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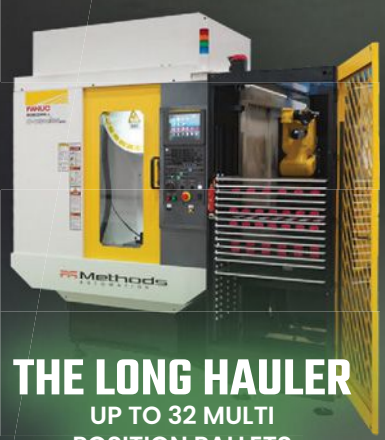

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manusummit.com

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TALENT & THOUGHT LEADERSHIP

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GET READY FOR INDUSTRY AI

STEVE PLUMB, Editor-in-Chief

ANY DOUBT ABOUT THE FUTURE OF AI in manufacturing was put to rest at CES in January. The technology dominated the annual electronics showcase, including a range of seemingly near-sentient humanoid robots and other AI-infused machines and automated solutions performing all manner of entertaining tasks—from cooking, vacuuming and folding laundry to dancing, playing table tennis and even dealing blackjack (CES is held in Las Vegas after all). While the demos focused on the fanciful and impractical, the talk was decidedly more businesslike.

Nvidia Corp. CEO Jensen Huang kicked things off with his opening keynote address focused on real world applications for agentic agents that are boosting productivity and freeing up developers, engineers and operators to focus on higher value-add duties. During the show, Nvidia debuted "Inference Context Memory Storage Platform" to optimize AI data centers, as well as its new Rubin computing architecture, which Huang touted as "state-of-the-art in AI hardware." Nvidia also partnered with Caterpillar Inc. on the Cat AI Assistant, which the construction equipment company is using as a "proactive partner" to monitor and provide customized recommendations for its Cat 306 CR excavator.

While Nvidia was present throughout the four-day event, a pair of other CES keynotes underscored AI's immense potential and rapidly advancing deployment.

Roland Busch, Siemens AG's president and CEO, christened a new manufacturing era. "The industrial AI revolution has already begun," Busch proclaimed in a presentation that also announced the introduction of Siemens' Digital Twin Composer software powered by Nvidia Rubin. "It (AI) becomes a force with direct real-world impact ... that transforms how we design and build, how factories produce, how infrastructure operates, how the world powers itself."

Lisa Su, who heads electronics giant Advanced Micro Devices Inc., went even further. "This moment in tech not only feels different, AI is different," Su told attendees, declaring AI to be "the most powerful tech that has ever been created." Likening the technology's ascension to the rapid adoption of the internet and mobile phones, she forecasts there could be as many as five billion active users within five years—an astounding number considering there are about 8.3 billion people alive today.

To fuel the growth, Su noted the need to increase compute capacity to train and run AI systems. Capacity has jumped a hundredfold over the last four years and a similar expansion is expected in coming years to keep pace with demand, she said. "Meeting that demand will take a broad portfolio of solutions form the largest systems in the cloud to AI PCs to embedded computing."

Elsewhere at CES, Hyundai Motor Group and its Boston Dynamics unit debuted Atlas, a humanoid robot developed with Google's DeepMind AI division designed for industrial work such as order fulfillment. It'll be deployed to Google DeepMind and Hyundai's Robotics Metaplant Applications center in coming months to assist human counterparts.

Such partnerships are essential, SME CEO and Executive Director Jeannine Kunz said during her presentation, noting that the average half life for manufacturing skills is already less than five years—and could be as little as two years with the advent of AI and other digital technologies. This makes training and upskilling even more critical, she asserted, noting the interdependence between tech and talent.

The importance of integrating AI and other advanced technologies with humans is evident throughout this issue of *Manufacturing Engineering & Technology*. In her feature, "Smart Strategies to Bridge the Skills Gap," Contributing Editor Karen Haywood Queen takes a deep dive on how manufacturers are using apprenticeships, partnerships with technical schools and new training techniques to better prepare workers for Industry 4.0 and Industry AI.

Meanwhile, Senior Editor Michael McConnell explores an underutilized resource—military veterans—and how their special skillsets can immediately aid manufacturers amid the ongoing workforce shortage. On the tech front, contributors Kip Hanson and Meaghan Ziemba tackle the latest advances in machine monitoring and multi-axis machining, respectively. Other highlights including an update on Advanced Functional Fabrics of America in the latest installment of our series on Manufacturing USA institutes, and BTX Precision Chief Revenue Officer Jamie Goettler's Executive Perspective on the impact of technology throughout manufacturing.

We hope you enjoy the issue!

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SME SPEAKS

FORGING THE FUTURE: HOW AI AND ROBOTICS SHAPE THE WORKFORCE

JAKE OKUN, Instructor, School of Manufacturing Systems and Networks
SME Member since 2022; 2025 30 Under 30 Honoree

THE HUM OF MACHINERY. The rhythm of creation. The spark in the eyes of my students the first time they bring an idea to life through code, motion and metal is where the future begins for me every day.

As a faculty member at Arizona State University, I have the privilege of teaching the next generation of engineers, innovators and dreamers. My mission is simple: to help students not only prepare for the workforce but also discover the excitement and endless possibilities that manufacturing, robotics and AI can offer as they discover their futures.

We're at a time when technology and creativity are genuinely coming together. The blend of AI, robotics and human-centered design is transforming how we build, think and approach solving real-world problems to find solutions that change our world. The factories of tomorrow will not just be filled with machines, but they will be powered by people who know how to teach machines to think, adapt and create alongside them. My role is to prepare my students for that world, helping them understand that the heart of machines is a mix of the technology itself as well as the people who design and make it work.

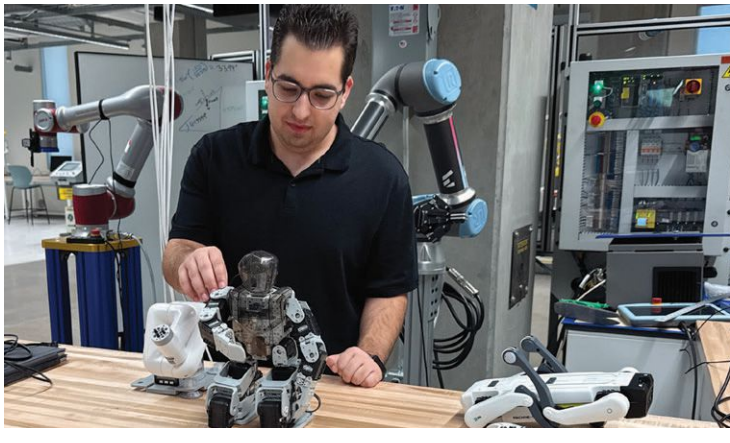
When I introduce students to manufacturing and robotics, I see the moment curiosity sets in. A student who once saw machines as intimidating suddenly realizes they're an extension of human imagination. Whether it's programming a robotic dog to mimic movement or designing a 3D-printed part inspired by nature, I watch as students connect abstract theory to tangible creation. That's the magic of teaching in this field—seeing ideas take physical form and witnessing the confidence that builds with each successful prototype they make.

Beyond the classroom, my work extends to mentoring younger students and introducing them to the world of STEM education from an early age. The next generation shouldn't just consume technology; they should create it. Through outreach programs and competitions, I've watched middle and high school students light up as they discover how science, technology, engineering, math and creativity intertwine. These moments of discovery are where passion is born. All students who call me their professor are given the opportunity to dream big, see themselves as inventors and believe they belong in spaces where innovation takes place.

In my journey as an educator, I've learned that real learning happens when theory meets action. Hands-on experience not only reinforces lessons but transforms them. When students operate a CNC machine, design a prototype in CAD or troubleshoot a robotic arm, they are mastering skills that will stick with them for life. It is in those moments of trial, failure and success that confidence emerges. Merging education with practice has taught me that giving students access to tools is powerful, but teaching them how to think critically through problem-solving is where transformation happens daily.

The challenge and the opportunity lie in bridging the gap between academia and industry. Too often, what's taught in classrooms doesn't fully reflect what's needed on factory floors or in design labs.

That's why I am passionate about collaboration between educators and industry leaders. Together, we need to bring real-world projects into classrooms and invite professionals to share their insights with students, preparing them for the workforce. When students see how their learning connects



Jake Okun says the key to preparing the next generation of manufacturers is collaborating with educators and industry leaders to bridge the gap between academia and industry. (Provided by Jake Okun)

editorial@sme.org

directly to careers, the path from education to employment becomes clearer and they become more enthusiastic.

AI is not replacing people; it's redefining the partnership between human creativity and machine intelligence. Robotics is about amplifying human capability. Manufacturing is dynamic, adaptive and deeply creative. When we teach students to see themselves as co-creators with technology, we unlock a workforce ready to lead in a world defined by innovation.

Preparing the next generation for this future means teaching more than technical skills. It's about nurturing adaptability, collaboration and empathy, the traits that make human-centered design so essential. Machines can calculate, but only people can care. The best engineers of tomorrow will not only design efficient systems; they will design meaningful systems that improve lives.

As I stand in a lab surrounded by whirring machines and eager minds, I am reminded that the future is built by students who dare to imagine what's possible, by mentors who refuse to let potential go unnoticed and by educators who see the classroom as a launchpad for innovation.

The hum of machinery still fills the room, but it's the heartbeat of my students' ambition that drives it all forward, which makes my job worth it every day. I am not just teaching manufacturing—I am shaping the makers of tomorrow. And that, to me, is the most exciting job in the world. ■

SME JOINS RENEWABLE ENERGY COLLABORATIVE

SME HAS BEEN SELECTED as one of five organizations nationwide to receive funding and participate in the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) Industrial Systems Energy Efficiency Development (ISEED) Collaborative. Over the next two years, SME will receive technical support and guidance from DOE national laboratories to develop and pilot technical assistance programs that strengthen the U.S. manufacturing workforce and increase adoption of energy-efficiency practices across manufacturing and other energy-intensive industries.

Through the program, SME will work in partnership with Lawrence Technological University in Southfield, Mich., to create and expand workforce development opportunities that prepare America's next generation of industrial workers. The effort will help manufacturers nationwide build specialized training programs that improve energy efficiency on

factory floors, strengthen the nation's manufacturing competitiveness and ensure long-term industrial adaptability.

"As one of the largest drivers of our economy, the industrial sector is critical to our nation's prosperity, security and competitiveness," said Jeannine Kunz, SME's executive director and CEO. "The future of manufacturing depends on our ability to develop people as quickly as we develop technology—and this collaboration is a powerful step forward in that mission."

The ISEED Collaborative will provide a total of $3 million in federal funding and technical assistance over a two-year period to five awardees. Each participating organization will work with DOE's national laboratories to design and pilot programs that can be expanded regionally and nationally.

To learn more about the ISEED Collaborative, visit **www.ornl.gov/iseed.** ■

THE (BLUE) SKY'S THE LIMIT FOR MANUFACTURING INNOVATIONS

SME IS ACCEPTING SUBMISSIONS for the 2026 Blue Sky Competition, which is designed to identify transformative concepts that can translate into wider applications via funding and partnerships with investors and government agencies.

Recent Blue Sky finalists and winners include academic and industry teams leveraging 3D bioprinting to manufacture human tissue in the operating room, designing "factories in space," and reimagining the AI-human interface to detect worker stress and fatigue to improve safety, ergonomics and collaboration.

"For nearly a decade, the Blue Sky Competition has nurtured some of the most radical ideas for taking American manufacturing to the next level and helped transition and scale them across industries," said SME Chief Manufacturing Officer Brett Conner. "As its name suggests, the Blue Sky Competition is about the unlimited possibilities to break new bounds to sharpen the nation's economic competitiveness and safeguard our security."

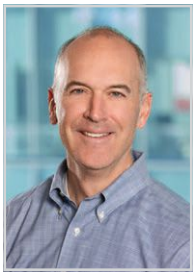
The deadline for submissions is April 1. Abstracts should be original, advance the future of manufacturing and demonstrate the potential for real-world impact. Finalists will be announced at SME's North American Manufacturing Research Conference (June 14-18), hosted by Penn State University. The overall winner, which will receive the David Dornfeld Manufacturing Vision Award, will be announced later in 2026.

Visit **www.sme.org/aboutsme/awards/blue-sky** for more information. ■

DRIVING SUSTAINABLE MANUFACTURING

INNOVATION IN MANUFACTURING PROCESSES

DAVE DUNCAN, Head of Sustainability, PTC



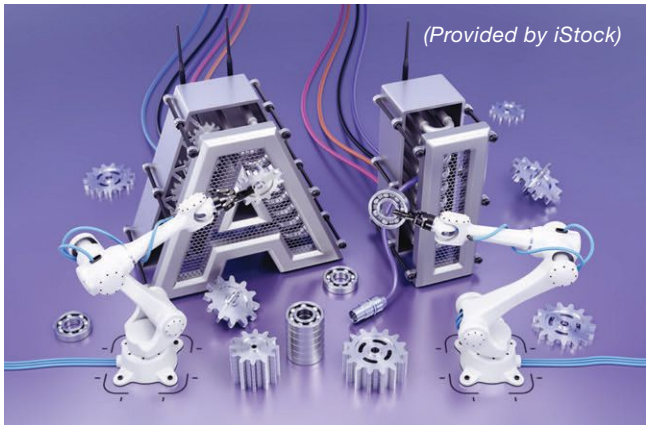
ACCORDING TO RECENT DATA, 55% of surveyed industrial product manufacturers are leveraging AI tools in their operations, and over 40% plan to increase investment in AI and machine learning over the next three years.

As manufacturers face mounting pressure to reduce their environmental footprint, AI is emerging as a critical tool, not just for efficiency, but for enabling a more sustainable and circular approach to industrial operations.

For years, the idea that Internet of Things sensors and alerts could solve everything dominated manufacturing, but their effectiveness has proven limited. Now, with AI-driven predictive maintenance powered by complete product data, manufacturers are unlocking new levels of sustainability that go far beyond what traditional approaches can achieve.

Anticipating Failures to Reduce Waste

At the heart of predictive maintenance is the ability to monitor equipment health by leveraging a wide range of data sources—including real-time sensor readings, historical performance records and information captured within service systems. By analyzing this range of equipment data, AI models can detect subtle patterns that signal impending issues, often long before they begin to cause negative impacts to the machines or a company's bottom line.



(Provided by iStock)

This foresight allows manufacturers to intervene proactively and profitably, replacing or repairing components only when necessary. That means a significant reduction in unnecessary part replacements and associated material waste. Instead of relying on fixed maintenance schedules that may lead to premature servicing, AI enables a more precise, condition-based approach that aligns with sustainability goals.

When integrated with service/asset-management platforms, predictive maintenance becomes part of a broader strategy to optimize asset performance across the lifecycle. These platforms provide a unified view of service history and asset hierarchies to enable more informed and sustainable decision-making when it comes to maintaining equipment.

Lowering Energy Consumption

Equipment that is poorly maintained or nearing failure often consumes more energy than necessary. Motors may run inefficiently, bearings may create excess friction and systems may operate outside optimal parameters. These inefficiencies increase operational costs and contribute to a larger carbon footprint.

AI-driven predictive maintenance helps identify these energy drains early on. By keeping machines in peak operating condition, manufacturers can reduce energy consumption across the board. In some cases, predictive insights can inform broader energy-optimization strategies, such as balancing or scheduling high-energy processes during off-peak hours.

Supporting the Circular Economy

Modern industrial equipment is increasingly designed as software-driven products, with embedded sensors and onboard logic that enable real-time monitoring and adaptive control. This intelligent design allows machines to perform their core functions, as well as continuously report on their own health, usage patterns and environmental conditions.

When paired with AI-powered predictive maintenance, these smart assets can detect early signs of wear, inefficiency or failure—often long before traditional methods would catch them. AI models analyze sensor data, historical

performance and service data to forecast when components are likely to fail, enabling timely interventions that prevent breakdowns and reduce unnecessary part replacements.

This proactive approach significantly extends the lifespan of equipment, reducing the need for premature replacements and lowering demand for raw materials. It also supports circular-economy principles by enabling more sustainable end-of-life strategies, such as refurbishment, remanufacturing or reuse. For example, if an asset has not been fully consumed or can be reclaimed, organizations can apply modernization or refurbishment to upgrade or restore equipment for continued use.

But the real power of this AI-powered system emerges when service feedback from asset-management and field-service teams is looped back into the product lifecycle. Field technicians capture valuable insights during maintenance—such as recurring failure modes, environmental stressors and usage anomalies—which are recorded in service-execution platforms. These insights inform engineering teams about real-world performance, helping prioritize design improvements that prevent future failures and improve remanufacturing and refurbishment capabilities.

> “AI models analyze sensor data, historical performance and service data to forecast when components are likely to fail.”

Building a More Sustainable Future

AI in predictive maintenance will help enhance resilience, making companies better able to adapt to supply chain disruptions, regulatory changes and shifting customer expectations.

By combining predictive maintenance with software-driven design and closed-loop feedback, manufacturers can unlock new value from existing infrastructure. These systems work together to ensure that sustainability efforts are embedded across the asset lifecycle, instead of being siloed within individual departments.

Manufacturers don’t need to drastically change their current operations to make this a reality; most are already collecting the data they need to power predictive maintenance. With the right AI tools and strategies, they’re able to unlock new value from existing systems and infrastructure.

As the manufacturing industry continues to evolve, predictive maintenance will play a central role in aligning operational excellence with environmental stewardship—a clear example of how digital transformation can serve both business and planetary goals, making manufacturing more sustainable. ■

SURVEY SAYS: MISPERCEPTIONS ABOUT MANUFACTURING

MANY AMERICANS STILL DISMISS INDUSTRY CAREERS

CARY GITTER, Associate Editor

MANY AMERICANS, especially younger generations, still hold negative perceptions of manufacturing careers, according to new research from the Manufacturing Corp. of America (MCA).

The Miami-based manufacturing investment company commissioned a national survey of more than 1,000 U.S. consumers ages 18 and up—representative of the general population by age, gender, region and ethnicity—conducted by Propeller Insights from Oct. 2-7, 2025.

Key findings include:

- 20% of total respondents—and 25% of female respondents—say they're not at all familiar with what modern blue-collar work actually involves.
- 62% of respondents believe schools and society push Gen Z away from the trades.
- 60% of 18-24-year-olds believe their generation looks down on blue-collar work.

When asked what would make hands-on skilled-trade careers more appealing to young people, 38% cited higher starting pay, 17% mentioned modern tools and tech, and 13% pointed to less negative stigma and greater social respect.

Jerry Bailey, who joined MCA in 2025 as president of manufacturing operations after more than 32 years at Toyota Motor Corp.—most recently as senior manager of safety and security—believes that a lack of communication and awareness around the trades is a large part of the problem. "There is very little of that taking place, either with counselors or through high school," Bailey tells SME Media. "So I think we've got to do a better job of getting in early, talking to the younger generation about the great careers that are available."

Bailey contends that the outdated, Dickensian view of manufacturing as a "dark, dirty and dangerous" enterprise is at odds with the modern state of the industry. "As we continue to use more technology and innovation, you see robotics, software, AI. You have areas that are clean and neat, so processes can operate effectively and smoothly.

Jerry Bailey, president of manufacturing operations at MCA, says there's still a lack of awareness about opportunities in manufacturing. (Provided by MCA)

The question is, how do we get that out there? How do we market it, and how do we make the younger generation aware of what those options are?"

MCA describes its mission as "strategically acquiring successful legacy industrial manufacturing businesses … (and) fostering innovation." The company's current holdings include Uniforce, MetalOne and Boss Lighting.

Bailey, who leads MCA's manufacturing-capability assessments and oversees the implementation of the company's "Improved Quality Systems" initiative, cites job fairs, open houses, and college or university co-op programs as positive ways to expose students to the possibilities available to them in manufacturing. This includes young people poised to take the reins, he says, describing them as digital natives.

"They've grown up with a lot more technology than my generation did, and we have to take advantage of that. Their ability to use it and use it effectively is a talent we have to really tap into, and that's going to provide them with options and alternatives we've not seen to this point."

Despite the workforce issues facing the industry and the misperceptions that need to be dispelled, Bailey continues to be hopeful. "I'm really an optimist," he says. Yet the challenge remains: "How do we utilize the skills and capabilities of individuals within Gen Z and provide them with a future that can allow them to do the things they want to do?"

U.S. CUTTING TOOL ORDERS ON UPSWING

CUTTING-TOOL SHIPMENTS topped $250 million in October, according to the Cutting Tool Market Report issued in December 2025 and compiled by AMT – The Association for Manufacturing Technology and the U.S. Cutting Tool Institute (USCTI). This marked an increase of 12.7% from September 2025 and 14.7% from October 2024.

In addition, year-to-date orders trended upward for the first time in 2025, totaling $2.1 billion, 0.6% higher than the same period last year.

Though the strong October figures may be attributable to onetime factors rather than a new baseline, "the overall picture continues to show a slow rise in industrial output, with the promise of more growth in 2026," Costikyan Jarvis, president of Jarvis Cutting Tools, said in a press release. "The year-to-date 2025 data versus 2024 data show a strengthening trend consistent with other economic indicators."

Mike Stokey, president of USCTI, shared a similarly measured sentiment.

"The latest three-month trend is looking more promising, but our industry is still flat to down over the past year," he noted. "I believe our industry is cautiously optimistic that 2026 will be slightly better than 2025. Obviously, that could change quickly based on any changes to economic policies." ■

AUTONOMOUS PLANE REPORTING FOR DUTY

NORTHROP GRUMMAN CORP. UNVEILED Project Talon, an autonomous aircraft built to fly alongside crewed fighters. As the latest addition to the company's autonomous portfolio, Project Talon was designed, built and on track to fly in under 24 months. The Northrop Grumman autonomous testbed ecosystem Beacon accelerated the aircraft, testing its avionics software in real-world environments.

Project Talon builds on Northrop Grumman's 500,000-plus autonomous flight test hours across seven decades of experience in autonomy. ■

editorial@sme.org

FORD, GM BACK OFF EV PLANS

REFLECTING LACKLUSTER DEMAND and the end of government incentives, both Ford Motor Co. and General Motors Co. are scaling back their electric vehicle (EV) operations after ramping up plans in recent years.

On Dec. 16, Ford announced it was ending production of the F-150 Lighting, an EV version of its top-selling pickup truck, and dropping plans for electric commercial vans in Europe and North America, opting to focus on vehicles with stronger consumer demand. The move means Ford will write off $19.5 billion in EV investments over the next few years.

And in a notice filed Nov. 20, 2025, GM announced plans to lay off 1,140 workers at its Detroit-Hamtramck assembly plant, aka Factory Zero, which produces electric versions of the GMC Hummer, GMC Sierra, Chevrolet Silverado, and Cadillac Escalade SUV and pickup trucks.

While battery-powered vehicles continue to gain U.S. market share, sales have not hit levels predicted a few years ago. Former President Joe Biden was aiming for electric models, including plug-in hybrids, to account for half of new-vehicle sales by the end of the decade. The Trump administration, however, ended EV tax credits that reduced consumers' buying costs by several thousand dollars. Analysts now predict only about 27% of the U.S. car market will be electric by 2030.

GM's announcement follows similar notices earlier this year that it was temporarily idling EV plants in Spring Hill, Tenn., and Kansas City, Kan., while ending production of the BrightDrop electric van in Ingersoll, Ontario.

Ford will maintain investments in hybrids, including plug-in hybrids, as well as gas-powered vehicles, according to CEO Jim Farley.

As part of the shift, the automaker announced that it was canceling a $6.5-billion contract with South Korea's LG Energy Solution to supply batteries for its electric vehicles. And Ford announced that a Tennessee auto plant now known as the Tennessee Electric Vehicle Center will be retooled and renamed the Tennessee Truck Plant.

Without the need for as many EV batteries, Ford said it would spend $2 billion to repurpose a Glendale, Ky., plant as part of a new energy storage business. The facility will make megawatt battery energy storage systems and modules.

Ford is not completely abandoning the EV market, however. A Louisville, Ky., plant will manufacture an electric truck that uses Ford's new "Universal EV" platform. ■

—Michael McConnell, Senior Editor

AI TO DRIVE MANUFACTURING MARGINS?

ARTIFICIAL INTELLIGENCE will continue to transform the manufacturing industry in 2026, according to the "Future-Ready Manufacturing Study 2025," conducted by Tata Consultancy Services Ltd. (TCS) in collaboration with Amazon Web Services (AWS).

The results revealed that while AI is expected to rapidly increase its impact on manufacturing operations and autonomous processes, businesses still face substantial gaps in readiness and capabilities. And agentic AI is emerging as a priority capability, accelerating autonomous decision-making across plants.

Some 75% of respondents expect AI to be a top-three margin driver by 2026 and nearly the same number envision AI agents managing 11%-50% of routine production decisions by 2028. While two-thirds of manufacturers report improved real-time supply chain visibility due to AI and more than 30% forecast meaningful productivity gains from AI-led modernization, just 21% say they are fully AI ready, exposing significant data and integration challenges.

"By embedding artificial intelligence into every layer of the operation and leveraging cloud-native architecture, manufacturers can move beyond simple automation to true autonomous decision-making," said Ozgur Tohumcu, general manager of automotive and manufacturing at AWS. "This study makes it clear: The future of manufacturing is not just digital; it is autonomous—powered by AI that learns, evolves and operates continuously." ■

—Cary Gitter, Associate Editor

MANUFACTURING TURNAROUND IMMINENT?

ALTHOUGH U.S. MANUFACTURING has been shrinking for most of the last three years, the statistics overlook sectors that are growing or may be about to expand, according to new reports.

IndustryWeek cited analysis from the Manufacturers Alliance and Oxford Economics that said the manufacturing industry is starting to grow, thanks to aerospace, pharmaceuticals, electrical equipment, and fertilizer and agricultural chemicals. Meanwhile, gas and utilities are peaking and construction is starting to slow.

Steel manufacturing is benefiting from the demand for motor vehicles and growth in the aerospace industry. However, high costs for primary metals are preventing further growth in sectors such as industrial machinery, analysts said.

Construction has grappled with high interest rates, labor shortages and materials cost issues. It will likely end its multi-year decline in 2026, experts project, thanks to growth in manufacturing and power-generation facilities spending.

Meanwhile, first-quarter machine and nondurable product demand is expected to drop. Semiconductors and pharmaceuticals, however, will continue to see strong growth, the analysis said. ■

—Michael McConnell, Senior Editor

PRATT & WHITNEY WINS $1.6-BILLION CONTRACT

AEROSPACE MANUFACTURER Pratt & Whitney has been awarded a $1.6-billion U.S. government contract for work on F135 jet engines. The engines are used in the three versions of the F-35 Lightning II fighters.

The contract includes depot-level maintenance and repair, spare parts replenishment, materials management, integrating propulsion systems, and software and engineering support for domestic and international customers. ■

—Michael McConnell, Senior Editor

OHIO MEP IN JEOPARDY

IN DECEMBER, FEDERAL AND STATE agencies halted all funding for the Ohio Manufacturing Extension Partnership (MEP). The U.S. Department of Commerce's National Institute of Standards and Technology (NIST), which oversees the MEP program, attributed the action to five reporting errors uncovered in an audit by the Office of Inspector General (OIG).

"My administration takes any instances in which concerns are raised regarding how the program is administered seriously," Ohio Gov. Mike DeWine said in a letter to Commerce Secretary Howard Lutnick. He added, "A potential monthslong suspension of all Ohio MEP funding … could amount to the permanent closure of these programs across the entire state. This would be detrimental to the future of manufacturing in Ohio."

As part of its efforts to reduce the size of the federal government, the Trump administration has attempted to terminate congressionally allocated funding for MEPs. MEPs in 10 states got a reprieve from earlier announced cuts following pressure from House Democrats. But on Oct. 10, a NIST letter announced that federal funding for the program would end starting in 2026 because it "is not consistent with the secretary's (Secretary Lutnick's) priorities."

With six offices throughout the state, Ohio MEP is a nonprofit initiative that "helps Ohio's small and medium-sized manufacturers to increase sales, create jobs and generate cost savings through technological innovation, workforce training and improved management practices," according to the organization's website.

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MAGNET—the Northeast Ohio partner of MEP, which has had $5.9 million in funding pulled—is asking federal and state leaders to restore Ohio's MEP funding until the OIG review is officially completed; release the audit report and allow the state's MEP offices to review and respond; and acknowledge the impact of cutting funding on 14,000 manufacturers and thousands of workers across Ohio. ■

—Cary Gitter, Associate Editor

ELI LILLY TO BUILD $6-BILLION ALABAMA FACILITY

DRUGMAKER ELI LILLY AND CO. is planning a $6-billion plant in Huntsville, Ala. The facility will manufacture orforglipron, a pill to treat obesity and Type 2 diabetes.

The company planned to submit the drug, Lilly's first oral, small-molecule GLP-1 receptor agonist, to regulators around the world by the end of 2025. Construction is expected to be completed in 2032 with the project eventually creating 450 permanent positions, including engineers, scientists and lab technicians.

"(The) investment continues the onshoring of active pharmaceutical ingredient production, strengthening supply chain resilience and reliable access to medicines for patients in the U.S.," David A. Ricks, Lilly chair and CEO, said in a press release. ■

—Michael McConnell, Senior Editor

LEGO'S FIRST 3D-PRINTED PIECE

ALL ABOARD FOR additive manufacturing: Lego Group's new, 956-piece Icons Holiday Express Train set features the first-ever 3D-printed Lego piece, a miniature blue replica of the set's main train, which was engineered by Lego's additive design and manufacturing team in Billund, Denmark.

The Icons Holiday Express Train set features the first-ever 3D-printed Lego piece. (Provided by Lego Group)

The team spent nine years developing a sophisticated 3D-printing system able to produce high-quality elements on a mass scale.

Additive technology offers new functional possibilities for the toy giant, which primarily uses injection molding for production, according to the toymaker.

"We can make all kinds of geometries that are not possible with injection molding—bricks with internal mechanisms, for example," Ronen Hadar, Lego's head of additive design and manufacturing, told 3D Printing Industry. The 3D-printed train piece demonstrates this capacity with features including spinning wheels and a puffing chimney.

The company's additive team has already doubled its printers' output rate as it aims to make 3D-printed parts a standard method for designers, with the same level of quality as injection-molded Lego bricks. ■

—Cary Gitter, Associate Editor

WAYMO EXPANDS SELF-DRIVING FLEET

WAYMO IS APPROVED to operate fully autonomous vehicles across the entire Bay Area and most of Southern California, with the state greenlighting operations in nearly 250 cities across 18 counties at an unspecified future date.

This is the largest geographic expansion of autonomous vehicle use is the state, according to the *San Francisco Chronicle*. Previously Waymo could operate only in San Francisco, San Jose and Los Angeles. The company also operates robotaxis in Atlanta, Austin and Phoenix.

In recent months, Waymo has announced plans to introduce self-driving cars in nine other U.S. cities through a partnership with Lyft. And the company plans to take its vehicles to London in 2026.

Waymo also is in talks with potential investors to raise $15 billion in funding in 2026, including from parent Alphabet Inc. (which also owns Google) at a valuation as high as $110 billion.

Amid the expansion, Waymo has had some safety concerns. The company issued a voluntary software recall for more than 3,000 of its vehicles, due to several incidents during which the robotaxis illegally passed stopped school buses. In September, a Waymo robotaxi in Atlanta passed in front of a school bus that had its red lights flashing and stop arm out. Meanwhile, the Austin (Texas) Independent School District (ISD) notified Waymo that since the beginning of the 2025-26 school year, there had been 19 occasions where Waymo vehicles "illegally and dangerously" passed ISD school buses, averaging 1.5 violations a week. And Waymo paused service during a December blackout in San Francisco that halted some of its vehicles in traffic, causing gridlock. ■

—Rachael Thomas, Editor

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HUMANOIDS ON THE FACTORY FLOOR: THE NEXT FRONTIER OF AUTOMATION

ALEX GREENBERG, Director of Robotics 4.0 Simulation, Siemens Digital Industries Software

MANUFACTURERS ARE INCREASINGLY INTERESTED in humanoid robots due to persistent labor and skills shortages, rising product complexity, and the need for greater operational resilience. Humanoids promise flexibility: Their humanlike form allows them to operate in environments designed for people, using existing tools and workstations without extensive reconfiguration.

However, it is important to recognize that most humanoid deployments remain experimental, and widespread productivity gains will depend on robust training for specific tasks, and significant advances in dexterity and perception.

Form Meets Function

The form factor of humanoid robots will evolve based on the operational requirements of the shop floor. For some applications, wheeled humanoids may be favored over bipedal systems because they can deliver higher efficiency and better performance in those scenarios.

For example, in a high-volume manufacturing facility where materials need to be transported quickly between workstations, a wheeled humanoid can move faster, maintain stability while carrying heavy loads and navigate smooth factory aisles more efficiently than a bipedal robot. This makes the wheeled design better suited for tasks such as part delivery, machine tending and traveling repetitive transport routes within an industrial environment.

While humanoids remain an exciting r&d development, integrating them is far more challenging than deploying traditional robots. Key hurdles include mobility in dynamic, cluttered environments; advanced perception; real-time navigation; dynamic collision avoidance; and safe collaboration with humans, other robots and machinery.

Unlike fixed industrial robots, humanoids must adapt to unpredictable scenarios and legacy machinery, requiring multidisciplinary planning across robotics, safety, operations and layout. Simulation tools, such as Siemens Process Simulate and Plant Simulation, are invaluable for virtually modeling these complexities, allowing manufacturers to identify and address integration challenges before physical deployment.

As humanoid r&d accelerates, virtual simulation becomes increasingly essential. By adopting simulation best practices, manufacturers can model their entire operational ecosystem—including humans, robots, automation systems and, eventually, humanoids—while ensuring optimal layout and minimizing downtime. This digital simulation environment makes it possible to evaluate clearances, hazards, turning radii, collision risks and automation behavior long before anything is deployed on the shop floor.

For example, BSH Home Appliances Corp. uses Siemens manufacturing-simulation software to solve complex automation and robotics challenges in manual-assembly environments. Using Process Simulate, BSH's teams identify bottlenecks, refine layouts for new robots, plan collaborative robot deployments, assess ergonomics and conduct virtual reality-supported design reviews.

As the industry prepares for a future that includes humanoids—essentially "physical AI" capable of humanlike tasks—advanced digital intelligence becomes even more important. Physical AI will only be as effective as the digital tools used to design, validate and optimize its role on the shop floor. That's why, as part of our ongoing collaboration with BSH, we've introduced agentic AI capabilities directly within Process Simulate.

These AI-driven capabilities bring reasoning and automation into engineering workflows, helping BSH engineers accelerate problem-solving and improve design quality. Agentic AI strengthens digital engineering today, while paving the way for effective humanoid integration tomorrow.

Real-world use cases, such as those at BSH, demonstrate how simulation and agentic-AI capabilities deliver immediate value and pave the way for future humanoid integration. The same simulation frameworks used to validate collaborative robots can eventually be applied to testing humanoid workflows, such as navigating human-designed storage, retrieving tools or assisting at mixed-automation assembly stations. By preparing digitally, manufacturers can ensure that when humanoids are ready for deployment, the shop floor will be ready for them.

Human-Centered Design

Humanoids are intended for performing dexterous tasks, including manipulating tools, parts and fixtures. However,

their ability to use human-centered equipment depends on achieving sufficient manipulation skills.

In the future, utilizing tools such as Process Simulate Human for humanoid simulation will enable manufacturers to perform reach analyses, grasp simulations, payload assessments and power consumption, helping to evaluate feasibility and minimize the need for costly redesigns. Early simulation is essential for determining what humanoids can do, how they will do it and where technical limitations exist.

One practical near-term application for humanoids is material handling. In this role, a humanoid retrieves standardized boxes of parts from a kitting area, navigates human-designed factory spaces (aisles, doorways and shared work zones) and places those boxes within easy reach of assembly stations.

Safe human-humanoid collaboration on the factory floor starts with well-designed workflows. These include safe handovers of tools or components, dynamic avoidance when workers enter a robot operating zone, and robust emergency-stop and fail-safe transitions for unexpected events. Manufacturing simulation software can help manufacturers design and validate these workflows and scenarios, ensuring that safety is prioritized and that human-robot interactions are productive and secure.

Building on a safety foundation, manufacturers can then use simulation to optimize humanoid movement and productivity. Simulation tools enable manufacturers to model humanoid movement, test different scenarios, and optimize workflows for throughput and efficiency.

By simulating motions, cycle times, path planning, collision detection and resource allocation, manufacturers can identify and resolve potential bottlenecks. This approach supports data-driven decision making and reduces risks associated with integrating new automation technologies.

> “While humanoids remain an exciting r&d development, integrating them is far more challenging than deploying traditional robots.”

Simulate, Validate, Automate

Using tools such as Process Simulate and Plant Simulation, companies can virtually test and refine their production environments before making costly physical changes or capital investments. This early validation helps identify integration challenges, confirm feasibility and ensure that

To successfully integrate humanoids, manufacturing simulation tools are essential to test feasibility, validate ergonomics, plan workflows and de-risk integration before deployment. (Provided by Siemens Digital Industries Software)

investments in humanoid robotics translate into real operational value.

To support this evolution in automation, Siemens continues to invest in next-generation technologies, such as simulation tools for flexible automation and autonomous automation driven by foundation models, machine vision and advanced sensors. Strategic partnerships and a strong r&d pipeline further expand our ability to model and support environments where automation and human-centric tasks coexist—an increasingly important capability as interest in the humanoid market grows.

Preparing Factories for Tomorrow

Given the current trajectory, manufacturers can start preparing for humanoid integration today. This starts with honest, evidence-based assessments of current processes and layouts using simulation tools, not with hype or unrealistic expectations.

Humanoids will become productive only when they achieve the required dexterity and are trained for specific, well-defined tasks. Early planning helps manufacturers reduce risk, validate opportunities and position themselves for success as the technology matures.

Humanoid robots offer tremendous potential for manufacturing, but their integration is complex and requires careful multidisciplinary planning. By leveraging advanced simulation and focusing on practical, evidence-based strategies, manufacturers can prepare for a future where humans and humanoids collaborate safely, efficiently and productively on the factory floor. ■

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NEW LEADERSHIP TEAM TAKES THE HELM AT MURATEC USA

Murata Machinery USA Inc. (Muratec USA) has appointed **KEIJI YUASA** president and CEO. Since joining the company in 2005, Yuasa has served as managing director of Murata Singapore Pte., as well as worked in corporate planning in human resources in Japan. He succeeds Toshiyuki Komori, who served as Muratec USA's president and CEO for four years. Komori returns to Muratec USA's parent company, Murata Machinery Ltd. (MML) in Kyoto, as executive sales manager for turning in MML's Machine Tools division.

In addition to Yuasa, Muratec USA also appointed Chuck Butts director of operations for its Textiles division and Kazuyuki Uratani as general manager of its Logistics and Automation (L&A) unit. Their predecessors, David Stalvey and Masatoshi Wakabayashi, remain with the company as a textile adviser and L&A executive director, respectively. ■

Sandvik Coromant has named **STEVE LIND** vice president sales, Eastern U.S. In this role, he will lead the sales region's commercial strategy and execution across key manufacturing segments, including aerospace, automotive, medical and general engineering. Lind joined Sandvik Coromant in 2002 as a sales engineer and has since held a series of increasingly senior commercial roles. Over the past seven years, he led solid round tools (SRT) sales across the Americas, with an emphasis on automotive aluminum. Since March 2025, Lind served as the acting sales cluster manager before being appointed to the U.S. East cluster. ■

Nidec Machine Tool America LLC announced that **TODD HUGHES** has rejoined the company as regional sales manager for the West Coast, overseeing gear machine tool sales across Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, Washington, Wyoming and British Columbia. In addition to the full line of Nidec gear-cutting and grinding machines, he will also handle the company's complete portfolio of gear-cutting tools and related services. Hughes' background includes nearly three decades of military service spanning logistics and combat arms. ■

Critical Manufacturing, a subsidiary of ASMPT Ltd., has appointed **PAUL STRAETEN** vice president of life sciences. Straeten brings more than 20 years of experience in manufacturing operations, supply chain and Industry 4.0 technologies across the biotechnology, pharmaceutical and medical device sectors. Prior to joining Critical Manufacturing, he led large-scale manufacturing execution system and SAP programs at Medtronic Inc. ■

IFS has named **ROBI GONE** chief information officer. Succeeding Helena Nimmo, who is retiring, Gone will lead the company's global information technology (IT) strategy. He joins IFS from Shell PLC, where he held senior IT leadership roles for more than a decade. Most recently, he served as IT global general manager for finance, leading Shell's digital transformation through next-generation enterprise resource planning systems. Prior to Shell, Gone held consulting positions at Deloitte and Accenture PLC. ■

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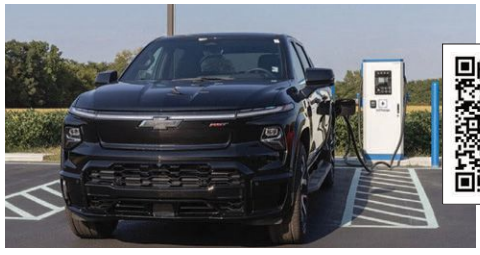
TOP WEB ARTICLES

General Motors to Cut 1,100 Jobs at Detroit EV Auto Factory

By Michael McConnell



AI Expected to Drive Manufacturing Margins in 2026

By Cary Gitter

AUDIO/VISUAL

LISTEN, WATCH, LEARN

Manufacturing Technology Series: Behind the Booth

Join SME Media's editorial team as we take a trip behind the booth of companies such as Hexagon Manufacturing Intelligence, Mitsubishi Materials and more at industry events in 2025.

Inside AMFT's Strategy for Growth

In this episode of "Advanced Manufacturing Now," Editor-in-Chief Steve Plumb sits down with Todd Smith, president and CFO of Associated Metal Forming Technologies (AMFT), a global leader in precision springs, deep-drawn parts, stamping and metal-forming solutions.

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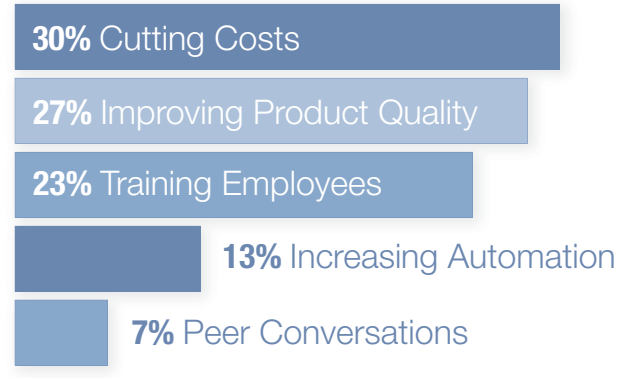

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WHY THE RIGHT CONVEYANCE SYSTEM MATTERS

BILL LEANNA, Sales Product Manager, TS Conveyors, Bosch Rexroth Corp.

CONVEYORS HAVE LONG BEEN THE BACKBONE of assembly lines. Every workpiece, from a small component to a larger assembly, relies on consistent movement between stations. What has changed is not the purpose of conveyance but the performance required of it. Higher mix, more frequent model changes, tighter takt times and increasing quality expectations are putting more pressure on the systems that move product through the line.

Choosing the right conveyance platform becomes an important early design choice to stabilize takt time, simplify operator tasks and make it easier to adjust the line when product requirements evolve. Selecting the wrong system tends to amplify bottlenecks, increase manual workarounds and complicate any future changes.

Finding the Right Match

Across many plants, one theme keeps surfacing: How well the conveyor matches the workpiece and process has a direct impact on how the line performs over its lifespan. When a platform is sized appropriately for the loads it carries, delivers parts to the station with predictable accuracy and supports the operator's interaction with the fixture, the entire line tends to run more consistently.

When any of those elements is even slightly misaligned, the effects appear in slower cycles, more adjustments at the station and extra operator compensation to keep the line moving.

Assembly environments today handle an increasingly wide range of product types. Some lines move light components where precision is everything. Others transport assemblies weighing several hundred kilograms, where the priority is steady, controlled movement and smooth transfer between stations.

Conveyors have to support that variety without adding unnecessary complexity or footprint. When the platform is appropriately sized and configured, it can be much easier to maintain consistent throughput, even as the product mix shifts.

Durability is especially important in these conditions. Conveyors in assembly operations run long hours and interact constantly with fixtures, tooling, pallets and operators. The mechanical components that support and guide pallet movement need to be robust enough to handle everyday use without introducing irregular movement. Over time, repeated stopping, positioning and pallet transfers put continuous stress on guides, belts and rollers. A platform built with accessible wear components and predictable maintenance intervals makes a meaningful difference in long-term uptime.

Another factor that affects daily performance is how accurately the conveyor presents each part to the station. Processes such as pressing, torquing and automated inspection rely on consistent positioning. If the pallet does not land in the same spot every time, everything downstream becomes more complicated. Tooling has to compensate, cycles stretch out and stations lose repeatability. Conveyors that can deliver stable, repeatable stops at each workstation help protect takt time and reduce variation, especially in high-mix lines.

Operator interaction is equally critical. Even the most advanced lines still depend on people to load components, clear alarms or perform quality checks. If the conveyor height, pallet layout or access points force extra reaching or awkward handling, operators will slow down, even if they don't intend to.

Did You Know?

The widespread adoption of conveyor systems has made them indispensable across industries. These systems have the capacity to minimize production damage, increase throughput speed and accuracy, and provide automated, adaptable and modular platforms. As business operations prioritize efficiency, sustainability and flexibility, the conveyor system market is projected to grow to $14.8 billion by 2030 due to the increased demand for advanced systems equipped with smart technologies, such as AI and machine-learning algorithms.

Source: Fortune Business Insights

Conveyor-based automation moves parts through a guarded production line while an operator works at a manual station. (Provided by Bosch Rexroth)

In contrast, when the system supports a natural, ergonomic workflow, operators maintain a steady pace and stations can hold their rhythm more easily. Simple considerations, such as fixture orientation, clearance around the pallet and access to return paths, can have a major impact on overall performance.

The Need for Flexibility

As product requirements evolve, flexibility plays a larger role. Manufacturers today need the ability to adjust their layouts, add stations or integrate new process steps without major reconstruction. Modern pallet-based conveyor platforms make this possible by offering modular sections, configurable routing and a range of pallet dimensions. Lines can be reconfigured, extended or repositioned with minimal disruption, which is essential as new variants are introduced or takt times shift.

Digital design tools are becoming an important part of this process as well. Layout software allows assembly teams to model pallet flow, accumulation and spacing before equipment arrives. By simulating how pallets move under different workloads, manufacturers can identify potential queuing issues, validate buffer capacity and determine where circulation gaps may appear. This helps prevent unnecessary component purchases and leads to better decisions about layout, workstation spacing and overall material flow.

In many cases, the biggest benefits of modern conveyance show up not in peak performance but in everyday reliability. Conveyors that run only when needed extend component life and reduce wear. Systems designed with accessible wear points shorten maintenance downtime. Platforms that avoid constant lubrication eliminate unnecessary steps for operators and technicians. All these small details accumulate into stronger, steadier performance over the life of the line.

At the end of the day, conveyance sets the pace for everything that follows. When conveyors are selected and configured with a realistic understanding of the product, the process and the operator, they support the line rather than asking the line to adapt around them. They help manufacturers maintain takt time, manage variation and respond to changing production needs without major disruption.

As assembly complexity continues to increase, conveyors will remain a central part of that success, not because they are the most visible component on the floor, but because they quietly determine how well everything else can perform. ■

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THAT'S A WRAP!

MANUFACTURING TECHNOLOGY SERIES 2025 ENDS ON A HIGH NOTE IN DALLAS

THE FOURTH AND FINAL EVENT of the 2025 Manufacturing Technology Series took place in Dallas Nov. 4-6. Produced by SME and AMT - The Association for Manufacturing Technology, the event gave attendees an all-access pass to exhibitors, industry trends, and the latest solutions and emerging technologies. More than 160 companies showcased their products to some 2,500 industry professionals—including SME Media Editor Rachael Thomas.

Meanwhile, Editor-in-Chief Steve Plumb and Senior Editor Michael McConnell toured Rivian's engineering center in Plymouth, Mich., to learn how the electric vehicle manufacturer uses 3D parts and equipment from Stratasys to speed and otherwise enhance its prototyping capabilities. ■

More than 100 students and educators attended the Bright Minds College Experience during Manufacturing Technology Series SOUTHWEST in Dallas. The program is designed for college students who are interested in a career in manufacturing. (Provided by Jason Loudermilk Photography)

Quantum Machinery Group displayed an eye-catching dragon made of metal auto parts near its booth at the Manufacturing Technology Series in Dallas. (Provided by Jason Loudermilk Photography)

An attendee takes a closer look at the FocusX, an optical 3D measuring device produced by Bruker Alicona. (Provided by Jason Loudermilk Photography)

Jonathan Dankenbring (left), Rivian's senior manager of prototype manufacturing, and Fadi Abro, senior global director of automotive and mobility for Stratasys, hosted SME Media and other journalists at Rivian's engineering center in Plymouth, Mich. (Provided by Stratasys)

Rivian launched production of its all-electric trucks in late 2021. The company sold more than 51,500 vehicles in 2024. (Provided by Rivian)

Stratasys produces a range of 3D-printed prototype parts and equipment for Rivian. (Provided by Steve Plumb)

Rivian uses 3D-printed equipment and/or parts about every 15 feet at its Normal, Illinois, electric truck plant. (Provided by Rivian)

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Provided by iStock

IN AI WE TRUST?

BITE-SIZED INSIGHTS

AMY BRYSON, Contributing Lead Editor

IN THE EARLY 2000s, "AI" meant something vastly different from artificial intelligence. Those two little letters were the initials of one of the most thrilling and polarizing NBA players to hit the court: Allen Iverson, also known as "The Answer."

Today, AI is synonymous with technological advances, machine learning and data analysis that make shops and factories smarter. It's often touted as a golden ticket to automate tasks, reduce downtime and improve quality—which all sounds great. But is AI really the answer to some of manufacturing's toughest challenges?

There's no doubt that technology opens up new ways of doing things. It's the backbone of Industry 4.0. Skeptics, however, are on the fence about how far to go down the AI rabbit hole. It's not just about perceived complexity or cost; it's about trust, or a lack thereof.

The TrustID Index, Deloitte's data-driven measurement tool, seeks to quantify trust among companies and various stakeholders based on four factors: humanity, transparency, capability and reliability. According to the index, AI is facing a trust problem, especially with frontline workers. This is due, in part, to skepticism about agentic-AI systems that don't just make recommendations but act independently. Simply put, people are concerned that if technology takes over decision-making duties that were once their own, they'll be out of a job.

Here's the rub: AI isn't going anywhere. Findings from the "Future-Ready Manufacturing Study 2025" conducted by Tata Consultancy Services and Amazon Web Services revealed that manufacturers increasingly rely on intelligence-driven operations and autonomy in manufacturing processes. In fact, 74% of those surveyed expect AI agents to manage as much as 50% of routine production decisions by 2028.

So how can manufacturers reconcile the potential gains achieved through AI-powered solutions with worker concerns? The answer is through trust building, says Deloitte, citing an all-hands-on-deck effort that can be broken down into five steps:

1. Know where you stand by measuring trust
2. Invest in employee skills development
3. Design AI solutions with worker input
4. Encourage digital experimentation
5. Make technology adoption a movement driven by frontline leadership

Realizing AI's true potential is filled with challenges and opportunities. Helping employees see how AI is a positive force in moving manufacturing forward is critical. That's where training and communication play a significant role. Deloitte data indicates that employees who received hands-on AI training report 144% higher trust in their employer's AI than those who did not.

Success also lies in taking a hard look at jobs and roles that will be reshaped or obsolete, as well as new roles that require advanced skills to be successful in a tech-driven environment.

AI and automation can save people the headache of performing repetitive, manual and dangerous tasks. Automation powered by AI tools holds the promise of creating demand for a new, highly skilled workforce focused on problem-solving and critical thinking.

Experts agree that human ingenuity and decision-making skills are still required. As good as it is, AI cannot yet replicate that kind of smart thinking. ■

ENGINEERING THERMAL PRECISION: THE CASE FOR ALUMINA CERAMIC TUBES IN NEXT-GEN MANUFACTURING

HABER MA, Senior Engineer in Advanced Ceramics, Adcerax

AS MANUFACTURERS PUSH toward digitalization, automation and energy efficiency, one factor quietly determines success: thermal precision. Every deviation in temperature control affects process quality, calibration cycles and equipment uptime.

To sustain consistent thermal environments, engineers are reevaluating materials that form the backbone of high-temperature systems. Among these, alumina ceramic tubes have emerged as essential components in the pursuit of reliable, next-generation manufacturing performance.

Thermal Stability and Performance Gains

Most high-temperature failures originate from oxidation, creep and thermal distortion. Common metals begin losing structural strength above 800°C and gradually deform under repeated heating cycles.

In contrast, high-purity alumina (Al_2O_3)—a crystalline form of aluminum oxide—maintains its strength and chemical stability up to 1,650-1,700°C. It remains dimensionally stable where metals would soften or corrode.

Typical engineering properties of 99% alumina ceramics include:

- Thermal conductivity: 20-30 $W \cdot m^{-1} \cdot K^{-1}$
- Thermal expansion: (CTE): 7.5-8.5 × 10^{-6} K^{-1}
- Flexural strength: 300-400 MPa
- Vickers hardness: 15-20 GPa

These values explain why alumina components resist cracking and warping, even under intense thermal gradients. In high-precision systems, such dimensional integrity directly supports process repeatability.

Alumina ceramics contribute measurable efficiency gains across multiple sectors. In furnaces and reactors, for example, low expansion and high rigidity preserve alignment and heat uniformity, reducing recalibration time.

As thermocouple protection tubes, alumina provides electrical insulation and contamination resistance, extending sensor life and accuracy. And the material's smooth, chemically inert bore minimizes fouling, helping maintain consistent flow in corrosive or abrasive environments.

Field data from users show maintenance intervals improving by 60%-70% after switching to alumina components—especially in cyclic or continuous thermal processes.

Furnace Dimensional Control

In heat-treatment operations, metallic tubes often deform or oxidize after short use, creating uneven temperature zones and unplanned stoppages.

A high-purity alumina furnace tube retains geometry and mechanical strength even after thousands of thermal cycles at 1,500°C.

Parameter	Stainless Tube	Alumina Tube
Max operating temp (°C)	~1,000	~1,600
Maintenance interval	1-3 months	9-12 months
Surface oxidation	Frequent	None
Dimensional deviation	±0.8 mm	±0.1 mm

This stability supports predictable maintenance scheduling, uniform heating and longer calibration cycles—three cornerstones of thermal process reliability.

Engineering Integration Guidelines

For effective system design:

- Select ≥ 99% purity alumina for general use, and 99.7% for clean-room or high-voltage systems.
- Control temperature ramp rates ($\Delta T < 100°C$/min) to prevent thermal shock.
- Use compliant seals or expansion joints when connecting ceramic to metal assemblies.

Adcerax engineers have refined microstructure and sintering profiles to achieve optimal density-to-toughness balance, ensuring dependable operation in demanding industrial settings.

Precision manufacturing does not rely on automation alone—it depends equally on materials that maintain ac-

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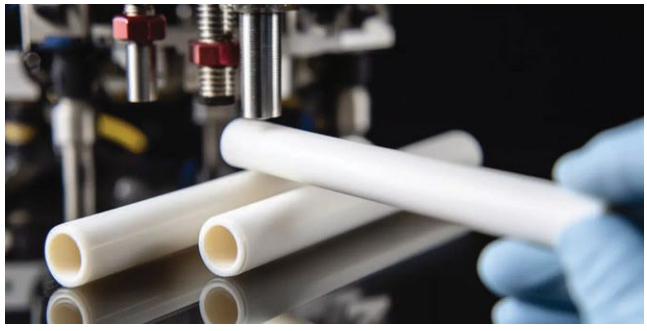

High-purity alumina tubes in industrial furnace applications. (Provided by Adcerax)

curacy under stress. Alumina ceramic tubes exemplify this principle: They enable stable thermal performance, extend component lifespan and reduce maintenance overhead.

As advanced manufacturing continues to evolve, materials engineering will remain the foundation for achieving true thermal precision and sustainable productivity. ■

NEW CNC MILLING MATERIALS

MISUMI GROUP INC.'S on-demand custom parts manufacturing service Meviy is introducing four new machining materials for CNC milling, which the company says gives engineers greater flexibility, improved performance and expanded design possibilities.

The new lineup includes three tool steels: SK105, O1 and DC53, with optional heat treatments, along with 316L stainless steel. The latter is widely used in environments requiring high corrosion resistance and clean, uncontaminated surfaces.

The additions support components such as chuck jaws, locators, conveyor equipment for receiving workpieces, manifolds, base plates and holders. Engineers can avoid substitute materials and instead select the most suitable CNC machining materials and surface treatments directly through Meviy, the company says.

Automated quoting is available for all four materials within a size range of 400 × 300 × 70 mm, and 316L stainless steel passivation is available through manual quotation. Available surface treatments for tool steels include:

- Electroless nickel
- Black oxide
- Hard chrome
- Nitriding
- Heat treatment

These newly added CNC machining materials are designed to support applications requiring enhanced wear resistance, high toughness, precise machining stability and exceptional corrosion resistance, according to the company.

In addition to the new CNC milling materials, Meviy has expanded its automatic quoting capabilities to include several copper and brass materials used for electrical and thermal conductivity, clean appearance, and strong machinability for electrical components, thermal transfer applications and decorative parts. ■

SPEEDING HYDROGEN TRANSPORTATION

GREENE TWEED SAYS its newly engineered composite closed impeller set a record-breaking tip speed of 688 m/s in testing—nearly double that of traditional metallic impellers. The technology underscores the potential of advanced composite materials to enhance performance, reduce costs and improve efficiency in transportation, storage and utilization of hydrogen, according to the Lansdale, Pa.-based company.

Transporting hydrogen through pipelines requires large centrifugal compressors to maintain pressure. Greene Tweed says conventional metallic impellers typically operate at speeds as high as 360 m/s for closed designs and 500 m/s for open designs before burst, limiting the achievable compression ratio for lighter gases and thus requiring more compressor stages, increasing the system size, cost and maintenance requirements. With Europe planning tens of thousands of kilometers of hydrogen pipelines by 2040, the demand for faster, more durable and cost-effective compressor technology is surging, the company notes.

Greene Tweed began developing its composite closed impeller in 2020, leveraging the high specific strength and temperature resistance of carbon-fiber-reinforced PEEK. The 688 m/s tip speed was achieved after three development and testing cycles.

(Provided by Greene Tweed)

In addition, Greene Tweed's composite closed-impeller design is said to be as much as five times lighter than conventional metallic impellers, while offering three times the strength-to-weight ratio. This design also boosts efficiency, as higher operational speeds improve hydrogen compression, supporting global clean energy goals, according to the supplier.

"We aim to revolutionize hydrogen infrastructure by breaking past the limitations of metals," Magen Buterbaugh, Greene Tweed President and CEO, said in a press release. "We are now collaborating with centrifugal compressor OEMs to bring this technology to real-world applications." ■

STRUKTOL TOUTS ADVANCED PP PROCESSING

STRUKTOL COMPANY OF AMERICA says its VMO Series, an advanced family of melt flow modifiers, is designed to optimize polypropylene (PP) processing, quality and versatility. Featuring a proprietary blend of fatty-acid derivatives and vis-breaking technology, the VMO Series delivers rapid and precise melt flow index (MFI) adjustments, according to the company.

The masterbatch approach can be used across extrusion, compounding or injection-molding operations. Compatibility with polypropylene containing up to 35% polyethylene (PE) extends the reliability and performance in both pure and recycled applications, Struktol says, even in the presence of contamination or intentional blending, supporting sustainability initiatives and greater use of recycled content.

(Provided by Struktol)

The VMO Series is available in a range of activity grades (VMO 058, 108, 208, 308, 408), providing customers the flexibility to match modifier activity with specific formulation and throughput goals, enabling the consolidation of raw materials and minimizing the need to inventory multiple base PP MFI grades.

Struktol says the technology allows manufacturers to accelerate throughput rates, boost efficiency and lower overall costs. Each grade maintains a stable and predictable dropping point between 74–86°C and a specific gravity of 0.98–1.0, allowing for reliable operation across a wide array of polymer formulations, according to the company. The VMO Series also supports circular manufacturing models and closed-loop recycling efforts. ■

CORROSION PROTECTION

INDUSTRIAL CATASTROPHES such as a September 2025 fire at an aluminum plant in New York can leave companies reeling from raw material shortages and temporary shutdowns. Political or economic issues can also leave assembly line workers stranded without the goods needed to complete their jobs.

A corrosion-protection strategy can help manufacturers cut losses and survive emergency disruptions in the supply chain, according to St. Paul, Minn.-based Cortec Corp. This includes instilling a "like-new" condition until operations can restart for automakers and other plants that assemble metal parts, Cortec says. Otherwise parts may be rusty and usable when supply chains are up and running.

Cortec VpCI-126 bags and VpCI emitters such as BioPad help guard against interim corrosion. These packaging materials release vapor-phase corrosion inhibitors that form a protective molecular layer on metal surfaces inside an enclosure. With the right dosage based on component size and storage environment, they can provide two years of protection, according to Cortec. For storage in non-climate-controlled warehouses or outdoors, a heavier-duty film such as VpCI-126 HP UV shrink film is available.

Metal coils can be protected by spraying the edges with proper inhibitors and wrapping them in VpCI tubing, Cortec says. Electronic chips, which have already seen shortages in recent years, can be stockpiled and protected against both corrosion and static damage by packaging them in EcoSonic VpCI-125 HP Permanent ESD bags. By keeping enough critical materials on hand to support production for several weeks or months, Cortec says manufacturers can be more prepared to survive the unexpected with fewer losses. ■

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LESSONS FROM THE SHOP FLOOR

BECAUSE CONSISTENCY IS EVERY BIT AS IMPORTANT AS SKILL AND EXPERIENCE

KIP HANSON, Contributing Editor

ONE OF MY MOST MEMORABLE LESSONS in the machine shop came from John "Blackie" Armstrong. I was but a few weeks on the job when he leaned over and said, "It doesn't matter how you do it, just be sure you do it the same way every time."

My erstwhile mentor was talking about handscrew operation and the importance of steady pressure on the cross slide and carriage (i.e., a consistent feedrate), regular tool sharpening, and always maintaining the same stance and hand placement—small details that lead to greater part accuracy on a Hardinge DSM-59 second-operation lathe.

SOP & Revisionist History

It's been many years since I threw my steel-toed boots in the back of the closet, never to be worn again, but I've continued to follow Blackie's advice. Granted, my version of "doing it the same way every time" is now mostly limited to the naming of computer files and consistent document formatting; but, still, there's no shortage of comparable guidelines for CNC machine shops.

For instance, programmers would do well to establish a standard operating procedure (SOP) that all team members must follow. It would include what I just suggested—consistent document formatting and file naming conventions—but also referencing tidbits such as part number and revision, customer and any other relevant information within the file name. Doing so will make searching easier and reduce the chance of someone inadvertently grabbing the wrong file.

Revision control applies to more than just manufactured parts—always update documentation with a numeric value and save previous versions in an archived "REV HISTORY" folder. Your shop's quality metrics will thank you.

Consistency Matters

A bit further down "consistency road" is the use of standard program headers that contain much of this same information as well as the programmer's name, all of which helps reduce mistakes and time lost answering, "Who the hell programmed this part, anyway?"

Shops should also establish similar best practices for where to place work offset datums, what tools belong in which pockets, how to apply cutter compensation, the use of safe start lines along with meaningful, properly formatted comments, subprogram routines and custom macros—consistency here and elsewhere equals less confusion, greater efficiency and fewer mistakes.

The consistent use of setup sheets, tool lists, inspection checklists and work instructions—even if the programmer is also the one setting up the machine and making the parts—also goes a long way toward eliminating confusion. And if all of the preceding is paperless, so much the better.

That said, every shop is different—brainstorm what might work best for your product and machinery mix, road test it for a few weeks, then adjust as needed before committing. Once finished, don't be afraid to change your SOP as the shop evolves (which it surely will). You'll find that making adjustments is much easier when there's a consistent starting point, rather than the chaos that often exists when shops wait too long to standardize their processes.

Similar rules of consistency apply to sheet metal fabricators, plastic injection molders, tool and die makers, and pretty much any manufacturer. Follow Blackie's suggestion, and your shop will not only become more efficient but also less prone to the chaos that ensues when years of tribal knowledge walk out the door.

Adapt or Die

Some will gripe about all this change, at least at first. Others may leave the company entirely, preferring to go down the street for another buck an hour and none of those "Big Brother" admonitions. Let them. Change is hard, but failure is harder.

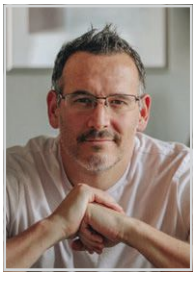
Sadly, I won't offer any additional advice for would-be handscrew operators. Hardinge Inc., née Hardinge Brothers—a company that was founded in a year when electric power and automobiles were still novelties and whose brand was once synonymous with precision—filed for Chapter 11 bankruptcy last year. A private equity firm purchased its assets, which it then divvied up among several smaller companies, including one based in China.

As McDonald's visionary Ray Kroc wrote in his autobiography, "Consistency is one of the most important factors in building and maintaining a successful business." Blackie would agree. ■

SMALL MANUFACTURERS CAN'T IGNORE ATTRITION RISKS

INNOVATION IN MANUFACTURING PROCESSES

CURTIS FORBES, Founder and CEO, MustardHub



ASK ANY SMALL MANUFACTURER what happens if they lose their best machinist. Production stops, customer orders sit waiting and finding someone with the skills to replace them takes weeks—maybe months.

Manufacturing monthly turnover jumped from 1.9% in February 2025 to 2.7% the following month. Tariffs and trade uncertainty are making good employees nervous: When they leave, they take years of experience with them.

Replacing a $15-an-hour team member costs $3,000 to $5,000 in lost productivity, onboarding and training time. That's a lot of money. Lose three people in a quarter and you're down $15,000. Lose more than that and you might not be able to fill orders. I've asked hundreds of small-business owners the same question: What happens if you lose 40% of your team tomorrow? Every single one had the same answer—they'd have to shut down.

The last year hasn't got any easier. Rising costs and tariffs mean companies need every person on the team working at full capacity. But preventing unnecessary exits is not only possible—it can save you tens of thousands of dollars while keeping your operation running smoothly.

A Leadership Blind Spot Threatening the Shop Floor

Most manufacturers don't have structured ways to recognize their people. That might not seem like a big deal until you listen to what workers say they need. According to MustardHub's 2025 workforce survey, 36% of respondents want regular appreciation and feedback. That also ranked as the No. 1 engagement driver for employees. (Not more money or better hours, though these are still important.)

When broken down by generation and role, 43% of surveyed boomer leaders reported already feeling engaged at work, and the majority don't require more appreciation. On the other hand, only 14% of Gen Z and 15% of millennial employees feel engaged right now, and two in five Gen Z and millennials say they need regular appreciation and feedback to stay motivated. Leaders who manage based on what keeps themselves engaged will miss what their younger workers actually need to stick around.

This disconnect costs people. While leaders think everything is running fine, younger machinists and welders quietly look at job postings, hoping to land somewhere that makes them feel more valued. Small manufacturers can't afford to lose skilled workers to competitors that figured this out first.

The problem likely will worsen as boomers age out of the workforce over the next few years. The next generation of workers won't tolerate being managed the way their parents were.

> "Two in five Gen Z and millennials say they need regular appreciation and feedback to stay motivated."

How Predictive Analytics Prevents Turnover

Predictive analytics used to be something only large companies could afford. Now it's becoming standard practice for small manufacturers who want to keep their teams intact. Basic systems analyze HR data such as hire dates, compensation levels and manager tenure against industry benchmarks to flag potential flight risk.

But the real power comes from layering in engagement signals. When someone hasn't received recognition in six months, stops participating in team activities or shows declining sentiment in workplace communications, that behavioral data makes predictions far more accurate. The system can spot disengagement before anyone gives notice.

The difference between being proactive and reactive is tens of thousands of dollars. Instead of scrambling to replace a machinist who just put in their notice, manufacturers can spot engagement gaps months earlier and address them through tailored approaches, such as targeted recognition, development opportunities or better manager coaching.

In tight labor markets, retention beats recruitment every time. One prevented exit can pay for an entire engagement system and then some. The manufacturers who will succeed in 2026 are those who stopped the bleeding before it started. ■

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SETTING STANDARDS FOR INDUSTRIAL AI

STEVE MUSTARD, Consultant, International Society of Automation

ARTIFICIAL INTELLIGENCE (AI) has been deployed in various forms for decades. Expert systems have emulated human decision-making, fuzzy logic and neural networks have supported closed-loop control systems, and machine learning has improved predictive maintenance and process optimization.

The 2022 introduction of ChatGPT provided the first large-scale generative-AI interface that the public could interact with as if it were a person. The generative pretrained transformer language model that ChatGPT is based on now forms the basis for many similar generative-AI implementations.

This widespread awareness of the possibilities of generative AI has led to renewed interest in AI, with companies seeking to integrate it into every aspect of their operations, including control rooms, production lines and maintenance workflows.

AI can yield important benefits. Machine learning models can predict bearing or structural failures, and generative AI can process data faster than any human team can. However, implementing AI is fraught with challenges, such as distrust, data chaos or a lack of structure. Successful implementations are far from certain. Applying the same engineering rigor and practices that are required for safe, secure and reliable operations can help overcome these challenges.

The path to a successful AI implementation involves a number of steps to build trustworthy, standards-aligned applications.

Establish an AI Design-and-Review Lifecycle

Organizations should borrow directly from the lifecycle methodologies defined in standards such as ISA/IEC 62443 and ISA-84/IEC 61511. These foundational standards define lifecycles that include scope definition, risk assessment, implementation and verification, and continuous improvement. The same concepts should be applied to AI. Projects should define expected inputs, environmental conditions and performance tolerances before design begins, asking questions such as:

- What variables will the model use?
- What range of operating data is valid?
- What constitutes “safe” predictions?
- What boundaries must trigger operator review?

Change control needs to be implemented, as with any other data source in the organization. Model training sources, assumptions and version history must be maintained so that AI models are treated like any other control logic and validated before release.

Implement Data Governance

Data governance is essential for building explainable and accountable AI in industrial environments. Engineers and regulators alike need to know why a model made a particular decision. Explainability is not just for compliance; it’s also how operators learn to trust recommendations.

Every model’s reliability begins at the sensor level, where calibration, scaling and time stamp ensure that incoming data reflects true process conditions. Each dataset must carry business context and ownership, such as a clear record of who collected it, under what conditions and for what purpose, so that decisions derived from it can be traced and audited.

Governance frameworks should maintain a transparent and justified model weighting, allowing engineers to understand not only what a model predicted but why. These practices can transform AI from an opaque tool into a traceable, standards-aligned system where data quality, interpretability and accountability are engineered from the ground up.

Address Cybersecurity From the Start

AI systems consume many forms of potentially sensitive information and intellectual property related to processes, products and operations. AI systems are vulnerable to new forms of attack, including data poisoning, data exfiltration, prompt injection and goal hijacking.

Implementing an AI project is no different from any other type of technology. New technology impacts cybersecurity risk. Cybersecurity should be addressed from

the outset. Data sources need to be validated, training data needs to be protected and audit logs are required for every model change.

Invest in People as Much as Models

AI literacy across engineering, maintenance and operations teams is crucial. Staff need training to understand model behavior, limitations and failure modes. Organizations should encourage a culture of questioning results rather than blindly accepting them.

Organizations should design AI into operations with a human in the loop. AI should be designed to advise and augment humans, not autonomously act beyond defined limits. As outlined in a position paper on industrial AI from the International Society of Automation, safety and security standards offer not only technical direction but ethical boundaries that can help inform AI implementations.

> "AI should be designed to advise and augment humans, not autonomously act beyond defined limits."

The Way Forward

AI has been part of industrial operations for decades through expert systems, fuzzy logic and machine learning. Generative AI has triggered a surge of interest in applying AI everywhere, from control rooms to maintenance workflows. Yet enthusiasm often outpaces engineering discipline.

To build trustworthy, standards-aligned AI, organizations should adapt proven control and safety frameworks, such as ISA/IEC 62443 and ISA-84/IEC 61511, to establish an AI design-and-review lifecycle with clear validation, version control and change management. Data governance, from sensor calibration and scaling to business-context ownership and transparent model weighting, is vital for explainability and accountability. Cybersecurity must be integrated from the start, protecting data sources and training sets against poisoning or exfiltration.

Success depends as much on people as on algorithms. Developing AI literacy and maintaining human-in-the-loop oversight ensures that AI enhances rather than replaces human judgment. By applying the same engineering rigor used for safety and reliability, organizations can realize AI's potential responsibly and sustainably. ■

Misconception: More Data Means Better AI

Industrial datasets are often messy, inconsistent and incomplete. Many organizations lack the data-governance discipline necessary to ensure that AI algorithms operate on reliable, validated and contextually meaningful information. The common assumption that more data automatically means better results is deeply flawed.

In fact, adding more data can often make models less accurate, less explainable and, in the case of generative AI, more prone to hallucination. This is where outputs sound plausible but are factually incorrect or fabricated. These errors frequently occur when the model absorbs contradictory, low-quality or irrelevant information, making it harder to distinguish signal from noise. The result is a model that may generate less reliable, responses. In industrial applications, this could mean producing incorrect recommendations by, for instance, mistaking a chemical-injection process for a water-injection process or vice versa.

That said, carefully curated and representative data can indeed enhance model performance. For example, instead of predicting an 80% chance of bearing failure within 10 to 30 days, a well-trained model might narrow that to a 95% chance of failure within 18 to 22 days.

Ultimately, the goal is not more data but better data—data that is accurate, contextualized and verified by domain experts. Without rigorous validation and human-in-the-loop review, simply feeding larger datasets into an AI model increases the risk of false confidence and operational missteps. ■

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OnRobot's D:PLOY platform is an example of a complete, off-the-shelf robotic system. Pre-built and preconfigured, it offers an alternative to so-called "turnkey" systems that need to be customized, programmed, integrated and deployed on-site, and with workpiece changes that often require an integrator at additional cost. (Provided by OnRobot)

HOW TO: DEPLOY AUTOMATION

KIP HANSON, Contributing Editor

SO YOU BOUGHT YOUR FIRST ROBOT. The integrator just packed up its tools, you passed the safety audit and the arm is busy with whatever task you deemed most pressing. Congratulations! You've taken the first step toward solving the skilled-labor shortage that's been plaguing your shop—and much of the manufacturing industry—for years, if not decades.

James Taylor

But now what? If the current assignment will keep your robo friend busy for the foreseeable future, feel free to bookmark this article for future reference. But it's more likely that you're already looking for its next job, whether that's loading and unloading a different machine, deburring parts and washing them afterward, filling boxes and loading them onto a pallet. Robots don't care. Just keep them busy or they might get bored and start planning a robotic uprising.

There's one hitch, however—robots don't have hands like humans, let alone brains that can figure these things out on their own—yet. Until that day comes, it's up to us to reconfigure what is clearly the newest form of extremely cheap labor for whatever you've tasked them to do. That means having fast, easy and economical ways to program them, change the gripper and make sure they don't inadvertently give one of their flesh-and-blood co-workers a boo-boo.

To address this increasingly common situation, *Manufacturing Engineering & Technology* sat down with James Taylor, chief commercial officer at OnRobot A/S. Since 2018, the Denmark-based company has made it its mission to "help small and midsized manufacturers optimize their processes and grow their businesses with greater flexibility, higher output and improved quality." We hope you'll find his responses enlightening.

1. When Small Shops Buy Their First Robot, What Mistakes do You See Most Often?

Taylor sees two mistakes, either of which can derail an automation project before it ever delivers value. The first is starting too big. Many small manufacturers look for a way to solve whatever is currently causing them the most grief, even if the process is very complex and a failure could wreak havoc in terms of part quality or delivery.

For instance, when the task requires multiple sensing steps, custom fixturing, long robot motions or tight timing, the learning curve steepens dramatically. “Many people try to automate the biggest, most complicated thing first,” Taylor says. “And when that becomes an impossible task, they tend to get frustrated and push it off to another day. Better to start with simple tasks, learn from your mistakes and gradually tackle more difficult work.”

The second mistake is the opposite: assuming automation is simple. Many automation newbies believe that “buying the bot” is the hard part and integration is easy. This assumption is especially true with cobots. “People think they can buy one, drop it on the floor and turn it loose,” Taylor says. “But the robot is only one component.”

Manufacturers tend to overlook end-of-arm tooling (EoAT), sensors, fixturing, programming, path planning, safety considerations and the broader application design. Unfortunately, even small gaps, such as choosing the wrong gripper or suboptimal part presentation, can make an otherwise simple project feel impossible. The root cause in either case is that shops tend to focus on the robot itself, not the application. A successful automation cell has to complete a task consistently and repeatably, and that requires EoAT and supporting tools just as much as the arm itself. As Taylor put it: “You need the task to work. And when you overemphasize the robot, you overlook the other critical pieces.”

2. Is it Realistic to Expect to Move Cobots Around the Plant for Various Jobs?

The idea of a single all-purpose droid that you can use anywhere on the floor is appealing—especially to high-mix, low-volume job shops. Taylor agrees that this happens, but with caveats. “If you’re talking about cobots, flexibility is a big part of the value proposition, especially in shops with short batches or seasonal work,” he says, noting that many small to medium-sized manufacturers were

sold on that flexibility, envisioning a device that can tend a lathe in the morning and load the parts washer in the afternoon.

All of this is possible, but only if the accessory package supports redeployment: adaptive grippers, quick-change end effectors, modular bases and software that makes path changes manageable. Without those pieces, the cobot becomes anchored to one place and can never reach its full potential.

Yet Taylor cautions against thinking of cobots versus industrial robots. "I don't like to talk in those terms, even if the market does. From my perspective, it's about the application. You pick the right solution for the job, regardless of its name, and tool it up accordingly."

Shops also need to consider speed: "If the application is long-running and the area can be fenced in, an industrial robot might be the right choice," Taylor says. "But if you need to redeploy that robot somewhere else in the shop once a week or once a month, then you need a different type of setup."

The takeaway? Yes, cobots can be flexible, but only with the right accessories and only when the application truly benefits from mobility. Otherwise, start with a fixed cell and expand later.

3. What Tasks are Good First Steps for Shops Just Getting Into Automation?

Regardless of the robot type, Taylor advises shops to look for low-complexity, low-risk wins. "While it may be tempting to look at the process with the greatest return on investment, there are often simpler ones that make a better starter," he says.

Such "starter tasks" typically share a few characteristics:

- They involve simple motions—pick up, move, set down.
- They have tolerant timing, i.e., are not cycle-time critical.
- They're performed today by "floaters," or workers who jump between tasks.
- They're repetitive and structured, with few part variations and clear pick points.

> "If you're talking about cobots, flexibility is a big part of the value proposition, especially in shops with short batches or seasonal work."
>
> – James Taylor, OnRobot

Palletizing is a standout example. "There are so many companies where someone walks over every 10 minutes, takes boxes off a conveyor, stacks them on a pallet and then walks back to whatever they were doing," Taylor says. "It's a really simple task that can be an easy win."

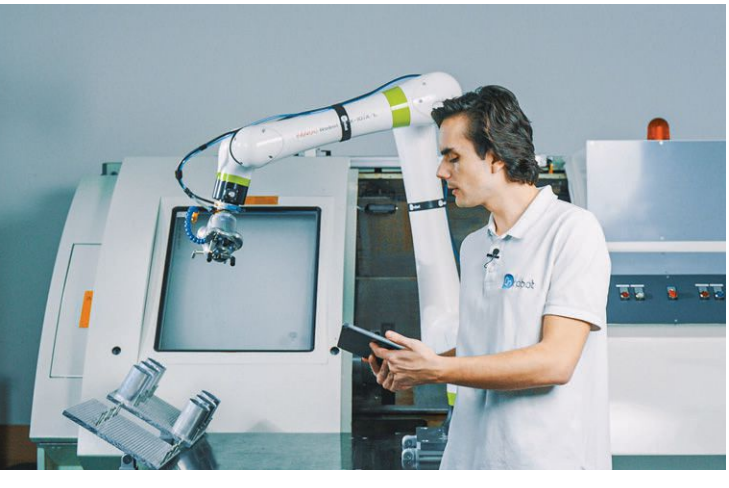
Other starter tasks include basic pick and place, conveyor-to-box loading and transfer moves between stations. These projects teach the shop how to work with grippers, adjust part presentation, set approach angles and manage operator interaction. They also build confidence. Once the shop has its first reliable cell running, it becomes far easier to tackle CNC machine tending or something even more complicated, such as vision-based bin picking. Taylor's advice: Choose the task with virtually guaranteed success. "Start simple, then build into the more complicated things."

4. Do Shops Underestimate the Role of Accessories When Deploying Automation?

"Absolutely," Taylor says. "Most first-time automation users don't realize how many standardized grippers, sensors, tooling kits and other integration aids exist on the market today. Many still assume robotics requires custom hardware and wiring, with heavy engineering support along the way. That mindset comes from an earlier era, when automation was built one cell at a time."

The reality has shifted. A task that looked impossible to automate five years ago might be trivial today because the accessory ecosystem has advanced so quickly, with off-the-shelf adaptive grippers, vacuum systems, force-torque sensors, vision modules, quick-change EoAT, lifting columns and software kits that you can drop into a new cell with minimal effort.

For small shops in particular, better accessories often matter more than the robot itself. The EoAT determines what the robot can pick up, the software determines how quickly operators can change jobs and sensors determine



OnRobot's D:PLOY platform removes a huge amount of manual work for integrators by automating program logic, signals exchange, event handling and robot-motion planning. (Provided by OnRobot)

how tolerant the system is to variation. Accessories are the difference between a robot that works sometimes and a robot that runs consistently across shifts. “Our philosophy is simplifying use,” he says. “Making it easier to integrate, program and set up—all of it reduces time and cost alike.”

5. With AI and Better Cameras on the Rise, is Bin Picking Finally Ready for Mainstream Use?

Some in the industry refer to bin picking as “the holy grail” of automation. The demand for it is apparent: Shops want robots to pull random, orientation-unknown parts out of boxes, tubs or gaylords without needing to stage them first. No more need for custom conveyors or fixtures—just drop the raw material into a bin, and the robot takes it from there.

The promise of AI-assisted 3D vision is that it can make all this possible at scale, yet Taylor remains cautious. “There have been advances recently, such as better camera technology, better algorithms and sensors,” he says. “But bin picking remains a lot more complicated than some salespeople make it sound.”

What makes it so difficult? Problems such as:

- Dirty parts with dried coolant
- Burrs or surface inconsistencies
- Shadows and reflective surfaces
- Mixed part geometries
- Poor lighting
- Significant depth variation inside a bin

These conditions remain challenging even for the most advanced vision systems. Bin picking is improving—but is not yet reliable across the wide range of parts seen in job shops.

Taylor’s advice for new users is clear: Don’t start with bin picking. Instead, begin with structured part presentation—simple trays, nests or repeatable locations—and work up to bin picking as the shop builds experience. “If your risk appetite is big, have at it,” he says. “But for many small and medium manufacturers, if the robot doesn’t work, it could cost them their annual profit.”

6. How Should Shops Think About Turnkey Automation vs. Off-the-Shelf Systems?

Taylor divides the automation market into two worlds: turnkey/custom and off-the-shelf/redeployable. Understanding the difference helps shops decide where to invest.

“Most of the industry today is turnkey,” he says. “Here you use standard hardware but design a custom solution engineered specifically for one task.” The advantage is precision—it’s possible to optimize turnkey cells for speed, throughput and accuracy, but the downside is a loss of flexibility. “It’s not practical to redeploy such systems. If you need to change the box size or change the setup, it can become costly. Furthermore, these partially engineered systems frustrate buyers with a lack of pricing transparency, hidden ongoing costs and long lead times—sometimes almost as long as a fully custom solution.”

Off-the-shelf systems are the opposite. They are complete, pre-built and preconfigured standard products. They must be easy to install, modify and move, relying on standardized software and predictable operator interfaces to achieve scalability for high-mix production. “If you’re changing production once a day or once a week, turnkey can’t solve that,” Taylor notes. “You need an off-the-shelf system.”

The vast majority of the robotics industry today relies on so-called turnkey systems, which, though often engineered and branded for a specific application, fall short of their name. These solutions typically utilize standard hardware but result in a custom solution engineered specifically for one initial task.

Simply put, manufacturers should match their automation strategy to their production behavior. If a shop runs long batches and rarely changes a setup, turnkey is efficient. But if they produce dozens of part numbers per week, need to adjust paths frequently or want to move a robot between machines, an off-the-shelf solution will be more economical

over time. Either way, the accessories matter just as much as the robot.

7. What Problem Does OnRobot's D:PLOY Platform Solve?

D:PLOY is Taylor's answer to the programming bottleneck in automation. "It removes programming completely from the automation equation," he says, comparing it to using Uber for a ride home: The user inputs a few key parameters, and the software handles all the route planning and logic behind the scenes. The goal? To simplify setup and redeployment.

Taylor explains that D:PLOY supports four standardized solutions: CNC tending, case packing, pick and place, and palletizing. In the latter, for example, the user enters the box dimensions, weight, pick location and pallet layout.

"Once those values are in, it's a matter of pressing the play button," Taylor explains. "All of the programming that would traditionally be done in the robot and gripper is automated, making what could be a week-long programming task into a two-minute configuration step."

Even more importantly, the automation becomes predictable—instead of wondering whether a robot will work after a job change, shops can adjust one or two parameters and resume production quickly and confidently. "It makes the value proposition completely transparent—install in a day. Redeploy in minutes," he says.

8. Should Shop Owners Buy D:PLOY Directly or from an Integrator?

Taylor points out that it's not a standalone purchase. Shops access the platform through an off-the-shelf robotic solution they purchased from their integrator or distributor. "D:PLOY is not an accessory; it's part of the application layer," he says. "It's like buying a computer with the operating system already installed."

Certified integrators and distributors use D:PLOY to build what Taylor refers to as "off-the-shelf" solutions—palletizers, CNC tending cells and similar offerings—using standardized components. They can then deliver an easily deployable system with the software to program it already built in. Yes, retrofits are possible, and some partners use D:PLOY to update older installations, but that isn't the primary purpose. "Retrofits do exist," Taylor explains. "But the big opportunity is buying complete off-the-shelf solutions."

9. Should Shops Wait for the Next Generation of AI or Robotics?

It's tempting to wait. Everyone sees rapid progress in AI, 3D vision, grippers and motion software. But Taylor strongly opposes waiting on automation. "Delaying value is always an option," he says, "but if you run your business that way, you have bigger challenges than automation."

He also points out that the U.S. is still grossly under-automated. During a recent webinar, Taylor saw data showing that most U.S. manufacturers—outside the automotive industry—still don't use robots at all. "It was enough to make my eyes jump," he laments. "There are far too many companies not leveraging the opportunities they have available to them right now."

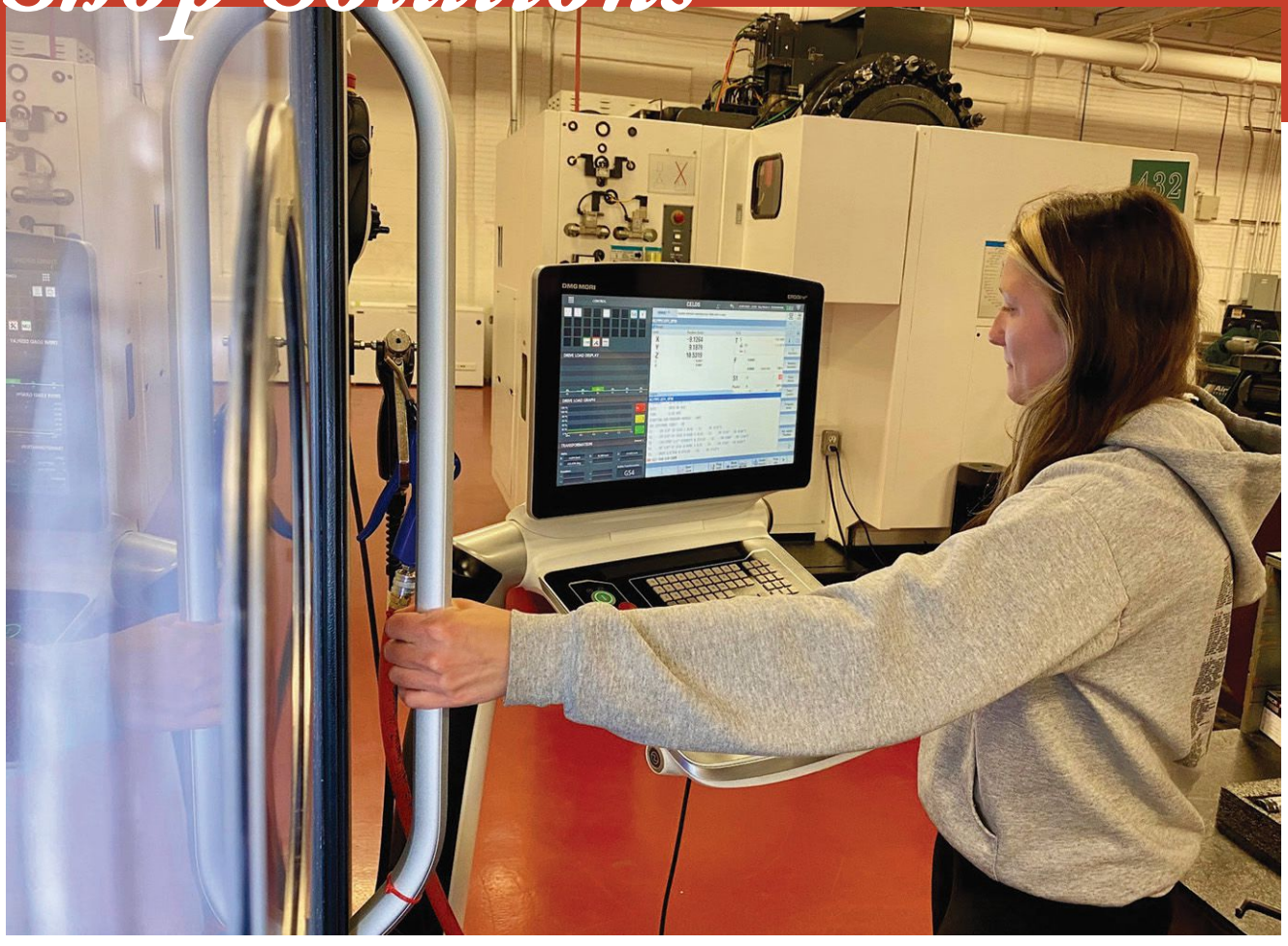
The new robotic palletizer Pallet EZ from Doig Corp., powered by OnRobot's D:PLOY platform, is an example of a complete, off-the-shelf robotic system. Unlike traditional automation systems that require weeks of integration and specialized expertise, Pallet EZ is ready to install and deploy the same day. (Provided by OnRobot)

The message is straightforward: AI will continue improving, but the current technology delivers value that simply can't be overlooked. As such, shops should automate whatever they can automate today, starting with simple accessories and predictable tasks. When the next generation arrives, they'll be well positioned to adopt it, rather than starting from behind the eight ball.

10. What Mindset Shift is Most Important for Small Manufacturers Exploring Automation?

Taylor's answer is simple: Stop thinking about buying a robot. Think about purchasing a solution. "Do you want boxes on a pallet?" he asks. "Then buy something that puts boxes on a pallet. Don't worry about whether it's AI-driven or not."

This shift—from robot-centric to task-centric—changes everything. It places grippers, sensing, fixturing, part flow, ergonomics, safety and operator interaction at the center of the decision process. Accessories become essential, not optional. In high-mix shops, this mindset makes redeployment easy. For more stable, high-volume manufacturers, a turnkey solution is more predictable. "Either way, the focus moves from the robot's capabilities to the application's requirements," Taylor concludes. "That's where automation succeeds or fails." ■



Acutec Precision Aerospace produces complex aerospace and defense components. (Provided by Sandvik Coromant)

PRECISION THROUGH PARTNERSHIP

OPERATING AT THE CUTTING EDGE of aerospace manufacturing is familiar territory for Acutec Precision Aerospace Inc. But to continuously push boundaries, it takes a culture that thrives on adversity, a problem-solving mindset and constant collaboration with expert tooling partners.

Acutec prides itself on being a leader in crafting complex components, specializing in tight-tolerance actuation components, hot-side engine parts, manifolds and mounts. Headquartered in a 200,000-sq-ft (18,581-sq-m) facility in Meadville, Pa., with facilities in Saegertown, Pa., and St. Stephen, S.C., the company focuses on advanced process development and automation, achieving high levels of unattended machining in a notoriously demanding industry.

Overcoming Machining Challenges

Producing high-mix/low-volume batches for aerospace and defense applications requires precision machining in challenging materials. For example, high-temp nickel alloys found in engine components are notoriously difficult to machine because of their high heat resistance and close tolerances, which can be as tight as ±0.00025 inches (0.00063 mm). Such precision requires the right tools and expertise. That's why Acutec prioritizes collaboration with partners such as Sandvik Coromant.

"Sandvik Coromant has been with us since almost the beginning, shortly after our company was founded," says Tom Stanton, operations director at Acutec. "Whenever we have a question or need to work through a challenging feature, we know we can count on them for solutions."

Whether it's weekly check-ins for ongoing project collaboration, technical support or grade testing of new inserts under development, Sandvik Coromant works in tandem with the Acutec team, allowing them to diagnose and overcome difficult machining challenges.

"Sandvik has a really good understanding of what we do and how we do it, and we have a really good understanding of how Sandvik approaches problems for solving. We take those two things and combine them," explains Lucas Warner, plant manager at Acutec's headquarters. In addition, Acutec's tooling management has matured significantly over time, according to Warner, and the company now has live setup sheets, as well as tool models and setups for every component that it machines.

"Sandvik provides a lot of the data for what the global inventory is looking like," Warner adds. "We can monitor that in real time to make sure we have the tooling we need for the projects we're working on."

Turning inserts are one example of tooling that Sandvik regularly monitors. Acutec's team can check the inventory on Sandvik Coromant's online web shop, and Sandvik helps Acutec with its tooling engineering by providing them with recommendations on improving speed and feed throughput and digital models, according to Richard Galla, Sandvik Coromant's account manager.

"We know when reviewing the tooling if the proposed inserts are available for implementation," Galla says. "The Sandvik CoroPlus Tool Guide allows Acutec to review and get suggested run parameters for the component features they are machining."

By outfitting an automated machining cell with modular Capto blocks and Sandvik Coromant Silent Tools, Acutec was able to prevent chip buildup around the cutting zone, eliminate chatter, stabilize processes and extend tool life. (Provided by Sandvik Coromant)

Tooling Up for Success

Beyond regular communication on global inventory, Acutec relies on Sandvik Coromant's range of turning inserts for roughing and finishing complex features and difficult materials. The inserts have enabled significant improvements in the tool life, precision and process stability that Acutec needs to keep operations running smoothly, the company says.

For example, Sandvik Coromant's S205, a chemical vapor-deposition turning insert grade for finishing operations, plays a pivotal role in one of Acutec's highly automated machining cells, which is located at the Meadville headquarters. Developed in 2019, the cell consists of five machines—including DMG Mori's NHX 4000 horizontal milling machine, DMU 50 universal milling machine and the NLX 2500 CNC turning center—that run Inconel 718 parts continuously with minimal human intervention and two supporting turning lathes.

Due to the stability and wear resistance of the S205 grade—which Acutec began implementing in 2023 and is primarily produced in the U.S.—the cell operates lights out with minimal downtime. For example, when monitoring the NHX 4000 one day in October 2025, the team discovered the machine was operating at a 95% uptime.

"We've tested everything in the world in that cell," Warner says, adding that the S205 offers increased productivity through higher cutting speeds in semi-finishing and finishing applications without compromising tolerances and surface conformity. Prior to the implementation of the S205 grade, Acutec used Sandvik Coromant's 1125 grade.

"If S205 is in there now, it means it outperformed dozens of other insert grades," Warner says. "It doesn't just help us extend tool life; it ensures every cut is precise, so we don't have to go back and make corrections, which is critical for lights-out production."

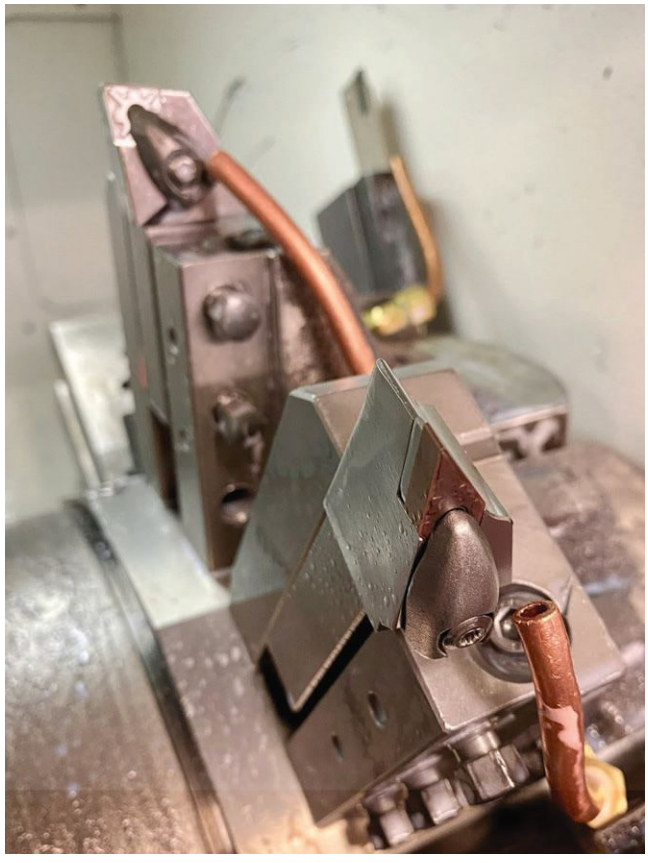
Sandvik Coromant also works with Acutec to find tooling solutions for more novel machining issues. In a recent case, Acutec was challenged with a newly developed coating for flight-critical helicopter rotor components, a project that took place throughout 2025 and is still ongoing. The new coating, which Acutec piloted the machining of for customers, was optimized for end-use performance characteristics rather than machineability.

"It's basically like trying to machine concrete," Warner says. "We were throwing all kinds of stuff at it—standard carbide, straight cobalt, even plastic inserts. But whatever we tried, we were lucky to get five or six pieces per edge before the tool was shot."

As Acutec exhausted various options, it turned to Sandvik Coromant for help, hoping its expertise and product line would yield a more effective solution. The team recommended special polycrystalline diamond (PCD) inserts, which are extremely hard tools ideal for abrasion resistance.

The results were transformative. With the new PCD grade, Acutec says it was able to go from five or six parts per edge to nearly 100 parts per edge.

Acutec Precision Aerospace produces high-mix, low-volume batches of complex aircraft components that require flawless precision. To push the boundaries of aerospace manufacturing, the company depends on cutting tools and expertise from partners like Sandvik Coromant. (Provided by Sandvik Coromant)



Sandvik Coromant recommended specialized inserts that allowed Acutec to go from five or six parts per edge to nearly 100 parts on one edge. (Provided by Sandvik Coromant)

Flexible Automation

While having the right inserts is critical, Acutec looks for every opportunity to refine its automated processes to stay competitive. To further these efforts, Acutec uses Sandvik Coromant's modular Coromant Capto tool-holding system, which offers quick-change capabilities that are said to drastically reduce setup times and improve process stability in highly automated environments.

In one application, the Capto system helped Acutec triple production throughput, which opened capacity gaps in the cell for running other jobs. Thanks to the system's flexibility, operators could quickly switch between multiple automated jobs in the same cell. While it has been used for a while, Warner says newer Capto designs have provided Acutec with more variety and tool-holding implementation.

Planning, Training and Innovating

The partnership goes well beyond hardware. Sandvik Coromant collaborates with Acutec on everything from preproduction planning to process optimization while also providing unique offerings ranging from on-site training to digital tool guide software.

"It's not just about asking Sandvik what tool to use. Sometimes, it's about asking how to approach the problem," Stanton notes.

Training and knowledge sharing is another hallmark. For about a decade, Sandvik Coromant has provided on-site, one-on-one and two-on-one training sessions for new Acutec employees. Such sessions help cultivate a deeper understanding of fundamental metal-cutting principles, an area of the company that Acutec recognized needed improvement.

The training sessions run for six months and focus on helping employees make informed tooling decisions, regardless of brand, to overcome machining challenges. Employees learn how to read inserts, understand tool changes, clean tools and detect premature tool failures. Acutec reviews employees' needs on a regular basis, Warner says, and works with Sandvik Coromant to determine new training opportunities.

"Through that training, our retention rates are continuously improving year over year," he says. "We invest a lot in our employees from a training perspective."

This comprehensive approach to partnership and problem-solving has led to closer collaboration and shared innovation, according to the partners. This includes solving day-to-day tooling issues and innovating processes to secure greater productivity in the future. ■

For more information about Acutec Precision Aerospace Inc., visit acutecprecision.com or call its headquarters at (814) 336-2214. To learn more about Sandvik Coromant, visit sandvik.coromant.com or call (800) 726-3845.

SUCCESS STORY

New scholarship empowers neurodiverse students

SME EDUCATION FOUNDATION

A PARTNERSHIP between the SME Education Foundation and Mitsubishi Electric America Foundation (MEAF) is helping enrich the manufacturing talent pipeline by providing scholarships to neurodiverse students. The new scholarship program — called the Mitsubishi Electric America Foundation Scholarships for Neurodiverse Students — was launched in April 2025.

"I think this is really an opportunity for us to expand our notion for what people who are neurodiverse can do, and I'm really excited about that," says Tara Havlicek, program manager for grants management, disability, inclusion and volunteer engagement at MEAF — the corporate foundation for the Mitsubishi Electric U.S. Group companies, which manufacture heating and air conditioning equipment, factory automation equipment and spiral escalators, among other products.

"As a foundation, we're focused on supporting the inclusion of people with disabilities — specifically on how to transition youth with disabilities from school to work," says Havlicek.

"It started off with accessible technology, and then we did after-school programming, but since about 2011, we've really been focused on this transition state," she says. "Like our board said, it's wonderful if we can make sure kids have playgrounds, but at the end of the day, if they can't be independent, if they can't have a job and a career, then we're not doing the best that we can."

Established in 1990 shortly after the Americans with Disabilities Act was passed, MEAF surveyed its board and employees about their priorities for the foundation — and children and disabilities rose to the top.

As part of its mission, MEAF has supported programs such as the Uniquely Abled Project, which started at the College of the Canyons in California. The project's focus is training young adults with autism to work in CNC machining and robotics, and in 2022 MEAF donated $200,000 to help replicate the program across the country.

MEAF also funds a program with Aspiritech to train young adults with autism for roles in quality assurance and software testing.

Havlicek has advice for educators and industry leaders who are trying to provide more inclusive pathways into manufacturing careers.

"For educators, I would say it's really about raising awareness and exposure to the manufacturing industry. Back when I did my first Disability Mentoring Day, the teacher brought in a group of 18- and 19-year-old students with disabilities, and they said this was the first time they had ever set foot in a workplace. So if you can, bring kids with disabilities in so they can see what the different career opportunities are in manufacturing, and dispel myths about what manufacturing looks like."

As for industry leaders, she suggests they make accommodations for persons with disabilities. "Accommodation isn't a bad word," she says. "Most of them cost little to nothing and they have benefits across the board." For example, she says adding pictures to work instructions might serve as an accommodation for a neurodiverse person, but it will also help all new hires as they are learning to do their jobs.

> **"Our main goal is really a mindset shift," notes Havlicek. "I think it's really important for people to understand that when you hire somebody with a disability, it's not charity — it's a benefit both for that employee and the employer."**

Regarding MEAF's new scholarship program with the SME Education Foundation, she says, "I'm grateful that the SME Education Foundation wants to pursue this avenue. We're excited for the partnership and proud to be supporting the scholarships for neurodiverse students."

SMART STRATEGIES TO BRIDGE THE SKILLS GAP

A closer look at workforce development initiatives that prepare and inspire the next-gen workforce

KAREN HAYWOOD QUEEN, Contributing Editor

We hear it often: As older workers retire—and take their critical hand-on-the-machine knowledge with them—the next-generation workforce isn't ready to step up, especially in an Industry 4.0 ecosystem. To help bridge this skills gap, manufacturers are increasingly leveraging apprenticeships, partnerships with technical schools, and short courses for quick wins and lifelong learning.

"As workers retire, there isn't the quantity in the pipeline to come into the workforce and do the work—machining, welding, fabrication," says Chad Schron, vice president of Tooling U-SME, the workforce-development arm of SME. "At the same time, you have this renaissance coming on in manufacturing with new technologies such as additive, robotics and IIoT," he adds. "Manufacturers can't develop the

Ethan Cope is part of an apprenticeship program at Grob's North American headquarters in Ohio that offers next-gen workers a chance to earn a living while preparing for careers in a technology-driven manufacturing environment. (Provided by Grob Systems)

workforce of today, let alone the workforce of the future. If major manufacturers are struggling, imagine how much small and medium-sized manufacturers are struggling."

The skills gap is across multiple generations of workers, observes Dora Smith, senior director, global academic and startup strategy, at Siemens Digital Industries Software.

"The accelerated pace of technological change means the traditional knowledge and skills taught even a few years ago are outdated," Smith says. "We're seeing a widening digital-skills gap that needs immediate attention. We must move beyond one-stop training and foster a culture of lifelong learning to ensure the workforce can adapt, innovate and thrive in this dynamic environment."

Evolving Skills Training

Over the last 20 to 30 years, the focus of skills training shifted from mechanical troubleshooting toward automation, robotics, programmable logic controllers, data analytics, simulation and digital twins, says Kim Humphrey, president and CEO of the Association for Manufacturing Excellence in Rolling Meadows, Illinois.

In fact, the top concern cited by more than a third of the 600 manufacturing executive respondents in a 2025 Deloitte Smart Manufacturing survey was "equipping workers with the skills and knowledge they need to maximize the potential of smart manufacturing and operations," says Victor Reyes, managing director, Deloitte Consulting LLP.

The future workforce won't be defined by AI replacing people, but by people who know how to use technology to work smarter, safer and faster, says Vineet Thuvara, chief product officer at Fluke Corp., an Everett, Wash.-based test and measurement device company. Training should blend real-world experience with the digital mindset driving modern industry, he adds.

"A clear trend we're seeing is the rise of tools that teach," Thuvara says. "Built-in guidance systems, such as embedded standards, automated prompts and pass/fail indicators, help new technicians build confidence from day one. For example, when a tester flashes green or red, the result is instantly clear, but the underlying numbers are still displayed. Over time, those numbers become second nature. It's a bridge between early confidence and long-term competence, where technology reinforces learning rather than replacing it."

Strengthening Soft Skills

Workers who came of age tethered to device screens during the pandemic need to develop soft skills, such as communication and conflict resolution, Schron asserts.

As with their predecessors, younger employees have their set of pros and cons.

"They bring creativity, adaptability and technological fluency to the workplace," says Kelvin Byrd, dean of Greenville (S.C.) Technical College's School of Advanced Manufacturing and Transportation Technology. "However, they often need additional development in soft skills, such as communication, resilience and professional accountability. Through experiential learning, we're helping students refine these skills before entering the workforce."

Communication, collaboration and problem-solving are just as important as being able to take a precise measurement, Thuvara adds. "Educators often say students across Gen Z (born between 1997 and 2012) and Gen Alpha (born between 2013 and 2025) are confident behind a screen but less practiced in presenting ideas, debating solutions or leading projects."

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Microcredentials Bridge the Gap

Microcredentials, which are short courses that demonstrate a learner's knowledge or training in a specific subject, are expanding rapidly, Smith explains, addressing specific skills gaps and providing a faster time to competency. Demand is high for courses on digital twins, digital transformation and sustainable business practices.

These courses often are stackable, allowing students to work toward a certificate or degree. The number of microcredentials available in the United States nearly tripled between 2018 and 2020, and 45% of U.S. workers report having some kind of alternative credential, according to the Society for Human Resource Management.

"The agility allows us to respond quickly to evolving industry needs, offering highly relevant, up-to-date skills that traditional longer-form degrees might struggle to incorporate rapidly," Smith says. "The flexibility enables learners to acquire specific knowledge and skills without committing to a full degree, making it ideal for working professionals or those looking to pivot careers."

Values that Matter

Unlike previous generations, next-gen workers are less motivated by tenure and more by opportunity and innovation, Byrd says. While seasoned workers often prioritized steady pay, long-term job security, pensions and predictable shift work, technology and rapid reskilling were less central.

The new workforce values purpose, flexibility, technology integration and rapid career mobility. They are highly collaborative and digital-first, and expect employers to provide meaningful work environments that align with their values, Byrd adds.

To that end, recruitment and retention strategies must focus on career development, mentorship, recognition, flexibility and high wages, Byrd says. "Employers who invest in ongoing learning and clearly outline advancement pathways tend to retain younger workers longer. A culture of innovation, teamwork and inclusion also resonates strongly with this generation."

Non-wage benefits, such as childcare, transportation and housing, are becoming increasingly important as part of a long-term retention approach.

"Today's workers prioritize career growth and continuous learning, opportunities to work with cutting-edge technology, a positive culture, teamwork, work-life balance and benefits that support personal well-being and skills mobility across organizations," Humphrey says. "They have a strong emphasis on teamwork, safety, inclusion and green manufacturing."

Partnerships Pay Off

Manufacturers are increasingly working with technical colleges and innovating on their own to educate and train workers on current tools, software and systems that manufacturers actually use.

"In the past five years, collaboration between manufacturers, high schools and trade schools has improved significantly," Humphrey observes.

For example, Fluke partners with more than 250 universities, 14 trade unions, and thousands of trade and technical schools worldwide, according to Thuvara. The company is now embedded in 246 of 1,100 apprenticeship programs and connected to more than 400,000 students and educators through SkillsUSA.

"We are in it for the long term and committed to this community," Thuvara adds. "These relationships ensure students learn with the same tools they'll use in the field."

Closing the skills gap means meeting learners where they are, he says. "We're also focused on access. Scholarships, free training and equipment grants help remove financial barriers and bring more people into the trades. Embedding this technology early helps students strengthen both their hands-on and analytical skills, building the confidence and fluency they need to thrive in modern, connected industries."

The Funding Conundrum

Even as technical schools become more important to bridge the skills gap, they receive less funding per student than traditional four-year schools, notes David Gillespie, president and founder of Virginia Technical Academy.

"The U.S. faces a paradox: High unemployment persists even as industries struggle to fill skilled trade positions," Gillespie says. "Historically, the U.S. Department of Education has defined eligibility for federal student funding, a system built primarily to support academic, degree-based institutions," Gillespie explains. "This framework leaves most trade schools—especially those emphasizing performance-based learning—without equitable access to resources, despite their essential role in preparing workers for high-demand industries."

Skilled trades education is different, Gillespie asserts.

KEY TAKEAWAYS

1. **Community and technical colleges prepare students for high-tech roles.**
2. **Microcredentials focus on specific skills and can stack up toward certifications.**
3. **Apprenticeships offer hands-on experience and long-term employment opps.**

Donovan Miller is a recent graduate of the Greenville Technical College mechatronics program. (Provided by Greenville Technical College)

"It's competency-driven, grounded in repetition, hands-on learning, and mastery of real-world tools and systems. Nonprofit and mission-driven training organizations like Virginia Technical Academy prove that hands-on, performance-based learning produces confident, job-ready graduates who meet employer needs from day one."

The Appeal, and ROI, of Apprenticeships

Employers and education providers are rapidly expanding registered apprenticeships and youth apprenticeships as a preferred pipeline, Humphrey says. According to the U.S. Government Accountability Office, there were about 940,000 participants in registered apprenticeship programs across industries in fiscal year 2024, she says.

Paid apprenticeships have been a key part of Grob System Inc.'s North American headquarters and manufacturing facility in Bluffton, Ohio, notes Training Manager Mark Reed. He explains that when Grob North America was started, the Grob family felt that it was necessary to follow the same apprenticeship-program model that was established in Grob's German headquarters.

"Apprenticeship in Germany is universally viewed as a necessary part of any skilled occupation," Reed says. "Because of that German heritage, it was not so much a decision of if, but how to have the apprenticeship. Investing in and training up our own technicians has been a big part of who we are as a company and has led to a lot of our success over the last 35 years here in the U.S.," he adds.

> **"Education and training need constant adaptation to remain relevant as industries shift toward AI-driven operations, connected infrastructure and digital diagnostics."**
>
> **– Vineet Thuvara, Fluke Corp.**

Since its first class of six apprentices, the four-year program has grown steadily. In the last three years it has jumped from 36 participants in 2023 to 45 in 2024 and to 57 last year, according to Reed.

Apprentices work three days a week at Grob and take classes two days a week for two years at nearby Rhodes State College. In those two years, students earn a degree in electromechanical engineering technology, with Grob paying for the education.

In years three and four, students are placed in a specific

department at Grob based on their interests. After completing the program, as well as their four-year commitment to Grob, students earn a Certificate of Completion of Apprenticeship issued by the Ohio State Apprenticeship Council in cooperation with the U.S. Department of Labor, certifying them as an industrial machinist technician.

"We justify the cost of paying for our apprentices' education by looking at the results … the success of former apprentices," Reed says. "The ROI we see is both immediate and long term. We can recruit the talent that we are looking for at a level that is unheard of in our area because of the company investment, providing immediate return."

Success Stories

Ethan Cope, a first-year apprentice going through the mechanical side of the Grob Systems program, chose this option because he didn't think a four-year college could provide the hands-on education he wanted. But while he heard many good things about the program, others were skeptical.

"The most pressure to get a conventional four-year bachelor's degree I ever got was from my parents, who were initially worried that I would not be able to realize my full potential here," Cope says. "The more they learned about the program, the more they realized that this was the perfect opportunity for me. ... I still meet people who are excited that I am working at Grob. With all the support I got, I decided that there was no other choice for me."

Cope is getting the hands-on education he sought.

"Everything we learn here at Grob has a practical, real-life application," he says. "Everything we do, no matter the project, has a purpose, and the skills learned from those projects carry me through to this day."

And his parents are fully on board with his decision. "Now

Beyond Microcredentials

Greenville (S.C.) Technical College's Bachelor of Applied Science in Advanced Manufacturing Technology (BAS-MFG) program is designed as a seamless pathway for graduates of technical associate degree programs—in mechatronics, CNC/machine tool, engineering and other manufacturing skilled trades—to continue their education without leaving the technical college environment, says Kelvin Byrd, dean of the School of Advanced Manufacturing and Transportation Technology.

Students enter the BAS program with an associate of applied science degree and complete upper-level coursework that builds leadership, project management, lean manufacturing, quality systems and advanced technology integration skills.

This applied baccalaureate model focuses on practical, industry-driven learning rather than purely theoretical instruction, Byrd says, bridging the gap between frontline technical expertise and supervisory or engineering-support roles, preparing graduates for immediate impact in manufacturing organizations.

Students in the program complete advanced courses in:

- Industrial management
- Operations planning
- Automation systems
- Quality control
- Process improvement
- Leadership

Coursework integrates applied research, data analytics and experiential projects with local manufacturers. A required capstone project allows students to collaborate with industry partners to solve real-world production challenges, making the learning experience both applied and employer-centered.

Kelvin Byrd, dean of the School of Advanced Manufacturing and Transportation Technology at Greenville Technical College, speaking at the 2025 Manufacturing Technology Series SOUTHEAST event. (Provided by Greenville Technical College)

"Unlike traditional bachelor's degrees that emphasize theory and general education, the BAS focuses on application and industry relevance," Byrd says. "Courses are taught by faculty with extensive manufacturing experience and are aligned with workforce needs identified by our industry advisory boards. The degree is intentionally designed for individuals advancing from hands-on technical roles to leadership or advanced technical positions, such as production supervisors, manufacturing engineers or operations managers."

Similar BAS programs exist at Wichita State University Tech, Purdue University Northwest and Eastern Florida State College. However, Greenville Tech's model is unique in its direct alignment with local and regional industry needs through partnerships with employers such as Bosch Rexroth, GE Vernova, BMW, Michelin, Lockheed Martin, Fluor and 3M, Byrd says.

"The initiative expands access for working adults and skilled technicians who might not otherwise pursue a traditional university path due to cost, location or scheduling barriers," Byrd says. "It also helps address the state's talent-pipeline shortage by creating a homegrown solution within the existing technical college system." ■

that I have been working here for some time, they believe whole-heartedly that going through the apprenticeship was the best choice that I could have made for myself. They are all in and support me through the ups and downs."

Grob's retention rate speaks for itself. The apprenticeship currently has a completion rate of 91% finishing four years, Reed says. Of the 611 people who have been a part of the apprenticeship in the last 35 years, 58% of them are still with the company, including two of the original apprentices. Apprentices comprise 35% of Grob North America's total workforce and nearly half of the skilled trades/technical portion of employees, he says.

Moreover, 75 former apprentices have advanced into management roles or what Grob considers nontraditional career paths within the organization. One of Grob North America's four-member executive team began their career as an apprentice.

Managing Change and Achieving Resilience

The pace of technological change makes it almost impossible for traditional educational models to keep up.

"Technology is evolving faster than the systems designed to teach it," Thuvara says. "Education and training need constant adaptation to remain relevant as industries shift toward AI-driven operations, connected infrastructure and digital diagnostics. That means building programs that evolve as quickly as the technology itself, and that requires closer collaboration between industry, educators and policymakers."

Another challenge is ensuring depth of understanding as tools become more intuitive. "Simpler interfaces can build confidence quickly, but they also risk creating surface-level knowledge if not paired with solid technical grounding," Thuvara explains. "We need to make sure new technicians not only know what the results mean, but also understand why they matter. That balance between usability and technical mastery is at the heart of workforce readiness."

U.S. manufacturers need to find the right mix of humans and machines to be competitive and resilient in the new landscape, Reyes says. This involves investing in data architecture, technology, governance, cybersecurity, talent and workflow redesign, as well as identifying the uniquely human capabilities that their engineers, operators, salespeople and others bring to the table in an AI-enabled world.

Strengthening digital supply chain tools could become essential for managing ongoing volatility and trade uncertainty, Reyes adds. Leveraging new growth opportunities, such as those created by the demand for semiconductors and data center components, as well as favorable policy incentives, will be important.

"At the same time, workforce planning should prioritize an adaptive approach that emphasizes agility, skills-based hiring, continuous upskilling and leveraging AI to accelerate onboarding and knowledge transfer," Reyes says. "Remaining focused on the long-term goal of creating a strong workforce, while also managing potential uncertainty and volatility, could be essential in the years ahead."

Dora Smith, senior director, global academic and startup strategy, Siemens Digital Industries Software, pictured with the winning team of the sustainability design hack at Realize LIVE Americas in June 2025 in Detroit. (Provided by Siemens)

Ultimately, the future of technical work will depend as much on empathy and curiosity as it does on engineering, Thuvara says. "The workforce that succeeds will be the one that pairs precision with understanding—people who can interpret data, collaborate across experience levels and keep learning long after the technology has changed." ■

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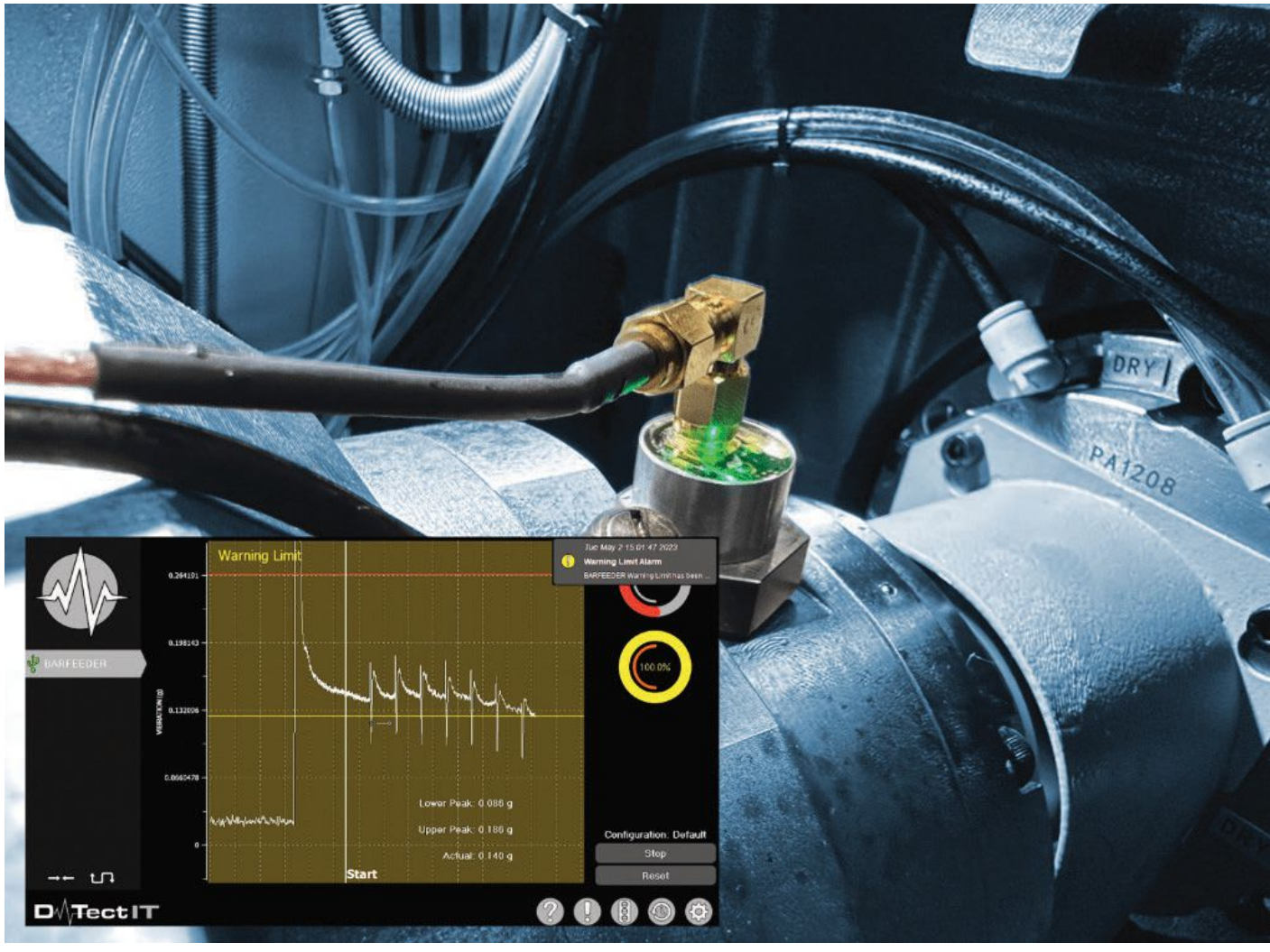

A vibration sensor is attached to the spindle used with Caron Engineering's DTect-IT to detect and control bar-feeder vibration automatically. (Provided by Caron Engineering)

Green, yellow, red. Back in the day, it was the andon light, aka "Christmas tree," sitting atop each CNC machine tool that indicated whether the equipment was running, idle or somewhere in between. And while this simplistic traffic-light approach is still fine for navigating city streets, it no longer works for any shop looking to maximize production efficiency.

Manufacturing grows a bit more demanding with each passing year, while the skilled labor pool gets a bit shallower. It's for these reasons and others that machine shops, sheet metal fabricators and plastic injection molders—or anyone who makes parts for a living—must look for ways to turn the behavior of machine tools and those who operate them into meaningful action, whether it's to reduce setup time, maximize tool life, engage in preventive maintenance or provide more accurate delivery dates to customers.

Proven Playbooks

Fortunately, the "traffic lights" of yesteryear—though still pretty—are giving way to a new generation of monitoring tools. Where keeping tabs on production activity once meant expensive Industrial Internet of Things (IIoT) sensor implementations and specialized IT support, even the smallest of shops can now deploy real-time dashboards with little more effort than plugging in a few Ethernet cables and mounting one or two big-screen TVs around the shop floor. Greater manufacturing efficiency, it seems, is quickly becoming a plug-and-play pursuit.

It wasn't so simple when the management team at LeClaire Manufacturing Co. of Bettendorf, Iowa, decided it was time to get a better handle on their sand casting, permanent mold, CNC machining equipment and heat-treating ovens. They wanted to figure out when it was actually producing parts, how effectively and why downtime seemed to be a regular occurrence. That was in 2017, and, as Mike Zimmerman explains, the quest to develop a machine-monitoring solution bore unexpected fruit: Not only did LeClaire gain the desired insights, but management also commercialized the homegrown system and shared it with others. More importantly, Caddis Systems was born.

BEYOND THE DASHBOARD

Forget the Andon lights. Skip the paper job cards. Integrated, real-time machine monitoring is the clear path forward for any shop pursuing a digital transformation.

KIP HANSON, Contributing Editor

Today, Zimmerman serves as Caddis Systems' vice president, responsible for growth and strategic initiatives. And while he's plenty proud of the software and the people behind it, he's found that prospective customers are often skeptical when first shown the product.

"Many reply with, 'But Mike, I can see all my machines. I know when they're running and when they're not, so why spend money on another system?'" Zimmerman says. "My response is that it's not a matter of knowing whether a certain machine is running, but rather about the ability to dig into details of the equipment's performance and how to improve it."

Case in point: Before launching its monitoring initiative, parent company LeClaire Manufacturing was spending about $200,000 annually on pump replacements for its foundry equipment. With Caddis now monitoring coolant temperature and sending alerts when the fluid exceeds 145°F, the maintenance crew knows when to service the unit. The result? The manufacturer has reduced its yearly pump spend to $15,000, a 94% savings, LeClaire says. Similar results apply to overheated spindle bearings, low lubricant levels and cycle-time anomalies—conditions shops often miss until a failure occurs.

Despite these successes, Zimmerman acknowledges that Caddis is less comprehensive than some of the monitoring systems on the market today. Rather than extracting every data point from a CNC control or PLC, the software concentrates on a narrow set of high-value indicators. Examples include discrete run/stop signals, temperature data and analog inputs, such as vibration and current draw. These allow the platform to operate across equipment ranging from 1960s-era machinery to modern CNC machine tools.

Such universality is deliberate, he adds, noting that many shops want better visibility without the cost of extensive IIoT sensor integration or enterprise software rollouts. They also want ease of use.

"You hook up power, attach it to a piece of equipment, and you're off and running," Zimmerman explains. "For many shops just beginning their digital journey, we represent a practical first step, one that replaces tribal knowledge and anecdotal understanding with data you can act upon."

KEY TAKEAWAYS

1. **Real-time dashboards and integrated platforms (ERP, MES, QMS) trump standalone traffic-light monitoring.**
2. **High-value data is better than trying to compile and make sense of "all the data."**
3. **Technology alone isn't enough; ease of use and culture will determine success.**

Deeper Connections

Corvallis, Ore.-based FactoryWiz enters the new year with renewed focus on the market's growing demand for deeper connectivity. That push applies not only to CNC machinery but also to the broader ecosystem of business and manufacturing platforms. Domenic Lanzillotta, vice president of sales and marketing for FactoryWiz, describes the shift clearly: An increasing number of shops want a monitoring tool that can share data across disparate systems.

"They need to have coordination between the production floor and the maintenance department, for example, or bidirectional data sharing between their machine tools and whatever quality management system (QMS) they're running," he says. "Machine monitoring becomes much more powerful when it connects to the workflows that depend on it, which is why this level of integration is really gaining steam in companies that realize the value of coherent, shopwide communication."

Quality data is one of the best examples. Some customers use FactoryWiz to link probing cycles from their machine controls directly into statistical process control (SPC) software. "We pull data from macro variables that the machining center or lathe populates, push it over to the QMS, and then adjust live dashboards on the shop floor accordingly," says FactoryWiz President Richard Hefner. "By synchronizing certain quality metrics with machine activity, operators can proactively correct dimensional variation during the run, not after a batch of bad parts

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moves downstream. Think of it as the glue that holds these processes together."

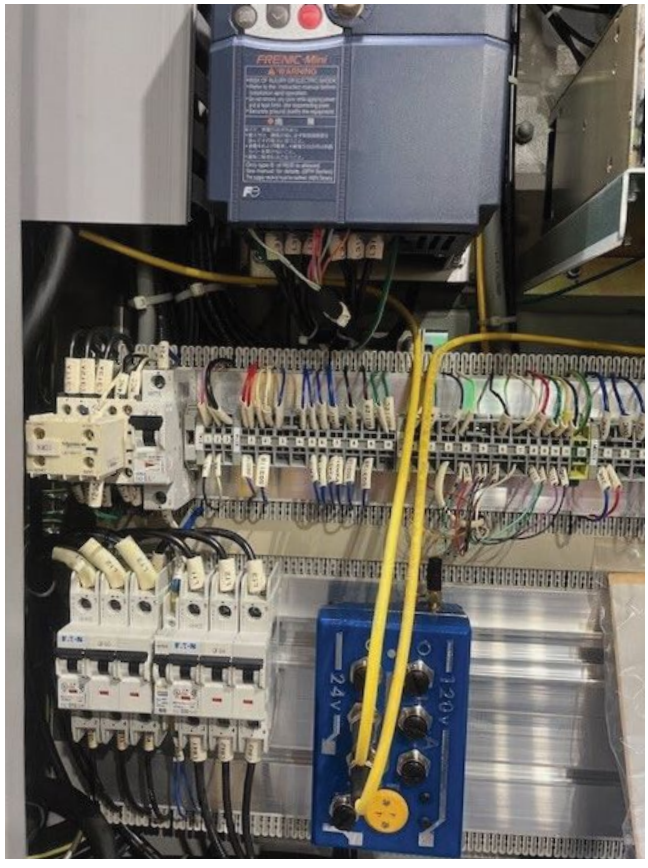
Enterprise resource planning (ERP) and manufacturing execution system (MES) integration is another fast-growing area. This includes increased activity among users of Epicor, Global Shop Solutions, JobBoss, Information Systems Engineering Inc.'s Paper-Less and other well-known systems, all of which Lanzillotta notes can use application programming interface (API) calls to exchange information with the FactoryWiz database.

The software also stands out because it is "on-prem" rather than cloud-based, a feature especially valued by aerospace and defense suppliers. "Many of these shops are limited as to what data they can share externally. Because of this, we operate within their security perimeter," Hefner says.

But technology alone doesn't guarantee success. Hefner stresses that the biggest barrier to any software implementation is cultural: Shops need internal champions who drive the project, manage change and communicate to team members how the company will use the resulting information. "It's not meant to determine how hard people are working; it's about figuring out what management doesn't even know is happening," he says.

When companies fail to assign ownership or communicate intent, he adds, adoption falters—not because the software lacks capability, but because operators don't know how greater visibility into production metrics will improve their work life.

FactoryWiz is also expanding into tooling analytics. The company now tracks tool changes made too early or too late, correlating those events with part quality and associated cost implications. "Tooling remains one of the most influential and least measured cost centers on the floor," Lanzillotta says. "And while it's certainly important to track cycle time, it's equally important to know when an operator replaces a tool and why they did so. Fortunately, it's easy to achieve this and much more with a robust monitoring solution."



Greater manufacturing efficiency is quickly becoming a matter of plugging in a few cables and installing a big-screen TV. (Provided by Caddis Systems)

Easy Does It

It should come as no surprise that FANUC America Corp. of Rochester Hills, Mich., approaches machine tool monitoring from its most fundamental layer: the CNC control. Through MT-LINKi—the company's data-collection infrastructure—shops can monitor variables such as spindle load, servo motor performance, alarm status, actual versus programmed feed-rate behavior, axis utilization and dozens of other operational values simply by plugging in an Ethernet cable.

That's according to Rob Taylor, senior account manager for aftermarket support, who explains that FANUC positions MT-LINKi as a practical, scalable way for shops to collect machine data directly from the CNC without requiring deep IT expertise. To demonstrate, he connected to an 0i-F Plus control and ran the discovery process.

"It pings the machine, comes back to tell me there's one programming path, three servo motors, a single spindle and it's going to collect 82 signals by default," Taylor says. "If this were an entire shop filled with CNC machines, you might have time to grab a cup of coffee while it interrogates each one and establishes a connection. It's that easy to implement."

While the preceding exercise is limited to FANUC controls, Lanzillotta is quick to point out that competing products are also fair game—they just require an additional step to install an MTConnect agent and map the desired control signals. That said, readers should be aware that non-FANUC controls typically expose fewer signals, although it's usually sufficient for monitoring spindle status, feed-rate overrides, alarms and other essential metrics.

MT-LINKi also records offsets using macro-variable history—a capability many customers overlook. By inserting a few lines of code into the tool-change routine, Lanzillotta

A ROBODRILL Plus technician interacting with FANUC's Series 31i-B5 Plus CNC panel. (Provided by FANUC America)

says, the system can capture tool numbers along with the corresponding geometry and wear offsets every time the machine changes tools.

"I'll set it up to monitor offsets 101 through 105," he explains while stepping through the demonstration interface discussed earlier. After a moment, Lanzillotta sorted the captured data. "I can see here when my offset values changed … and I can accurately determine the expected tool life. And, if I like, MT-LINKi can export the information to a CSV file or pass it along via the web API for analysis elsewhere."

A similar innovation is FANUC's new AI Servo Monitor, which adds predictive insight to MT-LINKi by analyzing changes in the machine's electromechanical behavior. "It works with the existing signals available from the CNC—there's no need for additional sensors," Lanzillotta explains.

"By monitoring the relationship between the speed and torque commands," he continues, "AI Servo Monitor can detect micro vibration, which it then uses to build a baseline model of normal operation. If an event causes it to exceed a threshold—a lubrication reservoir that's gone dry, perhaps—the system sends a notification that the machine is trending in an unexpected direction."

The Digital Factory

Caron Engineering Inc. of Wells, Maine, has also been busy with several new product developments. Users of the company's ToolConnect radio frequency identification (RFID)-based data-management system are gaining new capabilities through the introduction of MiConnect, a low-code, no-code application platform, according to President Rob Caron.

The announcement is significant because Caron Engineering developed the system for internal use—starting in 2015—and only recently made it commercially available, meaning full-scale adoption is still in its early stages. "Simply put, MiConnect allows people to use flowchart programming to build advanced manufacturing applications and share data with ERP, MES and other supervisory systems," Caron says.

The use of offline tool presetting, together with RFID, is also accelerating, he adds. The skilled-labor shortage is forcing shops to move in this direction, especially when coupled with automated tool management. An emerging trend, Caron describes, are CNC lathes and machining centers married to dedicated tooling robots. Here the arm—which typically rides on an overhead rail system—is responsible not only for loading and unloading tool assemblies into multiple machines, but also for leveraging RFID for tool verification and data exchange.

Such capabilities are becoming especially important as shops not only grapple with labor shortages but attempt to leverage the unattended "free hours" after everyone has gone home for the day—an achievement that is sadly undervalued and rarely executed, despite decades of supporting technologies.

Still, lights-out machining requires much more than a tool-changing robot and some intelligent tool tags. It's for this reason that Caron Engineering is known throughout the industry for its flagship Tool Monitoring Adaptive Control, or TMAC. As noted on the company's website, the system is "designed to detect tool wear and breakage as it happens—maximizing tool life, minimizing damage, reducing scrap and ensuring consistent, reliable machining."

Of course, such detective work requires the right sensors, ones that perform at a higher level than is available on many CNC machine controls. "Even on a brand-new machine, an increasing number of which support some level of remote monitoring, we still install our own sensors. They are the only ones that provide the necessary resolution, speed and precision for lights-out and lightly attended machining," Caron says.

A relatively new capability is an automatic bar-feeder vibration correction that uses Caron's DTect-IT CNC Sensor Analysis System platform. "We catch that vibration with our software and signal the CNC to reduce spindle rpm until the bar vibration settles down," says Chief Marketing Officer Brianna Toulouse.

"It's a closed-loop system, one that you can also use to monitor spindle-bearing health," she explains. "By programming it to take a five-second snapshot once a week during machine warm-up, we can predict when the bearings will need maintenance long before it becomes an expensive problem."

Data-Powered Production

Rob Caron highlights one of several joint development

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efforts, each of which is actively underway and highly relevant to current monitoring trends. “Datanomix recently introduced their TMAC AI product, which uses our TMAC data to perform advanced cutting analysis and inform customers how to set tool parameters for the best performance,” he says.

Greg McHale, the founder and CEO of Datanomix, agrees with Caron’s assessment, noting that the TMAC AI partnership represents a leap forward in smart machining. The collaborative offering uses high-resolution spindle signatures to classify cuts as “red, green, bad, good,” he explains, and suggests the correct limits for maximum process performance. The result is a closed-loop system that continuously refines cut behavior based on real machining data.

While manufacturers now have easy access to all manner of data—machine, quality, operations and financial—they too often lack “an interpretation of what all that data is trying to tell you,” McHale points out. “In other words, what’s actually going on out there.”

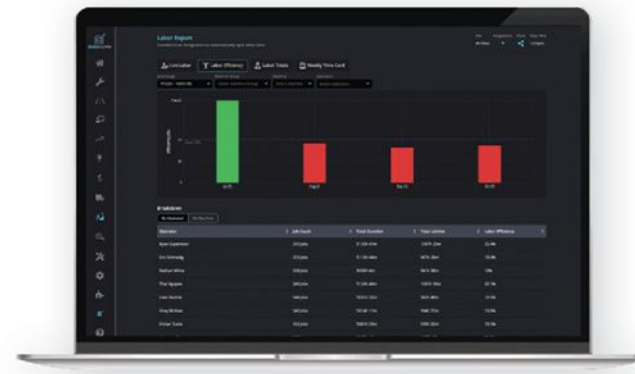
The purpose of artificial intelligence is not to overwhelm shops with more dashboards, he contends, but to deliver mission-critical inferences—where margin is lost, which jobs underperform, which production patterns matter, and what actions lead to greater customer satisfaction or profit.

Datanomix’s FactoryMate embodies that philosophy, McHale asserts, describing it as a system that analyzes machine behavior and converts it into guidance for operators, supervisors and executives. For operators, he says, it explains what’s running, where time is lost, potential risks and suggestions on what to do differently. Similarly, supervisors receive pattern-based prioritization, such as, “Of the 10 things you’re responsible for, these are the three I’d pay attention to.” At the same time, executives see job-level profitability analyses that connect actual machine performance to quoting assumptions and customer mix.

AI accuracy can depend not only on defining the data model correctly, but also on constraining it to relevant information. “Our focus is on helping manufacturers make the mission-critical, data-driven inferences that drive better business decisions,” McHale says. “Ultimately, this is what leads to greater customer satisfaction, greater sales performance or greater profit.”

In addition to the TMAC AI collaboration, Datanomix recently released its Universal ERP Connector, designed to link machine monitoring with dozens of ERP systems. Users simply select their ERP and enter an API key, and the system connects automatically. When ready, the connector unlocks several reporting capabilities, including job standards versus actuals, on-time delivery prediction, labor-efficiency analysis and machine-capacity modeling.

Datanomix’s research indicates that most shops dramatically overestimate their machine utilization—typically assuming 70% to 90% when reality is closer to 35%-45%, while labor efficiency, a newly introduced metric, shows how many hours of machine uptime operators actually deliver per hour worked, McHale notes. “Shops rarely understand this baseline,” he says, emphasizing that “improvement begins with visibility, not blame.”



The Datanomix Universal ERP Connector links machine monitoring to an ERP system in minutes. It unlocks detailed reports on job standards, labor efficiency and machine utilization. (Provided by Datanomix)

Datanomix also sees an emerging trend toward eliminating statistical process control. Customers increasingly ask for the means to ingest in-machine probing, coordinate-measuring machines, micrometer and vision data to detect dimensional trends automatically. As McHale puts it, traditional SPC requires humans to interpret charts, while AI’s job is interpretation. “The need for an operator to watch for reds and greens and take appropriate action is slowly going away.”

When shops express skepticism about AI, McHale encourages them to experiment—but to take the results with some skepticism. “I tell customers to use it for anything and everything they think it might help with,” McHale says. “You won’t know until you try.”

But go slowly, he laughingly advises. “AI is still in its infancy, or what I like to call the ‘interpretation chapter.’ We’re still a long way from the autonomous execution stage, but rest assured, it’s coming.” ■

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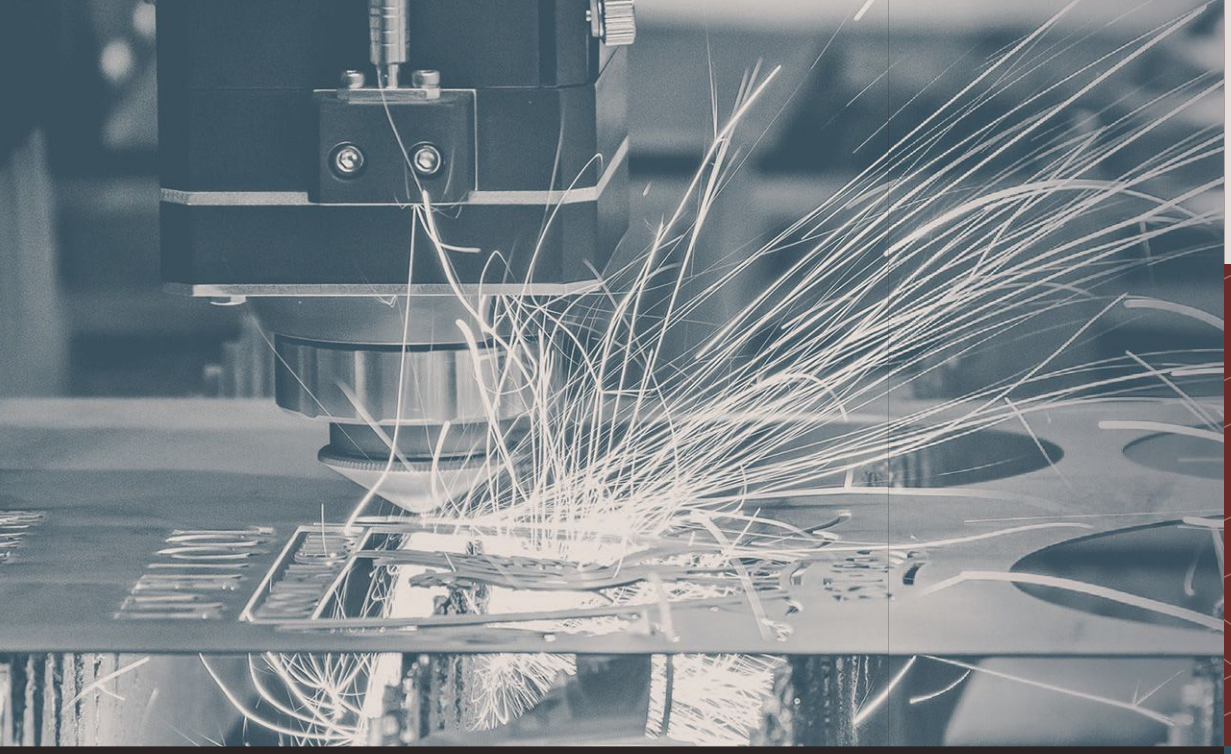

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Inside the Craft of *Multi-Axis Machining*

MEAGHAN ZIEMBA, Contributing Editor

Multi-axis machining has become one of the clearest signals of a shop's readiness for complex parts, shorter lead times and stronger throughput. But the work behind it is far from effortless. The shift from three axes to four, five or hybrid systems introduces a new level of spatial reasoning, machine behavior and process planning that many shops underestimate. As machines grow more capable and expectations rise, programmers and machinists face deeper layers of decision-making that reach beyond software.

We've spoken with five professionals who have lived those changes from different corners of the industry. Their experiences show how multi-axis work has evolved from a niche capability into something essential for precision and productivity. Each brings lessons from decades of shop-floor habits, growing automation, machine kinematics and the human intuition that still holds everything together.

It isn't only about toolpaths. It's about how people read machines, understand motion, predict behavior and make decisions when the metal, the setup or the geometry refuses to cooperate.

How Multi-Axis Became the New Standard

Don Casanova, owner and CEO of New Hope, Minn.-based Midwest CAM Solutions, remembers when early CNC work still relied heavily on touch, sound and being close to the machine. "You could feel the machine and hear what the cutter sounded like," he says. He started in an era when programming was done manually, and the only indicators of trouble were the cutter's tone or the way the machine vibrated against the hand. That experience stayed with him as he moved into five-axis work.

What caught him off guard wasn't the programming itself—it was "all the blind spots," the moments when the tool moved into places the operator couldn't see. Casanova explains how those early days felt "nervy" because every move required trust, and trust came only after learning how the machine behaved when tilted or rotated in unfamiliar positions.

As software evolved, simulation made it easier to visualize motion paths before metal was cut. This was a turning point, according to Casanova. Simultaneous motion no longer needed to feel like a leap of faith, because he could study the path and verify each move. "That change," he explains, "made five-axis programming more approachable, especially for shops stepping beyond three-plus-two (set-ups) for the first time."

Today, Casanova views multi-axis machines as essential rather than optional for job shops if they want to compete, because designers now expect their parts to be handled in a single setup whenever possible.

Al Whatmough, CEO of Toolpath Labs Inc. in Bedford Heights, Ohio, experienced the change from a different angle. As a machinist, he worked mainly with four-axis setups. It wasn't until Whatmough moved into advanced CAM development that he programmed five-axis tools at a deeper level and, over time, he noticed that these machines became less of a specialty purchase and more of a standard tool for reducing labor strain and increasing human productivity and consistency.

The shift, he says, resembles the early days of CNC, when shops kept a manual mill in the corner "just in case." Today, a three-axis machine tends to be kept for secondary needs, while their core work runs on five. "The shift reflects a broader understanding that fewer setups mean less room for error and faster turnaround," he explains.

At ATD Precision Manufacturing in Phoenix, Engineering and IT Manager Jamie Lerma's own "aha moment" came when the company began losing work to shops that adopted multi-axis machines. Once ATD made the transition, he saw how quickly the technology opened new opportunities.

But moving from four to five axes was a steep learning curve. "That one extra axis movement is what confuses most machinists," Lerma explains. "Once it clicks, everything else is easier—even transitions into more advanced systems, like a nine-axis mill-turn."

CNC machining a complex impeller. (Provided by Fathom Digital Manufacturing)

KEY TAKEAWAYS

1. **Multi-axis machining is becoming standard.**
2. **Skilled workers are central to the process.**
3. **The steepest learning curves are for spatial reasoning and fixturing.**

Hidden Complexities

While the appeal of multi-axis work is often tied to fewer setups and broader reach, the underlying complexity sits in places most new programmers don't expect—such as fixturing. Even experienced teams typically trip over fixturing problems more often than software issues, Lerma notes.

If the part isn't held in a way that matches the planned strategy, the programmer may chase errors that aren't actually in the code. Lerma encourages teams to simulate with the exact kinematics and workholding so that problems surface before the first chip drops, because "If those don't match, you'll chase problems that aren't in the software."

Such lessons often start in the classroom. When students move from three-axis systems into multi-axis work, the challenge isn't the toolpath—it's the spatial translation, notes Caleb Gullion, a CNC instructor at Calhoun Community College in Decatur, Ala. "On a three-axis machine, you only worry about the Z," he says. "On a five-axis, you have something on all four sides that you can crash into."

Teaching students to visualize motion paths becomes just as important as teaching them to program. Simulation helps, but the real learning happens when they begin predicting machine behavior before running the code, because true multi-axis skill comes from anticipating behavior, not reacting to it.

There are also intricate layers of decision-making behind hybrid machining. At Hartland, Wis.-based Fathom Digital Manufacturing, General Manager Chris Forgey says his team leans on tools that integrate milling and turning operations to improve throughput. But that same flexibility makes the programming more demanding.

Programming isn't just strategy—it's also about knowing which machine functions unlock the fastest path to an

Ty Neff, owner of Neff Machine, loads parts into a Haas machine. (Provided by Neff Machine)

accurate part. Forgey explains that newer tools, such as AI-assisted programming, help speed up routine steps, but "they never replace the human physics engine." A programmer still needs enough understanding to manage risk, evaluate tool engagement and judge whether the system's suggestions make sense.

Whatmough agrees. As CAM systems grew more accurate, the kinds of mistakes programmers had to watch for changed. Early crashes often came from mistyped code. Now they come from tool-length offsets, work offsets or misunderstanding how the machine's geometry interacts with the setup.

Whatmough describes a modern programmer's responsibility as knowing when to step in, the same way a pilot knows when to override autopilot. "The computer doesn't know the full context, so the human still has to guide it," he says. As automation increases, the craft shifts—not by taking decision-making away, but by raising the level at which those decisions happen.

Building Strategy Around Machines

Experienced programmers know that a good strategy is often built around restraint. Gullion tells his students that simultaneous five-axis motion is a tool, not a requirement. Beginners are drawn to it because it seems more advanced, but he stresses that most work doesn't need it. "Three-plus-two does most of the heavy lifting," he says. "True five-axis is saved for geometry that demands it, because it introduces more paths, more risk and more variables to watch."

ATD takes a similar tack. When deciding how to approach a new part, the team looks first at size and material. Harder materials with tight tolerances may require splitting work across machines—one for roughing and one for finishing—to prevent stress from creeping into the part.

Speeds, feeds and proven routines are cataloged inside ATD's CAM system, which provides users a reference point instead of guessing and starting from scratch. This helps match the process to the shop's strengths instead of forcing machines into uncomfortable roles, Lerma explains.

For shops just entering multi-axis work, Midwest CAM's Casanova recommends starting with a fourth axis to retrofit a familiar three-axis machine. "It gives them a taste of rotational movement without overwhelming them," he adds, viewing strategy through the lens of machine capability. From there, the shop can grow into more complex machines or even multitasking turning centers that cut both halves of a part in one cycle. The goal is to make careful moves that support customer demands and long-term competitiveness.

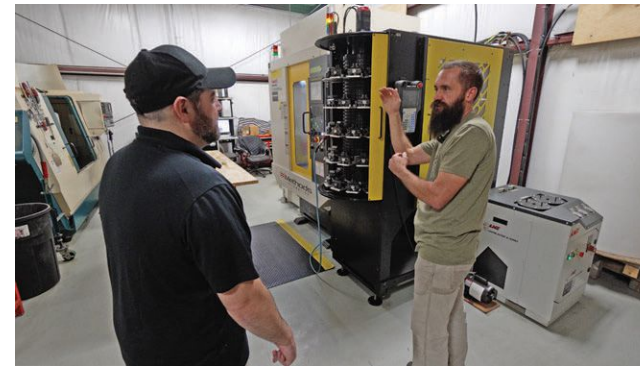
Whatmough adds another layer to strategic planning: machine geometry. And, in the case of five-axis machining, size can be misleading; a large trunnion with a small part creates more collision concerns, not fewer.

"Shops sometimes assume a bigger machine offers more flexibility, but, in reality, they may spend hours trying to avoid collisions between the spindle and the table," Whatmough explains. The right machine size is dictated by the part, not by a desire to scale up.

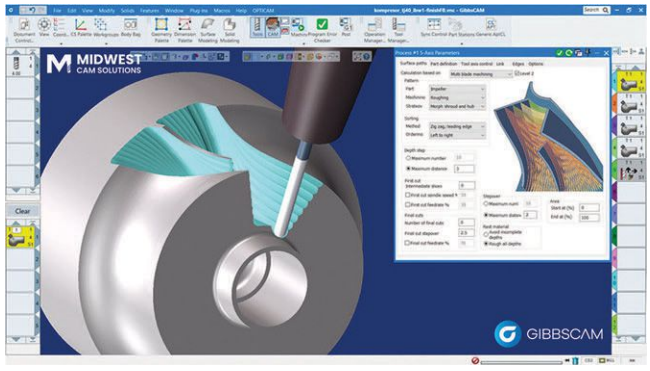
The Human Element

Even as automation improves, each of these experts emphasizes that multi-axis programming succeeds because of people, not software. ATD holds first-run meetings that bring together programmers, setup personnel and planners. In these meetings, the group decides on material shape, fixturing and tool selection before the first line of code is written. Lerma notes how these meetings "help everyone catch issues early," because each person sees the part from a different angle.

Intuition can also come through repetition. Gullion has students manually jog each axis every day before they



Justin Gray (left) of ToolPath Labs tours Conour Manufacturing (Winton, Calif.) with owner Shawn Conour. (Provided by Toolpath Labs)



GibbsCAM's MultiBlade module powers turbomachinery production—purpose-built for programming blisks, blings and impellers on multi-tasking machines. (Provided by Midwest CAM)

begin programming. "It helps them feel the machine," he says. Students learn to anticipate direction, movement and clearance. That simple exercise builds instincts that follow them into more advanced work, Gullion notes.

At Fathom, Forgey gives his team the tools to move faster without sacrificing awareness. When rough routines are automated, programmers can focus on decisions that matter, such as finish quality, cycle-time tradeoffs and avoiding unnecessary risk. Reducing mental load, he says, allows programmers to use judgment more effectively.

Programmers shouldn't rely too heavily on automated code tools either. "If we get dependent on it, we lose critical thinking," he says. He believes understanding code is still important—especially when mistakes occur—and encourages people to engage with AI tools now so they can learn their strengths and weaknesses before the next wave of software arrives.

Whatmough sees the future shifting toward human-guided automation. In his view, programmers will increasingly manage outcomes rather than typing every command. That means choosing constraints, shaping machine behavior and deciding what the software should optimize. It is not less human—it is more strategic.

What Lies Ahead

Over the next decade, manufacturers will face many new challenges, the experts agree. One of the biggest obstacles will be finding workers who can keep up with advancing technology. Machines, tooling and software will continue to evolve, Lerma notes, but without people who understand the craft behind them, progress stalls.

This includes programmers engaging with emerging tools. "Five years from now, waiting will put you behind," Casanova says, noting that early adopters will have a clearer sense of what works, what doesn't, and how to shape workflows that can scale and support long-term competitiveness.

Forgey sees opportunity in hybrid systems and lights-out machining. With the right setup, shops can run parts through integrated lathes and mills in ways that would have seemed out of reach only a few years ago. But that potential requires stronger programming foundations, he says, not weaker ones—and AI will assist workers rather than replace them.

But the most important shift may be the ratio of humans to spindles, Whatmough contends. For manufacturing to stay competitive, he believes programmers will need to support more machines without sacrificing quality, with multi-axis being the foundation to make this possible. "And shops that invest in training will outperform those that don't," he says.

Students will need deeper exposure to simulation, hands-on machine movement and real-world problem-solving, Gullion adds. To this end, multi-axis work rewards curiosity, patience and the willingness to step into complexity with confidence. The next wave of programmers, he says, will build speed by learning how to think—not just how to follow steps.

Where Technology and Intuition Meet

Multi-axis machining demands a blend of geometry, planning, machine understanding and judgment. Software can automate routines, avoid collisions and generate complex paths in seconds, but decision-making still rests with humans. The programmers and machinists guiding these machines translate ideas into motion, controlling multiple axes with a level of care that software alone cannot match.

The five experts featured here show that multi-axis excellence isn't just about mastering a toolpath. It's about understanding the entire environment—machines, materials, setups, code and the people running them. As shops continue adopting more advanced machines, the path forward depends on blending technology with intuition, letting automation support the craft while never replacing it.

Precision isn't a feature of a machine. It is the result of thoughtful work by the people who guide it. ■

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ATD Precision Manufacturing
602-276-2439 / www.atdpmfg.com

Calhoun Community College
256-306-2500 / www.calhoun.edu

Fathom Digital Manufacturing Corp.
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A solution to the looming worker shortage: America's military veterans

■ MICHAEL MCCONNELL,
Senior Editor

When Michael Figueroa decided it was time to close his two-decade Army career, he wasn't sure what would come next. As a first sergeant based in Fort Carson, Colo., he had supervised about 200 soldiers. But would that mean anything to civilian employers?

"I was very apprehensive," Figueroa recalls. "(After) 22 years of giving your all to the military and your country, there comes a point in time where you feel like you need to try something new. But it's that fear of the unknown."

Figueroa's concerns were far from unusual. Every year, about 200,000 U.S. service members leave the military. For many, their biggest fear is getting a job that matches their skills, expectations and experience.

There is also growing concern across the U.S. manufacturing industry, albeit about a different issue. With large numbers of longtime workers reaching retirement age—and not enough potential replacements on deck—executives fear companies soon won't be able to find enough skilled workers to build the machinery, equipment and products needed to keep the economy going.

The problem isn't new. Decades of federal disinvestment in vocational training programs and career counselors steering students toward other fields has led to a looming crisis. According to a 2024 report co-authored by consulting firm Deloitte Touche Tohmatsu Ltd., the U.S. could see 3.8 million open manufacturing jobs by 2033—and almost half may go unfilled.

Vets Meet a Need

The good news, experts say, is there's an underused labor pool uniquely suited to high-skill manufacturing jobs: America's military veterans. These men and women are comfortable working on complex equipment and following procedures. And the skills learned in many military jobs directly transfer to civilian positions such as mechanic, technician or operator.

Just ask Craig Coyle. A West Point graduate and former Army Apache helicopter pilot who now consults with manufacturing executives on how to solve workplace challenges, Coyle recommends employers strongly consider veteran candidates.

"If you just look at it from strictly an 'opportunity to source talent' perspective for manufacturers, why would you not pursue the veteran population?" Coyle asks. "You're talking about people who understand the power that purpose has."

Veterans have already shown their value to employers, Coyle adds. "If someone has proven success in the military, they're basically telling you, 'Look I am capable of understanding how to develop a skill set,'" he says, noting that soldiers appreciate work ethic, the importance of organizational structure and how to make decisions under pressure.

"You're looking at someone you're probably going to promote (into) leadership positions," Coyle says.

Translating Transferable Skills

Many military duties easily transfer to civilian positions. Military commanders can make excellent senior managers; first sergeants usually have extensive experience supervising large groups.

ON THE FRONT LINES OF MANUFACTURING

Technicians often have backgrounds troubleshooting complex systems and making repairs. And the soft skills successful veterans possess—adaptability, resilience and dedication—can make them excellent workers.

While veterans are able to translate their skills into civilian roles, employers often lack understanding about the relevant experience gained during military careers. This stems in part from the technical jargon and titles used throughout the armed forces: military occupational specialty (MOS), Air Force specialty code (AFSC) or non-commissioned officer in charge (NCOIC). These terms mean little to many civilian recruiters, and veterans may struggle to explain what they entail.

Ty Andrisek understands all of this, perhaps better than many. Andrisek is a 20-year Navy veteran and the corporate recruiter at Cincinnati Inc. He originally applied to be a technician at the metal fabrication machinery maker but found himself drawn to recruiting at the suggestion of an Air Force veteran in Cincinnati's human resources office.

It ended up being a great fit.

"I love it," he says. "It was one of those things that I had never really thought about much because I was so comfortable with the technical aspect of working with industrial machines because of my extensive experience maintaining and operating large electromechanical equipment in the Navy."

When talking with veterans interested in working at Cincinnati, Andrisek points out aspects of the job that will feel familiar to people with military experience.

"We're all focused on the same mission," he explains. "The field service aspect of the business is very militaryesque. … We're here to take care of our customers. We're here to keep the equipment up. It's a very similar focus to the kind of things that we did (in the military)."

At Hypertherm Associates, an industrial cutting products manufacturer based in Hanover, N.H., there are people on staff who can help its recruiters understand military job titles and how those duties translate to a position with the company.

"We've always had veterans working for us, and we've seen the commitment and dedication they bring," notes Alison Eko, the company's inclusion and diversity director. "So we've always tried to find ways to support our veterans."

Hypertherm, which is certified by the state as a "veteran-friendly" employer, has hired veterans for positions in operations, engineering,

At General Dynamics Land Systems, a military vehicle manufacturer, nearly one in five employees has a military background. Here an employee performs maintenance work on a MUTT XM robotic vehicle. (Provided by General Dynamics Land Systems)

human resources and recruiting. As an employee-owned company, it aims to foster a sense of community among employees, something that many service members say they miss after leaving the armed forces.

Several of the company's training programs align with military experience. This is attractive to veterans reentering the civilian workforce, points out Kristen Clark, Hypertherm's director of communications and change management.

"For people looking for job security, this is a great opportunity for them long term," she says. "The technical training that we offer to everybody is also a great support system for the transition. If somebody's never been a machinist before, that's fine because we will train them how to do that."

KEY TAKEAWAYS

1. **Many military skills transfer directly to manufacturing roles.**
2. **Employers often need help understanding military experience.**
3. **Training and culture are key to successful transitions for veterans.**

Walking the Walk

Jergens Inc., a manufacturer of workholding, precision electric screwdrivers and aerospace-related products with operations in Cleveland and Chicago, understands the support former military members need to have successful civilian careers. It also helps when members of a company's leadership are veterans themselves. That's the case with Jack Schron Jr., president of Jergens Inc.

"Our company was founded in 1942, so the military and veterans have been part of our DNA for the 83 years that we've been in business," Schron says. "Jergens is 100% veteran-owned. We believe wholeheartedly in hiring veterans."

What makes Jergens unique, Schron says, is that 30%-40% of the company's business is related to defense and aerospace work. That means many veterans will quickly feel comfortable with the products they work on.

"Whether they're coming into a management position or a production position, they see the exact same products they would have been using on active duty being manufactured right here," he says, adding that Jergens' products are used to make fighter jet ejector seats and missile systems.

"Someone coming out of the military—let's assume they were a mechanic, a flight mechanic or a mechanic on a piece of equipment," Schron adds. "Those skills are directly transferable to manufacturing because we have to maintain $300,000, $400,000, $500,000 pieces of machinery and equipment, and they're sophisticated."

Available Resources

Several public and private sector organizations help veterans such as Andrisek and Figueroa find civilian jobs. The list includes:

- Hiring Our Heroes (HOH), affiliated with the U.S. Chamber of Commerce;
- Hire Heroes USA, a charity that boasts of placing more than 110,000 veterans and their spouses in new careers; and
- Workshops for Warriors (WFW), which tries to match veterans with jobs in advanced manufacturing.

One of the best-known and most successful placement programs is the U.S. Defense Department-affiliated SkillBridge. For more than a decade, it has offered service members the chance to explore post-military careers while still earning military pay and benefits. More than 50,000 veterans have participated in the program, as well as numerous manufacturers—including Hypertherm.

With the permission of their commanding officer, veterans can sign up for an internship or apprenticeship with approved companies up to six months before their discharge date. If they're successful, they could be offered a full-time position when they leave the service.

The program allows employers to try out potential new workers without the immediate commitment of a full-time job offer. An estimated 1,700 private sector employers participate.

Understanding Culture

Few companies understand the benefits of hiring ex-service members better than General Dynamics Land Systems, a military vehicle manufacturer based in the Detroit suburb of Sterling Heights, Mich. Nearly one in five of its employees come from military backgrounds, according to company officials. And many veterans are

HELPING VETS FIND CIVILIAN CAREERS

Many organizations work with service members to help veterans transition back to civilian life (and employers fill open positions) by offering training, skills matching and job placement assistance. Here are a few.

Hiring Our Heroes
Sponsored by the U.S. Chamber of Commerce Foundation, this organization connects veterans, spouses and active service members with businesses that need their skills and ability. It offers networking and online training. *(www.HiringOurHeroes.com)*

My Next Move (for Veterans)
This website, sponsored by the U.S. Labor Department's Employment and Training Administration, is a clearinghouse of job information tailored to veterans. Jobs are sorted by interests, overlap with military skills, demand outlook and "clusters," including advanced manufacturing. *(www.MyNextMove.org/vets/)*

Workshops for Warriors (WFW)
This San Diego-based nonprofit says it is committed to restoring American manufacturing by placing veterans and those exiting the military into advanced manufacturing jobs. With accredited programs in CNC machining and welding, WFW says it has trained more than 1,600 veterans, civilians and transitioning military members. *(www.WFW.org)*

Hire Heroes USA (HHUSA)
This organization was founded in 2006 by John Bardis after he met a critically injured Army sergeant who was a patient at Walter Reed Army Medical Center. The sergeant told Bardis that he was most worried about finding a job after returning to civilian life. Bardis offered the man a job and went on to start Hire Heroes USA, which is said to have placed more than 110,000 veterans and their spouses in new careers. It lists manufacturing as one of the top careers for veterans. *(www.HireHeroesUSA.org)*

Society for Human Resource Management (SHRM)
This 77-year-old human resources organization advocates for and offers advice on workforce development and related issues. It runs a program and website, SHRM Hire Vets, offering service members job training and connecting employers with more than 200,000 veteran candidates. *(www.hirevets.shrm.org)*

Call of Duty Endowment
Named after the popular video game, this nonprofit was founded to help veterans find good-paying civilian careers. It provides grants to charities that provide job placement for veterans. Since its inception more than 15 years ago, the group says it has found work for some 150,000 veterans. Its website lists veteran-focused charities that meet its standards for aid and efficiency. *(www.CallofDutyEndowment.org)*

DoD SkillBridge
The DoD SkillBridge program offers job training through internships and apprenticeships in a soldier's last six months of service, with the opportunity for full-time work at the end of the program. It has helped place more than 9,200 people and cites partnerships with some 6,300 organizations. *(https://skillbridge.osd.mil)*

VetJobs
The charity helps veterans with resume writing and interviewing, creating LinkedIn profiles, skills training and placement aid. The organization says it has placed more than 114,000 veterans and military spouses in the last 15 years. *(www.vetjobs.com)*

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likely familiar with General Dynamics' products, which are used by U.S. and ally defense forces around the world.

"I feel veterans want to continue a mission," says Stacy Mercure, a General Dynamics Land Systems talent acquisition manager, noting a job there is an easy transition for many veterans. "(Working at General Dynamics) is a great way for them to continue their service. They bring a lot of dedicated skills that are important to us, leadership being one of them, (as well as) team management, communication and great strategic planners."

The company often partners with the SkillBridge program to connect with service members while they're still on active duty to see if they're interested in working at the company.

"We provide industry experience; we coach and mentor," says Kay Rupard, a talent development and operational excellence strategist. "The skillsets that they bring with them are very impressive, and some of them are even end users of our products, which we won't find from any other source."

Rupard says General Dynamics Land Systems is always hiring for manufacturing positions, pointing to current opportunities in leadership, production supervision, welding, mechanics, operations and assembly.

Finding a New Career

In Colorado, Michael Figueroa says he used the resources Hiring Our Heroes and other veteran-assistance organizations to help update his resume and practice interviewing skills. This helped him find a home at Entegris, a semiconductor materials supplier with 8,200 employees across 12 countries.

Recruiting veterans has been a longtime practice at Entegris. And the company redoubled such efforts with the opening of its Manufacturing Center of Excellence in Colorado Springs, Colo., a community with five major military installations.

"We have a good size military population in our workforce right now and, as we were starting to develop the new facility, we decided to really go after that as a target population," says Greg Schnipke, Entegris' senior director of human resources. "We're putting together a full advertising and recruitment campaign to put even more emphasis on our military population."

Entegris' goal is to have half of the center's eventual workforce of about 600 people be veterans or members of military families. To this end, the company is working with national and local organizations such as HOH, Mount Carmel Veterans Service Center and SEMI VetWorks, a group that works to attract military service members to the semiconductor industry.

For Figueroa, it was the company's

Hypertherm Associates encourages employees to donate their time. Here, employees (who are veterans themselves) volunteer at a Veterans Affairs facility. (Provided by Hypertherm)

focus on cultivating happy, long-tenured employees that attracted him. During one facility tour, he met workers with decades at Entegris.

"It told me that this company knows how to take care of its people," the 44-year-old production supervisor says. "I didn't want to look for my next 'job.' I was looking for my next career, and I found that here at Entegris."

The work culture was right, too.

"Entegris is big on following process, meeting our customer specifications, their unique needs," Figueroa explains. "And that's what we do best in the military: follow orders to the 'T.'"

Following orders. Meeting expectations. Seeing projects through. While a manufacturing worker shortage may be looming, veterans can check many of the requirements that companies are looking for now. A veteran-friendly workplace may be the competitive advantage of the future. ■

5 Reasons Veterans Make Great Manufacturing Workers

1. Tech savvy. Veterans likely spent much of their service working with some of the most advanced equipment in the world. They won't be intimidated by machinery on the shop floor.

2. A military approach to work. Analysis, planning, a can-do attitude and focus on results are attributes common in many service members, and they are sought-after among employers.

3. Proven skills. Many veterans have overseen complex projects and/or managed large teams. These skills are invaluable to many manufacturing companies looking to build a successful team.

4. Clear objectives. Manufacturing, like the military, has well-defined goals. You either build the part to specifications—or you don't. Success in other civilian work isn't always as obvious.

5. A safety mindset. Military members are trained to follow procedures to ensure the safety of themselves and others. Not following protocols could be a life-or-death situation. Veterans understand why rules must be honored.

Jack Schron Jr., president of Jergens Inc., says the company is 100% veteran-owned. (Provided by Jergens)

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Cincinnati Inc.
513-367-7100
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General Dynamics Land Systems
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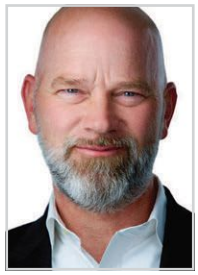
TODAY'S MANUFACTURING PARADOX: WHAT STAYS THE SAME AND WHAT MUST CHANGE

JAMIE GOETTLER, Chief Revenue Officer, BTX Precision LLC

"THE MORE THINGS CHANGE, the more they stay the same." Sometimes this old adage perfectly captures a moment; other times, nothing could be further from the truth. When it comes to manufacturing in the U.S. today, this saying fits well in one regard, while in another way, it doesn't fit at all.



On the one hand, what manufacturers care about has remained remarkably consistent. In the face of the constantly changing industry environment—think offshoring, reshoring, tariffs, technology, inflationary pressures, labor, regulation—what matters most to businesses has not changed.

Back in the early 2010s, I remember hearing a well-known consulting company present a U.S.-based manufacturing outlook to a large group of machine-shop owners and leaders at a regional conference. They were excited to share the preeminent concerns of U.S. manufacturers based on surveys and research. The top three issues were:

- **Competitiveness.** The ability to generate enough profit to flourish, reinvest, and withstand pricing and margin pressure.
- **Future growth**. Makes sense, right? Who wants to invest countless hours in strategy, training and execution, only to end up flat—or, worse, move backward?
- **The skilled-labor gap.** Yes, this was a challenge everyone saw coming, even back then.

> "In the face of the constantly changing manufacturing environment—think offshoring, reshoring, tariffs, technology, inflationary pressures, labor, regulation—what matters most to businesses has not changed."

These concerns are the same today—maybe in a different order, but they are what keeps manufacturing business leaders up at night.

Where the saying breaks down, however, is with one word: technology. The absolute necessity of adopting (even some) new technology in today's manufacturing environment is clear. Indeed, the more things change with tech, the more those who *don't* change can or will be left behind. In this respect, things most definitely are not the same.

Throughout 2025's four regional SME Manufacturing Technology Series events (EAST, WEST, SOUTHEAST and SOUTHWEST), I was asked to lead panel discussions alongside some tremendous industry leaders. The discussions lasted 90 minutes with a Q&A and were attended by the best of the best in U.S. manufacturing. The panels were called "Flip the Script: Discussion of Primary Concerns of U.S. Manufacturers and the Impact of Technology."

We began by sharing the three concerns I noted earlier (competitiveness, growth and the skills gap) and found agreement from the audience. The panel then strategically addressed each issue by highlighting the technology avail-

Script Flippers

Led by Jamie Goettler, a rotating group of experts participated in SME's Executive Perspectives panel, "Flip the Script: Discussion of Primary Concerns of U.S. Manufacturers and the Impact of Technology," at the Manufacturing Technology Series events in California, Massachusetts, South Carolina and Texas. The group included:

- Billy Bogue, president, Matsuura Machinery USA
- Ken Cowan, vice president, Paperless Parts
- Jamie Goettler, chief revenue officer, BTX Precision
- Sam Kusack, president, Kammetal
- Steve Plumb, editor-in-chief, SME Media
- Bradd Rodenroth, vice president of sales, Nexgen Tooling
- Luis Solano, customer engineering manufacturing lead, Google Cloud

SME Editor-in-Chief Steve Plumb (left) interviews Jamie Goettler, BTX's chief revenue officer, following a panel discussion at the Manufacturing Technology Series EAST in West Springfield, Mass. (Provided by SME Media)

able today, as well as where or how to start. We pondered numerous Industry 4.0 innovations and unpacked each of them, positioning the tech alongside the expected outcomes. So what were the questions, feedback and sentiments among the industry today?

Artificial Intelligence

The primacy of artificial intelligence wasn't a surprise for us, and probably is no surprise to you either. That said, AI just keeps getting better and better, and the use cases simply continue to grow. For those of you using it, think back to what you did with AI two years ago, one year ago and even three months ago.

If you're an adopter, the applications within your business seem unending: reading CAD models and prints, highlighting geometric dimensioning and tolerancing, machine- and cutting-tool selection (including within your own inventory), programming, toolpaths, operating parameters, fixturing strategies, scheduling, planning and so much more.

Industry research? No problem. Ask your AI platform of choice to help you find ideal end users based on your shop's capabilities and materials you prefer to machine, and you'll find a wealth of quality prospects.

So how does AI impact the primary concerns we noted? Rather, the question should be: How doesn't it? Ideal tool selection, toolpaths and machine selection will all save time and deliver optimal performance. And if time is money, then less time is less money, meaning your costs are now lower.

Growth? That's simple. Finding ideal customers will help you grow. Optimizing setup, scheduling and operating parameters will allow you to build more parts per shift, day, week, month and year. More parts equal more throughput, and more throughput means more sales growth.

Lastly, the skills gap is really about productivity throughout the facility. AI can help upskill workers faster through relevant content creation. It can work alongside team members to share captured tribal knowledge, suggest repairs or modifications, and help avoid failure patterns.

Although I've pumped up artificial intelligence quite a bit here—and for good reason—a friend and colleague of mine, Luis Solano of Google Cloud, suggested the following: Utilize AI as if it's an intern. There's an abundance of information there, however, its applicability should be rationalized and combined with human experience to make the best decision.

The bottom line: Go get started with AI if you haven't already.

The panel takes the stage at the final 2025 Manufacturing Technology Series event in Dallas. (Provided by SME Media)

Ken Cowan (far right) shares his insights following the Flip the Script panel at Manufacturing Technology Series WEST in Anaheim, Calif. (Provided by SME)

Robotics and Automation

As many in the industry would agree, robots and automation shouldn't replace roles that require humans to make decisions using reasoning from their experience, their senses and their environment. Yet this statement may be outdated soon as well. Look no further than the developments within the defense manufacturing sector and the application of AI-infused unmanned fighter jets, drones and more.

Robotics and automation should, however, be far more prevalent in the U.S. than they are today. In a study shared by the International Federation of Robotics, the U.S. ranks 10th in robotics adoption (measured by the number of robots per 10,000 workers). Among the countries ahead of the U.S. are China, Singapore, Germany, Japan and Denmark. But just because they're doing it, should we?

The answer is a resounding yes! There are several reasons for this. First, the U.S. Bureau of Labor and Statistics has shared that 26% of the country's manufacturing workforce—nearly 4 million workers—is over 55 years old. This means the skilled-labor shortage will soon worsen, and robotics and automation can, in part, help bridge the gap.

Another reason is—you guessed it—productivity, which can offset the concerns of competitiveness, growth and labor. Robots/cobots, flexible manufacturing systems, palletized systems and more can be set up by humans and programmed (or trained) to operate all day and night. Not running a production shop? Use a pallet system to set up multiple jobs with minimal human intervention. The return on investment for this tech is typically in the 12-to-18-month time frame.

Big Data

The last of the top tech to improve competitiveness, throughput and productivity is big data. If you're not capturing data throughout your facility, I suggest you begin to do so immediately.

Everything revolves around data these days. If you're failing to track data in part files, quote history and analytics, programming and operating parameters, tool life, surface finish, vibration, quality, uptime, downtime, parts movement through a shop and hundreds of other areas, you're missing out on keys to unlocking success. And by "success," I mean growing profitable sales at near-maximum productivity.

Cyber-physical systems, machine monitoring and other data-rich technologies will help you capture data, organize it and then use it to your advantage. Interested in keeping your AI within your own walls someday? That's great, but you need to create the foundation for that now.

More Hot Topics

Cybersecurity was another hot topic of discussion, particularly given the November 2025 mandate for the inclusion of Cybersecurity Maturity Model Certification in new Department of Defense contracts within the U.S.

Simulation was also prevalent among the panels. Beyond simply avoiding costly mistakes in programming, simulation can now suggest the ideal routing of parts through a shop. Don't want to test cutting tools and compromise production? Consider what's available on the market for cutting-tool applications that can suggest ideal toolpaths and operating parameters for your specific machine setup.

Other topics included augmented and virtual reality, cloud computing and systems integration. And there are dozens of other available or emerging technologies that I haven't touched on here. My advice for how to stay informed? Engage AI.

The moral of this story: While the economics of business have remained consistent for decades, the path to becoming a truly successful manufacturing organization now runs through technology adoption and effective change management. Embrace it and your company becomes leaner as well as more resilient, reliable, flexible and capable. And yes, it'll be more productive and prosperous, too. ■

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AFFOA: A DECADE OF FABRIC INNOVATION AND COMMERCIALIZATION IN THE U.S.

AMY BRYSON, Contributing Lead Editor

ADVANCED FUNCTIONAL FABRICS serve many complex functions. They transform traditional fibers, yarns and textiles into sophisticated, integrated devices and systems that allow for capabilities including communication, energy storage and health monitoring.

At the forefront of innovation in this space is Advanced Functional Fabrics of America (AFFOA), a public-private partnership founded in 2016 to bridge the gap between product ideation and commercialization. Funded by the Department of Defense (DOD) and one of 18 Manufacturing USA institutes, AFFOA uses its expertise in fibers and fabrics, as well as its ecosystem of 150 members across 38 states, to advance the domestic development of textile-based products with transformative capabilities for defense, health care and consumer applications.

Tackling Tough Tech

Advanced functional fabrics are in a category known as tough tech, which is comprised of science-based technologies that aim to solve global challenges related to health, climate change, energy and other issues. These tough technologies go beyond typical software development to building new physical infrastructure and industrial systems, often requiring significant research and development, as well as capital, to take breakthrough science out of the lab and into the market.

"In the tough tech space, it takes years to advance," says Sasha Stolyarov, CEO of AFFOA. "Over the past few years, there have been significant developments in the space of advanced fiber technology. A lot of the capabilities that were in their infancy have reached the stage of commercialization, with products on the market and system-level prototypes being built—not just component technologies, but actually full systems."

Stolyarov says a good example is from Nanowear Inc., the Brooklyn, N.Y.-based creator of SimpleSense, an FDA-approved remote diagnostic platform that is transforming home-based cardiometabolic health care. SimpleSense wearables deliver a cardiometabolic assessment and a continuous picture of a patient's health from the comfort of their home. The company says that the noninvasive undergarment monitors multiple patient vitals, such as heart rate, respiration rate, lung volume and physical activity. The collected information generates AI-enabled real-time analytics in the form of easy-to-read reports for physicians, providing a smarter way to care for patients remotely.

Another example is Auburn Manufacturing Inc. (AMI), based in Mechanic Falls, Maine. The company knows a lot about tough tech. They manufacture advanced textiles for extreme-heat environments. AMI also makes flexible barriers, modular insulation kits, reflective aluminized fabrics and fabrics enhanced with coatings to resist oil, moisture and abrasion.

"As a small manufacturer of heat-resistant fabrics, we have come across opportunities that we could not take advantage of due to a lack of in-house resources, such as materials, mechanical engineering, testing, etc.," says Kathie Leonard, AMI's president and CEO.

KEY TAKEAWAYS

1. **Advanced functional fabrics are known as "tough tech" that takes years to advance.**
2. **E-textile applications are on the rise across military and health care industries.**
3. **AFFOA and its ecosystem expedite product ideas from prototype to commercial availability.**

"AFFOA was formed to help specialty textile makers like AMI develop new products that are needed by the DIB (defense industrial base)," she adds. "We were approached by the aerospace industry a few years ago to supply silica fabric used in rockets as an ablative. AFFOA helped us find the proper equipment to further process our silica to meet rigid specifications. They also helped us access federal funding to develop prototype fabrics and to introduce our company to the aerospace industry."

Stolyarov points to this project as an example of AFFOA working directly with industry to solve a real-world problem. "Silica is critical for many of our military systems, and the U.S. only had one company that could supply that fabric," he says, citing significant supply chain vulnerability. "AMI tried on their own, but they needed sophisticated equipment and serious engineering horsepower to procure, validate and test the material to make sure it works. Our team worked with them for two years, and we got it going."

The project enabled AMI to stand up an aerospace-grade silica manufacturing line, creating a much-needed second source for the material in the U.S.

Challenges faced by Leonard and her team include a lack of in-house resources and funding for expansion of their operations, including new hires. She says AFFOA and its membership ecosystem stepped up to the plate to overcome those barriers. "AFFOA's staff has helped us to coordinate with others within and outside their organization to continue to move forward with automation, workforce training, etc. We are working to become a factory of the future." As a result of the partnership with AFFOA, AMI has qualified its silica material, grown its workforce and expanded its defense and commercial customer base.

Mission-Ready Military Solutions

According to Military Medicine, musculoskeletal injuries (MSKIs) represent the most substantial and enduring threat to U.S. military readiness, which is defined as the military's overall health and ability to accomplish its mission. Stolyarov says AFFOA has spent the past few years looking at ways to quantify rehabilitation from MSKIs.

Electroneurography (ENG) is an electrodiagnostic test that measures the function of peripheral nerves and records their electrical response. Stolyarov says that ENG signals have potential use in monitoring injury recovery. However, existing ENG products are made of bands and a rigid puck-like apparatus that makes them clunky, hard to put on and uncomfortable. AFFOA partnered with Pison Technology Inc. to tackle this problem.

Boston-based Pison is known for a wrist-worn wearable that uses ENG signals recorded at the surface of the wrist to control various devices, such as phones or drones, through hand gestures. "If you take that basic component and put it on the lower leg," Stolyarov explains, "you can pick up small muscular signals on the leg. If you look at a collection of those signals, you can get information, such as if the leg is giving normal, injury-free signals."

Sasha Stolyarov, CEO of AFFOA, says that advanced functional fabrics often take years to advance. (Provided by AFFOA)

The manufacturing process uses an embroidery machine to stitch conductive threads onto fabric for communication pathways and power. Soft electrodes contact the body and pick up electrical signals. The team engineered a full soft-system integration scheme using distributed ENG textile-sensor architecture to create a fabric-based system in a compression sleeve.

The best part? It's actually comfortable. So far, 10 compression sleeve prototypes have been produced and validated, and the sleeves are currently being evaluated by U.S. Army service members.

"This is an example of being able to combine disparate elements of electronics with fabrics to create fully integrated systems," Stolyarov says, sharing that the project helped AFFOA address some barriers to commercialization of other electronic-textile products.

Empowering an Ecosystem

"The ability to do these types of projects rapidly came about because of the infrastructure advances AFFOA has made in the past three years," he says. One example is the universal development platform (UDP), which serves as a development kit to remove the burden of creating new hardware or software platforms every time there is a new idea for sensing modality. "We can reuse the UDP to support a whole line of sensors, from temperature to strain to heart-rate monitoring, all through a consistent set of hardware and software. That never existed before. Now industry can leverage it, and AFFOA uses it internally to do rapid development." The UDP is soft-system-integration ready, and the architecture provides configurability and scalability, he adds.

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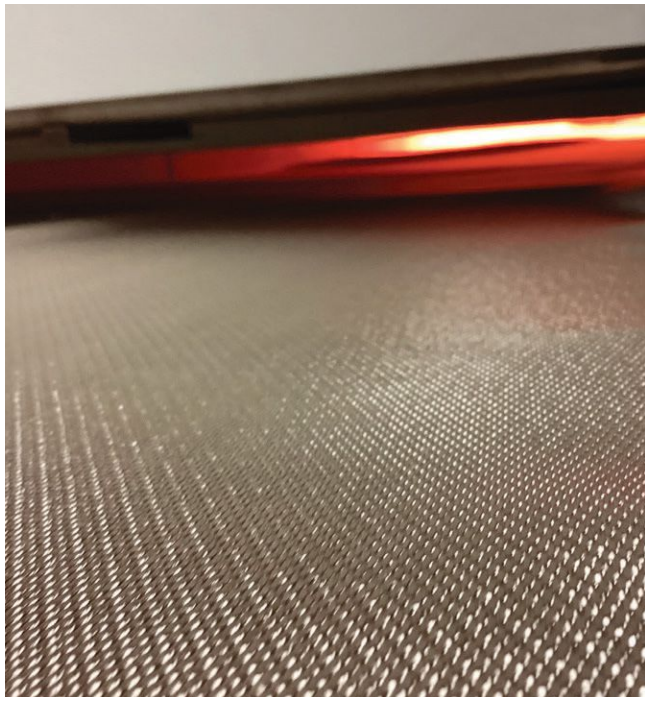
Auburn Manufacturing Inc. produces silica fabric with the help of AFFOA's manufacturing process team. This material is critical to the U.S. military and aerospace industry. (Provided by AFFOA)



Silica fabric is used in rockets as an ablative. (Provided by Auburn Manufacturing Inc.)

AFFOA also developed infrastructure resources for foundational e-textile elements. These include a database of documented conductors, encapsulants and electrical connections. AFFOA is also looking at design rules for manufacturing so its members can have tools to make rapid progress toward commercialization, Stolyarov says.

"People want to create scalable functional-fabric solutions, but there's a whole host of challenges our members face. AFFOA looks to fill gaps and support where we can," he explains. "People want to try something, but they struggle with getting prototypes made. If you think about manufacturing, it's very costly to stop and try something risky. That's a big barrier for advancement, especially for startups that don't have a rich infrastructure or equipment for prototyping. That's where we come in."

To address the barrier of limited market connections, especially with domestic partners, AFFOA helps members identify and collaborate with U.S. manufacturers that have relevant capabilities. Stolyarov says annual membership summits play a key role in making valuable connections for a startup with a great product to get in front of the right potential customer, such as the DOD or a large organization that might want to buy the product or license the technology.

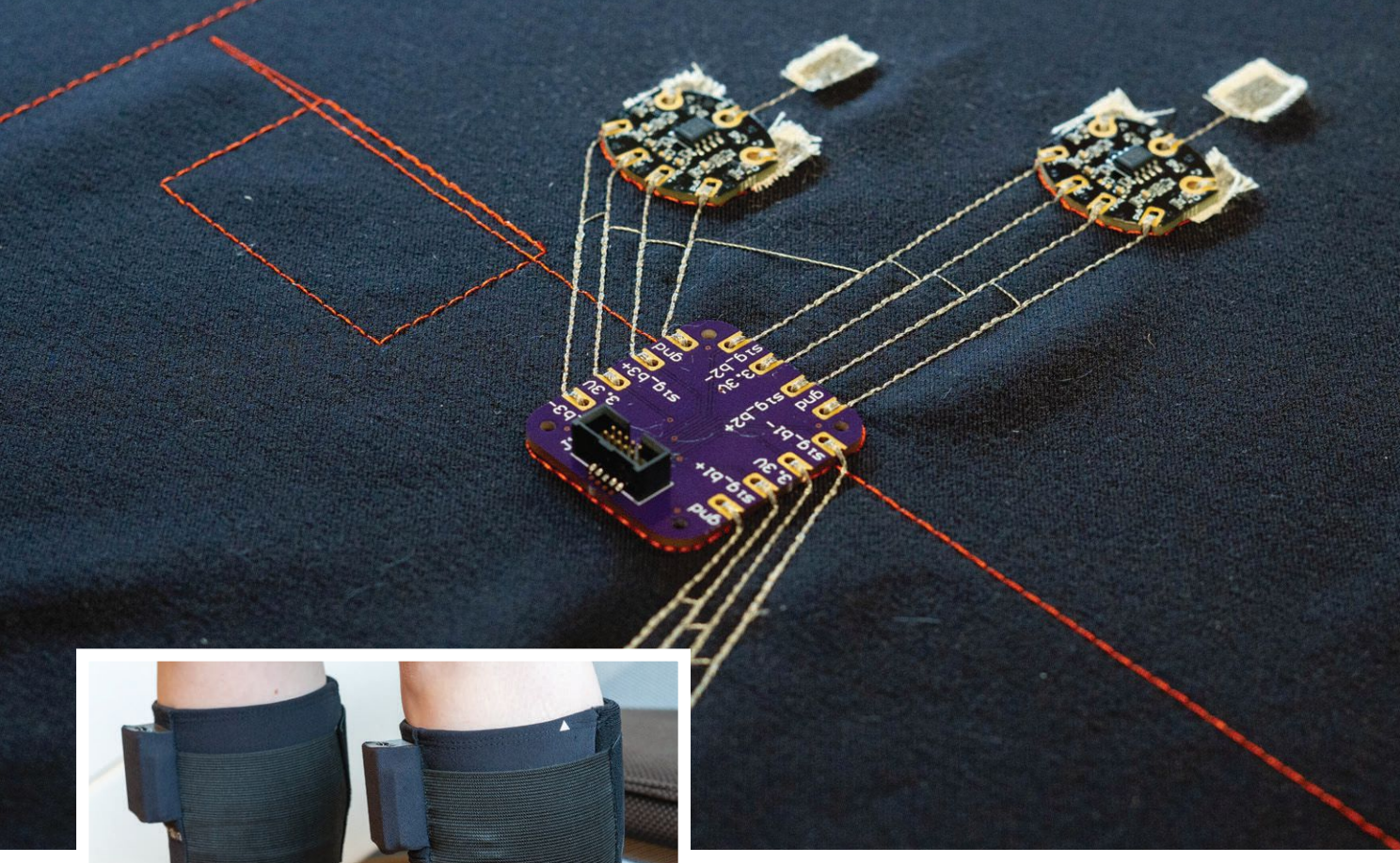
Preparing the Next-Gen Workforce

A commitment to workforce development is an area where AFFOA is making strides, Stolyarov reports. An assessment survey, as well as site visits and interviews with CEOs and workforce leaders at dozens of organizations, identified industry challenges related to recruiting and skills development. The insights informed an education and workforce development roadmap with five focus areas:

1. Expand the high school/career and technical education (CTE) program suite for the new/emerging workforce.
2. Establish a training and upskilling program suite for existing and emerging workforce needs.
3. Build textile industry awareness and share workforce-development best practices.
4. Grow a suite of programs to support interdisciplinary engineers, designers and innovators.
5. Develop a model for the modernization of the industry through a Facilities + Workforce Innovation Hub.

For example, one project will focus on developing fabric products for military tactical-gear applications, leveraging sew-free adhesive material. Goals include improving comfort and fit, conductive thread and bus encapsulation, and manufacturability of tactical gloves. AFFOA also plans to establish a scalable CTE training toolkit to bridge the gap between textile product design and manufacturing that allows student to learn in-demand skills.

Education programs partner with universities and high schools nationwide to get students exposed to functional fabrics and the realities of the industry. The aim is to cover key textile regions and connect hands-on learning with



Embroidered circuitry forms a stitched interface between hard printed circuit boards and soft garment components, integrating systems into apparel and other textiles. The calf sleeve (shown on the left) was designed by Pison Technology and AFFOA for an Army Phase 2 Small Business Innovation Research Award. (Provided by Pison Technology)

manufacturing or industry employers in local communities.

Late last year, AFFOA moved into a new headquarters in Bedford, Mass., with facilities designed to expand collaboration with partners across innovation and education priorities. The capabilities contained in the new end-to-end advanced fibers and fabrics prototyping facility reflect the ongoing diversification of AFFOA's customer base. AFFOA currently has dozens of contracts across different government organizations and commercial entities seeking help and support, and functions as a self-sustaining business model.

As innovation, supply chain and workforce priorities move forward, AFFOA continues to play a critical role in helping the U.S. advance technology and manufacturing readiness, unleashing the power of advanced textiles—from functional materials to breakthrough applications across industries.

"Many industries, like textiles, have been left behind due to offshoring of manufacturing," AMI's Leonard asserts. "In the mid-2010s, the creation of institutions like AFFOA was set up and funded by the U.S. government to strengthen manufacturing. We are grateful for that, and we're trying our best to be an example of what we can do with a little more help." ■

Barriers to Scalable Solutions

- Limited prototyping infrastructure increases time-to-market and costs.
- Gaps in design-for-manufacturing expertise lead to higher manufacturing costs, limited reliability and scalability.
- Lack of advanced digital design tools slows prototyping and iteration.
- Insufficient testing and evaluation tools make it harder to assess product reliability and performance and increase cycle-of-learning time.
- Lack of domestic supply chain knowledge forces companies to seek overseas suppliers, increasing cost, lead time, complexity and risk.
- Limited market connections make it difficult to validate product-market fit and establish customer traction.
- Skilled-workforce gaps reduce capacity.

NAVIGATING AI: HELP FOR SMALL AND MIDSIZE MANUFACTURERS

A CONVERSATION WITH COZETTE ROBINSON, CEO, CYR CONSULTING LLC

AMY BRYSON, Contributing Lead Editor

SMALL AND MIDSIZE MANUFACTURERS (SMMS) account for more than 98% of all manufacturers in the United States, and they often seek prescriptive guidance to navigate the complexity of Industry 4.0 and digital transformation. Cozette Robinson is the managing member of CYR Consulting LLC, a consulting firm that serves as a strategic partner for small and midsize manufacturers as they modernize operations and adopt digital and AI-enabled capabilities. She says many SMMs feel overwhelmed by the hype around artificial intelligence and struggle to see where to begin without significant disruption or cost.

To that end, Robinson has guided companies of all sizes through projects such as complex ERP cloud migrations and AI software integration. She shared her experiences at the 2025 Manufacturing Technology Series SOUTHEAST event in Greenville, S.C., during the session "From Hype to Hands-On: A Practical AI Playbook for Small & Medium Manufacturers." As part of any sound strategy, Robinson says it is critical to blend program management, process optimization and change leadership to strengthen efficiency, build internal capability and achieve measurable transformation without overwhelming lean teams.

Robinson offered up some practical advice to *Manufacturing Engineering & Technology* (*MET*) about how SMMs can identify high-impact opportunities, pilot small projects, and scale AI solutions that deliver measurable ROI and strengthen long-term competitiveness.

***MET*:** *How is AI impacting digital transformation in tangible ways?*
Robinson: AI delivers practical benefits across the manufacturing ecosystem. Tools like Microsoft Copilot Studio and Power Automate are helping teams classify unstructured data, summarize customer order notes and streamline workflows—reducing manual review time by 30%-60%. AI-driven forecasting is improving demand-planning accuracy, while AI agents support faster, more consistent decisions. For companies facing labor shortages and increasing complexity, these capabilities create immediate operational lift.

***MET*:** *How can leaders cut through the hype around AI and digital transformation?*
Robinson: The most effective leaders start with a specific business problem rather than a technological trend. A focused 90-day pilot allows teams to test feasibility, validate ROI and build confidence before scaling. Measuring success using business metrics—cycle time, accuracy, cost savings—keeps teams grounded in outcomes, not excitement.

***MET*:** *What are a some of the barriers to digital transformation that impact small and midsize manufacturers?*
Robinson: Common barriers include limited internal IT bandwidth, high costs of enterprise tooling, siloed systems and reliance on tribal knowledge as long-tenured employees retire. Many leaders also fear disrupting already stretched operations. These challenges are real, but they're manageable with a phased, well-scoped approach.

> "Measuring success using business metrics—cycle time, accuracy, cost savings—keeps teams grounded in outcomes, not excitement."
> – Cozette Robinson

***MET**: Can you share a few success stories you have seen among small and midsize manufacturers working toward digital transformation?*
Robinson: We've seen powerful results from targeted, practical efforts. One client implemented AI-enabled demand planning that reduced manual workload and improved supply alignment—delivered under budget. Another automated customer-service workflow involves unstructured order notes, significantly reducing processing time and improving accuracy. These wins demonstrate that scalable transformation doesn't require a massive overhaul; it begins with one high-impact use case.

***MET**: What is the most rewarding part of your work with manufacturers?*
Robinson: Manufacturing is built on pride, longevity and community—and being invited into that environment is incredibly meaningful. Many employees have been with their companies for 20 or 30 years, sometimes across multiple generations. There is a strong sense of family, and when we're on-site, we're often told, "We forget you're consultants—you're just part of the team."

Seeing individuals take pride in the products they create—and knowing our work helps strengthen that legacy—is deeply rewarding. There is nothing like walking into a retail store, spotting a client's product on the shelf, and knowing we played a role in helping that team deliver it with quality and consistency.

Essentials for Modernization

1. **Process clarity before technology.** Using proven methods—value-stream mapping, business-process model and notation, and the risk-up-front framework—aligns business processes before any system or automation work begins.

2. **Structured program leadership.** CYR Consulting has led initiatives such as AI-enabled demand planning, supply-model redesign and integrated business planning, including a recent project that delivered 20% under budget.

3. **Workforce capacity expansion.** Identify repetitive or decision-intensive tasks that are ideal for automation, enabling teams to shift from manual processing to value-added problem-solving.

Source: CYR Consulting LLC

SMMs can benefit from digital transformation programs by starting small, proving value in one area and then scaling change across the organization. (Provided by iStock)

***MET**: Why are in-person events, such as the Manufacturing Technology Series, important?*
Robinson: These events give manufacturers practical insights, peer experiences and technology demonstrations directly applicable to their operations. For small and midsize firms—many of which lack large innovation teams—this exposure accelerates learning, reduces barriers to adoption and connects them with partners who can support their journey.

For CYR Consulting, the Manufacturing Technology Series is equally important. It allows us to stay closely aligned with the real challenges and priorities facing manufacturers today. Engaging directly with attendees helps us refine our service offerings, strengthen collaboration, and ensure that our AI and modernization strategies remain grounded in the practical needs of the communities we serve.

***MET**: What are you looking forward to in 2026?*
Robinson: We're focused on expanding our AI-enabled workflow-automation services for midsize manufacturers, enhancing our practical AI playbook and supporting workforce upskilling across Virginia and North Carolina. Manufacturers in the region are investing heavily in modernization, and we're excited to help them build resilient, future-ready operations.

***MET**: What else should our readers know?*
Robinson: Digital transformation doesn't require large budgets or complex overhauls. It starts with one well-chosen process that consumes time, introduces errors or slows customers down. A focused pilot with clear metrics builds momentum quickly. For small and midsize manufacturers, transformation is achievable, measurable and often far closer than it seems. ■

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The Learning Zone features classrooms for professional and technical training as well as an entire simulated manufacturing floor in the facility's west-bay hangar. (Provided by Textron Aviation)

CAREER BUILDING TAKES FLIGHT IN WICHITA

WHAT IF HIRING, onboarding and manufacturing training could happen under one roof to provide a holistic workforce-development pipeline? This was the guiding vision behind aircraft manufacturer Textron Aviation Inc.'s Career & Learning Center, a $40-million project that included the construction of a 100,000-sq-ft (9,290-sq-m) facility on the company's East Wichita Campus in Kansas. After a soft launch in August 2024, the center had its grand opening in April 2025.

Headquartered in Wichita, Textron Aviation is home to the iconic Cessna and Beechcraft brands, and its aircraft account for more than half of all general-aviation aircraft flying today, the company notes. With a portfolio spanning business jets, turboprops and piston aircraft, Textron Aviation says it has delivered more than 250,000 aircraft to customers in some 170 countries.

The company currently employs 14,000-plus team members, and its Career & Learning Center grew out of a need to find new ways of hiring and training the next generation of skilled technicians.

This "one-stop shop"—as described by Jennifer Whitfield, a director of human resources at Textron Aviation whose purview includes talent development and training—is divided into four dedicated areas:

- The Career Zone focuses on hiring, with recruiters on hand to welcome walk-in applicants and to offer individualized support.
- At the Pre-Employment Zone, new employees can complete initial requirements, WorkKeys job assessments and new-hire training.
- The Learning Zone features classrooms for professional and technical training as well as an entire simulated manufacturing floor in the facility's 50,000-sq-ft (4,645-sq-m) west-bay hangar.
- The Design. Build. Fly. Zone introduces K-12 students and educators to the aviation industry through hands-on activities, including a Cessna 172 Skyhawk single-engine-aircraft flight simulator.

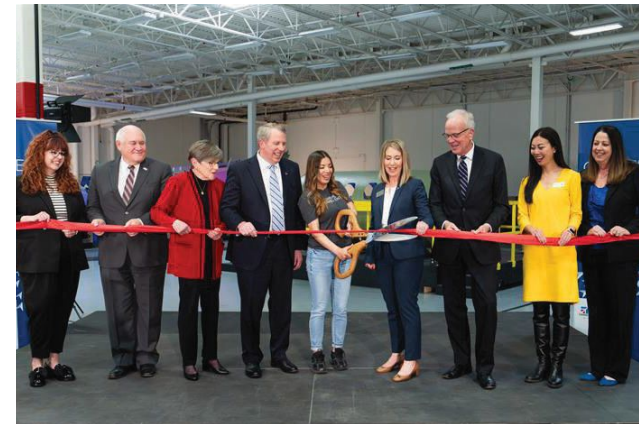
"Prior to this facility, we had spaces of manufacturing training tucked into different areas within our factories, but this gives us one location for people to complete their training, and it really grew our footprint," Whitfield says. "Teaching people how to manufacture aircraft cannot be done in a classroom setting via PowerPoint. They need to do the work with their hands."

Step Right Up

On any given weekday, the lobby at the Career & Learning Center is bustling with prospective employees interested in careers at Textron Aviation, whose roots in Wichita date back more than 95 years. The company estimates that about 5,000 people have passed through the center's doors thus far.

"The public walk-in aspect is new," says Michele Gifford, a human resources director who oversees recruitment and hiring. "We did not have a place previously where individuals could come in and get help with their application or just inquire about a job."

Because job postings full of technical language can be difficult to decipher for those new to manufacturing, the



Textron Aviation opened its 100,000-sq-ft Career & Learning Center in Wichita, Kan., in April 2025. (Provided by Textron Aviation)

Career Zone allows them to "have that conversation and really understand—based on their skills, abilities and hobbies—what might be the best fit for them," Gifford explains.

In the digital age, this type of face-to-face interaction is increasingly rare, and the company has found that potential

applicants value the opportunity to walk in and receive in-person assistance, Gifford notes. Textron Aviation also provides customer-service training to better prepare team members to interact with the public—a useful refresher after the distancing effects of the COVID-19 pandemic.

And when it comes to spreading the word about recruitment, "employees are our best advocates," Gifford says. "We get a lot of people who come here because their friend, their relative or their neighbor works at Textron Aviation. We are a large employer here in the city of Wichita and the state of Kansas, and our brand and our legacy being almost 100 years old helps us as well."

The company has a philosophy of "warm handoffs" from one phase of hiring to the next. Once a new employee completes onboarding and testing in the Pre-Employment Zone, they're guided along to the training team to continue their manufacturing journey.

Immersive Training

"We like to say that it looks like the factory, it sounds like the factory and it smells like the factory," Whitfield says of the simulated shop floor situated in the Career & Learning Center. New hires "are able to do their training in this very safe and controlled environment before they go to their new job."

Training can take anywhere from two to eight weeks, depending on the complexity of the role. "We start on day one by introducing them to the facility, providing tours. And then that second day, when they come back to training, I have a full staff greeting them at the door, welcoming them back, making sure they know where they're going," Whitfield adds.

All trainees take introductory classes on foundational basics, such as hand tools and blueprint reading, before branching off according to their new positions. Specialized courses include sheet metal training, composites, flight-control rigging, blueprint reading and paint.

"Once they finish their training, we do another 'warm handoff,'" Whitfield says. "We take them on a tour of their new location, introduce them to their crew lead, show them where the lockers are, where the restroom is, where they badge in and clock in for the day. Our buildings are big and can be daunting, so this really makes a difference to the employee."

Designated success coaches help new team members build "softer" job skills, including consistency and reliability, while an immersive values workshop emphasizes core company principles.

Existing employees can take advantage of programs such as recertification training and upskilling for mechanics, Gifford notes. In 2025, Textron Aviation partnered with The Manufacturing Institute's Heroes MAKE America initiative—in conjunction with Wichita State University Campus of Applied Sciences and Technology (WSU Tech)—to provide a six-week, fast-track airframe and power plant (A&P) certification for military veterans, "making it easier for those individuals to transition to high-wage occupations in industry."

> "Teaching people how to manufacture aircraft cannot be done in a classroom setting via PowerPoint. They need to do the work with their hands."
> – Jennifer Whitfield, Textron Aviation

Helping the Next Generation Soar

"Our K-12 mission is all about experience and exposure for students to aviation and advanced manufacturing careers," Gifford says.

To that end, Textron Aviation partnered with WSU Tech and Wichita Unified School District 259—the largest district in Kansas, with nearly 50,000 students—to create the state's first aviation career and technical education (CTE) pathway in 2018.

The company offers a six-week paid summer internship for high school students who go through a full application and onboarding process before spending 20 hours per week in a variety of roles, including on the shop floor and in engineering and human resources. In 2025, the participants included about 160 students, who can then transition into full-time positions upon graduation or be funneled into Textron Aviation's college-internship program.

For 14- and 15-year-olds, Camp HYPE provides a one-week opportunity to gain exposure to the field. Cohorts of teachers and CTE counselors also visit in the summer to learn more about the career options available to students.

Throughout the school year, Textron hosts student groups, leading them on tours of the manufacturing facility, the simulated factory and, of course, the Cessna 172 Skyhawk single-engine-aircraft flight simulator, one of the most recognized models in general aviation. There are age-appropriate STEM activities for younger grades as well, from building simple robots to constructing marshmallow catapults.

"All the instruction is done by our employees, who are really proud to work at Textron Aviation and excited to go share that with students, here on-site or out in classrooms," Gifford says.

For its huge investment in workforce development, as embodied by the Career & Learning Center, Textron Aviation received SME's 2025 Excellence in Manufacturing Training Award in May 2025—national recognition of a robust program that is already paying dividends for Wichita and throughout Kansas, as well as for the future of the U.S. aviation industry. ■

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REINDUSTRIALIZATION IN THE AGE OF DISRUPTION

OPINION, ANALYSIS AND IDEAS

NOEL H. NEVSHEHIR, Director of International Business Services and Global Strategic Partnerships, Automation Alley

GLOBAL SUPPLY CHAINS are being redrawn. Geopolitical tensions, tariffs and disruptions to shipping routes are reshaping the flow of goods and services. At the same time, manufacturers are reconsidering where and how they operate, with many exploring reshoring or friend-shoring to reduce risk and strengthen resilience.

This moment is not only about managing disruption. It's an opportunity to reimagine American manufacturing for the 21st century.

One truth is often overlooked in discussions about bringing jobs back: The positions that left decades ago—low-skill, labor-intensive roles—are not the jobs of the future. Modern factories are digital, automated and capital-intensive. They require advanced skills in areas such as robotics, data analytics, artificial intelligence and digital twins.

This is not a story of decline but one of evolution. Just as past industrial revolutions redefined work, today's transformation demands a workforce fluent in technology, creativity and problem-solving.

Workforce Challenges and Opportunities

Today there are more than 500,000 unfilled manufacturing positions in the U.S., and manufacturers have been struggling to fill those jobs for years. The gap is not simply the quantity of available workers; it's also about skills. To lead globally, the U.S. must accelerate workforce development in tandem with advanced manufacturing investment.

Automation Alley's 2025 Integr8 Playbook, "Global Trends & Supply Chain: Planning for a Shifting World"—published earlier this year—highlights workforce transformation as one of the defining challenges of the next decade. The report calls on industry and education leaders to invest in reskilling, digital training and new models of collaboration to close the gap. In addition to filling open jobs, we need to prepare for a future where manufacturing careers look very different from those of the past.

Rethinking Reshoring

Reshoring is often framed as a quick fix for economic security and job growth. But the truth is more complex: Bringing back low-skilled jobs, while politically tempting, clashes with the reality of modern, technologically advanced, capital-intensive economies. Building domestic capacity requires long-term investment in both infrastructure and talent.

Rather than silver bullets, we should view tariffs and industrial policies as pieces of a broader strategy. Real progress comes from pairing policy with industry leadership, technology adoption and workforce readiness. That's a formula that can ensure reshoring leads to lasting competitiveness rather than short-term disruption.

From Disruption to Leadership

If history has shown us anything, it's that American innovation thrives in times of disruption. The U.S. has a strong foundation: world-class research universities, leading technology companies and a culture of entrepreneurship. By aligning advanced manufacturing with advanced services such as software, design, engineering and finance, we can create powerful multiplier effects across the economy.

The path forward will not be easy. It will take years to fully reindustrialize in a way that balances security, efficiency and competitiveness. Success also depends on support from domestic policymakers, who have historically been slow to grasp the consequences of becoming dependent on foreign countries for critical materials and products, as well as labor union leaders adopting a long-term vision of what's best for their workers rather than short-term gains.

But the strategy for success is clear: Build a smarter, more resilient manufacturing ecosystem that generates prosperity by preparing for what is ahead. The question is not whether American manufacturing can return to past glory. It's whether we can shape a new era that embraces technology, empowers workers and secures supply chains for the future.

Industry leaders must invest in skills, digital tools and partnerships that prepare their organizations for this transformation. Policymakers can support this, but the real momentum will come from collaboration across sectors.

Reindustrialization is not about recreating yesterday. It's about building tomorrow. ■

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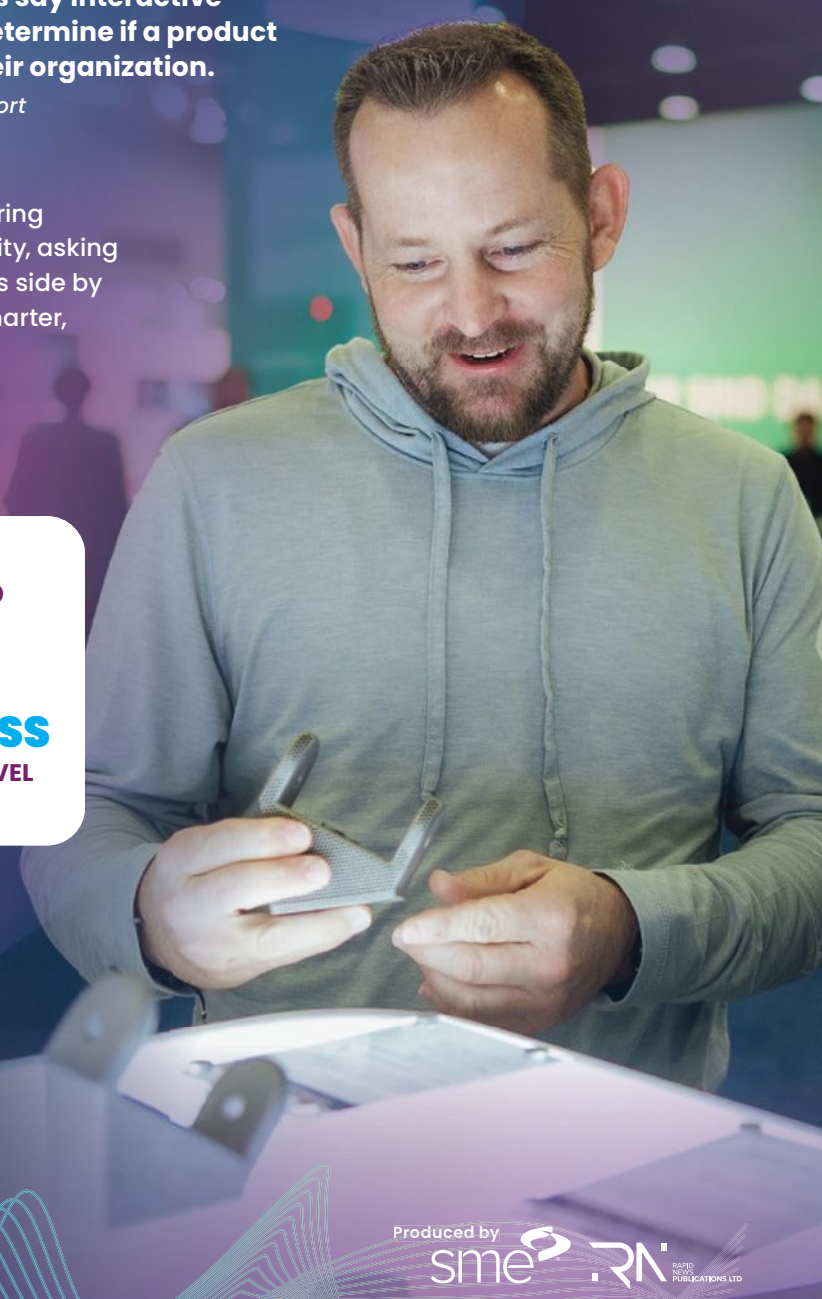

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