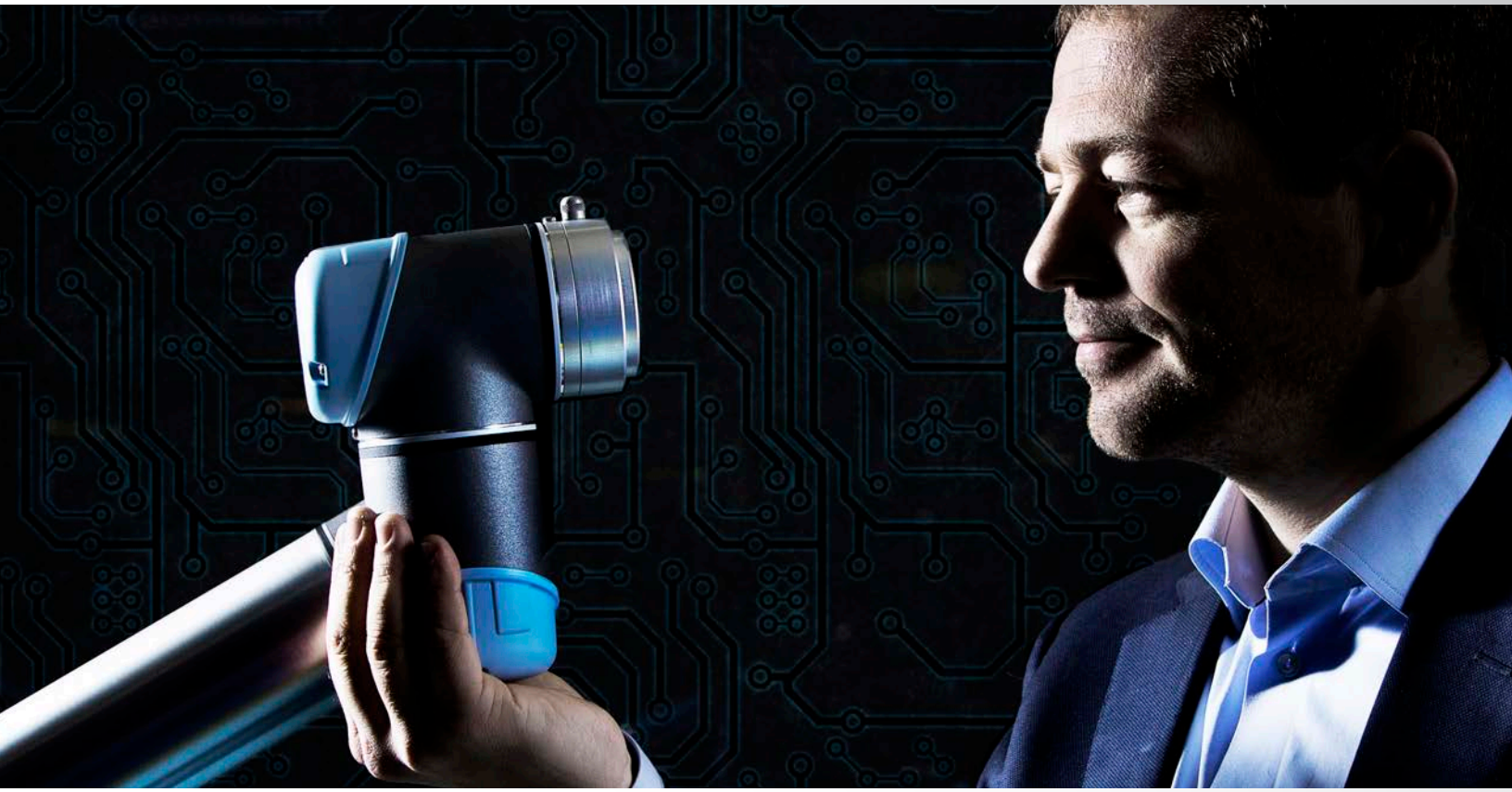
IndustryWeek®

# ROBOTS, HUMANS AND THE FUTURE OF WORK



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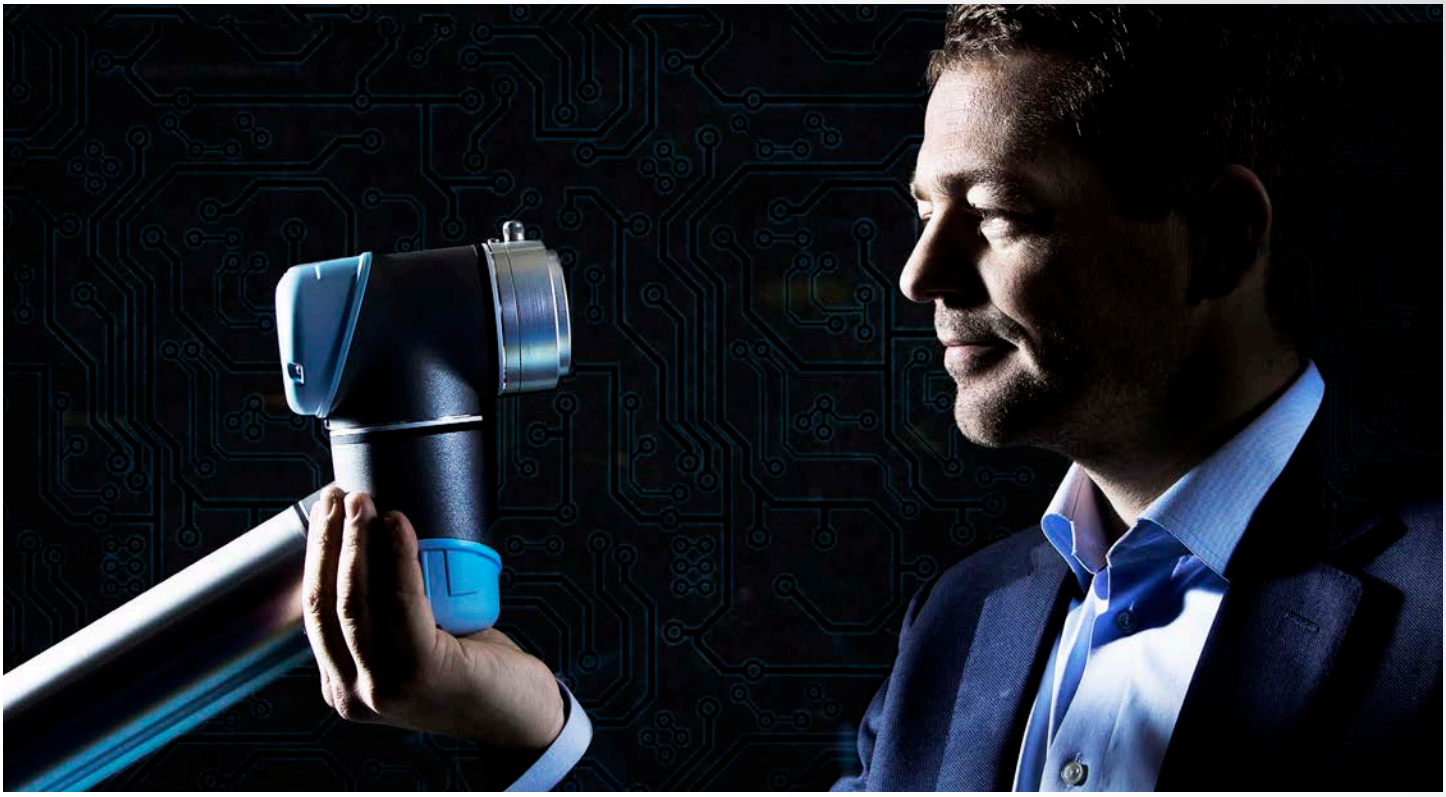
**TRAVIS HESSMAN**
Editor-in-Chief / Senior Content Director, IndustryWeek



# ROBOTS, HUMANS AND THE FUTURE OF WORK

*Automation takes the pain and repetitive strain out of manufacturing. But as the technologies proliferate, we still have one challenge left: to finally tap into the full potential of the human workforce.*



In our everyday coverage here at IndustryWeek, we often encounter themes and executive stressors that never seem to fade. We have, for example, the issue of skilled labor deficits, which has persisted in the industry for decades. Or we have the worry about job-stealing robots and machines, which goes back centuries. And behind it all, we have the steady drive of operational and technological improvements that pushes the industry ever forward… while also stirring the other issues ever back to the fore.

In today's manufacturing environment, though, these "evergreen" concerns are especially sharp.

On one side, as U.S. unemployment sinks to progressively lower rates and operations become progressively more high-tech, the challenge to find enough skilled workers to take on the new opportunities this economy presents is enormous. In many cases, it's simply impossible.

On the other side, a new breed of automation solutions—from cobots and low-code traditional bots to machine learning and AI (and everything in between) seem to offer a range of capabilities so broad that many worry they will not only help fill all of our unfillable positions but also eat into existing high-wage jobs.

These are significant issues and concerns that permeate the entire manufacturing industry.

So, rather than just touching on the subjects in our usual content mix, we decided to attempt to tackle it all—to tell a complete story of what expanded automation can mean to the manufacturing

workforce and their safety, to operations and efficiency, and how to develop a strategy for it all that really works.

Over the last few weeks, we have begun publishing an entire series of stories hitting these topics to tell the story in its full scope.

This year, we have begun publishing a series of stories hitting these topics to tell the story in its full scope, some of which is collected here. Through these articles, you will encounter a lot of recurring themes, but the one that really connects it all hardly deals with robots at all. It's about people.

Through them, we encounter a lot of recurring themes, but the one that really connects it all hardly deals with robots at all. It's about people.

And that is exactly where the focus needs to be.

## OH, THE HUMANITY

Until fairly recently, robots have served one primary purpose: to overcome the physiological limitations of human beings. They allow us to lift the unliftable and move the unmovable at speeds beyond natural comprehension.

In the process, they have allowed us to build bigger, better products, to grow and develop our society and meet its expanding needs. They gave our industries superhuman strength, leaving us to handle the human-powered work.

But now, automation has changed. The new robot generation has a different purpose: to overcome both the physiological and psychological limitations of human beings.

With traditional robots doing the heavy lifting, human workers are often left with the remaining repetitive tasks—running small, detailed operations, piece after piece, every shift, every day, forever without end. However—as carpel tunnel cases and end-of-shift quality metrics can attest—this work runs counter to how both our bodies and our minds work.

Simply put, it's not what humans are for.

And now, robots are beginning to save us from this as well. But in the process, we need to ask ourselves a very serious question: If humans aren't pallet trucks or pick-and-place machines, then what is our role in manufacturing?

This, I believe is the fundamental question of our times, and one every manufacturer and every executive needs to be asking.

The human asset goes far beyond labor. Every worker on the floor is filled with ideas, insights, perspectives and abstract creative genius that no machine and no software can duplicate. The challenge now is to redefine our strategies to tap into that, to harness the true human potential.

But, if any of this is going to work, that process must occur in concert with automation. If not, we risk gaining productivity at the cost of innovation—a miscalculation no business can afford to make.

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**JOHN HITCH**
Senior Technology Writer, IndustryWeek



# THE GREAT ROBOT TAKEOVER: FACT OR FICTION?

*It's inevitable. The robot invasion is coming. But that's not necessarily a bad thing.*

"If you were 22 and had a job where you were treated like a machine and knew you had about 30 years to go, how would you feel?"

This line is so timeless and universal that it could be from any era in any country, but it's a quote from a UAW official made in 1972 in Ohio's Mahoning Valley about the infamous unrest at General Motors' Lordstown plant.

In 1970, the plant had the most advanced manufacturing automation in the world. Its 26 robots performed 520 welds per car, churning out 100 Chevrolet Vegas per hour. At the time, the plant was the fastest in the world and represented the impact automation could have on production.

Automation cut the standard 60-second takt time down to just 36 seconds. The problem was, the humans on the assembly line could not reasonably match the robots' speed.

Quality often suffered as a result—kind of like that "I Love Lucy" bit with the chocolates and conveyor belt, only hilarity did not ensue. A control box was set on fire, seats and wiring were slashed, management cried sabotage. The overall discontent led to a 22-day worker strike in 1972 that cost GM $150 million.

It's a valuable lesson on why humans don't like being treated like machines.

Nearly 50 years later, the manufacturing industry is facing a similar battle. With a new breed of robots on the market and more sophisticated automation solutions arriving every day, many workers once again feel they're on the front lines of a full-scale robot takeover.

The fact is, robots will take some jobs and create others. And the tech is not that advanced…yet. Amazon, at the forefront of automation, says it's at least a decade from fully automating a single order.

But the takeover isn't all fiction. Or all bad. But it is becoming clearer, and how the tech will affect everythign from plant culture to quality to safety and viability. The goal is to help you sort out what's real and what isn't so you can make the right decisions in what we can all agree is an unprecedented era of change.

## THE AUTOMATION ARMY

For Mark Jagiela, CEO of automation and test equipment manufacturer Teradyne, the robot/human clash goes back a full generation. As a teen in the 1970s, his father worked for an industrial robot manufacturer serving automotive industry. At the time, the industry had a complicated love-hate relationship with automation—management loved the productivity, while workers hated the idea of being replaced.

"People blamed automation for displacement of jobs," says Jagiela. "Factory workers conspired to thwart automation by gumming up the works."

"I understand the emotion—people who don't have a job and seeing a machine doing something they can do," he adds. "It's not new; it's been around a hundred years since the industrial revolution began."

For many, the Lordstown antics of the '70s conjured images of the famous Scottish Luddites, who rebelled against some of the first industrial machines the previous century.

Meanwhile in Japan, businesses (and consumers) embraced robots of every kind, which Jagiela saw firsthand as general manager of Teradyne's Japan division.

"In the 1980s, Japan was viewed as the biggest threat to U.S. industry because of the leadership they had in automating auto- motive manufacturing and semiconductors," he notes.

Now the typical U.S. factory is fighting a war on two new fronts: One with time, specifically the aging workforce running out of it; the other with interest, which is totally lacking from the potential reinforcements due to the repetitive, boring nature of the jobs.

Jagiela, who became president of Teradyne in 2013 and CEO the following year, is seeking to broker a peace between Americans and automatons by marshalling a new legion of automated workers called collaborative robots, or cobots. Defined by safety features such as padded surfaces, limited speed, and force-torque sensors to prevent pinching and crushing, cobots are finding employment in factories and job shops of every size, as well as hospitals, homes, and everywhere in between.

The first recruit was Universal Robots, which introduced the first collaborative robot back in 2008 and is the current market leader in the space. The Danish company has grown around 500% since being acquired in 2015 by Teradyne and sold its 30,000th unit last year. (To put things in perspective, it only sold around 6,300 total from 2012 to 2015.)

According to the Robotic Industries Association, cobots, which accounted for an estimated 3% of all robot sales—or 11,416 in 2017—are expected to capture 34% of that market in the next seven years.

Next was Mobile Industrial Robots (MiR), the market leader in autonomous mobile robots, bought in 2018. The rapidly growing company, also headquartered in Denmark, has reported two consecutive years of 300% growth and hired on 100 more employees.

Finally, last year Teradyne also snapped up Cambridge, Mass.-based Energid, which makes a robotic control framework that makes it easier to train the machines to move more precisely.

With these critical divisions at his disposal, you could call Jagiela a key leader of the great robot takeover.

But first you have to buy in that a takeover is even happening. And if by that you mean that these new cobots are taking over for their larger industrial brethren locked in cages and the workers who would prefer a more cognitively challenging, less mundane workday, it's a clear fact. But if you are thinking more in terms of robots taking all the U.S. jobs—or at least the 47% predicted by University of Oxford researchers in 2013—Jagiela says that is a work of true fiction.

"It's pretty clear that prediction is wrong," he says of the damaging 6-year-old study that the robot industry can't seem to shake. "Nobody is confronted with any meaningful sense of robots stealing jobs. Look at employment."

In May U.S. unemployment hit 3.6%, the lowest since 1969. Japan has a 2.5% unemployment rate and its robot takeover happened three decades ago.

"Despite all this fearmongering and sensationalism, it's just not happening," he says. "And I don't think it will be. All the evidence suggests that historically it's been a tremendous benefit to job growth."

So nothing to fear but fear itself and all that, right? Not quite. Like everything with robotics, it's complicated.

"It's more of a societal benefit," Jagiela continues, "But that doesn't mean along the way the nature of work doesn't change and some people are going to be affected along the way in the short term."

## AUTO MATES

The first industrial robot, Unimate, started in a GM plant, and automotive productivity wouldn't be anything close to where it is without the automation innovations that followed. But until now the factory has split people and bots, due to obvious safety concerns.

But we're learning how much more efficient workers can be with a little help from technology, such as augmented reality. It's a lesson Ford seems to be quickly understanding as it rolls out more cobots onto the factory floor. Ford has about 100 cobots spread across 24 plants, using their new Advanced Manufacturing Center in Redford, Michigan, as a testing ground for new applications and where human work can become superhuman with a robot sidekick.

They have a Universal Robots silver, grey and powder-blue arm mounted with cameras to inspect vehicle chassis and another methodically sorting screws with a pair of parallel grippers. Next to those a more robust Fanuc CR-35ia cobot simulates running down fasteners in electric car battery packs.

"It's growing exponentially," says Harry Kekedjian, Ford advanced controls and digital factory manager, about the automaker's use of cobots. "The increase in efficiency they bring over traditional robots is opening up our eyes on different ways to process the work content that normally we wouldn't have thought of before."

The most successful implementation to date involves a KUKA LBR iiwa cobot, which performs vital but monotonous engine inspections. The machine's visioning system can be programmed to scan for discrepancies and then alert the nearby worker to fix electrical connections. This application is used on 16 lines across Ford engine plants. It's a perfect pairing because the robot excels at the task that humans generally find extraordinarily boring—basically staring down engine blocks all day like they're the back of a *Highlights* magazine.

One extra benefit is all the data are being collected, which allows designers to improve engineering and reduce faults in the future.

"Automated inspection allows us to get a better sense of how well we're performing a lot of those manual tasks and be able to provide that feedback instantly to the production team," Kekedjian says.

He adds that the automated quality scan backed by a human creates "a tremendous reduction in those early concerns at the dealership" while also improving productivity. He couldn't provide hard data, but says the proof is in the replication rate of the application, which continues to grow.

Most importantly, due to the safer nature of these cobots, which will shut off if they so much as brush up against you, and their use as augmenting tools and not replacements, the workforce is much more accepting of these bots.

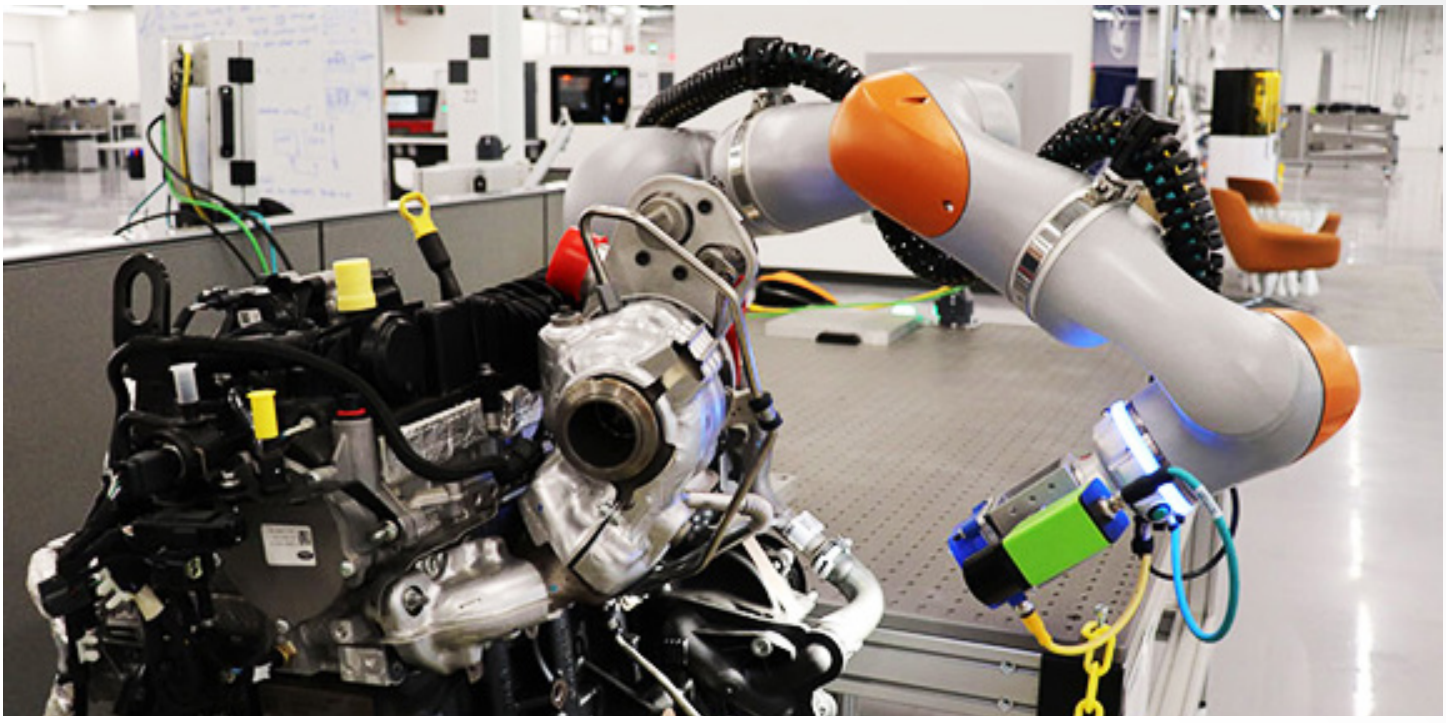
"We've had really good response with the collaborative robots as opposed to other types of automation," Kekedjian says. "They are usually being introduced to enhance the work, so it's there to help them do their job, which would be much more mundane and easy to miss."

## ENHANCING SMES

Autonomous Mobile Robots were more conspicuous at Ford. Some KUKA mobile platforms are parked in a corner, one with the 7-axis robot on top. During a holiday party at the center in December, Ford employed this machine to roll around and hand out drinks.

At IMTS in 2018, KUKA had a similar set up for inspecting a car's paint job.

At MiR's sprawling display, a MiR200 had a UR-5 on top to simulate picking up PCBs. These are certainly effective at showing what robots can do for large companies, but Jagiela



has his sights set on disrupting industrial work on a much bigger battlefield: small and medium enterprises.

SMEs comprise nearly 99% of the total number of businesses in America, and they need the most help. When asked to think of the most representative candidate that Teradyne's tech can help, Jagiela imagines a small manufacturer in middle America, Iowa or perhaps Minnesota, where a worker is pushing a cart of material from the warehouse to "islands of people " at disparate cells, where a dozen more workers busily assemble product.

He sees a solution where a low-profile mobile robot, fitted with sensors to safely navigate and able to carry more than 1,000 pounds, delivers new material to a mix of maybe seven workers and three cobots, then takes the assembled product back to the warehouse.

He says this incremental path is a real strategy for SMEs to become globally competitive.

"The small company no longer has this massive barrier or disadvantage," says Juergen von Hollen, Universal Robot's president. "They have a tool similar to the large companies that generates efficiencies and scale."

Von Hollen points to the cobot's flexibility. While a typical industrial robot is fixed in place and needs a huge footprint and safety gating, cobots can be placed virtually anywhere, programmed to do many jobs. And they also fit into SMEs more modest investment timeline.

"With the megatrend towards mass customization, it becomes more and more difficult to create a business case of five, 10 or 20 years for a very static automation process or line," von Hollen says. "If it's more than three years, most companies are not willing to take the risk. The world has changed."

That's perhaps why cobots could have a third of the market by 2025: they are affordable, automated Swiss army knives.

"We're bringing back the concept of the robots as a tool," von Hollen says. "That's all it is."

It's actually that and more. Recent data from small business mentoring company SCORE says that 89% of small manufacturers cannot fill all their job openings. And in 2018, it took more than three months to fill a production job, Deloitte found, an increase of 33% from 2015. The future looks even bleaker. The Manufacturing Institute and Deloitte's 2018 Skills Gap study reports less than half of the 4.6 open manufacturing jobs over the next decade will be filled.

So it's not as much SMEs need cobots to remain globally competitive. They will need them to exist at all.

## COHABITATING WITH COBOTS

About 30 miles north of Ford's innovation center, a 67-year-old contract manufacturer called Fitzgerald Manufacturing Co. has found how valuable cobots can be to solve the local skills gap. In 2018, I spoke with their president Kevin LaComb about their recent implementation of Rethink Robotic's Sawyer, a red cobot with a touchscreen that can become an emoting face.

Sawyer takes metal motion control cylinders, short or long, from a pin board, to a honing machine. When the parts are done, it washes, dries and packages them. Previously, a human would have to sit there and do this fairly simple job, instead of running one of the shop's 100+ other more complicated machine tools.

"Humans would be bored to tears," says LaComb, adding that boredom eventually affects quality. "No one really understands how that creeps into the finished product."

Sawyer doesn't get bored or distracted. It also rarely stops and is able to run up to an entire day sometimes without an adjustment. "Sawyer runs seamlessly, and there's not a lot of hand holding and babysitting," LaComb says.

This cobot currently costs under $40,000 and at the time LaComb estimated the ROI would come at seven or eight months. The added productivity allows Fitzgerald to accept more jobs and keep employees. In 2018, LaComb said the company had 86 employees but was short about a dozen.

"We have to remain relevant and this is a path forward in many directions," LaComb says. "It's harder and harder to find people, and when we do find good people, we're driving to put them on more advanced processes."

Rethink closed down in October of 2018, after a decade of operation. The HAHN Group, which installs about 2,000 robots a year, acquired its IP, so Sawyer (but not two-armed sibling Baxter) lives on. HAHN plans to combine the proprietary software called Intera, which "allows programming in a matter of minutes," with their German engineering knowhow to innovate more customer-oriented cobots, says Philipp Unterhalt, CEO of Rethink Robotics and HAHN's managing director.

## TAKEOVER NON-FICTION

Cobots do allow companies to accept more business and spackle the gaps left by today's monotony-averse younger workers. But no one really knows what these cobots will evolve into as artificial intelligence takes hold and the grippers becomes more dexterous. Predictions range from creating one billion jobs to stealing 2 billion. These saviors could become an invasive species soon enough.

There's a greater problem American manufacturers have right now when it comes to robots.

"We don't have enough plant technicians to take care of automation being put into manufacturing in the United States," Universal Robots' von Hollen says. "These are high paying job. You create another industry that requires people to do these things."

Overall, the level of robotics knowledge the next generation has versus what it needs is concerning. At our Manufacturing & Technology event in Pittsburgh earlier this year, I asked three high school females from a successful robot club if they are considering robotics as a career. All three said "no."

There's clearly still a disconnect, and the real takeover needs to be part of the whole robot narrative.

Robots aren't just going to be in factories in the next decade, but also hospital floors delivering drugs or moving patients, in homes assisting the elderly or disabled, and hopefully doing my yardwork. They are going to be everywhere, and we need to prepare.

So, the real story from here needs to be how to create the skilled workers to install, run and maintain these robots, and how to responsibly transition the people replaced by automation to new jobs. Boston Dynamics' Atlas regularly goes viral for new feats of agility, while Japan's National Institute of Advanced Industrial Science and Technology is using the HRP-5P humanoid robot to (slowly) perform heavy labor such as drywalling.

In ten years, it's conceivable that robots will assume more trades jobs. We have a new opportunity to redefine labor and restore humanity and dignity to the workers who break their bodies to boost productivity. It's a debate that's gone on for long enough and we have the technology to end it.

The question is, do we have leaders able to will it into reality?

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**LAURA PUTRE**
Senior Editor, IndustryWeek



# MEET YOUR NEW ROBOT CO-WORKER

*Digital transformation requires not just changes in technology but rethinking organizational structure, leadership, workplace culture and work itself.*

Everyone's heard the trope of the manufacturing worker who resists change and—sometimes with good reason—sees technology as a threat. But Dale Mark has a different story to tell about workers and technology from the front lines of a plant floor in Marengo, Illinois. Mark is vice president of operations for UniCarriers, a forklift manufacturer that has been incrementally introducing automation and digital technology into its operations over the past 15 years.

"When we were first installing robots or building automation, there were some people that really embraced it," Mark says. "Other people were skeptical. And today I think there's more of a sense that people crave the technology."

He mentions one of many tiny affirmations: Plant leadership recently introduced a pilot project to manage employees' continuous improvement suggestions on an app. There was no hand-wringing, no harping that the old way was better. Instead, he says, "the response was almost like, 'What have you been waiting for!?'" Marks says it makes sense, as smartphones have become increasingly a part of people's daily lives.

Likewise, when Irene Petrick and Faith McCreary, a pair of Intel researchers, embarked on a study of manufacturers' challenges around digital transformation, to their surprise they heard little about technological hurdles. Instead, organizational problems prevailed.

Through a multimedia diary app where they could share stories of their work and the technologies they encountered, the overwhelmingly under-age-40 batch of respondents told of IT and OT clashes, departments like purchasing and operations running in their own lanes rather than collaborating, and a hesitancy from leaders to share data that could help workers do their jobs better.

"Workers want to be involved early, they think they *should* be involved early, and believe they have a lot to contribute from a knowledge perspective about the processes," says Petrick.

It's the leaders who are more hesitant around technology, Petrick says, as digital transformation has evolved into something much bigger than investing in a piece of automation equipment to rachet up a particularly plodding task. Work is changing, artificial intelligence is opening up possibilities and hierarchies are flattening as information-sharing across roles becomes the difference between understanding your customer or process and being snuffed out by a competitor.

"Workers interacting with the manufacturing processes themselves are hungry for change and know they have to do things differently in the future to remain competitive," Petrick says. "Senior leaders seem to be a little more risk-averse, and middle managers are all over the board."

That apprehension stems not from the technology itself, but from the broad cultural and organizational changes it brings.

Digital-savvy manufacturers and people who study them say that involving your people early in digital strategy, investing in training, rethinking and reassigning jobs as tasks, finding your technology champions, and looking for new opportunities are important parts of the equation.

## INVOLVE YOUR PEOPLE EARLY

People must be integral to a digital strategy from the beginning, big or small, say Ravin Jesuthasan and John W. Boudreau, authors of *Reinventing Jobs: A 4-Step Approach for Applying Automation to Work*. And the authors don't mean people in the sense of "How many people can we substitute robots for?"

"It's very easy to get locked into saying, 'Give me back 20% of the labor cost because the robots are doing 20% of the work," says Boudreau. "It doesn't work that way."

Petrick advocates involving engineers, supervisors, tradespeople and line workers with expertise in their areas in "meaningful engagement forums" in the early stages of digital strategizing. Not an annual townhall meeting, but open dialogues "where people come prepared to talk about the environment they work in, the machines they work with, the insights they have and how they've worked with those machines for a long time."

Mike Mikula, chief engineer for Ford's Advanced Manufacturing Center, says that when designing applied technology for the factory, his team will bring in both hourly and salaried people "very early in the process" so they can talk about their challenges, share their expertise of the process and contribute ideas for improvement. This not only improves the end result; it empowers team members who will be using the technology, giving them a voice and a stake in its success.

For instance, when Mikula was a Ford area manager, he oversaw the automation of a particularly cumbersome-to-human-operators gear machine at the Van Dyke transmission plant in Sterling Heights, Michigan, that was slowing up the line.

"The cycle time of the line was very short, with people working very diligently at a very high speed," he recalls. "Many people would have a hard time executing the task in the time that was allowed." His engineering team consulted with skilled tradespeople and team leaders on the floor "to ideate around what we could do to help people execute the meshing of the gears in the time we had allotted." Mikula's team took those ideas and worked with different suppliers to come up with solutions, then did a design review with the same hourly workers "to agree on concepts to pursue to production and keep them engaged through the development of the production process. It required a significant amount of creative thinking, and we really did get valued input from everybody."

## RETHINK WORK

Jesuthasan and Boudreau advise that leaders stop using the term jobs and instead break down work into tasks—often, tasks that are unsafe or physically difficult for humans to perform—and then determine which tasks are

practical for robots to take over and which ones people can shift to and grow into, developing new proficiencies and ways of looking at the operation that increase productivity and open new opportunities for growth. After that, it's just a matter of looking at which traditional skills translate best into which new roles.

Maybe it's middle managers spending more time on coaching their team and becoming more savvy in interpreting data instead of devoting their days to allocating work and monitoring and tracking people, which automation can take over at the granular level. Maybe it's automating welding processes, then training welders to run a new CNC machining center.

## INVEST IN TRAINING

Fifteen years ago, UniCarriers began adding automation and digital technology to its operations, bringing in CNC machining and robotic welding. That was the beginning of a digital strategy that has brought automation to painting processes, lights-out laser cutting and a new ERP system to connect with data collection.

"We didn't have it all figured out," Mark said. It was the company's first step on the road to the "fairly well-defined factory 4.0 roadmap" it has today, "where we're constantly looking at technologies and where we think they apply and where we can implement them in the future.

Retraining workers for data-driven jobs is a big part of that strategy, and Mark says it's a key reason the company's workforce has not contracted with automation—instead, it's actually grown considerably. Training is a combination of in-house (including apprenticeships) through suppliers and a partnership with a local community college.

A retrained welder now rotates between operating robotic welding cells and the CNC machining center. What the new job lacks in hands-on work, it makes up for in higher thinking and less wear and tear and repetition, Mark believes.

The former welder "is more well-versed and can have more flexibility, which I think you know many individuals like," says Mark. "Also, doing manual welding full-time is strenuous work," so the job becomes more ergonomic. "The individuals like that and they recognize that."

UniCarriers' digital strategy also had provisions for retraining for "a new level of support that was more technically skilled maybe than the typical operator, but didn't require a degreed engineer"—a maintenance technician who could program robots and laser cutting machines. "That was an area that we really had to develop internally," says Mark.

## THINK BIG

The redeployment of its talent has opened up opportunity for UniCarriers to bring more manufacturing in-house. When the company started its automation journey, it was building forklift frames but outsourced the components for the masts—the vertical lifting mechanism on the front of the forklift.

"There were very large pieces of rail that have to be processed prior to welding, and we had previously had that work done on the outside by a supplier," says Mark.

The engineering team studied that process, and determined the company could cut costs and reduce inventory by doing the work in-house. They were right, and the company soon began looking for other ways to insource. The Marengo plant now assembles its internal-combustion forklift engines and transmissions in-house as well. (UniCarriers already owned the engine technology and purchased the transmission supplier a few years ago.)

"We made that investment and then we trained our employees to run those machines, and now we're making tight tolerance machine castings that go into transmissions for forklifts day in and day out," Mark says. The forklift business is very competitive, he adds.

Becoming more vertically integrated allows UniCarriers to control the cost, quality and delivery, and gain an edge on the competition.

The workforce is organically a part of that strategy and change, says Mark. "When we're looking to develop a new application or a new process, we always involve the shop-floor employees and supervisors early on because they're the experts," he says. "And we draw from their knowledge to understand how we can make the process better and learn where we might have problems today and how we can eliminate those troubles in the future."

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**JILL JUSKO**
Senior Editor, IndustryWeek



# LEAN AND ROBOTS:
## DYNAMIC DUO OR DISRUPTIVE DISASTER?

*For many, the conversation about lean manufacturing and automation frequently is reduced to man versus machine. The reality is far more nuanced.*

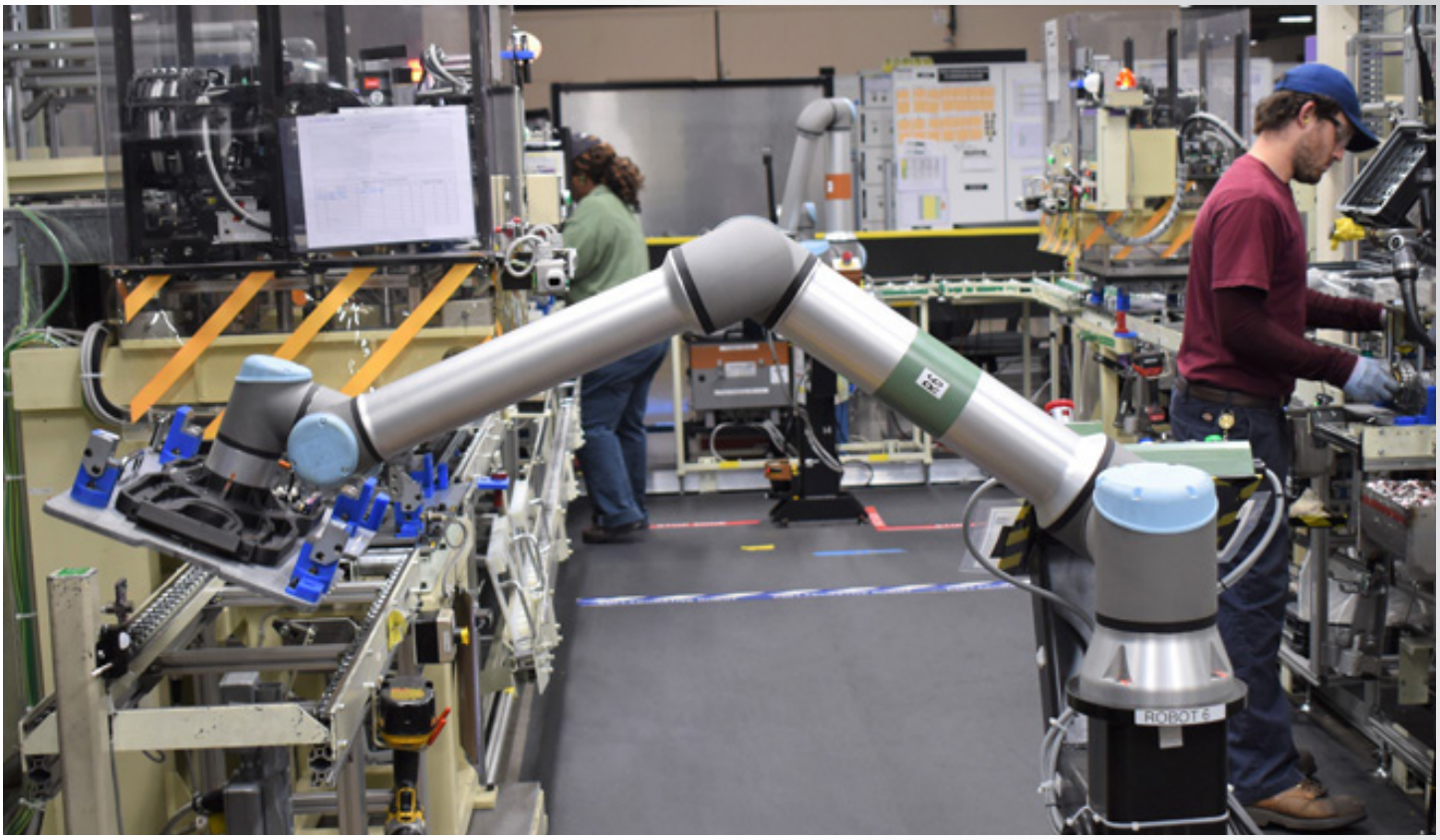
Lean—be it lean manufacturing or the lean enterprise—has long been an oddly divisive topic of conversation, right down to its very definition.

"The folks who coined the term in the late 1980s developed a set of lean characteristics, starting with keeping the end (value to the customer) in mind. Key principles included removing waste from value streams, developing continuous product flow and ultimately driving down manufacturing cycle times to more rapidly respond to customers' changing needs and wants. Moreover, the people who engage with the value stream are active participants in its continuous improvement.

Nevertheless, a solid percentage of manufacturers see lean primarily as a cost-reduction strategy. While reduced costs may be an outcome of lean improvements, cost reduction is not at its heart. Another misconception? That lean manufacturing applies only to high-volume, low-mix production. Follow the origins of lean back far enough (think Toyota) and you will discover that the need to produce small quantities of many product variations were a driver of what became the vaunted Toyota Production System.

Then there is lean and automation, including robots. For many, a conversation about lean manufacturing and automation frequently is reduced to man versus machine—with headcount reduction as the end game.

"There is one group of folks who feels like any sort of automation or robotics is evil and violates the principles of



lean. There's also the other end of the spectrum that says robots are going to make lean irrelevant going forward," says Jim Morgan, a senior advisor, product and process development, at the Lean Enterprise Institute.

Of course, the reality is more nuanced.

"Both arguments, at least for me, don't work. The premise of it being antagonistic is problematic," says Morgan, who is co-author (with Jeffrey Liker) of The Toyota Product Development System, as well as the recently released Designing the Future. An engineer, Morgan spent 10 years at the Ford Motor Co., serving his last eight years there as director, Global Body Exterior and SBU Engineering.

"Lean principles and robots can enhance each other," Morgan says.

It's about balance, he suggests. "Lean is very people-centric. It's about 'How can we make the environment better for the people who are doing the work—and robots and automation in general are absolutely a way to do that."

Morgan cites Toyota, whose lean credentials are unassailable, as one example.

"Some of the Toyota plants that I've toured, they make really excellent work of cobots… especially as the workforce ages," he notes. "They can create a much better working environment for those folks. But lean is still at the heart of the system, and the robots are just another tool that we can utilize to create a better environment."

Toyota recently showed off that very premise at its Huntsville, Alabama, engine plant, which has the capacity to produce 670,000 engines per year. The facility introduced its first collaborative robot in 2017 and currently has eight in action. It hopes to boost that number to 15 by year's end. The cobots' focus is on jobs that require repetitive, monotonous motions.

"We want [cobots] to do the moving, handling, pushing work so our team members… can focus on the critical thinking aspects of the project," explained Toyota engineering manager Jason Abney to ABC TV affiliate WAAY in early May.

"The robots are intended for collaboration, not replacement," Abney said. "We never reduce the amount of team members we have at the facility. We will reduce the effort to that area. We will take that team member to another needed area in the facility."

Indeed, replacing workers is precisely the opposite of what Toyota has planned in Huntsville. In March, the automaker announced plans to add two engine lines as part of a $288 million expansion project that is also expected to add some 450 jobs.

The expansion will boost engine capacity to 900,000 by the end of 2021, the company said.

## LEAN: NO LESS A REQUIREMENT THAN SAFETY GLASSES AND EAR PROTECTION

While perhaps the most visible example of a company blending the strengths of lean manufacturing and robotics, Toyota is hardly alone in that regard.

AGCO, for instance, has embraced lean manufacturing and continuous improvement.

"It is a global fundamental requirement at all of our plants," says Peggy Gulick, director of digital transformation at the agricultural equipment maker, which produces brands such as Challenger and Massey-Ferguson. And while not every AGCO facility is at the same level of lean implementation, "it's no less of a requirement than safety glasses and ear protection and steel-toed shoes."

Technology is also paramount. Technology, she says, "is just another step in the whole continuous improvement journey. You're never going to reach perfection; you just get better every day at what you do—and technology has given us even more options to introduce to our plant to do that."

AGCO's Jackson, Minnesota, plant—a 2017 IndustryWeek Best Plants winner—is an illustration of lean and technology acting in concert. Indeed, IW described the facility as the "junction of advanced manufacturing technology and lean culture" in an article heralding the plant's accomplishments last year. Google Glass, for example, is prevalent on the shop floor, where several hundred workers wear the eyepieces to quickly access work instructions and other information. The technology provided a productivity return twice what leaders had originally expected, while a lean culture of employee problem-solving and policy deployment bolsters the effectiveness of such technologies.

Robots are installed across ACGO's global footprint of manufacturing facilities, in component manufacturing areas, for welding and paint, and elsewhere. Gulick says the company is immersed in gaining knowledge about collaborative robots and their potential value to the business. She says the most successful cobot installation within AGCO is likely the one in Brazil, where the technology is laying adhesive on iron housings that become part of finished goods.

At AGCO, implementing technology—robots or otherwise—is not done simply for the sake of new technology. That type of reasoning is never going to drive much value back into the enterprise, Gulick suggests.

AGCO's lean approach is this: "AGCO solves problems. If we have a problem and there is some grand new technology like a robot or cobot that's out there, we will try it. We will bring it in; we will fail if that's what's going to happen, and we will learn from our mistakes and then grow our solutions to include that new knowledge," Gulick says.

In Brazil, for example, the company brought in the cobot to address excess material costs that arise when too much adhesive gets applied. A facility in Germany, on the other hand, is working with cobots to reduce monotonous work currently done by the human workforce. That effort remains a work in process.

"We'd rather have the humans where they're making decisions," Gulick says.

AGCO is among lean enterprises that perform lean audits every year, or every other year for smaller locations. Interestingly, but perhaps not surprisingly, facilities that score the highest on those lean audits are the locations most likely to be supportive of and progressive with bringing in process or technology innovations.

Gulick says it's not hard to understand why. "They're ready," she says. "They have the [lean] foundation; they've built in policy deployment, they've built in problem-solving."

These are the plants ready to add advanced tools to their solution box "and bring it in any time that they can use it," she says.

## WE DO NOT WANT PEOPLE BEING ROBOTS

People are at the heart of a lean system, says LEI's Morgan. "We want their intelligence, we want their passion, we want to engage all of our team members."

While Viking Plastics doesn't state its lean leanings in exactly those words, its approach shares similar sentiments.

"We believe the secret sauce of lean is growing people, educating people and putting our creative minds to work to help make work better," says Viking's Shawn Gross, engineering manager. Corry, Pennsylvania-based Viking Plastics is a privately held injection molder that produces sealing solutions and custom molded components. It has multiple U.S. locations and several outside of the United States.

"Our philosophy is that we want to grow all of our employees into 'process engineers.' We want them to see the value in what they do, and we want them to see the waste in what they do. We train people to see waste and then require and request that they be part of the solution through '2 Second Lean.'"

> *"We believe the secret sauce of lean is growing people, educating people and putting our creative minds to work to help make work better."*
>
> **– SHAWN GROSS**
> Viking's engineering manager

"2 Second Lean" was developed by Paul Akers, founder of woodworking products company FastCap, and author of a book by the same name. The model keeps lean simple and focused on small daily improvements, which Gross says has helped Viking sustain its lean efforts since 2011.

The company sees no conflict between lean and automation. "We fully embrace technology, innovation and automation to help improve productivity and quality, and we do this while growing people to adapt to our changing manufacturing environment," Gross explains. "We don't see lean as an austerity program. It is not intended to be a slash-and-burn, get-rid-of-people process."

Viking's Corry location has significant amounts of automation, including robots above the molding machines that remove parts, as well as box and sort them. The company also has a robotic arm. It has a 3D printer, error-proofing and high-speed inspection systems, just to cite a few of its advanced technologies.

The use of robots, Gross says, allow people to do more value-added processes that engage their minds. "We do not want people being robots, doing repetitive, mindless tasks."

Moreover, because Viking emphasizes the workforce's value to the company, it is not uncommon for anyone—not just a member of the automation team—to ask why a piece of equipment hasn't been introduced in a certain area to eliminate the need for a human to perform a routine, mindless task. Or to make small, daily improvements that lead to a two-person operation being reduced to a one-person operation.

Such employees—and automation—aren't in danger of improving Viking associates out of a job at the company, Gross notes. On the contrary, those employees move to positions within the company that provide greater value both to the manufacturing company and the employee. A position in the quality lab is one such example.

Moreover, the collaboration between lean and automation is driving impressively low external quality defect rates, with some product lines shipping tens of millions of parts a year with zero defects, Gross says.

Ultimately, whether lean and robots are a dynamic duo or disruptive disaster depends on the human beings making the decisions about how such technologies are implemented. Are robots optimizing processes at the local level at the expense of the larger system? That's not lean. Are they helping improve quality? Is lean still at the heart of the system?

"The same lean principles apply whether it's robots or people," says Morgan.

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**DAVID SPARKMAN**
Contributing Writer, IndustryWeek



# ROBOT SAFETY:
## IT'S NOT SCIENCE FICTION, IT'S THE LAW

*OSHA has been addressing the issue of robot safety for more than 30 years.*

Some journalists and commentators can't seem to write about industrial robots without making the inevitable references to science fiction writer Isaac Asimov and the "Terminator" movies. The truth is that robots have been around for many decades—and so have the laws and regulations addressing their safety issues.

It was 1987 when the Occupational Safety and Health Administration (OSHA) issued its Guidelines for Robotics Safety. The agency said at that time, "With the burgeoning use of robots in industry, it is feared that without adequate guarding and personnel training, injury rates for employees working with robots may increase."

Robots have long been deployed to perform unsafe, hazardous, highly repetitive and unpleasant tasks, with the express intent of reducing potential hazards associated with those functions while increasing productivity. Perhaps the only labor leader to fully embrace automation was John L. Lewis, president of the United Mine Workers Union, precisely because it made underground mining safer for his members.

Attorneys for the law firm of Seyfarth Shaw LLP point out that early robots, which mainly conducted pre-programmed tasks and did not have the advanced computer intelligence that many now possess, created potential hazards not only under normal operating conditions, but also during programming, adjustment, testing, cleaning, inspection and repair periods.

From the robots' introduction, it was quite common for employees—such as operators, programmers and maintenance workers—to walk within the robot's work envelope while power remained available to the device's moveable elements.

"Now, some 30 years after their widespread appearance in the workplace, robotics and computer automation have permeated nearly every industry, including manufacturing, warehousing and even retail, potentially exposing additional workers to hazards. In Japan, some coffee shops now serve coffee utilizing robotic baristas," the lawyers observe.

Some safety experts believe OSHA's current regulations are inadequate and need extensive updating. Last year the National Institute for Occupational Safety and Health (NIOSH) created a Center for Occupational Robotics Research to assess potential benefits and risks of robot workers and develop guidance for safe interactions between humans and robots.

The center is the result of an alliance agreement that OSHA, NIOSH and the Robotic Industries Association signed in October 2017. The pact calls for them to work together to enhance OSHA's and NIOSH's technical expertise, improve awareness of workplace hazards associated with robots and identify areas of needed research to reduce workplace hazards.

"Robots working collaboratively with humans present a new workplace risk profile that is not yet well understood," said John Howard, NIOSH's director at the time. "Not only

is this a new field for safety and health professionals; little government guidance or policy exists regarding the safe integration of robots into the workplace."

When the new center was announced, NIOSH researchers had already been able to identify at least 61 robot-related workplace deaths that took place between 1992 and 2015.

"We suspect fatalities will increase over time because of the growing number of industrial robots being used by companies in the U.S., and from the introduction of collaborative and co-existing robots (cobots), powered exoskeletons and autonomous vehicles into the work environment," says Dawn Castillo, director of NIOSH's Division of Safety Research and the center's program manager.

## OSHA IS WATCHING

While there are no OSHA regulations that specifically address robot safety at present, that doesn't mean the agency won't come after an employer when an accident involving a robot occurs. Just ask automaker Nissan North America Inc., which in August was forced to pay a $12,675 OSHA penalty after it was upheld by an administrative law judge.

In July 2016, a Nissan contract employee was in the process of replacing a motor on a robot on the first floor of a company facility at the same time that three company maintenance technicians conducted a preventive maintenance inspection on a conveyor on a floor above. When the contract employee was done with his work, he started the conveyor back up. At that moment, a technician placed his hand on the conveyor belt and was pulled into it, amputating three of his fingers.

The judge upheld Nissan's citation for violating the OSHA standard covering training requirements. "The standard requires initial training be sufficient for employees to acquire the skills necessary to perform safe lockout," the judge said. "For the technicians working on [the overhead conveyor], Nissan's training did not meet this standard."

OSHA's Lockout/Tagout (LOTO) and other regulations require employers to protect employees from unexpected energization of machinery by, among other things, making sure all sources of energy are dissipated when the machines are not in use and installing a lock to prevent accidental startup.

When it comes to robots, the primary source of protection from unexpected movement is a programmable logic controller (PLC). Under OSHA's rules, PLCs are expected to limit robots from moving when not performing their pre-programmed tasks and functions, or if a certain condition is met—such as when an interlocked door is open.

While these PLC devices typically "fail to safe," OSHA has been reluctant to accept them as equally effective means of employee protection along the lines of machine guarding or LOTO, the Seyfarth Shaw attorneys note.

Intrinsic faults within the PLC control system of the robot include errors in software, electromagnetic interference, as well as radio frequency interference, OSHA believes. In addition, the agency holds that these errors can occur due to faults in the hydraulic, pneumatic, or electrical sub-controls associated with the robot or robot system.

## OSHA'S TECH MANUAL

To help employers, OSHA has created an online technical manual for employers to learn about the hazards associated with robotics and automated machinery, including those that stem from malfunctions or errors in programming or interfacing with peripheral equipment.

In addition, the Robotics Industries Association offers an extensive safety program for employers on its website that

covers everything from ANSI standards and RIA technical reports (which OSHA relies on) to public and in-house safety training opportunities that are available from the association.

The OSHA technical manual groups robotic incidents into four categories: impact or collision accidents, unexpected movements, component malfunctions, and unpredicted program changes related to the robot's arm or peripheral equipment that result in contact accidents.

Here are some specific dangers OSHA says you should look out for:

**Crushing and trapping accidents.** Situations where worker's limbs or other body parts can be trapped between a robot and other peripheral equipment, or the individual may be physically driven into and crushed by other peripheral equipment.

**Mechanical part accidents.** OSHA defines a mechanical accident as one that involves breakdown of the robot's drive components, tooling or end-effector, peripheral equipment, or its power source. Examples of mechanical failures include the release of parts, failure of gripper mechanism, or the failure of end-effector power tools, including grinding wheels, buffing wheels, deburring tools, power screwdrivers and nut runners.

**Other accidents resulting from working with robots.** This category includes equipment that supplies robot power and control and represents potential electrical and pressurized fluid hazards. For example, ruptured hydraulic lines could create dangerous high-pressure cutting streams or whipping hose hazards. OSHA also lumps into this category environmental accidents from arc flash, metal spatter, dust, electromagnetic, or radio-frequency interference that also can occur, and equipment and power cables on the floor that can present tripping hazards.

OSHA adds that other expected sources of potential robotics hazards include human errors in programming, interfacing peripheral equipment, or connecting live input-output sensors to the robot or a peripheral device which can cause dangerous, unpredicted movement or action by the robot.

The incorrect activation of the "teach pendant" or control panel is a frequently-found human error, the agency observes. "The greatest problem, however, is operators' familiarity and complacency with the robot's redundant motions so that an individual places himself in a hazardous position within the robot's 'work envelope' while programming the robot or performing maintenance on it."

Another problem is unauthorized access by employees who may not be familiar with safeguards in place or their activation status. Pneumatic, hydraulic, or electrical power sources with malfunctioning control or transmission elements in the robot power system can disrupt electrical signals to the control or power-supply lines. Other hazards include electromagnetic or radio-frequency interference (transient signals) that can affect robotic operation, OSHA warns.

"While OSHA does not have regulations specific to robots in the workplace, employers would be wise to conduct job hazard analyses and evaluate any existing or potential robotic equipment installation, to abate any hazards posed by these machines," the Seyfarth Shaw attorneys stress.

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*David Sparkman is founding editor of ACWI Advance, and a contributing editor to* EHS Today.

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**IDAN HAIM**
Contributing Writer, IndustryWeek



# 5 RULES
## FOR DESIGNING FOR AUTOMATION

*Don't get your robots (and people) in a tangle. A few basic considerations will cut down on problems later.*

While many factory processes are not yet automated, new products in the era of Industry 4.0 must—at the very least—be prepared for automation. Automation technologies require new and complex design considerations that engineers must take into account. We call this set of considerations Design for Automation (DFA).

A DFA-ready product is critically important on the road to Industry 4.0, as it allows manufacturing companies to reduce product costs, decrease assembly time, and increase production volume with zero changes required.

Here are five simple rules to follow as you prepare your products for the future:

### 1. THINK LIKE A ROBOT.

Imagine a robot in an assembly line, with its robotic arms. Compared to human arms, robotic arms are quite limited in their motion range and capabilities. They can, however, be fitted with several different tools depending on the specific needs for assembly—like parallel grippers, vacuum cups and electro-magnets.

When designing a product for automation, it's important to imagine the robot trying to assemble the parts. See if you can find a way to transfer the part from a tray to the designated location in the assembly line that is convenient not for a human hand but for a robot hand. For example, a magnet would be the easiest way for a robot to grasp a magnetic part; a three-finger gripper would make most sense for a circular part.

### 2. ONE DIRECTION IS BEST (NO, I'M NOT TALKING ABOUT THE BOY BAND).

Many of us have experienced the pleasure of opening a brand-new iPhone from the box. When you open the box, the first thing you see is your shiny new phone. After you remove the phone, you pull out the cover that sits beneath the phone to find all of the phone's accessories – charger, headphones, manual and more. The method by which Apple assembles this packaging is exactly the opposite of the consumer's

unpackaging experience: start with the box, adding in the various layers, and ending with the box cover.

Now compare this to the assembly of a vehicle. You start with the chassis, add the motor from the top, lower it to the chassis, seats enter from the sides, trunk is assembled from the back, and so on. Assembly, in this case, happens from all directions.

Which of these assemblies is simpler? Answer: the iPhone package, with its one direction. When it comes to the assembly process, directions matter because every time you have to change direction, you also have to change the orientation of the assembly, or the orientation of the tools that you assemble with—therefore increasing the time required to assemble. Obviously, a one-direction assembly is not always possible with complex products, so a good rule of thumb is: the process with the fewest directions of assembly needed is always best.

### 3. CONSIDER OFF THE SHELF.

All manufacturers rely on off-the-shelf parts (OTS) to complete their products, whether it's fasteners, dowel pins, electrical connectors or others. To ensure your product is

DFA-ready, it is always a good idea to ask yourself if those miscellaneous parts are approachable for automation. I recommend always asking the company from which you buy the parts if they are usable for automation. Sometimes, they may not give you a straight answer. In that case, follow the two rules above.

Take, for example, the commonly used locking plunger (pictured, below). Now ask yourself, "can a robot hold it?" Also, "How many possible directions do we need in order to assemble with this part?"

Through this mental exercise, you'll probably realize that the button plunger in this second image below—with its rotatable lever—lends itself to automation much better.

## 4. PREPARE FOR THE CAMERA.

Cameras serve an important purpose in an inspection line, locating parts, reading barcodes, counting components and inspecting defects. It's important to design your DFA-ready parts in a way that can accommodate this important phase of the production cycle. First, if a barcode on a part needs to be read, make sure labels are visible to minimize movement of the robot while assembling. If they are facing the same direction, it will be much easier to apply labels on the product and easier to read their barcode (without changing the camera orientation). Second, when a robot is handling inspection, be sure to define the phase accordingly in order to reduce inspection time as well as faulty rejected parts. For example, scratches on a plate would be quite easy for the human eye to detect, but much more difficult for robotic vision.

## 5. DON'T FORGET ABOUT THE PACKAGING.

Just as crucial as the product you produce is the packaging of that product. When designing the packaging, don't forget to apply the above rules. Not only does DFA-ready packaging allow for quicker assembly, it can also ensure consumers experience that same magical unboxing moment they had with their latest iPhone.

With these simple rules as your guide, your products will be set up for success in the Industry 4.0 era.

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*Idan Haim is a mechanical designer at software and robotics company Bright Machines. Previously, he held roles as a mechanical engineer at AVT and Q Core Medical. He graduated from Tel Aviv University with a B.S. in mechanical engineering in 2015.*

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**KEN PULVERMAN**
Contributing Writer, IndustryWeek



# ROBOT MIMICRY OR MASTERY?

## THE END OF BENCH MANUFACTURING IS NEAR

*If humanity's future in manufacturing is inserting a few screws because our hands are still more dexterous than most affordable robots, then we are doomed.*

At the recent IndustryWeek Manufacturing & Technology conference, I had a chance to go on one of the plant tours. The factory was making a device that had maybe 10 parts in it. Robots dutifully prepared trays of the key components so that human employees at seven different stations with a tact time of 30 seconds or less per station could assemble the device. They had a very nice looking and cleanly organized work station with a thick squishy foot pad to avoid the fatigue of working on your feet all day.

When we asked the plant manager why humans do the bench work versus other jobs in the factory like pick and pack, he said that the *pick and pack* of the trays of components was done by robots because it was a source of tedium and potentially repetitive stress injury.

Don't get me wrong. This was an incredibly well-run factory, but if humanity's future in manufacturing is inserting a few screws because our hands are still more dexterous than most affordable robots, then we are doomed.

I could tell as I watched the people doing the work, they were good at their jobs, fluidly grabbing parts and punching in screws in motions so smooth it was almost ballet-like. On the other hand, I imagined them getting up at 6:30 a.m., making breakfast for the kids, driving to work, clocking into the job, and getting to their bench only to then be prized for essentially how well they moved their hands. I know that the factory I toured offers reasonable wages, a nice work environment, and is generally a very good employer. But if I could wave a robot magic wand and apply these folks to higher-order tasks, I would.

What was clear is that their company probably feels the same way, but the reality is that affordable industrial robots don't have the dexterity of humans – and won't – for some time.

The operative word here is *affordable*.

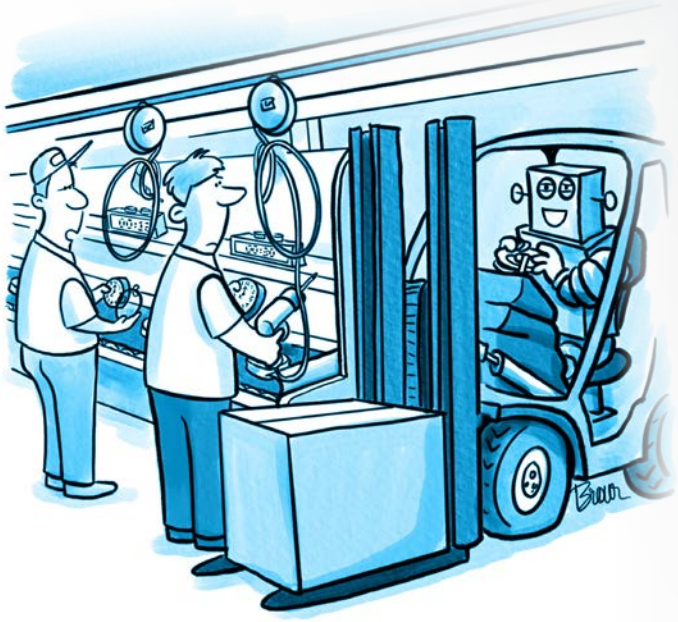
Advanced automation is already showing that incredible dexterity is already possible at scale, as evidenced in this video from a manufacturing facility in China. That, however, doesn't mean that every design of every product could even utilize this equipment today. Some designs were created with the human hand in mind. When we think about designing for manufacturability in the future, we'll be designing for the robot "hand."

Every manufacturer is wrestling with the enduring role of humans in the factory. Most manufacturing leaders have a clear view that they'll be adding significantly more automation, but have yet to clearly plot out the enduring roles for humans.

There are jobs that are clearly ready to go away, like *pick and pack* (Amazon and others have already replaced this function with robots), packaging and palleting (which was already automated at the factory I toured).

I would contend that bench is the next to go.

Now, bench zealots will argue that some bench jobs are super complex and require lots of judgement and critical thinking. And they would be right. The reality, though, is that those are the minority of what is out there. Manufacturers need to look no further than the bench to demand solutions from advanced manufacturing and robotics companies.



At the same time, manufacturing should literally be engineering into their future the lasting role for humans. With millions of jobs destined to come back to the United States alone because of reshoring, these jobs will be far more sophisticated and will be a good source of both great wages and the full use of human potential.

What manufacturers need to think about is how humans can move from robot mimicry to "robot mastery." By this, I mean what tasks in advanced manufacturing best leverage human skills to be the master of the technology that, if harnessed correctly, can help us maximize output? "Harness correctly" is the key phrase here, and that is where human judgement comes in. According to research by Salesforce on how the Fourth Industrial Revolution is changing the future of work, 73% of hiring managers believe creative-thinking skills will be increasingly important in increasingly automated industries.

Some things we humans are uniquely good at in these settings include:

**Changeovers:** Changing the state of robots and equipment from one state to the other. We may need to be reminded of some of the finer points with standardized digital procedures, but at each stage there is critical judgment that determines success or failure.

- **Identifying improvements:** While the product mix for most companies is ever-changing, industrial engineers are always playing catch-up to ensure that the latest mousetrap is the best possible one for that task. Humans on the line provide a critical eye as to what still needs to be optimized – which itself is a never-ending journey.
- **Corrective Action:** Even in the most thoughtful factory design, things go wrong and not every corrective action is well understood. Humans play a critical role in making sure these happen quickly and making smart decisions all along in the process.
- **Troubleshooting:** This may happen before or after a corrective action, but it's the human who is uniquely capable of working through routines to determine what went wrong and why to install a permanent change that eliminates the possibility of this happening again.
- **Safety:** If you imagine a world with a lot more robots and automation, there are a lot more ways to potential get injured. Humans can uniquely identify potential safety issues and eliminate them. Safety may also soon take on a broader definition as well, when you have multi-million-dollar robots rolling across the factory floor. We will all have a vested interest in keeping them "safe," too.
- **Quality:** Robots can detect anomalies with cameras and sensors, but they have no notion of what actual quality is. They aren't judging the fitness for purpose of an object, but rather only some characteristic that it can measure. This will be an incomplete notion of quality for some time. Even if the quality of every component of an item, like a farm tractor, could be measured as it is being produced, the understanding of the system as a whole – the tractor – functions as intended is generally a judgement only humans can make.

Moving forward, one of the critical decisions that manufacturing leaders must make is how they will organize their own teams to design their futures. Every company should be gathering complete data on their work processes to determine when and where automation will make sense. Some obvious findings will emerge – like my belief that most bench assembly work is ripe for robots.

As part of this, manufacturers need to design the jobs of the future. They must carefully consider where they can leverage the full potential of humans and turn them into robot masters, and design the support systems that will help them best work with each other and with the increasingly sophisticated machines around them.

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*Ken Pulverman is the chief marketing officer of Parsable, which provides mobile process execution and measurement technology via mobile devices to help manufacturers—including advanced manufacturers—make complex processes simple. The goal: to modernize work to attract new talent, execute complex work more precisely and rapidly and continuously improve work processes.*

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