SPECIFICATION & EXECUTION OF SIMULATION MODELS & EXPERIMENTS
(with focus on engineering)

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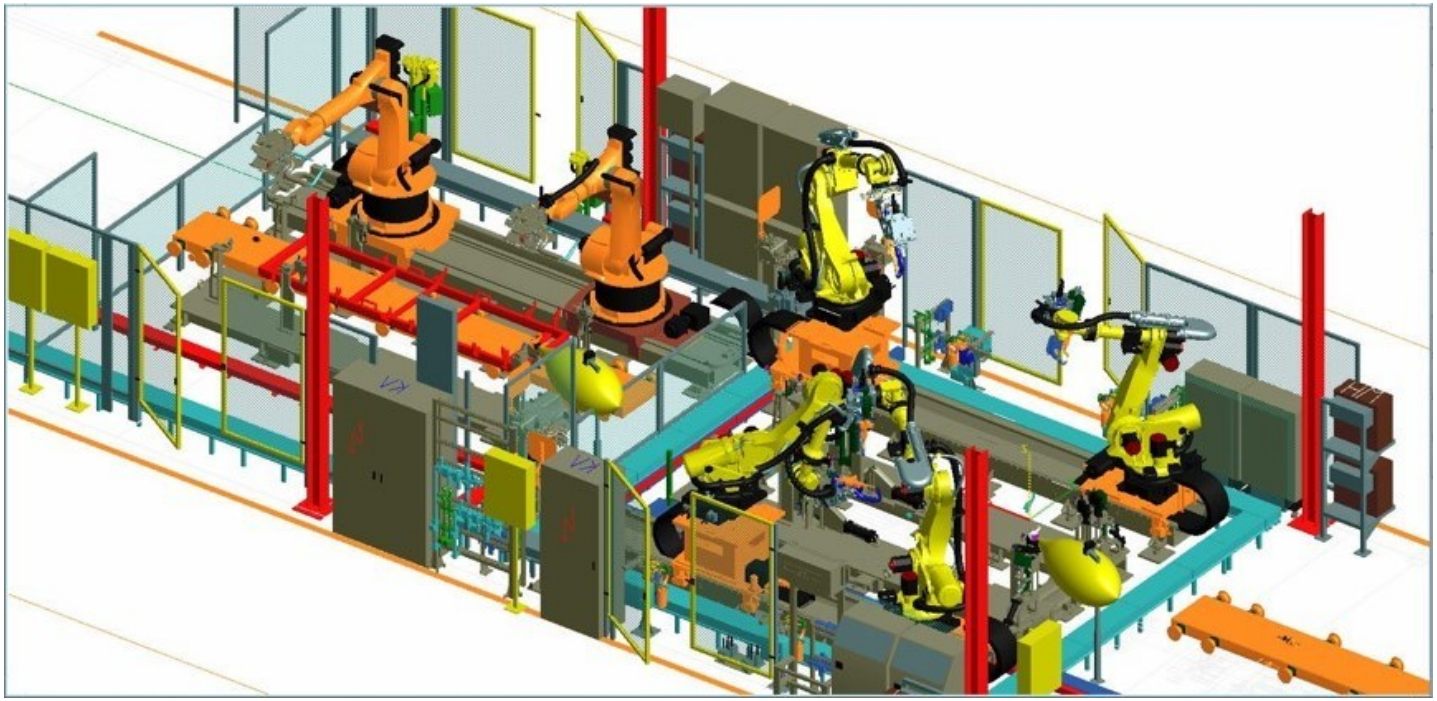
Outline

1. Introduction & Motivation
2. SES/MB Approach & Extensions (eSES)
3. From Experimental Frames (EF) to Experiments
4. Automation of Experiments
5. Conclusion & Further Works

2nd to 4th are based on the submitted (10/2018) PhD Thesis: Artur Schmidt, Variantenmanagement in der Modellbildung und Simulation unter Verwendung des SES/MB Frameworks.

The RG CE(A)

We are engineers with focus on the dev of comp. methods and tools for solving engineering problems.



Our Methods & Tools

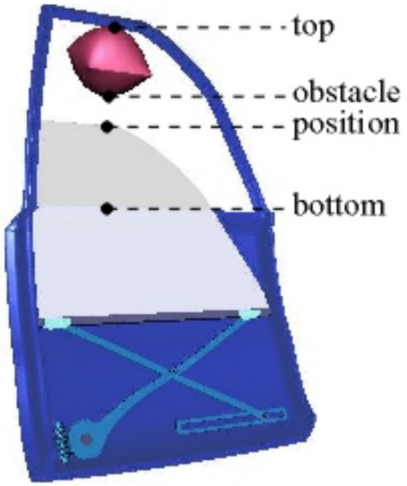
- Methods
  - **M&S** (DEVS, SES/MB, ...)
  - Control engineering
  - Distributed & parallel computing
  - Machine Learning (NN, RL, ...), ...
- Software
  - **SCEs:** MATLAB/Simulink, Octave, Open Modelica, ...
  - Python, C, ...

Why is the Topic Important for Eng.?

- Today‘s cars have more than 50 single electronic control units (ECU); each may be instantiated in many different ways.[1]

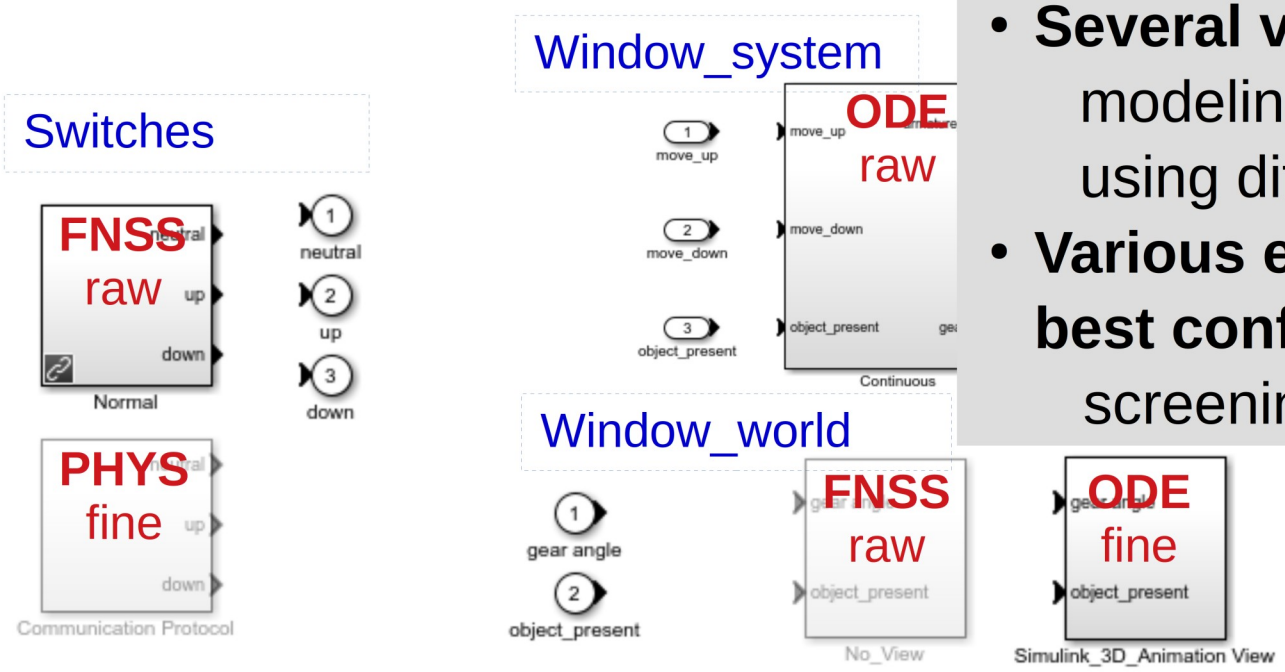
- Soft. dev. of ECU is a model-based process

  Typical problems/requirements using the example of a **power window controller** (PWC)[2]



[1] **Sebastian Oster**, Feature Model-based Software Product Line Testing, PhD thesis, Darmstadt, 2011.
[2] **The MathWorks**, Power Window Controller Example, MATLAB/Simulink Doc.

Model-Based Dev of PWC



- **Several variant submodels**
  modeling diff. levels of detail using diff. modeling methods
- **Various experiments to find best configuration**
  screening, …, optimization

… and more non-variant submodels

ONE MODEL & ONE EXPERIMENT (METHOD) ARE NOT ENOUGH to design perfect controllers!

Need to manage various models and experiments.

Our Goals

- Improvement of today‘s model-based dev process using the System Entity Structure / Model Base (SES/MB) approach

Status: „SES as an organizer of **models & frames**“ [1]
(**FAMILY of MODELS**)

1. Extension of the SES/MB approach to a FAMILY of MODELS and EXPERIMENTS (in short **E**)

2. Infrastructure for experiment automation

[1)] **B.P. Zeigler**, Multifacetted Modeling and Discrete Event Simulation, Academic Press, 1984.

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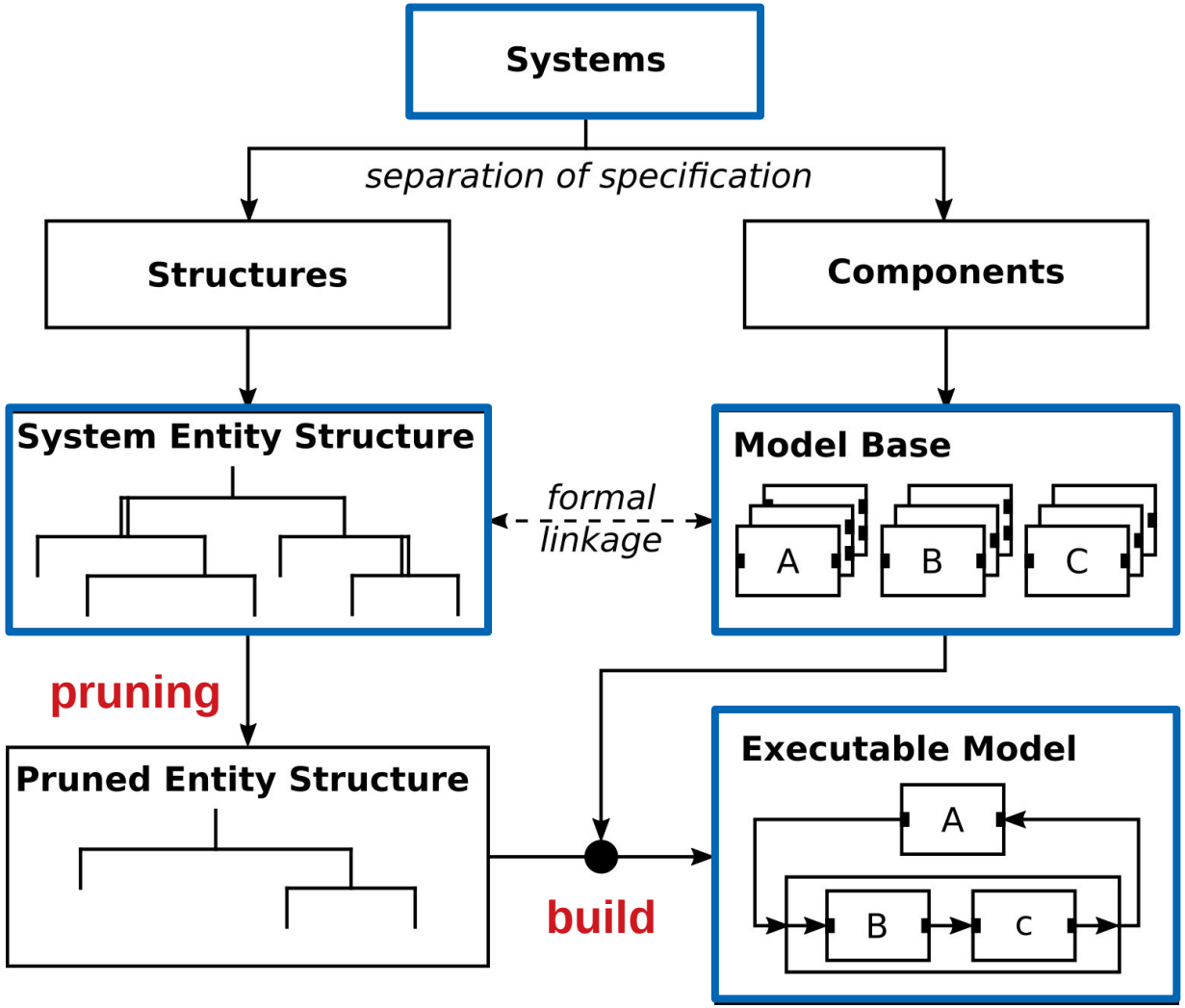
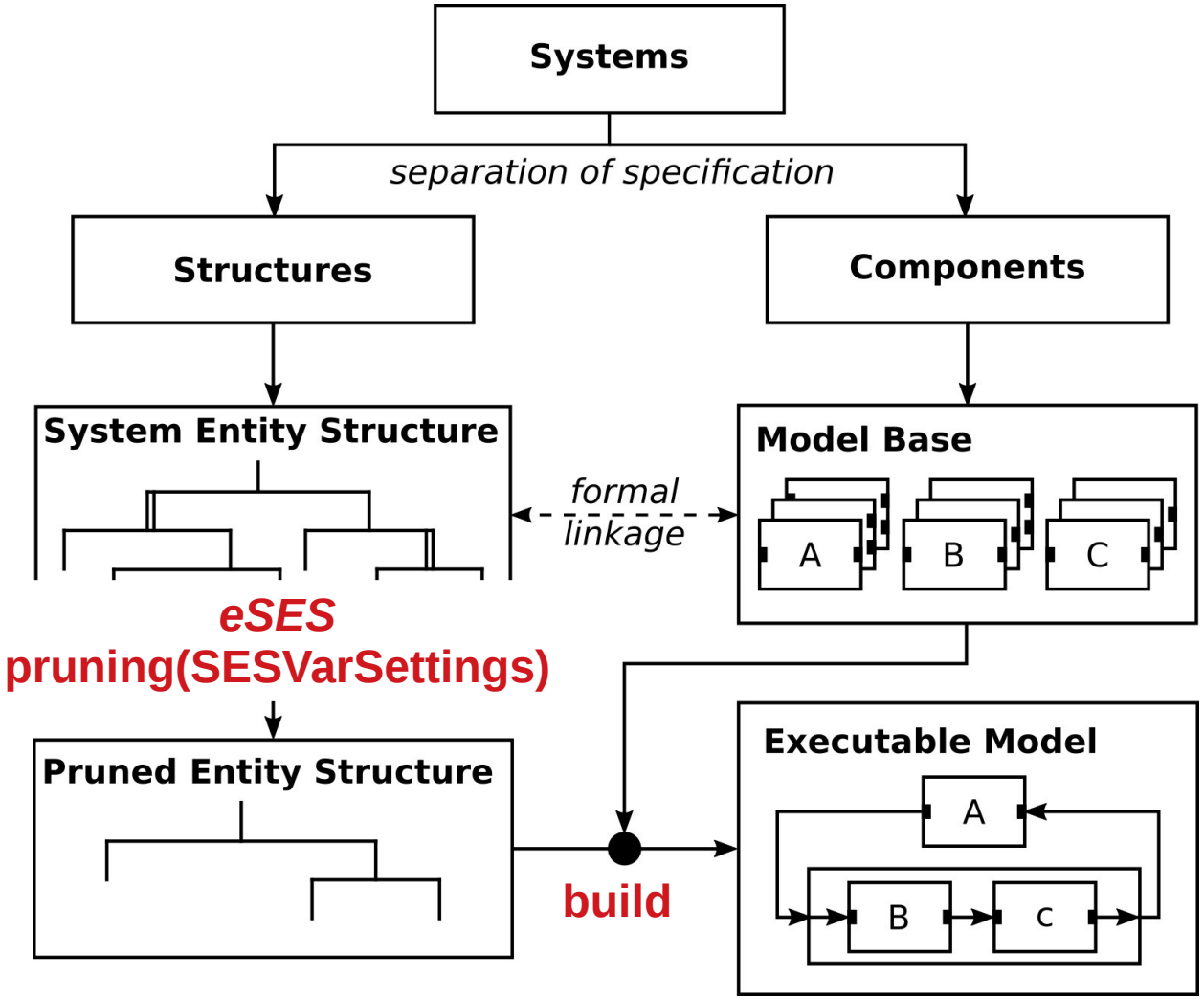
SES/MB Approach



- **SES** specifies **a family of models** (structures, params)
- **MB** organizes configurable, composable **basic models**
- **pruning** derives a **unique model config**
- **build** generates an **exec. model config** for a simulator

SES/MB Approach



eSES Extensions

- **SES Variables**
  SES Functions
  - **SES input interface**
  - **variable config of node attributes** (**couplings**, selection rules, variables)
- Semantic constrains
- Specific mb Attribute

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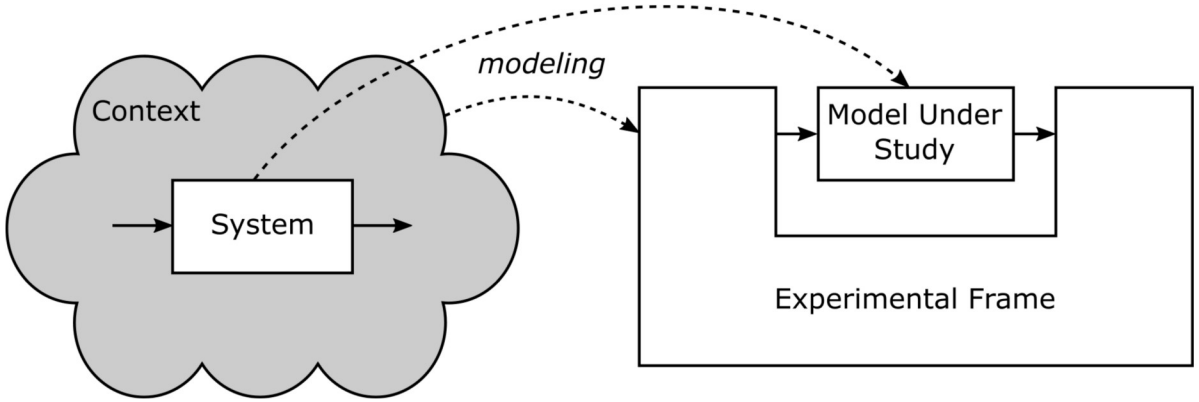
Concept of Experimental Frame (EF)[1, 2]



Model Under Study (MUS)
Experimental Frame (EF)

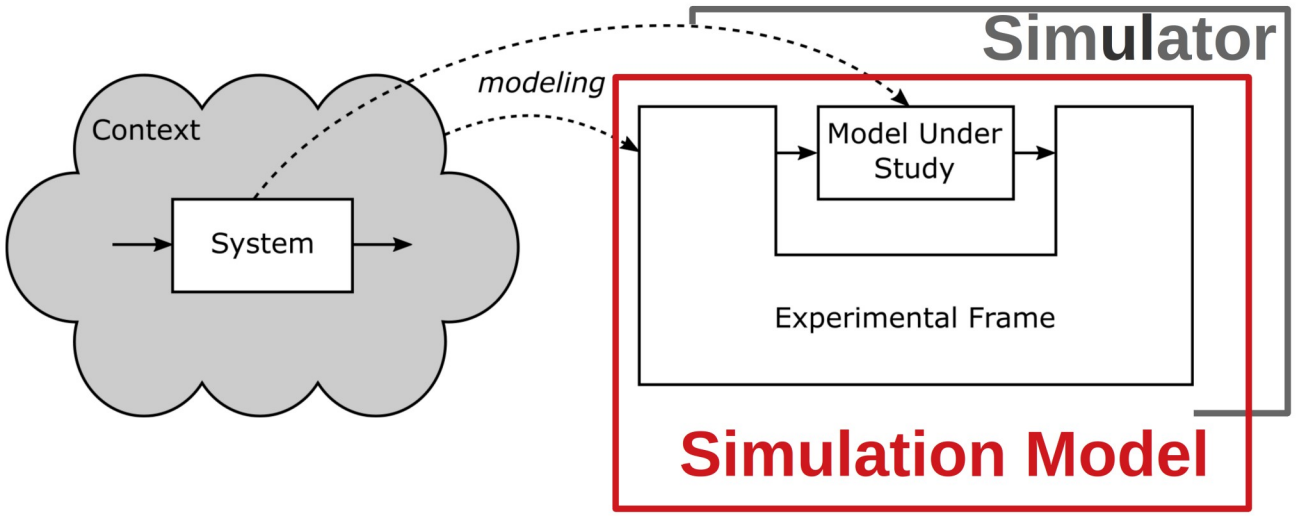
EF defines the context for using a model
(circumstances of experimentation)

- Objectives, boundary conditions, ...

- **Different EF for one model**
- **One EF for several models**
- **Modular, hierachical structure of EF**

1) **B.P. Zeigler**, Theory of Modeling and Simulation, John Wiley & Sons, 1976
2) **Fig.** in accordance with M.K. Traore, A. Muzy, Capturing the dual relationship between simulation models and their context. Simulation Modeling Practice and Theory, Elsevier Pub.,14(2006)126-144.

Concept of Experimental Frame (EF)[1, 2]

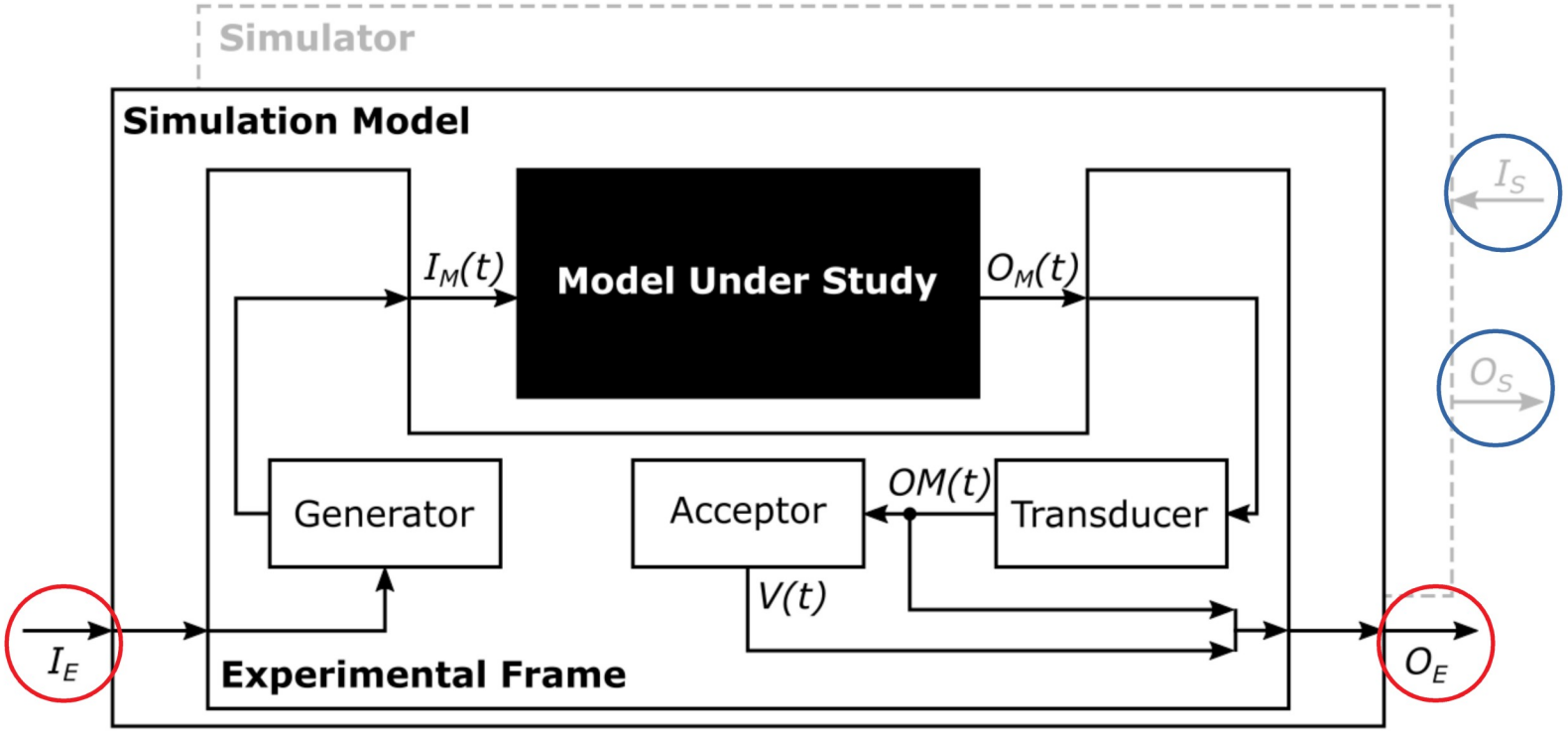


Model Under Study (MUS)
Experimental Frame (EF)

EF & MUS → **Simulation Model**
which is executed by a **Simulator**

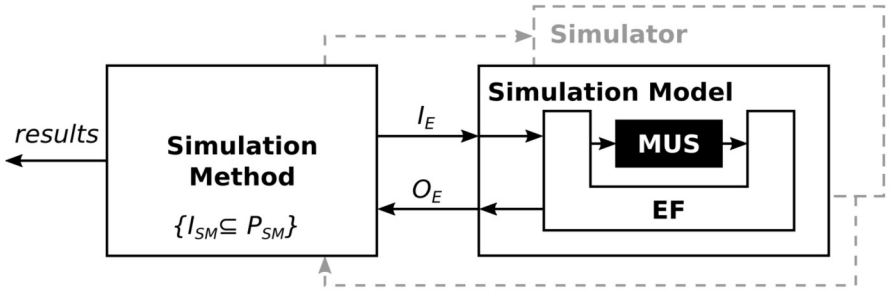
1) **B.P. Zeigler**, Theory of Modeling and Simulation, John Wiley & Sons, 1976
2) **Fig.** in accordance with M.K. Traore, A. Muzy, Capturing the dual relationship between simulation models and their context. Simulation Modeling Practice and Theory, Elsevier Pub.,14(2006)126-144.

Common Implementation of EF



Experiment (E) provides input vals {I_E, I_S} for Simulation Model & Simulator and gets output vals {O_E, O_S} from both.

(1) Structures and Classes of Experiments

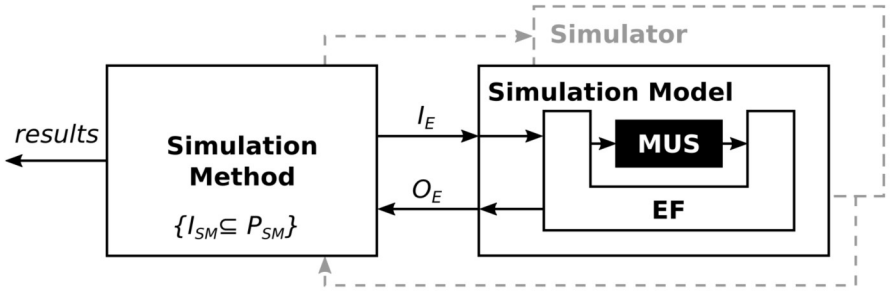


EXPERIMENT CLASS

- **Simple**
  {Simulation Method}
  ➔ Mod. parameters

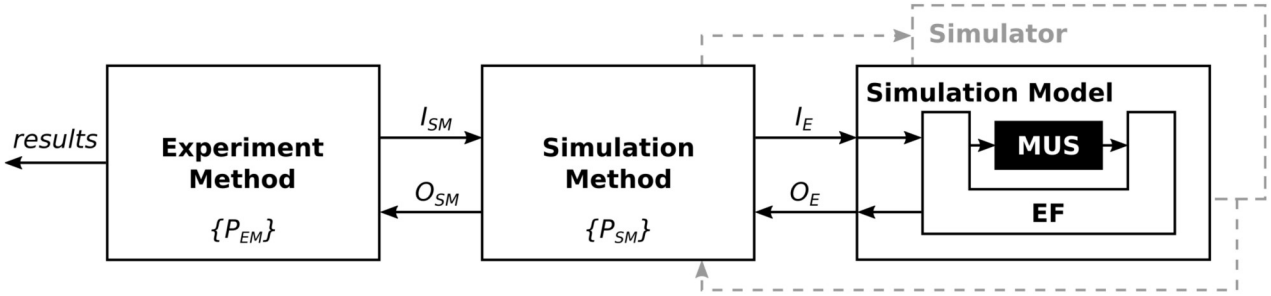
- **Simulation Method** provides input vals to **Simulation Model & Simulator** and gets output vals from both.

(2) Structures and Classes of Experiments



EXPERIMENT CLASS

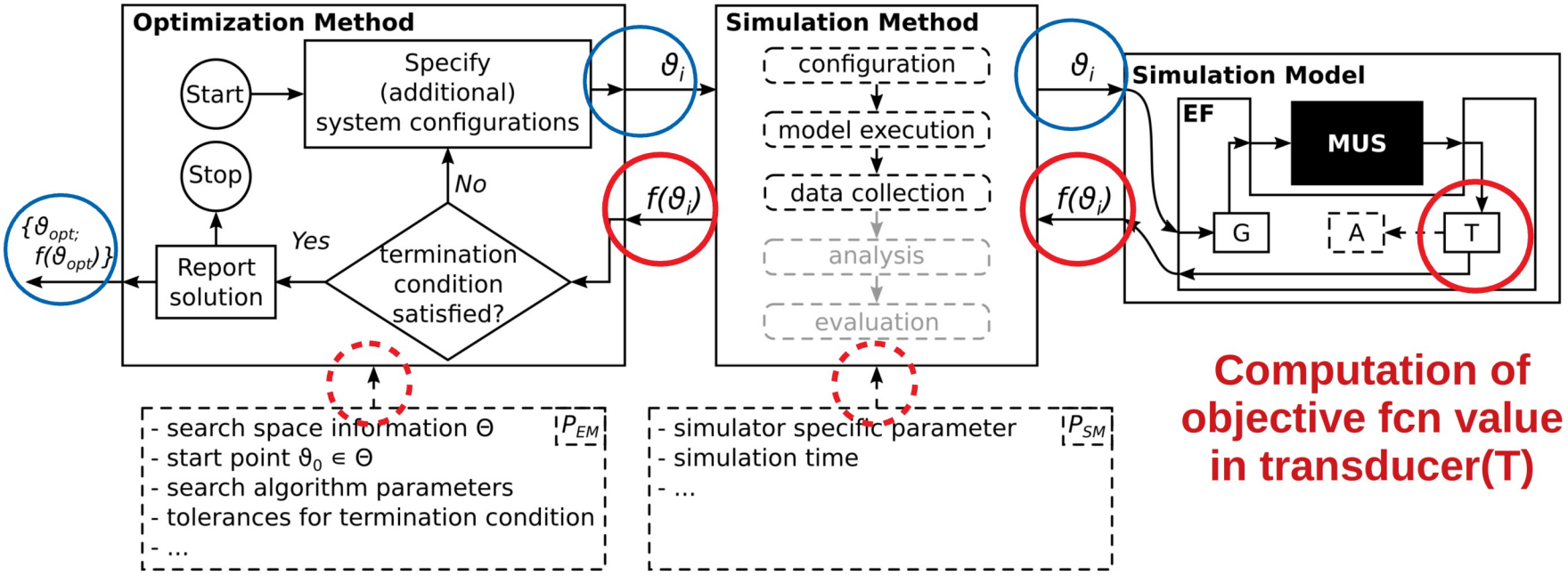
- **Simple**
  {Simulation Method}
  ➔ Modify parameters



- **Complex**
  {Simulation Method, Experiment Method}
  ➔ Modify parameters

- A supervisory **Experiment Method** (e.g. optimization) drives the **Simulation Method.**

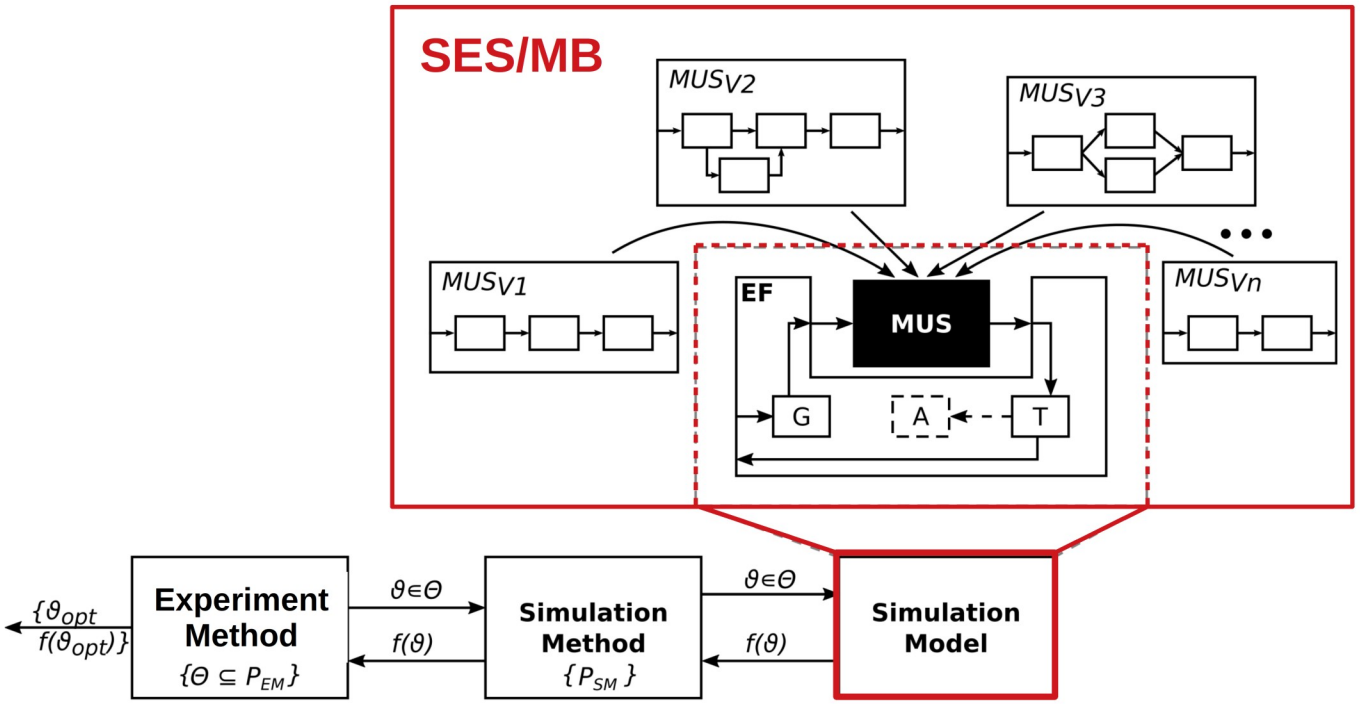
Ex. of Complex Exp. - Sim-based Param. Optim.



Computation of objective fcn value in transducer(T)

Experiment Method (Optimization Method) **interface corresponds to** methods in **numerical libraries**

(3) Structures and Classes of Experiments

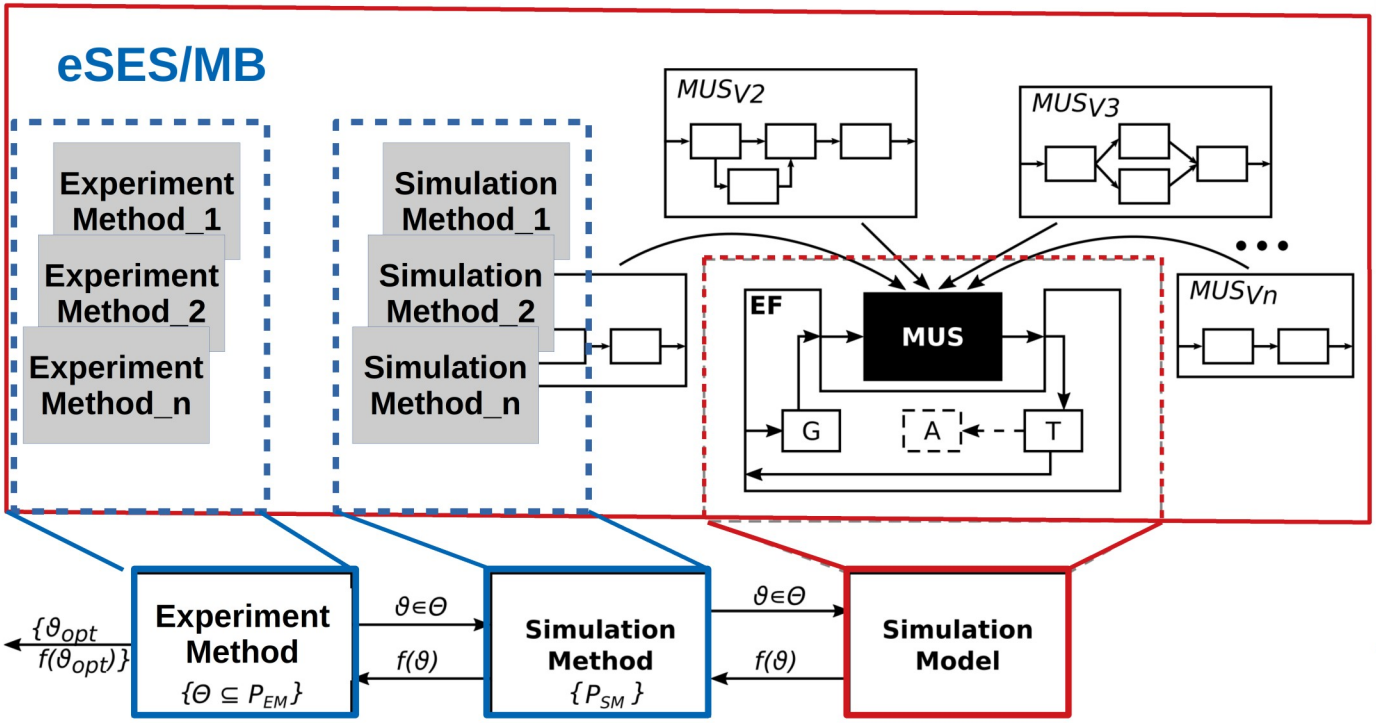


EXPERIMENT CLASS

- **Simple**
  {Simulation Method}
  → Modify parameters
- **Complex**
  {Simulation Method Experiment Method}
  → Modify parameters
- **Family of Models**
  {SES/MB Simulation Method Experiment Method}
  → **Modify structures**
  → Modify parameters

Model management using SES/MB provides a **Simulation Model (structure & parameter config)**, representing a specific member of the **Model Family**

(4) Structures and Classes of Experiments



EXPERIMENT CLASS

- **Simple**
  {Simulation Method}
  - ➔ Modify parameters
- **Complex**
  {Simulation Method
  Experiment Method}
  - ➔ Modify parameters
- **Family of Models**
  {SES/MB
  Simulation Method
  Experiment Method}
  - ➔ Modify structures &
  - ➔ Modify Parameters
- **Family of Mod & Exp**
  {eSES/MB
  … }
  - ➔ Modify structures
  - ➔ Modify parameters
  - ➔ **Modify Simulation**
  - ➔ **and Exp. Methods**

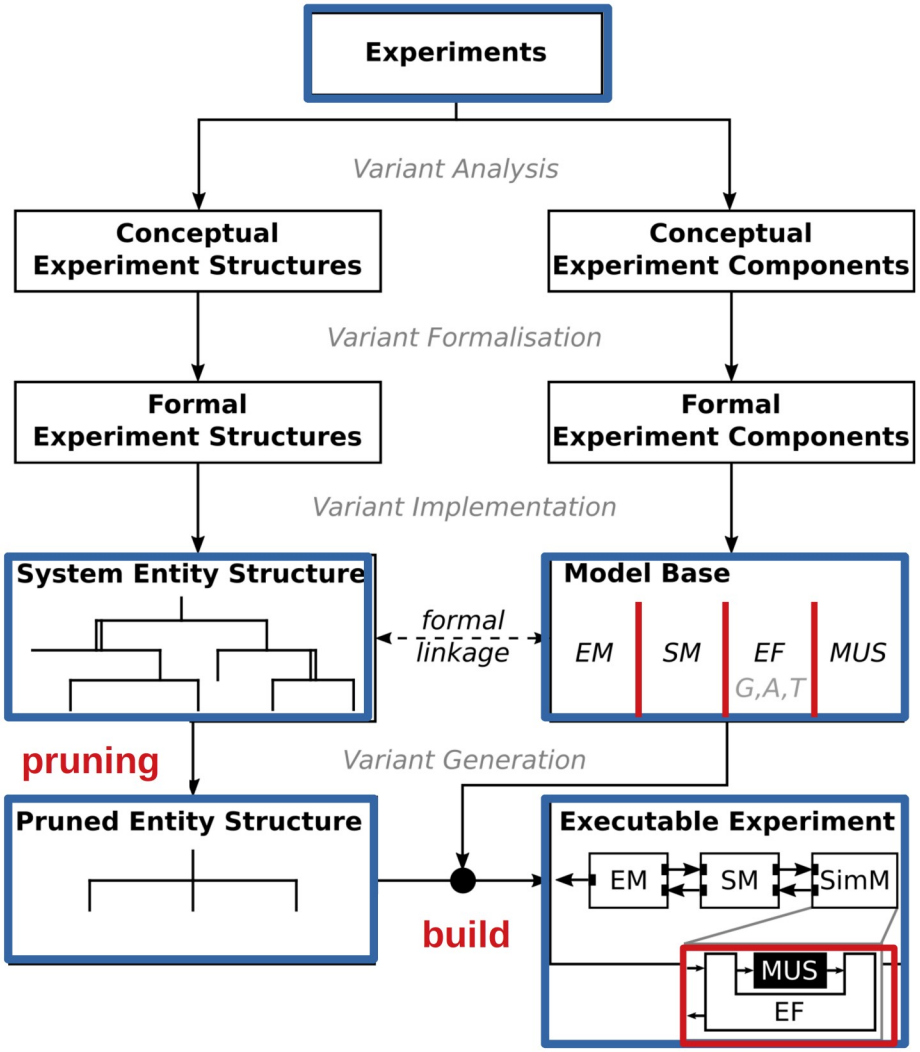
Model & Experiment management using eSES/MB provides an **Experiment config** (Simulation Model, Simulation & Experiment Method) representing a specific member of the **Model & Experiment Family**

Family of Models & Experiments (E)

means a set of various

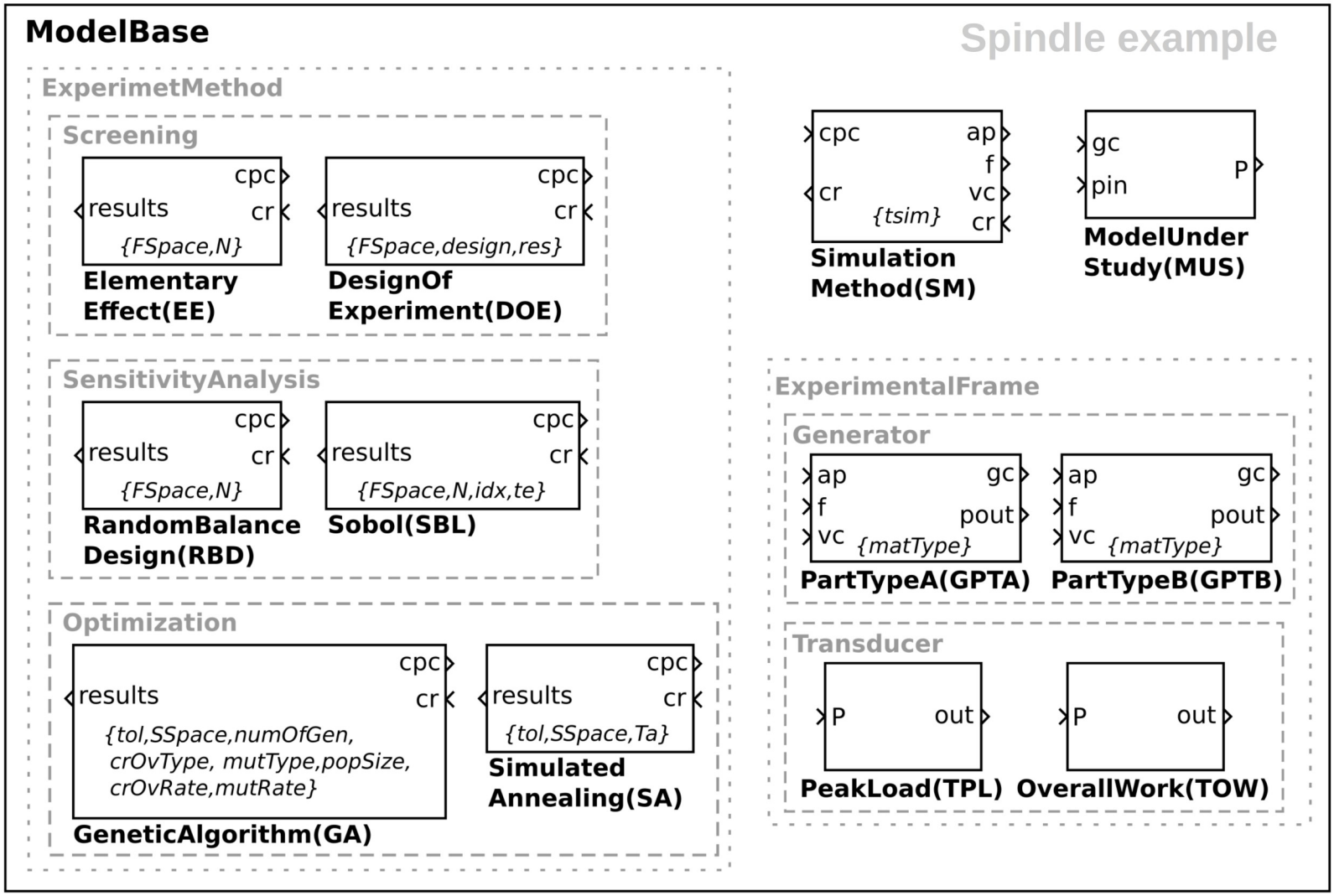
- Models Under Study (MUS)
- Experimental Frames (EF)
- Simulation Methods
- Experiment Methods

eSES/MB for a Model & Experiment Family (E)

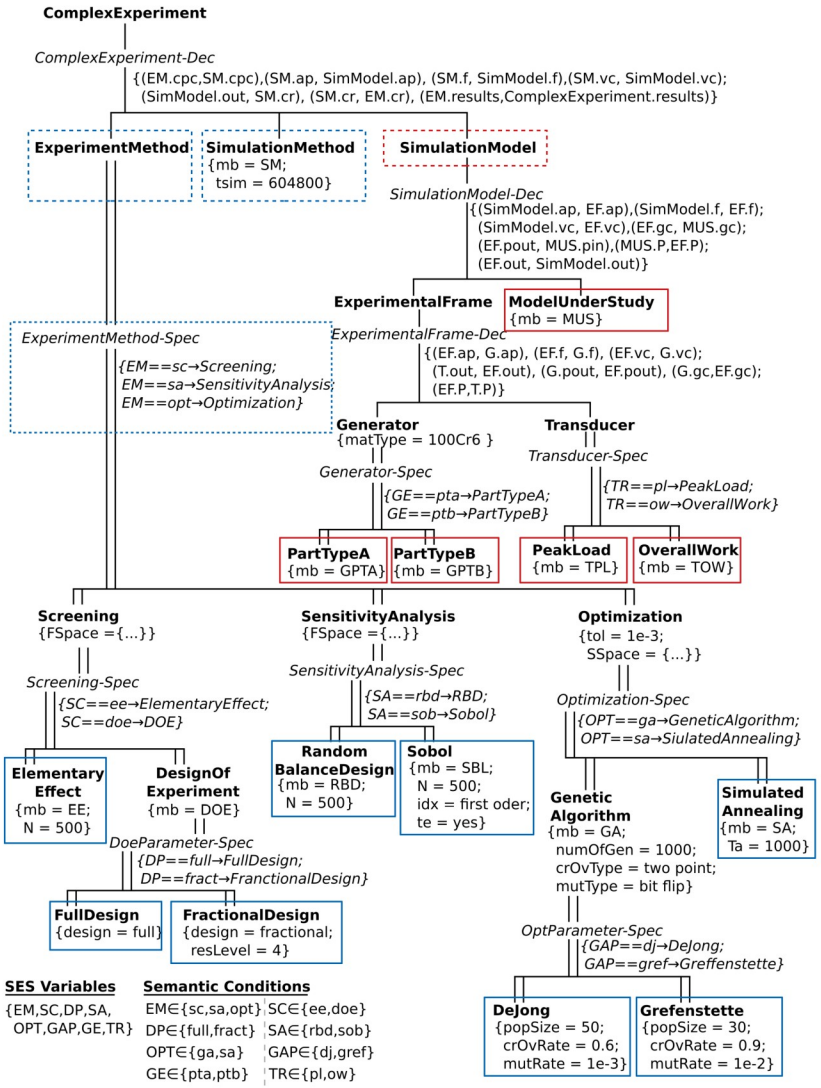


- **SES** specifies a **family of models & experiments** (**E**)
- **MB** organizes **basic models and components** for composing:
  - **MUS** – Models Under Study
  - **EF** – Experimental Frames
  - **SM** – Simulation Methods
  - **EM** – Experiment Methods
- **pruning** derives a **unique E config**
- **build** generates an **executable E config**

Ex: Part of MB for Model & Experiment Family



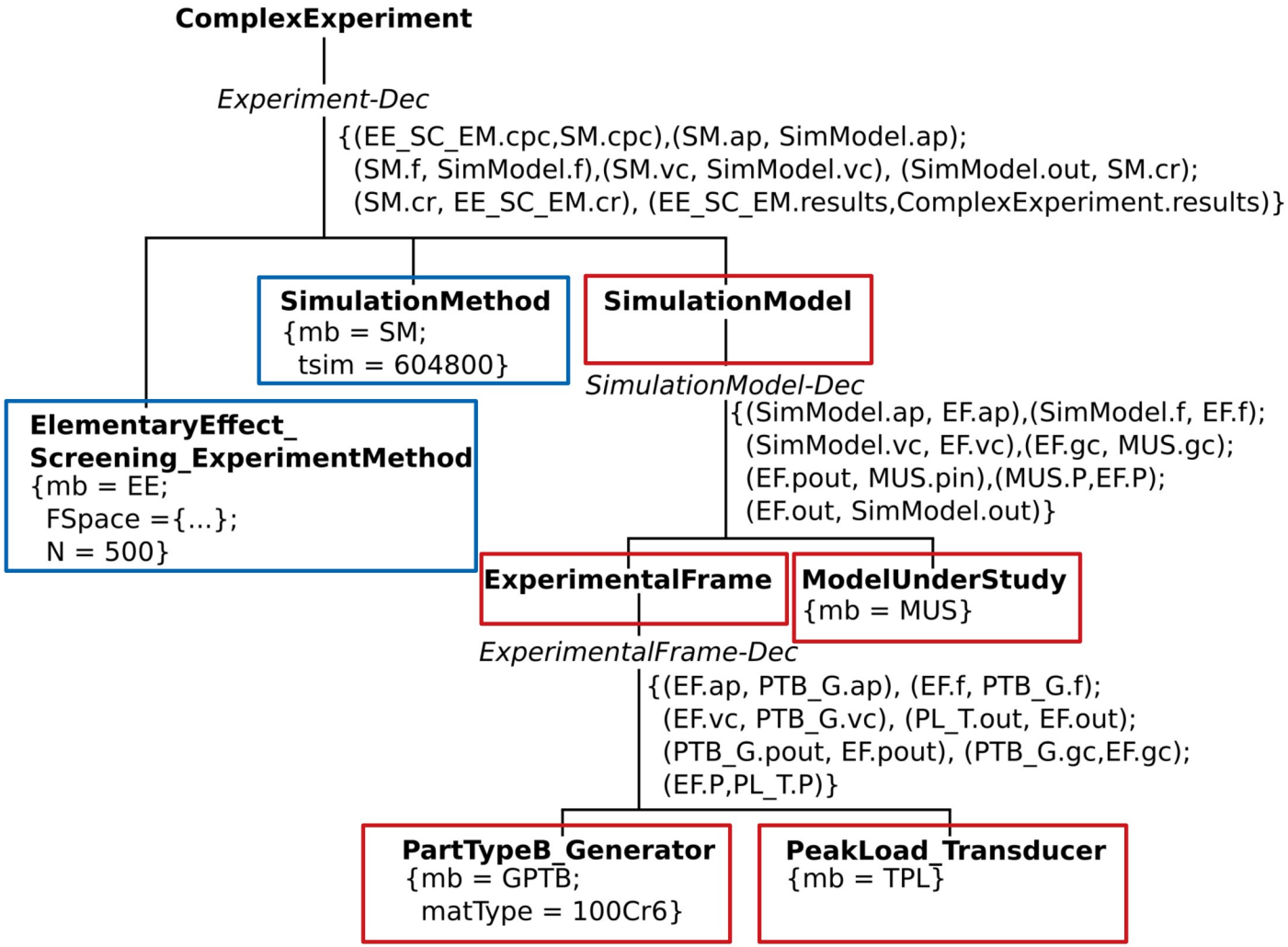
Ex. Part of eSES Specifying a Family of Models & Exp. (E)



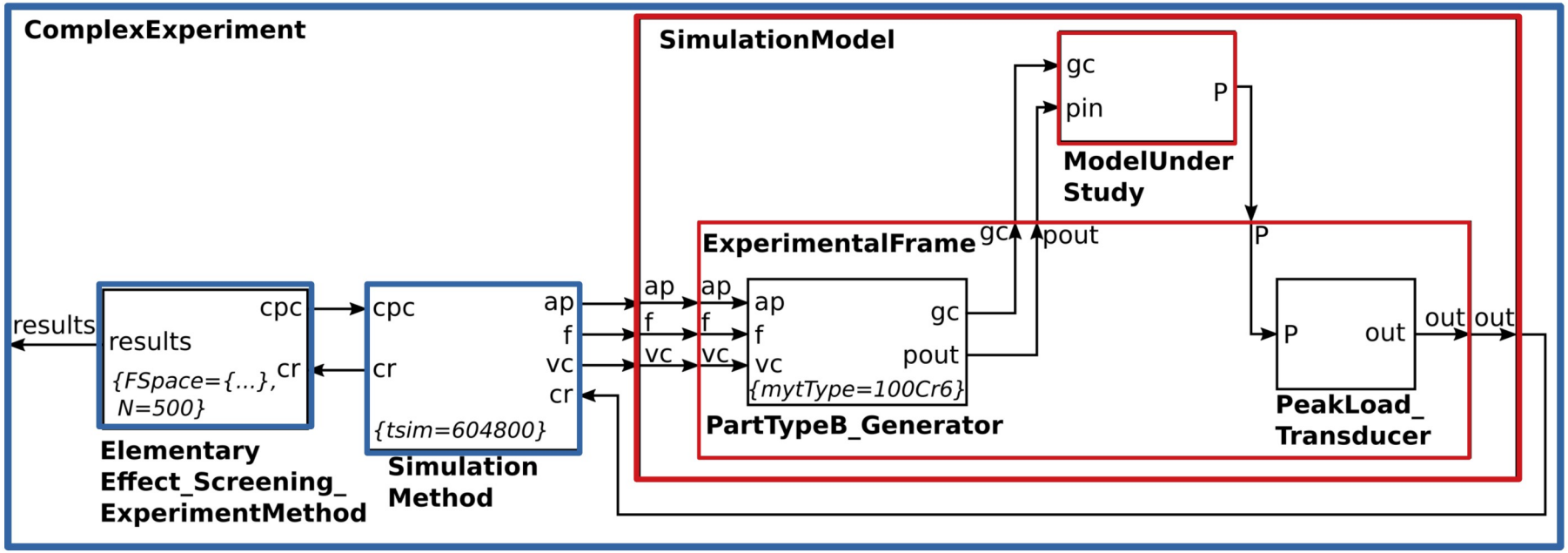
eSES specifies a **family of models & experiments** (**E**) with:

- **1** Model Under Study
- **4** Experimental Frames
- **1** Simulation Method
- **8** Experiment Methods

Ex. PES Specifying a Unique Experiment Config (E)



Ex. of an Executable Experiment Config
(built based on PES & MB)



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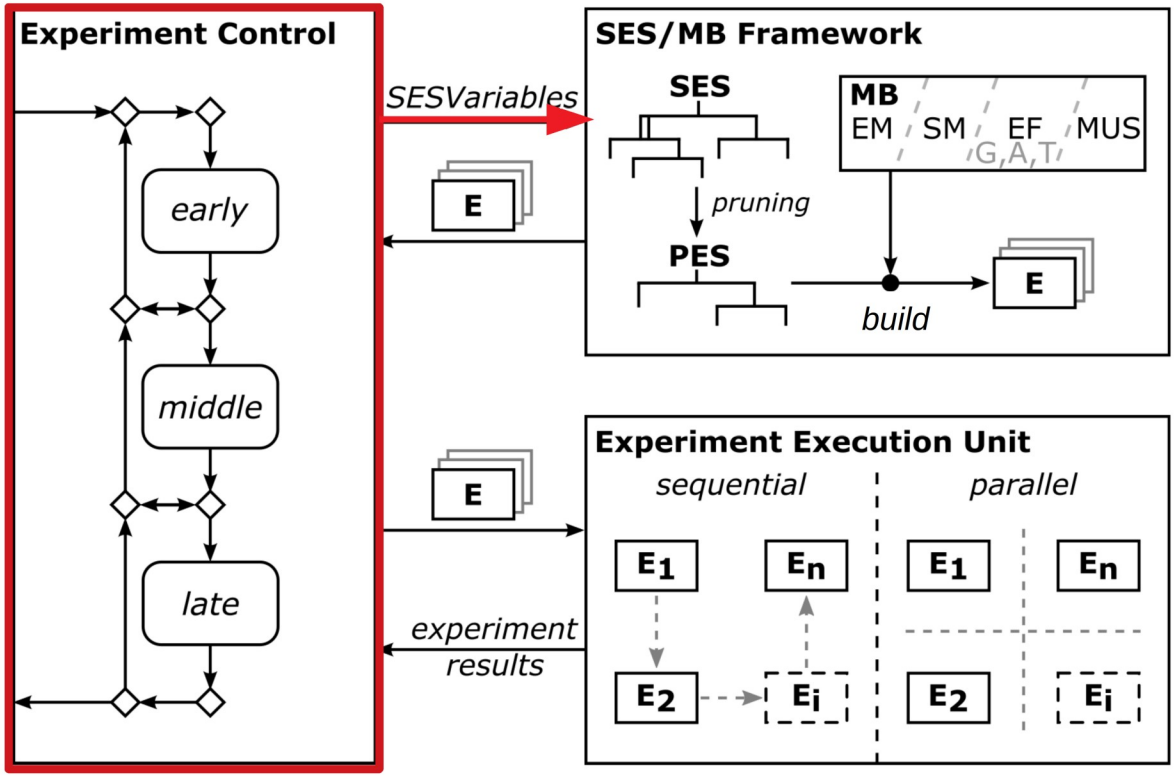
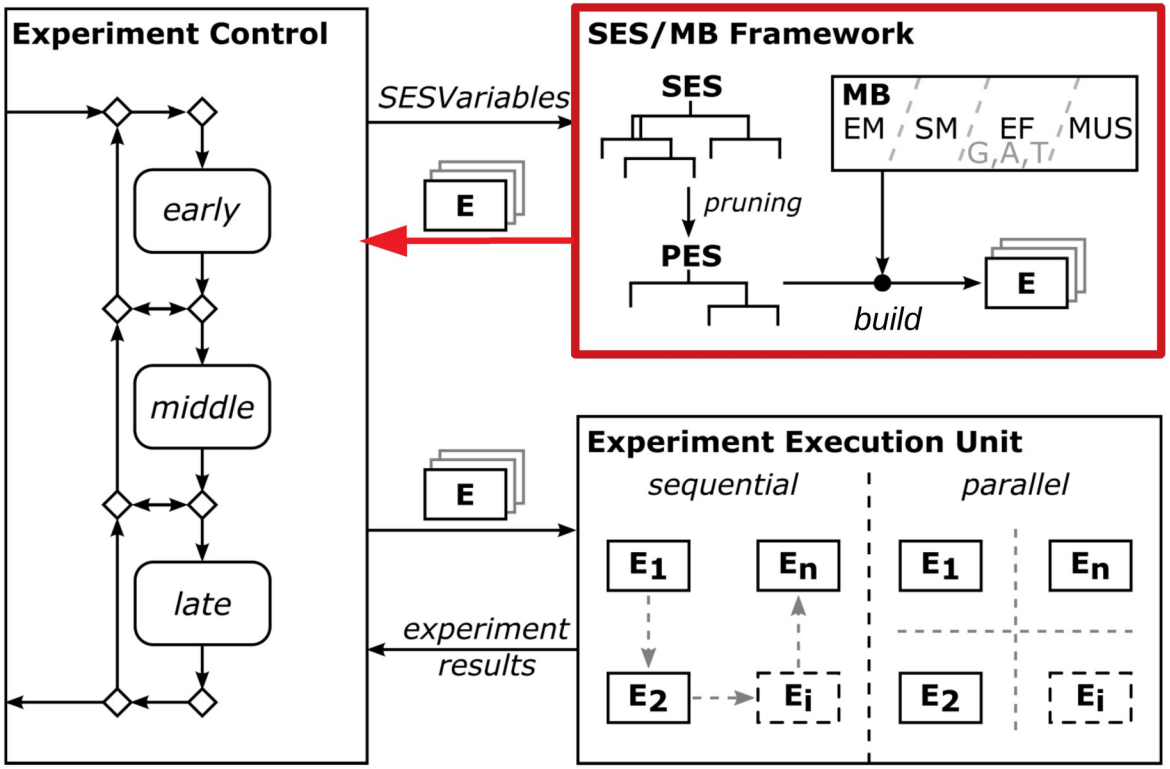


- **Experiment Control** activates **generation of a set of E** by the **eSES/MB ...**
- **Experiment Control** activates **execution** of a set of **E** by the **Execution Unit** (real exec. env.)
- **Experiment Control** analyzes results and **reacts recursively**

Infrastructure



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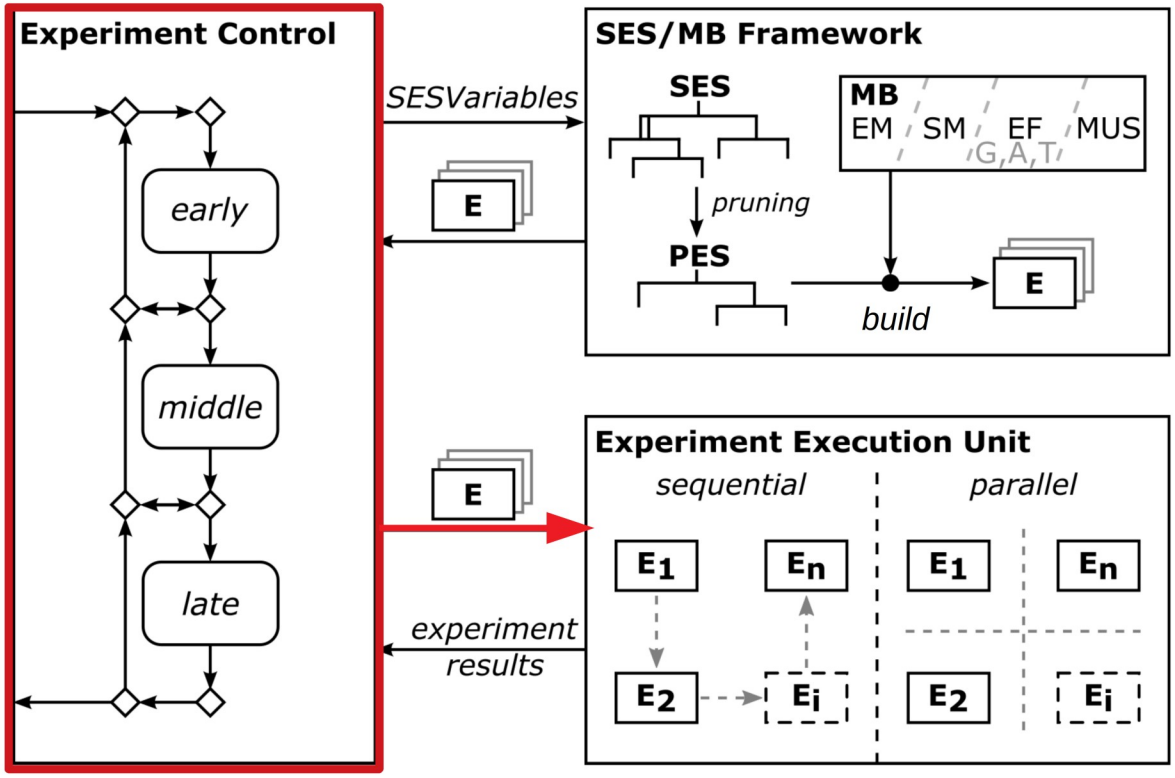

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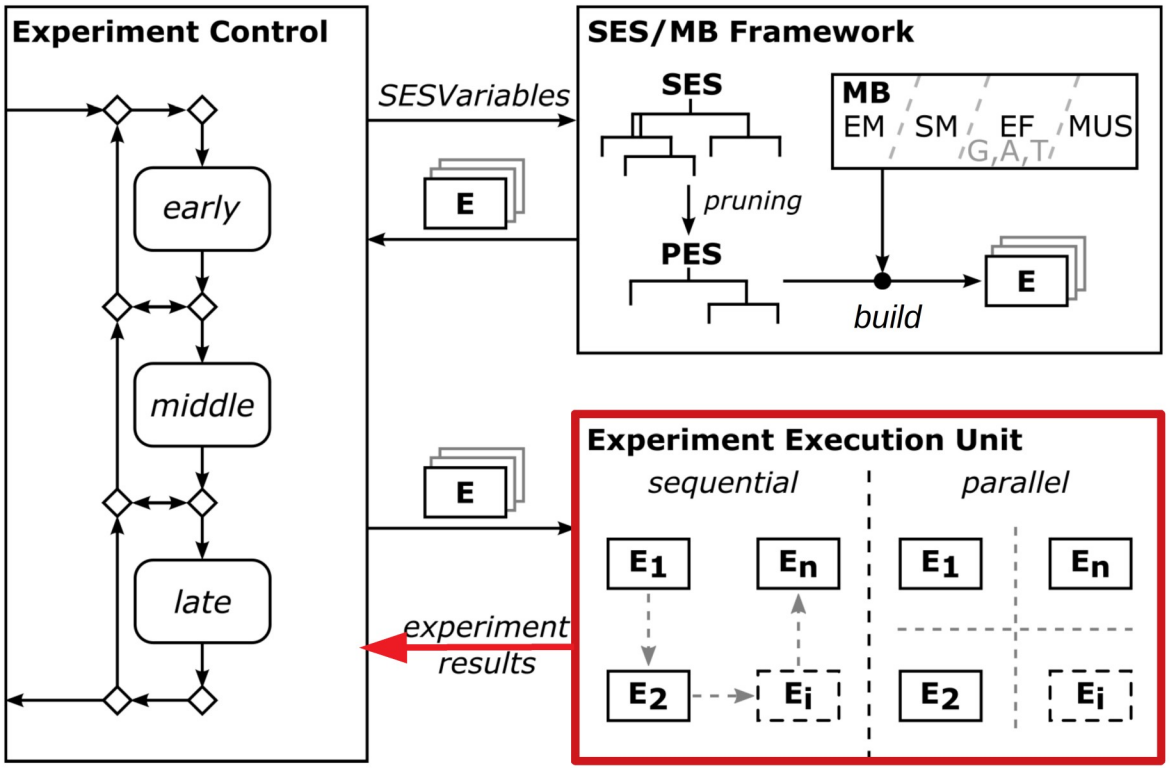

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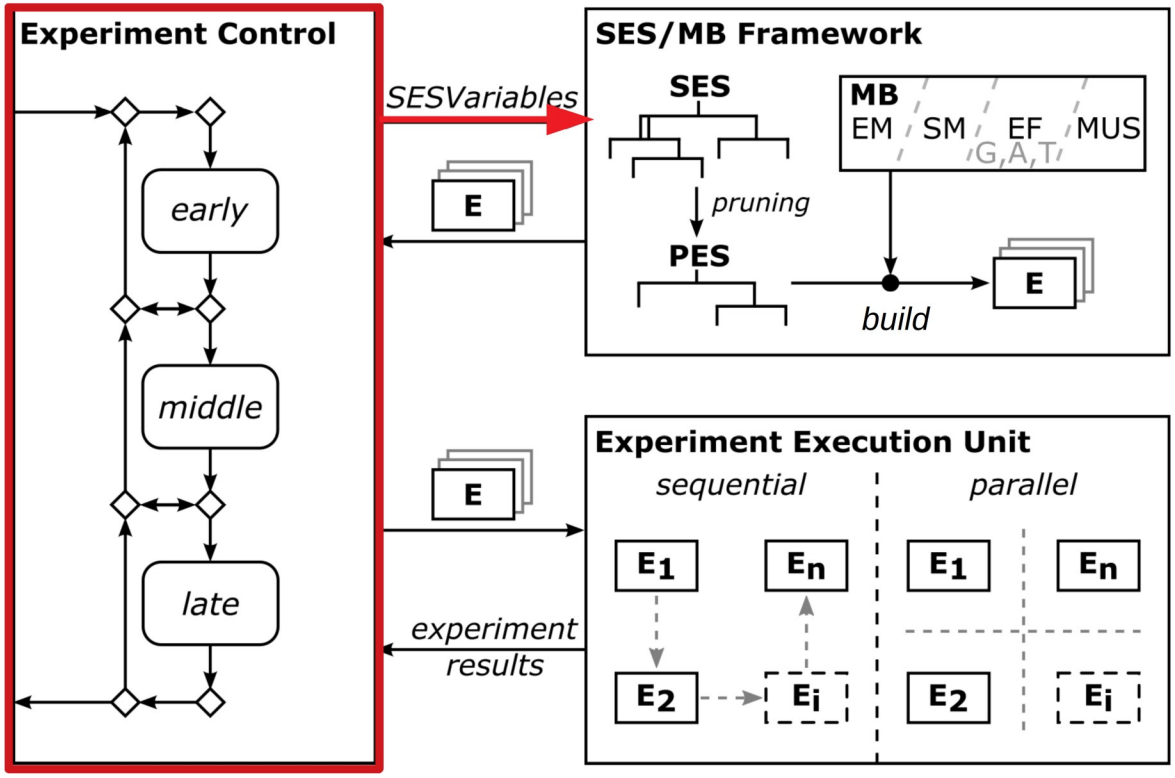

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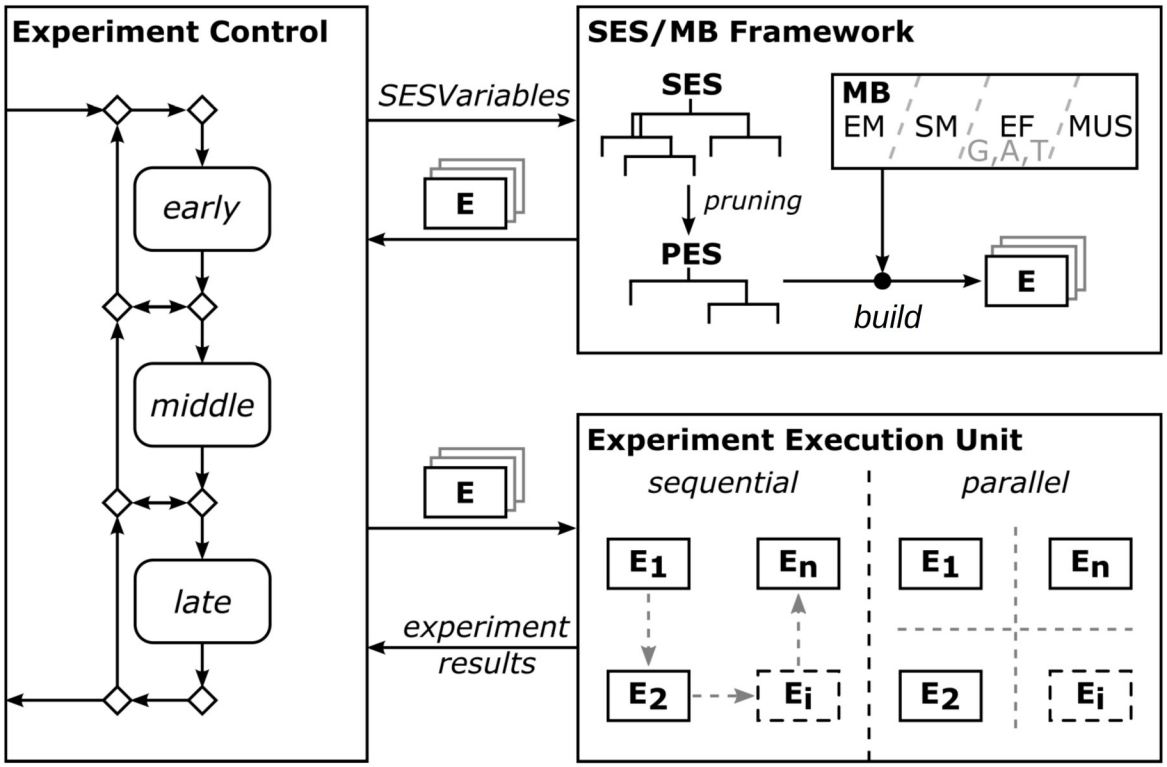

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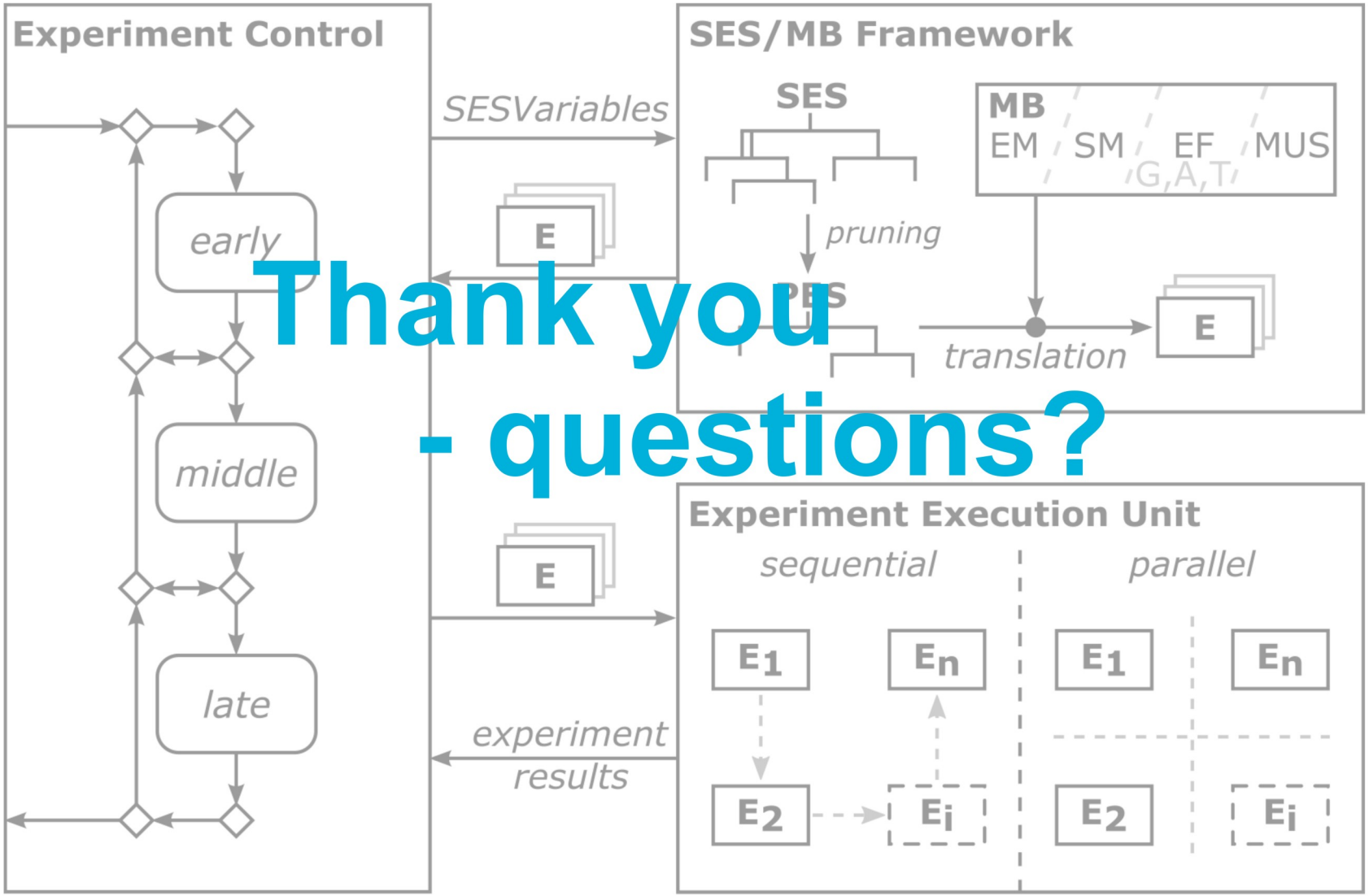
Prototypes by FG CEA

- **MATLAB/Simulink/Simevents...** ; **MATLAB/DEVS**
- **WIP:** Python/OpenModelica/FMI

SES Tbx

Conclusion & Further Works

- ✔ Approach for spec. of family of models & experiments
- ✔ Infrastructure for automation of experiments
- ✔ Prototypes in MATLAB & Python (WIP)
- Improvement of approach & prototypes
- More technical proofs by applications
- Acceleration of computation by DP methods
- Integration with learning methods (RL)


Experiment Control
early
middle
late
SESVariables
E
experiment
results
SES/MB Framework
SES
pruning
MB
EM
SM
EF
MUS
G,A,T
translation
E
Experiment Execution Unit
sequential
parallel
E1
En
E2
Ei
Thank you
- questions?