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The Executable Digital Twin: A Digital Thread Approach to Boosting Machine Productivity

Colm Gavin
Portfolio Development Manager
Siemens Digital Industry Software

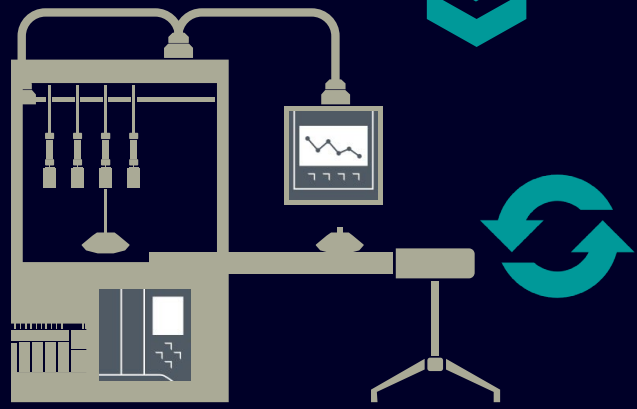
Tyler Newcombe
Portfolio Development Lead – Consumer Products & Retail
Siemens Digital Industry Software

Consumer Packaged Goods is Evolving
Challenges & Opportunities

3. Product diversity & customization

- **Input material in batches**
- **Different provision sources**
- **Environmental conditions**
- **Variable storage timing**

1. Uncontrollable variations in input material properties



Off-target product

2. Slow feedback loop due to many human interactions

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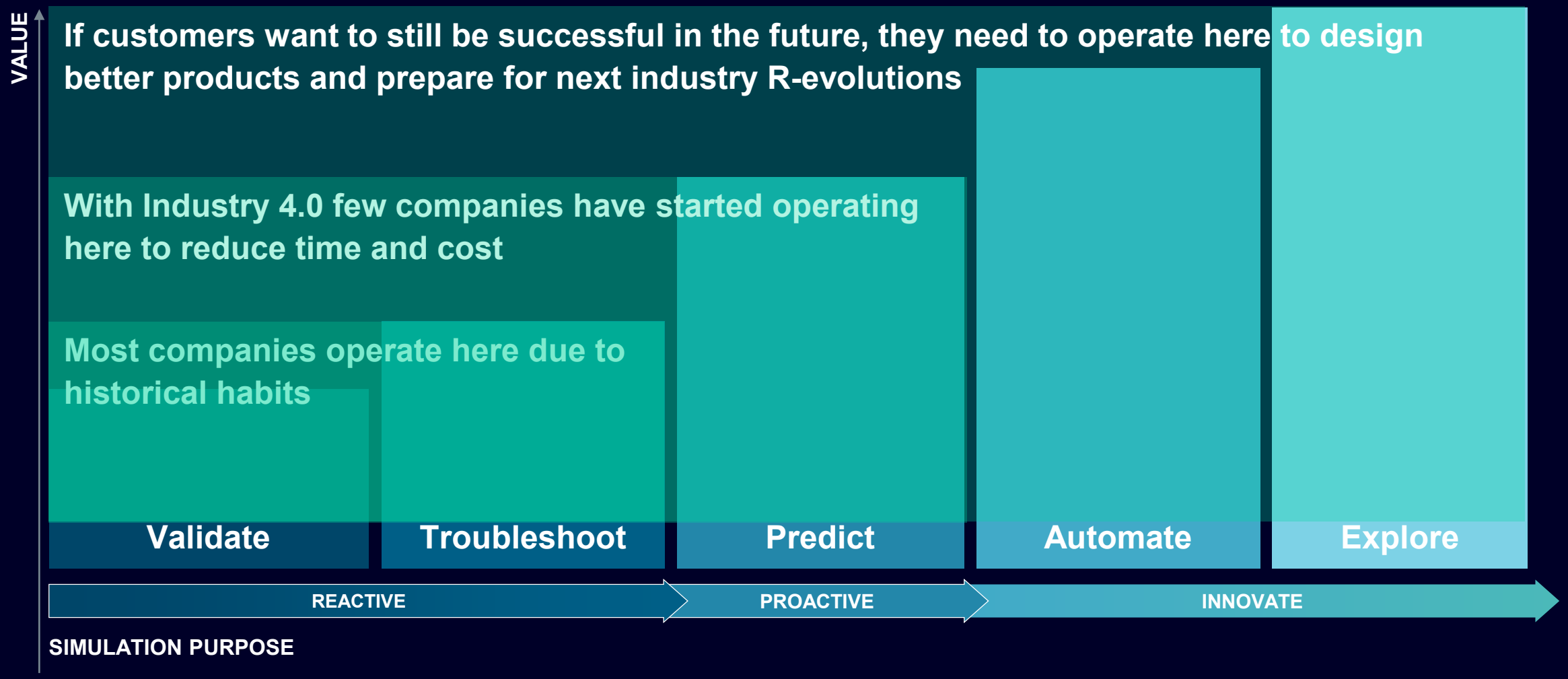
Consumer Packaged Goods is Evolving
Challenges & Opportunities



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Consumer Packaged Goods

Industry Solutions

Integrated Lifecycle Management

Smart Product & Process Design

Enterprise Recipe Management

Smart Manufacturing

Production Design & Optimization

Flexible Manufacturing

Traceability & Lifecycle Intelligence

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Digital Enterprise

Combining the real and the digital worlds with the comprehensive Digital Twin

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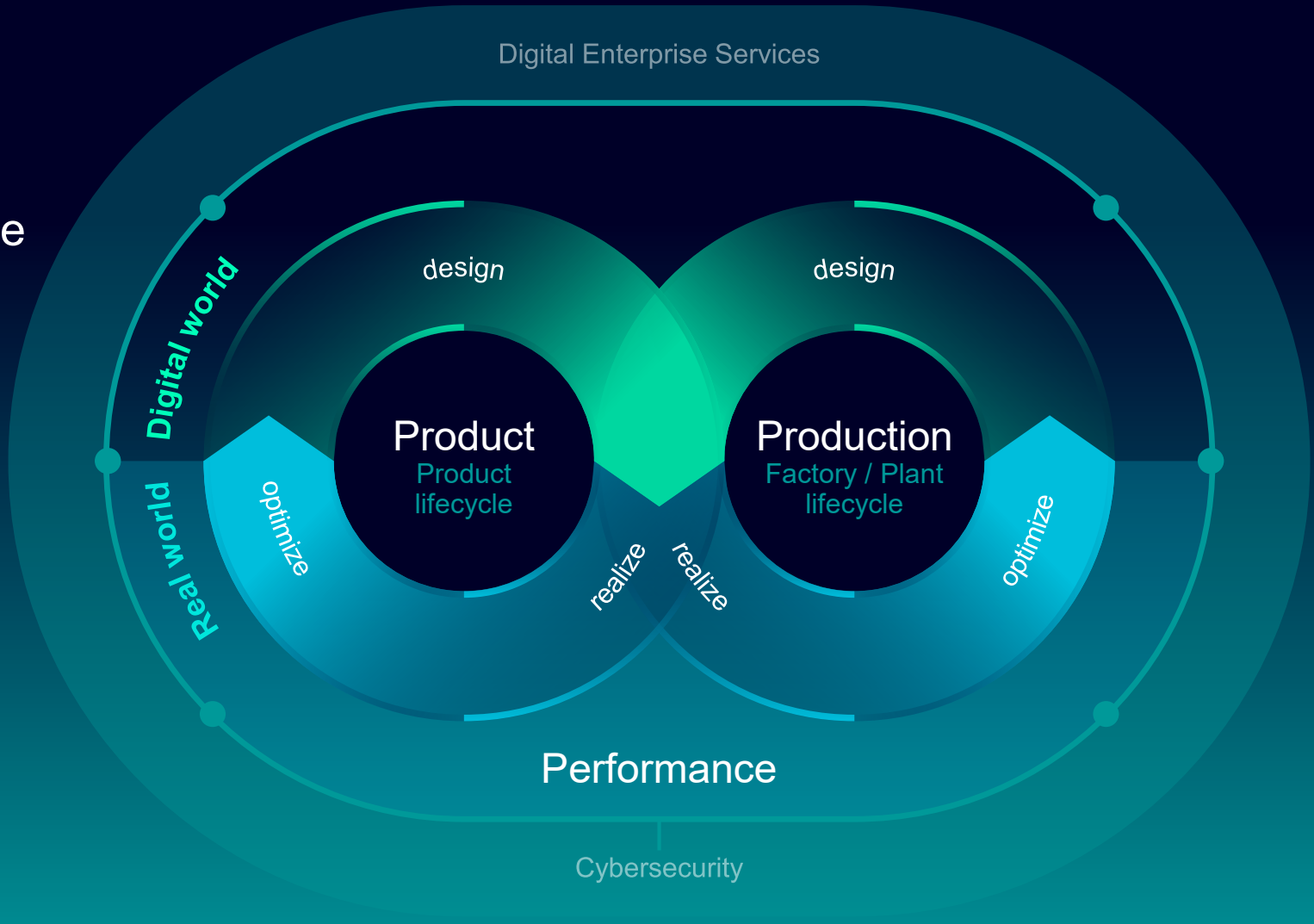
Digital Enterprise

Combining the real and the digital worlds with the comprehensive Digital Twin



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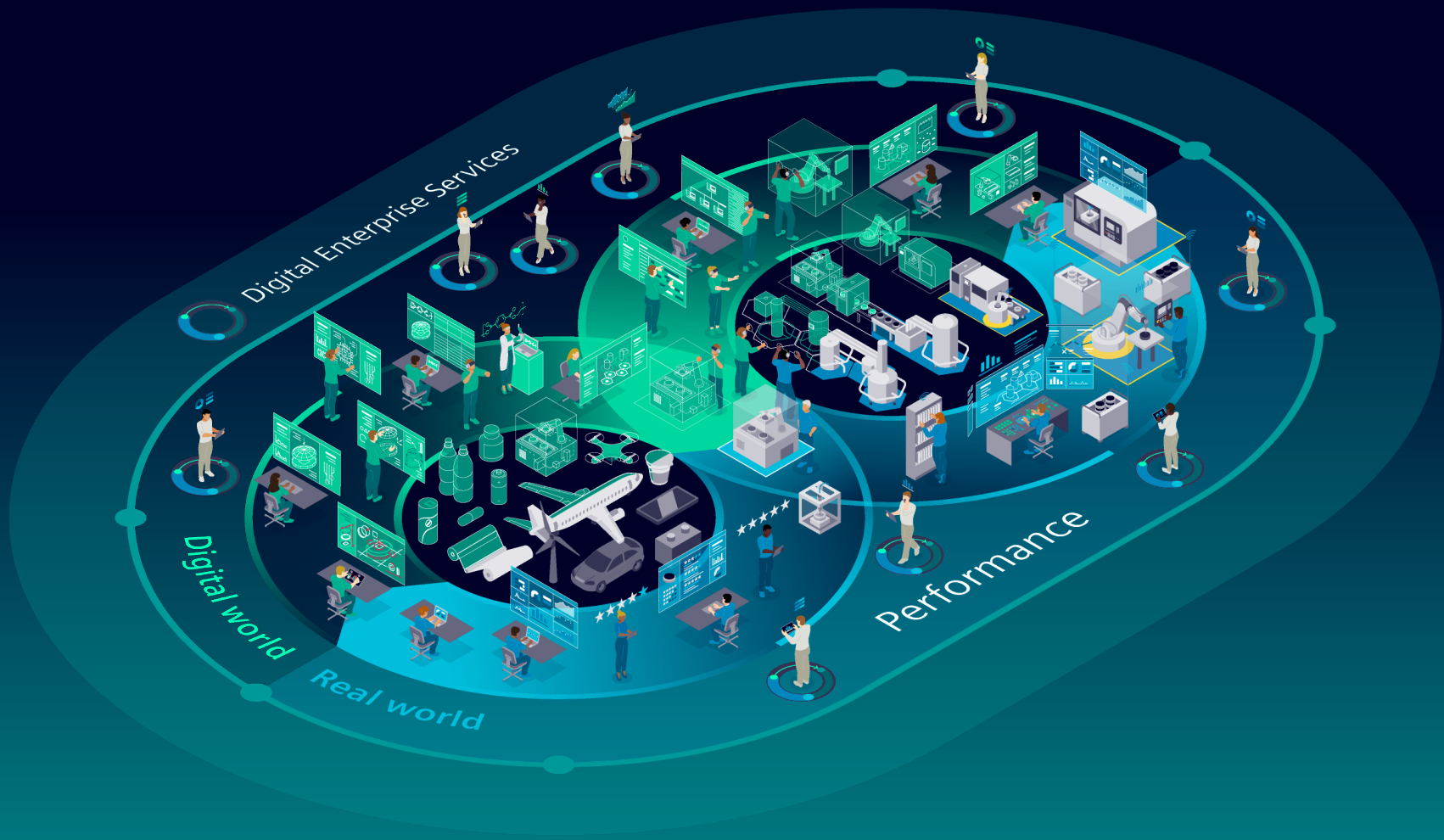
Digital Enterprise
Next level flexibility with digital threads



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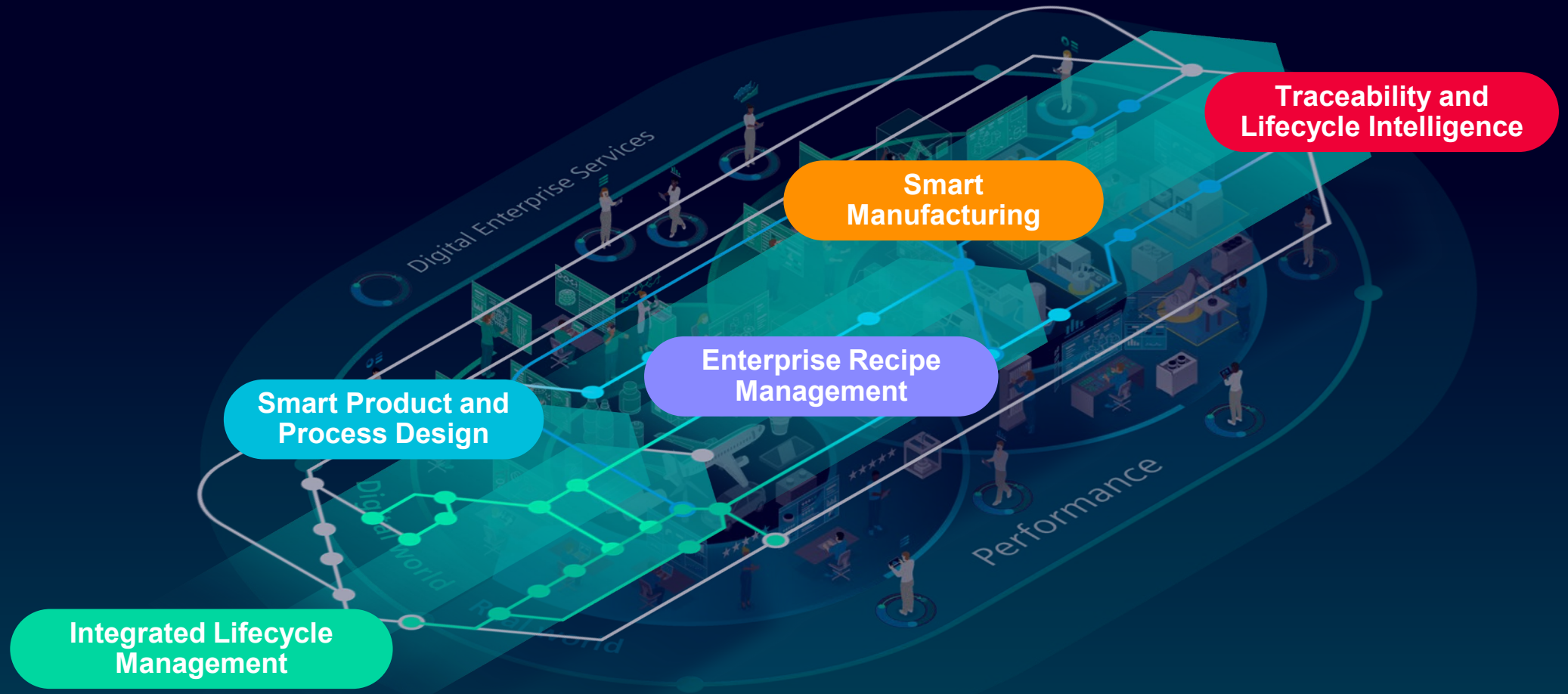
Next level flexibility with digital threads



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Siemens Solution
From Digital Twins …

Precise virtual representation of a physical product or process

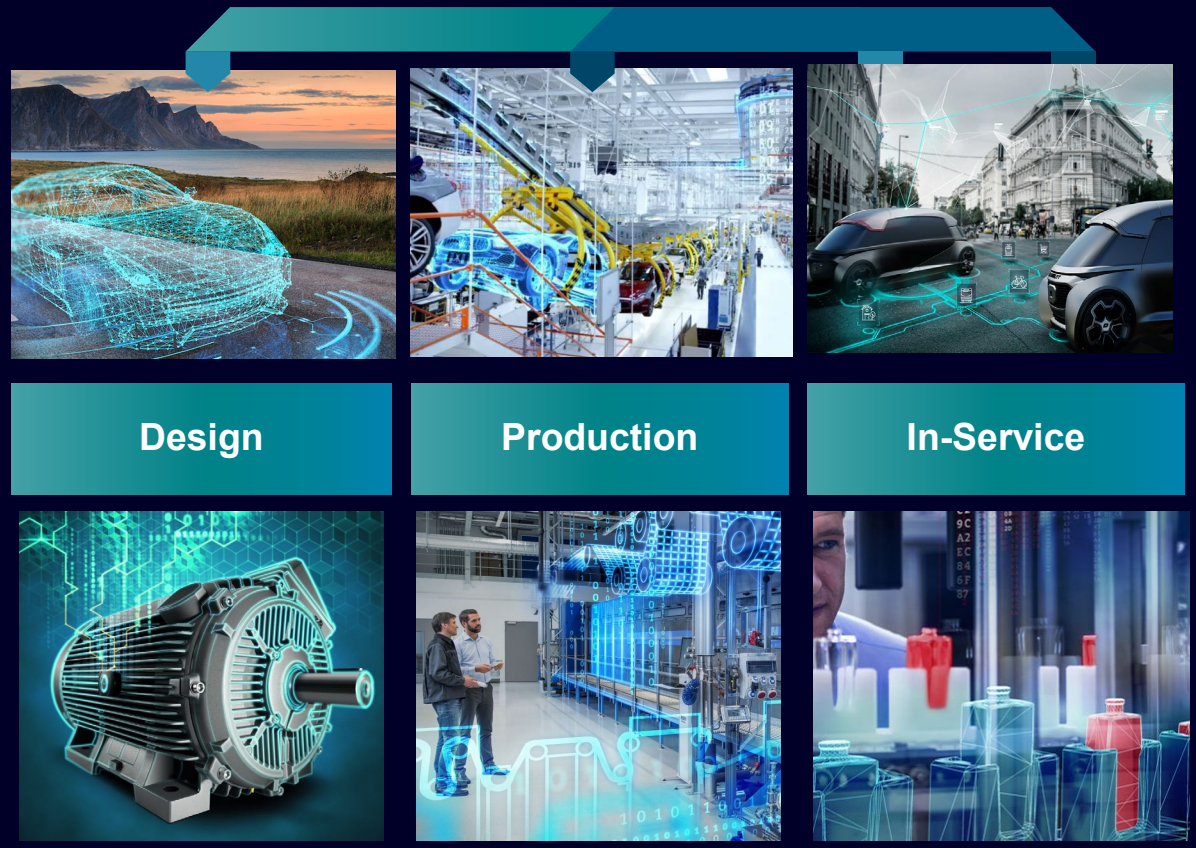
Used across its lifecycle to simulate, predict and optimize the product and production system

Made up of multiple representations or models for different aspects of physical behavior

An evolving object with a lifecycle that needs to be managed

Closed-loop digital twin provides for bi-directional connectivity between the physical asset and the virtual representation

feed back insights to continuously optimize product and production



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Siemens Solution
… to Executable Digital Twins (xDT)

For smarter products, systems, processes

Digital
xDT
Real

Self-contained executable digital behavior of an asset

Leveraged by anyone at any point in lifecycle

- **Developed & released by experts**
- **Real time enabled**
- **Self-adapting/calibrating**
- **No additional solvers required**
- **Deployed from edge to cloud**
- **Leveraging virtual sensors**

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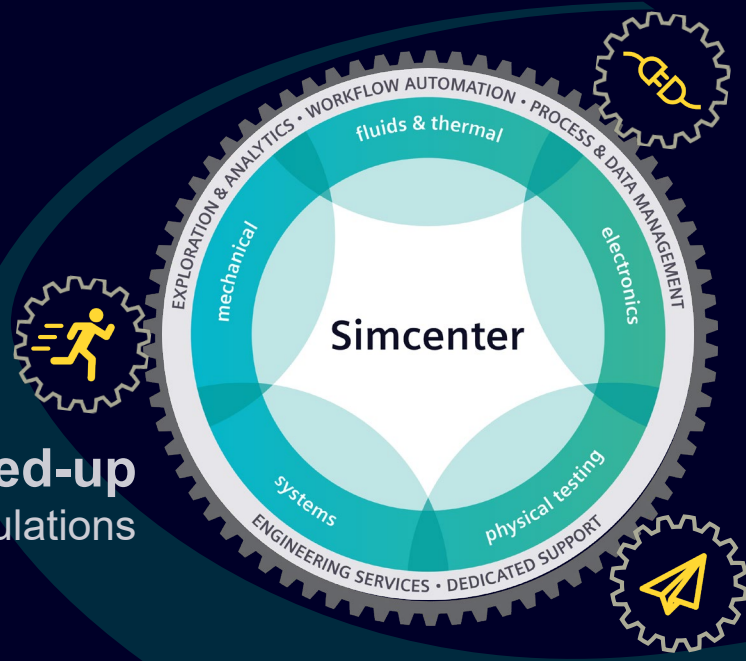
Key Enabler for Executable Digital Twin - Simcenter ROM Builder



Speed-up simulations

Combine physical testing and simulation

ROM

Reduced
Order
Modeling

Deploy models internally or externally

- A digital twin catalyzer
- An enabler for xDT*
- A tool-agnostic solution

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(*) eXecutable Digital Twin

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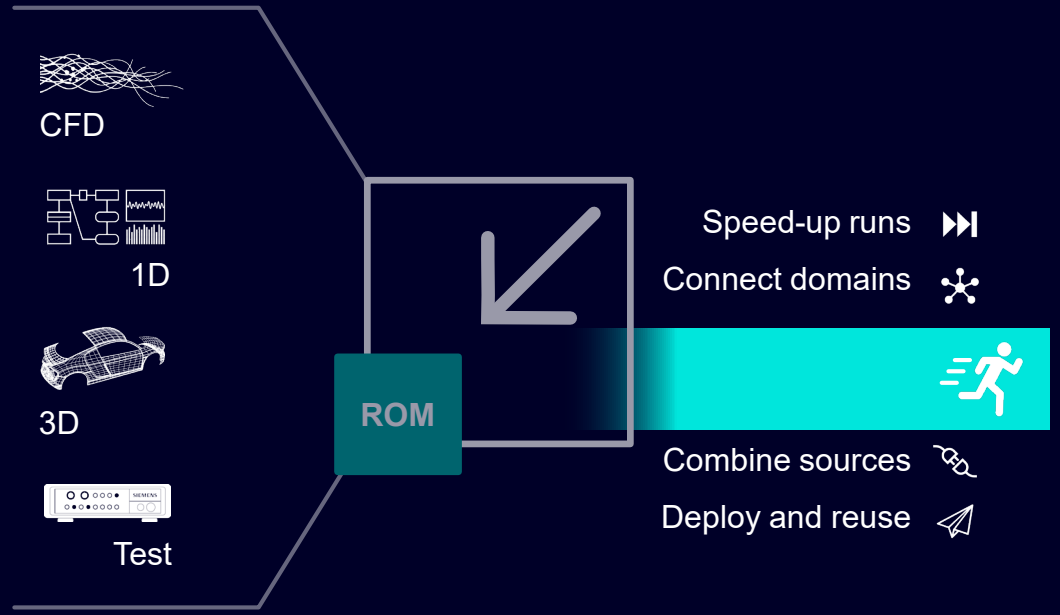
For simulation users, the Simcenter ROM Builder creates simplified, tool-neutral, re-usable models by processing simulation and field data.



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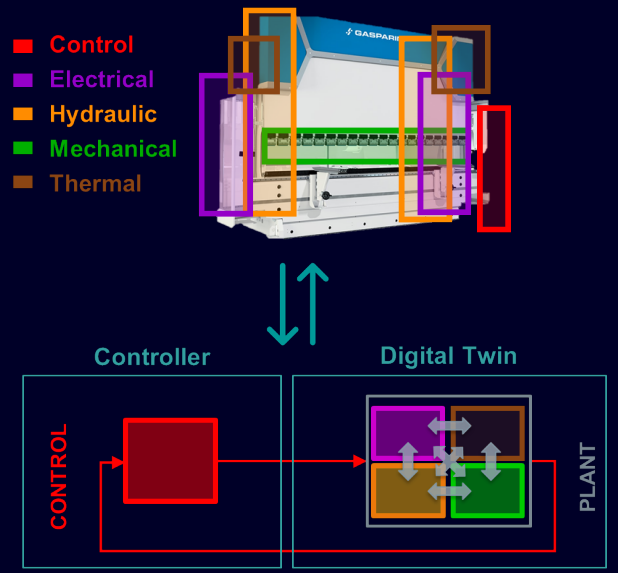
Siemens Solution
Technical Approaches with Digital Twins: Virtual Commissioning and Virtual Sensing (xDT)

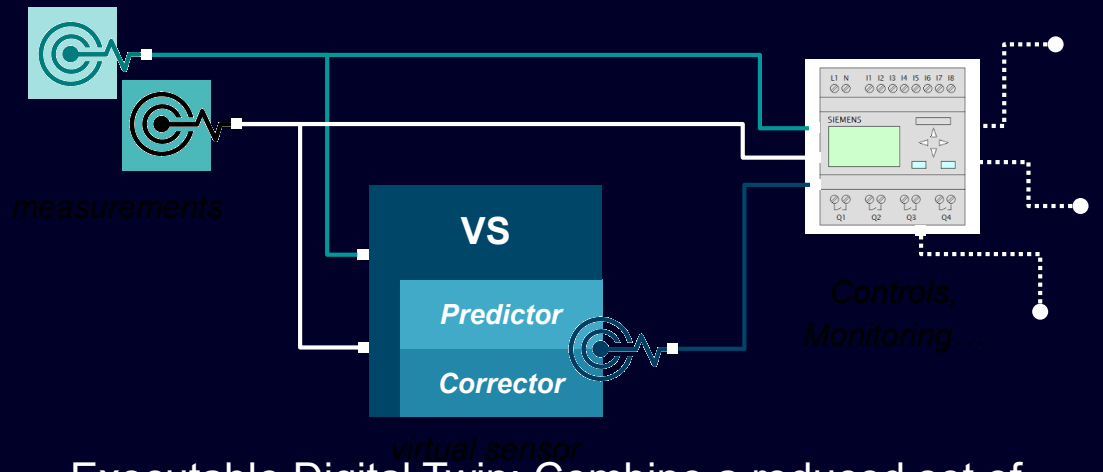
Virtual Commissioning and Virtual Sensing (xDT) – What?

VIRTUAL COMMISSIONING



Digital Twin of the system to support the automation code development, integration and tuning

VIRTUAL SENSING (xDT)



Executable Digital Twin: Combine a reduced set of measurements and a real time model to virtually sense variables

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System Simulation with Simcenter Amesim

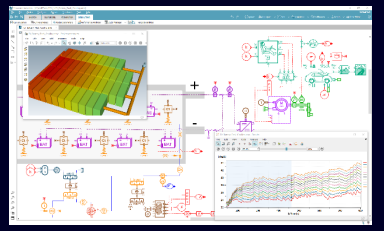
Systems modeling and simulation for every phase of development

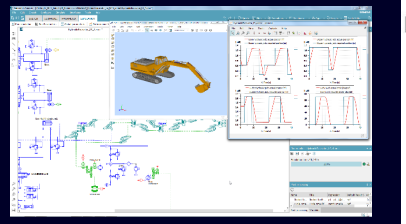
Extensive library of multi-physics components

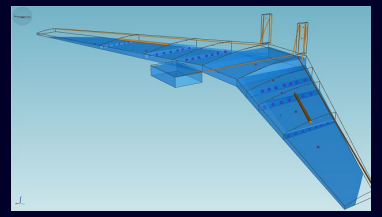
Systems sizing and integration

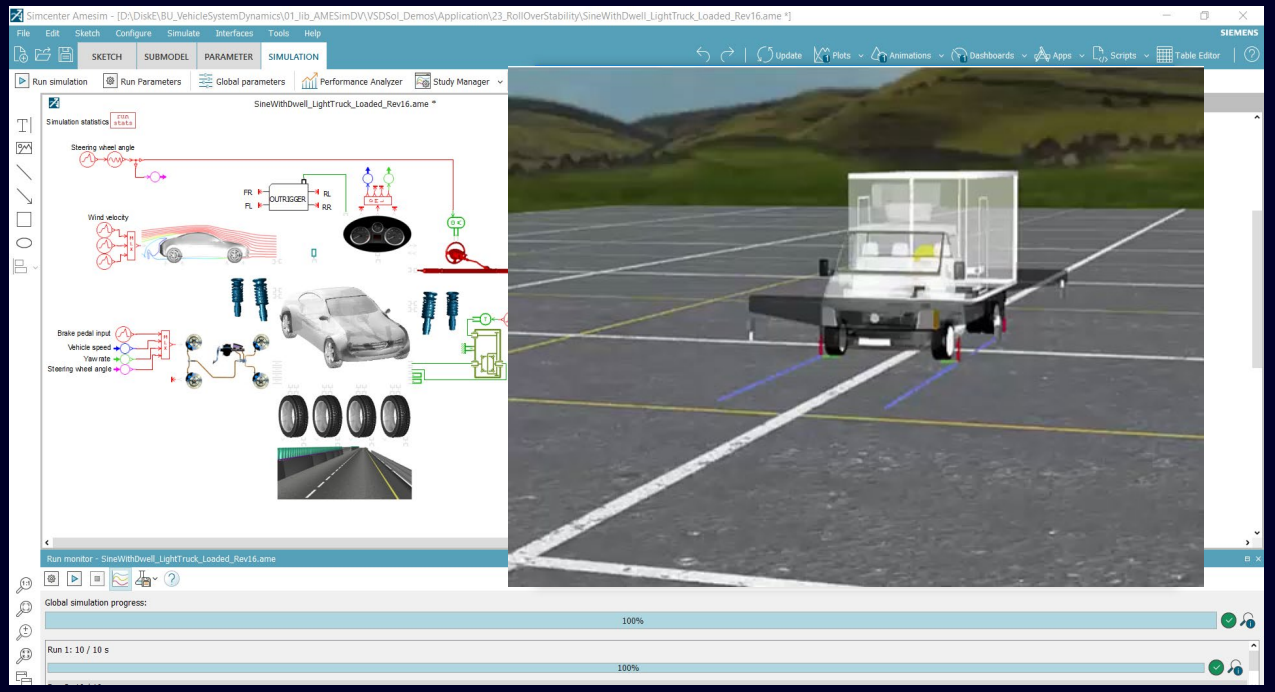
Performance balancing

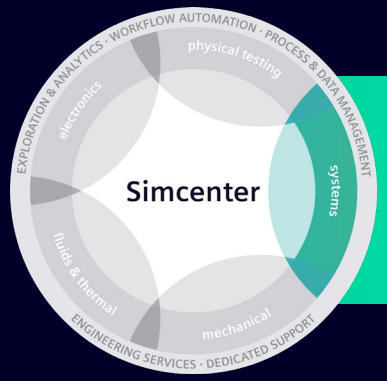
Controls verification and validation in real-time (HiL)











Virtually assess and optimize the performance of mechatronic systems

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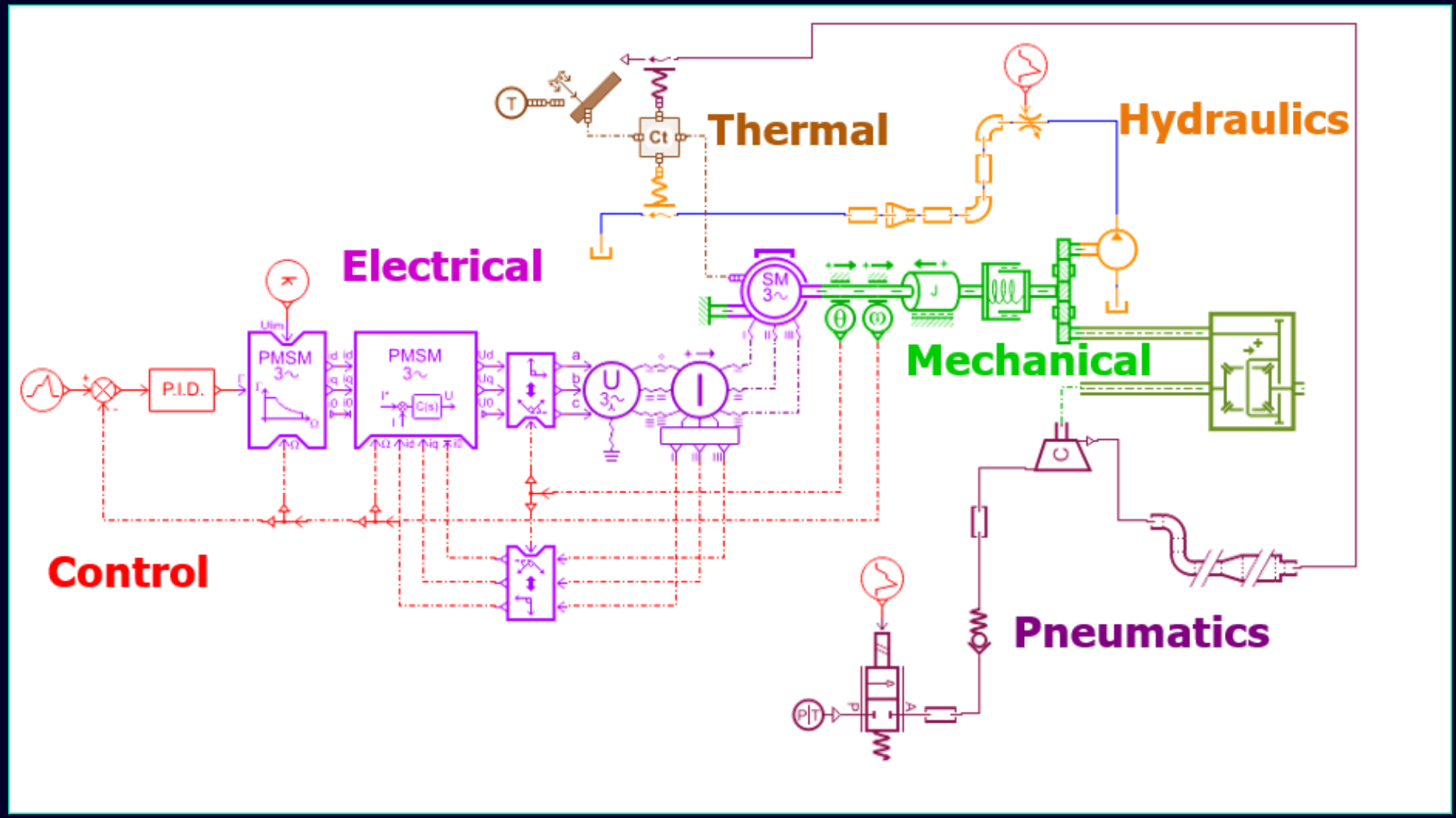
System Simulation in a Nutshell



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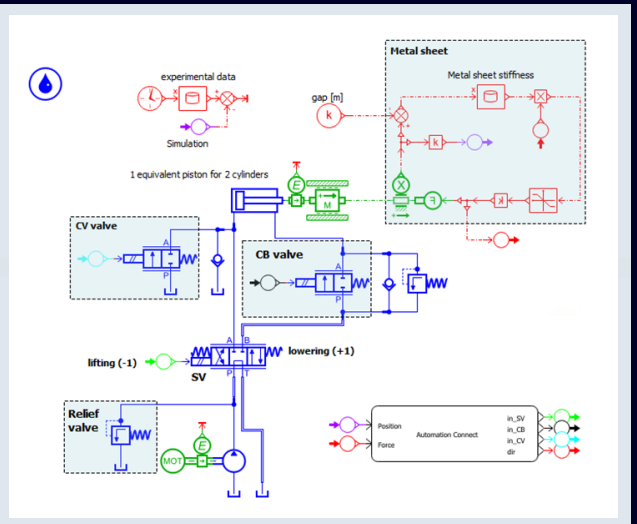
Virtual commissioning at the Unit Level

Automation | Electrical components | Component physics | Production machine | Simulation trained AI

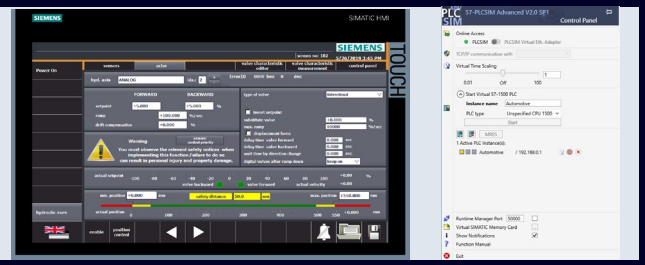
Physical and kinematic model
Mechanical components

Electrical model and behavior model
Component (e.g. drives) and periphery behavior

Automation model
Logic of the PLC program and visualization



System Level Simulation



Virtual controller

Capabilities

- Size components according to performance needs
- Verification of PLC and drive logic with out-of-the-Box behavior models for drive control
- Reuse of models for in operation simulation for additional information on the current state of the machine and additional safety loops (virtual sensors)

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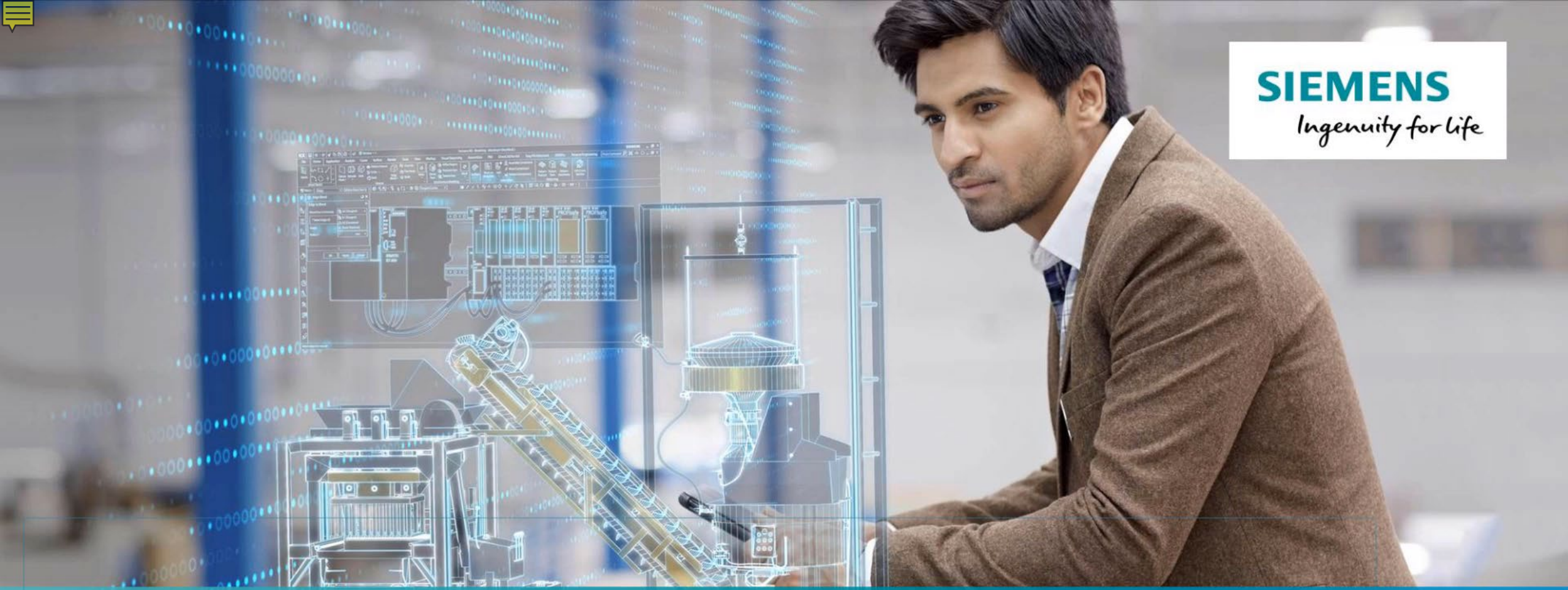

Virtual commissioning with Simcenter Amesim and PLCSIM Advanced

Leveraging Simcenter Amesim Automation Connect for control validation

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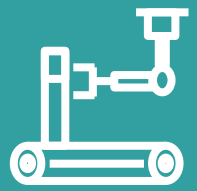
Executable Digital Twins (xDT) to Improve Assets Automation
Implementation process

Implementation of xDT – How?



1

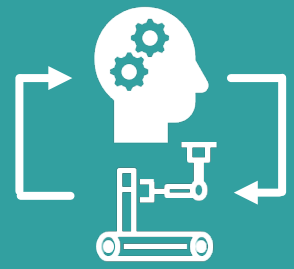
Develop the digital twin model

Equation driven models
Geometry based models
Surrogate models
Hybrid models

2

Virtual sensor synthesis

Reduced Ordered Models x RT compatibility
Predict KPIs based on parameter settings and operational feedback



3

Control upgrade

Advance control algorithm to overcome traditional approaches' limitations

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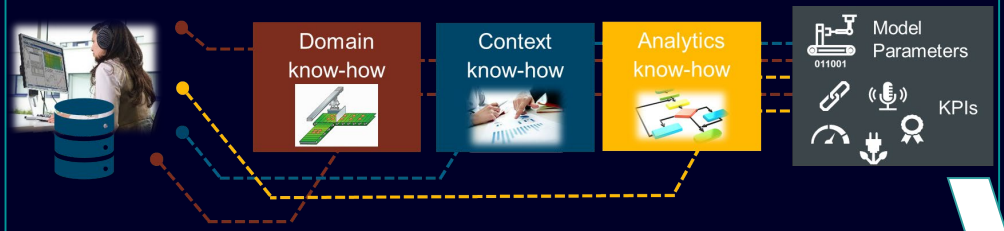
Executable Digital Twins (xDT) to Improve Assets Automation
Implementation process

1. System understanding and digital twin model

011001

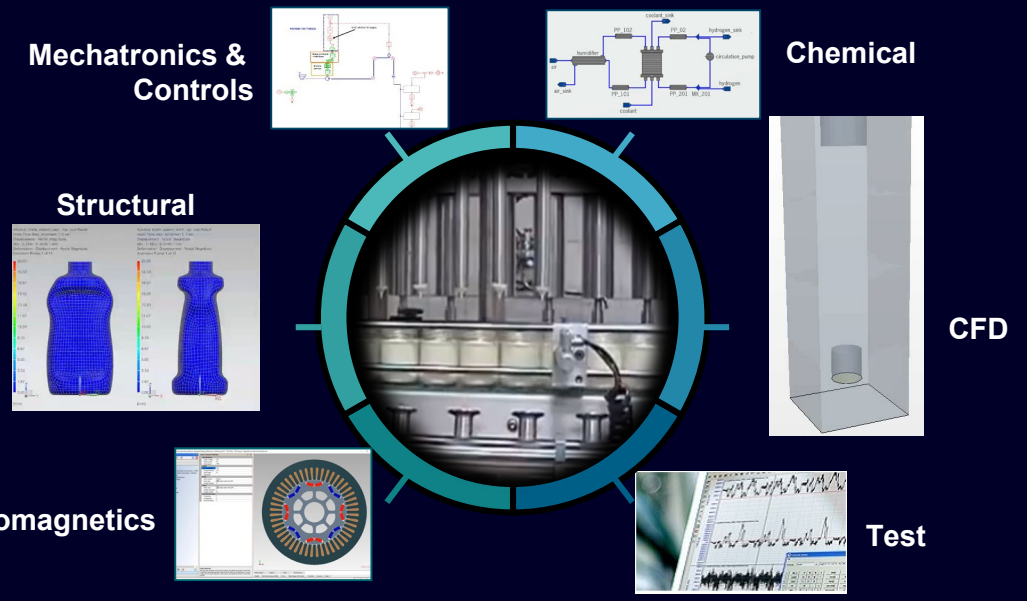
Analysis of historic data



Develop surrogate models of systems with high level of non-linearities and cross coupling between the inputs towards the outputs.

Digital twin

011001



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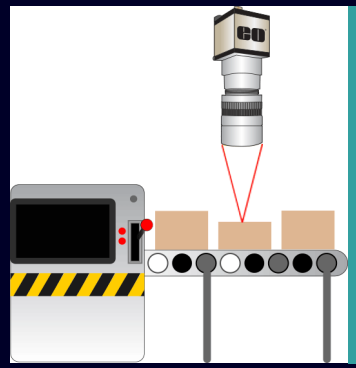
Executable Digital Twins (xDT) to Improve Assets Automation
Implementation process

2. Virtual sensor synthesis

Leveraging Digital Twin to **create compound sensors** to properly **close the control loop** and estimate the full impact on the KPIs.

Contamination & ageing



Event recognition

Component life time

Sensory characteristics

Material properties

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Executable Digital Twins (xDT) to Improve Assets Automation

Implementation process

3. Deploy to Industrial Edge

IT

Simulation model

Industrial Edge

LiveTwin

OT

Real PLC

Vibration

Speed

Torque

Target & Actual Values

Real Target Values

Real Actual Values

xDT

Virtual Sensor

(1) Virtual Sensing

Virtual Actual Values

Online Trend Analysis

(2) Condition Monitoring

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Reduce downtime and increase quality with better thermal management control system using xDT

More efficient production process

Lower cost

Higher quality product

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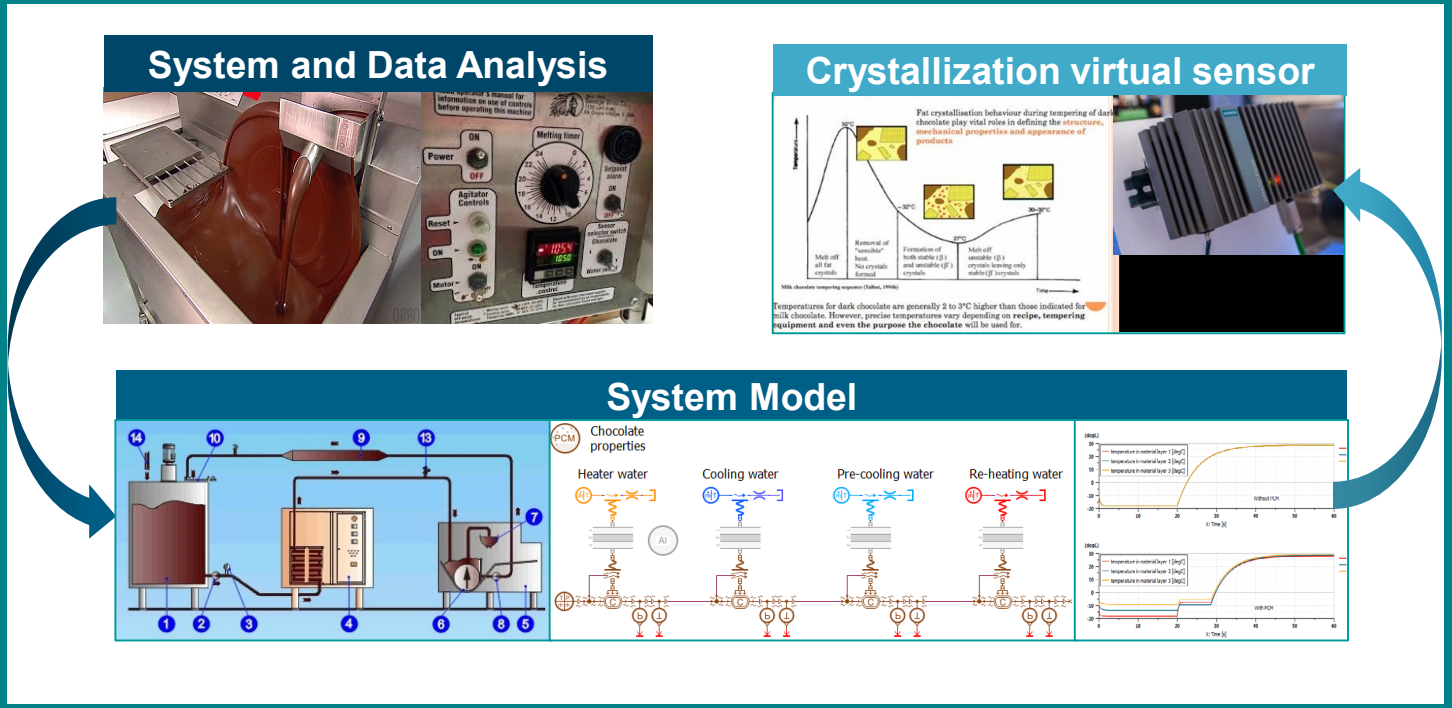
Chocolate temper unit optimization
- Extension of the chocolate production time between 2 cleaning sessions of the unit

Challenge

Improve temper unit control algorithm to maintain stable chocolate organoleptic characteristics over time considering machine performance degradation

Solution

Temper unit system model to capture influence of machine properties degradation on chocolate crystallization structure deployed as virtual sensor on edge device



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Improve production efficiency and quality with automated quality control using xDT

- More efficient production process
- Lower cost
- Higher quality products

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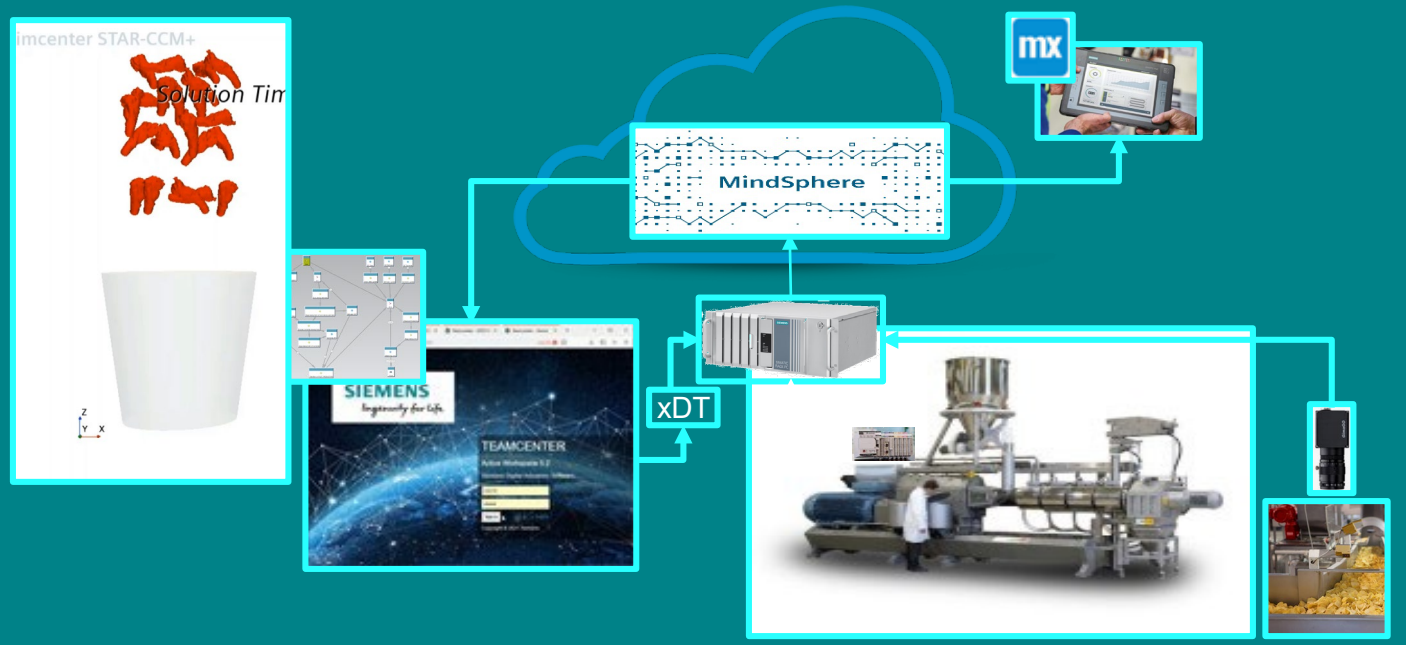
Automated Quality Control

Challenge

Extruder-based food products need to satisfy specific shape requirements for quality and packaging but the relationship with the extruder control is complex

Solution

xDT implementation integrating vision-based feature extraction, packaging related virtual sensor, and machine learning based extruder control



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Improved operational control and performance while reducing costs

Enhanced information

xDT provides a path to a digital future

>10% Reduction on operational costs

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Improve operational efficiency of water reservoirs

Challenge

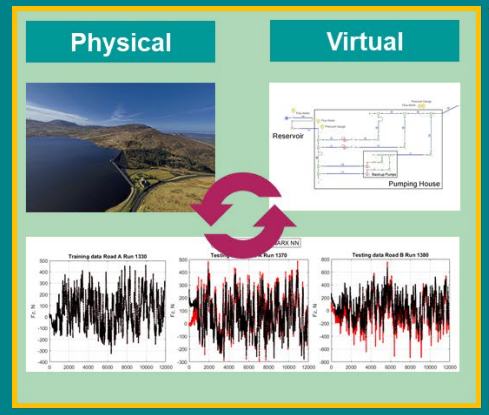
Over/underfilling the reservoirs causes shortages

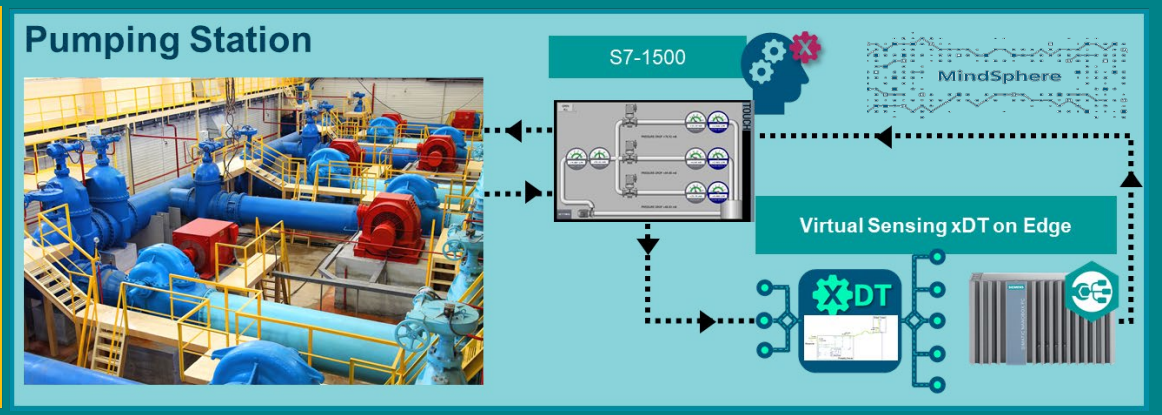
Uncertainties in the piping layout and impossibility to measure in some locations

Current control strategy relies on operator experience

Solution

Real-time full-fidelity model providing virtual measurements of fluid flows, liquid levels and energy usage. This enables the smart control of the plant and increase sustainability.





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Siemens simulation solutions
From Digital Twins (DT) to Executable Digital Twins (xDT)

Precise virtual representation of the physical product or its production line

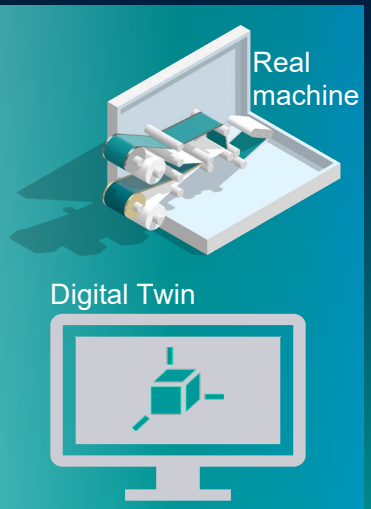
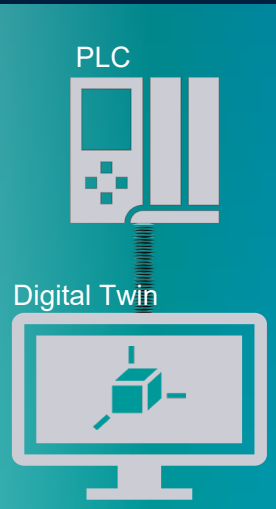
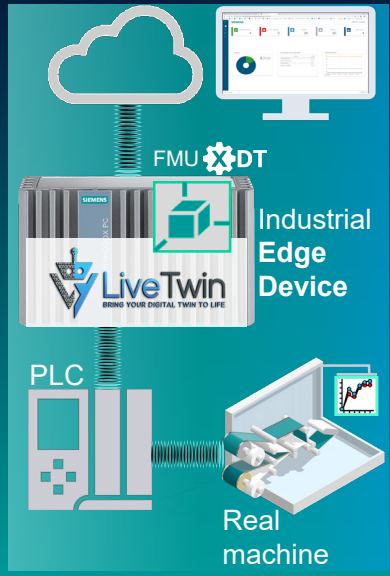
Used **across its lifecycle** to simulate, predict and optimize the product or its production line

Made up of **multiple representations or models** for different aspects of physical behavior

An **evolving** object with a lifecycle that needs to be managed

Closed-loop digital twin provides **bi-directional connectivity between the physical asset and the virtual representation**

Feedback insights to continuously optimize the product and its production

Stage	Design	Virtual commissioning	In-operation
Why	• **Impact** of new technologies on **KPIs** (production rate, energy, NVH, final product quality) • **What-if scenarios**	• **Validate PLC** codes in a **risk-free environment** • Reduce **on-site commissioning time and costs** • Virtual **operator training**	• Measure the unmeasurable • In-service **extended data monitoring** and **performance** optimization • **Predictive maintenance**
How			

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Thank You!

Colm Gavin

Portfolio Development Manager
Siemens Digital Industries Software

Mobile (339) 293-9994

E-mail colm.gavin@siemens.com

Tyler Newcombe

Portfolio Development Lead – CP&R
Siemens Digital Industries Software

Mobile (724) 553-9070

E-mail tyler.Newcombe@siemens.com

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