WHITE PAPER

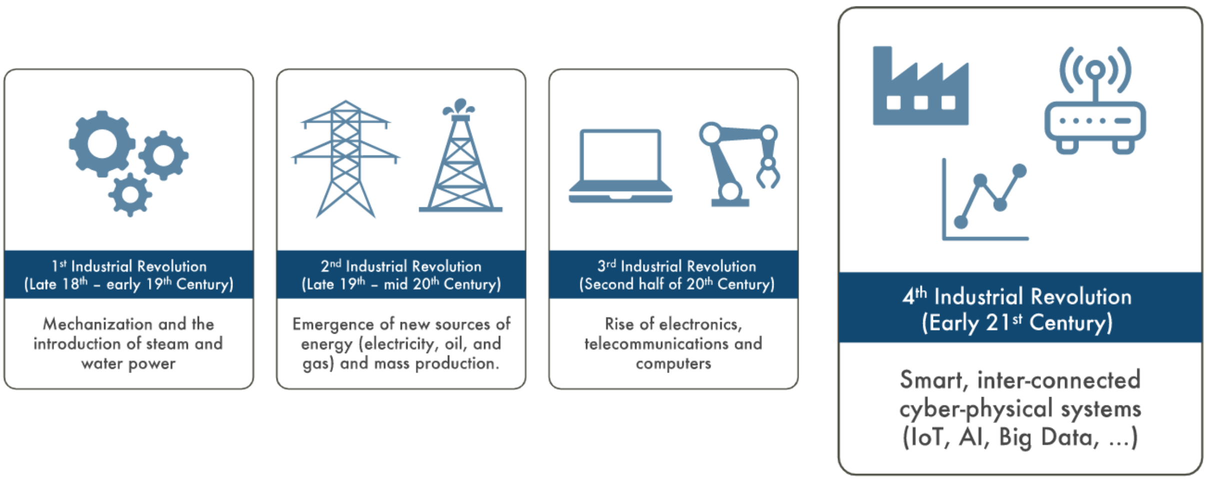
Demystifying Industry 4.0

MathWorks®

Introduction

Industry 4.0, or the fourth industrial revolution, is the automation of traditional manufacturing and industrial processes using technologies such as Industrial IoT, big data analytics, artificial intelligence, robotics, and autonomous systems. Industry 4.0 aims to increase manufacturing capability, productivity, and efficiency. It also enables flexible, customer-centric production and reduces operation and maintenance cost.

The term Industry 4.0, a follow-on to the first three industrial revolutions, was first introduced in 2012 at the Hanover Fair by the Working Group on Industry 4.0, which presented a set of Industry 4.0 implementation recommendations to the German federal government to promote the computerization of manufacturing. Related terms are smart manufacturing, smart factory, and factory of the future.



The four industrial revolutions.

Why Industry 4.0?

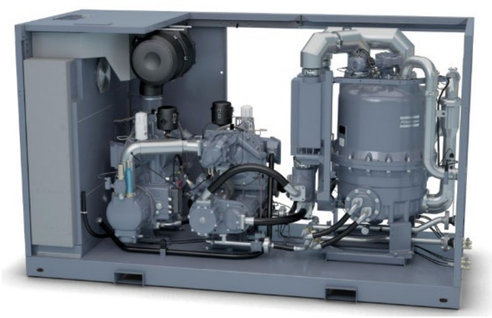
Industry 4.0 has the promise to increase manufacturing connectivity between machines and between machines and humans in both physical and virtual worlds through OPC UA, the communication protocol that connects IT systems (such as ERP and CRM) and OT systems (such as PLCs, SCADA, and Industrial IoT) and helps address the interoperability challenge. Industry 4.0 also enables optimal decision-making by using data-driven approaches such as statistical analysis, predictive analytics, AI, machine learning, and deep learning.

The potential benefits of industry 4.0 vary by types of organization, as shown in the following sections.

Original Equipment Manufacturers (OEMs)

OEMs often create models during the design of their production equipment. Industrial IoT enables those models to become digital twins of the operating machines to optimize machine performance given the specific operating state and condition. OEMs can provide predictive maintenance as a value-added service to factory operators to increase the reliability, availability, and maintainability (RAM) of their equipment. At the same time, OEMs may also be able to get feedback on their equipment performance in the field for future design improvement.

Case Study: Atlas Copco



> "To get access to any data, it just takes two lines of MATLAB code. After 10 minutes you have all the data on any given model worldwide and can start analyzing it."
>
> — *Carl Wouters, Atlas Copco*

Challenge

Build platform to enable predictive maintenance for air compressors

Solution

Use MATLAB and Simulink to integrate simulation and data analytics for digital twins that serve as a single source of truth

Key Outcomes

- Easy interaction with application-specific data sources
- Vast range of data analytics and simulation capabilities
- Ability to combine databases with a physical model
- Open information sharing between teams from engineering, sales, and service

System Integrators

System integrators help factory operators establish interconnections between production equipment, deliver factory-level performance, and enable visibilities and analytics of the overall process through cloud-based or on-premises infrastructure. System integrators may also develop digital twins of the whole factory process to enable virtual commissioning of the factory to validate and optimize factory performance without having to wait for the completion of physical factory construction and equipment installation.

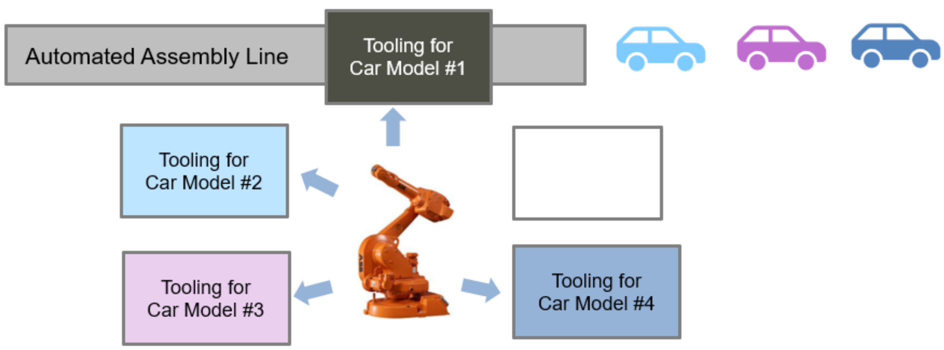
Factory Operators

Factory operators want to keep their factory running at the optimal efficiency, maximal productivity, and lowest operational and maintenance costs while producing products that meet their customers' requirements on features, quality, speed, and cost. Industry 4.0 benefits for factory operators can be characterized in four areas:

- Flexible production
- Mass customization
- Operation performance optimization
- Reliability, availability, and maintainability

Flexible Production

Industry 4.0 enables factory operators to easily adapt to changes in the type and quantity of the product in production. Industrial robotics, automated guided vehicles (AGVs), and computer-aided manufacturing (CAM) systems are normally used extensively in a flexible production system.



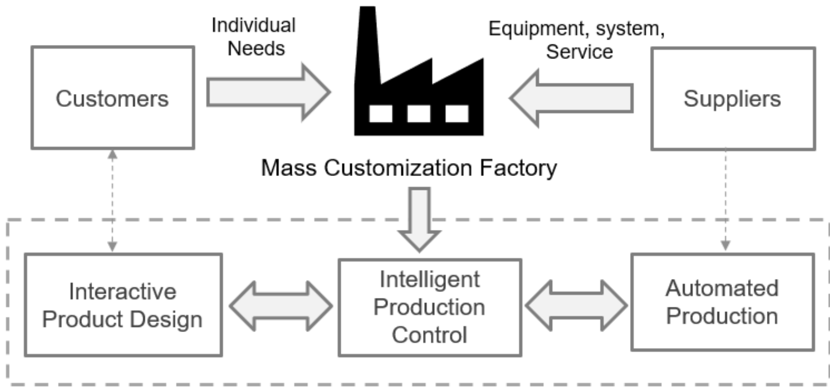
Changing assembly line configuration automatically based on car model desired.

Mass Customization

Combining the flexibility and personalization of customer-made products with the low unit costs associated with mass production, Industry 4.0 will drive the next wave of mass customization.

- Factory operators must identify opportunities for customization that create value for customers and support these through smooth, inexpensive transactions for both consumer and producers.
- It is also critical to have a manageable cost structure and level for producers despite the increase in manufacturing complexity.

Flexible production and mass customization help producers improve their efficiency, lower production cost, and increase product differentiation, giving them a competitive advantage. They can also reduce the costs associated with the excess inventory by implementing just-in-time production and logistics to minimize inventory.



Using mass customization to enable customers to specify their individual needs for the product and produce it with low cost.

Operation Performance Optimization

For factory operators, system-level operation and performance optimization are the keys to improve throughput and lower operation cost to remain competitive in a global market. With real-time connectivity and data capturing using Industrial IoT, operators can get visibility into the full manufacturing process in detail and holistically and discover process issues that need attention. They can use statistical analysis, machine learning, and AI algorithms to process and analyze real-time data to not only identify process inefficiencies but also predict what will happen and take actions to avoid problems from happening in the first place. A digital twin of the manufacturing process can be used to run through different scenarios, pinpoint the root cause, and provide actionable insights to maintain and improve operation performance.

Reliability, Availability, and Maintainability (RAM)

Predictive maintenance is at the center of RAM. With predictive maintenance, asset reliability can be improved by minimizing the number of unexpected breakdowns, thereby maximizing availability. Furthermore, using Industrial IoT, digital twin, and advanced analytics such as AI, machine learning, and deep learning, factory operators can apply prescriptive maintenance to not only know what happened and what will happen, but also what to do, given that knowledge. Therefore, the operation and maintenance cost as well as the impact of machine failures or process breakdowns can be reduced significantly.

The benefits that Industry 4.0 can bring will get deeper and broader as technology advances. For example, when 5G technology becomes more feasible and practical, factory operators can make better decisions based on faster, real-time data. They can also apply virtual reality (VR) and augmented reality (AR) in their operation, maintenance, and training activities to further increase productivity and efficiency. Similarly, OEMs and system integrators can use VR/AR to generate more value-added services for factory operators and help themselves in the product design, simulation, and commissioning.

Case Study: Mondi

"As a manufacturing company we don't have data scientists with machine learning expertise, but MathWorks provided the tools and technical knowhow that enabled us to develop a production preventative maintenance system in a matter of months."

— Dr. Michael Kohlert, Mondi

Challenge

Reduce waste and machine downtime in plastics manufacturing plants

Solution

Use MATLAB to develop and deploy monitoring and predictive maintenance software that uses machine learning algorithms to predict machine failures

Results

- More than 50,000 euros saved per year
- Prototype completed in six months
- Production software run 24/7

Industry 4.0 with MATLAB and Simulink

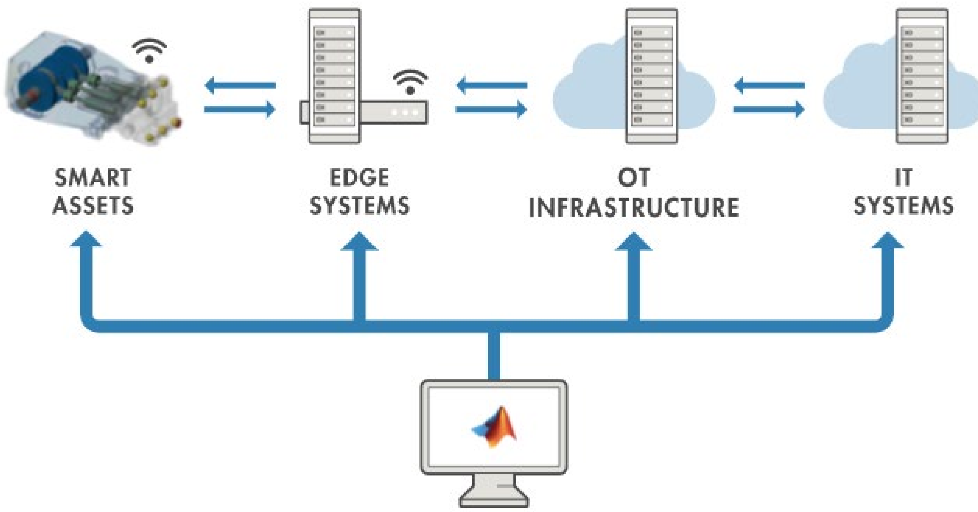
Industry 4.0 is a set of technologies that work together to enable manufacturers to gain value from having their factory machines and the manufacturing processes become connected and smart. It is recommended to make changes incrementally and in phases to achieve ROI quickly and build knowledge that can be reused as subsequent changes are then made.

MATLAB® and Simulink® offer a wide array of algorithm and modeling authoring capabilities, connectivity options, the ability to reuse artifacts, and flexible deployment options into Industry 4.0 infrastructure. There are four major Industry 4.0 capabilities that we see companies are building using MATLAB and Simulink:

- Industrial Internet of Things (IIoT)
- Advanced data analytics and AI
- Robotics and autonomous systems
- Digital twin development and deployment

Industrial Internet of Things (IIoT)

IIoT is the foundation of Industry 4.0. IIoT infrastructure needs to be built to store, access and manage data with multiple time frames and from various components/assets. Smart assets and processes may generate high-speed dynamic data and need to be processed in real time for control and protection. Low-speed, slow-changing data may be valuable for long-term trend analysis and correlation.



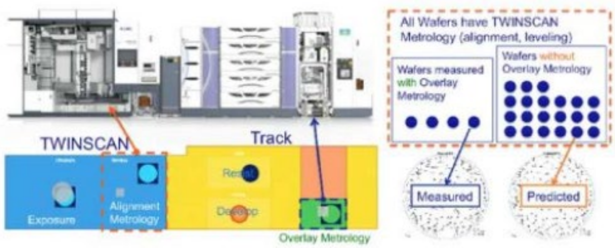
Deployment options across IIoT infrastructure

MATLAB and Simulink can help design, prototype, and deploy IoT applications such as predictive maintenance, operation optimization, supervisory control, and more. With OPC Toolbox™, you can read, write, and log OPC data from devices, such as distributed control systems, SCADA, and PLCs and perform real-time data analytics.

Advanced Data Analytics and AI

With the increasing amount of data and advanced data analytics enabled by high computing power, more and more value can be generated from data. MATLAB makes it easier and faster for engineers with domain knowledge to perform data analysis; build AI, machine learning, and deep learning models; and deploy them to the asset, edge, and cloud applications.

Case Study: [ASML]()



Cutaway of a TWINSCAN and Track as wafers receive alignment and overlay metrology.

> "As a process engineer I had no experience with neural networks or machine learning. I worked through the MATLAB examples to find the best machine learning functions for generating virtual metrology. I couldn't have done this in C or Python—it would've taken too long to find, validate, and integrate the right packages."
>
> *— Emil Schmitt-Weaver, ASML*

Challenge

Apply machine learning techniques to improve overlay metrology in semiconductor manufacturing

Solution

Use MATLAB to create and train a neural network that predicts overlay metrology from alignment metrology

Results

- Industry leadership established
- Potential manufacturing improvements identified
- Maintenance overhead minimized

Robotics and Autonomous Systems

Flexible manufacturing and mass customization require industrial robots and AGVs as well as co-bots that work together with humans. MATLAB and Simulink provide an integrated design environment and tools engineers can use to transform their concept into design and to simulate and validate their design through desktop simulation, software-in-the-loop (SIL), and hardware-in-the-loop (HIL).

Case Study: Clearpath Robotics

OTTO 1500 self-driving vehicles for materials transport.

"ROS is good for robotics research and development, but not for data analysis. MATLAB, on the other hand, is not only a data analysis tool, it's a data visualization and hardware interface tool as well, so it's an excellent complement to ROS in many ways."

— *Ilia Baranov, Clearpath Robotics*

Challenge

Shorten development times for laser-based perception, computer vision, fleet management, and control algorithms used in industrial robots

Solution

Use MATLAB to analyze and visualize ROS data, prototype algorithms, and apply the latest advances in robotics research

Results

- Data analysis time cut by up to 50%
- Customer communication improved
- Cutting-edge SDV algorithms quickly incorporated

Digital Twin Development and Deployment

For Industry 4.0 applications, asset and process digital twins play an important role in fault detection and diagnostics, predictive maintenance, and operation optimization.

Case Study: Baker Hughes

Truck with positive displacement pump.

"MATLAB gave us the ability to convert previously unreadable data into a usable format; automate filtering, spectral analysis, and transform steps for multiple trucks and regions; and ultimately, apply machine learning techniques in real time to predict the ideal time to perform maintenance."

— Gulshan Singh, Baker Hughes

Challenge

Develop a predictive maintenance system to reduce pump equipment costs and downtime

Solution

Use MATLAB to analyze nearly one terabyte of data and create a neural network that can predict machine failures before they occur

Results

- Savings of more than $10 million projected
- Development time reduced tenfold
- Multiple types of data easily accessed

Summary

The industrial world is rapidly changing with the emergence of Industry 4.0, which encompasses the growing complexity of software and an ever-increasing amount of data.

The increasing code base on industrial systems is a challenge for classically trained engineers who rely on traditional methods for programming and testing. Also, sensors on modern equipment collect a significant amount of measured data that needs to be analyzed to gain knowledge about product quality, energy consumption, machine health status, and other economically relevant parameters. This is where the use of machine learning algorithms—for predictive maintenance, for example—is beneficial to derive actionable insights.

The biggest impact of Industry 4.0, however, is on the people working in the factory of the future. By using MATLAB and Simulink, more engineers and scientists, not just data scientists, can make use of AI and advanced data analytics. The factory of the future requires engineers who can build models, deal with large data sets, and handle the respective development tools. Therefore, companies building and operating industrial equipment should be ready for a future in which Industry 4.0 is merely the beginning.

Next Steps

- Work with MathWorks Consulting to speed up your MATLAB and Simulink projects
- See how leading organizations have successfully engaged with MathWorks Consulting
- Explore MATLAB and Simulink for industrial automation and machinery