



Robotic Industries Association

Collaborative Robots

End User Industry Insights

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Collaborative Robots: End User Industry Insights

The field of collaborative robots is currently the hottest area of interest within the robotics industry, and with good reason. The notion that humans can now work safely, side by side with a robot employee is both intriguing and groundbreaking. The recent interest in this field has paved the way for many informational articles examining collaborative robot technologies that exist in the market today. From a business perspective, however, there is still much to be discovered.

The purpose of this paper is to provide insight into some lingering questions surrounding the business case for collaborative robots and their functionality:

Which industries are most conducive for collaborative robot operation?

What features are most important to end users of collaborative robots?

Will collaborative robots replace traditional industrial robots?

What are the motivations behind design decisions of collaborative robot manufacturers?

Are collaborative robots the right choice for my business?

To answer these questions, RIA interviewed decision makers at end user companies in a variety of industries including aerospace, automotive, electronics, life sciences, and plastics. Due to the sensitive nature of their collaborative robot projects, however, these companies have requested to remain anonymous. In order to understand both sides of this industry, RIA also interviewed technical experts from leading robot manufacturers.

This two-pronged research approach has generated insights of interest to both end users and robot manufacturers alike.

Aerospace

Automation is growing very rapidly in the aerospace industry, which is leading to many opportunities for robot manufacturers. This industry is also one of the most demanding in terms of robotic payloads. End users in aerospace often find themselves working with large, heavy parts. Because of this, safety-rated monitored stop applications have emerged as one of the most common types of collaborative robot operations. For these types of applications, many end users are making use of traditional, high-payload robots (ABB, KUKA, FANUC, etc.) complete with sensors and safety equipment.

In a recent interview with RIA, an aerospace executive described an example of a safety-rated monitored stop collaborative robot application:

“During a robotic process, a worker can step into the workspace and clean or wipe off a part. Then, leave the space and press a button, for the process to resume. The entire system doesn’t have to be shut down completely for the interim cleaning task.”

Some aerospace users are also employing safety-rated soft axis and space limiting operations. This optional feature, available on newer robots, may have different names depending on the robot manufacturer, but the functionality remains the same. Safety-rated software is used to control the robot motion so that restricted space can be more flexibly designed. Case studies have shown that that this saves both floor space and cost in the system design.

Despite the high payload demands, power and force limiting robots (PFLRs) are also finding their niche in this industry. A number of users have already deployed Baxter (Rethink Robotics) and UR (Universal Robots), just not for the heavy-duty industrial applications.

The main reason users haven't adopted as many PFLRs is the lack of available applications, not price:

“Those (PFLRs) are suited for the small pick-and-place type of applications and we just haven't had that many applications to apply them,” an end user told RIA. “Price is not a primary factor.”

Instead, these robots are deployed for development work and other new areas. For example, Baxter robots are currently being deployed in this industry to test applications to reduce ergonomic issues associated with workers performing repetitive motions.



1. Courtesy of Universal Robots

In the past, end users in aerospace were unable to apply as much automation as they wanted because the technology wasn't advanced enough and systems were too difficult to develop. Now, with offline programming capability and increased machine accuracy, as well as the need to remain competitive in the current economic environment, everything is coming together.

Collaborative robots are certainly finding their place in the aerospace industry, but the need for humans isn't going away. All of our interview participants were quick to dispel the misconception that collaborative robots are coming to take human jobs. Instead, they suggest, we need to view them for what they are, productivity enhancing tools for humans to use.

A leading aerospace company elaborated on this need for collaborative human-robot interaction (HRI):

“We have been very successful in applying robots to small subassembly kinds of operations. But when you start getting into much larger parts, you have a stronger requirement for human and robot interaction, more-so than you might have in an automotive plant. You can't fully automate all the processes. There are a lot of manual technical operations that still have to be done. So you would like to do those with people nearby and have the capability to know where somebody is and safely operate in that environment. It's not practical to have all the fencing around.”

The lack of a need for rigid safety fencing is a feature of collaborative robots that many in this industry value and it factors strongly into the purchasing decision.

Some aerospace users primarily employ collaborative robots to increase efficiency and reduce chronic injuries. To achieve this, risk assessments and testing are of utmost importance. After the due diligence, collaborative robots have given operators great benefits by relieving them of tedious work and raising them to a higher status, technician level, with more responsibility and even a higher pay grade.

Despite their early adoption of collaborative robot technology, many in this industry would like to see more functionality in future generations of collaborative robots. It is clear that users would like their employees to have the ability to work closely with robots, however many companies cannot yet achieve this on a grand scale. For safety reasons, these companies would first need to see the development of better people-detection systems on the robots. Real-time 3D space monitoring and the need for better force sensing and control are also desired by some in this industry.

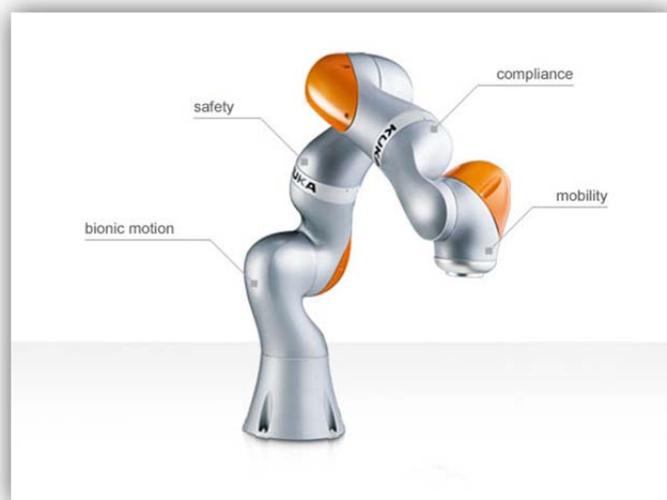
A cultural acceptance of collaborative robots is growing in the aerospace industry, which could spur growth of HRI applications. Along the way, special training and tightly controlled processes will be commonplace where any HRI operation is implemented.

Automotive

The automotive industry has been the single largest driver of the robotics industry worldwide for decades. Today, automotive OEMs, as well as tier suppliers are making use of new collaborative robot technologies. Below we will examine some applications in which automotive users are deploying collaborative robots, as well as their desires for the technology in the future.

Similar to the aerospace industry, many current applications of collaborative robots in automotive applications are for ergonomic issues, meaning the robots are often taking over dull, dirty and dangerous jobs. Quality, however, is also of great importance. In a majority of cases, a collaborative robot can control its forces better than a human, and therefore be more consistent.

Traditional robot installations with safety fences are fixed points of production and require significant rescheduling for different automotive models. The relative inflexibility of these traditional cells often leads to increased costs (both in time and money) when users need to move or repurpose them. Power and force limiting robots allow them to move the robot to new positions in 1-2 hours and continue production. Saving on cost of production downtime and reducing the needed floor space are valuable benefits of collaborative robots to some



2. Courtesy of KUKA Robotics Corporation

automotive users. Another popular form of HRI is intelligent lift assist robots. Complete with servomotors, they are used for hand guiding large or difficult to handle parts.

The deterrent for some automotive users with regard to newer, highly publicized, PFLR type collaborative robots (Baxter, UR, etc.) has been the cost and availability relative to the overall capability of the machines:

“Light-duty payloads, fairly slow, and pretty expensive,” remarked an automotive OEM. Since the price point and overall capability of these machines are still limited, many end users are waiting to see what each robot manufacturer’s response is to these newer models. “It (collaborative robotics) is a very fascinating, exciting emerging field, but somebody will have to take a larger step for it to be practical for people like us (automotive OEMs) to embrace and start running with it.”

In applications where collaborative robots are already in use, however, human workers have reacted to them positively:

“It’s a boring and dull job that the robot is doing and they (human employees) are happy to look forward to doing other jobs. We’re not destroying jobs. We’re shifting them to more interesting applications.”

Currently many of the collaborative PFLRs being installed by automotive users have a limited 10 kg payload. This is a problem for many users, who would like to see that payload ceiling increase to 30 kg at a minimum. Some automotive OEMs are actively supporting research in that direction.

A number of automotive users are also interested in more user-friendly interfaces for controlling and programming collaborative robots. For instance, with Baxter’s LCD face, they would like to see the ability to communicate across assembly lines or with other robots.

Coupled with the features above, lightweight, easily portable, and modular collaborative robots that can be assembled in 1-3 hours would be ideal for some automotive users. Additionally, this industry is hungry for open source software, such as the Robot Operating System (ROS).

In many cases, mainstream automotive OEMs are looking for “full-proof” tried and true solutions. The uncertainty surrounding safety standards for collaborative robots is something automotive users are keeping their eye on:



3. Courtesy of FANUC America

“The industry needs something very prescriptive in terms of what is really allowed, and in the meantime it’s going to be on a slow, case-by-case basis,” according to a leading automotive OEM. “Having real definitive, prescriptive specifications that say this is what the machine does and can do, and you can validate that, I think that’s pretty important.”

When asked about the PFLRs like Rethink’s Baxter and Universal’s UR, they went on to express both the advantages and disadvantages they see with the technology:

“That’s the beauty of a limited-capability machine, because it moves so slow and produces so little force; you don’t have to worry about somebody getting hurt. So that’s one approach. The other approach is that you still have to be efficient in your operations. You have to be able to pick stuff up and be able to move it at a reasonable speed, in a reasonable distance, to actually fit into your overall manufacturing process.”

Electronics

The demands of the electronics industry are markedly different than the aerospace and automotive industries. Processes that electronics manufacturers would like to automate include creating circuit boards, final assembly applications, inserting parts into injection moldings, metal stamping, and numerous other CNC processes. In order to be automated effectively, these processes require a great deal of flexibility, precision, and speed out of a robot system. Today’s collaborative PFLRs are not precise enough yet for these operations.



4. Courtesy of ABB Robotics

Electronic manufacturing processes are, in many cases, less demanding from a payload perspective than those in aerospace or automotive. As a result, some electronics companies are more motivated by factors such as ROI (price), small footprints, and the ability to omit safety fencing when it comes to collaborative robots.

Take for instance, a circuit board assembly line – At the end of the line, someone needs to remove the circuit board from the conveyor and load it into different test stations, and then based on the

performance of that test, it goes to another conveyor belt. This is a great application for PFLRs. Users can deploy a PFLR for 20-30 percent of the total cost of deployment of a traditional robot for these tasks.

Some also noted that the more sophisticated PFLRs being offered by traditional robot manufacturers are “legitimately performing robots” but the price point is too high, so they can’t use them:

“Normally, a robot is a quarter or less of the total installed cost, so if you buy a \$20,000 robot, it’s hard to integrate it for less than \$80,000 or \$100,000. The best-case scenario might be \$50,000.” – Worldwide Electronics Manufacturer

For a traditional robot system, there is a great deal of fixturing and tooling necessary for any given application. Since some electronics companies need to frequently augment their automation around new products, a problem arises when they need to redeploy these traditional robot cells, an end user told RIA:

“We may only get 30% of the cost back after redeployment. The other 70% is lost because it was targeted at the original application.”

On the other hand, electronics companies can buy a PFLR for approximately \$25,000 and deploy it for another \$10,000. Then if they want to move it to a new application, they may only need to spend another \$5,000 to \$10,000 for redeployment. In most cases, the selling point for these companies is centered on this fact, where the majority of the value invested in a collaborative robot system is easily reusable.

The PFLRs of today can already be found in these factories doing material handling and machine loading/unloading applications. Some companies in this industry would like to see marked increases in precision for future generations of collaborative robots. Users are intrigued at the possibility of using a PFLR collaborative robot in process applications like assembly once the robots are advanced enough, but until then, plan to look into other forms of collaborative operation (such as speed and separation monitoring with traditional robots plus sensors).

As electronics companies are installing collaborative robots, they are finding more interesting and important work for their human employees. Many employees are excited to accept their new roles in less dangerous and monotonous jobs. In some companies, there is modest safety training for employees working near these robots.

Most agree, however, that collaborative robots are already easy to setup and use.

In some instances, companies use safety technologies like light curtains with collaborative robots. This is usually the case if the robot is moving at higher speeds, or handling certain kinds of parts. In electronics, there exist a number of cases where the design of the work process itself is a key safety feature. In these situations, work cells are configured in such a way to contain the robot's motions and prevent people from easily entering the work envelope.

Assembly is an important area in the electronics industry, but one that hasn't been effectively penetrated yet by collaborative robots. This is due to the lack of capability in the machines themselves, and the high cost of custom feeders and tooling. Technology like machine vision is helping make collaborative robots more functional, but not at a pace that will change users' employment of them yet. For new application areas in the electronics industry to open up for collaborative robots, users need to first see better vision, better feeders, and better dexterity.



5. Courtesy of Rethink Robotics

Adding this functionality while keeping the price points low will surely prove to be a challenge for collaborative robot manufacturers. Even then, while increased functionality is important, some electronics manufacturers are still motivated most by ROI:

“The fact that we can deploy a robot cell for say \$35,000 is really, by and large, the enabler for us to use these robots (referring to PFLRs). It’s not that they are bringing new capabilities to the table, or that they are expanding the realm of applications that robots can be useful, because no one is really addressing the application issues at the moment.”

Life Sciences

In addition to downstream material handling processes, collaborative robots are finding their way into laboratories and other life sciences applications. Today, collaborative robots are employed in applications such as handling microtiter well plates, drug discovery, prescription preparation, and automating research in disease compounds. Robots in general have been in use in laboratories for years, just not in a collaborative sense.

That is not the case anymore, as collaborative robots are working their way into a number of life sciences applications, like lab automation. Collaborative SCARA-type robots in laboratories can now follow up on the large-scale screening activities of traditional, higher payload robots. Before, this process would have been handed off to human researchers to do manually. Collaborative robots are bridging these processes.

Some end users report one of the key reasons for adopting collaborative robots is to eliminate safeguarding and promote easier interaction between scientists and robots.

“That really helps with the interaction and making these systems work well. As soon as you put up guarding, then the only people that interact with them (the robots) are the specialized operators.”

While larger, traditional robotic systems require trained engineers or technical biologists to operate, collaborative robots are less intimidating. The ability for anyone to walk up and use them is a draw for some end users:



6. Courtesy of Adept Technology

“The idea with the collaborative robots is that with a little bit of training, any scientist in the organization can come up and use them.”

Despite the non-intimidating nature of collaborative robots, the market still needs more education on the safety and functionality of these machines. Some engineers in the life sciences industry have voiced resistance to installing collaborative robots, citing their lack of reliability and precision. What the engineers often don’t understand at the outset is that while collaborative robots aren’t as reliable or precise as traditional robots that process thousands of plates per day and run 24/7, that’s not their intended purpose.

Many of these companies have actually reported productivity increases after the installation of one or more collaborative robots.

Mobile robots, like Adept's LYNX robot, are also helping to reduce contamination risks to human biologists. These autonomous indoor vehicles can collect fluids and cultures with a greater level of repeatability and safety than their human counterparts. Outside the laboratory, collaborative robots are also helping pharmaceutical companies sort and package their products.

These types of applications will only continue to grow as collaborative robots get smarter and more capable. Looking ahead, many companies in the life sciences industry would like to see the programming aspect of these collaborative robots get even easier. It is important for all of their employees, technically trained or not, to be able to feel comfortable programming and using collaborative robots.

Plastics

Robotics and automation in the plastics industry have been growing in recent years, and collaborative robots are successfully carving their niche. One style of traditional robot used by plastics manufacturers (for consumer products) is 3 to 7 axis cartesian robots. These robots are often installed on top of injection molding machines and tasked with removing plastic parts to either package or stack. This system allow



7. Courtesy of Nachi Robotic Systems

for hands-off molding, where the product comes directly out of a mold and into a box. While common, this application is not collaborative in any sense, as the robots need guarding and safety switches present.

Since the main molding operations are delegated to traditional robots, collaborative robots have instead made inroads into this industry by mastering downstream processes, such as packing parts in boxes. In some instances, dual-arm PFLRs are used by plastics companies to pick parts off conveyors and place them in boxes for final packaging.

With quality control inspectors working around the robots very closely, it is imperative that they operate safely. Some end users report that their robots can safely pack and inspect parts 24/7, while human workers check in periodically to make sure the parts and design are satisfactory. Since the robot's motion is very repetitive, and not ideal for human work, many employees displaced by them in this are happier in their new roles:

“All of our robots (including Baxter) were received very well by our employees because they saw the growth potential in the company and how strong it's made us over the past 6 or 7 years where we've bought robots, sometimes 10 at a time. We've also stuck to our belief that having robotics does not take people's jobs away. It makes more jobs. It gives people a chance to learn the new technology and take away the more mundane tasks like taping boxes and grunt work, and perhaps handling parts that are hot, or perhaps having to wear ear

plugs in an area, where Baxter doesn't. So those people can move onto more interesting jobs.” – Worldwide Plastics Manufacturer

While PFLR collaborative robots are currently used primarily for downstream processes, end users are hopeful that software and hardware updates will allow for more future capabilities. Much like the life sciences industry, end users in the plastics industry are attracted to the ease of programming collaborative robots:

“The idea is to avoid downtime. Anything that makes programming and installing the robot quicker will help us justify installing more of them [collaborative robots].”

While Baxter and Universal Robots are already relatively easy to program, traditional robot manufacturers (ABB, FANUC, KUKA, etc.) are also focusing on providing more intuitive interfaces for their collaborative robot systems.

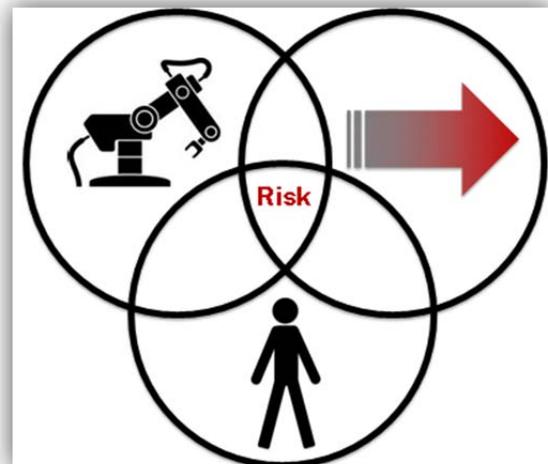
For its main manufacturing processes, it is likely that the plastics industry will adopt other forms of collaborative robot operation in place of PFLRs. Due to the high throughput and speed of these applications, many users will find that speed and separation monitoring is a more effective approach. In this type of operation, traditional robots can be combined with a suite of sensors or light curtains to provide a safe work envelope without sacrificing efficiency. Along the way, the highly visible PLFR collaborative robots will likely continue to carve a niche in downstream material handling applications.

Opinions of Collaborative Robot Manufacturers

Safety is Top Priority

Amidst all design decisions that go into manufacturing a collaborative robot, the one feature that is unanimously agreed upon is that the technology needs to be safe. While there is widespread agreement that collaborative robots need to be safe, how to go about achieving that is a hot point of contention.

Erik Nieves, Technology Director at Yaskawa Motoman, spoke with RIA about a number of complex variables that factor into the safety of a collaborative robot. First of all, manufacturers must consider whether or not there will be human contact in the application. If the answer is yes, then PFLRs would be an appropriate choice for that application, as they are designed to limit the amount of damage they could do to a human worker if they ever made contact. If the answer is no, then a collaborative robot operation can be achieved with traditional robots using sensors, laser scanners, or light curtains to slow or stop the robot when there is imminent human contact. The latter is more appealing to users who are interested in maximizing their efficiency in a human-robot environment, as the traditional robots often have higher payloads and faster speeds.



Take the automotive industry, for example. While the body shop world is mature with automation, the final assembly world is not. Mr. Nieves told RIA that while these final assembly jobs are suited for automation, the technology just isn't there yet. With the recent growth and investment in robotic technology, five years down the road he could see that changing.

Types of Collaborative Robots and Application Considerations

Recently, power and force limiting robots (PFLRs) like Baxter and Universal Robots have garnered the most publicity when it comes to the term “collaborative robot,” but there are other types as well. Below is a summary of the types of collaborative robots and applicable applications:

- **Power and Force Limiting** - Where incidental contact initiated by robot is limited in energy to not cause operator harm
 - Forces robot can exert are limited
 - Robot system design eliminates pinch points, sharp edges, etc.
 - Robot complies and reacts when contact is made
 - Applications
 - Small or highly variable applications
 - Conditions requiring frequent operator presence
 - Machine tending
 - Loading/unloading
- **Hand Guiding** - Where an operator leads robot movement through direct interface
 - Robot stops when operator arrives (safety-rated monitored stop)
 - Operator grasps enabling device, activating motion
 - Robot motion responds to operator commands
 - Non-collaborative operation resumes when operator leaves collaborative workspace
 - Applications
 - Robotic lift assist
 - Highly variable applications
 - Limited or small-batch productions
- **Speed and Separation Monitoring** - Where the robot speed reduces when an obstruction is detected
 - Separation distances are monitored (scanners, vision systems, proximity sensors)
 - Robot speed directly correlates to separation distance—zones dictate allowable speed
 - Stop condition given if direct contact proximity is attained (Safety-rated monitored stop)
 - Applications
 - Simultaneous tasks
 - Direct operator interface
- **Safety Rated Monitored Stop** - What the collaborative robot does in the presence of an operator or obstruction
 - Stop-motion condition ensured
 - Drive power remains on
 - Motion resumes after obstruction clears
 - Robot motion resumes without additional action
 - Protective stop delivered if stop condition is violated

- Applications
 - Direct part loading or unloading
 - Work-in-process inspections
 - Speed and separation monitoring – standstill function

While companies such as Rethink Robotics and Universal Robots have developed power and force limiting robots, traditional robot manufacturers like ABB, KUKA, FANUC, Nachi, and Yaskawa Motoman are investing primarily in other forms of collaborative robotics.

At the end of the day, it will depend on a given user's application to determine which collaborative robot is right for them. In the life sciences industry, for example, companies are very concerned with safety and ease of use. Precise Automation's PF400 collaborative robot was originally designed and targeted for the life sciences industry.



8. Courtesy of Precise Automation

Jim Shimano is Program Director with Precise Automation, and in a recent discussion with RIA, explained the motivations behind their design. "Precise's PF400 robot was intrinsically designed to be safe," he said. "By including components like low gear ratio, fully back-drivable motors into our design, the PF400 achieves power and force limiting through design, not control." Mr. Shimano remarked about how the PF400 isn't meant to replace high-payload, super-fast, traditional robots, but rather complement them. Precise Automation has found success in both life sciences and electronics with their PF400, and is always researching new opportunities.

Mobility is a feature of collaborative robots that is intriguing to many users. Terry Hannon, Chief Business Development and Strategy Officer for Adept talked to RIA about their LYNX robot, a truly autonomous intelligent vehicle or AIV. Simply put, the LYNX consists of a mobile base, with a 4-axis robot on top, and can move from work station to work station in factories, warehouses, or laboratories. What makes the LYNX unique is Adept's focus on eliminating the need for infrastructure guidance systems, like floor markings or navigational beacons. Today, customers in the life sciences, electronics, and semiconductor industries appreciate the flexibility of the LYNX in their facilities. The features Adept is focusing most on in their development of the LYNX and other collaborative robot technologies are ease of use, mobility, and speed.

The collaborative robot movement is also impacting the end effector industry. Samuel Bouchard is President of Robotiq, a manufacturer of flexible robot grippers, and he believes there is a lot of potential for this growing market. Bouchard told RIA that because of smaller payloads and less repeatability, collaborative robots are easier on tooling. Collaborative robot grippers also need to be more flexible than traditional grippers due to the likelihood they'll be repurposed. Of course, safety is also top of mind for Robotiq, as with the rest of the industry. Mr. Bouchard sees the possibility of widespread adoption of

collaborative robots, but thinks it will take some time. In the interim, Robotiq plans to continue manufacturing innovative end effector solutions for the collaborative robots of today.

Conclusion

Collaborative robotics certainly has a promising future, but there are still challenges that need to be overcome. In aerospace and automotive, for example, many users would like collaborative robots to have higher payloads and faster speeds, while some life sciences and plastics users instead desire easier programming and increased precision. Further, in the electronics industry, ROI and total cost of deployment seem to be the most important factors for a number of users.

Robot manufacturers are developing different types of collaborative robots in order to address those needs. Power and force limiting robots (PFLRs) are often thought of as “the face” of collaborative robotics, with companies like Rethink Robotics and Universal Robots receiving a lot of recent publicity, but they do not represent the only form of collaborative robot operation. There is also hand guiding, speed and separation monitoring, and safety rated monitored stop for end users to consider.

If there are two things that end users and manufacturers agree upon, it's the need for robust safety standards and educational programs to further the understanding of collaborative robots. This is already starting to take shape with the ANSI/RIA R15.06-2012 standard, the ISO/TS 15066 standard, and the International Collaborative Robot Workshop events. This is a growing field that offers many new possibilities for manufacturing in a number of industries. The ability for humans to work safely alongside robots holds the potential to transform workplaces around the globe.

