model (SysML)

?

Simulation model(s)

Simulation model:

- Quantitative & executable for one discipline
- Target development
- Virtual verification

Qualitative System Model

SysML model to automatically set-up:
- Co-Simulation model in Model.CONNECT™
- 1D simulation model in CRUISE M

Quantitative System Model
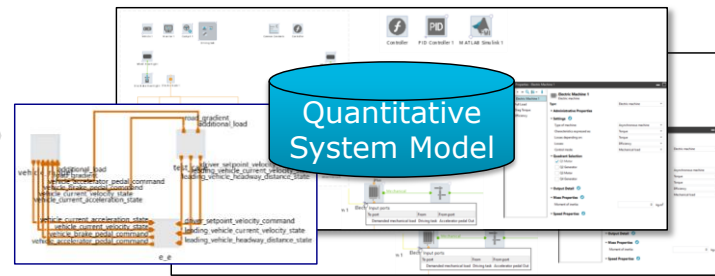
Reduce effort for simulation model set-up from approx. 19 week up to ~6 weeks

Source: AVL List

Next Steps

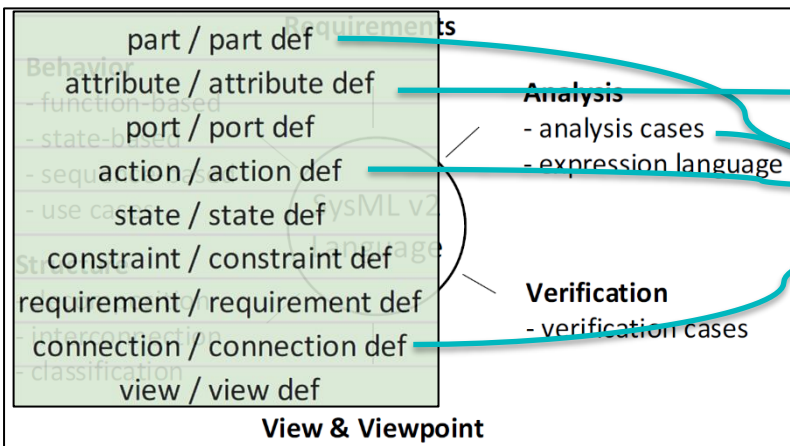# Identify relevant information objects for simulation

Category	Description	Example	Example format	Authoring system
Management	Administrative data about simulation task	Projekt number, projekt name	Excel, email	Project management
	Validation plan	Project design validation plan	Excel	Excel
	Simulation task definition	Simulate the vehicle driving performance	PPT, SSP-Traceability	Sharepoint, PLM, SPDM
MBSE	Requirements	Vehicle energy consumption in WLTP drice cycle	ReqIF, SSP-Traceability	Requirements management
	System architecture	Components, interfaces	XMI, JSON	MBSE / SysML
	Simulation parameter values	Vehicle mass	CSV	Excel, SPDM
	KPIs	12 kWh / 100 km	CSV	SPDM
	Test case	WLTP	PPT, ReqIF	Requiremements mgmt., test mgmt.
	Test specification	WLTP velocity profile incl. ambient conditions	CSV	SPDM, test mgmt.
Simulation	(Co-)simulation architecture	Coupling of component simulation models	SSD	(Co-)simulation tool
	Simulation tool	Simulink		Simulation tool
	Simulation model interfaces		FMI	
	Simulation results (raw)	Time series of power usage	CSV	Simulation tool
	Simulation results (post-processed)	12.3 kWh / 100 km	CSV	Simulation tool
	Post processing routine	Script for computing energy consumption from power	py	Data analytics platform

Identify relevant information objects for simulation

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MBS	Requirements	Vehicle energy consumption in WLTP drice cycle	ReqIF, SSP-Traceability	Requirements management
				mgmt., test mgmt.
	Test specification	WLTP velocity profile incl. ambient conditions	CSV	SPDM, test mgmt.
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Target: Define a systematic, robust, comprehensive list of information objects relevant for MBSE and domain simulation
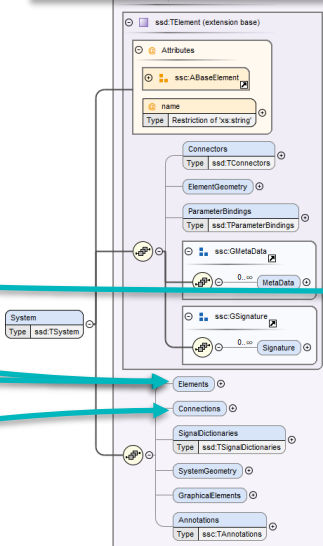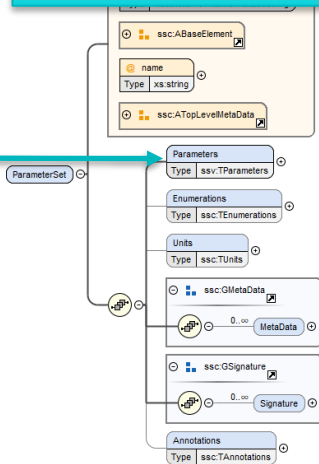
Connect SysML V2 to domain simulation

SSD System

SSV Parameterset

SSP LS-T: STMD

Source: Friedenthal

Target: Define a systematic, robust, comprehensive mapping from SysML v2 to SSP & SSP LS-T
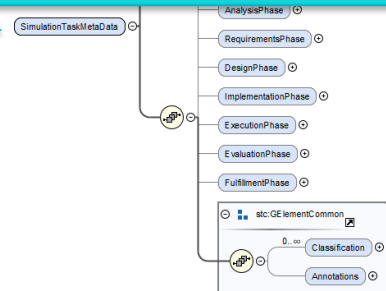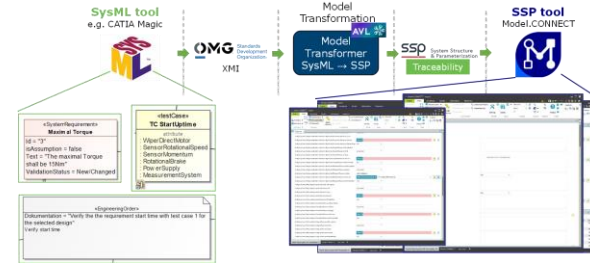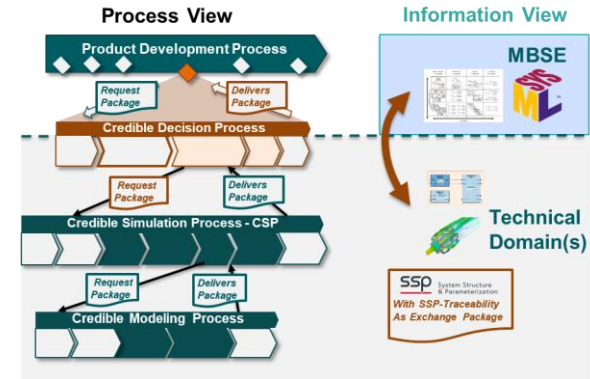
Conclusion & takeaways

- **MBSE** is a way to handle system-level complexity in product development

- **System architecture model** defines system structure & behavior

- **Coupling** of MBSE and domain simulation supports engineering processes

- Prostep SmartSE leverages **standards to ensure interoperability**

- Prostep SmartSE works on a **robust recommendation** to integrate SysML and SSP

Thank you for your attention