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Robotics, Automation, and AI:
Explosion of New Markets Across Broad Segments of the Economy

Contents

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Investment Overview

The migration of robotics, automation, and artificial intelligence (RAAI) technology outside the factory floor and into myriad new market applications began a decade ago but really accelerated in the last five years beginning in about 2015. Key insights from this report include:

1. ***What caused the RAAI revolution?*** Dramatic declines in the cost and functionality of critical sensors, along with the emergence of more standardized operating software, made applying RAAI technologies to new markets inside—but especially outside—the factory floor increasingly feasible and economically compelling. Rising labor shortages spawned the emergence of collaborative robots (cobots) in factories, while the accelerating shift to online retailing has created new markets in which to deploy RAAI technologies, such as distribution warehouse automation. The advent of autonomous mobile robots (AMRs) has expanded the use of autonomous guided vehicles (AGVs) to automate movement of products in both factories and warehouses.

2. ***How are RAAI technologies deployed?*** AMR functionality is controlled by increasingly standardized embedded operating software. AMR coordination is achieved by orchestration software that synchronizes the operation of multiple AMRs for product movement, order picking, and inventory replenishment. In factories, the speed of cobot operation was initially constrained by cobots' lack of situational awareness to avoid injuring workers, but still enabled manufacturers to expand their production. The imminent introduction of advanced machine vision is expected to enable cobot speed to markedly increase without jeopardizing the safety of adjacent workers.

3. ***Key next RAAI-enabling technologies include 3-D vision and 5G wireless.*** The emergence of advanced machine vision is now on the cusp of creating a new generation of cobots that use cameras, LIDAR, and infrared sensors to enable faster but safe collaborative applications, unleashing a new wave of productivity gains. Vision-guided robots (VGRs) are highly adaptable to dynamic operating environments by soon (late 2020/early 2021) combining safety certified 2-D and 3-D vision hardware with sophisticated software and large computing power to process immense quantities of visual data in real time. Advanced VGRs use algorithms to enable precision controlled movement. Fully functional 5G wireless with nominal latency, real-time speed, and vastly faster transmission rates will link robotic devices with real-time computing to enable fully dynamic integrated performance functionality. When fully operational in perhaps three to five years, 5G is expected to enable broader deployment of autonomous RAAI technologies in unstructured environments such as outdoors. Currently, most commercially viable autonomous RAAI technology applications have occurred in more structured indoor environments. Much like real-time wireless video streaming created the last buildout wave of cloud computing (often in remotely located data centers), 5G could spawn the emergence of localized micro-data centers to process the expected explosion in real-time data processing.

4. ***Critical RAAI hurdles and constraints that are likely to determine RAAI company end-game strategy.*** Once a new RAAI market has become commercially established and proved, the largest challenge for smaller private companies is the ability to fund aftermarket support infrastructure. We believe the elevated aftermarket support infrastructure investment is likely to result in most RAAI companies being acquired by private equity or larger established industrial companies with established aftermarket service networks rather than going public.

5. ***Key emerging new RAAI markets.*** Several new commercially viable applications of RAAI technologies have been created over the past five years, including cobots and AGVs for automated manufacturing, distribution warehouse automation, autonomous robotic indoor security and guarding, automated online grocery order fulfillment, recycling automation, industrial and commercial AMR floor care, and AMR cleaning for hazardous industrial environments.

Exhibit 1
Robotics, Automation, and Artificial Intelligence (RAAI)
New Derivative Industrial RAAI Markets

Market	Market Status	5-Year Market CAGR
Distribution Warehouse Automation	Established	~15%-20%
Recycling Automation	Accelerating	~10%-12%
Cobots and AGVs for Automated Manufacturing	Accelerating	~15%-20%
Online Grocery Fulfillment	Rapidly Emerging	~100%+
Guarding and Robotic Security Automation	Emerging	~8%-10%
Industrial and Commercial Floor Care AMRs	Emerging	~20%-25%
AMR Cleaning for Hazardous Industrial Environments	Emerging	~8%-10%
Automated Commercial Space Vehicle Construction	Nascent	~5%-10%

Source: William Blair estimates

Potential Winners and Losers From Commercialization of RAAI Technologies

A usual area of focus as new disruptive technologies emerge is whether software or hardware will emerge as the critical value driver and over time provide and capture the majority of the value created by the commercialization of new RAAI technologies. Currently, most developers of new products, systems, and solutions using RAAI technologies have tended to internally develop their own operating software that they then combined with off-the-shelf, lower-cost components to create discrete robotic solutions. The current market focus is to develop fully functional but safe stationary or mobile robotic devices that can operate autonomously. Low-cost LIDAR, infrared, and other sensors that enable autonomous operation have required core mobility functions to be processed onboard because of the data lag (still elevated latency) inherent in all current cloud computing.

In the future, however, deployment of fully functional 5G cellular is expected to enable autonomous robots to process information on a real-time basis in highly unstructured or variable environments. We anticipate this will create a next generation of devices that can operate in highly dynamic outdoor environments versus today's primary focus on structured (typically indoor) locales. Fully functional 5G is expected to enable functions such as real-time data collection, object identification, and global path planning optimization for a connected set of devices that today typically operate autonomously. Ultimately, the ability to dynamically capture and process data on a real-time basis is likely to create a large increase in the coordinated functionality for multiple types of real-time connected devices.

We are aware of only one company, Brain Corporation, that has attempted to develop standardized operating software to enable autonomous mobile robotic operation of traditionally human-operated equipment (for commercial floor equipment manufacturers). In other cases, the critical technology to transform the functionality of existing devices (such as safe high-speed operation) like cobots has been developed separately and sold independently to cobot manufacturers. A similar interim safety solution, infrared light walls, was developed for traditional "caged" production robots that lacked situational awareness vision systems, making them safer to operate near production employees. Therefore, in some cases the RAAI technology and software solutions are sold to existing device manufacturers, while in other situations where no previous large installed base existed (such as robotic recycling equipment), RAAI technology solutions are being sold on an integrated turnkey basis.

Commercialization of new technologies is typically disruptive to existing market participants. There are likely to be numerous existing direct and indirect participants operating in or adjacent to new RAAI technology markets that could benefit, while others could be handicapped or even potentially displaced. We have attempted to highlight some of the potential established, accelerating, and emerging market segments that are commercially deploying new RAAI technology solutions that could positively or negatively effect existing end-market participants.

Exhibit 2
Robotics, Automation, and Artificial Intelligence (RAAI)
Commercialization of RAAI Technologies

	Advantaged	Disadvantaged
Distribution Warehouse Automation	Class-6 Delivery Truck Manufacturers Fulfillment Solutions Providers	Class-8 Heavy Duty Truck Manufacturers
Recycling Automation	Synthetic Fabric Providers Plastic Bottle Baler Producers	Landfill Operators
Cobots and AGVs	IT Training Companies High-Speed Vision Systems Providers	Forklift Manufacturers
Online Grocery Fulfillment	High Density Urban Grocers Last-Mile Delivery Services	Small Grocers Meal Delivery Plan Services
Guarding and Robotic Security Automation	Large Contract Security Guarding	Small Contract Security Guarding Security Guard Equipment Suppliers
Industrial and Commercial Floor Care AMRs	Large Commercial and Industrial Floor Cleaning Equipment Manufacturers	Commercial Janitorial Services

Source: William Blair

Distribution warehouse automation. The largest driver of warehouse automation is the rise of online retailing and the growing shortage of warehouse distribution workers. The desire for ever-shorter order-to-delivery times has resulted in a rapid increase in the number of distribution warehouses operated by leading online retailers. In 2015, five-day delivery was standard; in 2019, it moved to two days. We estimate that by 2023, one-day could become standard, and by mid-decade same-day delivery could become the norm. As a result, distribution warehouses to serve the United States are mushrooming from regional to urban, and in the future, this could move to local and even ultra-local. We believe the likely beneficiaries of the localization of U.S. distribution facilities will include electric Class 6 (and eventually electric Class 7) delivery trucks, most likely at the expense of larger traditional Class 8 diesel truck manufacturers, including Freightliner Trucks, Western Star Trucks, Peterbilt, Kenworth Trucks, International Trucks, AB Volvo, and Mack Trucks.

While most traditional truck manufacturers are working to develop electrical-powered Class 8 alternatives, we believe the shift to smaller, shorter-distance electric delivery trucks is likely over time to at best restrain the growth of large Class 7 diesel trucks and potentially result in a decline in the installed base of large Class 8 diesel trucks. Cummins Inc. anticipates modest growth from 2018 through 2030 in the North American installed base of Class 8 diesel truck engines, with the majority of the growth coming from natural gas and a little from electric Class 8 trucks. Rising sustainability concerns and tightening local regulations favoring electric delivery vehicles are accelerating the shift to Class 6 electric vans from Mercedes-Benz and start-up electric vehicle producer Rivian. In September 2019, Amazon ordered 100,000 Rivian electric delivery vans targeted to begin initially entering service starting in 2021. In January 2020, United Parcel Service ordered 10,000 electric delivery vans from Arrival. Federal Express has been using electric delivery vehicles since 2009, and in November 2018 ordered 1,000 Chanje electric delivery trucks.

Another likely set of beneficiaries from the trend to increasingly local automated distribution warehouses to be last mile is fulfillment companies. In September 2019, William Blair senior analysts Matt Pfau (SaaS), Ryan Merkel (specialty distribution), and Dylan Carden (consumer technology and specialty retail) published a detailed report, Where's My Delivery? Investment in Fulfillment Technologies on the Rise as Consumers Demand Quicker Deliveries, on fulfillment technologies. The report provides an insightful discussion on e-commerce, fulfillment and last-mile delivery,

distribution warehouses, and on-demand warehouse providers, which are all likely to be material beneficiaries of increasingly localized automated warehouse distribution centers. Please see page 21 for a more in-depth look into the distribution warehouse automation space.

Recycling automation. The largest driver of automated sorting and recycling processing is the need to improve the economics associated with recovering and converting inorganic post-consumer waste. This has been augmented by a growing shortage of labor, increasing safety requirements, and the rising standards for improved quality and purity of recycled waste. The decision by China beginning in 2018 to reduce (and soon likely ban starting in 2021) the import of mixed office paper, 24 types of plastic, and other solid waste material has accentuated the deteriorating economics for post-consumer inorganic waste recycling. China's "National Sword" policy, enacted in January 2018, banned the import of most plastics and other materials by China's recycling processors, which reprocessed nearly half of the world's recyclable waste for the past quarter century. The policy bans various plastic, paper, and solid waste, including plastics such as PET, PE, PVC, and PS. It also sets a much tougher standard on the limit of contamination in scrap plastic and other metals, increasing mandated purity thresholds for imported waste from 90%-95% to 99.5%. As a result, the ability to automate the identification, accurate sorting, and processing of material streams for material recovery and recycling facilities is critical to restoring the economics of recycling.

One sector that is likely to benefit from automated recycling will be producers of synthetic fabrics as the cost of recycled PET feedstock for production of synthetic fabric comes down with the growing use of automated waste sorting equipment. Key producers of synthetic fabric from recycled inorganic waste include Unifi, Pure Waste Textiles, Poole Company, Miller Waste Mills, Greenblue, PolyQuest, Diyou Fibre, Loop Industries, and Waddington Group. Another possible beneficiary may be producers of plastic bottle balers that shred, compact, and band recyclable plastic bottles at collection points for transport to recycling centers. Leading producers of recyclable balers including Kadant, Harris, Voss, Maren Engineering Corporation, International Bailer Corporation, Action Compaction Equipment, BE Equipment, and ACE Equipment. As a rising percentage of the inorganic post-consumer waste stream is able to be recycled cost-effectively, this could reduce volumes at landfill operators such as Waste Management, Republic Services, Inc., Clean Harbors, Stericycle, Inc., Progressive Waste Solutions Ltd., Waste Connections Inc., Covanta Energy Corporation, Advanced Disposal Services LLC, Recology Inc., and Rumpke Consolidated Companies, Inc. It should also help reduce plastic pollution in the world's oceans. Please see page 74 for a more in-depth look into the recycling automation subsegment.

Cobots and AGVs for automated manufacturing. The introduction of cobots that could safely work alongside production workers became increasingly prevalent about the middle of last decade. At a time of growing shortages of skilled production workers, cobots effectively provided a way for manufacturers to increase production without expanding their employee base. Likely winners will be companies that help "upskill" and "reskill" workers to become more capable in an increasingly digital economy. The Manufacturing Institute expects manufacturers will spend $26.2 billion on internal and external training initiatives for new and existing employees in 2020 to try to overcome the top challenge for manufacturers since early 2018 of a the growing shortage of skilled production workers. In the United States, there are more unfilled job openings than there are unemployed Americans. It has been estimated that as many as one-third of American workers will need new skills or have to switch occupations by 2030, in part because of the rapid rise of AI, machine learning, and automation. While many companies in the past have funded free college courses as a benefit and offered professional training courses in specific disciplines, today the need to offer enhanced training is critical to a company's ability to attract and retain a productive and committed workforce. In August 2019, the Business Roundtable acknowledged that employers must not only compensate employees fairly, but also support them through training and education that helps them develop new skills in a rapidly changing world.

In essence, the rapid deployment of cobots is just one of several catalysts that is beyond the growing need of corporations—both manufacturers and service companies—to evolve and enhance their employees' digital skills to enable their work to be more productive and meaningful. Amazon is investing $700 million to upskill 100,000 of its U.S. employees by 2025 for skills such as machine learning, coding, and software development. Top IT training companies include New Horizons Computer Learning Centers, LearnQuest, NIIT Learning Solutions Ltd., Global Knowledge, Pluralsight, O'Reilly Media, Skillsoft Limited, Learning Tree International, The Training Associates, ROI Training, Udemy, Inc., TechData Corporation, Infosec Inc., GP Strategies Corporation, LinkedIn Learning, Arrow Education Services Inc., Online Consulting, Inc., Firebrand Training Ltd., CGS Enterprise Learning, Fast Lane Consulting and Education Services, Inc., Simplilearn Company, The Judge Group, DevelopIntelligence Company, and ATG Learning Academy.

A second sector expected to experience rapid growth from the commercialization is providers of advanced high-speed 2-D and 3-D vision systems. These companies provide advanced motion planning processors and software algorithms combined with real-time vision systems to allow cobots to react instantly to changes in their environment, enabling safe, collision-free motion in dynamic manufacturing environments. The incorporation of automated real-time dynamic motion control systems with cobots, once fully certified and tested by TÜV Rheinland Company (projected for late 2020 or early 2021), is expected to dramatically increase their speed of operation and, as a result, the productivity of manufacturers using cobots. Companies exclusively focused on developing dynamic motion control solutions for cobots include Mujin Incorporated, Veo Robotics, Inc., and RealTime Robotics Inc. Additional participants in the dynamic robotic motion sensor market include Rockwell Automation, Pilz GmbH & Co. KG, Sick AG, and Keyence Company.

One segment of the market that could be adversely affected by the growth of AGVs is traditional forklift manufacturers. The AGV market is shifting from lead-acid batteries to lithium-ion batteries that charge faster, typically are lighter and more compact, and have longer runtimes and a greater charging life. AGVs also operate autonomously, a major growing advantage in the face of labor scarcity for manufacturers and industrial distribution facilities. In recent years, companies in the logistics and warehousing segment have been the largest users of AGVs. Key AGV producers in the $2.0 billion (2019) global AGV market include Swisslog Holding AG; Dematic; Bastian Solutions, Inc.; Daifuku Co., Ltd.; JBT; Seegrid Corporation; Toyota Industries Corporation; Hyster-Yale Materials Handling, Inc.; Balyo; E&K Automation GmbH; Kollmorgen; KMH Fleet Solutions; Elettric80 S.P.A.; Fetch Robotics, Inc.; inVia Robotics, Inc.; Locus Robotics; Schaefer Systems International, Inc.; System Logistics Spa; and Scott. We estimate that the approximately $2 billion AGV market could grow at a HSD annual rate to perhaps $4 billion by the end of this decade, versus MSD growth for the global forklift market over the same period. Some producers participate in both the AGV and forklift market, and the global forklift market is more than 8 times the size of the worldwide AGV market. These two factors are likely to mitigate the magnitude of the impact of a shift to AGVs.

Globally there are five classes of forklift trucks, including electric rider trucks (Class 1 and Class 2), motorized hand trucks (Class 3), and internal combustion-powered trucks (Class 4 and Class 5). According to the Industrial Truck Association, from 2015 to 2018 global electric (64% of the world market) and internal combustion forklift truck sales grew 2.8% (to 260,180 units) and 2.7% (to 253,146 units), respectively. Given rising concerns about sustainability and the need to improve efficiency and reduce carbon emissions, forklift manufacturers are shifting to fuel cells for powered forklifts. Leading providers in the $17 billion (2018) global market for forklifts include Toyota Industries Corp., The KION Group, The Jungheinrich Group, Mitsubishi Logisnext, Hyster-Yale Materials Handling Inc., Crown Equipment, Anhui Heli, Komatsu, Hangcha Group, and Clark Material Handling. Please see page 65 for our analysis of the cobot and AGV markets.

Online grocery fulfillment. The percentage of grocery sales generated by online orders (both delivered to and picked up by the customer) was 6.4% of US grocery retail spending in 2019 according to GlobalData and is expected to rise to 9.7% by 2022 as consumers seek to reduce the time they spend shopping for groceries and grocery stores are becoming physically overwhelmed. The logistical congestion point for most grocery stores to shift from personal shopper to some type of automated order fulfillment system typically occurs when online sales rise to 7% or more. Therefore, most grocery stores have begun a multiyear program to construct either automated centralized (2-D) or localized in-store automated (3-D) micro-fulfillment systems. Alternatively, Amazon is using technology in its new Amazon Go Grocery stores to sharply reduce the complexity and time for shoppers still wishing to physically shop for their groceries. The aggregate investment to automate fulfillment of online grocery orders is projected to cumulatively total as much as $100 billion by 2025, according to Fabric Chief Commercial Officer Steve Hornyak in an October 2019 interview with Grocery Dive.

If correct, we believe the winners could include potentially higher sales of private-label and store brands of non-fresh foods as the impact of branded non-fresh foods wanes with customers ordering online. We believe grocery stores located in urban centers that install localized in-store automated (3-D) micro-fulfillment systems may be able to capture incremental market share due to timelier pickup or delivery of online grocery orders versus grocery stores using automated centralized (2-D) fulfillment systems. In addition, as online grocery orders continue to gain market share steadily, we believe last-mile grocery delivery companies could benefit from increased home delivery sales. These could include Peapod Online Grocer, LLC, Instacart, Target Corporation's Shipt, Amazon Fresh, VONS, and Fresh Direct LLC.

As the commercial rollout of automated robotic online grocery fulfillment systems progresses, we believe it could adversely affect smaller and less capitalized grocery stores and local grocery chains that are unable to afford the investment to automate their online grocery fulfillment. Amazon's Whole Foods, Target, Costco, and Sprouts are larger grocery stores that have not yet announced plans to shift to automated online grocery fulfillment systems. With its new Amazon Go Grocery cashier-less grocery store format (similar technology to its smaller Amazon Go but about 5 times larger), rather than automated online order fulfilment, Amazon is focused on speeding the grocery shopping process for customers who still want to come to the physical store to purchase their groceries and home supplies.

Another food-retailing category that could be adversely affected is meal delivery plan services, many of which were founded in the first part of the last decade. These companies typically deliver preportioned ingredients and recipes to subscribers on a weekly basis for easy and quick home preparation. With the emergence of online grocery shopping in the past couple of years as a logistically viable alternative to in-store grocery shopping, demand for preportioned home delivery meals is likely to decline. Included here would be Kroger Company's Home Chef, Hello Fresh SE's Green Chef and EveryPlate, Yucaipa Company LLC's Fresh & Easy, Martha & Marley Spoon's Dinnerly, Blue Apron, and Sun Basket, Inc. Please see page 35 for a more in-depth look into the online grocery fulfillment market.

Guarding and robotic security automation. While the technology used to insure perimeter and on-premises security monitoring has steadily evolved, the commercial contract guarded security market has been relatively static over the past several decades. Recent technological advancements in sensors, software, and robotic mobility and dexterity have created security AMRs that are starting to alter the $85 billion global contract security market, which is distinct from the annual market for security cameras, access controls, and monitoring systems that in 2019 totaled an estimated $100 billion annually, according to Cobalt Robotics.

The current global AMR indoor security addressable market is estimated to be $10 billion, according to Cobalt Robotics, with the outdoor security AMR market expected to become viable with the introduction of fully functional, low-latency 5G cellular networks. However, growing advances for indoor deployment of AMR security robots; broadening use of security orchestration, automation, and response (SOAR); safe cloud storage of public security data and expanding use of blockchain technology; tethered drones; cybersecurity; and AI experts are swiftly transforming the traditional guarded security market. Typically, security AMRs charge during the day and patrol during the night using as many as 60 different sensors.

Since the middle of the last decade, large contract security companies have stepped up their investments in robotics, cybersecurity, and AI, while smaller contract service companies have been slower to similarly invest in enhanced security technology. The significant investments in security AMRs, cybersecurity, and AI have accelerated the consolidation of the U.S. contract security market in recent years. In 2017, Statista and the U.S. Census Bureau estimated the US security guard and patrol services markets totaled $26.2 billion and rose to an estimated $27.7 billion in 2019.

Since security AMRs tend to be assigned dangerous, dull, and dirty patrols, robots initially have been complementary additions to contract guarding company security forces. However, we expect the workforce transformation of contract guarding services to accelerate, with fewer human security guards on patrol replaced by a rising number of cybersecurity, AI, and other advanced security technology experts. In the United States, where security AMRs and advanced security adoption rates are highest, the top contract security guarding companies include Universal Protection Service LP, Allied Universal Corp., Securitas North America AB, G4S Secure Solutions USA, U.S. Security Associates, National Security Alliance, SOS Security, Covenant Service Worldwide, Walden Security, SecurAmerica, Whelan Security, Command Security Corp., Andy Frain Services, and Universal Protection Service LP.

Another key supplier to the contract security sector that is unlikely to benefit from the market's shift to embrace technology is producers of security guard equipment supplies and consumables. Security AMRs do not need guns, holsters, uniforms, uniform badges, flashlights, two-way radios, body armor, protected guard booths, notepads and pens, guard belts, body cameras, or specialized footwear. Security guard training companies are also likely to see their mission evolve to teaching security technology experts rather than testing and training security guards. Please see page 76 for a more detailed review of the key competitors in the security robot field.

Industrial and commercial floor care AMRs. Like several other labor-intensive jobs, the estimated $62 billion U.S. market employing more than 1.9 million people for commercial janitorial services to clean retail, airports, schools and colleges, industrial warehouses, and healthcare and public facilities is now being rapidly transformed by the emergence of floor cleaning AMRs. Historically, the most important driver for commercial janitorial services has been GDP growth. These AMRs can improve the quality of cleaning, reduce the time to clean, and overcome increasingly stringent health and safety regulations governing the commercial janitorial services sector. Today's floor cleaning robots have routing algorithms, 4G LTE connectivity, proximity sensors, and cameras to ensure they operate safely, efficiently, quietly, and effectively. With labor accounting for an average 80% of the cost of commercial floor cleaning, industrial and commercial floor care AMRs have recently been deployed by Walmart, large industrial distribution warehouses, and commercial facilities such as airports to autonomously vacuum, polish, and clean floor surfaces.

The global AMR cleaning market is projected to grow at a 16% compound annual rate and rise from $2.1 billion in 2018 to $4.4 billion by 2023. Of this, an estimated $0.4 billion is located in North America, with the vast majority composed of residential AMR floor cleaning. The current market for AMR commercial floor cleaning is thus still considered an emerging market. However, the AMR commercial floor care subsegment is projected to grow at a 25% compound annual rate through

2027, according to Brain Corporation, the leading provider of AMR operating software, which has partnered with leading global producers of commercial floor care equipment. We believe the top U.S. commercial janitorial companies, many of which are franchises, are likely to be adversely affected by the rise of industrial and commercial floor care AMRs, including JAN-PRO, Coverall, ServiceMaster Clean, Vanguard Cleaning Systems, CleanNet USA, Anago Cleaning Systems, Stratus Building Solutions, Inc., Buildingstars International, O.P.E.N. America, Inc., Office Pride Commercial Cleaning Services, City Wide Maintenance, System4 Facility Services Management LLC, and Image One Facility Solutions. Please see page 62 for a more detailed conversation on autonomous robotic software developers and their commercial applications.

Exhibit 3
Robotics, Automation, and Artificial Intelligence (RAAI)
Public Companies to Benefit or Be Adversely Affected by Emergence of RAAI Technologies

	Advantage	Disadvantage
Distribution Warehouse Automation	Honeywell, KION Group, TERADYNE, DAIFUKU	Daimler AG, PACCAR, NAVISTAR, VOLVO, Cummins
Recycling Automation	unifi, KADANT	WM, Republic Services, Clean Harbors, Stericycle, Progressive Waste Solutions, Advanced Disposal
Cobots and AGVs	Microsoft, TERADYNE	TOYOTA, KOMATSU
Online Grocery Fulfillment	amazon, TARGET, Walmart, Woolworths Group, Kroger, Loblaw	HelloFresh, Blue Apron
Guarding and Robotic Security Automation	Private Robotic AMR Manufacturers	Private Manned Security Companies
Industrial and Commercial Floor Care AMRs	Nilfisk, TENNANT	Private Janitorial Companies

Source: William Blair

Risks

Key risks to the advancement and adoption of robotics, automation, and AI include the following:

Timing and rollout of wireless 5G. We expect one of the next RAAI-enabling technologies will be the rollout of wireless 5G. When fully operational, 5G will be transformational for enabling real-time situational awareness and autonomous AI-directed coordinated operability. We believe this enhanced functionality is likely to accelerate adoption rates, particularly for outdoor RAAI technology applications, by enabling enhanced reliability and safe high-speed operation. To date, the rollout of 5G coverage in the United States has been more of an incremental evolution than the long-awaited revolution in wireless speed, nominal latency, and enhanced transmission capacity. Overseas, deployment of commercially viable 5G appears to be progressing more rapidly in countries such as China, South Korea, and Switzerland. Broad-based wireless 5G is expected to be fully operational in the United States over the next three to five years. However, should the rollout be delayed, we would expect to see a slower rate of commercial adoption for more advanced RAAI capabilities, including more nimble, edge-computing robots as well as outdoor AMRs. Delayed availability of 5G in the United States could also shift technological market leadership to markets where 5G networks have already become ubiquitously available.

Global safety certification. The emergence of advanced machine vision is now on the cusp of creating a new generation of cobots that use cameras, LIDAR, and infrared sensors to enable faster but safe collaborative applications, unleashing a new wave of productivity gains. Today there is a race from vision and software manufacturers to bring adaptive robots to market (fast cobots) enabled by advanced 2-D and 3-D machine vision systems. One of the largest hurdles for adaptive robotics today is the ability to secure global safety certification from internationally recognized TÜV Rheinland. This is typically a multiyear process, with market leaders still an estimated 9 to 12 months away from receiving final certification. Any delays in advanced machine vision developers' ability to secure certification would delay the anticipated adoption and proliferation of high-speed adaptive robotic applications.

Access to capital. Over the last decade, there has been a growing interest by venture capital and private equity for investment in the rapidly evolving and nascent RAAI space. While there is no lack of funds available for a start-up with highly promising innovative technology (solidified by the spike in start-ups for AMR, robotics, and AI software companies over the last decade), if access to new development funding were to be curtailed, we would expect the pace of RAAI technology commercialization could be materially slowed and many private RAAI companies dependent on continued development funding could be forced to sell or close down.

Market rationalization. While most new and future RAAI markets are projected to be quite large, it is unclear how rapidly various RAAI end-markets are likely to eventually consolidate. The basis for sustainable market leadership can be highly varied across different RAAI markets and likely include but not be limited to the ability to introduce commercially viable RAAI solutions; sustain aftermarket customer support; secure collaborative distributor networks, consulting partnerships, and key customers alliances; and ensure interoperability with applicable OT information control systems and IT enterprise platform providers. Given the large number of competitors in some RAAI subsectors (there are currently over 100 AMR/AGV and autonomous software providers), we anticipate there will likely be consolidation and natural attrition as the growth rates of various RAAI markets eventually mature. For prospective customers and investors, this requires prudently assessing companies' defendable moats and the evolving technological requirements of key served markets to properly discern long-term RAAI technology winners.

Importance of partnership. With the breadth of solutions coming to market, many distributors, engineering consultants, and customers can be overwhelmed when trying to identify the best RAAI solutions to optimally meet their needs. Given the state-of-the-art nature of many RAAI technology offerings, it remains critical for most RAAI technology developers to remain focused on their core competencies. However, long-term commercial success for emerging RAAI technology companies may require partnering with complementary companies to seamlessly integrate their solutions and expand customer access by aligning with key distributors and systems integrators that can expand critical sales channels and if necessary assist with aftermarket customer support.

Defining RAAI Applications and Their Commercialization

This report aims to assess new industrial end-market applications for RAAI. We have attempted to highlight leading public and private industrial companies in the rapidly expanding industrial RAAI sector and also provide a mosaic of how industrial applications of RAAI technology are likely to be commercialized. This report is a culmination of our own research and discussions with industry experts in the RAAI sectors, including top executives at private companies as well as public industrial companies.

- Industrial RAAI report objective and scope:
  - Assess RAAI industrial end-market applications for traditional factory automation and the newer first derivative application of RAAI technologies
  - Highlight leading public and private companies in the rapidly expanding industrial RAAI sector beyond traditional industrial factory automation
  - Provide a mosaic of how industrial applications of RAAI technology are now being commercialized across homogenous large and smaller discrete end-markets
  - Not focused on healthcare, cybersecurity, and exclusively software RAAI technology applications

Several RAAI technology applications are not covered in this report. The scope and breadth of RAAI applications and end-markets continue to expand rapidly, becoming notably broader over the last three to five years. We have purposely not attempted to address certain segments of the RAAI sector that are not primarily related to industrial applications of robotics and automation technologies. For instance, we have not discussed the many RAAI technologies used in the healthcare segment, including genomics, healthcare robotics, medical instrument robotics, and telehealth software.

Also, while almost all industrial RAAI technologies incorporate or use software, we have not attempted to address RAAI technologies that are exclusively software based, such as warehouse automation software, online order entry software, or network cybersecurity and business process software. In addition, this report is focused on indoor industrial applications of RAAI technologies and does not include outdoor drones, outdoor AMRs, and other external RAAI technologies that may require the still incomplete commercial rollout of 5G wireless to achieve their full potential. In short, this report focuses on the application of RAAI technologies to industrial markets that typically combine software with tangible robotics and automation hardware.

Key Industrial RAAI Report Conclusions

- Moderate (5%-20%) growth for traditional industrial factory automation RAAI markets:
  - Growth led by accelerating deployment of cobots
  - Subsequent utilization of higher-speed adaptive cobots that use advanced software, machine learning with 2-D vision, followed by low latency 3-D vision
  - Core traditional manufacturing factory automation cadenced by automotive shift to electric vehicles, more moderate global capital spending on production automation but aided by growth in cybersecurity and deployment of virtual reality (VR) and eventually 5G

  - Corporations cautiously moving to horizontally link their global manufacturing sites and subsequently digitally integrate their supply chains

- Rapid growth (10%-60%) for new derivative RAAI technology markets:

  - First derivative RAAI industrial automation solutions (initially focused on indoor applications pending 5G fully achieving targeted functionality)

  - End-market growth driven by homogenous logistical automated solutions (automated warehouses and online automated grocery fulfillment) and numerous smaller, more early-stage, discrete end-market applications

- Unlike other high-growth start-up sectors, we sense the majority of private companies in the RAAI sector are unlikely to go public. Instead, leading companies are likely to seek larger private investors to fund their rapid growth. Ultimately, many are likely to be acquired by larger diversified industrial companies as well as larger firms specializing in RAAI to provide them access to critical complementary RAAI products and aftermarket support to enhance their long-term growth potential.

Industrial automation has moved far beyond the factory floor and spawned numerous new high-growth applications for RAAI. After more than three decades of improving the efficiency of global assembly and manufacturing operations, industrial automation and robotics have rapidly moved beyond the factory floor to encompass myriad new higher-growth RAAI end-markets. Amazon moved first to begin to broadly deploy robotic automation outside the factory floor with its $775 million acquisition of Kiva Systems in 2012. This acquisition was the cornerstone initiative to move robotics and automation into automating its distribution warehouse system. However, it took until 2014 for Amazon to fully implement the use of Kiva robots and begin to automate its distribution operations. In 2015, Kiva became Amazon Robotics, and its mission changed to only automating Amazon's internal warehouses. At the same time, the advent of much lower-cost hardware sensors as well as early standardized operating software for AMRs began to emerge about 2015, which created a plethora of new RAAI applications and markets.

Several factors have converged to accelerate the application of RAAI technologies across a widening spectrum of new end-market applications. These include a rapid decline in the cost of RAAI technologies accompanied by their rising accuracy, capability, flexibility, and reliability. This was accompanied by a growing shortage of workers, the rise of e-commerce and e-retailing, consumers' preference for ever shorter order-to-delivery times, the digital integration of increasingly global supply chains, and a rise in seasonal demand variability. Collectively, these factors created a perfect storm for explosive growth in first derivative applications of RAAI technologies.

We believe the key factors that contributed to the rapid growth of RAAI technologies since the middle of the last decade can be classified as technology developments, macroeconomic forces, and continued technological advancements, which would likely include the following:

- ***Technology advances:***

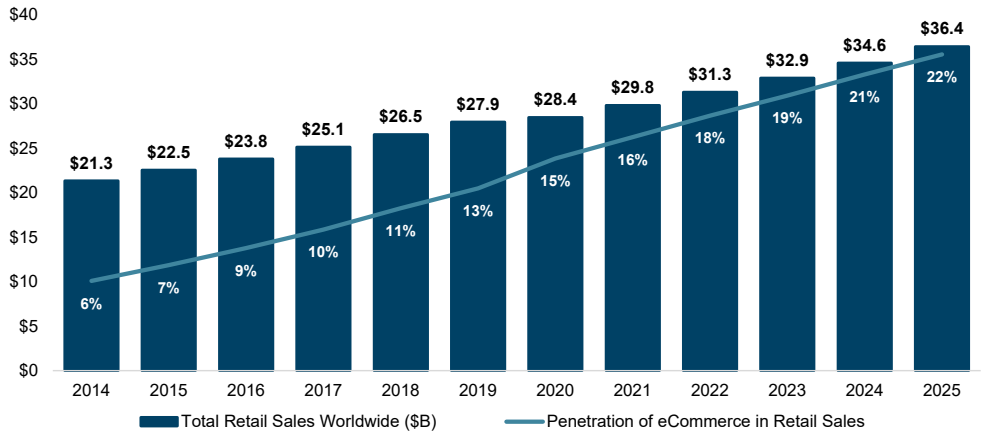
  - Rapid sharp decline in cost of critical RAAI sensing, computing, and standardized software operating systems

  - Sharp rise in RAAI functionality, accuracy, flexibility, and reliability aided by lower-cost edge and cloud computing

  - Commercially viable capture of big data enables machine learning, deep learning, and predictive analytics
  - Commercially effective and viable cybersecurity
  - Potential of digital integration of global manufacturing operations and supply chain integration

- ***Macroeconomic factors:***
  - Rise in e-commerce and e-retailing
  - Growing shortage of workers
  - Premium assigned to shorter order-to-delivery times
  - Localization of distribution logistics to enable quicker delivery
  - Increasing seasonal demand variability for e-commerce and e-retailing
- ***Next technological breakthroughs:***
  - Safety-certified 3-D robotic vision systems
  - Fully functional G5 wireless communications (particularly critical for more dynamic outdoor applications requiring real-time latency)

Exhibit 4
Robotics, Automation, and Artificial Intelligence (RAAI)
E-commerce Growth Forecast through 2025



Source: Company reports

Rise of e-commerce represents first major catalyst to spawn RAAI technology applications outside the factory. While total retail sales in the United States have grown at a 3% compound annual rate over the past 10 years, e-commerce retail sales have grown at a 14% compound annual rate over the same period, reflecting changing consumer attitudes and the benefits of ease of access to the customer. A recent report by Shopify projects the U.S. e-commerce market to grow

46% between 2018 and 2023. Global e-commerce sales have grown at a 20% compound annual rate over the past 10 years and are expected to grow to roughly $7 trillion by 2025 from about $3 trillion in 2018.

Supporting, but in no way fully explaining, e-commerce's rising penetration of total retail sales in the United States and on a global basis is the emerging strength of direct-to-consumer business models, sometimes referred to as digitally native vertical brands, which seek to develop lasting customer relationships by using their online presence to develop content and campaigns that emphasize the experiential aspect of using or enjoying their products. These models often, but not exclusively, use online platforms to connect and interact with their customer base to market their products.

The evolution of the traditional retail industry sales model introduces complexities all across the value chain, as online business models may require as much as three times the warehousing space of traditional store-based fulfillment, and strains across supply chains to be able to maintain optimal inventories and move items and goods in a timely and cost-efficient manner remain omnipresent. Such a broad and persistent change in market dynamics represents the primary driver of the intensification of warehouse automation to improve logistics by improving speed and quality of delivery while maintaining worker safety and managing costs for businesses and customers.

Labor shortage driving demand for warehouse automation solutions. Specifically in the United States, companies operating warehouse facilities have seen significant reductions in the availability of qualified skilled labor for the factory floor. This significant labor shortage grows even more acute during periods of peak labor demand centered on the holiday season. In addition, and partly as a result of the shortage in available labor, wages have continued to rise, creating significant margin headwinds even when the appropriate labor is secured. These factors culminate in growing demand for warehouse automation solutions, which reduces a warehouse's minimum human labor requirement and better allows manufacturing facilities to meet peak seasonal demand.

Partly resulting from rising e-commerce market activity, the global logistics industry has become significantly constrained with respect to securing adequate labor, as online retail is more logistically rigorous on a per-unit basis versus traditional storefront retail. These labor constraints are expected to intensify as consumer expectations require ever quicker and more-immediate delivery from the point of purchase.

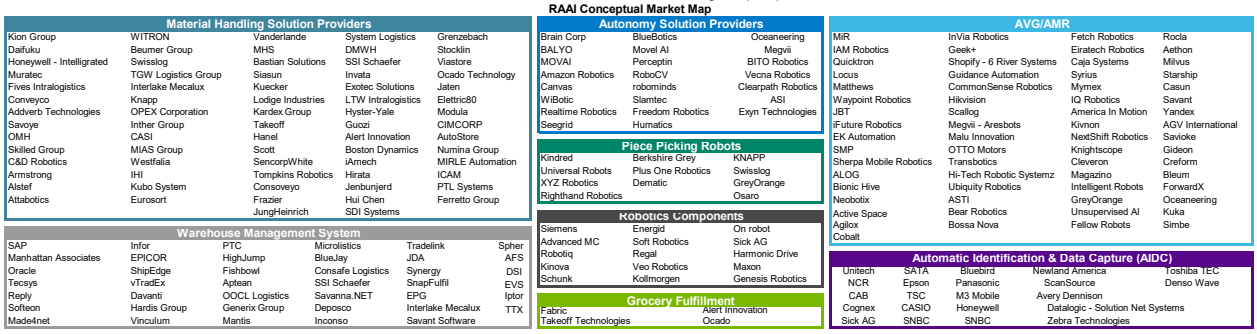
We sense the evolution of companies deploying newer applications of RAAI technologies may not follow the same template of other high-growth sectors. Unlike most high-growth start-up sectors, the majority of private RAAI companies are unlikely to go public, in our opinion. For instance, while new commercially viable industrial applications of RAAI technologies continue to emerge at an accelerating pace, we ultimately believe a critical challenge for many new companies may be the ability to support aftermarket service for their rapidly growing installed base of RAAI products. While software upgrades can be continuously downloaded autonomously, the resources to perform aftermarket product service support and performance optimization are likely to be burdensome for smaller start-ups as their installed base expands. This occurred for many of the early 3-D metal printing companies, which ultimately were acquired by larger manufacturers that could fund their critical aftermarket support and new product development. Typically, most industrial RAAI technology start-up companies focus their initial product rollout in North America, with overseas markets (typically Europe and Southeast Asia) deferred until their systems have become critically proven and commercially well established. It is quite possible that third-party integrators emerge to install and service the installed base of the more established industrial RAAI technology leaders.

This pattern of commercialization and growth was also evident in the security industry, with installers and aftermarket service and monitoring companies supporting security hardware manufacturers. However, security solutions historically were more homogenous in their design and

installation than many of the newer RAAI technology products coming to market. For instance, while the emerging market for online automated grocery fulfillment draws on many of the foundational technologies used in warehouse automation, they are applied quite differently. For instance, both use AI to optimally prioritize picking various products for an order, but for automated grocery fulfilment, products must be further sorted and stored depending on whether they are frozen, refrigerated, or ambient temperature products.

Moreover, in the security industry, hardware companies tended to provide a turnkey solution, whereas many RAAI technology companies today are producing only one component or a portion of an integrated automation solution. As a result, we believe many of the leading RAAI technology companies will seek larger private investors to fund their rapid growth. Ultimately, we sense that many RAAI component suppliers are likely to be purchased by larger diversified industrial companies or large firms specializing in RAAI that can provide access to critical complementary RAAI products and aftermarket support to enhance their long-term growth potential. In short, we sense the popcorn has started to pop for the many RAAI technology companies started during 2015-2018.

Exhibit 5
Robotics, Automation and Artificial Intelligence (RAAI)
RAAI Conceptual Market Map

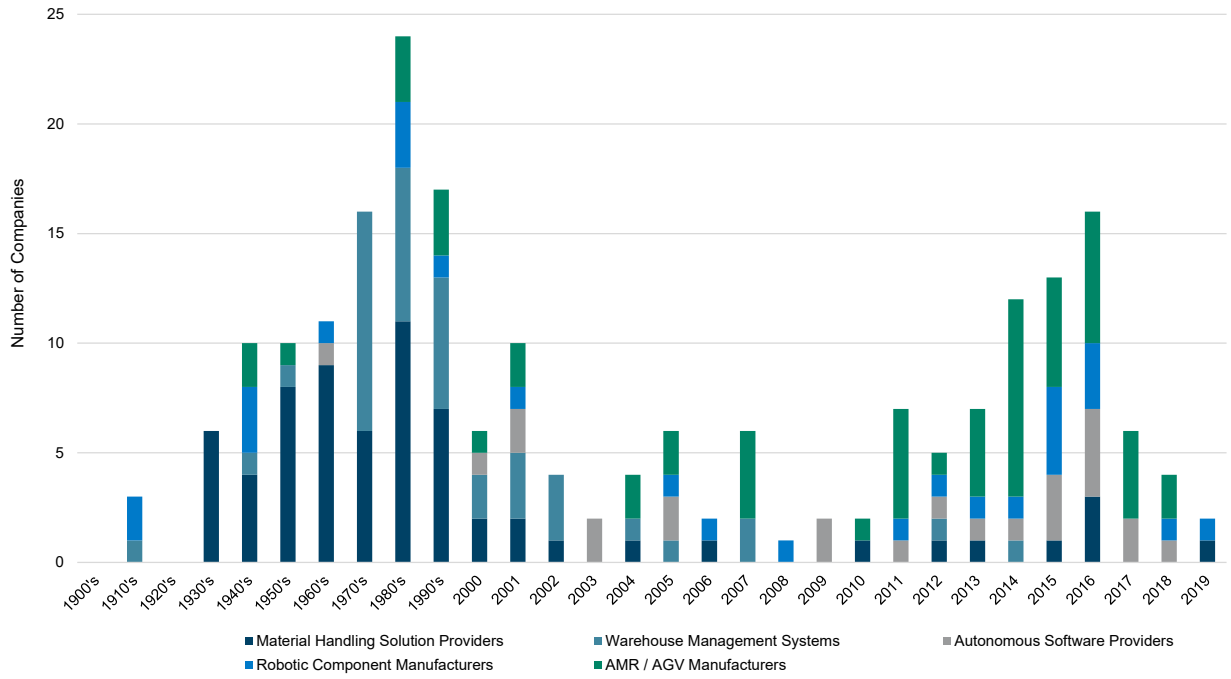


Source: LogisticsIQ

Rise of RAAI Applications From Factory Automation

Over the last two decades, there has been a steady increase in the founding of autonomous robot and autonomous software providers, as well as for robotic component manufacturers. This has largely been a result of the technological strides made in sensing and cloud-based AI software, led by a growing need for improved order fulfillment to compete better in the highly competitive e-commerce landscape. As shown in the exhibit below, the establishment of warehouse management and material-handling companies peaked in the 1970s and 1980s, respectively, whereas the growth in AMR companies in particular has expanded at a rate of 5 to 10 companies annually from 2011 through 2017.

Exhibit 6
Robotics, Automation, and Artificial Intelligence (RAAI)
Warehouse Automation Companies by Year of Founding



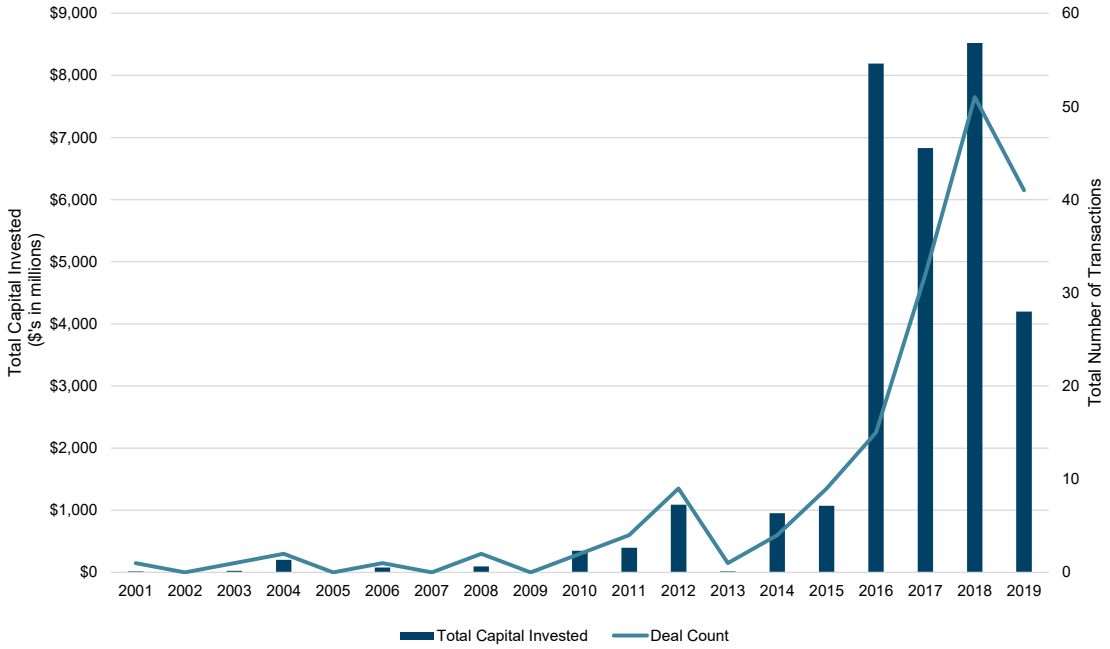
Source: Company reports

On an absolute basis, the flow of capital has largely come from increased M&A activity with an emphasis on logistics and warehouse automation. M&A activity in the automation space peaked in 2016 and 2017, with notable transactions including Honeywell's purchase of automation supplier Intelligrated for $1.5 billion, KION Group's acquisition of Dematic for $3.3 billion, KUKA's purchase by Mecca International for $6.4 billion (in a two-part transaction), and ABB's acquisition of Bernecker & Rainer for $2.3 billion.

By deal flow, the number of transactions in the sector has also increased steadily over the last few years, as shown in the exhibit below, with growing interest from venture capital funds in the AMR and AI software sectors. This has been partly predicated on Amazon's upending of the AMR sector in early 2012, following the acquisition of Kiva Systems. Following Kiva's purchase, Amazon brought the company's services in-house and severed outside supply agreements, thereby increasing its ability to provide two-day shipping at more profitable price points. To help fill the void, numerous AMR companies have come to market, and investors have taken notice of the large market opportunity.

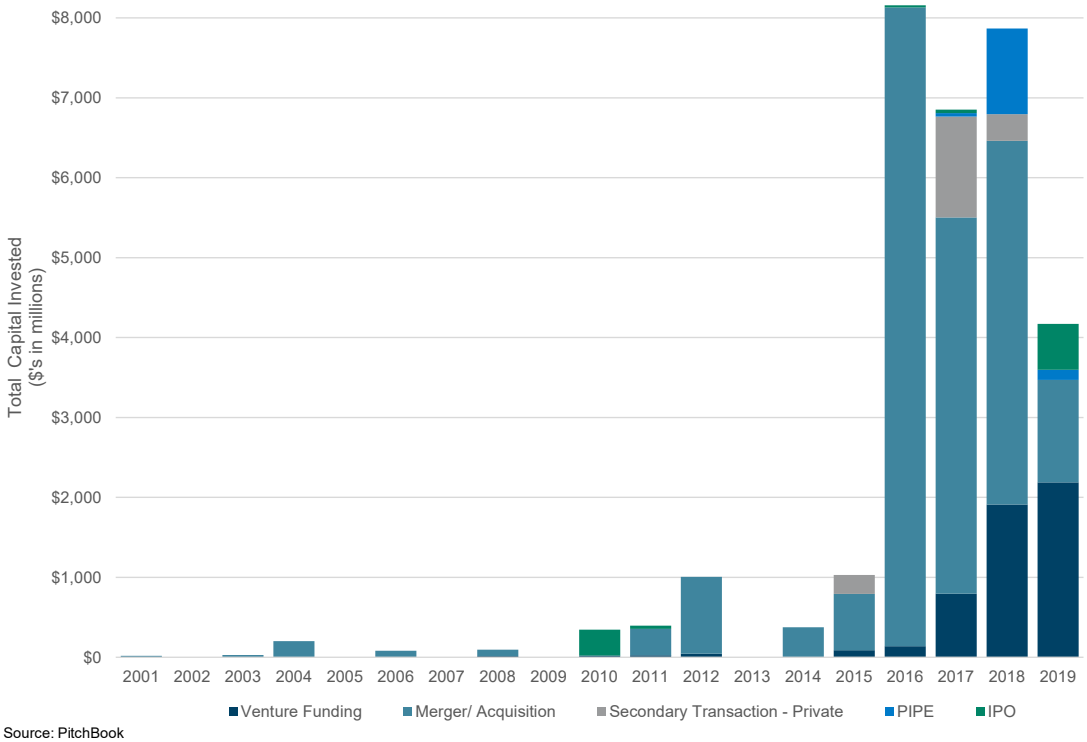
While there has been a handful of IPOs in the space (all international), we expect to see a greater emphasis on M&A activity given the asset-heavy, capital-intensive business model of most robotic and AMR start-ups, which makes scale and exponential growth more challenging. More specifically, the robots-as-a-service format that many start-ups operate under requires a large installed base of robots to rent to customers. However, even in a volume-based, direct sales model, there is a service and maintenance component that necessitates large economies of scale to achieve profitability. We thus anticipate the majority of RAAI start-ups will look for an exit over the next several years in the form of M&A activity, particularly as increased R&D costs, to stay ahead of the commoditization curve and rising aftermarket support cost, become unwieldly to manage for most.

Exhibit 7
Robotics, Automation, and Artificial Intelligence (RAAI)
RAAI Transactions (2001-2019)



Source: PitchBook

Exhibit 8
Robotics, Automation, and Artificial Intelligence (RAAI)
RAAI Types of Transactions (2001-2019)



Source: PitchBook

Exhibit 9
Robotics, Automation, and Artificial Intelligence (RAAI)
Notable Automation and Robotics M&A

Automation

Company	Date	Deal Size	Target Description	Country	Subsegment	Acquirer
Fortive (Automation & Specialty)	10/1/2018	$ 2.5B	Factory automation and robotic motion controls	United States	Warehouse and Distribution Automation	Altra Industrial Motion
Piab	6/14/2018	$ 794M	Manufacturer of automation technology products	Sweden	Machine Automation Systems	Patricia Industries
PTC	6/11/2018	$ 1.0B	PIPE investment for 8.4% in CAD software provider	United States	Software provider for IoT and augmented reality	Rockwell Automation
Bernecker + Rainer	7/6/2017	$ 2.3B	Machine and factory control systems, HMI, and motion controls	Austria	Machine Automation Systems	ABB
Vanderlande Industries	5/18/2017	$ 1.3B	Material handling and logistics automation systems	Netherlands	Warehouse and Distribution Automation	Toyota Industries
AutoStore	1/1/2017	$ 524M	Developer of automated storage and retrieval systems	Norway	Automated storage and retrieval systems	EQT Partners AB
Dematic Group	11/1/2016	$ 3.3B	Integrated automation technology, software, and services	United States	Warehouse and Distribution Automation	KION Group
Intelligrated	8/30/2016	$ 1.5B	Automated material handling services	United States	Warehouse and Distribution Automation	Honeywell
Swisslog Holding	12/15/2014	$ 357M	Logistics and material handling automation, process improvement	Switzerland	Warehouse and Distribution Automation	KUKA
Wynright Corporation	10/2/2013	-	Integrator and provider of intelligent material handling systems	United States	Warehouse and Distribution Automation	Daifuku
Elexis	8/4/2011	$ 227M	Industrial automation, handling, and precision systems	Germany	Automation Technology	SIEMAG Weiss

Robotics

Company	Date	Deal Size	Target Description	Country	Subsegment	Acquirer
AutoGuide Mobile Robots	11/14/2019	$ 165M	Manufacturer of high-payload AGVs	United States	Autonomous Mobile Robots	Teradyne
6 River Systems	10/17/2019	$ 450M	Manufacturer of mobile cobots and cloud-based software	United States	Autonomous Mobile Robots	Shopify
Canvas Technology	4/10/2019	-	Spatial AI for end-to-end autonomous goods delivery	United States	Artificial Intelligence for Autonomous Navigation	Amazon
Cloos Welding Technology	1/16/2019	$ 120M	Developer of robotic welding systems	United States	Industrial Robots	Estun Automation
Aethon	1/1/2019	$ 100M	AMR's for hospitals and medical supply chain	United States	Autonomous Mobile Robots	ST Engineering
IAM Robotics	12/31/2019	-	AMRs and autonomous robotic systems	United States	Autonomous Mobile Robots	Unknown
Genesis Systems Group	11/5/2018	$ 115M	Developer of robotic welding systems	United States	Industrial Robots	IPG Photonics
Gimatic SRL	10/31/2018	$ 432M	Robotic grippers, end-of-arm-tooling, sensors and other components	Italy	Industrial Automation	Barnes Group
Nimak GmbH	10/29/2018	$ 118M	Developer of robotic welding systems	Germany	Industrial Robots	Jiangsu Hagong
Piab	6/14/2018	$ 794M	Robotic components and end-of-arm-tooling manufacturer	Sweden	Automation Technology Products	Patricia Industries
RedZone Robotics	6/4/2018	$ 57M	Pipeline and wastewater asset robotic inspection technology	United States	Autonomous Mobile Robots	Milestone Partners
Mobile Industrial Robots	4/25/2018	$ 273M	Manufacturer of mobile cobots	Denmark	Autonomous Mobile Robots	Teradyne
Energid Technologies	2/1/2018	$ 28M	Developer of real-time motion control software	United States	Collaborative Robots	Teradyne
Robotic Drilling Systems	9/5/2017	$ 60M	Developer of autonomous robotic drilling systems	Norway	Autonomous Mobile Robots	Nabors Industries
E2V Technologies	3/28/2017	$ 782M	High performance image sensors and custom cameras	United Kingdom	Industrial Machine Vision	Teledyne
Point Grey Research	10/3/2016	$ 253M	Advanced visible imaging cameras and solutions	Canada	Industrial Automation	FLIR Systems
KUKA	1/1/2017 7/13/2016	$ 1.3B $ 5.1B	Supplier of industrial robots, intelligent automation solutions, and individual components to complete production lines	Germany	Industrial and Collaborative Robots	Mecca Int'l (88% ownership)
Paslin	3/22/2016	$ 302M	Design and deployment of automated assembly and welding systems	United States	Manufacturing Assembly and Automation Systems	Wanfeng
Adept Technology	10/23/2015	$ 200M	Vision-guided robotics systems and services	United States	Autonomous Mobile Robot Components	Omron
Universal Robots	7/11/2015	$ 350M	Developer of robotic arms for industrial processes	Denmark	Industrial and Collaborative Robots	Teradyne
Evolution Robotics	10/1/2012	$ 74M	Developer of robotic services for mobile device navigation	United States	Vision and Autonomous Navigation	iRobot
Kiva Systems	5/1/2012	$ 775M	Developer of robotic solutions for automating distribution centers	United States	Autonomous Mobile Robot Systems	Amazon

Sources: PitchBook, William Blair

Exhibit 10
Robotics, Automation, and Artificial Intelligence (RAAI)
Notable Robotics Funding

Company	Date	Funding Stage	Deal Types	Deal Size	Post Valuation	Total Funding	Investors	Country	Company Description
Vecna Robotics	01/07/2020	Early Stage VC	Series A1	$ 50M	$ 225M	$ 64M	Blackhorn Ventures, Tectonic Ventures, Fontinalis Partners	United States	Automated robotic solutions for material handling
Gecko Robotics	12/16/2019	Late Stage VC	Series B	$ 400M	$ 265M	$ 47M	Drive Capital, Next47, Founders Fund, Y Combinator	United States	AMR for dangerous environments
Automation Anywhere	11/21/2019	Late Stage VC	Series B	$ 290M	$ 6.8B	$ 840M	SoftBank Investment Advisers, Goldman Sachs Merchant	United States	Robotic process automation software
AMP Robotics	11/13/2019	Early Stage VC	Series A	$ 16M	-	$ 23M	Sequoia Capital, Baidu Ventures, Sidewalk Infrastructure	United States	Recycling robots
Fabric	10/23/2019	Early Stage VC	Series B	$ 110M	-	$ 136M	Corner Ventures, La Maison, Aleph, Innovation Endeavors	United States	On-demand fulfillment technology for faster delivery
Starship Technologies	08/20/2019	Late Stage VC	Series A	$ 40M	-	$ 82M	Morpheus Ventures, TDK Ventures, QU Ventures, Shasta	United States	Self-driving robotic delivery vehicles
Scale AI Inc	08/05/2019	Late Stage VC	Series C	$ 100M	$ 1.0B	$ 123M	Founders Fund, Spark Capital, Thrive Capital	United States	AI for robotic and autonomous data imaging
Fetch Robotics	07/23/2019	Late Stage VC	Series C	$ 46M	$ 221M	$ 94M	Fort Ross Ventures, SoftBank Investment Advisers	United States	Manufacturer of AMRs
Cobalt Robotics	06/25/2019	Early Stage VC	Series B	$ 37M	$ 237M	$ 54M	Coatue Management, Toyota AI, Fifth Wall Ventures	United States	Security cobots
Tempo	05/14/2019	Late Stage VC	Series C	$ 50M	-	$ 80M	Point72 Ventures, Lockheed Martin, Lux Capital	United States	Circuit boards for robotics, drones, and other electronics
Locus Robotics	04/11/2019	Late Stage VC	Series C	$ 26M	$ 184M	$ 67M	Zebra Ventures, Scale Venture Partners	United States	Manufacturer of AMRs
Ouster	03/25/2019	Early Stage VC	Series A1	$ 60M	-	$ 100M	Runway Growth, Silicon Valley Bank	United States	3D sensors for robotics, autonomous vehicles, drones
Horizon Robotics	02/26/2019	Early Stage VC	Series B	$ 600M	$ 3.0B	$ 700M	CITIC Securities Int'l, China Minsheng Investment	China	AI brain processing unit
Kryon	02/26/2019	Late Stage VC	Series C	$ 40M	-	$ 53M	Oak HC/FT, Vertex Ventures, Fort Ross Ventures	Israel	Robotic process automation platform
Humatics	01/07/2019	Early Stage VC	Series A1	$ 28M	$ 100M	$ 56M	Tenfore Holdings, Airbus Ventures, Lockheed Martin	United States	Spatial intelligence platform for navigation
Veo Robotics	01/01/2019	Early Stage VC	Series A1	$ 15M	$ 70M	$ 28M	GV, Baidu Ventures, Nikon	United States	Software and 3D sensors for cobots
Covariant	01/01/2019	Early Stage VC	Series A	$ 20M	$ 150M	$ 27M	Baidu Ventures, Samsung NEXT Ventures, Lux Capital	United States	Software for robotic AI
RightHand Robotics	12/17/2018	Early Stage VC	Series B	$ 23M	$ 88M	$ 34M	Menlo Ventures, GV, Playground Global, Martix Partners	United States	Robotic piece-picking EoAT
Robotiq	12/11/2018	Late Stage VC	-	$ 23M	$ 23M	$ 23M	Battery Ventures	France	Robotic EoAT component manufacturer
Geek+	11/21/2018	Early Stage VC	Series B	$ 150M	-	$ 203M	GGV Capital, D1 Capital, Warburg Pincus	China	Manufacturer of AMRs and AI technologies
IAM Robotics	11/15/2018	Late Stage VC	Series A	$ 20M	-	$ 21M	KCK-US, Vic Kapur	United States	AMRs and autonomous robotic systems
Bright Machines	10/23/2018	Early Stage VC	Series A	$ 179M	$ 679M	$ 229M	Eclipse Ventures, FlexTronics, Lux Capital, EDBI	United States	Software platform for manufacturing and robotics automation
QKM Technology	10/15/2018	Late Stage VC	Series C	$ 146M	-	$ 166M	Guangdong Technology Financial Group	China	Light-weight industrial and autonomous robots
GreyOrange	09/06/2018	Late Stage VC	Series C	$ 140M	-	$ 179M	Mithril Capital, Project Verte, Mitsubishi	Singapore	AMRs and autonomous robotic systems
Blaize (AI)	09/05/2018	Late Stage VC	Series C	$ 65M	$ 390M	$ 100M	Denso, Nsitexe, Temasek Holdings	United States	Computer hardware for AMRs
Sarcos Robotics	09/05/2018	Late Stage VC	Series B	$ 30M	-	$ 46M	DIG Investments, Caterpillar Ventures, GE Ventures	United States	Developer of mobile robots for hazardous environments
XYZ Robotics	08/16/2018	Early Stage VC	Series A	$ 80M	-	$ 80M	Gaorong Capital	China	AI-powered sorting robots
Knightscope	07/10/2018	Late Stage VC	6th Round	$ 50M		$ 98M	Silicon Valley Bank	United States	Autonomous security robots
Bossa Nova Robotics	06/21/2018	Late Stage VC	Series B1	$ 29M	$ 179M	$ 77M	Cota Capital, Black Diamond Ventures	United States	Manufacturer of AMRs
inVia Robotics	06/13/2018	Early Stage VC	Series B	$ 20M	$ 70M	$ 30M	Point72 Ventures, Upfront Ventures, Embark Ventures	United States	AMRs and autonomous robotic systems
6 River Systems	01/09/2018	Early Stage VC	Series B	$ 25M	$ 150M	$ 47M	Menlo Ventures, iRobot Ventures, Norwest Venture Partners	United States	AMRs and autonomous robotic systems
Brain Corp	07/19/2017	Late Stage VC	Series C	$ 114M	$ 240M	$ 125M	Softbank Vision Fund, Qualcomm Ventures	United States	Developer of AI for robotics
Clearpath Robotics	10/05/2016	Late Stage VC	Series B	$ 30M	-	$ 42M	iNovia Capital, Caterpillar Ventures, GE Ventures	Canada	Products and services for AMRs
Seegrid	08/23/2016	Late Stage VC	Series E	$ 25M	-	$ 36M	Giant Eagle, Beacon Foundation	United States	Vision-guidance for AGV's and AMRs

Sources: PitchBook, William Blair

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Exhibit 11
Robotics, Automation, and Artificial Intelligence (RAAI)
Notable Robotics IPOs

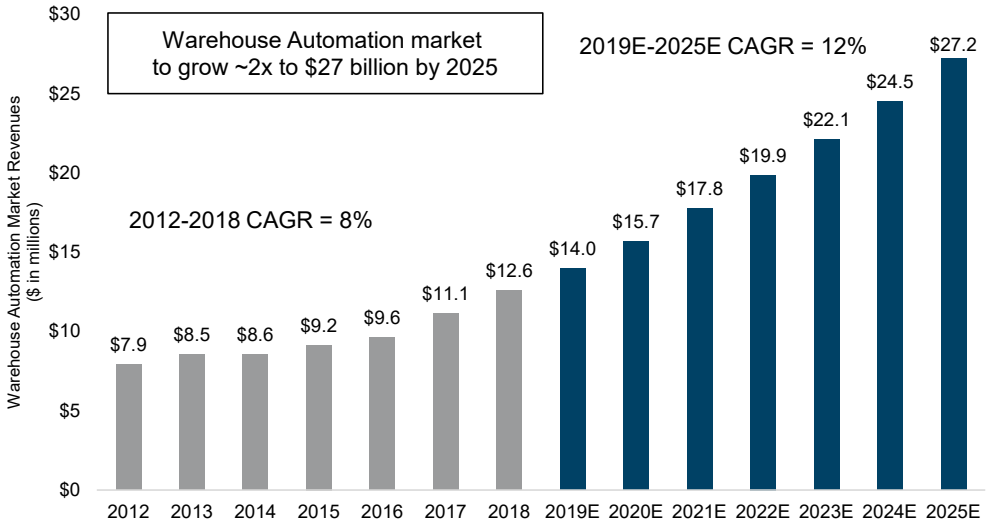
Company	Ticker	Date	Target Description	Market Capitalization	2019 Revenue	2020E Revenue	2020E EBITDA	Price / Sales FY1	EV / EBITDA FY1
Guangzhou Risong Intelligent Technology Co.	SHG: 688090	02/17/2020	Industrial robots, intelligent technologies, and automation systems	$890	$120	-	-	-	-
Jiangsu Beiren Robot System Co.	SHG: 688218	12/13/2019	Industrial robot automation for welding	$616	$69	$88	$13	7.0	45.1
SP SYSTEMS Co.	KRX: 377830	08/16/2019	Industrial gantry robots for logistics and factory automation	$43	$45	$50	$5	0.9	8.8
Arcure SA	PAR: ALCUR	03/01/2019	Vision solutions for securing industrial robot perimeters	$26	$8	$12	($4)	2.2	N/M
Octopus Robots SAD	PAR: MLOCT	03/16/2018	Autonomous mobile robots and modular robots	$1,702	-	-	-	-	-
Balyo SA	PAR: BALYO	06/09/2017	Manufacturer of material handling robots	$52	$23	$35	($8)	1.5	N/M
Shanghai Kelai Mechatronics Engineering Company	SHG: 603960	03/17/2017	Industrial robotic and flexible automation systems	$924	$116	$157	$32	5.9	28.7
Guangdong Topstar Technology Company	SHE: 300607	02/10/2017	Manufacturer of industrial robots and automation solutions	$1,033	$230	$319	$52	3.2	19.9
SIASUN Robot & Automation Co.	SHE: 300024	10/30/2009	Manufacturer of industrial, mobile, and service robots	$3,788	$436	$492	$87	7.7	44.5

Sources: PitchBook, William Blair

RAAI Market Dynamics

Warehouse automation remains the largest, fastest-growing industrial application of RAAI technologies outside conventional factory automation. We believe the rise in e-retailing and e-commerce is having a profound impact on localizing the freight logistics system, particularly in North America and China and to a lesser extent Europe. The drive to shorten the time from order to delivery in the online fulfillment process is expanding (localizing) the number of distribution centers. To make distribution centers economical and dynamic, the global warehouse distribution centers have increasingly turned to automation. ABI Research estimates globally there will be more than 4 million robots operating in 50,000 automated distribution warehouses by 2025, a more than 12-fold increase from 4,000 robotic warehouses operating in 2018. In the United States alone, by 2025 ABI Research projects there will be 23,000 automated warehouses versus 2,500 in 2018. LogisticsIQ anticipates the global warehouse automation market will reach $27 billion by 2025, up from $13 billion in 2018, with AGVs and AMRs expected to account for $4 billion. Other burgeoning RAAI end-markets include automated online grocery fulfillment, recycling automation, guarding and robotic security automation, last-mile AMR delivery, industrial and commercial floor care AMRs, AMRs to clean hazardous industrial environments, AGVs, and even automated production of commercial space rockets.

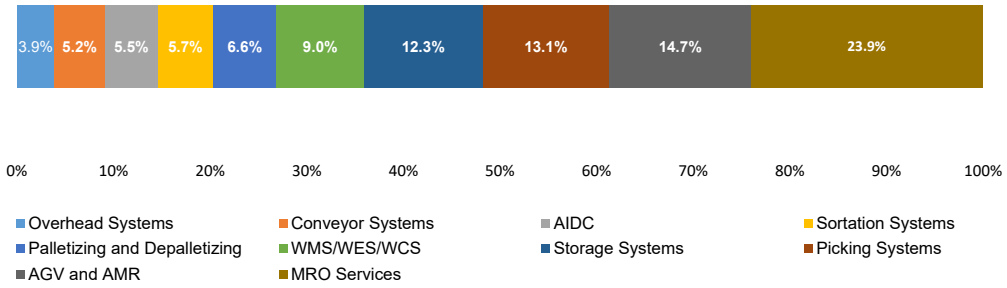
Exhibit 12
Robotics, Automation, and Artificial Intelligence (RAAI)
Warehouse Automation Market Growth Through 2025



Sources: Company data, LogisticsIQ Research

Supplying these new RAAI markets are producers of industrial robots, cobots, robot component manufacturers (including automated robotic picking systems, sensors, 2-D and 3-D vision systems, laser markers, and barcode readers), warehouse handling and inventory management systems, distribution logistics automation, manufacturing automation systems integration and digital supply chain management, predictive data analytics, artificial intelligence, GPS software for outdoor delivery AMRs, and drones. Venture capital investment in RAAI simultaneously began to surge, reaching $2.73 billion in 2017 to fund 271 new RAAI companies. Today, we believe the market for RAAI technology in markets outside traditional factory manufacturing applications has never been larger.

Exhibit 13
Robotics, Automation, and Artificial Intelligence (RAAI)
Warehouse Automation Market (2025)



Source: LogisticsIQ research

Near-term, high-speed 3-D vision is likely today's most enabling RAAI technology, while 5G is likely to take time to become transformational. Over the past five years, some new markets deploying RAAI technologies outside factory automation have become more established, while others are now just beginning to emerge and some are still very early in becoming commercially viable. So far, most of the commercially viable applications of RAAI technologies have been deployed for indoor applications, where the latency (or operating response times) has so far been far superior than is available from 4LTE outdoors wireless service. When operating outdoors, AMRs require real-time response due to the much greater variability of the operating environment versus indoor deployment.

We sense that the arrival of fully functional 5G wireless is likely to be a requisite for outdoor RAAI technology applications to become highly reliable and commercially viable. However, when 5G becomes universally operable at its promised performance levels, we sense that it has the potential to be just as or more transformative than high-resolution, high-speed 3-D machine vision, which is just now becoming available. This is applicable to achieving the growth potential of traditional factory automation and robotics as well as first derivative RAAI technologies. Also, 5G is expected to enable orchestrated operation of autonomous devices on an integrated basis by connecting stationary and integrating the coordinated operation of AMR devices.

To date, the rollout of 5G coverage in the United States has been more of an incremental evolution than the long-awaited revolution in wireless speed, latency, and capacity. Although all four (AT&T, Verizon, T-Mobile/Sprint) major U.S. carriers have some sort of 5G service available to consumers, what has been rolled out so far could best be described as a work-in-process, in our view. While expected to be a material game-changer for both the traditional factory automation sector and deployment of new RAAI technologies, 5G's current functionality is egregiously short of promised critical performance thresholds for network speed, coverage, and responsiveness (or latency). The delays in commercializing 5G's potential has been hampered by the use of alternate radio frequencies by U.S. carriers to deliver the 5G service and the pending consolidation of Sprint and T-Mobile, which will result in three dominant wireless carriers in the United States.

The Federal Communications Commission (FCC) divided the wireless spectrum set aside for 5G into three categories: low band, midband, and high band. The low band, also currently used by broadcast TV and mobile data, has proved to be the slowest because of very high utilization. The low band offers the widest currently available coverage. The high band, which offers the greatest amount of untapped millimeter wave bandwidth, provides the fastest 5G speeds but is limited by the distance that millimeter wave signals can travel. The result is that carriers need more towers to cover the same area.

The midband has less bandwidth than the high band, affords easier coverage than high band, but remains nominally used by the four main wireless carriers. This reflects the fact that the FCC has been slow to make midband spectrum available because of its use by satellite providers and military radar systems. Continuing to follow U.S. 5G's current development trajectory will require different hardware systems to transmit and receive different signals transmitted on three different bands without standardized performance. To address this, the FCC is accelerating efforts to auction more midband spectrum for 5G. Ultimately, it is likely that all major U.S. cellular providers will likely have to migrate their service to a common spectrum band, perhaps midband, to ensure cost-effective, highly pervasive, and uniformly consistent indoor and outdoor seamless coverage across the United States.

Given that the FCC is still working to accelerate awarding midband frequencies to U.S. carriers, we do not anticipate the full potential of standardized 5G will likely become available for at least another few years. Low latency or lag-free response times enable real-time decisions that, along with upload and download speeds that are 10 to 100 times faster than current 4LTE, will be critical for 5G to become the foundational backbone for wirelessly controlled traditional factory automation and first derivative RAAI technologies. This is particularly true for AMRs and other RAAI technologies expected to be deployed outdoors where real-time responsiveness is far more vital given the much more highly variable operating environment.

Achieving a fully viable ubiquitous 5G wireless system is a widely viewed as a critical determinant of a country's global competitiveness. Overseas deployment of commercially viable 5G appears to be progressing more rapidly in countries such as China and South Korea, which are using midband 5G. South Korea and Switzerland already have significantly higher (about 90%) seamless uniform country coverage (including rural areas) than in the United States. While this is easier to achieve in smaller countries such as South Korea or Switzerland than the United States or China, a critical additional 5G functionality benchmark is universally consistent depth of performance indoors and outdoors. Another consideration in the United States is how the U.S. cellular service provider consolidation process proceeds, which could be another factor to enable standardized ubiquitous U.S. 5G service.

During the last decade, several new derivative nontraditional markets have emerged for RAAI technologies. Some of the more prominent emerging applications of RAAI technologies beyond the traditional historical industrial manufacturing automation and robotics market, currently all indoor applications, include:

- New derivative industrial RAAI markets:
  - Distribution warehouse automation—established
  - Recycling automation—accelerating
  - Last-mile AMR delivery—accelerating
  - Online grocery fulfillment—rapidly emerging
  - Guarding and robotic security automation—emerging
  - Industrial and commercial floor care AMRs—emerging
  - AMR cleaning for hazardous industrial environments—emerging
  - Automated commercial space vehicle construction—nascent

The traditional factory automation market for RAAI technologies also continues to grow, albeit at a more modest rate. In the industrial manufacturing automation market, traditional factory automation and robotics are experiencing continued growth driven by the commercial

introduction of cobots beginning in about 2015. Cobots have the ability to work simultaneously adjacent to skilled production workers without jeopardizing their safety (i.e., outside fenced-off robot production cells). Cobots have made possible the ability to overcome the constraints of requiring infrared light walls to prevent worker injury from "uncaged" industrial robots. However, early cobot throughput and productivity was limited by the use of slower 2-D vision systems to ensure that they would not injure or harm production workers.

To overcome this, industrial automation companies have turned to faster predictive learning systems using 2-D vision systems for controlling and operating cobots at higher speeds. These are expected to soon be supplemented by inherently faster 3-D vision systems that incorporate machine learning whose safe operation is now completing independent certification. Both of these developments are poised to create a market for adaptive cobots, which due to much faster 2-D predictive learning and faster software processing control systems and more accurate 3-D processing capabilities can operate at higher speeds (motion velocity) without the risk of injuring immediately adjacent production workers. The result is enhanced productivity and throughput on manufacturing lines without undue risk of injury when operating adjacent to skilled production workers. The new adaptive cobots also overcome the frequent shutdown and restarting of production lines historically characterized by the use of uncaged traditional robots operating within the confines of infrared light walls.

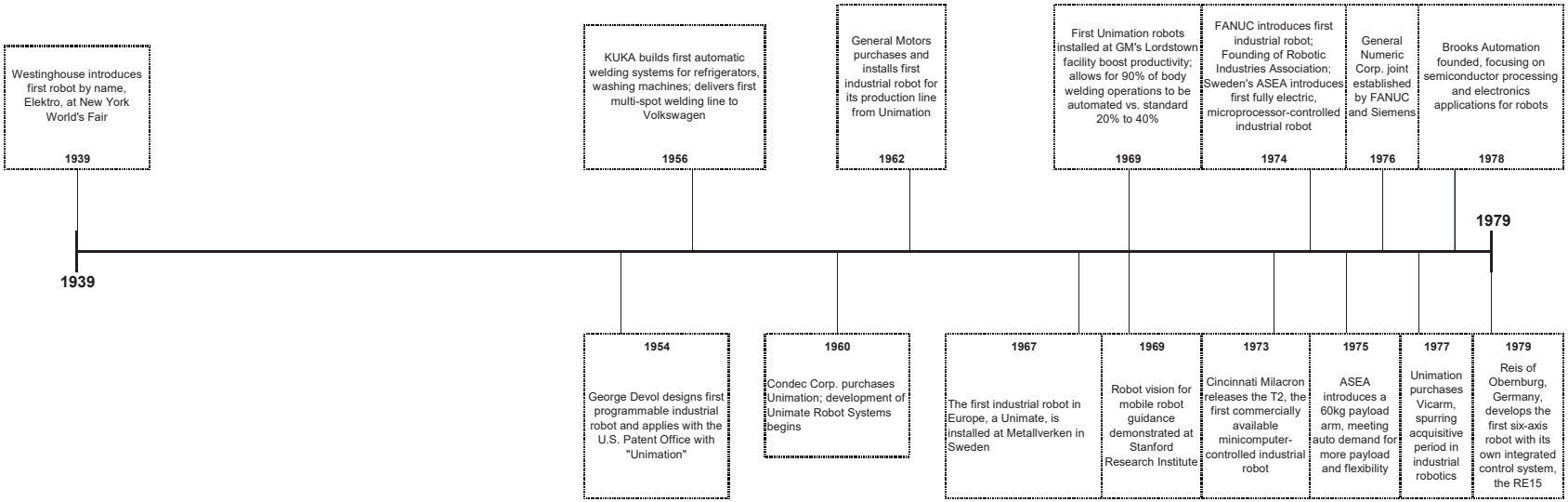
The advances in high-speed, accurate, and safe computer or machine vision are now truly on the cusp of becoming broadly available, aided by significant advances in lower-cost rapid computing. According to Peter Howard, CEO of Realtime Robotics, the machine vision market for larger kilo robots is currently about $6 billion. We believe that machine vision is likely to be the next critical RAAI-enabling technology to enter a period of above average growth as the cost of machine vision comes down and removes many of the incremental safety costs associated with infrared light walls to allow safe operation of cobots.

In addition, 3-D machine vision will accelerate the speed at which product quality, sorting, product identification, and automated production can consistently be performed. Because machine vision should also materially facilitate much more accurate product tracking, traceability, and data collection, the value that can be extracted from automated production can significantly increase beyond improved production speed, safety, and throughput. High-quality, consistent data is also expected to enable deep learning, a subset of machine learning that uses advanced algorithms to replicate the neural processing of the human brain. When coupled with the power of AI, machine vision will also sharply improve the functionality and accuracy of automated inspection, even for highly minute and irregular rather than standardized imperfections. With the advent of advanced machine vision, highly tactile automated grippers, and machine learning, cobots not only are significantly expanding the dexterity of their tasks, but also will soon be able to dramatically speed up their pace of operation without compromising worker safety, with the advent of real-time situational awareness.

Traditional Factory Automation Was the Origin of Many RAAI Technologies

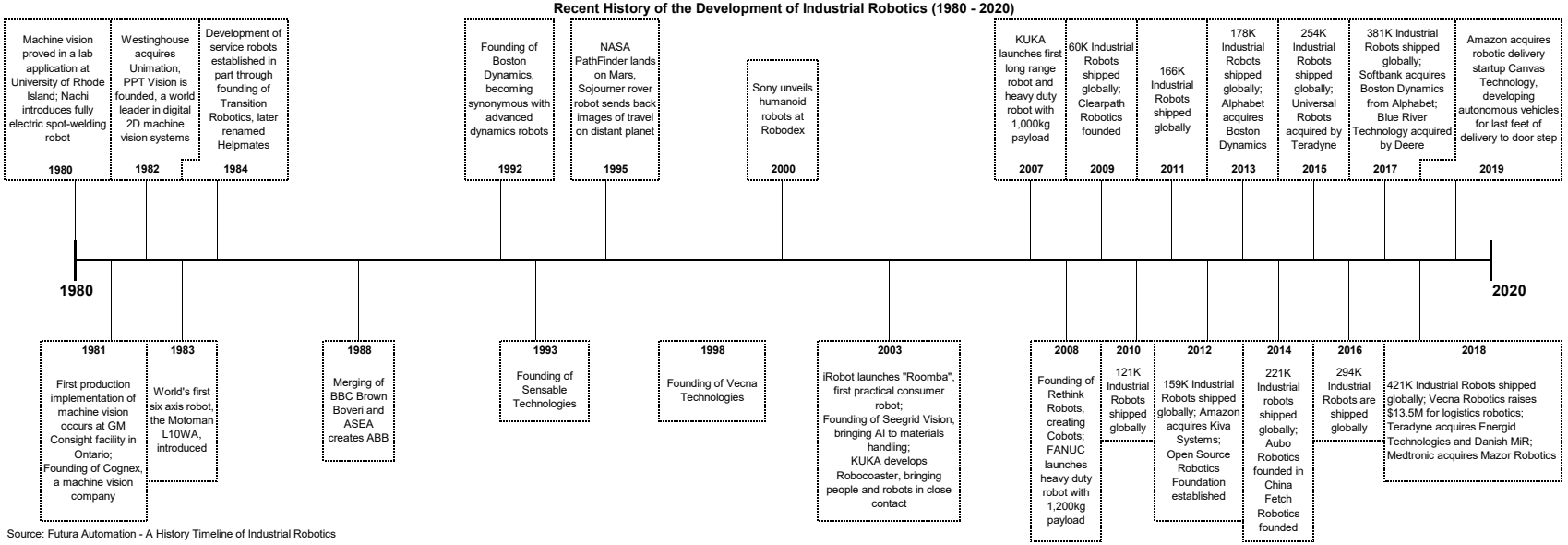
The origins of industrial automation: controlling and coordinating industrial production. The concept of industrial automation has several connotations. To most, it involves the process of using intelligence to direct and coordinate machines to transform raw material or partly assembled components into a final product. Henry Ford's assembly lines represented some of the first ways to produce standardized production of goods using specialization of human labor with skilled expertise. Ford established the first car production assembly line in 1913, enabling car assembly time to drop to about one and a half hours from 12 hours. Individuals became proficient at one task and manually repeated their area of expertise on a moving assembly line. The result was a continuous production process that enabled quicker and lower-cost production than individuals attempting to complete all the tasks to produce one car. Henry Ford's early production lines were increasingly mechanized or automated as the use of electricity in factories expanded in the 1930s and 1940s and replaced steam engines, one of the first sources of mechanized output.

Exhibit 14
Robotics, Automation, and Artificial Intelligence (RAAI)
Early History of the Development of Industrial Robotics (1939 - 1979)



Source: Futura Automation - A History Timeline of Industrial Robotics

Exhibit 15
Robotics, Automation and Artificial Intelligence (RAAI)
Recent History of the Development of Industrial Robotics (1980 - 2020)



Source: Futura Automation - A History Timeline of Industrial Robotics

The idea of automated industrial production emerged from the idea of coordinating sequential production processes that use electric motors and hydraulic- and pneumatic-assisted devices to reduce the amount of human labor used in a production process. Despite mechanized assistance to reduce the amount of labor required in the production process, a systematic way to coordinate the production process, including timing and sequencing of production steps, was required to form the foundation of automated production. Accurate electrical cam timers, micro-switches, drum sequencers, dedicated closed-loop controllers, and protective relays emerged after World War II, particularly in Japan, during the dawn of the age of semiconductors in the late 1950s and early 1960s. Over time, manufacturing lines increasingly evolved to become a coordinated set of production steps, with each step governed by a specific machine tool responsible for one component of the production process.

Since computers did not become commercially viable until decades later, automobile production was not able to begin to operate on even a partly autonomous basis until the 1980s. The advent of all-electric robots that replaced cumbersome pneumatic and hydraulic mechanized production first emerged in the 1970s following the award of the first robot patent to Unimation in 1961. Early electro-mechanical robots were developed for simple one-function production processes such as spot welding.

As the number of robot axes steadily expanded with the emergence of all-electric robots, the need for mini-computer robotic control systems began to appear in the 1970s and significantly expanded robot functionality. The formation of the Robotics Industry Association (RIA) in 1974 helped establish industry safety standards for robots. As the importance of programming steadily increased, the need for standardized computer numerically controlled language to operate robots ushered in the ability to not only program robots, but also introduce 2-D machine vision in the 1980s to enable dynamic robotic operation.

It was not until lower-cost computing power became more widely available in the late 1970s and 1980s that programmable logic controllers (PLCs) emerged on the factory floor. These ruggedized digital computers were designed to be flexible and easily programmable to enable reliable operation in dirty, hazardous environments. In effect, PLCs acted as the machine-language translators to coordinate a set of sequential production processes performed by a disparate machine tools sourced by various manufacturers. By being able to integrate the operation of a set of discrete machine tools that often operated with their own unique machine operating system, the dawn of computer-integrated manufacturing began to emerge in the 1980s, led by the global automotive industry. Initially, PLCs were used to orchestrate the coordinated operation of discrete manufacturing processes with single control loops to automate the assembly line for products such as cars and appliances.

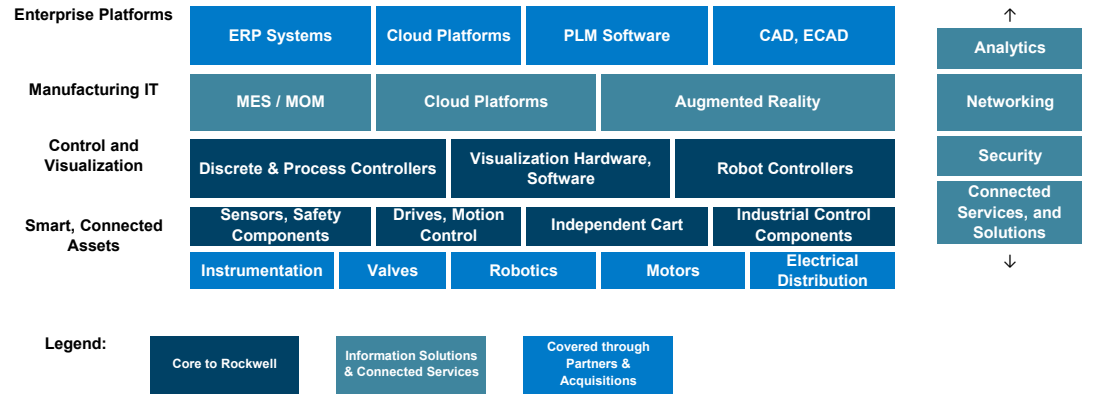
Over time, integrated industrial control systems (ICSs) emerged to operate increasingly complex discrete, batch, and continuous process manufacturing operations. Distributed control systems (DCSs) enabled the integration of modular control systems supplied by various manufacturers via a high-speed network to enable flexible interconnection and reconfigurable control systems. The arrival of electronic processors, high-speed electronic signaling networks, and graphic displays became standard components of integrated control architecture (ICA) that first arrived in the 1990s, such as Rockwell Automation's LOGIX and more recently Siemens' Mindsphere.

With the introduction of its FactoryTalk software in 2004, Rockwell Automation's LOGIX was the first ICA that could seamlessly interface manufacturing ICSs with enterprise platforms, such as enterprise resource planning (ERP), computer-aided design (CAD), electronic computer-aided design (ECAD), and product lifecycle management (PLM) software, to enable more dynamic management of a company's manufacturing with inputs from its enterprise platforms. Today, manufacturing operating technology (OT) systems such as manufacturing execution systems (MESs) and

manufacturing operations management (MOS) enable digital twin simulation of new manufacturing control process, often with the assistance of augmented reality (AR) visualization software, to help modify and optimize the performance of companies' discrete manufacturing production sites.

The convergence of OT and information technologies (ITs) represents a new growth frontier for traditional factory automation. Another source of potential growth for traditional industrial automation producers is the ability to move beyond OTs that control, integrate, and coordinate manufacturing processes that optimize the efficiency of their manufacturing production facilities to incorporate ITs that can enable coordinated simultaneous operation of multiple distinct manufacturing locations. OT has traditionally referred to the hardware and software control systems that detect and effect change by directly monitoring and controlling physical devices and processes. Examples of OT including SCADA, PLCs, HMIs, and modern manufacturing control architecture that is used to coordinate and operate modern automated production facilities. By contrast, IT traditionally described anything related to computing technology. Historically, IT has been separate and distinct from OT. However, as the need emerges for companies to horizontally integrate their production facilities around the world and also begin to digitally link their production facilities to their largest suppliers, the historically different worlds of OT and IT control are now beginning to converge.

Exhibit 16
Robotics, Automation, and Artificial Intelligence (RAAI)
Rockwell Automation Suite Capabilities



Source: Company reports

The prior exhibit presents a graphical portrayal of how Rockwell Automation seeks to provide factory automation systems for its customers in an increasingly digital environment. Rockwell today directly supplies operational, software, and visualization (virtual reality) controls that connect to smart connected assets in the customer's manufacturing and production facilities. Rockwell historically has integrated various control devices and components with factory automation and robotic manufacturing with its LOGIX control architecture.

LOGIX acts as the symphony director to connect and orchestrate the sequential operation of a customer's production facilities with manufacturing IT systems, which interface with enterprise management IT platforms using Rockwell's *FactoryTalk* and *PlantPAx* software. Rockwell's *FactoryTalk* software supports an ecosystem of advanced industrial applications, including IoT. Rockwell's *PlantPAx* system uses a common automation platform to seamlessly integrate critical areas of a manufacturing site—connecting process, discrete, power, information, and safety control into one plantwide infrastructure.

Rockwell provides manufacturing IT solutions through its Information Services and Connected Solutions (ISCS) business. ISCS is part of its Architecture and Software business, which includes its *Connected Enterprise* software designed to horizontally coordinate and link various global

manufacturing sites of its industrial automation customers. Industrial factory automation and process control companies' ability to scale and move from beyond their historical OT manufacturing domain into IT have so far proved challenging. Not only are their customers besieged with a vast array of OT and IT solutions and integration hurdles, but the pace of real-time connectivity (to reduce latency), the debate over whether to use cloud or edge computing, and how to deploy cybersecurity to protect the integrated operation of their manufacturing systems also have slowed the pace of customer deployment.

In the near term, we expect that factory automation providers' growth is likely to be driven by the expanding use of cobots, particularly higher-speed cobots with the commercialization of advanced processing high-speed 2-D and 3-D vision systems. We also expect the subsequent deployment of AI to enable adaptive cobots will be a key growth driver for traditional factory automation suppliers.

Traditional Factory Automation Is Steadily Evolving, but Growth Increasingly Correlated to Global GDP

Global manufacturers are increasingly looking to coordinate, integrate, and optimize the performance, cost, and seamless operation of their factories. To accomplish this, they are trying to horizontally link and integrate their global production operations to enable more dynamic global production management capabilities given the variable regional economic and geopolitical environments in which they operate.

Today, IT and OT are becoming more connected and interdependent, largely due to both control systems being connected to and increasingly reliant on the internet. We refer to this historical separation of IT and OT as the "continental digital divide" for the next generation of traditional industrial automation suppliers and historical corporate IT solution providers. While the emergence of connected production devices, IoT and 4.0 have increasingly aligned OT and IT, they have created significant new challenges to achieve new levels of corporate (as opposed to manufacturing) efficiency, optimal resource allocation, cybersecurity, and integrated operating synergies.

Perhaps most notable, the leading providers of manufacturing automation OT systems such as Rockwell Automation, Emerson Electric, Siemens, and ABB approach corporate wide OT and IT integration markedly differently from historical corporate IT systems providers such as Oracle, IBM, SAP, Accenture, and other providers of corporate IT, ERP, and integrated corporate operating systems. Historically, IT systems providers have not provided manufacturing systems designed to optimize factory operation and production. Instead, OT factory automation and process control providers have typically developed domain expertise about their customers' specific business that are critical to enable them to develop and provide the optimal factory automation and process control solutions for their manufacturing customers.

Exhibit 17
Robotics, Automation, and Artificial Intelligence (RAAI)
Top North American and Global Industrial Automation Vendors

Top 50 North American Industrial Automation Vendors

		2018 North American Revenue ($ billions)			2018 North American Revenue ($ billions)
1	Emerson	$5.23	26	Endress+Hauser	$0.32
2	Rockwell Automation	$4.00	27	Eaton	$0.30
3	ABB	$2.28	28	Sick AG	$0.30
4	Fortive (Danaher)	$2.12	29	Mitsubishi Electric	$0.28
5	Schneider Electric	$2.03	30	Festo	$0.28
6	Ametek EIG	$1.45	31	Turck	$0.23
7	GE	$1.23	32	Yokogawa Electric	$0.23
8	Siemens	$1.15	33	Aspen Technology	$0.20
9	Honeywell	$1.03	34	OSIsoft	$0.19
10	MKS Instruments	$1.02	35	Yaskawa	$0.18
11	Teledyne Instruments	$0.82	36	Weidmuller	$0.17
12	Roper Technologies	$0.72	37	IFM	$0.14
13	Spectris	$0.66	38	Wago	$0.14
14	National Instruments	$0.57	39	Phoenix Contact	$0.14
15	Flowserve	$0.54	40	Parker	$0.12
16	Advantech	$0.52	41	Vega	$0.11
17	Mettler-Toledo	$0.51	42	Horiba	$0.11
18	AVEVA	$0.48	43	MTS	$0.10
19	Wika	$0.47	44	Metso	$0.10
20	IMI	$0.46	45	Bosch Rexroth	$0.09
21	Belden	$0.39	46	Beckhoff	$0.09
22	Badger Meter	$0.37	47	Toshiba	$0.09
23	Omron	$0.37	48	Lenze	$0.09
24	Thermo Fisher Scientific	$0.36	49	Pepperl+Fuchs	$0.09
25	TechnipFMC	$0.34	50	Harting	$0.09

Top 50 Global Industrial Automation Vendors

		2018 Global Revenue ($ billions)			2018 Global Revenue ($ billions)
1	Siemens	$13.70	26	Wika	$1.18
2	Emerson	$11.67	27	IFM	$1.11
3	ABB	$9.97	28	Wago	$1.10
4	Schneider Electric	$7.31	29	Yaskawa	$1.09
5	Rockwell Automation	$6.72	30	Beckhoff	$1.08
6	Mitsubishi Electric	$4.07	31	Teledyne Instruments	$1.03
7	Honeywell - Intelligrated	$3.67	32	AVEVA	$1.02
8	Fortive (Danaher)	$3.66	33	Weidmuller	$0.97
9	Yokogawa Electric	$3.51	34	azbil Group (Yamatake)	$0.91
10	Omron	$3.16	35	Roper Technologies	$0.90
11	GE	$3.08	36	Lenze	$0.90
12	Ametek EIG	$3.03	37	Harting	$0.90
13	Endress+Hauser	$2.89	38	Bosch Rexroth	$0.87
14	Phoenix Contact	$2.80	39	Eaton	$0.84
15	IMI	$2.13	40	Fuji Electric	$0.81
16	MKS Instruments	$2.08	41	Pepperl+Fuchs	$0.79
17	Spectris	$1.99	42	Turck	$0.78
18	Sick AG	$1.93	43	Samson	$0.73
19	FANUC	$1.89	44	Thermo Fisher Scientific	$0.73
20	Festo	$1.84	45	Horiba	$0.69
21	Advantech	$1.78	46	Krohne	$0.66
22	TechnipFMC	$1.61	47	Hitachi	$0.64
23	National Instruments	$1.36	48	Belden	$0.63
24	Flowserve	$1.27	49	Burkert	$0.63
25	Mettler-Toledo	$1.21	50	Balluff	$0.57

Source: Control Global

Given the marketplace's gradually evolving resolution of the alternative IT versus OT solution propositions, traditional factory automation suppliers are continuing to invest in expanding their OT partnerships, form new joint ventures, and make acquisitions to enhance their OT software and analytics solution offerings to expand their digital integration and asset optimization capabilities for their customers. Over the past two years, Rockwell has made significant investments in PTC to expand its augmented reality software automation configuration capabilities and formed the Sensia joint venture with Schlumberger to provide integrated oil-and-gas digital services.

Rockwell also over the past year has acquired Emulate 3D to integrate its automation software with 3-D computer-aided design; acquired MESTECH Services for technology consulting and integration services; and earlier this year announced an agreement to acquire Avnet Data Security Ltd. to expand its cybersecurity offerings. The goal is to help double the $300 million in fiscal 2019 (September) sales of Rockwell's ISCS to about $600 million by 2022.

A critical objective is to increase Rockwell's recurring SaaS and analytics revenues. This is expected to help lessen Rockwell's reliance on its cyclical end-markets as recurring revenues rise from 35%-36% in fiscal 2019 to the low to mid-40% range over the next three to five years. Emerson has undertaken a similar effort; it has completed six software solutions and digital analytics acquisitions since early 2018 to expand intelligence solutions offered to its automation solutions process control customers.

While most offer open factory automation control architectures that connect manufacturing automation products and control systems from multiple suppliers, some such as Siemens' *Mindsphere* offer a more proprietary cloud-based IoT open operating system to connect customers' products, plants, systems, and machines. In addition, all industrial automation control providers seek to help customers capture critical operating data that can be used to generate advanced analytics to minimize production disruptions and produce predicative analytics that can be used to further optimize manufacturing production efficiency.

Honeywell's and Teradyne's Acquisitions Signify How Growth of New RAAI Technology Markets Is Now Rapidly Eclipsing Historical Factory Automation

New RAAI technology end-markets are already attracting strong investment by large industrial manufacturers such as Honeywell and Teradyne. For over 40 years, Honeywell's Automation and Control Solutions (ACS) business has been a leading supplier in the continuous process segment of the industrial factory automation and control market. In this market segment, Honeywell primarily competes with Emerson, Yokogawa, and ABB, and to a lesser extent Rockwell, Aspen

Technology, Invensys Operations Management, and Schneider. Honeywell's ACS has been a leading provider of process automation controls and consumables used by the oil and gas; refining; pulp and paper; industrial power generation; chemicals and petrochemicals; biofuels; life sciences; and metals, minerals, and mining industries.

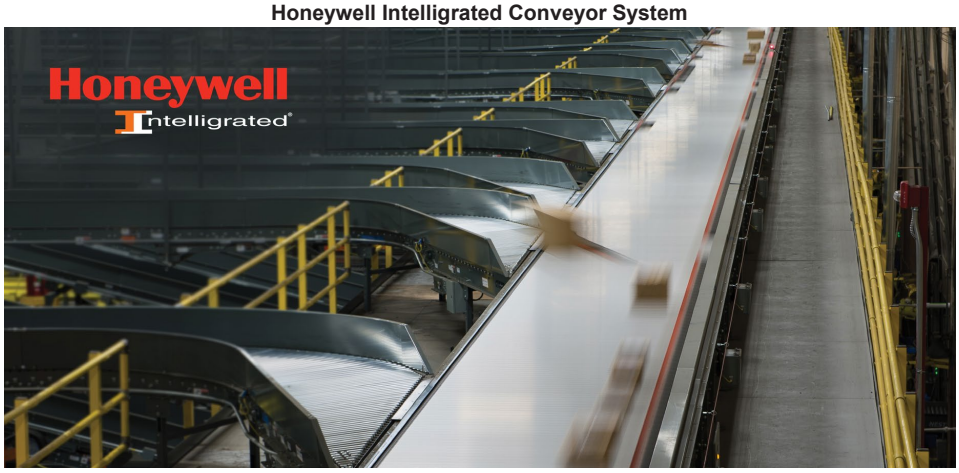
Serving the continuous portion of the traditional industrial automation market, ACS provides integrated process control and advanced safety, a complete set of software solutions to connect and integrate plants including data analytics and process control dynamic modeling visualization. With smart, connected measurement and control devices, combined with software solutions and open interfaces for data access, ACS enables users to better manage plant assets and optimize productivity. ACS also provides industrial security solutions including a complete set of industrial cybersecurity solutions as well as a suite of virtualization and cloud engineering solutions that transform, accelerate, and de-risk project execution.

It was perhaps somewhat initially surprising to see Honeywell in July 2016 acquire Intelligrated, a leading provider of turnkey warehouse automation solutions, for $1.5 billion, or roughly 12 times estimated 2016 EBITDA. Intelligrated's core technology used sensors, motion controls, and scanning technologies that, while different from those used by Honeywell's ACS business, leveraged and built on many of Honeywell's legacy strengths in the continuous process control segment of the traditional industrial control market. Intelligrated is now part of the Sensing and Productivity Solutions (S&PS) segment of Honeywell's ACS business.

Intelligrated is the largest provider of warehouse automation solutions in North America and the second largest globally. It designs, manufactures, integrates, and installs complete warehouse automation solutions, software, and services that result in smarter distribution and fulfillment operations. Its supply chain and warehouse solutions drive improved productivity and lower costs for retailers, manufacturers, and logistics providers around the world.

At the time it was acquired, Intelligrated had estimated 2016 sales of $0.9 billion; we estimate sales approximated $1.4 billion in 2019. In the three years before its acquisition by Honeywell, Intelligrated's sales grew at a compound annual rate of about 13%, outpacing its served end-market. Intelligrated has a large and growing customer base of more than $5 billion, including leading *Fortune* 500 retailers, manufacturers, and logistics providers worldwide; top consumer products companies; 30 of the top 50 U.S. retailers; and half of the top 100 internet retailers.

Exhibit 18
Robotics, Automation, and Artificial Intelligence (RAAI)
Honeywell Intelligrated Conveyor System



Source: Honeywell International

Intelligrated is a leading provider of turnkey warehouse automation solutions focusing on a total addressable market that Honeywell estimates to be about $29 billion. Intelligrated is well positioned to take advantage of favorable macro trends, including e-commerce growth (which LogisticsIQ projects should grow at a 14% compound annual rate from 2019 to 2025), more efficient fulfillment requirements, and the growth of omnichannel capabilities in retail. The business operates out of five manufacturing facilities with plenty of excess capacity to allow it to scale as volume increases.

While Europe (about $9 billion addressable market) and China (about $4 billion addressable market) constitute a low percentage of Intelligrated's revenues, these regions are a core focus of Honeywell going forward. In Europe, Honeywell is investing to develop a more customized warehouse automation portfolio, given that in Europe land is more constrained than in North America and will require solutions for narrower, taller, and less standardized warehouse layouts. In China, Honeywell recently invested in Flux, a leading warehouse management system provider. Honeywell will hold a minority stake in Flux's China business but control a majority stake in its global joint venture with the company. Honeywell believes its China presence will help pull through significant business for Intelligrated.

Honeywell does not view its Intelligrated acquisition solely as a warehouse automation play, but rather the beginning of a much larger transition into transportation logistics and sourcing. Intelligrated's business includes three components: warehouse automation project installation, aftermarket service and support, and ongoing software to continually optimize the dynamic performance of Intelligrated's installed base. Intelligrated sales are predominantly composed of new greenfield project installation, which while lumpy is expected to grow at strong double-digit rates for the next three to five years before likely moderating to mid- to high-single-digit growth. While notably smaller but more profitable, Intelligrated's service and software business is growing in excess of 20% annually. Honeywell believes the evolution of the mix of Intelligrated's business is likely to follow a similar path of its Process Solutions business, which initially in the 1980s and 1990s was predominantly a greenfield project business. In October 2019, Honeywell formed Honeywell Robotics, an advanced technology center of excellence focused on innovating and developing AI, machine learning, computer vision, and advanced robotics for use across supply chains.

Based in Pittsburgh, Honeywell Robotics will help shape the warehouse and distribution center of the future, particularly as companies look to automated solutions, software, and robotics to deliver increased speed, accuracy, and throughput in complex material-handling environments. With over 25 years at the forefront of warehouse automation technology to help customers improve productivity and efficiency, Honeywell appears committed to becoming a globally integrated leader in the transportation logistics and sourcing sector.

Consumer expectations have caused a seismic shift in supply chain operations. According to eMarketer, online shopping accounts for nearly 15% of total retail sales and is expected to grow to 22% by 2023, representing over $6.5 trillion in sales. Online purchasing, combined with same- or next-day delivery options, has stressed the labor market to the point of a shortage. Nearly 80% of distribution center operations are still performed manually, according to a recent DHL "Robotics in Logistics" study. With the growth of the automated warehouse industry outpacing the available supply of labor by a rate of 6 to 1, this growth is creating significant opportunities to automate supply chains. Joseph Lui, a robotics innovator with an extensive background in digital data, autonomous technologies, and the industrial IoT, heads Honeywell Robotics. Before joining Honeywell Robotics, Lui was director of industrial IoT and automation technologies, robotics for Amazon.

With continued advances in lower-cost AI, machine learning, and computer vision, Honeywell Robotics looks to commercialize innovative, breakthrough technologies to help customers alleviate skilled labor shortages, reduce safety risks, and eliminate inefficient tasks. Honeywell Robotics

believes advanced warehouse execution systems; 3D-vision storage and sortation solutions to improve capacity and efficiency; and AMRs all represent only the beginning of the digital transformation of the warehouse distribution function.

To accelerate its warehouse automation business, Honeywell Robotics plans to leverage Honeywell's Momentum™ warehouse execution system, a configurable enterprise software platform that orchestrates equipment, labor, and inventory for distribution centers. Momentum can help streamline the deployment and integration of advanced robotics by providing warehouse managers with a single, centralized system to manage their operations and automation technology.

Honeywell also is collaborating with AI researchers at Carnegie Mellon University's National Robotics Engineering Center to develop breakthrough robotics technologies for distribution centers. The company, through its Honeywell Ventures investment fund, also has made strategic investments in robotics companies, including Soft Robotics and Attabotics, to help automate complex tasks in dynamic environments to maximize productivity and labor efficiency.

Teradyne is another established industrial company that has rapidly emerged as a new integrated supplier of cobots and AMRs. While Teradyne was established as a dominant global leader in its semiconductor test equipment market, the company expected that near-term sales for this business on average were likely to grow at an annual rate of only 3%-4%. To enhance its growth potential, Teradyne decided that it would enter the robotics and automation market. However, it did not want to compete with the four major industrial robot manufacturers (ABB, Kuka, Fanuc, and Yaskawa). Instead, it was looking for a way to enter the robotics market with a low-payload robot that could perform higher-precision tasks that can easily mimic the performance of a human on the assembly line.

So in 2015, Teradyne decided to upshift its growth potential from its historical core business as one of two leading global suppliers of semiconductor test equipment with the purchase of Danish cobot producer Universal Robots (UR) for $285 million plus $65 million of conditional incentive performance payments. From sales of $38 million in 2014, UR's revenues grew to $234 million in 2018, and it holds a 60% share of the global cobot market. UR sold its first cobot in 2008, and by mid-2019 its global cobot installed base exceeded 34,000. While automatic electronics test equipment still accounts for about three-quarters of Teradyne's sales, the company has steadily expanded its footprint from cobots into AMRs with several recent acquisitions. In 2015, Industrial Automation (IA) accounted for just $42 million, or 2% of Teradyne's sales, but by 2018 IA revenues reached $261 million, or 12% of the company's sales. In 2019, Teradyne's IA revenues from cobots, AMRs, and motion control software organically grew 12% (14% including acquisitions) to $298 million and accounted for 13% of Teradyne's total 2019 $2.3 billion in sales. However, Teradyne lowered AI's projected 2019-2022 CAGR to 20%-35%, from 30%-40% previously, due to recent slower growth in global manufacturing. Encouragingly, Teradyne projects AI's sales should increase at least 20% in 2020.

In 2018, Teradyne acquired another Danish automation company, Mobile Industrial Robots (MiR), which produces AMRs for payloads of less than 1,000 kg for intralogistics material handling, for $272 million. Founded in 2013, MiR had annual revenues in 2017 of $12 million, which are estimated to have grown to more than $40 million in 2019. In 2018, Teradyne also acquired Energid, a provider of motion control software. In 2019, Teradyne purchased AutoGlide Mobile Robots for $58 million. AutoGlide's 2018 sales were $4 million, and produces transport AMRs designed for payloads up to 4,536 kg (or 10,000 pounds).

AutoGlide's AMRs feature a flexible modular architecture that allows its AMRs to function as autonomous, highly maneuverable forklifts as well as tugs for accurate and easily repeatable tasks across multiple routes. Its fleet management software enables easy route creation and modification for

heavy-payload specialized AMR vehicles such as pallet stackers, tugs, and forklifts. Whereas MiR has an installed base of thousands worldwide, AutoGlide targeted sales of 80-100 transport AMRs in 2019 and up to 200 in 2020. Teradyne remains the global leader in cobots and offers AMRs for autonomous mobile transport for loads of 100 to 4,536 kg for industrial and warehouse logistics markets. Given its appetite to expand its industrial automation revenues to $1 billion in the relatively near future, it will be interesting to see where Teradyne decides to next expand its industrial automation participation.

Key Private Warehouse Automation and Integration Providers

Fortna. Fortna, based in West Reading, Pennsylvania, helps distributors design and implement supply chain solutions and transformations, often through the advent of material handling automation and with the assistance of warehouse execution software systems. These systems are designed to improve customer returns by optimizing operating costs, driving higher throughput, and improving service to customers. For more than two decades, Forna's portfolio has included providing intelligent warehouse control capabilities through its FortnaWCS (the original) and FortnaWES (the upgrade) products, which are MHS and WMS agnostic and improve workflow, labor, and equipment efficiency across a broad set of systems and automated solutions. Since its founding in 1946, Fortna has secured funding from a number of different sources through multiple capital raises, most recently by garnering an undisclosed amount of development capital supplied by Thomas H. Lee Partners in March 2019.

GrayMatter. Founded in 1991, Pittsburgh-based, GrayMatter is a leading provider of operational technologies (OT) and Industrial IoT consulting services to the manufacturing, water and energy industries in North America. GM's operational technologies seek to deliver data driven, process automation solutions in an effort to optimize its customers' operations, resulting in increased productivity, enhanced security and improved monitoring and intelligence capabilities. GM is also a provider of implementation services and software solutions designed to deliver high returns for machine-level automation and digitization projects, optimizing its customers' operations while ensuring safe and reliable performance. Hamilton Robinson Capital Partners acquired GrayMatter in December 2017.

TREW Automation. TREW Automation was founded in January 2019, following a controlling equity investment by private equity firm Orchard Holdings Group. Headquartered in Mason, Ohio, TREW Automation, serves the North American retail, warehouse, distribution, manufacturing and e-commerce industries, operating as a leading provider of full-service turnkey automated material handling solutions, including software, machine controls, robotics (through a series of partnerships including IAM Robotics, GreyOrange and Exact Automation), conveyor sortation and order fulfilment. While not currently focused on mega-distribution centers (typically costing more than $40 million), the company can support new greenfield installations, as well as brownfield modernizations and expansions. TREW is also a leading provider of aftermarket service offerings including a full suite of maintenance, repair and productivity solutions. Given its private equity support, the company is fully funded today, but continues to evaluate strategic partnerships, as a way of opening additional sales channels into new markets.

Viastore Systems. Founded in 1999, Viastore Systems is a global supplier of integrated material handling systems for distributors and manufacturers, including automated picking, sorting and conveyor systems. The company provides consulting and integration services for a variety of end markets, including automotive, e-commerce, food & beverage, consumer and healthcare. Viastore is based in Stuttgart, Germany with U.S. offices in Grand Rapids, Michigan.

WITRON Logistik + Informatik GmbH. WITRON is a global provider of logistics and order picking systems, including warehouse management, transport, and delivery systems, and material handling solutions. Operating throughout Europe and North America, the company primarily serves the retail and general industrial industries. WITRON was founded in 1971 and is based in Parkstein, Germany.

From the Factory Floor to the Grocery Store

Online Grocery Fulfillment Could Soon Become Larger Than Warehouse Automation

Online grocery fulfillment could be the next breakout RAAI end-market outside traditional industrial automation. With warehouse automation sales expected to more than double from an estimated $13 billion in 2018 to about $27 billion by 2025, according to LogisticsIQ Research, the automation market is scanning the horizon for the next large market likely to rapidly deploy RAAI technologies. The need for faster, more automated delivery for online retailing and a huge shortfall in available warehouse workers were critical external factors that help create the need for automated warehouse management.

Aided by Amazon's early investment in automated warehouse technology, the rapid drop in cost for critical hardware, the emergence of standardized operating software for AMRs, and improved highly tactile grippers and vision systems to automate pick and place collectively enabled the creation of warehouse automation as the first new RAAI mega market over the past five years. The growth of automated warehouse investment is also being accelerated by the structural change in North American freight logistics to localize distribution centers that enable closer physical access to customers to support ever-shortening order fulfillment times.

New RAAI technologies, a massive existing real estate footprint, and a desire to reduce the time spent grocery shopping point to online grocery fulfillment as the next potential RAAI megamarket. Investors are now scanning the horizon for what the next mammoth new RAAI market might be. We believe that many of the same factors that enabled the rapid buildout of the automated warehouse market could also similarly be applicable to online grocery fulfillment. The grocery business is another large key retailing sector facing the same labor shortage challenges in addition to the need to reduce the average 60 hours per year consumers spend shopping for groceries, which is more than for any other type of product.

According to retail advisory firm Brick Meets Click, online grocery sales accounted for only about 6.3% of grocery-related spending by households in the United States, and it believes this could reach 7% of the U.S. grocery market in 2020. According to John Lert, CEO of Alert Innovation, in the not-too-distant future it is possible online grocery sales could approach the 20% of apparel that is purchased online by U.S. consumers today. The technology to enable online grocery fulfillment has several new dimensions of critical functionality versus automated warehouses such as three alternative product temperatures (ambient, refrigerated, and frozen).

With available RAAI technology, this creates the need (for some consumers the desire) for hybrid automated and manual order fulfillment formats. In addition, groceries tend to be considered a vital need by consumers rather than a desired product that they have been increasingly willing to buy online. Despite notable differences, new online grocery order automated fulfillment centers using RAAI technologies and hybrid grocery store formats are now beginning to be rolled out commercially.

The initial shift to introduce technology to reduce the time consumers spend shopping originated with self-checkout kiosks that were first introduced in the late 1990s; they were produced by NCR, Diebold, Crane Company, Fuji Electric, Hitachi, and several others. The ability to lower costs by reducing checkout cashiers was an early driver of market adoption of self-checkout scanning, particularly by big-box retailers. According to a recent PYMNTS Self-Service Kiosk Report, in the United States an estimated 71% of retail grocery shoppers have tried or regularly opt to use self-checkout systems when available.

Global Market Insights estimates the self-checkout system market could reach $4 billion by 2024, up from an estimated $2 billion in 2019. More recently, handheld self-scanning devices for retail shoppers emerged as the next logical iteration to improving retailing economics, free shoppers from extended checkout lines, and overcome labor shortages for retail cashiers. Perhaps most important, several forces now point to the grocery industry—a long-time holdout due to its more complex automation needs—being on the cusp of accelerating and pervasive disruption in their historical logistical distribution processes and systems.

The latest innovation to simplify and accelerate the consumer in-store retail shopping experience has been cashierless convenience stores. In the United States, the first retailer to introduce this format was Amazon GO, a retail store that features no lines, no checkouts, and no registers. Following initial testing with Amazon employees in December 2016, Amazon GO opened to the public in early 2018 and has since been selectively rolled out at 22 locations. Amazon has eight Amazon GO stores in New York City, six in Chicago, and four each in San Francisco and Seattle. These stores typically occupy 1,200-2,300 square feet and focus on offering prepared foods, snacks, and a few grocery items for working professionals between 6 a.m. and 8 p.m., with the majority of sales occurring during the workweek. The Amazon GO store concept uses computer vision, deep learning algorithms, and sensor fusion to automate much of the purchase, checkout, and payment steps to complete a retail purchase. The goal is to make the time spent in the store as quick as possible.

Given the store's level of automation, it provides real-time supply chain and inventory management. Other enabling technologies include geofencing and the requirement a consumer has a smartphone to use the Amazon GO app. The app registers a consumer's entry at turnstiles at the store's entrance that scan a QR code generated by the Amazon GO app and also allows customers to add others shoppers to their Amazon account. This enables the purchases from multiple related shoppers to be collectively recorded and charged to the same bill. Cameras on the ceiling of Amazon GO stores monitor consumers' selections, while the shelves have weight sensors to detect consumers' product selections. Removing a product from the shelf adds it to the customer's virtual cart, which is reversed if the item is replaced on the shelf.

While the Amazon GO store helps reduce the time a consumer needs to spend shopping, the small footprint limits the store's ability to accommodate the varied (ambient, chilled, and frozen) temperature formats across a broad array of products. Amazon GO also does not allow consumers to place an order online for immediate pickup once the customer arrives at the store. Therefore, we sense that Amazon GO is likely to have exceptional success for specialty retail locations such as convenience stores, where availability of a smaller set of product offerings rather than a broad array of products is most important.

In late February 2020, Amazon opened its first Amazon Go Grocery store in Seattle's Capital Hill neighborhood about a mile from the company's downtown headquarters. The operation of Amazon Go Grocery is a template off the same technology developed for the Amazon Go store format. This store occupies roughly 10,400 square feet and stocks about 5,000 items, including some produce, meat, and other fresh food, as well as baked goods and food prepared by local businesses. Amazon Go Grocery will carry Whole Foods' 365 brand and other private-label products, alcoholic beverages, as well as staples and household goods. The goal of Amazon Go Grocery is to combine product availability and low prices with the convenience of quick shopping. Although shopping at Amazon Go Grocery will not require any human interaction, the store will be staffed with employees to restock the shelves and answer customers' questions, check IDs for liquor purchases, and facilitate cash payment if the customer desires. Otherwise, payment is automatically billed to customers via their Amazon Go App preferred credit or debit card.

The Amazon Go Grocery format provides shopping carts and recycled reusable shopping bags but has no checkout lanes. It appears that the Amazon Go Grocery model is to leverage the convenience and simplicity of its Amazon Go stores but not attempt to compete but rather complement its Whole Foods chain's more traditional grocery store design. For instance, Amazon Go Grocery stores will neither exclusively carry typically higher-priced organic food nor stock the same broad array of products found in Whole Foods or offer in-store customer pickup for online orders or home delivery. However, the first Amazon Go Grocery will offer validated one-hour underground parking and feature a self-service coffee bar, but no staffers are available to assist shoppers with loading their groceries in their vehicles. Therefore, Amazon Go Grocery is Amazon's answer to expediting the customer's shopping experience without the need for investing in automated centralized or local fully automated micro-fulfillment robotic systems. Another critical benefit of the Amazon Go Grocery format is a reduction of labor costs, which account for about 50% of Whole Foods' expenses.

Amazon may have been first, but it is not alone in working to automate the checkout-free, technology-driven retail format. AiFi, a Santa Clara, California, start-up founded in 2016, is a technology company that has developed a checkout-less retail store format using computer science, AI, computer vision, and deep learning. Like Amazon Go, AiFi's retail format uses an extensive array of cameras, sensors, and AI to monitor what customers buy, and also uses a smartphone app that records the customer's arrival and fully automates payment to provide an expedited shopping experience. However, AiFi believes its retail format is scalable for large traditional grocery stores and can accommodate up to 500 simultaneous shoppers and track tens of thousands of SKUs in the retail store. Like Amazon Go, AiFi can track shoppers' behavior, the order in which they select items to purchase, and items returned to the store shelf.

AiFi's system also uses facial recognition software to individually identify customers when shopping and, for repeat customers, provide customized shopping recommendations. A critical element of AiFi's system is the expectation that the current high cost of its retail format will be able to be reduced with volume. To help offset the cost initially, AiFi anticipates that users will be charged a subscription fee for the convenience of checkout-free, expedited shopping. For all totally automated retail store formats, a perhaps larger question is the extent to which shoppers are willing to exchange privacy (nonstop surveillance when in the store) for a quicker shopping experience. AiFi believes its cashierless store format could also be also optimal for its NanoStore format, a retailing footprint occupying as little as 160 feet that would be ideally suited for airports, college campuses, subway platforms, and other public locations with limited retail space or that might be used on only a temporary or seasonal basis.

Grabango is yet another technology start-up computer vision company that has developed a checkout-free retail format featuring a plug-and-play autonomous shopping system suitable for warehouse club-sized retailers occupying up to 100,000 square feet. Founded in 2016 and based in Berkeley, California, Grabango has identified six levels of retail checkout automation: 1) no automation, 2) machine readable barcodes to expedite checkout clerk scanning, 3) self-checkout, 4) conditional automation (automated detection of items selected by a shopper that eliminates checkout scanning), 5) highly automated (dynamic automated customer shopping that automatically records payment), and 6) full automation (including the ability to automatically process products that are sold by weight).

Grabango believes its checkout-free, fully automated retail format is scalable for all size retail stores, can offer a scaled degree of customer shopping automation to accommodate all types of retail shoppers, does not have to require a specialized app, can be profitable for the retailer, and does not have to exclude cashiers and customer service (due to the variability of shopping automation). While this "one system customizable retail automation" may sound overly ambitious, Grabango in July 2019 announced a checkout-free partnership with Giant Eagle for its existing stores located in the United

States. Giant Eagle is a top-20 U.S. grocery chain, operating 474 retail locations across a wide variety of grocery store formats. Similar to Amazon Go and AiFi's checkout-less retail formats, Grabango believes its retail automation solution can materially reduce the extended amount of time customers historically have spent to shop, check out, and complete their shopping experience.

The continuing rise in online retail grocery sales suggests that automated grocery fulfillment may be the major market ripe for transformation. The steady rise in online retailing has created unique challenges for grocers. According to Grocery Dive, nearly 37% of shoppers affirmed in 2019 that they had purchased groceries online in the prior year, up from 23% in 2018. Still, despite online grocery sales growing 16% in 2019 according to advisory firm Brick Meets Click, it estimates about 7% of all U.S. grocery sales could be generated by online orders in 2020. It has been estimated that when e-grocery sales reach 7%-8% of a store's volume, congestion from manually picked online orders will become a pronounced negative for a store's traditional cliental. Brick Meets Click estimates store pickup and delivery services to support online grocery orders were available to 90% of all households in the United States as of September 2019, up from 81% in 2018.

According to Global Data, 5.5% of all U.S. grocery spending was made online in 2018, with projections to reach 9.7%, or an estimated $133.8 billion in total sales, by 2022. We have seen several midsingle-digit 2019 estimates for online grocery's share of total U.S. grocery sales According to IBISWorld, the U.S. online grocery market has grown from $12 billion in 2016 to $26 billion in 2018. Nielsen and the Food Marketing Institute and is expected project that consumer spending on e-grocery could reach $100 billion in 2025 and capture as much as 20% of retail grocery sales. What appears to be occurring is a rapid rise in the percentage of consumers who prefer a combination of both traditional in-store shopping and the ability to buy their groceries online.

Initially, grocery stores filled online orders manually with personal shoppers who individually went throughout the store to assemble customers' orders. The rise in online grocery orders, congestion in store aisles, diminished product availability (stock-outs) for customers shopping onsite, and quicker delivery times necessitating faster order picking all have become growing issues for grocery retailers to ensure online grocery orders remain a viable long-term strategy. As a first alternative, grocery stores switched to off-site, highly automated centralized fulfillment centers (CFCs) typically located outside but adjacent to urban centers.

Another pressing issue for grocery stores was how to make online orders profitable to fulfill, particularly for costs associated with last-mile delivery. Interestingly, a growing percentage of grocery customers prefer to be able to shop both in-store and online. This underscores what seems to be a critical guidepost for all grocery venders: the need to be omnichannel retailers.

While the majority of customers still go to grocery stores to shop, online orders can be assembled for curbside pickup (buy online/pick up in store [BOPUIS]) or delivered directly to the customer with third-party on-demand fulfillment services such as Instacart. Whereas it costs grocers about $5 to get an order to the curb if the customer shops in the store (still the most profitable for grocers), it costs an average $15 for BOPUIS orders that are picked by store employees for customer pickup ("click-and-collect").

In recent years, consumers in urban centers have preferred in-home delivery, while those outside core city locations in the suburbs have generally remained content to shop in-store. Grocery stores are now weighing myriad dynamic criteria and logistical alternatives to profitably automate fulfillment of online e-grocery orders: 1) automate centralized 2-D robotic fulfillment centers to create a spoke-and-hub system for several dozen regional grocery stores; 2) have robotic micro-fulfillment systems located directly in grocery stores; 3) have cashier-less stores that speed customers who shop through a highly automated convenience or grocery store.

Micro-fulfillment centers emerge as the hyperlocalized automated solution. To address growing store congestion and make online fulfillment profitable, a new solution that has emerged is to construct micro-fulfillment centers (MFCs) hyperlocally directly within the grocery store premise. By being located close to where shoppers live, store congestion and last-mile delivery costs are reduced significantly.

By automating the vast majority of online order picking with MFCs, hyperlocal automated fulfillment can significantly reduce last-mile delivery costs while making better use of grocery stores' expensive and frequently underused space. MFCs use vertical rack systems (typically about two stories or 24 feet high) and robotic picking systems to retrieve the majority (often about 80%) of the items most frequently ordered online, including refrigerated and frozen foods. Only fresh fruit, vegetables, and meat are still typically hand-collected by store employees (although new robotic picking with enhanced 3-D vision may change this).

Another advantage of MFCs over manual in-store pickup by personal shoppers is it reduces the need for a grocery retailer to hire additional staff to meet surges in online grocery orders. Ideally, the optimum solution using automated fulfillment will be improved speed, accuracy, productivity, and overall retailer efficiency and profitability for online grocery orders.

Exhibit 19
Robotics, Automation, and Artificial Intelligence (RAAI)
Online Grocery Order Fulfillment Model Comparison

	MFC	CFC	Manual Pick
Location	In Store	Regional Distribution Center	In Store
Size (Sq. ft.)	10,000 to 20,000	300,000 to 400,000	1,000 to 2,000
Cost	$3 million to $5 million	$50 million to $60 million	< $0.25 million
Breakeven Period	1 year	3 to 4 years	< 1 year
SKUs	15,000 to 18,000	50,000 to 60,000	40,000 to 50,000
Items Picked Per Hour	800	300 to 400	60 to 80 per picker
Time to Pick 50 Items	4 to 7 minutes	6 to 7 minutes	35 to 50 minutes
Fulfillment Window	2 hours	Same or Next Day	Same Day
Cost to Fulfill Order	$5 to $6	$5 to $6 (including transportation)	$7 to $9
Orders Per Week	3,500 to 4,000	260,000	130 to 140 per picker
Congestion Threshold	None	None	6% to 7%
Benefits	Hyperlocal Scalable and Reconfigurable	Regional	Hyperlocal
Handicaps	Small Investment Some Store Redesign	Large Investment Nominal Store Redesign	Nominal Investment Modest Store Redesign

Source: Company reports

A typical MFC can be configured to use only one-third of the space of an average grocery store, or about 10,000-20,000 square feet, and handle 15,000-18,000 SKUs. Whereas personal shoppers can pick 60-80 items per hour to fulfill online grocery orders, MFCs can pick up 800 products per hour, or about 10 times as many as a store worker. A typical 50- to 60-product online grocery order is able to be assembled and prepared for delivery in four to seven minutes. This allows MFCs in a typical grocery store to be able to fulfill 3,500-4,000 online orders each week within two hours after the online order is received.

MFCs can be completed within three months after the start of construction and typically cost $3 million-$5 million, versus two to three years for an automated regional CFC (also referred to as "dark stores" due to their lack of customers in the facility). CFCs can cost as much as $60 million but stock 50,000 or more SKUs and provide automated fulfillment for online grocery orders for 15-20 or more nearby stores, typically on a same- or next-day basis. Because MFCs are hyperlocal, they can accommodate same-day or shorter delivery times than CFCs and typically have lower costs for BOPUIS and home-delivery online grocery orders. This allows MFCs to offer more flexible and shorter order fulfillment times for online grocery orders than automated CFCs. With growing pressure to cost effectively accommodate rising online grocery orders, it has been estimated that grocers could spend as much as $100 billion on micro-fulfillment technology and solutions over the next five years as they transform the $667 billion (2019) U.S. grocery industry, according to IBISWorld.

Several companies have emerged that provide turnkey MFC solutions for grocery retailers, including Takeoff Technologies, Fabric (formerly CommonSense Robotics), Alert Innovations, Dematic, and Swisslog/Autostore. In many cases, MFC suppliers have partnered with logistics and automation warehouse solutions companies to ensure their integrated automated fulfillment solutions can be optimally designed, and seamlessly deployed and integrated with retailers' online customer order systems and supply chains.

Takeoff Technologies has an exclusive agreement with Knapp AG of Germany, while Alert Innovation has partnered with Murata Machinery, Ltd. (known as Muratec) of Japan to provide logistics, automation, and fulfillment integration expertise for its MFC customers. Takeoff Technologies and Knapp anticipate opening 50 MFC locations across North America by the end of 2020 that will cost an estimated $150 million but be capable of processing $1.5 billion of online grocery orders annually.

Alert Innovation's Alphabot system uses robots that can move linearly and vertically and super capacitors to store energy that are charged every time the robot moves vertically. Alert Innovations has also developed a new hybrid store format called Novastore that combines an MFC with a fresh market retail store. A Novastore has two floors, is 45 feet high, but only occupies 17,000 square feet, while outside parking areas are typically three to four times as large as the store footprint. The first floor offers conventional self-service shopping for fresh produce and meat, but has no checkout lanes and no traditional center store. All packaged goods are ordered by customers electronically either in the store or remotely online. Customers can order fresh goods online or select their own fresh items in the store. For customers who opt to select their own fresh products on-site, order completion time typically takes only five to eight minutes after it is finalized.

Ocado Group plc, based in the United Kingdom, has emerged as the leading provider of large automated CFCs that are designed to serve 15-20 or more local grocery stores located in a major urban market. Ocado's solution is perhaps the most advanced at streamlining robotic picking from its typically 300,000- to 400,000-square-foot centralized fulfillment centers and can stock 54,000 SKUs. However, the CFCs' robotic picking system operates only on a 2-D plane, not a 3-D like MFCs. By also operating vertically, MFCs are able to dramatically reduce the footprint, cost, time to build, and payback period for their automated online grocery fulfillment system versus a regional automated fulfillment center. Given their very different size and corresponding investment, we believe that localized MFCs are likely to have shorter payback periods versus centralized automated fulfillment centers. With spoke and hub logistics, automated fulfillment centers also typically have higher last mile distribution costs given their centralized location to support typically dozens of locally affiliated grocery stores.

Not surprisingly, the leading robotically automated online fulfillment providers have announced partnerships with the leading U.S. grocers over the past couple of years and several have just recently opened MFCs located within retail grocery stores or have begun constructing CFCs. At this point, there appear to be two alternative philosophies in how to best embrace robotic automation to fulfill online grocery orders. At the risk of oversimplification, they could best be described as automated CFCs to serve large regional areas versus hyperlocalized MFCs constructed within an existing grocery store location.

While both seek to leverage the power of automated robotic picking to fulfill online grocery orders, in some cases grocery stores will at least initially use a combination of manual grocery store picking to supplement certain portions of their online grocery order fulfillment. As discussed below, most but not all grocery store chains and general merchandise retailers that also sell groceries in North America are now embracing automation to develop a timely, economic, and fully viable way to respond to the growing consumer interest in online grocery fulfillment. As one provider of MFCs noted, ordering groceries online is no longer a luxury, but it is rapidly becoming a necessity if grocery stores do not want to lose market share.

Exhibit 20
Robotics, Automation, and Artificial Intelligence (RAAI)
Online Grocery Order Fulfillment Solution Providers

	MFC	CFC	Manual Pick
Retailers - Supplier	Walmart - Alert Innovation Ahold Delhaize - Takeoff Technologies Loblaws - Takeoff Technologies Wakefern Foods - Takeoff Technologies Sedano's - Takeoff Technologies Albertsons - Takeoff Technologies Woolworths Group - Takeoff Technologies	Kroger - Ocado Sobeys Inc. - Ocado	Whole Foods Target Costco Sprouts

Source: Company reports

MFCs are also being deployed in smaller separate locations to fulfill online orders for clusters of local grocery stores. In 2018, Albertsons picked Takeoff Technologies to install MFCs for it grocery stores and opened two pilot MFCs in Safeway stores in San Francisco and San Jose, California, in late 2019. Albertsons is the second-largest grocery retailer in the United States; as of the end of 2019, it operated 2,260 stores in 34 states and the District of Columbia. Albertsons includes chains such as Safeway, Jewel-Osco, Vons, Pavilions, Randalls, Tom Thumb, Carrs, Acme, Shaw's, Start Market, United Supermarkets, Market Street, Amigos, Haggen, and United Express. Albertsons has committed to opening 50 MFCs using Takeoff Technologies' hyperlocal automated distribution systems over the next couple of years.

Koninklijke Ahold Delhaize N.V., which operates more than 1,824 grocery stores in 23 states in the United States (and about 6,500 worldwide) in conjunction with its online grocery unit Peapod, has selected Takeoff Technologies to build MFCs for its Stop & Shop grocery chain to expand the growth of its automated online grocery order fulfillment. Stop & Shop opened its first MFC in January 2019 in Windsor, Connecticut. Using an in-store MFC from Takeoff Technologies, it is integrated with its online grocery business Peapod and enables online order fulfillment for both Stop & Shop and Peapod. This dual MFC capability is unique to Ahold Delhaize. Ahold Delhaize's U.S. distribution network includes 15 traditional and e-commerce distribution centers, which serve its Food Lion, Giant Food, Giant/Martin's, Hannaford, and Stop & Shop supermarket chains, as well as Peapod. The company expects to expand its automated distribution network to 22 facilities in the United States by 2023.

In late 2019, Loblaws selected Takeoff Technologies to build a pilot 12,000-square-foot MFC in one of its superstore locations in Greater Toronto, which is expected to become operational in 2020. Loblaws, a Canadian supermarket chain with almost 2,500 stores located primarily in the provinces of British Columbia, Alberta, Ontario, and Quebec, is based in Brampton, Ontario, and is a subsidiary of Loblaw Companies Limited, Canada's largest food distributor. The MFC will work in conjunction with Loblaws' PC Express online grocery ordering platform, which currently operates 700 PC Express pickup sites at grocery and drug stores and transit stations throughout Canada. Loblaws envisions that when a PC Express order is received, it may be split between automated and manual picking depending on the products ordered. Loblaws anticipates that its MFCs will be used to pick the highest-velocity items. So far, Loblaws has remodeled seven stores in Western Canada to accommodate increased online order volume, where the company has its highest PC Express penetration.

Not all of Takeoff Technologies' automated robotic fulfillment solutions are being constructed within individual grocery stores. Many smaller grocery store chains operating near or in major urban centers are instead deploying Takeoff Technologies' automated robotic fulfillment systems to support multiple individual grocery stores. Takeoff Technologies has partnered with Wakefern Foods Corporation, the largest retailer-owned grocery cooperative in the United States, with 353 supermarkets. The first Takeoff Technologies automated robotic fulfillment center opened in July 2019 in Clifton, New Jersey, and is designed to support Wakefern's ShopRite grocery stores using ShopRite's Home online grocery platform. The new 24,300-square-foot mini-warehouse is located in Clifton and fulfills online grocery orders for 10 ShopRite stores in northern New Jersey and New York.

In a similar use of automated fulfillment centers to support a cluster of retail grocery stores, Takeoff Technologies partnered with Sedano's Supermarkets, the leading U.S. Hispanic grocery chain based in Florida. In February 2019, Sedano's opened a Takeoff Technologies automated fulfillment center to support its 16 Miami areas stores. If successful, Sedano's could expand the number of automated fulfillment centers to support the majority of its 35 stores throughout Florida.

In Australia, Takeoff Technologies has partnered with Woolworths at three initial beta sites that are expected to open in 2021. Woolworths Group, based in New South Wales, Australia, operates 1,024 supermarkets throughout Australia and New Zealand.

Walmart, which is the largest grocery retailer in the United States by revenue with 4,676 retail locations, has partnered with Takeoff Technologies' competitor Alert Technologies for its MFC automated online grocery fulfillment solution, which Walmart envisions deploying hyperlocally within its individual stores. As of November 2019, Walmart offered online grocery delivery from about 1,400 stores, up from 800 a year earlier, and 3,100 of its stores offered its in-store pickup service for online grocery orders. For grocery and general merchandise online orders, Walmart has constructed Pickup Towers at its store locations for customers to collect their groceries and merchandise orders.

In October 2019, Walmart announced its Delivery Unlimited program, offering customers unlimited grocery delivery for $98 per year or $12.95 per month. In three cities in the United States, Walmart also began testing a new service called InHome, whereby its employees will deliver online grocery orders directly to customers' home refrigerators. The company also offers a service called Pickup Point that for a fee allows customers to collect their online orders for groceries and merchandise at off-store locations. Walmart also announced a new agreement with robotics company Nuro Inc. to test grocery deliveries to customers' homes using driverless vehicles.

In early January 2020, Walmart opened a store in Salem, New Hampshire, that uses Alert Technologies' Alphabot MFC. In 2020, Walmart plans to install the Alphabot MFCs at stores in Mustang, Oklahoma; Burbank, California; and Rogers, Arkansas, near where Walmart is based. Walmart is also using Alert Technologies' Alphabot automated storage and dispensing system in a store located in Sherman, Texas, while its Burbank store has created a mezzanine within its local store that uses Alert Technologies' Alphabot system. What seems clear is that while Walmart appears fully committed to Alert Technologies' Alphabot MFC automated system, it is trying various ways of deploying the system in its stores.

After first meeting with Alert Technologies in early 2016, Walmart agreed to fund the development of Alphabot in exchange only for commercial rights and no equity stake in Alert Innovation. While the Alphabot system has been designed exclusively for Walmart and can handle many nonfood items that can be found at Walmart's supercenters, Alert Innovation is also working with its partner Muratec to develop MFCs for other retail formats. Walmart is also evaluating ways to use its base of almost 4,700 U.S. stores to potentially include more services such as healthcare and selling technology such as predictive analytics to retailers in other businesses. So far, Walmart has not committed to using Alert Technologies' Novastore hybrid format.

Centralized automated grocery fulfillment centers are a second robotic fulfillment solution being embraced by some large grocery retailers. Kroger operated about 2,758 grocery and multidepartment stores in the United States as of late 2019, and it is the largest supermarket chain by revenue and the second-largest retailer behind Walmart. In 2018, Kroger signed an agreement with Ocado Ltd. Plc to build three automated centralized fulfillment warehouses (also known as "sheds") to fill online grocery orders in Forest Park, Georgia; Lake County, Florida; and Monroe, Ohio, near where Kroger is based in Cincinnati. Kroger broke ground on its first Ocado centralized automated grocery fulfillment center in Monroe in June 2019 and expects its first stand-alone

centralized automated shed to come online in 2021. The Forest Park centralized automated distribution fulfillment center is expected to be a 375,000-square-foot facility that will cost $55 million, which is also expected to commence operation in 2021.

Ultimately, Kroger plans to build 20 Ocado centralized automated sheds in the United States, with the remaining locations to be identified and announced by 2021 and begin operation by the middle of the decade. Should Kroger fail to specify the location of its 20 committed sheds by the end of 2021, its partnership with Ocado would lapse and no longer be exclusive. Kroger's initial approach appears to be more of a hybrid solution that anticipates balancing local stores experiencing elevated online grocery orders by shifting fulfillment to neighboring Kroger locations. Kroger is also considering designating separate areas in its stores for customer pickup of online grocery orders.

Sobeys Incorporated, Loblaws' largest grocery store competitor in Canada with 1,547 stores, has also selected Ocado for its centralized automated distribution fulfillment model to fulfill online grocery orders placed on its Voilà platform. The first centralized automated fulfillment center for Sobeys is in Vaughan, Ontario, to support stores in the Greater Toronto area starting in 2020 followed by a second centralized automated distribution center in Pointe-Claire, Montreal, in 2021 to support its Voilà par IGA platform for stores in Ottawa and major cities in Quebec.

Still other major grocery and general merchandise retailers have yet to embrace MFCs or CFCs. One major grocery and general merchandise retailer that has yet to deploy automated distribution technology in its stores is Target. Target operates 1,868 stores and 41 distribution centers in the United States. Target is using its existing store employees to fulfill both pickup and delivery e-grocery orders and also general merchandise pickup orders placed through its website or mobile app. Target's Ship, acquired in December 2017, has been a critical fulfillment component for Target's June 2019 launch of its dedicated online grocery shopping site on Target.com. Target is testing an automated warehouse facility in Perth Amboy, New Jersey, to assist its smaller format stores throughout the New England region that lack the capacity to stage orders on-site. The company is using this automated warehouse hub to develop critical logistical models to optimize its path toward potentially broader use of automated CFCs or perhaps MFCs in the future.

Amazon, which operates 483 stores and 110 fulfillment centers in the United States, has one of the most advanced automated warehouse and fulfillment networks in the retail industry. So far it has not moved to incorporate MFCs within its 483 Whole Foods retail grocery stores located in the United States. However, it offers accelerated delivery and pickup options for online grocery orders under its Amazon Prime Now and AmazonFresh programs. Operating in 15 U.S. cities and unlike Amazon Prime Now, where delivery is included as part of customers' annual Amazon Prime subscription, AmazonFresh costs an additional $14.95 per month. AmazonFresh was opened before Amazon's acquisition of Whole Foods. As previously noted, the new Amazon Go Grocery format offers "just walk out" simplicity and speed without the need to invest in localized automated micro-fulfillment robotic picking systems. With its new Amazon Go Grocery cashierless grocery store format (similar technology to its smaller Amazon Go but about five times larger), rather than automated online order fulfilment, Amazon is focused on speeding the grocery shopping process for customers who still want to come to the physical store to purchase their groceries and home products. Today, the jury remains out on which solution (automated centralized or in-store MFC for online delivery or pickup, hybrid automated localized MFC, or checkout-less autonomous shopping) to expedite the grocery shopping experience will prove most satisfying to customers while being financially viable for grocers.

Key Automation Fulfillment Providers

Alert Innovation. Alert Innovation's flagship products, the Alphabot Automated Storage and Retrieval System and Automated Each-Picking System, can operate as both a 2-D mobile robot and a vertical lift. The company's goal is to transform the Alphabot into the most capital-efficient and broadly scalable design of each of these fully automated fulfillment solutions on the market, ranging in scale from store-level micro-fulfillment centers all the way up to highly centralized, massively scaled long-tail e-commerce fulfillment centers. Alphabot makes possible for the first time a new kind of supermarket featuring automated service rather than self-service, called the Novastore. In a Novastore, the entire center store is replaced with an Alphabot micro-fulfillment center that can pick ambient, chill, and frozen grocery orders in minutes. While fresh produce and meats will still be self-service, customers can shop these products (or order remotely as well), pay on their phone, and leave the store without any queuing for checkout. Alert Innovation, founded in 2013, is based in North Billerica, Massachusetts. The company secured angel funding in 2016, has 31 issued or pending patents on its technology, and opened four trial stores with Walmart in early 2020.

Exhibit 21
Robotics, Automation, and Artificial Intelligence (RAAI)
Alphabot Operating in Micro-Fulfillment Center

Source: Alert Innovation

AutoStore. Based in Norway, with North American headquarters located in Derry, New Hampshire, AutoStore has developed an automated storage and retrieval system (ASRS) that utilizes robots and ports to move goods in a timely and space-efficient manner. The cube system is capable of operating in tight, dense areas enabling quick order fulfillment for customers that operate small urban facilities up to large, spacious warehouses. With the fastest order fulfillment system per square foot, AutoStore services a number of different industries with critical and time-sensitive applications and products, including e-commerce and more recently moving into grocery micro fulfillment. Originally founded in 1996 after being spun out of Hatteland, AutoStore was most recently acquired in a leveraged buyout by Thomas H. Lee Partners, with the former owner, EQT, retaining a 10% share of the company.

Fabric. Formerly known as Commonsense Robotics, Fabric is a developer of on-demand fulfillment technology. Founded in 2015 and based in New York City, the company rents storage space in its state-of-the-art MFCs, reducing the need for up-front capital expenditures to its customers while

allowing for faster, more flexible order execution. Catering to the grocery, business-to-business, and retail markets, Fabric's vertically integrated storage stacks are easily traversed by an army of mobile robots for more efficient automated storage and retrieval. Fabric has raised $136 million to date, most recently through a series B round in October 2019 for $110 million, to help grow its U.S.-based commercial, operations, and technical support teams.

Ocado Technology. Founded in 2000 and based in Hatfield, England, Ocado is a world leader in technology for grocery e-commerce. Ocado is also a 50:50 shareholder (with M&S) in Ocado Retail Ltd., the world's largest online-only grocery retailer, with 721,000 active customers across the United Kingdom. Through Ocado Solutions, the company provides the Ocado Smart Platform (an end-to-end suite of solutions) to leading grocery retailers around the world. These fully integrated solutions span online shopping channels, automated fulfilment, and last-mile delivery. Ocado Solutions is partnered with nine leading grocery retailers worldwide, including Kroger in the United States, which has announced it will build up to 20 highly automated CFCs nationwide over the first three years of the partnership. At the heart of a CFC is Ocado's robotic grocery picking system, which typically deploys thousands of bots across a 3-D grid to pick and optimize the storage of products. The robots are controlled through its proprietary LTE mobile technology in the 4G unlicensed spectrum, which allows the bots to operate as a dense, orchestrated swarm, moving across the grid at speeds of up to 4 meters per second. The Ocado Smart Platform includes Ocado's proprietary end-to-end software systems, alongside a physical fulfilment ecosystem that includes a range of CFC sizes. In addition to Kroger in the United States, Ocado is partnered with Aeon in Japan, Coles in Australia, Sobeys in Canada, Morrisons in the United Kingdom, Groupe Casino in France, ICA in Sweden, Bon Preu in Catalonia, and Ocado Retail in the United Kingdom. Ocado became a publicly traded company in 2010 and recorded 2018 revenues of £1.6 billion with EBITDA of £60 million.

Exhibit 22
Robotics, Automation, and Artificial Intelligence (RAAI)
Ocado Centralized Fulfillment Center

Source: Ocado Technologies

Takeoff Technologies. Takeoff is a developer of an e-grocery platform that uses automated micro-fulfillment centers to enable its customers to achieve order fulfillment at a hyperlocal scale. Orders are placed online through Takeoff's customers' platforms and fulfilled using robots in Takeoff's vertically integrated micro-fulfillment centers. Takeoff has partnered with Knapp, a leading provider of automated warehouse solutions, for the development of its robotics technology. The company was founded in 2016 and is based in Waltham, Massachusetts. Takeoff raised $25 million in September 2019 to help accelerate its North American, European, and Australian rollout. Takeoff has raised $85 million to date for a post-valuation of $500 million.

Industrial Robots and Collaborative Robots (Cobots)

The earliest robots were designed to replace dangerous jobs. The earliest robot was created over 80 years ago when Bill Taylor developed the first pick-and-place industrial robot known as Gargantua in the late 1930s. The crane-like device, which was programmed by paper tape and powered by a single electric motor, was used to stack blocks in preprogrammed patterns. Development of more functionally capable robots was cadenced by the invention of critically enabling technologies. These included numerically controlled (NC) machines, the emergence of early computers in the 1950s, and integrated circuits in the 1970s.

Early industrial robots were used to replace workers for heavy, dangerous, and monotonous tasks. However, these early machines had no ability to externally sense what was occurring around their environment and were typically used for simple but dangerous pick-and-place work, such as moving stamped metal formed by heavy presses. Because they as well as the work they performed were dangerous, robots until just this past decade had to operate in safety cages to ensure that no employees were accidently hurt. As robot functionality improved with the ability to be programmed to perform multiple tasks, operate with several degrees of freedom (multi-axis), and use arms attached to different special purpose devices, industrial robots in the 1970s and 1980s were increasingly viewed as able to reduce costs, increase productivity, and enhance quality, particularly for dangerous work.

The Robotic Industry Association (RAI) was created in 1974 to help create safety standards for robots and sponsor conferences and educational forums on robotics with leading robot manufacturers, users, system integrators, component suppliers, research groups, and consulting firms. However, from 1992 to 2015 there were 61 deaths attributable to industrial robot accidents. It was not until 2017 that OSHA, NIOSH, and RAI signed an alliance to work together to enhance technical standards and identify potential workplace hazards attributable to traditional industrial robots and emerging human-robot collaborative installations.

Robot growth comes in waves, driven by enabling new technologies. Advances in robotics historically have come in waves, first with new technology that enables expanded or new functionality, followed by volume production and miniaturization that lowers the cost and footprint of an industrial robot.

Exhibit 23
Robotics, Automation, and Artificial Intelligence (RAAI)
Estimated Industrial Robot Installed Base
2020 (units in thousands)

1	Fanuc	778
2	Yaskawa	582
3	ABB	487
4	Kawasaki	210
5	Nachi	193
6	Kuka	162
7	Denso	160
8	Epson	75
9	Comau	62
10	Omron / Adept	56
11	Universal	34

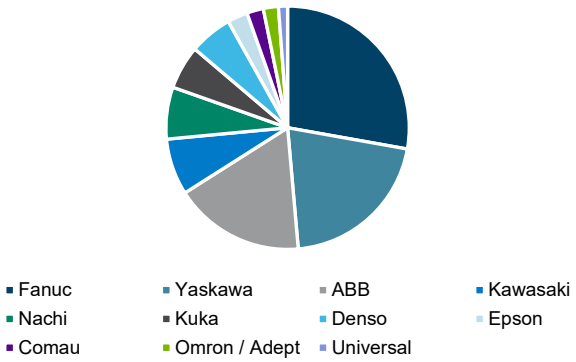
Sources: Asian Robotics Review, William Blair estimates

Technology advances in the 1950s and 1960s spawned the first functional robots that initially were used by heavy industrial manufacturers in the 1970s and 1980s. In 1962, Unimation sold its Unimate robot to General Motors, the first industrial robot to be deployed by a major manufacturer. By

1967, the company that would become ASEA, and today ABB, developed a robot capable of spray painting. In 1973, KUKA of Germany developed the first robot with six electro-mechanical axes. This was followed by ASEA of Sweden in 1975 introducing the world's first fully electrically driven robot that was microprocessor controlled by Intel's first chipset. When Nachi Robotics of Japan attached servo gun technology to a robot in 1979, it created the first spot welding robot, which was accompanied by OTC Japan the same year when it introduced the first dedicated arc welding robot. As new robot functionalities were created, in the 1980s new robots were introduced at the average rate of one a month.

The automotive industry became the first industry to deploy industrial robots broadly during the 1980s. As servo motor sizes decreased and could be installed directly into the arm of a robot, the number of axes of control mushroomed, with Yaskawa America Inc. introducing a robot with 12 axes of control in 1988. Greater dexterity and movement rapidly expanded the number of new applications robots could perform. In 1992, FANUC Robotics Corporation created a prototype of the first intelligent robot. By 1994, the ability to synchronize the motion of two robots was commercially introduced.

Exhibit 24
Robotics, Automation, and Artificial Intelligence (RAAI)
Estimated Global Industrial Robot Market Share (2020)



Source: Asian Robotics Review, William Blair estimates

However, overzealous investments in automation in the automotive industry resulted in industrial robots that broke the windows of cars moving down a General Motors assembly line in 1988, with multiple robots also painting each other. The malfunctioning of premature and inadequately tested new robotic technologies in the late 1980s led to a period of retrenchment in the deployment of industrial robots in the 1990s. During this time, productivity improvement increasingly shifted to focus on Six Sigma to eliminate errors before they could occur, as well as various Japanese production optimization strategies designed to improve production throughput, worker engagement, and job satisfaction.

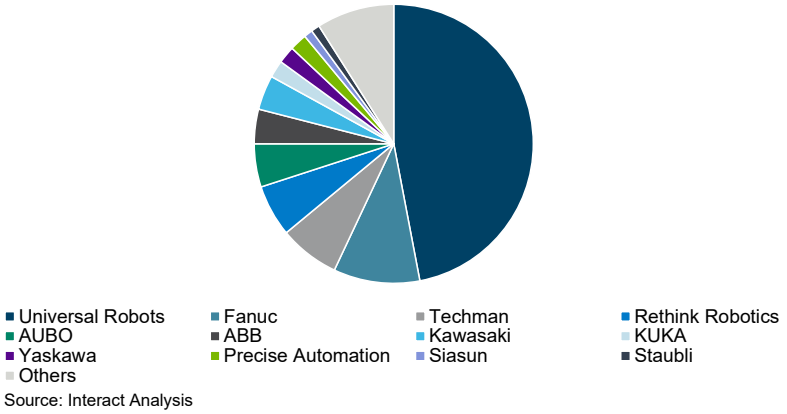
It was during the 1990s that cell manufacturing began to more widely replace automated manufacturing lines. During this time, leadership in the global industrial robotics market shifted to European and Japanese companies, which acquired many of their more financially challenged U.S. competitors. Advances in robots from the mid-1990s until about 2010 were incremental and evolutionary refinements rather than new breakthroughs incorporating new technology that could materially enhance industrial robot functionality.

The introduction of cobots has reignited widespread interest in industrial robots. The global industrial robot sector returned to strong growth with the introduction in 2008 of the first robots that could operate outside a caged environment needed to protect nearby production workers. This generated a quantum leap in industrial robot functionality and opened numerous new applications for industrial robots that previously could not be performed when operating solely in protected areas within a manufacturing plant. By being able to physically operate adjacent to workers in a common workspace, robots moved from performing heavy and dangerous tasks requiring the ability to lift and move heavy payloads to much smaller machines possessing far greater dexterity. Traditional industrial robots operating in protected confines within a plant were used for welding, painting, grinding, and deburring; material handling and palletizing; and large product assembly and disassembly.

In contrast, the new smaller but much more flexible and accurate movement of cobots allows them to be used for precision work such as printed circuit board assembly, packaging, labeling, product inspection, and testing. These new cobots could be easily reprogramed for an array of assignments where precise repetition and accurate movement of much lighter payloads was more important than sheer speed or strength to perform dangerous operations. The introduction of cobots opened a vast new array of jobs and tasks that could be automated and accelerated the use of robotics, which had long been heavily tied to the global automotive industry, across several new manufacturing end-industries.

As of 2016, according to the International Federation of Robotics (IFR) based in Germany, auto production accounted for 35% of robots deployed globally and electrical/electronics manufacturing 31% of robots' global installed base. As the popularity and widespread adoption of consumer electronics rapidly grew over the past decade, the number of robots working in China's electronics manufacturing sector has accelerated, while even more than doubling from 2013-2014. However, new markets have emerged and are emerging for widespread deployment of robots, including the healthcare industry (to move patients, medications and supplies, and automated robotic surgery), the foodservice sector (to automate food production), automated logistic handling, and law enforcement and the military.

Exhibit 25
Robotics, Automation, and Artificial Intelligence (RAAI)
Estimated Global Collaborative Robot Market Share (2020)



Source: Interact Analysis

Cobots were first introduced by Universal Robots ([UR] now owned by Teradyne) in 2008 and began to become widely embraced by a much broader set of manufacturers early the next decade. While cobots initially had to operate much more slowly to avoid injuring adjacent workers, they could now perform tasks requiring much greater precision and accuracy. This further transformed

the functional capabilities of industrial cobots: lowering costs while increasing product quality and reliability. Because the first generation of cobots used 2-D vision that did not possess the capability to respond immediately to changes in their environments, their speed of operation had to be reduced versus traditional high-speed protected industrial robots.

With a vast array of new capabilities and end-market applications created by cobots, the IFR noted total global unit sales of industrial robots (including cobots) increased at an average rate of 12% from 2011 to 2016. With the accelerating shift of manufacturing to China that began in the 1990s and accelerated rapidly for two decades, China has maintained and expanded its position as the biggest industrial robot and cobot market. The IFR reported China's industrial robot unit sales grew an average 31% annually from 2011 to 2016.

Geographically, five countries (China, South Korea, United States, Japan, and Germany) accounted for 74% of all robots sold in 2016. On a global basis, the average number of robots installed worldwide per 10,000 manufacturing employees was 74 in 2016. By region, the highest robot density in 2016 was in Europe (99), followed by the Americas (84) and Asia (63). By country, in 2016 the IFR reported South Korea had the highest density (631 per 10,000 manufacturing employees), followed by Singapore (488), Germany (309), Japan (303), the United States (189), and China (89).

Somewhat counterintuitively, the countries with the highest industrial robot deployment also tend to have the lowest unemployment levels. The World Economic Forum (WEF) in a report entitled "The Future of Jobs 2018" has estimated that robotic automation, artificial intelligence and algorithms are expected to create 133 million new jobs for the 75 million jobs they displace by 2022. On average, every industrial robot deployed that displaces a worker typically creates 1.7 new jobs related to robot sales, service, coding, programming, robot manufacturing, and robot operation. Typically, the new jobs to support industrial robots pay better and tend to be less repetitious, more due to their more skilled, problem-solving nature, while also being more rewarding. Although China's deployment of robots per 10,000 production workers was low relative to other manufacturing centers around the world, its robot density more than tripled from 25 in 2013. South Korea's globally highest robot density reflects its leadership in electrical and electronics and more recently automotive manufacturing, including leadership positions in flat-panel displays, memory chips, and advanced electronics.

Since 2015, a new driver for the deployment of robots has rapidly emerged: a shortage of skilled production workers, particularly in the United States. With the advent of 3-D real-time vision systems as well as the multiplicative benefits expected from 5G networks when they achieve their full capability, a new wave of technologies is expected to expand the functionality of industrial robots and cobots. The speed of industrial cobots in manufacturing venues is expected to improve materially because of the ability of cobots to adapt instantaneously (very low or no latency) to their surroundings and coworkers. This is widely forecast to materially increase the productivity of adaptive cobots.

Within the next few years, we believe the arrival of 3-D vision systems and 5G is expected to result in new robots likely incorporating at least one intelligent capability, such as dynamic situational awareness, predictive analytical capability, predictive self-diagnostics, peer-learning, and autonomous cognition. If correct, this is likely to usher in another resurgence in industrial robot sales during the 2020s. Also, lower costs for components and increasingly standardized operating software have allowed cobots to become mobile and operate autonomously.

The advent and commercial introduction of low-cost, highly reliable autonomous mobile robots (AMRs) is now spawning a surge in new applications in manufacturing as well as automating other environments outside the factory floor, such as warehouse automation and automated online

grocery fulfillment. This next wave of growth for industrial robots is likely to benefit from both new functionality from the arrival of new enabling technologies but also two other critical favorable external factors: the rise of e-commerce and a growing shortage of workers.

The Push Toward Adaptive Robotics

Adaptive robotics are the third wave of robotic automation and expand on the capabilities of cobots through added safety measures that allow for enhanced speed and performance, and transferable, machine learning AI that allows for the accomplishment of new tasks in unstructured environments. Because today's cobots stop on impact with humans or other objects, they sacrifice payload and speed to operate with adequate safety. This has been the primary hurdle for the adoption of cobots today, as many operators are unwilling to forfeit the superior productivity gains allowed by traditional industrial robots for the added benefit of worker maneuverability on the factory floor. Furthermore, cobots require professional integrators with advanced coding skills to be deployed in an effective manner, increasing both cost and setup time.

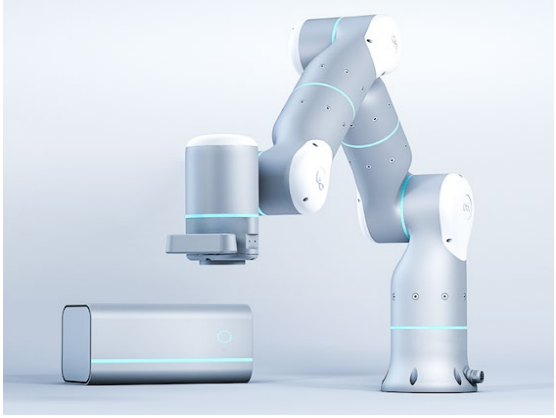
There are several robotic motion control and vision companies taking their own unique approaches to bridge the gap between collaborative and adaptive robotics today. Astutely, most are robot-agnostic, working to build advanced AI and vision systems that can be incorporated on any of the leading industrial and collaborative OEMs. It is far too early to determine who the key players will be over the next 5 to 10 years. Given that no real solutions exist today, we believe speed to market and ability to develop key partnerships with the robot OEMs will likely play a crucial role in a company's success. This is partly predicated on the business model of most robotic component manufacturers, which despite their software-driven solutions, generate revenues primarily on a per-unit basis, as opposed to many AMR manufacturers that wrap their installed base with a SaaS model.

As a result, we believe the companies' business models necessitate the need for linking their offerings to large OEMs to drive market share and sustain their operations over time. Another hurdle dictating the speed for launching a product, and an essential component for wide adoption, is a company's ability to secure safety certification from TÜV Rheinland, a third-party provider of safety verification for standards set by the International Standards Organization (ISO). This is typically an expensive process, particularly for a start-up, and can take several years to secure, absent any delays.

Key Adaptive Robotics Manufacturer

Flexiv. Flexiv is a turnkey manufacturer of adaptive robotic systems, integrating force control, computer vision, and AI. The company's core offering, the third-generation RIZON adaptive robot, combines direct force control with advanced AI, driving greater tolerance in positioning variance, high disturbance rejection, and intelligent transferability for quick redeployment between similar product lines or tasks. Together, this enables the robot to handle complex tasks in unstructured environments, including polishing, parts assembly, precision insertion, force-based quality testing, and other tasks requiring payloads of less than 17 pounds. Founded in 2016 by a team from Stanford University, the company is based in Santa Clara, California, and has raised $20 million in funding to date, with notable investors including GSR Ventures and Gaorong Capital.

Exhibit 26
Robotics, Automation, and Artificial Intelligence (RAAI)
Flexiv RIZON Adaptive Robot



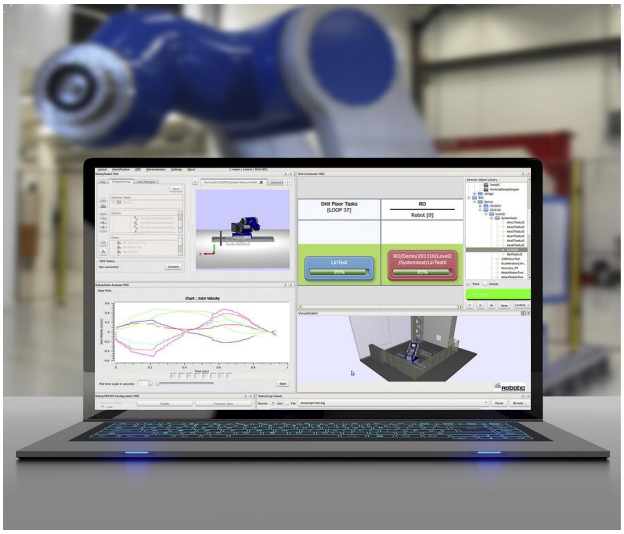
Source: Flexiv

Key Motion Control and Software Providers

Covariant. Covariant, founded in 2017 after being spun out of the University of California, Berkeley Foundation, develops AI software for robots with the capability to achieve deep imitation learning, deep reinforcement learning, and meta learning. Covariant observes the far-reaching potential of industrial robotics and automation, and aims to develop its Covariant Brain programming to enable robots to sense, see, reason, and respond to the world around them. Whereas other software developers may seek to "teach" robots to master specific and separate tasks, Covariant focuses on developing software designed to assist the robot in learning so that it can develop far more expansive functionality beyond that of a cyclical loop. The company has raised $27 million to date, comprising seed funding of $7 million in 2018 and an incremental $20 million of series A venture funding in 2019, which will be used directly to develop the Covariant Brain AI learning software.

Energid Technologies. Energid is a developer of the most advanced real-time motion control software for commercial, collaborative, critical, and industrial robotics. The company's flagship software, Actin, acts as a powerful robotic control framework and dynamic motion kernel, offering real-time adaptive control capabilities that include smart collision avoidance, joint-limit avoidance, singularity avoidance, strength optimization, and control of highly redundant kinematics, which allows for unlimited degrees of freedom for robotic applications. The company serves many end-markets, including surgical operations, oil and gas, agriculture, factory automation, and fulfillment. Actin is sold through an annual subscription fee, but given its mission-critical status once customers begin to build out their operations on its platform, it results in a steady source of recurring revenue. Teradyne acquired Energid, based in Bedford, Massachusetts, in February 2018 for an undisclosed sum.

Exhibit 27
Robotics, Automation, and Artificial Intelligence (RAAI)
Energid Actin Toolkit



Source: Energid Technologies

Kollmorgen Automation AB. Kollmorgen is a leading provider of motion systems and components for robots. The company manufactures millions of different variations as well as customizable solutions for its core product offering, including automated platforms, motors and drives, linear actuators, and gearheads. Kollmorgen is also the world's leading provider of vehicle automation kits, NDC Solution, for automated guided vehicles. With an installed base of more than 20,000 vehicles, the NDC Solution is applicable for any type of navigation: natural as well as barcode, reflector, magnetic tape, and other types of infrastructure-led navigation. The company was acquired by Altra Industrial Motion in October 2018 as part of its acquisition of Fortive's Automation & Specialty Platform for $2.96 billion.

Exhibit 28
Robotics, Automation, and Artificial Intelligence (RAAI)
Kollmorgen Automation End-Markets

Source: Kollmorgen Automation AB

Mujin, Inc. Mujin is a manufacturer of a motion planning AI-equipped intelligent robot controller, Mujin Controller, for fulfillment and factory automation. The controller uses 3-D vision and a proprietary robot control system, OpenRAVE, to drive real-time motion planning with minimal data inputs and complete collision avoidance. Mujin has an installed base of over 1,000 robots; notable customers include Canon, Honda Motor Co., JD.com, and Fast Retailing Co. Founded in 2011, the company is based in Tokyo.

Exhibit 29
Robotics, Automation, and Artificial Intelligence (RAAI)
Mujin Motion Planning AI Applied in Robotic Palletizing Operation

Source: Mujin, Inc.

Pilz GmbH & Co. Pilz is leading manufacturer of sensors, safety relays, control systems, and drives for the automotive, packaging, wind energy, transport, and press industries. The company has been accredited with developing the first emergency stop relay "PNOZ," as well as the first safe camera system "SafetyEYE" for 3-D zone monitoring, similar to a light screen for industrial robots. Pilz also manufactures collaborative robotic arms for industrial and non-industrial use, including robotic operating system modules allowing for immediate use in industrial and service robotic environments, rapidly reducing the time to program and launch of a robot on the factory floor. The company is privately held and based in Ostfildern, Germany.

Realtime Robotics. Founded in 2017, the Boston, Massachusetts–based company is a manufacturer of motion planning processors and AI software that allow robots to instantly react to changes in their environment, enabling collision-free motion in dynamic manufacturing environments. The company launched its path planning processor, RapidPlan, in 2018, which allows for up to 8,000 motions at 30 frames per second and operates 1,000 times faster than conventional approaches running on high-end graphics processing units (GPUs). The enhanced speed drastically increases manufacturer cycle times and throughput while reducing workcell programming (multiple robots operating a specific task), a process that can take several months, by up to 80%. Typically, adding a second robot to a workcell can increase productivity by only 20% to 30% due to overlap. RapidPlan's system of allowing the robots to communicate autonomously not only increases the payback period from reduced installation costs, but also can drive a 75% increase in workcell productivity. RapidSense is Realtime Robotics' collaborative robotic solution, using 3-D cloud data and vision systems to avoid dynamic obstacles such as people. Realtime Robotics is also working with TÜV Rheinland to secure safety certifications for its RealSense solution, expected to be completed over the next 12 to 18 months. The company has secured $11.7 million in funding to date to help

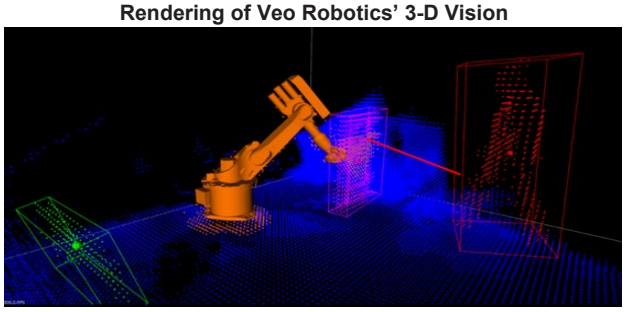
accelerate the development of new commercial product launches, while growing its team in an effort to support its key customers globally (Q&A With Management of Robotics Software Provider Realtime Robotics).

Exhibit 30
Robotics, Automation, and Artificial Intelligence (RAAI)
Realtime Robotics' RapidSense Operating in Unstructured Environment

Source: Realtime Robotics, Inc.

Veo Robotics. Veo Robotics, based in Waltham, Massachusetts, was founded in 2016 by President and CEO Patrick Sobalvarro, Vice President of Engineering Clara Vu, and Chief Architect Scott Denenberg. Veo Robotics develops software and designs and manufactures hardware (boards, circuitry, vision systems, etc.) for a patented 3-D vision-based software system that allows large robots to understand their operating surroundings so they can safely work with humans in a quicker and more efficient, collaborative manner. The company has launched its beta version with compatibility on all big four robotic manufacturers (ABB, Fanuc, KUKA, and Yaskawa) with its full release targeted for April 2020, once it has secured safety certification with TÜV Rheinland. The company has secured $28 million in funding since its founding, most recently through a series A1 follow-on offering in February 2019 for $15 million. Management believes it will require an additional $20 million-$30 million to accelerate its commercial expansion into international markets and develop the next generation of Veo systems (Q&A With Management of Collaborative Robotics Solutions Provider Veo Robotics).

Exhibit 31
Robotics, Automation, and Artificial Intelligence (RAAI)
Rendering of Veo Robotics' 3-D Vision



Source: Veo Robotics

Robotic End-of-Arm Tooling

Robot grippers, or end-of-arm tooling (EOAT), are the physical interface between an industrial and collaborative robot arm and the workcell. EOATs have traditionally been broken out into four subsegments: 1) vacuum grippers (highly flexible suction cups), 2) the traditional pneumatic grippers (compact and light-weight tooling jaws or fingers), 3) hydraulic grippers (for heavy-duty purposes), and 4) the increasingly popular servo-electric grippers (flexible electric motor controlled jaws). Over the last decade, there has been a growing need for improved dexterity from many industries. This has been led by demand from the labor-intensive automotive industry, but is now being outpaced by growth in other end-markets, including electronics, e-commerce, and food and beverage. While a traditional manufacturing robot will look for improved speed and accuracy in a production line, collaborative or automated mobile robots require nimble response times for safety, and many new start-ups have come to market to fill the various voids.

There has been an influx of new technology causing a lot of noise in the components market today. This has created a great deal of confusion in the relatively young and quickly evolving marketplace, as distributors and customers attempt to discern the best solutions for their problems. Given the large breadth of product offerings, components manufacturers find themselves in a predicament of not only competing to develop best-in-class solutions, but also discerning how to take their products to market. One effective measure has been a focus by manufacturers on customer education, although because of the physical limitation of distributor capacity (the primary sales channel), many have turned down new technology in an effort to simplify their offering. This has been apparent early on, as the various professional integrators have shown a proclivity to recommend the robots, sensors, and grippers with which they are most familiar.

It appears likely that the long-term winners in the space will be those that are able to scale quickly and bundle their offerings into an all-encompassing solution, thereby wrapping sales channels by playing to the distributor's desire of working with fewer suppliers. However, with different potential competitors seeking to launch applications that could serve the various tiers in the robotics space, it is important for components manufacturers to use their first-mover advantage and sustain continued investment and development into higher-tech products that continually outpace the competition.

Key Robotic EOAT Manufacturers

OnRobot. Denmark-based OnRobot was founded in 2018 following the merger of three robotic component manufacturers: On Robot (plug-and-play electric grippers), OptoForce (force and torque sensors), and Perception Robotics (bio-inspired robot grippers). Led by former Universal Robots CEO Enrico Iversen, with financing from the Danish Growth Fund and Summit Partners, the company has grown into a top-two provider for EOAT in the rapidly growing collaborative robotics space. Focusing on the small to midsize market with payloads of less than 55 pounds (about 35% to 45% of the robotic market), the tool manufacturer offers eight products today (grippers, vacuums, and tool-locking mechanism) that are simple and robot-agnostic, easily fitting into a click-on-system. Given its breadth and broad applicability, the company has seen strong support in the distribution channel, which we expect to snowball as it looks to launch 25 to 35 new products in the coming year. OnRobot recorded triple-digit revenue growth in 2019, albeit off a small base, and has the funding and scale through visibility to achieve profitability by 2022. OnRobot's long-term aspiration is to be the one-stop-shop supplier for every application, across all industries. To achieve this goal, the company expects to drive internal R&D and prioritize technology-focused acquisitions.

Exhibit 32
Robotics, Automation, and Artificial Intelligence (RAAI)
Select OnRobot EOAT Offering

Source: OnRobot

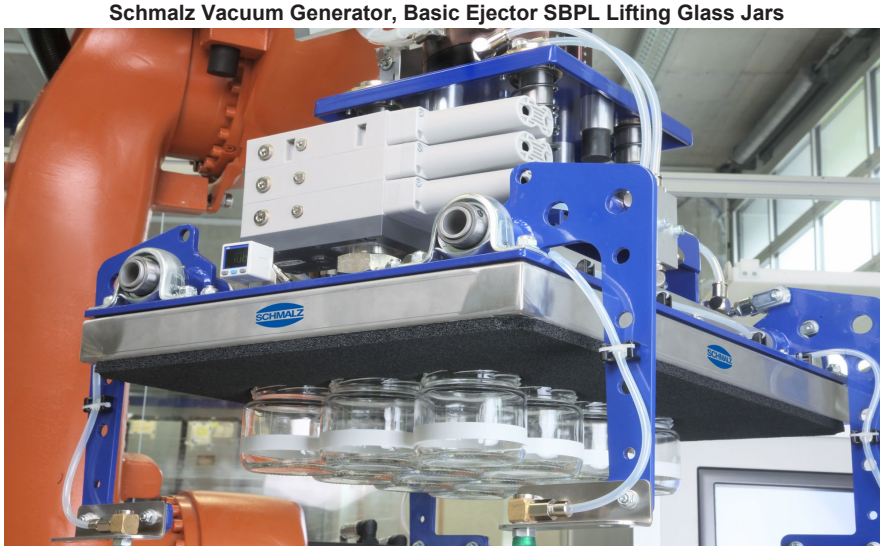
Robotiq Inc. Founded in 2008 in Levis, Quebec, Robotiq operates as a components and software provider with a complete solution for cobot cell development. Robotiq's Lean Robotics methodology offers a systematic way for end-users to design, integrate, and operate a robotic cell to get to production faster, increase productivity, and achieve ROI quickly. This has helped drive the market for collaborative robotics, at a time when factory operators remain tempered on the costly, complex, and nascent nature of the young industry. Robotiq works with a global network of over 190 distributors in 48 countries to support growth in automotive, electronics, aerospace, general industry components, electronics, and other industries. The company's plug-and-play product offering includes flexible robotic application-driven solutions including adaptive and vacuum grippers, sensors, vision systems, and programming software to make automation easy, fast, and accessible for global manufacturers and SMEs without needing extensive technical knowledge. The products are easy to install and program; they can grip parts of many different sizes, bring the senses of touch and vision to robots, introduce human-robot collaborations, accelerate robot projects, and optimize robot performance through their software applications. The company offers on-demand training for its products and solutions on its online learning platform. The employee-owned Robotiq received its first round of funding for $23 million in December 2018 from Battery Ventures to help drive product development, international expansion, and customer support capabilities. Management expects a continued focus on product innovation in an effort to further simplify cobot applications.

Exhibit 33
Robotics, Automation, and Artificial Intelligence (RAAI)
Robotiq EOAT Product Offering

Source: Robotiq, Inc.

Schmalz Inc. Based in Glatten, Germany, the family-owned Schmalz is the world's leading provider of vacuum automation and ergonomic handling solutions. Schmalz's product offering serves a broad range of applications, including vacuum components and gripping systems for automation, vacuum lifting devices and crane systems for manual work processes, and vacuum clamping technology for wood and metal processing. The company's plug-and-play modular vacuum systems are applicable for both industrial and cobots (payloads up to 35 pounds). The company spends 9% of its roughly $150 million to $200 million in annual revenues on R&D, and is working to expand its capabilities in its third vertical, energy storage systems.

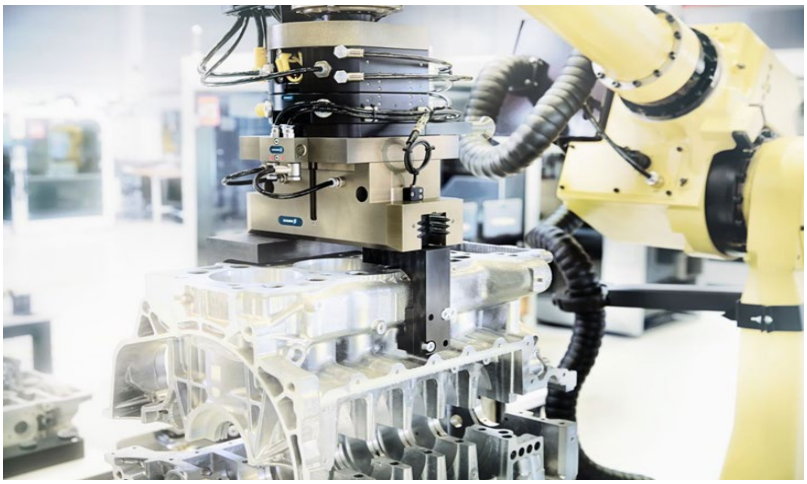
Exhibit 34
Robotics, Automation, and Artificial Intelligence (RAAI)
Schmalz Vacuum Generator, Basic Ejector SBPL Lifting Glass Jars



Source: Schmalz

Schunk. Family-owned and operated out of Lauffen am Neckar, Germany, Schunk is the largest provider of clapping technologies and grippers for industrial robots. The company boasts the world's largest product portfolio of standard chuck jaws (over 1,200 products), clamping technologies (over 10,000), and standard grippers (over 10,000). With a focus on continuous R&D and new niche developments, Schunk has recently made a push into the higher-margin, lower-payload cobot market, and we believe it is well positioned given its global scope and broad distribution network.

Exhibit 35
Robotics, Automation, and Artificial Intelligence (RAAI)
Schunk PGN-Plus Gripper



Source: Schunk

Soft Robotics. Soft Robotics has developed a fundamentally new set of self-adaptive and dexterous robotic hands that remove the need for sensors, vision systems, or other costly electromechanical devices. The company's plug-and-plug solution allows robots to grasp objects of varying size, shape, and weight with the same EOAT. SuperPick, the company's flagship offering, uses AI to operate in hard-to-navigate unstructured environments and adds a vacuum to its compliant grippers for increased payload of up to 45 pounds. By using material science, rather than numerical computation, the company is able to simplify the machine-learning problem of robotic grasping by two to three times, with speeds of up to 600 picks per robot per hour. Founded in 2013, the company employs about 50 people and is based in Bedford, Massachusetts. To date, Soft Robotics has raised $29.3 million, with a focus on accelerating its commercial penetration and new product development. Notable investors include ABB Technology Ventures, Honeywell Ventures, Yamaha Motor, Samsung Global Research, and the U.S. Department of Defense.

Exhibit 36
Robotics, Automation, and Artificial Intelligence (RAAI)
Soft Robotics mGrip

Source: Soft Robotics

Software for Robotic Piece-Picking

The process of piece-picking has been automated for years, although new developments in robotics and AI have expanded the applicability and value proposition of automation. Relative to full-case or pallet picking, piece-picking is typically a lower-volume process and thereby lower-margin when taking into consideration the high labor costs associated with sorting individual SKUs. However, given that piece-picking is a relatively simplified problem compared with manufacturing or assembly (more structured environments, similar processes), it has been the most sensible area to start for software developers.

A primary challenge of robotic piece-picking historically has been the inability of sensors to recognize certain SKUs, such as reflective or translucent packaging. This has been improving with the evolution of sensors and layered software that triangulates object identification, but overall machine learning becomes more expensive as customers demand greater accuracy. Traditional computer vision cannot handle the breadth of the SKUs that human workers are required to pick and place in today's distribution and warehouses. Many software providers have chosen an 80/20 type of approach where human workers will work with the robots to fill in the 20% of SKUs that they cannot identify.

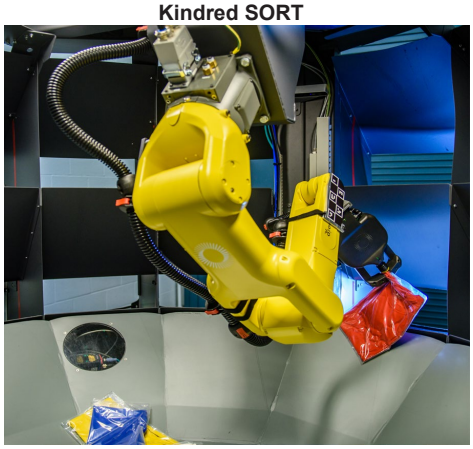
Through machine learning, deep learning, and reinforcement learning, robots are increasing their ability to handle various objects as algorithms continue to develop through data collection and trial and error. One of the benefits of machine learning has been the advent of closed-loop data, which does not require human input as required with an open-loop setting. With deep learning, the system relies on deep neural networks to achieve results. This is an extremely powerful solution but requires a large amount of labeled data for the system to process, which can be expensive and time-consuming to secure in the physical world. Therefore, deep learning systems must lean on other forms of machine learning (meta, transfer, and imitation, as well as simulation) to leverage the scale and efficiency necessary to perform in a real-world environment. Over time, we anticipate that the leaders in software development will be those that are able to quickly scale their e-commerce and warehouse distribution capabilities to more complex verticals such as manufacturing and assembly.

Key Robotic Piece-Picking Software Developers

Berkshire Grey. Based in Pittsburgh, Berkshire Grey is a developer of material-handling systems. Its intelligent robotic systems provide automated omnichannel fulfillment solutions for application in various commercial settings. Berkshire Grey's material-handling system is designed to help customers improve fulfillment accuracy and timing and is built to be adaptable to a broad assortment of products and parcels. The company's robots are programmed to react in real-time, allowing their placement and integration into dynamic environments, while cloud-based software allows the robot to continuously learn and improve perception, sensing, planning, and movement. Berkshire Grey's robotic order picking system is optimally designed for e-commerce fulfillment by means of conveyer or mobile robotic picking. Founded in 2013, Berkshire Grey has raised nearly $328 million through January 2020 through several rounds of financing.

Kindred. San Francisco-based Kindred is a robotics and AI company developing piece-picking solutions for e-commerce fulfillment. The company's flagship offering, SORT, is an AI-powered robotic putwall solution that combines vision, grasping, and placement to separate multi-SKU batches into individual customer orders. SORT integrates easily into many of the top warehouse management systems and can be operating on day one. The company requires no capital expenditures from its customers; rather, it operates on a pay-for-performance business model. The company was founded in 2014 and has raised $48 million to date, for a post valuation of $85 million.

Exhibit 37
Robotics, Automation, and Artificial Intelligence (RAAI)
Kindred SORT



Source: Kindred

Osaro. Osaro is a San Francisco-based industrial-grade AI software company specializing in vision and control systems for robots for automated storage and retrieval systems (ASRSs). The company's main product offering, Osaro Pick and Vision, integrates with automated storage and retrieval placing systems to perform various picking and placing tasks, enabling fully automated distribution centers. Osaro's systems have one of the largest ranges in the industry, with systems designed for inventories with over 100,000 SKUs. The software is compatible with all major robotic platforms, components, and warehouse management systems, and the company has partnered with many top system integrators and robot manufacturers to accelerate the adoption of its products. The company was founded in 2015 and has raised $30 million to date, for a post valuation of $63 million, with funds expected to grow its talent pool and drive R&D for growth into additional verticals such as food, automotive, and electronics manufacturing.

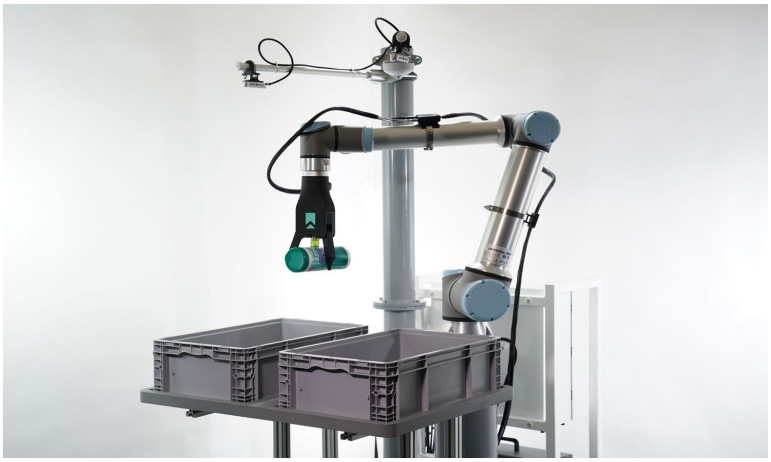
Exhibit 38
Robotics, Automation, and Artificial Intelligence (RAAI)
Osaro Software on Cobot

Source: Osaro

Plus One Robotics. Plus One Robotics, based in San Antonio, Texas, and founded in 2016, develops robot perception software and solutions that enable mechanized pickers to sense their environments and pick or manipulate items for movement or fulfillment. Plus One's PickOne perception software identifies the 6 degrees-of-freedom pick points for items in a designated zone and sends their points to the customer's robot, which facilitates accurate picking and placement. The company's supervisor software suite, Yonder, enables supervised autonomous operation for robots, thereby allowing one person to oversee many robots with flexibility and the ability to intervene in any particular operation when necessary, all from a remote location. Plus One Robotics had raised $10.65 million of funding as of September 2018, most recently through $8.3 million of series A venture funding led by Pritzker Group Venture Capital. Plus One's most recent capital raise will be allocated toward building out engineering and sales staff.

RightHand Robotics. A leading provider in robotic piece-picking solutions for e-commerce order fulfillment and intralogistics, RightHand Robotics' RightPick is a software-driven solution that reduces delivery costs and time to deployment for batch picking, ASRS, and belt sorters. RightPick uses computer vision and cloud-based machine learning AI to drive an industry-leading rate of picking (up to 1,000 units per hour) over a broad range of SKUs (over 500,000 at a time). The company has also developed a proprietary two-in-one vacuum and finger gripper, ReFlex Hand, that can reliably keep up with the pace and range of its software. Founded in 2014 and based in Somerville, Massachusetts, RightHand Robotics has raised $34 million to date, for a post valuation of $88 million.

Exhibit 39
Robotics, Automation, and Artificial Intelligence (RAAI)
RightHand Robotics ReFlex Hand



Source: RightHand Robotics

XYZ Robotics. Founded in 2018 and primarily based in Shanghai and with an alternate office in Boston, XYZ Robotics develops sorting robots empowered with AI for applications in supply chain management. XYZ's robotics primarily consist of mechanized arms that use AI and deep learning to automate processes that optimize the customer order placing and fulfillment process. Practical applications include automated picking and rebinning stations, vision processors, and tooling stations. In August 2019, XYZ Robotics raised $8 million of series A venture funding from several investor groups, led by Gaorong Capital and Morningside Venture Capital. XYZ Robotics intends to use the funds to develop logistics and industrial automation efficiency solutions through its hand-eye coordination technology.

Autonomous Robotic Software

Autonomous robotic software is underpinned by three core fundamentals: safety, awareness, and the ability to navigate complex environments. The industry has made strides in recent years and now reached an inflection point as companies begin to commercialize cobots and vehicles capable of successfully traversing indoor environments such as warehouses, offices, shopping malls, retailers, etc. This has largely been led by the rapid advancements made in sensor technology and edge processing, which allows for more complex algorithms to be run closer to robot level, and thereby have quicker decision-making capabilities.

One of the more exciting developments for autonomous mobile robotics is the coming wave of 5G and its promise of low-latency cloud computing. We expect 5G to eventually emerge as the next generation of nominally latent, high-speed broadband wireless communication that can become a catalyst for growth in applications requiring real-time dynamic input. However, at its current stage of commercialization, 5G's rollout is still a work-in-process.

Ultimately, 5G should enable robots to process much more information offline, increasing a robot's capability to perform advanced functions such as data collection, object identification, or global path planning optimization. However, the potential data lag inherent in all cloud computing means

it is still not suitable for safety-critical functions such as navigation and obstacle avoidance. Core mobility functions will still be processed onboard to meet strict safety guidelines, but additional non-safety critical functions will flourish with the emergence of 5G technology.

The challenges of autonomous navigation are amplified significantly when attempting outdoor travel, where inconsistent terrain, faster speeds (particularly on roads where vehicles must comply with federal and local regulations), and varying levels of internet connection add layers of complexity that have been difficult to meet in a fully autonomous manner. Still in its infancy, there is sufficient runway for multiple winners in the autonomous vehicle and robotic solutions space, with the ABI estimating a $135 billion opportunity for automation in the industrial and commercial space by 2027. As technology evolves, we expect faster and more accurate navigation systems, with an increased focus on outdoor applications.

Key Autonomous Robotic Software Developers

Balyo SA. Paris, France-based Balyo specializes in navigation technology for material-handling solutions, including the autonomous robotization of pallet jacks, tractors, trucks, fork lifts, etc. Founded in 2005, the company seeks to make AGV technology more scalable, flexible, and affordable. Balyo has partnered with European leader Linde Material Handling (forklifts) and U.S.-based Hyster-Yale Group (world's fifth-largest manufacturer of material-handling trucks) to expand its market presence. In June 2017, Balyo went public on the Euronext Paris. The company increased its revenues from €2.8 million in 2015 to more than €23 million at by the end of 2018.

BlueBotics SA. Founded in 2001 in Saint-Sulpice, Switzerland, BlueBotics provides navigation technology for autonomous mobile vehicles. The company's flagship product, Autonomous Navigation Technology (ANT), is an easily installed hardware and software solution that uses natural structures in the environment as reference points, negating the need for infrastructure investment. The company focuses on industrial automation and service robotics (AGVs and AMRs) for both new vehicles and retrofits, with an installed base of 2,000 vehicles globally. Core end-markets include warehouses, shop floors, cleanrooms, and hospitals. In September 2018, Forestay Capital acquired a stake in the company.

Exhibit 40
Robotics, Automation, and Artificial Intelligence (RAAI)
BlueBotics Enabled AGVs

Source: BlueBotics SA

Brain Corp. Brian Corp, based in San Diego, was founded in 2009 by Chairman and Chief Executive Officer Eugene Izhikevich and board member Dr. Allen Gruber. Brain Corp is an application-agnostic company specializing in autonomous software to support the production, deployment, and operations of commercial robots across various industries and applications, with a focus on indoor, commercial floor scrubber solutions and vacuums. The company's primary product is BrainOS, a cloud-connected operating system that allows commercial-grade robots the ability to navigate autonomously and avoid obstacles, adapt to changing environments, collect and manage real-time data, and interact with end-users and other cobots. The company does not manufacture robots, but rather operates as a traditional SaaS model. In addition to software, it provides hardware reference design and services to help developmental partners integrate BrainOS into their robotic products. Brain Corp completed its series C financing from Softbank Vision Fund for $114 million, bringing its total funding to $125 million, allowing management to take a more global lens (Q&A With Management of Autonomous Robotic Software Provider Brain Corp).

Exhibit 41
Robotics, Automation, and Artificial Intelligence (RAAI)
Tennant T7AMR Rider-Scrubber Using BrainOS

Source: Brain Corp.

Seegrid. Pittsburgh-based Seegrid was founded by Dr. Hans Moravec in 2003. The company is a leading provider of connected self-driving vehicles for material handling in factories and warehouses. The company's AGVs use a series of stereo cameras that work in unison to continuously capture and build a 3-D view of the world around them. This is viewed as a superior option to more rigid infrastructure-based solutions that required the installation of wire, tape, or laser reflections for navigation and allows for more flexible route changes while reducing costly downtime. The company has raised over $36 million through 10 rounds of funding since its inception, with proceeds to be used to fuel new product development, customers-support resources, and the commercialization of its product offering.

Vecna Robotics. In 2018, Chief Executive Officer Daniel Theobald founded Vecna Robotics, based in Boston. Vecna provides automated robotic solutions for material handling, hybrid fulfillment, and workflow optimization for the distribution, warehousing, and manufacturing markets. Vecna's systems use multimodal sensors (off the shelf), topological reasoning, locally coordinated decision-making, and user-friendly interfaces to transform material-handling equipment into more efficient, fully autonomous machines. The company provides three distinct software offerings. First, Pivot.AL is a multi-agent AI orchestration engine that integrates WMS and MES systems, analyzes customers' operations, and adjusts their processes to optimally coordinate workflow for robots and humans. Second, Autonomy Stack transforms material-handling equipment into intelligent self-driving autonomous vehicles. And third, Beacon is a service that analyzes data collected by Vecna robots to

optimize their deployment and performance. Historically funded organically or through grants, the company secured its first outside equity investment from Drive Capital for $13.5 million in August 2018 and anticipates additional funding in the future to drive its commercial aspirations.

Autonomous Mobile Robots and Guided Vehicles

Leaps in technological innovation surrounding AI and cloud-computing, along with sensors and robotic mechanics, have enabled rapid growth in the burgeoning warehouse automation space. This evolution has been led by a change in consumer shopping habits and the rise of e-commerce, as well as decade-low unemployment rates in North America that have made finding and retaining talent a material challenge, exacerbated by the dull, dirty, and often dangerous aspects of working in warehouses. Labor shortages and the need to reduce ever-growing labor costs while also increasing throughput, accuracy, and working capital management will continue to represent the strongest drivers in favor of making capital investments in robotics.

E-commerce and the desire for quicker and more flexible order fulfillment are also core sources of growth for the robotics industry as a whole. Consumers enjoy access to a plethora of choices and are willing to pay for add-on services like faster on-time delivery. The Amazon effect has been a serious disruptor in how traditional brick-and-mortar retailers have historically operated. Given the rapidly evolving e-commerce market, retailers face an existential crisis that necessitates increased e-commerce–driven capital expenditures. Some small to midsize retailers have opted to use Amazon for their e-commerce sales fulfillment, which is expensive and necessitates relinquishing some control of their brand.

Following the purchase of Kiva Systems (a manufacturer of robotics and inventory management systems) by Amazon in 2012, a large vacuum was created in the North American e-commerce fulfillment market, as many of Kiva's small to midsize e-commerce customers struggled to keep up with Amazon's two-day shipping. To fill the void, there has been an influx of start-ups, with more than 60 different companies now competing in what has become a highly fragmented AMR and AGV market.

The commercial robot market is expected to grow to over 4 million units throughout 50,000 warehouses by 2025, according to ABI Research. This compares with less than 4,000 warehouses with commercial robots at the end of 2018, or a 40%-plus CAGR over that time. More conservative estimates by Tractica suggest global shipments of warehouse and logistic robots of 938,000 units by 2022, up from 194,000 at the end of 2018, generating revenues of $30.8 billion, up from $8.3 billion in 2018.

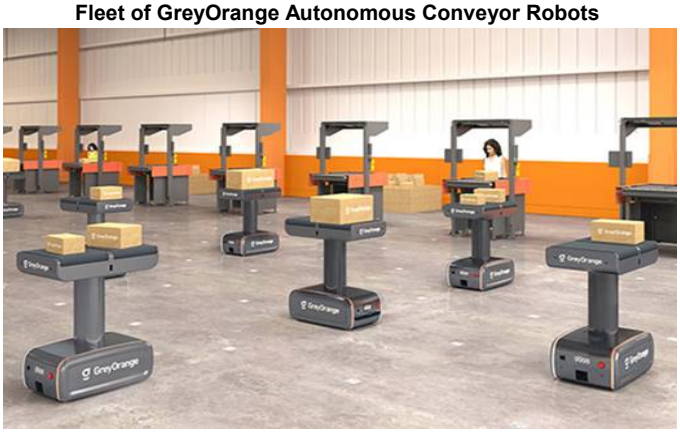
There are generally two types of AMR/AGV systems: those based on fleet management, routing the robots from an origin to a destination, and those based on pick optimization that integrate people and machines into a process flow for improved throughput. However, there are various levels of functionality all aiming to solve similar problems. In a typical warehouse, employees walk up and down aisles or stacks picking SKUs for fulfillment. With the addition of human-assisted cobots, workers are able to increase their efficiency and accuracy by traveling with a semi-autonomous robot that tells the worker which SKUs to pick and carrying the items while they work. In a goods-to-person (G2P) system, fully autonomous robots bring racks or pallets of goods to a stationary worker to pick, reducing the time needed to traverse large warehouses while increasing picking rates by as much as 80%.

Exhibit 42
Robotics, Automation, and Artificial Intelligence (RAAI)
AMR Lifts Mobile Storage Unit for Delivery to Centralized Station for Picking

Source: Eiratech Robotics

Fully autonomous manipulation and picking robots offer another option that is quickly gathering interest as the technology improves. Using autonomous robots with mobile picking arms, AMRs can replicate speeds equivalent to or greater than human workers, operating 24/7 with no fatigue. There are also more niche AMR offerings, including mobile conveyors for the moving of pallets or batched items onto conveyor belts for sorting; mobile robots for retail and warehouse inventory management; customer service robots for brick-and-mortar retail operations; mobile security robots; and automated cleaning systems, among others.

Exhibit 43
Robotics, Automation, and Artificial Intelligence (RAAI)
Fleet of GreyOrange Autonomous Conveyor Robots



Source: GreyOrange

The majority of AMR systems can be implemented in existing brownfield facilities, greatly increasing the accessibility of autonomous solutions to a broader audience. Furthermore, the robots-as-a-service (RaaS) business model, under which many AMR providers are structured, has also worked to encourage adoption. Charging a monthly fee for the software and robot rental allows traditionally large capital expenditures to be treated as more fluid operating expenditures. The enables warehouses to better scale their operations, for instance adding robots during the peak holiday season, while improving affordability of the systems by directly tying the costs to the consumption of services required.

Finding and securing highly skilled talent, particularly software engineers, represents one of the more imposing broad-based, near-term challenges for AMR and AGV manufacturers. In addition, the lack of industry knowledge and software expertise within the various manufacturers' target

markets looms as a significant concern. Since most solutions require a material investment and somewhat of a leap of faith that the overall payback will deliver as promised, market participants have exhibited caution in rushing to commit themselves as first adopters. This is being slowly overcome through customer education, and we expect will dissipate entirely as AMR/AGV sales snowball and the compelling value proposition forces companies to play catch-up against competitors that have already integrated warehouse automation solutions.

Over the mid- to longer term, however, we expect to see many AMR/AGV manufacturers close their doors or be acquired by larger industrial conglomerates. This is partly predicated on our stance that there appears to be a lack of material differentiation among the majority of the AMR/AGV manufacturers, as we consider the capital intensity required to service and maintain a growing and globalizing installed base. As adoption increases, we expect the industry to see greater competition on price and commoditization of the basic AMR functionality.

Over the long term, we expect the eventual market winners are likely to be those committed to strong partnership networks, which can help capture market share early on, while continuing to invest in improved, noninvasive solutions and software. One of the key reasons AMRs have taken off while other robotic solutions have shuttered over the last decade has been their direct focus on solving tangible automation needs. The ability for companies to keep investing in more cutting-edge services, driving throughput, speed, and accuracy, should act as a moat in dictating who the frontrunners will be once the industry begins to correct.

Key Autonomous Mobile Robot and Guided Vehicle Providers

6 River Systems Inc. Founded in 2015 and based in Waltham, Massachusetts, 6 Rivers is a provider of turnkey automation solutions for warehouse and e-commerce fulfillment. Its flagship product, "Chuck," is a human-assisted cobot that uses cloud-based pick optimization software to coordinate all the tasks on the warehouse floor. Autonomously leading warehouse associates through their day-to-day tasks, the fleet of cobots help reduce walking time while speeding up all other warehouse tasks (picking, inventory replenishment, sorting, etc.). The turnkey Chuck system can be integrated into existing facilities and any warehouse management system. The company boasts a strong set of customers, including DHL, Lockheed Martin, XPO Logistics, and Office Depot. In October 2019, 6 River Systems was acquired by Shopify, Inc. for $450 million in consideration. While Shopify intends to use 6 River Systems technology in its own operations, it will continue to sell its product suite to external customers.

Exhibit 44
Robotics, Automation, and Artificial Intelligence (RAAI)
6 River Systems' "Chuck"

Source: 6 River Systems, Inc.

Bossa Nova Robotics. San Francisco-based Bossa Nova Robotics was spun out of Carnegie Mellon's Robotics Institute in 2005 with a focus on robotic technology for retail operations. The company specializes in AMRs and drones for retail and warehouse inventory management. Using its advanced AI systems, the company's robots patrol retail aisles capturing 10 times the data with double the accuracy of a typical manual inventory management process. This allows for missing items to be identified and replaced three times faster, as tasks that once took as long as two weeks can now be performed twice daily. The company recently launched Bossa Nova 2020, an AI and automation-based inventory data management solution providing real-time "state-of-the-store" insights for brick-and-mortar operations. Bossa Nova's largest customer is Walmart, which recently announced an order for the deployment of robots at an additional 650 stores. This brings Bossa Nova's total installed base to 1,000 Walmart stores in the United States, out of the 4,769 Walmart stores at the end of 2019. Bossa Nova has raised nearly $77 million, with its most recent raise of $29 million in June 2018 aimed at helping the company's international expansion.

Exhibit 45
Robotics, Automation, and Artificial Intelligence (RAAI)
Bossa Nova Automated Mobile Robot

Source: Bossa Nova

Caja Robotics. Israel-based Caja Robotics was founded in 2014 with a focus on software and robotics for warehouse automation. The company offers two robots for its goods-to-person solution, a lift AMR for storage optimization and replenishment, and a cart AMR for picking and material handling. Caja's systems use cloud-based software and machine learning AI for 4-D fleet management navigation, inventory optimization, and simulation. The company's system is compatible with new and existing facilities, and easily integrates into any warehouse management system. Caja raised an undisclosed sum through venture funding in late 2015.

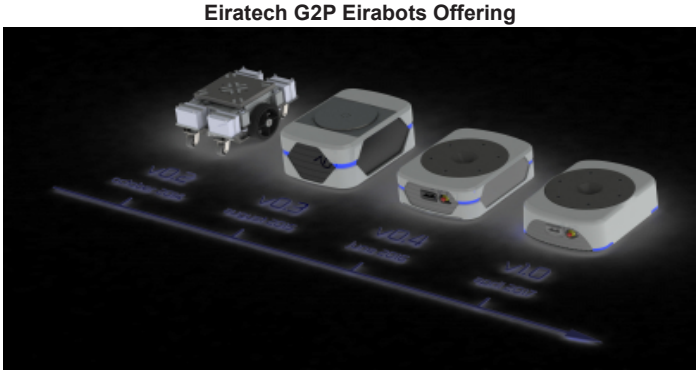
Eckhart. In operation since 1958, Lansing, Michigan–based Eckhart provides comprehensive advanced industrial solutions for several blue-chip industrial manufacturers, with products and services including AGVs; assembly and weld tooling; robotics and flexible automation; 3-D printing and additive manufacturing; and engineering services. AGVs are Eckhart's primary standardized automation product, complemented by custom-designed assembly tooling and engineering and manufacturing systems integration solutions. Eckhart was acquired by LFM Capital in 2015, unlocking a consistent source of capital that has allowed the company to diversify away from its heavy automotive exposure through acquisitions and internal investments, into various other industrial end-markets (Q&A With Management of Robotics and Warehouse Automation Provider Eckhart).

Exhibit 46
Robotics, Automation, and Artificial Intelligence (RAAI)
Eckhart "Autocraft" Autonomous Guided Vehicle

Source: Eckhart

Eiratech Robotics. Founded in 2014 by current CEO Alexey Tabolkin, the Dublin-based company has developed a complete G2P robotics automation platform for easy integration into distribution centers and industrial warehouses located in markets with high labor costs. Eiratech uses a fleet of robots to identify, seek, and retrieve stacks of goods, bringing stacks of items to centralized pickers for packing and dispatch. This increases accuracy and efficiency and dramatically improves personnel utilization while significantly reducing costs. By eliminating up to 70% of time employees waste walking and searching for items during the fulfillment process, Eiratech's e-fulfillment and material-handling systems can increase the goods picking rate in a warehouse to as much as 600 items per person, per hour. For small to midsize customers, Eiratech can develop a complete end-to-end warehouse automation solution, while the API software platform can also be easily integrated with warehouse automation control systems for larger customers. As a relatively young and financially stable family-and-friends-funded organization, the company does not have an immediate need for outside financing; however, management is open to potentially collaborating with a strategic partner that could help scale the business (Q&A With Management of Robotics and Warehouse Automation Provider Eiratech Robotics).

Exhibit 47
Robotics, Automation, and Artificial Intelligence (RAAI)
Eiratech G2P Eirabots Offering



Source: Eiratech Robotics

Geek+ Inc. With a global installed base of over 7,000 robots across a number of industries, including retail, pharmaceuticals, and manufacturing, Beijing-based Geek+ has grown into the leading provider of warehouse and logistics solutions in China and the APAC region. Founded in 2015, the company offers a wide range of automation solutions, including picking and moving systems (G2P AMRs for e-commerce fulfillment with payloads over 2,200 pounds), sorting systems (mobile conveyor sorting robots), and autonomous material handling (autonomous forklifts). Key customers include technology giant Alibaba Group, Chinese electronics company Xiaomi Corporation, China's second-largest courier SF Express, and Chinese retailer Suning.Com Co. Geek+ has raised over $200 million to date, with its most recent funding prioritized for the expansion of its production facility, increasing its annual production run-rate to 10,000 robots from 4,000 previously.

GreyOrange. Based in Singapore, GreyOrange is a global provider of robotic systems for warehouses, distribution centers, and fulfillment centers, with strong market share in the APAC region, including its status as the top provider in India. The company's core offering is a G2P picking system that uses an autonomous mobile robot, "Butler," capable of moving mobile storage units of up to 3,500 pounds, for transporting mobile storage units to a stationary robotic arm, "Butler PickPal," for picking and distribution. Butler PickPal can operate as a stand-alone, fully autonomous unit or alongside humans in a collaborative manner, while delivering up to twice the productivity as a traditional human picker. GreyOrange also offers a sortation system that includes linear conveyors and mobile conveyor robots for batch sorting. GreyOrange has raised nearly $180 million to date, most recently through a series C offering for $140 million, with proceeds expected to be used for U.S. expansion and R&D.

Exhibit 48
Robotics, Automation, and Artificial Intelligence (RAAI)
GreyOrange "Butler" Automated Mobile Robot

Source: GreyOrange

Fetch Robotics. Melonee Wise is the CEO of Fetch Robotics, which was founded in 2014 and based in San Jose, California. The company's Cloud Robotics Platform provides autonomous robots for material handling and data collection in warehouses, factories, and distribution centers. Specifically, customers can use the AMRs for automated material transport or automated data collection (perform inventory counting by automatically scanning RFID tags). The company also produces a robotics platform for researchers to collaborate and develop more mobile robotic technologies. In July 2019, the company raised $49 million as part of its series C round, led by Fort Ross Ventures. The company has raised $97 million in funding to date.

Exhibit 49
Robotics, Automation, and Artificial Intelligence (RAAI)
Fetch Robotics' Goods-to-Person AMR

Source: Fetch Robotics

IAM Robotics. IAM Robotics, founded in 2012, is the leader in automated mobile manipulating robots for e-commerce and order fulfillment. The company's Swift Solution uses a 3-D photo booth and barcode scanner "Flash" for product data collection; a warehouse management system agnostic AI software interface "Swiftlink"; and "Swift," the first AMR with a robotic piece-picking arm and tote for automated storage and retrieval. Based in Pittsburgh, IAM Robotics was acquired by an undisclosed investor in December 2018.

inVia Robotics. InVia Robotics was founded in 2015 by CEO Lior Elazary, COO Dan Parks, and CTO Randolph Voorhies. InVia provides fully autonomous warehouse robotic picking systems for e-commerce distribution centers and supply chains. The company produces AMRs capable of picking warehouse totes 24/7 with a proprietary suction arm that can lift up to 40 pounds on an autonomous robotic scissor lift with a vertical reach of 8 feet. The key components of inVia's product offering include: 1) inventory picking and management, 2) inventory replenishment and replacement of returns, and 3) Smart Sortation, which identifies the most efficient workflows for inventory retrieval to packing. InVia has obtained $29 million in funding since its founding in 2015, allowing the company to increase its headcount and robot production, and may look into another round of funding in 2020 to support its growth strategy (Q&A With Management of Robotics and Warehouse Automation Provider inVia Robotics).

Exhibit 50
Robotics, Automation, and Artificial Intelligence (RAAI)
inVia Picker Robot

Source: inVia Robotics

Locus Robotics. Locus Robotics, based in Wilmington, Massachusetts, was founded in 2014. The company produces autonomous robots (LocusBots) for e-commerce fulfillment to assist workers in the picking process. The LocusBots communicate with the LocusServer, which integrates with a customer's WMS system through APIs and custom integrations. Staying in a stationary location, LocusServer leverages humans' picking ability by sending bots to various areas of the warehouse for SKU retrieval. The company also developed a management platform to gain insight into performance and activity and manage operations and workflow. In April 2019, the company raised $26 million as part of its series C round, led by Scale Venture Partners and Zebra Ventures. The company has raised $59 million in funding to date for a post-valuation of $184 million.

Exhibit 51
Robotics, Automation, and Artificial Intelligence (RAAI)
LocusBot

Source: Locus Robotics

Mobile Industrial Robotics. Mobile Industrial Robots (MiR) is a Danish manufacturer of collaborative AMRs for manufacturing and warehousing materials handling. The company offers four material-handling options varying in payload capacity (220 to 2,200 pounds), and two towing robots (ideal for production, logistics, and healthcare environments) supporting the transportation of loads up to 1,100 pounds. MiR's cobots can reach speeds of 4.5 miles per hour and can service greenfield and brownfield manufacturers, lowering the barrier for customers of all sizes to automate their operations. Teradyne, Inc. acquired the company in April 2018 for $271.2 million.

NextShift Robotics. Founded in 2016 and based in Lowell, Massachusetts, NextShift is a low-cost supplier of autonomous mobile robots for order fulfillment and cellular manufacturing workflows. NextShift's AMR, the TM-100, uses patented vertical lift capabilities for the autonomous loading, transport, and unloading of totes, as well as a proprietary material-handling system that helps navigate its AMRs throughout the warehouse, retrieving SKUs from stationary human pickers. The company's systems are easily deployed and compatible with new and existing warehouses. NextShift has raised $1.9 million to date, including seed financing of $1.5 million and a $0.4 million convertible loan.

Simbe Robotics. Simbe Robotics was founded in 2014 and is based in San Francisco. The company's flagship product, the Tally system, is composed of AMRs for retail inventory management. The company has deployed robots in 12 of the top 250 global retailers. Simbe raised $26 million through a series A funding in September 2019. The company intends to use the funds for R&D and support the manufacturing of 1,000 Tally units over the next two years. The company has also reached an inventory financing agreement with SoftBank Robotics, building on its existing partnership with SoftBank Robotics America as a way to leverage SoftBank's global reach and scale.

Swisslog Holding AG. Swisslog Holdings is a global provider of logistical solutions for warehouses, distribution centers, and hospitals. The company is an end-to-end supplier of automation solutions, including material-handling AGVs, G2P AMRs for retrieval and storage, order picking cobot arms, conveyor systems, and a warehouse management system, "SynQ." Swisslog was purchased by KUKA AG in December 2014 for $330 million, expanding the company's R&D opportunities and market access.

Waypoint Robotics. Waypoint Robotics, a spinoff of Stanley Innovation (a skunk works' sister company), which is a subsidiary of Stanley Elevator Company in 2017, is led by CEO Jason Walker with the goal of developing and building AMRs for functional application in factories, laboratories, and other manufacturing, industrial, and commercial facilities. Located just north of Boston in Merrimack, New Hampshire, Waypoint offers two turnkey autonomous robots. The company's flagship AMR model is the Vector (payload capacity of 300 to 600 pounds) with a compact design and enabled with omnidirectional mobility to navigate tight floorplans right out of the box. The heavy-duty MAV3K is an industrial strength (3,000-pound payload capacity), omnidirectional robot that allows for smooth and nimble material handling. The company is looking for strategic partners to help drive commercialization of its leading robotic technologies.

Exhibit 52
Robotics, Automation, and Artificial Intelligence (RAAI)
Waypoint Robotics' AMRs

Source: Waypoint Robotics

Other Robotic Solutions

Recycling Robotics

Recycling has historically been a highly complex, labor-intensive, and expensive endeavor. In recent years, however, the convergence of machine learning AI and robotics has unlocked major opportunities to automate vast portions of this process, allowing for more cost-effective and consistent solutions. Several factors are driving adoption of autonomous solutions, including a shortage of labor; rising safety requirements; the need for improved bale quality and reliability; global legislation governing imported recycling streams; and sharply increased vision technology and robotic picking functionality at lower cost points in recent years.

Low unemployment and persistent staffing shortages are a constant challenge for the recycling sector. The dirty, dangerous, and difficult nature of the work is ideal for automated, high-speed robotic solutions. Labor represents about 50% of expenses for recycling facilities. By incorporating automated sorting solutions, facilities can free a material portion of its workforce while wrapping sections of the waste stream process that have not been able to be sorted mechanically with traditional waste stream separation technology.

Furthermore, recent Chinese restrictions on imported recyclable products, along with global efforts to reduce waste and carbon emissions, have been material drivers of improved purity and the need for autonomous solutions. Enacted in February 2018, China's National Sword policy bans the import of 24 types of plastic, paper, and solid material, and raises contamination levels of scrap plastics and other metals to 99.5% purity, from 90%-95% previously. This blindsided the global recycling markets and swiftly increased the urgency for operators to reduce costs, increase efficiency, and improve the purity of separated products while finding new solutions for the developed world's waste.

According to Steve Miller, CEO of Bulk Handling Systems, the global waste recycling service market was about $280 billion in 2018, up from an estimated $260 billion in 2017, and is expected to grow 5%-10% annually over the next decade. Given the very low market penetration, we believe automated recycling market can grow about 20%-25% through about 2030. Bulk Handling Systems believes there were an estimated 180 robots deployed in the United States and Canada in 2019, up from 10 in 2018, for the sorting of residential and commercial recyclables, mixed-waste, plastics, shredded electronics, and construction and demolition debris.

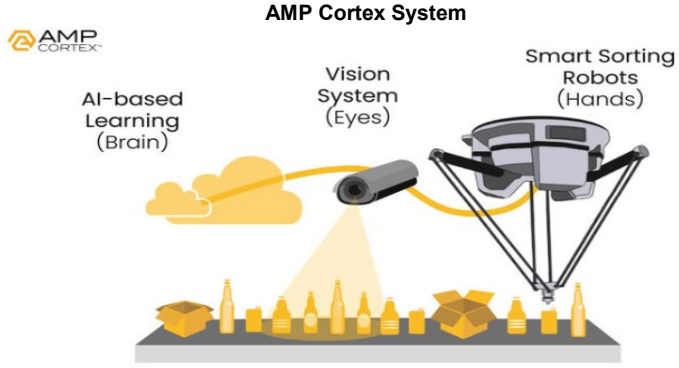
It is very early days for recycling automation, with the majority of early activity taking place in North America and a largely untapped international market. Given the size of the tangible addressable market and unique offerings from key market participants, we believe that there is plenty of room to grow for all to succeed.

Key Recycling Robotic Manufacturers

AMP Robotics. Based in Louisville, Colorado, AMP Robotics was founded in 2014 with a focus on reducing contamination and the reliance on manual sorters in the recycling process. AMP Robotics is a leading provider of AI-powered robotic sorting solutions that automate the identification, sorting, and processing of material streams for material recovery facilities (municipal solid waste) and recycling facilities (construction and demolition, e-waste, metal scrap, and auto-shredding). AMP's robotic systems pick at a rate of 80 items per minute, twice the optimal human rate, operating 24/7 while maintaining accuracy without suffering from fatigue. The company has raised $22.6 million in funding to date, using the proceeds to establish a strong pipeline to support the construction of a

profitable, sustainable automated recycling business. AMP Robotics is the second-largest provider of automated recycling systems in North America, with over 50 deployments at the end of 2019 (Q&A With Management of Recycling Robotics and Artificial Intelligence Provider AMP Robotics).

Exhibit 53
Robotics, Automation, and Artificial Intelligence (RAAI)
AMP Cortex System



Source: AMP Robotics

Bulk Handling Systems. Founded in 1976 in Eugene, Oregon, as a supplier of material-handling systems (conveyors, screens, structures) for wood product manufacturers, Bulk Handling Systems (BHS) has since transformed into the global turnkey "Green Solutions" provider of automated material handling for the solid inorganic and organic waste, recycling, waste-to-energy, and construction and demolition industries. The company is private after being acquired from the original owners by Emerging Acquisitions in 2005. Since then, the company has increased its revenues to over $125 million annually, from $5 million in 2005, and has added over 270 employees through organic growth and a series of acquisitions, including National Recovery Technologies (optical material sorting, closed 2012), Nihot Recycling Technology (air-controlled waste separation, closed 2013), and Zero Waste Energy (organic waste processing into biogas, closed 2015). In 2017, BHS launched its industry-leading Max-AI AQC (autonomous quality control) for the robotic sorting of plastic and paper streams using 2-D optics and an AI machine-learning platform. The product line was expanded in May 2019 following the launch of BHS's Max-AI AQC-C product offering, which pairs its original Max solution with up to four additional cobots, increasing sorting capacity by 40 picks per minute (per cobot) for up to three different material types, including plastics, metals, and paper. BHS is by far the largest player in the automated robotic recycling space, with more than 110 Max-AI systems worldwide as of the end of 2019 (Q&A With Management of Environmental Solutions Provider Bulk Handling Systems).

Exhibit 54
Robotics, Automation, and Artificial Intelligence (RAAI)
Bulk Handling Systems' Max-AI AQC-C

Source: Bulk Handling Systems

Security Robots

The security market has historically been static, with relatively little technological advancement in access controls or manned security guards. This provides a meaningful opportunity for the advent of security robots, where recent technological advancements are allowing for security AMRs to supplement the benefits of traditional security. While we do not anticipate the outright replacement of manned security guards by robots anytime soon, by combining the best attributes of machines (attention, recall, superior sensing capabilities) with the best attributes of people (warmth, responsiveness, adaptability), there is a strong value proposition for a safer and more encompassing solution.

Cobalt Robotics pegs the total physical security market (manned security guards) at $85 billion, expected to grow to $120 billion by 2023 (an 8% CAGR). In addition, the annual market for cameras and access controls is estimated at another $100 billion. With only 500 indoor security robots deployed today, Cobalt sees a tangible addressable market of about $10 billion given where technological capabilities stand today.

Given the dearth of competitors in the market today, we believe the largest challenge to security AMR adoption is overcoming the status quo, or rather trying to perpetrate change in a largely fixed industry. Another challenge is the cultural perception surrounding indoor security and monitoring, as many people in the industry are uncertain about how to view security robots and often are even hesitant to talk about their active security layouts with outsiders. However, through customer education, demonstrating the economic advantages, data and insights, and enhanced risk detection that may not be identifiable to the naked eye, we believe that there is a strong argument for adoption.

Key Security Robot Manufacturers

Cobalt Robotics, Inc. Chief Executive Officer Dr. Travis Deyle and Chief Technology Officer Erik Schluntz founded Cobalt Robotics in 2016. Cobalt Robotics is the premier manufacturer of autonomous security robots for indoor use in offices, museums, data centers, hospitals, and other commercial buildings where the indoor premises are compliant with the American Disabilities Act (ADA). Cobalt's autonomous robot is five feet tall, is equipped with a touchscreen and over 60 sensors, and can scan badges, act as a mobile PA system, detect leaks and intruders, and remotely communicate with access control to open doors and maneuver closed areas. The goal of Cobalt Robotics is to fill the gap between electronic security/access control systems and manned guards with a technological solution that improves indoor safety conditions while enhancing building

functionality. The company has raised $55 million since 2017 and is looking to secure additional funding in 2020 to accelerate its international presence (Q&A With Management of Autonomous Security Robotics Solutions Provider Cobalt Robotics).

Exhibit 55
Robotics, Automation, and Artificial Intelligence (RAAI)
Cobalt Robot

Source: Cobalt Robotics, Inc.

Knightscope. Founded in 2013 and based in Silicon Valley, Knightscope is a leading developer of autonomous data security solutions for the detection and prevention of crime. All of Knightscope's products offer similar capabilities with various degrees of mobility, including 360-degree video streaming, live audio broadcasts, and the detection of people, license plates, and thermal anomalies. The company has developed a stationary monitoring machine, the K1 Stationary, for surveillance of indoor and outdoor public areas (airports, malls, parking lots). The K3 Indoor and K5 Outdoor are security AMRs designed for the patrolling of indoor public area such as malls, hotels, casinos, and hospitals, as well as corporate campuses, parking lots, or other outdoor areas with flat surfaces. Knightscope is also developing K7, an AGV designed for the security needs of more rugged, off-road environments. The company has raised nearly $100 million in funding and has reserved the ticker KSCP on the Nasdaq for a potential IPO.

Exhibit 56
Robotics, Automation, and Artificial Intelligence (RAAI)
Knightscope Fleet

Source: Knightscope

Dangerous Environments

Gecko Robotics. Pittsburgh-based Gecko Robotics was founded in 2013 with a focus on inspection robotics for the industrial service industry, including oil and gas, power, and the pulp and paper industries. Using acoustic, laser, electromagnetic, and other nondestructive testing modules, Gecko's robots scale walls and maneuver through difficult and dangerous environments, collecting data on industrial infrastructure that may not be detectable with the human eye. While a lot of general inspection work is possible through drone technology, a benefit of AMRs is the ability to test the structural integrity of a facility through surface contact. The company recently secured $40 million in funding through a series B, with proceeds to be used for scaling the business, including the hiring of software and product engineers.

RedZone Robotics. Based in Pittsburgh, RedZone Robotics develops specialized robotics and software to assist in pipeline inspection and wastewater asset management. Upon the company's founding in 1987, RedZone set out to develop condition assessment robots for implementation in the mining, nuclear, and other heavy industries. After working with the city of Pittsburgh to develop the Responder platform, which aids in the inspection of large pipes and facilitated the first multisensor inspections in the industry, RedZone exclusively turned its focus to wastewater solutions. RedZone's wastewater management tools provide critical analytics to support cities, contractors, and engineering companies as they assess the condition of existing infrastructure. After 20 years of growth through selective acquisitions and successful product launches, RedZone was acquired by Milestone Partners in 2018 in the form of a leveraged buyout for $56.8 million, with Monroe capital providing $21 million of debt financing to complete the transaction. Given the precarious condition of the U.S's declining quality of infrastructure, RedZone's inspection and analysis tools are expected to service strong demand in the coming years as the country begins to pivot toward rebuilding and replacing previously long-standing structures.

ULC Robotics. ULC Robotics, founded in 2001, is located in Hauppauge, New York. The company manufactures pipeline inspection robots and UAV aerial drones to help energy and utility companies repair and maintain their critical infrastructure in the United States and United Kingdom. The company's less invasive product offering improves the inspection and repair process by minimizing the environmental and social impact while increasing safety and operational efficiency. This is achieved by reducing costly and disruptive street excavations for the repair and maintenance of natural gas pipelines, while also using unmanned aerial drones for the inspection of hundreds of miles of power lines in half the time and expense as having employees physically walk the lines.

The prices of the common stock of other public companies mentioned in this report follow:

ABB Ltd.	CHF 20.88
Accenture Plc Class A (Outperform)	€188.86
Advanced Disposal Services, Inc.	$32.98
Advanced Micro Devices, Inc.	$50.11
Altra Industrial Motion Corp.	$29.35
Amazon.com, Inc. (Outperform)	$1,975.83
Aspen Technology, Inc. (Outperform)	$110.20
ASTI Holdings Limited	SGD 0.04
AT&T Inc. (Market Perform)	$38.18
Avery Dennison Corporation	$121.76
Balyo SA	€1.49
Barnes Group Inc.	$56.62
Blue Apron Holdings, Inc. Class A	$2.72
Brooks Automation, Inc.	$35.84
Casio Computer Co., Ltd.	¥1,809
Clean Harbors, Inc.	$73.63
Cognex Corporation	$47.56
Crane Co. (Market Perform)	$66.26
Cummins Inc. (Market Perform)	$156.44
Daifuku Co., Ltd.	¥6,240
Daimler AG	€37.63
Datalogic S.p.A.	€ 12.93
Deutsche Post AG	€ 26.52
Diebold Nixdorf Incorporated	$6.12
Emerson Electric Co. (Market Perform)	$66.67
Estun Automation Co. Ltd. Class A	¥11.94
Fanuc Corporation	¥17,660
FedEx Corporation	$136.41
PT Fuji Finance Indonesia Tbk	105 Rp
FLIR Systems, Inc. (Outperform)	$40.81
Fortive Corp.	$72.07
General Motors Company	$31.53
Generix Group SA	€ 6.70
Hangzhou Hikvision Digital Technology Co., Ltd Class A	¥35.53
Harmonic Drive Systems Inc.	¥4,525
HelloFresh SE	€ 25.00
Hirata Corporation	¥5,130
Hitachi,Ltd.	¥3,692
Honeywell International Inc. (Market Perform)	$171.19
Hyster-Yale Materials Handling, Inc. Class A	$46.48
IHI Corporation	¥2,181
International Business Machines Corporation	$134.22
IPG Photonics Corporation	$131.59
iRobot Corporation	$49.78
Jiangsu Hengrui Medicine Co., Ltd. Class A	¥87.80
JBT Corporation (Outperform)	$98.95
Jungheinrich AG Pref	€ 17.91
Kadant Inc. (Outperform)	$90.35
Kardex AG	CHF 152.00
KION GROUP AG	€48.70
Komatsu Ltd.	¥2,152

Kroger Co.	$30.96
KUKA AG	€ 29.15
Loblaw Companies Limited	C$188.86
Lockheed Martin Corporation	$402.03
Matthews International Corporation Class A	$30.54
Microsoft Corporation (Outperform)	$170.55
Mirle Automation Corp.	NT$34.70
Nabors Industries Ltd.	BMD 1.63
Navistar International Corporation	$35.33
NCR Corporation	$25.23
Nilfisk Holding A/S	137.00 kr.
Ocado Group PLC	£11.53
Office Depot, Inc.	$2.49
OMRON Corporation	¥5,780
Oracle Corporation (Market Perform)	$50.54
PACCAR Inc	$69.45
Panasonic Corporation	¥1,021
PTC Inc.	$70.82
Republic Services, Inc.	$96.56
Rockwell Automation, Inc. (Market Perform)	$192.25
SAP SE	€111.50
Schneider Electric SE	€96.10
Seiko Epson Corp.	¥1,460
Shopify, Inc. Class A (Market Perform)	C$512.23
SIASUN Robot & Automation Co., Ltd. Class A	¥15.94
Siemens AG	€91.96
Sony Corporation	¥6,811
Sprint Corporation (Not Rated)	$9.57
Stericycle, Inc. (Outperform)	$64.87
Target Corporation	$107.82
Tennant Company	$77.33
Teradyne, Inc.	$62.47
T-Mobile US, Inc. (Outperform)	$93.81
Toshiba Corporation	¥3,025
Toyota Industries Corp.	¥5,650
Toyota Motor Corp.	¥6,974
Unifi, Inc.	$20.76
United Parcel Service, Inc. Class B	$95.82
Verizon Communications Inc. (Market Perform)	$58.12
Volvo AB Class B	SEK 149.20
Walmart Inc.	$116.77
Waste Connections, Inc.	C$136.19
Waste Management, Inc.	$120.29
Woolworths Group Ltd	A$37.04
Yokogawa Electric Corp.	¥1,674
Zebra Technologies Corporation (Market Perform)	$216.04

IMPORTANT DISCLOSURES

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DOW JONES: 26121.30
S&P 500: 3023.94
NASDAQ: 8738.59

Additional information is available upon request.

Current Rating Distribution (as of March 6, 2020):

Coverage Universe	Percent	Inv. Banking Relationships *	Percent
Outperform (Buy)	70	Outperform (Buy)	23
Market Perform (Hold)	29	Market Perform (Hold)	9
Underperform (Sell)	1	Underperform (Sell)	0

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