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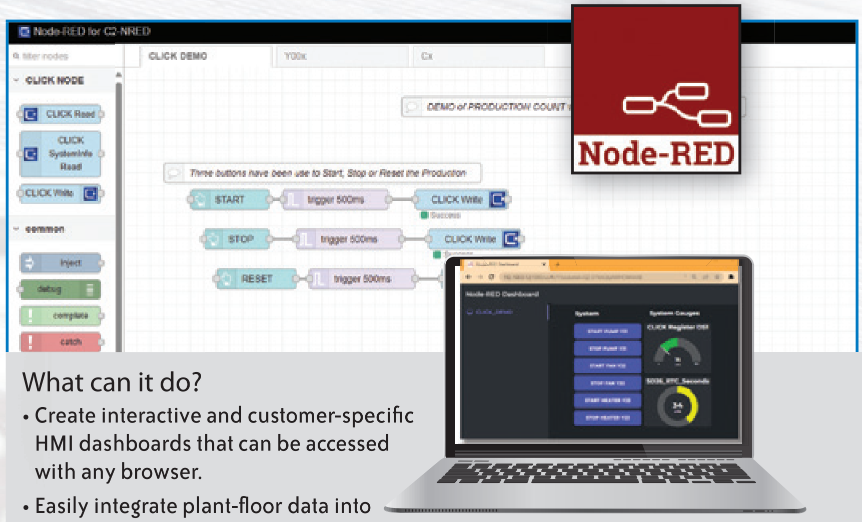

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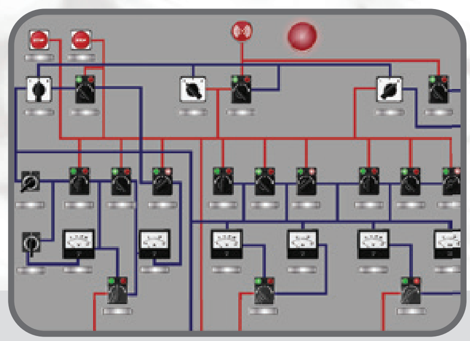

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A Message From The Editor

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A Fluid, Evolving Transformation

This 10th edition of the Industrial Automation & Control Trends Report from Automation.com is NOT comprehensive. It does not make many predictions or provide data regarding which trends are most important. But it does highlight topics important to manufacturing, industrial and automation professionals across industries and around the world: artificial intelligence (AI), augmented reality, communications protocols, open automation technology, remote operations, sustainable manufacturing and more.

The voices in this issue are varied and so are the opinions. Many, no doubt, will create some lively discussions within ISA Connect or on LinkedIn. I highly recommend it.

What we're NOT talking about in this issue is "Industry 5.0," what some are saying is the next step, the newest thing, the evolution of the 4th Industrial Revolution.

That's because I agree with Jeff Winter, an Industry 4.0 & digital transformation enthusiast and member of the ISA executive board: "I love what Industry 5.0 stands for—human-centricity, sustainability and resilience... But the name... I just can't get behind it," said Winter.

"If you think Industry 4.0 is a fixed set of nine technologies cooked up in Germany in 2011, then, yeah, Industry 5.0 might feel like the necessary next chapter," Winter continued. "But if, like me, you see Industry 4.0 as the era we're still living in—a fluid, evolving transformation—we haven't finished this revolution yet, let alone started the next one."

Enjoy the trends in this issue. Use them to chart the course of your own company's transformation. Then take a few minutes to let me know what trends you want to know more about, or which ones you're actively pursuing. Bonus points if you want to write an article describing your journey. I'd love to publish your insights next.

Renee Bassett, Chief Editor
Automation.com

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Physical AI Will Reshape the World

Forget LLMs. Physical AI will take us from basic automation to augmentation and fully autonomous systems.

By John Robins and Mat Gilbert

In all the exciting discussions about artificial intelligence (AI) over the past year, the physical world has been largely overlooked. The conversations around chatbots and other tools enabled by large language models (LLMs) focus primarily on digital applications and little on the physical challenges that AI can address. Physical AI technology is ready to solve real-world problems by fusing AI and physical systems to create products that mimic human cognitive, sensory and physical capabilities.

Physical AI is the next frontier of the intersection of the digital and the physical, and leveraging all it has to offer is key for industry leaders who want to stay ahead both today and tomorrow. Researchers and major AI players are already working on physical AI projects, including testing millions of robots for factory use and developing new learning models. The market for one aspect of physical AI—embedded AI used in industrial automation systems, healthcare devices, autonomous vehicles and elsewhere—is projected to reach $45 billion in 2029.

The path to physical AI

The origins of physical AI can be traced back to key advances in four key technologies: classical robotics, artificial intelligence, embedded computer systems and edge AI devices. Together, these fields are driving physical AI in their evolution from automation to augmentation to autonomy. Each stage of physical AI evolution builds on earlier developments to deliver unique capabilities.

The automation stage uses physical AI-enabled devices and systems to handle specific tasks with little to no human intervention. For example, assembly line robots can free up line workers for other tasks. At this stage, physical AI relies on predefined rules. If the assembly line breaks down, a human has to step in to resolve the issue.

At the augmentation stage, physical AI enhances human capabilities by taking actions or providing recommendations based on the system's analytics and insights. Predictive maintenance, which analyzes industrial equipment sensor data to alert humans when a machine is about to break down, is a widely adopted example of augmentation-stage physical AI. Another example is an image-processing system that rapidly assesses patient medical scans for anomalies and flags them for review.

When physical AI reaches the autonomy stage, it can deploy advanced sensing, learning and decision-making abilities to operate without the need for human input, even when conditions change. The most popular example in this category is self-driving vehicles, but that's far from the only use case. Package delivery drones and energy grid management systems could optimize resources and drive efficiencies. Autonomous maintenance systems could reduce the need for workers to go into risky environments, and in the health care space, patient monitoring and treatment using wearable devices is a rapidly growing area.

Applications of physical AI

In addition to supporting more efficient and safer processes, physical AI has the potential to maintain processes. Global workforce shortages are a growing challenge, with 75 percent of employers having trouble hiring enough people in 2023, compared to just 36 percent a decade ago. Robots, embedded systems and other physical AI applications can help orchestrate autonomous processes to overcome worker shortages.

Predictive maintenance, which analyzes industrial equipment sensor data to alert humans when a machine is about to break down, is a widely adopted example of augmentation-stage physical AI.

For example, autonomous taxis and trucks will soon be able to move people and products using physical AI sensing, real-time data processing and navigation capabilities. Much like the advances in Generative AI at the edge, which enable real-time decision-making with localized data processing, physical AI applications such as autonomous vehicles rely on similar principles to navigate changing environments and enhance efficiency. In warehouses and factories, autonomous robots already handle some assembly tasks and have the potential to handle sorting, retrieval and other tasks.

Physical AI can also enable immersive experiences for many purposes, from gaming and augmented retail to industrial training. Physics-based simulations that create realistic virtual environments are especially valuable for training AI models to do specific tasks without risking damage to equipment or product quality as the system learns. These simulations are similar to digital twins already used for training, with the addition of real-world data to create a near limitless range of scenarios.

For example, a virtual simulation of a beverage factory assembly line could generate virtual models of cans with a huge variety of defects to train the AI system to detect as many problems as possible before it's applied to the real assembly line. This can reduce the cost of AI training, reduce the time needed for training and increase the accuracy of the model once it's deployed.

We see three key industries where physical AI offers especially promising orchestration and immersion use cases.

In consumer and connected spaces, AI-driven home automation has the potential to increase energy efficiency, comfort and security using in-home sensor data and other inputs like weather and power grid demand data. Robotic vacuums and smart speakers are on the path to eventual autonomy, and they already augment daily life for many users. Augmented reality consumer experiences like virtual try-ons or room design can be more realistic and useful with real-time object recognition and interaction.

In health care, AI-powered robotic surgical systems can enhance the precision of procedures and improve outcomes. Physical AI in wearables can help with patient monitoring as well as early detection and diagnosis of diseases. Patients undergoing rehabilitation and their physical therapists will be aided by AI-driven robots that enable and monitor personalized treatment and exercises.

In climate tech and the industrial space, physical AI environmental sensors deployed in complex systems will support real-time monitoring and control of emissions and other outputs, incorporating predictive modeling of climate patterns and local environmental

conditions and assist governments and businesses with disaster preparedness planning. Physical AI-based training and automation can address labor shortages and skills gaps, while giving smart factories the predictive maintenance capabilities they need to minimize waste and run at maximum efficiency.

Exploring possibilities with physical AI

As powerful as current use cases like image analysis and predictive maintenance are, physical AI's potential to transform industries and address major global challenges is much greater than the solutions we have today.

Just as organizations are racing to adopt LLM AI tools to build interactive, natural interfaces, it's wise for organizations to start thinking now about how physical AI can add value or solve problems. The key, as with any new technology, is to start small and plan methodically, with a problem statement, a data-informed product-market fit and a plan to develop or source the talent needed to make the product or solution a reality. With those elements in place, it's possible to run a pilot program, fine-tune it and learn from its deployment before scaling up with increasingly large physical AI use cases.

Starting to explore the possibilities of physical AI today will give organizations advantages in terms of the learning curve, scaling and progression from basic automation to augmentation and fully autonomous physical AI.

ABOUT THE AUTHORS

John Robins is director and head of AI & Data and Industrial Business at Synapse, part of Capgemini Invent. As a product management and business growth executive with more than 18 years experience, Robins specializes in bridging the physical and digital worlds. In his current role, he works with ambitious clients to build novel deep-tech products leveraging IoT and AI technologies across industrial, hi-tech, automotive, telco and food/agtech markets. Previously, Robins led product management at a large consumer electronics company and ran an industrial IoT startup. Additionally, he is a member of the TinyML Working Group and a Gartner Product Management Ambassador.

Mat Gilbert, director, head of AI & Data at Synapse, part of Capgemini Invent, is a distinguished technology leader at the forefront of new product development, integrating advanced AI, data analytics and smart sensing technologies to create solutions that benefit both people and the planet. With a future-focused approach, Gilbert spearheads innovations that incorporate ethical and environmental considerations, working as a technical authority in the technology sector. His work not only expands the possibilities of technological advances but also ensures that these innovations are sustainable and human-centric.

Edge AI: From Niche to Mainstream

What happens when intelligence isn't just something we access through screens or devices, but something embedded in the world around us? When it is woven into our environments, shaping decisions and unlocking new ways of working and living?

Edge AI is making intelligence feel present—alive in ways we're just beginning to grasp. It's shifting AI from something we access to something that moves with us, anticipates needs and creates new opportunities across industries. Real-time patient monitoring in hospitals, smarter supply chains and AI-powered creative tools are just a few examples. With this shift comes not only new possibilities but also new responsibilities.

Moving beyond efficiency and automation, the conversation is shifting from "How do we use AI?" to "How does intelligence exist around us?".

By Savannah Kunovsky

In my work at IDEO, I've seen how emerging technologies reshape industries and redefine how we interact with the world. Edge AI is shifting the conversation from "How do we use AI?" to "How does intelligence exist around us?". It's moving beyond efficiency and automation, becoming something embedded into our environments in ways that feel seamless, responsive and even alive.

From next-generation AI hardware designed for low-power, high-performance edge computing to breakthroughs enabling generative AI to run on-device, the landscape is shifting rapidly.

Edge AI first gained traction in industries where real-time decision-making was essential. Autonomous vehicles, industrial automation and health care couldn't afford to rely on cloud processing. What started as a solution for latency, bandwidth and security challenges is growing into something much larger. Today, it is driving new business models, shaping more intuitive interactions and transforming everything from adaptive health care systems to real-time retail.

Hospitals are already using edge AI-powered patient monitoring systems like Biobeat, which track vital signs without needing constant cloud connectivity. In manufacturing, companies like Stream Analyze are embedding AI-driven quality control directly into production lines, reducing defects and improving efficiency. In logistics, P&O Ferrymasters has increased load efficiency by 10 percent by using AI-driven, real-time tracking and automated decision-making. These aren't experiments. They are real, present-day innovations that make intelligence more immediate, responsive and deeply integrated into everyday life.

Rethinking how intelligence is designed

The 2025 Edge AI Technology Report, published by Wevolver, comes at a moment when edge AI is shifting from a nice innovation to a foundational layer of technology. From next-generation AI hardware designed for low-power, high-performance edge computing to breakthroughs enabling generative AI to run on-device, the landscape is shifting rapidly. As the technology evolves, leaders across industries will need to rethink how intelligence is designed, deployed and experienced. This report offers insights into that transformation. Highlights include:

- **Technological enablers of edge AI.** The report examines advances in hardware and software that support edge AI deployment, such as innovations in specialized processors and ultra-low-power devices, which are overcoming the limitations of processing power and scalability in resource-constrained environments. This part also explores the integration of lightweight, real-time explainability techniques to enhance transparency and trust in AI decisions.

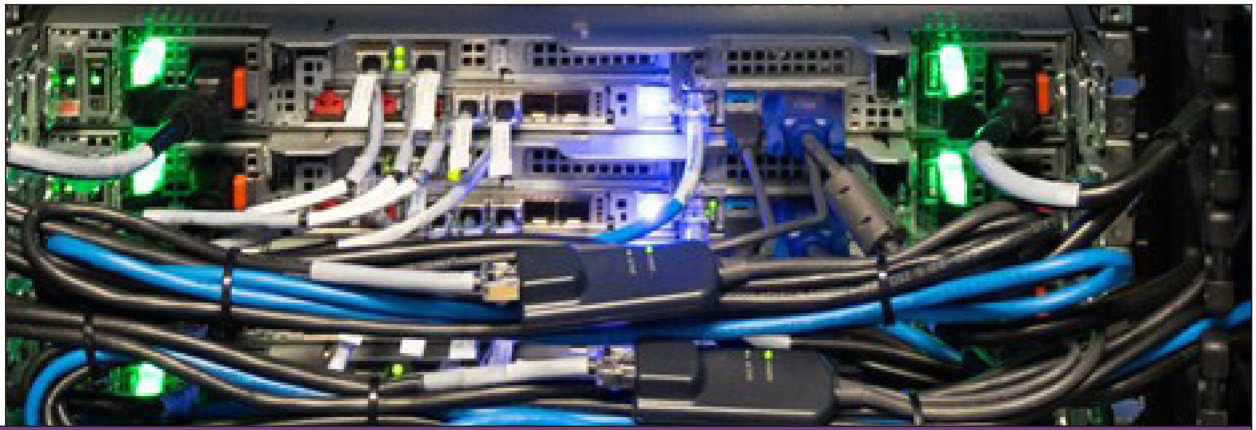
- **Edge AI's role in transforming industry operations.** Edge AI is impacting operational models across industries by enabling real-time analytics and decision-making capabilities. Specific case studies, such as predictive maintenance in manufacturing, illustrate the practical applications and advantages of deploying AI at the data source.
- **Future technologies and innovation.** Emerging technologies that are likely to impact the future development of edge AI include federated learning, quantum neural networks and neuromorphic computing. These innovations will enable more autonomous systems capable of self-learning and real-time adaptation, reshaping competitive dynamics across industries.

The edge has always been more than just a place where data is processed. It is where intelligence becomes immediate, responsive and integrated into the world around us. Today, it is also where new ideas, interactions and possibilities are taking shape.

ABOUT THE AUTHOR

Savannah Kunovsky is managing director of IDEO's Emerging Technology Lab, one of more than 100 organizations that publish on Wevolver, a community of engineers. The full Wevolver 2025 Edge AI Technology Report is available for download.

ExxonMobil: Pioneering Open Automation Technology



A U.S. chemical plant is the first to deploy the Open Process Automation at commercial scale.

By ExxonMobil Newsroom

Did you know that at every large manufacturing site there are tens of thousands of individual instruments—things like pumps, valves and pressure gauges that monitor and control the operation?

They're the nervous system that keeps everything humming. Cool, right?

You know what's even cooler? ExxonMobil thinks it's high time for a revolution in the technology used to control all these instruments. That's why we've helped lead the development of a new control system architecture that uses the same types of technologies that power the Internet and smartphones.

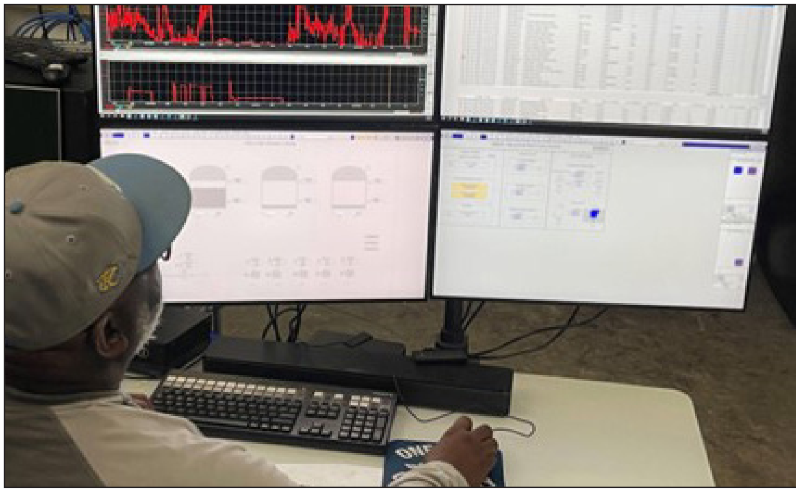


Figure 1. An operator at ExxonMobil's Resin Finishing Plant monitors the plant's operations using the new Open Process Automation console.

This new technology is called Open Process Automation (OPA), and we're proud to be the first company in the world to deploy it at scale at a commercial operation—at our Resin Finishing Plant in Baton Rouge, La (Figure 1). The plant makes high-quality adhesive resins used in products like tapes, sealants and medical adhesives.

Lower costs, more innovation

What's so special about OPA? The key word is "open."

Just like technologies that let you easily download an app, or plug new hardware into a USB, OPA's modular, plug-and-play design lets manufacturers quickly install upgrades and deploy new technologies from different vendors. It's a big change from the closed, proprietary systems used at most industrial sites today.

OPA can deliver a range of benefits, but the big two are:

- Reduced costs: We estimate OPA will cost at least 20 percent less over its lifespan compared to traditional industrial control systems.
- More innovation: With OPA, we can quickly implement new applications that optimize the performance and output of our refining and chemical sites. Such optimization can result in improved efficiency and better products for customers (Figure 2).

OPA also supports our ongoing priority of maintaining secure operations: This new system incorporates state-of-the-art cybersecurity protections, and its flexibility would enable us to quickly incorporate new ones in the future.

OPA: Not just for the energy industry

We aim to deploy this new automation technology at more of our sites around the world. And by sharing what we're learning in Baton Rouge, we hope to encourage OPA's adoption across other manufacturing industries, such as food and beverages, metals and mining, automotive and pharmaceuticals.

Still, we recognize that changing the industry standard for process control system technology will take time, and more than just ExxonMobil. That's why we've been working with other companies across a range of industries.

We're a founding member of Open Process Automation Forum, the information-sharing arm of The Open Group, a global consortium of more than 100 companies promoting vendor-neutral technologies like OPA.

Figure 2. ExxonMobil's new Open Process Automation control panel in Baton Rouge: streamlined and scalable, with standards-based, open technology enabling innovation at a faster pace than existing systems.

A decade-long effort pays off

ExxonMobil has been leading the push toward OPA for more than 10 years. It started when a group led by ExxonMobil engineers began advancing what was then a novel concept: applying standards-based, open architecture technology to an industrial control system.

In 2018, these innovators were awarded a U.S. patent, which ExxonMobil later donated to The Open Group to help accelerate the development of OPA systems across industries. In 2020, a prototype at our research facility in Clinton, N.J. became the first OPA system to control a hydrocarbon process under high pressure and temperature. The success of that project—and extensive test-bed development—paved the way for the installation in Baton Rouge.

David DeBari, a veteran ExxonMobil process control engineer whose name is on that 2018 patent, sees OPA as a "quantum leap forward" in technology—akin to when industries shifted away from pneumatic controls in the early 1980s. "I've been doing automation and process control work my whole career and it's great to see ExxonMobil leading the way."

"Moving to an open, secure, standards-based system will help promote innovation and increase the return on automation investments. By demonstrating the technology at scale, we're making it easier for industry. We're paving the way," said Whit McConnell, chief automation and process control engineer

Whit McConnell, chief automation and process control engineer, said, "Moving to an open, secure, standards-based system will help promote innovation and increase the return on automation investments. By demonstrating the technology at scale, we're making it easier for industry. We're paving the way."

All photos courtesy ExxonMobil.

ABOUT THE AUTHOR

The ExxonMobil Newsroom produces information for ExxonMobil, one of the largest integrated fuels, lubricants and chemical companies in the world. This article first appeared on February 10, 2025. To learn more about the company that makes a range of products essential to modern life, click here.

Augmented Reality Will Change Manufacturing Workflows

Prepare now for the transformation and benefits that AR technology will bring.

By Hélène Druet

Augmented reality (AR) is no longer just a futuristic technology to monitor—it has become a powerful tool reshaping the manufacturing industry. From enhancing worker productivity to bolstering operational efficiencies, AR solutions are proving their worth across manufacturing environments. But what does the future hold?

Here we analyze the evolving landscape and identify five key trends for AR in manufacturing in 2025. These trends promise to redefine how manufacturing professionals and organizations leverage AR for innovation and growth. They are not merely theoretical concepts or long-term visions but instead represent the new and tangible advances that users can benefit from today.

Flexibility of hardware

Gone are the days of being locked into one specific AR hardware provider. By 2025, manufacturers will enjoy increased flexibility in their choice of devices, effortlessly switching between AR platforms or systems. This interoperability makes AR adoption more scalable and cost-effective, providing businesses with the agility to leverage the best tool for every task.

Imagine using smart glasses for assembly operations one day and a projection system the next—all without compatibility issues or extended downtimes. This ability to adapt will empower manufacturers to maximize the value of their AR investments.

One of DELMIA's Augmented Experience customers, a global leader in aerospace, provides operators with the flexibility to conduct quality inspections using either a tablet or a camera. This allows workers to select their preferred tool for each task, every day, based on their comfort and workflow. It's a great example of adapting to user needs—whether it's technological familiarity, ergonomic preferences like sitting or standing, or overall ease of use, ensuring smooth adoption of augmented reality solutions.

Smarter AR applications

AR is a technology that increasingly depends on artificial intelligence (AI), and the two are becoming closely integrated. AR involves connecting the real world with the virtual, helping users understand their environment through localization and contextual definitions. AI enhances this by analyzing reality and interpreting environments at an advanced level, effectively aligning and synchronizing the virtual twin of a product with the real world.

In 2025, we anticipate a stronger reliance on AI, particularly for quality inspection applications. AR systems enabled with AI will identify defects much quicker and reliably. Another area where AI is going to bring a lot of value is in its ability to improve tracking initialization, enabling rapid and accurate alignment of the digital 3-D data and the real part for straightforward visualization of AR instructions.

AI's role will go beyond troubleshooting or identifying flaws. Predictive algorithms and machine learning will enhance workflows, providing operators with actionable insights in real time. This integration will make AR tools more intuitive, reducing complexity while improving outcomes.

AR is a technology that increasingly depends on artificial intelligence, and the two are becoming closely integrated.

Automated AR work instruction creation

Creating AR work instructions for manufacturing processes can be labor-intensive, especially in the case of frequent changes in the 3-D model and configurations of the parts. However, automation is set to streamline this in 2025. Advanced software will generate AR-guided instructions directly from CAD models and process definitions, supporting automated updates. Additionally, AI will contribute to enhanced processes and work instructions definition, further accelerating the automation of the content creation process.

This innovation will significantly reduce implementation time while ensuring instructions are always up to date with the latest designs or processes. Workers will benefit from accurate, clear and visually immersive directions that reduce errors and improve precision on the shop floor.

Enhanced integration of technologies

AR in manufacturing is expected to make a significant advancement through greater integration with third-party technologies, resulting in a more enhanced and immersive experience. This development will go beyond simply displaying work instructions and will allow increased interaction with work cells and the surrounding environment.

For example, we anticipate connections to smart tools and voice modules, which will expand the possibilities for connected workers. Voice modules will allow workers to interact with AR systems simply by speaking, enabling hands-free operation. Meanwhile, smart tools—like sensors, torque wrenches or IoT-enabled equipment—will feed real-time data into the AR interface, creating a unified

and smarter workspace. By leveraging the AI capabilities mentioned earlier, these technologies become more intuitive by integrating multi-modal interactions through vision (AR) and dialogue (voice), paving the way for a virtual assistant.

This level of connectivity will reduce cognitive workload, enhance comfort and allow workers to focus on decision-making rather than repetitive tasks. The result? Improved productivity and safer, more intuitive work environments.

Improved collaboration

As the adoption of AR systems continues to expand in manufacturing, together with the use of the virtual twin, we are witnessing an exciting trend toward improved and extended collaboration. With an increasing number of AR platforms interconnected, professionals will soon collaborate seamlessly across multiple devices, operators and even machines, such as robots. Powered by the virtual twin, which serves as a reference point and ensures digital continuity, this connectivity will enable real-time information sharing, synchronized actions and coordinated decision-making.

By connecting multiple AR devices, several operators can work together on the same task simultaneously, improving coordination. For example, technicians could collaborate on complex assembly processes, such as those in aerospace or automotive manufacturing. This trend not only increases productivity but also enhances teamwork, reduces errors and is particularly valuable in industries where precision and collaboration are critical.

Enhanced AR systems collaboration can also foster cross-departmental coordination for faster problem-solving. For example, if an operator identifies a defect, they can immediately report it to a quality inspector, who can then provide real-time AR guidance for diagnosis and correction. This rapid response cycle helps resolve issues quickly and efficiently, ensuring smoother production.

This real-time collaborative model could also extend to interactions with production teams spread across multiple sites, further strengthening the agility and overall efficiency of the manufacturing process.

Understanding these trends isn't just about having a competitive edge—it's about preparing for the transformation that AR will bring to manufacturing workflows. Whether you're leading a digital transformation initiative, managing IT strategies or heading AR-based projects, staying ahead of these trends will be critical for driving progress.

ABOUT THE AUTHOR

Hélène Druet is senior offer marketing manager at DELMIA.

Manufacturing Business Leaders Embrace AI

By Jack Smith

As in other business sectors, manufacturing business decision-makers are adopting tools and applications powered by artificial intelligence (AI) at a rapid pace. According to a new survey, 71 percent of manufacturing decision-makers anticipate that adopting AI will significantly enhance productivity. Employees are benefiting from the automation of routine tasks, saving an average of 10 hours per month and enabling them to focus on other higher-value activities.

These results and more are from [*The AI Opportunity in Manufacturing Report*] released in April by TeamViewer, a provider of digital workplace solutions. The report discusses the potential impact that artificial intelligence will have on manufacturing business operations.

A majority report using AI weekly, making it a regular part of business operations.

AI adoption and maturity

AI use in manufacturing has increased due to global challenges such as labor shortages and supply chain disruptions. Currently, 78 percent of manufacturing leaders report using AI weekly, up from 46 percent the previous year, making AI a regular part of daily operations.

With this growth, perceptions of AI maturity and confidence have also risen. While 72 percent of respondents consider their organizations' AI adoption mature, only 28 percent of manufacturing leaders regard themselves as AI experts, indicating an ongoing need for education and skill development.

Manufacturers use AI for customer support automation (28 percent), data analysis (23 percent) and supply chain optimization (19 percent), with AI-powered forecasting and decision-making applications growing. “Young workers, being digital natives, are driving AI adoption in manufacturing,” said Mei Dent, chief product and technology officer at TeamViewer.

Advances for businesses and workers

AI is facilitating considerable advances for both businesses and employees within the manufacturing sector. A significant 77 percent of decision-makers consider AI indispensable for enhancing efficiency, automating repetitive tasks to minimize downtime and allowing staff to engage in more strategic activities. In addition, 78 percent of these leaders indicate that AI has empowered them to concentrate on high-level decision-making.

In addition to improving efficiency, AI is useful for enhancing product quality and minimizing defects. Respondents report that AI resulted in a 33 percent quality improvement compared to a 20 percent average improvement across various industries using other methods.

AI enables workers to analyze data and make decisions, with 74 percent reporting improved abilities in these areas. Additionally, 72 percent of workers state AI helps them acquire new skills, and 71 percent regard it as important for career advancement. Financially, 71 percent of manufacturers anticipate AI will increase revenue in the coming year, projecting a growth rate of 188 percent.

Barriers to broader adoption

Although AI presents significant potential for transforming the manufacturing sector, several challenges hinder its wider adoption. Foremost among these concerns are security

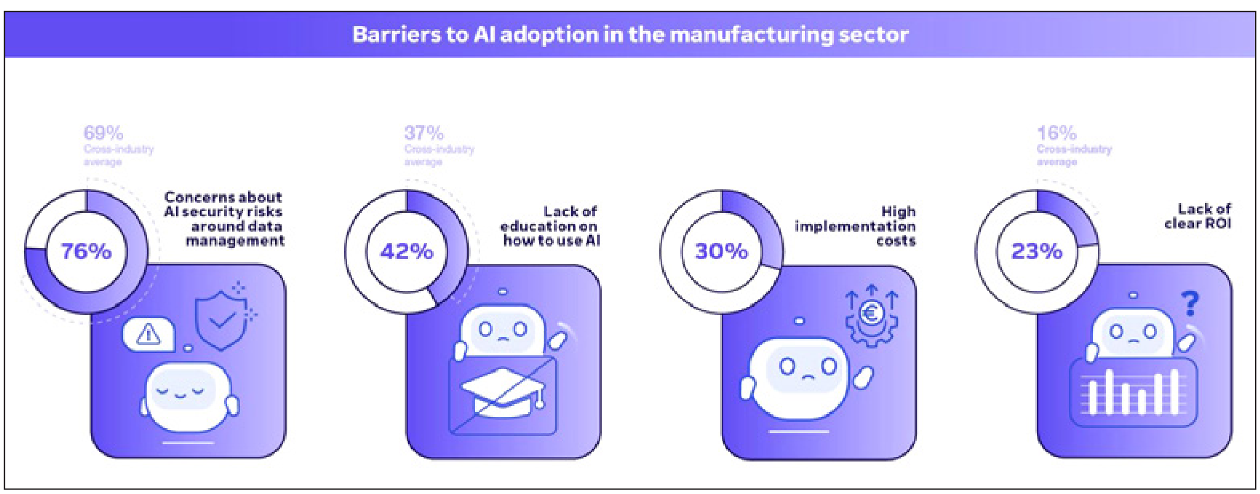


Figure 1. Concerns about AI security issues hinder its widespread adoption.

issues, with 76 percent of respondents citing AI-related data risks—an incidence higher than the cross-industry average (Figure 1).

Other notable barriers include a lack of AI education (42 percent), high implementation costs (30 percent), and insufficient financial support for scaling AI initiatives. However, manufacturers are optimistic, with 81 percent anticipating increased AI investment in the coming year. Addressing these obstacles through targeted education programs, strategic financial planning and clear communication about AI's long-term value will be crucial for achieving broader adoption.

Looking ahead

Investment in artificial intelligence is critical for manufacturing to achieve its full potential. The prioritization of education is evident, with 96 percent of respondents acknowledging the necessity of further training to mitigate associated risks, and 74 percent affirming plans for additional educational programs. Leadership plays a pivotal role as well, with 68 percent endorsing the appointment of a "Chief AI Officer" to oversee strategies and ensure responsible adoption.

Leadership plays a pivotal role, with 68 percent endorsing the appointment of a "Chief AI Officer" to oversee strategies and ensure responsible adoption.

"AI has already proven its ability to transform businesses, but we've only scratched the surface of its potential," Dent explained. "By focusing on collaboration, education and responsible adoption, manufacturers can harness AI to achieve remarkable results while fostering innovation."

ABOUT THE AUTHOR

Jack Smith is senior contributing editor for Automation.com and *Automation.com Monthly* digital magazine, publications of ISA, the International Society of Automation. Jack is a senior member of ISA, as well as a member of IEEE. He has an AAS in Electrical/Electronic Engineering and experience in instrumentation, closed-loop control, PLCs, complex automated test systems and test system design. Jack also has more than 20 years of experience as a journalist covering process, discrete and hybrid technologies.

Industrial Control Systems Drive Precision Agriculture

Comprehensive standards can build on the integration of GPS, sensors and data analytics.

By ISA Newsroom

Precision agriculture represents a transformative approach to farming, leveraging advanced technologies to optimize agricultural productivity, enhance resource efficiency and promote sustainable practices. Robust industrial control system (ICS) frameworks play a critical role in advancing precision agriculture. This paper highlights the importance of establishing comprehensive ICS standards and enhancing educational initiatives to support the widespread adoption and effective implementation of precision agriculture technologies.

Many governments support the development of precision agriculture technology and sustainable farming practices. Examples include Australia's Department of Agriculture, Fisheries and Forestry; Canada's Agriculture and Agri-Food Canada (AAFC) program; the United States Department of Agriculture's Agriculture Innovation Agenda (AIA), and the European Union's Common Agricultural Policy (CAP). Also, in the United States, the National Institute of Food and Agriculture funds research projects in smart agriculture.

Despite this support in some countries, however, the U.S. Government Accountability Office (GAO) has stated, "While precision agriculture technologies, such as variable rate fertilizer applications and yield monitoring, have been available since the 1990s, only 27 percent of U.S. farms or ranches used precision agriculture practices to manage crops or livestock, based on 2023 U.S. Department of Agriculture (USDA) reporting."

Precision agriculture relies heavily on the integration of various technologies, including GPS, sensors, data analytics and automation. Industrial control systems (ICS) serve as the backbone of these technologies, enabling seamless communication, real-time monitoring and precise control of agricultural operations.

The key components of ICS in precision agriculture include:

- **Sensors and actuators.** These measurement and control devices collect data on soil conditions, weather, crop health and machinery performance, providing critical inputs for decision-making processes that in turn result in actions such as changes in irrigation settings, climate control or movement of planting, harvesting or spraying machinery.
- **Data management systems.** These centralized platforms aggregate and analyze data, offering actionable insights to farmers for optimizing planting, irrigation, fertilization, application of pesticides and harvesting. Such systems can greatly reduce the workload for those required to complete regulatory reports.
- **Automation systems.** These systems enable the automation of various farming tasks, reducing labor costs, enhancing precision on usage of fertilizers and pesticides, improving overall efficiency and minimizing impact to people and environment.

The rapid proliferation of precision agriculture technologies has led to a fragmented landscape of proprietary systems and solutions, with a notable lack of standards, as referenced in a 2024 US GAO report. This lack of standardization poses significant challenges, including interoperability issues, data compatibility concerns, maintenance challenges and increased costs for farmers. It also creates safety and environmental risks.

Establishing comprehensive ICS standards is essential to addressing these challenges and unlocking the full potential of precision agriculture in several key areas:

- **Interoperability.** Developing common communication protocols and data formats to ensure seamless integration of diverse technologies and systems.
- **Security.** Implementing robust security standards to protect sensitive agricultural data and safeguard against potential threats.
- **Scalability**. Creating scalable solutions that can be adapted to various farm sizes and types, from small family-owned farms to large commercial enterprises.
- **Sustainability.** Promoting sustainable practices through standards that prioritize resource efficiency and safety and environmental stewardship.

Enhancing education and training

Realizing the full benefits of precision agriculture will require investing in education and training programs to equip farmers, agronomists and agricultural technicians with the necessary skills and knowledge.

To this end, the International Society of Automation (ISA) advocates educational initiatives including curriculum and professional development, public awareness campaigns, and research initiatives that explore new applications of ICS in agriculture.

Collaboration among academic and technical training organizations can be especially helpful for developing specialized curricula that cover the principles of ICS, data analytics and precision farming techniques, as well as sustainable farming concepts.

The integration of industrial control systems is pivotal to the success of precision agriculture. By establishing comprehensive standards and enhancing educational initiatives, we can ensure that precision agriculture technologies are accessible, secure and effective. ISA is committed to leading these efforts, fostering collaboration among stakeholders, and promoting the widespread adoption of precision agriculture practices and sustainability concepts.

ISA is the primary developer of a widely used series of international consensus standards addressing the security of industrial automation and control systems. The ISA/IEC 62443 series of standards provides a flexible and comprehensive framework to address and mitigate current and future security vulnerabilities in those systems. These standards are among numerous ISA standards and guidelines that support manufacturing and supply chain efficiency and safety.

As part of its commitment to the education and certification of automation professionals, ISA actively supports global efforts to establish training and competency programs. An example is the Automation Competency Model developed by ISA for the U.S. Department of Labor. This model defines the key skills, knowledge and abilities that automation professionals need from entry level to advanced career level. It is updated regularly to ensure that emerging technologies are included, recognizing that the automation profession is constantly evolving.

Industry leaders, policymakers, academic institutions, sustainability champions and the agricultural community are called to join us in this mission. By working together, we can develop the necessary standards, provide valuable education and training, and drive the advancement of precision agriculture for the benefit of farmers and society as a whole.

ABOUT THE AUTHOR

The ISA Newsroom is the source for position papers, technical whitepapers and news from the International Society of Automation (ISA). As a non-profit, international professional association, ISA develops widely used safety and performance standards for automation; provides education, training and certification programs for automation professionals; publishes books and technical articles and provides networking and career development programs for automation professionals worldwide. This position paper was first published in November 2024.

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INSIDER INSIGHT

Exploring Industrial Communication Protocols

Industrial automation—the control of machinery and processes by autonomous systems using technologies like robotics and computer software—is one of the major forces driving Industry 4.0. This automation is driven by high-speed communications between devices and software. For the wide variety of industrial automation devices to communicate, a standard communication protocol must be employed. Essentially, industrial protocols are communications protocols that ensure connectivity between machines, devices and systems as part of an industrial network.

Initially, industrial communications were based on serial connections. Many of the serial-based protocols—generally called Fieldbus networks—are still used today, such as Modbus and Profibus. However, in the past decade or so, industrial automation has shifted away from serial toward Ethernet communications, which results in protocols like EtherNet/IP and Profinet. Though to a much lesser extent, wireless communications like WLAN and Bluetooth are also being deployed in industrial automation applications. Broadly, the major industrial automation communication protocols can be divided into industrial Ethernet, Fieldbus and wireless.

SEALEVEL SYSTEMS INCORPORATED

By Drew Thompson

Understand the choices for industrial communication protocols for most applications.

Industrial Ethernet

Among the three major industrial network categories, industrial Ethernet is the largest and the fastest growing. According to the annual HMS Industrial network market shares report, industrial Ethernet applications account for 71 percent of the global market of newly installed nodes in factory automation; this represents a 7 percent growth from 2024. There are two main reasons for this: Ethernet connections have higher speeds than serial fieldbus and wireless connections, and Ethernet cables can be effectively extended to much longer distances than either serial connections or wireless connections.

Among the industrial Ethernet protocols, there are several that stand out.

PROFINET

According to the same HMS report, PROFINET (**Pro**cess **Fi**eld **Net**work)—and the next entry—EtherNet/IP—are tied for the most used industrial network protocols, with each holding an 18 percent market share. PROFINET is developed and maintained by PROFIBUS & PROFINET International (PI), a non-profit trade organization. In general, PROFINET is employed more often across Europe than in the U.S.

PROFINET is an open Ethernet-based protocol that grew out of and is a direct extension of PI's experience with the serial-based PROFIBUS protocol. Because of the close relationship between the two protocols, PROFIBUS devices can integrate seamlessly into a PROFINET system.

The PROFINET protocol defines the communication between components, like alarms, diagnostics, functional safety and additional information. Standard Ethernet cables connect PROFINET components within a network, which allows other Ethernet protocols to coexist within the same infrastructure. Alongside PROFINET, user can employ other Ethernet-based protocols like SNMP, MQTT or HTTP to complement the network.

EtherNet/IP

EtherNet/IP is open-source and is managed and developed by the Open DeviceNet Vendors Association (ODVA), a tax-exempt business league that includes a wide variety of hardware and software manufacturers. Whereas PROFINET is used mostly in Europe, EtherNet/IP is used primarily in the U.S.

EtherNet/IP combines the Common Industrial Protocol (CIP) with standard Ethernet technology. CIP is a media-independent, object-oriented communication protocol designed for industrial automation applications and based on the producer-consumer communication model. The CIP protocol incorporates a comprehensive stack of messages and services that support the integration of industrial automation applications with enterprise Ethernet networks and the Internet, facilitation of data exchange between network components, monitoring and control, synchronization and network management.

One of the major benefits that EtherNet/IP offers is the ability to connect legacy devices. EtherNet/IP's structure allows the ability to connect devices from any OEM to the network, thereby enabling access to the machine data platform. This eliminates the need for proprietary protocols that require expensive investment into a single vendor's product.

EtherCAT

Ethernet for Control Automation Technology (EtherCAT) is an open-source Ethernet protocol. EtherCAT was initially released by Beckhoff Automation in 2003. Then, in 2004, Beckhoff donated the rights to the EtherCAT Technology Group.

EtherCAT has a few unique features and characteristics. The protocol uses a distributed clock mechanism. Each device in the EtherCAT network synchronizes its internal clock to a reference clock. This timing feature allows precise and synchronized communications across all devices on the network. EtherCAT uses a master-slave structure and transmits data throughout the network in a novel way. The master is the only device that is allowed to transmit data, but each slave device can read, modify and add data as the original transmission is passed through the network. This eliminates the need for data to traverse the entire network loop, which reduces communication latency and enables real-time control and response.

Fieldbus

According to the HMS report, Fieldbus networks account for 22 percent of the global market of newly installed nodes in factory automation. That represents a 2 percent decrease in 2024. While Fieldbus networks have been declining in deployments since 2018, there are still many use cases where a Fieldbus protocol may be more applicable than an Ethernet protocol:

- **Legacy systems:** If using existing automation systems or devices that use Fieldbus protocols, it can be more practical and cost-effective to continue using Fieldbus to maintain compatibility with those systems. Replacing all the devices or retrofitting them to use Ethernet-based protocols can be a complex and expensive undertaking.
- **Limited bandwidth:** If a system has low bandwidth requirements, such as simple input/output (I/O) control or monitoring applications, Fieldbus protocols are sufficient. Ethernet-based protocols may be unnecessary if the network bandwidth is underutilized.
- **Deterministic behavior:** Fieldbus protocols offer inherently deterministic behavior. The timing and sequence of data exchange can be highly predictable and consistent. This is particularly important for applications that require precise control and synchronization such as motion control or distributed control systems. While Ethernet networks are fast, they are not deterministic. The speed of Ethernet can overcome some determinism concerns, but not all of them.

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Modbus

Modbus, initially developed in 1979, is the oldest protocol in this list. Traditionally, Modbus was/is implemented using RS-232, RS-422 or RS-485 serial connections. There are several different Modbus protocols, but far and away the most common is Modbus Remote Terminal Unit (RTU).

Modbus RTU makes use of a compact, binary representation of the data for protocol communication. The RTU format follows the commands/data with a cyclic redundancy check checksum as an error check mechanism to ensure data reliability. A Modbus RTU message must be transmitted continuously without inter-character hesitations. Modbus messages are framed (separated) by idle (silent) periods.

Like every protocol on this list, Modbus has some major benefits and some significant drawbacks. To start with the positives, Modbus is very easy to implement. As it is open source, and has been around since 1979, there are innumerable pages of documentation, use cases and best practices available. Finally, implementing Modbus is incredibly cost-effective.

Modbus also has some drawbacks. First, RS-232, RS-422 or RS-485 serial connections have significantly slower transfer rates than Ethernet connections. Modbus supports a limited set of data types that are primarily focused on numerical values and discrete inputs/outputs. Handling more complex data structures, such as strings or arrays, may require additional encoding or custom implementation. Finally, as Modbus is a basic protocol, it lacks advanced features like built-in diagnostics, redundancy mechanisms or extensive error handling.

PROFIBUS

PROFIBUS (**Pro**cess **Fi**eld **Bus**) is the most widely deployed Fieldbus protocol. PROFIBUS—like its cousin PROFINET—is developed and maintained by PROFIBUS & PROFINET International (PI), a non-profit trade organization. In general, PROFIBUS is employed more often across Europe than in the U.S.

The general principle of PROFIBUS is collecting multiple inputs and outputs from the field into a local I/O device and then transferring the data through just one cable to the master. This approach saves costs by the omission of additional hardware and cabling. Also, it saves engineering time as it streamlines network installation, maintenance and troubleshooting.

There are benefits and drawbacks to using PROFIBUS as a protocol. In terms of benefits, PROFIBUS can support much higher transfer speeds than Modbus. PROFIBUS deployments are known for robustness and reliability and can withstand harsh industrial environments. PROFIBUS is a very robust protocol that was designed to automate entire plants. It works extremely well in multivendor applications, with modems and has detailed diagnostics.

Deploying a PROFIBUS network is very complex and requires specialized knowledge and experience. While the protocol is faster than Modbus and other serial networks, it is still significantly slower than Ethernet-based networks.

Wrapping up

Ultimately, the choice of industrial communication protocol depends on the requirements and constraints of the application. For simple networks with deterministic control requirements, or networks with a small, fixed number of devices, a Fieldbus protocol will often be the best choice. For large networks or networks that are projected to grow, or networks that require high-speed data transfers, an Ethernet-based protocol is likely more suitable.

Drew Thompson is a technical writer and content specialist for Sealevel Systems, a leading designer and manufacturer of embedded computers, industrial I/O and software for critical communications. A writer/editor by training, Thompson spends his days creating and delivering content relevant to Sealevel's technical community and business partners.

Understand DC UPS Systems for Mission-Critical Applications

By Markus Bicker and Tom Bicker

In a world shaped by digital transformation, AI and smart manufacturing, uninterruptible power supply (UPS) systems have become essential to maintaining operational continuity. A reliable 12 V, 24V or 48 Vdc backup is crucial for safeguarding sensitive systems and processes across many industries, including industrial automation, edge computing, vision systems, infrastructure, energy and process technology, health care and more.

As designed, DC UPS systems deliver uninterrupted power to dc-operated devices during outages, voltage drops or voltage flicker. Each system typically combines a charging and control unit with a dedicated energy storage module—such as Li-Ion, $LiFePO_4$ batteries or ultracapacitors—to ensure fast, reliable backup.

These systems protect critical components like industrial PCs, Industrial Internet of Things (IIoT) gateways, motor drives, sensors, security infrastructure and medical devices. They help maintain uptime, prevent data loss and ensure process continuity.

Available for 12 V, 24 V and 48 Vdc applications (optionally with ac or dc input), UPSs are ideal for decentralized environments where they're directly integrated into machines or control panels to keep operations running even during unexpected power events.

Operational demands affect DC UPS choices.

Choosing energy storage technologies

Selecting the right energy storage technologies for DC UPS systems is essential due to varying requirements such as environmental conditions, backup durations, as well as lifespan and maintenance considerations—all of which directly impact the total cost of ownership (TCO). Different technologies (Figure 1) provide different benefits:

Lithium iron phosphate ($LiFePO_4$). $LiFePO_4$ batteries offer outstanding safety and lifecycle performance. With up to 6,000 full charge/discharge cycles, they provide long-term stability, minimal maintenance and resistance to thermal runaway, which makes them ideal for mission-critical industrial and medical installations. Their inherent safety profile ensures minimal fire or explosion risk, which delivers peace of mind where uptime and security are paramount. They also offer long backup durations that make them a dependable choice for extended outages. With a lifespan of at least 10 years, this battery technology offers a low TCO.

Lithium-Ion (Li-Ion). Known for high energy density and compact form factors, standard Li-Ion batteries support space-constrained applications. While their efficiency is notable, they are more sensitive to temperature extremes and overload conditions and generally offer lower cycle life than $LiFePO_4$. They are best suited for applications where compact size and cost sensitivity are more important than maximum durability or resistance.

Supercaps (Ultracapacitors). With an extremely long service life of up to 500,000 cycles and fast charge/discharge capability, Supercaps—based on the principle of electric double layer capacitor (EDLC)—provide instant, powerful energy boosts. Energy storage solutions with Supercaps are ideal for short to medium duration bridging periods. They are maintenance free and very durable, which makes them perfect for applications that require a set-and-forget solution with minimal upkeep.

System designs

System designs are tailored for specific environments and application requirements. These designs include modular DC UPS systems, all-in-one DIN-rail-mounted systems and IP-protected systems for harsh environments.

Modular DC UPS systems. Modular architectures combine UPS electronics and battery packs in scalable configurations available as open-frame designs or in DIN rail

Figure 1. The Bicker DC UPS portfolio includes units equipped with supercap energy storage or $LiFePO_4$ batteries.

enclosures. These systems allow flexible sizing and energy expansion that supports a wide range of power needs. Modular systems can be configured with different energy storage technologies that offer application-specific adaptability and easy integration.

Designed for outdoor or rugged use, IP65/67-rated DC UPS systems resist dust, water and mechanical stress, which makes them ideal for infrastructure, edge deployments or remote field installations.

All-in-one DIN-rail-mounted DC UPS systems. Compact, space-saving and installation-friendly, DIN-rail UPS units integrate energy storage and UPS functionality in a single enclosure. Optimized for industrial automation and control environments, they support rapid deployment into control cabinets. The DC UPS systems available with integrated $LiFePO_4$ or supercap energy packs are characterized by a long service life and low TCO.

IP-protected systems for harsh environments. Designed for outdoor or rugged use, IP65/67-rated DC UPS systems resist dust, water and mechanical stress, which makes them ideal for infrastructure, edge deployments or remote field installations. Their robust construction ensures reliable operation under extreme conditions—from factory exteriors to remote sensor and measuring stations.

Final thoughts

The choice of DC UPS system depends on specific operational demands, ranging from industrial manufacturing to medical diagnostics and edge-based systems. With modular flexibility, integrated DIN-rail options and rugged outdoor solutions, today's DC UPS offerings deliver tailored reliability where it's needed most.

Combining high-performance energy storage options like safe and long-lasting $LiFePO_4$ batteries, power-dense Li-Ion cells or maintenance-free Supercaps, users can deploy backup systems that ensure uninterrupted performance with minimal risk. In an increasingly connected and automated world, these technologies are more than a safeguard—they are a strategic foundation for reliable, uninterrupted operation.

Tom Bicker (left) and **Markus Bicker** (right) are co-CEOs of Bicker Elektronik. As a father-son team, they combine experience and innovation to lead the company into the next generation with a shared passion for reliable, high-quality power supply systems.

Secure Data Connections to the Cloud

SKKYNET™

By Xavier Mesrobian

> Demand for secure connectivity between OT and cloud systems has never been greater.

There has never been a time when process data was more in demand and cybersecurity threats to infrastructure and mission-critical systems have been so great. Secure data connections from operational technology (OT) to the cloud are critically important. The most secure system is one that exposes zero attack surface to outside networks and the Internet.

There are currently two software technologies that can provide this level of protection: MQTT and tunnel/mirroring. MQTT is more widely known but has a few drawbacks. A good tunnel/mirroring implementation with a unified namespace provides the same level of protection while addressing those issues. Complementing these, data diode hardware can be used instead of a software firewall.

Closing inbound connections

The key to maintaining a zero-attack surface is closing all inbound connections (Figure 1), using a data diode or closing all inbound firewall ports. Unfortunately, most industrial protocols follow a client-server model where the client must make an inbound connection to the server.

MQTT solves this problem by making outbound connections to an MQTT broker, typically run by a cloud service. Tunnel/mirroring uses a software component on the production side that connects to the data source

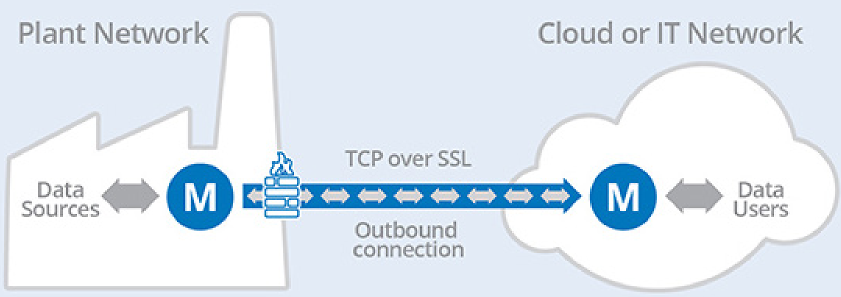


Figure 1. Closing inbound connections.

and makes an outbound tunnel connection to a similar component on the cloud server.

Overcoming MQTT drawbacks

Despite its ability to make outbound connections through a firewall, MQTT has some drawbacks that must be addressed if it is to be useful for large-scale OT/IT [information technology] or industrial Internet of Things (IoT) applications. For example:

- MQTT brokers do not preserve time order among data values on different topics. This means that events in the physical system could be delivered out of order.
- MQTT's quality of service (QoS) levels are inadequate for complex scenarios and are unable to guarantee eventual consistency.
- MQTT struggles with overload situations which risks inconsistencies between the data producer and consumer.

Tunnel/mirror technology does not suffer from these disadvantages.

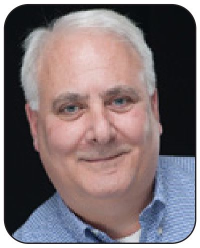
- Time order among data values on different topics is preserved.
- Data quality information is mirrored across the tunnel, which keeps clients immediately informed of any disconnections or bad data quality.
- There is guaranteed consistency that ensures clients are always updated with the most recent value, even when the system is temporarily overloaded.

Network segmentation using a DMZ

In addition to keeping firewalls closed, the best practice for networking industrial data is to segregate networks typically using a demilitarized zone (DMZ) (Figure 2). This ensures there are no direct connections to corporate networks, and that only known and authenticated actors can enter the system at all.

Implementing a DMZ in an industrial IoT environment is problematic for MQTT. Getting data out of a plant through a DMZ typically requires two or more servers linked together. MQTT can be chained, but it requires each node in the chain to be aware that it is part of the chain and to be individually configured. The QoS guarantees in MQTT cannot propagate through the chain, so daisy chaining makes data at the ends unreliable.

A secure tunnelling implementation can support daisy-chained servers across a DMZ as it can mirror the full data set at each node. Implemented properly, it can provide access to the data both to qualified clients, as well as the next node in the chain. The tunnel/mirror software used should be able to guarantee consistency so that any client or intermediate point in the chain will be consistent with the original source.



Xavier Mesrobian is Board of Directors at Skkynet, a global leader in industrial data connectivity. With more than 25 years in the industry, Skkynet software and services are used in more than 29,000 installations in 86 countries, including the top 10 automation providers worldwide.

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EMPOWERING **AI** INNOVATION

A Practical Approach to Sustainable Manufacturing

By Deana Fu

The need for sustainable manufacturing practices is more urgent than ever. Businesses are motivated by cost savings and environmental concerns to make their processes more responsible. This article discusses practical strategies for manufacturers to achieve sustainability, starting with their own production and extending to their end users. By doing so, the entire supply chain—from suppliers to manufacturers to end users—can collectively meet financial, environmental and social responsibilities.

Financially prudent decisions benefit both the business and the broader community.

Efficient and sustainable manufacturing

Modern industrial automation products are designed to optimize energy usage throughout the manufacturing process. This results in energy savings during the asset's lifecycle and enhances resource efficiency and longevity, which leads to significant cost savings for both manufacturers and users.

There are 3 steps that manufacturers should follow when designing their equipment to get started on this journey:

1. **Adopt modern technology.** Hunter Fan adopted modern technology to enhance sustainability by using direct drive motors in its industrial fans; the direct drive motors are lighter, more energy-efficient and require less maintenance than conventional high volume low speed (HVLS) fans. Mitsubishi Electric developed a VFD firmware solution to optimize the performance of these motors. Additionally, it replaced the operator interface with glass touchscreens powered by power over Ethernet (PoE) (Figure 1). This innovation allows flexible placement of controls, reduces the need for separate power infrastructure and facilitates easy reconfiguration and expansion, which leads to lower installation costs and reduced material usage.
2. **Right-size components.** Hunter Fan's shift from a one-size-fits-all approach to right-sizing components highlights the sustainability benefits of customization. By tailoring solutions to meet specific

customer needs, it avoids the inefficiencies and unnecessary energy consumption associated with oversized components. This approach not only reduces utility bills but also enhances overall efficiency. For example, at an airport, installing Hunter HVLS fans led to nearly 30 percent energy savings, demonstrating the cost-effectiveness and environmental benefits of using appropriately sized components in large spaces.

3. **Use data to identify more improvement areas.** Once the operations were going well, Hunter Fan looked for ways to add new features and functionalities. For example, it wanted to group fans together and power them on and off instead of individually. It also wanted to be able to control the fans through various building automation systems so it could program on and off times and vary fan speeds based on current temperatures. Once connected to a building system, users can implement a reporting system for energy usage that can identify areas for improvement and track progress.

Precision reduces failure and material waste

Modern technology offers the ability to produce goods more accurately, which reduces material waste without compromising throughput. Manufacturers can strive for higher precision in their machine controls to operate in line with today's sustainability standards and showcase a commitment to environmental responsibility.

Figure 1. At Hunter Fan, operator interfaces were replaced with glass touchscreens powered by PoE.

Balpack, an original equipment manufacturer (OEM) for packaging machinery, collaborated with Mitsubishi Electric and HPE Automation to develop a precise torque control system for capping small bottles (Figure 2). This system boasts unlimited speeds and torque control adjustable to 0.1 percent, which reduces errors and material waste. As a result, Balpack is helping its customers reduce their carbon footprint.

Recycling instead of disposing

Electronic waste, or e-waste, has become one of the fastest-growing waste streams in the world. In 2022, approximately 62 million metric tons of e-waste were generated globally, nearly doubling since 2010. Despite this growth, waste management remains inadequate, with more than 75 percent of e-waste still going undocumented. By 2030, the global total is expected to exceed 80 million metric tons.

The growing consumption of electronic products with shorter life cycles and fewer repair options drives this rapid increase. Only 17.4 percent of e-waste is properly collected,

Figure 2. Balpack, Mitsubishi Electric and HPE Automation developed a precise torque control system for capping small bottles.

treated and recycled. This emphasizes the urgent need for improved recycling and recovery infrastructure.

Benefits of forward compatibility

Forward compatibility enables businesses to integrate new technologies with legacy systems incrementally, enhancing old equipment without needing simultaneous upgrades. This approach extends the value of reliable equipment, which reduces e-waste significantly. Longer-lasting products require fewer resources—such as raw materials, energy and water—for manufacturing new devices. By extending the lifespan of existing products, the demand for new raw materials decreases.

Yupo, a synthetic paper manufacturer, transitioned from Mitsubishi Electric A Series programmable logic controllers (PLCs) to Q Series PLCs after more than 30 years of reliable use. The forward compatibility of the Q Series with existing automation systems was crucial, which allowed Yupo to upgrade only the PLCs while reusing the input/output (I/O). This approach saved costs, reduced upgrade time and extended the life of existing I/O, which delayed the retirement of the I/O as e-waste. The installation was completed during a brief one-week shutdown, thereby ensuring production resumed smoothly.

Final thoughts

Sustainable manufacturing transcends mere environmental responsibility; it embodies the essence of making financially prudent decisions that benefit both the business and the broader community. It necessitates a collaborative effort among manufacturers, machine makers and users to identify and implement practical steps that foster sustainable practices throughout the entire value chain to achieve a circular economy.

Find more Mitsubishi Electric Americas case studies online.

Deana Fu is the sr. director of strategic marketing at. In her role, Fu oversees research and promotional activities to highlight how the company's offerings help customers address their unique needs. Mitsubishi Electric solutions include robots, motors, drives, CNC, SCADA and custom-engineered solutions.

Remote Operations Need Peak-Performance Batteries

Inexpensive off-the-shelf solutions may be adequate for certain consumer electronic devices powered by alkaline or lithium-ion batteries, especially when the batteries are easily replaceable and operate in moderate environments. However, consumer batteries typically do not meet the needs of industrial applications, especially those that involve hard-to-access locations, extreme environments and large-scale installations where multiple simultaneous battery failures could be highly disruptive and costly.

Specifying an ultra-long-life lithium battery requires detailed due diligence to understand the power requirements and challenges specific to each application. This process can be facilitated by a qualified applications engineer who—using proprietary data intelligence—can help identify the optimal power supply solution that provides the best long-term value.

Applications matter

Too often, the battery specification process is treated as an afterthought rather than a crucial step in maximizing product performance and cost effectiveness. Understanding application-specific power needs and validating the choice of battery is essential to ensuring reliable operation in remote or extreme environments where replacement is costly or impossible.

TADIRAN BATTERIES

By Sol Jacobs

> Expert recommendations can help optimize the supply of power to wireless devices in remote locations.

Design optimization starts by understanding each application's unique performance requirements. The answer can vary depending on whether the device is providing backup power or is serving as the main power source, whether extended shelf life is necessary, whether the power demand calls for a primary cell or if it requires energy harvesting coupled with rechargeable Li-ion batteries. Answers to questions like these can vary significantly across Industrial Internet of Things (IIoT) applications like supervisory control and data acquisition (SCADA), process control, robotics, asset tracking, safety systems, environmental monitoring, machine-to-machine (M2M), machine learning (ML) and wireless networks.

Key considerations for specifying a battery include electrical, environmental, size and weight.

Electrical requirements. Start by knowing maximum, nominal and minimum voltage needs; higher voltage batteries may reduce the number needed.

Battery capacity, measured in Ampere-hours (Ah), determines the cell's maximum theoretical life based on annual energy consumption. High capacity and energy density are crucial for miniaturization. Calculating the average current drawn helps estimate annual losses in capacity. High pulses, if needed, should also be considered for advanced functions such as two-way wireless communications. Predicting capacity loss also involves accounting for storage time and expected losses due to self-discharge.

Environmental requirements. Extreme temperatures impact battery performance by reducing capacity, causing voltage drops and increasing self-discharge rates. Some battery chemistries perform better under such conditions (see Table 1).

Understanding the operating environment is crucial for remote wireless devices in extreme conditions. You must calculate expected temperatures during operation and storage, including time spent in each phase. Bobbin-type lithium thionyl chloride ($LiSOCl_2$) batteries offer the widest temperature range (-80°C to 125°C), the highest ca-

Primary Cell	$LiSOCL_2$ Bobbin-type with Hybrid Layer Capacitor	$LiSOCL_2$ Bobbin-type	Li Metal Oxide Modified for high capacity	Li Metal Oxide Modified for high power	$LiFeS_2$ Lithium Iron Disulfate (AA-size)	$LiMnO_2$ Lithium Manganese Oxide
Energy Density (Wh/Kg)	700	730	370	185	335	330
Power	Very High	Low	Very High	Very High	High	Moderate
Voltage	3.6 to 3.9 V	3.6 V	4.1 V	4.1 V	1.5 V	3.0 V
Pulse Amplitude	Excellent	Small	High	Very High	Moderate	Moderate
Passivation	None	High	Very Low	None	Fair	Moderate
Performance at Elevated Temp.	Excellent	Fair	Excellent	Excellent	Moderate	Fair
Performance at Low Temp.	Excellent	Fair	Moderate	Excellent	Moderate	Poor
Operating Life	Excellent	Excellent	Excellent	Excellent	Moderate	Fair
Self-Discharge Rate	Very Low	Very Low	Very Low	Very Low	Moderate	High
Operating Temp.	-55°C to 85°C, can be extended to 105°C for a short time	-80°C to 125°C	-45°C to 85°C	-45°C to 85°C	-20°C to 60°C	0°C to 60°C

Table 1. Numerous primary lithium battery chemistries are available.

pacity and energy density and can endure humidity, shock and vibration.

Size and weight requirements. Size and weight restrictions can impact battery selection. Miniaturization improves logistics and ergonomics by reducing space and weight. Smaller batteries also serve to reduce the high cost of transporting hazardous goods according to UN and IATA regulations.

A structural integrity application

Resensys provides a powerful platform for protecting infrastructure systems against aging and malfunction by remotely monitoring strain (stress), vibration (acceleration), displacement, crack activity, tilt, inclination, temperature and humidity. These high-precision sensors provide durable and reliable structural-monitoring solutions for bridges, tunnels, buildings, dams and cranes, to name a few.

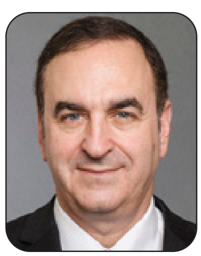
Resensys wireless sensors are mounted beneath bridge trusses (Figure 1) to measure structural stress. These locations are highly inaccessible and the use of a bobbin-type $LiSOCl_2$ battery serves to maximize return on investment by extending operating life and by increasing product reliability in harsh environments.

Figure 1. Structural stress sensors mounted beneath bridge trusses require extended-life life bobbin-type $LiSOCl_2$ batteries.

High pulses for wireless communications

Certain low-power remote wireless devices require high pulses up to 15 A to power remote wireless communications. Standard bobbin-type $LiSOCl_2$ cells can't provide these pulses due to their low-rate design. However, a hybrid solution has been developed that combines a standard bobbin-type $LiSOCl_2$ cell for low-level base current in combination with a patented hybrid layer capacitor (HLC) that generates pulses up to 15 A when needed. As the cell nears its end-of-life, the HLC exhibits a voltage plateau that indicates a "low battery" status.

While consumer devices often use supercapacitors for similar purposes, they are typically unsuitable for industrial applications due to limitations like short power duration, linear discharge, low capacity, low energy density and high self-discharge rates. Supercapacitors linked in series require expensive cell-balancing circuits, which drain extra current, thereby reducing battery life further.



Sol Jacobs is the vice president and general manager at Tadiran Batteries.

AI Will Fail Manufacturers in 2025

If you are an average manufacturer in the U.S., 2025 is not the year to invest in artificial intelligence (AI). If your goals are to modernize and improve your manufacturing process, AI is simply not a practical solution. In fact, you should likely avoid AI like the plague to maximize return on investment (ROI). Any investment in AI will lead to remorse. This seemingly anti-AI message is, however, not an anti-progress message.

In fact, the reason companies should avoid AI in 2025 when they look to improve their manufacturing is because there is a near guarantee that you are better off investing in tools that supplement your factory's human intelligence (HI) instead. I place my automation honor and an American dollar bill on this bet.

The state of American manufacturing

There are around 250,000 manufacturing companies in the U.S. While the data is not entirely conclusive, it's estimated that somewhere between 50 percent and 70 percent of these manufacturers have no form of automation deployed in their manufacturing. It's 2025; we are focused on reshoring manufacturing. Yet at least half of manufacturing in this country is driven by our stagnation and a shrinking human labor pool. That's a problem.

By Drew Baryenbruch

> Empowering the controls team with time-series data from automated machines means you are moving forward on a digitization journey.

We're talking Industry 4.0 while the majority of manufacturing lives in a sub-Industry 3.0 world (Figure 1).

Marquee automation users (think automotive or food processors) may have advanced systems that could leverage AI for value. The rest of us should invest elsewhere. If you have no automation in your process, your spending should be on automating your processes. If you have some automation, your expenditure should be on expanding that automation and giving data access to those systems. The value proposition that can be unlocked by gaining data from your automation systems might end

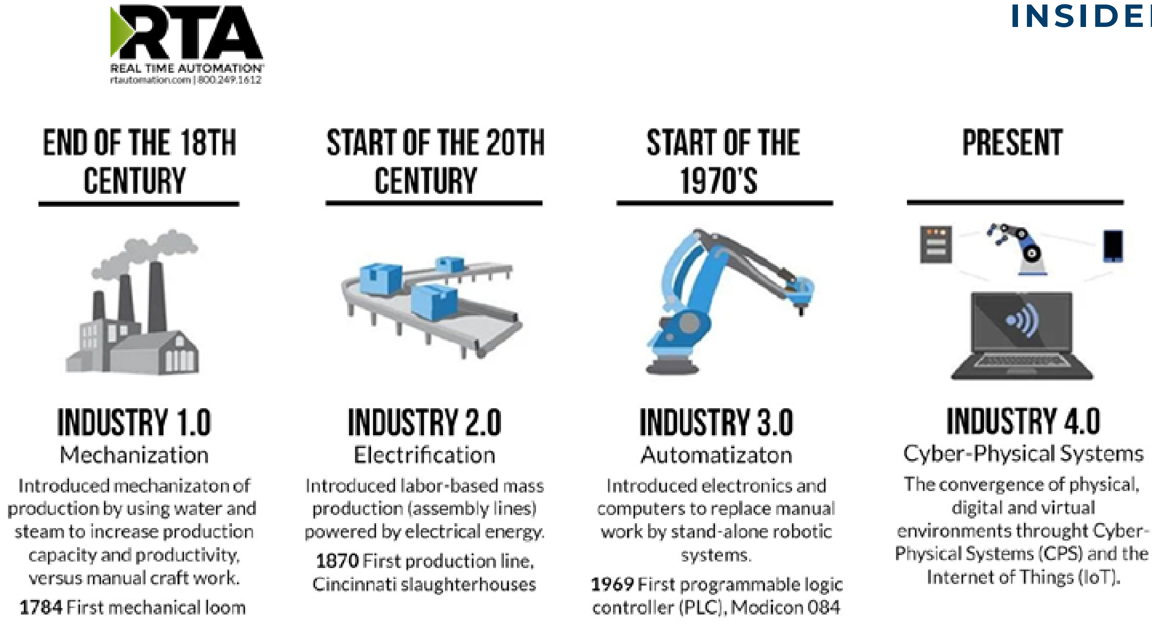


Figure 1. U.S. manufacturing timeline. We're talking Industry 4.0 while the majority of manufacturing lives in a sub-Industry 3.0 world.

with AI, but it can start giving significant value without any AI.

Manufacturers in this country should be focusing their automation efforts on empowering HI, not AI. The beauty of digitization, Industrial Internet of Things (IIoT) and Industry 4.0 efforts is that, at their simplest, they are information access initiatives. They aim to bring together data from the factory floor and present it as information to humans and business systems. All these initiatives support the fundamental value of accessing control data.

This data, once accessed, can be modeled and saved in time-series records. These simple logs of information blow open the automation value door. With time series records, you can trend, troubleshoot, measure efficiency and build predictive models. Interpreting this information to find value is NOT a challenge that requires AI. The challenge is creating this information so HI can act on it.

It's more efficient to invest in HI

Your control engineers and operators know your machines and processes. Many can service and diagnose issues in real time by sight, sound and occasionally taste. These people are valuable resources. Their experience is an under-leveraged HI resource. These are the people who need to be empowered with access to time-series control information first.

Business systems can benefit from information locked in operational technology (OT) networks, but that value will pale in comparison to the value your operations teams can add. This is the team of individuals who can logically comprehend the relationships among system variables. They know what additional vibration and heat lead to. They see an encoder skip and know how a slowing actuator will impact the process. Giving these teams historical records of data from all inputs on a machine will vastly increase their ability to do root-cause analysis. The quicker they solve problems, the more efficient your operations become.

Bridging IT and OT

Connecting people or information technology (IT) systems to OT networks is the first step needed to empower either AI or HI (it's also one of the more challenging steps). OT is the hardware and software that monitors and controls devices, processes and infrastructure used in industrial settings. This is all the technology we use and deploy on the factory floor and includes industrial automation communication protocols.

The main purpose of OT is to turn the physical world into digital signals; basically, to connect and represent real-word variables as data. IT, on the other hand, must take data and turn it into information for users and other systems to ingest.

For IT to get real value from OT data, that data must be modeled. This gives each data point the context, meta data, state and values needed to make it usable in IT systems. Data context is imperative for us to get the full value from our automation expenditures. To leverage data analytics and AI tools, factory floor data must be given context. A PLC doesn't need meta data; it is programmed to react to data values. However, that same data value moved to the cloud needs context. The context of this information will empower your operators and managers.

Operators are not going away

AI systems today could be trained on all of the information that operators have. Models can be created that can improve root cause analysis and support preventive maintenance, but today, this comes at a significant cost. Training AI tools on your data and building these efficient models will keep a highly compensated data scientist, working with expensive tools, employed for a long time. This data scientist is great, but their system knowledge will come from your operations team, and unlike your operations team, this data scientist is not employed to fix anything. Trusting your operations team to leverage historic data with HI is a significantly more efficient place to start.

Focusing on HI empowerment is not a counter to future AI

Empowering your controls team with time-series data from your automated machines means you are moving forward on a digitization journey. This data access offers the best return by first being used by your HI. In the future, this same data access can be leveraged by AI. The smart manufacturer will allow AI tools to further mature, and first focus on the ample low-hanging fruit that HI can harvest.

Drew Baryenbruch is president of Real Time Automation and a 19-year veteran of the industrial and building automation industry. He has worked on thousands of applications, helping bridge the gap between the legacy Fieldbus technology and Ethernet-based technology, and has helped device manufacturers bring hundreds of automation devices to market.

The Replace, Repair or Retrain Decision

By Brandon Glenn

> Knowing when to repair an aging machine, purchase a new one or ensure team members are using them efficiently is important.

There comes a time in any product's lifecycle when a difficult decision may have to be made. Whether it's a faithful old pick-up truck, that trusty 9-iron that always bailed you out or a tired 3-axis mill that seems to get a little farther from tolerance with each turn, it's easy to get attached.

Shop owners are familiar with these decisions. How do you know when it's time to fish or cut bait? Do I keep investing in replacement parts and take the hit on more downtime, or bite the bullet and invest in a new machine? Are my employees positioned for success on our current machine lineup or do we need to reassess our capabilities and retrain operators to do more work that the machines can handle better?

These can be tough decisions but consider the following four steps for making the best choices for your needs.

STEP 1: Assess machinery and operator skill levels

Good machines that are well maintained enable you to produce better and more accurate parts. However, there are a few variables to consider when determining what it takes to optimize shop performance and get to that level.

How frequently do you repair a certain machine? Does this machine still meet current production demands, or is it slowing operations (and profitability) down? How do ongoing annual maintenance costs—combined with your scrap rate—compare to the amortized costs of a new machine? Is it compatible with other machines in the shop (and industry), or does it stand out in its obsolescence and perform like a dinosaur among newer, more efficient and technologically advanced machines? Evaluate how a quality machine tool can pay for itself in time. Consider how your return on investment can provide a good comparison of where you are now, where you want to go and what it will take to get there.

When you evaluate your machines, you should also evaluate the people who operate them. Continuing education and training opportunities also can help breathe new life into old habits. Is it the older model lathe that needs an update, or is the real issue, “the loose nut behind the wheel?” Regardless of skill level or machine familiarity, technology changes with time, and there is always an opportunity for employees from shops of any size to refresh their skillset and learn about new techniques with education and training.

That’s why Okuma established the [Okuma Machine Tool Academy] (Figure 1) in partnership with Rowan-Cabarrus Community College. Learn new skills or enhance time-honed talent with hands on and classroom instruction. Improve job performance and satisfaction. Boost employees’ confidence with personal and professional development. Check out the upcoming class schedule and sign up for updates so you never miss an opportunity to give your team the added skills they need to raise your shop’s game.

STEP 2: Evaluate repair versus replacement costs

We put our machines and our tools through a lot, and we expect a lot out of them in return. You can switch out ball screws and even change a spindle, but the years and revolutions take a toll. Sometimes, machines simply reach critical mass. Do the accumulating costs of repairing the same machine outweigh what you could put into a new, more productive machine?

If you’ve been in business long enough, you probably feel like you never have enough machines, so the thought of getting rid of one or spending just to have the same number of machines can be troubling. Honest consideration of the total cost of ownership (TCO) and the return on investment (ROI)—not including better performance with fewer interruptions you can expect with a new machine—can (and should) bear considerable weight on a purchasing decision.

Figure 1. Okuma Machine Tool Academy is operated in partnership with Rowan-Cabarrus Community College.

OKUMA

When you buy a vehicle, you consider the ongoing, expected lifetime costs of maintenance, fuel, depreciation, etc. The same should be considered with your CNC machine tool; about 15 percent of a machine's total cost is in its initial purchase price, with the balance of 85 percent being realized over the lifetime of its operational costs. Warranty is another consideration. Our Affordable Excellence machines come with an industry-leading three-year warranty on parts and a five-year OSP control warranty. When you buy an Okuma machine, we consider you a customer for life.

STEP 3: Understand new machine advantages

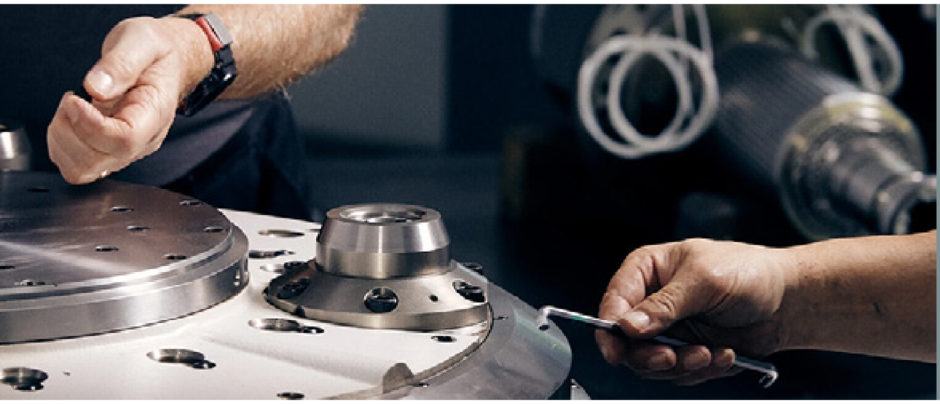
What do you do with an aging machine lineup? Throw more money on the fire to try and fix machines or take on a little debt with new machines? Before long, you've spent tens of thousands to fix an old machine. Costs accumulate when you're dumping money into something that could have been replaced for the same cost years ago.

We referenced compatibility with other machines, and technological capability is an equally important consideration to make: how much more can I do today with a new machine than I could with an older machine that likely doesn't have the added benefits of technological innovation we've experienced in the last 10 to 20 years?

Not only does your tired but aging machine also lack the advances you need to be more productive and efficient, but you—and your customers'—confidence waivers. You also just don't trust the old ones to press a button and walk away. When you employ new technology, you unlock an expanded scope of capabilities, including introducing automation to your shop. Investing in built-to-last machines is a great sales tool that shows your customers you're committed to innovation and delivering precise and dependable parts.

Or consider a new machine with a next-generation CNC control. What happens when you upgrade an older mobile device with a new one? You're initially shocked at the enhanced performance and security upgrades and wonder how you got by for so long with an older, slower, outdated model. The same is true with your CNC control. Purchasing a new machine can be an eye-opening experience when you realize the greater processing power and performance that comes with a next-generation control like the Okuma OSP-P500 (Figure 2). You'll be able to run multiple programs simultaneously on a simple and secure interface that is also more energy efficient.

Figure 2. Okuma OSP-P500.



About 15 percent of a [CNC] machine's total cost is in its initial purchase price, with the balance of 85 percent being realized over the lifetime of its operational costs.

STEP 4: Realize new machine benefits

What happens when you and your team lose trust and faith in the machines to make good parts? You'll waste a lot of downtime, money and materials reworking excessive test pieces that only end up in the scrap bin—in addition to frustrating machine operators. If you spec out pricing on one part and need to make five to get there, your returns will be very skewed; with very expensive materials, it can add up quickly. You'll also spend more time rearranging production schedules than producing parts.

Investing in a new machine is an important decision that requires due diligence and careful consideration, but don't be intimidated. There are options available, regardless of the size or scope of your operations, that empower you to take on more profitable jobs and do more than you ever thought possible. One option is the Okuma Affordable Excellence line, an offering that makes quality machine tools available to everyone thanks to Okuma's accessible pricing program.

While replacing aged equipment with newer, more energy-efficient products certainly can impact capital expenditure budgets, these can be offset by lower operating expenses over its lifecycle. That's because, as no surprise to anyone, newer products like windows, refrigerators or vehicles are engineered to be more efficient so you can do more with less.

Conclusion

If your operating structure follows a low- to no-debt model that relies on low overhead and uses cash to pay for capital expenses, the prospect of taking on new machine debt and lower margins may seem daunting. But there are always options—financing, budgeting replacement costs throughout the lifecycle of the equipment or overcoming your own misconceptions about new machine costs and the many ways that can be mitigated, including increased capabilities that yield greater returns.

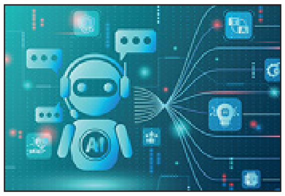
Brandon Glenn is director of sales at Okuma America Corporation.

More from Automation.com

Automation.com's topical compilation for May focuses on current industry trends. Find out what's happening in augmented reality in 2025, the latest information about agentic AI, and how to align legacy OT systems with modern systems. Also, just when you thought you were getting the hang of Industry 4.0, now people are talking about Industry 6.0. Stay informed about all the trends in automation by subscribing to Automation.com.

IIoT & Digital Transformation

2025 Trends for Augmented Reality in Manufacturing: Augmented reality (AR) is no longer just a futuristic technology to monitor—it has become a powerful tool reshaping the manufacturing industry. These five trends promise to redefine how manufacturing professionals and organizations leverage AR for innovation and growth.



How to Cross the Agentic AI Bridge to Physical AI in Manufacturing: Agentic AI goes beyond perceiving and generating; this type of artificial intelligence plans, makes decisions, uses tools and executes tasks autonomously—without being told what to do and without coding. However, agentic AI is not the destination; it's the bridge connecting the industry to Physical AI and the ability to access systems that understand friction, gravity, spatial relationships and real-world cause and effect.

Factory Automation & Control

Industry 6.0: How the Next Industrial Revolution Will Reshape Manufacturing: Industry 6.0 will build on the principles of Industry 5.0, incorporating technologies such as AI, quantum computing, advanced robotics and big data analytics into the manufacturing process. This next revolution presents a future where manufacturing is driven primarily by intelligence, with little human intervention on the factory floor. Let's take a closer look at what the manufacturing industry can expect as the 6th industrial revolution unfolds.

Case Study: Yamaha Robotics Delivers Flexible Automation Boosting Automotive Parts Manufacture's Output: Yamaha Motor Robotics FA Section has delivered a 10% uplift in output for a customer manufacturing automotive parts, by superseding conventional conveyors with a system comprising LCMR200 modules.

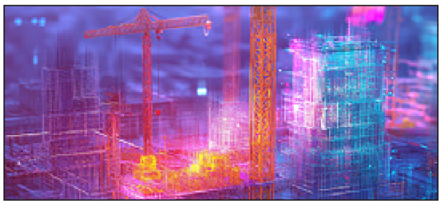
Process Automation & Control

Capturing Process Data Without Process Penetrations: Non-Intrusive Instrumentation Delivers Flexibility: New technologies make reading some process variables and equipment conditions through metal or plastic pipe surfaces or tank walls possible, all without a process penetration. Let's examine four non-intrusive technology families and where they are particularly suited to providing missing process data.

Winning in the Age of Industrial AI with Innovation and Sustainability: At ARC Advisory Group Forum 2025, an ExxonMobil keynote speaker challenged attendees to think about integration and interoperability. In the presentation, called "Be a Part of the Future: A Journey to a More Visual Way of Working," Michael Hotaling suggested that industry-wide transformation will happen by collaborating between suppliers and asset owners, separating hardware from software, separating software from data and deploying agentic AI models within the ecosystem.

Industrial Cybersecurity & Safety

OT Cybersecurity Best Practices: How to Align Tools Across Legacy and Modern Systems: In 2025 and the years ahead, the challenge is no longer about bridging an IT/OT divide—it's about building layered, adaptable security architectures that apply familiar tools in environment-specific ways, across both legacy infrastructure and modern digital systems.



The Shift Toward a Business Outcomes Mentality in OT Cybersecurity: The shift in mindset toward business outcomes is timely, and needed. It will drive demand for data which we must have. It will promote collaboration between governmental and commercial entities—even competitors—and steer both users and providers alike towards solutions that make a real impact.

Enterprise Architecture and Networks

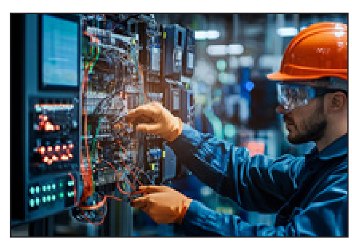
Digital Twins Revolutionize Cybersecurity: The advent of digital-twin technology in operational technology (OT) cybersecurity marks a significant leap in securing critical infrastructure. In OT cybersecurity, digital twins offer unparalleled advantages, enabling proactive vulnerability detection, enhanced incident response and robust risk management.

Seven Strategies for Making the Most of Manufacturing Data: Automated systems of data collection, record keeping, reporting, analysis and visualization are becoming essential for manufacturing. How do you take all this data, extract the right information and put it in the hands of manufacturers when they need it? The answer comes from three solutions: ERP, MES and QMS software.

Operations and Management

Improving Life for the Workforce with Automation: At its core, automation isn't just about machines running longer; it's about making better use of human potential. When workers are freed from the grind of constant loading, unloading and monitoring, they're able to shift their focus to solving problems, refining processes and maximizing the capabilities of new technology.

Configuration Change Management, Interoperability Play Roles in Mitigating Risks: In today's industrial landscape, ensuring the safety and reliability of plant operations is paramount. With complex processes, intricate machinery and interconnected systems, maintaining a safe working environment requires diligent attention to detail and proactive measures. Effectively addressing configuration change management and interoperability can help industries significantly improve safety standards and mitigate potential risks.



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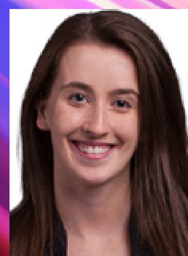

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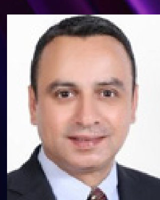

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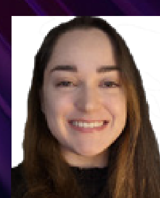

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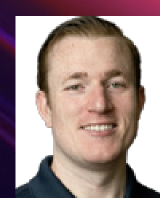

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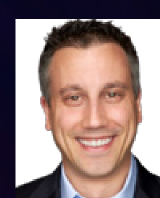

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