MathWorks
AUTOMOTIVE CONFERENCE 2024
Europe

AI with Model-Based Design: Reduced-Order Modeling

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Key Takeaways

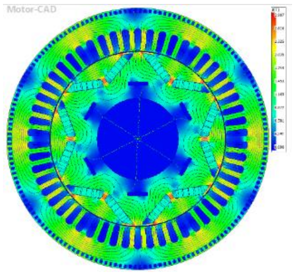
Challenge: High-fidelity models often prohibitively slow

Artificial Intelligence techniques can be used to create faster **Reduced-Order Models (ROM)**

MATLAB & Simulink enables engineers to create ROMs **without prior AI knowledge**

What is Reduced Order Modeling (ROM)?

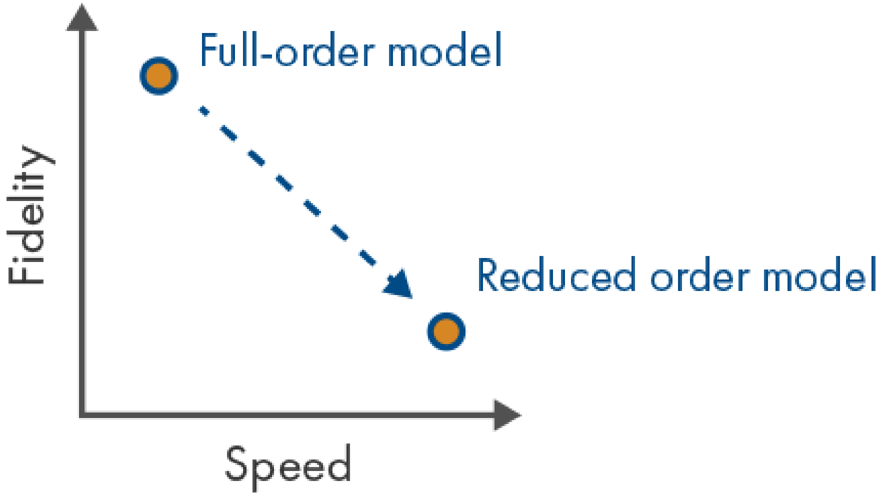
Full-order model



Simplified representation of full-order model

Reduced computational complexity

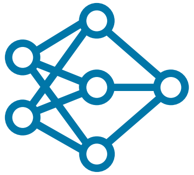
Preservation of dominant behavior



How to perform Reduced Order Modeling?

Reduced order model

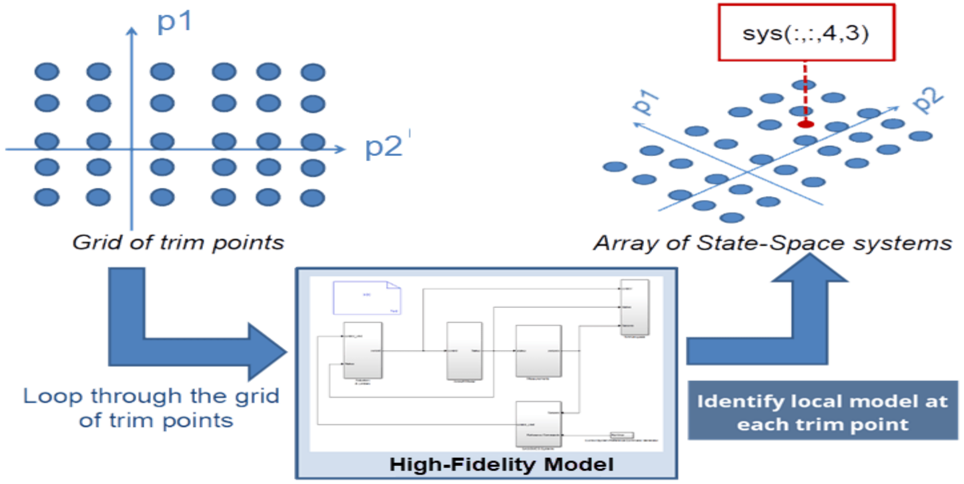
- **AI-Based Data-driven**

  Inputs →  → Outputs

  AI model

  focus today

- **Linearization**

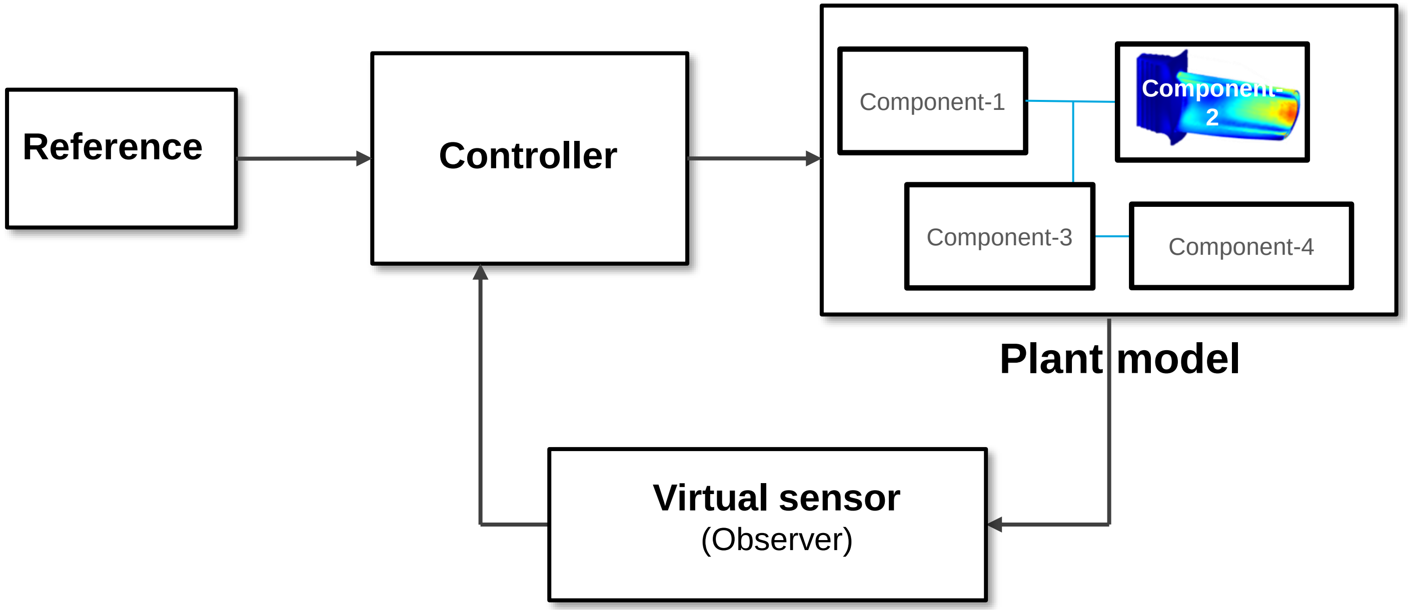
  

- **Model-based**

  FEA Software → **Simulink Simscape Multibody Control System Toolbox**

Applications of Reduced Order Modeling

- Perform simulations and SIL / HIL / PIL testing



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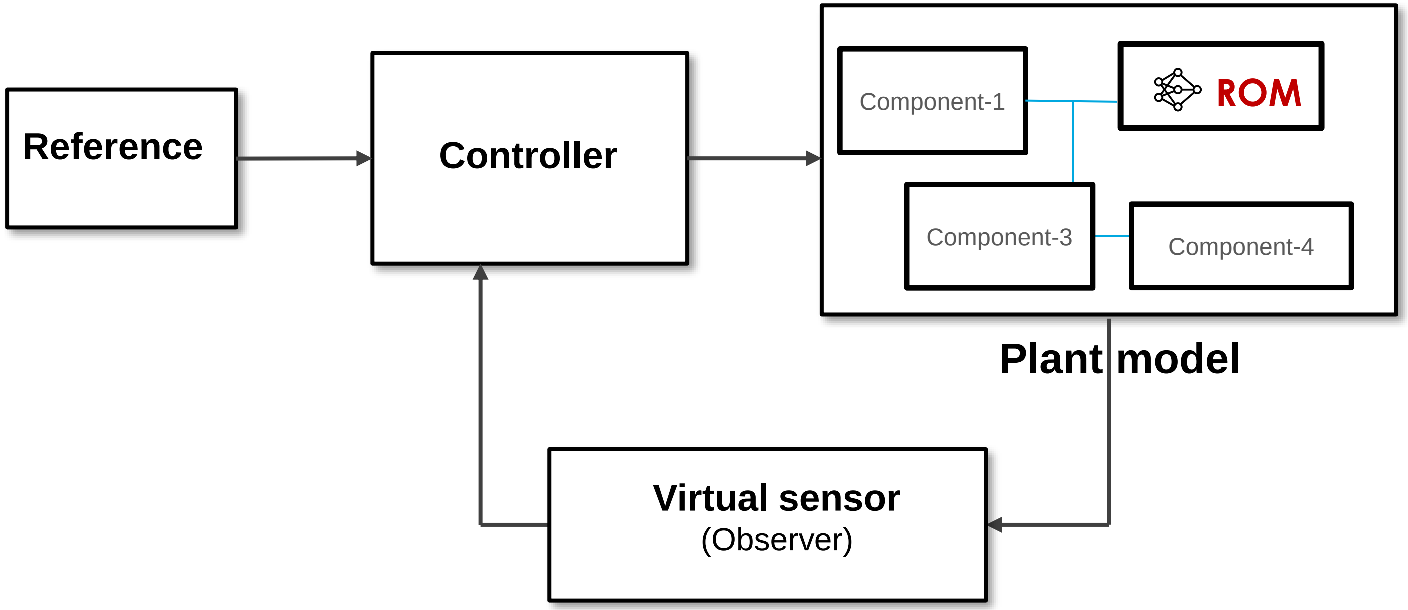
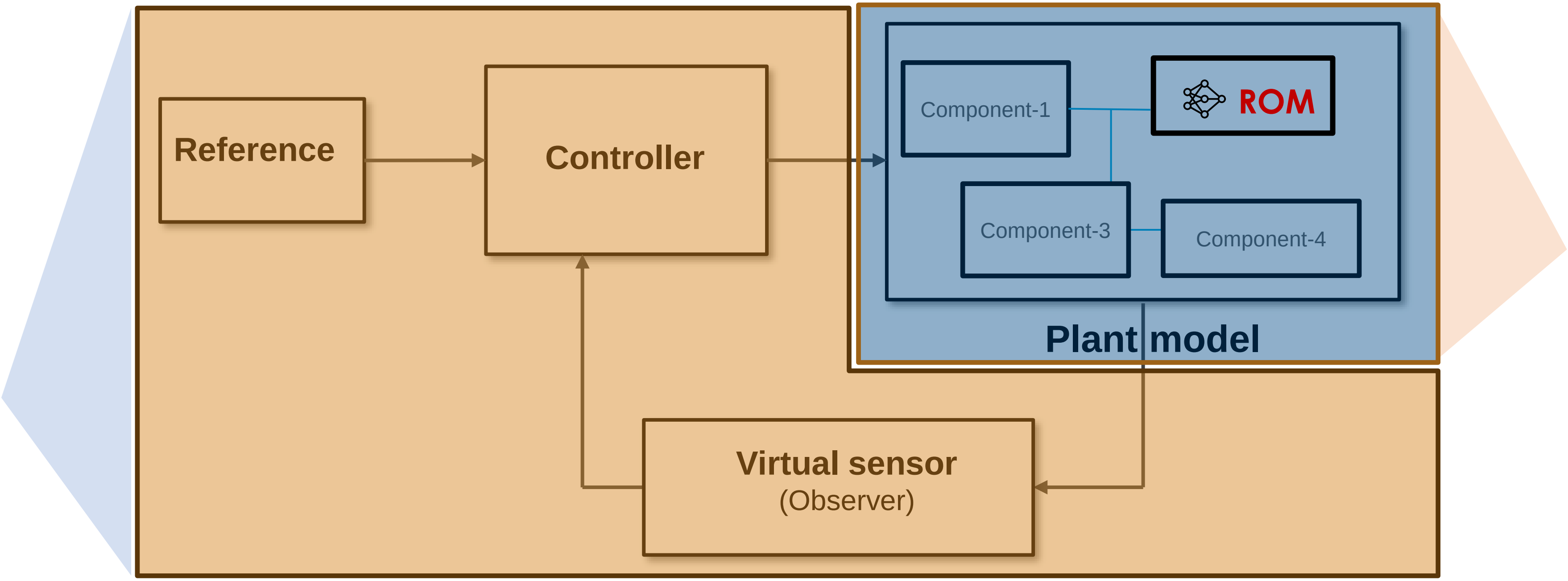


Applications of Reduced Order Modeling

- Perform simulations and SIL / HIL / PIL testing

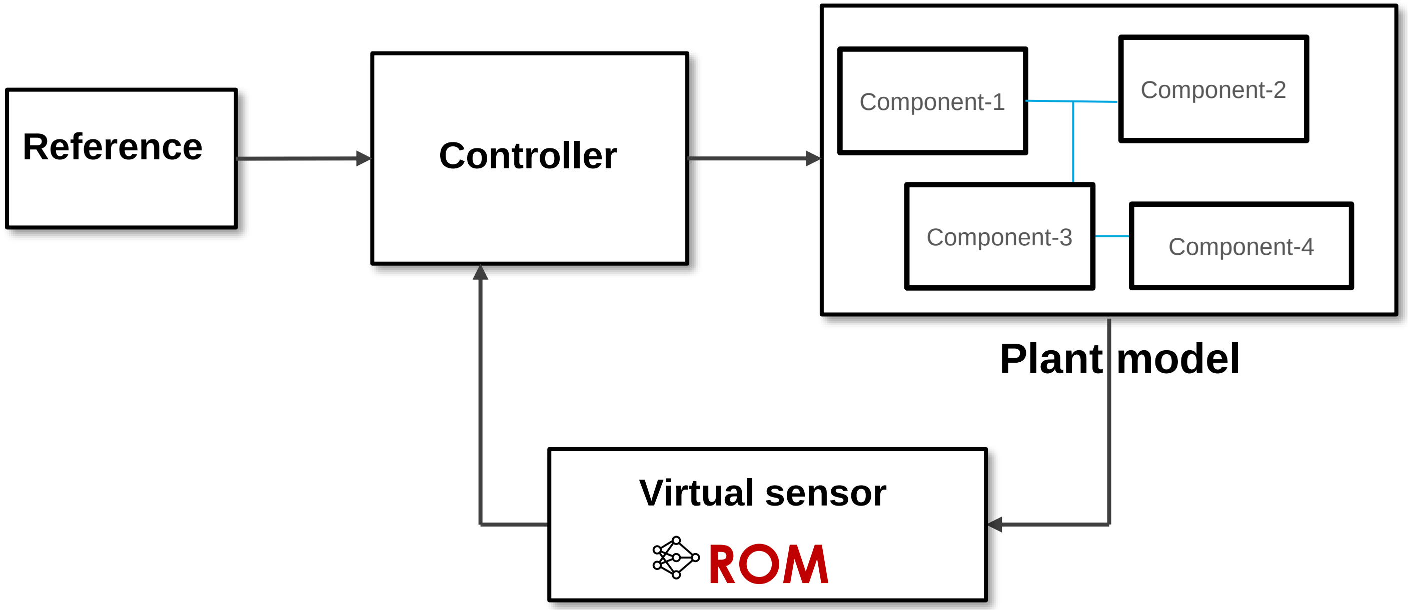
Control algorithm deployed on the embedded hardware



Plant model running on the real-time target machine

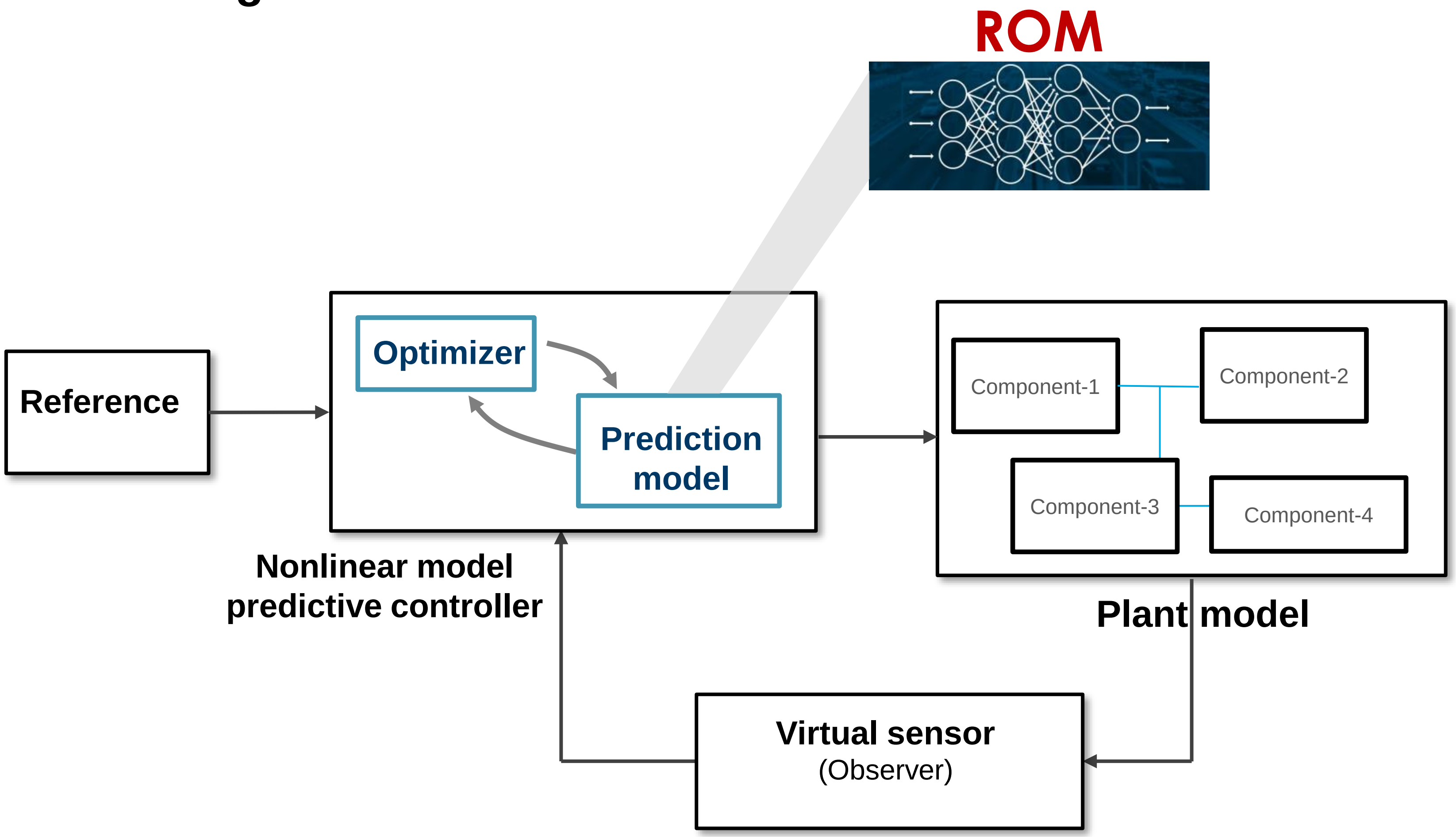
Applications of Reduced Order Modeling

- Perform simulations and SIL / HIL / PIL testing
- **Virtual sensor modeling**



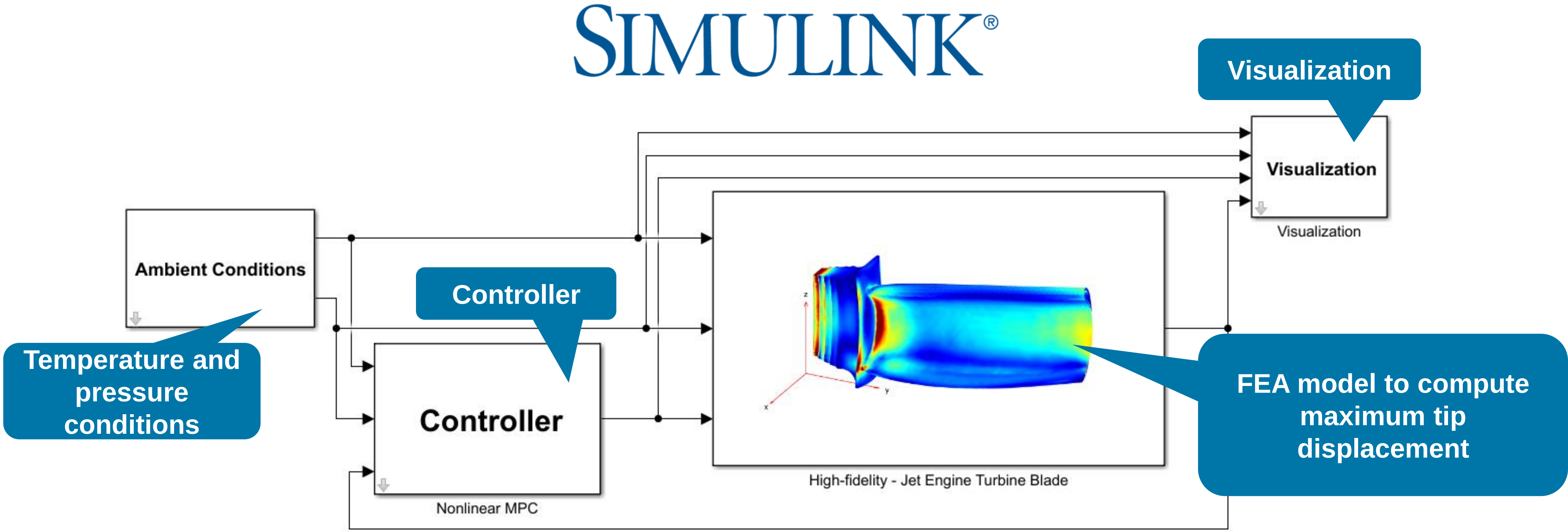
Applications of Reduced Order Modeling

- Perform simulations and SIL / HIL / PIL testing
- Virtual sensor modeling
- **Control design**



Example overview

Replacing a high-fidelity jet engine turbine blade model with an AI-based reduced order model



Closed-loop temperature control

Example overview

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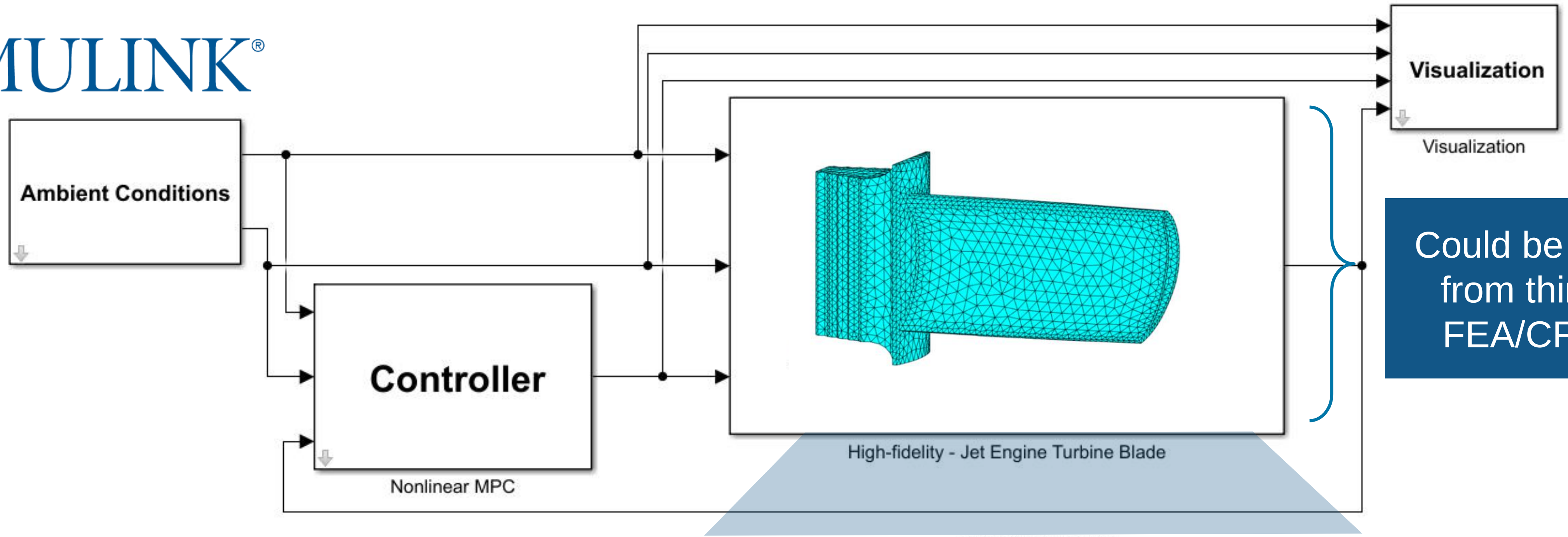
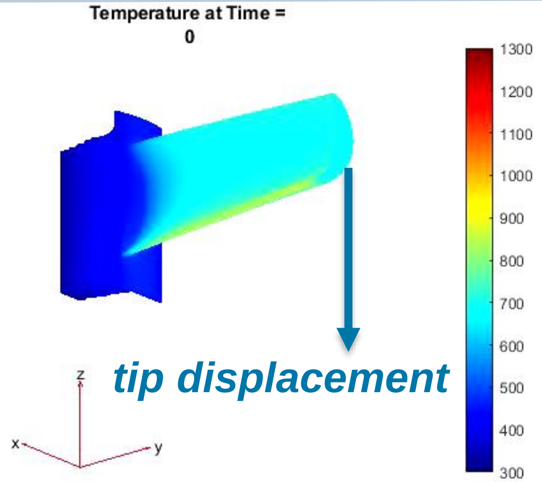


Could be imported from third-party FEA/CFD tools

~30 seconds per time step for solving FEA models

Not suitable for control design and HIL testing



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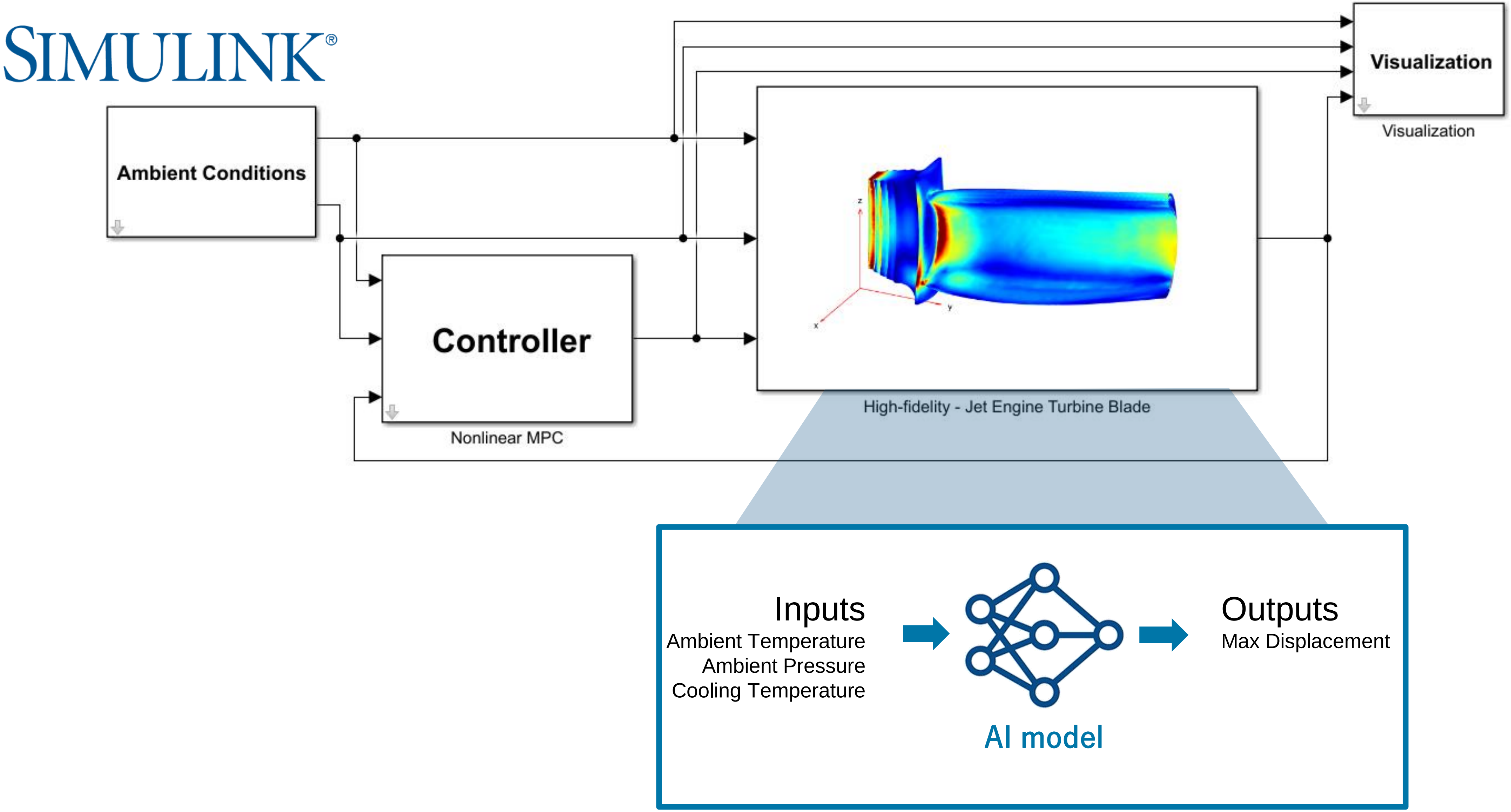

Introducing Simulink Add-On for Reduced Order Modeling

Products and Services

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Reduced Order Modeling with MATLAB and Simulink

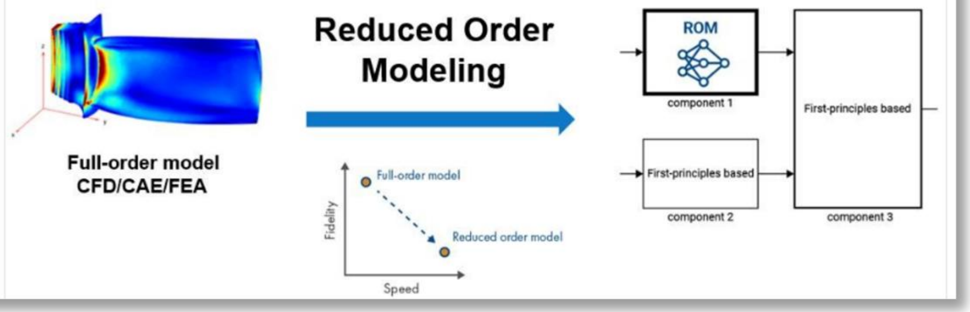
Create AI-based reduced order models

Download add-on (beta)

Simulink Add-On for Reduced Order Modeling provides an app for creating reduced order models (ROMs) of subsystems modeled in Simulink, including full-order, high-fidelity third-party simulation models. You can use reduced order models for system-level desktop simulation, hardware-in-the-loop (HIL) testing, control design, and virtual sensor modeling.

With Simulink Add-On for Reduced Order Modeling, you can:

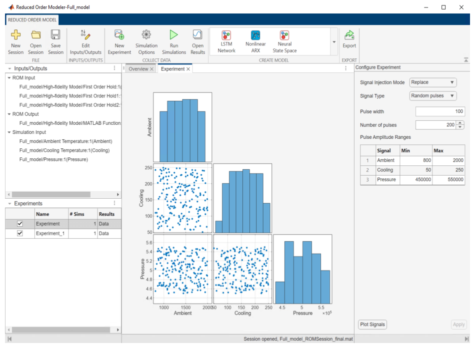
- Set up the design of experiments and generate input-output training data from a full-order, high-fidelity subsystem
- Train and compare AI-based reduced order models using pre-configured templates
- Export AI-based surrogate models to Simulink for system-level simulation, control design, and HIL testing
- Export reduced order models as Functional Mockup Units (FMUs) for use outside of MATLAB and Simulink (with Simulink Compiler)

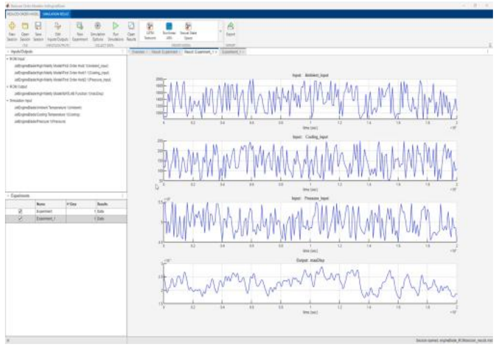


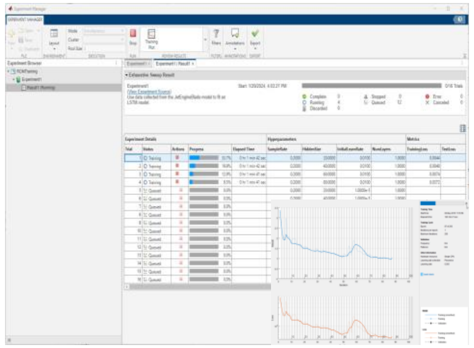
[Reduced Order Modeling with MATLAB and Simulink]

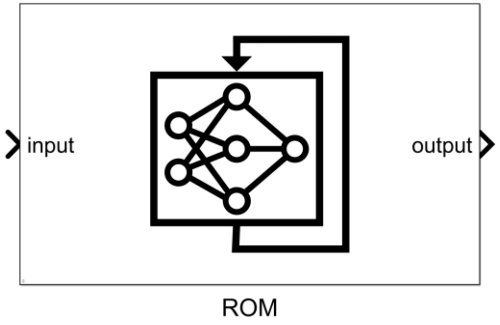
Workflow for Reduced Order Modeling App

Design experiments → **Run experiments** → **Train ROM** → **Export**

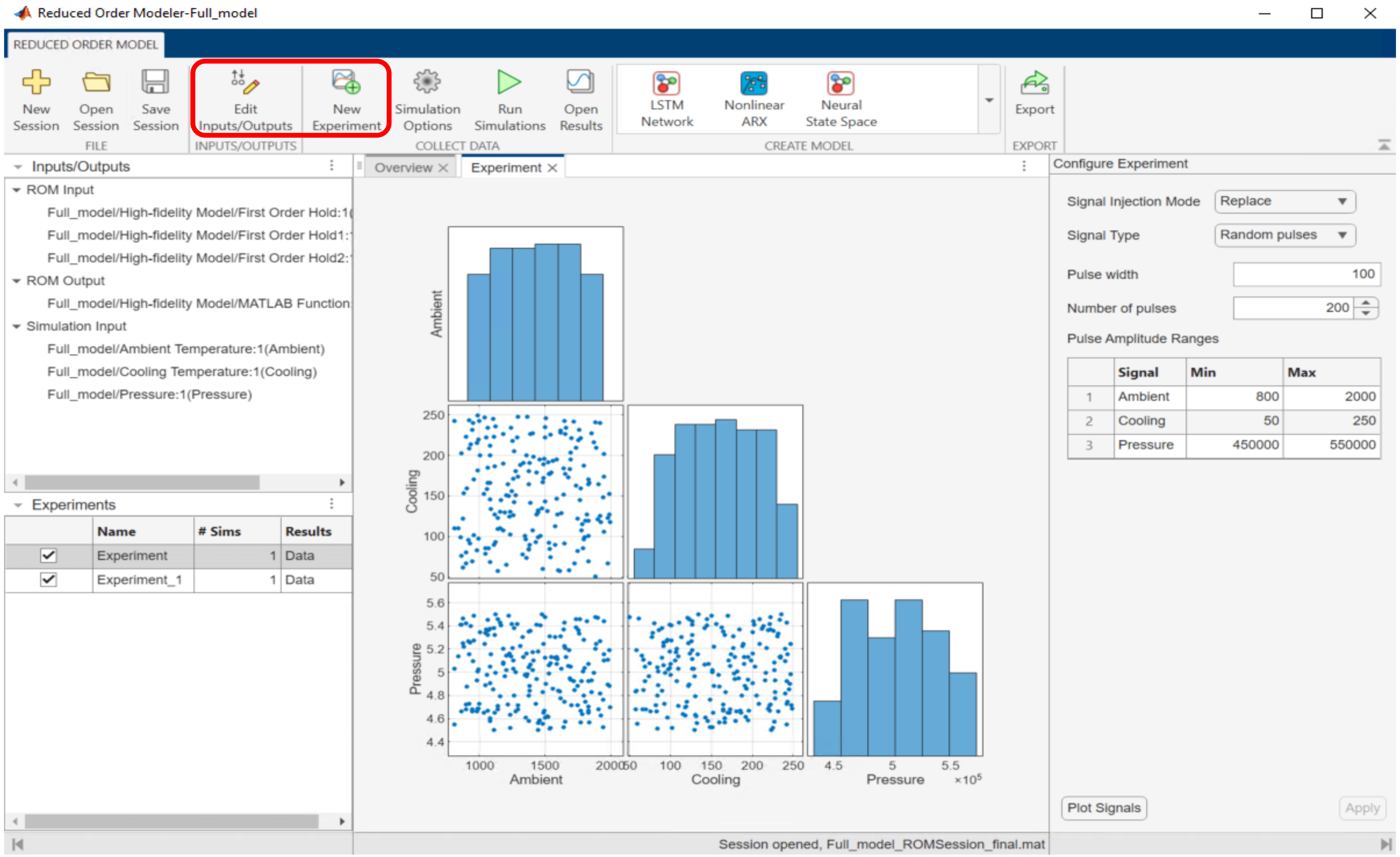




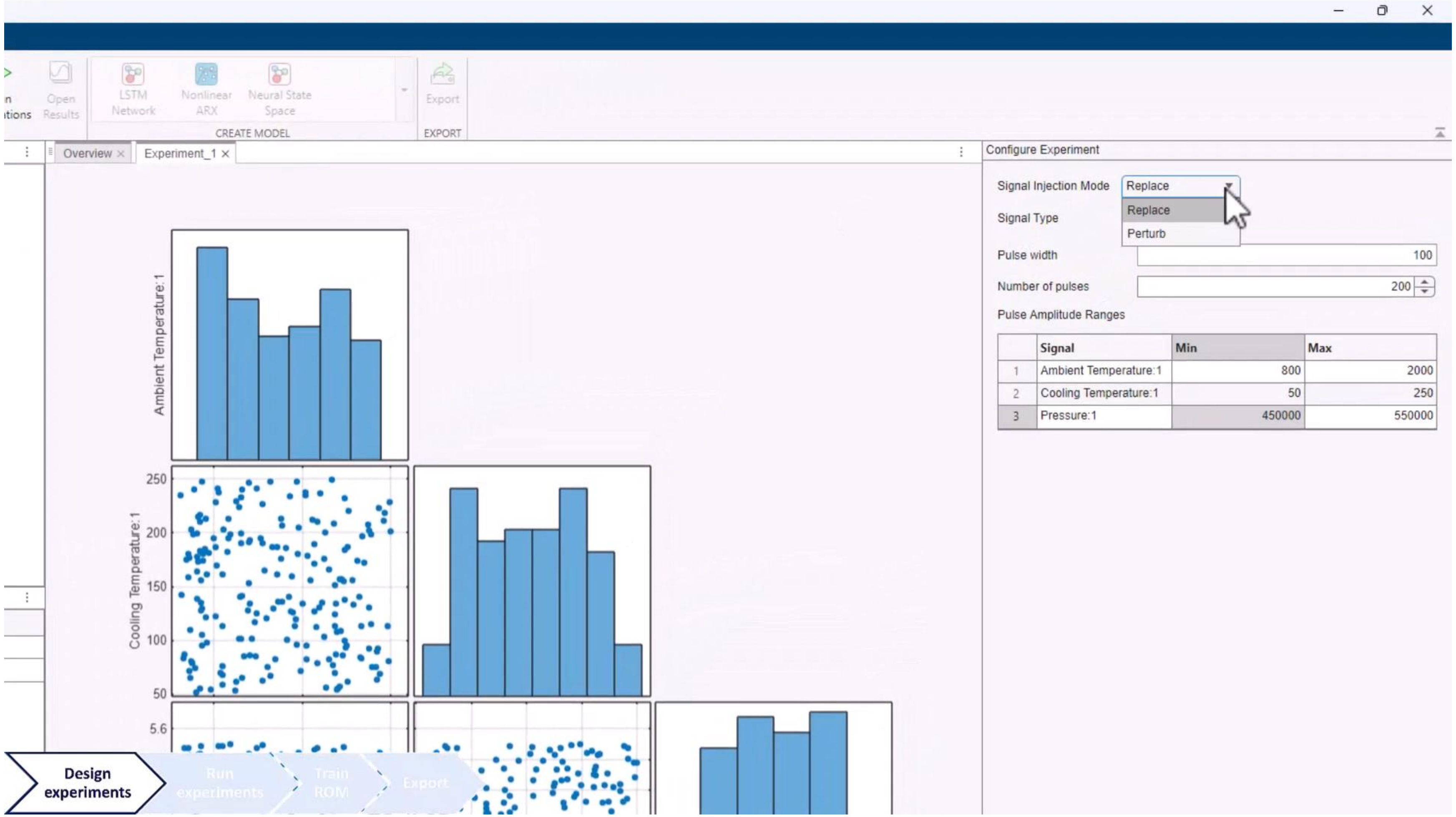




Design experiments → Run experiments → Train ROM → Export



Design experiments | Run experiments | Train ROM | Export



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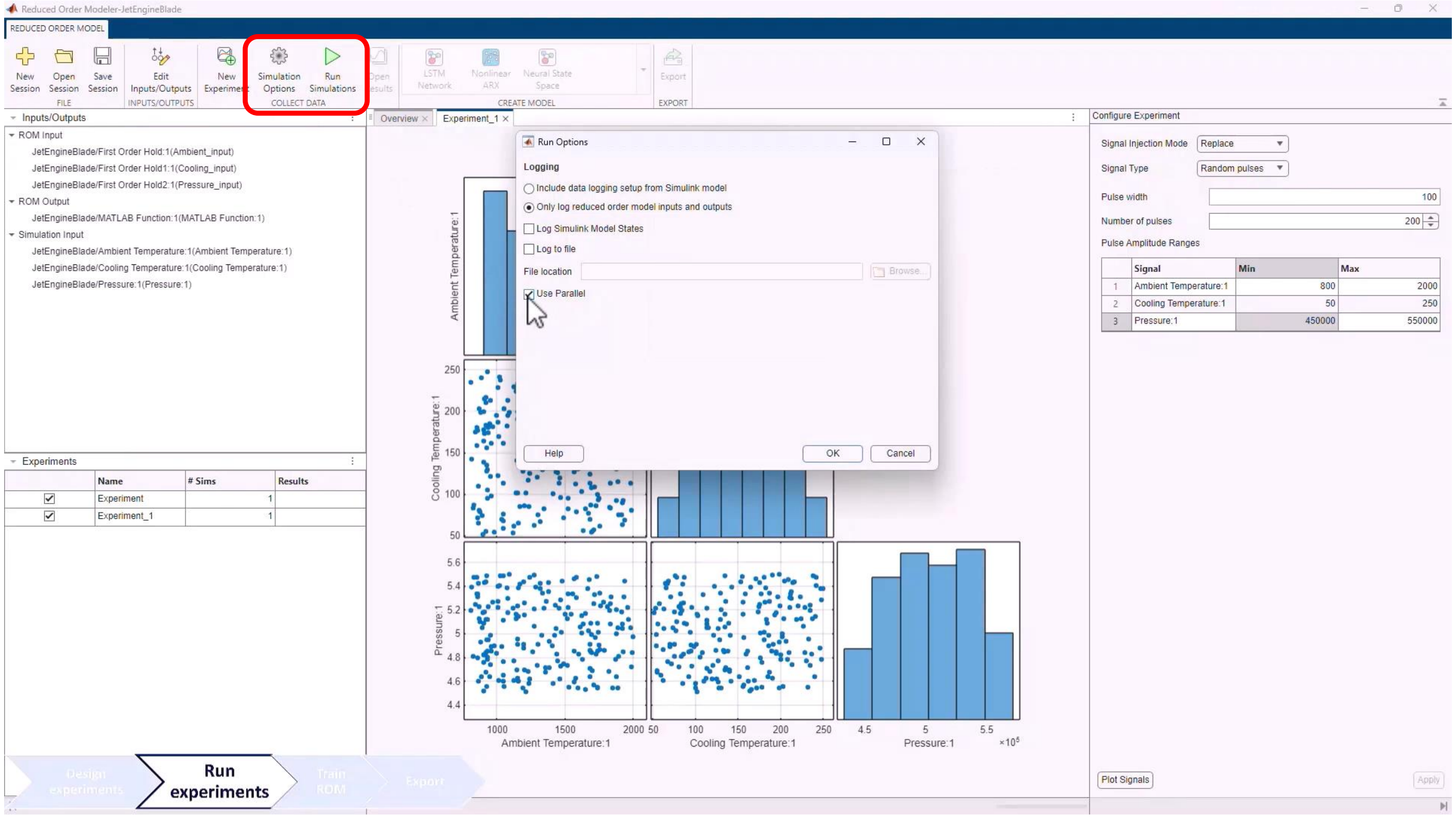

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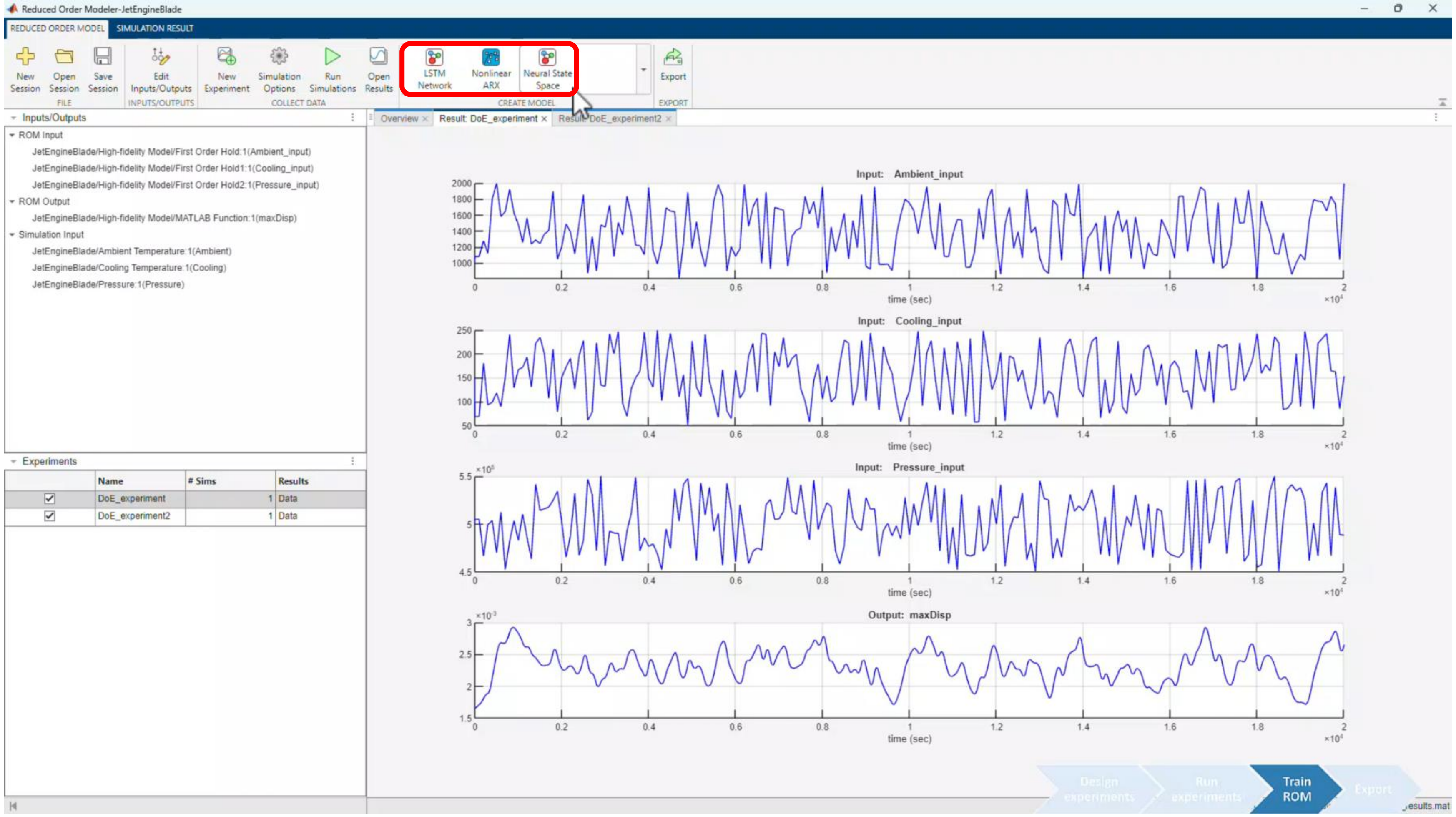

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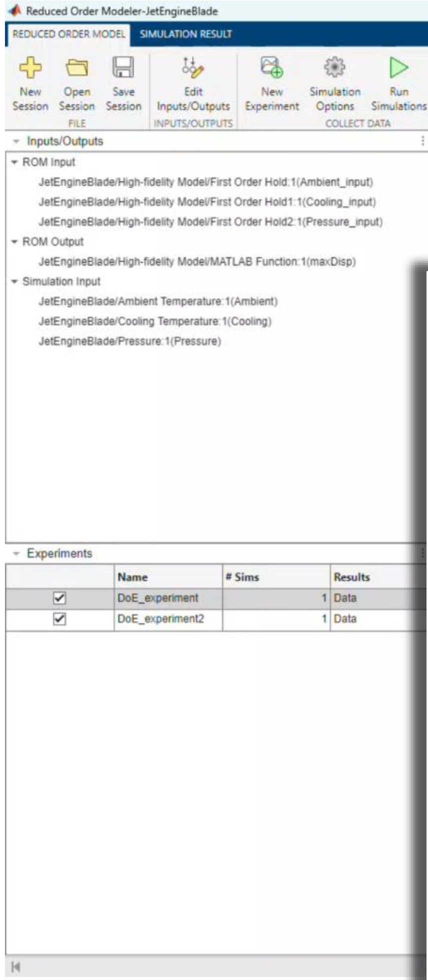
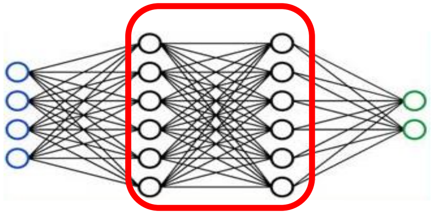
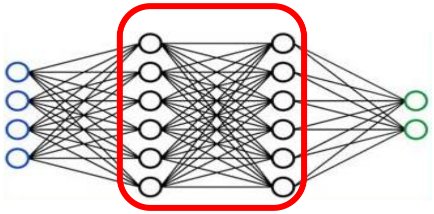



Hyperparameters

$$\begin{cases} \dot{x} = f(x,u) \\ y = g(x,u) \end{cases}$$



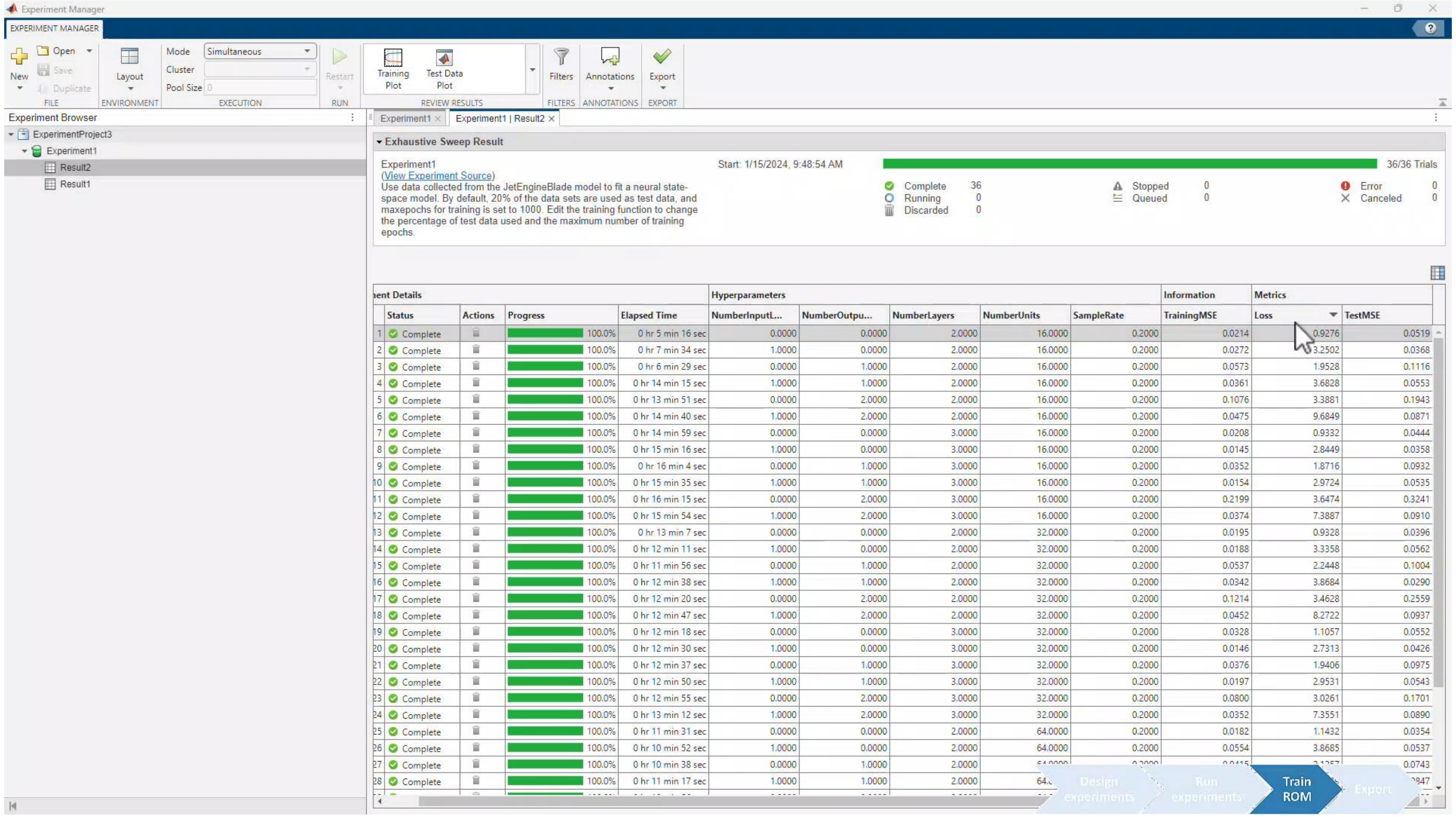
State Network (f)



Output Network (g)

Neural State Space model
(also known as Neural ODE)

Design experiments → Run experiments → **Train ROM** → Export



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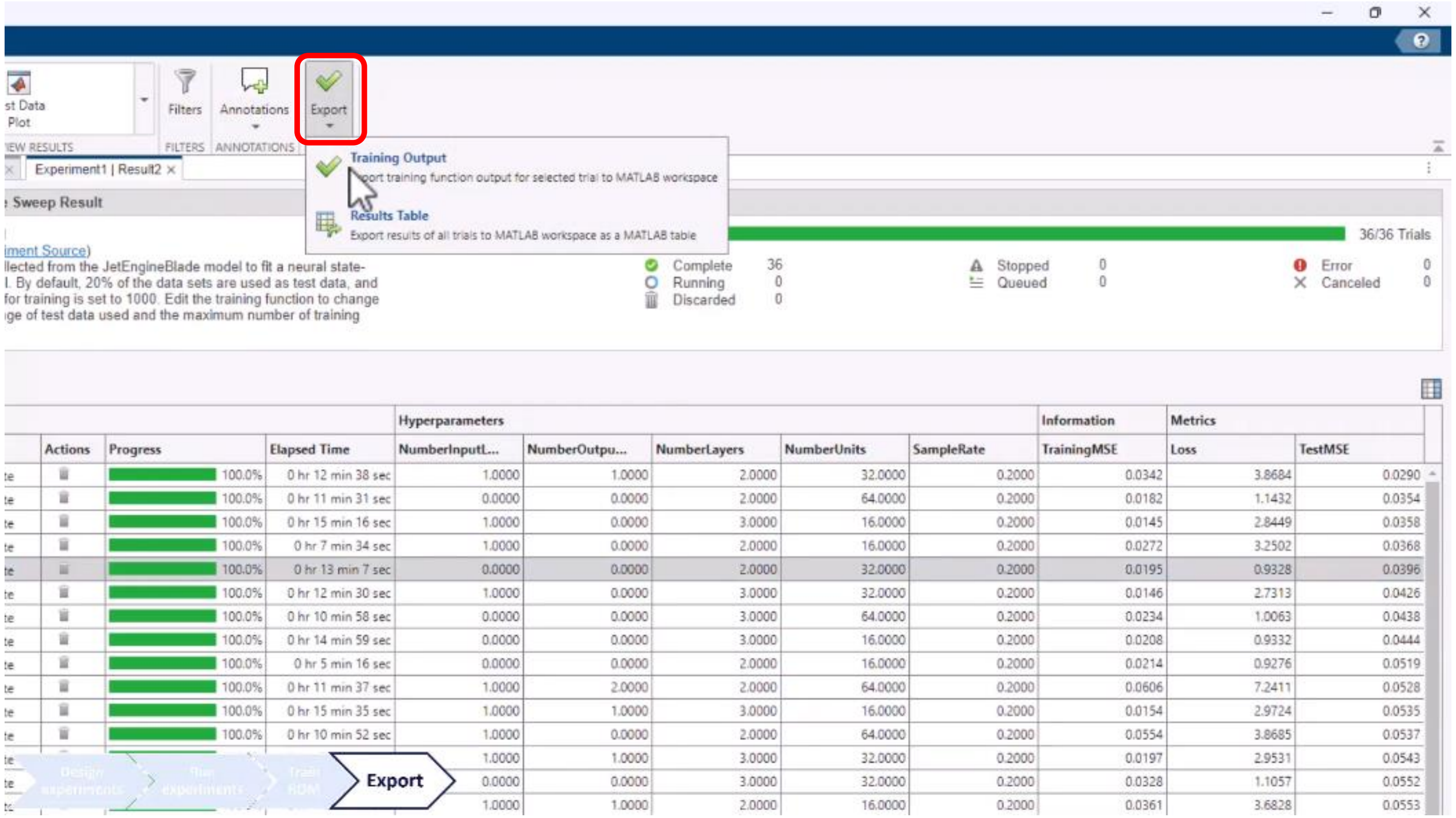

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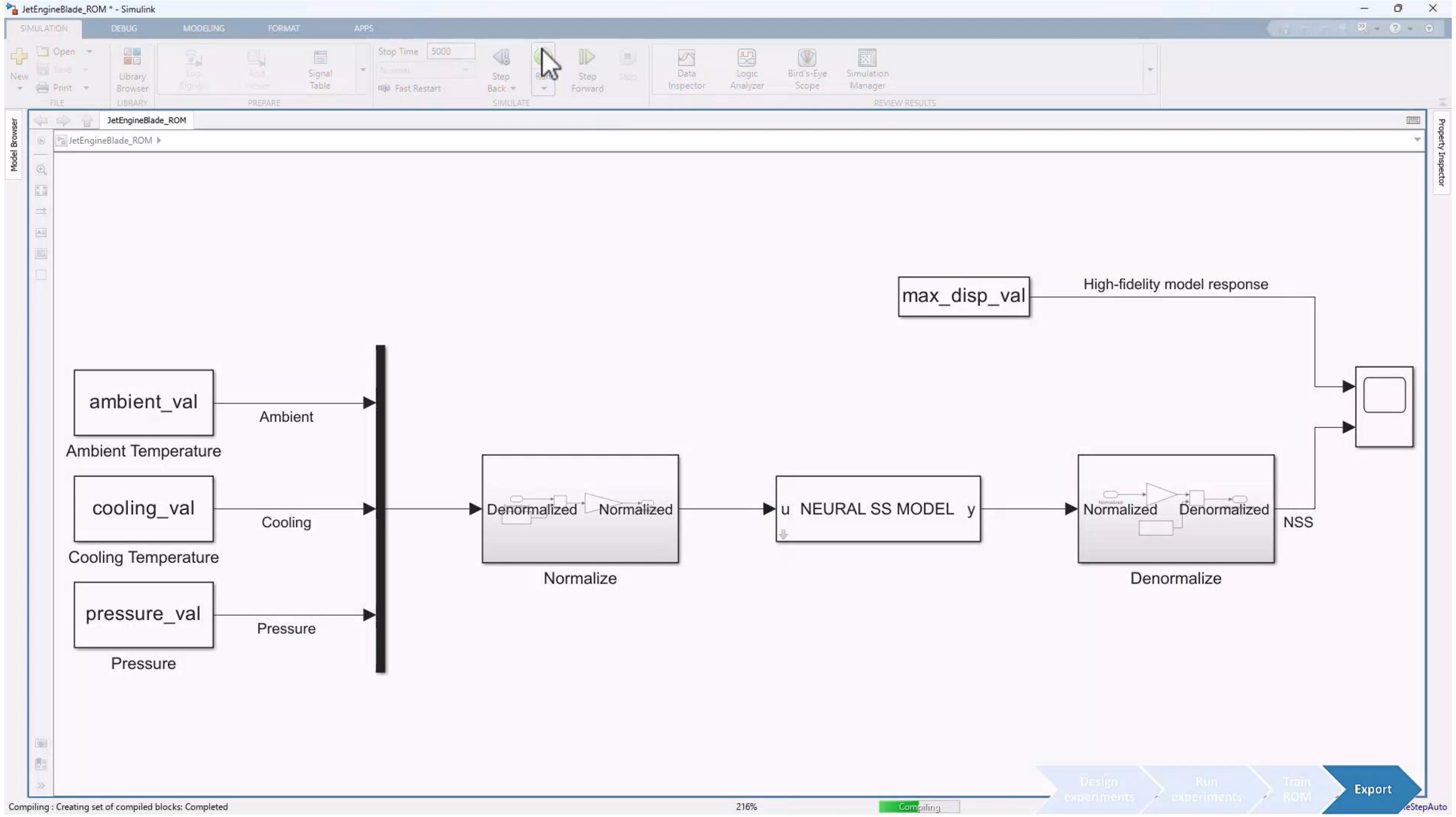
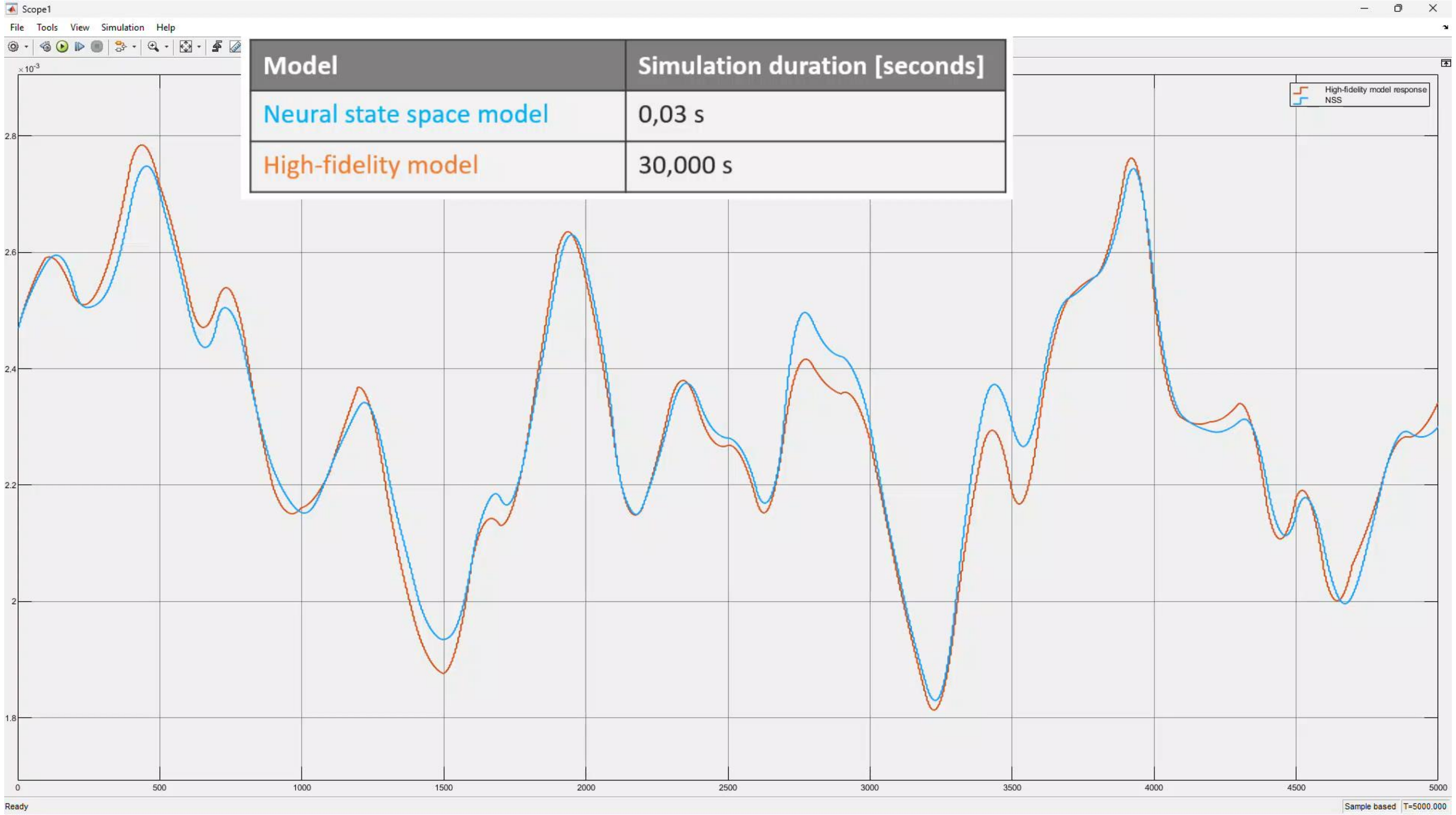
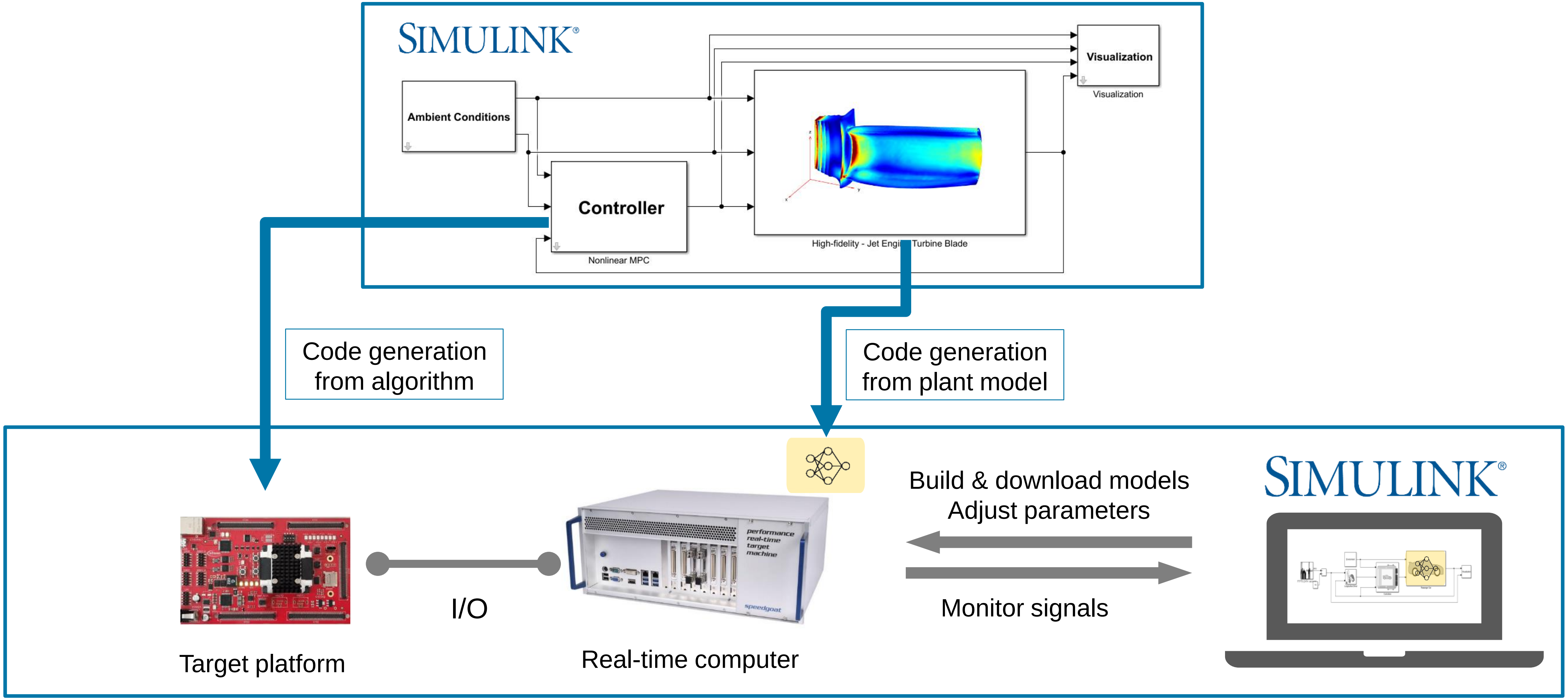


Simulation and test

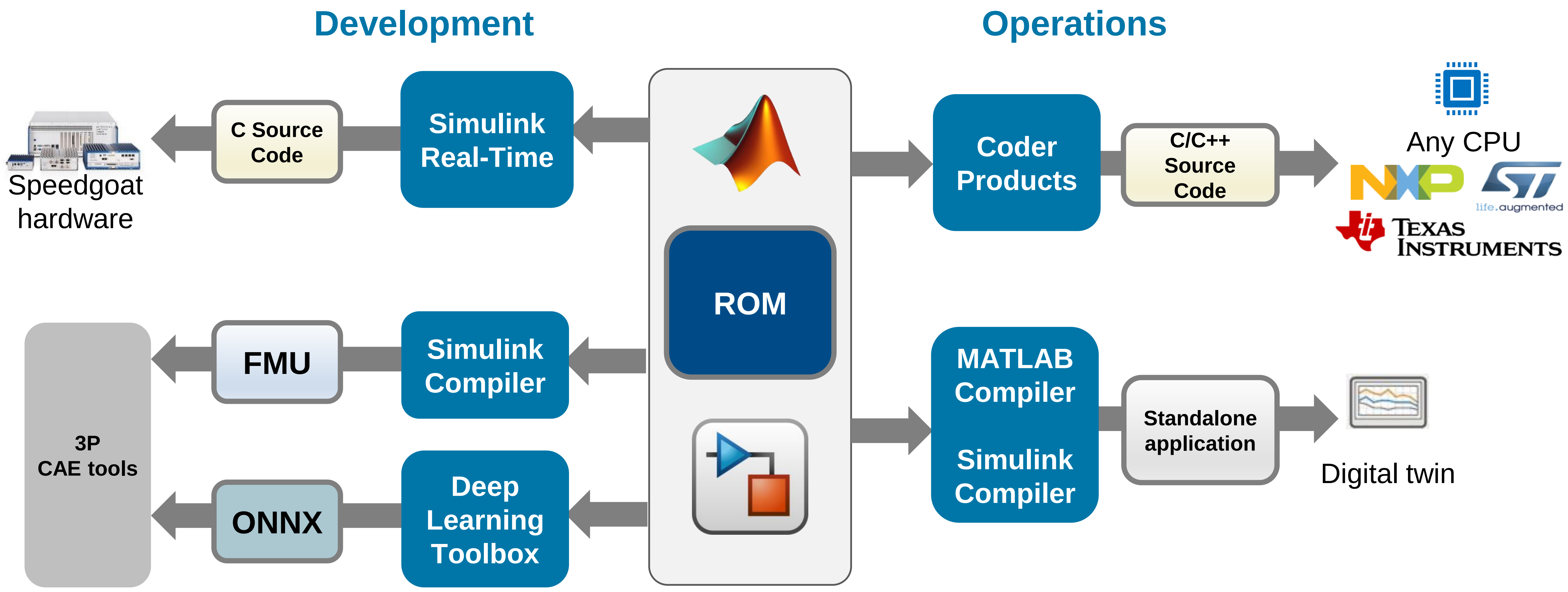


Model	Simulation duration [seconds]
Neural state space model	0,03 s
High-fidelity model	30,000 s

Hardware-in-the-loop simulation



Deployment of Reduced Order Models



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Thank you

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