



International Council on Systems Engineering
A better world through a systems approach

Appropriate Simulation Model Identification during Model-Based Systems Engineering

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Model-Based Systems Engineering

Model-Based Systems Engineering (MBSE) is promoted and increasingly integrated in industry.

Formalization of information in explicit computer readable models.

Promoted in the INCOSE 2035 vision.



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

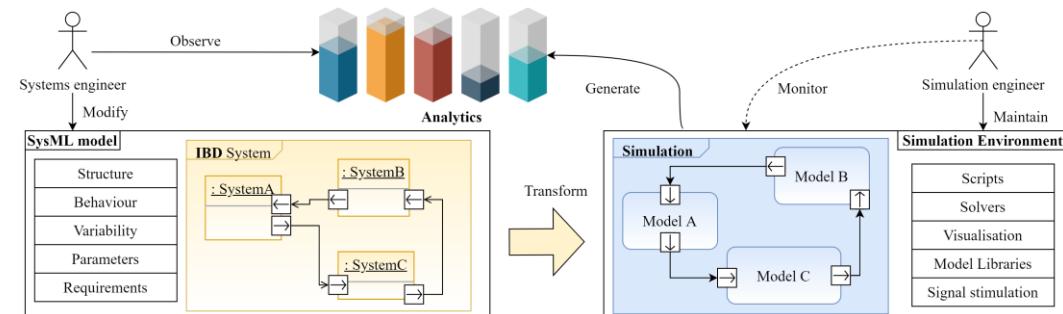
Systems engineers routinely compose task-specific virtual models using ontologically linked, digital twin-based model-assets. These connected models are updated in real-time providing a virtual reality-based, immersive design and exploration space. This virtual global collaboration space is cloud-based, 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.

Simulation as an enabled technology

Through MBSE simulation can be more readily accessible through availability of models.

Simulation can be attached to the entire life cycle of a system.

Enables increased opportunities for V&V and testing.

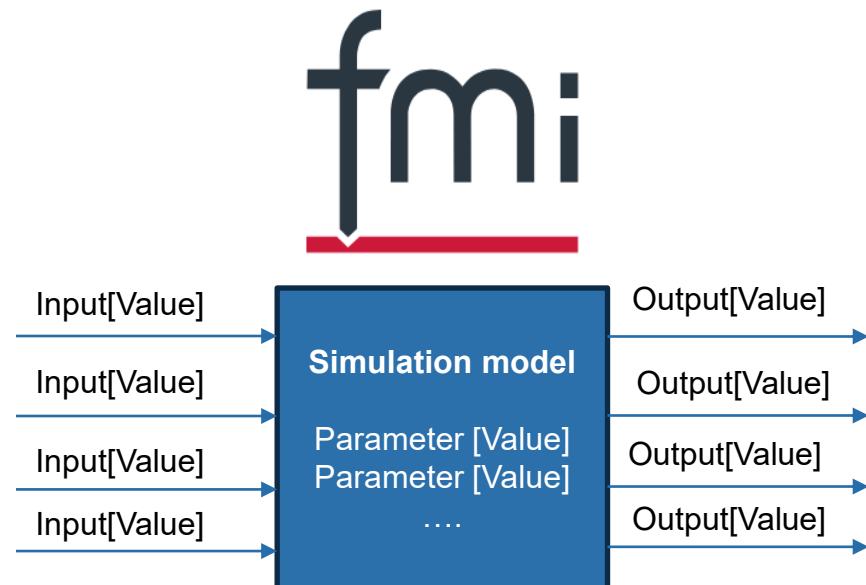


Standards role in simulation

To support simulation, standards play an important role.

For modeling, standards like SysML are widespread and supported by many tools.

Simulation is supported by standards like FMI.

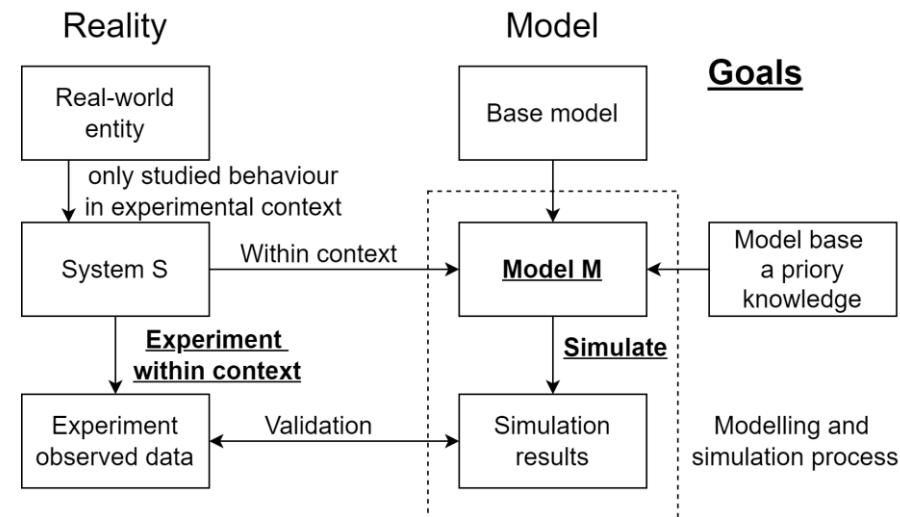


What do we mean with appropriate?

In the simulation community there has been more formal investigations to the topic of appropriateness.

Multi-Paradigm Modelling (MPM) is a specific community that has investigated this topic.

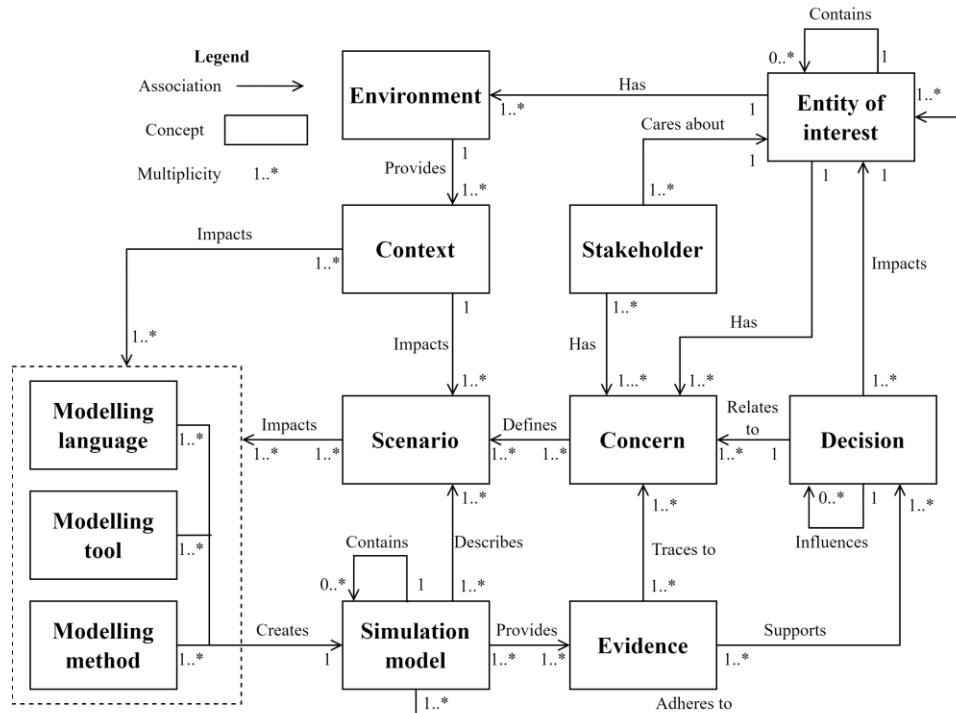
They offer a conceptual view on this topic as seen on the right.



Extension to MBSE

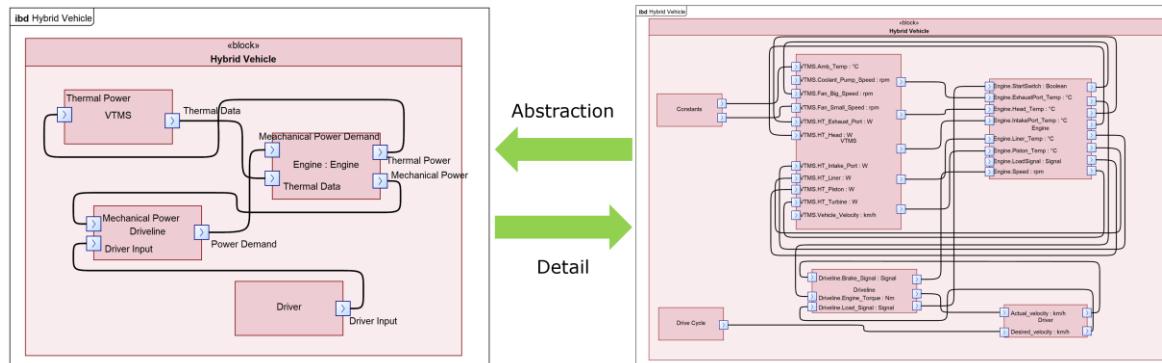
While the view presented by MPM is useful as a concept, we argue it is not sufficient for SE/MBSE, but rather a specific experiment on a system.

We provide a conceptual extension towards a number of central systems concepts, as seen on the right.



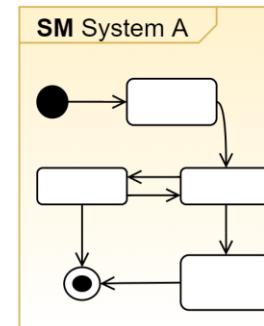
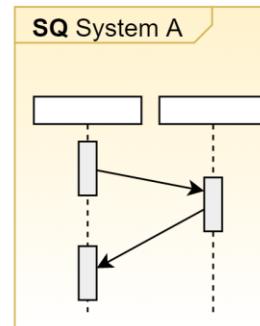
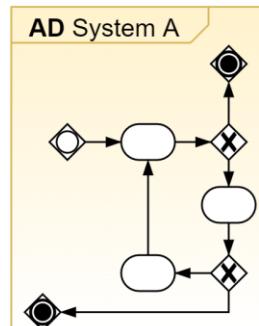
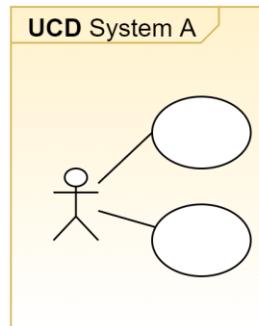
Abstraction

- What are the properties of interest?
- What information can and should be modelled about the system?
- What is the effort required for new model generation?
- Will there be other related models?
- Will there be several layers of model abstraction?
- What decisions are supposed to be made with simulation?



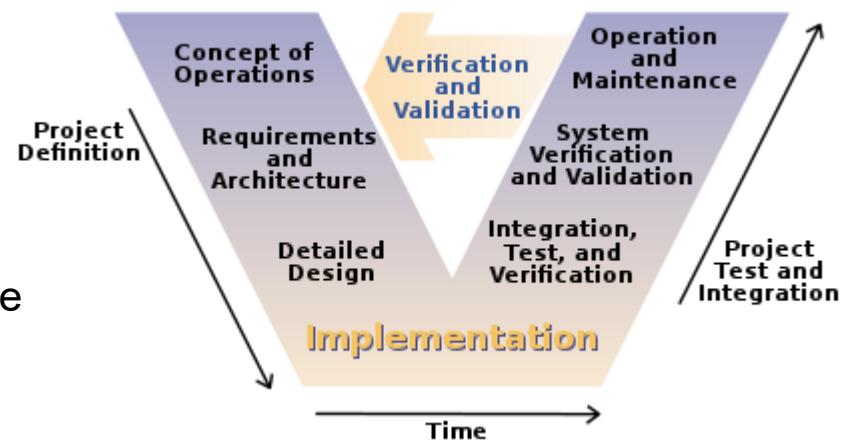
Formalism

- What information needs to be captured in the model?
- What formalisms are compatible with the simulation needs?
- What kind of analysis is required from the model?
- Who are the users of the model?
- What tool support exists for the execution of the formalism(s)?
- What is the needed execution speed?
- Are there formalisms compatible with model-exchange/co-simulation standards?
- Can relevant formalisms be transformed into other formalisms?



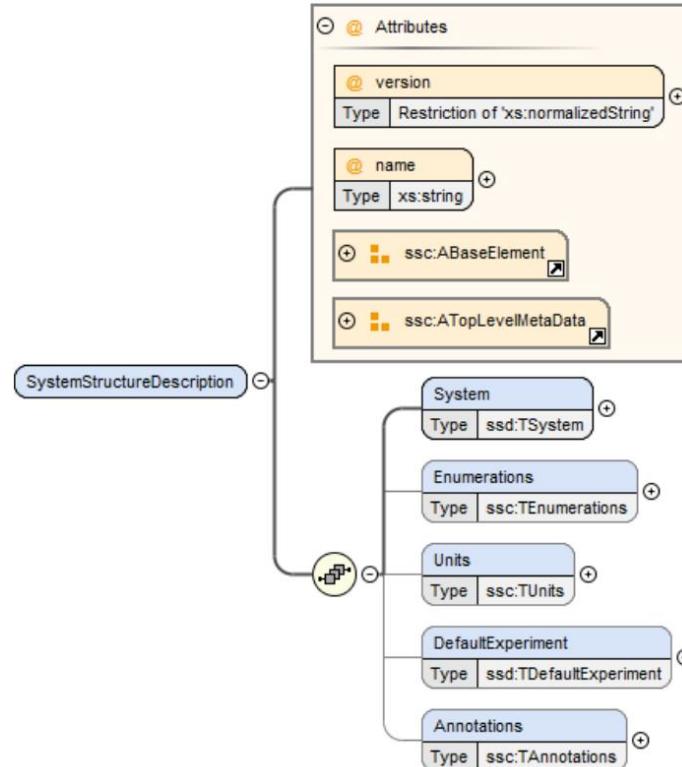
Method & Process

- What support from simulation is required for decisions?
- Who are the intended users?
- Who will consume the model output?
- Who will provide the model input?
- What model data formats are used across the organization?
- What can/should be automated?



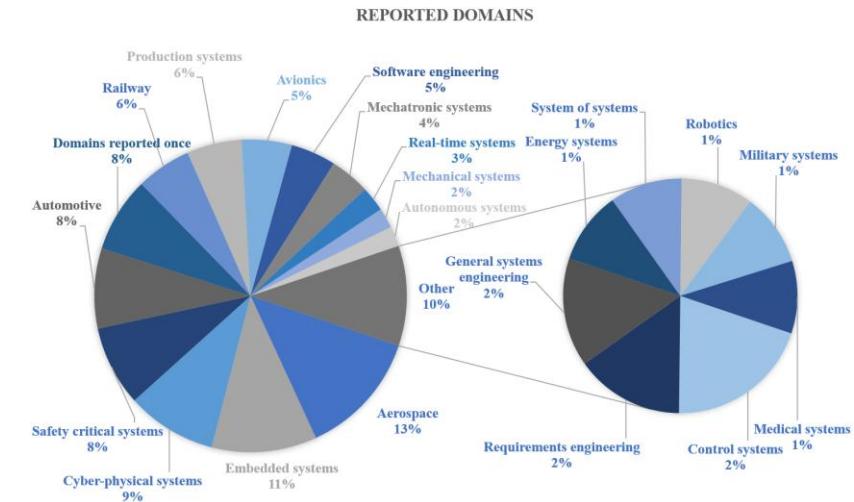
Traceability

- What information needs to be traced?
- How should the information be traced?
- What data standards need to be considered?
- Who should access the model?
- When should traceability links and data be updated?



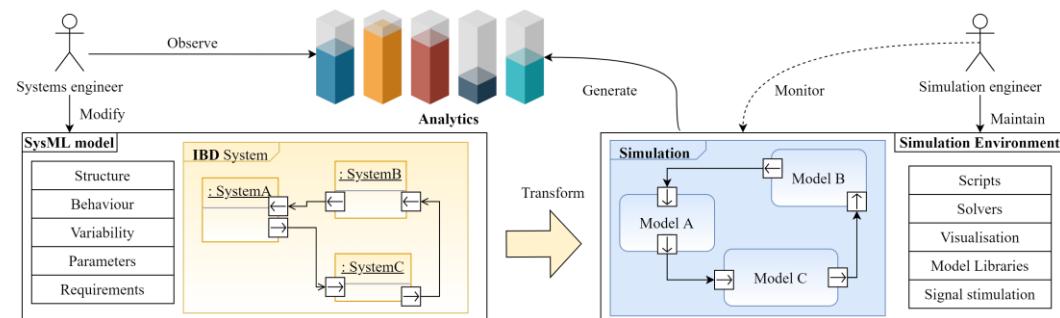
Tooling

- What are the costs for tools involved?
- What is the range offered by the tools in terms of simulation?
- Are the tools compatible with the tools already in use at the organization?
- What standards do the tools support?
- What capabilities do the tools offer in addition to simulation?
- Are the tools domain-specific or domain-agnostic?



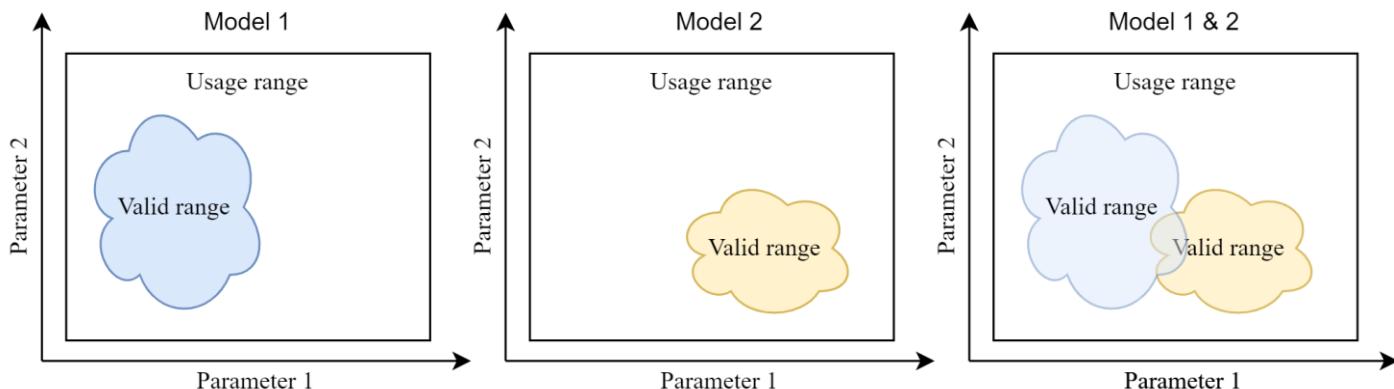
Re-use

- What kind of models should be re-used?
- What formats of data are needed to support re-use?
- What infrastructure is needed to support re-use?
- What tools should be able to access re-usable models?
- What information is required as metadata to support re-use?



Validity range

- Do you have explicit conditions for when a model can be used?
- Are there explicit purposes for the given model?
- What assumptions or simplifications are applied in the model?
- What constraints exist in the model interfacing?
- What uncertain elements are attributed to the model?
- How has the validation of the model been performed?



Discussion & Conclusion

- The paper is rather high-level and mostly meant as a guideline rather than a prescribed solution.
- Our experiences are largely coming from working with simulation and could therefore be somewhat biased towards that domain.
- Automation necessitates increased awareness and inclusion of the discussed topics in the paper.
- We hope the checklist can be used for high-level discussions about modeling and simulation.



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