Antwerp - workshop

2023-11-23

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Supervisors – Antonio Cicchetti, Jagadish Suryadevara

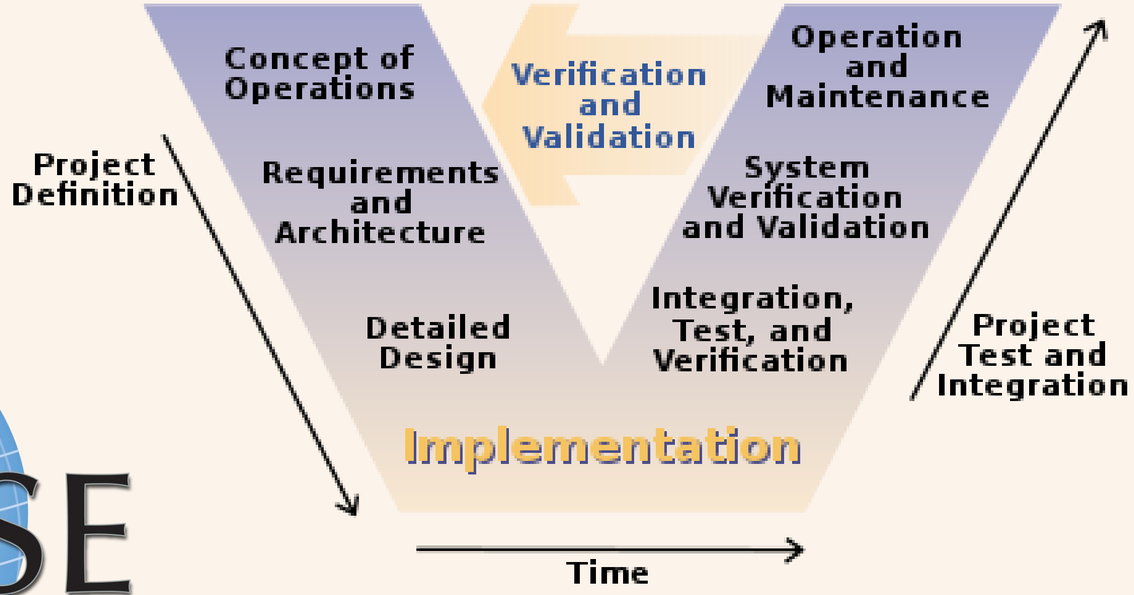
Systems engineering (SE)

Systems engineering

systems engineering **v**

systems engineering **v diagram**

systems engineering **v model**



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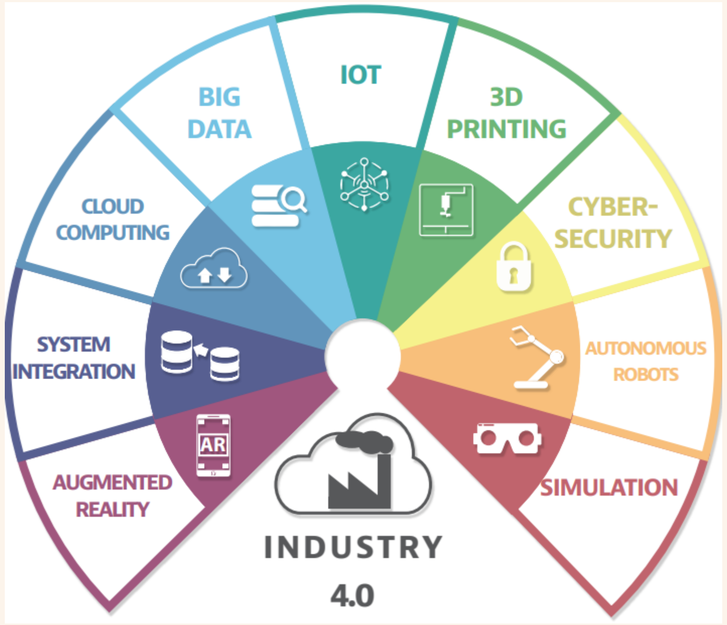
Complexity increase in processes and products

Paradigm shift(s) in systems engineering

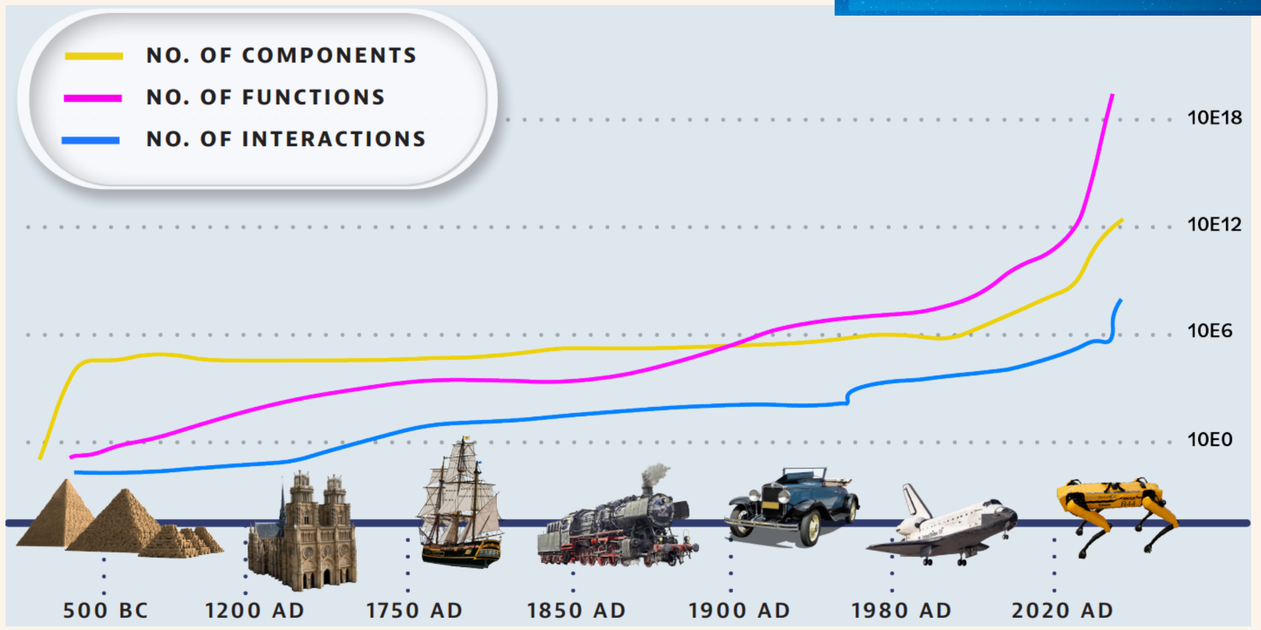
How to manage?



INCOSE

SYSTEMS ENGINEERING VISION 2035

ENGINEERING SOLUTIONS FOR A BETTER WORLD



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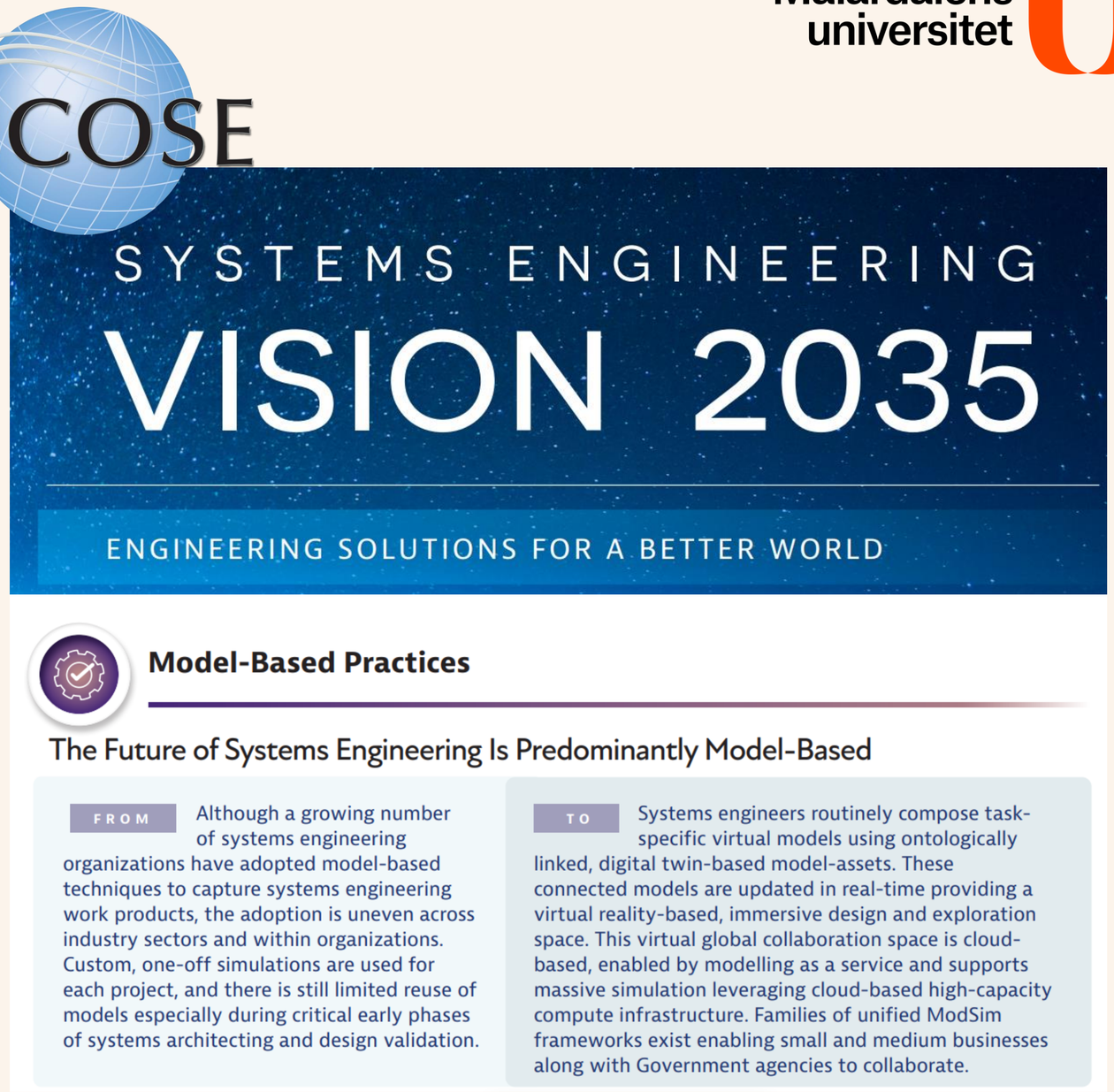
Model-Based Systems Engineering (MBSE)

Models are abstract representations of something *real* for a *cognitive* purpose

Promotes integration, traceability, communication, and so on.



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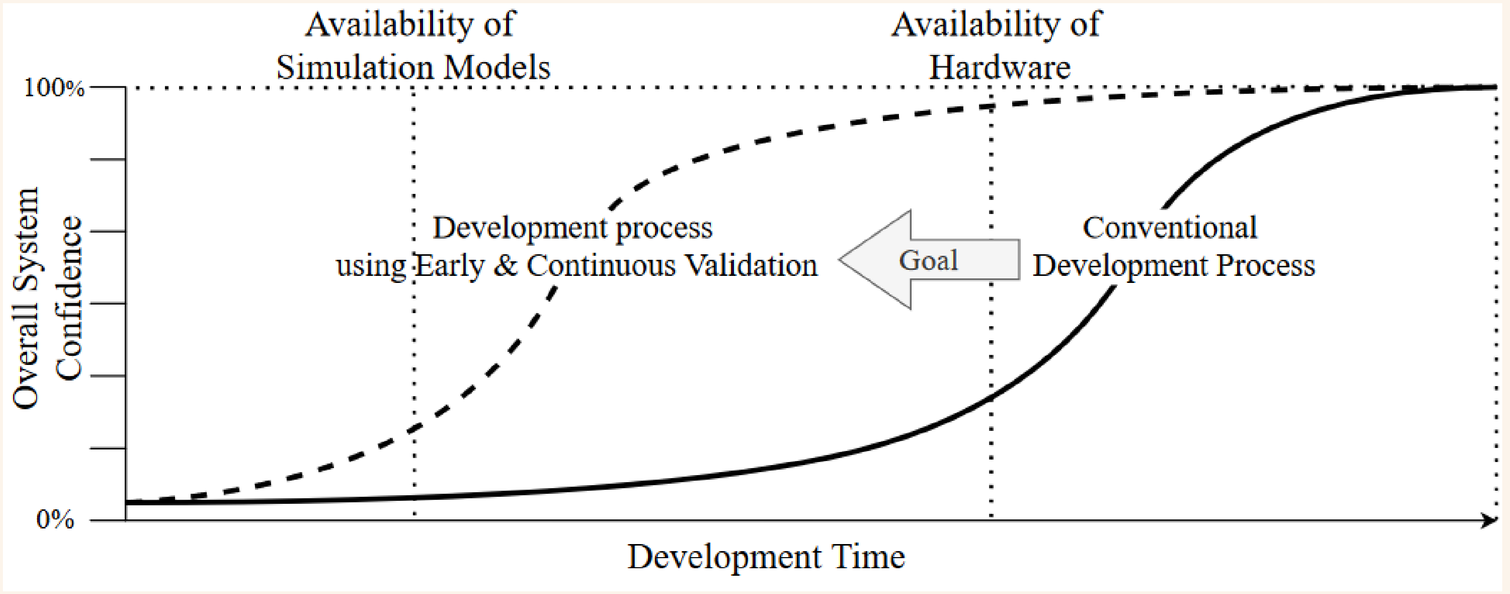
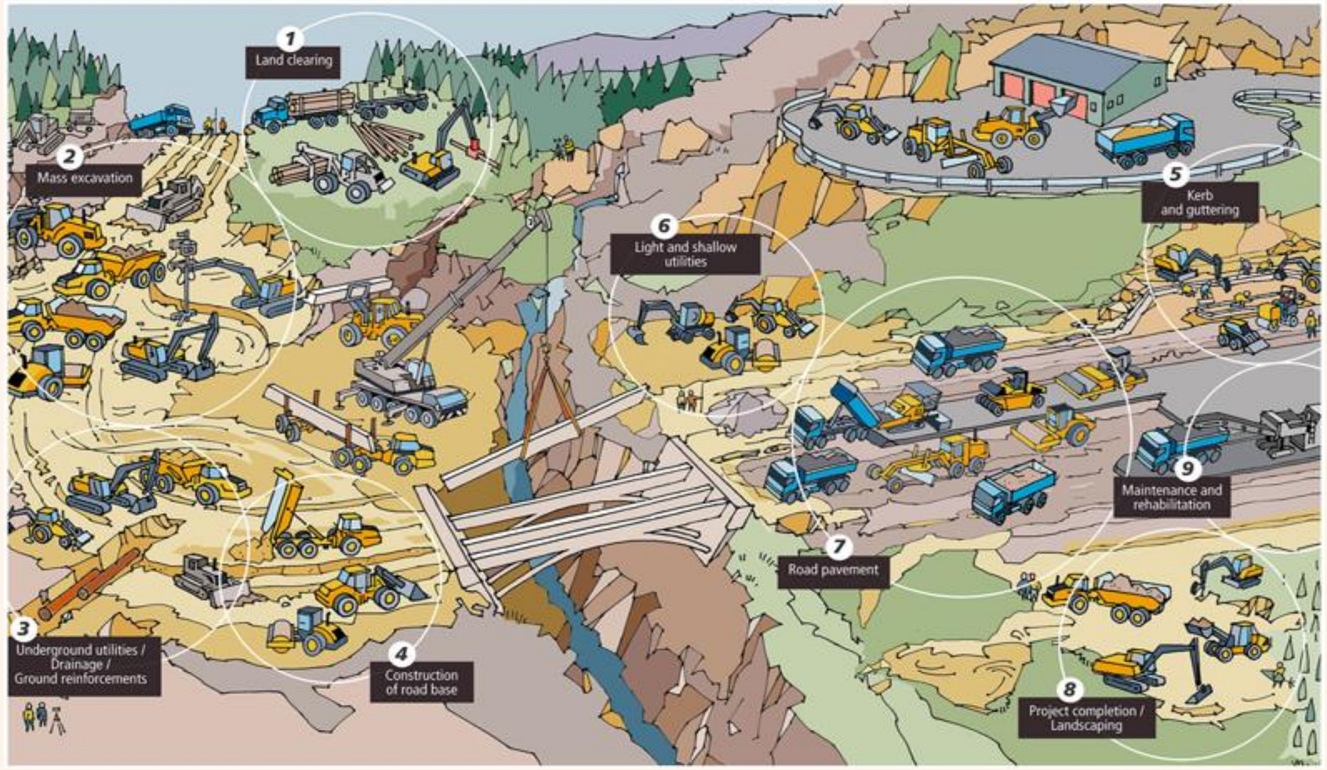
Models allow more detailed system behavior analysis *earlier*

Validation & Verification (V&V) is enabled by model-based methods

However, currently the maturity of early V&V in MBSE is still immature



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.



- VCE is a global manufacturer in the Construction equipment domain
- Complexity raising in a historically hardware domain due to software (think about machines yesterday)

- Current practices rely on manual tooling and methods for Systems Engineering
- Need for increased automation

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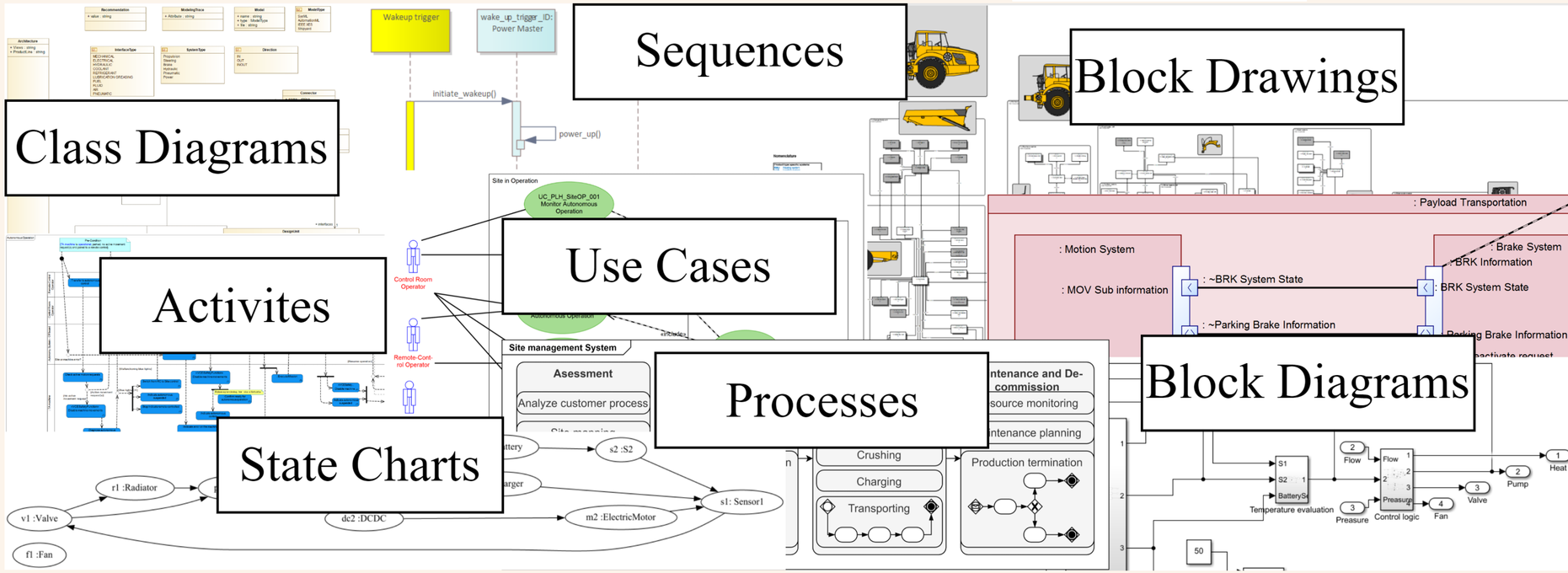
SE artefacts at early stages are often models of various abstraction and rigor

Rarely models are made in the same tool/notation or by the same engineers

How can these Views be leveraged for *early* V&V *together*?

VOLVO

AIDOaRt



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Provide model-based approaches for industrial SE practitioners to leverage heterogeneous model artefacts for early system behavior V&V

- RQ 1: What are the current best practices and applications of model-based approaches in SE for early V&V?
- RQ 2: How can industrial SE practitioners use heterogeneous models for behavior analysis in the scope of early MBSE stages?
- RQ 3: How can light-weight model-based methods facilitate initial holistic system architectures for behavior analysis?

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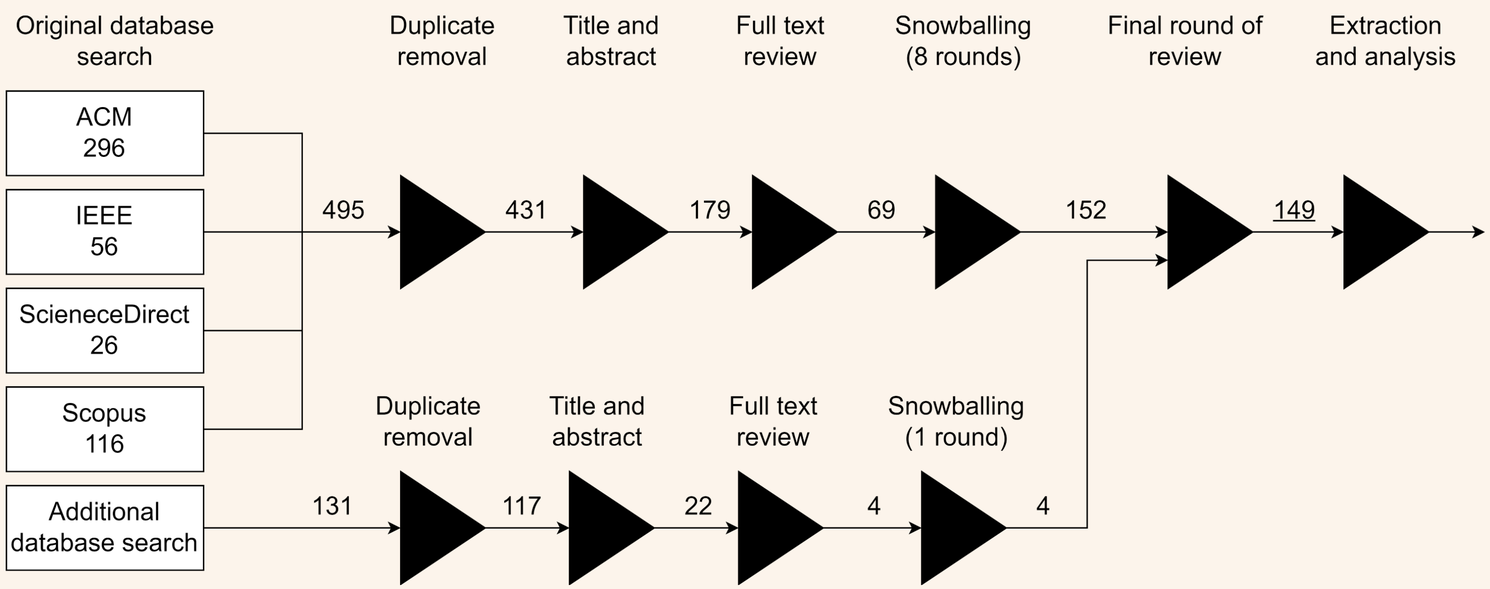
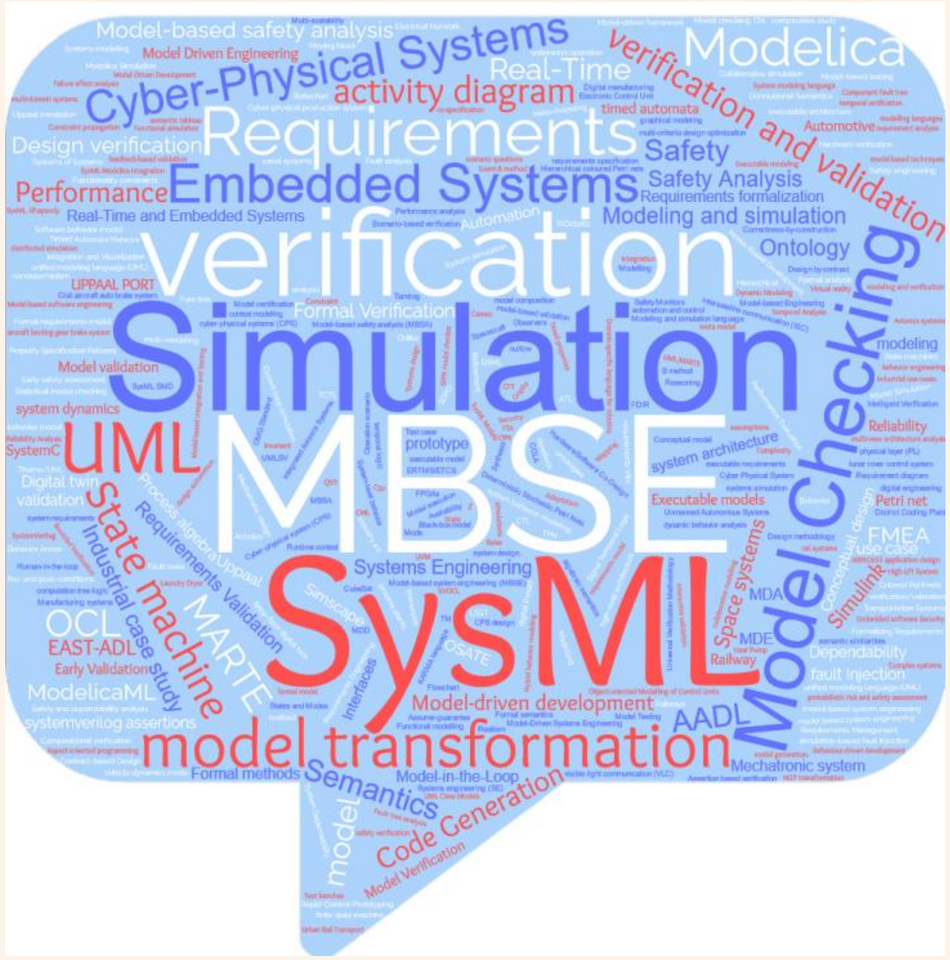
Contribution 1

A systematic literature review on the concept of early V&V in model-based systems engineering.





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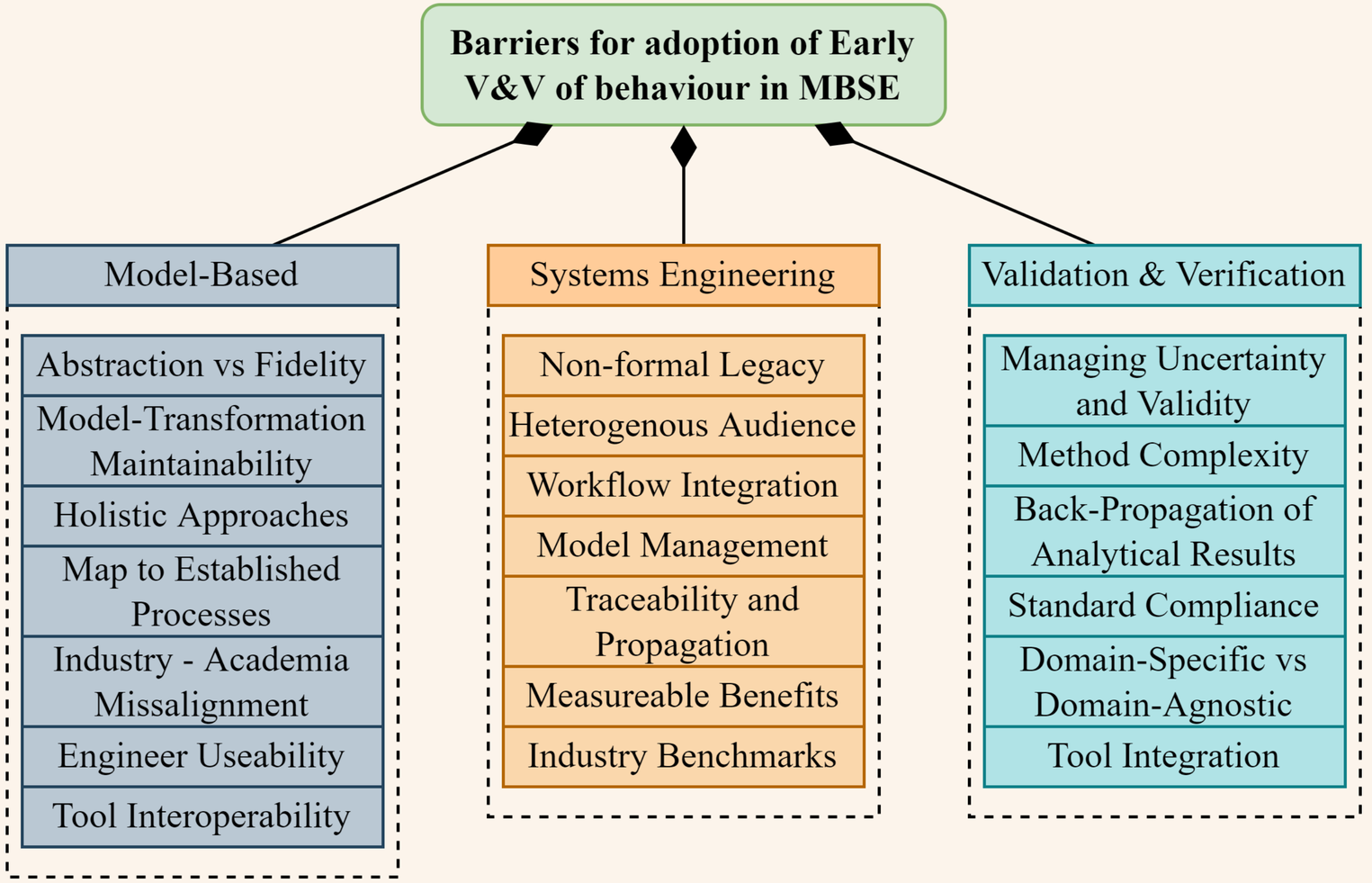

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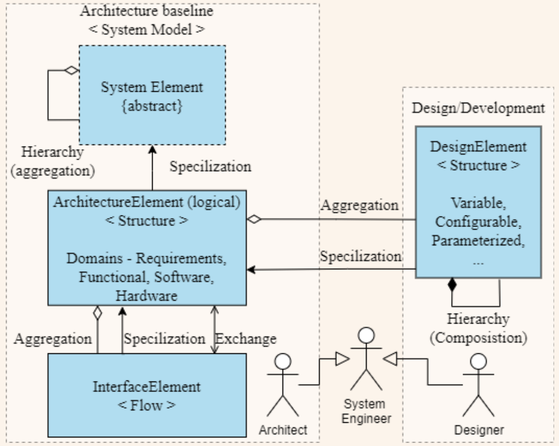
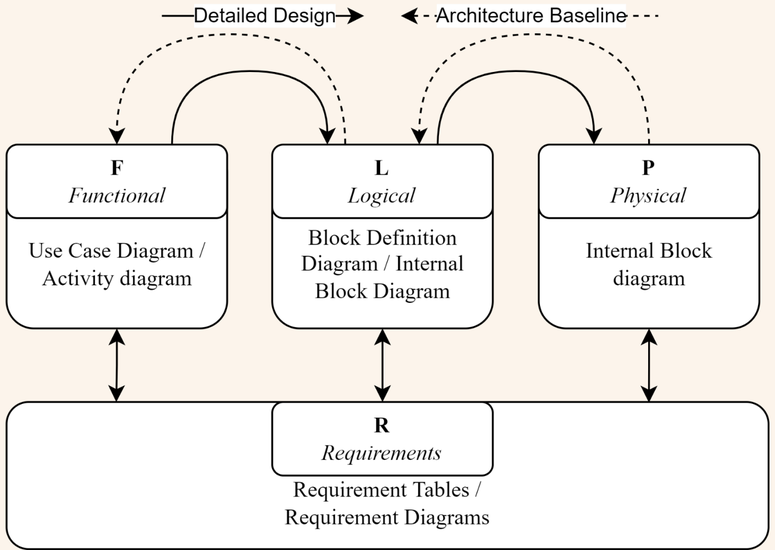
Contribution 2

Initial proposal and definition of light-weight bottom-up MBSE approach for architecture definitions.

- Current existing MBSE methods (top-down) map poorly to legacy methods that are bottom-up
- The adoption of MBSE is a general problem in industry, particularly for practitioners who are non-modelers
- We leverage an existing ontology for architecture and design in CE domain to propose a light-weight method for architecture baseline creation.





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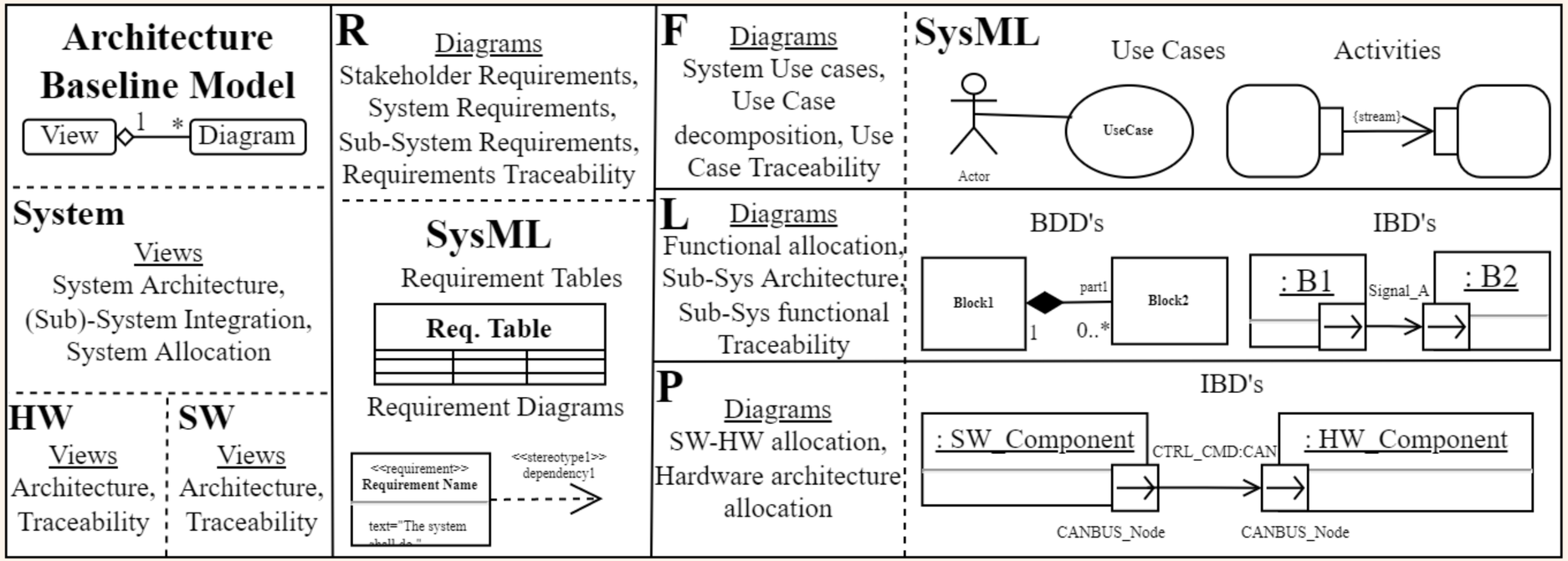

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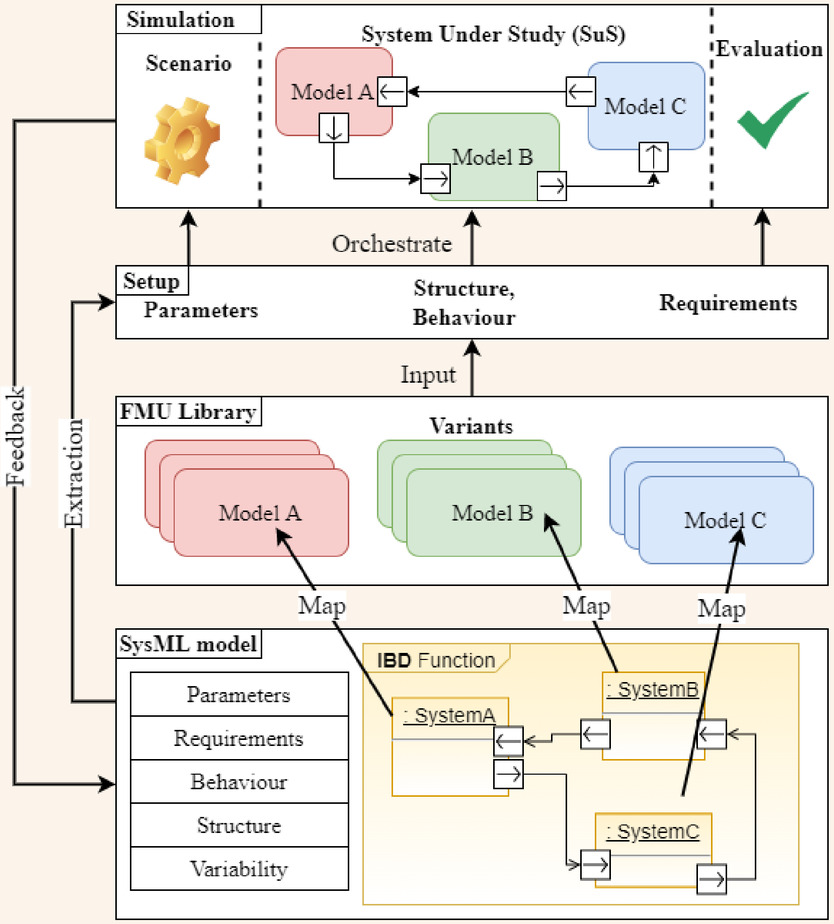
Contribution 3

Industrial experience, opportunities, and challenges for simulation, and Co-simulation of system behavior at early stages of development

- Co-simulation is hyped in literature for MBSE workflows, particularly using the Functional Mock-up Interface (FMI) standard.
- Through experience of integrating Co-simulation in architectures seen in the figure, we have collected experience in dealing with Co-simulation (notably using FMI)
- We identify several challenges and current inhibitors with the current integration in MBSE



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Contribution 3

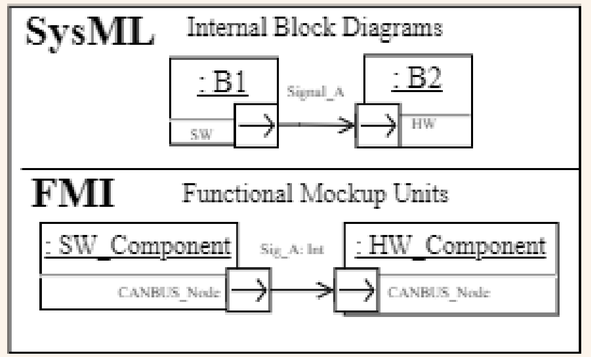
Industrial experience, opportunities, and challenges for simulation, and Co-simulation of system behavior at early stages of development

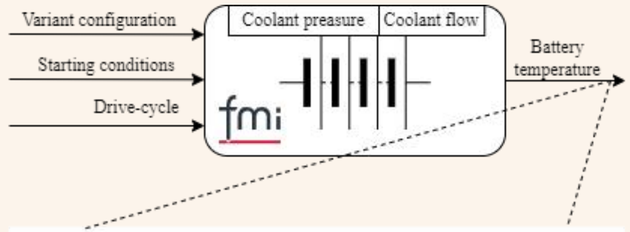
Identified high-level barriers:

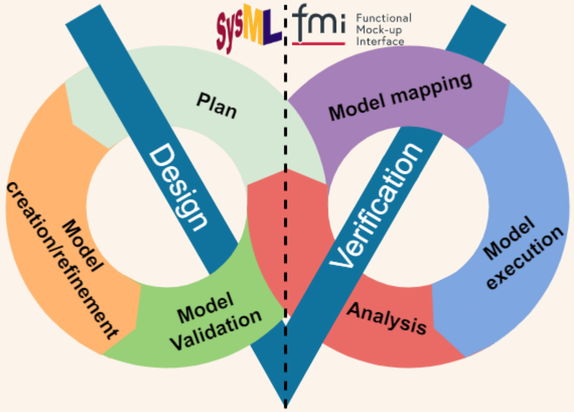
- Integration in MBSE workflows
- Technical soundness of FMI standard

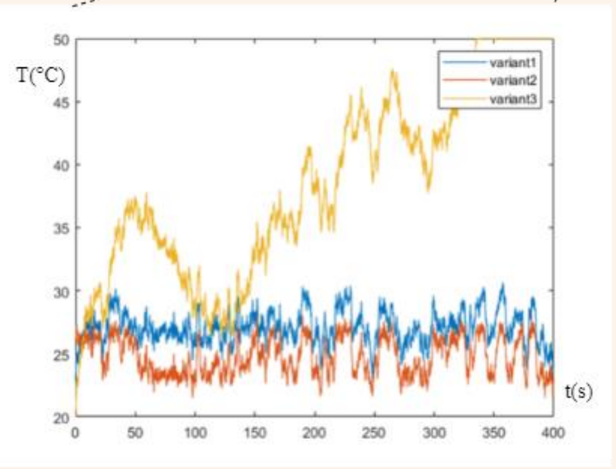
(Most common co-simulation standard)

- Automation
- Value demonstration

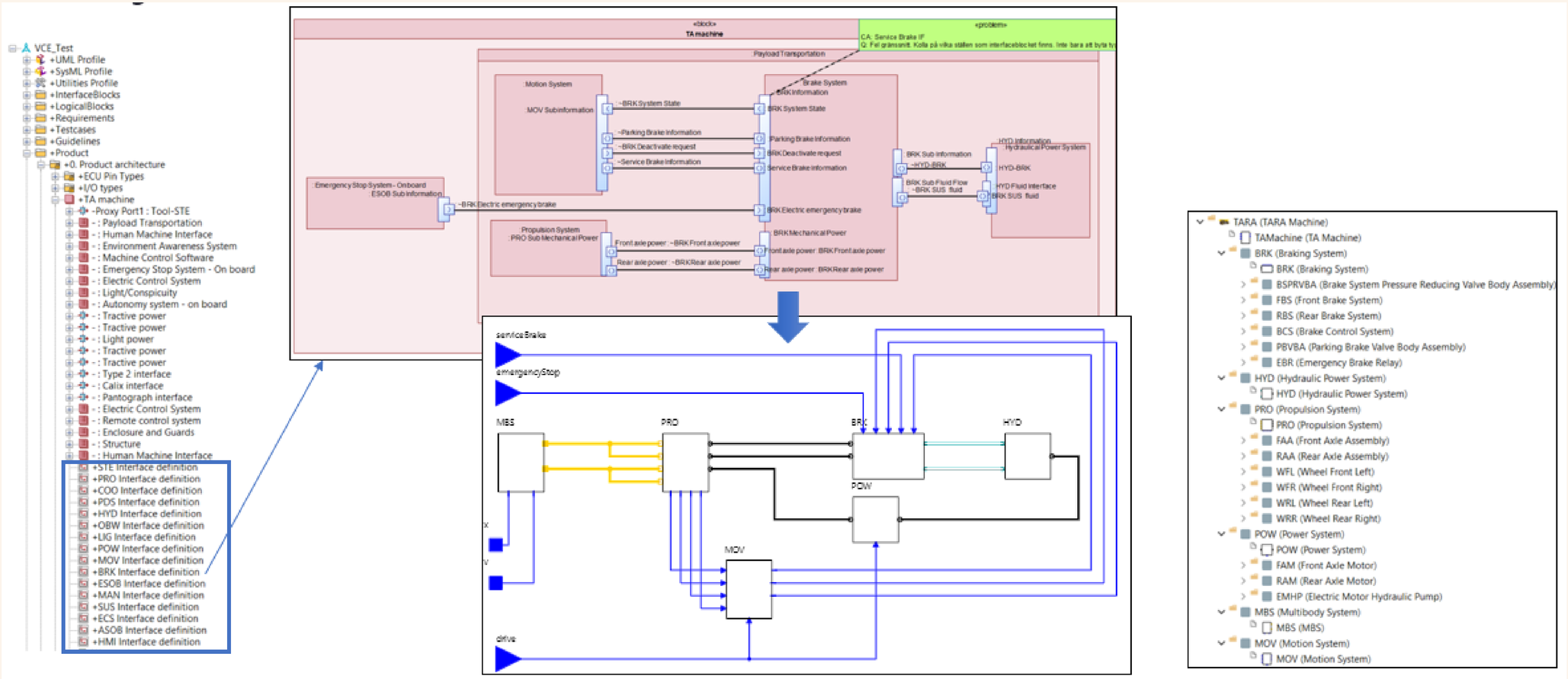








MBSE & FMI – Industry example



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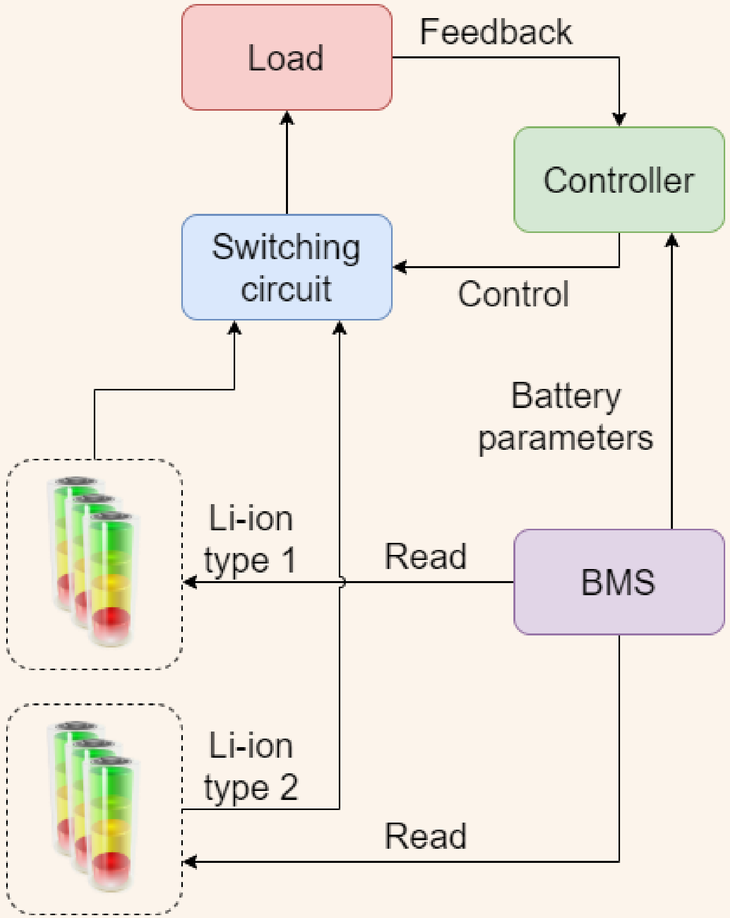
Contribution 4

Implementation and evaluation of an early validation MBSE methodology for heterogeneous system simulation

- Heterogenous battery systems are complex battery systems involving two or more cell types on a joint output
- The high complexity creates a need for sophisticated control during run time, but also trade-off before implementation
- A method to quickly and iterativly model a ”good enough” system model for *early* trade-off analysis was created and validated by building a physical prototype.



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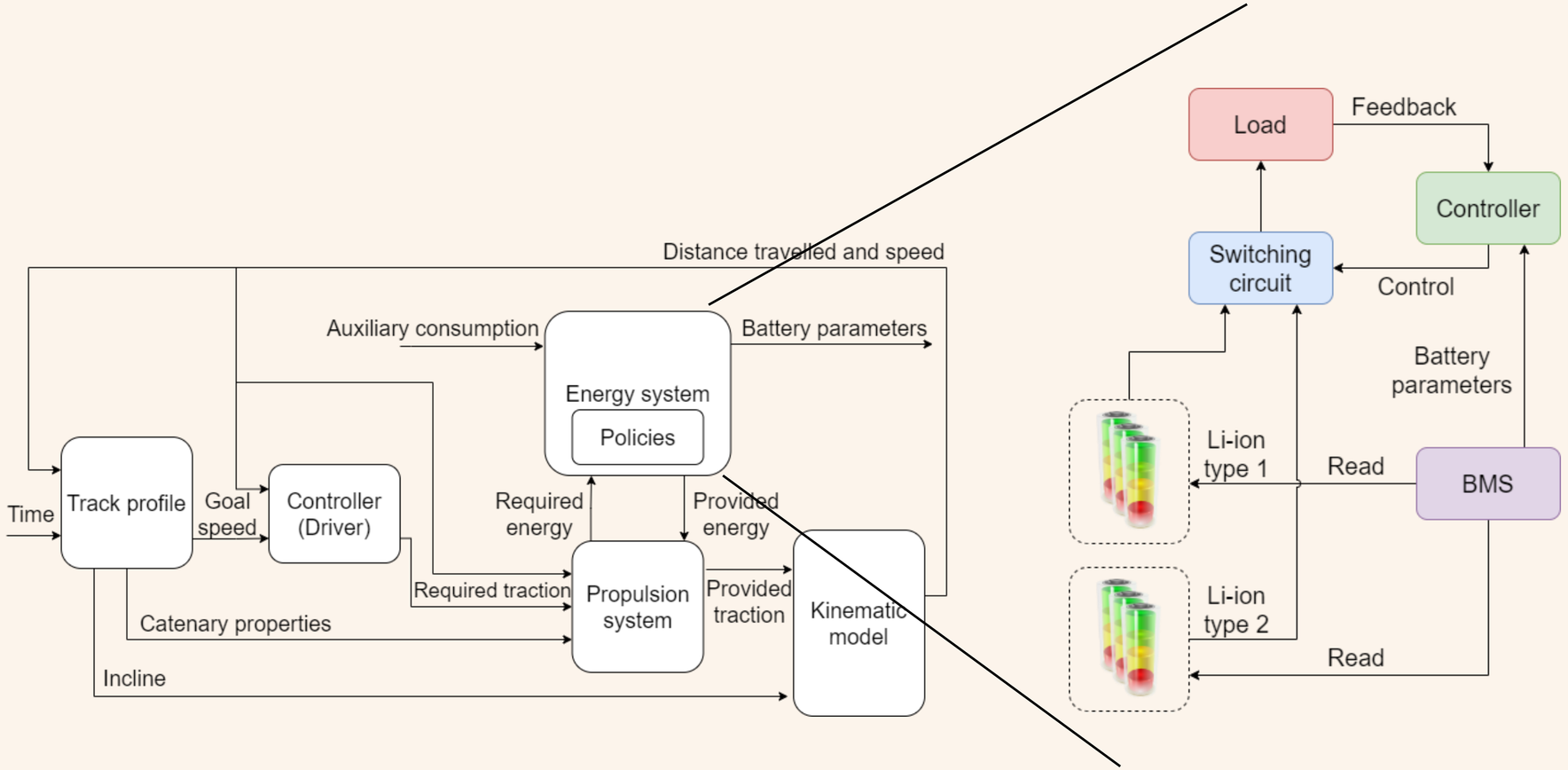

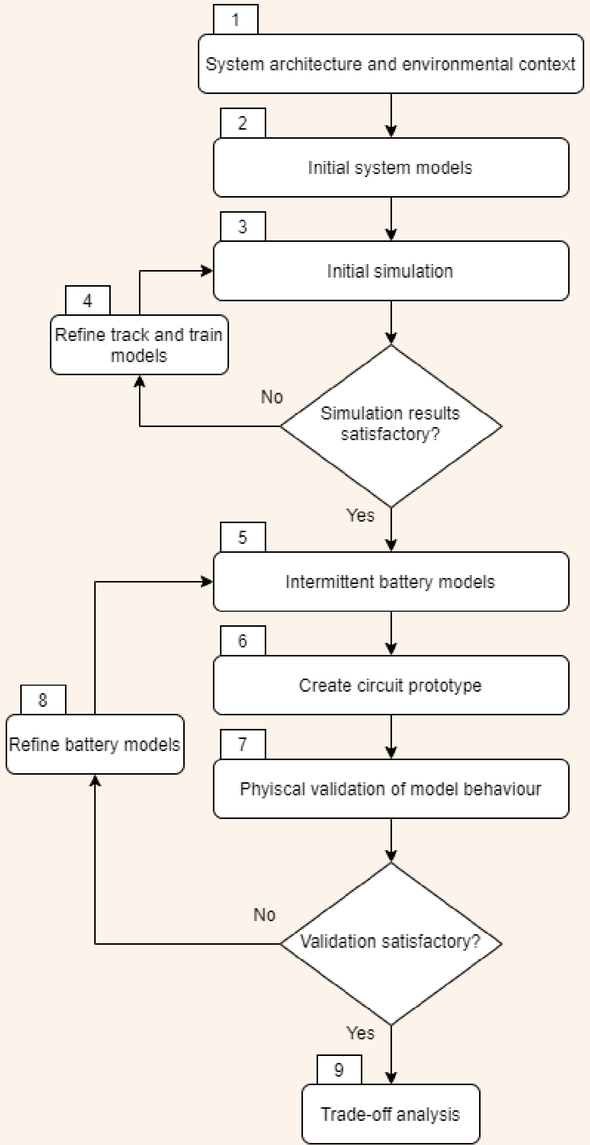

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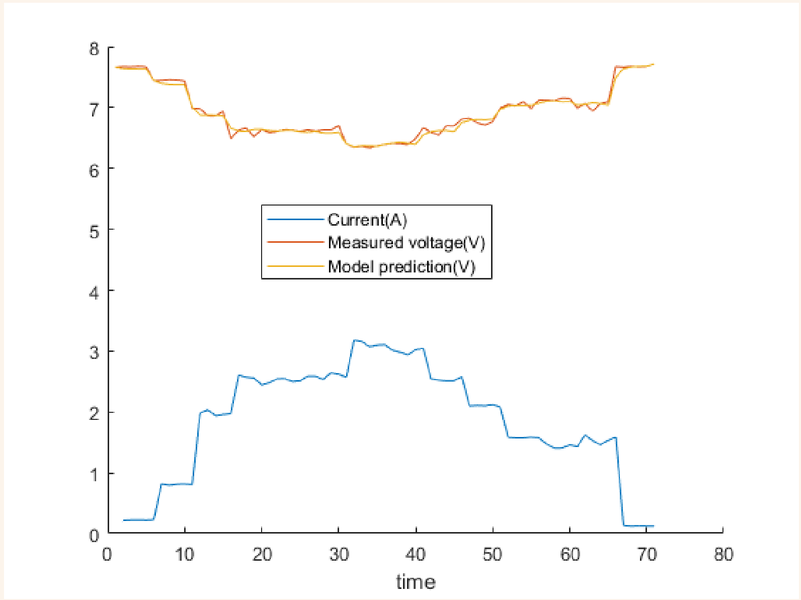
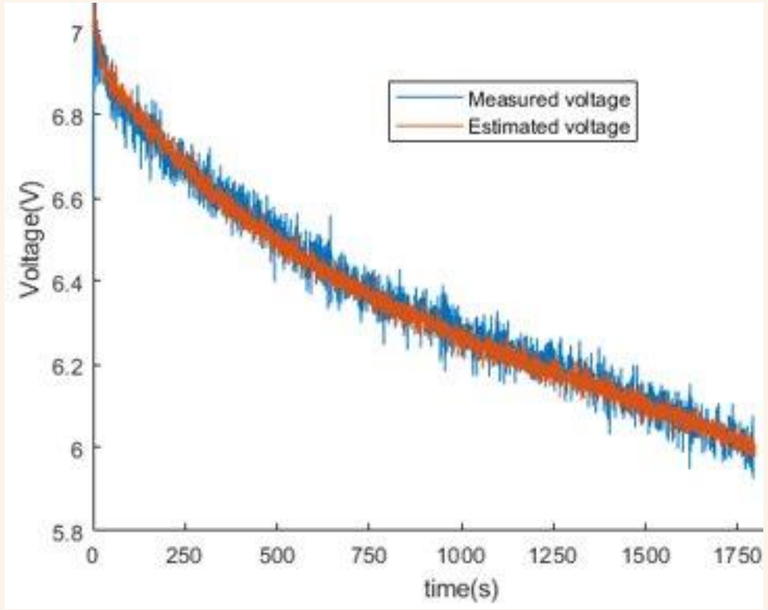
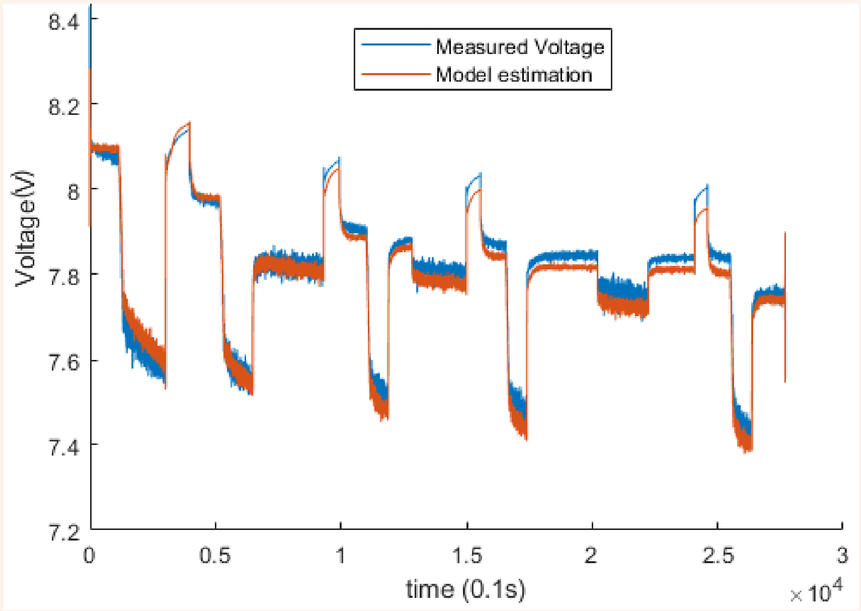
Short time dynamics



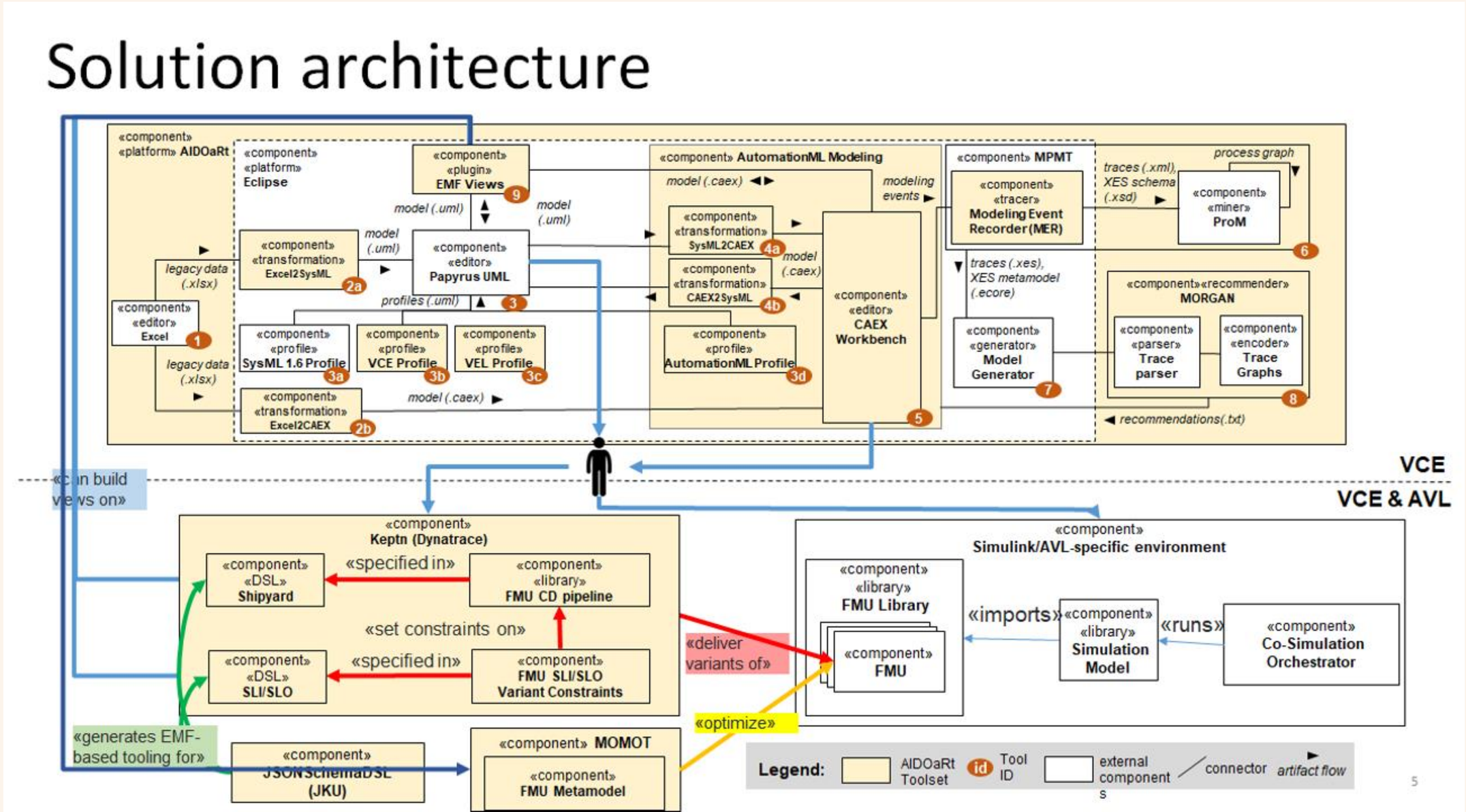
Regular discharge test



Train use case



AIDOaRt context



Introducing Automation