ROBOGLOBAL®
INVESTING IN INNOVATION

EXPLORING OPPORTUNITIES ACROSS THE LANDSCAPE OF AI

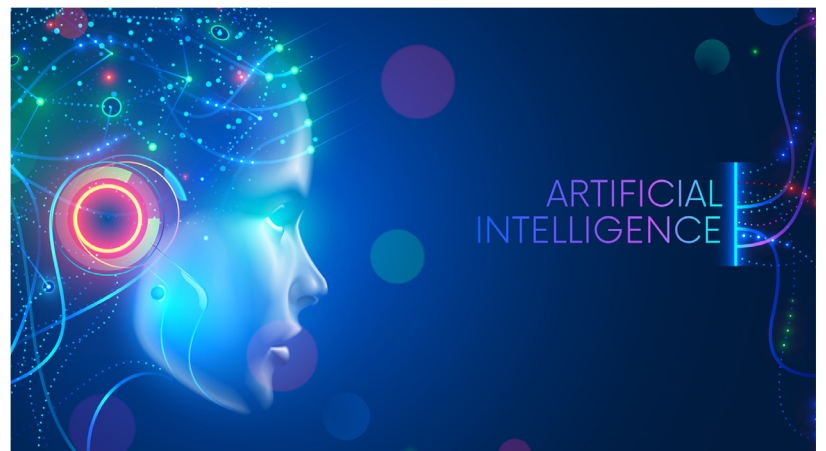*By Lisa Chai, Senior Research Analyst, ROBO Global*

SUMMARY

Artificial intelligence (AI) has the potential to be one of the most significant technological developments in human history, transforming our lives at home and at work. We believe that the AI revolution is a multi-decade investment theme set to transform and disrupt the world we live in as it reaches its full potential. In the past decade, major advancements in hardware, as well as massive and growing data sets, have unlocked opportunities to leverage the real power of AI. As the adoption of AI matures in the years ahead, organizations that successfully apply all AI has to offer will emerge as the clear winners in their respective spaces—and those who falter will quickly fall by the wayside.

For investors, this global race for AI dominance is creating an unprecedented opportunity. But success in this area requires deep insights into the quickly evolving landscape of AI and the ability to discern between hype and opportunity. **The ROBO Global Artificial Intelligence Index (THNQ)** is uniquely designed to capture this transformation of AI, benefit from its ability to help companies rise to leadership positions, and identify tomorrow's winners early to maximize the potential for growth.

In this white paper, we explore the history of AI, its expansive applications, and the case for investing in AI as advancements continue to accelerate in the coming decades.

INCLUDED:

- **Artificial Intelligence: The Transformational Technology of our Digital Age**
- **An Introduction to AI**
- **AI Adoption: Why Now?**
- **The Evolution of AI Hardware**
- **The Rise of the Data Economy**

- **The Growing Need for AI Talent**
- **Commercial Applications for AI**
- **Expanding Use Cases for AI**
- **The State of Enterprise Adoption of AI**
- **The Future of AI: Achieving True Intelligence**
- **The AI Race Continues**

ARTIFICIAL INTELLIGENCE:
THE TRANSFORMATIONAL TECHNOLOGY OF OUR DIGITAL AGE

Artificial intelligence (AI) has the potential to be one of the most significant technological developments in human history, transforming our lives at home and at work. We believe that the AI revolution is a multi-decade investment theme set to transform and disrupt the world we live in as it reaches its full potential.

While AI was first introduced in 1950s by computer scientists, it took over half a century to obtain all of the technological building blocks necessary to take the concept from mere vision to the delivery of real-world applications. In the past decade, major advancements in hardware—including more powerful semiconductor processors and cheaper, more abundant storage—as well as massive and growing data sets have unlocked opportunities to leverage the real power of AI. As the adoption of AI matures in the years ahead, organizations that successfully apply what AI has to offer will emerge as the clear winners in their respective spaces, and those who falter will quickly fall by the wayside. The **ROBO Global Artificial Intelligence Index (THNQ)** is uniquely designed to capture this transformation of AI, benefit from its ability to help companies rise to leadership positions, and identify tomorrow's winners early to maximize the potential for growth. The evolution of AI and the deployment of machine learning capabilities presents a massive growth catalyst for many companies. The result: the biggest opportunity for true wealth creation in our lifetime.

While consumers may be most familiar with AI's many manifestations in the retail arena, such as Amazon's Alexa, Google Assistant, Apple's Siri, and the growing number of smart devices we use on a daily basis, enterprises and industries have been quietly adopting AI to enhance critical business processes for years. Today, AI in both the consumer and commercial sectors has reached a tipping point. The pace of progress for AI technology has increased significantly and, as a result, the number of practical applications has grown exponentially. It is our belief that AI is now poised to take its place as today's most powerful driver of innovation and growth, creating vital opportunities in every industry and geography, and bolstering the global economy for decades to come.

> "AI stands out as a transformational technology of our digital age—and its practical application throughout the economy is growing exponentially."
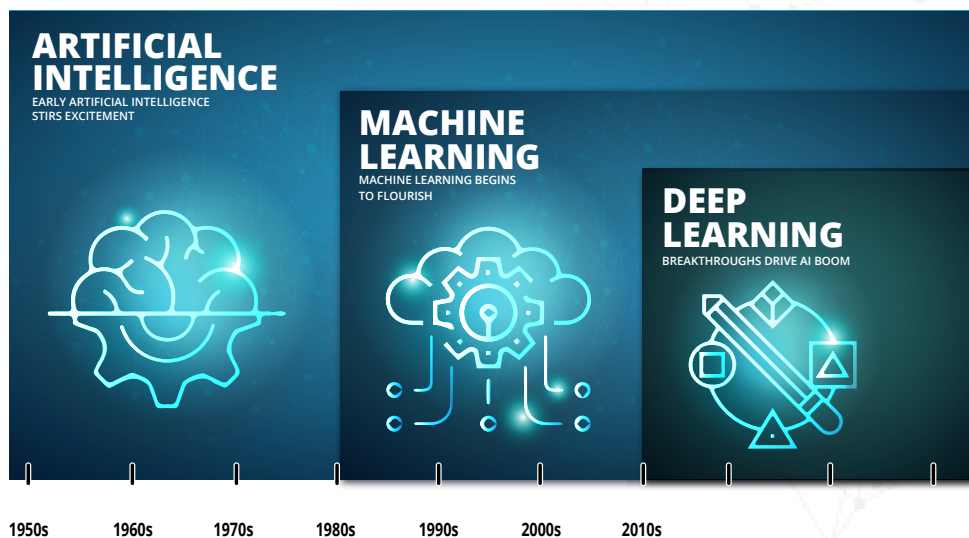
McKinsey Global Institute

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AN INTRODUCTION TO AI

Artificial Intelligence—or AI—refers to computer systems that simulate human intelligence. AI systems are programmed to think like humans and perform human-like tasks, such as learning and problem solving, and its applications and reach are seemingly endless. One subfield of AI that is responsible for the vast majority of advancements and use cases today is machine learning. **Machine learning** makes it possible for systems to learn automatically and to improve from experience without additional programming. Machine learning algorithms make possible many of the services we now use on a daily basis. Personalized feeds from Instagram and Facebook. Customized recommendations from Netflix and Spotify. Search results from Google and Baidu. Voice assistants like Siri and Alexa. Smart home devices like Roomba and Nest. Every one of these services is fueled by machine learning algorithms and their ability to turn data into action.

What makes AI, machine learning, and other AI-driven algorithms unique is their ability to learn from data. AI systems are capable of using basic training data provided by data scientists to identify relationships, understand how those relationships interact, evaluate multiple scenarios, and make independent decisions. The better the training data is—whether it includes images, text, audio, or video—the better the predictive AI model is able to perform.

Deep learning is a subfield of machine learning. Deep learning utilizes algorithms that use **artificial neural networks** that are inspired by neural networks in the human brain to enable machines to find patterns within a given data set. The system can then use a variety of computational nodes to dig through the data and learn to solve problems without human intervention.

These companies comprise only a part of the fast-growing cybersecurity market. Recent estimates predict the global cloud security market to reach $27.2B by 2025, growing at a CAGR of 25.86% from 2017 to 2025.[4] This is good news for users of AI-enabled cybersecurity solutions, for consumers, and for investors in these much-needed technologies. While the providers listed above are each delivering valuable solutions to help prevent cyber attacks today, we predict that the future will bring an evolving mix of best-of-breed companies, and that these companies are likely to introduce a new generation of autonomous AI-powered solutions that will draw market share from legacy vendors. We expect the market to evolve rapidly, making it mandatory for investors to seek broad exposure based on the most current research and information.

ARTIFICIAL INTELLIGENCE
EARLY ARTIFICIAL INTELLIGENCE STIRS EXCITEMENT

MACHINE LEARNING
MACHINE LEARNING BEGINS TO FLOURISH

DEEP LEARNING
BREAKTHROUGHS DRIVE AI BOOM

1950s   1960s   1970s   1980s   1990s   2000s   2010s

AI ADOPTION: WHY NOW?

Ultimately, the value of AI lies not in its complex algorithmic models, but in each organization's ability to harness those models to accelerate productivity and profitability. The potential impact of AI, machine learning, and deep learning is massive. McKinsey estimates that AI will create between $13.5T to $15.8T in value across 19 industries over the next decade:
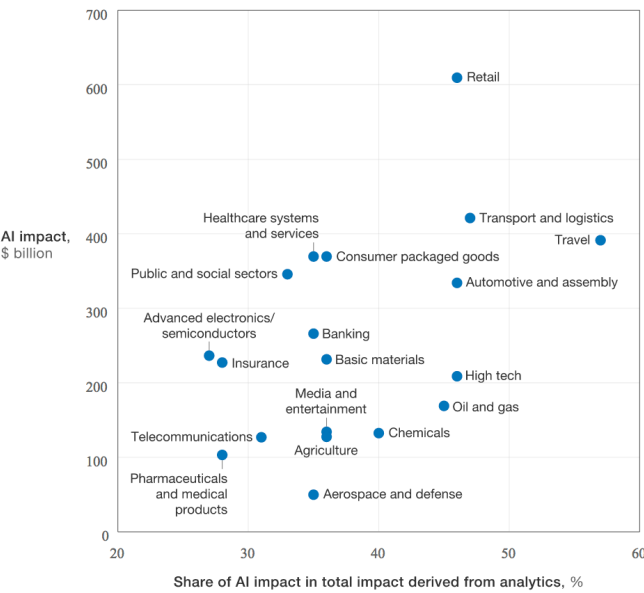
McKinsey&Company | **Source:** McKinsey Global Institute analysis

Though AI's potential has been clear for quite some time, there are a number of factors that have made it possible for adoption to gather speed in the past decade. The shift from traditional business processes to those that rely on AI to increase speed and efficiency is now in play at every point in the supply chain, from research and development, to manufacturing and production, to marketing and finance, to sales and distribution, to customer service. The key factors driving this shift include:

- Cheaper, more powerful AI hardware
- Cheaper AI-powered software
- Cloud hosting that supports faster, easier implementations

- Better understanding of business risks and opportunities at the executive level
- Expanding use cases

Robust research funding in both the private and public sectors has also played a role. Our research indicates that funding for AI companies in the US has grown at a CAGR of 82% over the past decade, rising from $50M in 2010 to just under $20B in 2019. Worldwide funding of AI startups has also risen at an impressive pace, totaling nearly $27B in 2019, an increase of 35% in just 12 months.

We believe that investments in AI will continue to surge, outpacing the overall US venture capital market. According to data from the National Venture Capital Association, 285 AI-related companies in the US raised almost $7B in the first quarter of 2020. At that record pace, the Q1 2020 PitchBook calculates that AI funding would have easily topped the $20B raised by 1,500 companies in 2019. The majority of those deals were in machine learning applications, followed by **computer vision** technologies. According to CB Insights, from 2010-2015, early-stage deals predominated, while mid- to late-stage deals represent an increasing share of investments vin more recent years.
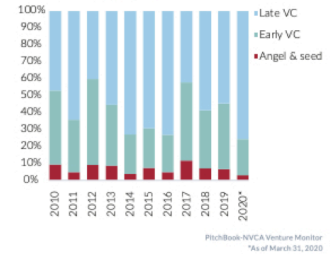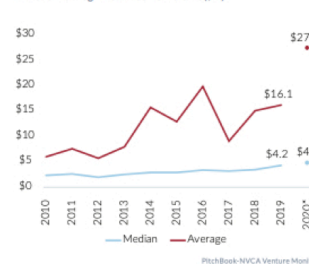

Deals by sector: AI & ML
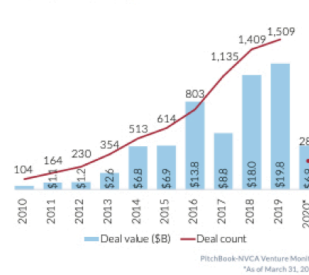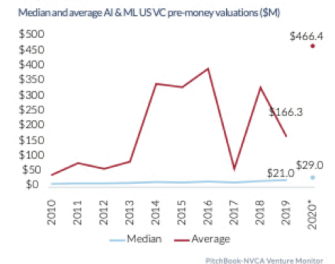
THE EVOLUTION OF AI HARDWARE

The rapid evolution of AI hardware has increased the ability of companies and entire industries to adopt AI today. Processing power is often one of the largest expenses associated with AI adoption, and innovations in the past decade have driven down these costs significantly.

In the world of AI, the cost of processing power matters. It can require at least a month of computing time to train an AI algorithm effectively. Google estimates the cost of that training at ~$100M. This is why AI-specific chips have been the most disruptive advancement in AI infrastructure to date. **Accelerators** are a class of microprocessors designed to enable faster processing with lower power consumption and at a fraction of the previous cost. This is especially important in machine learning, neural networks, and computer vision. Both established semiconductor companies that are already shipping AI chips as well as non-traditional chip companies seeking to expand their position in cloud computing have invested a significant amount of resources into developing AI chips tailored to meet the needs of these AI technologies. NVIDIA is currently the dominant player in AI workloads thanks to its powerful GPU chips, and the company's newest chip, the GeForce RTX 3080, is expected to push it even further ahead of the competition.

Next-generation AI hardware solutions like NVIDIA's A100, which was introduced earlier this year using the company's new **Ampere architecture**, are more powerful and more cost efficient at meeting the needs of increasingly sophisticated training models. As enterprises shift their architectures to the cloud and edge computing, more powerful silicon chips are required to support new capabilities to process and analyze more complex data sets. Currently, ROBO Global Index members such as **NVIDIA, AMD, Google** and **Xilinx** are all competing to meet the needs of the new modern architecture that can support the AI environment. Emerging but promising companies such as Graphcore, Eswin, Mythic, and Wave are also making their mark in the AI chip world. McKinsey predicts a tripling in revenue for AI processing chips from $17B to $65B by 2025, while Research and Markets projects the global AI chip market will grow at a CAGR of 45% to reach $90B by 2025.

THE RISE OF THE DATA ECONOMY

Data, of course, is fundamental to the AI revolution. Data is what advanced processors actually process, and it is what serves as the fuel for AI's intelligence. The amount of data being created by businesses and consumers is enormous, and it continues to grow every day. According to the World Economic Forum, by the beginning of 2020, the amount of data in the world was estimated to be 44 zettabytes—with each zettabyte equaling 1,000 bytes to the seventh power. It's a quantity that is almost inconceivable, and yet the pace of data creation is continuing to accelerate more rapidly every day, largely due to the widespread adoption of AI and the **Internet of Things (IoT)**. As organizations continue to move their IT architectures to the cloud to drive productivity and innovation, we are seeing companies increasing their investments in AI to automate processes, develop new products and services, increase efficiency, and reduce costs.

There are already clear leaders in the space that are developing and enabling AI applications. However, AI developers are not the only beneficiaries of this shift. Organizations that are actively integrating and leveraging AI into their operations are also reaping valuable rewards. As data sets continue to grow and algorithms become more advanced in their ability to turn that data into meaningful information, the opportunities to harness the power of AI and machine learning throughout the economy will accelerate just as quickly.

THE GROWING NEED FOR AI TALENT

Talent is another major component—and expense—of AI development and implementation, and it is an area that is changing as quickly as the science itself. For the first time in history, large corporations have surpassed the academic world of data science in AI development. As a result, AI research is better funded than ever—even as academics continue to build the body of knowledge required to advance AI functionality, either through their work at academic institutions or after being persuaded to forego academia to join highly-funded AI teams in the corporate world.

The need for talent has grown, in part, due to the desire to build in-house AI capabilities—an initiative that requires expensive computer equipment, the use of service providers to engage the most powerful AI features and capabilities, and a team of experienced AI experts capable of building data centers and migrating entire infrastructures to the cloud. According to ROBO Global research, the demand for AI skills is already outpacing supply. There are currently fewer than 10,000 PhDs who are true data scientists that possess the skills necessary to run a team of machine-learning engineers to solve complex AI problems and train quality data sets.

Tech giants like Google and Amazon have been the biggest acquirers of data science talent, and the seemingly endless financial resources of large tech organizations have been slowly decimating the AI talent pool in academia thanks to the aggressive recruiting of top talent in recent years. If this trend continues, it will be increasingly difficult for midsize enterprises to acquire the talent and data science expertise they need to achieve their AI goals.

On the flip side, this reality presents opportunity. Companies that provide new AI business models— providers of data center and network hosting, end-to-end AI-powered engines and platforms, AI-as-a-Service, Platforms-as-a-Service, and more—are set to emerge as leading disruptors in the AI landscape by alleviating at least some of the need for in-house AI expertise. At the same time, the drive to hire new talent presents a lucrative opportunity for the next generation of AI specialists. According to IBM, the number of data science

and analytics job listings is projected to grow by nearly 364,000 listings, reaching approximately 2.7M by end of 2020. Meanwhile, the US Bureau of Labor Statistics cites that job growth in data science/analytics is expected to reach 11.5M by 2026.

COMMERCIAL APPLICATIONS FOR AI

ROBO Global's Artificial Intelligence Index (THNQ) is uniquely designed to capture each of the fundamental areas of AI that are being used to power commercial applications and add value to the digital transformation that is now under way:

- **Deep Learning** is extremely effective at finding hidden patterns and insights from large datasets in matter of minutes. For example, AI-powered software engines and applications help identify potential operational efficiencies, as well as potential business and sales process productivity improvements.

- **Natural Language Processing (NLP)** uses deep learning algorithms that can understand speech, extract meaningful syntax, and automatically translate from one language to another.

- **Computer Vision (CV)** uses image recognition technology to identify faces for security purposes, as well as for popular social media applications, such as helping users to easily tag friends in a picture or automatically generate photo albums of family and friends. In the future, facial recognition will be used for an even broader range of applications—from making retail purchases to taking out bank loans.

- **Generative Adversarial Networks (GANs)** are algorithms that use two neural networks to generate new, synthetic instances of data that can pass for real data or images. Their ability to generate portraits, paintings, and music often seen on social media sites, create an image that can be used by police to find missing persons, and support medical diagnosis and drug discovery are transformative. While the benefits of this technology have been offset somewhat by negative use such as the creation of fake social media accounts for fraudulent activities, the benefits of GAN can be extraordinary if used appropriately.

EXPANDING USE CASES FOR AI

As with any new technology, the expansion of use cases has been key to the growing enthusiasm for AI and widespread adoption. Following are some of the most interesting, innovative, and impactful use cases to date:

• **Personalized Shopping and E-Commerce:** Chatbots, virtual agents, and advanced customer service systems are rapidly evolving to support revenue growth and disrupt how customers engage with retailers and manufacturers. The combination of NLP and predictive analytics helps retailers identify buying trends and quickly launch automated campaigns to attract customers. In-store and virtual store experiences are becoming highly personalized thanks to computer vision solutions that bring an immersive 'connected store' experience into dressing rooms and living rooms. Advanced imaging technology and facial recognition will soon make retail transactions possible without the customer touching a wallet or removing items from a shopping basket. Within the THNQ index, **Shopify**, **Wix**, and **Zendesk** are examples of companies that are seeing phenomenal growth from the demand for their e-commerce solutions.

• **Financial Services:** One of the first industries to adopt AI, financial services companies are now seeing revenue growth of 700bps on average that is directly attributable to AI initiatives (compared to companies with no AI investments) according to a recent Deloitte survey. The Deloitte study also highlights that 60% of leading financial services firms are defining AI success by improvements to revenue, with 47% seeing improvements in customer experience. Recently, JPMorgan Chase disclosed that it uses AI to perform legal checks of commercial loan agreements, freeing up 360,000 hours of legal review per year. Fraud detection, insurance processing, and credit score management are other strong use cases where AI has been shown to be very effective and has greatly impacted businesses and consumers all over the world. THNQ index members Blue Prism, Fair Isaac, and Verisk Analytics are some of the key players that are leveraging NLP systems to help clients with Robotic Process Automation (RPA) and risk

management tools to enable transparency on decisions that impact billions of dollars of assets.

• **Human Resources:** Major companies across multiple industries, including AT&T, Microsoft, Procter & Gamble, and CapitalOne, use AI and machine learning to navigate through thousands of applications, organize interviews, conduct initial screenings, and search professional social media sites for talent sourcing. Using AI to screen candidates saves recruiters from the manual task of sifting through thousands of resumes, making the hiring process quicker and more efficient, and augmenting recruiters rather than replacing them. THNQ Index members, including CornerstoneOnDemand and ServiceNow have cloud solutions that intersect AI and HR functionalities, including personalized e-learning and training for employees.

• **Healthcare:** AI-powered wearable devices, drug discovery, and cancer diagnosis are just a few areas where we are seeing important developments in the healthcare industry. Using AI to create medicines specific to an individual's genome is another key application, and many medical companies are actively developing and embedding AI into the innovation process. AI has also made great strides in disease diagnosis. For example, stroke is currently the fifth cause of death in the US; AI-enabled tools are now being used to identify the type of stroke a patient has suffered and pinpoint the location of the clot. Alibaba has created an AI algorithm that can diagnose the novel coronavirus in as little as 20 seconds, 45x faster than a human. **Illumina**, **Veracyte**, and **Dassault** are among the THNQ index members that are driving breakthroughs in the healthcare industry.

• **Virtual Assistants & Smart Home Appliances:** As of 2019, there were an estimated 3.29 billion digital voice assistants being used in devices around the world. And while Apple's Siri and Amazon's Alexa may now only be capable of responding to simple voice commands with simple answers, in the future we will have much deeper conversations with our virtual assistants thanks to the power of deep learning. More than 85,000 smart home devices work with Alexa now, almost 9x as many as at the beginning of 2018. More than 100 distinct products

have Alexa built in, and it can now execute over 100,000 skills. More than a companion, Alexa is evolving to assist us with everything from rebooking a cancelled flight to ordering online groceries through its deep learning algorithms. Other smart home devices such as iRobot's AI-powered vacuum cleaner, Roomba, and its AI-driven mop, Braava, can essentially self-clean a home and communicate with one another.

- **Driverless Delivery:** We are still inching towards realizing the full potential of deep learning and neural networks in play for self-driving vehicles and autonomous drones. In 2020, we still remain years
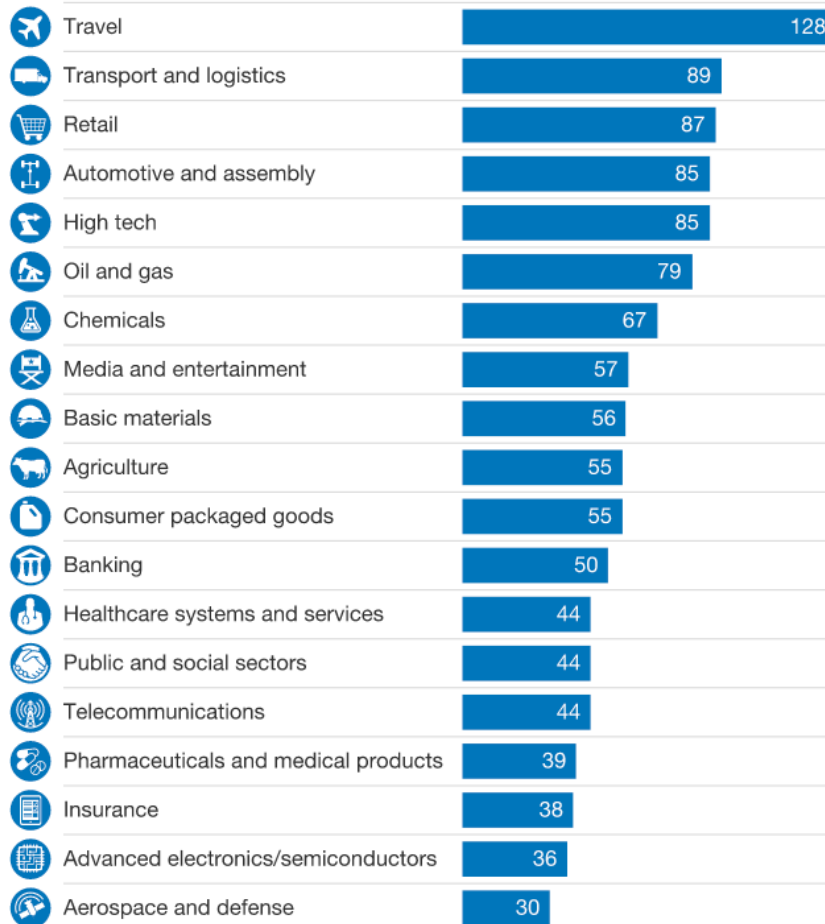
away from achieving **Level 5 status for self-driving cars**, but great progress is being made. The benefits to fully autonomous vehicles are many. According to a PwC forecast, 40% of the total mileage in Europe could be driven by autonomous vehicles by 2030. Self-driving trucks are expected to assuage the pending shortage of truck drivers in the future. Autonomous drones take driverless capabilities to the air, and they are being developed to execute a wide range of tasks, from transporting medical supplies within a hospital, to monitoring inventory on the highest warehouse shelves, to completing 'last-mile' deliveries of consumer goods.

In more than two-thirds of our use cases, artificial intelligence (AI) can improve performance beyond that provided by other analytics techniques.

Breakdown of use cases by applicable techniques, %

Full value can be captured using non-AI techniques — 15

AI necessary to capture value ("greenfield") — 16

AI can improve performance over that provided by other analytics techniques — 69

Potential incremental value from AI over other analytics techniques, %

Industry	Value
Travel	128
Transport and logistics	89
Retail	87
Automotive and assembly	85
High tech	85
Oil and gas	79
Chemicals	67
Media and entertainment	57
Basic materials	56
Agriculture	55
Consumer packaged goods	55
Banking	50
Healthcare systems and services	44
Public and social sectors	44
Telecommunications	44
Pharmaceuticals and medical products	39
Insurance	38
Advanced electronics/semiconductors	36
Aerospace and defense	30

McKinsey&Company | **Source:** McKinsey Global Institute analysis
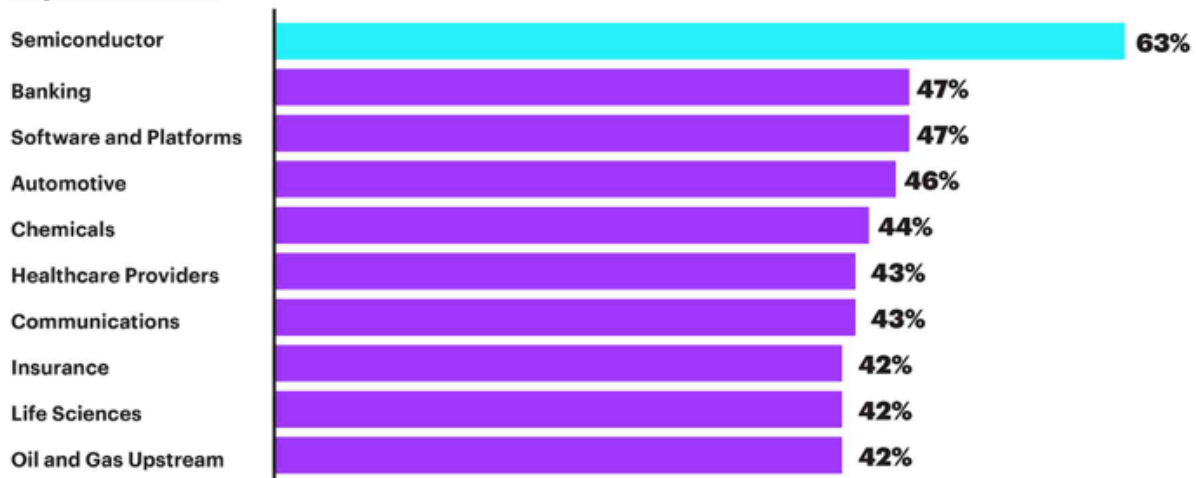
THE STATE OF ENTERPRISE ADOPTION OF AI

O'Reilly's latest 2020 survey sheds light on what AI adoption looks like in the enterprise, stating that "deployments are shifting from prototype to production" at a rapid pace. According to 1,388 survey responses from data scientists to CTOs, 85% of the respondents are evaluating AI or already using it in production. Digging a little deeper, every industry was represented, and this survey showed a huge increase of AI adopters—up from 27% in early 2019 to 52% today. This indicates that adoption and production of AI capabilities are rapidly increasing. We expect to see a dramatic increase in commercial use cases over the next 12 months.

- In terms of AI-adoption hurdles for the evaluators of the technology, shortage of talent is still a big issue, but it is not the only impediment.
- 58% of the survey respondents cited the lack of machine learning modeling and data science expertise as a major challenge.
- A lack of understanding and maintaining a set of business use cases came in close second.

In a separate survey, Accenture found that four in five semiconductor executives are currently using and/or piloting AI within their business operation. This is the highest use case among the 20 industries surveyed. Accenture asserts that AI will be a major growth driver for the semiconductor industry in light of high manufacturing costs and the growing complexity of chip development. This is a positive indication that AI is likely to open up new market opportunities and improve the design and fabrication process for traditional industries, such as the semiconductor industry, that are in need of reviving.

Two-thirds of semiconductor executives expect AI to have the greatest impact on their business over the next three years

Top 10 Sectors

Sector	%
Semiconductor	63%
Banking	47%
Software and Platforms	47%
Automotive	46%
Chemicals	44%
Healthcare Providers	43%
Communications	43%
Insurance	42%
Life Sciences	42%
Oil and Gas Upstream	42%

N=6,672 Business and IT Executives

Source: Accenture Technology Vision 2019

THE FUTURE OF AI: ACHIEVING TRUE INTELLIGENCE

Among the many applications for artificial intelligence that are making a splash across a wide range of industries, there are two paradigms, supervised and unsupervised learning, that have the potential to fulfill AI's promise of true intelligence.

- **Supervised Learning** is best suited to problems where there is a set of available reference points or set data to train the algorithm. For example, a study from Stanford University used a model to detect skin cancer from images. In this case, the training set contained images of skin labeled by dermatologists as having one of several diseases. The supervised machine-learning model was able to identify signals from its training set that indicated each disease, and then use those signals to make predictions on new, unlabeled images. We have seen many companies with strong solutions around this type of supervised learning that result in simpler AI systems that work.

- **Unsupervised Learning** is best suited for flagging outliers in a dataset. Using an unlabeled dataset, the algorithm receives no explicit instructions and works to make sense of the data by extracting features and patterns on its own. Banks use this approach to detect fraudulent transactions, using unsupervised learning to look for unusual patterns in customers' purchasing behavior. For instance, if the same credit card is used in New York and London within the same day, the bank and the customer will receive a fraud alert in real-time.

An additional branch of machine learning we are excited about is **reinforcement learning** (RL). RL is still in the emerging phase, but it is very promising. Different than other types of machine learning, RL does not require a lot of data; instead, it learns by trial and error. This is basically the same principle as a video game where users learn how to beat a virtual enemy and then get rewarded with a bonus point. This technique is especially useful for training robots and autonomous vehicles where datasets are limited. Google DeepMind has used RL to develop systems that can play games—including video games and board games such as Go—better than human champions. RL is a very active field at the moment, and we anticipate seeing exciting companies and use cases emerge over the coming years.

THE AI RACE CONTINUES

Currently, the US is the global leader in developing and using AI, though China is close behind. As the race continues, both countries boast a growing number of tech companies that are investing heavily in AI. But achieving AI dominance will require much more than just investments in AI. Becoming the global leader in AI will require a healthy ecosystem of AI companies, strong AI capabilities and inputs—including skills, the latest research, and massive data—and organizations that are highly motivated to use AI for real commercial applications. It may also require government support of development and broad adoption of AI through both policy and funding. Many other countries, including China, Germany, France, and the United Kingdom, are developing significant initiatives to gain global market share in AI. While the US has taken some important steps, it has so far lacked the sense of urgency needed to propel the next phase of AI development and adoption. What's needed today is a proactive strategy that helps push competitiveness, strengthens national security, and maximizes the benefits of AI.

For investors, this global race for AI dominance is creating an unprecedented opportunity. But success in this area requires deep insights into the quickly evolving landscape of AI and the ability to discern between hype and opportunity. The **ROBO Global Artificial Intelligence Index (THNQ)** is designed specifically to capture the global opportunity of AI.

GLOSSARY:

Robotic Process Automation (RPA): technology that extracts the list of rules and actions to perform by watching the user doing a certain task.

Computer Vision (CV): methods to acquire and make sense of digital images (usually divided into activities recognition, facial/images recognition, and machine vision).

Natural Language Processing (NLP): sub-field that handles natural language data (language understanding, language generation, and machine translation).

Neural Networks: subsets are deep learning and GANS (Generative Adversarial Networks) - modeled after the neuronal structure of the human/animal brain that improves its performance without being explicitly instructed on how to do so.

Autonomous Vehicles or Systems: robotics and intelligent machines systems that without human intervention use reasoning, intelligent perception, dexterous object manipulation, and plan-based robot control.

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McKinsey Global Institute

Nvidia

O'Reilly

Pitchbook

PwC and CB Insights MoneyTree report 1Q'2020;

Statista

ROBO Global currently offers three innovative index portfolios, including our Robotics & Automation Index (ROBO), Healthcare Technology & Innovation Index (HTEC), and Artificial Intelligence Index (THNQ). To learn more, visit our website at **www.roboglobal.com.**