AUTOMATION 2022 ANNUAL REPORT

AUGUST 2022

- Digital Manufacturing Architectures
- Industry 4.0, OPAF, Other Global Initiatives
- Transformative Technologies: 5G Wireless, OPC and More
- Megatrends: Sustainability, Supply Chain, Workforce Changes

7th Annual Industrial Automation & Control Trends Report

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Introduction

Ensuring Growth Through Digital Transformation

The manufacturing industry is at a tipping point providing the opportunity to pull ahead of competitors with digital transformation enabled by many ideas and technologies. Digital transformation is a way for manufacturers to overcome labor shortages driven by demographics and be responsive to changing customer requirements.

As industry rolls forward through the economic disruption that still plagues supply chains and the technology changes that support innovation, digital transformation continues. This is my seventh annual trends report, and what is evident from my ongoing coverage is that certain organizations are able to change and grow, while others remain stagnant, often hesitant to take up some of the most forward-looking concepts.

Progressive automation industry experts understand that new technologies as well as proven tools and techniques are being applied to improve the productivity, profitability, and competitiveness of manufacturers. Experienced industrial automation veterans are collaborating with younger professionals who understand open systems, the Industrial Internet of Things (IIoT), and computing industry technologies, which leads to creating highly effective solutions at manufacturing organizations.

The foundations of manufacturing and production are being reshaped by the integration of manufacturing/production into the entire business system. A digital manufacturing architecture offers a streamlined approach to enterprise-wide

ABOUT THE AUTHOR

Bill Lydon is contributing editor of Automation.com and ISA's *InTech* magazine. He has more than 25 years of experience designing and applying automation and controls technology, including computer-based machine tool controls, software for chiller and boiler plant optimization, and a new generation building automation system. Lydon also was product manager for a multimillion-dollar controls and automation product line, and later cofounder and president of an industrial control software company.

clarity that allows stakeholders to adjust operations based on real-time insights—in other words, it offers data transparency, which increases reliability, quality, production, profitability, safety, flexibility, and informed decision-making. Real-time digital manufacturing is about becoming a more effective, holistic, competitive—and growing—business.

> **Real-time digital manufacturing is about becoming a more effective, holistic, competitive—and growing—business.**

Organizations are driving forward to provide roadmaps, models, and standards for manufacturing digitalization. Open standards are essential for effective manufacturing business digitalization, which is evident in the information technology (IT) and commercial computing industry. The influence of IT, IIoT, and the computing industry is leading to a great deal of collaboration among these groups.

These are the trends I see shaping industrial automation. Supplementing my insights in this year's report are other views on essential topics you should focus on as this year rolls into the next. As always, I invite you to share your thoughts, criticisms, and perspectives as well. I look forward to talking with you through LinkedIn (https://www.linkedin.com/in/blydon/) or via email at wlydon@automation.com.

Bill Lydon

Essential Industrial Communications: Getting to the Edge

OPTO 22
Your Edge in Automation.™

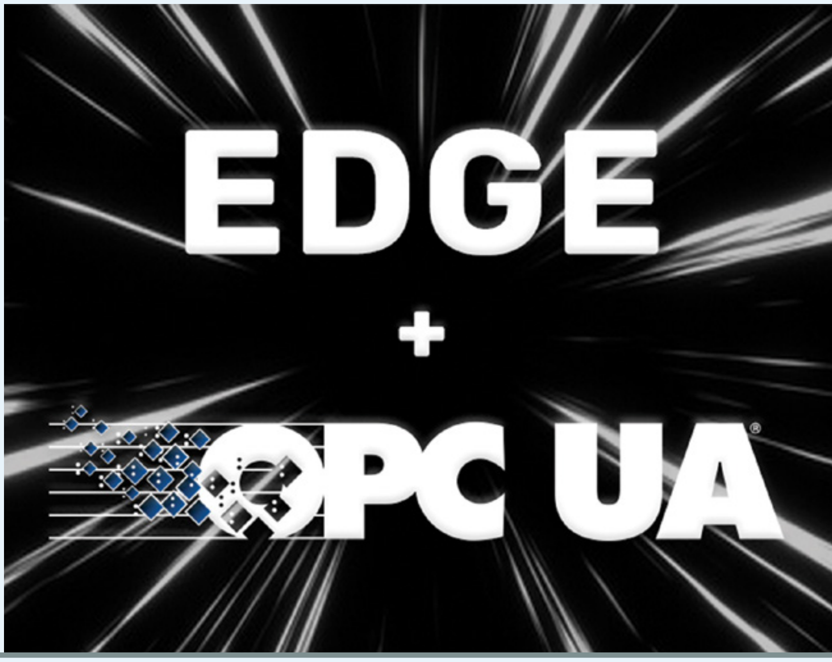
By Benson Hougland, Opto 22

Developments in automation have brought us from using Windows to proprietary SCADA and HMIs to edge computing and powerful software, promising new levels in industrial communications.

As we enter the so-called fourth industrial revolution, which aims to finally close the gap between distributed automation systems and business systems, consider some of the developments that got us here and where they point for the future.

The PC revolution of the 1990s led to the popularity of the Microsoft Windows operating system (OS) and broad interest in using its graphical interface to see what was happening on the plant floor. But the automation industry had expanded rapidly in the preceding decades, introducing many new protocols and devices. To use Windows, early supervisory controls and data acquisition (SCADA) and human-machine interface (HMI) developers had to create a suite of proprietary software drivers to communicate with every device the system might encounter. It was a time-consuming and expensive process and, in the race to expand the available portfolio of supported devices, it generally led to limited driver functionality.

In response, Microsoft and a small group of automation vendors, including Opto 22, developed OLE for Process Control using Microsoft's Object Linking and Embedding (OLE) technology. Now called Open Platform Communications, OPC defined a common specification based on a client-server model that allowed Windows-based SCADA/HMI software to communicate indirectly with plant floor hardware by means of an OPC server, which housed all the drivers needed to communicate with those devices. With OPC, vendors could more easily develop software for industrial systems and



the quantity and diversity of data that could be extracted improved.

But challenges remained. Taking advantage of OPC required a Windows-based computer or server to exchange operational data from plant floor devices with the software that needed this data. OPC Unified Architecture (OPC UA) was developed to meet this challenge by making it possible to run OPC at the edge of networks, directly embedded into industrial processors and devices.

"Together, OPC UA and these new edge controllers and I/O systems significantly simplify the task of communicating operational data between plant floor systems and the software systems businesses rely on every day."

At the same time, we saw much greater interest in closing the gap between automation and business networks. As a result, automation manufacturers began introducing edge-oriented controllers and input/output (I/O) systems. These devices offer state-of-the-art, powerful CPUs that combine traditional real-time control and sensing functions with the communication, storage, security, and data processing functions previously found only in higher-level systems.

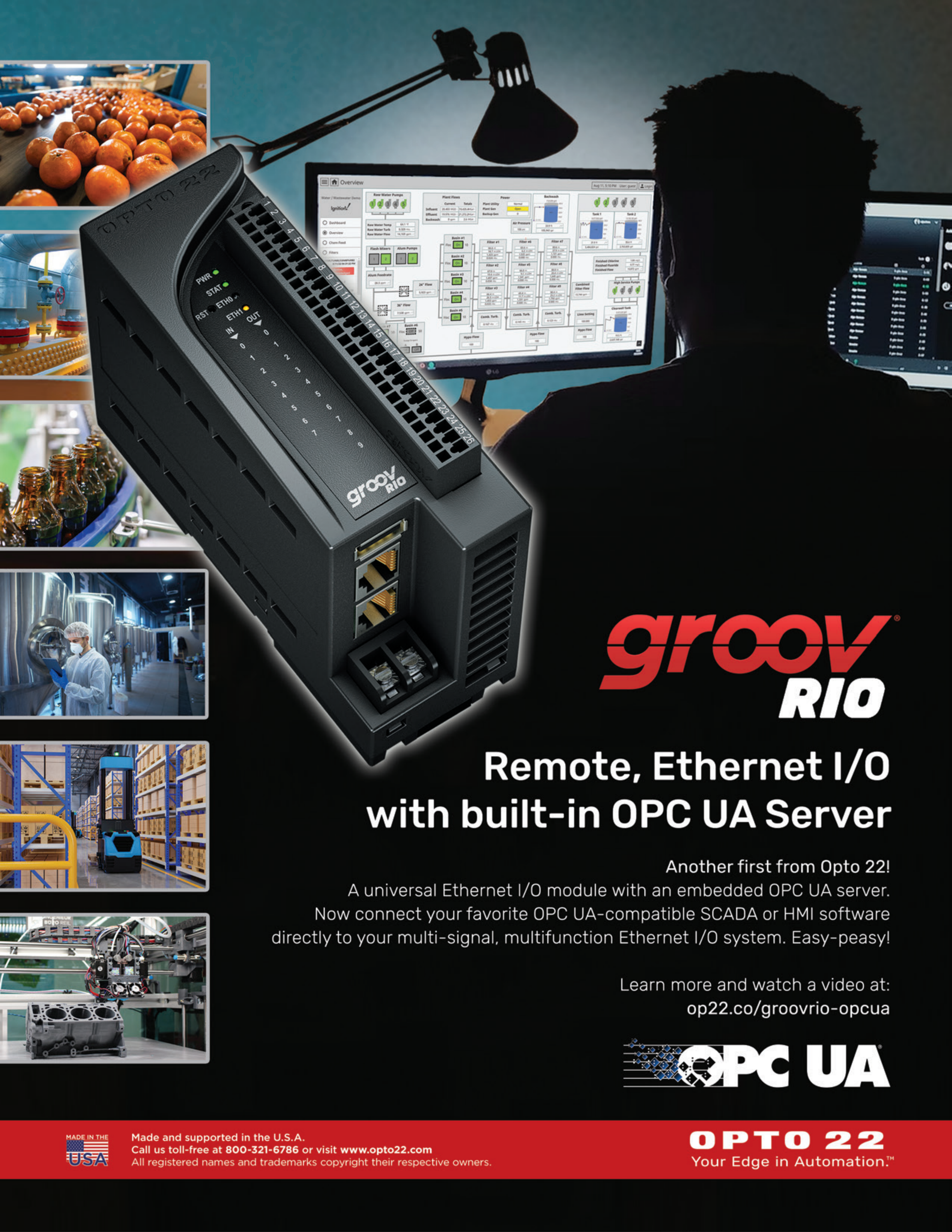
Together, OPC UA and these new edge controllers and I/O systems significantly simplify the task of communicating operational data between plant floor systems and the software systems businesses rely on every day.

This combination has brought us to where we are today, with modern concepts like the Industrial Internet of Things (IIoT) and Industry 4.0. We can clearly see the value and significance of open-source protocols and software. We can work on long-neglected capabilities like cybersecurity for industrial systems. We can again draw on innovations in information technology (IT) to outfit control systems for the tasks we need them to perform.

Our history points clearly to the future, where edge computing capabilities and powerful software running on these platforms are ushering in new levels of industrial communications. As automation professionals working on digital transformation, we can see how edge devices and interoperability standards are paving the way for companies to flourish.

About the Author

Benson Hougland is vice president of marketing and product strategy at Opto 22. With 30 years of experience in information technology and industrial automation, Hougland drives product strategy for Opto 22 automation and control systems that connect and secure the real world of OT with the systems and networks of IT and cloud. Hougland speaks at trade shows and conferences, including IBM Think, ARC Forum, and ISA. His 2014 TEDx Talk introduces non-technical people to the IoT.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Manufacturing Business Systems Become Integrated, Real Time, and Data Driven

Significant advances in technology, communications, and software enable digital manufacturing synchronization across the entire business structure.

BY BILL LYDON

In any business, functional silos create overlaps in processes and gaps in knowledge that impede collaboration, efficiency, and, ultimately, growth. This is increasingly true in manufacturing, which has traditionally been kept apart from the rest of an organization's business systems. As digital transformation continues to take hold, more companies are realizing that this setup only serves to delay valuable data to the stakeholders who most need it to make decisions that affect the entire enterprise's viability.

Why integration is transformational

The transformation to integrated, real-time, data-driven manufacturing seen in initiatives worldwide is reflexive and stems from the awareness of inefficiencies, lost opportunities, and poor decisions based on lack of immediate data that can be responded to. With the technology available today, manufacturing can, and should be, integrated like other parts of the business structure.

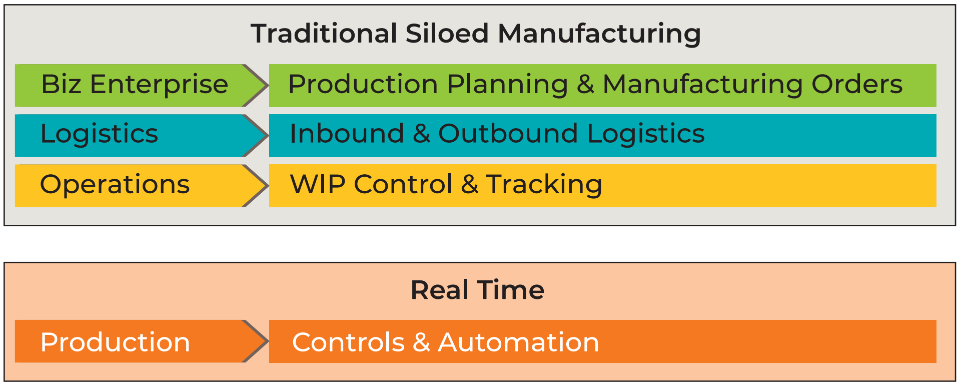

Figure 1. Industrial plant and process systems typically have been manually or loosely coupled with manufacturing business systems. Manufacturing Execution Systems (MES) and other overlay methods have tried to close the gap but cannot do so without increased complexity and duplicated data.

The most efficient manufacturing businesses will operate in this type of environment, replacing the enterprise resource planning (ERP) of yore (figure 1). It no longer makes sense to create manual work orders to initiate inventory release or production, and then to be blind to what happens in production until plant information is fed back into the system, the so-called "backflush." Manufacturing execution systems (MES) improve plant visibility and real-time work order/inventory release/production but result in complicated, duplicative models, higher costs, and questionable reliability, while not providing enough insight into product availability. Digital integration changes all of that.

The real-time, data-driven DMA

The shift to a digital manufacturing architecture (DMA) is a fundamental building block for transformation (figure 2) that has implications from the enterprise level to the farthest end of manufacturing and production—sensing and control devices.

The distributed system includes applications on embedded processors in sensors, actuators, bar code readers, cameras, and other field devices that can be controlled locally, but equally important, they can also be accessed remotely for complex calculations and adjustments at any time.

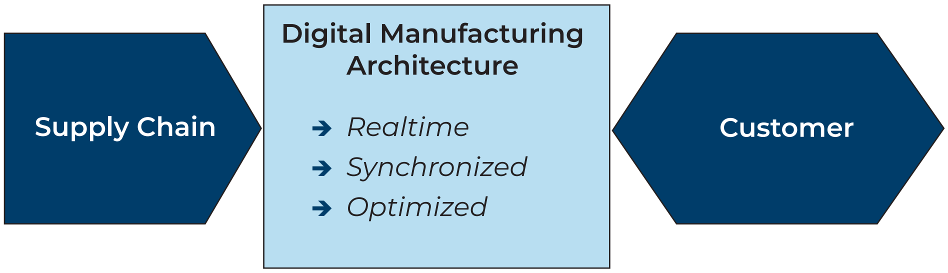

Figure 2: Digital manufacturing architecture (DMA) optimizes and synchronizes internal and external production resources in real-time based on changing parameters.

This architecture allows for real-time transaction processing and synchronization with manufacturing, creating a closed loop.

In addition to being highly integrated, effective DMAs:

- Provide immediate visibility throughout the entire enterprise
- Deliver unified, accurate, and timely data for decision-making
- Adjust to changes in supply chain, cost, and customer demand to optimize internal and external resources.

> **Customer orders, supply chain factors, and factory operations are fed into the digital twin, an ideal operating model of the plant and its processes.**

Enterprises that have been using plant floor computing to try to achieve real-time synchronization have had to continually integrate information technology (IT) and operational technology (OT). The next step is transitioning to a highly integrated architecture that provides immediate visibility from the manufacturing and production stage, throughout the supply chain, and ultimately to customers and other stakeholders.

The most effective architecture requires orchestrating and optimizing all elements of the process for flexibility in the face of external changes, including supply chains, customer demands, costs,

availability, energy, and sustainability requirements. The emerging DMA technology leverages advances in distributed computing and open systems to accomplish this and achieve synchronized, real-time, optimized production (figure 3).

Customer orders, supply chain factors, and factory operations are fed into the digital twin, an ideal operating model of the plant and its processes. Real-time linkages throughout the system create a closed loop (figure 4) with constant feedback, whereby analytics, artificial intelligence, and machine learning adjust and optimize operations.

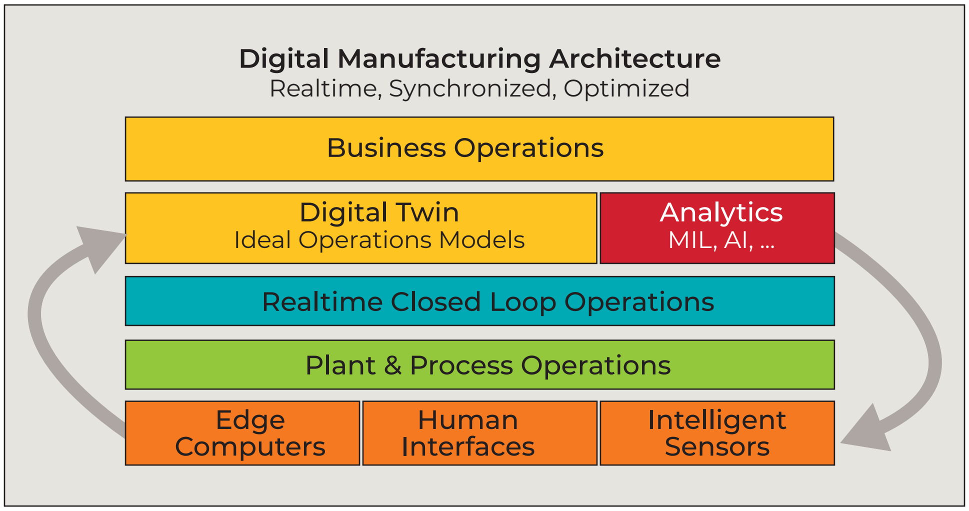

Figure 3. Digital manufacturing architectures allow for variability from the factory floor to the edge.

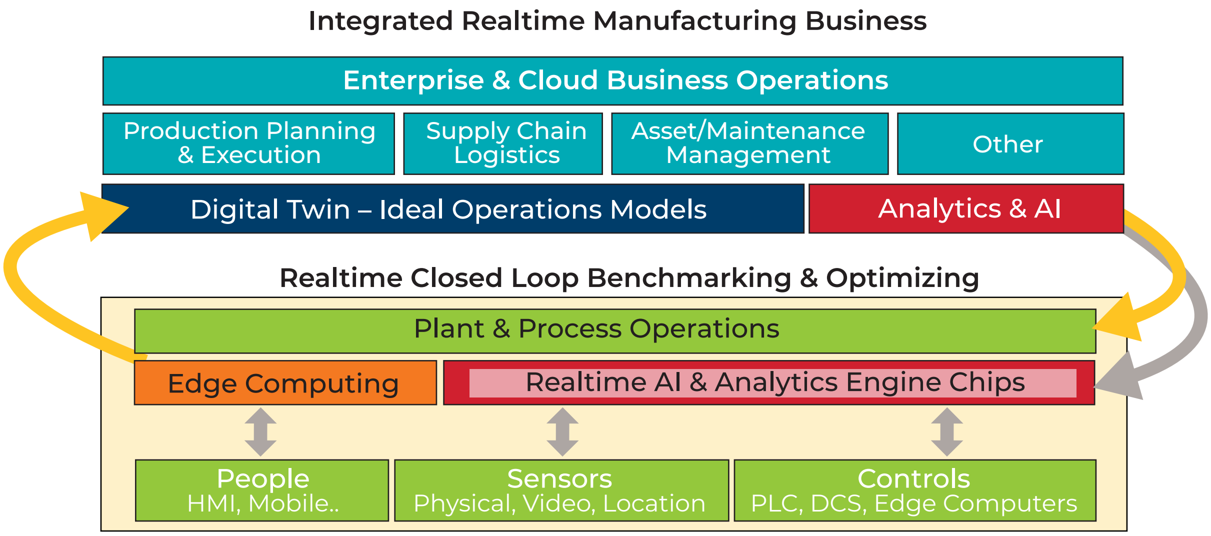

Figure 4. Optimized closed loop operations of all industrial functions.

Key takeaways

Real-time digital manufacturing is about becoming a more effective, holistic, and competitive business. The foundations of manufacturing and production are being reshaped by the integration of manufacturing/production into the entire business system.

A digital manufacturing architecture offers a streamlined approach to enterprise-wide clarity that allows stakeholders to adjust operations based on real-time insights, i.e., data transparency. This increases reliability, quality, production, profitability, safety, flexibility, informed decision-making, and overall competitiveness as a business.

Each organization needs to find the best way for its teams to achieve the goal of efficient and profitable production through digitalization, but it starts with integrating IT, OT, engineering, production, and other departments. By combining these stakeholder groups, instead of maintaining siloed departments, businesses gain the deep knowledge and expertise embedded in them and unleash new thinking, innovation, and results, along with their business-critical data.

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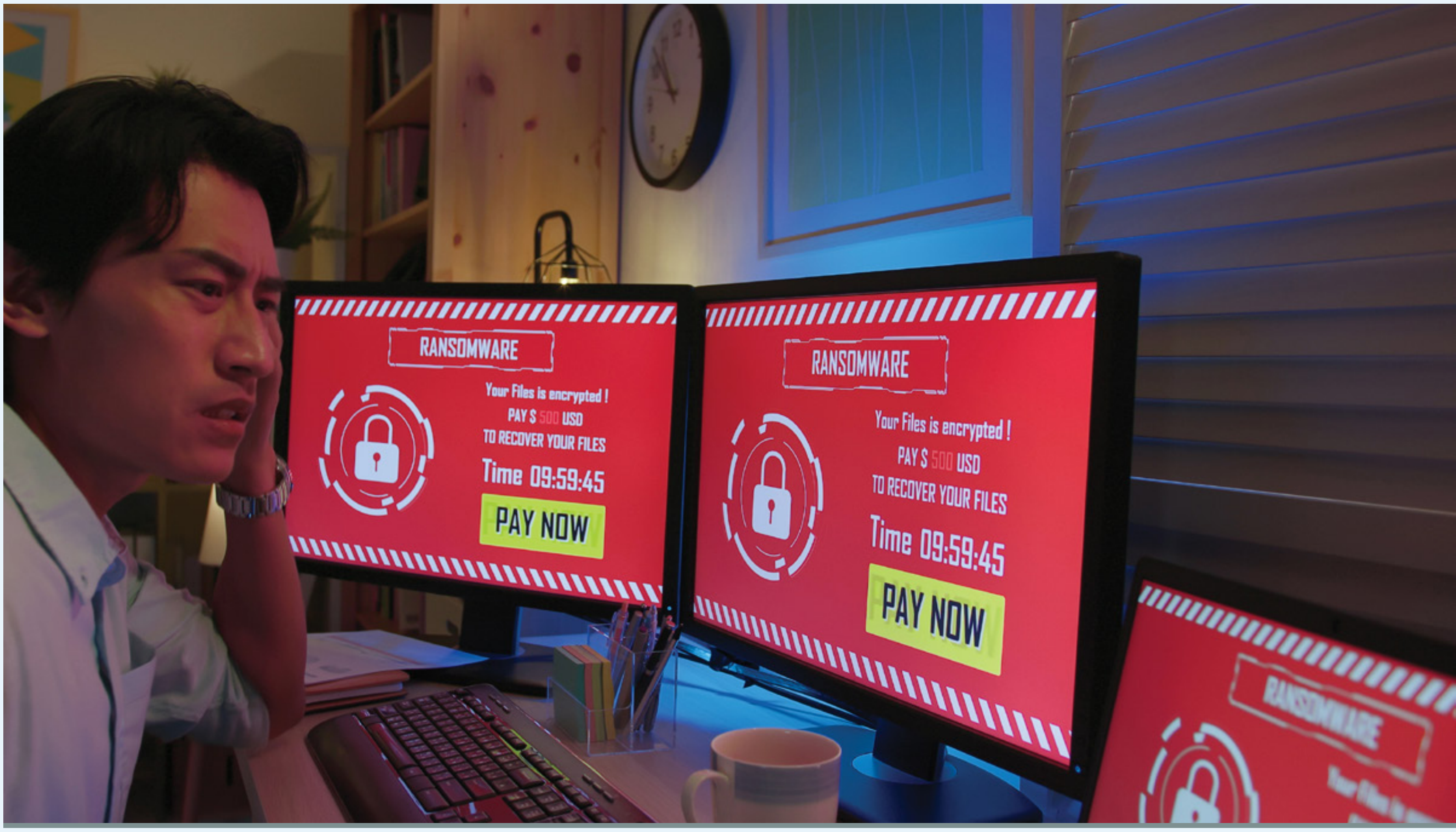
Essential OT: Monitoring and Detection Is a Necessity

Matt Morris, 1898 & Co., part of Burns & McDonnell

Safeguarding the operational technology (OT) environment has never been more important; its importance will only increase.

For anyone still contemplating if an attack will occur and not when, consider a point made in a recent Forbes article: cyber sabotage against critical infrastructure and functions has been increasing for a decade. Hackers always look for the weakest point, which gives a wide range of targets for disrupting, taking or, of denying aspects of the power or energy system.

Energy production and transport companies, such as liquid natural gas (LNG), power utilities, ports, and pipelines, are often targeted by nation-states because of the utilities' importance to national security. Cyber-attackers constantly develop and execute focused campaigns to disrupt, degrade, or destroy critical functions. It could be targeted, sophisticated sabotage or



collateral damage from ransomware or malware. The weaponizing of operational technology (OT) will only accelerate and broaden, as hackers are shifting their focus from information technology (IT) to OT environments.

"The probability, impact, and frequency of OT-focused attacks have ramped up significantly, yet the industry is still dealing with an estimated 3-million-person shortage for cybersecurity talent."

This shift signifies a transition from primarily data protection to far more consequential areas, such as power generation at utility plants, safety instrumentation systems for protecting workers, and organizations' overarching critical functions.

This trend means that OT network and communications monitoring is no longer a nice-to-have. Instead, it has become an essential tool in asset owners' cyber posture. A monitoring capability that is designed, implemented, and tuned well has more to offer than simply monitoring against cyberattacks, as certain solutions can uncover other risks and inefficiencies that could impact worker safety and business continuity, in addition to compliance to regulatory and/or corporate policies. The goal is to minimize the risk of disruption by improving efficiency, reducing costs, and streamlining operations to maximize profitability.

The OT cyber community has a huge dilemma. The probability, impact, and frequency of OT-focused attacks have ramped up significantly, yet the industry is still dealing with an estimated 3-million-person shortage for cybersecurity talent. The talent gap is worse in the OT world due to additional systems knowledge requirements, cybersecurity standards, and the like. Asset owners urgently need monitoring and detection but lack resources to implement them effectively. They are beginning to turn to solutions and service providers, which have not been able to operate well within OT environments in the past. A new variety of OT-focused service provider must emerge to help asset owners improve mean time to detection and time to respond, two of the more important metrics for identifying and dealing with incidents that could negatively impact system reliability and resiliency.

About the Author

Matt Morris is a managing director at 1898 & Co., part of Burns & McDonnell, where he leads the consultancy's security, risk, and critical infrastructure cybersecurity practices.

Societal Megatrends Drive Opportunities and Requirements

From workforce changes and supply chain disruptions to evolution of semantic data models, socioeconomic trends push industry to respond.

BY BILL LYDON

Economists, futurists, and others in the business of predicting change and helping others adapt often point to societal and socioeconomic forces as drivers of both disruption and opportunity. These macroeconomic drivers transcend time and technology to create new opportunities for manufacturers as well. Here, we'll explore some of the megatrends that are playing out on the world's stage and how they are industrial businesses.

Workforce Changes

The labor shortage means two things for manufacturers: Low labor cost is no longer viable as a competitive advantage, and, therefore, automation is a necessity to be competitive. The good news is that this results in increased productivity, quality, and efficiency. However, automation requires an upskilled, educated workforce to facilitate it. Now more than ever, manufacturers must face a changing environment in which these workers demand higher wages in return for the greater value they are delivering.

It pays to keep in mind that wages and employee training are good investments. Enterprises that continually allow their employees to learn about new technologies, methods, and techniques are at an advantage, because they are less likely to be surprised, and their businesses less likely to be disrupted by a competitor's manufacturing and automation innovations.

Also, relying on current vendors for manufacturing technology or hoping that a salesperson knocks on the door with a miracle product that improves business dramatically limits the possibility of success, and may in fact set a company on a path to failure. Instead, the mega trend we are seeing in reaction to the labor shortage is paying more to get more.

> **"Productivity and responsiveness are being improved with technologies that directly connect workers to manufacturing systems and make them an informed, integral part of production in real time."**

Similarly, productivity and responsiveness are being improved with technologies that directly connect workers to manufacturing systems and make them an informed, integral part of production in real time.

Examples are mobile computing and communications technology. The connection of workers is being accelerated by the wide, expanding range of commercial off-the-shelf technologies including voice and video headsets, smart glasses, and virtual reality devices. Further, the various available systems are providing workers with such productivity enhancers as:

- Manuals anywhere
- Equipment identification and lookup
- Real-time superimposed data
- Audiovisual linking to subject matter experts
- Direct access to inventory availability.

Tools such as these can also lower overall manufacturing costs.

From the customer's perspective, this trend meets their growing requirements for relatively quick product customization and the ability to see the status of their orders, including the production history. Thus, digital technologies are enabling new connections between manufacturers, their end users, and all parties in between. As a result, many manufacturers are rethinking how they interact with customers and developing business models and revenue streams made possible by digitalization.

Real-time dynamic supply chains

Synchronizing supply chains with manufacturing requirements optimizes production efficiency. Supply chain visibility has never been more critical since the pandemic in coordinating production and shipments.

Environment preservation and sustainability. Manufacturers are recognizing the need for energy efficiency, climate protection, and sustainability. A major part of achieving these goals is digitalization. Advanced controls and automation, accelerated by machine learning, artificial intelligence, and other technologies are helping make it possible for companies to commit to sustainability programs.

Disruptive innovation

Disruptive innovations adopted by manufacturers are achieving superior results, whether they are new applications in existing processes or ones that totally replace traditional methods. Industrial examples include replacing mechanical methods (i.e., cable, pulley) with hydraulics or gearboxes and mechanical camming with programmable coordinated motion with mechatronics.

The subtle part of disruptive innovation is that many times it is the result of using current off-the-shelf technology creatively in conjunction with new technology. By combining the old and the new in novel ways, better solutions arise that provide significant improvements, ease of use, and additional functions.

Many times, established suppliers see the disruptive innovations as unattractive for a range of reasons and try to ignore them. An example in the industrial automation industry is the initial resistance of traditional suppliers to replace proprietary human-machine interface (HMI) hardware and software with PCs and Windows-based software. A recent example related to industrial automation and manufacturing is a “smart helmet,” a safety helmet combined with goggles that displays instructions, safety information, and mapping on the wearer’s safety screen.

The subtle part of disruptive innovation is that many times it is the result of using current off-the-shelf technology creatively in conjunction with new technology.

Companies that do not take advantage of the appropriate disruptive innovations are likely to become uncompetitive at some point and to be leapfrogged by their competitors. Conversely, companies that leverage disruptive innovations position themselves to become leaders in their industry.

Technology cost and reliability

Commercial technology, including smartphones, gaming products, tablet computers, automotive electronics, and sensors, have achieved reliability appropriate for industrial automation at a significantly low price point with higher performance. Manufacturing automation requirements for high reliability has meant that commercial technologies were not adopted until they were ready. Now there is a wide range of commercial technologies that meet these requirements. An illustrative example is the Ethernet that was commercially used in the 1970s was adopted in the 2000s for industrial network communications once the technology was proven and incorporated into a single integrated semiconductor chip. Only then was it universally added to industrial controllers.

Semantic information to the edge

Semantic data models are growing significantly, creating relationships between data when the data is organized and providing meaning without human intervention or additional processing. Industrial automation and control is adopting semantic data messaging from sensors and controllers, providing inherently usable information rather than cryptic messaging. Semantic data is structured to add context and meaning that are immediately usable by applications streamlining communications. This improves quality and ensures data consistency. OPC UA and companion specifications are an example of semantic data models that implicitly define how such information relates to real-world applications.

Efficiency is achieved by eliminating the need to decode generic messaging and relate it to applications. Basic examples are a representation of pressure sensors by Modbus registers or an industrial protocol analog representation that must be related to an application by an engineer programming and configuring to define the relationship.

Technologies such as machine learning and artificial intelligence, which are consumers of data, benefit from semantic methods that improve performance, intelligence, and overall services and products. Semantic data makes data relationships easy to understand and simplifies application program development while providing better visualization and efficient data reporting.

Evolving manufacturing industry environments

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, even though there was resistance to change, the PLC eventually replaced large banks of relays using new technology.

To overcome current resistance to change, it is important to look back at past manufacturing and process automation leaps to see how far industry has come because of them. Leveraging disruptive innovations and technological developments, the entire manufacturing business is being digitally integrated to create highly efficient, competitive, profitable, and sustainable organizations that rely on digital integration to synchronize and optimize supply chain, customer requirements, plant floor operations, and outbound logistics.

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Essential Recovery: Restoring an HMI

MAVERICK TECHNOLOGIES
A Rockwell Automation Company

By Bruce Billedeaux, MAVERICK Technologies

Human-machine interfaces (HMIs) should not be taken for granted. Have a good plan to quickly restore operation setup—just in case.

It is said that a backup system is only as good as the trust you put in it. On the surface, your backup system is good, meaning that the trust level is high, as your business success relies on it. But would you stake your job on the ability to restore your control room human-machine interface (HMI) within an hour of a major equipment failure or, worse, a ransomware attack?

What if...

Consider a possible real-world situation. A severe weather event or a ransomware attack occurs at your facility. The lightning strike, flood, or ransomware attack takes down your primary and redundant secondary server. You are not worried because you have a solid backup of the HMI files. You call information technology (IT) and,

fortunately, they have a replacement server in stock. Let the recovery begin.

First, make sure that the hard drive is formatted correctly. Luckily, the partition is preconfigured, so you can skip formatting the hard drive. Now you load the operating system.

Depending on the media, it can take between 30 minutes and five hours to load Microsoft Windows onto a clean computer. Did anyone back up the Windows configuration file? No? Now the entire Windows server setup must be performed. Do you have the manufacturer's manual for the automation system? You remember a specific configuration is required prior to loading the vendor software.

Finally, the operating system (OS) is loaded. Now you can get the HMI software going. The disks are in the file cabinet next to the new server, but the server doesn't have a DVD drive. Can you download the software from the vendor's website? Three hours later, the software is downloaded and installed.

Next, you grab that backup from a USB stored in a cabinet in the data center. You begin the application installation, but you get an error after 30 minutes. The vendor's website indicates that a software patch is required for one of the features on your HMI. You download and install the feature patch and begin the application installation again. Forty-five minutes later, the application is fully installed.

You use the application tool to restore the configuration, tag names, and graphic files. It restores without error. You refresh the control room workstation screens with fingers crossed. No new data? What is wrong? You forgot to configure the network interface cards on the server. You find the correct IP addresses on labels on the old servers and refresh the workstations, and new data populates.

Success!

In the end, the operation was successful, but it was a frustrating endeavor with a lot of time, money, and other resources wasted on something that is easily remedied. By acknowledging that a good backup and recovery plan includes more than just the application configuration files, recovery will be quicker and more certain. For a less stressful and more reliable process, partner with your automation integrator to perform and, more important, test backups.

"By acknowledging that a good backup and recovery plan includes more than just the application configuration files, recovery will be quicker and more certain."

Adapted from "Would you bet your job on your HMI backup system recovery plan?" by Bruce Billedeaux in MAVERICK's newsletter, www.insideautomation.net.

About the Author

Bruce Billedeaux is a senior consultant at MAVERICK Technologies with more than 28 years of network and process automation expertise in the commercial building and industrial central utility environment. He is also a member of MAVERICK's cybersecurity solutions team.

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Transformative Technologies Move Automation Forward

System-wide Internet protocol communications, 5G wireless, OPC standards, and more are transforming industrial systems.

BY BILL LYDON

Advances centered around Internet protocol (IP) technology are dramatically improving industrial control and automation communications. Advanced physical layer technologies including single-pair Ethernet as well as time-sensitive networking (TSN) improvements enable industrial automation to leverage Internet of Things (IoT) technologies and standards, bringing the benefits of IP to industrial edge devices including sensors, actuators, vision, robots, controllers, contactors, and drives.

Single-pair Ethernet (SPE)10BASE-T1 is an exciting development enabling seamless Ethernet connectivity from sensor to enterprise. 10BASE-T1 is a 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 IP. SPE data transport consistent with global standard IP communications will accelerate this trend.

The SPE two wire design lowers installed cost with more than 75 percent smaller cable diameter, reduced weight, lower cost, smaller connector size, and 30 percent more bend radius than CAT 5. SPE also opens the possibility to reuse existing installed twisted pair field wiring for Ethernet communications simplifying plant and machine retrofits.

SPE is an enabler for intelligent field devices including sensors, actuators, vision, robots, controllers, contactors, vibration monitors, and motor drives. These intelligent devices perform control at the edge and communicate non-control operations data including quality measurements, production efficiency, asset monitoring, diagnostics, and predictive maintenance advisories directly to manufacturing operations, business enterprise, and cloud systems. System-on-Chip (SoC) technology makes immediate processing in any field device practical due to lower cost with high performance since they are being used in volume products such as smartphones and personal health trackers.

Multidrop configurations are possible with the 10BASE-T1S part of the specifications providing 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. This can now be accomplished with SPE using standard IP communications.

The power over data lines (PoDL) feature of the specifications provides 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.

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.

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 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.

“5G may well be the ideal wireless industrial automation networking mechanism, and companies are installing private 5G networks in manufacturing plants.”

TSN holds the promise of providing a unifying deterministic network shared by all applications throughout the computer industry. The TSN vision is 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.

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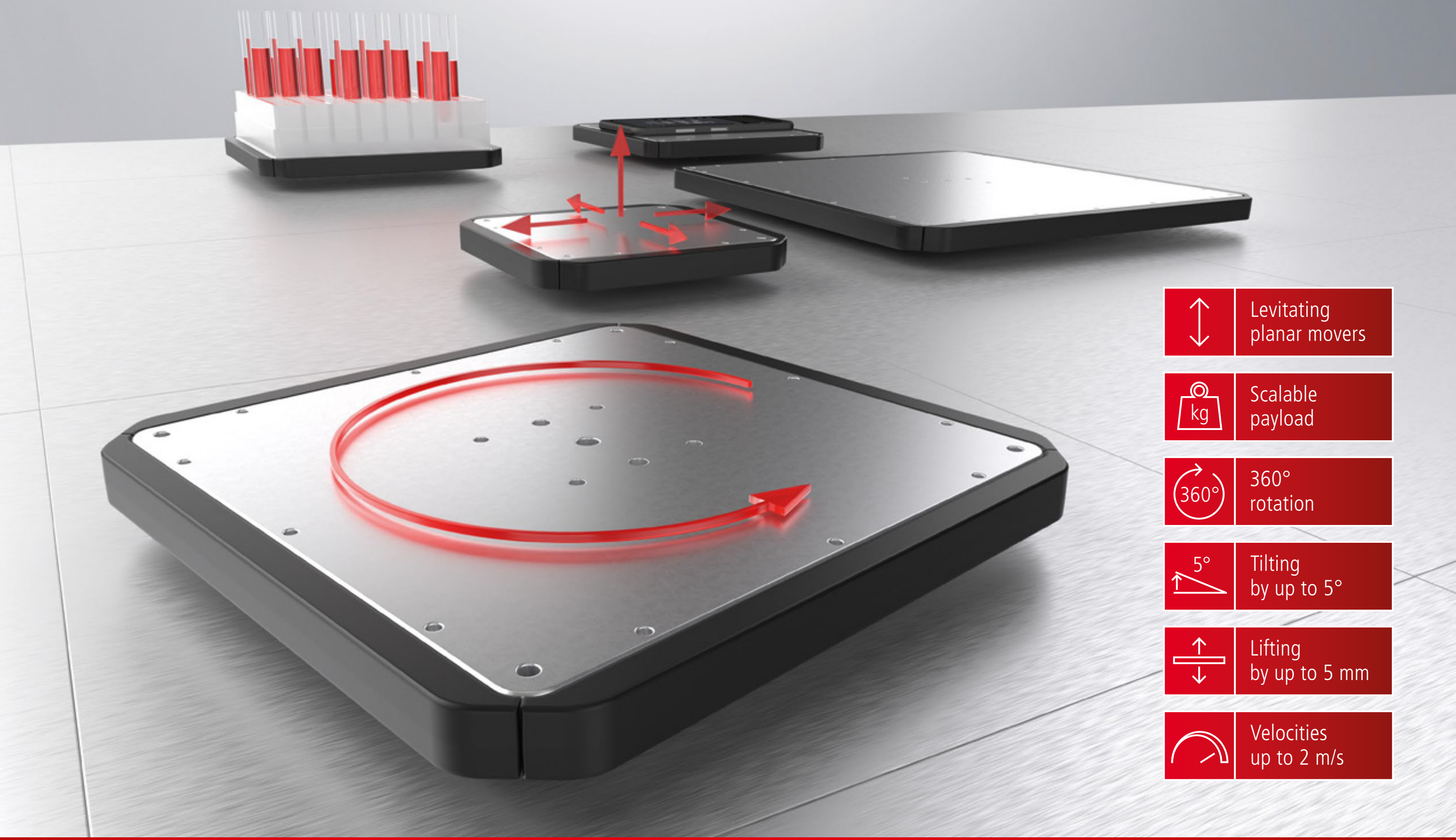

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XPlanar enables new dimensions of freedom in product and material handling: Levitating planar movers fly over flexibly arranged planar tiles accommodating nearly any track layout and path planning.

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New Automation Technology **BECKHOFF**

Since TSN is a totally managed shared network architecture, all network traffic including new TSN Ethernet switches and routers and 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.

Time-Sensitive Networking Task Group of the IEEE 802.1 is the working group developing the standard for this 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. However, 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. To take advantage of TSN time scheduling, control programming software and controller firmware would 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. These standards are evolving.

5G wireless

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 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 controlling 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 companies

The 5G technology offers 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. There are three major benefits of 5G networks, according to IEEE: High data rates (1-20 Gbit/s), low latency (1 ms), and larger network capacity and scalability.

According to the report published by Allied Market Research, the global industrial 5G market generated $12.47 billion in 2020, and is estimated to garner $140.88 billion by 2030, witnessing a CAGR of 27.5 percent from 2020 to 2030. The report offers an extensive analysis of changing market dynamics, value chain, top segments, regional scenarios, key investment pockets, and competitive landscape.

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 networks will 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 outlines relevant use cases, requirements, and other information.

The OPC ecosystem

OPC Foundation standards, semantic data models, and ecosystem are growing significantly making multivendor secure and reliable data exchange in industrial automation applications. They are becoming widely adopted by IT, operational technology (OT), and cloud suppliers creating a valuable and efficient distributed industrial manufacturing architecture. The ecosystem is a community that uses the OPC data model standards and contributes OPC Companion Specifications to address use cases to achieve a unified vendor independent data interchange that simplifies data exchanges, lowers application engineering labor, and improves quality. Stakeholders include developers, users, software, services, and other stakeholders.

OPC UA standards are platform-independent and ensures the seamless flow of information among devices from multiple vendors. Since 1996, the OPC Foundation has facilitated the development and adoption of the OPC information exchange standards with the mission is to enable industry vendors, end users, and software developers to achieve interoperability in their manufacturing and automation assets—secure and reliable interoperability for moving data and information from the embedded world to the enterprise cloud. The Foundation serves more than 850 members worldwide in the industrial automation, IT, IoT, IIoT, M2M, Industry 4.0, building automation, machine tools, pharmaceutical, petrochemical, and smart energy sectors. OPC's most recent projects include:

- The OPC Field level communications (FLC) initiative has a goal of delivering an open, cohesive approach to implement OPC UA in field devices using harmonization and standardized application profiles including sensor 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.
- OPC companion specifications support OPC UA scalability. OPC UA supports a wide range of application domains, ranging from field level (e.g., devices for measurement or identification, programmable logic controllers), to enterprise management support with companion specifications. The growing number of companion specifications created by a wide range of industry groups focus 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 other organizations. These joint specifications represent the majority. The released joint companion specifications can be found here. The Joint working group program is defined here.

VDMA Companion Specifications

The VDMA is a host of several European and global sector committees that represents the broad machine building and parts of the process industry (figure 1). VDMA contends that interoperability is key to success. This interoperability will be brought about by:

- interface development through standards
- integration into the shop floor through standard interfaces
- access to standardized production data.

OPC UA for Machinery forms the basis for interoperability because it can be referenced from other companion specifications or implemented as standalone model. It can be developed together with all OPC UA working groups. It defines harmonized basic building blocks for broad use. Forty of the VDMA working groups standardize the interfaces of machines and components in individual industries. All basic information models are brought together in the Companion Specification.

As an open interface standard, OPC UA is a central prerequisite for the successful introduction of Industry 4.0 into production. OPC UA ensures the interoperability of machines and systems, which can be linked and redesigned as required.

OPC UA serves as basis for the Global Production language. VDMA envisions interoperability through cross domain information models, domain-specific harmonized information models, OPC UA meshed communication networks, and proprietary communications

To make this vision a reality, VDMA is working with its member companies to develop industry specific OPC UA Companion Specifications, thus creating a global language of production.

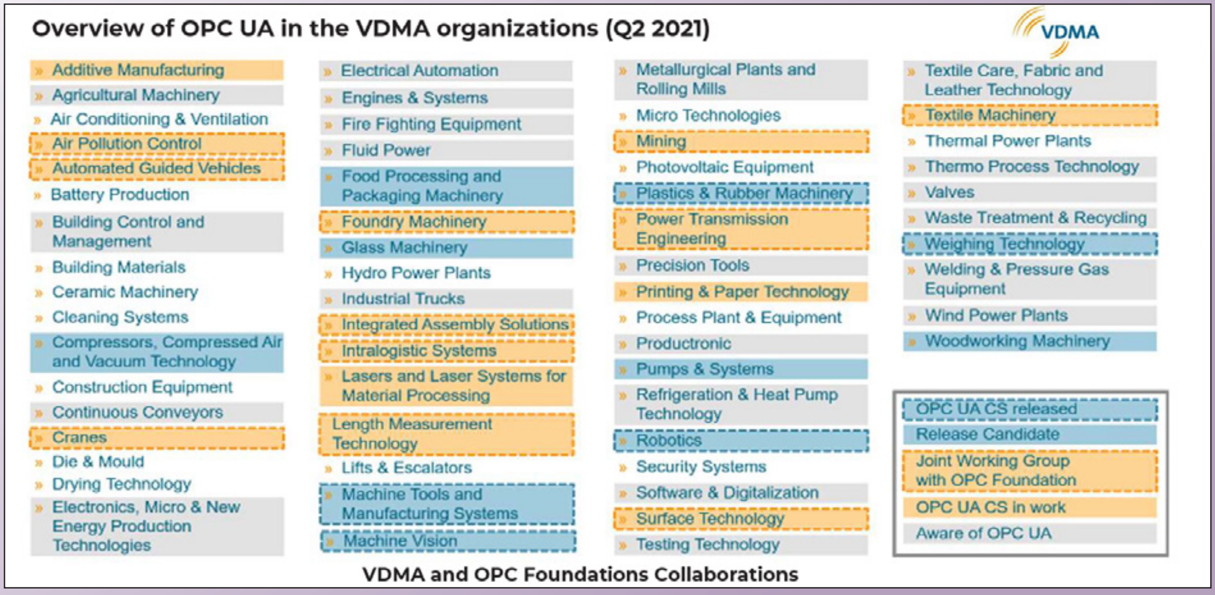

Figure 1. Overview of OPC UA in the VDMA organizations.

- 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.

CESMII OPC UA Cloud Library

The CESMII OPC UA Cloud Library is an example of jointly created companion specifications. The OPC Foundation in cooperation with Clean Energy and Smart Manufacturing Innovation Institute (CESMII) launched a globally available OPC UA cloud library. The co-developed online library has growing contributions from all major cloud vendors leveraging open interfaces and is available for sharing, finding, and collaborating on OPC UA information models.

The UA Cloud Library already contains more than 65 OPC UA information models created by individual companies as well as international standards organizations like AutoID, DEXPI, MDIS, MTConnect, and more than 30 VDMA working groups as part of the OPC UA Companion Specification work. The UA Cloud Library can be accessed from the OPC Foundation website at: http://UACloudLibrary.OPCFoundation.org The open-source reference implementation can be accessed at: https://github.com/OPCFoundation/UA-CloudLibrary.

Specifications, thus creating a global language of production.

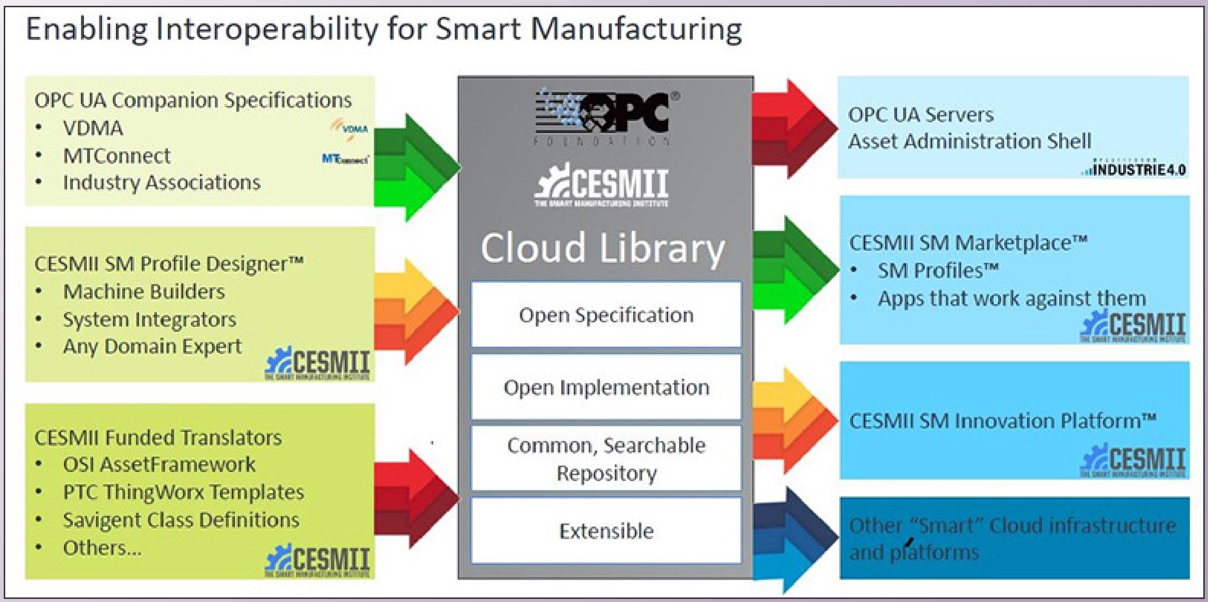

Figure 2. The UA Cloud Library contains more than 65 OPC UA information models created by individual companies as well as international standards organizations.

Edge control and automation

Distributed manufacturing architecture (DMA) requires processing at the 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 percent of data will be created and processed outside traditional centralized data centers or the cloud by 2025.

Enterprise, cloud, and edge computing are complementary creating a more responsive synchronized system architecture that increases performance and reliability. Time critical applications execute onsite, using real-time data by eliminating network latency and provide higher cybersecurity protection. Coupled with a cohesive plan for managing the data and infrastructure creates a more responsive system architecture unifying workflows from edge to enterprise/ cloud. Edge computing reduces communications latency and ensures bandwidth is available for necessary systemwide communications.

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 manufacturing 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. Linux containerized architectures provide a platform for multiple functions to run virtualized on industrial computers.

Field devices. 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. 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) that includes various electronic parts such as a central processing unit (CPU), I/O ports, internal memory, analog input, output blocks, and in many Ethernet, Wi-Fi, Bluetooth, and other communications.

"An exciting development are inference chips that execute AI, ML and other sophisticated applications in parallel with multiple processors at high speed."

The NAMUR Industry 4.0 for Process and other initiatives envision how distributed control across field devices perform 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.

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 can enhance 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 "AI chips" brings the computing right into edge devices.

Robotics explodes with possibilities

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 of robots is the integration of vision systems, image recognition, AI, location awareness, and digital manufacturing system integration. which enables a wide range of new applications.

Robots programmed like playing a game are a high impact automation development for increasing manufacturing productivity and are particularly 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 that they cause no harm or destruction. With these robots, protective fences and cages are not required and therefore they can enable flexibility and lower implementation costs. These robots are particularly attractive with high return on investment.

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.

Robot sales continue to grow in Europe, Asia, and the Americas. In 2021, a new record of 486,800 units were shipped globally—an increase of 27 percent compared to the previous year. Asia/Australia saw the largest growth in demand: Installations were up 33 percent reaching 354,500 units (figure 3). The Americas increased by 27 percent with 49,400 units sold. Europe saw double digit growth of 15 percent with 78,000 units installed. These preliminary results for 2021 have been published by the International Federation of Robotics. For more trends on the global robotics market please visit IFR´s website at https://ifr.org/.

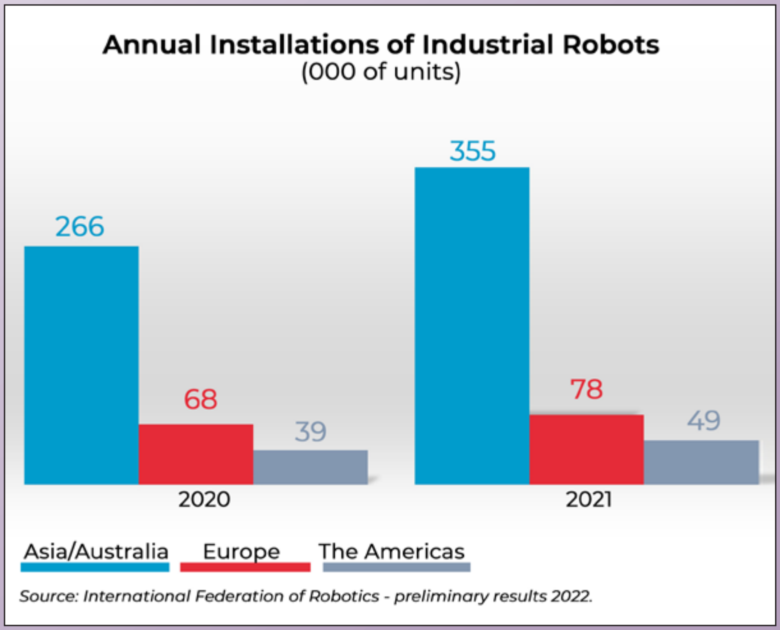

Figure 3. Asia/Australia saw the largest growth in demand, with a 33 percent increase in installations, reaching 354,500 units.

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 prices under $90 U.S. Applications possibilities include optimization of production, 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.

The Allied Market Research recently published noted the global artificial intelligence chip industry accounted for $8.02 billion in 2020, and is expected to reach $194.9 billion by 2030, growing at a CAGR of 37.4 percent from 2021 to 2030.

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

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Essential HMI/SCADA Software: Increased Connection

By Bernard Cubizolles, GE Digital

Human-machine interfaces (HMIs) and supervisory control and data acquisition (SCADA) software provide necessary visibility into manufacturing operations.

In today's rapidly changing industrial landscape, manufacturers and utilities must embrace modern human-machine interface/supervisory control and data acquisition (HMI/SCADA), and digital transformation to keep up with the pace of change, meet growing operations challenges, and remain competitive. HMI/SCADA software runs industrial plants around the world, helping operators make critical decisions to run machinery. These technological innovations are reshaping the industrial landscape.

Industrial organizations also are dealing with high rates of retirement of aging workers who have deep knowledge and expertise. These individuals are being replaced by younger workers who lack the same knowledge but are digital natives with skills and experience with mobile devices and web-based technologies.

Technology suppliers in the automation ecosystem have the challenge and opportunity to help industrial companies cope with these changes while achieving their desired outcomes. The starting point for many companies is the implementation of a modern HMI/SCADA software solution.

An HMI/SCADA is a category of software-based control system architecture that uses networked data to provide operators with a graphical user

interface (GUI) that allows them to monitor the performance of many pieces of equipment and issue process commands and settings.

It allows operators to improve situational awareness, the mobility of visualization anytime and anywhere, and important equipment control, which provides a centralized view of operations. HMI/SCADA collects data from remote terminal units (RTUs), programmable logic controllers (PLCs), and other control devices. This data is presented to an operator using an HMI, which allows the operator to see what is going on in the plant in real time.

"Technology suppliers in the automation ecosystem have the challenge and opportunity to help industrial companies cope with these changes while achieving their desired outcomes."

HMI/SCADA also can be connected to other technologies such as a data historian to allow historical trending and other analysis. In fact, the foundation starts with capturing industrial data, combining it with other meaningful data sources for context, and managing a historic record. It is data, turned into information, that provides the basis for meaningful outcomes. HMI/SCADA lets you guide newer operators through the right steps to take, and users can enable mobility and remote monitoring for greater efficiency.

The advent of connectedness has brought about incredible opportunities for industry.

Operators in manufacturing environments often have oversight over many pieces of equipment. HMI and SCADA solutions allow them to precisely monitor, control, and visualize every aspect of their operations in a centralized manner.

With the increased visibility that HMI/SCADA affords, there are many applications for its use. Industrial processes such as those in manufacturing or power generation, infrastructure processes like water treatment or oil and gas pipelines, and facility processes like those that control heating and ventilation are all good uses for HMI/SCADA.

In today's connected industry, HMI/SCADA is just one of many industrial technologies adding value to and enhance industrial capabilities. With HMI/SCADA, industrial companies can precisely monitor, control, and visualize every aspect of their operations for intelligent control. With a quick glance, operators know what's important and the right actions to drive increased efficiency and reduced costs.

About the Author

Bernard Cubizolles is the global product marketing manager of HMI and SCADA for GE Digital. He has been with General Electric for more than 10 years and holds a PhD in applied physics.

Open Standards, Global Initiatives Help Modernize Operations

BY BILL LYDON

Organizations are driving forward to provide roadmaps, models, and standards for manufacturing digitalization.

Open standards are essential for effective manufacturing business digitalization, which is evident in the information technology (IT) and commercial computing industry. The influence of the IT, Internet of Things (IoT), and computing industry is leading to a great deal of collaboration among these groups. Key initiatives are listed throughout this article.

Multi-vendor open standards foster a broad selection of products and vendors for end users to choose from; 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 share 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, which benefits all users. Open standards are emerging all over the world to target many specific needs. Here are the ones influencing OT application development.

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

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 the 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, Italy, Portugal, and Indonesia.

The RAMI 4.0, Reference Architecture Model Industrie 4.0 (Industry 4.0) developed by the German Electrical and Electronic Manufacturers' Association (ZVEI) has gaining broad acceptance throughout the world describing manufacturing enterprises.

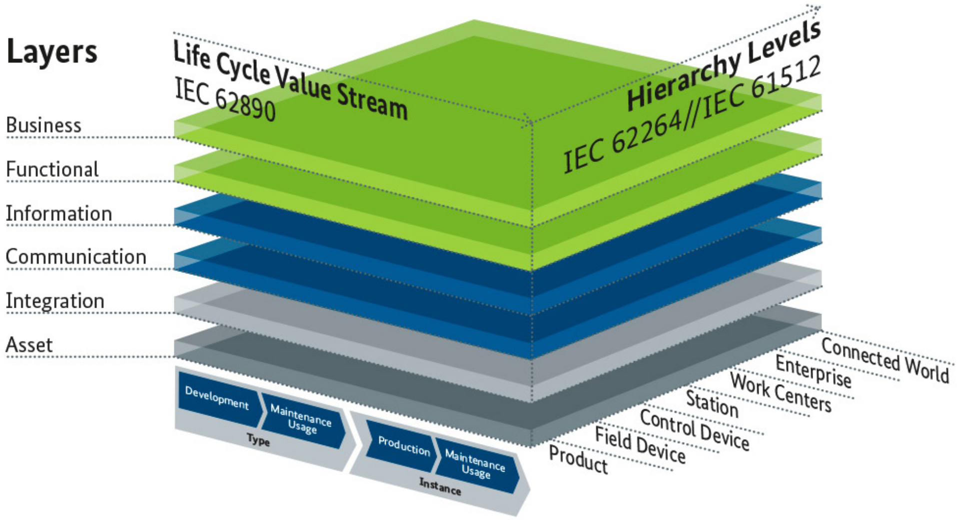

Figure 1. RAMI 4.0 is a three-dimensional map showing the most important aspects of Industrie 4.0. It ensures that all participants involved share a common perspective and develop a common understanding," explains Kai Garrels, chair of the working group Reference Architectures, Standards and Norms at the Plattform Industrie 4.0, and head of standardization and industry relations at ABB (www.plattform-i40.de).

The Open Group, the Open Process Automation Forum

The Open Group's Open Process Automation Forum (OPAF), formally launched November of 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, which has led to the deployment of higher function software designed to lower lifecycle cost. The defense avionics industry is a good example of one that has transitioned from a proprietary solution to fully open systems architecture. Digital automation architecture synchronizes the entire manufacturing business for profits.

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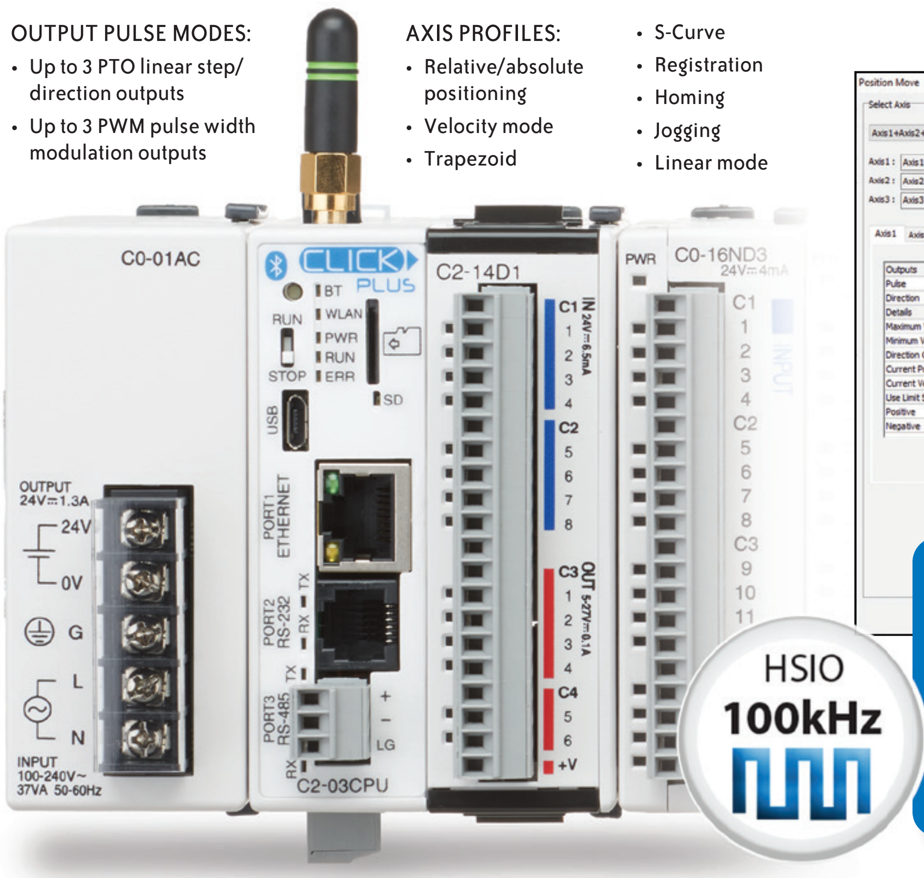

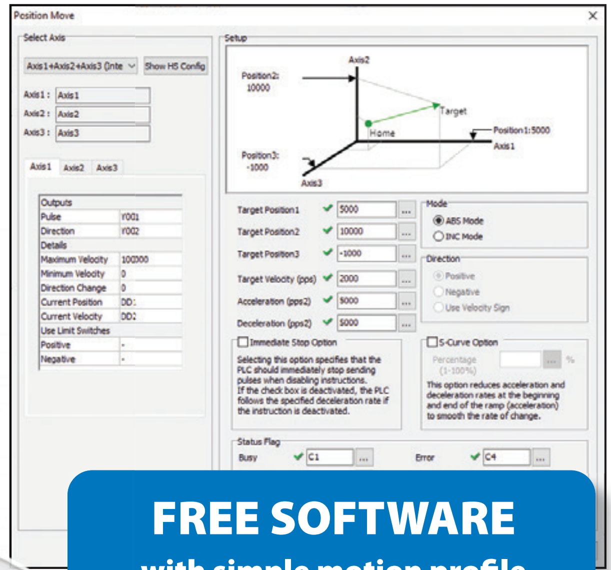

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Sparkplug is an open-source software specification that provides MQTT clients the framework to seamlessly integrate data from their applications, sensors, devices, and gateways within the MQTT Infrastructure. Sparkplug provides an open and freely available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

Industry 4.0 for Process

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, and 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.

Modular design for system flexibility

Open standard modular design is a growing trend that empowers subject matter experts to concentrate on manufacturing and production to achieve objectives, rather on 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 and operation.

This modular production addresses common user complaints where vendors deliver various pieces of equipment that do not directly and intelligently communicate with control, automation, asset management, and business systems. Modularity offers benefits such as reduction in cost (customization can be limited to a portion of the system, rather overhauling the entire system), interoperability, shorter learning time, and design flexibility. This also lowers the dependency of users on the uniqueness of unique vendor 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.

PackML

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 that is an industry technical standard for the control of packaging machines. 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.

Module type package

"Module type package" (MTP) is a key concept for standardized non-proprietary 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 is provided by the module manufacturer in an XML-file called a "module type package (MTP)." The MTP includes many attributes including alarm management, safety and security, process control, HMI, and maintenance diagnostics.

Multivendor control standards

There are emerging initiatives for a common control runtime software engine to make all industrial controls compatible to achieve multivendor program transportability with two current IEC 61499-focused initiatives, namely Eclipse 4diac and UniversalAutomation.org runtime.

The major architectural difference between IEC 61499 and IEC 61331-3 is the program execution models. The IEC 61331-3 follows the traditional PLC architecture with a deterministic model of reading inputs, resolving logic, and executing outputs. IEC 61499 is event driven; the main function block is triggered to execute based on an event signal presented to the input of the "event execution control" input that then activates execution of "encapsulated functionality" that is defined to be executed (figure 2). This provides the user with a great deal of control over function executions with the responsibility to coordinate execution timing to meet application requirements. The most common event architecture people use today is Microsoft Windows.

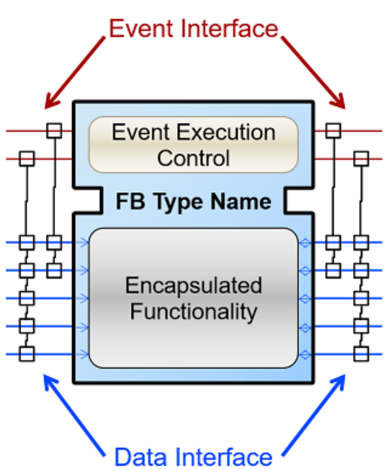

Figure 2. The main function block is triggered to execute based on an event signal presented to the input of the "event execution control" input that then activates execution of "encapsulated functionality" that is defined to be executed.

Eclipse 4diac

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 distributed 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. It has been successfully applied in several industrial systems including manufacturing systems, logistics, power and energy applications, robotics, and building automation.

In 2007 the IEC 61499 open source 4DIAC project was started and now offers all software necessary to program and execute control and automation applications.

4diac engineering software

The 4diac IDE is built on the established Eclipse open-source framework, which allows an easy integration of other plug-ins to the 4diac IDE providing new or extended functionality. IEC 61499 based systems follow an application centric design, which means that the application of the overall system is created at first. Each application is created by interconnecting the desired function blocks (FB) in terms of a function block network (FBN). As soon as the hardware structure is known, it can be added to a project's system configuration and the already existing application can be distributed onto the available devices.

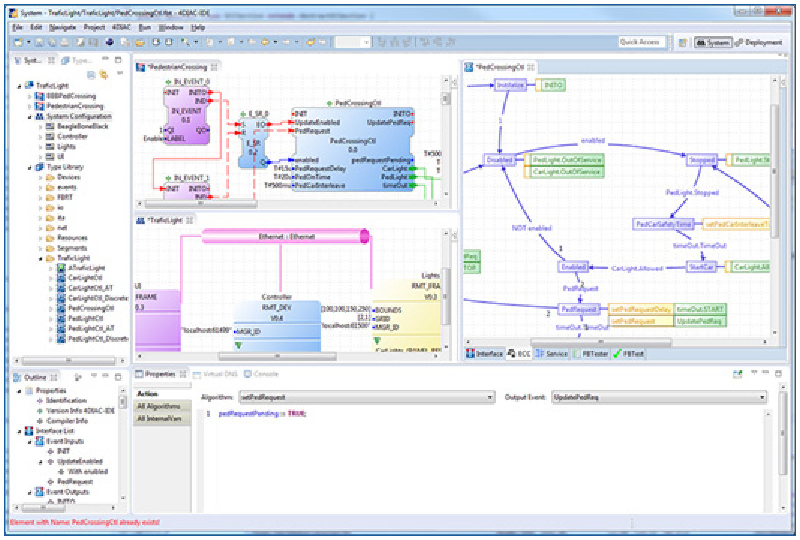

Figure 3. 4diac IDE is based on the Eclipse framework.

4diac FORTE: IEC 61499 runtime environment

The 4diac FORTE is a small portable implementation of an IEC 61499 runtime environment targeting small, embedded control devices (16/32 bit), implemented in C++. It supports online-reconfiguration of its applications and the real-time capable execution of all function block types provided by the IEC 61499 standard. 4diac FORTE supports all IEC 61131-3 edition 2 elementary data types, structures, and arrays. It provides a scalable architecture that allows 4diac FORTE to adapt to the needs of the application. Applications can consist of any IEC 61499 element as basic function blocks (BFBs), composite function blocks (CFBs), service interface function blocks (SIFBs), adapters, and sub applications.

4diac LIB: IEC 61499 function block library

The 4diac function block library (4diac LIB) contains function blocks (FB) that are available on 4diac FORTE and can therefore be used to create IEC 61499-compliant control applications.

UniversalAutomation.org.

UniversalAutomation.org launched November 2021 is an independent, not-for-profit association providing paying members in good standing a controlled IEC 61499 runtime engine software through a shared source licensing agreement. The initial UniversalAutomation.org runtime engine is the Schneider Electric nxtControl IEC 61499 Runtime Engine licensed royalty free to the organization by Schneider Electric. Based on membership level, users have licenses to use in the IEC 61499 runtime code in product offerings. Further details can be found here.

UniversalAutomation.org is early in development with only an IEC 61499 runtime engine offering at this early stage compared to 4diac, which has a complete open-source IDE engineering software suite and IEC 1499 runtime engine. The licensing approach is another major difference:

- The components of Eclipse 4diac are provided under Eclipse Public License, Version 2.0.
- UniversalAutomation.org shared source licensing agreement, unlike open-source software, prohibits members from making changes independently and is governed by voting members.

Deploying systems requires members to develop an IEC 61499 editor supporting the UniversalAutomation.org runtime engine. The organization does not intend to create an IEC 61499 editor or compiler. UniversalAutomation.org plans to define a set of rules and syntax designers at member companies will use to create compilers compliant with the UniversalAutomation.org IEC 61499 runtime engine code. John Conway, president of UniversalAutomation.org said the quickest way today is to license EcoStruxure Automation Expert editor software from Schneider Electric.

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