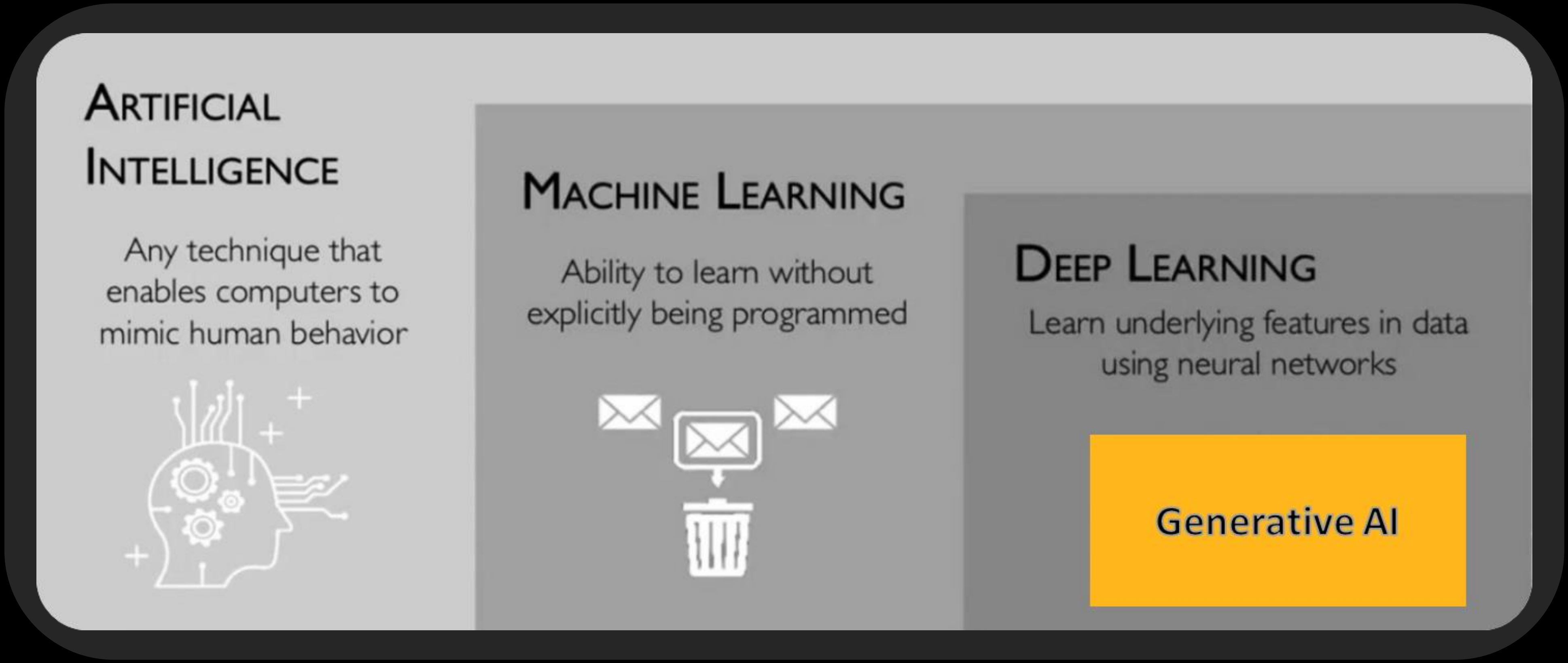
Powering Innovation That Drives Human Advancement

Leveraging AI/ML with Physics to Accelerate Engineering Workflows

Anchal Jatale

Application Engineering Manager: Energy, Chemical & Process

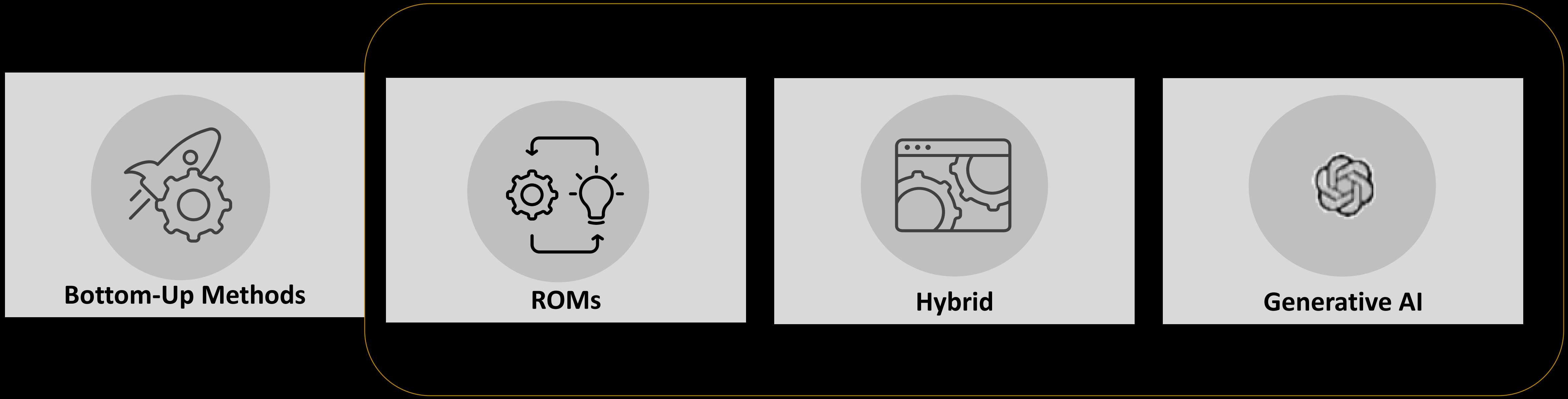
What does AI/ML mean to you?



Pervasive insights enabled by AI/ML is revolutionizing engineering

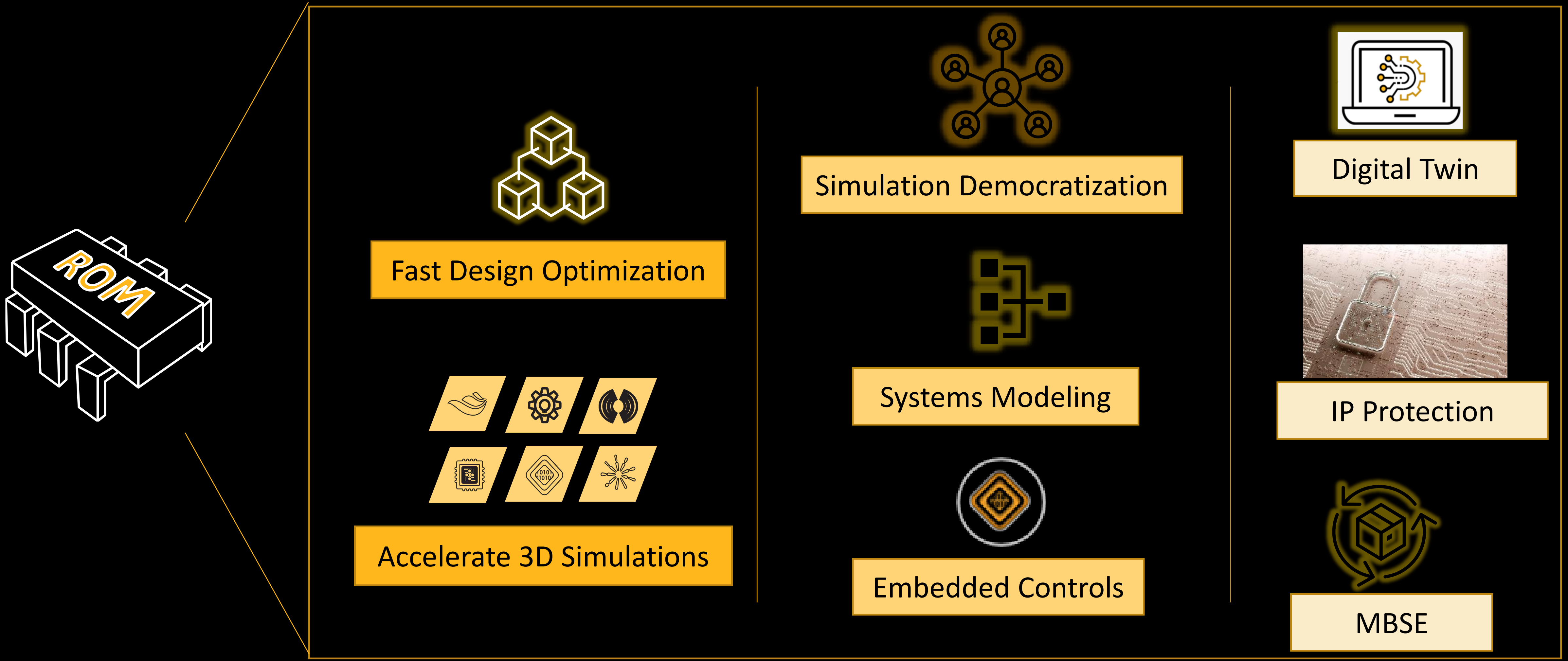
Improve productivity	• Learn more from smaller number of tests and computations.
Generate actionable insights	• No compromises in the quality of insights generated from smaller number of tests and computations performed. • Make use of insights hidden in your historical data for future designs.
Drive outcomes	• Achieve your engineering goals faster, and with confidence. • Lower physical testing, digital twins, lower maintenance costs etc.

AI/ML solution enhancing physics modeling



ROM Technology is a Key Enabler

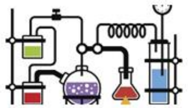
ROMs

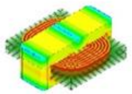


ROM Generation Workflow

ROMs

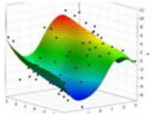
TRAINING DATA GENERATION





~Hours?
Simulations/ Test

ROM GENERATION

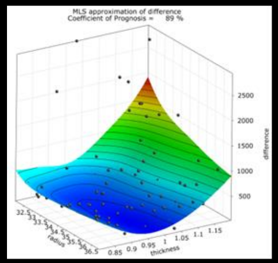


~Mega/Kilo Bytes

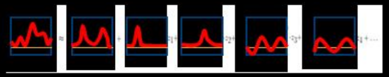
ROM CONSUMPTION

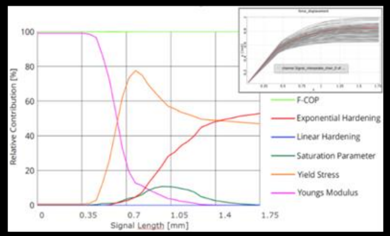
- FMU
- Twin
- Excel

0D ROM
for scalars

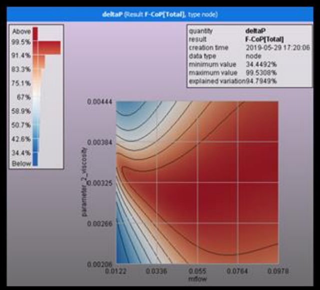


1D ROM
for signals & curves

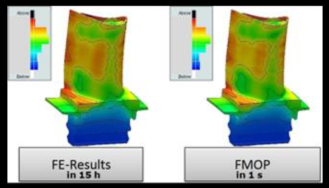




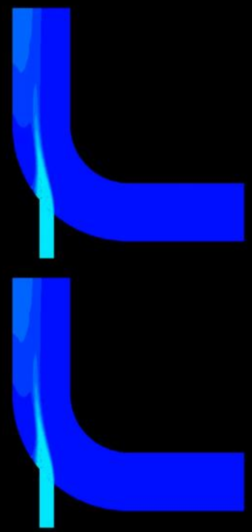
2D ROM
for Wavefronts &
Performance Maps



3D ROM
for Fields



4D ROM
for Transient Fields

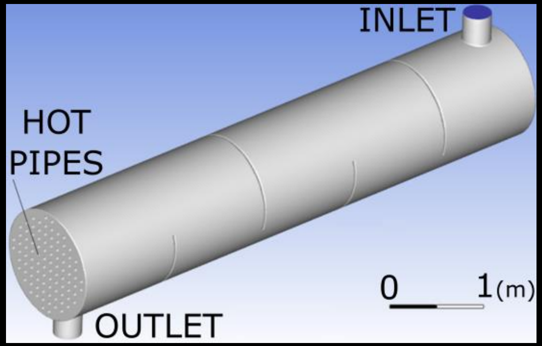


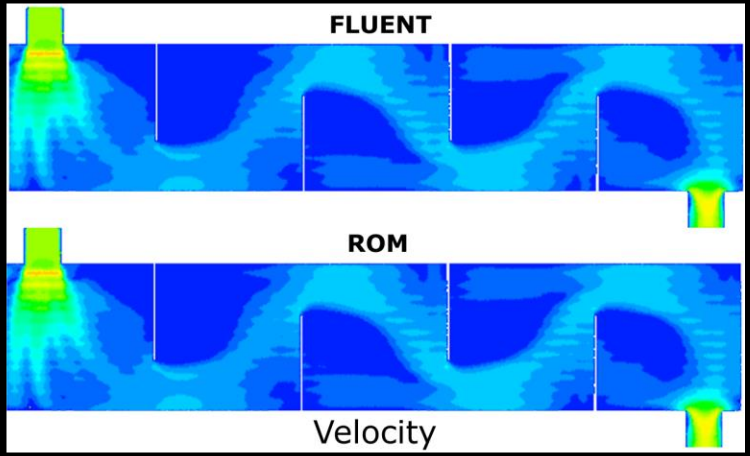
Static ROM – Heat exchanger maintenance

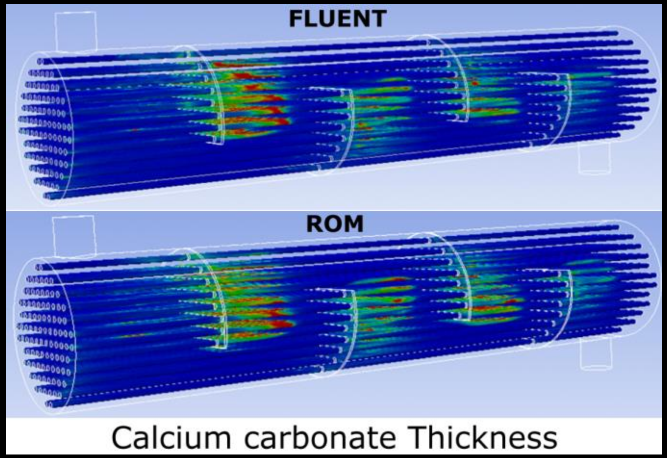
- **User challenge**
  - Predict failure to anticipate maintenance
- **Ansys solution**
  - Steady state Fluent model (~6M cells)
  - Static ROM with 16 design points
  - Calcium carbonate thickness
  - Export/Deploy twin on IoT platform

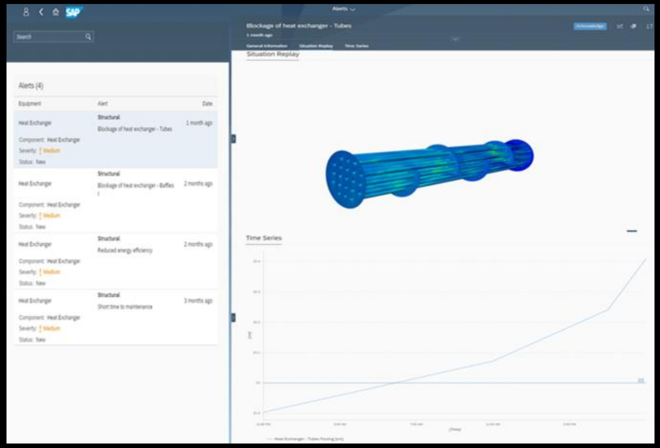
FLUENT 16CPU->5h

ROM 1CPU->5s





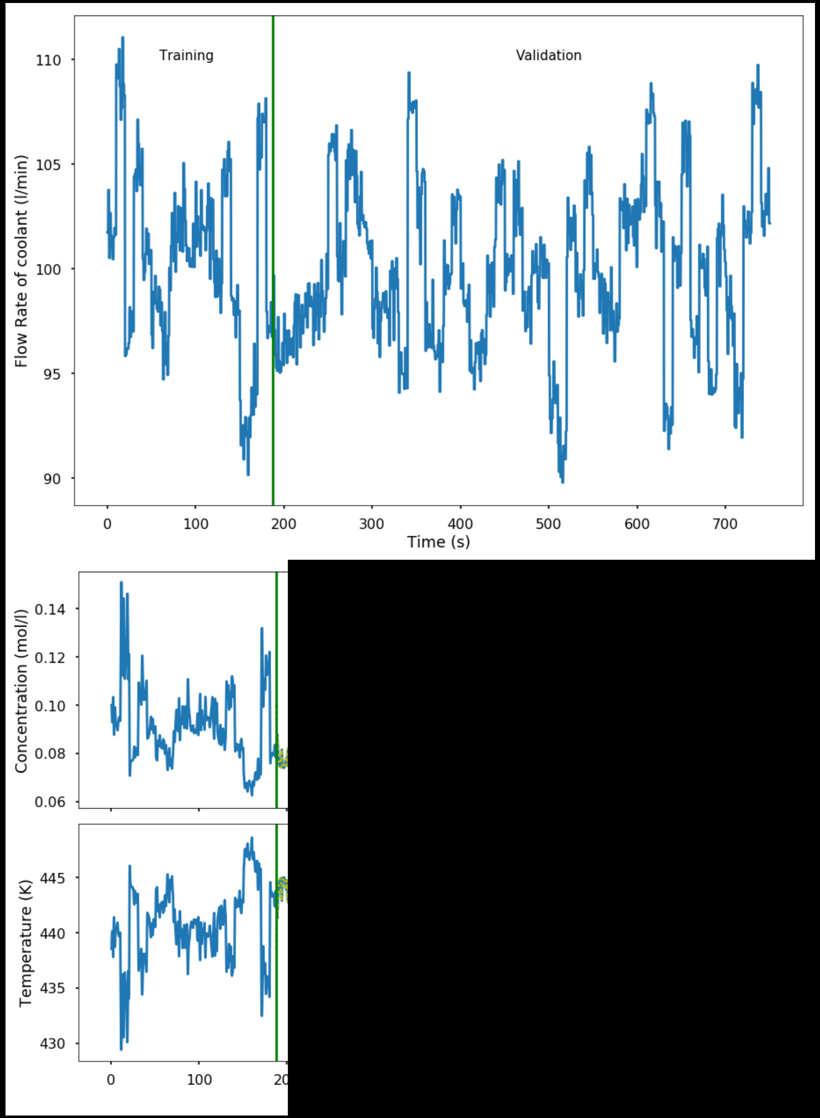




ROMs

ROM for Exothermic Reaction in a Mixed Tank

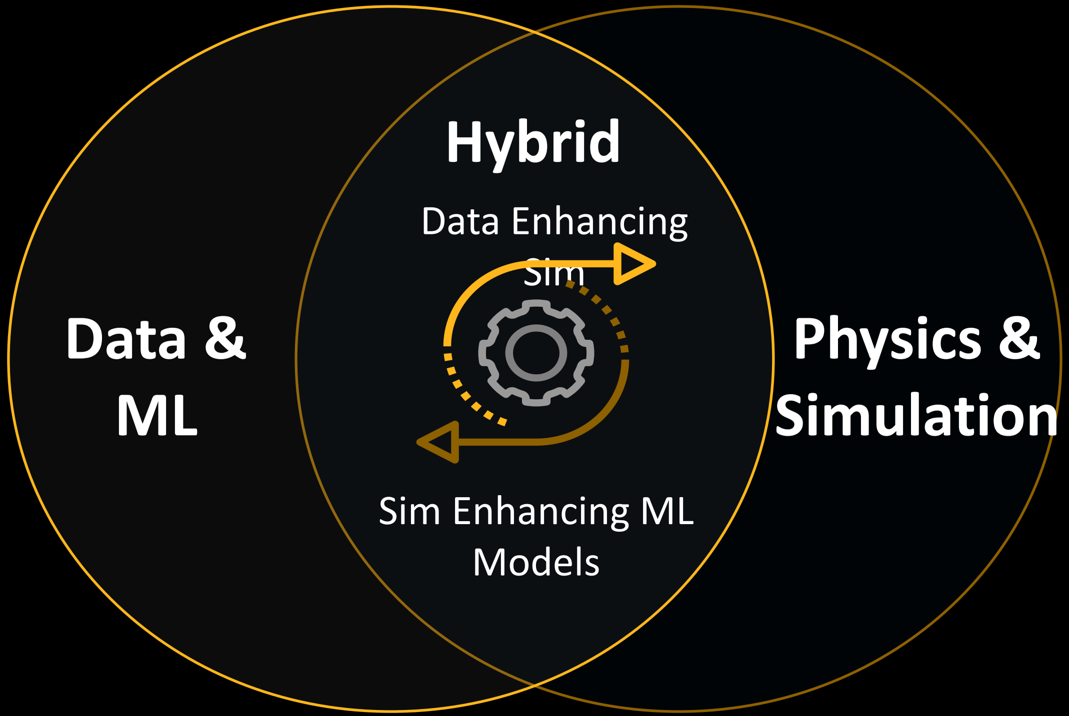
- Exothermic reaction in a reactor
- Temperature and conversion controlled by modifying the flow rate of coolant.
  - Input: Coolant flow rate
  - Output: Conversion and Temperature
- 750s of experimental data available.
  - First 180s of data used for learning
  - Remaining data used for validation.
  - Data captured @ 1Hz

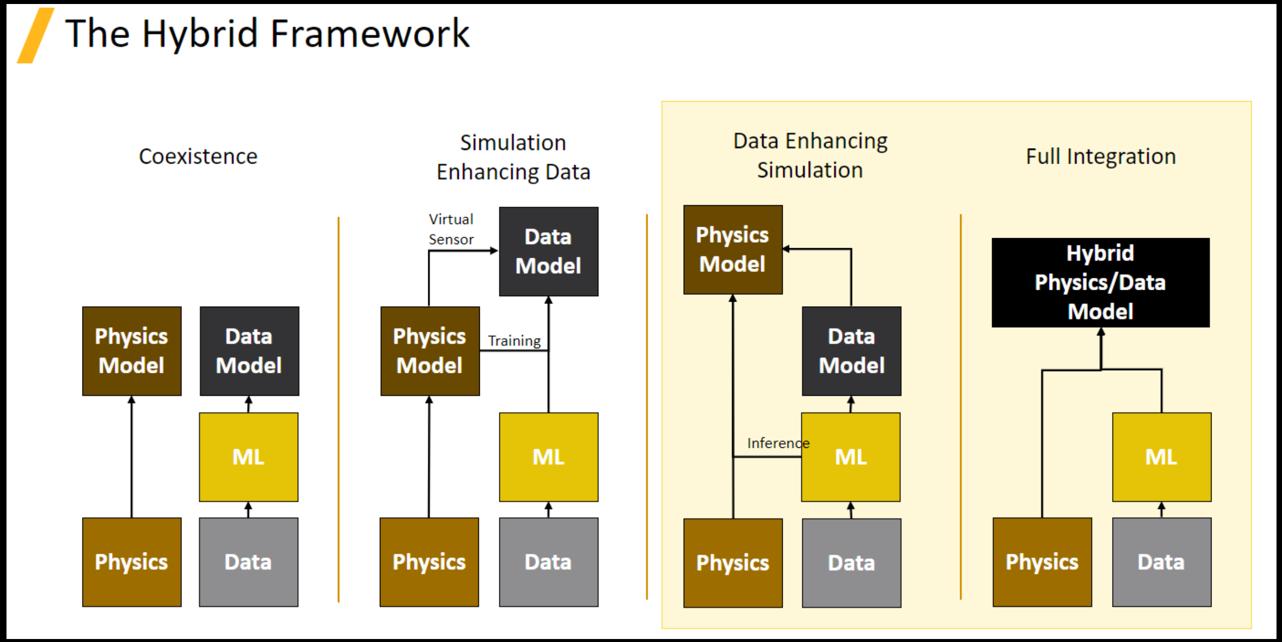


De Moor B.L.R. (ed.), DaISy: Database for the Identification of Systems, Department of Electrical Engineering, ESAT/SISTA, K.U.Leuven, Belgium, URL: http://www.esat.kuleuven.ac.be/sista/daisy/, [Used dataset: Continuous stirred tank reactor, section Process Industry Systems, code number [98-002]]

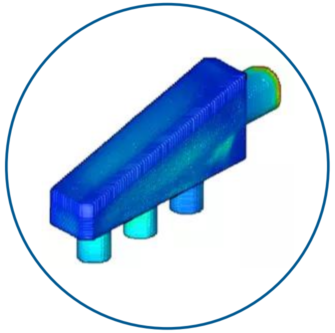
Hybrid Analytics and Fusion Models

Hybrid Analytics is a toolset for combining multiple streams of data using machine learning techniques.





Key Use-cases for Hybrid Analytics



Virtual Sensor

Virtual sensors provide missing information

Fleet Deployments

Use data to match the asset's unique behavior and environment

Brownfield Deployments

Learn missing behavior/information by enhancing a model with data

Greenfield Deployments

Decrease cost by replacing physical sensors with virtual sensors

Inverse Problem

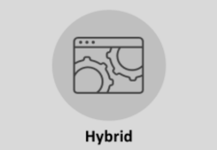
Infer what inputs or operating conditions would lead to the desired behavior

Sparse Data

Quantify uncertainty for any amount of data and return meaningful results

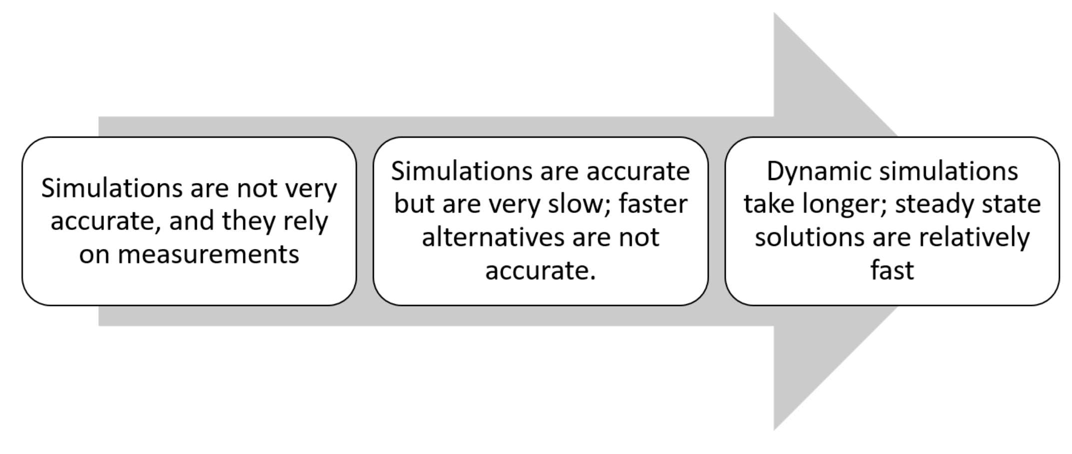
Incomplete Physics Modeling

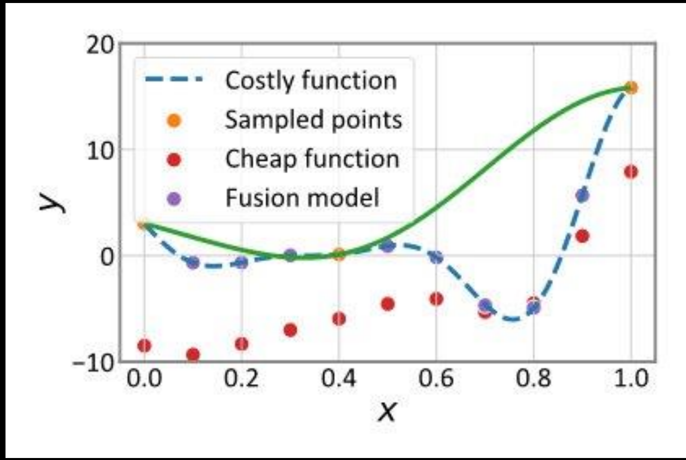
Model the residual between the known/modeled physics behavior and the expected behavior



Fusion Models

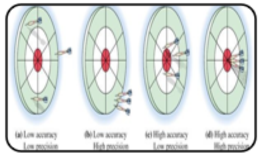
Capture residual physics and improve ROM by fusing two streams of data





Reduce physical testing

- *Low-fidelity: simulation*
- *High-fidelity: testing data*



Predict with limited information

- *Low-fidelity: 0D-1D simulations*
- *High-fidelity: 3D simulations*

Reduce computational costs and time

- *Low-fidelity: Steady state*
- *High-fidelity: Dynamic simulations*

Profit from historical data

- *Integrate data from historical designs*
- *Make them relevant for current designs with simulations*

Erosion on vertical bends

Reduce computational costs and time, Profit from historical data

Hybrid

Challenge

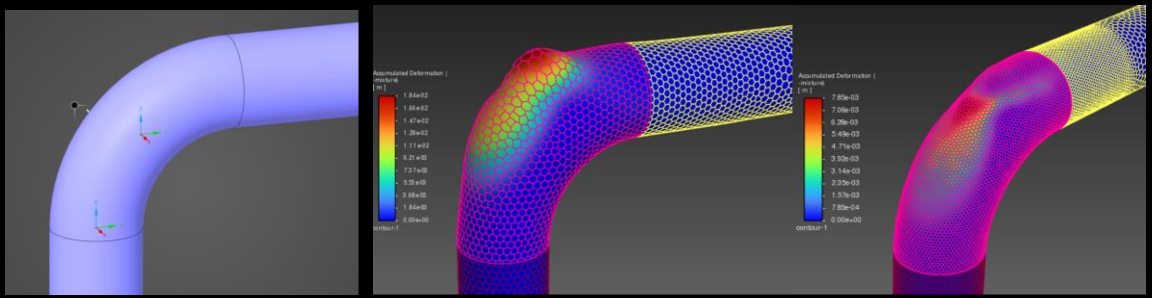
- Robust and reliable equipment design
- Limited information about fluid properties to operating conditions
- Verry slow progressing phenomena
- Testing multiple Erosion models to suit your application

Solution

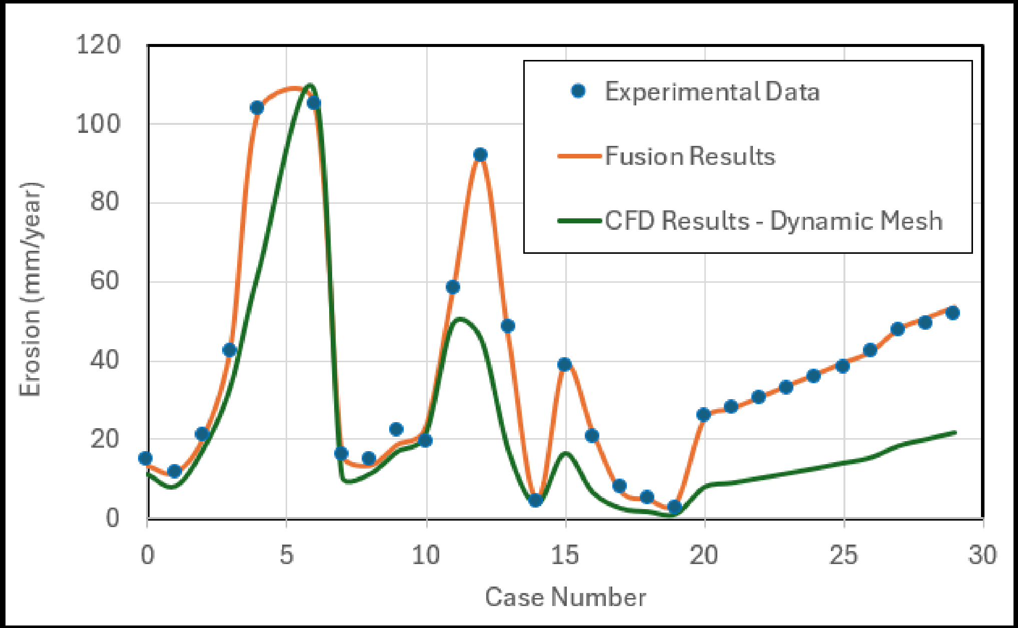
- Perform steady state analysis using any erosion model in Ansys CFD to get a decent solution
- Increase the accuracy of the prediction by fusing with portion of available field data
- Validate with the remaining field data to grow the confidence in the model prediction

Benefits

- Save the engineering time in trial and testing to achieve desired accuracy
- Significant error reduction in comparison to the cheap function
- Accurate fleet deployment : one model to be used for different field assets



Experimental data are from Vieira. et al. (2017) and Parsi et. al. (2015) University of Tulsa – ECRC Laboratory



Training: 22 points
Validation: 7 points

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Ansys

Time-Efficient and Accurate Blend Time Prediction in Mixing Tanks

Hybrid

Challenge

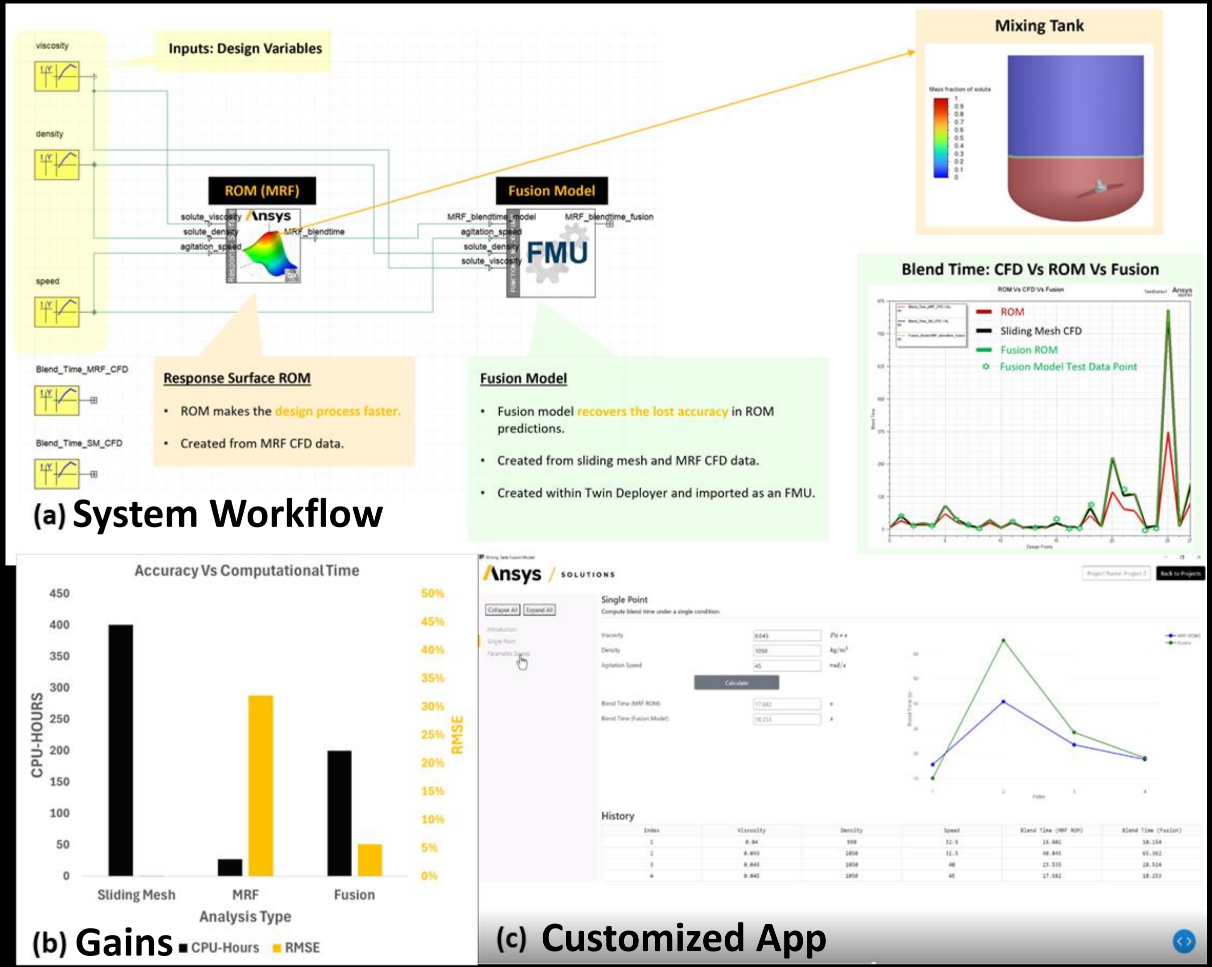
- Need for efficient and accurate blend time prediction in mixing tanks at different agitation speeds and for distinct liquid properties (distinct density and viscosity).
- 3D CFD simulation tools provide approaches that are either computationally efficient or accurate, but not both.

Solution

- Applied **machine learning** approach (Fusion model) to improve the accuracy of the Multiple Reference Frame (MRF) model by **learning** from few accurate Sliding Mesh model data points.
- Created a **Fusion-Reduced Order Model** and integrated the workflow into an interactive **custom App**.

Benefits

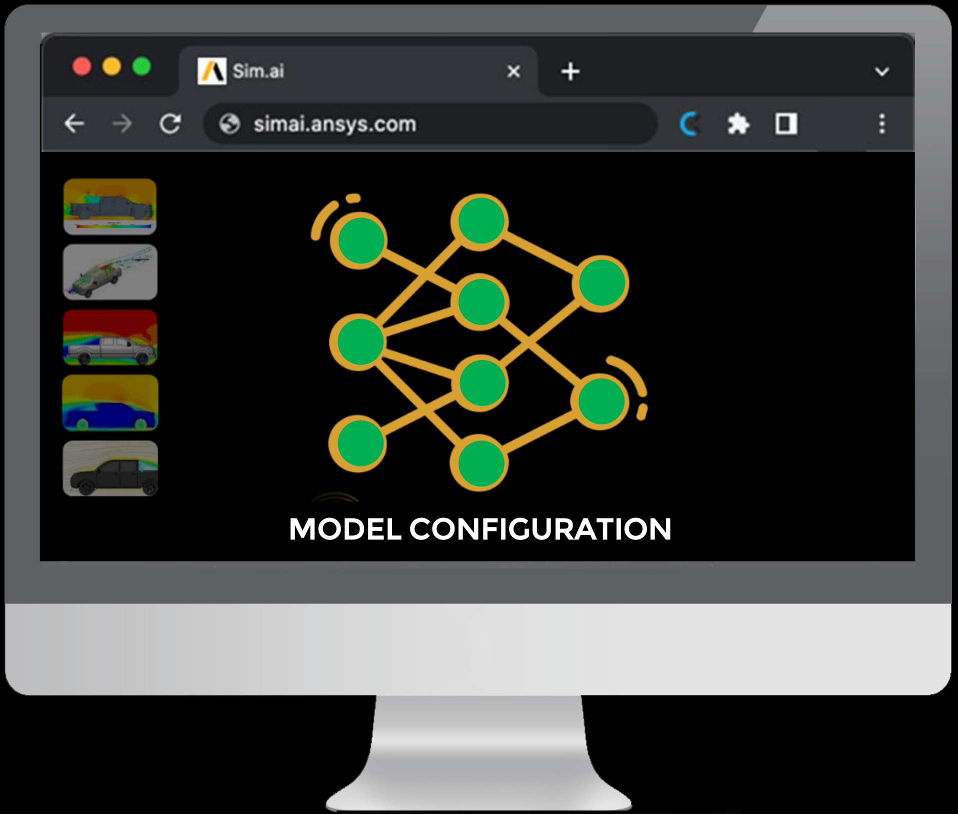
- Error reduction in MRF model predications from **32% to 1.5%-5.7**%.
- Reduction of CPU hours required to construct the design space by **~50%** versus the purely sliding mesh approach.
- Building an interactive easy-to-use custom App for **non-expert users** for quick and accurate blend time predication.

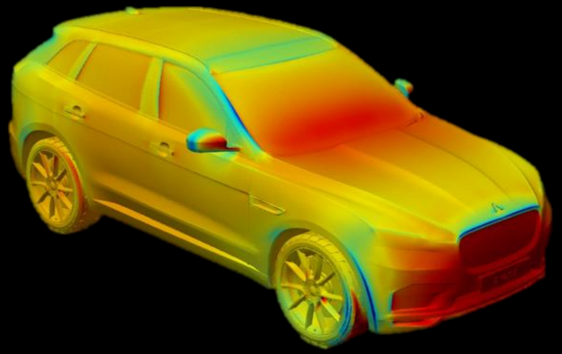


Predict at the Speed of AI

Generative AI

New Design





Performance Prediction

Fast. Reliable. Accessible.

1- UPLOAD *Your Past Data*

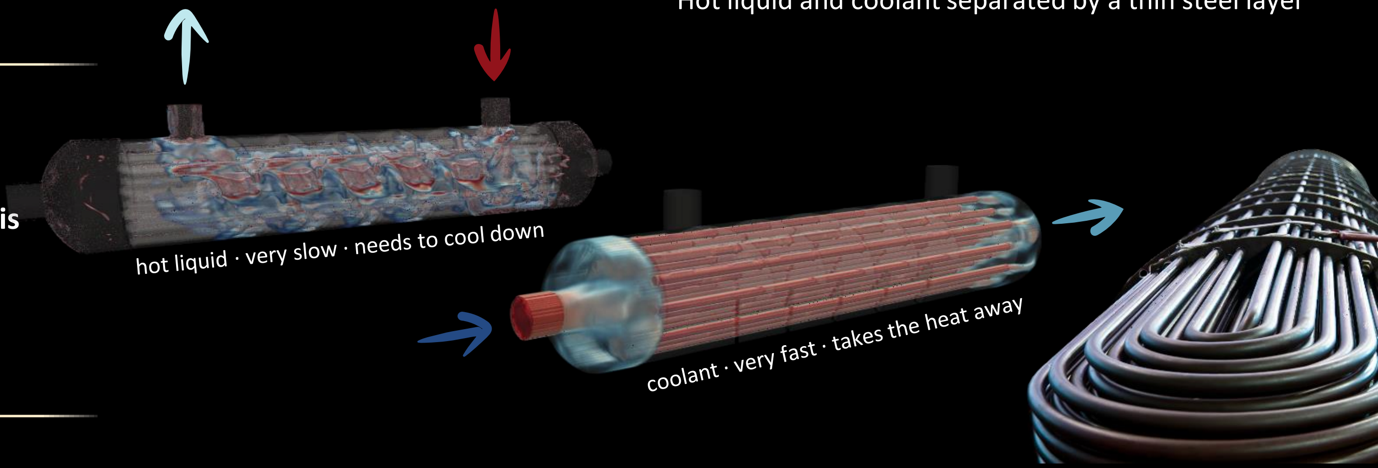
2- TRAIN *Your AI Model*

3- PREDICT *In Seconds*

Shell and Tube Heat Exchanger

A Complex System with Hundreds of Pipes and Baffles

Hot liquid and coolant separated by a thin steel layer

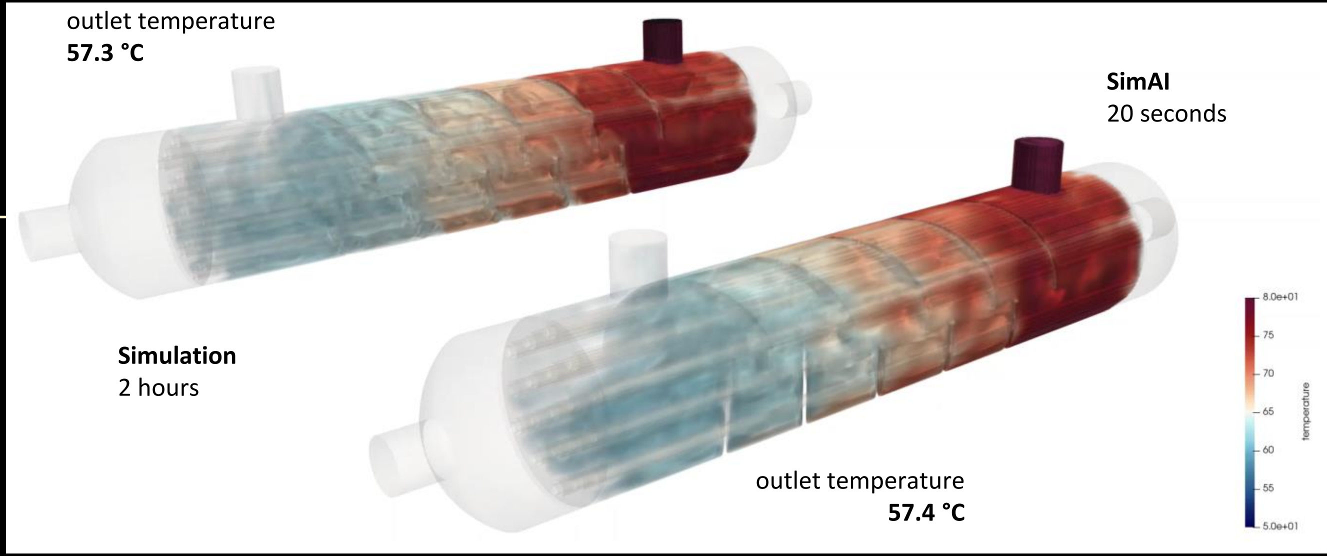


Challenge

- Design an **efficient yet economical heat exchanger**.
- Compare multiple designs and make situational trade-offs, **making sure your design is optimal**.

Solution

- 250 conjugate heat transfer (CHT) simulation results are used to create an AI model of the shell and tube heat exchanger, with topology changes in terms of the number of tubes, baffles, their orientation, relative positioning and inlet coolant velocity.
- **SimAI prediction on a new heat exchanger geometry in less than 1 min**.
- **SimAI outlet temperature error compared to the CHT simulation is less than 0.2% for the unseen design.**



Benefits

- **Reduce** computational time **by 99%.**
- **Evaluate 3,600 designs in the same time** it takes to run a standard simulation and focus on multi-objective optimization instead.

Solid Suspension in Stirred Tanks

Challenge

- Distribution of the solid phase (a product, a reactant or a catalyst) affects mixing scales and availability of solids to chemical reactions, and therefore overall performance of the tank.
- **Cloud height**, defined as the location of the clear liquid interface, is a critical measure of process performance.
- Need to evaluate range of configuration and operating scenarios.

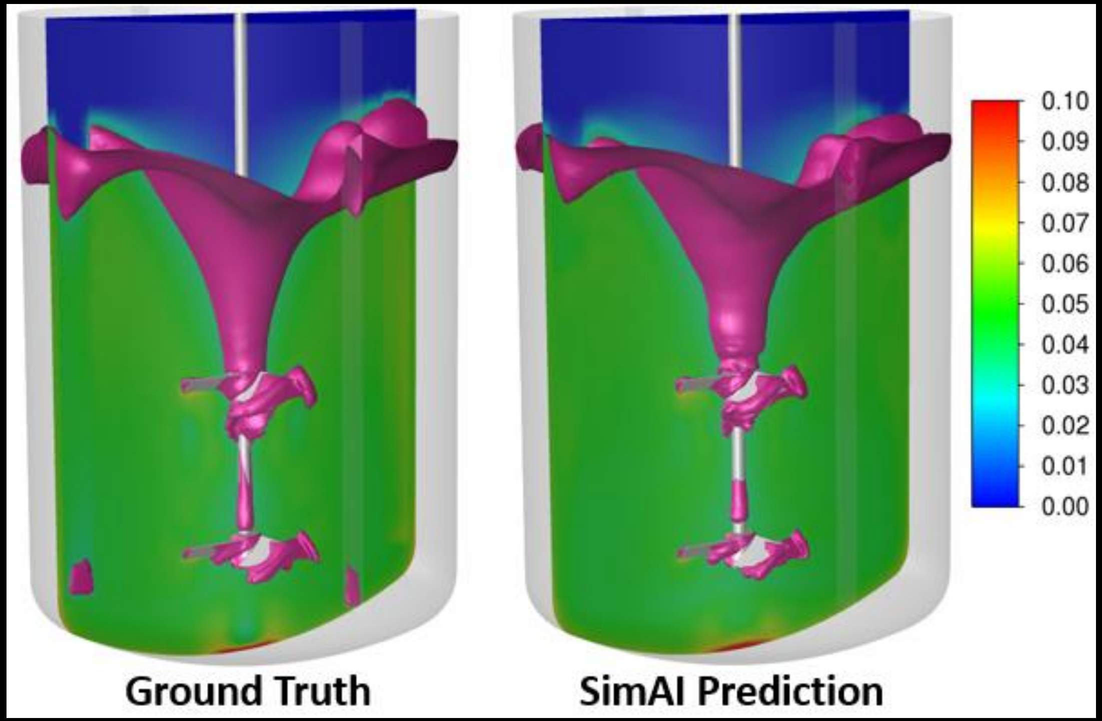
Solution

- ~ 28 accurate **Liquid-Solid Multiphase** CFD simulation results are used to create the AI model of Stirred Tanks, with **topology changes** in terms of number of impellers. Agitation Rate and % Solid Loading variations are also captured.
- **AI Prediction on Solid Volume Fraction Field in 30s.**
- AI **Cloud Height** error compared to CFD: **~2%** and accurate 3D Volume Fraction field predictions.

Benefits

- Faster design space exploration and optimization for variation in Stirred Tank component configuration and operating parameters of Agitation Rate and % Solid Loading.
- Use historical data to build an accurate AI model that understands change in Impeller type and its effect on Cloud Height.

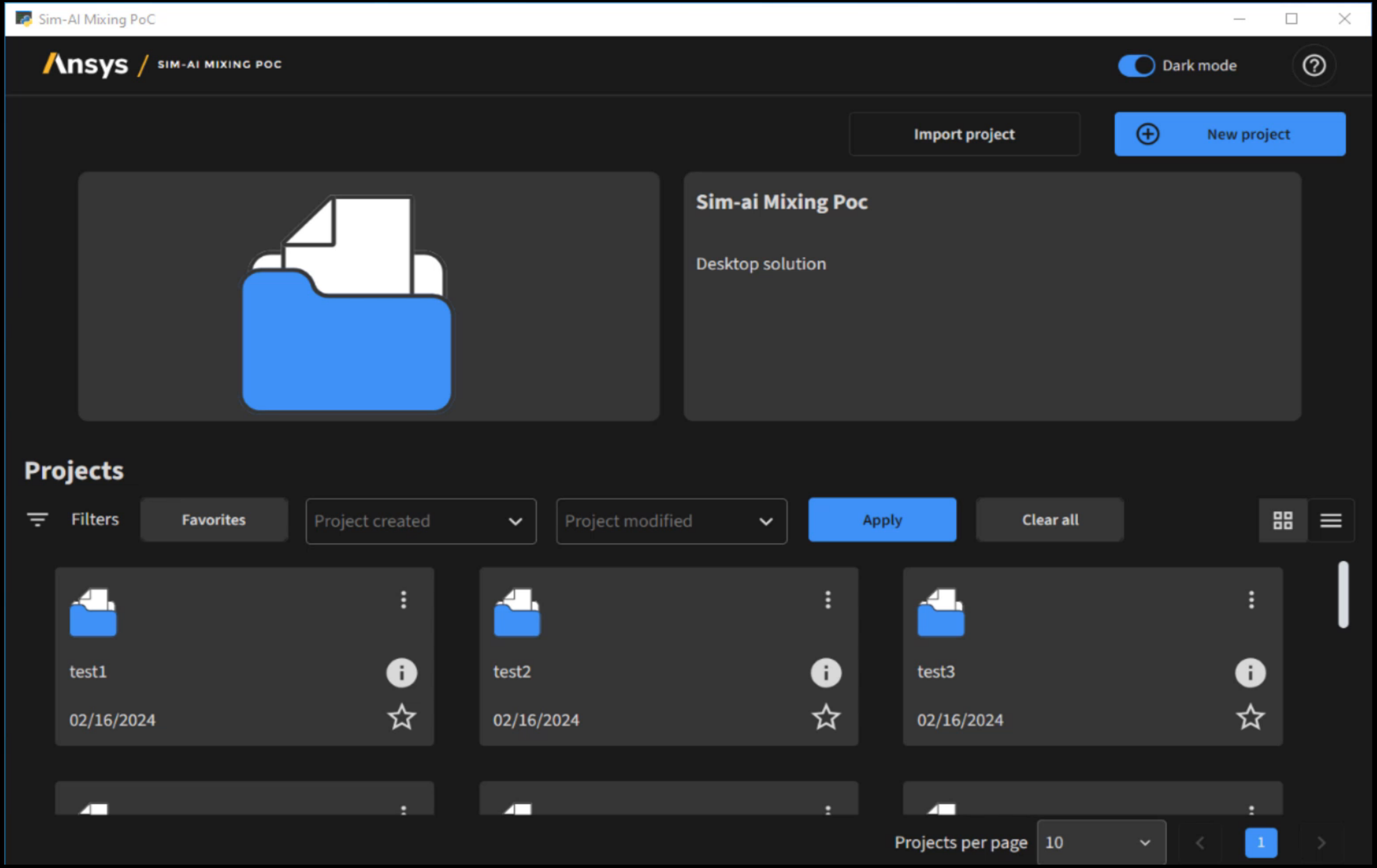
Solid Phase Volume Fraction on Unseen Design



Fluent : 12h on 64 of cores **SimAI : ~30s**

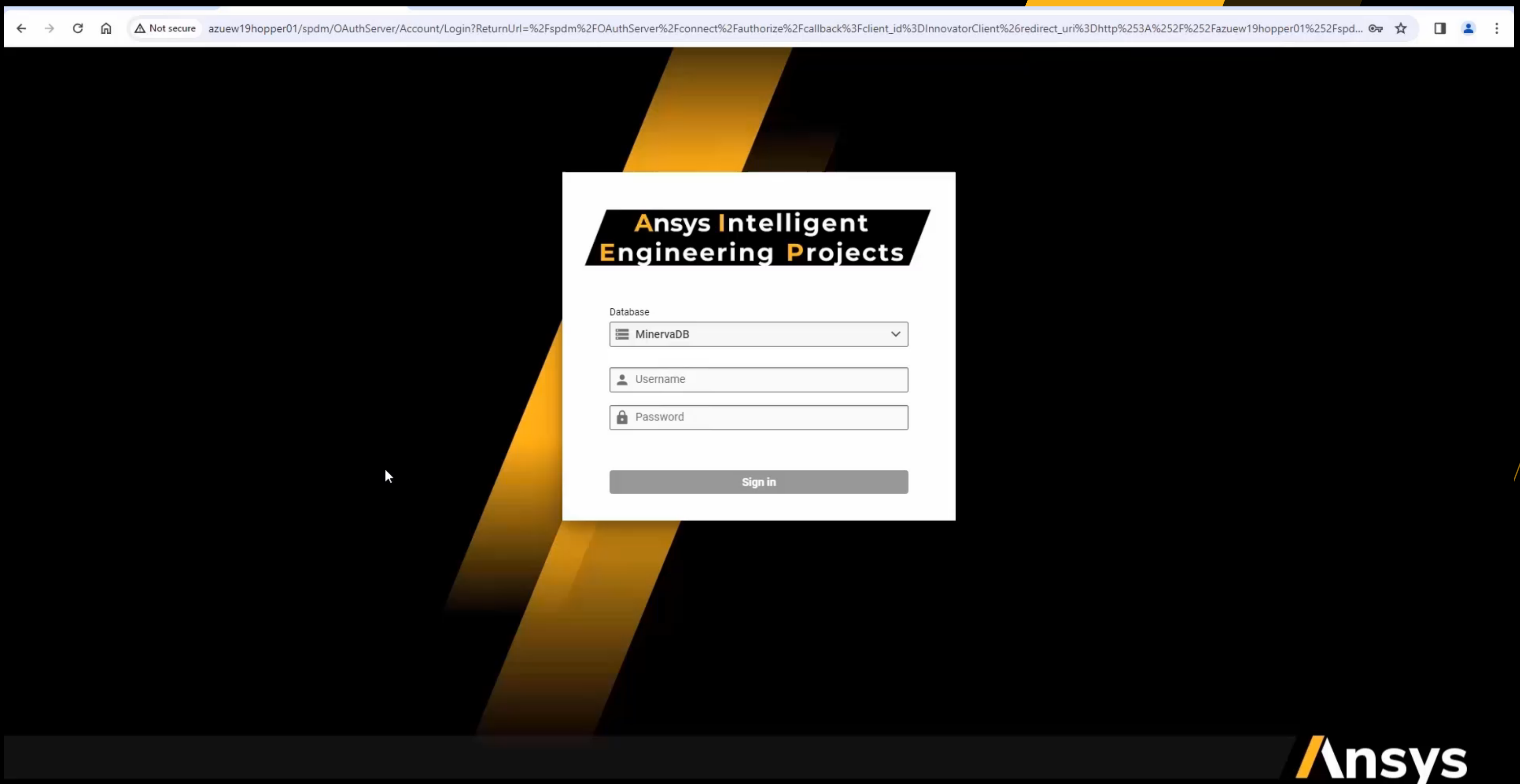
Automation : AI Enabled Mixing App

- App utilizes AI model created by 30 steady state 3D simulations of variety of different mixing tanks



How Everything Comes Together …..

Leveraging Ansys Intelligence design Workflow



Challenge

- Automate the design and verification of Differential Vias
- Enabled for non-expert users
- Reduce development process time by 50%

Solution

- Automated model extraction, analysis and real-time visualization
- Large-scale optimization accounting for all parameters and combinations
- Customized platform to meet independent needs

Results

- 75% reduction in development process time
- $MM in sales from real-time quoting

Ansys