A WORD FROM OUR SPONSOR

The End of the Factory Acceptance Test and Other Trends 3

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The End of the Factory Acceptance Test, and Other Trends

Technological advancements hit an inflection point four years ago, and now it seems that the sky is the limit regarding the usefulness and adoption of new automation techniques. We see today’s digital transformations ultimately leading to autonomous operations, which will enable an entirely new business ecosystem that includes the “outcome-as-a-service” business model. In addition, control system architectures are opening up and they will work seamlessly not only with applications such as artificial intelligence and machine learning (AI/ML), cloud computing, digital twins, edge computing and the industrial internet of things (IIoT), but also with robotics.

While the pandemic was a huge disruption, it actually accelerated the adoption of new technology. Our customers expedited their digital transformations and deployments of augmented reality, secure remote services, and global collaboration applications to support remote operations and employees working from home.

Although their people are now returning to work at the office, these companies will continue using the remote-enabled technologies due to the many benefits they offer. For example, they are leading to a major change in the way control system projects are conducted.

While innovative project management methodologies, standardized components such as smart junction boxes, and virtualization couldn’t quite accomplish it, the pandemic might have finally brought an end to the factory acceptance test (FAT). Customers found that using virtual FATs expedited project scheduling and reduced costs. There are no travel hours, no travel expenses, and no need to work around team travel schedules. Progress with the virtual FAT is encouraging project engineers and managers to reconsider all the available technologies that allow them to conduct future projects with either no FATs or substantially curtailed FATs.

In a similar vein, we see mobile robots transitioning to the mainstream in process industry applications. While factory automation robotics have been perfected over many years, robotics in the process industries are emerging only today. They are seamlessly integrating with control systems and related applications for asset performance management, predictive maintenance, and process optimization. They are working closely with digital twins and AI/ML applications in the Cloud and at the Edge.

The pandemic accelerated some of the robotics trends. In lieu of employees working on-site, robots could fulfill duties such as routine inspection rounds and incident investigations. A robot could enter a hazardous area that would be very risky to a human or one that would require lengthy preparation time due to the necessity of personal protection equipment (PPE) or a fire suit. A drone could replace a
human who would need to climb a very tall ladder. The robots do not necessarily replace people but allow them to perform tasks with higher value while significantly reducing risks. By performing the “dirty and dangerous” tasks, they allow the human workforce to accomplish more meaningful work.

Digital transformation is impacting practically every organization in the industries we serve and is a key driver behind the accelerating adoption of open architecture. According to the Open Group, which is responsible for the Open Process Automation Standard (O-PAS), digital transformation requires the low-cost implementation of change, i.e. the ability to make rapid, iterative, and data-driven innovations in plant operations at a fraction of the cost that had previously been possible. This demands overcoming the restrictions to innovation that result from closed, proprietary systems.

Digital transformation is also enabling the evolution of the “as-a-service” business model to become outcome-as-a-service. While it may be a surprise, data-as-a-service has been available for more than 20 years. Although complete outsourcing of the operations and maintenance of an entire facility—such as process-plant-as-a-service—is further in the future, smaller-scale initiatives such as equipment-, process unit-, feedstock-, or catalyst-performance-as-a-service are emerging.

As they digitally transform, many plants are in the early stages of the journey from industrial automation to industrial autonomy, or IA2IA™. According to our global process industry survey, 64% of end-users expect to establish autonomous operations over the next decade. Autonomy is the ability of a system to sense the state of its environment, analyze the data it has collected to find operational problems or changing resource demands, and dynamically adapt to the environment to resolve issues and address rapidly evolving business demands at optimal cost.

The move to industrial autonomy has gained momentum due to the impact of COVID-19 and is at the forefront of efforts to improve worker productivity, quality, and safety. Outcomes will range from a connected, empowered workforce to highly agile operations that can rapidly adapt and respond to market dynamics. Plants that make these changes now will be ready for the next big disruption when it arises.

Kevin McMillen, Yokogawa Corporation of America

ABOUT YOKOGAWA

Yokogawa provides advanced technologies and services in the areas of measurement, control, and information to customers across a broad range of industries, including energy, chemicals, materials, pharmaceuticals, food, and water. Yokogawa addresses customer issues regarding increasingly complex production, operations management, and the optimization of assets, energy, and the supply chain with digitally enabled smart manufacturing, enabling the transition to autonomous operations.

Founded in Tokyo in 1915, Yokogawa continues to work toward a more sustainable society through more than 17,500 employees in a global network of 119 companies spanning 61 countries. For more information, visit www.yokogawa.com.
INTRODUCTION

Manufacturing Digitalization: Embrace Change for Growth and Profits

These are exciting times to be involved in industrial automation. The changes that come from the digitalization of manufacturing and production systems through the use of new technologies are starting to have impacts that will be as transformational as the introduction of programmable logic controllers and distributed control systems were years ago. New technologies from outside the realm of traditional automation solutions, as well as the rapid expansion of proven tools and techniques, are being applied to improve the productivity, profitability, and competitiveness of manufacturers.

Automation professionals are critical to successfully selecting and applying new technologies and guiding management to maximize an organization’s success. The collaboration of experienced industrial automation veterans with younger professionals that understand open Internet of Things (IoT) and computing industry technologies is already leading to the creation of highly effective solutions at manufacturing organizations. The dozen trends highlighted here manifesting the manufacturing digital revolution.

This is my sixth annual trends report, and the usual caveat applies: I can never know with certainty what the future will hold. But I’ve spent many years talking to a wide range of users, suppliers and industry consultants, synthesizing what I’ve heard. So, as always, I invite you to share your thoughts, criticisms, and perspectives as well. I look forward to talking with you through LinkedIn or via email at wlydon@automation.com.

Bill Lydon
The Open Road to Autonomy

The road to industrial autonomy is open and variable, offering myriad choices for operational excellence. Whether your company is at the start of its journey or well on its way, Yokogawa enables smooth transition from industrial automation to industrial autonomy—IA2IA. Key to that transition is OpreX, our evolving suite of solutions and products comprising control, measurement, execution, and lifecycle that will help customers optimize everything from business management to operations. Yokogawa. Advancing your IA2IA.

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Evolving Manufacturing Industry Environments

Leveraging disruptive innovations and technological developments, the entire manufacturing business is being digitally integrated, creating a high-efficiency organization to stay competitive, increase profits, and achieve sustainability. Digital integration synchronizes and optimizes supply chain, customer requirements, plant floor operations, and outbound logistics.

Major manufacturing and process automation technology leaps come in cycles and have included programmable logic controllers (PLCs), distributed control systems (DCS), industrial Ethernet networks, plant historians, and open user interfaces. Each major industrial control and automation leap has been the application of technology developed and widely used in other applications. For example, the PLC replaced large banks of relays using new technology, and there was resistance to change. It is important to learn the lessons of past major manufacturing and process automation technology leaps.

Manufacturers that do not embrace this change risk losing their competitive positions and profits. Many times, history repeats itself. Consider the history of the automotive industry and the loss of market share by the United States. In 1913, Henry Ford’s methods, including the assembly line, produced a Model T in 93 minutes lowering cost and crushing rivals.
The industry environmental has changed the factors of success requiring manufacturers to redefine and reinvent the entire business with aggressive digitalization and automation.

LOW LABOR COSTS NOT A WINNING MANUFACTURING STRATEGY
Low labor costs are no longer a winning strategy for most manufacturers, with the lower cost and ease of applying automation increasing return on investment to achieve flexible, high quality, and efficient production.

The digital manufacturing business architecture unifies the entire organization to achieve greater success.

DEMOGRAPHICS
In many countries, there is an ongoing shift from a labor-rich to a labor-scarce economy with lower birthrates coupled with aging population. The Population Reference Bureau notes:

- Total fertility rates are below the replacement level of 2.1 births per woman in 91 countries and territories, mostly in Asia and Europe, as well as in the United States.
- Western Europe and Southern Europe have the largest shares of people ages 65 years and older (21%), while sub-Saharan Africa has the smallest share (3%).

CUSTOMERS DEMAND CUSTOMIZATION AND RESPONSIVENESS
In addition to standard off-the-shelf products, there is a growing demand for customized products, which can be accomplished with new automation technologies more efficiently than manual production. This is happening in both discrete and process industries.

For example, the pharmaceutical industry is exploring and investing in precision medicine, used interchangeably with “personalized medicine” and “individualized” medicine, which is an approach focused on individual patient differences in genetics, environment, and lifestyle rather than "one-size-fits-all" drugs based on biomarkers and genetic variations. The drug development industry is betting heavily on personalized medicine, as leading life sciences companies have nearly doubled their investment in personalized medicines in the last five years, and expect an
additional 33% increase over the next five years. In 2009, one of the Grand Challenges for Engineering initiatives sponsored by National Academy of Engineering (NAE), personalized medicine was identified as a key and prospective approach to “achieve optimal individual health decisions,” therefore overcoming the challenge to “Engineer better medicines.”

SUSTAINABILITY AND RESOURCE EFFICIENCY

The socioeconomic value of sustainable and resource efficient manufacturing is widely understood as a major goal benefiting the environment, employees, and communities. Sustainable and resource efficient economically viable manufacturing operations can be achieved leveraging automation for nonpolluting production, highly efficient energy, and natural resource use.

"The industry environmental changes require manufacturers to aggressively digitize and automate."

REAL-TIME DYNAMIC SUPPLY CHAINS

As further highlighted by the supply chain disruptions related to the current COVID-19 pandemic, agility across manufacturing supply chains is essential. Automated digital synchronization with supply chains improves manufacturing efficiency, increases customer responsiveness, and lowers costs. This accomplishes real-time Lean manufacturing allowing all suppliers to operate more
efficiently. For example, process industries can optimize production based on changing raw material prices and quality.

Innovations include paperless systems, autonomous mobile robots and other forms of robotics, machine learning and artificial intelligence (AI), and better digital data to support an end-to-end supply chain involving multiple tiers of a company’s supply chain. Goals include real-time balancing and optimization of supply orders and demand including unexpected changes.

TECHNOLOGY ACCELERATION PROVIDES MANUFACTURING OPPORTUNITIES

Technology continues to accelerate in all parts of the economy from smart personal devices to autonomous vehicles. This is resulting in continually growing computing power at lower cost, more powerful software, and a wide range of accurate and low-cost sensors including vision, sound, and movement. There is essentially no difference between the ruggedness and reliability of consumer, vehicle, and industrial electronics. In addition, these applications have spawned a wide range of new innovative sensors.

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Real-Time Manufacturing Business: Digital Integration

Manufacturing digitalization is about becoming a more effective, holistic, and competitive business. The foundations of manufacturing and production are being reshaped by their integration into a comprehensive real-time business system, creating more efficient and responsive production to increase sales and profits.

Manufacturing and production in most organizations have been loosely coupled to the rest of the company's business systems, resulting in inefficiencies, lost opportunities, and poor decision-making.

Business systems, and particularly enterprise resource planning (ERP), were not synchronized in real time, but simply created work orders and inventory releases sent on paper or electronically to initiate production operations. The manufacturing business was blind to what happened in production until later when plant information was fed back into the system, the so-called "backflush." This has changed with business systems executing and processing real-time transactions to satisfy the needs of modern supply chain and customer-facing system requirements to be responsive in the Internet era.
TREND 1. Digitalization Driving Manufacturing to New Heights

Manufacturing execution systems (MES) have been used out of necessity to gain plant visibility, but complicate systems duplicating operating models in the business system, receiving work orders and inventory releases to run production in real time. This additional layer contributes higher support cost with lower reliability and availability.

The shift to real-time manufacturing business enterprise architecture is a fundamental building block for manufacturing digital transformation.

Real-time digitalization provides unified, accurate, and timely data for decisions across the entire business, knocking down silos. Data transparency throughout the organization provides the basis for better decision-making and accurately informed personnel, leading to winning behaviors.

DIGITAL MANUFACTURING ORGANIZATIONAL INTEGRATION

Accomplishing digital manufacturing successfully to achieve the benefits requires functional integration of information technology (IT), operations technology (OT), production, and automation groups collaborating to create flexible and synchronized manufacturing. The term “siloed departments” is used a great deal but is imprecise. Collaboratively leveraging deep knowledge and expertise embedded in silos unleashes new thinking, innovation, and new results. Each organization needs to find the best way for their teams to achieve the goal of efficient and profitable production. Stakeholder groups including engineering, IT, OT, purchasing, quality, manufacturing operations, and automation should work collaboratively to achieve the benefits of digitalization. Major digitalization goals include a shared focus on delivering improved safety, reliability, and a better customer and employee experience throughout the digital space.

Successful organizations share a passion for creating something new and are eager to be pioneers and try new things, creating stronger reliability, better quality, increased production, greater profitability, improved safety, manufacturing flexibility, informed decision-making, and enhanced overall competitiveness as a business. This was succinctly described in a presentation at the 2019 ARC Orlando conference:

Manufacturing digitalization is about becoming a more effective, holistic, and competitive business.
We are really focused on being a real-time company, using and leveraging the data we have to drive better decisions, be a more sustainable company, and a favored company.

—Melanie Kalmar, Dow Corporation

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Worldwide Industry 4.0 Initiatives

The impact of open manufacturing initiatives continues to advance worldwide as countries and industry recognize the need to modernize, while the Industry 4.0 movement continues to accelerate. This has defined a model for all industrial manufacturing organizations to use to achieve the goal of holistic and adaptive automation system architectures. Sustained competitiveness and flexibility to dynamic technological growth can only be accomplished by leveraging these advanced technologies, using automation as a center to enable a successful transition. Germany's Industry 4.0 initiative ignited worldwide cooperative efforts in other countries, including China, Japan, Mexico, India, and Indonesia. Asian economies have been active in taking advantage of these new initiatives. This is a familiar pattern characterized by Japan’s post-World War II record period of economic growth in significant market share gains in several markets including automotive, television, and electronics.

ITALY INDUSTRIA 4.0 NATIONAL PLAN

In February 2017, the Italian Ministry of Economic Development launched the Industria 4.0 National Plan (I4.0). The new strategy puts in place horizontal measures accessible for all enterprises with an objective to boost the investment in new technologies, research and development, and revitalize the competitiveness of Italian companies. The plan provides a wide array of measures...
TREND 3. Worldwide Industry 4.0 Initiatives

in the short, medium, and long term with strategic measures focused on innovation, competitiveness, and skills development. Complementary measures are put in place supporting efforts of Industria 4.0 in different areas. Altogether, the government has earmarked €18 billion for the initiative.

Germany’s Industry 4.0 ignited worldwide cooperation including China, Japan, Mexico, India, and Indonesia.

MADE IN CHINA 2025
Released in 2015, Made in China 2025 is the government’s 10-year plan to update China’s manufacturing base by rapidly developing 10 high-tech industries with the goal of transforming China into a “manufacturing superpower.” Goals include developing electric cars and other new energy vehicles, next-generation information technology (IT), telecommunications, advanced robotics, artificial intelligence (AI), agricultural technology, aerospace engineering, new synthetic materials, advanced electrical equipment, biomedicine, high-end rail, and high-tech maritime engineering. Chinese policymakers drew inspiration from the German government’s Industry 4.0 development plan. The overall goal is to reduce China’s dependence on foreign technology and promote Chinese high-tech manufacturers in the global marketplace. China 2025 has set specific targets: By 2025, China aims to achieve 70% self-sufficiency in high-tech industries, and by 2049 — the hundredth anniversary of the People’s Republic of China — it seeks a dominant position in global markets.

MAKE IN INDIA
Make in India covers 25 sectors of the Indian economy and was launched by the Government of India to encourage companies to manufacture their products in India with dedicated investments into the country’s manufacturing industry. The Make in India initiative has been providing support for both small and large companies to develop advanced manufacturing capabilities and invest in technology upgrades. There is also a focus on infrastructure modernization as part of this effort including smart cities. In addition to creating jobs, these initiatives are appealing to a new generation of workers with different values and skills.

JAPAN SOCIETY 5.0
Boldly identified as “Society 5.0,” Japan describes its initiative as a purposeful effort to create a new social contract and economic model, which fully incorporates the technological innovations.
of the fourth industrial revolution. It envisions embedding these innovations into every corner of its aging society. Underpinning this effort is a mandate for sustainability, bound tightly to the new United Nations global goals, the Sustainable Development Goals (SDGs). Japan wants to create, in its own words, a “super-smart” society, and one that will serve as a roadmap for the rest of the world. With Society 5.0, the Japanese government and companies are working together to put developments in technology, especially in AI and automation, at the service of improving human society and evolving civilization.

INDUSTRY 4.0 IN MEXICO

The Mexico future manufacturing journey is described in Crafting the Future: A Roadmap for Industry 4.0 in Mexico. It is widely known that Mexico is a world-class manufacturing hub with 50% of exports being manufactured products including a large portion of highly sophisticated technologies. In fact, more than 80% of high-tech exports in Latin America are produced in Mexico. S. E. Rogelio Granguillhome, the Mexican ambassador to Germany said, “Just like Germany, Mexico finds itself in the middle of the industry 4.0 era in which the talent of our people and the use of cutting-edge technology will transform Mexico into an innovation, research, and development center.”

MAKING INDONESIA 4.0

The country launched the initiative “Making Indonesia 4.0” to revitalize manufacturing with the introduction of Industrie 4.0 concepts. Indonesia is the world’s largest island state, comprising some 17,500 islands on an area of 1.9 million square kilometers. The largest and most famous islands are Java, Sumatra, and Sulawesi. With a population of 260 million, Indonesia is the world’s fourth most populous nation. The metropolitan region of the nation’s capital, Jakarta, is home to around 30 million people. The population of Indonesia is young, with an average age of around 30 years.

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Digital Manufacturing Architecture Provides Visibility

Digital manufacturing architecture (DMA) is coming into focus driven by the need for an integrated, responsive, and efficient real-time manufacturing business from enterprise to the farthest end of manufacturing and production: sensing and control devices.

Enterprise systems have been continuing to absorb plant floor computing through efforts to achieve real-time synchronization and accelerate the continued integration of information technology (IT) and operational technology (OT) groups. Completing this task, manufacturing digitalization is transitioning to a highly integrated architecture.

The new architecture provides immediate visibility throughout the entire manufacturing and production enterprise to all stakeholders including supply chain and customers (see Figure 1).

The most effective manufacturing and production architecture requires the orchestration and optimization of all the elements including supply chain and customer requirements for flexibility. Even before the COVID-19 pandemic, supply chains have been a challenge with varying costs and availability, and it is critical to balance all the factors of production for the best possible outcomes. Factors include customer demand, variable input costs, supply
TREND 4. Digital Manufacturing Architecture Provides Visibility

Digital manufacturing architecture
- **Realtime**
- **Synchronized**
- **Optimized**

**Figure 1:** Digital manufacturing architecture (DMA) optimizes and synchronizes internal and external production resources in real time based on changing parameters.

chain delays, and customer-facing system requirements to be responsive in the Internet era.

The new emerging DMA leverages advances in distributed computing and open systems to achieve synchronized real-time optimized production that adapts to external changes including supply chain, customer needs, energy, and sustainability requirements.

The core of the business system based on customer orders and supply chain factors direct factory operations are fed into the digital twin, which is an ideal operating model of plant and process (see Figure 2). The application of analytics, artificial intelligence, and machine learning optimize operations. Real-time linkages throughout the system create a real-time closed-loop operation with constant feedback used to adjust and optimize production.

**Enterprise systems absorb plant floor computing achieving real-time manufacturing business synchronization.**

**DISTRIBUTED DIGITAL MANUFACTURING ARCHITECTURE**

The DMA integrates the entire business, applying the latest distributed computing advances to achieve flexible real-time synchronized and optimized closed loop operations of IT and Operational Technology OT groups.

The new hybrid computing architecture distributes applications to the most logical locations in production and manufacturing. This distributed system includes applications on embedded processors in sensors, actuator, bar code readers, cameras, and other field devices for local control and optimization with the ability to access and use remote computing resources for complex calculations and tuning.
TREND 4. Digital Manufacturing Architecture Provides Visibility

The core of the business system based on customer orders and supply chain factors directs factory operations. These orders are fed into the digital twin, which is an ideal operating model of plant and process. Internal algorithms based on digital twin, analytic, and artificial intelligence (AI) host analysis.

 Appropriately distributed applications reside in the cloud, on premise enterprise servers, industrial edge computers, and intelligent sensors/actuators that communicate and coordinate actions, achieving a single cohesive system. This is accomplished with the application of proven technologies used broadly in high volume applications including the Internet of Things (IoT), autonomous vehicles, and personal devices. The building blocks include cloud computing, hybrid architectures, AI, machine learning (ML), image processing/recognition, simulation, and sensor advances.

Hybrid computing architecture distributes applications to the most logical locations in manufacturing.

Based on open standards, the new architecture is flexible and scalable, and facilitates upgrading components without affecting the overall system. Advantages include:

- **Fault Tolerance**: distributing computing to the lowest logical level provides greater fault tolerance.
- **Low Latency**: distributed computing to the lowest logical level ensures control, calculations, and optimization is done closest to the point of use providing real-time response.
The manufacturing industry recognizes the lessons learned by the computer industry years ago that multivendor distributed system architecture relies on open standards and certifications. For example, the Internet would simply not function without open standards.

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Open Architecture “Use Cases” — the Next Frontier
Open Standards: Essential for Innovation

Open standards are essential for effective manufacturing business digitalization, which has been proven in the information technology (IT) and commercial computing industry. Several organizations are driving forward to provide roadmaps, models, and standards for manufacturing digitalization. The influence of the IT, Internet of Things (IoT), and computing industry is leading to a great deal of collaboration among these groups. Key ones are listed below.

Multi-vendor open standards foster a broad selection of products and vendors for end users to choose from, and this competition is what drives innovation. Application developers can take advantage of the levels of compatibility afforded by the standards, which, in turn, helps developers create new applications that might not have been previously possible.

The shared investment and creative talent from many companies designing to shared open standards is much larger and stronger than any single supplier. The most obvious examples are the open Internet standards, which are the cornerstone of the Internet’s success. They enable its existence, facilitate its growth, and provide a platform that supports creativity, benefiting all users.

Open standards are emerging all over the world to target many specific needs. Here are the ones influencing OT application development.
Open standards leverage the investment and creative talent from many companies and users.

OPC FOUNDATION

OPC Foundation has interoperability standards for secure and reliable data exchange in the industrial automation space and in other industries becoming widely adopted by IT, operational technology (OT), and cloud suppliers for building the distributed industrial manufacturing architecture. It is platform-independent and ensures the seamless flow of information among devices from multiple vendors. OPC’s most recent projects include:

Field level communications (FLC). The FLC Initiative goal is to deliver an open, cohesive approach to implement OPC UA in field devices using harmonization and standardized application profiles including sensor input/output (I/O), motion control, safety, system redundancy, standardization of OPC UA information models for field level devices in online and offline scenarios (e.g., device description resp. diagnostics), and mapping of OPC UA application profiles related to real-time operations on Ethernet networks including TSN. A major goal is vendor-independent end-to-end interoperability into field level devices for all relevant industry automation use cases.

Companion specifications. OPC UA has been designed for scalability and supports a wide range of application domains, ranging from field level (e.g., devices for measurement or identification, programmable logic controllers [PLCs]), to enterprise management support with Companion Specifications. These Companion Specifications are created by a wide range of industry groups focused on applications that simplify engineering and provide a common semantic model for multivendor interoperability. OPC Foundation has three ways Companion Specifications can be created:

- Internal: These are models created by OPC internal working groups. They are associated with the Unified Architecture specification.
- Joint: These are models created in a joint working group between the OPC Foundation and another organization. These joint specifications represent the majority. The released joint companion specifications can be found here. The Joint working group program is defined here.
- External: Companion specifications can also be created independent of the OPC Foundation.
- To support creating companion specifications, the OPC Foundation created a template. It is available for download here.

Several companion specifications have already been created.
INDUSTRY 4.0 FOR PROCESS
An effort focusing on the application of Industry 4.0 concepts to improve process automation is being driven by NAMUR, ZVEI, VDI, VDMA, and ProcessNet.

The Industry 4.0 for Process effort describes smart networked sensors as a foundational part of the Industry 4.0 process architecture. These sensors communicate with controls and automation systems simultaneously, and directly with business systems. This effort, the application of Industry 4.0 concepts to improve process automation, is being driven by NAMUR and VDI/VDE in collaboration with several prominent leaders in the industry, including ABB, BASF, Bayer Technology Services, Bilfinger Maintenance, Endress+Hauser, Evonik, Festo, Krohne, Lanxess, Siemens, and Fraunhofer ICT. The concepts are expressed in NAMUR’s Process Sensor 4.0 Roadmap, which describes smart networked sensors as a foundational part of the Industry 4.0 process architecture.

RAMI 4.0 REFERENCE ARCHITECTURAL MODEL
The RAMI 4.0 Reference Architectural Model provides companies a framework for developing future products and business models. RAMI 4.0 is designed as a three-dimensional map showing these companies how to approach the deployment of Industry 4.0 in a structured manner. A major goal of RAMI 4.0 is to make sure all participants involved in Industry 4.0 discussions and activities have a common framework with which to understand each other. The RAMI 4.0 framework is intended to enable standards to be
identified to determine whether there is any need for additions and amendments. This model is complemented by the Industry 4.0 components. Both results are described in DIN SPEC 91345 (Reference Architecture Model Industrie 4.0). DIN represents German interests within the International Organization for Standardization (ISO). Today, roughly 85% of all national standard projects are European or international in origin.

Putting the RAMI 4.0 model in perspective, in the glossary of the VDI/VDE-GMA 7.21 Industrie 4.0 technical committee, a reference model is defined as a model that can be generally applied and can be used to derive specific models. There are many examples of this in technology. The most well-known is the seven-layer ISO/OSI model, which is used as a reference model for network protocols. The advantage of using such models is a shared understanding of the function of every layer/element and the defined interfaces between the layers.

THE OPEN GROUP, THE OPEN PROCESS AUTOMATION FORUM

The Open Group’s Open Process Automation Forum (OPAF), formally launched November 2016, continues to advance since it published the first standard in a series. OPAF is focused on developing a multivendor standards-based, open, secure, and interoperable process control architecture. The Open Group has a track record of success in this area with the FACE standard. This standard has led to the deployment of higher functioning software designed to lower lifecycle costs. The defense avionics industry is a prime example of one that has transitioned from a proprietary solution to a fully open systems architecture. OPAS Striving for Architecture — Digital automation architecture synchronizes entire manufacturing business for profits.

ECLIPSE FOUNDATION

Founded in 2001, the Eclipse Foundation has several projects related to industrial manufacturing digitalization. The Eclipse Foundation fosters and supports open-source software collaboration and innovation and is home to the Eclipse IDE and more than 350 open-source projects including runtimes, tools, and frameworks for a wide range of technology domains such as the Internet of Things, industrial, automotive, geospatial, systems engineering, and many others. Manufacturing industry projects include:

Eclipse BaSyx. The Eclipse BaSyx project is the open source result of the German research project BaSys 4.0, which is funded by the Ministry for Education and Research (grant no. 01IS16022). Eclipse BaSyx is the open-source platform for next-generation automation. Providing common Industry 4.0 components and an extendable software development kit (SDK), the platform accelerates the development of Industry 4.0 solutions. The Eclipse BaSyx platform addresses challenges like changeable production...
TREND 5. Open Standards: Essential for Innovation

to enable individualized goods, exploiting Big Data analytics and connecting heterogenous devices and systems, while minimizing downtime and other associated costs. Eclipse BaSyx realizes the following technologies implementing central pillars of Industry 4.0 production architectures:

- **Virtual automation bus** enables cross-network and cross-protocol peer-to-peer communication between manufacturing machines (shop floor) and IT.

- **Asset administration shells** are digital representatives of production assets, i.e., their digital twins. These assets may be physical or non-physical in nature. The asset administration shell of an asset contains sub-models providing, for example, its interface as well as status and live data.

- **Control components** realize uniform service interfaces for devices. They separate the implementation of production services from the production processes and make the production changeable. Control components also realize more abstract services, which abstract from the details of the implementation, and are therefore easier to use. Control components are realized by means of run-time environments.

*Eclipse 4diac* is an open-source project fostering the further development of IEC 61499 for its use in distributed industrial process measurement and control systems (IPMCS) and further distribute research results from the original contributors. From the beginning, it provided everything necessary to program and execute distributed IPMCS. 4diac became one of the main sources for IEC 61499-based research and development (see for example
TREND 5. Open Standards: Essential for Innovation

the 4diac Users’ Workshop series). It has been successfully applied in several industrial systems, including manufacturing systems, logistics, power and energy applications, robotics, and building automation.

**Sparkplug.** Sparkplug is an open-source software specification that provides message queuing telemetry transport (MQTT) clients the framework to seamlessly integrate data from their applications, sensors, devices, and gateways within the MQTT Infrastructure. Sparkplug provides an open and freely available specification for how edge of network (EoN) gateways or native MQTT-enabled end devices and MQTT applications communicate bidirectionally within an MQTT infrastructure.

**Eclipse Milo.** The Eclipse Milo project provides all the tools necessary to implement OPC Unified Architecture (UA) client and/or server functionality in any JVM-based project.

- A stack implementation, compatible with the latest version (1.03) of the UA specifications.
- An SDK built on the stack that enables development of compliant UA client and server applications.
- Licenses: Eclipse Distribution License 1.0 (BSD) and Eclipse Public License 1.0.

**EDGEXFOUNDRY**

The Linux Foundation’s Edgex Foundry is a vendor-neutral, open-source project that provides a common open framework for IoT edge computing and an ecosystem of interoperable components that unifies the marketplace and accelerates enterprise and industrial IoT. The project is aligned around a common goal: The simplification and standardization of industrial IoT edge computing, while allowing the ecosystem to add significant value. Edgex Foundry leverages cloud-native principles including microservices and platform independence but is architected to meet specific needs of the IoT edge. This includes accommodating both IP- and non-IP-based connectivity protocols, security, and system management for widely distributed compute nodes, and scaling down to highly constrained devices.

Edgex Foundry has gone through rapid refinement as illustrated by the reduction of computer resources from the initial 2.5 GB to 128 MB memory requirement suitable for embedding in sensors and control devices.

**ALLOTROPE FOUNDATION**

Founded in 2012, Allotrope Foundation is an international consortium of pharmaceutical, biopharmaceutical, and other scientific research-intensive industries developing advanced data architecture to transform the acquisition, exchange, and management of laboratory data throughout its complete lifecycle.
TREND 5. Open Standards: Essential for Innovation

Its first initiative is the development of the Allotrope Framework for analytical data, consisting of a standard data format, class libraries for interfacing with applications, and semantic capabilities to support standardized, structured metadata.

Allotrope aims to make the intelligent analytical laboratory a reality — an automated laboratory where data, methods, and hardware components are seamlessly shared among disparate platforms, where one-click reports can be produced based on data generated by any analytical instrument, and where data integrity is built-in. Allotrope’s vision of an intelligent analytical laboratory will be realized through the creation of an “ecosystem” in collaboration and consultation with vendors and the scientific community. Our shared mission is to develop new approaches to improve data access, interoperability, and data integrity through standardization, which ultimately serves as a key enabler of data-driven innovation.

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RAMI 4.0 Reference Architectural Model for Industrie 4.0

EdgeX Foundry and the Quest for Multivendor Interoperability

EdgeX Foundry IoT, IIoT, and Industry 4.0 unifying architecture

Inside Dell’s Ongoing Quest for Digitalization Acceleration
IP Communications: Enterprise to Field Devices

The Internet protocol (IP) is the core of communications now being standardized for sensors and other field devices. Today IP-based networks supporting industrial and building automation leverage the advantages of Ethernet infrastructure products produced in high volume, lower hardware costs, software, and support. Efficiently driving the IP to industrial edge devices — including sensors, actuators, vision, robots, controllers, contactors, and drives enables industrial automation to leverage the wave of new Internet of Things (IoT) technologies and standards. This also enables the growing number of smart sensors with embedded processors that incorporate asset management, analytics, predictive maintenance, and control functions to efficiently communicate.

The IP is the principal communications protocol for relaying datagrams across network boundaries. IP defines packet structures that encapsulate the data to be delivered. It also defines addressing methods used to label the datagram with source and destination information.

SINGLE-PAIR ETHERNET

10BASE-T1 single-pair Ethernet (SPE) is an exciting development enabling seamless Ethernet connectivity from sensor to enterprise, connecting the IoT universe. 10BASE-T1 is a new 10 Mbps single-pair Ethernet physical layer network technology under the IEEE 802.3cg
specification focused on automotive and industrial applications. It lowers cost, weight, cable diameter, and connector size using the Internet Protocol. SPE data transport consistent with worldwide standard IP communications will accelerate this trend.

The 10BASE-T1S part of the specifications provides collision-free, deterministic Ethernet-based transmission over a multi-drop network without Ethernet switches, which means even greater total installed cost savings. 10BASE-T1S implemented without switches requires fewer cables and less power. Multidrop technology already has been providing installed cost advantages when using existing automation networks, including Modbus, DeviceNet, Profibus, and CANopen. That can now be accomplished with SPE using standard IP communications.

The Power over DataLines (PoDL) feature of the specifications provide a way to power remote devices. The specification allows for 12-, 24-, and 48-volt operation; 12 volts is convenient for battery-powered and mobile applications, while 24 volt is a common voltage for control panels and controllers.

ADVANCED PHYSICAL LAYER

Single-pair Ethernet is the basis for the advanced physical layer (APL) being developed to bring Ethernet to field-level instruments in hazardous areas. Ethernet at the field level will make digitalization for process industries a reality with its universality and speed. Current and voltage will be limited to have an intrinsically safe solution for Zones 0 and 1/Div. 1. The main goal is to adopt proven technologies and options in the process automation field. The general topology will be based on the well-known trunk-and-spur configuration.

Incorporating Internet protocol (IP) in edge devices including sensors, actuators, vision, robots, controllers, contactors, and drives enables industrial automation to leverage Internet of Things (IoT) technologies and standards.

The FieldComm Group, ODVA, Profibus, and Profinet International joined to support the standardization of an APL suitable for use in demanding process instrumentation applications. This initiative leverages the work of the IEEE 802.3cg Task Force, including amendments to the IEEE 802.3 Ethernet standard for an Ethernet physical layer operating at 10 Mb/s over single-pair cable with power
TREND 6. IP Communications: Enterprise to Field Devices

delivery. Additional developments define the requirements and develop the necessary technology to achieve an industrial Ethernet suitable for use in hazardous locations up to Zone 0, Div. 1.

TIME-SENSITIVE NETWORKING

There is a great deal of discussion and development around time-sensitive networking (TSN) that some believe will become the unifying deterministic network shared by all applications throughout the computer industry. Since TSN is a totally managed shared network architecture, all network traffic including all industrial protocols in the plant would need to conform and be compliant with the TSN set of standards to achieve deterministic and reliable communications. Based on interviews and discussions I’ve had with people involved in the IEEE committees, they report the entire standard will be completed in a few years. In addition, the standard requires new TSN Ethernet switches and routers.

TSN is a set of standards under development by the Time-Sensitive Networking Task Group of the IEEE 802.1 working group for highly deterministic synchronized networking. The TSN Task Group was formed in November 2012 by renaming the existing Audio Video Bridging Task Group and continuing its work. The standards define mechanisms for the time-sensitive transmission of data over deterministic Ethernet networks.
Creating a practical multivendor TSN architecture has challenges and adds new layers of complexity for industrial Ethernet networking. Network timing has been tightly coupled to network configuration and management. One such network, in my experience, was the Allen-Bradley, ControlNet network, which is no longer a commercial product. This was a tightly time-scheduled prioritized communications and managed network dedicated to industrial control and monitoring with the goal of high speed deterministic communication. While complex, the scope of the issue was dedicated to industrial automation applications, with one set of software and controllers from a single vendor, Allen-Bradley. In contrast, TSN is seen as a common multivendor shared network for multimode communication for general computing, voice-over-IP (VoIP), professional audio, video, file transfer, industrial automation, building automation, and any other data communication.

To take advantage of TSN time scheduling, it would seem that control programming software and controller firmware will have to be redesigned to accommodate the definition of input/output (I/O) points and variable timing specifications.

Since the goal is to support multiple industrial network protocols along with data multimedia applications, this will require an industry-wide shared network manager and an application programming interface (API) standard to which all vendors need to conform. Yet, when asking multiple people about standardization in this area, it is clear there is no open defined standard and certainly no identified certification group on the horizon.

Several industry groups are working toward resolving issues to have an open standard.

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TSN (Time Sensitive Networking): Lack of timing mechanism remains an elephant in the room.

802.3CG Overview 10 MB/S single-pair Ethernet
5G Wireless Communications: High Expectations

The idea of wireless industrial automation has long been an elusive goal on the wish list of many users but may become more mainstream with 5G communications that delivers higher performance and determinism. 5G may well be the ideal wireless industrial automation networking mechanism, and companies are installing private 5G networks in manufacturing plants.

5G technology is ramping up to high-volume production for consumer, commercial, and Internet of Things (IoT) applications that will increase capabilities and lower costs. This is the same phenomena that created the compelling case for standard Ethernet to be adopted for industrial communications networks (i.e., Modbus TCP/IP, EtherNet/IP, Profinet, EtherCAT). Another factor is IoT devices are extremely rugged, inherently meeting industrial automation requirements off-the-shelf.

Expectations are running high for the potential of 5G wireless communication for industrial applications. 5G makes monitoring and control of a broader range of devices practical, such as using the connected screwdriver and nut runner to automatically control torque as well as communicate data quality, track and trace, and productivity data. 5G technology is being deployed by mobile
TREND 7. 5G Wireless Communications: High Expectations

operator networks and private networks with applications in industrial IoT, enterprise networking, and critical communications.

High performance and deterministic wireless industrial automation may become mainstream with 5G.

MANUFACTURING BENEFITS

The 5G and technology offer benefits for manufacturing and wireless communications in production plants including control and automation for a wide range of applications including:

- Sensors and actuators
- Automated guided vehicles
- Augmented reality devices
- Wireless tooling
- Video cameras (defect detection, auto ID reading, track and trace, etc.)
- Remote expert audio/video devices.

Companies are already starting to deploy private 5G networks within plants and are seeing increases in performance, determinism, low latency, and reliability.

At the 2018 Hannover Messe, Beckhoff and Huawei demonstrated high-speed and deterministic coordinated motion over 5G wireless communications at that was convincing.

There are three major benefits of 5G networks, according to IEEE:

- High data rates (1-20 Gbit/s)
- Low latency (1 ms)
- Larger network capacity and scalability.

Awareness and acceptance are high as indicated in a survey by Morning Consult on behalf of Verizon; more than 700 business technology decision makers responded.

- Thirty nine percent of C-Level executives ranked 5G a top priority.
- Forty nine percent of manufacturing respondents ranked 5G important for supporting automation.
More than 82% of manufacturing respondents consider real-time supply chain and production tracking a valuable use case.

More than 60% of manufacturing respondents consider autonomous guided vehicles (AVGs) a valuable use case.

There are many working to support the growth of 5G wireless in industrial organizations. The 5G Alliance for Connected Industries and Automation (5G-ACIA) serves as the central and global forum for addressing, discussing, and evaluating relevant technical, regulatory, and business aspects with respect to 5G for the industrial domain. The 5G Alliance notes that one of the main differences between 5G and previous generations of cellular networks lies in 5G’s strong focus on machine-type communication and IoT. The capabilities of 5G thus extend far beyond mobile broadband with ever-increasing data rates. 5G supports communication with reliability and extremely low latencies, while facilitating massive IoT connectivity.

5G-ACIA says manufacturing may see 5G having a disruptive impact as related building blocks such as wireless connectivity, edge computing, or network slicing find their way into future smart factories. The organization has published a whitepaper, 5G for Connected Industries and Automation, which provides an overview of 5G’s basic potential for connected industries, in particular, the manufacturing and process industries, and outline relevant use cases, requirements, and other information.

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Edge Computing: Processing at Nodes and Field Devices

Distributed manufacturing architecture (DMA) requires processing at manufacturing processes to achieve performance, simplify system architecture, and ensure high reliability and availability. Processing in edge computers and CPUs embedded in field devices including, sensors, actuators, motor controls, bar code readers, cameras, and other field devices host local control and optimization with the ability to access and use remote computing resources for complex calculations and tuning internal algorithms based on digital twin, analytics, and artificial intelligence (AI) host analysis. These edge CPUs run standard operating software platforms to take advantage of a wide range of multivendor applications.

Edge computing is a growing trend. As noted by Gartner, What Edge Computing Means for Infrastructure and Operations Leaders predicts 75% of data will be created and processed outside traditional centralized data centers or the cloud by 2025.

EDGE COMPUTERS

The growing trend is to use industrial edge computers as a preferred platform in place of programmable logic controller (PLC) and distributed control system (DCS) controllers as a fundamental building block to efficiently digitize and integrate the entire
managing business from enterprise to sensors and actuators. Industrial automation is the only industry that still uses dedicated proprietary computers, PLCs, and DCS controllers, rather than standard computing platforms at the edge of systems for local control, optimization, analytics, and data refinement.

FIELD DEVICES
System-on-Chip (SoC) technology makes immediate processing in field devices practical since they are being used in high volume, driving costs down and increasing power. The SoC is an integrated circuit (IC), which includes various electronic parts such as a central processing unit (CPU), input and output ports (I/O ports), internal memory, analog input, output blocks, and in many Ethernet, Wi-Fi, Bluetooth, and other communications.

The NAMUR Industry 4.0 for Process and other initiatives envision how the distributed control across field devices performing in-situ control, optimization, and diagnostics. These field devices also communicate non-control operations data (i.e., quality, production efficiency asset monitoring, etc.) directly to enterprise and cloud systems.

“CPUs embedded in field devices host local control and optimization on standard operating software platforms to take advantage of a wide range of multivendor hardware and applications."

AI CHIPS
An exciting development are inference chips that execute AI, machine learning (ML), and other sophisticated applications in parallel with multiple processors at high speed. Server and cloud, AI, and ML solutions are suitable for a wide range of applications but compute costs, network communication speed, and latency factors pose limitations for many real-time industrial and process applications. This new class of inference chips bring the computing right into edge devices. There are a number of these being manufactured today including Hailo, Nvidia, Intel Myriad-X, and Google Edge TPU. The high-volume application driving the price of these down is image processing and recognition, particularly for security systems. The chips are already available on industry-standard add-on modules using the M.2 and mPCIe connector standards found in many computers including embedded industrial PCs at single piece prizes under $90 U.S. Applications possibilities include optimization of production,
TREND 8. Edge Computing: Processing at Nodes and Field Devices

Processes, track and trace, logistics, quality, machine functions, and predictive maintenance by eliminating inherent limitations of server and cloud solutions with processing at the edge.

HYBRID CLOUD

Cloud providers have added hybrid cloud software to run on standard platforms onsite for high performance and reliability, providing greater flexibility. This is ideal for digital manufacturing systems. For example, AI and ML applications running at the enterprise or cloud build models downloaded to the edge processing running these applications in real time with no dependency on network latency and availability. As the physical controlled and optimized process changes, this feedback is sent back to the models, which recalculate an update in the real-time edge model.

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Modular Design for System Flexibility

Open standard modular design is a growing trend to empower subject matter experts to concentrate on manufacturing and production to achieve objectives rather than low-level engineering and programming tasks.

Modular design subdivides a system into modular functional components with embedded control, automation, and defined behaviors and interfaces. For example, skid subsystems using defined open interfaces can be independently created, modified, replaced, or exchanged with other modules or between different systems, making use of industry standards for interfaces, which ensures interoperability. Modular system design elements can be upgraded multiple times during a system’s lifetime without purchasing a completely new system, improving cost or operation.

The modular design principle subdivides a system into smaller parts called modules (such as modular process skids), which can be independently created, modified, replaced, or exchanged with other modules or between different systems.

MODULE TYPE PACKAGE

The module type package (MTP) is a key concept for standardized nonproprietary description of modules for process automation. The structure of modular plants described is in many ways a recasting of ISA88 and ISA95, with automation using plug-and-
produce models that are vendor-independent descriptions of the information needed to integrate modules. For this, the data generated during the engineering of a module are provided by the module manufacturer in an XML-file called a “module type package.” The MTP includes many attributes including alarm management, safety and security, process control, human-machine interface (HMI), and maintenance diagnostics.

This modular production initiative, started in addition to the Industry 4.0 for Process effort, addresses common complaints users have, where vendors deliver various pieces of equipment that do not directly and intelligently communicate with control, automation, asset management, and business systems.

This also lowers the dependency of users on the uniqueness of unique vendors' interfaces and lock-in. Industry is moving toward modular use-case defined models for equipment and processes to achieve a wide range of benefits including:

- Modularity
- Design efficiency
- Installation, commissioning, and startup efficiency
- Standardized and reliable data
- Interoperability
- Higher reliability and quality.

"Modular system elements can be upgraded multiple times during their lifetime without the purchase of a completely new system, improving cost or operation."

**BIOPHORUM**

The [BioPhorum](https://www.bpforum.com) MTP standard initiative is a great example of a modular standard applied to pharmaceutical production use cases. Users and vendors collaborated moving toward the goal of achieving plug-and-play equipment interoperability for the biopharmaceutical and other industries.

BioPhorum's vision is to develop the guidelines for MTP files to be used with modular equipment commonly found in biopharmaceutical processing. Achieving plug-and-play dramatically reduces engineering labor, lowers project execution time, and increases quality. At the heart of plug-and-play is the VDI/VDE/NAMUR 2658 standard that defines the MTP. The
TREND 9. Modular Design for System Flexibility

Objective of BioPhorum’s plug-and-play concept is to effortlessly integrate intelligent unit operations in the S88 procedural batch engine of the overlying supervisory automation system of a good manufacturing practice (GMP) compliant facility. OPC UA is used as the way to communicate MTP data between systems.

MTP also focuses on addressing common complaints users have when vendors deliver various pieces of equipment that do not directly and intelligently communicate with control, automation, asset management, and business systems requiring significant investment to integrate into plant operations. Today, the addition of hardware, software, and application engineering for interfaces to integrate these decreases system reliability and increases lifecycle maintenance cost.

PACKML USING ISA-88

PackML is an example of module design created by the Organization for Machine Automation and Control (OMAC) in conjunction with the International Society of Automation (ISA) using ISA-88 State Model concepts as an example of a modular design element, which is an industry technical standard for packaging machine control. PackML brings a common “look and feel” and operational consistency to all machines that make up a packing line. The standard PackML information model can be easily loaded into any OPC UA server TR88.00.02-2021.

Modularity offers benefits such as reduction in cost (customization can be limited to a portion of the system, rather than needing an overhaul of the entire system), interoperability, shorter learning time, and design flexibility.

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Joint forces between PLCopen, OPCF and the OMAC Packaging Workgroup facilitates a standardized and “off the shelf” PackTag data exchange via OPC UA

Digital Reference Architecture Principles for Data-Driven Pharma Factory

BioPhorum MTP Testing Plugfest
Programming Democratization and Empowerment

There are a growing number of applications that empower manufacturing professionals to create applications without writing code. This wave of change is being driven with concepts from smartphone application frameworks, social platforms (i.e., Facebook and LinkedIn), business applications (i.e., Salesforce, Shopify), and a growing list.

Software programming gurus have always been an inefficient way for users to create applications and get results. That is why vendors will be introducing more applications that allow control and operations people to configure systems and deploy applications without using a programming language. This is new to the industry, but hardly new to the world.

Decades ago, the spreadsheet was the first big development that allowed users to directly create analysis and applications without requiring a programmer, and it resulted in dramatically improved productivity. More recently, Facebook has been a great example of people creating webpages without ever programming. More relevantly, programmable logic controller (PLC) ladder logic was a significant productivity-enhancing tool that allowed people to directly create applications without computer programming.
New tools enable people who understand the processes and characteristics, directly improving productivity.

MORE KINDS OF EASY-TO-USE SOFTWARE

In manufacturing industries, there will be an acceleration of these kinds of easy-to-use software to create applications without programming, as they leverage Internet of Things (IoT) and other computer industry developments. At the forefront of these changes will be the integration of real-time industrial automation and control, product lifecycle management (PLM), CAD, and simulation enabling visual design, virtual commissioning, and direct deployment without procedural programming. This is a general trend in all software.

An example is several software offerings that provide manufacturing and production people with visual and intuitive tools, to use the vast amount of existing plant data to gain insight, optimize operations, and create predictive analytics without being a data scientist.

The most important knowledge in a plant are people in the company that understand the processes and characteristics, and new tools empower them to directly improve productivity, profitability, and competitiveness of manufacturers.
ANALYTICS

Digital manufacturing architecture (DMA) supports build-on open computing, which makes analytics possible including embedded in sensors, edge computers, enterprise, and cloud. The wide use of analytics throughout the computer industry has resulted in a wide range of open-source analytic tools and frameworks that are easily applied to manufacturing and production. This is accelerating the benefits of digitalization, simplifying integration, expanding the number of options available for applications, and making applications portable across vendor platforms.

In a recent KPMG survey, Thriving in an AI World, 93% of industrial manufacturing leaders are “bullish” on artificial intelligence (AI) adoption, say, “AI is moderately to fully functional at their organization, and wished their company would more aggressively adopt AI technology.” And 72% of industrial manufacturing business leaders say, “COVID-19 sped up the pace of AI adoption at their company.” The perceived value of AI was high: 27% Expected level of value; 40% Somewhat more value; and 16% Significantly more value.

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Cybersecurity Integration: Driving to the edge

IP communications from enterprise to field devices allow industrial plants to leverage the broadly used sophisticated information technology (IT) and Internet of Things (IoT) cybersecurity technologies. Manufacturing companies can deploy a holistic cybersecurity strategy for the entire manufacturing or production enterprise including supply chain and customers.

EMBEDDED CYBERSECURITY AT THE EDGE

IoT technology is starting to deploy cybersecurity at the fundamental root entry points for intruders, using powerful systems on a chip (SoC) embedded in edge devices. IoT applications are becoming pervasive including consumer, municipal, industrial, connected vehicles, connected health, smart farming, and smart supply chain, driving these developments. The introduction of cybersecurity SoC is an architectural improvement designed to address the broad scope of cybersecurity challenges. The key building blocks include cybersecurity functions and features embedded in SoC, incorporating microprocessors, communications, cyber encryption, cloud security services, secure update services, and other functions.

The goal is to incorporate this new breed of cybersecurity processors in IoT devices to implement more cybersecure systems and components, including programmable logic controllers (PLCs),
controllers, sensors, actuators, motor controls, and other intelligent devices.

Because the cybersecurity of Level 0,1 devices is not being addressed elsewhere, the ISA99, Industrial Automation and Control Systems Security committee has established a new task group to identify if Level 0,1 devices are adequately addressed in the existing IEC 62443 series of standards, particularly IEC 62443-4-2.

ISA99, Industrial Automation and Control Systems Security committee is addressing edge cybersecurity.

Some of the more prominent cybersecurity initiatives are described in the following sections.

"IP communications — enterprise to field devices — leverage sophisticated information technology (IT) and Internet of Things (IoT) cybersecurity technologies.

MICROSOFT AZURE SPHERE
The Microsoft Azure Sphere strategy includes a chip design, a cloud security service, and a Linux kernel with the goal of better securing billions of IoT devices around the world. In 2016, Microsoft announced it had co-designed a field programmable gate array (FPGA), to enhance the intelligence of its cloud servers. This was the first instance of a Microsoft-designed chip. Microsoft’s representatives at the 2018 Hannover Messe described how the Azure Sphere includes a microcontroller (MCU) design, which the company is licensing, royalty-free. Other features include:

- **The Microsoft hardware security module Pluton Security Subsystem** creates a hardware root of trust, stores private keys, and executes complex cryptographic operations to create secure devices.

- **A new crossover MCU** combines a Cortex-A processor with the Cortex-M class processor.

- **Built-in network connectivity** provides secured, online experiences and ensures devices are up to date.

The first Azure Sphere chip is the MediaTek MT3620, which incorporates Arm Cortex-A7, which Microsoft shared as the result of years of close collaboration and testing between MediaTek and Microsoft. Other early partners include Arm, who worked closely for the integration of Cortex-A application processors into Azure Sphere MCUs.
In October 2019, Qualcomm Technologies announced at its 5G Summit in Barcelona, Spain, it is developing the first cellular chip optimized and certified for Microsoft’s Azure Sphere IoT operating system. Qualcomm Technologies’ new Azure Sphere-certified chipset for IoT will include hardware-level security, come preconfigured with the Azure Sphere, and will automatically connect to Azure Sphere security cloud services.

**GOOGLE CLOUD IOT CORE**

The Google [Cloud IoT Core](https://cloud.google.com/iot-core) is a system designed for the management of connected IoT devices, like sensors, with Google’s cloud. The platform also serves as a pipeline for securely getting data to and from those devices. This effort has been enhanced through Google’s Partner ecosystem, which offers devices and kits that work with the Cloud IoT Core. These partners include: Allwinner Technology, Arm, Intel, Marvell, Microchip, Mongoose OS, NXP, Realtek, Sierra Wireless, and SOTEC. Microchip, specifically, provided a prime example of a Google chip partner delivering trusted and secure authentication with the ATECC608A chip.

**Video Resource:** [Google Cloud IoT Core Authentication Use Case](https://www.youtube.com/watch?v=dQw4w9WgXcQ)

**AMAZON FREERTOS**

Amazon is promoting the [Amazon FreeRTOS](https://aws.amazon.com/freertos), an IoT operating system for microcontrollers qualified through The Amazon FreeRTOS Qualification Program (Amazon FQP). Amazon FreeRTOS is open source, and it extends the FreeRTOS kernel, a real-time operating system for microcontrollers. The Amazon FQP outlines a set of security, functionality, and performance requirements that all microcontrollers (along with the associated hardware abstraction layers and drivers) must meet.

Amazon FreeRTOS has a large ecosystem of existing tools developed for the system. Amazon FreeRTOS includes software libraries designed to help users program the needed IoT capabilities into devices such as the configuration of devices to a local network using common connectivity options like Wi-Fi or Ethernet. Amazon FreeRTOS also includes an over-the-air (OTA) update feature to remotely update devices with feature enhancements or security
patches. To secure this operating system, the Amazon FreeRTOS comes with libraries to help secure device data and connections, including support for data encryption, key management, and transport layer security (TLS v1.2), which helps devices connect securely to the cloud. Partners today that fully support Amazon FreeRTOS features and capabilities include Espressif, Microchip, NXP Semiconductors, and STMicroelectronics.

**ARM PLATFORM SECURITY ARCHITECTURE**

ARM has a Platform Security Architecture (PSA) that includes Mbed’s Arm. TrustZone technology is an SoC and CPU system-wide approach to security. TrustZone is hardware-based security built into SoCs by semiconductor chip designers who want to provide secure end points and a device root of trust. The family of TrustZone technologies can be integrated into any Arm Cortex-A and the latest Cortex-M23 and Cortex-M33 based systems.

The Arm Mbed IoT Device Platform is made up of two sets of products: Device software and cloud-based device management services. These products are designed to securely move data from sensor to server. The Arm Mbed IoT Device Platform is a fully integrated device management solution. It provides the operating system, gateway, device management services, and partner ecosystem to speed adoption and deployment of IoT solutions. Further, the Arm Mbed IoT Platform provides connectivity and communication for constrained devices. Partner companies have enabled 6LoWPAN, Bluetooth low energy, Thread, LoRa, WiFi, NFC, RFID, Mobile IoT (LPWA), cellular, and Ethernet on Mbed. The Mbed IoT platform secures the device itself from untrusted or malicious code, the communications between device and cloud, and the lifecycle of the system itself using uVisor, Mbed TLS, and Mbed Client respectively.

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- Cybersecurity: Where Does the Reasoning Begin?
- Cybersecurity Strategy at Ford – IT & Automation Cooperation
Robotics Innovations Enable New Applications

The application of robotics is accelerating and, considered broadly includes large robots, collaborative robots, autonomous guided vehicles, and innovative combinations for production and material flow. Accelerating the application of collaborative-type robots is the integration of vision systems, image recognition, artificial intelligence, location awareness, and digital manufacturing system integration, which enables a wide range of new applications.

**Video:** Example innovative robotic application [https://youtu.be/l63CxPa-DYk](https://youtu.be/l63CxPa-DYk)

I am convinced collaborative robots, which can be programmed for maneuvers like playing a game, are the highest impact automation development to manufacturing. Furthermore, they are especially effective for small and medium manufacturing enterprises. Collaborative robots are a new breed of lightweight and inexpensive robots, with safety features that enable people to work cooperatively with these devices in a production environment. Collaborative robots can sense humans and other obstacles and respond by automatically stopping so they cause no harm or destruction. With these robots, protective fences and cages are not required and therefore in many cases, they can be applied with high flexibility and lower implementation costs. These robots are particularly attractive with high return on investment.
Robot adoption is accelerating worldwide as vision and artificial intelligence enable a wide range new of applications.

This breed of robots is following a similar pattern that ignited the personal computer revolution, providing a product with less power than larger offerings, but with added value for a broader number of users. The rate of robot adoption is accelerating throughout the world, particularly in China, which has become the largest purchaser of robots in the world.

For more trends on the global robotics market please visit IFR's website.

Video: FACTS about INDUSTRIAL ROBOTS: Robot Density worldwide
TREND 12. Robotics Innovations Enable New Applications

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IFR says robots will create more than two million jobs