Machine builders empowered for virtual factory acceptance tests

Digital twins focus efforts of mechanical, electrical and automation engineering on common goal

Manufacturers increasingly require machine builders to furnish them with digital twins for use in virtual factory acceptance tests. By harnessing digital twin technology in their design processes and practices, machine builders not only meet their clients' demands, they also increase their productivity, and that of their clients, in other important ways.

"With a comprehensive digital twin solution and virtual commissioning, manufacturers can reduce costs and time to market. They can create 3D CAD models of machines that simulate the machine's real behavior, with the simulations controlled by a virtual PLC. Thanks to these tools, mechanical, electrical and automation engineers can work collaboratively to increase first-time quality," said Colm Gavin, portfolio development manager, Siemens Digital Industries Software.

Gavin was speaking as a presenter on a recent CFE Media & Technology webcast sponsored by Siemens. As outlined in the webcast, additional benefits of digital twin technology are listed on the next page.

Equipment makers can reduce start-up times inside facilities, including swift validation of machine sequencing and throughput, easy error handling and fault recovery. At the same time, machine builders can reduce travel and other costs associated with on-site factory acceptance tests.

"If we do design reviews at an early stage in the development cycle and we do that virtually, it saves time and expense, especially at a time when travel is so restricted," said Gavin.

- The flexibility of a machine's design can be demonstrated through simulations. In the event of subsequent retrofits, feasibility is easily verified.

- Production of quality parts and capabilities for predictive maintenance are confirmed.

• Operator training can be accomplished proactively, prior to the machine's delivery.

Machine builders traditionally experience a disjuncture or gap occurring between the engineering of a machine and its standup and testing. Moreover, engineering processes tend to proceed step-by-step, from mechanical to electrical to automation. Use of a digital twin allows for a seamless, concurrent processes.

Manufacturers have essential requirements for their Machine Builders

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Reduced Startup Time

Flexible Product Handling

Quality Parts

Operator Training

HOW IT WORKS

NX is Siemens' advanced CAD/CAM/CAE solution. Scott Felber, Siemens NX marketing manager, also spoke on the webinar, and began by outlining some of the technologies involved.

"A comprehensive digital twin encompasses product, production and performance. We begin with a virtual machine driven by virtual controllers. The digital twin comes to life when it's connected to the physical world. We move from virtual product into virtual production, into actual production, to the actual product," Felber said.
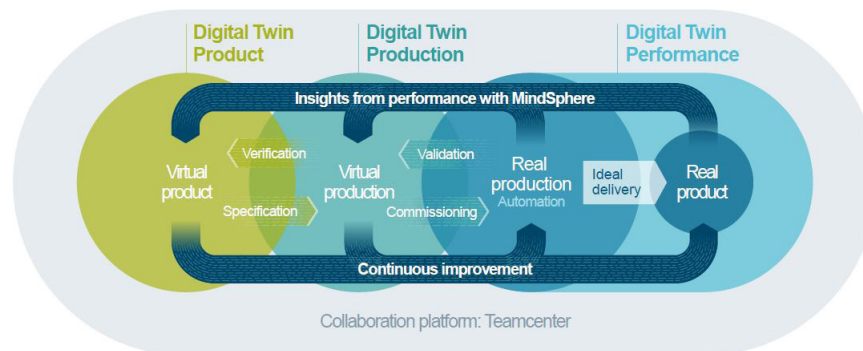
Machine commissioning involves the use of specifications, commissioning documents and testing. Success in meeting requirements is confirmed

by means of feedback. Traditionally, this feedback was derived during the machine's installation and implementation on shop floors.

"Alternatively, today it's possible to establish the feedback loop much earlier, using Siemens MindSphere, our IoT platform, for continuous improvement based on operational feedback. Using this feedback, we can drive requirements validation," Felber said.

Comprehensive Digital Twin

Digital Twin Product · Digital Twin Production · Digital Twin Performance

Insights from performance with MindSphere

Virtual product — Verification — Virtual production — Validation — Real production Automation — Ideal delivery — Real product

Specification — Commissioning

Continuous improvement

Collaboration platform: Teamcenter

Traditionally, a machine builder proceeds step-by-step. The sales force gathers requirements. They work with concept engineering groups to define the machine and its performance.

Within engineering, detail design originates with the mechanical engineering group and then proceeds to electrical specification. Once the mechanical work is underway, the automation group can get involved, to answer questions about how the machine will operate, what happens when there is a fault and so forth. But until the machine is installed on the shop floor, it's difficult to finalize the code, Felber said.

The machine is subsequently built, shipped to the user, stood up, and only then can the factory acceptance tests begin.

"Using a digital twin, we're able to streamline this process. By running the model with the automation, we can simulate the mechanical components and early-on develop the interfaces with the automation software," said Felber.

A virtual PLC and virtual human-machine interface (HMI) work with the digital twin to simulate how the machine will behave in operation.
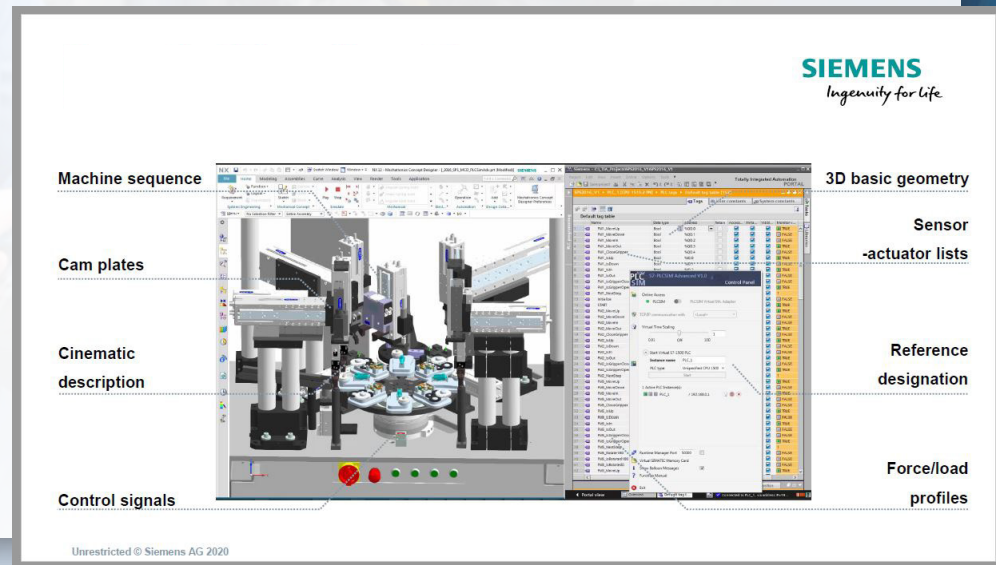
RETURN ON INVESTMENT

"We're often asked, 'Okay, where is the cost justification?'" Gavin said. "The answer is that actual commissioning time can be reduced anywhere from 10% to 30% or more. The quality of the work is improved as well."

The Six Sigma/Quality Rule of tens says that the cost of an unidentified error increases by a factor of 10 as it transitions from one value-added level to the next. The earlier the error is identified the less cost is needed to fix it.

Time and expense are involved in developing a digital twin. It pays for itself, however, because it allows correcting errors while avoiding the cost of field work, where costs compound quickly, Gavin said.

It can take weeks or even months to commission a machine. The machine builder may need to station service people at the job site the whole time. If extensive travel is involved, expenses compound rapidly. This can become a personnel retention issue. "Some clients are drawn to digitalization purely from a personnel retention standpoint," Gavin said.

If expensive materials must be tested on the machine, there's a scrappage issue. Clients don't like having to scrap expensive components, just to test the machine.

Simulation allows errors to be identified early in the product life cycle, reducing onsite issues and real commissioning time

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**Six Sigma/Quality Rule
Rule of tens**

"The rule of tens says that error-related costs for an unidentified error increase by a factor of 10 from one value-added level to the next. The earlier a error is identified and corrected, the cheaper this is for the organization. (…)"

Planning — $1
Development — $10
Startup — $100
Operation — $1000

Cost per error
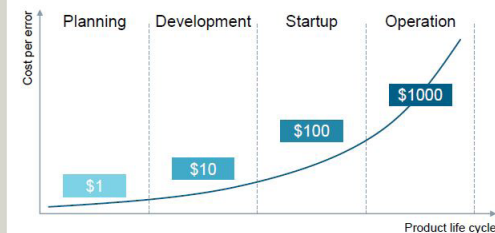
Product life cycle

Conclusion
The quality of the engineering project must be increased as early as possible in the product life cycle!

1) This assumes that the error would otherwise not be detected until operation

Gavin sees machine builders taking advantage of digital twins for four main reasons.

Eliminating errors. "This clearly resonates from an automation standpoint," Gavin said.

Sequencing of operations. A better-quality machine results from improved communications among mechanical, electrical and automation engineering departments.

Training. With a virtual HMI, virtual PLC and digital twin, operators can be trained before the machine is built.

Validation and documentation. For the end user, a virtual factory acceptance test provides validation. Moreover, at handover, clients want more than just 2D or 3D diagrams and a Word document describing how the machine runs. They want to have the tools that were used to execute the machine design and sequencing and therefore have a better understanding of how the machine will run.
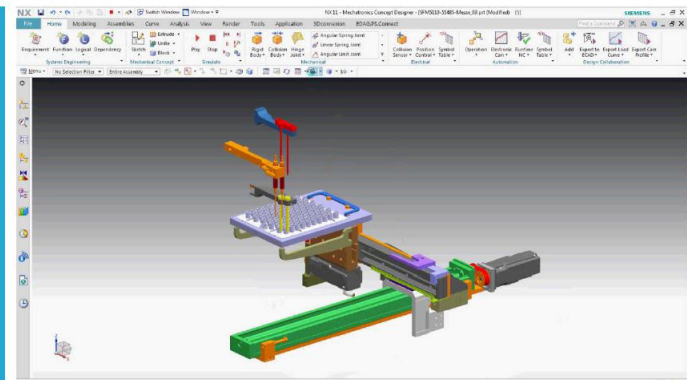
PORTFOLIOS AND PLATFORMS

NX is a single platform that contains all the tools needed to break down barriers between disciplines. NX is the world's most productive modeling environment because it models across multiple disciplines. NX allows engineers, designers and software application developers to collaborate and share information across the traditional barriers that exist today in single-discipline solutions.

"NX allows companies to use one set of data across engineering and manufacturing disciplines," said Felber.

Felber points to several emergent engineering technologies playing a role in NX.

Mechatronics Concept Designer enables multi-discipline collaboration, reusing of existing knowledge and better decision-making from concept to product evaluation. A functional model provides a common language for engineering disciplines to work together in parallel. Data includes joints, motion, sensors,
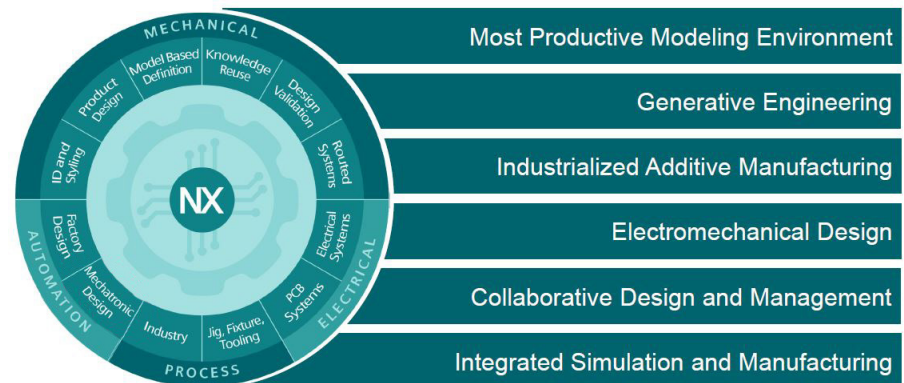
actuators, collision behavior and other kinematic and dynamic properties for each component.

"Mechatronics define the machine from a physics standpoint," Felber said. "It's not just a cinematic simulation of a machine, but a real physics-based simulation of how that machine will work, and especially important with high-speed machinery."

Generative design is a CAD engineering software function in which a designer collaborates with artificial intelligence algorithms to generate and evaluate hundreds of potential designs for a product idea.

NX: Where engineering meets tomorrow

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NX

MECHANICAL — Product Design, Model Based Definition, Knowledge Reuse, Design Validation
ELECTRICAL — Routed Systems, Electrical Systems, PCB Systems
PROCESS — Jig, Fixture, Tooling, Industry
AUTOMATION — Mechatronic Design, Factory Design, Build Spaces

- Most Productive Modeling Environment
- Generative Engineering
- Industrialized Additive Manufacturing
- Electromechanical Design
- Collaborative Design and Management
- Integrated Simulation and Manufacturing

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AUTOMATION STANDPOINT

"From an automation standpoint, we've been able to simulate PLC programs and HMIs for years now," Gavin said. "But what if the mechanical system needs to interact with the automation system? Or, if I have robots, a manufacturing cell, a production line or an entire plant? There are many different use cases for simulation."

Simulation tools may start with the PLC or HMI but can as easily simulate drives or use of robots, size components for systems-level simulation, simulate the actual machine running, or at the highest level, perform simulation of the entire plant.

Siemens Amesim is the suite of tools used to model, analyze and predict the performance of mechatronics systems. It combines 1D simulation, 3D computer-aided engineering (CAE) and physical testing with intelligent reporting and data analytics.

"With PLCSIM Advanced and Virtual HMI, we can use the Amesim tool to simulate how the designed components will behave. A series of equations lies behind each data set, whether it be a valve or an electrical component. Amesim is a multi-physics simulation tool, so thermal, hydraulics, fluids, electrical or mechanical components, all can be simulated, modelling how the components really behave. Interfacing by means of our Virtual PLC and Virtual HMI we can determine whether those components are sized correctly," said Gavin.

Virtual Commissioning for Production Machines

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Physical and kinematic model
Mechanical components
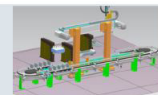
Electrical model and behavior model
Component (e.g. drives) and periphery behavior

Automation model
Logic of the PLC program and visualization

With NX MCD, SIMIT & PLCSIM Advanced

- **Definition & validation** the mechatronic concept of the machine directly with the CAD model in the early phases of development

- **Better collaboration** by sharing data between mechanical, electrical and automation departments

- Define mechatronic model including kinematic, sensors, actuators, logic and signals

- **Reuse** of mechatronic components for a faster machine design

- **Optimization of machine design** before the first prototype (sequence, traveling path, speed of motors, position of sensors...)

- **Verification of PLC code** together with machine kinematic and HMI

- **Out-of-the-Box behavior models** for machine components

The Mechatronics Concept Designer takes these capabilities further, with CAD visualization, along with our Virtual PLC, and drives simulation if need be.

Process Simulation is a tool for use with robotics. The Process Simulation tool simulates end-of-arm reach, welding and the robot's path. Components in the robot cell can be simulated and connected to a virtual PLC. We simulate the complete cell, and not just the robot behavior, Gavin said.

"Our Virtual PLC, PLCSIM Advanced for the Siemens S7-1500 PLC, simulates the complete automation program. APIs allow high-speed, synchronous communication to any of the modeling tools," Gavin said. "The ability to simulate the entire automation program differentiates these solutions

from those of competitors. Moreover, we can simulate multiple instances if multiple PLCs control the machine. APIs are also available for third-party applications."

Plant Simulation is about material handling simulation, and the arrangement of machines in a factory. Statistical tools allow analysis of throughput capacity.
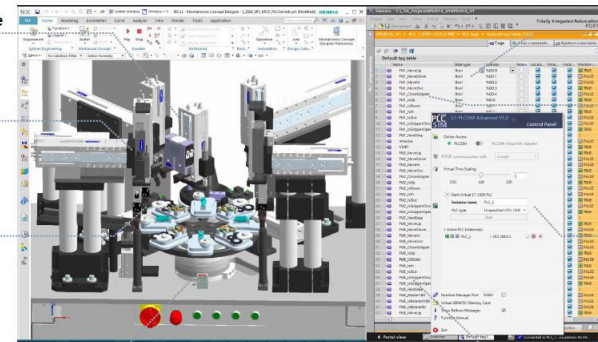
FINAL WORDS

Gavin concluded by noting that Siemens recognizes that not every manufacturing enterprise will have resources in-house to develop a digital twin. Therefore, two starter packages are available for working with the Mechatronics Concept Designer. While using PLCSIM Advanced for high-speed synchronous control is preferred, this applies even with a third-party controller.

"The extended starter package allows for 40 hours of digital twin development, including for the Mechatronics Concept Designer and PLCSIM Advanced. We develop that digital twin with you so you can work and learn. We can mentor you in how to use the software as well," Gavin said.

The basic starter package is a service offering whereby Siemens uses the Mechatronics Concept Designer to develop the digital twin for the client.

"We leave you with the Mechatronics Concept Designer player. You can play the model against your automation codes, use it for training purposes, or for marketing and sales promotion purposes.

If you don't have the resources to work with the software, Siemens resources are available for that. The basic starter package gets you going with the player version, while the extended starter package is available for those in the U.S. that need 40 hours of full digital twin development to get started," Gavin said.
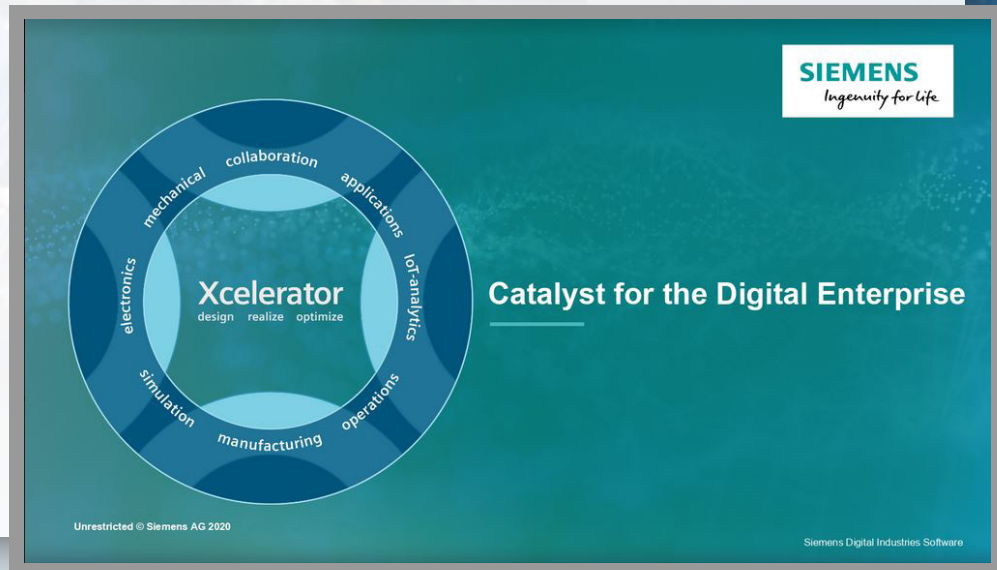
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PRESENTED BY:

SCOTT FELBER

Scott Felber is an NX product engineering software marketing manager with Siemens Digital Industries Software. Scott has more than 30 years with Siemens Digital Industries Software and holds a Master of Science in engineering management from Marquette University, and a Bachelor of Science in industrial engineering from the University of Wisconsin, Milwaukee.

COLM GAVIN

Colm Gavin has worked for Siemens for 19 years and is currently responsible for the promotion of digitalization topics, from Siemens Digital Industries Software group for machine and line builders. Colm holds a bachelor's degree in manufacturing engineering from Trinity College in Dublin, Ireland.

| CLICK HERE TO VIEW THE ON-DEMAND WEBCAST FROM CONTROL ENGINEERING

| EXPLORE THE POWERFUL 3D MODELING CAPABILITY OF NX CAD FOR DESIGNING MECHANICAL PARTS AND ASSEMBLIES

| TIA PORTAL ENGINEERING AND SIMULATION IN THE CLOUD

CONTROL ENGINEERING