Antwerp - workshop 2023-11-23

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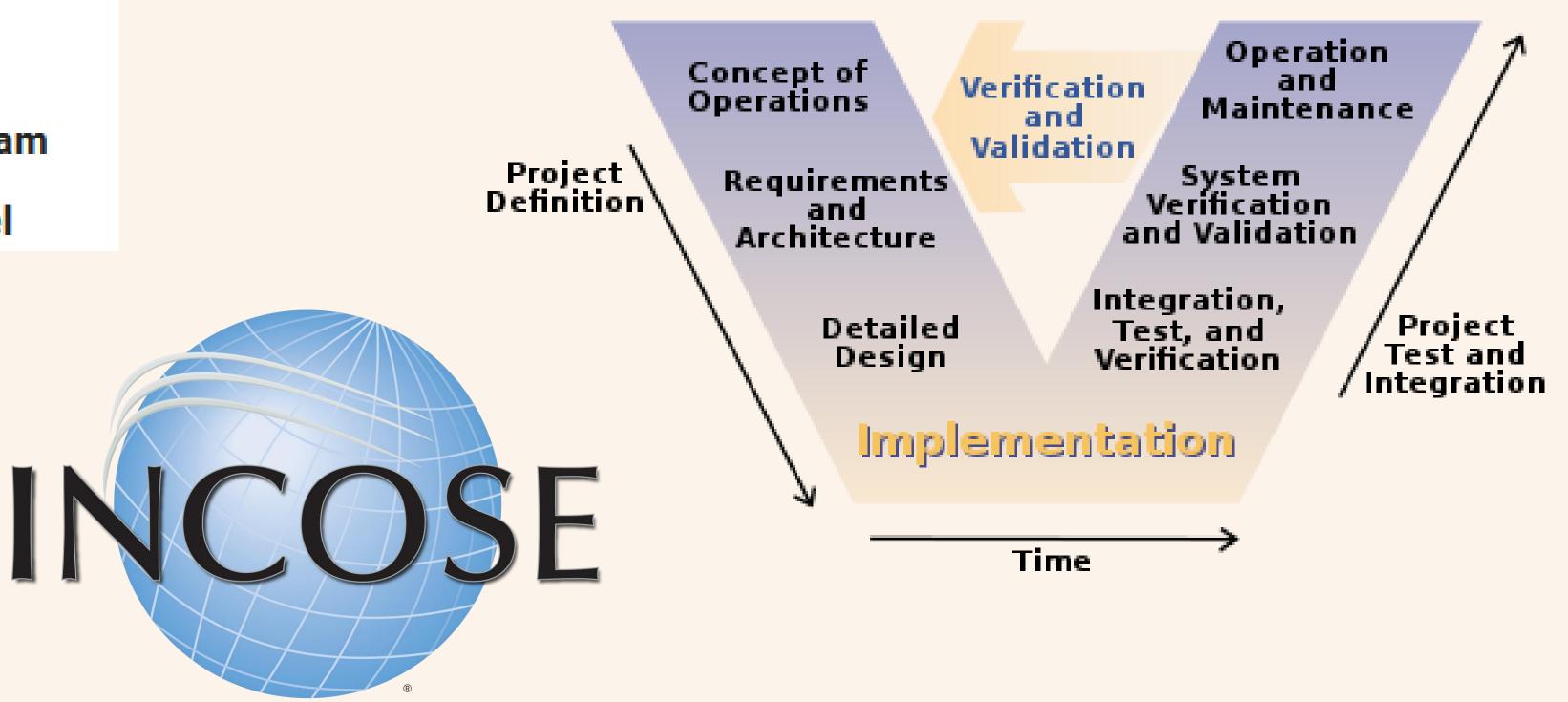


Systems engineering (SE)

Systems engineering

systems engineering **v** systems engineering **v diagram**

systems engineering v model

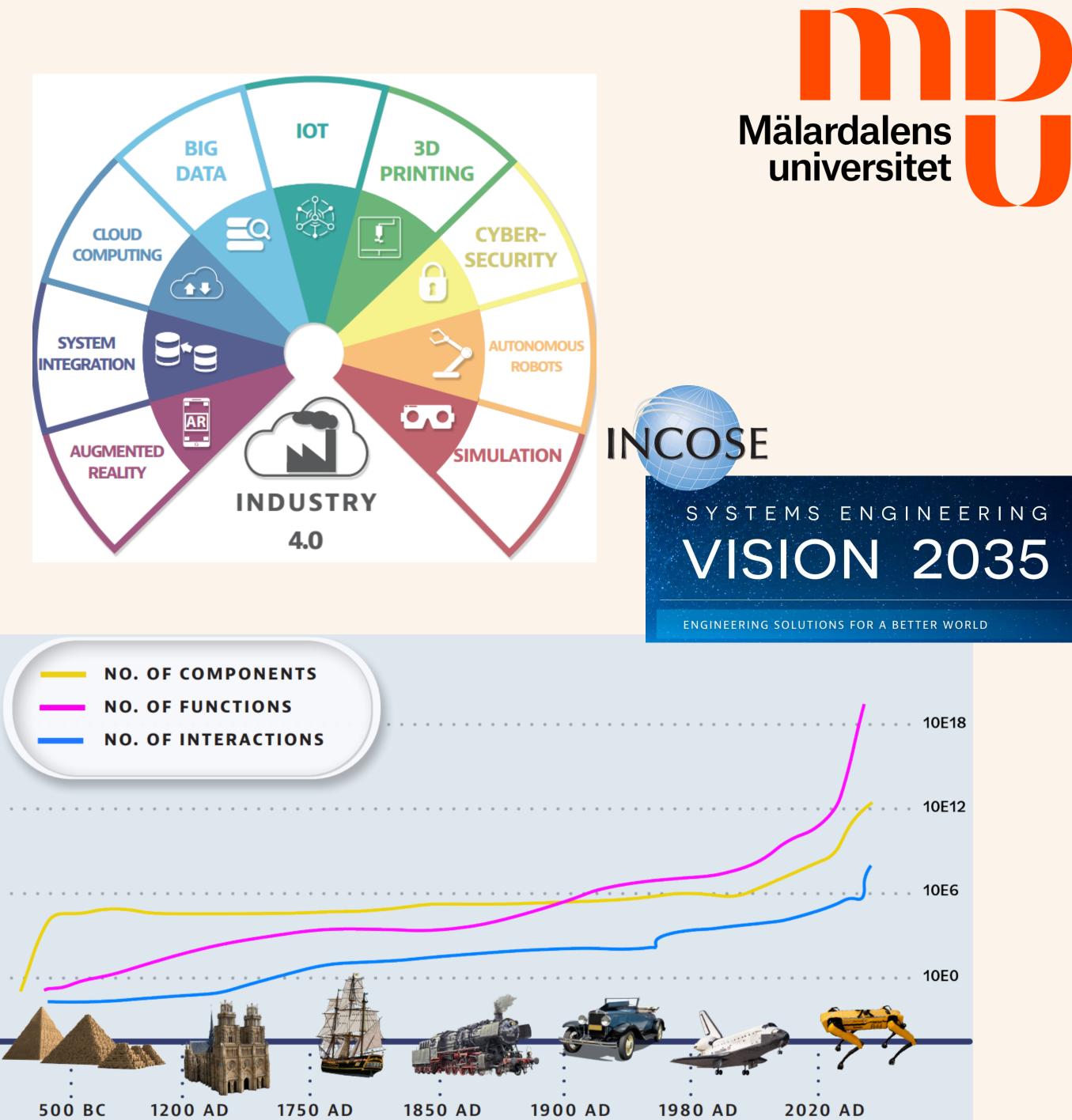




Complexity increase in processes and products

Paradigm shift(s) in systems engineering

How to manage?



INCOSE

Model-Based Systems Engineering (MBSE)

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

Promotes integration, traceability, communication, and so on.



SYSTEMS ENGINEERING VISION 2035

ENGINEERING SOLUTIONS FOR A BETTER WORLD



Model-Based Practices

The Future of Systems Engineering Is Predominantly Model-Based

Although a growing number FROM 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.

Systems engineers routinely compose task-ТО 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 cloudbased, 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.

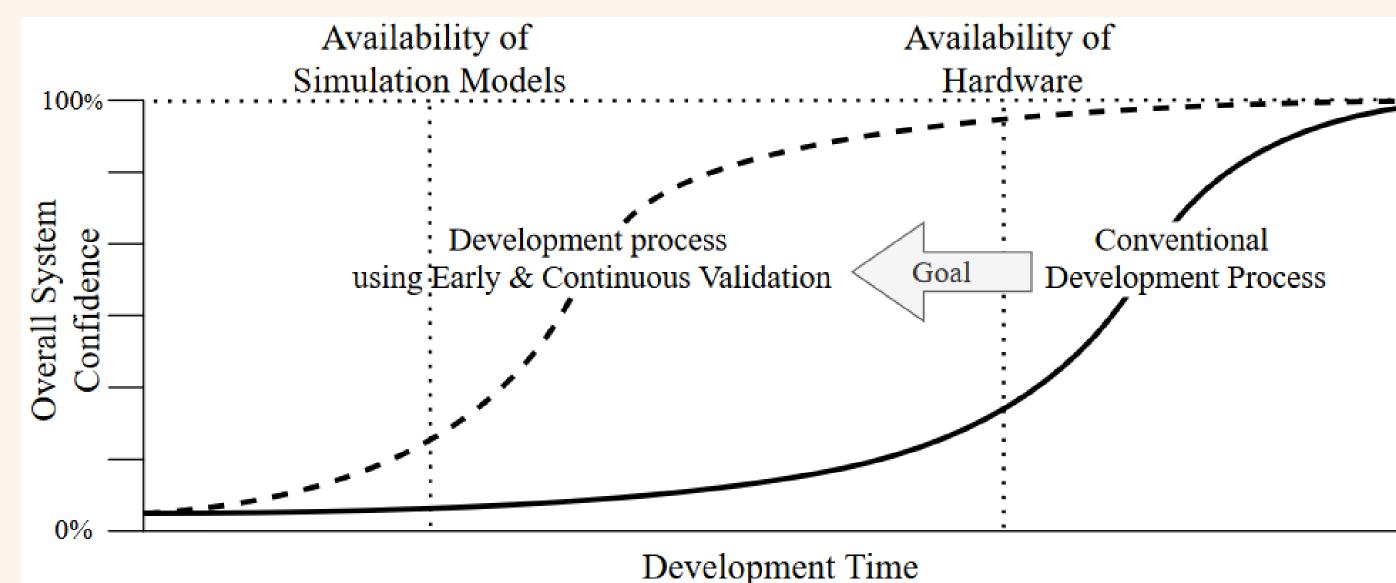




Models allow more detailed system behavior analysis earlier

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

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



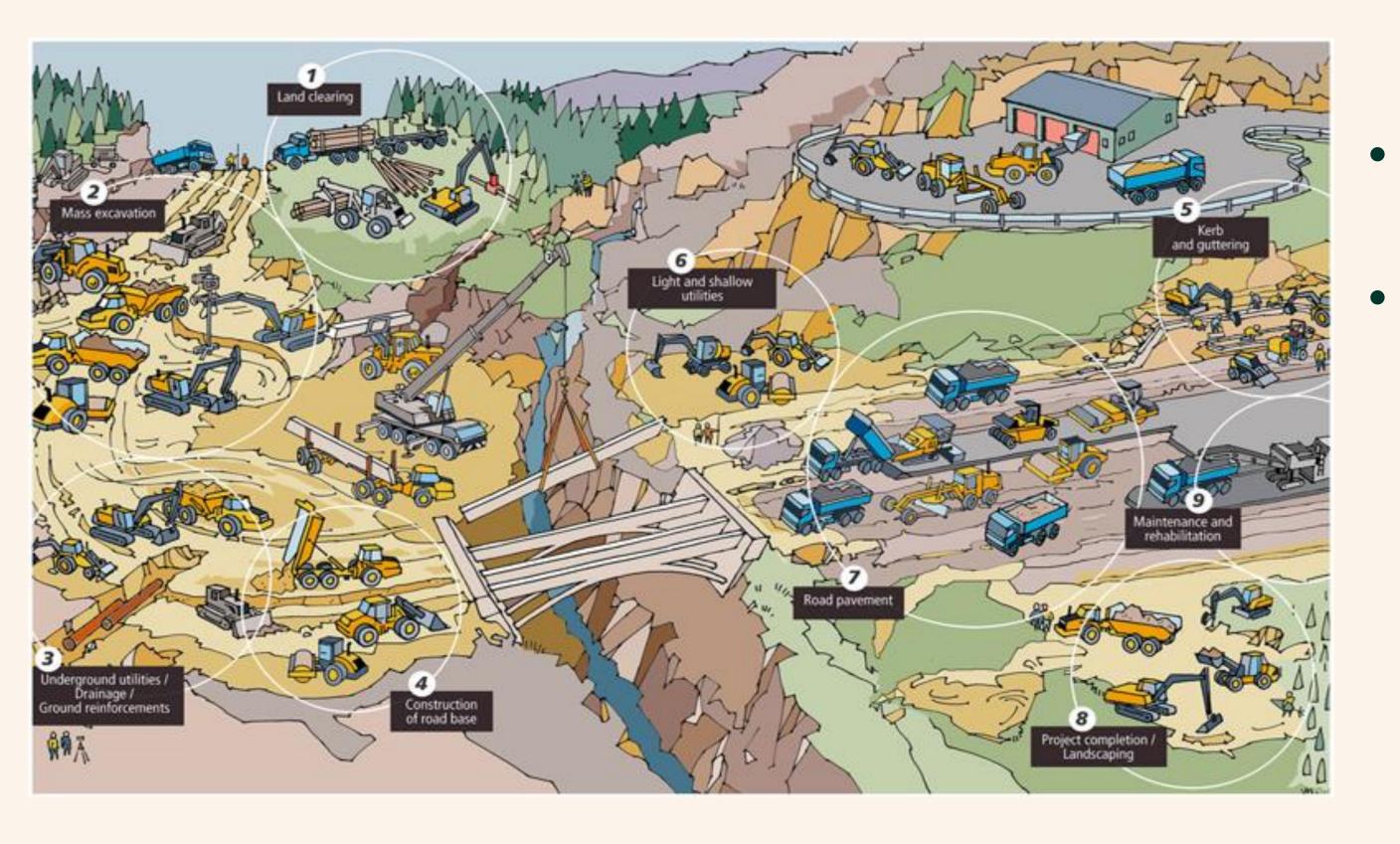


Abdo, K., Broehan, J., & Thielecke, F. (2023). A Seamless and End-to-End Approach for Early and Continuous Validation of Next-Generation Avionics Platforms. In Software Engineering 2023 Workshops. Gesellschaft für Informatik eV.

Författare/presentatör

Institution och eventuell avdelning

Här står titeln på presentationen på två till tre rader Här står titeln på presentationen på två till tre rader Här står titeln på presentationen på två till tre rader



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

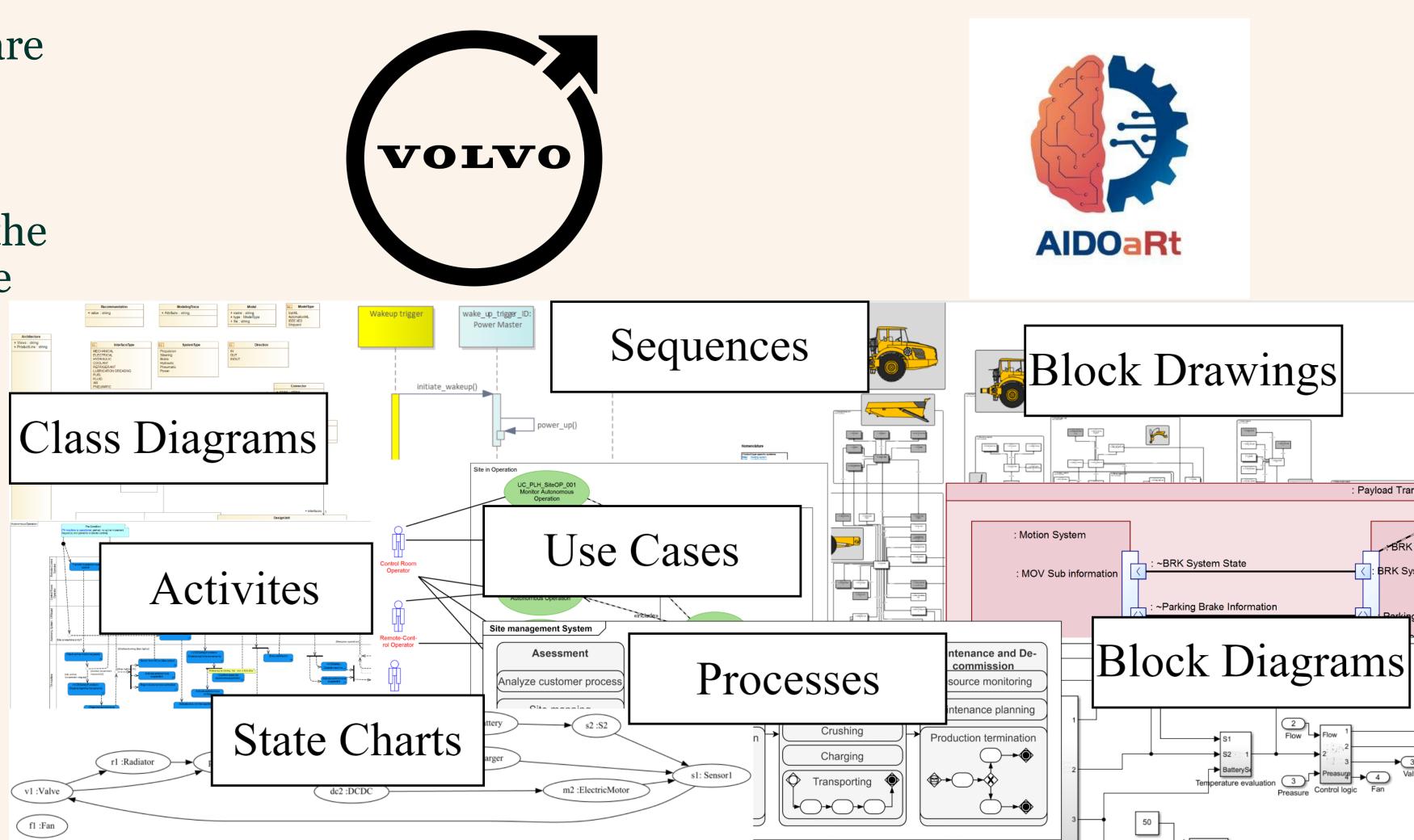


VCE is a global manufacturer in the **Construction equipment domain Complexity raising in a historically** hardware domain due to software (think about machines yesterday)

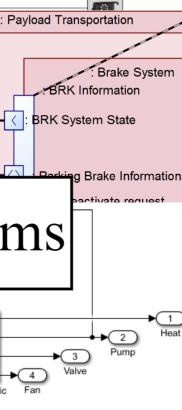
SE artefacts at early stages are often models of various abstraction and rigor

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*?







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

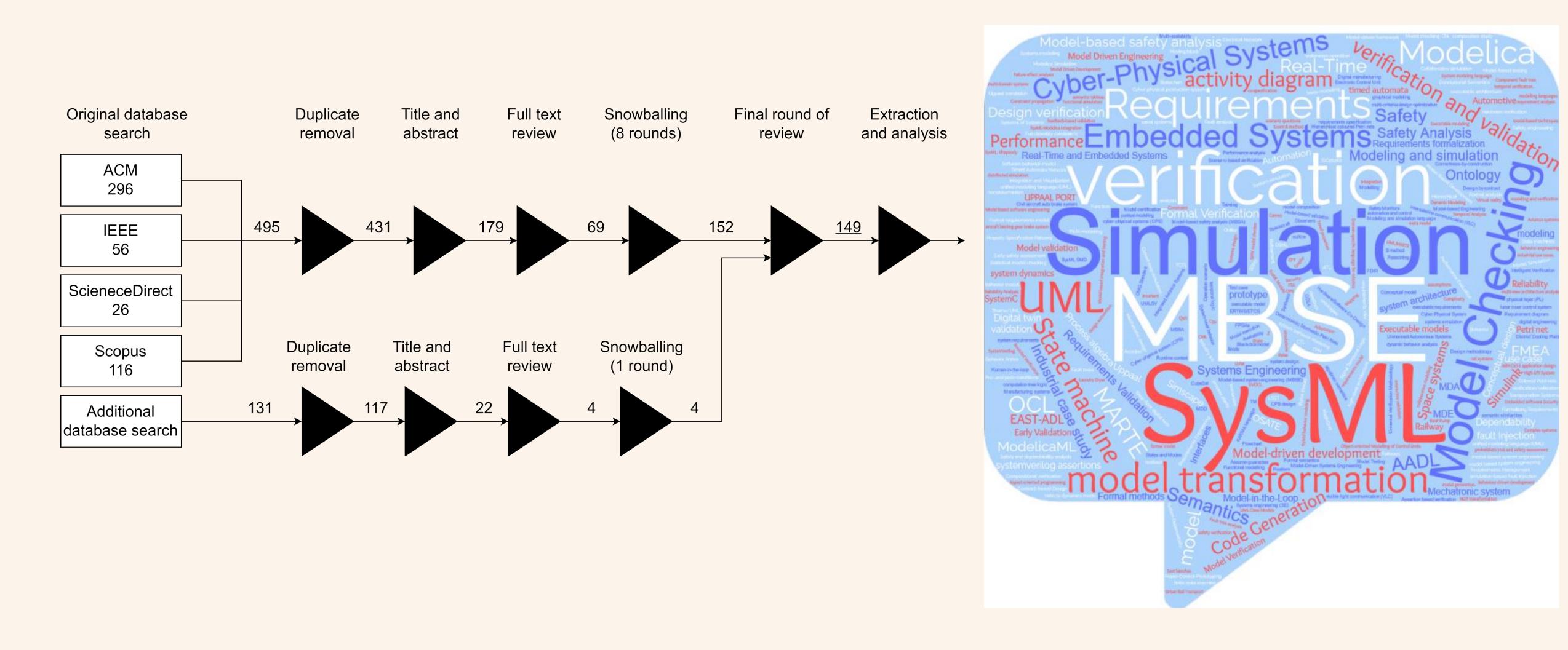
- RQ 1: What are the current best practices and applications of model-based approaches in SE for early V&V?
- RQ 3: How can light-weight model-based methods facilitate initial holistic system architectures for behavior analysis?



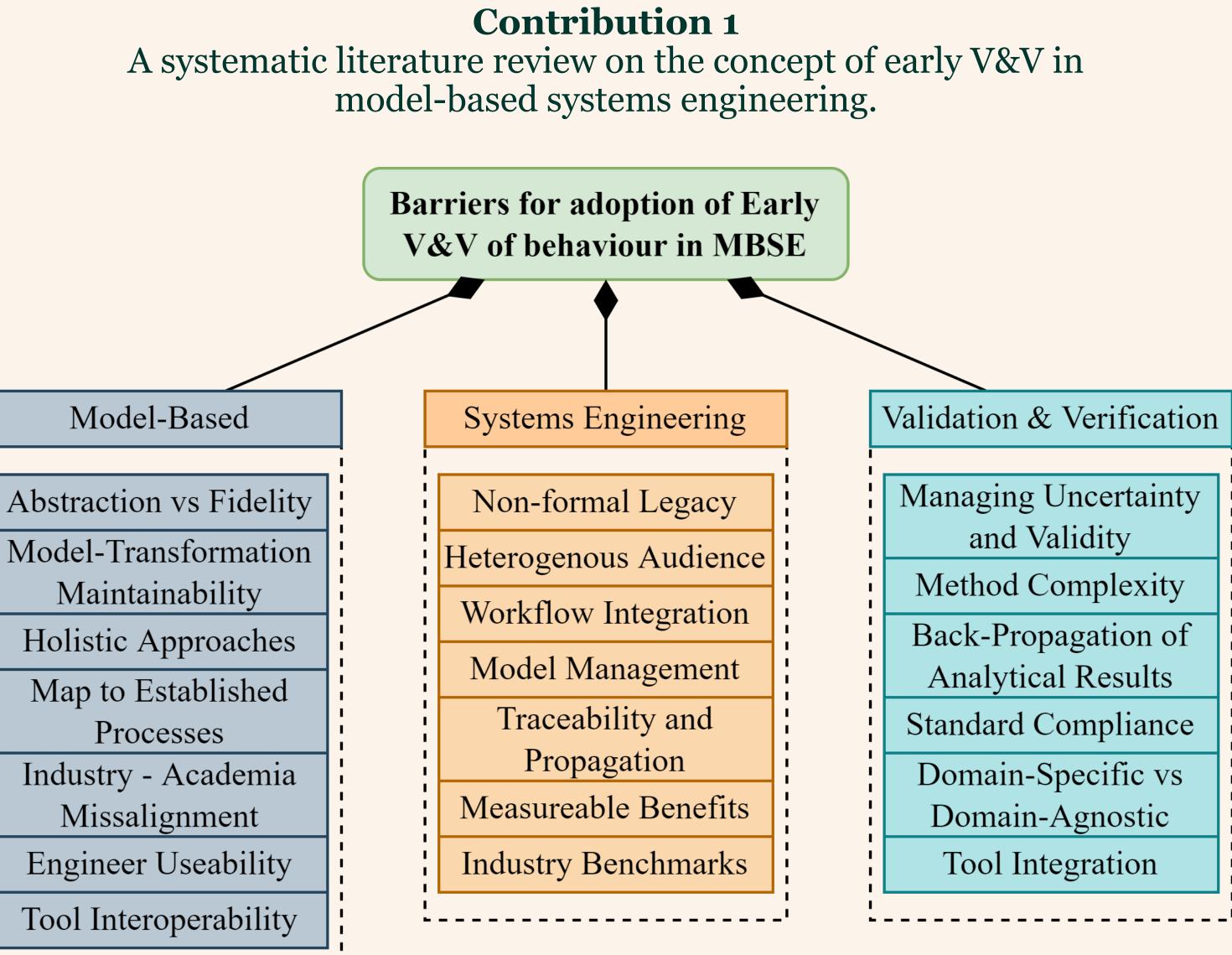
• RQ 2: How can industrial SE practitioners use heterogeneous models for behavior analysis in the scope of early MBSE stages?



Contribution 1 A systematic literature review on the concept of early V&V in model-based systems engineering.





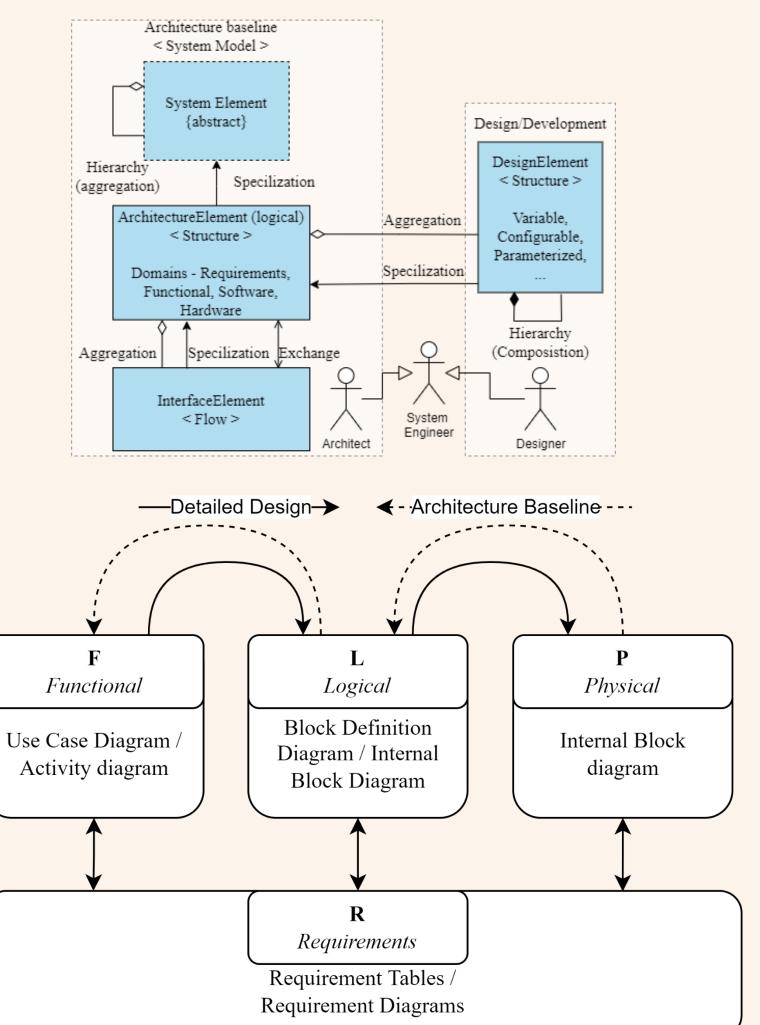




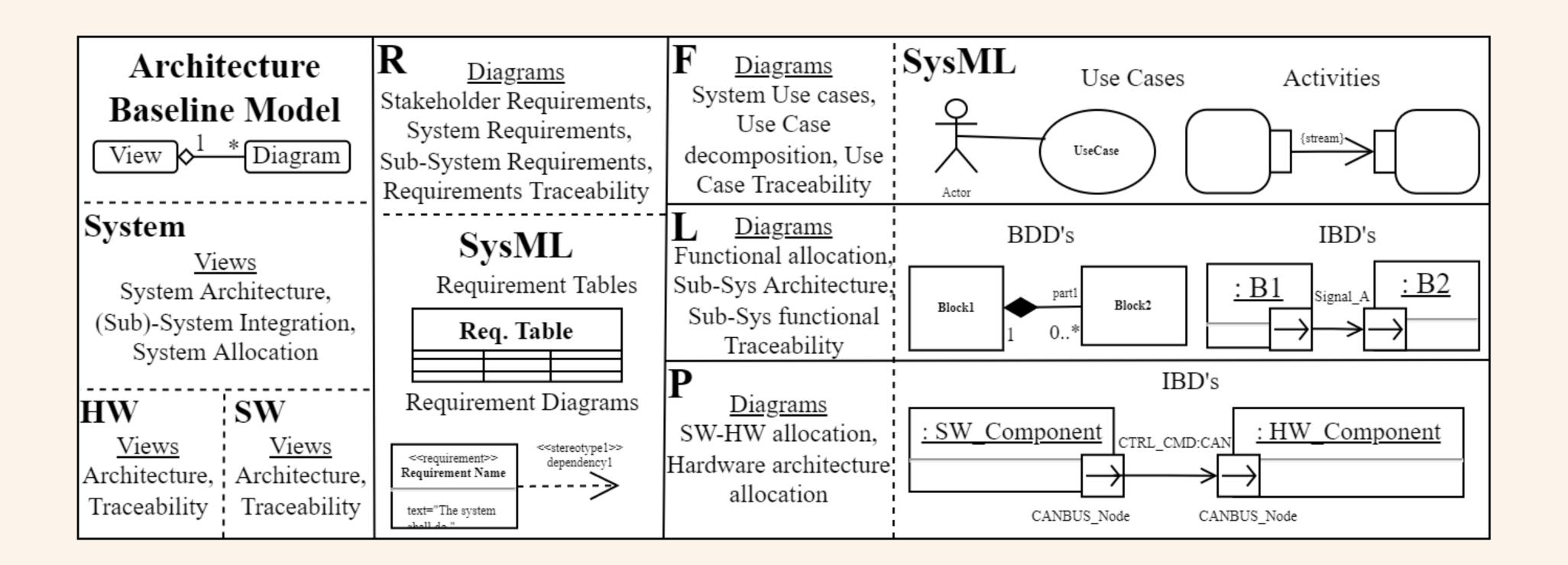
Contribution 2 Initial proposal and definition of light-weight bottom-up MBSE approach for architecture definitions.

- 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.





Contribution 2 Initial proposal and definition of light-weight bottom-up MBSE approach for architecture definitions.

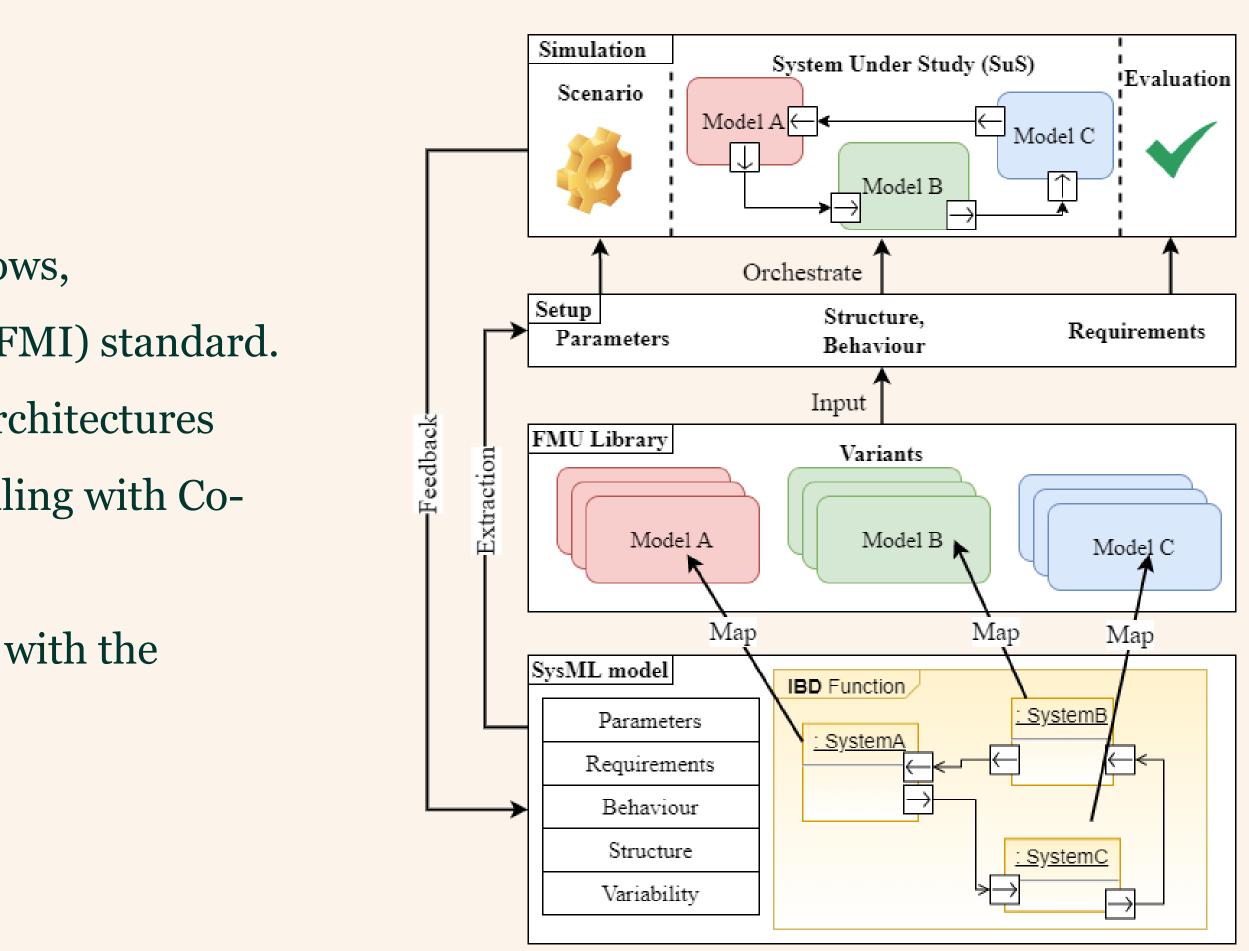




Contribution 3 Industrial experience, opportunities, and challenges for simulation, and Cosimulation of system behavior at early stages of development

- 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 Cosimulation (notably using FMI)
- We identify several challenges and current inhibitors with the current integration in MBSE



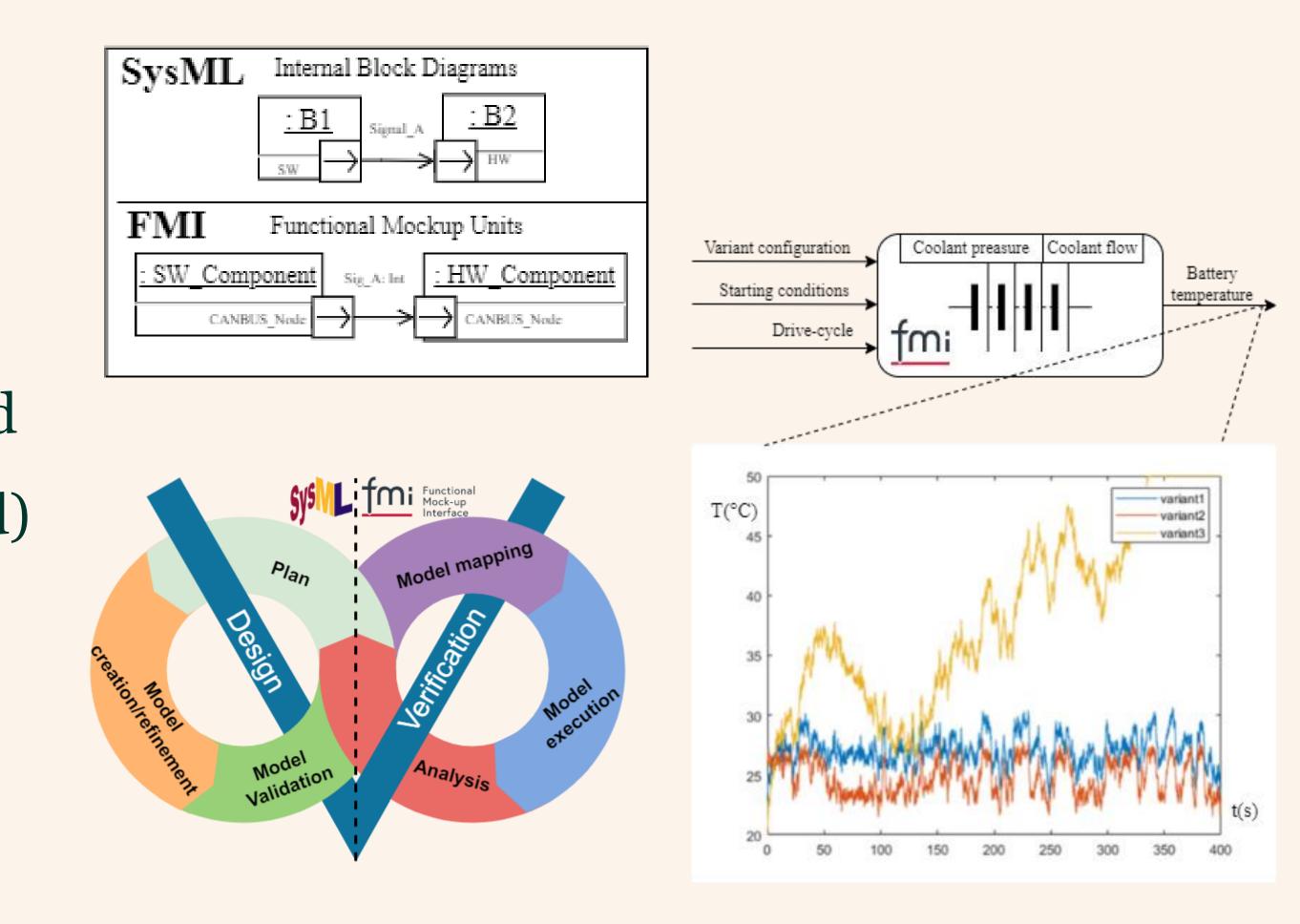


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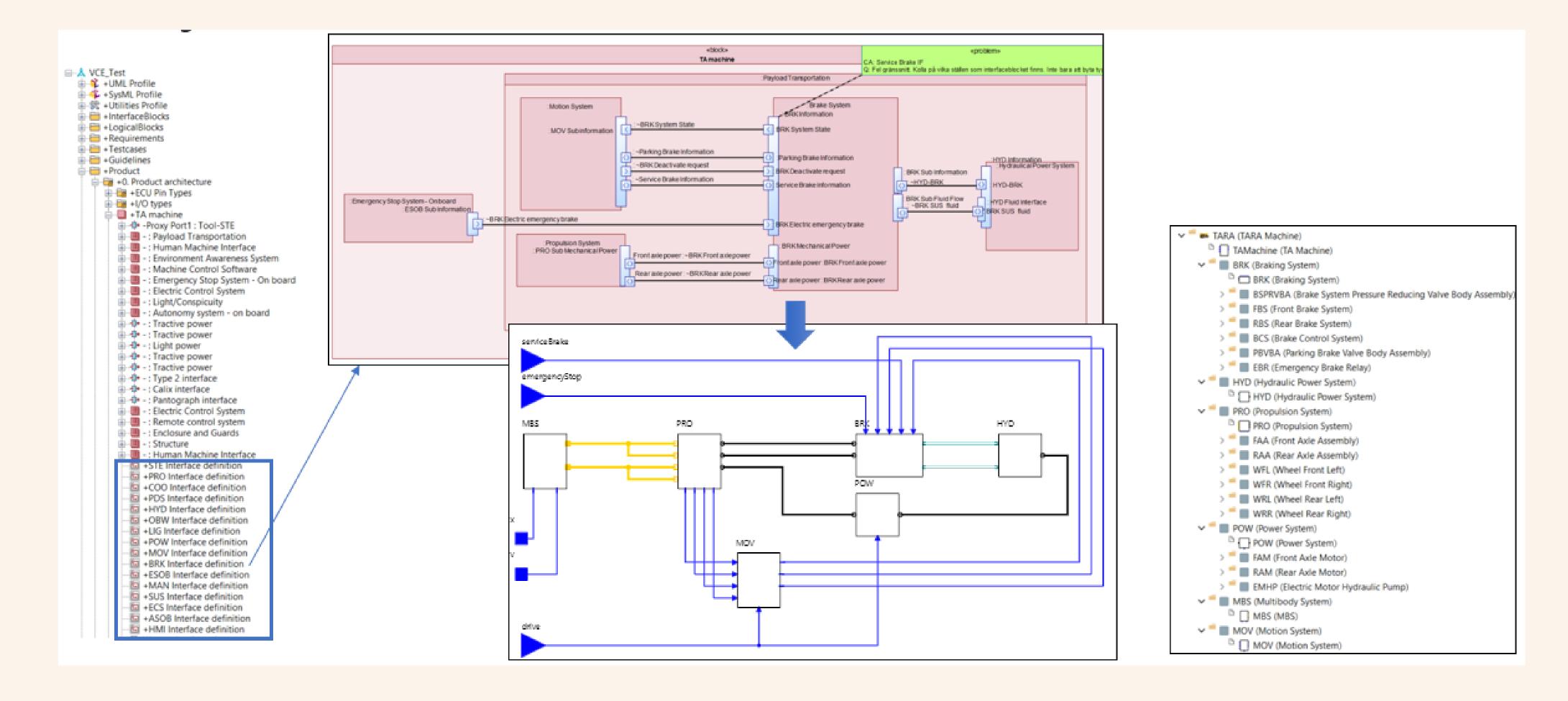
Identified high-level barriers:

- Integration in MBSE workflows
- Technical soundness of FMI standard (Most common co-simulation standard)
- Automation
- Value demonstration





MBSE & FMI – Industry example

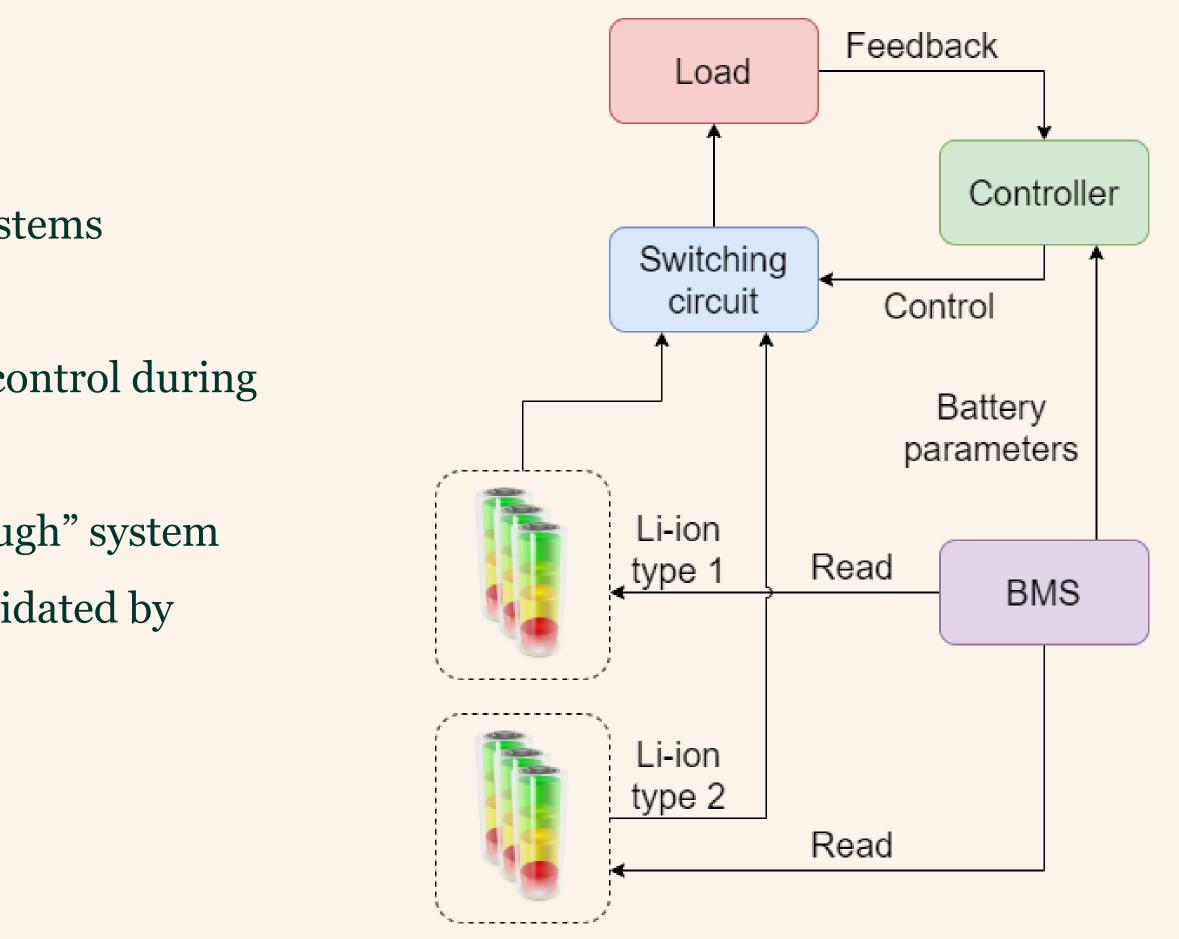


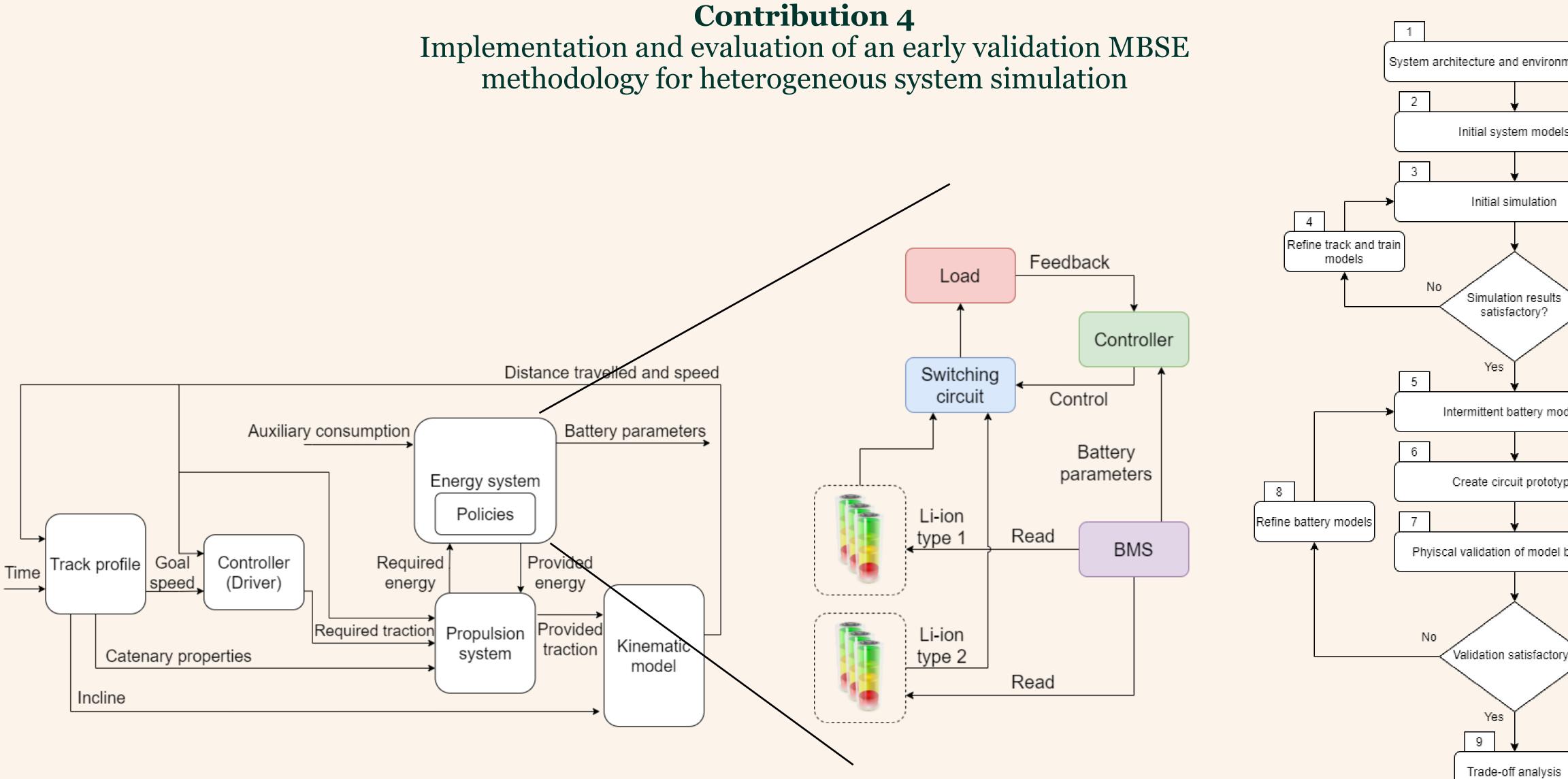


Contribution 4 Implementation and evaluation of an early validation MBSE methodology for heterogeneous system simulation

- 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.







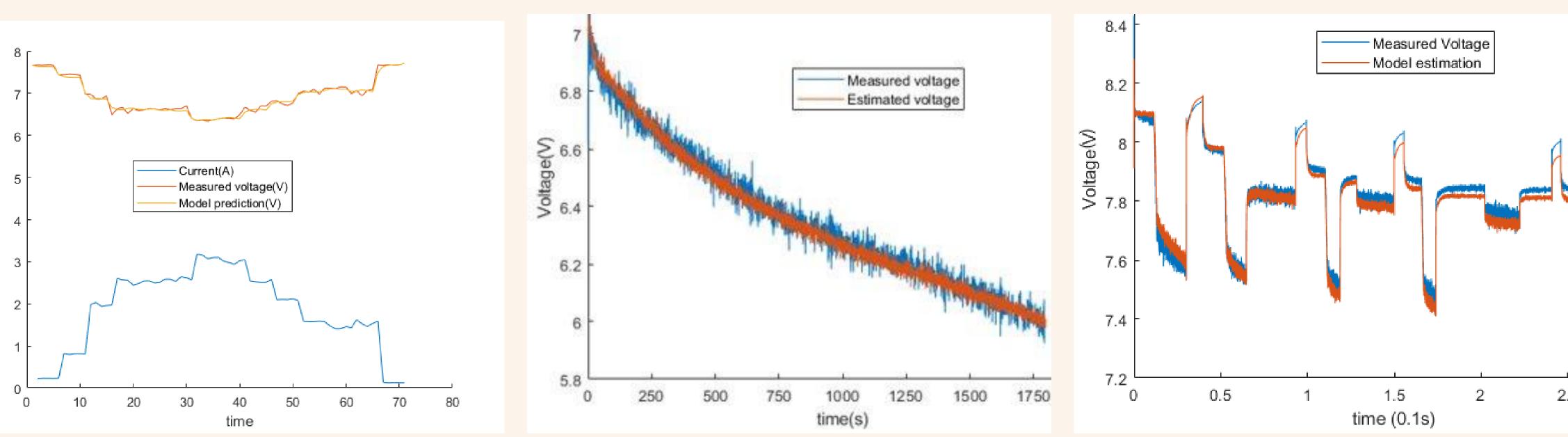


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Contribution 4 Implementation and evaluation of an early validation MBSE methodology for heterogeneous system simulation









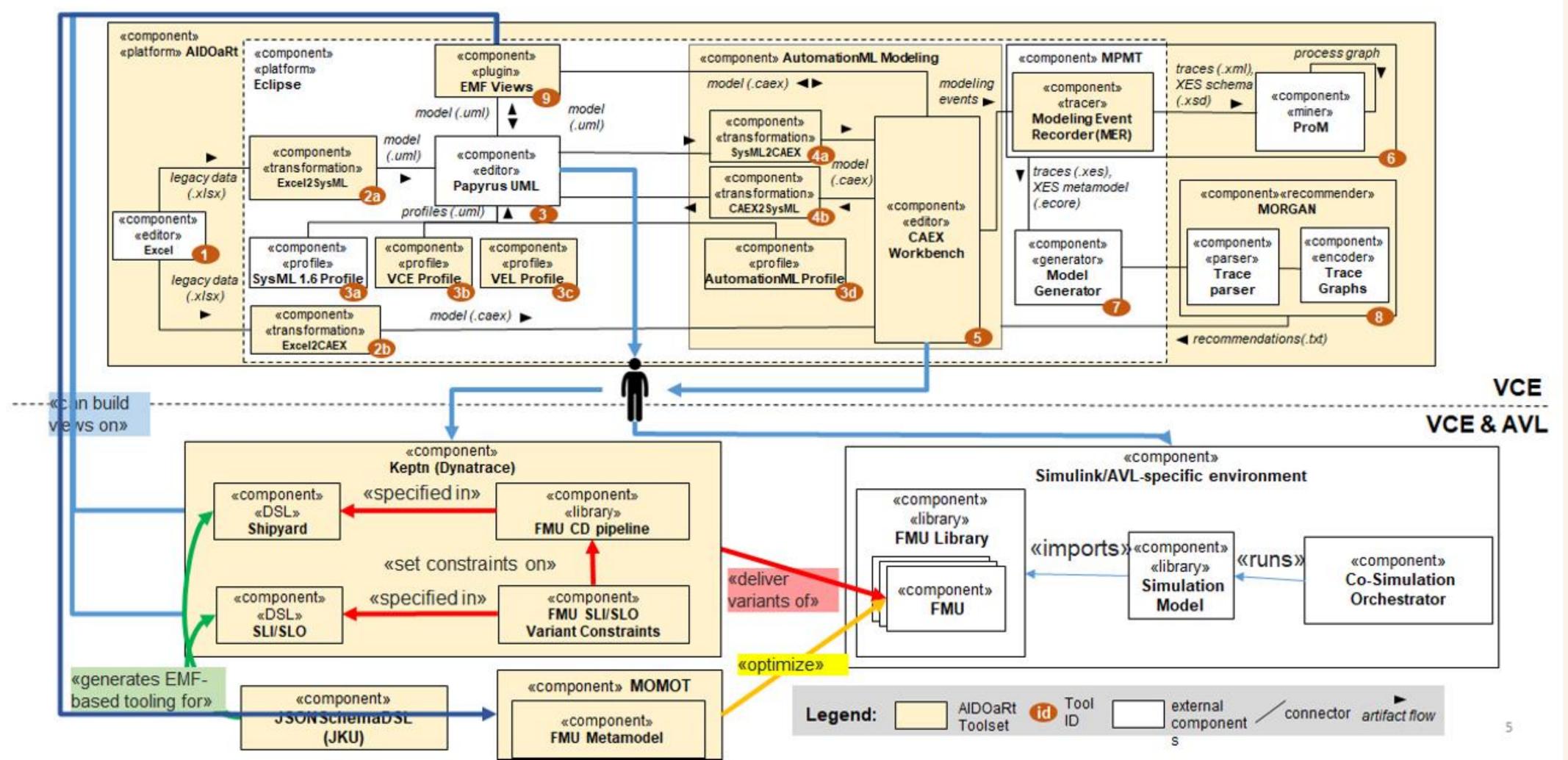
Regular discharge test

Train use case

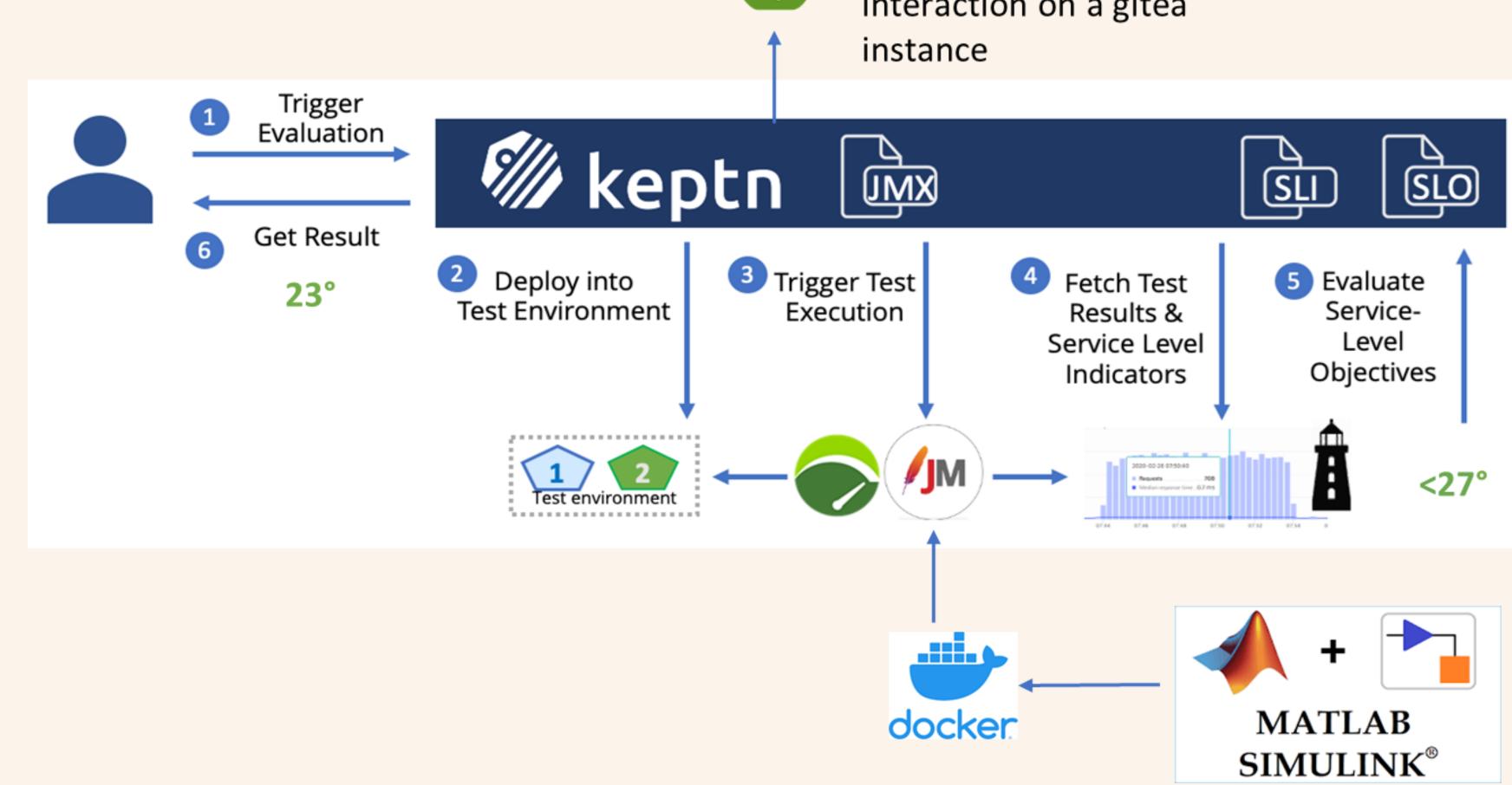
2.5 3 $imes 10^4$

AIDOaRt context

Solution architecture



Introducing Automation







Store and log any interaction on a gitea