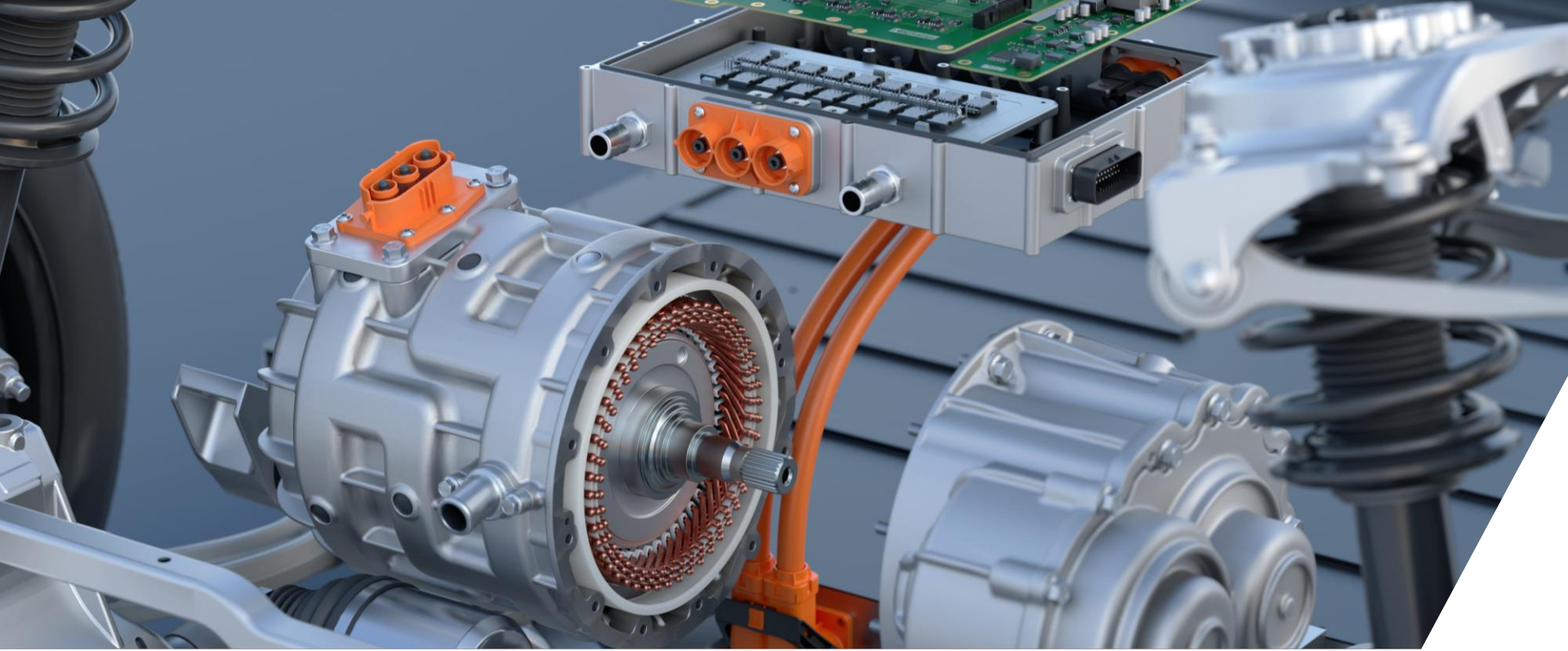

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AI SURROGATE MODELS OF POWER CONVERTERS WITH ROMAI

Rafael Sánchez Garciarivas / Senior Solution Engineer – Systems Integration

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Agenda

- This will be recorded -> YouTube
- Slides & models will be shared

1 Introduction

My background & announcements

2 Context

Resonant power converter simulations

3 Demo

Training & testing AI ROMs

4 Extended Applications

5 Q&A

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My Background

Joined Altair in 2022

- Customer success for systems integration tools
  - 0D & 1D systems modeling
  - Data-driven AI Modeling
  - Workflow Automation

- Education:

Electromechanical engineering

Masters in electrical engineering

  - Heavy focus on applied AI

- Based in Mexico
- Let’s connect: LinkedIn

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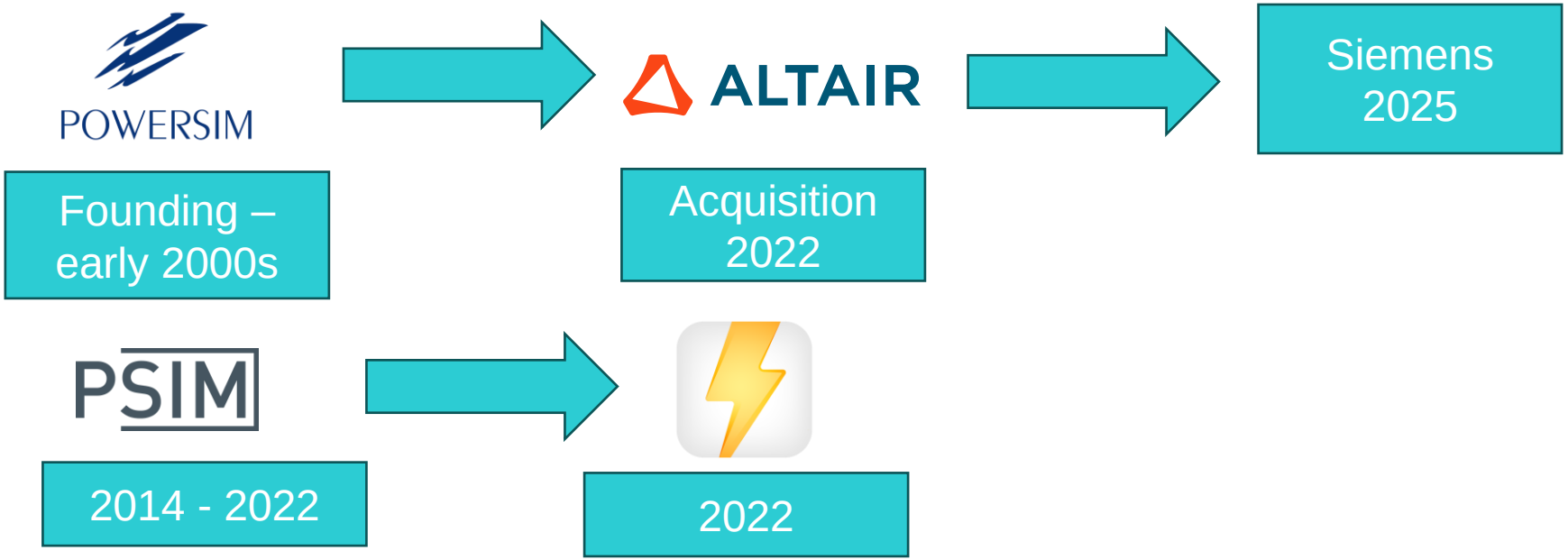
Siemens Acquisition



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Monthly Cadence of Power Conversion Webinars

Focus on new applications for PSIM:

- Reduced fidelity modelling
- Automated optimization
- Coupling with Flux & FluxMotor (electro mag FEA)
- Coupling with 3D thermal Solvers

Application areas:

- Battery chargers
- Motor drives
- Grid connected systems

Upcoming webinars:

- **June 12** – Fast track eDrive efficiency map generation

Register here!

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POWER CONVERTER SIMULATIONS

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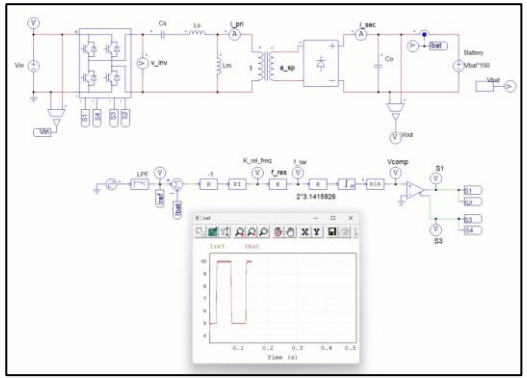
Power Converter Simulations

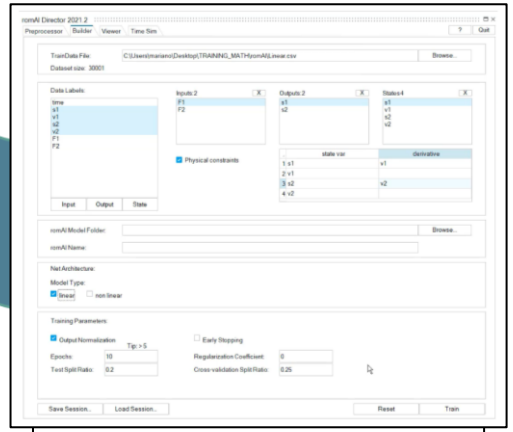
Altair romAI

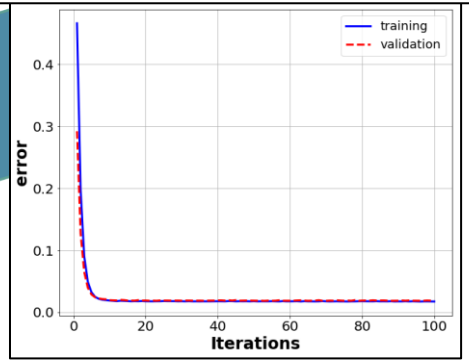
High-fidelity simulation



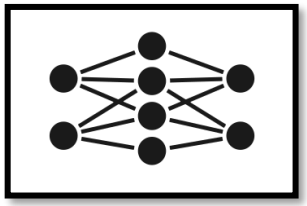
Training data

Machine Learning

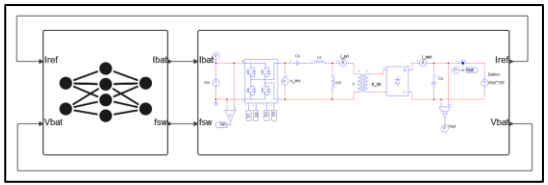




romAI



Accelerated Simulation



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Power Converter Simulations

Context

- Trend towards electrification makes power conversion a key aspect of everyday life.
- Power converters: Make power supply suitable for specific applications and equipment.
- They transform electrical energy from one form to another, e.g.:
  - Change voltage
  - Change frequency
  - AC -> DC
- **Resonant converters** are getting a lot of attention due to their **high efficiency** and **low EMI.**
- However, they are **highly nonlinear** and **hard to control**.

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Power Converter Simulations

Problems

- **High-frequency switching** makes resonant converters **computationally intensive to simulate**.
- Simulations can become **prohibitively slow** when run over **long timeframes** or when converters are part of **larger systems**.
- **Acceleration techniques** for simulation thus become valuable for design optimization, validation, and system integration.
- Simplified models that abstract dynamics are good enough for steady-state analysis.
- However, **dynamics are critical** when analyzing **load changes**, **faults** or **control interaction**.

Challenge: Reduce computational burden while still capturing dynamics!

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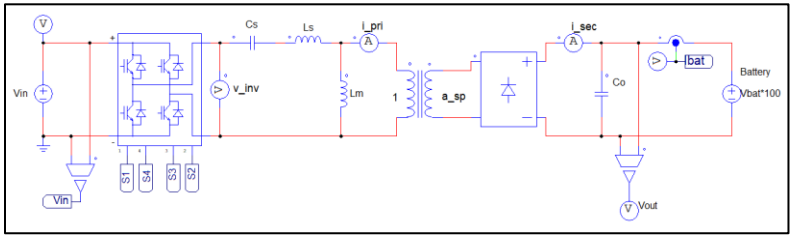
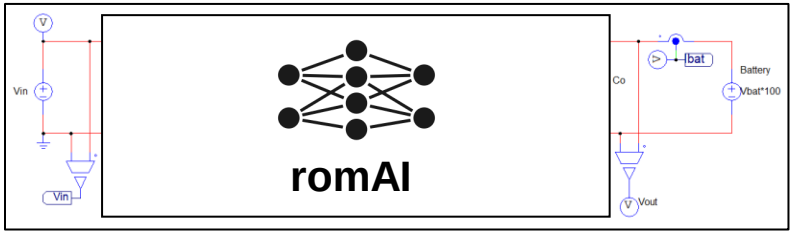
Power Converter Simulations

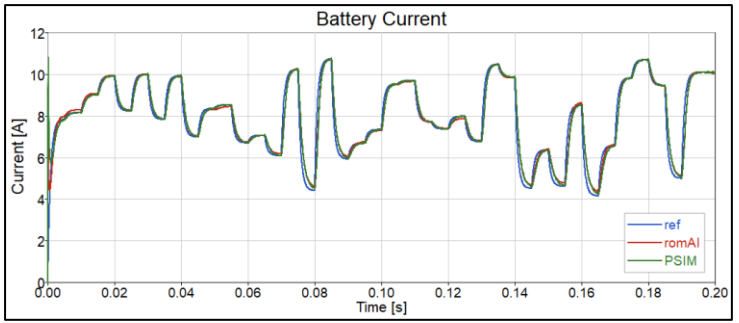
Solution

High-fidelity model:



Surrogate model:





Accurate and fast results!

20 seconds of simulation time:

PSIM: > 45 minutes **romAI: < 1 second**

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Tools

PSIM

Power Electronics

- Fast and accurate power converter simulation
- Controller design through frequency response
- Thermal simulations capturing conduction and switching losses

HyperStudy

Design of Experiments

- Solver agnostic tool for DOEs, fit models and optimization
- Leverage multiple CPU cores
- Perform sensitivity analysis

Compose

Scripting Environment

- Math and systems modeling solution
- Engineering toolbox for efficient computations
- Multi-language workflow automation

Twin Activate

Block Diagram Modeling

- Multi-domain co-simulation support
- Physics or data driven approaches
- Digital Twin, system of systems simulations

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DEMO

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EXTENDED APPLICATIONS

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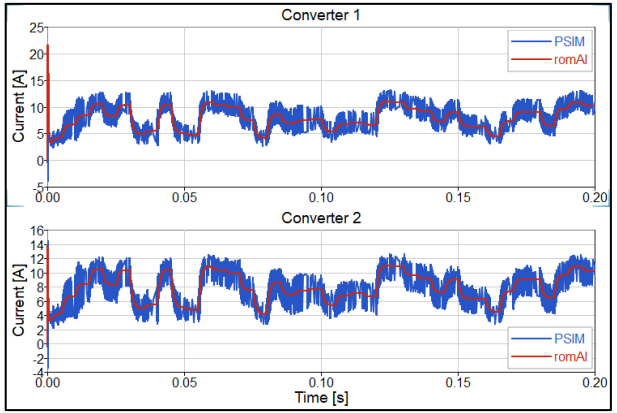
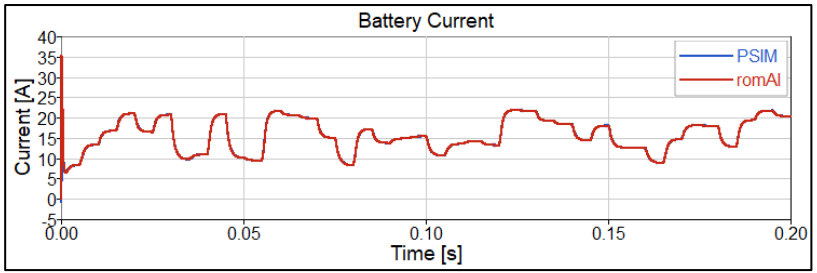
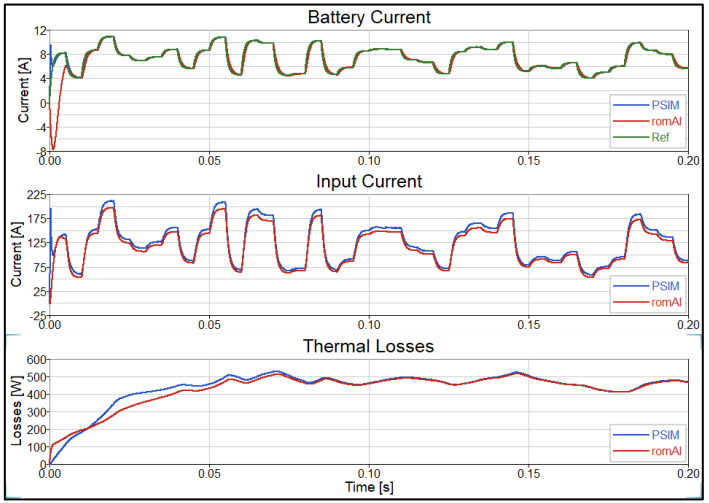
Extended Applications

- Battery charging with parallel converters





- Input current & thermal losses prediction



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Altair romAI

Machine Learning + Dynamics Systems Theory

Dataset

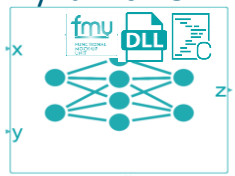
	A	B	C	D	E	F	G	H	I
1	time	Xref_mm	Yref_mm	X_mm	Y_mm	X_dot	Y_dot	TX_deg	TY_deg
2	0	0	0	0.1478	2.29719	0.002035	-5.00691	-0.13154	-0.75129
3	0.005	0	0	0.14781	2.272156	0.001635	-4.02188	-0.1229	-0.64688
4	0.01	0	0	0.147817	2.256972	0.000992	-2.43939	-0.11618	-0.66437
5	0.015	0	0	0.14782	2.247762	0.000601	-1.47957	-0.11099	-0.7383
6	0.02	0	0	0.147823	2.242176	0.000365	-0.8974	-0.107	-0.83284
7	0.025	0	0	0.147824	2.238788	0.000221	-0.5443	-0.10394	-0.92927
8	0.03	0	0	0.147825	2.236733	0.000134	-3.46057	-0.10162	-1.01857
9	0.035	0	0	0.147825	2.204182	6.809494	-9.0794	-0.09988	-0.74168
10	0.04	0	0	0.21592	2.145939	18.91092	-2.3765	-0.98042	-0.34267

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

$\theta(x, u)$- parameters

f(), g() - state space functions

Dynamic ROM



Black-box

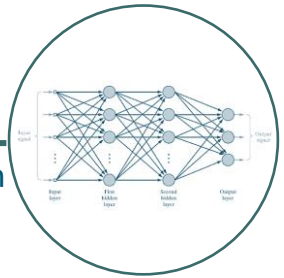
User

Dynamic System Theory

$u(t)$ - input vector
$y(t)$ - output vector
$x(t)$ - state vector

Artificial Intelligence

Layers
Neurons
Epochs



Multi-Layer Perceptron
Neural-Network

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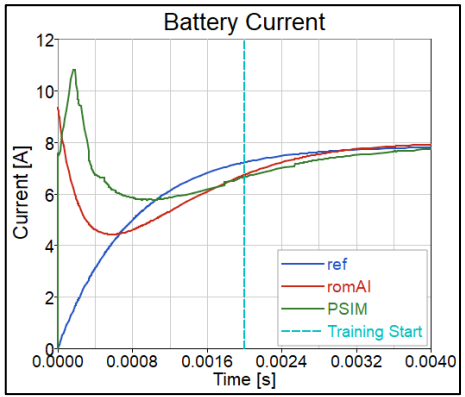
Extended Applications

Good Practices

Data

- Prioritize dynamics of interest.
- Reduce timeframe to accelerate training.

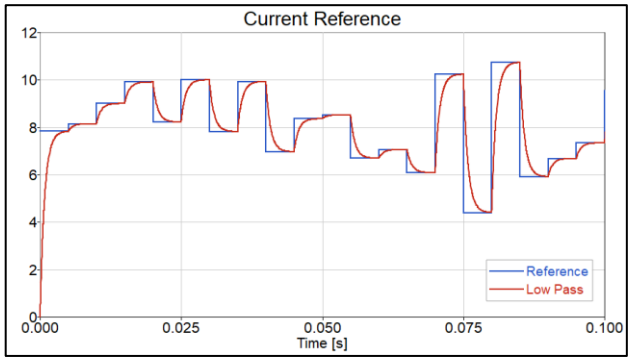


Neural network structure

- Small models:
  - Layers: 2 - 4
  - Neurons: 20 - 40
- Don’t overtrain & save model snapshots.
- These rules are not fixed!

Simplify the task!

- Filter training data
- Validation dataset
- Make it easy for romAI.



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Extended Applications

Lessons Learned & Next Steps

Current takeaways:

- Open & closed loop systems feasible
- States: Switching frequency or output itself
- Other abrupt input changes allowed

Next efforts:

- PFC as sources for resonant converters
- System simulations with several converters
- Modeling other power supplies

Unanswered questions:

- How to model
- What's going on with starting transient
- Dataset size
- Time step size

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Resources

- Altair Community power electronics romAI articles:
  - Accelerating Battery Charging Simulations with Altair romAI: Part 1 & Part 2
  - Training a neural network with PSIM data using romAI
  - Creating Datasets from Results Files for Altair romAI
  - romAI - Tips & Tricks for Beginners
- Self-paced introductory eLearnings:
  - romAI
  - Twin Activate
  - HyperStudy
  - Compose

THANK YOU

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#ONLYFORWARD

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