

V O L V O

EARLY VALIDATION & VERIFICATION IN MODEL-BASED SYSTEMS ENGINEERING

Volvo Construction Equipment | Portfolio & Architecture - CE42200 | Johan Cederblad | Open

2026-03-06

Agenda

- Volvo CE overview
- The context of my PhD research
- Examples/use cases
- Main take-aways
- Connecting to Volvo CE
- Discussion



Building strong societies worldwide through people and technology

180

markets

13

production facilities

15,000

employees

10

R&D facilities

5,100

supply partners

265

dealers





Cyber security

Services

Systems of
Systems

Software

Electrification

164 MACHINE
MODELS

1,000,000+

POSSIBLE
CONFIGURATIONS

Framing MBSE

Model-Based Systems Engineering (MBSE)

Formalization of knowledge in models, from the start of development

Current status

- Industrial hype but difficult adoption
- SysML-based
- No clear best practice

Where the field is moving

- Digital Thread/Twin/Engineering
- Simulation as continuous capability



SYSTEMS ENGINEERING
VISION 2035

ENGINEERING SOLUTIONS FOR A BETTER WORLD



Model-Based Practices

The Future of Systems Engineering Is Predominantly Model-Based

FROM Although a growing number of systems engineering organizations have adopted model-based techniques to capture systems engineering work products, the adoption is uneven across industry sectors and within organizations. Custom, one-off simulations are used for each project, and there is still limited reuse of models especially during critical early phases of systems architecting and design validation.

TO Systems engineers routinely compose task-specific virtual models using ontologically linked, digital twin-based model-assets. These connected models are updated in real-time providing a virtual reality-based, immersive design and exploration space. This virtual global collaboration space is cloud-based, enabled by modelling as a service and supports massive simulation leveraging cloud-based high-capacity compute infrastructure. Families of unified ModSim frameworks exist enabling small and medium businesses along with Government agencies to collaborate.

What are models?

Mapping

– A model exists in relation to something.

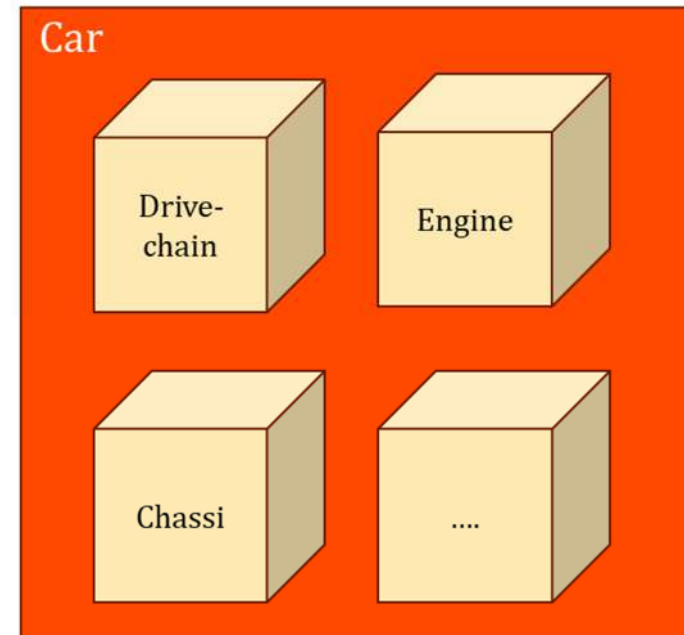
Reduction

– A model is “less” than the original.

Pragmatism

– A model has a purpose to its existence.

Example: The picture on the right is a simple representation of a car to help communicate.



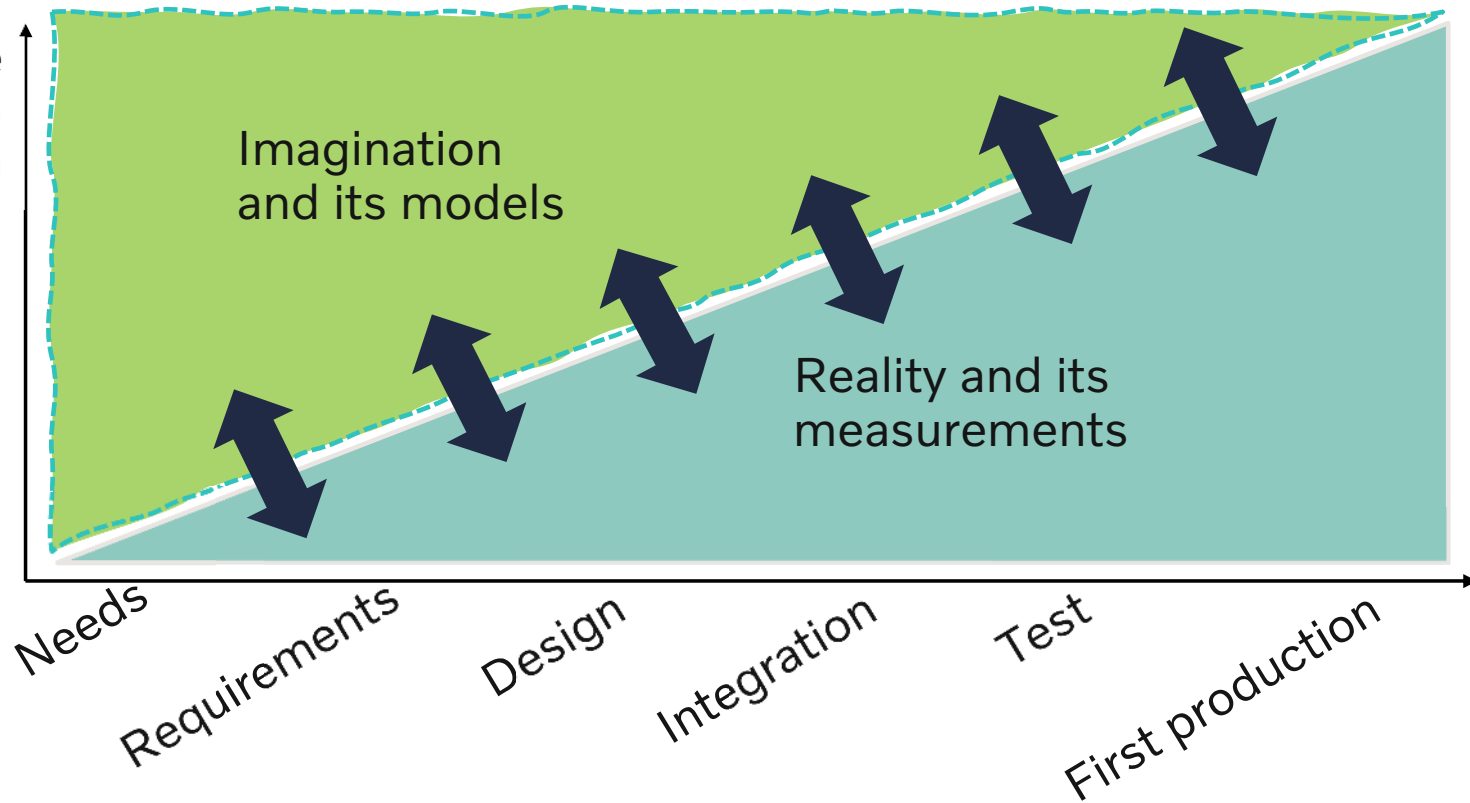
Stachowiak, Herbert. Allgemeine modelltheorie, 1973.

What good are models?

Available information about system

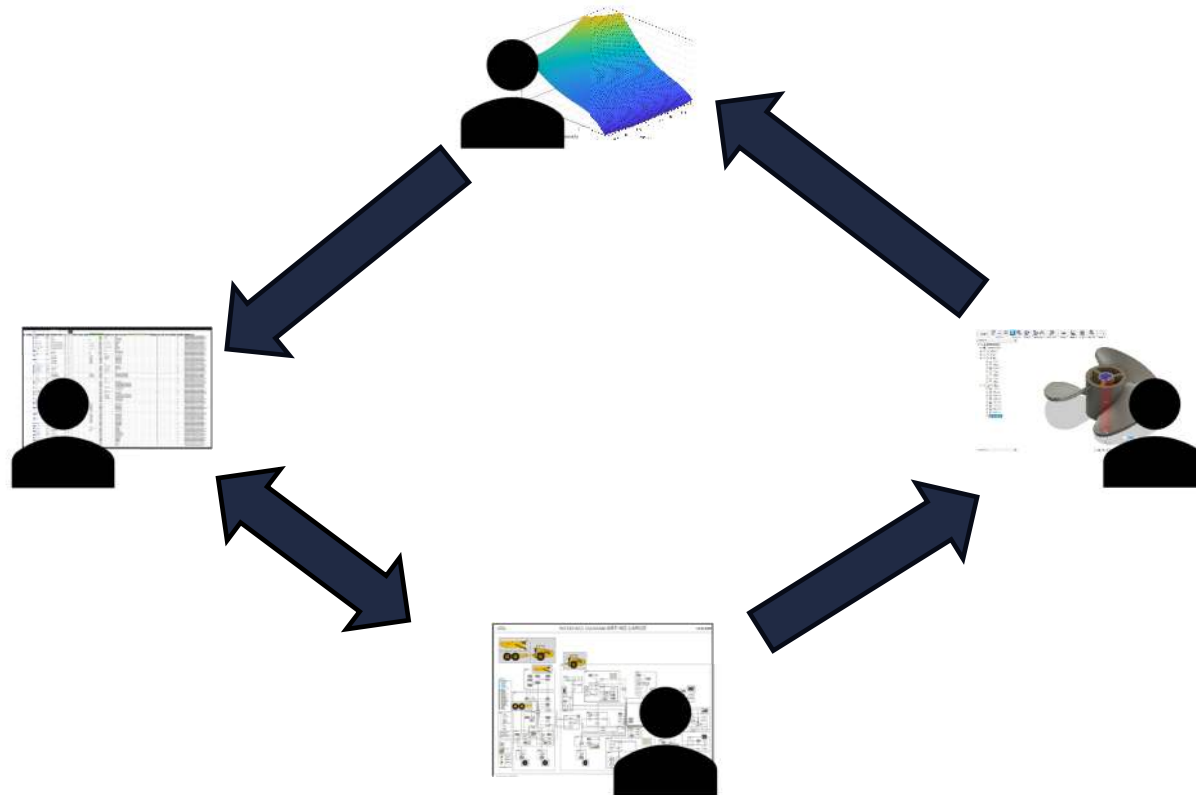
Imagination and its models

Reality and its measurements

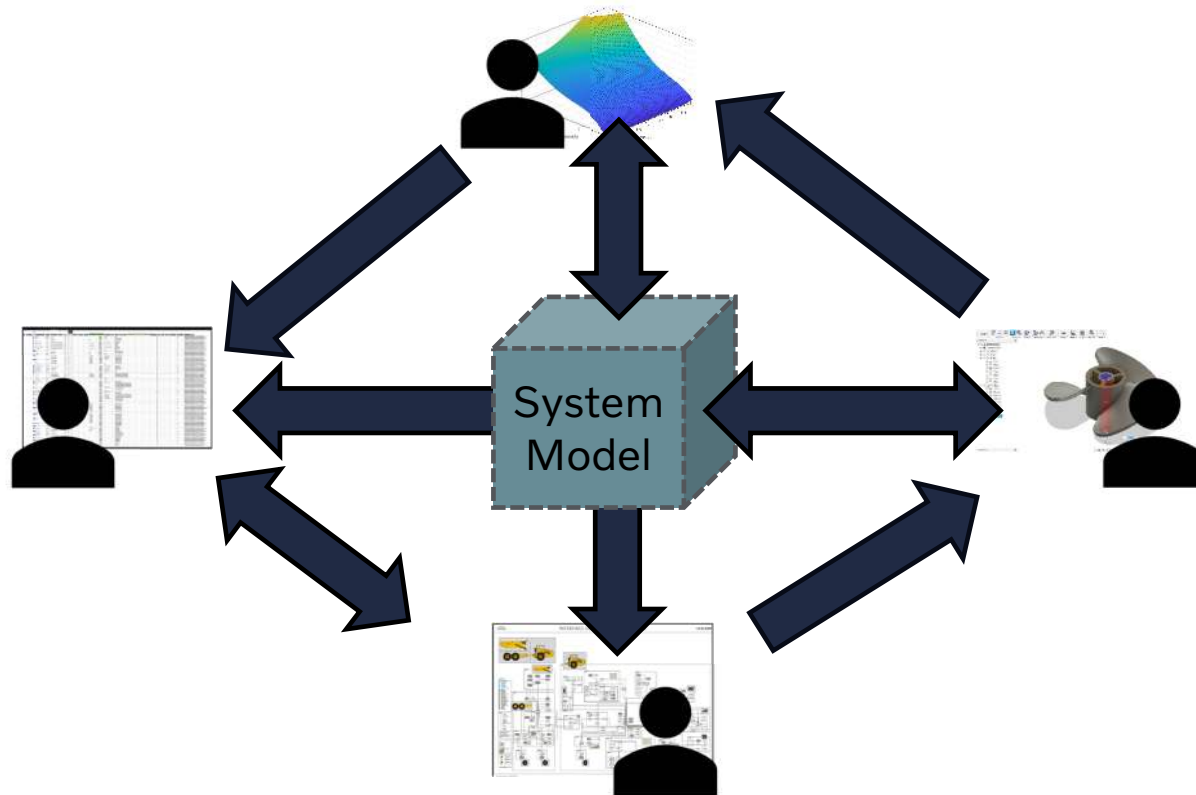


This slide is inspired by Maarten Bonnema's keynote at ISSE 2025

How do we work with models



How do we work with models



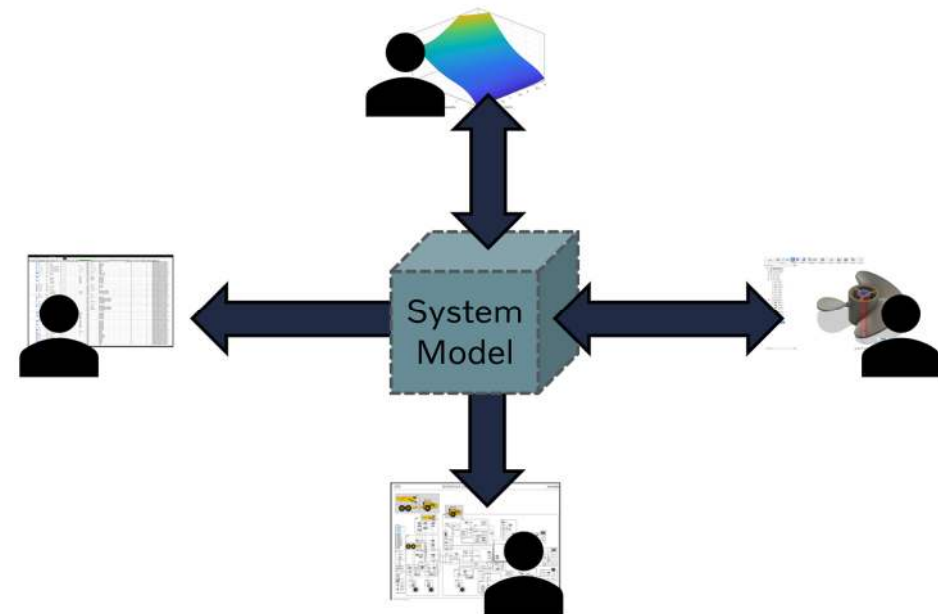
Why MBSE?

Formalisation of knowledge/data enables increased operations on this knowledge/data.

Centralized storage of information.

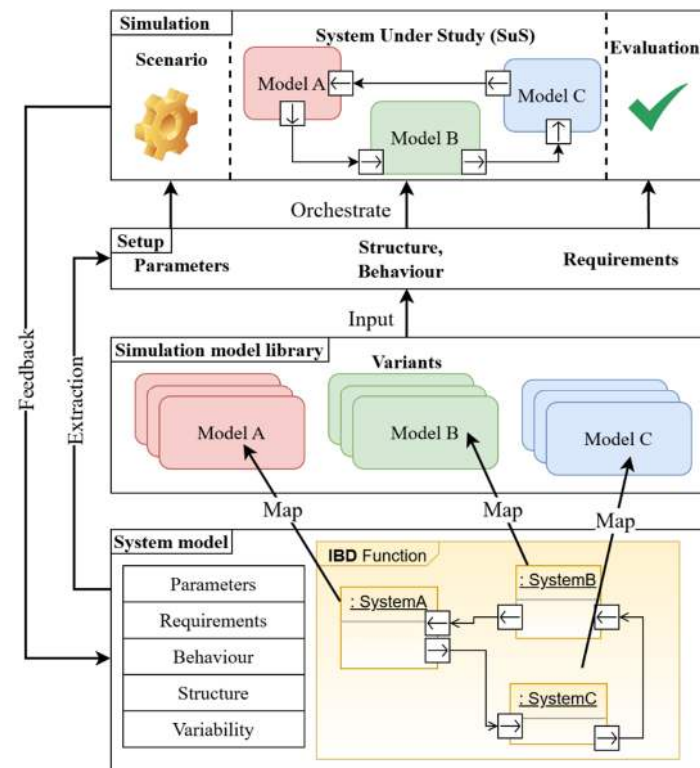
Structure and integration of views.

Increased access to V&V capabilities.



Concept of early V&V from the thesis

- Conceptual example based on a systematic literature review.
- Leverage centralized model to drive simulation.
- Information mapped to existing simulation model library.
- Extract data from a system model to orchestrate and parameterize model.



A birds-eye view from literature

Challenges

Modelling

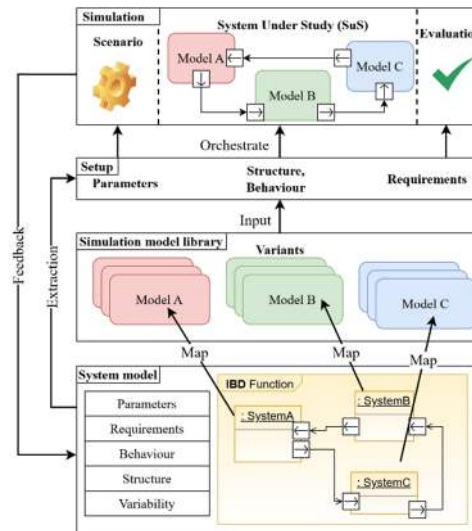
- Modelling Guidelines
- Domain Interfacing
- Engineering usability
- Classifying uncertainty
- Scalability

Organisational

- Process integration
- Traceability and Propagation
- Non-Formal Legacy
- Heterogenous Audience

Methods

- Representation of Results
- Standard Compliance
- Maintainability



- C1: Collaboration**
- C2: Validity**
- C3: Uncertainty**
- C4: Re-use**
- C5: Automation**
- C6: Presentation**

Enablers

Interoperable Data



Collaborative Modelling



Continuous Modelling



Standard Support



Black-box co-simulation

Models are only observed at their interfaces.

Little to no observation into the internal model structure & parameters.

Emphasis on re-use and support structure around the models themselves.

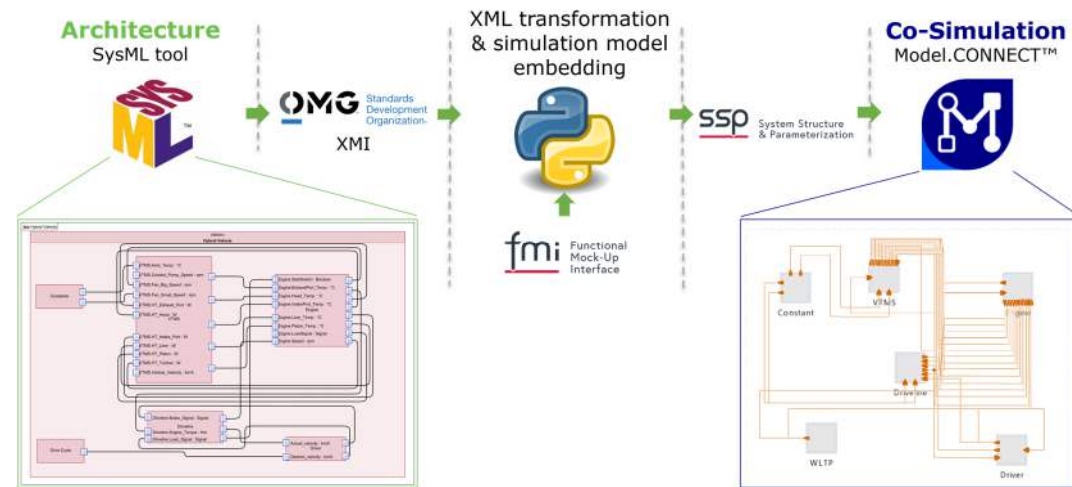


Standard based co-simulation

SysML for architecture modelling, FMI + SSP for simulation, and Python as bridge.

Using PTC modeler for SysML in demo, and Model.CONNECT from AVL.

Example of a Battery-Electric Vehicle (BEV)

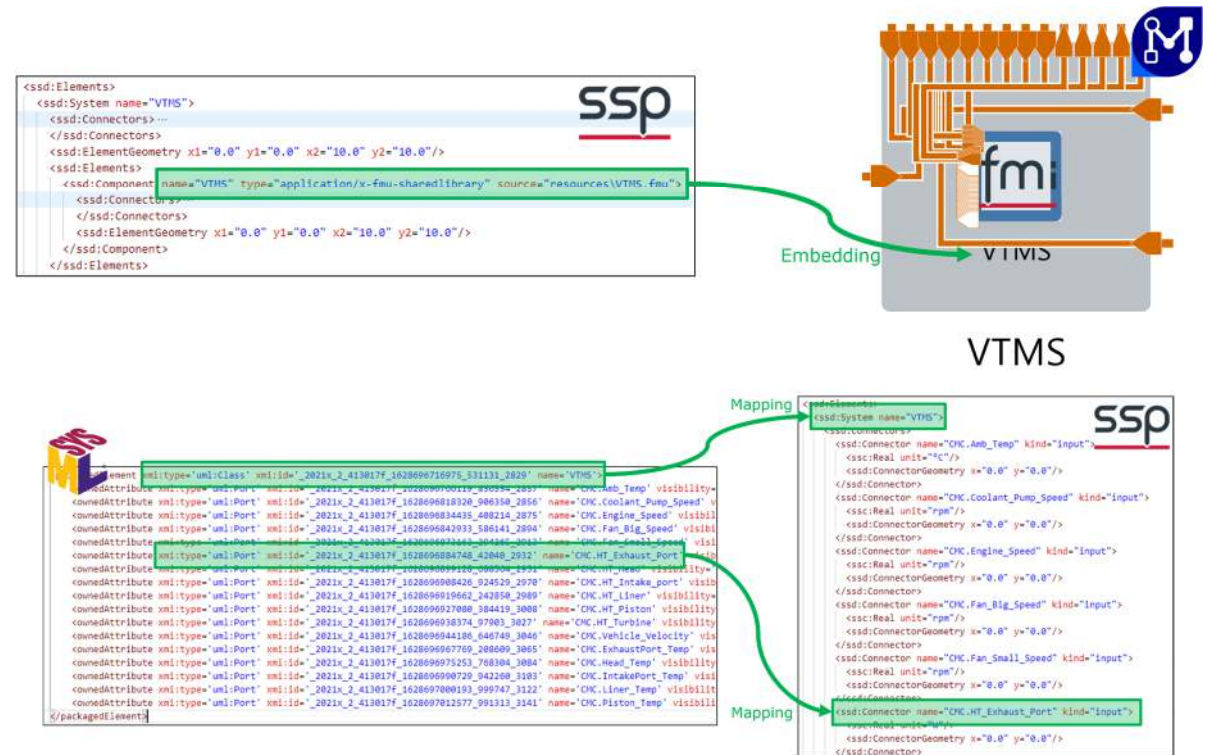


Standard based co-simulation

Open standards help with interoperability and collaboration across teams and functions.

FMI + SSP are a useful means of promoting layered standardization.

SysML V2 is looking like a strong standard for system modelling, increasing the attractiveness of a standard-based approach.



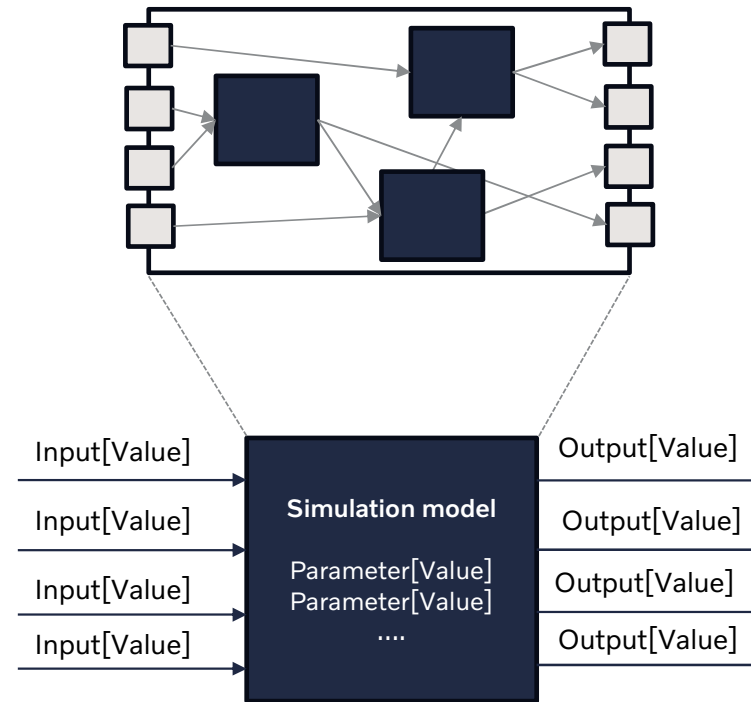
Gray-box co-simulation

Model interior is understood in some capacity.

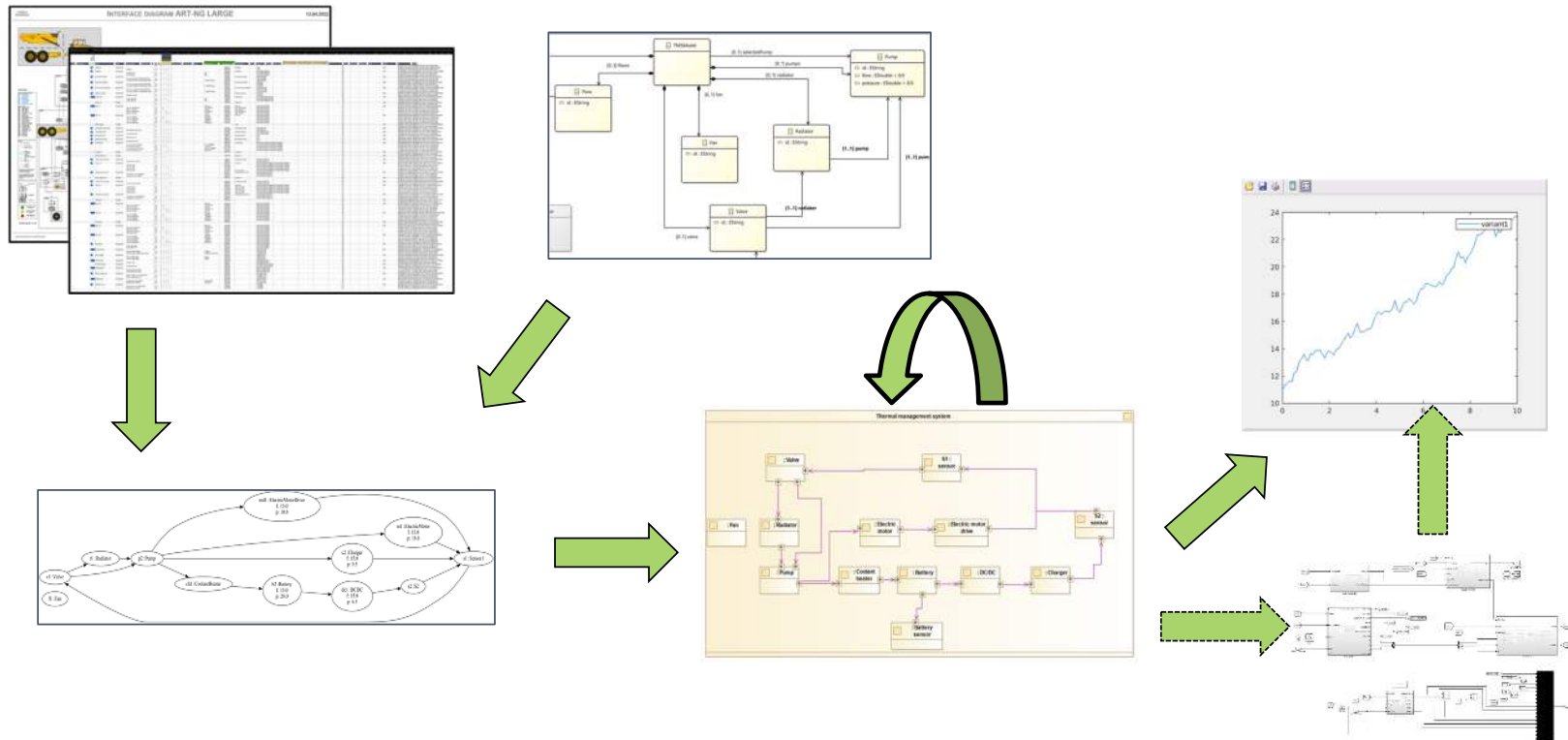
More information than just interfaces, e.g, internal structure and specific algorithms.

A large span of implementation as there are many model aspects to consider.

Some aspects can be black-box while others are white-box.



Example from AID0aRt project



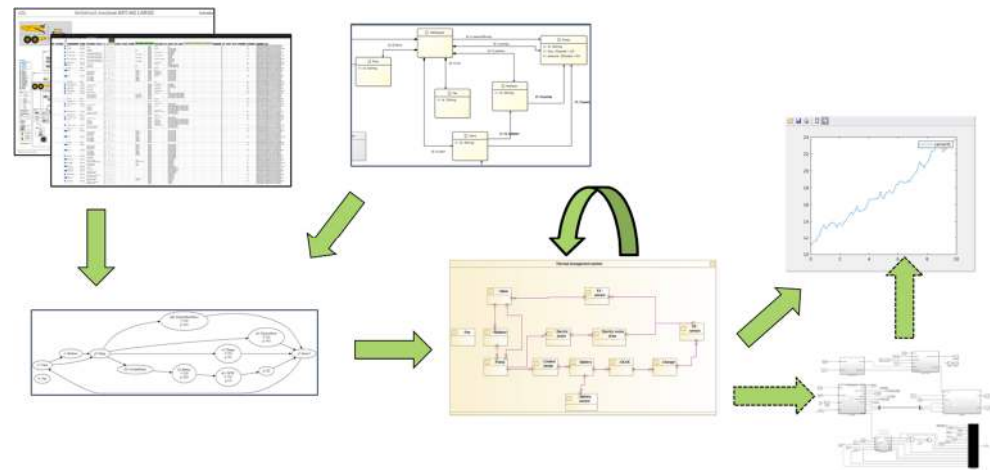
Example from AID0aRt project

Integration with office products as a starting point.

Using model-driven engineering methods to support model transformation and text-to-model generation.

Language agnostic architecture graphs generated and visualized, before making SysML models.

Simulation added as a final step of the process by bridging existing models through standards like FMI.



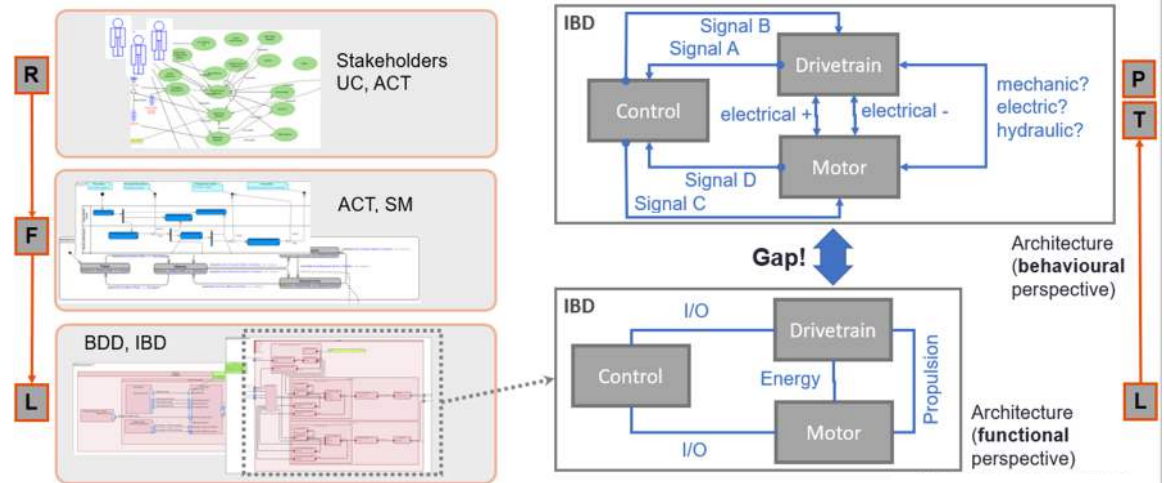
Example at VCE

Problem; How to match architecture models with simulation models?

Finding a means of bridging the abstraction gap.

Creation of guidelines and structure (RFLP) to align modelling views and capture information.

Bridging the gap Architecture - Behaviour

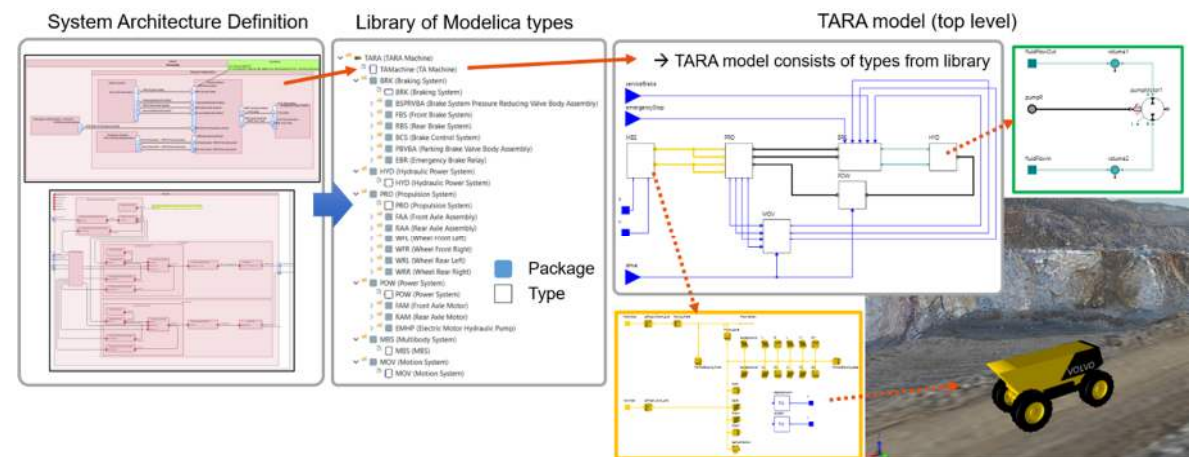


Example at VCE

Using structured architecture model we drive simulation generation.

The Modelica standard library used as a library of simulation components to build simulation.

Final simulation placed into existing environments for trade-off analysis & Visualisation.



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1,000,000+ POSSIBLE
CONFIGURATIONS

Modern needs

Despite increasing complexity there is a need for increased speed, from minimum viable product to market viable product.

The launch of products should come earlier, even if development can stay at a similar pace.

Need for top-down management and configurability, thinking in terms of functions and capabilities.

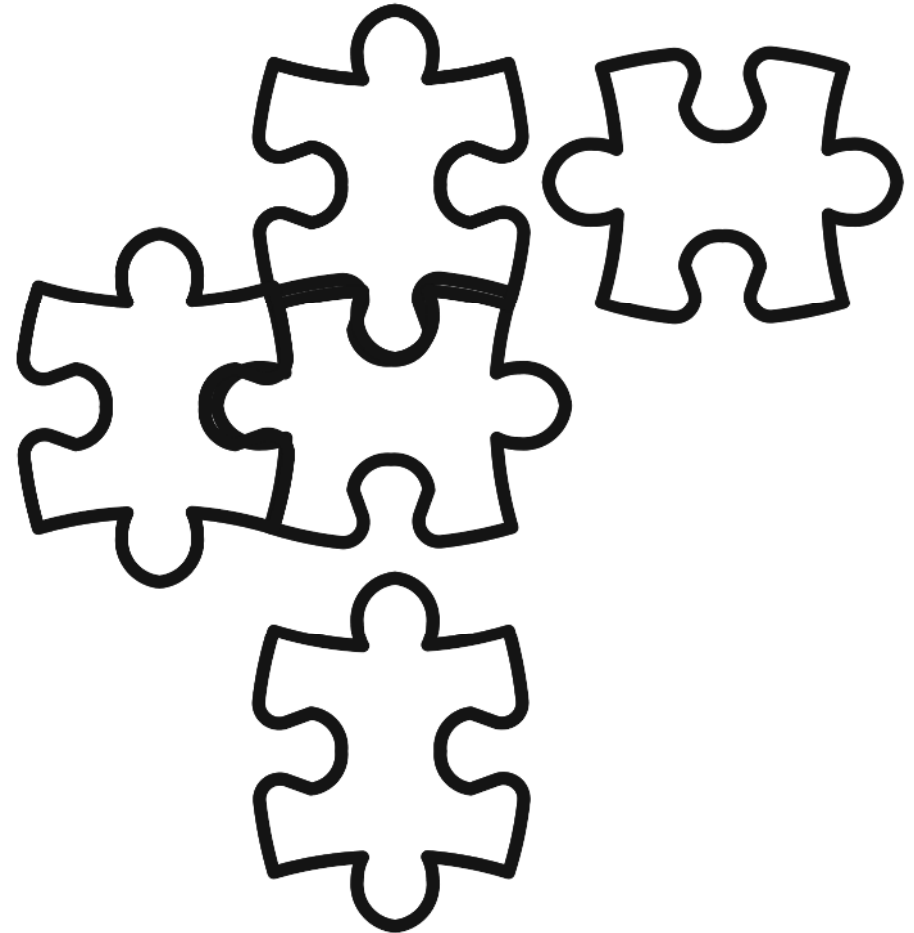


Traditional solution

Hardware modularity at the architecture layer.
Commonality, sharing, and re-use.

Well-known interfaces and management of
hardware components, sub-systems, and
systems.

Several factors cause new challenges to
supporting modularity as historically done;



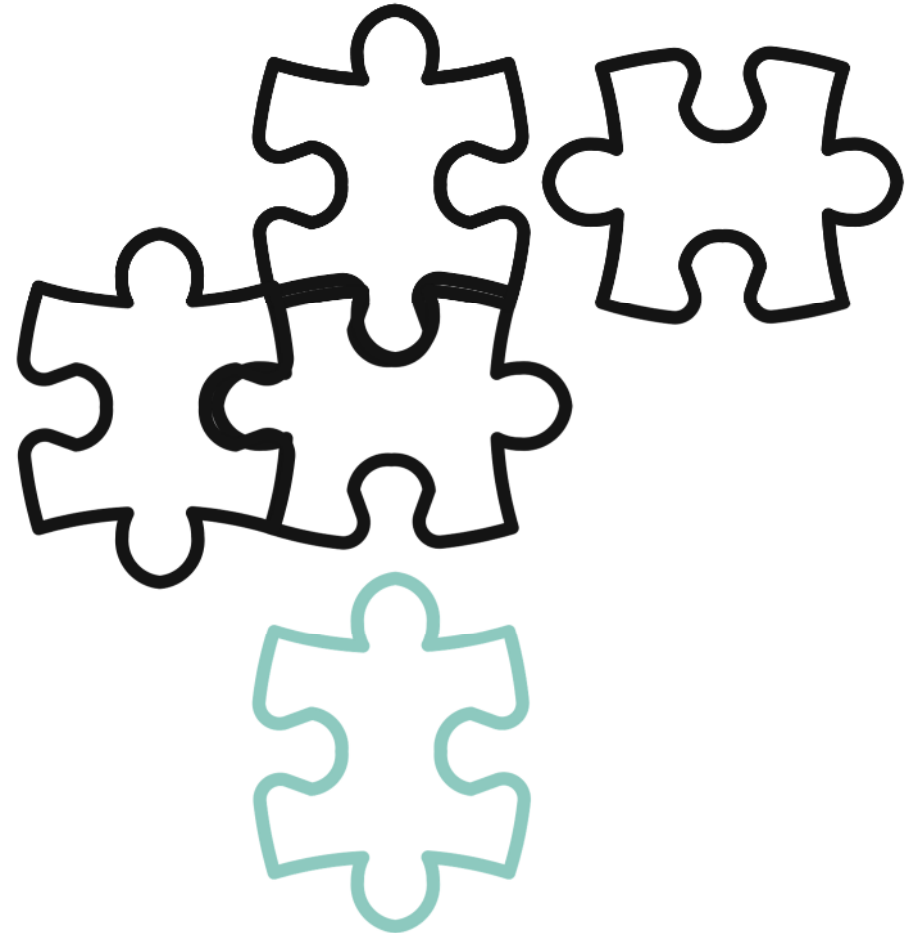
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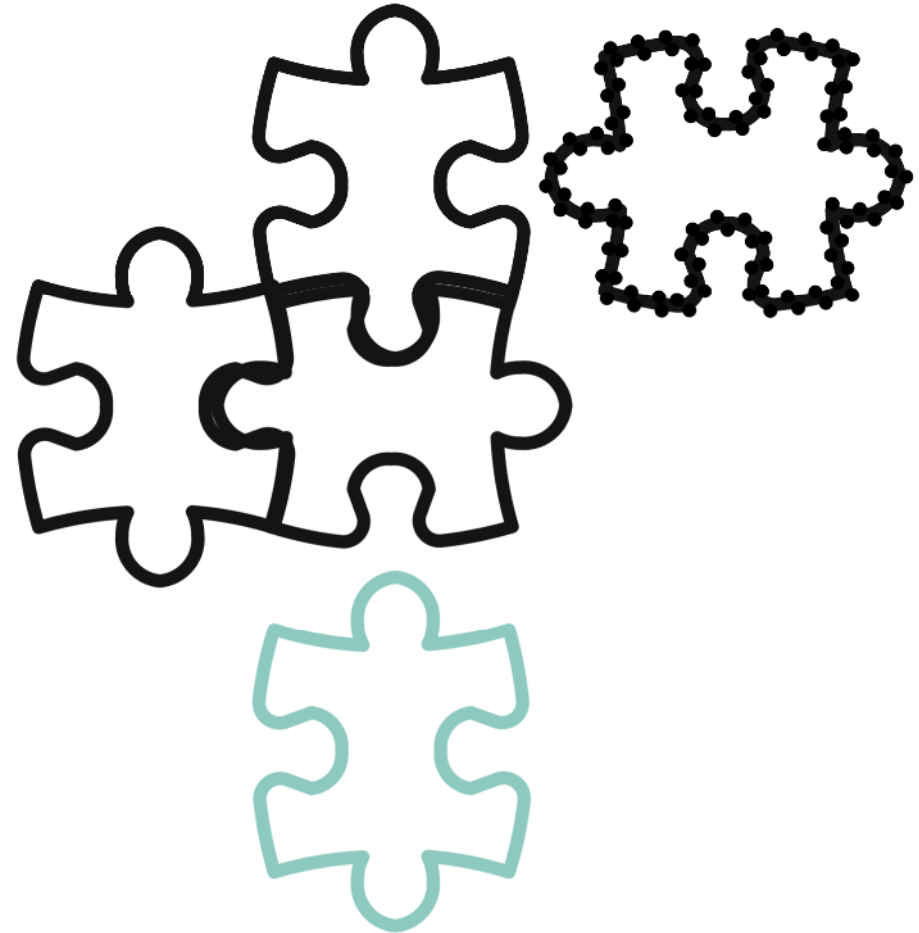
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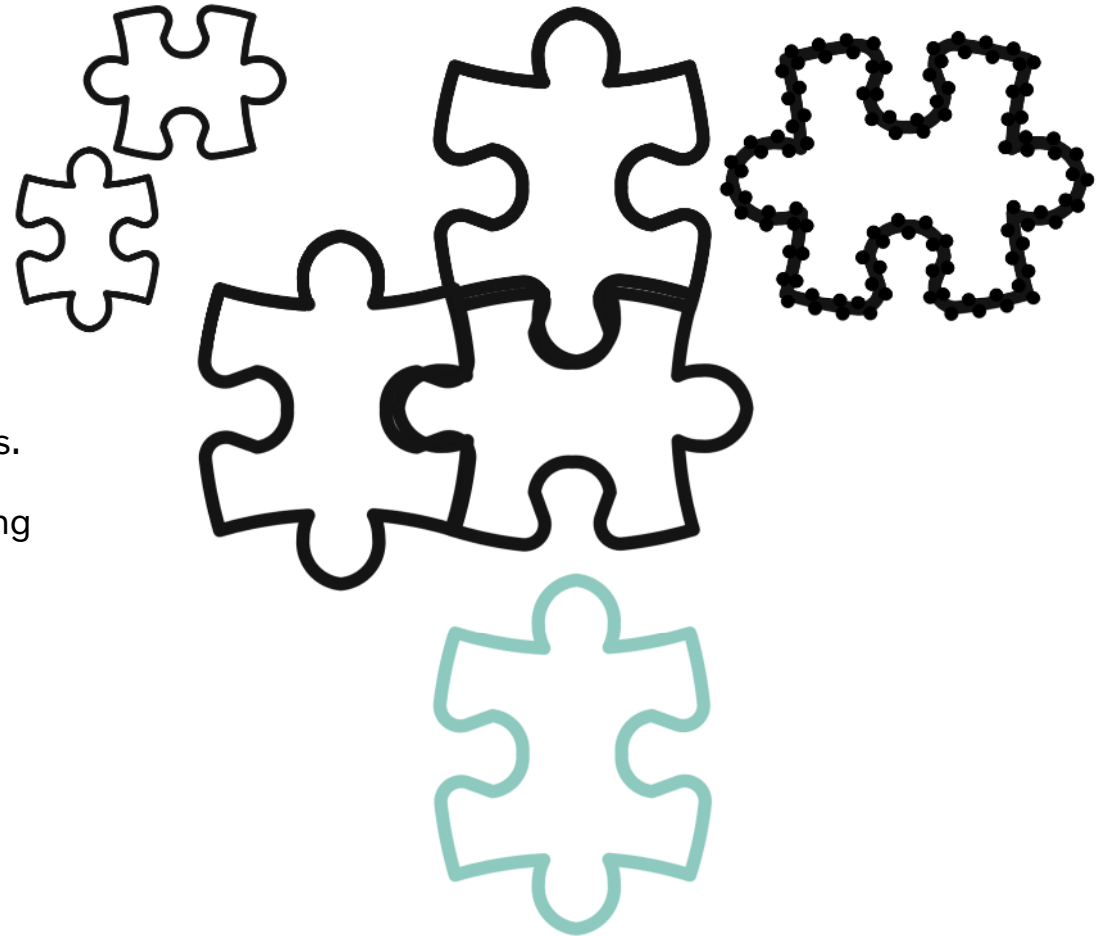
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- Software
- Services
- Increase of machine features



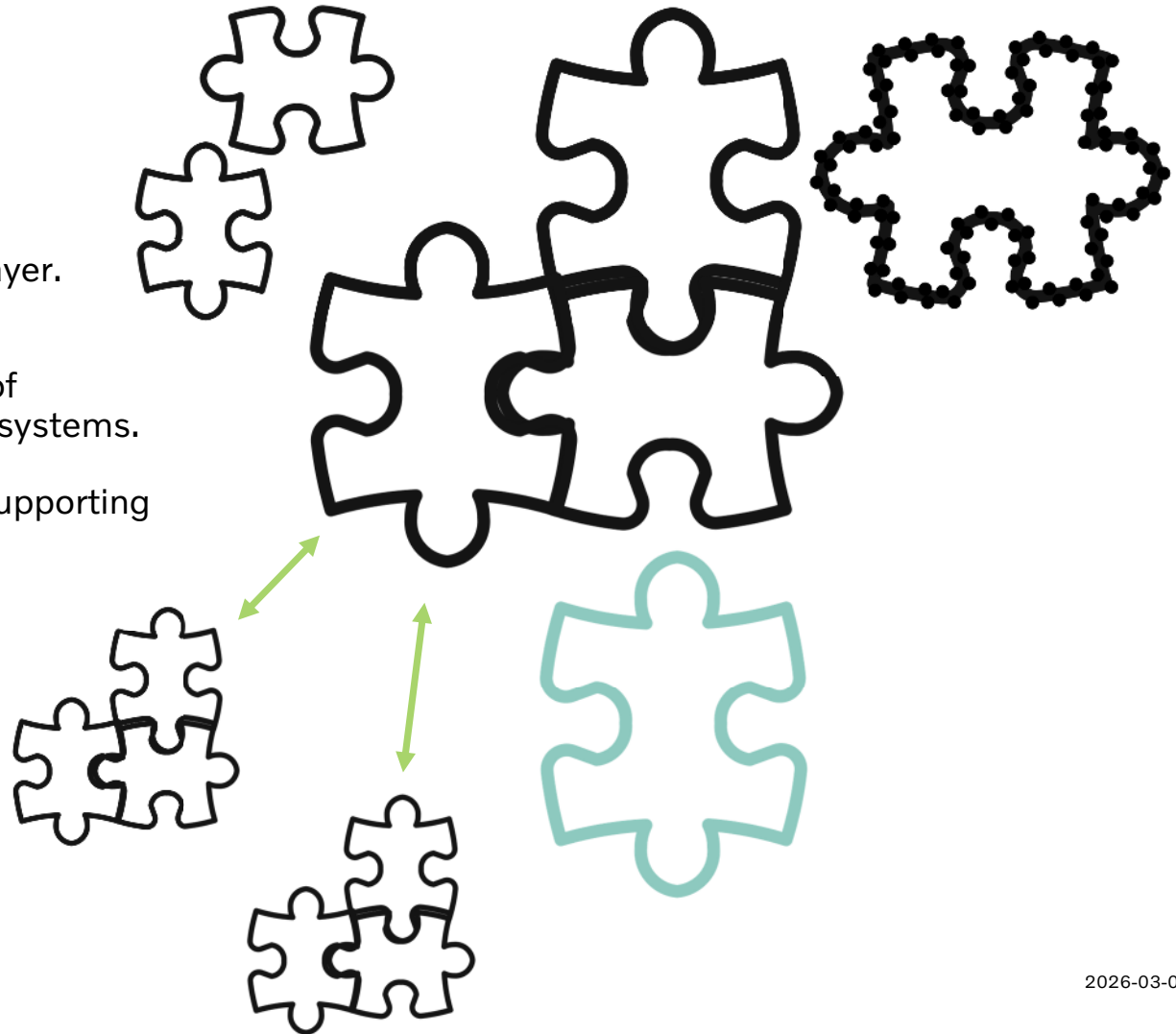
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- Services
- Increase of machine features
- Systems of Systems



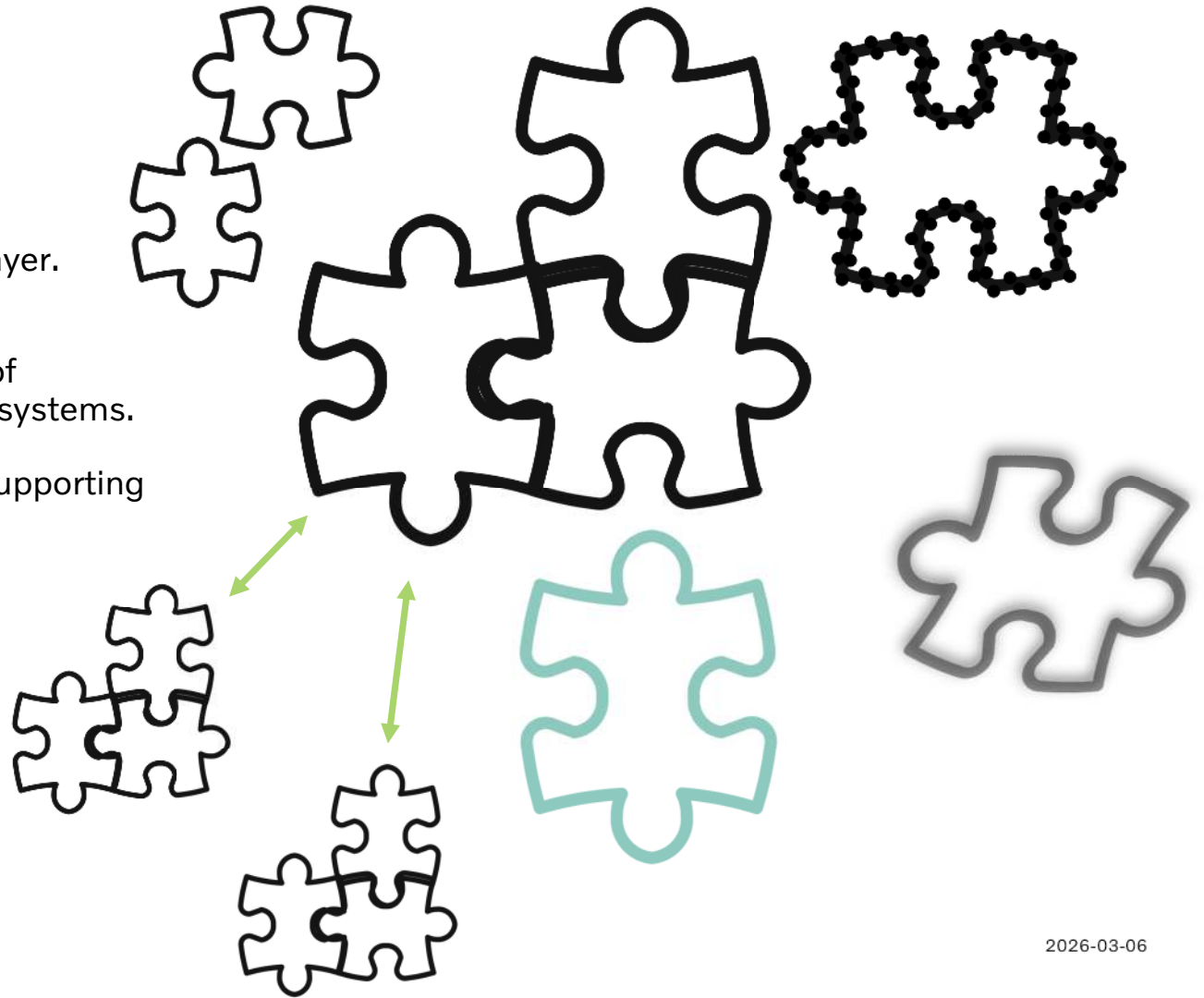
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modularity as historically done;

- Software
- Services
- Increase of machine features
- Systems of Systems
- Customer & competitor infrastructure



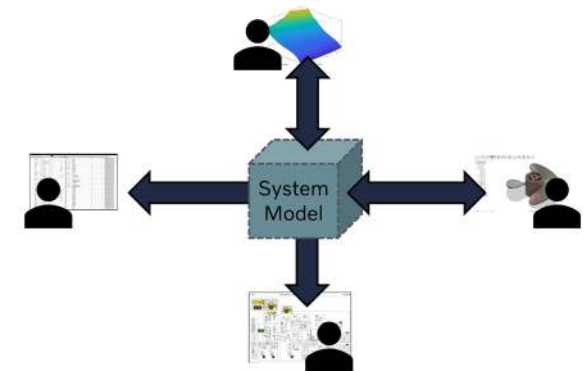
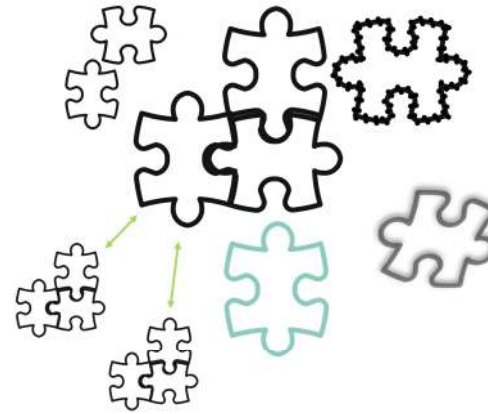
Modern solutions

Need to move the traditional thinking of modularity and architecture to encompass current contexts.

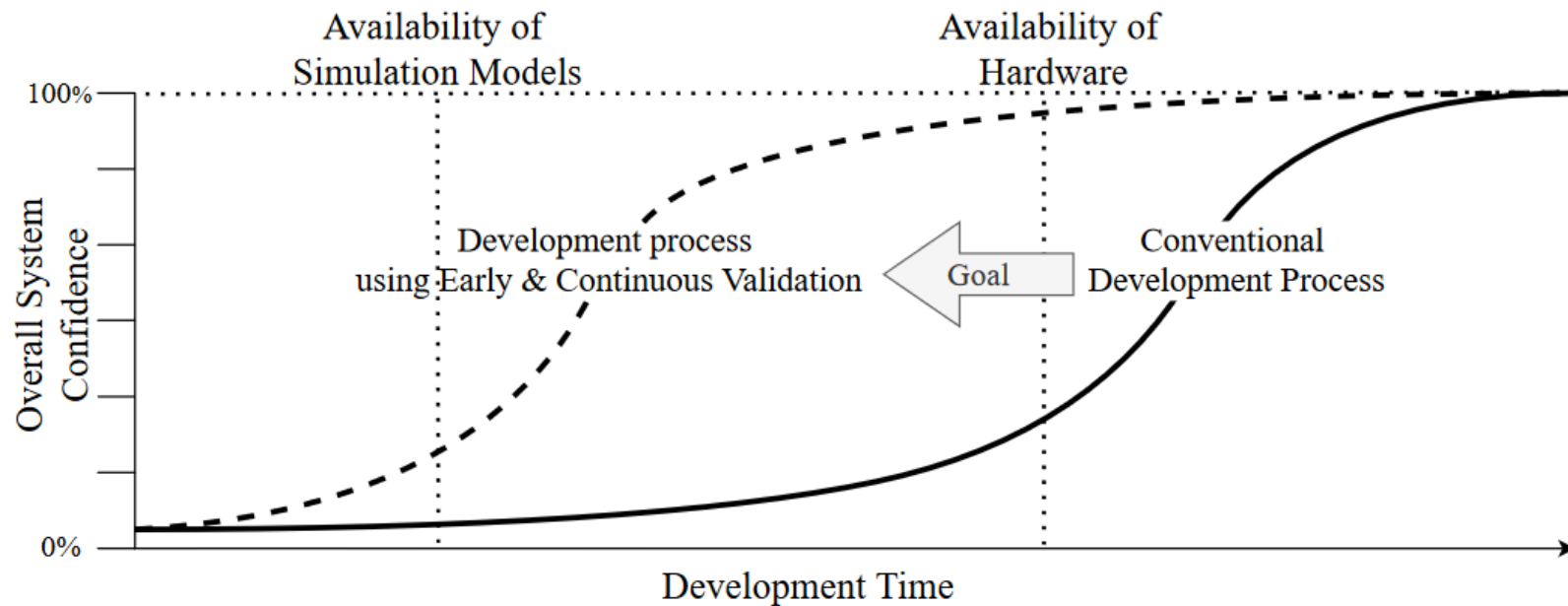
Translate existing practice into a model-based practice to address complex product/service development;

- Commonality
- Technology sharing
- Re-use
- Functional & logical views
- Architectural principles

Connect MBSE initiatives to virtual V&V practices to promote speed in time to market without sacrificing product confidence.



The role of simulation to address modern needs



Abdo, K., Broehan, J., & Thielecke, F. (2023). A Seamless and End-to-End Approach for Early and Continuous Validation of Next-Generation Avionics Platforms. In *Software Engineering 2023 Workshops*. Gesellschaft für Informatik eV.

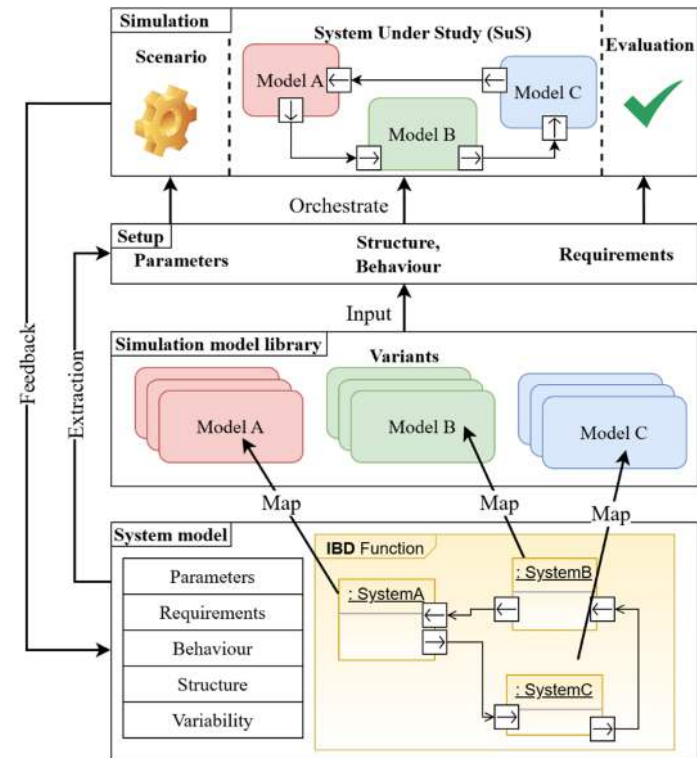
Ending notes & discussion

“Doing simulation” can mean many different things.

One should emphasize that MBSE is systems engineering, and there is a difference between **MBse** and **mbSE**.

Model management is essential but without a one size fits all.

Without a structure and understanding of the system context and its information, analysis makes little sense.



VOLVO

1. What is required to trust a simulation in your context?

2. What is the difference between a design/analysis model and the system architecture model?

3. How can you reason about what simulation model is appropriate in a decision-making context?

V O L V O

Notes

Notes

Definition – future (intended world)
Design – future to present (existing)
Realisation - present (physical/virtual)

V-model for every system level, longer process further down. Realisation must happen at every step, same with definition, while design is singular.

SAAB generally builds their simulators bottom-up.

Excuse me sir paper presents their 7 view framework for simulation from an MBSE perspective.

Erik developed several frameworks for how to take SysML → pipelines, also a good starting point for how to go to FMI/SSP.