Heading into 2019, we explore the major trends shaping robotics, automation, and AI. The ROBO Global Robotics & Automation Index captures those trends for today’s investors.
While healthcare and consumer robotics delivered double-digit returns, these were not enough to offset significant losses in the more cyclical, industrial-oriented sectors of the index. Manufacturing and industrial automation declined as economic momentum weakened in Asia and Europe and US-China trade issues took a toll on the top three industrial and engineering powerhouses, Japan, Germany, and Taiwan.

After a phenomenal 46% return in 2017, the ROBO Global Robotics & Automation Index declined in 2018.
Despite the recent market downturn, earnings trends remain very solid with median EPS growth of ~15% in the first nine months of 2018.

Even in the face of a more cautious outlook for industrial end-markets due to weakening order rates, earnings estimates in aggregate have been relatively stable, supported by upgrades in healthcare, consumer products, security, and energy.

This leaves the ROBO index trading on a median forward P/E of 19x, 3x below its long-term average valuation of 22x, a level unseen since January 2016, near the bottom of the last industrial cycle. This compares to 27x in the summer of 2017.

In 2019, we expect another year of double-digit EPS growth as industrial and factory automation markets bottom out before summer, and structural growth in demand continues across a variety of other RAAI technologies such as sensing, computing, and AI, and applications including logistics, healthcare, and 3D printing, among others.

Here’s a look at the key trends and companies supporting that growth...
As we enter a new year, robotics, automation, and AI (RAAI) continues to gear up for the future. All expectations point to an even bigger, faster, and more innovative year than the last. Indeed, 2019 will be the year that business historians will view as the pivotal moment in time that divided those companies that fought to protect outdated methods and processes, and those whose successes were driven by their belief and investments in a flexible, RAAI-driven future.
“No longer confined to the factory floor, many new applications are now being deployed at scale in hospitals, on farms, in e-commerce distribution centers, on the roads, and in our homes. Clearly, the robotics and AI revolution is marching forward at a rapid pace.”

Louis-Vincent Gave
CEO, Gavekal Research
Co-Founder of ROBO Global
ROBO Global Strategic Advisor
If the US economy remains in expansion, the global industrial cycle will trend up before the second half of 2019

Despite manufacturing and industrial automation's poor performance in 2018 (-27%), history tells us that down cycles typically last 12-18 months, which implies that we are nearing the bottom of the cycle. Even so, the reasons for the slowdown were clear:

- Slowing economic and industrial momentum in Asia and Europe prompted investors to aggressively sell stocks geared to China factory automation.

- By summer, issues were compounded by a dramatic reduction of capital expenditures by Chinese manufacturers due to rising uncertainty around trade with the US. The result: Japan’s largest exporters of factory automation equipment and components, including Toshiba Machine, Daihen, Harmonic Drive, THK, Nachi-Fujikoshi, Yaskawa, and Nabtesco, all declined >30%, while Taiwanese manufacturers of pneumatic and electric actuators Airtac and Hiwin, and industrial laser specialist IPG Photonics—all of whom were highly exposed to the Chinese market—also suffered losses in excess of 30%.

The good news: valuations for these companies are now becoming attractive, particularly in Japan where quality companies are now trading below book value and in single-digit P/E multiples.
Companies worldwide will fully embrace digitalization

As the manufacturing industry becomes increasingly open to the idea of digitalization, we will see more companies empowered to implement fully interoperable IoT solutions to achieve their target business goals.

As a result, they will play a larger role in the services aftermarket—while offering their customers opportunities to reduce time-to-market and purchasing costs, and shift capital expenditures to operating expenditures.

In the manufacturing world, IoT is about so much more than simply gaining production insights. These opportunities ahead for manufacturing and IoT will shape the next industrial revolution.
“2019 is going to be the year of the robotic gripper. With the help of machine learning, AI, and new materials, advancements in gripper technology will open up major new markets both in terms of manipulation and handling of materials. This shift will have deep consequences far beyond traditional manufacturing.”

Henrik Christensen, PhD
Qualcomm Chancellor’s Chair of Robot Systems and Professor of Computer Science at UC San Diego; Co-founder and Strategic Advisor, ROBO Global
Once the cycle turns, industrial robotics will regain its spot as a prime growth driver

In China, penetration remains remarkably low despite an impressive surge in shipments in recent years, driven in part by the aggressive top-down policy approach of China 2025. In 2017, China had fewer than 1 robot per 100 manufacturing workers, compared with 3+ in Japan and Germany, and 6+ in South Korea and Singapore. Fanuc, Yaskawa, and ABB are well positioned to benefit. Last month, ABB announced a new plan to build a $150M factory near Shanghai where it will use cutting-edge automation and robotics technologies to make robots for automotive, electronics, and other general industries.

Cyclical trends to watch include:
- Industrial augmented reality
- Smart manufacturing automations
- Fast track prototyping of next-gen products
- AI-powered industrial robots for synthetic polymer
- Digital twin: improvements in testing and monitoring
- Broader adoption of additive manufacturing
- Generative design

1 According to the International Federation of Robotics
COLLABORATIVE ROBOTS

Designed to work side-by-side with people, autonomously, or with limited guidance, collaborative robots are expected to remain the fastest growing segment of industrial robotics.

Teradyne’s Universal Robot, the leader in collaborative robots, is on track to grow sales by 40-45% in 2018. Overall, the Industrial automation segment—including UR, MiR and Energid—is poised to grow at a rate of 50-55% through 2021.

“In line with our strategy to reinforce our competitive moats and to be the industry standard for collaborative robots, we continue to build out UR’s global infrastructure.”

Mark Jagiela
Teradyne CEO
Converting analog signals from the physical world into data for the digital world is the first step towards automated systems

In 2019, sensors will continue to proliferate as costs decline and performance capabilities improve, fueling ever greater machine intelligence and enabling autonomous systems.

We expect computer vision to remain the hot spot and grow in the 10-20% range, benefiting companies that focus on factory automation such as Cognex, Keyence, and Isra Vision.

3D vision, long prohibitively expensive and complex, looks set to explode, with the likes of Isra Vision in manufacturing, Koh Young in semiconductor and electronics inspection, as well as FARO and Hexagon in metrology and surveying.

Computer vision is also enabling collaborative robotics and advanced driver assistance – we expect Ambarella to announce customer engagements for its CV2 chips in security, robotics, and automotive.
In December, Walmart announced plans to deploy floor-scrubbing robotic janitors armed with computer vision and AI capabilities in hundreds of its stores by the end of January 2019.

An autonomous navigation system uses multiple sensors to scan the robots’ surroundings for obstacles, including people, allowing them to be used when customers are in the store.
Advances in computing power, artificial intelligence, and other software developments have added new capabilities to robotic and automation platforms.

The overall ability for robotic platforms to cope with a greater degree of variability will continue to drive quality improvements in all sectors. Software companies such as PTC, Cadence Design, Autodesk, Manhattan Associates, and Dassault are helping companies in manufacturing and industrial automation to unlock the value being created at the convergence of the physical and digital worlds through IoT, augmented reality, 3D printing, digital twin, and Industry 4.0.

**Key benefits and drivers:**
- Tighter links between supply and demand
- Acceleration of product introduction
- Simplification of manufacturing processes for highly customized products
Software companies like Autodesk and PTC are transforming their respective industries.

Autodesk is driving the development of future design and manufacturing technology to help accelerate product development and enhance customer experience. Its recent acquisition of PlanGrid, a leading cloud provider of construction project management, further enhances the company’s design and construction platform.

PTC’s strategic partnership with Rockwell Automation will align its respective smart factory technologies and direct integration with computer-aided design and enterprise planning systems which will accelerate the design and deployment of new manufacturing configurations and allow flexible systems to respond in real-time to changes to supply/demand or material availability.

“There is a huge opportunity to streamline all aspects of construction through digitization and automation.”

Andrew Anagnost
Autodesk CEO

“Together, we will offer the most comprehensive and flexible IoT offering in the industrial space.”

Blake Moret
Rockwell Automation CEO
Data centers around the world will actively adapt to the new, enormous computing requirements created by the rapid development of AI.

In 2018, Nvidia's Graphics Processing Units (GPUs) dominated the AI training space. Datacenters have been testing multiple chips and modules with dozens of semiconductor vendors and expect to meaningfully ramp up deployment in 2019.

While there is no such thing as a general-purpose data center chip, it is clear that cloud providers are hungry for big leaps in performance and bandwidth to support the computational requirements of today's environment.

Companies such as Nvidia and Xilinx offer a wide range of solution sets that support this emphasis on latency, throughputs, flexibility, and software optimizations to drive advancements for many years.
5G technology will redefine network infrastructure as companies gain new capabilities that will transform business models and industries.

2019 is the year 5G will come to life, marking a turning point in communication as chip makers, service providers, and device makers race to design and introduce upgraded networks, devices, and services.

In addition to speed improvements, 5G is expected to unleash a vast IoT ecosystem that will connect billions of devices.

While real-world applications may not run on fully implemented 5G networks until late 2019, 5G networks are now being designed to deliver the performance needed for a fully ubiquitous connected world. 5G will deliver a **10-100x improvement over 4G and 4.5G networks**, up to 10Gbps data rates, and connect up to 100x devices per unit area compared to today's 4G LTE infrastructure.
AI & MACHINE LEARNING
Machine learning and AI have been making headlines for the past few years, enabling everything from self-driving cars to a champion computer chess player. But at long last, the practical value of machine learning (ML) is being realized.

**Banks** are using ML to identify suspicious activity in real time and prevent fraud. **Physicians** are using it to analyze and compare millions of patient records to identify trends and improve diagnosis and treatment. **Retailers** are using it to personalize customer experiences at the individual level. ML is being used to identify new energy sources, accelerate supply chains, and improve national security.

2019 will be the year edge computing enables ML to reach beyond the data centers and the Cloud to play a key role in getting intelligence into robots out in the field.
GPUs from **Nvidia** continue to dominate the machine learning segment for virtually all providers of hyperscale datacenters and cloud services. P3dn (the dn stands for disk and networking) is the company’s newest GPU-powered instance on EC2. With 4X more network bandwidth and 1.5X as many CPUs, P3dn is one of the most powerful GPU offerings on the cloud, enabling users to tackle even larger problems. As inferencing requirements for applications such as natural language processing (NLP) and voice translation grow in complexity, Nvidia has the perfect solution to tackle the massive infrastructure of a datacenter environment such as AWS.
Xilinx is the current front-runner in the duopoly of machine learning (with Nvidia right at its heels).

The company supplies programmable logic devices, including FPGAs, programmable Systems on Chips (SoCs), and 3D Integrated Circuits, all of which play a key role in the shift towards the flexible and heterogeneous compute architecture required for AI.
HEALTHCARE
Healthcare is on the cusp of massive change as a confluence of drivers create a wave of new robotics investments

Aging demographics, pent up demand, new medical advancements, and AI powered medical diagnostics are driving the healthcare industry to expand the development and application of many new practical, automated solutions.

The result will be continued investments in robotics and AI, as well as a new wave of M&A by traditional healthcare companies in the medical device and instrument arena as they seek new avenues for growth.

Today, healthcare accounts for 10% of the ROBO Index, with a focus on robotics guidance and surgery, laboratory automation, genomics, and AI healthcare applications. The sector returned more than 21% in the first 11 months of 2018.
Adoption rates of IoT-enabled asset tracking & inventory management systems in hospitals will double by 2020\(^1\)

These solutions will play a key role in improving patient safety and operational efficiency using technologies such as Radio frequency identification (RFID) from Zebra Technologies. RFID uses Radio-Frequency Electromagnetic Fields to identify the location of hospital items carrying special tags with the help of the readers located in hospital corridors, patient rooms, and across large medical facilities.

With RFID and IoT, it's now possible to track and visualize hospital assets' location and movements in real time, reducing search time for surgical tools, blood pressure monitors, and more.

\(^1\) According to the IDC
DNA sequencing leader Illumina is continuing to drive a monumental collapse in the cost of genome sequencing. In 2003, the first whole human genome sequencing cost ~$2.7B. In 2018, the average lab charge ranged from $3K-$5K. By 2020, that cost is expected to drop to ~$100. Illumina’s recent acquisition of Pacific Biosciences gives the company access to native long-read technology to enable new insights and additional technology breakthroughs. Because DNA may offer the next treasure trove of big data for AI applications, this may be one of the most important inflection points for the healthcare industry, in decades.

“Illumina has a longstanding commitment to democratize sequencing, enabling customers of all sizes to gain access to highly accurate sequencing technology with the broadest scope of applications.”

Francis deSouza
Illumina CEO
Intuitive Surgical continues to dominate in robotic-assisted surgery. Its more than 4,500 da Vinci systems have helped perform over 3 million minimally invasive surgeries worldwide.

Shares of Intuitive Surgical have experienced 28% compounded annual return since the company went public in 2000 and were up ~50% in 2018. As the range of applications expands from urology and gynecology into hernia repair, colorectal and general surgery, those numbers are likely to climb.
As surgical robots continue to gain traction in orthopedics, the number of providers and M&A in the space will accelerate.

In 2018, spine robotics surgery pioneer Mazor Robotics—which has been the best performing constituent of the ROBO Index in the past three years—agreed to be acquired by Medtronic for over $1.6B.

Index member Globus Medical is also making headway in this area, driving significant technological advancements across a complete suite of spinal products.
FOOD & AGRICULTURE
2019 will see another record investment year for food & agriculture—especially in the private company arena

The food & agriculture investment landscape has exploded over the past decade, especially in the area of precision agriculture. As that investment continues, the farming community will increasingly adopt a data-driven economy, using imagery, sensors, and AI platforms for precision and predictive agriculture.

**Automation** is set to be another big mover as labor costs and shortages drive producers to seek solutions for harvesting requirements. Using AI algorithms, farmers can tell which part of the field is more productive and devote resources and time to farm more efficiently. Robotic pickers will have soft and nimble grippers that are more refined and have capabilities to harvest more types of crops using AI.

An uptick in M&A is also likely as non-traditional companies such as Google and Amazon enter the sector.
Companies like **Deere** and **Trimble** are pushing innovation, using machine learning and advanced sensing technology to drive farming into the future.

Deere’s smart farms will use mini data centers with precision farming platforms that ubiquitously use smart devices to communicate with drones and autonomous tractors.

Deere is also continuing to improve autonomous driving technology using advanced GPS and sensing technology for all seasons and terrains. As the farming industry moves steadily into technology platforms, it is critical that the solutions are flexible and agnostic. Trimble’s field and software solution platforms work with most of the equipment on the farm, regardless of manufacturer, allowing farmers to leverage existing infrastructures and further reduce costs.
2019 will bring a huge rise in AI-powered consumer technology

The focus has clearly shifted from next-gen smart phone devices to sophisticated, AI-powered applications. The biggest impact will be in mobile AI, which will increase the connection between users and their phones via AI-enabled apps, content, and third-party features.

Electronics will continue to get an upgrade with advanced AI engines. Products such as TVs, refrigerators, and small electronic devices will use machine learning and deep learning techniques to communicate with users and each other.
Autonomous vacuums from **iRobot** now operate using simple voice commands thanks to integration with Alexa, Siri and Google Assistant. Advanced mapping technology remembers the layout of your home and uses that data to clean efficiently every time.

While iRobot has traditionally been focused on vacuuming and mopping, the company’s vision is to be a part of the bigger ecosystem of consumer robots that work collaboratively to further enable the smart, connected home.

“I’m very excited about our game changing new products, our vision of the smart home and iRobot’s role in it and the pipeline of new products on the horizon.”

*Colin Angle*
*iRobot* CEO
Innovations in autonomous cars will expand rapidly

With billions of dollars in R&D and numerous acquisitions, the technologies that enable autonomous cars will move from the research lab to the road. The latest sensor technologies will improve adaptive crash control, and the addition of tens of millions of miles logged will provide the data needed to support deep learning inference to make self-driving cars a reality.

While fully autonomous vehicles are years away, by early 2020, ride sharing companies are hoping to have Level 4 cars operating in controlled environments. Goldman Sachs Group predicts that robo-taxis will help the ride sharing business grow from $5B in revenue today to $285B by 2030. Innovative technologies like these are vital to this rapid growth:

- Chinese automaker Byton recently launched facial recognition cars that provide keyless access and operation. The cars have special sensors that even measure the driver’s heart rate and blood pressure.
- GM’s Cruise Automation unit will be using Lidar developed by Strobe, a solution that uses laser beams to map the road ahead and guide the car to enable faster, safer driving.
- While still in testing, Daimler’s cars using Nvidia’s intelligent chip can now drive at Level 5. The company plans to deliver Level 5 cars commercially in 2-3 years.
- Baidu has been developing an open source software for autonomous vehicles for the past 5 years.
“The Holy Grail of delivering truly autonomous self-driving cars is almost within our reach, [We are at] a point in time where we can realistically discuss the future of full autonomy on the roads.”

Daniela Rus, PhD
Director of MIT’s Computer Science and Artificial Intelligence Laboratory (CSAIL), ROBO Global Strategic Advisor
The rise of online shopping is driving development and adoption of a vast range of robotics and automation technologies across the industry.

E-commerce companies, traditional retailers, and transportation and logistics companies are racing to compete in the new world of online retail. Amazon delivers more than 5 billion items in under two days to its Prime members using the 100,000+ warehouse automation robots in its distribution centers. And still, the penetration rate of warehouse automation remains in the low single digits.

Companies like Japan's Daifuku and Germany's KION are working to fill the gap. And Zebra Technologies' track & trace solutions will no doubt remain in high-demand. Industrial conglomerates such as Honeywell continue to make significant organic and external investments in warehouse and logistics automation capabilities. Meanwhile, the competition in the online grocery segment is heating up, following Amazon's acquisition of Whole Foods. In 2019, UK's online grocery giant Ocado will deploy its cutting-edge automation technology for America's biggest supermarket chain, Kroger.
“2019 will be the year that robots start to perform order fulfillment for e-commerce to address the huge shortage of human workers. Robots grasping an increasingly diverse set of products will be made possible by advances in research, deep learning, and Cloud Robotics, the latter extending to Fog Robotics with edge computing and inference engines.”

Ken Goldberg, PhD
Professor and Chair of the Industrial Engineering and Operations Research Department at UC Berkeley, ROBO Global Strategic Advisor
SECURITY & SURVEILLANCE
The drone industry is expected to grow to more than $82B in annual revenue by 2025

Consumer drones have become mainstream, but advancements in the underlying technologies that enable drones to fly autonomously and safely are rapidly expanding how and where drones are being used. The FAA projects that there are now more than 1.2M drones in the US alone, and Congress recently provided the FAA with authority to issue modifications to waivers and accelerate the process of obtaining permits for certain operations. That change should produce a meaningful rise in waivers to the FAA's BVLOS (beyond visible line of sight) rule which has been a hurdle for commercial applications.

In the security world, drones offer a level of constant, maneuverable surveillance that cannot be achieved using stationary cameras. Used for surveillance both indoors and out, drones will use video features that support image recognition over long distances and advanced computer vision algorithms that enable intelligent features such as multipoint navigation and target tracking—all with higher accuracy than ever before.

As the commercial application of drones continues to expand, expect to see outside players entering the industry through partnerships and collaborations to integrate existing industry solutions.
Two companies that are likely to benefit the most from the FAA’s new commercial-friendly regulations are AeroVironment and Ambarella.

AeroVironment’s drones and data analytic platform were used to aid National Park Service recovery efforts from the California Woolsey fire to deliver aerial imagery and actionable intelligence to guide disaster assessment and recovery efforts. The company is the biggest drone provider to the US Government.

Ambarella is an enabler of real-time video compression for the commercial and consumer drone markets. The company just introduced a new CV25 camera System-on-Chip (SoC) that combines advanced image processing, high-resolution video encoding, and CVflow computer vision processing.

Both companies’ next-generation drones are more lightweight and compact, with powerful visual awareness and an advanced suite of sensors that should help drive strong sales growth in 2019.
“The use cases for indoor drones seem almost limitless, and for every case there are start-ups feverishly developing prototypes... Your best bet: invest in the core technologies that support the drone revolution. Sensing. Computing. Processing & AI. Integration.

Companies that deliver on the promise of drones—in whatever capacity—will put every one of these technologies in high demand.”

Raffaello D’Andrea, PhD
Professor of Dynamic Systems and Control at ETH Zurich
Co-founder of Kiva Systems (now Amazon Robotics)
Founder of Verity Studios
Co-founder and Strategic Advisor, ROBO Global
3D PRINTING
The worldwide 3D printing industry is expected to witness a CAGR of 26% to reach $33B by 2023. Gartner has projected the global 3D printing market to be worth $17.7B by 2020. Why do the analysts predict such tremendous growth?

First and foremost, the competition is fierce. HP is launching a new 3D metal printer with new Jet Fusion printers. Stratasys is planning to launch a platform for short-run metal applications using specialty materials for its new commercial 3D printers. The UK's Renishaw just announced a partnership with a topology optimization software company. ParaMatters is applying CogniCAD software that makes 3D printing easier for manufacturers of all kinds. 3D Systems is hoping to protect its leadership position with its new product line that offers improved print productivity.

Every one of these companies is solving complex, customized manufacturing challenges by combining metal technology, advanced materials, and software innovations. From commercial manufacturing to consumer printing, new capabilities and lower cost printers have transformed 3D printing from a futuristic concept into a new reality.

1 According to Markets and Markets research
While every one of these shifts is tremendous in itself, these trends combined create a **unique and exciting opportunity for investors**. AI is widely considered to be the catalyst for the next big technological shift, on par with the industrial revolution, the computer age, and the smartphone generation. Tractica forecasts that the revenue generated from the direct and indirect application of AI software alone will grow from $5.4B in 2017 to $105.8B by 2025.

What’s clear is that this growth is just the beginning. Looking forward into the next decade, the advancements we will see in 2019 will seem like baby steps in comparison to what robotics, automation, and AI will be able to achieve—and deliver—in the years ahead. Investors who grasp this reality today know just how important it is to begin to capture this growth opportunity now.
ROBO provides exposure to best-in-class companies across the entire value-chain of robotics, automation & AI

The ROBO Global Robotics and Automation Index was created more than 5 years ago with the sole mission of giving investors a way to gain exposure to robotics, automation, and AI in the earliest stages. Including 80+ stocks across 12 subsectors in 14 countries, the index is driven by deep research, the insights of leading experts in the fields of robotics and AI, and a focus on market-cap diversification.

By maintaining minimal overlap (<2%) with the ACWI and <35% overlap with newer, less sophisticated robotics and AI-focused indices, the ROBO index may be the ideal option for anyone who is hoping to make robotics and AI a valuable part of their own future.
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