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Model Inconsistencies and Solution Approaches to Maintain Consistency in Model-based Systems Engineering

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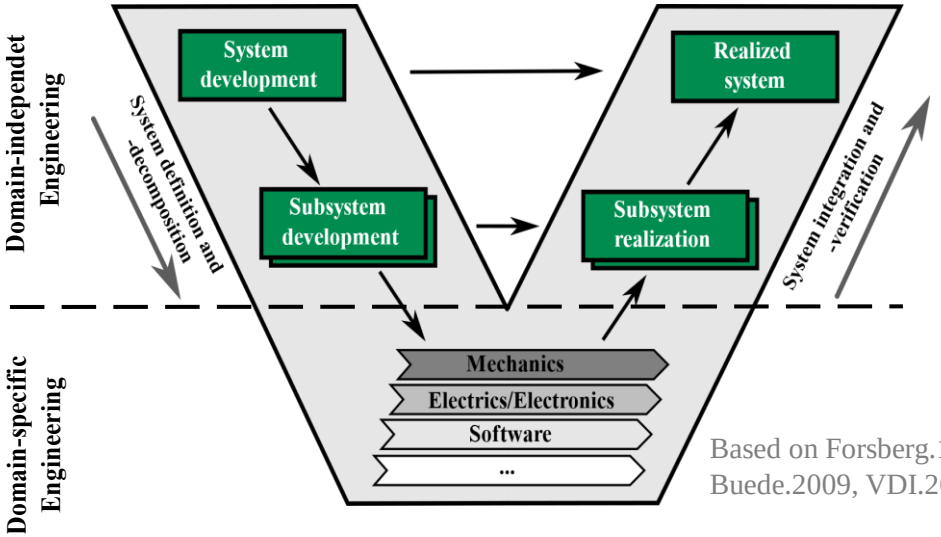
Resume of the presenter

- **2012:**
  Master degree in *Business and Engineering* at Clausthal University of Technology
- **2012 – 2020:**
  working in different positions at automotive industry
- **Since 2020:**
  PhD-candidate at Clausthal University of Technology

  Research interest:
  Model-based Systems Engineering

Domain-independent and domain-specific engineering

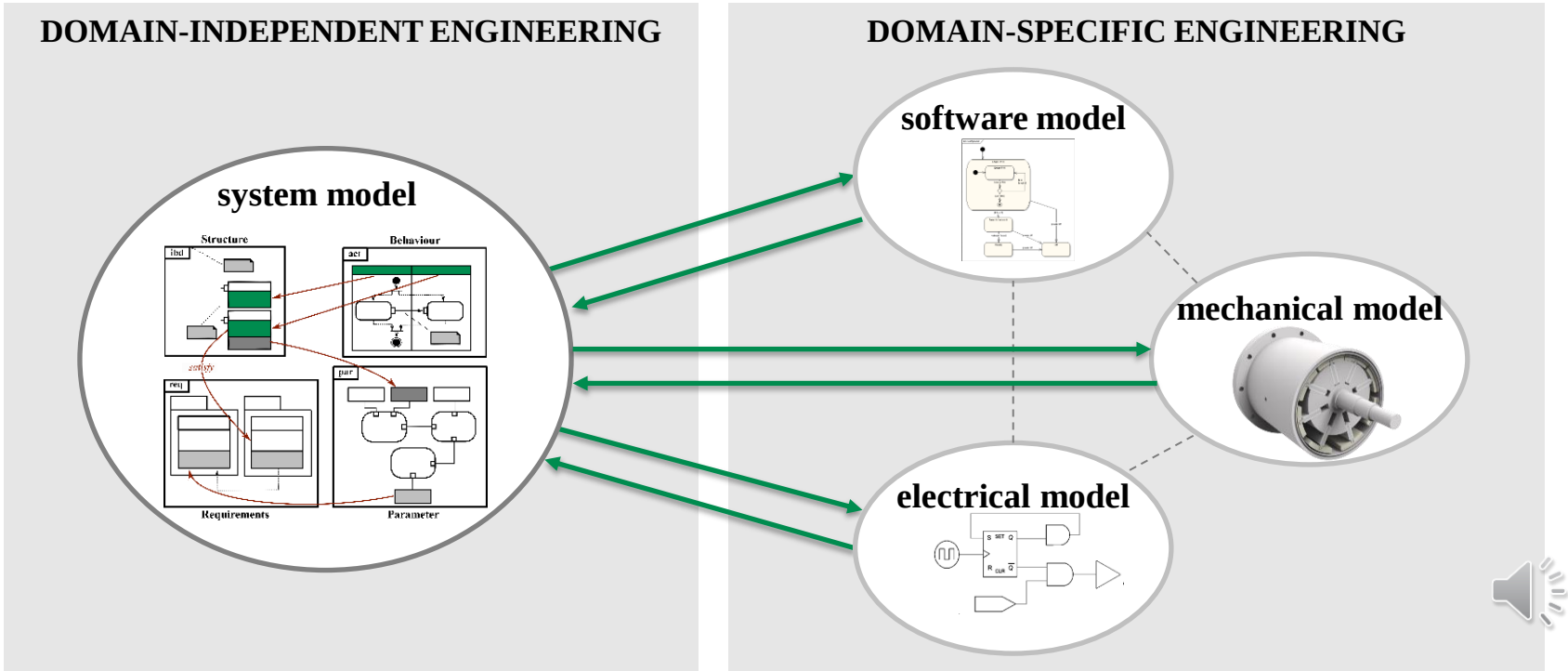


Based on Forsberg.1995, Buede.2009, VDI.2021

- Vee-Model is characterized by a Top-Down proceeding
- Elemental elements of this proceeding are
  - a successive system definition and decomposition
  - domain-specific implementation
  - and successive integration and verification

Domain-independent and domain-specific engineering apply different kind of product models

Relations between system model and domain models

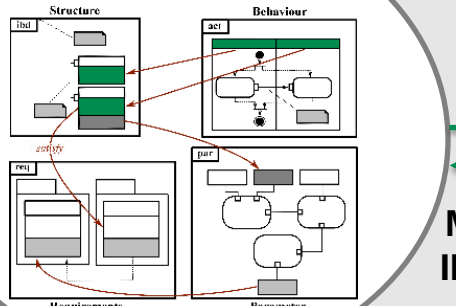


Relations between system model and domain models

DOMAIN-INDEPENDENT ENGINEERING

DOMAIN-SPECIFIC ENGINEERING

SysML model

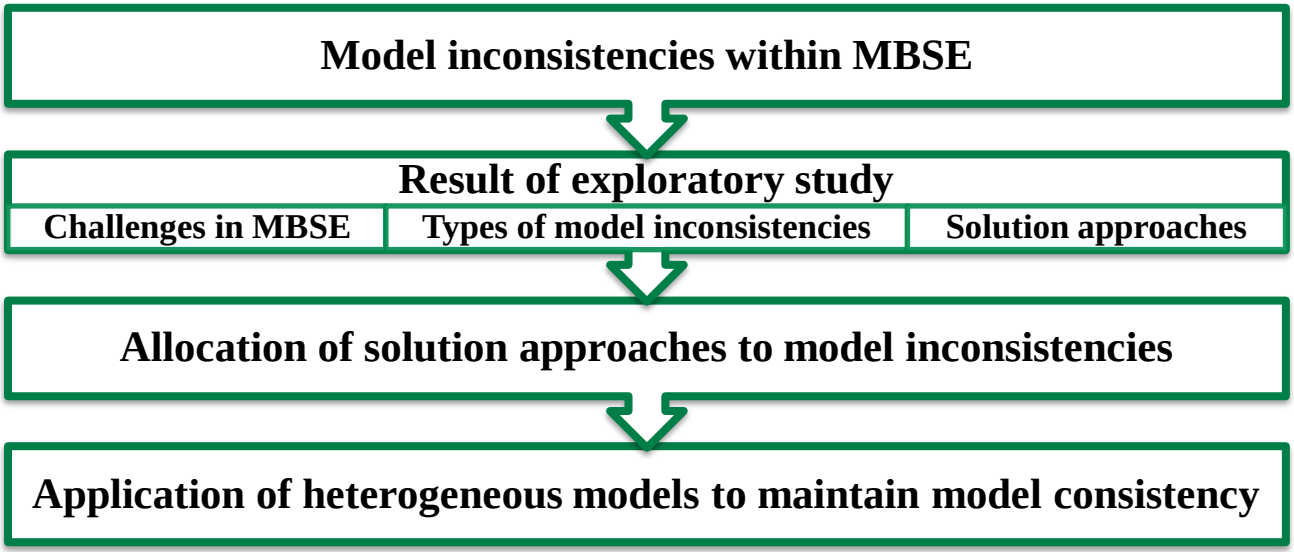


MAINTAIN CONSISTENCY

MANAGEMENT OF INCONSISTENCIES

CAD model

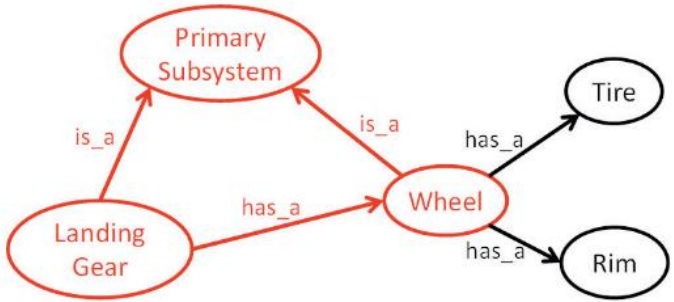
Structure


Model inconsistencies within MBSE
Result of exploratory study
Challenges in MBSE
Types of model inconsistencies
Solution approaches
Allocation of solution approaches to model inconsistencies
Application of heterogeneous models to maintain model consistency

Model inconsistencies within MBSE

- Basically, inconsistency can be understood as logical contradiction or irrational existence among facts, artefacts or concepts
- In the context of this presentation, model inconsistency is the violation of domain-specific or domain-independent engineering rules or constraints
- Examples for model inconsistencies:
  - violation of well-formedness rules,
  - inconsistencies in redundant information,
  - mismatches between model and test data,
  - not following heuristics or guidelines

Model of a systems with an inconsistency marked in red

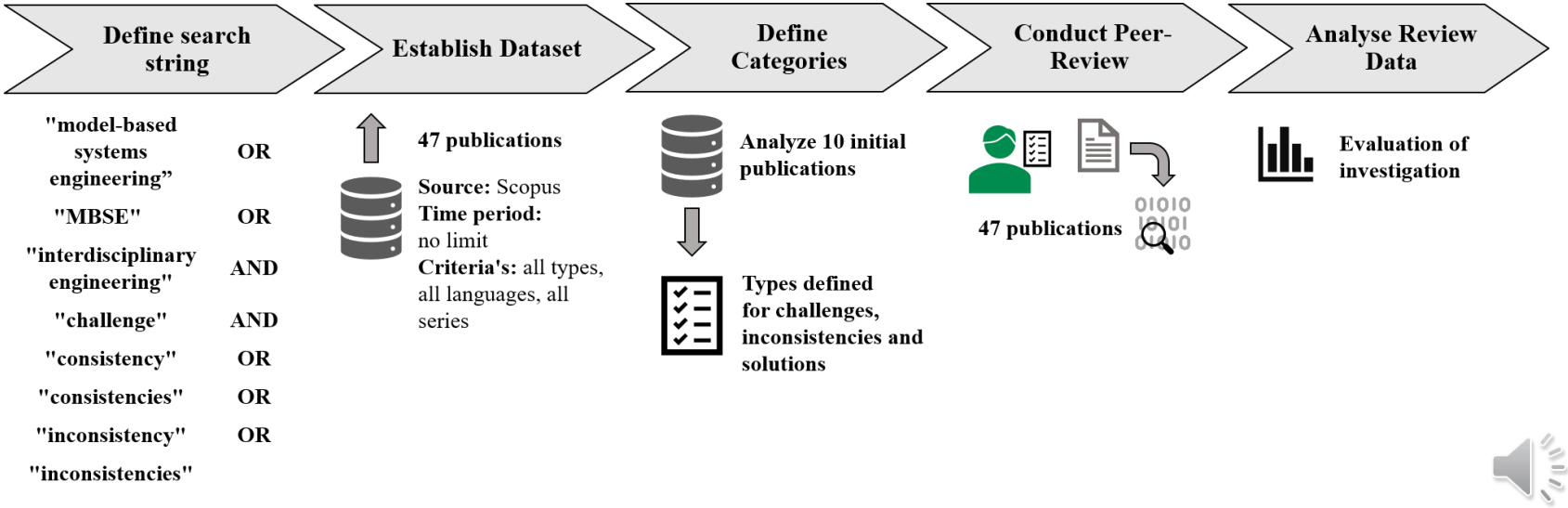


Herzig.2014

Rule: primary subsystems may not contain other primary subsystems

Result of exploratory study

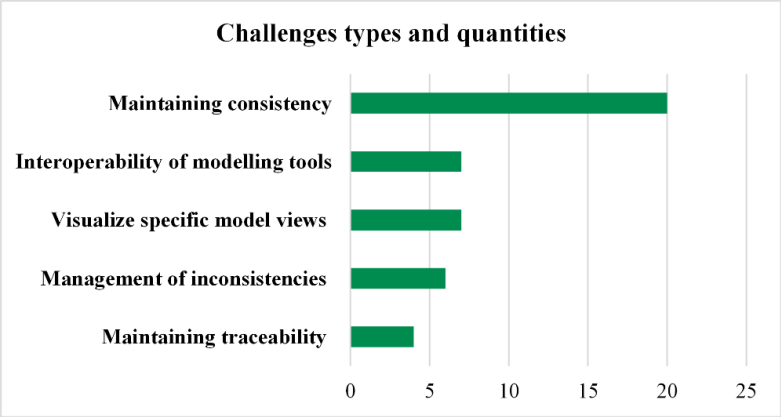
Study proceeding



Result of exploratory study

Challenges in MBSE

- Five challenges are frequently reported in literature:
  - ***maintaining consistency***
  - ***interoperability of modelling tools***,
  - ***visualize specific model views***,
  - ***management of inconsistencies,***
  - ***maintaining traceability***.

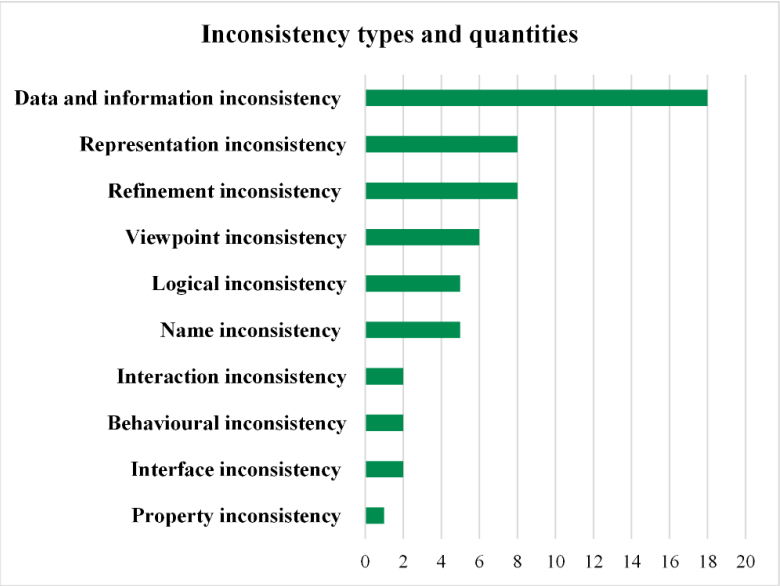


The main challenges are to maintain consistency during the engineering process and to identify and solve any model inconsistencies at the time of creation.

Result of exploratory study

Types of model inconsistencies

- Within the study ten different types of model inconsistencies were identified
- Six out of ten inconsistency types are more frequently stated in literature (at least five enumerations)

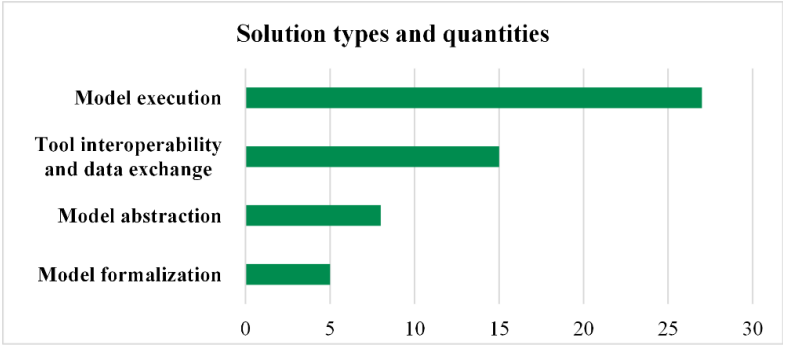


Many different types of model inconsistency, which consider different perspectives, like model presentation or representation (data structure).

Result of exploratory study

Solution approaches

- Within the study different solution approaches were identified and classified into four solution types:
  - ***model execution***,
  - ***tool interoperability and data exchange***,
  - ***model abstraction,***
  - ***model formalization.***



Model execution and synchronization as well the interoperability of tools are most frequency mentioned in literature to maintain consistency.

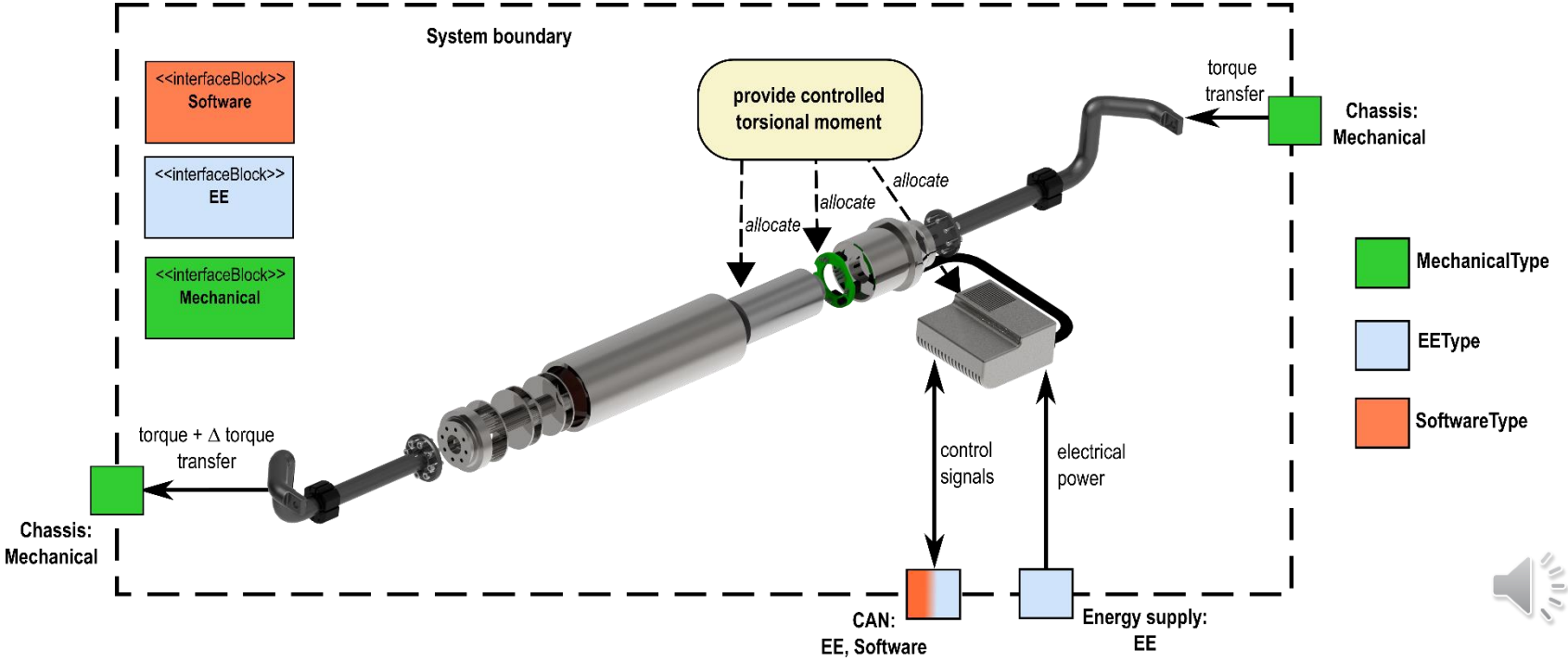
Allocation of solution approaches to model inconsistencies

- Allocation between the identified inconsistency types and solution types
- Gives advice which solution types can support managing the different inconsistency types

The high variety of model inconsistencies requires different solution approaches in parallel to ensure model consistency.

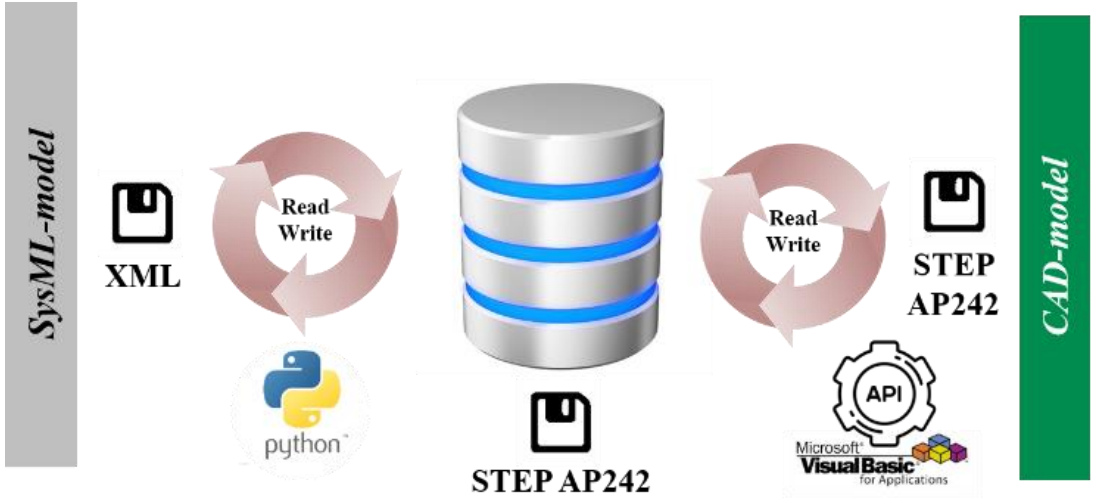
Inconsistency type	Solution type
Data and information inconsistency	Model execution
	Tool interoperability and data exchange
Representation inconsistency	Model execution
Refinement inconsistency	Model abstraction
Viewpoint inconsistency	Tool interoperability and data exchange
Logical inconsistency	Model formalization
Name inconsistency	Model execution
	Tool interoperability and data exchange
Interaction inconsistency	Model execution
Behavioural inconsistency	Model execution
Interface inconsistency	Model execution
	Tool interoperability and data exchange
Property inconsistency	Model execution
	Tool interoperability and data exchange

Application of heterogeneous models



Linkage of SysML-model and CAD-model

- Precondition: Linkage of SysML-models and CAD-models
- Therefore, the data structure of each model element needs to be investigated and linked



Interface concept, to link SysML- and CAD-models

Application of heterogeneous models

- Supports by overcoming the following challenges:
  - ***maintain consistency***,
  - ***interoperability of modelling tools***,
  - ***visualize specific model view,***
  - ***maintaining traceability***.
- Combination of solution types:
  - ***model execution***,
  - ***tool interoperability and data exchange***,
  - ***model abstraction*** as well ***model formalization***.

- Thereby following inconsistency types will be addressed:
  - ***data and information inconsistency*** due to the linkage of model elements based on data structure
  - ***representation inconsistency*** due to the integration of different views and perspectives into one model
  - ***refinement*** and ***logical inconsistencies*** due to the integration of model elements with different abstraction or different semantics and syntax into one presentation.

Thank you for your attention!

References:

- K. Forsberg and H. Mooz, “Application of the `Vee' to Incremental and Evolutionary Development”, Center for Systems Management, Cupertino, 1995.
- D. M. Buede, “The engineering design of systems: Models and methods”, 2. ed., Wiley, Hoboken, 2009.
- VDI/VDE 2206:2021-11, „Entwicklung mechatronischer und cyber-physischer Systeme“, Beuth Verlag, 2021.
- S. Herzig and C. Paredis, ”A conceptual basis for inconsistency management in model-based systems engineering”, Procedia CIRP, 2014.