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Contents

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Executive summary

Driven by complementary technological developments in other areas, the robotics sector has perhaps never been as promising as it is today. Parallel advances in computer vision and the Internet of Things (IoT) have substantially expanded use cases for robotics, with many enterprises—including agriculture, logistics, healthcare, and construction—piloting robot applications for the first time. Mobility underpins increased robotic usefulness, as contemporary robots are equipped with sensors such as lidar and computer vision to help them autonomously navigate their environments. This new ability, combined with labor shortages, geopolitical concerns, and productivity-obsessed shareholders, has many companies looking to robots to accelerate their business competitiveness.

The existing global robotics opportunity covers a nearly $40 billion market across hardware, software, and eight additional industry-specific areas. While robots are finally seeing wider adoption across the continuum, warehousing and logistics use cases are experiencing the highest demand, driven by pandemic-accelerated e-commerce and supply chain efficiency considerations. This report explores innovation and disruption across the 10 segments and provides commentary on recent acquisitions, a timeline of robotic development, and an isometric landscape of the notable companies leading their respective categories.

Figure 1.

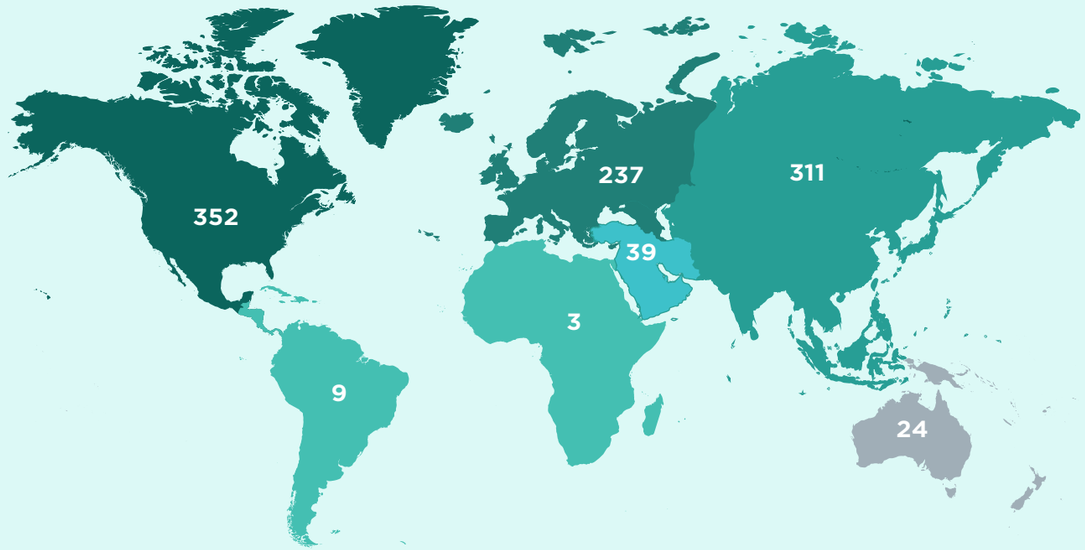
Robotics market size ($B)

2020	2021	2022	2023	2024	2025	2026	CAGR
$28.0	$35.7	$45.5	$58.0	$74.0	$94.3	$120.3	**27.5%**

Source: PitchBook Emerging Tech Research | Geography: Global

Figure 2.

Company count breakdown by geography*



814 companies

2,269 investors

$21.2B VC raised**

1,816 deals**

Source: PitchBook | Geography: Global | *As of November 22, 2021 | **Since 2009

Robotics timeline

PROJECTED

Unimate, the first-ever industrial robot, is installed.

1961
Installed in a General Motors (NYSE: GM) factory in New Jersey, the demonstration would pave the way for using robots in manufacturing.

iRobot (NASDAQ: IRBT) releases the Roomba vacuum.

September 2002
Probably the most popular consumer robot of all time. Consumer robotics has yet to advance far past this milestone.

Boston Dynamics introduces canine-inspired robot, Spot.

June 23, 2016
The robotics and engineering powerhouse developed a four-legged mobile robot platform, which is now being used in applications from industrial inspection to public safety.

Mobile robot orders are expected to exceed industrial robots for first time.

2022
In a turning point for robotics, AMRs will incur more demand, a trend expected to accelerate continuously throughout the decade.

The first robotic-assisted surgery takes place.

1985
Used during a neurosurgical biopsy, the technology would become increasingly popular, culminating in the 2000 launch of the da Vinci Surgery System, the first robotic system approved by the FDA.

Amazon (NASDAQ: AMZN) acquires Kiva Systems.

August 6, 2012
Now Amazon Robotics, its technology, along with competitor variations, is quickly dominating the warehouse automation market.

Nuro is cleared for commercial operation in California.

December 23, 2020
The first driverless company to clear this hurdle, Nuro aims to redesign delivery services through its robotic delivery vehicles.

Industrial robot cost is expected to fall below $25,000.

2024
Cheaper robots, in addition to business models such as Robotics-as-a-Service, are expected to spur increasing demand for industrial robots.

1960 1980 2000 2010 2020 2022 2030

The MQ-1 Predator, the first remotely piloted military drone, takes flight.

July 3, 1994
A significant evolution in military technology, the Predator drone would become synonymous with American air superiority and presage an era of increasingly automated defense systems.

AlexNet wins the ImageNet challenge, a leap forward for computer vision.

September 30, 2012
AlexNet, a convolutional neural network (CNN), proved the viability of AI to outperform humans in object identification. Future iterations of the idea are present in many of today's robots.

Built Robotics raises a $33 million Series B.

September 19, 2019
In another step for a long stagnant construction industry, Built Robotics applies autonomous tech to construction machines such as bulldozers and excavators.

Softbank invests $2.8 billion in AutoStore (OSL: AUTO).

April 6, 2021
The Norway company's robotic warehouse solution allows customers to store up to 4x the inventory space. E-commerce remains the hottest area of investment.

China aims to supply 70% of domestic market with homegrown robotics.

2025
Made in China 2025, China's ambitious development plan, aims to increase self-sufficiency and technological prowess in a shift away from the West.

Industry growth drivers

Advancements in computer vision have transformed robotics into a true general-purpose technology. Though the first digitally programmable robot appeared in 1961, robotic applications have long been confined to capital-intensive industries such as manufacturing, aerospace, and defense, with robots tackling repetitive or highly bespoke tasks. Popular conceptions of robotics often bring to mind automotive assembly lines—and, indeed, the aforementioned first robot, Unimate, was installed in a General Motors factory in 1961.[1] In the following decades, generalizing robotic technology into other industries largely flopped, as technological constraints revealed robots as uneconomical relative to human labor. In recent years, however, the confluence of increased computing power and the growth of computer vision, a subfield of artificial intelligence (AI), is enabling robots with unprecedented capabilities.

Computer vision systems are designed to empower machines with a facsimile of human intelligence—specifically the ability to identify, label, and process objects in the physical world. Though computer vision refers to the software element, advances in hardware such as better cameras and lidar sensors have greatly improved both the volume and quality of data being fed into the computer, and more powerful computing infrastructure has enabled computer vision algorithms to work at scale. Robots, which once had to be pre-programmed for specific tasks, are now being equipped with these systems to allow them to autonomously make decisions. The implications for robotics are manifold, but have played out primarily in mobility, logistics, and agriculture. Newly "intelligent" robots can autonomously move about in often-complex environments such as warehouses and construction sites, as well as differentiate between irregular objects such as packages or plants. Gartner Research (NYSE: IT) expects that innovation around computer vision will generate revenue in excess of $275 billion by 2025 in direct and secondary effects, and robotics is a large part of that story.[2]

Autonomous mobile robots (AMRs) represent the largest growth opportunity in robotics. While stationary robots may be reprogrammed or re-outfitted, their most significant limitation comes from their statuesque nature, which requires users to redesign physical spaces to accommodate robotic machinery. Additional installation complications arise from the fact that humans are often prohibited from working near robots due to safety concerns. AMRs, by contrast, are adaptable to a wide range of use cases in diverse environments. The technology underlying these machines is so versatile that NASA utilized it aboard the Ingenuity helicopter on Mars, which navigated unknown terrain 173 million miles away with no ability to receive direct instructions from human operators.[3]

AMRs serve as a basic platform on which companies can build an array of capabilities. Restaurants can use them as "runners" to deliver food and bus tables. Hospitals use AMRs to support staff and transport medical supplies. Farmers are beginning to rely on AMRs for pollination as bee populations decline, allowing robots to navigate fields and decide what and where to pollinate. The most prominent use case, however, has been in logistics and fulfillment, wherein global demand for goods continues to create new supply chain-focused opportunities. The number of sites with deployed AMRs is expected to reach over 53,000 by 2025, a significant jump from the 9,000 at the end of 2020. Even then, experts believe

1: "A Brief History of Industrial Robotics in the 20th Century," *Advances in Historical Studies*, A. Gasparetto and Lorenzo Scalera, January 2019.

2: "Emerging Technologies: Tech Innovators for Computer Vision," Gartner, Nick Ingelbrecht, Tracy Tsai, and Tuong Nguyen, December 10, 2020.
3: "NASA's Mars Helicopter Ingenuity Makes Historic First Flight," *The Wall Street Journal*, Robert Lee Hotz, April 19, 2021.

INDUSTRY GROWTH DRIVERS

this number will still fall short of 30% market penetration, thus leaving significant room for growth.[4] Moreover, according to an ABI Research report, of the 8 million robots expected to ship in 2030, nearly 6 million will be mobile.[5]

Labor shortages are intensifying the need for automation solutions. Businesses across food service, construction, logistics, and agriculture are all struggling to staff operations, despite offers of increased wages and benefits. In the United States, the labor participation rate of 58.8% has yet to recover to its pre-pandemic high of 61.1%, a situation likely due to some combination of tighter immigration rules, government stimulus, and increased demand for more-flexible work arrangements.[6] Given these supply-side constraints, businesses are increasingly looking to automate more aspects of their operations—if not to save labor costs than simply to ensure continuity in operations when shocks such as a global pandemic occur. As Tom Bianculli, CTO at Zebra Technologies (NASDAQ: ZBRA) describes it, "Automation is not about return on investment, it's about continuity of business."[7]

While automation has long been a business consideration, not until recently could tasks such as bricklaying, order fulfillment, and pollination be done robotically. Annual North American robot sales through Q3 2021 neared 29,000 units, collectively valued at $1.5 billion in sales, which already surpasses the all-time annual high set in 2017.[8] While the use of robotics in the automotive industry continues to grow, non-automotive orders experienced the largest increase—of 53%—thereby emphasizing that the broader appeal of robotics is extending to more industries and use cases. Gartner listed labor availability as the primary consideration among enterprises in determining whether to introduce more automation and robotics into warehouse operations.[9]

E-commerce demand is driving further investment into robotic fulfillment solutions. It's a well understood narrative at this point that the pandemic accelerated digital commerce by at least a couple years, with global online retail as a share of all retail rising to 19% in 2020 from 16% in 2019.[10] Rather than being a transitory phenomenon, however, many believe the pandemic has permanently reshaped consumer behaviors related to e-commerce, due to a combination of improved technology and lower costs. Deloitte expects holiday e-commerce sales in 2021 to grow between 11% and 15% over 2020.[11]

Servicing this demand is a vast network of warehouses, workers, software, and increasingly, robots. In 2012, Amazon was well ahead of the trend when it acquired Kiva Systems, an early signal that robotic solutions would be crucial to scaling order fulfillment operations. Fast forward to today, and more than $3.5 billion has been put toward warehouse automation, with many companies deploying AMRs similar to those Kiva was using over one decade ago.

4: "Mobile Robots Rapidly Mainstreaming – By 2025, AGVs and AMRs Deployed in 53K Facilities," Robotics Business Review, Ash Sharma, October 12, 2021.
5: "Industry Trends and Market Potential – What's Next?" Association for Advancing Automation, Tanya Anandan, December 14, 2020.
6: "Employment-Population Ratio (EMRATIO)," FRED, November 15, 2021.
7: "Robotics Supply Helping Hand to Speedy Order Fulfillment," *Financial Times*, Harry Dempsey, November 14, 2021.
8: "Q3 Robot Sales of $1.48B Put 2021 on Track for Biggest Year Yet, Says A3," Robotics247, Eugene Demaitre, November 11, 2021.
9: "Are Robots the Answer to Pandemic-Proofing Warehousing and Logistics Operations?" Gartner, Dwight Klappich and John Johnson, July 9, 2020.
10: "Global E-commerce Jumps to $26.7 Trillion, COVID-19 Boosts Online Sales," UN Conference on Trade and Development, May 3, 2021.
11: "Deloitte: Holiday Retail Sales Expected to Increase 7-9%," Deloitte, September 14, 2021.

INDUSTRY GROWTH DRIVERS

Amazon alone uses over 350,000 autonomous robots to service its fulfillment centers, which are 800,000 square feet on average and staffed by more than 1,500 full-time workers.[12,13]

Amazon's dominance and economies of scale have allowed it to steadily reshape consumer expectations, with shoppers now frustrated by delivery times over 48 hours. In response, competitors both large and small are increasingly turning to highly automated micro-fulfillment centers (MFCs)—smaller warehouses equipped with AI and robotic automation and located in denser urban areas closer to consumers. MFCs and their associated technology have been estimated to reduce the costs of fulfillment by as much as 75%.[14] Given tailwinds from pandemic-accelerated e-commerce and the broader MFC trend, an estimated 4 million commercial warehouse robots are expected to be installed in over 50,000 warehouses worldwide by 2025.[15]

12: "Robotics-Powered 'Microfulfillment' Startup Fabric Raises $200M," VentureBeat, Kyle Wiggers, October 26, 2021.
13: "Our Facilities," Amazon, n.d.
14: "Micro Fulfilment Is The 2021 Supply Chain Strategy To Watch," Techwire Asia, Joe Devanesan, February 24, 2021.
15: "Robotics-Powered 'Microfulfillment' Startup Fabric Raises $200M," VentureBeat, Kyle Wiggers, October 26, 2021.

Outlook

Collaborative robots will gain traction in manufacturing, but more slowly than advocates concede. Collaborative robots, or cobots, have been talked up in recent years as a more affordable robotic solution for small to medium-sized enterprises unwilling to invest in large, capital-intensive robotic machinery. As their name implies, cobots are intended to work alongside human counterparts, automating physically demanding or tediously repetitive work so humans can focus on detail-oriented or erratic tasks that are too difficult for a programmed machine to execute. Relative to their larger robot counterparts, cobots are lighter, cheaper, and able to be repurposed, thus making them a more flexible asset. By leveraging collision avoidance technology and working at slower velocities, a necessity due to their close proximity to human workers, cobots are also safer. When combined with the aforementioned advances in computer vision, cobots are estimated to grow from a $475 million market in 2020 to $8 billion by 2030.[16]

Despite these advantages, there are many challenges to widespread cobot adoption. For starters, the same safety constraints that enable human-machine collaboration limit the capabilities of the robotic asset, thereby decreasing its work speed and strength of force. One OEM manufacturer even claimed "collaborative robotics is slow-motion robotics."[17] Additionally, while cobots may cost less than larger robotic machinery, and while that cost is decreasing, more complicated programming interfaces necessitate increased servicing and repurposing costs. Adjustments in a manufacturing process will require changes to a cobot's programming, which tends to require high-salary coders—nullifying cost-savings objectives. An MIT study found that companies ideally want a cobot system that "would enable workers to directly reprogram and repurpose robots to do new tasks that meet changing production needs without requiring the workers to have extensive programming expertise."[18]

Considerations of technological sovereignty will power China to AI and robotic supremacy. To support its world-leading manufacturing industry, China maintains more industrial robots than any other country, with annual installations in 2019 amounting to 140,500—more than twice as many as Japan, the next-highest country.[19] Despite this supremacy in volume, the number of robots per 10,000 factory workers, a measure used to indicate the technological sophistication of manufacturing operations, sits at only 187 in China, far behind automation leaders such as Singapore, Japan, and South Korea.[20] Nonetheless, the landscape is quickly shifting as China has identified AI and robotics as technologies crucial to economic prosperity and national defense. In 2020, for the first time, Chinese academic articles cited on the topic of AI outnumbered US articles—a leading indicator of relative computing prowess.[21] Despite the uncertain regulatory environment, several leading VC investors, including Sequoia Capital China and Softbank, are deploying capital into companies such as Hai Robotics and Agile Robots.

An increasingly contentious geopolitical environment between the US and China underpins all of this. Both countries have a vested interest in creating some degree of self-sufficiency around key technologies deemed vital to national defense, such as robotics. US firms such as Apple (NASDAQ: AAPL) continue to explore relocating various supply chain infrastructure to nations such as India and Vietnam, while China likewise looks to build out its semiconductor

16: "Cobot Market to Grow to $8B by 2030, Report Finds," Collaborative Robotics Trends, Cobot Trends Staff, June 4, 2021.
17: "The State of Industrial Robotics: Emerging Technologies, Challenges, and Key Research Directions," MIT, Lindsay Sanneman, Christopher Fourie, and Julie Shah, November 2020.
18: Ibid.
19: "Battle of the Robots Still Favors Japan and Europe – For Now," *The Wall Street Journal*, Jacky Wong, January 19, 2021.
20: "Robot Race: The World's Top 10 Automated Countries," International Federation of Robotics, January 27, 2021.
21: "China overtakes US in AI research," Nikkei Asia, Akira Oikawa and Yuta Shimono, August 10, 2021.

fabrication expertise. While such a strategy is time intensive and redundant, as each country could simply trade each other's comparative advantage, it enables each government to exert more control over technological development and application. While both nations are far too dependent on each other economically to fully sever ties, the trend is clearly toward more domestic control. As for robotics development, China's manufacturing dominance, state-directed funding, and enticement of foreign capital will likely give it an edge over the US.

Autonomous killer robots are quickly becoming a reality, thus changing the nature of warfare. In August 2020, an AI-controlled F-16 developed by Heron Systems faced off against an Air Force pilot in a virtual simulation. It vanquished its human opponent with five kills to zero.[22] Three months later, Israel's Mossad carried out one of the most sophisticated assassination missions in modern memory, utilizing an AI-assisted robotic machine gun to kill one of Iran's leading nuclear scientists.[23] Once the realm of science fiction, stories of this nature are now a reality for global intelligence and defense organizations.

The US is doubling down on robotics investment, with the US Army's funding increasing from $17 million in 2015 to $379 million today.[24] Advocates insist better technology can help avoid collateral damage and save soldiers' lives while remaining firmly controlled by human operators. Still, a natural progression toward more autonomous systems seems destined to play out. Even the fastest human reaction time can take a quarter second to respond—too slow for incoming missiles or drone swarms that could threaten military assets. While science fiction has already highlighted the greatest potential concerns via dystopian outlooks, those operating in the reality of today's geopolitical environment will likely seek to implement AI and robotics in deterrent, or defensive, capacities.

Smaller-scale, proven use cases in construction are necessary before robotics takes hold. The construction industry has long been derided for its lack of innovation, with McKinsey noting in 2017 that over the past two decades, construction has experienced the fewest productivity gains relative to other sectors.[25] Construction sites remain one of the most complex areas to digitize, where integrating new technologies to potentially improve return on investment (ROI) in the long term often loses to the need to meet shorter-term cost objectives. In recent years, however, progress has been made, with technologies such as site inspection drones, project management software, and even virtual reality being used in larger construction projects.

For robotics to break into a traditionally stagnant industry such as construction, companies will first need to prove their value on a small scale by automating the more tedious aspects of site work and demonstrating clear ROI. Even then, a core aspect of success relies on experience—familiarizing workers with machines to enable seamless integration within a project, without requiring constant monitoring. Labor shortages and safety concerns are enhancing the push for robotics. In Japan, for example, 35% of all construction workers are 55 or older, a demographic trap that surely awaits larger economies such as China, Germany, and even the US.[26] Promising areas of construction robotics development include drywalling, site inspection, bricklaying, and modular construction. Even 3D printing, which is far from mainstream, is seeing greater uptake.

22: "Heron Systems' AI Pilot Just Beat a Human in a Simulated Dogfight," Engadget, R. Lawler, August 21, 2020.
23: "The Scientist and the A.I.-Assisted, Remote-Control Killing Machine," *The New York Times,* Ronen Bergman and Farnaz Fassihi, September 18, 2021.
24: "Big Boost in Spending for Military Robots," National Defense, Jon Harper, January 4, 2021.
25: "Improving Construction Productivity," McKinsey & Co., Filipe Barbosa, Jan Mischke, and Matthew Parsons, July 18, 2017.
26: "Dam Built by Robots? Japan's Obayashi Tests It Out," Nikkei Asian Review, Go Sakurai, July 23, 2020.

OUTLOOK

Lack of AMR standardization poses adoption challenges. With broader consolidation in the warehouse automation space still far off, robot interoperability represents a key obstacle for warehouse operators requiring multiple AMR vendors. Given the number of new entrants in the warehouse automation space, fulfillment centers are likely to deploy solutions from different vendors within the same warehouse. Yet the lack of robot standardization and interoperability will likely cause complications when separate AMRs, often running on similar types of code, lack the proper protocols to communicate with each other. While there will unlikely be a quick fix to this long-term industry constraint, companies are making some progress. In May of 2021, a consortium of companies working with nonprofit MassRobotics published the first interoperability standard.[27] A few months later, FedEx (NYSE: FDX) demoed the interoperability standards with several contributing robotics companies, thus marking another step toward establishing a precedent.

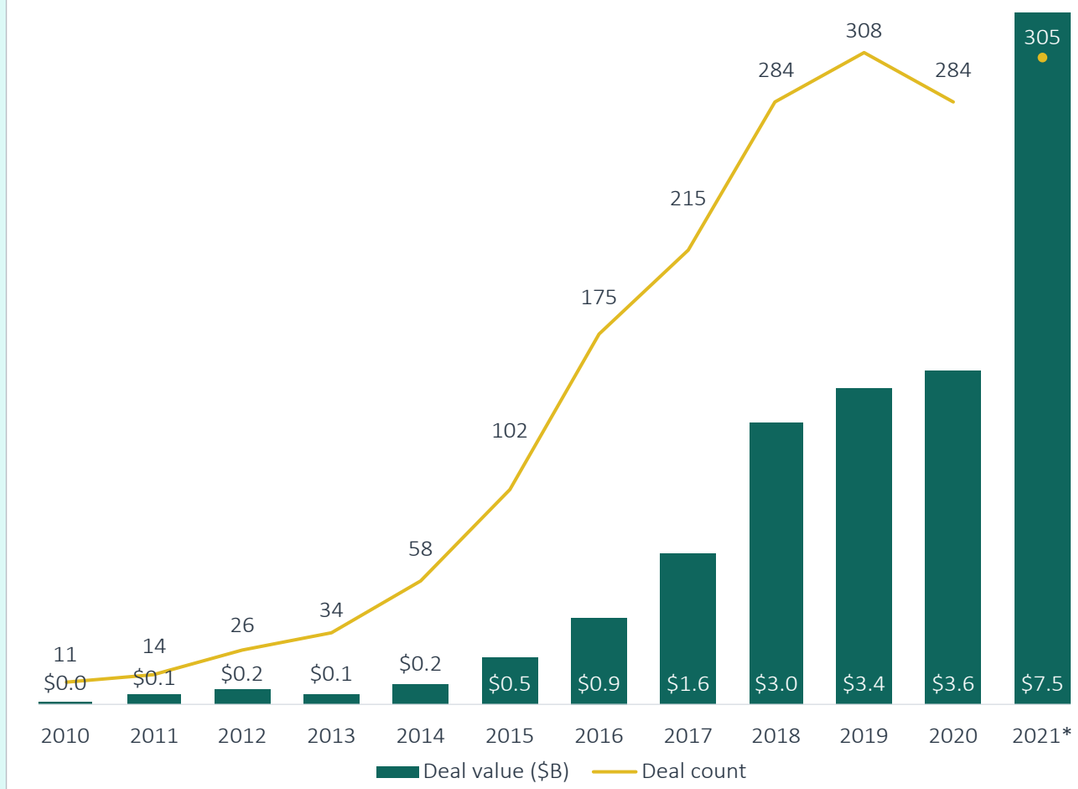
Consumer robots continue to represent an ephemeral novelty. While the advancement of AMRs has been an exciting development for many enterprises, consumers have been excluded. Sensing this gap in the market, and likely drawing from its experience with robotic systems and consumer AI devices such as speakers and e-books, Amazon recently announced Astro, the household robot. The machine, marketed as a mobile virtual assistant that can video chat, monitor security, and ferry objects, builds upon many of Amazon's specialties. Amazon undoubtedly envisions the device as a continuation of the "always-on" connected future toward which many Big Tech companies are working.

Yet Astro is almost comically redundant to use. While it can carry objects from room to room, its carrying capacity is small, and it requires that objects be manually placed into and removed from the robot—which is likely more time consuming than a person delivering the item themselves. Similarly, to video chat—a task phones and computers already do quite well—the user must either stoop to the floor or lift the robot to table height. The list goes on. Like the many failed products from companies such as Anki, Jibo, and Kuri, Astro will likely join the list of consumer robots that failed to solve a clear market need. Until that happens, these robots will remain nothing more than interesting gimmicks, unlikely to experience widespread adoption.

27: "MassRobotics Debuts Robot Interoperability Standards," Transform Industry, Chris Middleton, May 19, 2021.

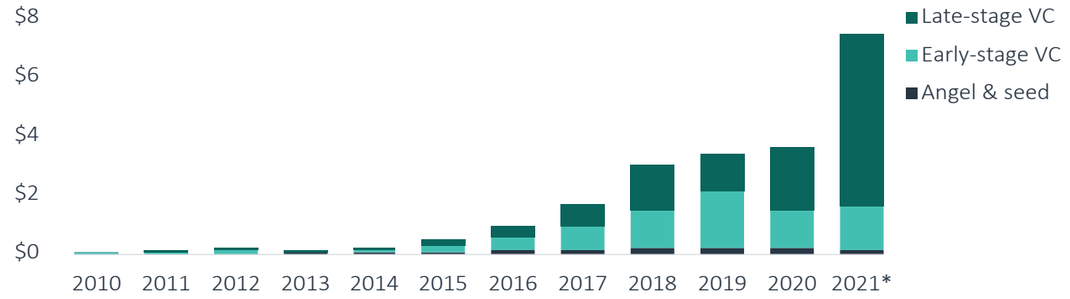
VC activity

Figure 3. ROBOTICS VC DEAL ACTIVITY



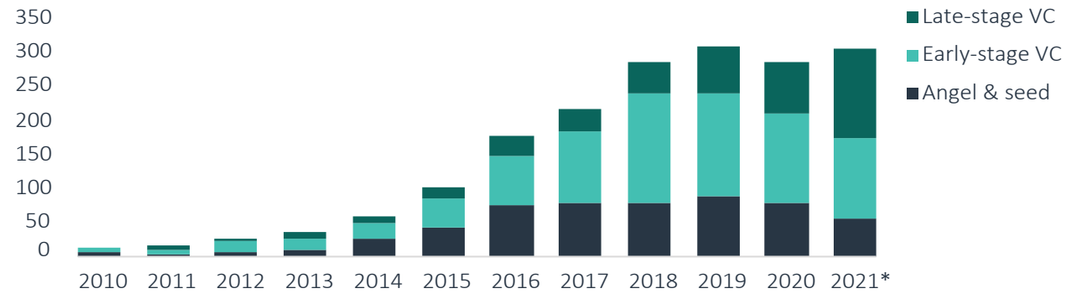
Source: PitchBook | Geography: Global | *As of November 22, 2021

Figure 4. ROBOTICS VC DEAL VALUE ($B) BY STAGE



Source: PitchBook | Geography: Global | *As of November 22, 2021

Figure 5. ROBOTICS VC DEAL COUNT BY STAGE



Source: PitchBook | Geography: Global | *As of November 22, 2021

Figure 6.

Notable robotics VC deals

COMPANY	STAGE	DEAL SIZE ($M)*	SUBSEGMENT	CLOSE DATE
Monarch Tractor	Series B	$61.0	Agriculture	November 17, 2021
Gaussian Robotics	Series C	$187.2	Service (cleaning robots)	November 10, 2021
Edge Medical	Series C	$200.0	Healthcare	November 8, 2021
Nuro	Series D	$600.0	E-commerce	November 2, 2021
Fabric	Series C	$200.0	Logistics	October 26, 2021
Dexterity	Series B	$140.0	Warehouse automation	October 13, 2021
Hai Robotics	Series D	$200.0	Warehouse automation	September 22, 2021
Iron Ox	Series C	$53.0	Agriculture	September 22, 2021
Agile Robots	Series C	$220.0	AI	July 9, 2021
CMR Surgical	Series D	$607.2	Healthcare	June 27, 2021

Source: PitchBook | Geography: Global | *As of November 22, 2021

Robotics VC ecosystem market map

Click to view interactive market map on the PitchBook Platform.

Market map is a representative overview of venture-backed or growth-stage providers in each segment. Companies listed have received venture capital or other notable private investments.

Healthcare & biotech

Surgery

CMR SURGICAL · EDGE MEDICAL 精锋医疗 · THINK SURGICAL · yomi BY NEOCIS · mimic

Life sciences

MEGAROBO 镁伽 · MultiplyLabs · Genepoint 基点 · AETHER · Automata

Disinfection

UBTECH · XENEX Germ-Zapping Solutions · BLUE OCEAN ROBOTICS · BeoCare 贝科思 · PURO UV Disinfection Lighting

Other

EPICA INTERNATIONAL · 微云 · TMiRob 达米机器人 · 智慧林

Industrial

Manufacturing

Path Robotics · FLEXIV · ROKAE · JAKA 节卡 · VEO ROBOTICS

Construction

DOXEL · CANVAS · BUILT ROBOTICS · blueprint robotics · SafeAI

Inspection

PERCEPTO · GeckoRobotics · TETRAVEL 天创电子 · 博铭维智能科技 BOWAWELL ROBOTICS · hibot

Other

AMP ROBOTICS · MIRAI · COBOT · 智昌集团 EMERGEN · 欣巴科技

Food & beverage

Food & beverage

MISO ROBOTICS · creator · 天使之橙 · dishcraft · BEAR ROBOTICS

Security & defense

Security & defense

SHIELD AI · KNIGHTSCOPE · Roboteam · COBALT · ROBOTEX

E-commerce

Warehouse automation

Geek+ · Fabric · LOCUS · HAI ROBOTICS · DEXTERITY

Last-mile delivery

nuro · STARSHIP · coco · REFRACTION AI · TeleRetail

Software

Artificial intelligence

AGILE ROBOTS · INVITIVE · MECH MIND · brain corp · roobo

Other

HUMATICS · READY ROBOTICS · PLUS ONE ROBOTICS · wandelbots · 迦智科技 IPLUSMOBOT

Professional

Service

CloudMinds · GAUSSIAN ROBOTICS 高斯机器人 · KEENON 擎朗 · pudu · CANDELA

Other

FORMIC · SCYTHE · SIXAI · EAI · AVA ROBOTICS

Hardware

Components

镭神智能 LeiShen Intelligent System · NextVPU 黑芝麻智能 · robot · AMORPHOLOGY

Other

tēmi · HAN'S ROBOT 大族新瓴人 · synapticon · Agility Robotics

Consumer

Education

sphero · EVOLVER · 童心制物 makeblock · Embodied · MIKO²

Other

trifo · robart · NARWAL · HACHIBOT · vincross

Agriculture

Agriculture

XAG · IRON OX · MONARCH · f'fth season

Key players

Figure 7.

Key VC-backed robotics companies

COMPANY	SEGMENT	GROWTH THEME	PRODUCT FOCUS	TOTAL VC RAISED ($M)*	LATEST FINANCING DATE*
Virtual Incision	Healthcare	Surgical robots	Minimally invasive surgery	$55.6	October 1, 2021
Mech-Mind	Industrial	AI	Computer vision	$191.4	September 27, 2021
Blue White Robotics	Agriculture	Autonomous vehicles	Autonomous farm machinery	$48.5	September 23, 2021
Locus Robotics	E-commerce	Warehouse automation	AMRs	$312.5	August 30, 2021
Pudu Tech	Professional	Service robots	Parcel delivery robots	$190.9	August 29, 2021
Miko	Consumer	Education tech	Learning robot	$50.9	August 11, 2021
Covariant	E-commerce	Warehouse automation	AI	$147.0	July 27, 2021
Path Robotics	Industrial	Autonomous manufacturing	Welding robots	$171.0	July 20, 2021
Hans Robot	Hardware	Collaborative robots	Robotic machines & components	$85.8	June 25, 2021
GreyOrange	E-commerce	Warehouse automation	AMRs	$314.2	June 2, 2021

Source: PitchBook | Geography: Global | *As of November 22, 2021

Figure 8.

Key VC-backed robotics companies (cont.)

COMPANY	SEGMENT	GROWTH THEME	PRODUCT FOCUS	TOTAL VC RAISED ($M)*	LATEST FINANCING DATE*
Rokae	Industrial	Manufacturing	Collaborative robots	$77.7	May 30, 2021
Knightscope	Security & defense	Public safety	Patrol & monitoring robots	$80.8	May 14, 2021
Miso Robotics	Food & beverage	Autonomous robots	Fast food robots	$54.7	May 14, 2021
Robotise	Professional	Service robots	Parcel delivery robots	$17.8	April 1, 2021
Xaircraft	Agriculture	Autonomous vehicles	Autonomous farm machinery	$246.2	March 16, 2021
Starship	E-commerce	Last-mile delivery	Robot delivery vehicle	$116.2	January 28, 2021
Remebot	Healthcare	Surgical robots	Neurosurgery navigation & positioning system	$85.4	November 30, 2020
Exotec	E-commerce	Warehouse automation	Order picking system	$112.4	September 29, 2020
Built Robotics	Industrial	Construction	Autonomous construction machines	$48.0	June 9, 2020
OnRobot	Hardware	Modular robotics	Robotic components & grippers	$27.6	December 19, 2019

Source: PitchBook | Geography: Global | *As of November 22, 2021

KEY PLAYERS

Figure 9.

Key robotics incumbents

COMPANY	SEGMENT	COMMENTARY	MARKET CAP ($B)*	NOTABLE ACQUISITIONS
Intuitive Surgical	Healthcare & biotech	Intuitive's (NASDAQ: ISRG) expertise extends to robotic-assisted surgery, with an emphasis on minimally invasive procedures. The company is best known for its da Vinci Surgical System, which was first introduced in 2000. Robotic-assisted surgeries are becoming more prominent due a combination of accumulated experience and better tech.	$121.7	Scholly Fiberoptic; Unison Surgicals Company
ABB Group	Industrial	ABB Group's (NYSE: ABB) robotics and discrete automatiton division develops robotic solutions for a wide variety of industries from healthcare to manufacturing. The company is particularly well positioned in China, where it has invested significantly in new robotics technology and production capacity in Shanghai.	$71.9	ASTI Mobile Robotics; Codian Robotics; ChargeDot; Intrion
Fanuc	Industrial	Fanuc (PINX: FANUY), a Japanese company with an operating subsidiary in the United States, focuses primarily on manufacturing robotics and automation. In addition to a wealth of long-standing manufacturing experience, the company has recently increased investment into the collaborative robotics trend.	$39.3	Life Robotics
Ocado Group	E-commerce	One of the largest online grocery retailers in the world, Ocado Group's (LON: OCDO) market dominance is due in part to the automation initiatives of its Ocado Solutions division. Ocado's logistics technology consists of a combination of supply chain management software and fulfillment robots designed to enhance delivery margins.	$19.1	Haddington Dynamics; Kindred
Autostore	E-commerce	Autostore (OSL: AUTO) is notable for its cube storage automation technique, a combined software and robotics approach that saves warehouse space and speeds up intra-warehouse logistics. Softbank took notice—acquiring 40% of the business earlier this year.	$16.1	N/A

Source: PitchBook | Geography: Global | *As of November 22, 2021

Figure 10.

Key robotics incumbents (cont.)

COMPANY	SEGMENT	COMMENTARY	MARKET CAP ($B)*	NOTABLE ACQUISITIONS
Brooks Automation	Healthcare & biotech	Brooks Automation (NASDAQ: AZTA) provides precision vacuum robots and other integrated automation systems to life sciences businesses. The company currently offers a number of collaborative robot solutions for various biotech use cases.	$8.7	Precise Automation
Ambarella	Software	Ambarella (NASDAQ: AMBA) develops AI-enabled chips, which are seeing increased usage in computer vision applications such as those used on board autonomous mobile robots. The company offers a range of chips, some purpose-built for neural network workloads.	$6.7	Oculii
iRobot	Consumer	A consumer robotics company, iRobot most notably created the Roomba Vacuum in 2002. Future opportunities may present themselves in the education market and via the use of AMRs for various domestic chores.	$2.3	Root Robotics; Robopolis
Berkshire Grey	E-commerce	Berkshire Grey (NASDAQ: BGRY) utilizes AI and robotics to automate fulfillment, supply chain, and logistics operations. The company aims to provide competitive advantage via pick, pack, move, store, organize, and sort technologies. The company went public via a SPAC earlier this year.	$1.3	N/A
Boston Dynamics	Hardware	Boston Dynamics develops mobile robotic platforms capable of being used across a variety of industries. Though it was recently acquired by Hyundai, its release of Spot, an autonomous, flexible, mobile robot, has both inspired potential robotic applications and set the technological bar for other companies developing similar robotic platforms.	N/A	Kinema Systems

Source: PitchBook | Geography: Global | *As of November 22, 2021

KEY PLAYERS

Figure 11.

Key VC investors in robotics

INVESTOR	DEAL COUNT*	ANGEL & SEED	EARLY-STAGE VC	LATE-STAGE VC	INVESTOR TYPE
SOSV	28	15	9	4	VC
SEQUOIA	22	1	8	13	VC
(Lenovo Capital and Incubator Group)	18	2	10	6	CVC
TOYOTA VENTURES	16	7	8	1	CVC
源码资本 SOURCE CODE CAPITAL	16	0	6	10	VC
ALUMNI VENTURES GROUP	14	7	5	2	VC
(Shenzhen Capital Group)	13	0	9	4	VC
明势资本 Future Capital (Future Capital Discovery Fund)	13	2	10	1	VC
IDG Capital	12	2	4	6	VC
(Shunwei Capital)	11	0	6	5	VC

Source: PitchBook | Geography: Global | *As of November 22, 2021

Key acquisitions

John Deere acquires Bear Flag Robotics for $250 million on August 5, 2021.

The agricultural machinery giant's embrace of robotics is a positive sign for how far mobile autonomy has come, but also a reflection of changing labor dynamics in the agricultural sector. Startups such as Bear Flag Robotics, and recently Monarch Tractor, are demonstrating the efficacy and scalability of autonomous tractors, showing how even one farmer can deploy and monitor an entire fleet of machines. Agriculture has long been an industry wherein the results of mechanization and automation have increased productivity but adversely affected labor. Today, in a reversal, an aging and difficult-to-replace labor force is driving the adoption of automation tech to help prevent disruptions to the food supply chain.

ABB Group acquires ASTI Mobile Robotics for $190 million on August 2, 2021.

ABB Group, which specializes in industrial and collaborative robotics, did not want to see the AMR growth train pass it by; it used this deal to promptly add AMR expertise to its already sizeable robotics portfolio. ABB CEO Sami Atiya had noted that more customers were inquiring about mobile robots—an indication of the maturity and ROI demonstrated by the technology.[28] The acquisition saves ABB from having to develop an in-house AMR solution, and a recent partnership with Switzerland-based Sevensense should enhance its AMRs with 3D vision-mapping technology, thus further illustrating its increased focus on mobile robots as a pillar of the business.

DoorDash acquires Chowbotics for an undisclosed amount on February 8, 2021.

Prior to the acquisition, Chowbotics was known primarily for its food preparation robot, Sally, which contained 22 compartments that could be stocked with various ingredients to prepare meals such as salads and rice bowls. The acquisition was a bold gambit from DoorDash (NYSE: DASH), which is betting that pandemic-driven trends in food ordering, such as increased usage of food delivery apps, mark a permanent change in user behavior. Given that the company controls more than half of the food delivery market in the United States, it believes that the technology, in combination with its merchant partnerships, can help to accelerate growth, primarily through speeding up the deployment of new menu items.

Zebra Technologies acquires Fetch Robotics for $290 million on July 1, 2021.

Roughly two years into a pre-existing partnership, Zebra Technologies decided to fully integrate Fetch Robotics' cloud platform into its warehouse and fulfillment automation portfolio. The acquisition will supercharge Fetch's reach into warehouses by giving it access to all of Zebra's customers, thus accelerating the rollout of its systems. Fetch, which will likely still operate somewhat independently, is focused on interoperability—a key area of concern for AMR adoption. Its platform is built with unification of disparate systems in mind, and, if successful, will be an area that Zebra can flout as a competitive advantage in an increasingly complex marketplace.

28: "ABB Drops $190M for AMR Supplier ASTI Mobile Robotics," Robotics Business Review, Steve Crowe, October 26, 2021.

KEY ACQUISITIONS

Sweetgreen acquires Spyce for an undisclosed amount on August 24, 2021.

Similar to peer Chowbotics, though using different machinery, Spyce's robotic kitchen and conveyor belts cook and prepare salads and hot bowls without human involvement. Sweetgreen (NYSE: SG), a salad chain, may have similar intentions to DoorDash, given its 2019 acquisition of Galley Foods, a meal delivery service with then-early ghost kitchen expertise. Unlike DoorDash, the company owns and operates 140 fast-casual restaurants, wherein it will look to integrate Spyce's technology to save on costs and increase convenience. Labor, in particular, is again a theme, as Sweetgreen's dine-in experience was stifled by the pandemic. Sweetgreen's array of acquisitions and willingness to experiment with the restaurant experience may be conducive to virus-conscious consumers unwilling to visit crowded restaurants or wait in lines.

Ocado acquires Kindred Systems for $262 million on November 2, 2020.

Though mobile robots have received much of the spotlight in light of computer vision advancements, logistics applications represent a greater near-term opportunity given soaring e-commerce demand. Ocado Group, which operates a logistics business focused on online grocery, already had some expertise in this field prior to the acquisition, but Kindred's technology allows it to accelerate automation initiatives and expand into new markets. Robotic pick-and-place systems, like the types that Kindred Systems develops, is a high-growth area of automation that could expand the scope Ocado's business as it seeks to become a key provider among MFCs. Ocado also acquired Haddington Systems, a robotic arm designer and manufacturer. Haddington's innovative use of 3D printing can help to keep robot manufacturing costs down as the company expands deployment of the technology.

Robotics adoption forecast

Figure 12. ROBOTICS ADOPTION FORECAST*

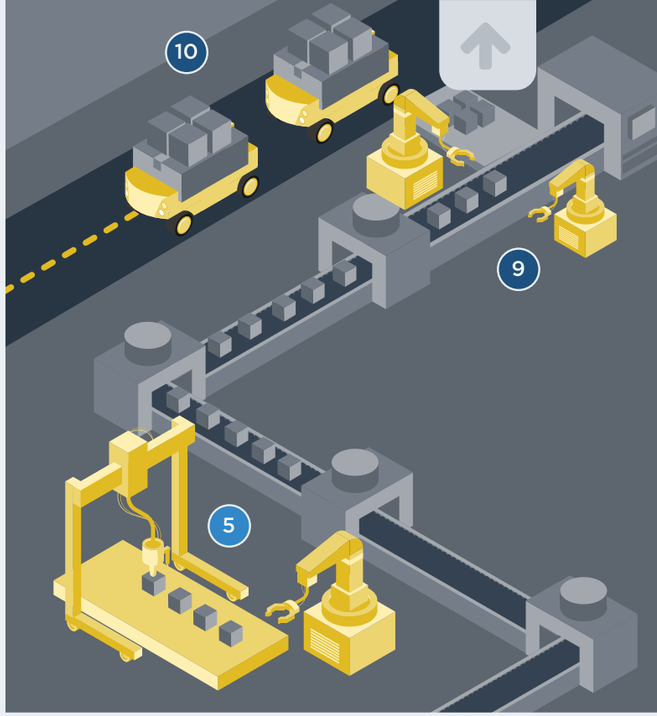
Business descriptors	Persona Cohort	Tech enthusiasts Innovators	Visionaries Early adopters	Pragmatists Early majority	Conservatives Late majority	Skeptics Laggards
Criteria for adoption	Adoption risk Market penetration Adoption reason	Very high <5% Forced innovation	High 5% to 15% Forward thinking	Moderate 15% to 50% Solution competitive with status quo	Low 50% to 90% Solution necessary to stay competitive	None 90% to 100% Solution exceeds old tech
Healthcare & biotech	Disinfection		2025		2030	
	Surgical				2030	
	Laboratory		2025		2030	
	Hospital assistants		2025		2030	
E-commerce	Pick & place	2025		2030		
	AMRs		2025		2030	
	Last-mile delivery	2025				
Industrial	Cobots		2025		2030	
	Inspection		2025		2030	
	Construction	2025		2030		
Agriculture	Autonomous tractors	2025		2030		
	Pollination robots	2025		2030		
	Indoor farming	2025		2030		
Food & beverage	Food/drink preparation	2025		2030		
	Vending		2025		2030	
Security & defense	Monitoring & patrol	2030				
	Military			2025	2030	
Professional	Cleaning		2025		2030	
	Professional service	2025		2030		
Consumer	Education	2025		2030		
	Vacuums		2025		2030	
	Domestic assistants	2030				

● Present

Source: PitchBook | Geography: Global | *As of November 22, 2021

Robotics emerging tech landscape

- Healthcare & biotech
- Industrial
- E-commerce
- Hardware
- Software
- Consumer
- Professional
- Agriculture
- Food & beverage
- Security & defense



ROBOTICS EMERGING TECH LANDSCAPE

Healthcare & biotech

1 **Surgery**
Startups developing robots for surgical applications such as minimally invasive operations

2 **Life sciences**
Startups developing robots for applications in laboratories such as drug manufacturing or biotechnology research

3 **Disinfection**
Startups developing robots to disinfect spaces using primarily UV light on mobile platforms

4 **Other**
Startups developing robots for a range of healthcare applications, including, but not limited to, assistive therapy, medical supply transport, and scanning

Industrial

5 **Manufacturing**
Startups developing robots to be used in factory environments. This includes collaborative robots.

6 **Construction**
Startups developing robots for use on construction sites. Robotic tasks include bricklaying, drywalling, site monitoring, and digging.

7 **Inspection**
Startups developing robots for industrial inspection use cases. These robots can autonomously survey physical assets to ensure that there are no abnormalities.

8 **Other**
Startups developing robots for a range of other industrial use cases such as cleaning, exoskeletons, and recycling

E-commerce

9 **Warehouse automation**
Startups providing robots for fulfillment, logistics, and warehousing use cases

10 **Last-mile delivery**
Startups developing robots to deliver goods over short distances, often in urban environments

Hardware

11 **Components**
Startups developing parts for robots, including chips, modular components, and motors

12 **Other**
Startups developing miscellaneous robot hardware such as underwater vehicles, factory arms, and cobots

ROBOTICS EMERGING TECH LANDSCAPE

Software

13 AI
Startups developing artificial intelligence algorithms to program robots for tasks such as autonomous mobility and fulfillment. The most common application is computer vision.

14 Other
Startups developing a range of software for various robot applications, such as operating systems, programming interfaces, and analytics platforms

Consumer

15 Education
Startups developing robots to help children develop formative learning skills in STEM, language, and social & emotional intelligence

16 Other
Startups developing robots for a range of miscellaneous consumer tasks such as vacuuming

Professional

17 Service
Startups developing robots targeted toward commercial entitites for the purpose of assisting businesses or their customers with tasks such as cleaning and package delivery

18 Other
Startups developing robots for a range of miscellaneous commercial tasks such as field marking, pest control, videoconferencing, and lawn mowing

Agriculture

19 Agriculture
Startups developing robots for use in agricultural environments, handling tasks such as indoor farming, pollination, harvesting, and planting

Food & beverage

20 Food & beverage
Startups developing robots for a variety of restaurant tasks such as food delivery, food and beverage preparation, vending, and dish cleaning

Security & defense

21 Security & defense
Startups developing robots to be used in military environments or security roles in civilian areas