Integration of high order Functional Mock-up Units and Machine Learning prediction in 1D simulations

Dimitris Daniel, Athanasios Mademlis BETA CAE Systems SA

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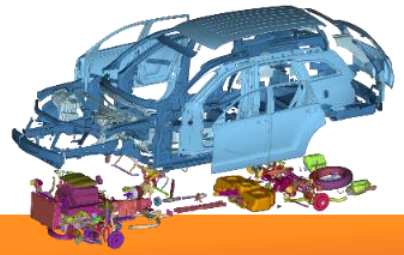
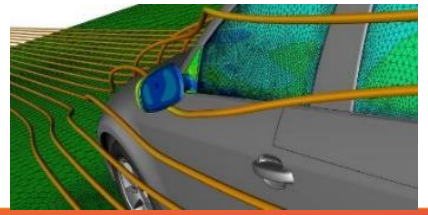
Completing the 3D Simulation Flow



$$\left(\frac{\partial(\rho\vec{V})}{\partial t} + \nabla\cdot\rho(\vec{V}\cdot\vec{V})\right) = -\nabla p + \rho\vec{g} + \mu\nabla^2\vec{V}$$



Geometry | **Modeling** | **Solving** | **Results Intelligence**

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RETOMO
CT-scan images to geometry

KOMVOS
Model management

ANSA
Pre-processing

EPILYSIS
Structural, NVH, SPH, Optimization

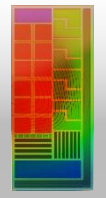
FATIQ
Fatigue prediction

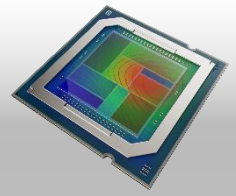
META
Post-processing

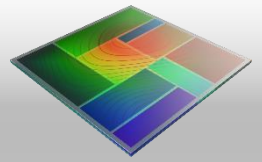
ANSERS
Simulation & Test results review

SPDRM
Process & data management

Chiplets, IP, ICs | Package | Board | Systems | Datacenter







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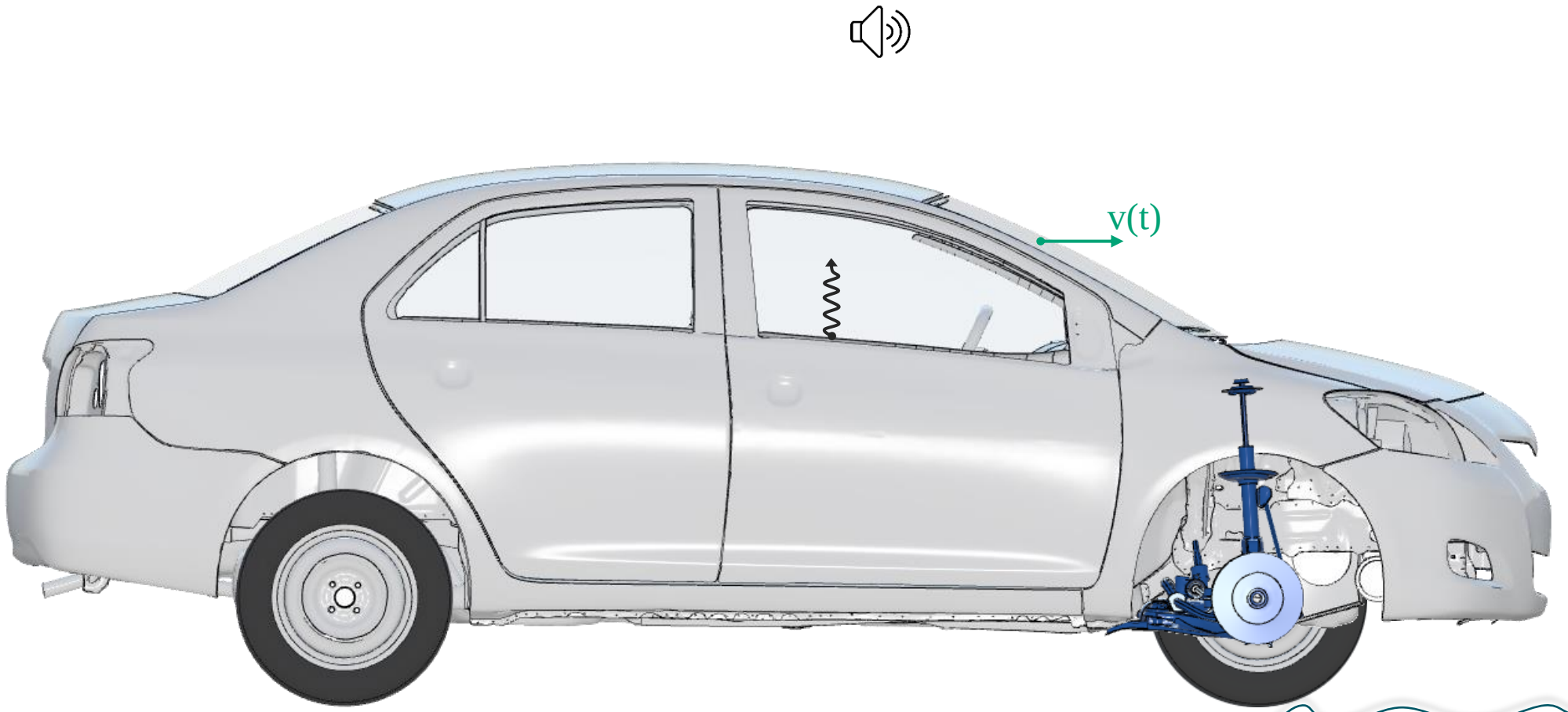
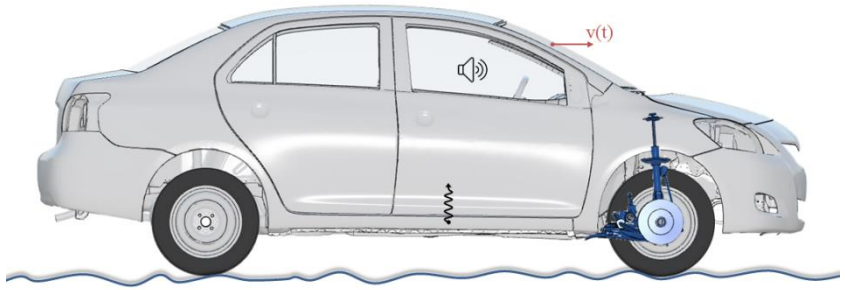
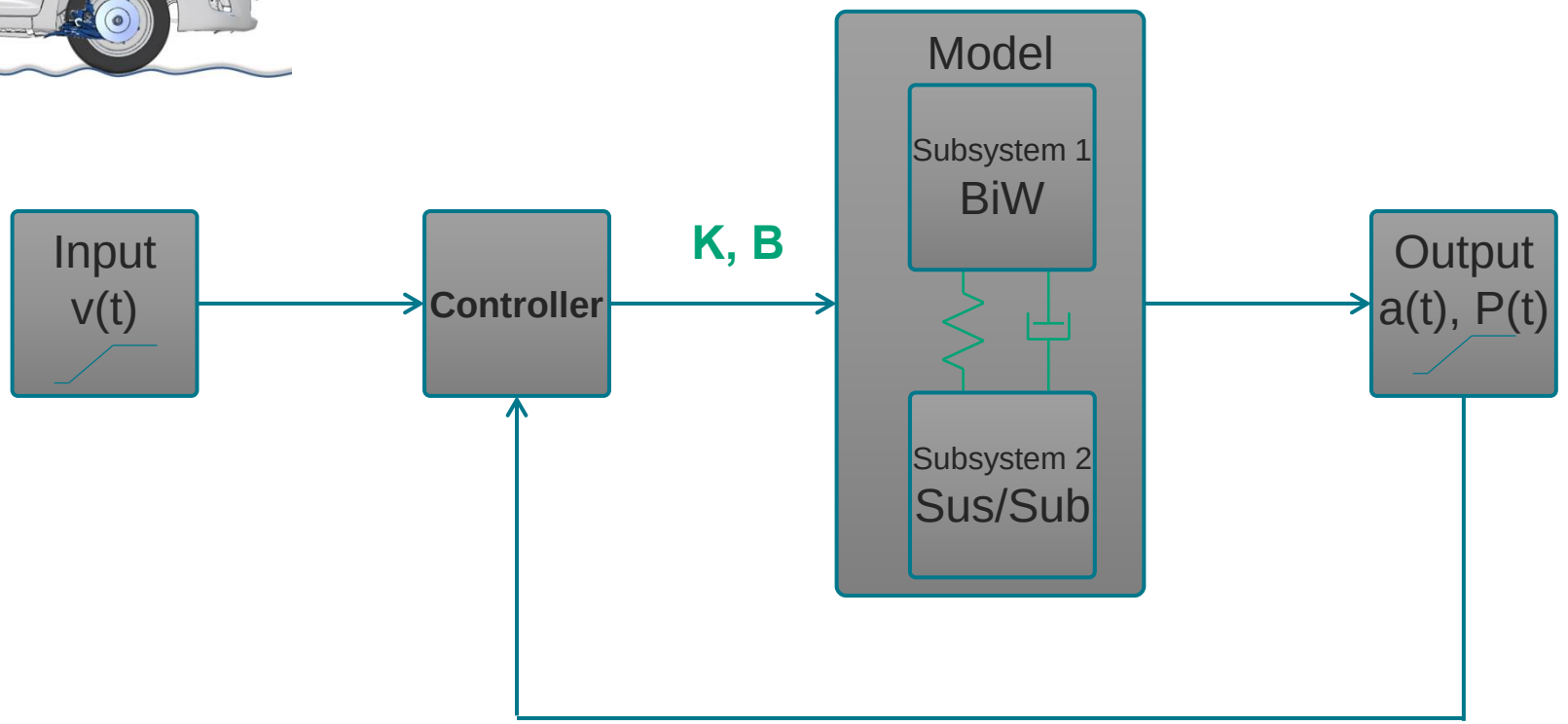
Study overview



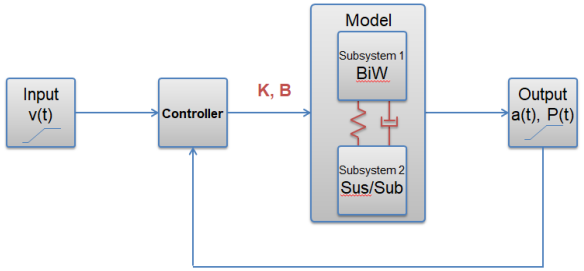
Study overview





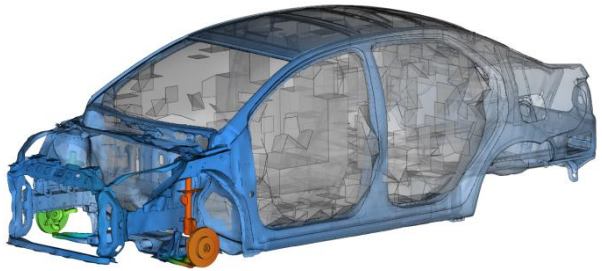
Problem Description

1D Simulation



- **Quick**
- **Multidisciplinary**
- **Inaccurate**

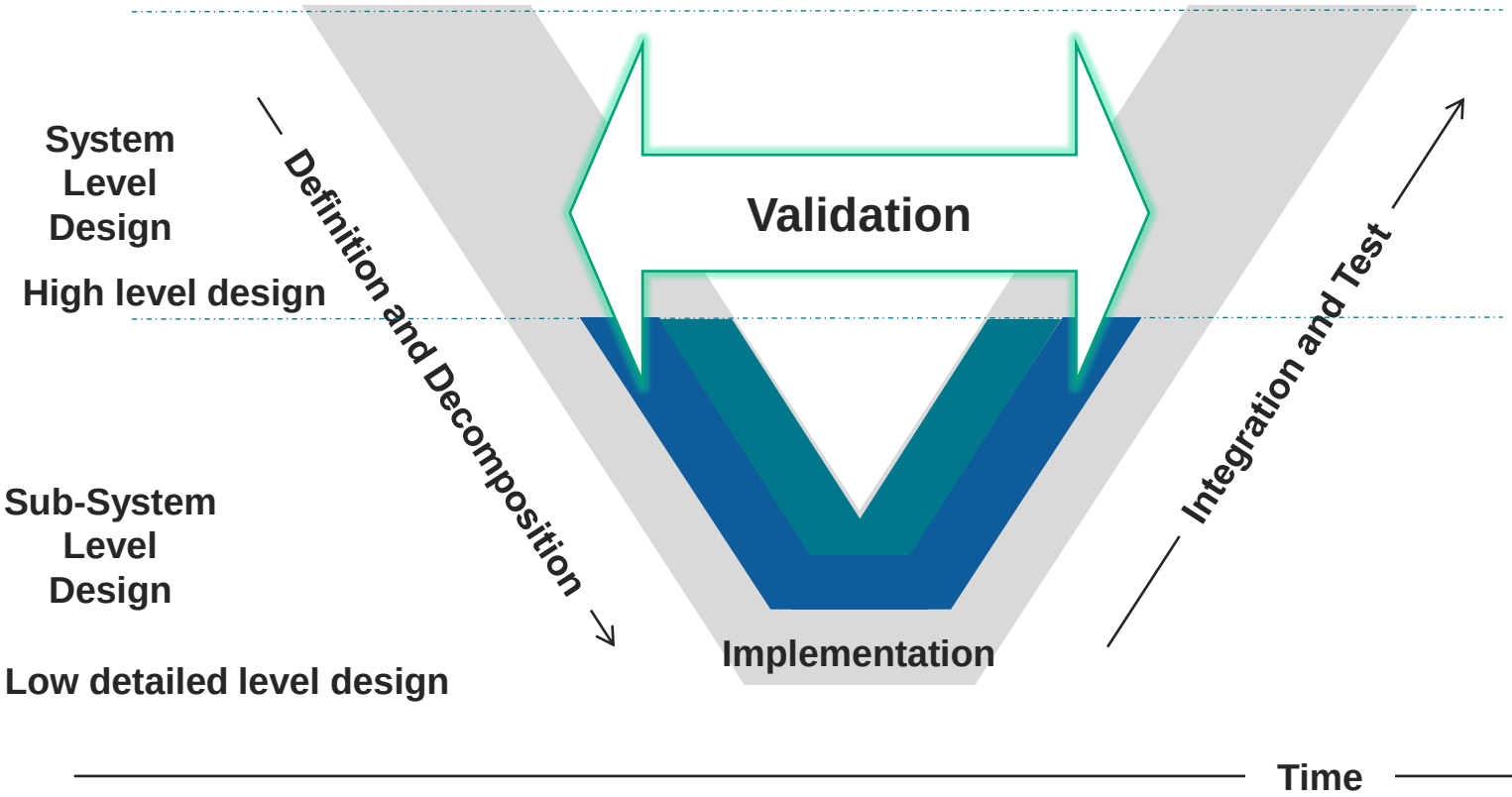
Finite Element Analysis



- **Time consuming**
- **Not Multidisciplinary**
- **More accurate**
- **Difficult to reuse data from previous analyses or measurements**

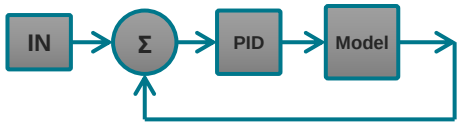
Model Based Design

Concept Requirements Design Implementation Test



Models

Mathematical representation of a physical object.



Simulations

Show how the model evolves under different conditions

Validation

Do our models represent the physical objects?

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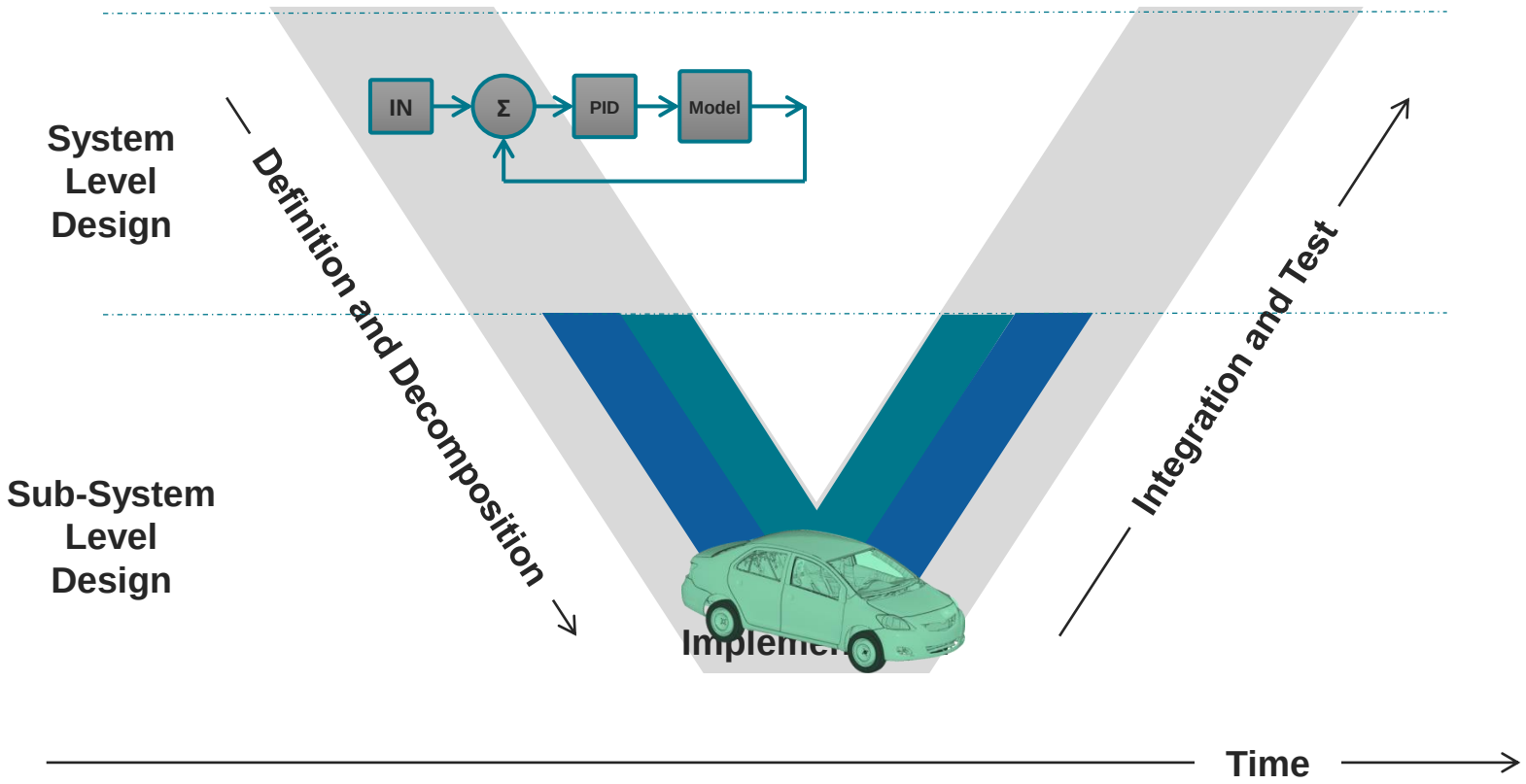
Get more from Model Based Design

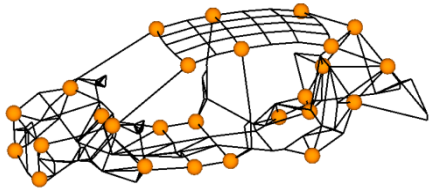


- **No common model**
- **Unconnected databases**

- **Detailed models into high level design**
- **Measured data**
- **Data from previous analyses**

Get more from Model Based Design

FE model
Measurements



Reduced Order Model

MKB

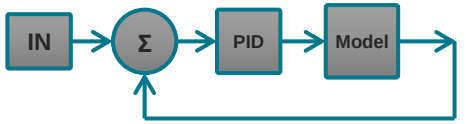
ABCD

DOE

Response surface Surrogate model

ML Predictor

1D Simulation

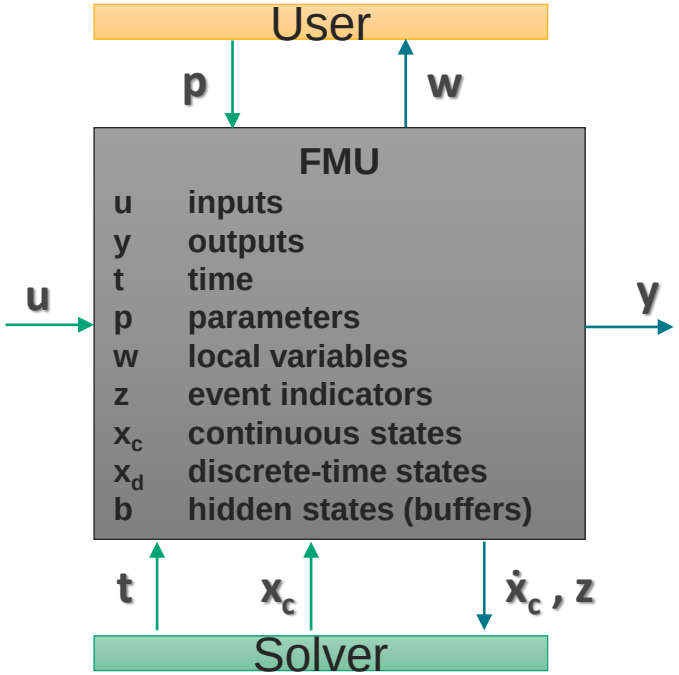


FMU

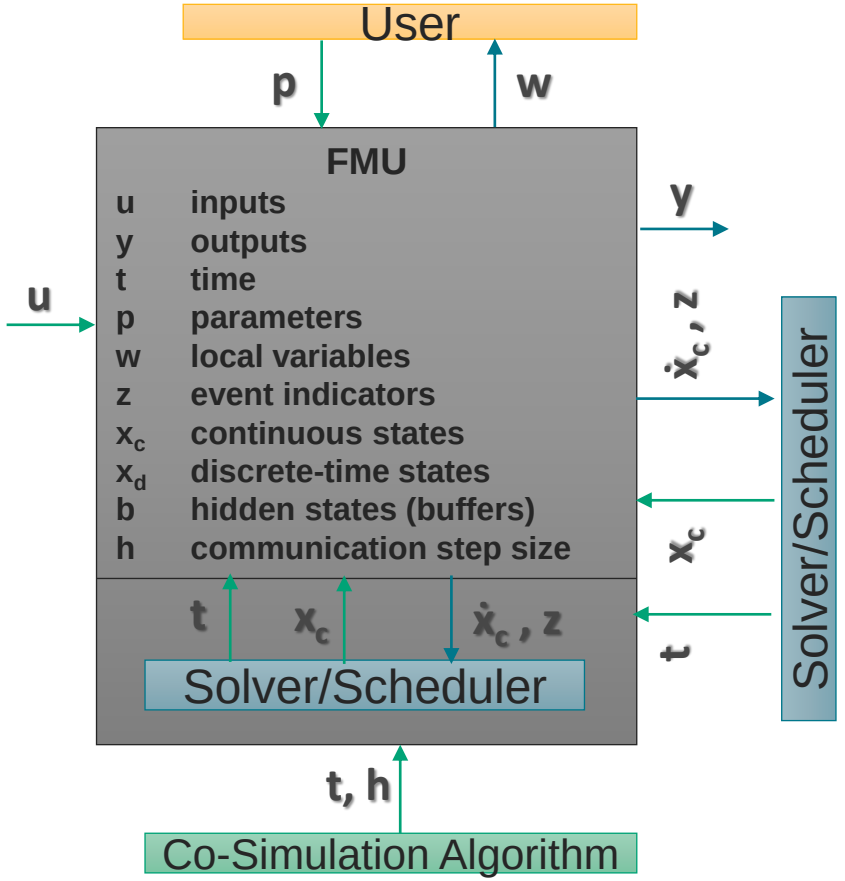
What is a Functional Mock-up Unit?

Functional Mock-up Unit concept

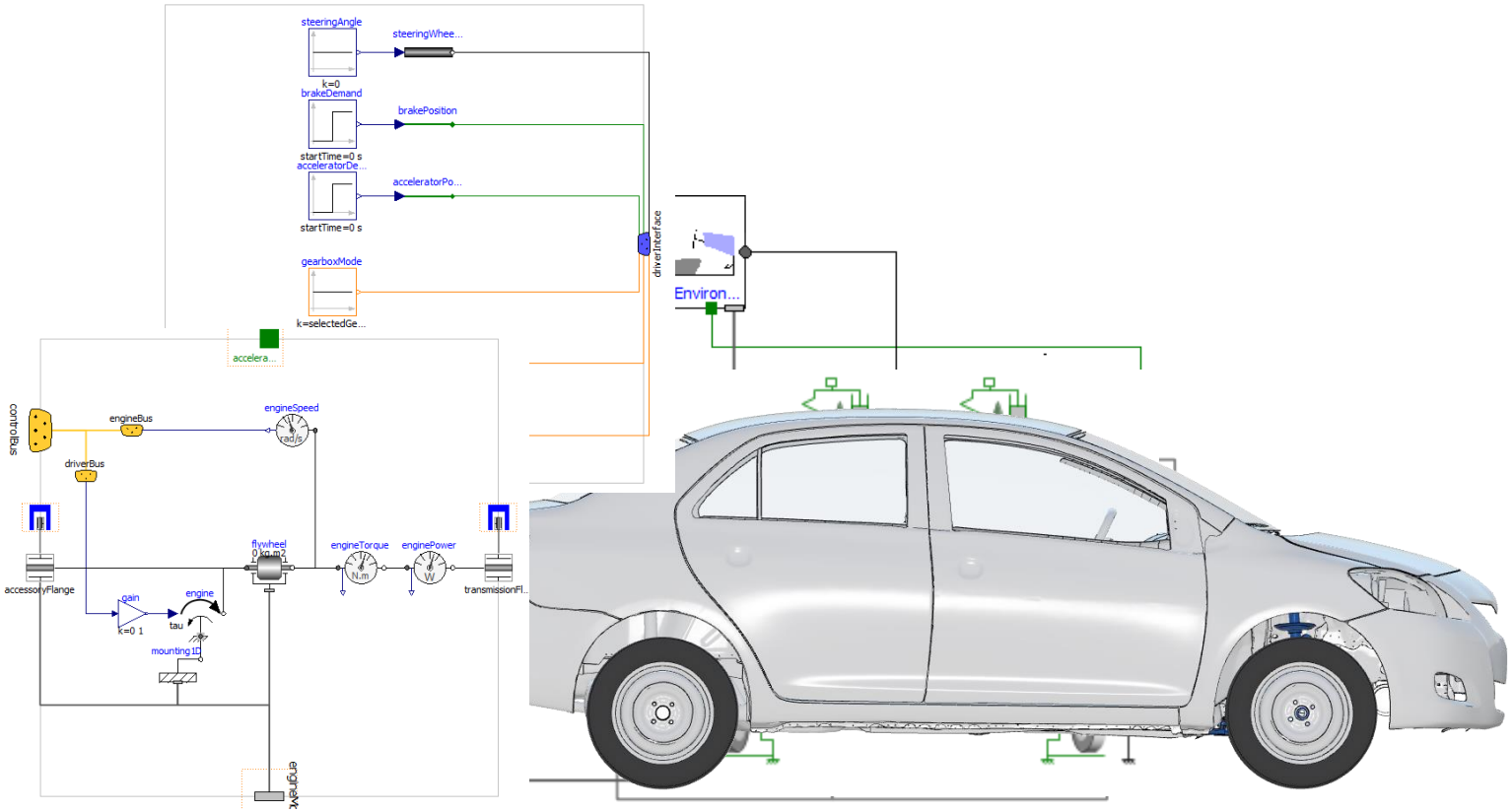
model exchange



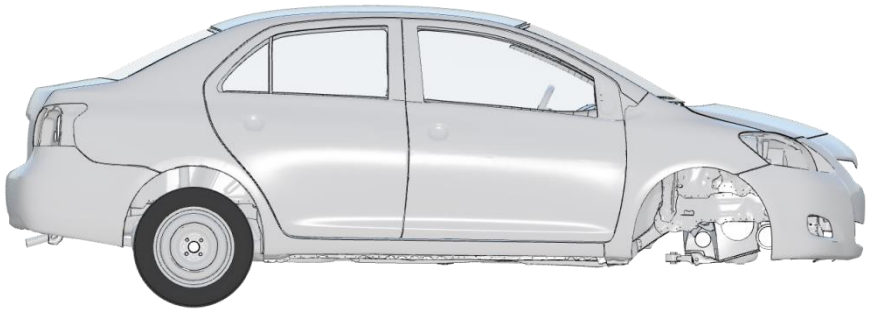
co-simulation



Embed 3D simulation data into control system simulations



3D Simulation models into FMU



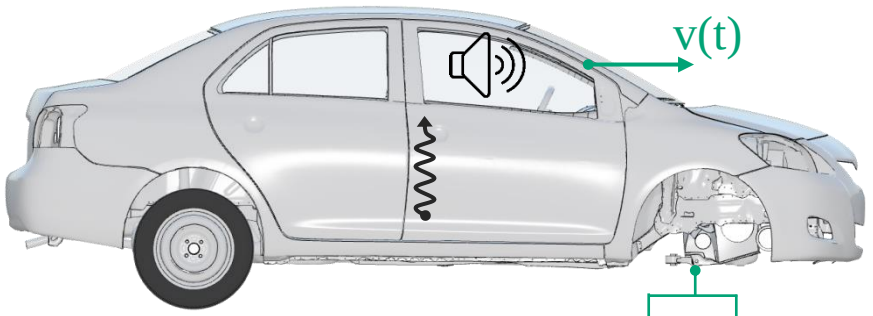
Transient Modal Superposition with Fluid Structure Interaction

Parameterized FMU for Co-Simulation

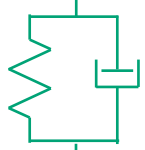
From Measured or Analytical TFs to ABCD SS

FMU for Modal Exchange

Predictor into FMU



K, B, v

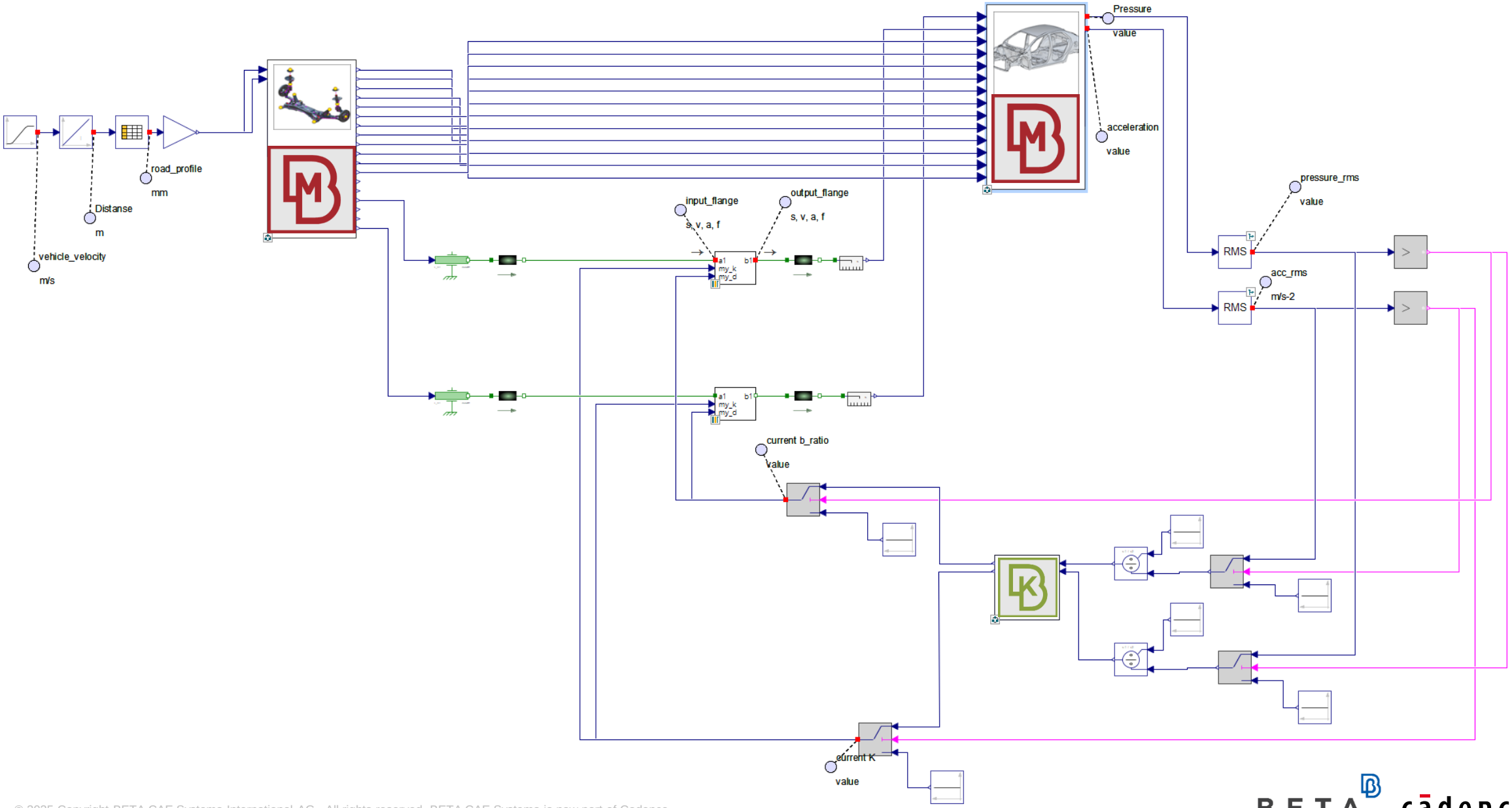


a, P

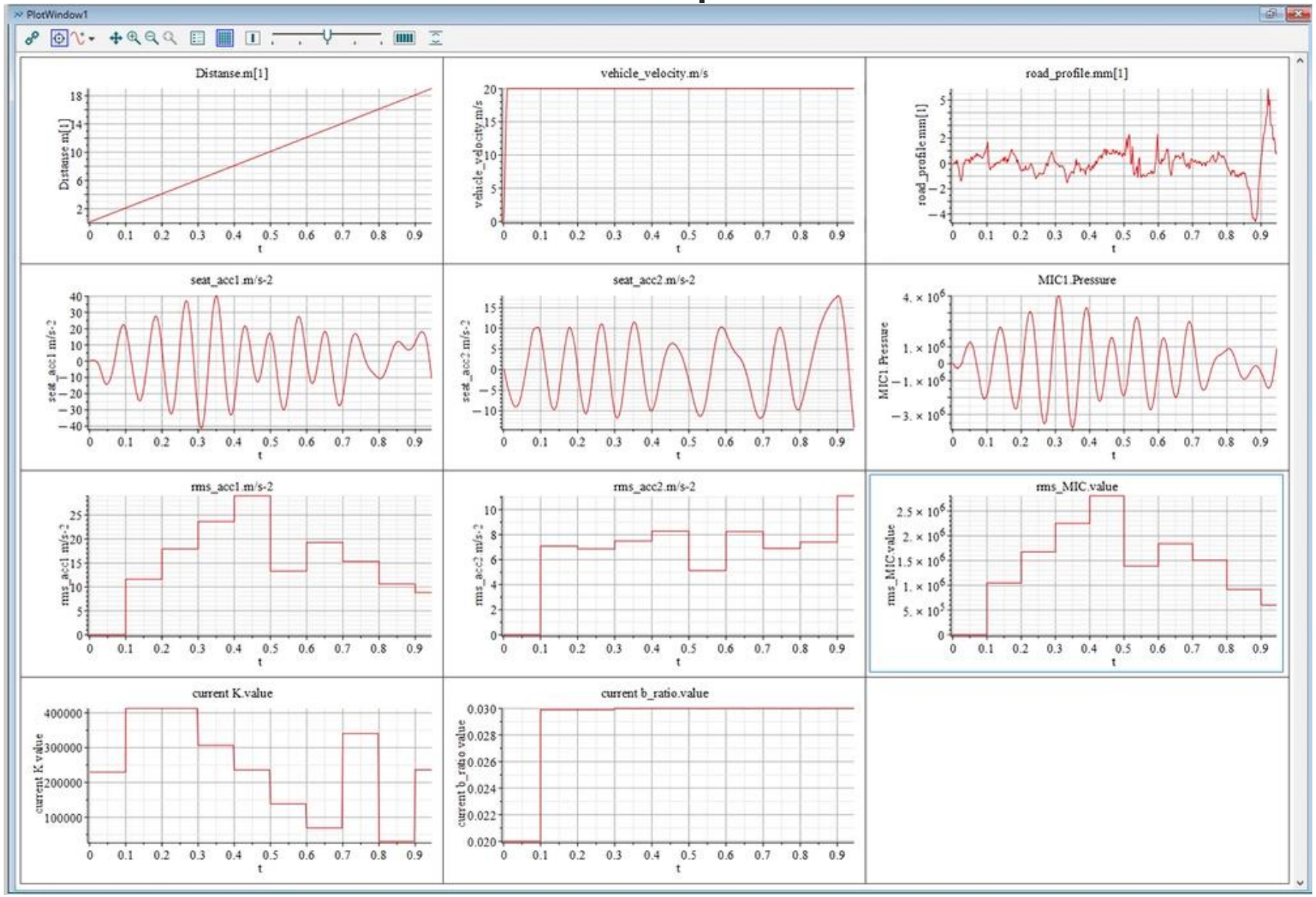
ML Predictor

FMU
for
Co-Simulation

1D Simulation setup



1D Simulation setup



Key takeaways

- Integrate detailed 3D simulation or Test data into 1D simulations
  - Increase efficiency and accuracy of control system simulations
  - Achieve early validation
  - Take into consideration features which can not be modeled in 1D simulations (i.e. Fluid – Structure weak interaction)
  - Expose as parameters FE quantities (e.g. eigenfrequencies and modal damping) which can not be traditionally modeled in 1D simulations
    - DOE
    - Optimization
- Efficient multidisciplinary collaboration
- Utilization of existing history data (analytical or measurements)

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