

Artificial Intelligence & Machine Learning

3Q 2019





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This Emerging Technology Research report is updated on a quarterly basis to reflect changes in venture capital deal activity and other market related updates deemed valuable by the research analyst. The previous quarterly report can be accessed **here**.



Recent news and insights

Event

October 25, 2019

Google announces incorporating BERT models into Search

PitchBook view

Google announced that they have introduced BERT (Bidirectional Encoder Representations from Transformers) natural language processing (NLP) technology into their core search algorithm. This addition is meant to enable the entire context of a query to be understood by the algorithm rather than considering each individual word. Google identifies longer, more conversational queries (especially those using “for” and “to”) as the area where the most improvement will come, estimating that one in 10 Google searches will be understood better by incorporating BERT. Besides the potential improvement of the technology, the short amount of time between the release of this research and its inclusion in commercial products is notable. The initial blog post introducing the open-sourcing of BERT came on November 2, 2018, just under a year from this new announcement. Google is a leader in the AI & ML industry, and while this rapid implementation is expected, the fact that NLP has reached an accuracy threshold that makes it commercially viable should encourage the development of more applications.

September 23, 2019

Facebook acquires CTRL-Labs

AI hardware products have been more squarely in the spotlight through 3Q 2019 as the advances in software encourage specialized hardware to take advantage of that. In September, Facebook made a large bet (reported price over \$500 million) on **CTRL-Labs**, which specializes in making devices that allow humans to control computers using their brains. For Facebook this looks to be a further expansion into their focus on creating an AR/VR platform following their earlier acquisition of Oculus and other related investment. For **CTRL-Labs** and their backers (Amazon Alexa Fund, GV, Lux Capital, Spark Capital and others), this is likely a highly successful exit, coming just over three years after the company’s first VC round and achieving a significant valuation step-up over their Series B that closed this February.



RECENT NEWS AND INSIGHTS

Event

September 4, 2019

Startup uBiome files for bankruptcy after raising more than \$104 million in VC funding

PitchBook view

More news about struggles for high-profile startups came to light in 3Q. Consumer healthcare provider **uBiome** filed for bankruptcy and liquidated assets. **uBiome** sold home kits that linked gut microbes to health conditions, and while there had been questions around the efficacy of the product, the bankruptcy stemmed primarily from operational failures, including improper insurance billing practices and potentially misleading marketing tactics. While this is an unfortunate outcome for several big-name VC investors, including 8VC, Andreessen Horowitz and Y combinator, we are nonetheless encouraged that the failure did not stem from problems with the technology.

July 30, 2019; September 13, 2019

DataRobot raises \$206 million Series E and Element AI raises \$151 million Series B

Real-world implementation is one of the next challenges for AI & ML technology and a few mega-rounds during 3Q went to startups with this focus. First, in July, **DataRobot** raised \$206 million, bringing the total capital raised by the ML automation startup to \$431 million. A few months later, **Element AI** closed a massive \$151 million Series B round. Both companies focus on assisting companies to implement AI & ML solutions more efficiently by reducing the time and knowledge burdens on in-house teams. These startups fall into a category of businesses providing AI-as-a-Service, or automated ML products that augment and amplify internal data science teams' resources or allow non-technical teams to implement AI & ML solutions. As the pace of AI & ML adoption accelerates, one primary obstacle has been hiring and retaining skilled workers. We believe companies offering these AI-as-a-Service products can help reduce hiring challenges and may be well-positioned for growth. Furthermore, the outsized venture deals in the space will likely encourage more interest and investment in similar businesses.



Executive summary

Artificial intelligence (AI) is the area of computer science that focuses on creating intelligent machines that can perceive their environment and make decisions to maximize the chances of reaching their goals. Machine learning (ML) is a subfield of AI that aims to give computers the ability to learn iteratively, improve predictive models and find insights from data without being explicitly programmed.

We view AI & ML as important tools in the technology arsenal for enterprises. We believe AI & ML technology could conceivably imitate the utility and ubiquity of the internet as a tool in transforming business—a potential that translates into an exceedingly large addressable market. Spending on AI & ML technologies is not only sizable—on track to reach \$36 billion in 2019, according to IDC—but is also growing at a rapid clip with an estimated CAGR of 38% from 2018-2022.¹ Retail and financial services continue to lead this investment, with customer chatbots, recommendation engines and fraud-detection products representing some of the most commercially developed categories of AI & ML. As more AI & ML applications are rolled out into the real world, we are interested to watch the speed of progress, especially because including humans in the equation can lengthen implementation timelines.

We believe the cost-savings potential of AI & ML has incentivized initial use and implementation. Combining internal company data with AI & ML tools can help automate and optimize several enterprise processes across sales, marketing, customer service and HR functions. This can improve productivity and allow employees to focus on higher-level, value-added tasks. While a few early adopters such as Google and Microsoft have

developed deep AI & ML capabilities in-house, there is still a great deal of untapped potential for enterprise adoption both within and outside of the technology industry.

We believe that as AI & ML technology becomes more pervasive, some functionalities will likely become commoditized. AI-as-a-Service has already begun rolling out through the major cloud platforms (Amazon Web Services, Microsoft Azure, Google Cloud, etc.), and as computing costs diminish, we expect it will become easier for companies and individuals to explore and implement AI & ML technology. While this is likely to drive more demand across the industry, it could pressure smaller providers that offer AI & ML applications, including pure-play image recognition or NLP.

1: "Worldwide Spending on AI Systems Will Grow to Nearly \$35.8 Billion in 2019, According to New IDC Spending Guide," IDC, March 11, 2019



Key takeaways

AI & ML investment full speed ahead while benefits remain scarce: An October 2019 survey by MIT and Boston Consulting Group found that 68% of organizations were experimenting with or fully using AI. While this momentum is a positive sign, business leaders are still not citing their efforts are resulting in much tangible value. Realization of the cost-savings or new business opportunities from AI & ML will be critical over the next few years to sustain necessary levels of investment.

AI & ML application potential continues to expand: While there are many use cases for AI & ML that are commercially viable, some of the most ambitious projects remain in the research stage. These include AI in new drug discovery and implementations of reinforcement learning, among others. With new discoveries in the field weekly or even daily, defining AI & ML in a way that captures its full potential is a bit of moving target. This diverse applicability is a principal reason that AI & ML is seen as a potentially paradigm-shifting technology and receives so much attention from both enterprises and consumers.

Hardware is critical, yet often overlooked: While AI & ML discussions regularly center around software, we believe advancements in hardware are often overlooked. Traditional graphical processing units (GPUs) are capable and versatile but customized chips are becoming more popular as computing requirements elevate. Both incumbents and startups are developing new hardware. While Google is putting their custom tensor processing units (TPUs) to use for many recent breakthroughs, independent leaders such as **Cerebras** and **Graphcore** have developed other novel designs to cater to AI & ML applications.



Primary AI building blocks

Natural language processing (NLP)

Applications: speech recognition, sentiment analysis, content categorization, document summarization, translation and contextual extraction

NLP refers to the field of computerized understanding, interpretation and manipulation of human language. Enabling human-to-machine communication via spoken or written language unlocks an endless number of potential datasets and abilities for computers. NLP breaks language down into smaller pieces in order to understand how those pieces create meaning when combined. This raw and unstructured text or speech data is then given a numerical structure that machines can process to enable capabilities such as speech recognition, sentiment analysis, content categorization, document summarization, translation and contextual extraction. Common approaches include convolutional neural networks (CNNs) and recurrent neural networks (RNNs), which support word-embedding techniques and memory capabilities that help with NLP use cases that require context.

Computer vision

Applications: image recognition or analysis, robotics and autonomous driving

Computer vision refers to the field of AI that allows a machine to comprehend and describe visual inputs. Perception of the environment is a critical AI capability for labeling datasets such as photos and video to allow for further learning and analysis. In the case of robotics or autonomous driving, computer vision is necessary for image recognition and to enable machine navigation through the physical world. Similar to how CNNs break

language down into words or parts of words, computer-vision CNNs use filters to extract smaller features from images to make it easier for machines to recognize and interpret new visual input.

Information analysis & learning

Applications: ML and decision-making, pattern recognition

This AI function refers to the machine's ability to process and analyze large quantities of data to provide answers to queries. Information & analysis learning is key for generating insights and actionable outputs from extremely large datasets, an important value proposition for AI. This function also involves ML, which enables a computer to learn and make decisions based on data. We break down the blocks of ML in the next section.



Primary ML building blocks

Dimensionality reduction

Applications: data organization to improve speed of data discovery and analysis

With ML, there are often many features or variables that make visualizing the data difficult, which increases computing power requirements. Dimensionality reduction algorithms determine a set of principal variables by excluding variables that are highly correlated with other features of the data. While this can cause some data loss, the increasing size of datasets makes this function critical in order to reduce storage requirements and model-training time. Dimensionality reduction operations include data discovery, compression and visualization as well as feature selection and extraction.

Clustering & classification

Applications: customer segmentation, targeted marketing, recommender systems, anomaly detection, image classification and customer retention

Predicting a category label (e.g. spam or not spam) for a new datapoint is a primary use case of supervised (i.e. classification) and unsupervised (i.e. clustering) ML. Algorithms using classification and clustering technology group data into categories to help power ML applications, including customer segmentation, targeted marketing, recommender systems, anomaly detection, image classification and customer retention.

Regression

Applications: predictive analytics and forecasting

Unlike classification outputs, which predict a discrete class or category, regression algorithms predict a real value. These outputs are judged based on the deviation from the actual value in the training data, usually measured by root mean squared error (RMSE). Regression algorithms enable ML techniques to address a different set of questions such as those of predictive analytics and forecasting applications.

Reinforcement learning

Applications: real-time decision-making, robot navigation, learning tasks, skill acquisition

Reinforcement learning is the branch of ML that learns with no training data, solely training by iterating through its environment in order to maximize a programmed reward. This structural difference in initial data requirements opens up many use cases such as real-time decision-making, robot navigation, learning tasks and skill acquisition. This technique is important for more advanced tasks that require time-sensitive, high-fidelity decision-making.

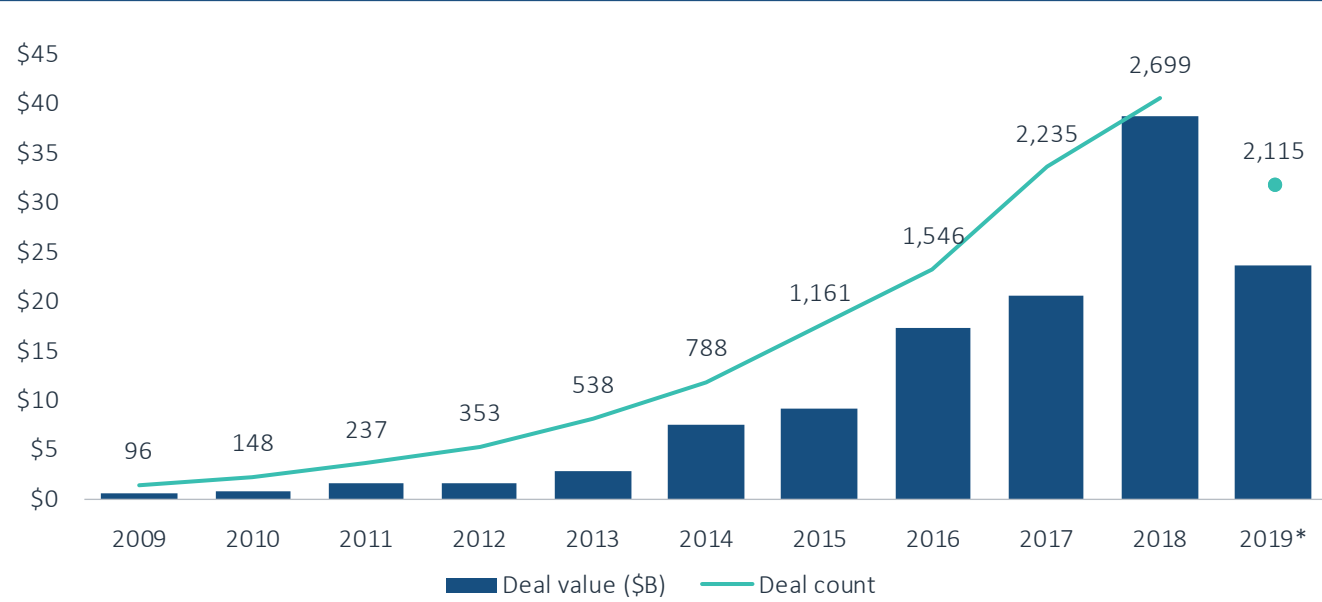


VC activity

VC capital investment in AI & ML is on pace to be slightly short of 2018’s peak, but plenty of encouraging signs remain in the landscape. The \$23.5 billion in total VC investment through 3Q is still on pace for 2019 to be the second strongest year. In addition, 2018 included seven deals above \$1 billion (including Uber, Bytedance and Kuaishou), which accounted for \$9.4 billion in value, whereas no deals of that size have been completed in 2019. In another encouraging sign, 2019 deal count is on a trajectory to set a new decade high.

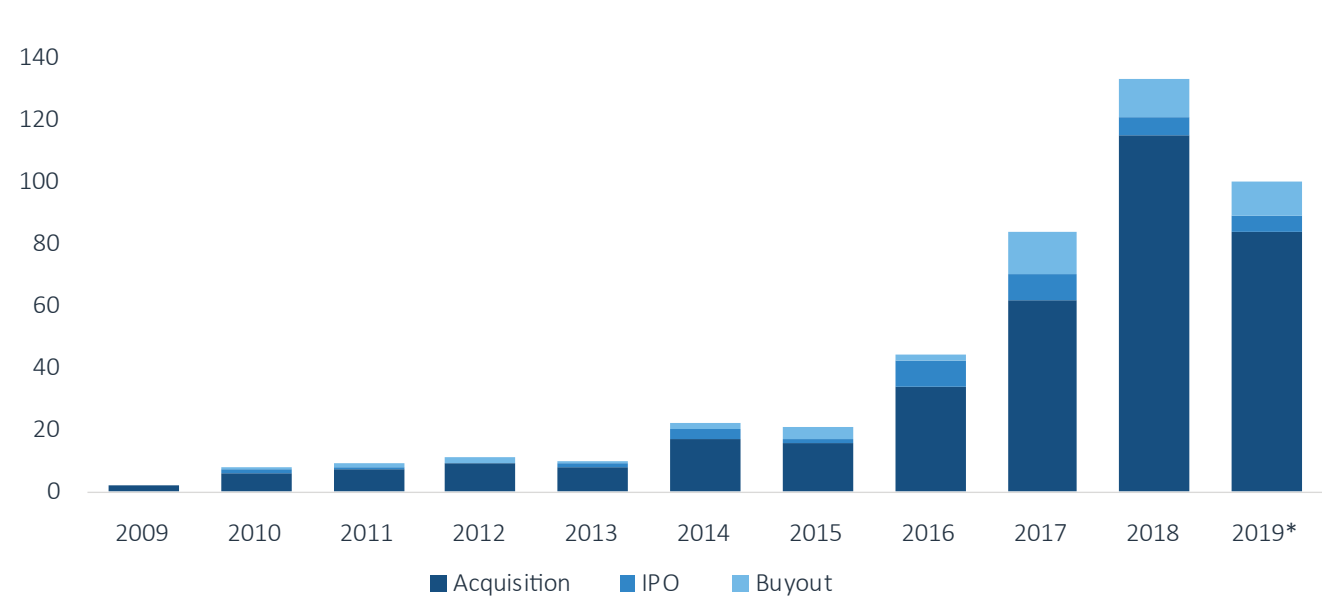
The AI & ML exit market remains robust, with 2019 marking the second consecutive year with 100 completed exits and a new record in exit value. Even excluding Uber’s IPO, which accounted for 77% of the total \$88 billion in exit value this year, 2019 is still shaping up to be a record year for exit value and count. As corporations seek to incorporate AI & ML technology, we expect acquisitions will remain an attractive option relative to building these capabilities in-house. We also expect large technology incumbents to persist as the most active acquirers in the space.

Figure 1. VC DEAL ACTIVITY



Source: PitchBook | Geography: Global | *As of September 30, 2019

Figure 2. VC EXITS (#) BY TYPE



Source: PitchBook | Geography: Global | *As of September 30, 2019



AI & ML market map



Companies included are VC-backed, segmented by primary use case and sorted by total capital raised.

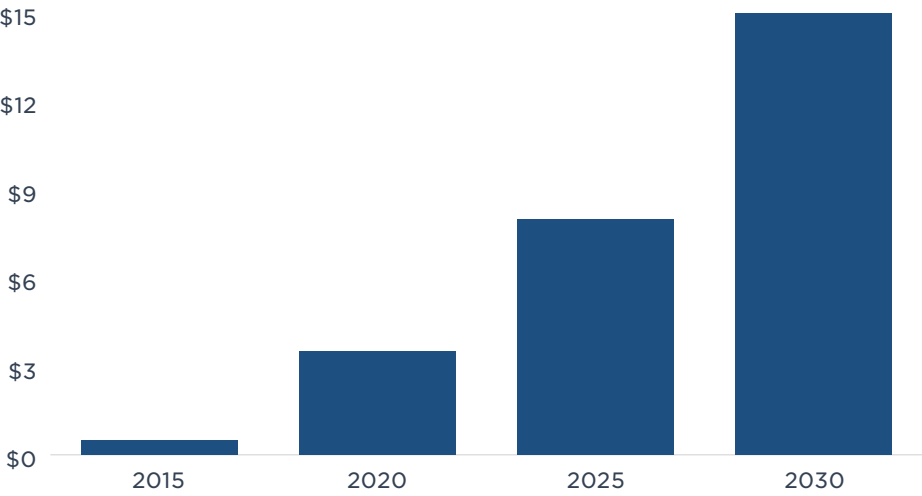
SEGMENT DEEP DIVE

Transportation



TRANSPORTATION

Figure 3. MARKET SIZE (\$B)



Source: Roland Berger and PitchBook estimates. Represents estimated autonomous vehicle software revenue

APPLICATIONS

Attractive characteristics of businesses in the space include large and expanding TAM, limited variable costs, disruption potential and recurring nature of transportation services.

Companies in the space generate revenue by selling or licensing software and/or vehicles.

Three primary AI applications in our dataset:

- Computer vision
- Reinforcement learning
- Information analysis & learning

KPIS

- Autonomous miles driven
- Number of interventions per 1,000 miles
- Number of emergency decelerations per 1,000 miles
- Duration of transfer of control between driver and vehicle
- Vehicle down-time (mechanical/sensor repairs, or ridehailing occupancy)
- Fleet size
- Number of patents

KEY PROVIDERS



NOTABLE DEALS

drive.ai

June 2019
\$77M

Acquired by:
Apple

tu simple

September 2019
\$215M Series D

INDUSTRY DRIVERS

- Continued investment in autonomous and semi-autonomous vehicles
- Fleet management and planning for consumer and commercial applications
- Potential cost efficiencies for ridesharing and commercial transportation



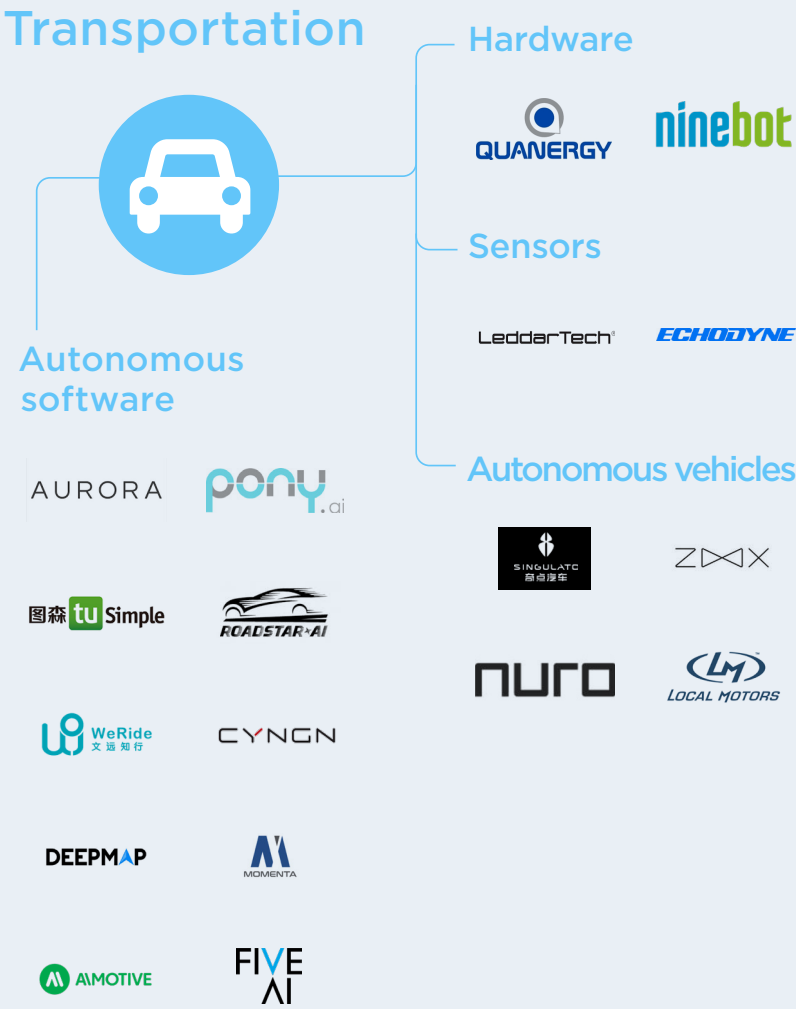
TRANSPORTATION

Overview

Autonomous transportation represents one of the most transformational areas of development for AI & ML technology and includes consumer mobility and commercial use cases such as long-haul trucking and last-mile delivery. AI & ML is likely the best technology for processing the massive amount of data involved in the self-driving process, including input from cameras, radar, lidar and other sensors.

Investment into this space has continued to swell in recent years, reflecting not only investor interest, but also the high capital intensity required for R&D. Recipients of AI & ML-focused investment include younger startups such as **FiveAI** and **Local Motors** as well as established players, including Uber and Lyft. However, we believe real-world autonomous ridesharing remains a distant opportunity. The tepid market response for the IPOs of both Uber and Lyft—two leaders in the quest to commercialize autonomous driving—reflect an investor base that is giving these companies little credit for this emerging, yet unproven, technology. Other companies are taking a different approach, such as self-driving delivery company **Nuro**, which may be closer to real-world applications. **Nuro** recently received a round of funding from SoftBank (a frequent investor in mobility) and is set to begin a trial of its autonomous delivery system in Houston, Texas, an expansion of the company’s partnership with Kroger to provide deliveries in Scottsdale, Arizona.

We expect multiple winners in the broader transportation AI market as widely utilized software and hardware solutions could lead to increased usage by individuals and businesses. We also believe the data-intensive nature of the technology could potentially drive strong network effects for market leaders. Companies that own and license autonomous mobility software may be well-positioned to benefit from increased use.





TRANSPORTATION

Opportunities

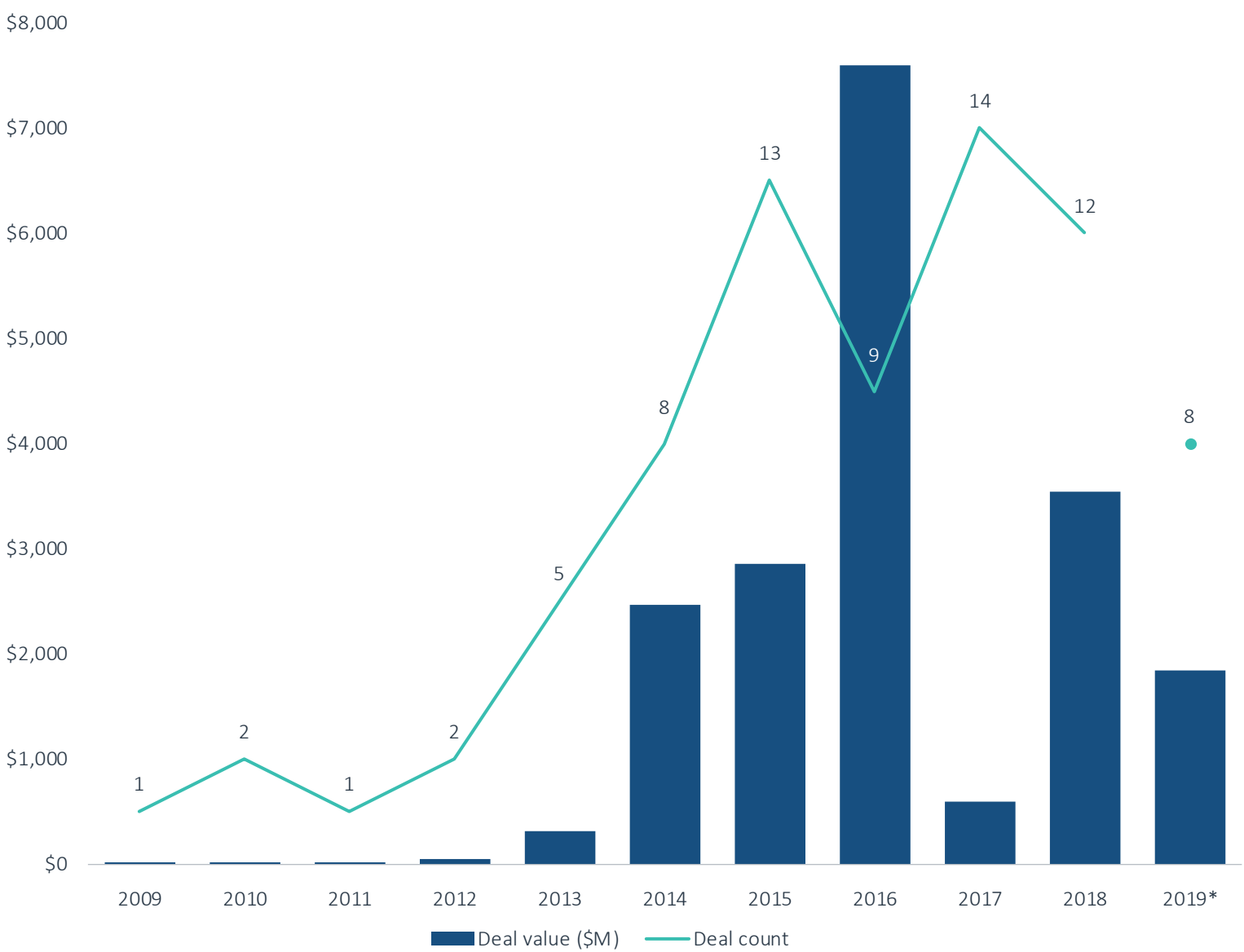
Computer vision in autonomous driving: The ability of an autonomous vehicle to perceive its environment in real time is crucial to the safety and functionality of these systems. This technology forms the foundation of AI & ML transportation use cases. Without a high-quality vision system, the rest of the technology stack fails. Different autonomous software providers take varied approaches to the types of sensors used. For example, **Waymo's** autonomous vehicles conceptualize the world via a 360-degree camera, radar and multiple lidar feeds, while Tesla eschews lidar and focuses principally on cameras.

Reinforcement learning: Reinforcement learning represents one potential solution to some of the headwinds associated with autonomous driving. The technology is widely used within the gaming industry to create systems that can adapt to the unpredictability of the environment and instantly respond to changing situations. UK startup **Wayve** recently released video and research of its reinforcement system (using deep deterministic policy gradients) demonstrating how its technology was able to successfully detect and navigate a lane within just 20 minutes using only one camera. The relatively lower requirements of training time and computing power relative to the lidar-based models used by large autonomous vehicle companies such as **Waymo**, make this technology an attractive approach.

Considerations

Significant capital requirements: While most investment has gone to established players like Uber and Lyft, newcomers **Nuro** and **Aurora Innovation** raised massive rounds in 2019 of \$940 million and \$600 million, respectively. Rounds of this size

Figure 4.
Transportation VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



TRANSPORTATION

early in a company's lifecycle underscore the massive amounts of capital needed for research and development (R&D) in the autonomous transportation space in order to compete with well-capitalized peers. Further, building vehicles or maintaining a fleet of autonomous vehicles increases the capital intensity of current mobility software providers. High capital needs and ongoing maintenance expenses may serve as a drag on margins for companies in the space.

Significant technology and regulatory challenges remain: The level of communication among vehicles, fleets and transportation infrastructure will be key to ensuring safety and traffic management for autonomous driving systems. The complexities of navigating both computer- and human-controlled vehicles on the road is a top priority for fully autonomous systems. Accidents involving autonomous vehicles draw scrutiny from governments and media and can potentially impede advances in the field. Clear regulatory standards will be needed to ensure the safety of the systems in operation.

Outlook

Reinforcement-learning technology to provide more efficient autonomous transportation: For now, we expect data-heavy training models will continue to lead technological efforts, with actual miles driven and simulated miles providing a competitive advantage for autonomous systems. However, the iterative learning process of reinforcement applications, which more closely approximates how humans learn, could drive efficiencies from fewer training data points and computing power requirements. Longer term, we believe solutions taking different approaches via reinforcement learning or other novel methods could become dominant in the space.

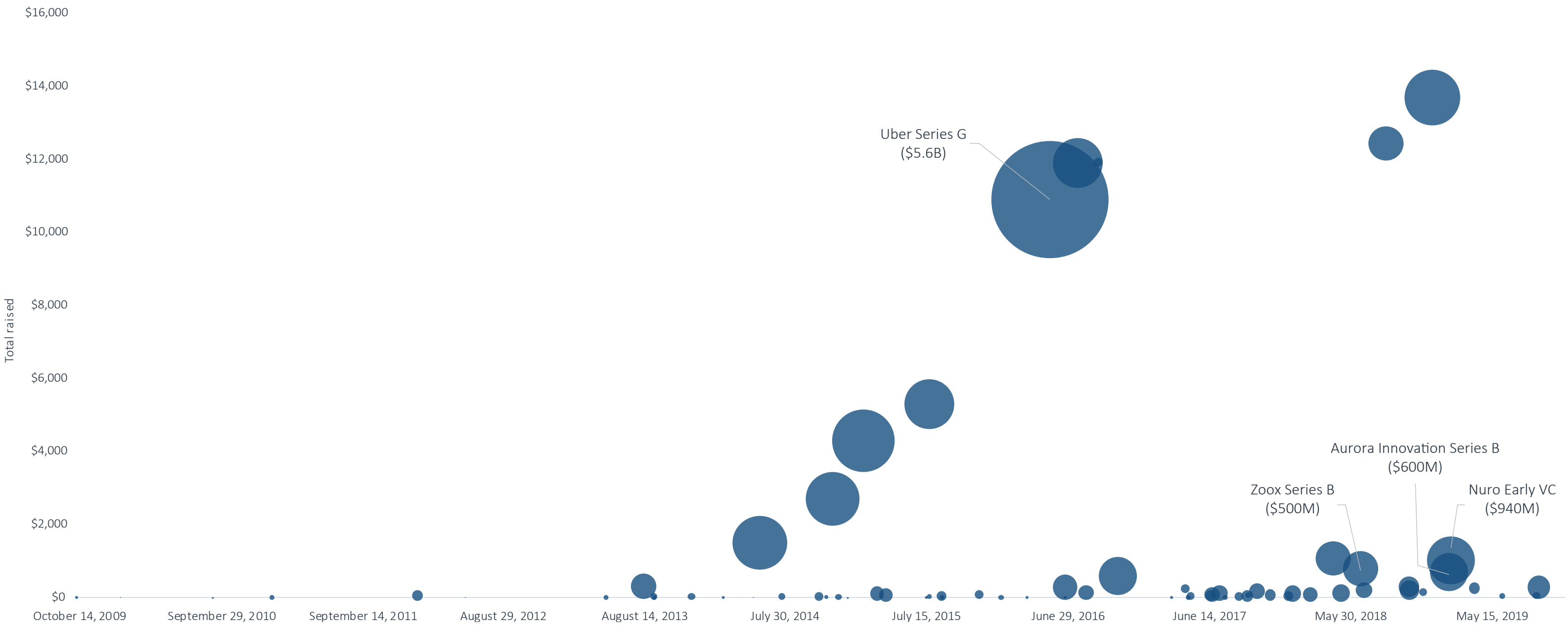
Fully autonomous driving could cause a domino effect of innovation: While the industry remains primarily focused on personal mobility, several enterprise applications and tangential opportunities could lead to the creation of completely new markets. These include providing services to passengers (as they are not driving), automated delivery of goods and vehicle communications networks. Long-haul trucking and local delivery routes could be optimized to run nearly 24/7, dramatically improving asset-utilization rates. We believe this emerging enterprise autonomous mobility market could be prodigious and one of the first to reach commercial implementation.

Software adoption and lower consumer costs to catalyze demand: We believe widely applicable and highly compatible software and hardware solutions will lead to increased adoption of autonomous driving technology among individuals and businesses. Lower per-mile driving costs of autonomous driving is likely to spur demand even further as consumers flock to these relatively cheaper services.



TRANSPORTATION

Figure 5.
Top transportation VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

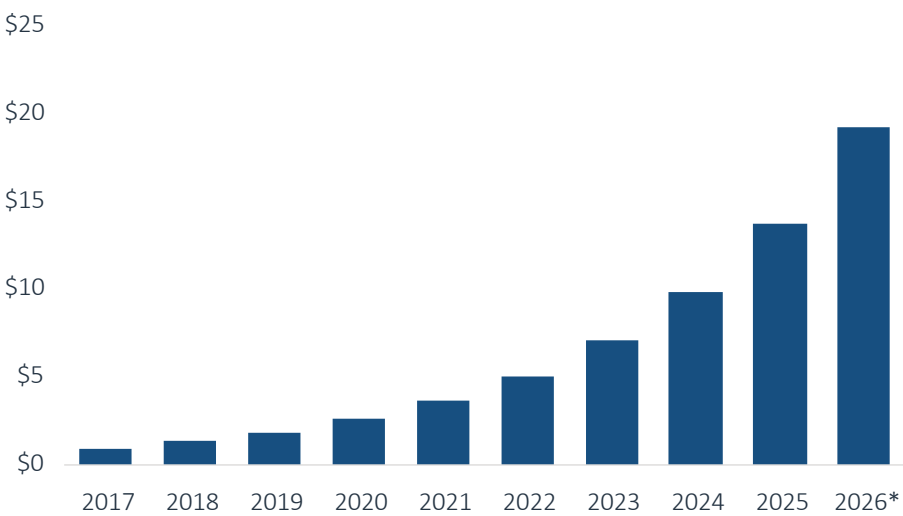
SEGMENT DEEP DIVE

Healthcare



HEALTHCARE

Figure 6. MARKET SIZE (\$B)



Source: Statistics MRC, PitchBook Estimates
Represents estimated global healthcare AI revenue

BUSINESS MODEL

Attractive characteristics of businesses in the space include TAM, cost savings potential, improvement of health outcomes and penetration capability.

Companies in the space generate revenue by selling software or a product powered by AI & ML technology.

The main AI & ML applications in our dataset:

- Computer vision
- Reinforcement learning
- NLP
- Information analysis & learning

KPIS

- Patient health outcomes
- Patient confidentiality
- Utilization rate, labor and assets
- Precision or error rates
- Clinical trial success rates

KEY PROVIDERS



NOTABLE DEALS

 **flatiron**

April 2018
\$1.9B

Acquired by:
Roche

 **SOPHIA GENETICS**

January 2019
\$77M Series E

INDUSTRY DRIVERS

- Digitization of healthcare data
- Focus on providing real-time care and diagnosis, potentially in a remote or automated setting
- Continued efforts to reduce cost and drive efficiencies within the healthcare eco-system



HEALTHCARE

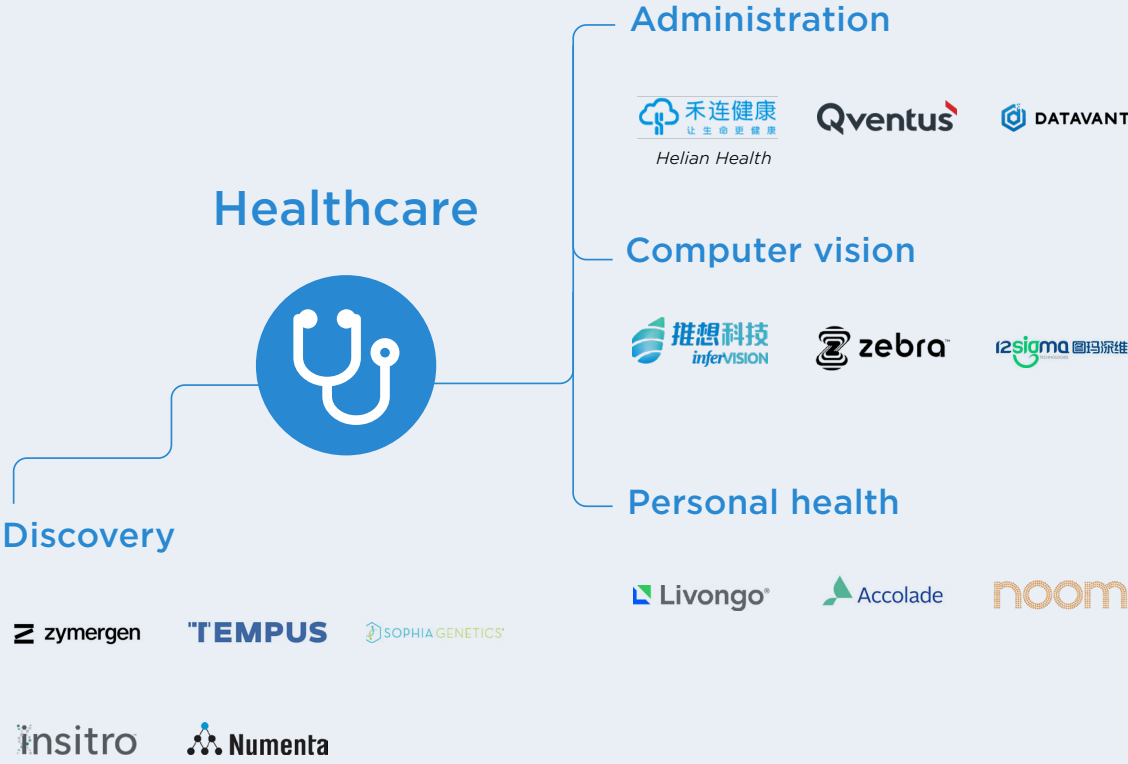
Overview

We see potential healthcare use cases for nearly all the technology building blocks of AI & ML, from patient care to administration. With healthcare costs representing roughly 18% of US GDP, it is not surprising that this market attracts considerable investor interest.

We believe widespread data digitization in healthcare provides a favorable backdrop for expanding implementations of AI & ML, which can drive quicker, more accurate patient recommendations and help hospitals run processes more efficiently. Biotechnology and other genome sciences also stand to benefit from the ability to process larger amounts of data and derive new insights.

Computer-vision applications are also being adopted for detecting and diagnosing skin cancer, pneumonia, lung sarcoidosis, TB and certain early-stage cancers. Implementing these technologies at the clinic level represents an opportunity to improve patient outcomes while also increasing the ability to see more patients.

However, disparate and unstructured data can be problematic, and we believe most AI & ML use cases achieving commercial success rely on vast, cleanly labeled datasets. Over time, we expect healthcare data will become more standardized and accessible, further enabling AI adoption. For example, companies such as **Innovaccer** are focusing on aggregating disparate data sources held in silos both inside organizations or between different parties. While regulatory and institutional barriers present headwinds to data access, we believe that as individuals and healthcare operators begin to see the benefits of utilizing AI & ML, and data-security tools gradually catch up with the needs of AI, these datasets should become more widely available.





HEALTHCARE

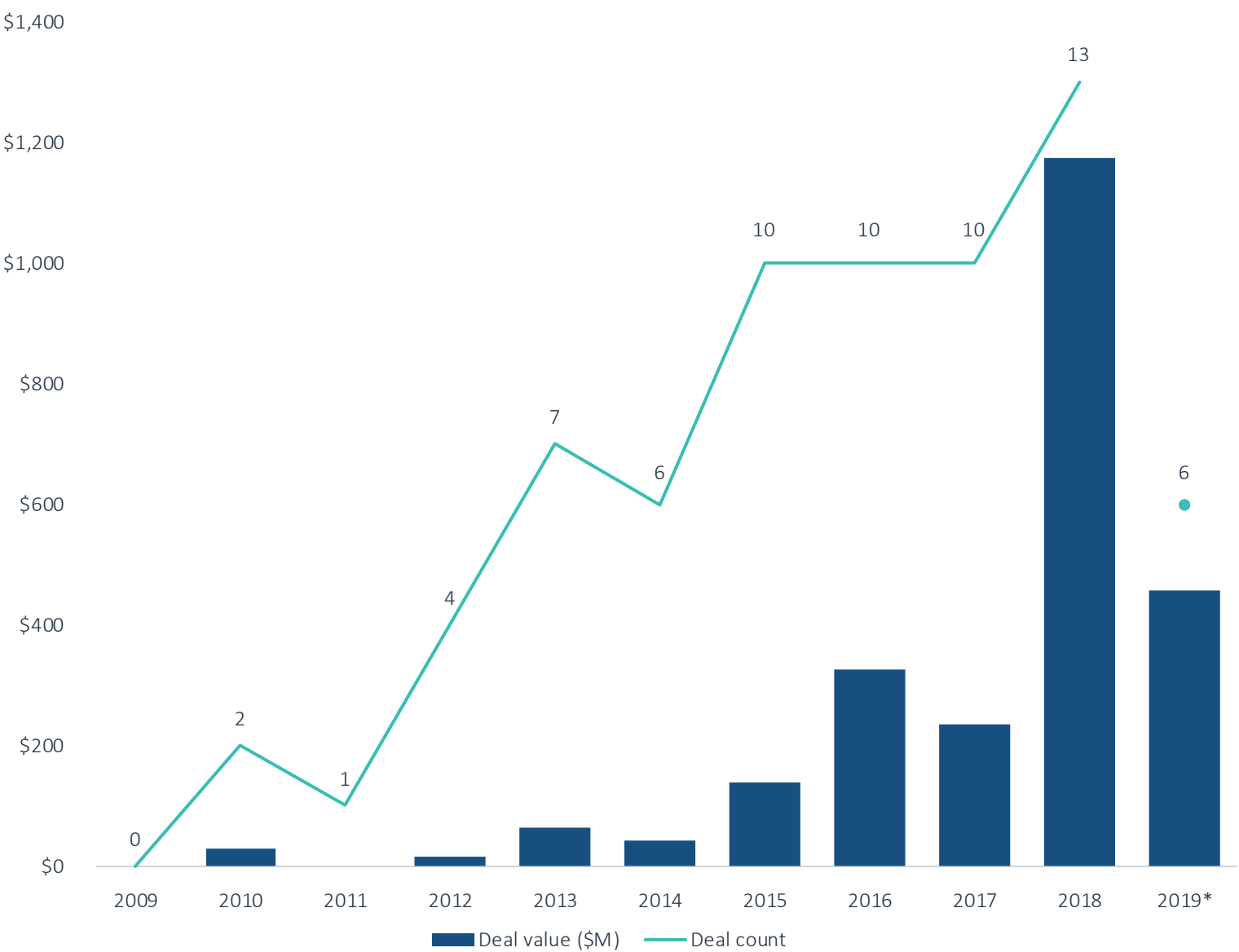
Opportunities

NLP for document and text analysis: NLP is used in automatic scribing, note-taking via voice recognition and in analyzing documents to structure data and provide clean datasets for downstream use cases (such as updating records, automating patient notes, aggregating trial results, etc.). We believe this represents huge potential efficiency gains while enabling the aggregation of data to improve patient outcomes. A key part of the process for healthcare data management company **Tempus** is employing NLP technology on aggregated clinical records to structure text into actionable datapoints.

Computer vision in diagnosis: Applications in computer vision have already achieved some early successes in healthcare, with analysis systems of medical imaging providing low error-rate diagnosis for skin cancer, pneumonia, TB and other illnesses. For example, **Zebra Medical Vision**, an Israel-based healthcare startup, uses data from millions of medical images to deliver analytics to radiologists to automatically detect various medical issues of the lungs, liver, bones and cardiovascular system.

Reinforcement learning for new drug formulation: Reinforcement learning in healthcare could potentially offer exciting use cases including personalized medicine and computerized drug discovery. Methods including contextual bandits (and other specialized algorithms) could help improve personalization in healthcare by enabling more timely and effective personalized health interventions via mobile health applications, such as **Accolade’s** Maya intelligence engine. Other opportunities include drug discovery software that can help researchers to predict outcomes of novel molecular combinations, enabling personalized treatment for a patient’s genome and much more.

Figure 7.
Healthcare VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



HEALTHCARE

Considerations

Fragmentation in healthcare inhibits widespread ML usage: While the depth of data within the healthcare space is immense, its widespread use for general ML applications is hindered by fragmentation across the industry. With valuable datasets siloed within healthcare and insurance providers, broad aggregated use is not currently feasible, slowing the implementation of ML solutions in the industry. This is understandable given that healthcare data is particularly confidential. Safe and secure data is a primary focus among operators before it can be used in data-science applications.

Patient preference for human-based healthcare represents another barrier to adoption: The direct reasoning behind decisions and inferences made by ML is opaque, contributing to the perception of ML as a “black box.” Improvements in explainability are being researched and will likely be critical to adoption within this segment.

Outlook

Labor productivity to drive the first wave of adoption: In the near term, we believe the most compelling AI & ML opportunity in healthcare is service augmentation. We see significant efficiency gains across job functions as automation and assistance-related applications of AI & ML become more widespread. Examples include use of **Deepmind's** Streams application by the NHS in England to alert clinicians when a patient's health deteriorates. Additionally, computer-vision technology has the potential to help increase the speed and precision of medical-imaging diagnoses, significantly assisting radiologists and physicians in providing improved healthcare outcomes.

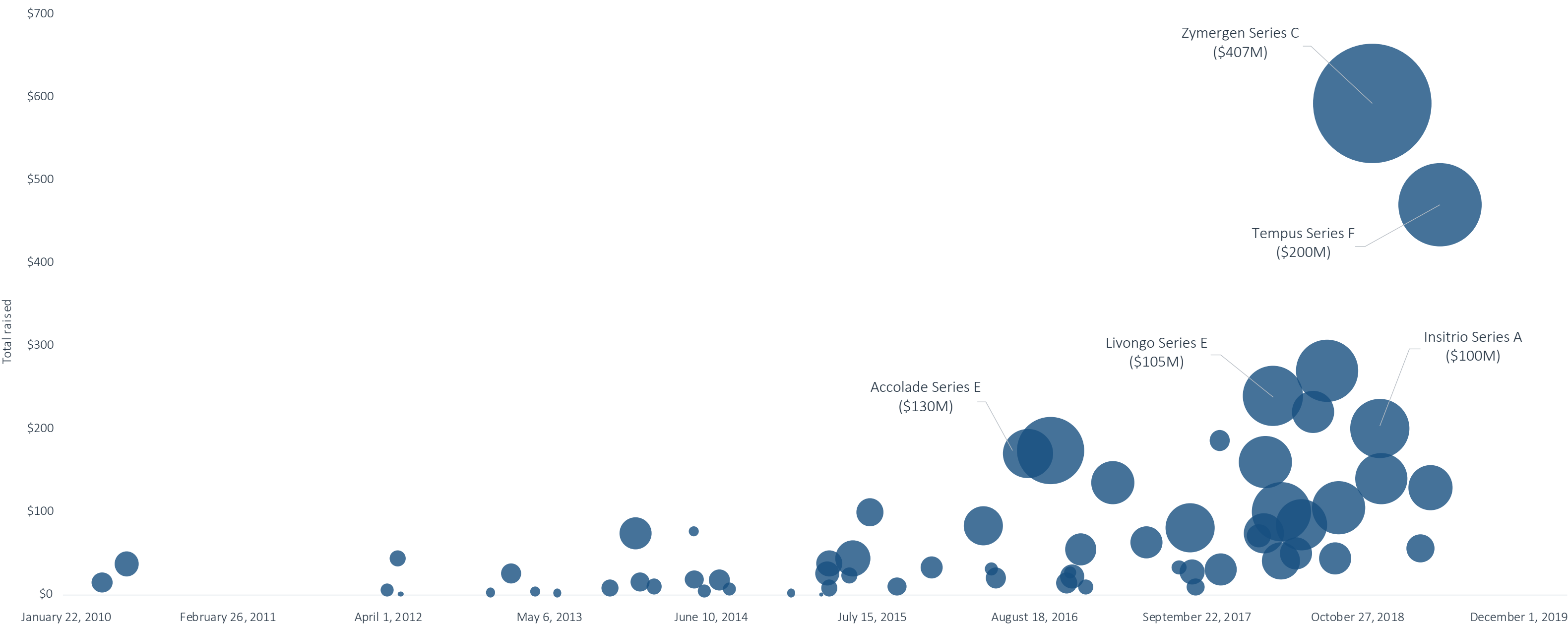
AI & ML will help reduce the burden of growing health expenses: Total spend on healthcare is expected to continue growing at 5.5% over the next five years and continues to be a significant burden for much of the population. We believe this ongoing need to provide more expansive healthcare services underscores the importance of deploying AI & ML technologies that have the potential to contain costs.

ML could lead to new drug discovery: The potential to use ML technology for development of new drugs represents another growth opportunity. However, given the relative lack of data in how molecules impact physiological processes (compared to computer vision, for example, where data is abundant), drug discovery remains nascent, and we view this as a longer-term opportunity. **Insitro** is working to combat the lack of data in the drug discovery segment by leveraging existing high-quality datasets and creating data sets that are tailor-made for ML applications. The startup recently inked a three-year research collaboration with Gilead Sciences to use its ML models to identify promising drug candidates and accelerate the process of finding a way to treat nonalcoholic steatohepatitis (NASH), a buildup of fat in the liver.



HEALTHCARE

Figure 8.
Top healthcare VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

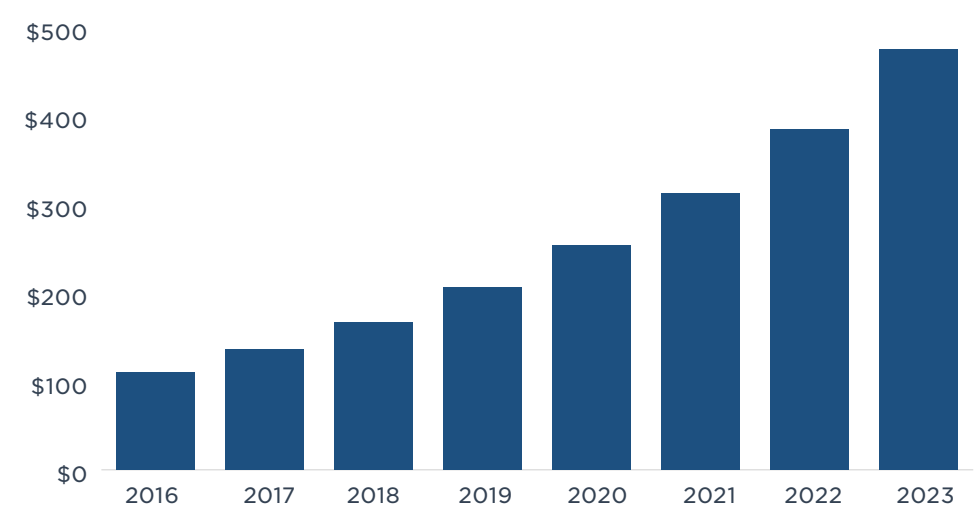
SEGMENT DEEP DIVE

Agriculture



AGRICULTURE

Figure 9. MARKET SIZE (\$M)



Source: Prescient & Strategic Intelligence and PitchBook estimates.
Represents estimated global agriculture AI revenue

APPLICATIONS

Attractive characteristics of this industry include data availability, willingness of adoption, cost-saving potential and environmental benefits.

Companies in the space generate revenue by selling software, hardware or both to agricultural operators

The main AI & ML applications in our dataset include:

- Regression analysis
- Classification & clustering
- Computer vision

KPIS

- Crop yield, per acre, plant, etc.
- Yield growth
- Labor per output
- Water use per output
- Estimated production potential
- Field utilization rate
- Waste percentage

KEY PROVIDERS



NOTABLE DEALS



September 2017
\$305M

Acquired by:
John Deere



January 2019
\$11.5M early-stage VC

INDUSTRY DRIVERS

- Continued demand to improve farming efficiency and yield
- Rising demand for food as population expands
- Demand for better food harvesting and transportation logistics technologies



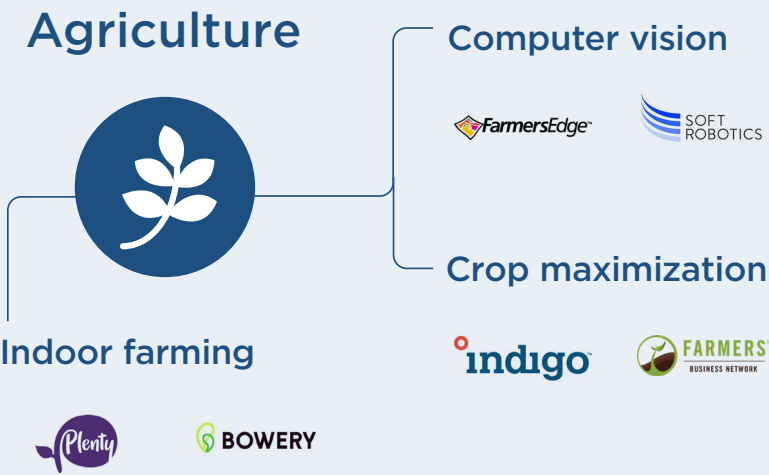
AGRICULTURE

Overview

The agriculture industry has traditionally been a relatively expedient adopter of new technologies driven by the need to incrementally increase output while reducing natural resource consumption. The industry also is characterized by very repeatable processes, which create fertile territory for data-driven improvements. For this reason, we view the implementation of AI & ML technologies as both a natural and necessary paradigm shift for the industry. Some of the most common applications of AI & ML in the agriculture industry include robotics and analytics platforms that leverage singular or multiple datasets to anticipate effect on crop yield.

We believe AI & ML technologies will be critical in meeting the steadily rising demand for hyper-efficient food production across the globe. Innovative technology-enabled solutions such as indoor and vertical farming have had success in increasing yield through the controlled use of water and other resources despite having a smaller physical space. These controlled environments allow companies to collect better data which can then be used by AI & ML models to optimize crop growth. Two of the private market leaders in this space are **Plenty** and **Bowery Farming**, which produce leafy greens for local markets without pesticides and with minimal water consumption.

For traditional farmers, AI & ML can provide detailed and specific feedback via sensors delivering real-time data flows. Some examples include using herbicides more surgically, such as the See & Spray technology from **Blue River Technologies**, which purports to cut herbicide use by 90%. In addition to material cost savings, these technologies can provide environmental benefits such as reduction in the growth of herbicide-resistant weeds.





AGRICULTURE

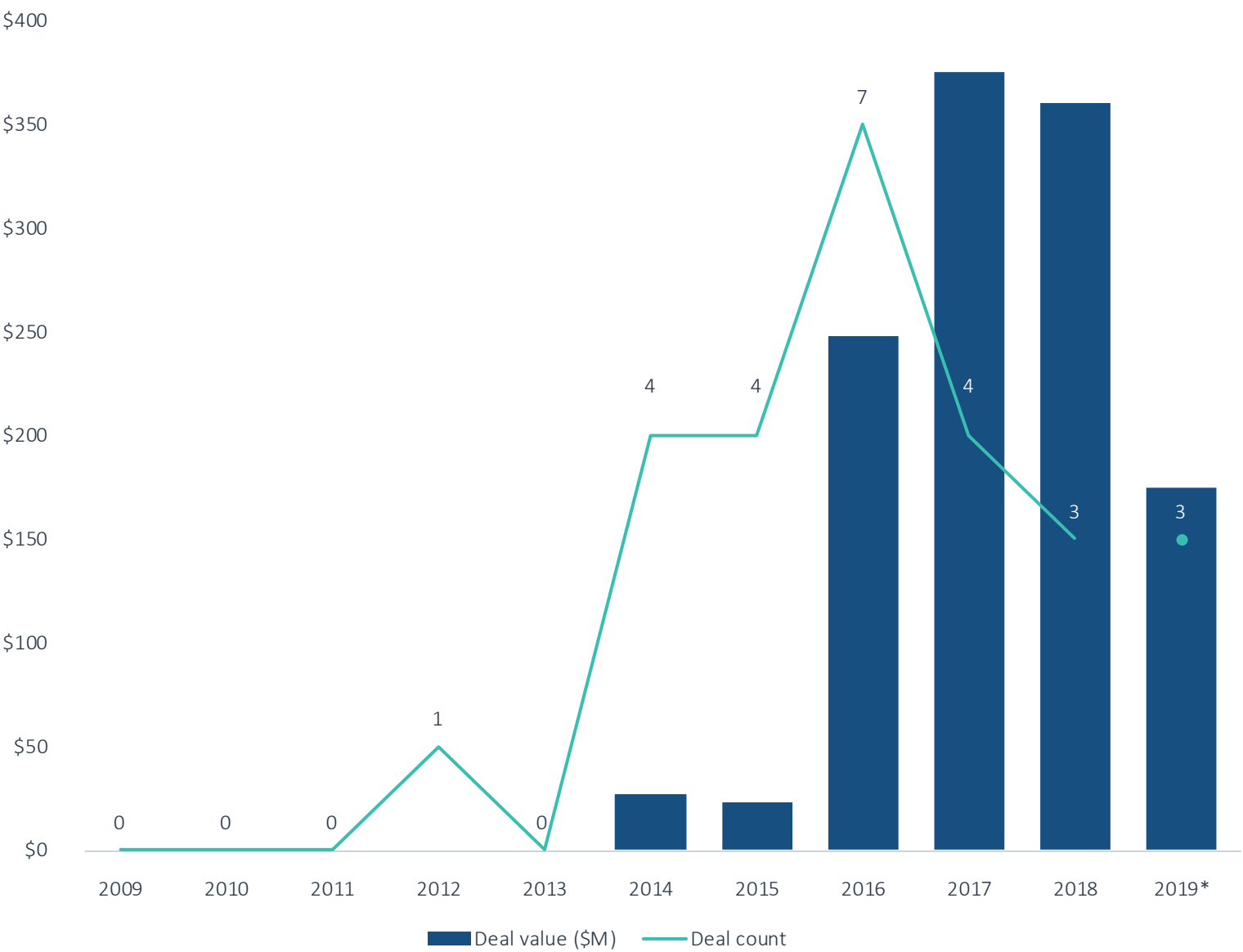
Opportunities

Regression analysis in weather forecasting: The value of regression algorithms lies in their ability to make estimates and forecasts, identify trends, price products, assess risk and more. This is used heavily in Israel-based **Taranis**’ precision agriculture solutions in features such as hyperlocal weather forecasting and crop-disease prediction, both of which drive more efficient resource utilization.

Computer vision to make satellite imagery actionable: Computer vision is a natural fit for the agriculture market, from analyzing satellite photos of farmland, to picking and sorting produce, to autonomous machinery—all of which boast the potential for increased crop quality and farm productivity. As there can often be serious mismatches between labor supply and demand, robotic harvesting solutions can help to solve these problems, allowing farmers to maximize their production and improve profit per acre. Startups such as **Harvest CROO** (robotic strawberry picker) and **Abundant Robotics** (robotic apple picker) are looking to solve these problems for specialty crops which tend to have more time-sensitive harvest periods.

Clustering & classification for predictive maintenance: Classification algorithms are critical for taking advantage of IoT and sensor data in the agricultural space. Outage predictions and anomaly detection of equipment or sensor data can provide operators with suggestions for targeted interventions or preventative equipment maintenance to reduce downtime and increase yield.

Figure 10.
Agriculture VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



AGRICULTURE

Considerations

Replicating data across environments: A limiting factor for AI & ML's use within agriculture is the pure number of factors that must be considered for each environment. Results from one area may not be applicable to other locales, making testing/validation more difficult and slowing implementation. For example, factors or patterns that work in California may not translate to Chile or sub-Saharan Africa. This complication comes from not only having to understand the internal system of a crop or livestock, but also predicting how it reacts with the external systems of the physical world. Temperature, precipitation and soil composition are exceedingly varied across the globe, and often represent uncontrollable variables. This adds a further level of complexity for agricultural AI & ML models.

High costs to farmers: Advanced analytics software and new equipment may dissuade some buyers as agriculture AI companies look to recover R&D expenses. This initial capital-expenditure hurdle could serve to slow the pace of adoption until the benefits outweigh the costs. While there will likely be rental and sharing options for some of the large hardware and robotic equipment applications, the effects are worth considering. On the company side, manufacturing highly specialized robotics is a capital-intensive business and may require significant fundraising support to scale.

Outlook

AI to help maximize food production: We expect AI & ML technologies will prove critical in helping the agriculture industry improve yield to support strong demand trends in

related products and services. For instance, the US Department of Agriculture estimates that 90% of crop losses are related to extreme weather. With the help of more robust and plentiful data, AI & ML solutions such as **ClimaCell** are working to provide increasingly hyperlocal and accurate forecasts, which should allow farmers to make improved decisions. The technology could also be critical in resource efficiency as more farming regions focus on conservation and sustainability.

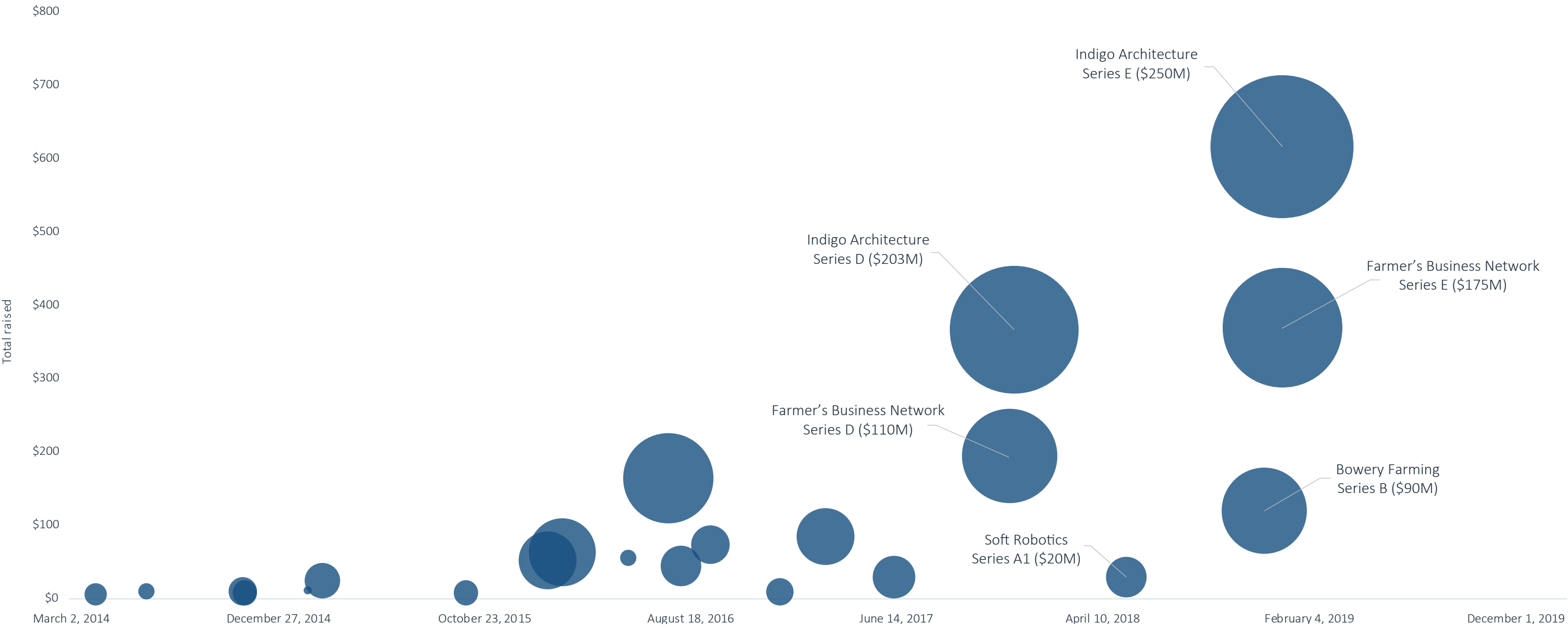
Proliferation of computer vision applications should continue: We expect computer vision software to build on its early success in the agriculture market, with use cases ranging from satellite and drone imaging to individual fruit assessment. As image recognition algorithms and satellite imagery become more commonplace, companies can leverage and customize these applications for agricultural purposes. **Farmers Edge** is an early player in this space, providing clients with satellite imagery of their fields with analytics layered on top to scan for developing changes and generate easy-to-understand maps to power decision-making.

Spread of connected devices to catalyze adoption: The falling cost of sensor hardware will lead to further penetration of IoT applications in agriculture. Cheaper sensors will enable an expansion of input devices supplying and processing larger and more robust streams of data to ML algorithms. The proliferation of connected devices is likely to be critical to the development of soil and crop health analysis, helping to determine water needs, soil deficiencies, temperature levels and other variables to help optimize crop yield.



AGRICULTURE

Figure 11.
Top agriculture VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

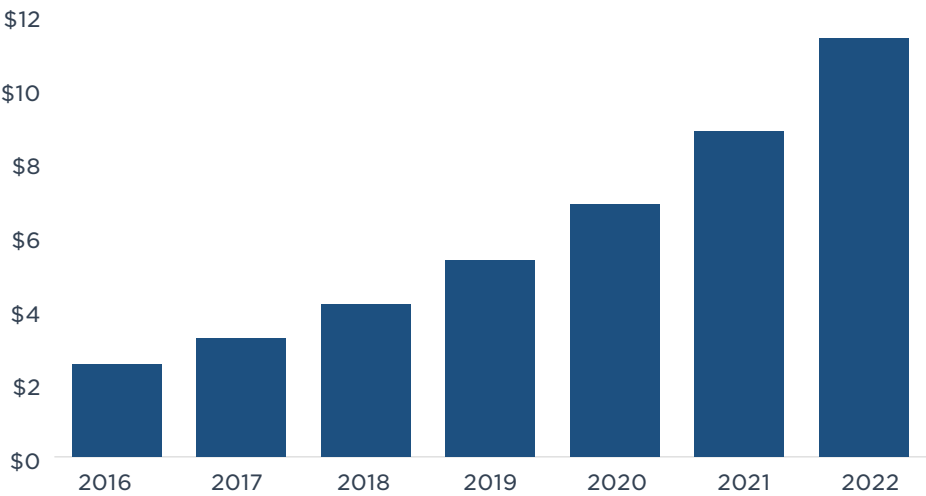
SEGMENT DEEP DIVE

Financial services



FINANCIAL SERVICES

Figure 12. MARKET SIZE (\$B)



Source: Market Study Report and PitchBook estimates. Represents estimated global AI in BFSI (Banking, Financial Services and Insurance) revenue.

APPLICATIONS

Attractive characteristics of this industry include data availability, large TAM, propensity toward automation and potential to reduce legacy costs.

Companies in the space generate revenue by implementing AI software solutions in the enterprise or charging a fee to consumers.

The main AI & ML applications in our dataset:

- Regression analysis
- Classification & clustering
- Reinforcement learning

KPIS

- Return on Investment
- Productivity gains
- Precision or error rates
- Fraud rate
- False positives fraudulent transactions

KEY PROVIDERS

TRADESHIFT

wealthfront

Lemonade

affirm

zest finance

Wecash

MoneyLion

sift

NOTABLE DEALS

KENSHO

April 2018
\$550M

Acquired by:
S&P Global

FIGURE

February 2019
\$80M Series B

INDUSTRY DRIVERS

- Industry-wide focus on reducing costs, and more data-driven planning
- Customer preference for more on-demand, automated processes
- Improved analytics and database software make large legacy data sets more actionable



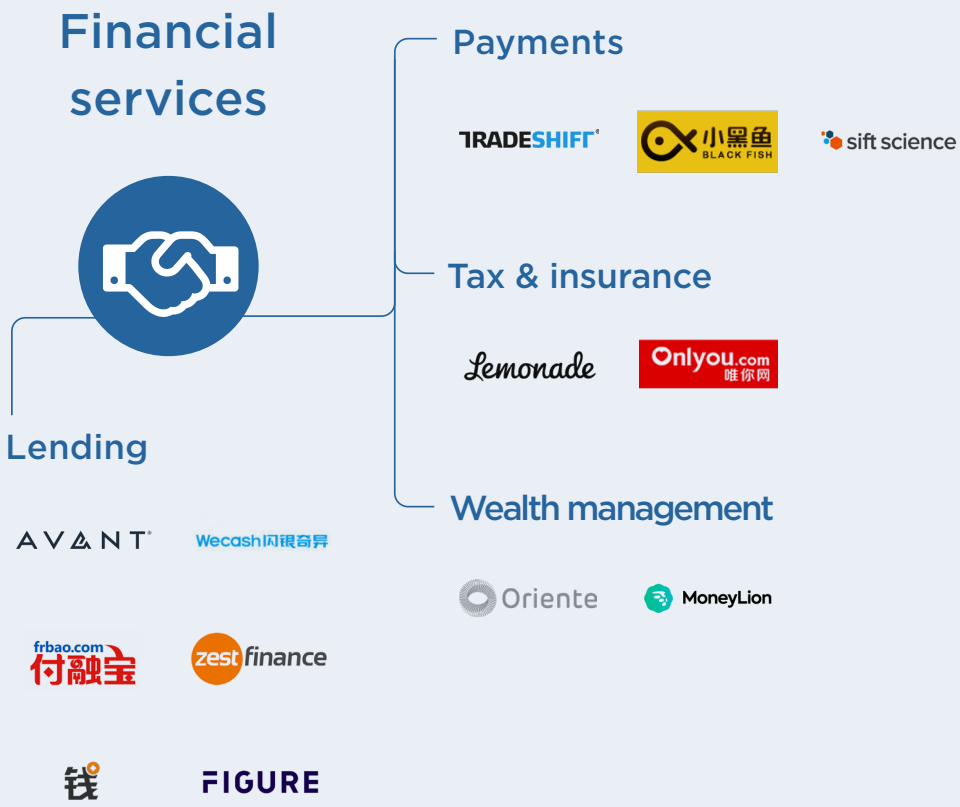
FINANCIAL SERVICES

Overview

We see many AI & ML opportunities in the financial services space and believe the technology has the potential to help banks save hundreds of millions of dollars by driving improved productivity throughout the whole enterprise. Multiple reports from Autonomous NEXT, Bain, McKinsey and Accenture all suggest a nearly trillion-dollar cost-saving opportunity for AI & ML across the financial services industry. Driving this estimate are projections of 20%-40% of automation potential in banking, investment management and insurance, with specific emphasis on the front and middle office. According to a recent McKinsey survey, financial services firms have been more readily implementing AI & ML solutions in services operations and risk management functions, with 49% and 40% of respondents, respectively, reporting adoption.² Risk management solutions were also cited by companies as an area of AI & ML that was generating significant value for their businesses.

Chat bots have been the most widely recognizable low-hanging fruit for adding AI to the customer experience, and most large banks are already employing some sort of AI-powered customer service tool. These bots are crucial in helping banks automate the most routine customer service requests and can drive significant cost savings. More recently, banks have been introducing always-on digital assistants embedded within mobile apps to help customers navigate the mobile-banking process while recommending other products and services. However, implementation of chatbots hasn't come without hiccups. For many users, chatbots have failed to live up to the lofty claims from some solutions in place. Various customer surveys have found that individuals often feel that chatbots talk in circles and waste their time, which can damage the reputation of the company.

2: "AI Adoption Advances, but Foundational Barriers Remain," McKinsey & Company, November 2018





FINANCIAL SERVICES

On the capital markets side, AI is emerging as an important tool in contract automation software and for developing trading algorithms to assist in trade execution. For consumer products, AI is automating the process of providing personalized asset allocation and diversification strategies. **MoneyLion** provides personalized portfolios and full rebalancing and management as part of their broader personal finance product.

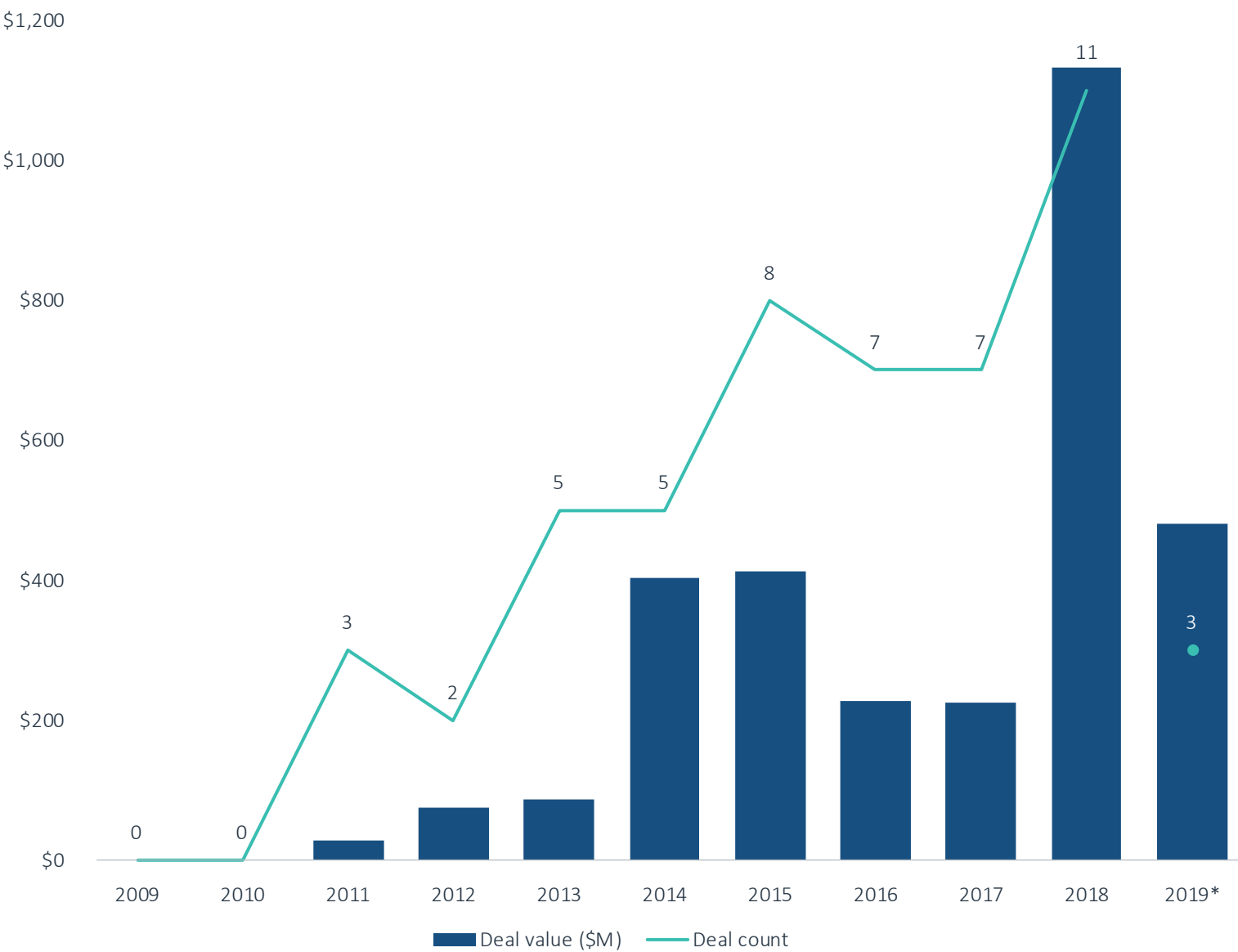
Compliance is another pain point for many banks, and AI & ML-based tools have emerged in recent years to help banks automate procedures, with a focus on money laundering and Know-Your-Customer. Recently, it was reported that via a partnership with recently acquired **Ayasdi**, HSBC had managed to reduce costly money-laundering investigations by 20%, without reducing the number of cases that actually merited more scrutiny.

The potential for AI & ML technology to replace people with robots remains controversial in financial services. With routine tasks automated, the fear is that this may lead to the loss of thousands of jobs. On the other hand, it is also argued that automation won't necessarily reduce net jobs, but it will require employees to develop different skillsets. Rather than tellers, banks will need data researchers and application developers to manage the AI & ML platforms used to deliver services.

Opportunities

Regression analysis and pattern recognition in alternative data sources: Use of quantitative strategies by robo-advisors and hedge funds has become increasingly standard in recent decades, and AI & ML fits perfectly into this business model. The increased ability to analyze and extract value from a diverse universe of data is crucial, especially in a competitive space where even the slightest edge counts. As the technology continues to improve, we expect new datasets to be used and the number of strategies to proliferate.

Figure 13.
Financial services VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



FINANCIAL SERVICES

Clustering & classification in fraud detection: Fraud detection is likely one of the most impactful use cases and is already utilized by many large financial institutions. As ML algorithms process more transaction data, they can determine an extremely accurate threshold for “normal” transactions and reduce false positives. Classification of data also aids in the loan-approval process, as the machine can optimize underwriting techniques based on numerous factors that best determine the success or failure of a loan.

Customer service improvements with natural language processing: Within financial services there are many administrative processes that are ripe for automation via ML, freeing up employees to focus on more value-additive tasks and increasing productivity. These include automating repetitive customer service tasks, improving convenience and customer satisfaction while reducing labor costs.

Considerations

Data limitations: While financial data might be relatively abundant, the cleanliness and applicability can be a limiting factor for AI & ML use cases. When training models on market data, we are constrained to historical past data. While this gives a clear and detailed picture of the past, markets have experienced quite a few statistically improbable events. As machine learning, especially neural networks, focuses heavily on generalization and interpolation, these datasets pose some difficult obstacles. In other use cases such as lending approvals, the data used to train models can result in unintended discrimination (bias that has recently been leveled at Apple’s new Apple Card). Since the training data is used to generalize within the dataset, bias in training can lead to sub-optimal outcomes.

Explainability: With the implementation of AI & ML in financial services, companies will have to decide how much authority to give the algorithms, and plan for a scenario where things don’t go as intended. For full commercial use, auditability will be key to ensuring regulatory compliance and in determining accountability.

Privacy and security: With increasing focus on privacy and security regulations (for example the EU’s GDPR), financial institutions using AI & ML must ensure that data is being handled properly.

Outlook

Deeper penetration of existing products: We expect further explicit initiatives and investment into AI & ML by traditional financial institutions as well as pure-play startups. These programs will drive further expansion of the technologies we see in use today including customer service, chatbots, fraud detection, robo-advising and underwriting.

Focus on employee-assistance AI: We expect AI & ML implementations will be focused on human assistance and/or augmentation, which will allow for more productivity per worker, freeing humans to focus on more value-add tasks. For instance, utilizing robot process automation, including offerings from **UiPath** and others, on repetitive tasks for back-office employees at banks to reduce time spent on recurring tasks and reducing human error.

Increased investment in forecasting and personalization tools: Classification techniques that use data to identify large trends and/or business cycles could aid firms in prediction accuracy. These techniques can be informed by traditional market data as well as alternative datasets and inputs from more unstructured sentiment analysis. Similar to



FINANCIAL SERVICES

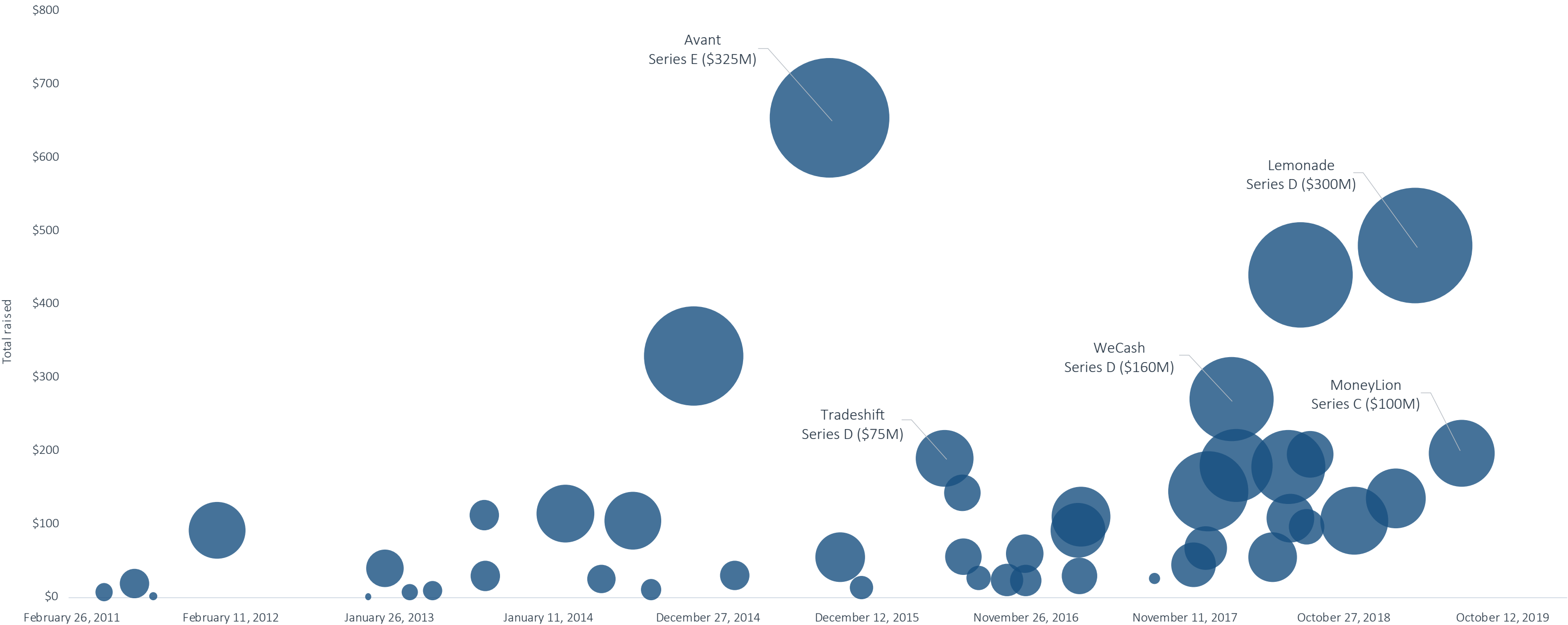
the practices of media and ecommerce businesses, financial services companies are also likely to increase investment into personalization technology to improve sales and recommendations for banking and investing products.

Focus on algorithm management and governance: With increased use of AI & ML, companies will need solutions that can manage the functioning and performance of algorithms, while also ensuring proper oversight. For full commercial use, AI & ML applications should be auditable to ensure compliance with regulations and to discover if there may be bias in the output. The ability to explain and audit decisions made by the algorithm will be critical in determining accountability and ensuring compliance.



FINANCIAL SERVICES

Figure 14.
Top financial services VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

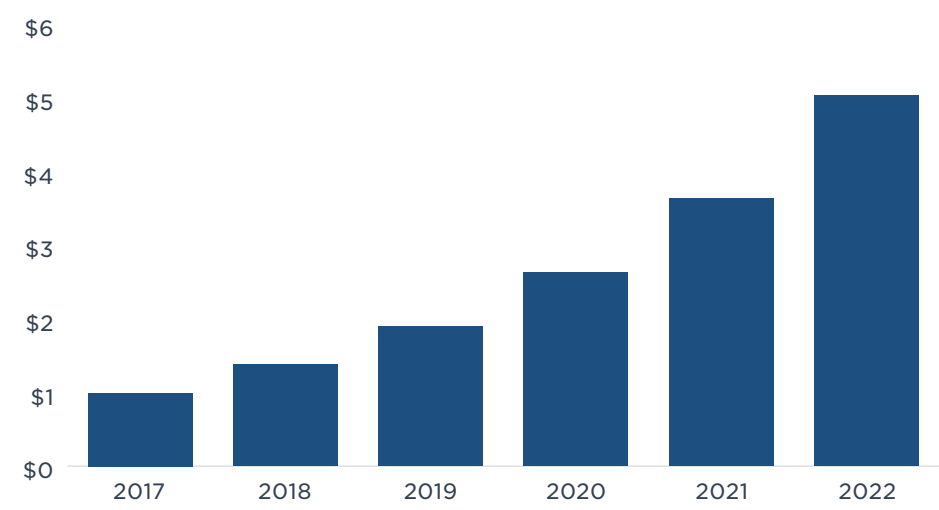
SEGMENT DEEP DIVE

Retail and advertising



RETAIL & ADVERTISING

Figure 15. MARKET SIZE (\$B)



Source: Marketsandmarkets and PitchBook estimates. Represents estimated global retail AI revenue.

APPLICATIONS

Attractive characteristics of this industry include data availability, proven success of technology in action and number of use cases.

Companies in the space generate revenue by selling software solutions or providing the software as a service.

The main AI & ML applications in our dataset:

- Clustering and classification (i.e. targeted product recommendations)
- Reinforcement learning (i.e. personalized marketing)
- Computer vision

KPIS

- Conversion rates
- Sales growth
- Inventory days on hand
- Stock-out
- Precision/error rates of the algorithms
- Productivity gains

KEY PROVIDERS



NOTABLE DEALS



January 2019
\$60M Series C



February 2018
\$183.6M IPO

INDUSTRY DRIVERS

- Continued growth of online retail driving new opportunities for advertising
- Increasing quantities of user data available to retailers to drive consumer engagement
- Trend toward personalized commerce experiences to increase sales conversion
- Demand among retailers to better target potential customers



RETAIL & ADVERTISING

Overview

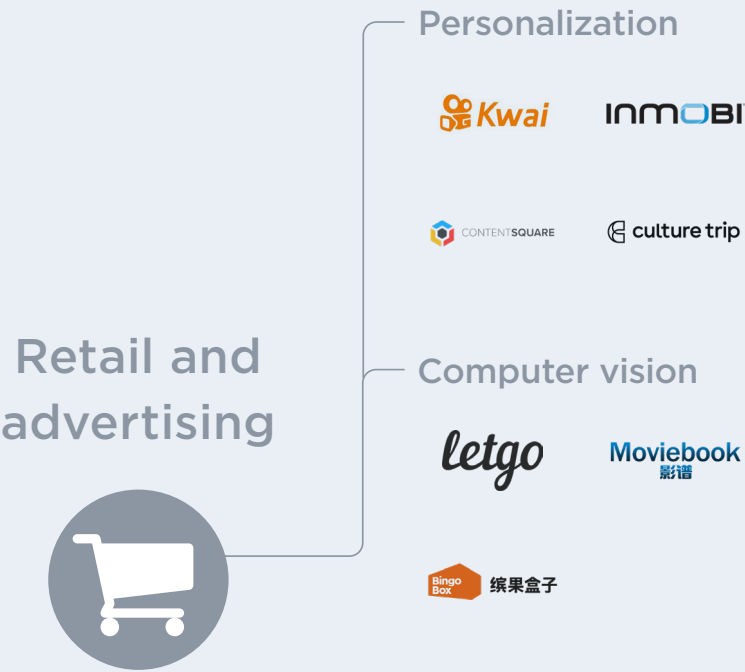
We believe retail and advertising are logical markets to benefit from AI & ML due to the inherent availability of large quantities of customer data. As advertisers and retailers seek new ways to engage consumers and increase sales conversion, AI & ML solutions are providing valuable tools to support these strategies. Adoption in the industry has been encouraging, with a recent IBM survey finding that 40% of responding retail and consumer product organizations had already implemented some form of intelligent automation, with 80% planning to pursue the strategy by 2021.³ Some of the most common expected use cases revolved around supply chain and demand forecasting as businesses look to gain the slightest edge over the competition.

Increasingly, as advertisers seek ways to sustain customer engagement via digital channels, AI & ML is emerging as an invaluable tool. For example, AI & ML can help improve customer segmentation, providing more accurate and detailed groupings and more effective targeting and personalization. Consumer behavior data can also be used to serve relevant ads or discounts in near real time and to power recommendation engines, helping retailers capitalize on ecommerce growth.

Optimizing the retail experience is another focus area for AI & ML applications. For instance, RetailNext allows retailers to gather more insight in the physical world by analyzing data from smartphones to gauge length of customer visits, unique traffic and pass-by traffic.

Cashier-less retail such as AmazonGo and **BingoBox** seek to reduce in-store friction through the use of sensors and cameras that track what customers are adding to their

³: “The Coming AI Revolution in Retail and Consumer Products,” IBM Institute for Business Value, January 2019





RETAIL & ADVERTISING

carts (or holding in their hands). AI & ML can help manage these automated stores, ensure products are stocked on shelves and ensure customers are billed correctly.

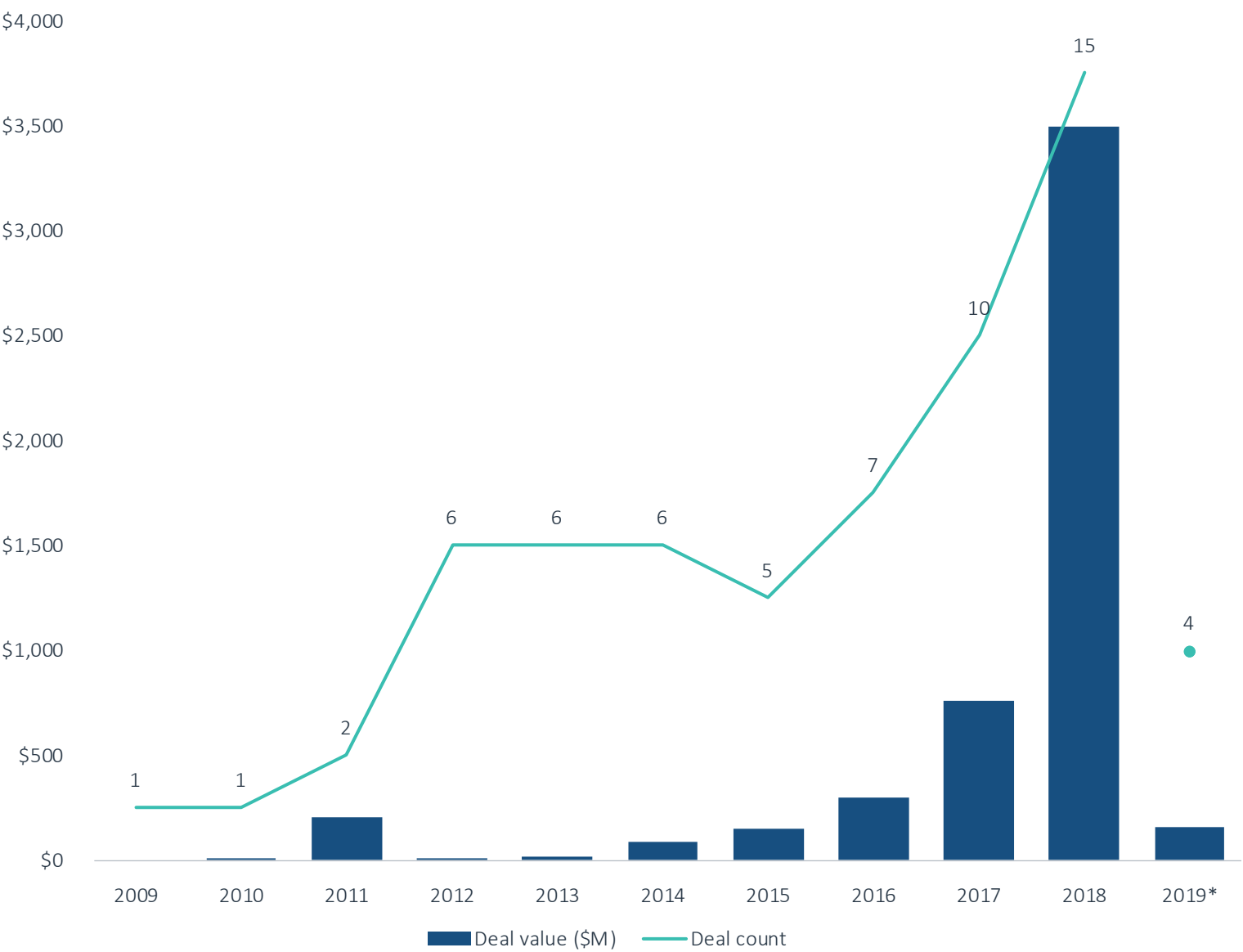
Opportunities

Clustering & classification for personalized marketing: Classification of data is one of ML’s major capabilities, enabling sophisticated demographic bucketing and customer segmentation. Categorizing customers is an important prerequisite for providers of marketing and retail applications; for example, providing inputs to recommender systems can surface relevant products to a specific segment of customers in a timely manner.

Reinforcement learning enabling recommender systems: Reinforcement learning can be very helpful in providing personalized marketing systems. Personalized discounts, more targeted reach-outs and customized recommendations can be well calibrated by tracking demand and price sensitivity. By serving an individual the correct advertisement at the right time and optimizing pricing, companies can maximize the effect of their marketing dollars and capture more sales. Additionally, once the user is engaged, an effective recommendation engine can drive larger average orders, further increasing profitability.

Computer vision for inventory management: We expect computer vision to have wide-ranging impacts on retail. Among other things, computer vision can prompt personalized ads or recommendations based on a customer’s appearance; it can monitor stores in real time at the shelf level and prompt employees to re-stock certain items; and it can power an entirely cashier-less in-store retail experience. **Letgo** uses computer vision to enhance the consumer’s experience with its product by identifying the object in the photo for easier discoverability and a smoother process for the sellers.

Figure 16.
Retail & advertising VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



RETAIL & ADVERTISING

Considerations

Transparency of AI & ML models could serve as a limiting factor for deeper integration in this end market: Companies developing AI & ML solutions for the vertical must ensure that the models do not reinforce biases through either the data or the model itself. Understanding the outputs of ML models is an ongoing struggle, and until there is a research breakthrough in explainability, this remains a common concern for implementation.

Privacy concerns: The retail and advertising industries are another AI & ML end market that is heavily rooted in the use of personal data. With recent lapses in protection and governance of personal data, there will likely be more concerns surrounding data-science products in consumer-centric use cases. Regulatory changes, such the EU's implementation of GDPR this year, have far-reaching effects into how AI & ML-focused companies will have to operate, especially if other jurisdictions follow suit. Adherence to these higher standards will likely add operation costs and could slow implementation in some geographies. This can also affect individual behavior without the intervention of government, as potential customers may choose an alternative based on privacy concerns.

Misinformation and false advertising are also a potential threat to the proliferation of AI & ML adoption in this segment, as these negative perceptions and experiences can affect future consumer interactions within the space.

Outlook

Recommendation systems to become more ubiquitous: The recommendation functions of AI & ML products in the retail and advertising end market is where we see significant

opportunity over the near-to-medium term. Best-of-breed companies in the retail & media industry, such as Amazon and Netflix, are already using these features to improve the user experience and upsell additional products. Companies with access to large, clean datasets will likely have an edge in deploying this technology.

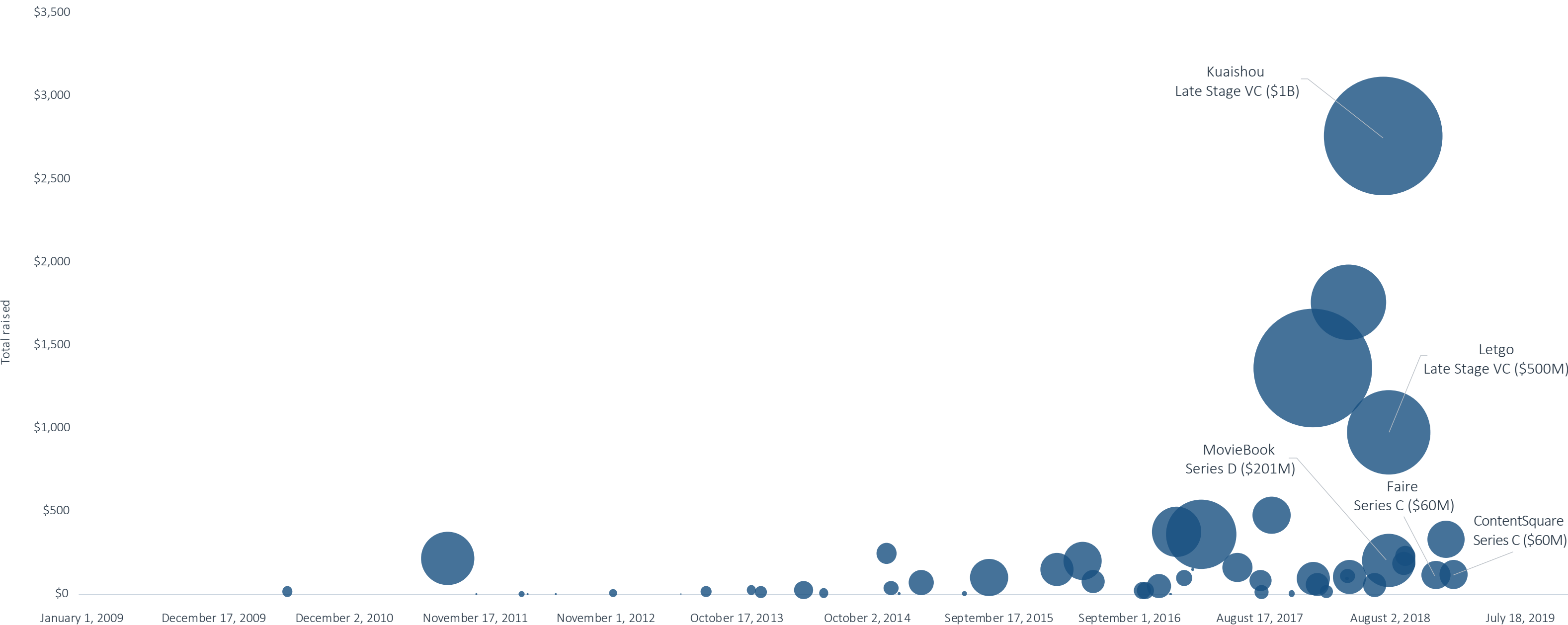
More focus on personalization: We believe better customer targeting can help advertisers be more cost-efficient with smaller distribution, and therefore we can expect personalization to emerge as a key area of AI & ML investment.

Computer vision will alter the retail experience: We expect computer vision to have wide-ranging impacts on the retail experience. From placing ads based on the consumers appearance to inventory management and cashier-less retail, this technology is likely to be very disruptive to companies not able to offer similar experiences.



RETAIL & ADVERTISING

Figure 17.
Top retail & advertising VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

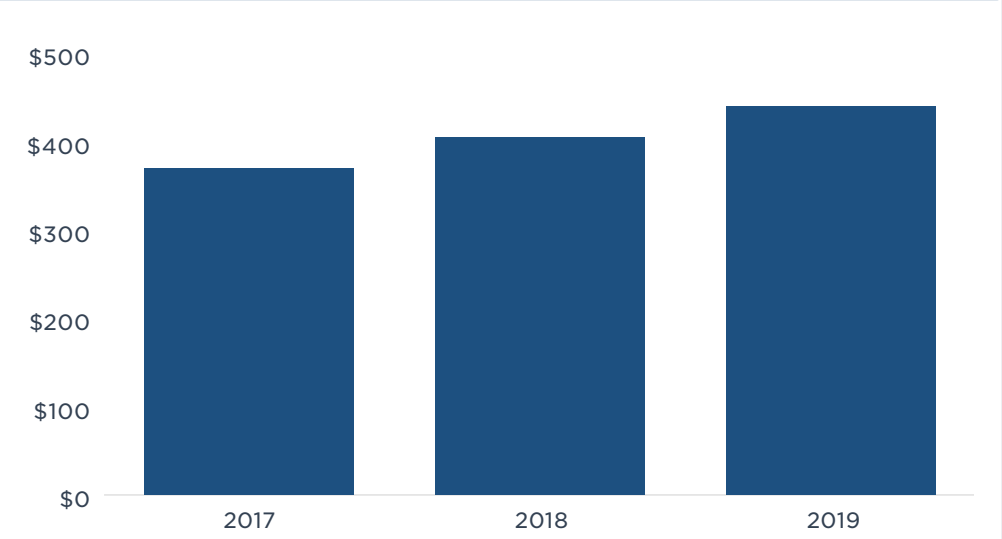
SEGMENT DEEP DIVE

Information technology



INFORMATION TECHNOLOGY

Figure 18. MARKET SIZE (\$B)



Source: Gartner. Represents estimated global software spend.

APPLICATIONS

Attractive characteristics of this industry include technologically advanced customers and the generally stable industry trends of IT investment.

Companies in the space generate revenue by selling software delivered via the cloud or run on-premise. Some companies also provide outsourced professional services.

The main AI & ML applications in our dataset:

- Regression analysis
- Clustering & classification
- NLP and computer vision

KPIS

- Latency/throughput
- Productivity/ROI
- Precision or error rates
- Statistical analysis output (e.g. ANOVA test, Friedman test, Quade test)

KEY PROVIDERS



NOTABLE DEALS

nervana
SYSTEMS

August 2016
\$408M M&A

Acquired by:
Intel

databricks

February 2019
\$250M late-stage VC

INDUSTRY DRIVERS

- The natural evolution of IT toward more automated processes and optimized workflow
- Continued shift to cloud infrastructure, requiring automated network optimization
- Enterprise need to utilize internal data and extract valuable insights



INFORMATION TECHNOLOGY

Overview

We believe AI & ML will play a key role in the ongoing evolution of cloud computing and enterprise technology infrastructure. This is because AI & ML technologies have the potential to increase efficiency across not only the enterprise, but the entire cloud-computing landscape. This industry is often referred to as AIOps and represents a significant opportunity; IDC forecasts the market for global AI-systems to reach \$79 billion in 2022.⁴ We expect IT infrastructure management to be a critical component of this industry as the growing complexity of cloud-computing necessitates more sophisticated methods of improving efficiency and gaining visibility into networks.

One area where AI & ML is having a significant impact on enterprise computing is IT automation, which promises to reduce underutilized computing infrastructure while also freeing IT operations workers to focus on application development as opposed to IT management. Automation is becoming increasingly relevant as computing activity shifts to the cloud, where enterprises pay based on resource usage and are incentivized to ensure they do not consume more than they need.

We believe AI & ML technology is uniquely suited for IT automation. This technology has the capability to not only monitor infrastructure utilization in real time but can also predict future use, ensuring that adequate cloud resources are available during peak usage. Another enterprise pain point relates to time and cost of application deployment, which can be a very involved process for companies without a large IT team. A subset of AI & ML companies are focused on this problem, supplying developers and data scientists with tools that can help automate processes related to application deployment, diagnostics and compliance.

4: "Worldwide Spending on Artificial Intelligence Systems Will Grow to Nearly \$35.8 Billion in 2019, According to New IDC Spending Guide," IDC, March 11, 2019





INFORMATION TECHNOLOGY

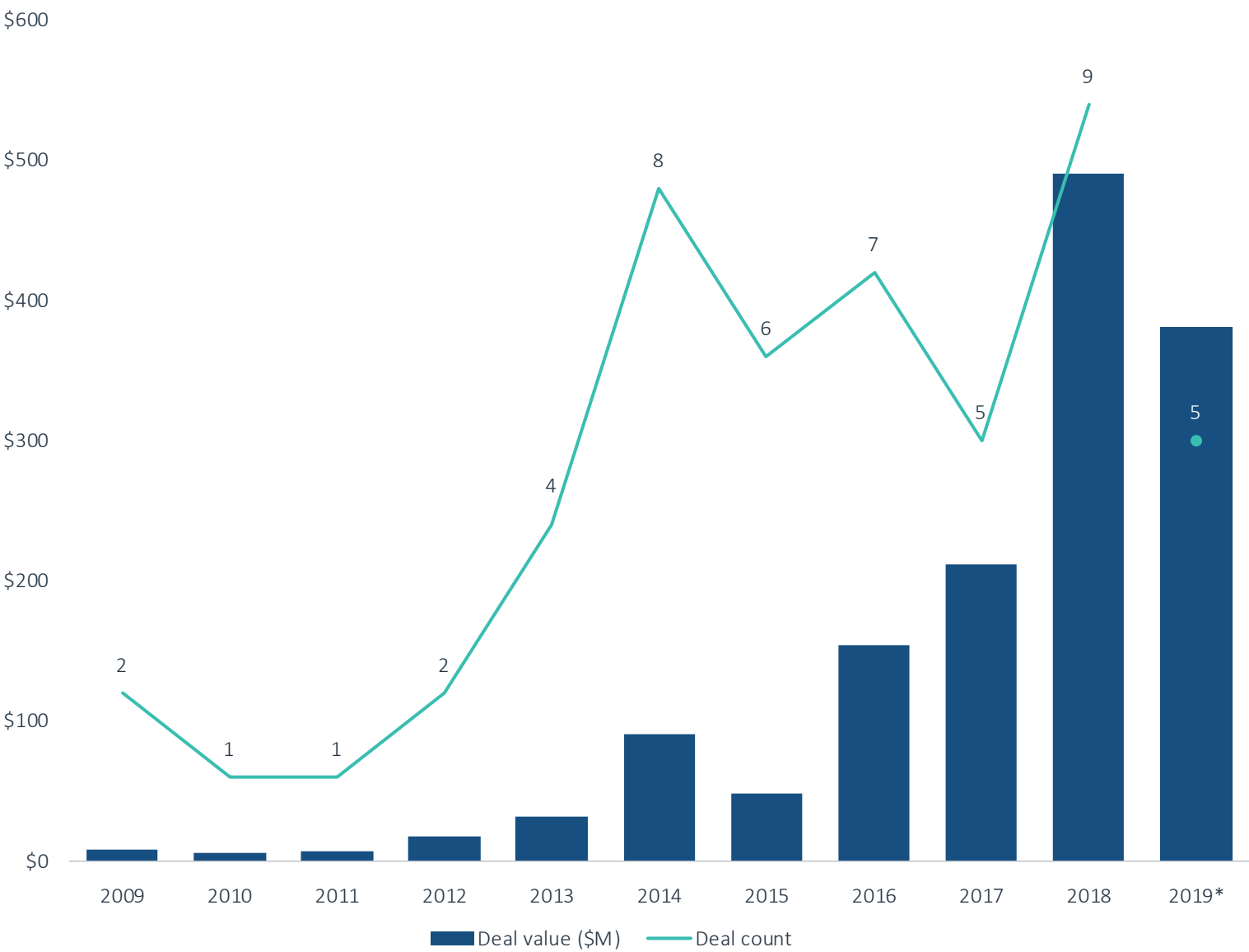
Opportunities

Regression for energy use optimization: We believe regression technologies can help optimize network assets and employee time by accelerating products to market, streamlining workflows and cutting costs on operating network hardware. For instance, RStor’s orchestration product allows seamless coordination of on-premise and cloud-computing resources and recommends where to run workloads based on data processed by the software. ML operations (MLOps) solutions can assist developers in rolling out ML applications, with tasks ranging from data-pipeline building to handling the compatibility of different file formats and monitoring performance of the models.

Clustering & classification for IT alert management: IT optimization solutions provide the ability to detect anomalies in network usage, cluster IT alerts around certain events and more. AI provider **Moogsoft** does this via unsupervised learning algorithms to group incoming IT requests into related “situations,” which gives IT professionals a much more streamlined and digestible workflow.

NLP and computer vision in pre-processing data: NLP and computer vision technologies can be useful in training AI & ML platforms by providing data training and testing environments for various applications. For example, AI-training platform **Figure Eight** (acquired by Appen) integrates NLP and computer vision technologies to bring structure to unstructured datasets.

Figure 19.
Information technology VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



INFORMATION TECHNOLOGY

Considerations

Success depends on AI & ML proliferation: Companies in this space are dependent on the success of the broader market they service. This means that companies in this segment, as more-or-less service providers to AI & ML developers, rely more on the current technology cycle's—and particularly AI's—success. Currently, widespread adoption of AI & ML technology appears extremely likely; however, there is still risk that IT companies may have to pivot away from their current focus.

Finding balance between customizability and standardization: Off-the-shelf AI & ML products or building tools may have some immediate use cases, but customization is often needed for more sophisticated clients. Shifting to more professional services could drive lower margins relative to other software. Providers will also need to ensure transparency and auditability of models.

Security risks: With access to other company's datasets, including customer data, operators in the IT space must be mindful of potential breaches that would compromise their business and reliability. Even one cybersecurity incident can do irreversible damage to a brand and business. Companies need to do all they can to ensure security.

Outlook

Dynamic allocation of IT infrastructure represents long-term opportunity: As cloud infrastructure enables more on-demand IT resource consumption, we believe ML algorithms will be critical in facilitating the corresponding resource allocations in real time. Predicting

resource demand is another potential use case of ML technology that will enable computing-infrastructure providers to anticipate where IT resources will be needed in the future, helping streamline delivery of IT services.

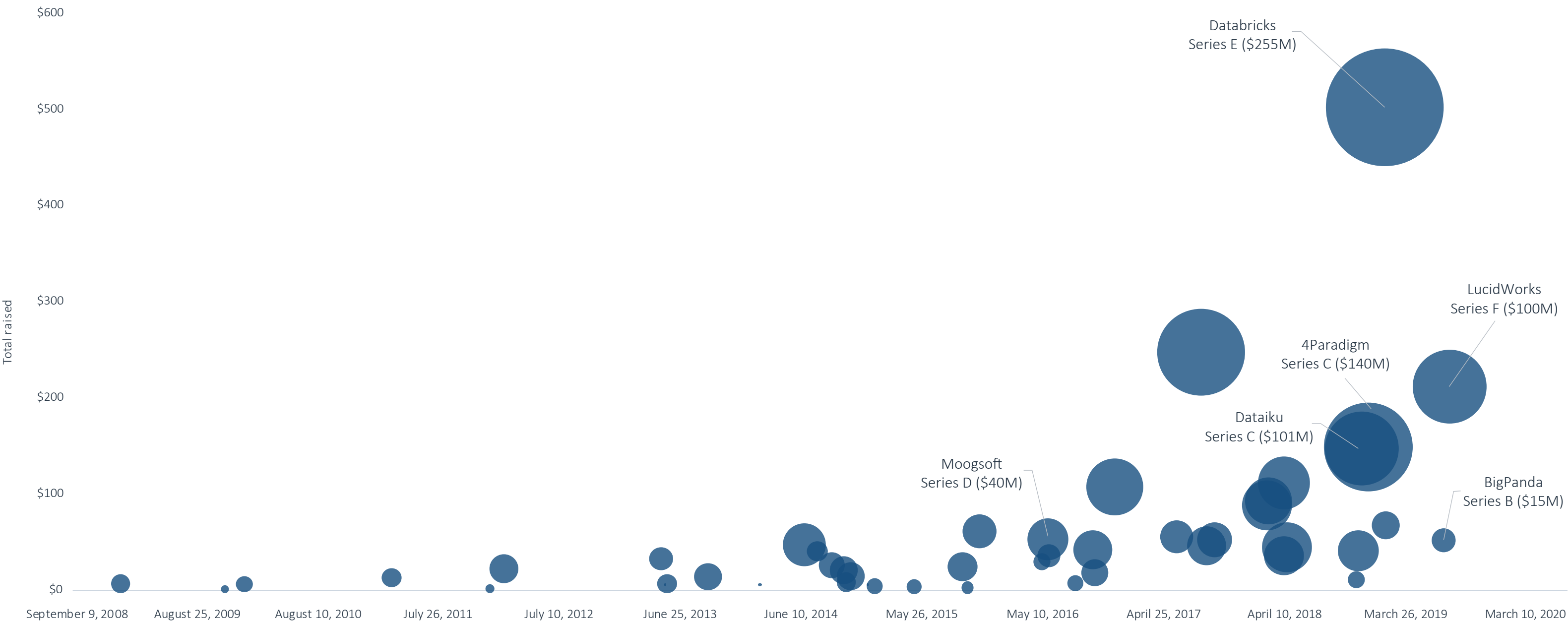
Distributed computing and edge framework present growth opportunity: IoT and edge computing will require even more coordination between public clouds and distributed devices, as well as new security threats. We believe AI & ML applications will be critical in facilitating the rollout of these next-gen architectures.

Broader AI & ML adoption key to success of IT segment: More adoption and implementation of AI & ML technologies across the IT landscape will be key to driving demand for support functions that companies in this space provide. While AI & ML currently represents only a fraction of enterprise IT spend, IDC forecasts growth approaching 40% over the next few years, which we expect will catalyze demand across the burgeoning ecosystem of AI & ML developer tools.



INFORMATION TECHNOLOGY

Figure 20.
Top information technology VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

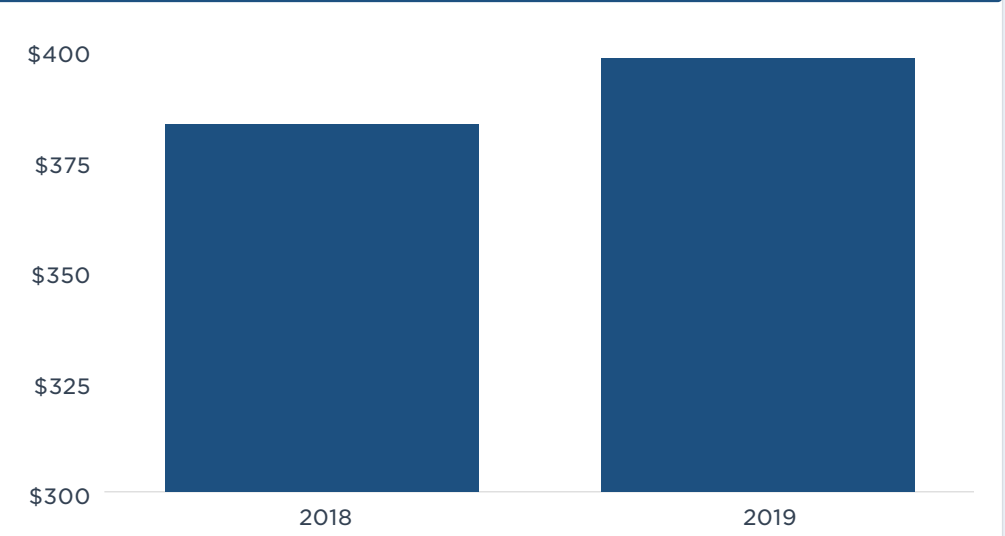
SEGMENT DEEP DIVE

Consumer AI



CONSUMER AI

Figure 21. MARKET SIZE (\$B)



Source: Consumer Technology Association. Represents estimated consumer electronics industry revenue.

APPLICATIONS

Attractive characteristics of this industry include TAM, ease of adoption and network effects.

Companies in the space generate revenue by selling products or software to individuals, and alternatively can monetize user data via advertising.

The main AI & ML applications in our dataset:

- NLP
- Computer vision
- Classification & clustering

KPIS

- Cost to service the customer
- Customer acquisition cost
- Repeat customers or users
- Engagement rate
- Precision or error rates
- Gross margin

KEY PROVIDERS



NOTABLE DEALS



April 2019
\$25M Series C



October 2018
\$527.5M IPO

INDUSTRY DRIVERS

- Demand for personalized technology solutions
- Continued use of personal AI tools, such as voice assistants and chat bots
- Demand for more augmented reality and recommendation services



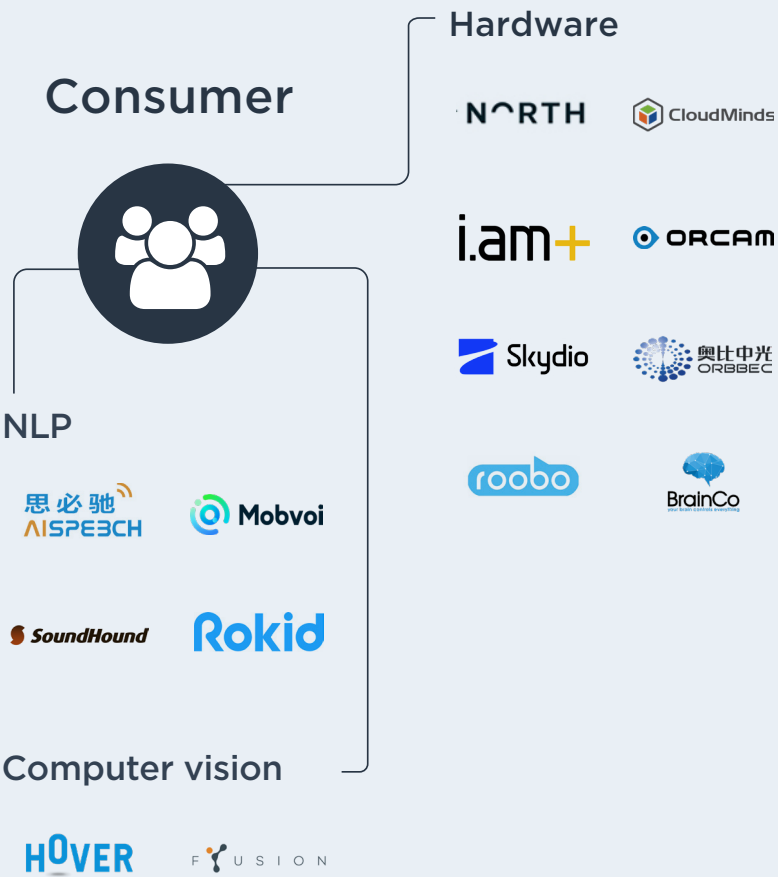
CONSUMER AI

Overview

While IT-focused AI & ML is primarily fixated on driving speed, agility and cost-savings across the enterprise, consumer AI focuses on providing positive and/or innovative personal experiences that can improve customer service functions or help sell products and services. Many consumers are likely already interacting with multiple applications powered by AI & ML in the form of voice assistants, recommendation engines and social media analytics. Smart speakers are a prime example of this, with 119 million purchased in the US in 2018, a 78% jump from the prior year, according to a survey from NPR and Edison Research.⁵ Usage is also trending positively, with another survey reporting that nearly 75% of smart speaker owners used the device at least once a day, with 57% using the device multiple times a day.⁶

We see voice as a key emerging user interface for AI-based consumer electronics. These tools utilize AI to understand and process the many ways in which consumers “ask” for things, turning spoken language into coded inputs that can be “answered” by computers. We believe AI assistants have improved significantly in recent years, and, given the impressive growth of in-home devices, we expect this market will continue to grow. The current technology still has a way to go to be truly conversational, but new approaches within reinforcement learning or deep generative models and the tailwinds of elevated consumer usage will keep improving the products.

This segment also includes consumer hardware applications that use AI & ML. While wearables make up much of this segment, consumer robotics and drones are a space



5: “The Smart Audio Report,” NPR & Edison Research, January 2019
6: “Here’s What People Are Really Doing With Their Alexa and Google Home Assistants,” Venture Beat, Arte Merritt, November 17, 2018



CONSUMER AI

where we see a lot of activity in the private markets. Recently, **Skydio**, the creator of a consumer drone that uses computer vision to fly and track a person or object, raised \$42 million in a Series B in February 2018. We see this segment benefiting from the falling costs of sensors, cameras and other inputs that should also reduce manufacturing costs.

Opportunities

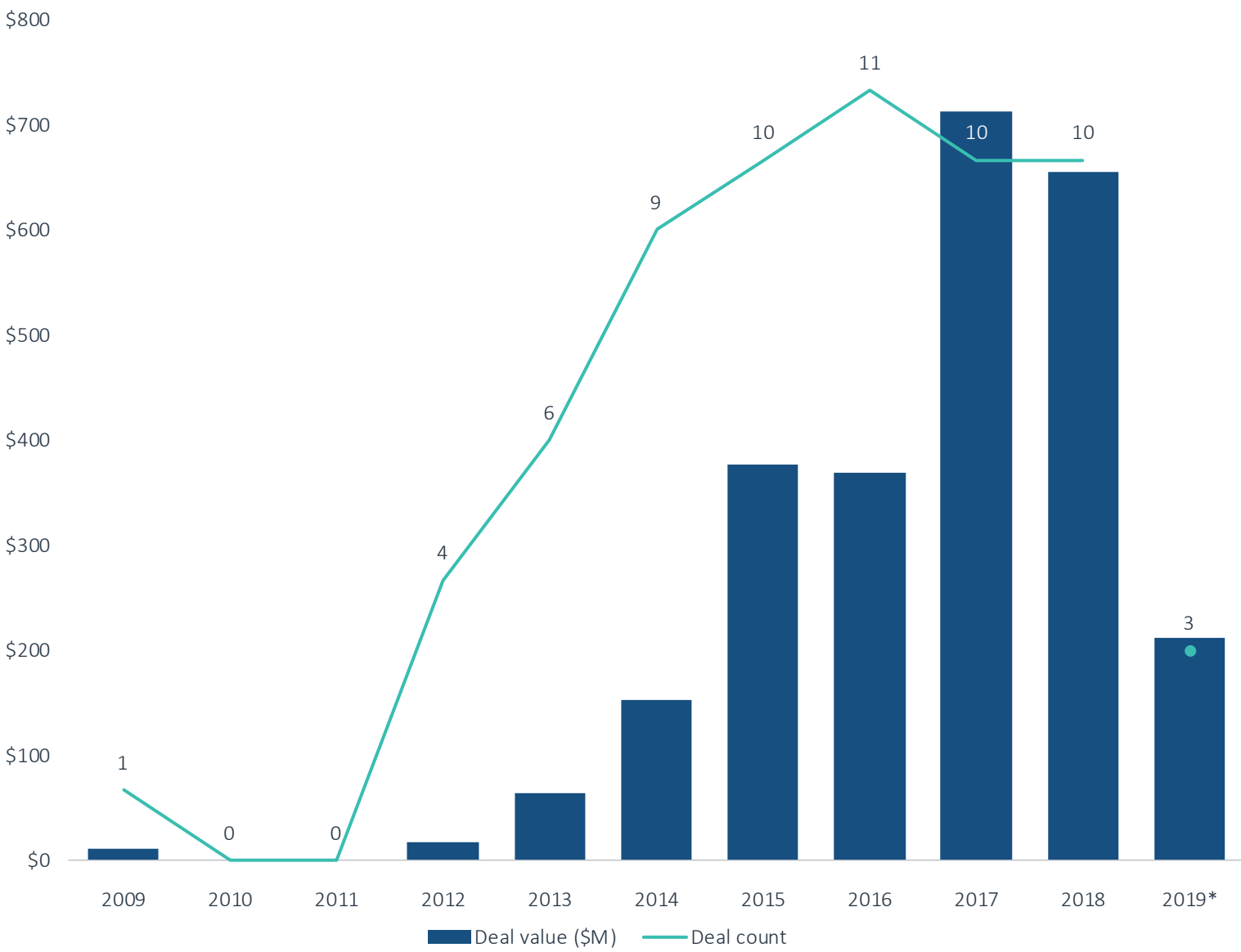
NLP for revolutionizing user interfaces: NLP capabilities form the foundation for any AI & ML application that interacts with voice or text input from consumers. Providers of voice assistants, robots and smart-home applications are essential users of this technology. We believe voice has the potential to become the next universal user interface, meaning NLP is likely to become embedded into a vast majority of consumer technology. For instance, **SoundHound** provides a product called Houndify that allows customers to integrate voice and conversational intelligence into their applications.

Computer vision for biometrics and personalization: Computer vision is the technology that will power augmented reality and facial recognition products. Common applications could include ecommerce functionality and digital identity with biometrics, both of which we expect will be important areas of future investment. Other consumer use cases include camera-tracking technology and driver-assist technology.

Considerations

Privacy concerns: An issue that has recently come to the surface is the privacy and security of an individual’s data, which is the basis of a majority of consumer applications of AI & ML. The reliance on sensitive personal data could become an issue for companies operating in

Figure 22.
Consumer AI VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



CONSUMER AI

this space as potential and enacted regulations or public opinion increase compliance and data-handling costs pressuring future profitability. Popular opinion plays a key role here as well, which could cause many users to either avoid some of the use cases or opt to not share data, neutralizing the network effect and model improvement that more input data provides. It will be crucial for companies in this space to tread lightly and consider the public relation implications of failures or mistakes.

Customer acquisition costs and churn must be kept in check: Selling to individual consumers provides a large number of potential clients; however, it results in lower value per sale. For instance, while it may be easier to sell to one individual than one enterprise, it takes a multitude of sales to achieve the same value. Given that there is often a much lower switching cost for an individual, customer retention is also more difficult, pressuring the company to continue to innovate, improve customer service and more—all of which increase costs.

Lower barriers to entry: The consumer space possesses somewhat lower barriers to entry which encourages more competition from both other AI & ML companies and non-AI products or services.

Outlook

We expect quick adoption of consumer AI & ML: We expect significant adoption of new technologies over the near term, similar to the explosion in smart-speaker usage, as consumers' online activities are increasingly driven by AI & ML technology. We expect this will foster strong demand among businesses seeking new ways to engage with their customers and increase sales.

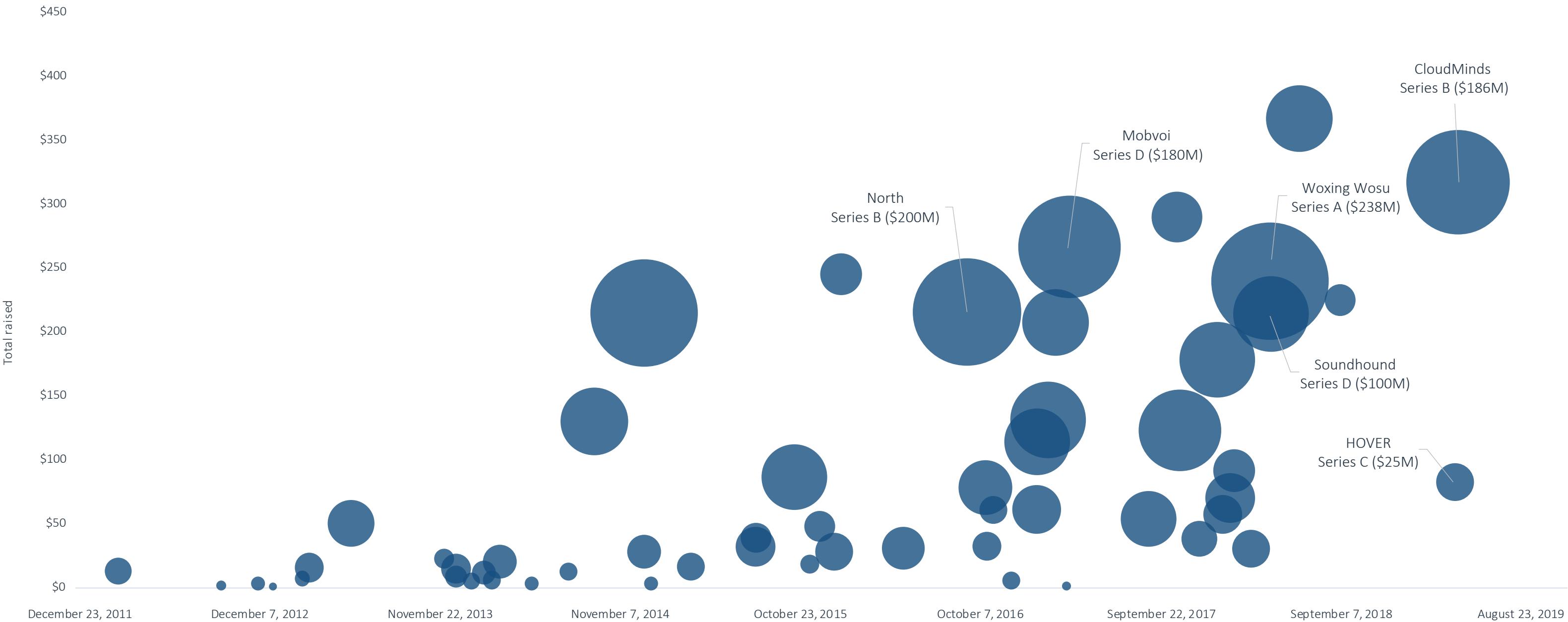
IoT is an area of expansion for consumer AI: The expansion of mobile devices will create more opportunities to connect across external networks (such as coordination between different products in a smart home) and other touchpoints (such as connecting home and car, larger city networks or automatically ordering groceries when running low). We see voice-based software becoming central to many consumer applications of AI & ML, leading to accelerated research and improvement in related technology. For example, virtual assistant software is likely to play a more substantial role as complex smart homes increasingly require an easy-to-use central interface that can interact with multiple systems.

Advancement of hardware will be crucial to the consumer AI market: Advancements in hardware will create new opportunities for devices related to smart homes, personal robotics and wearable technology. These products will generate significant amounts of data with the potential to enhance features and capabilities for consumers while building network effects for leading platforms.



CONSUMER AI

Figure 23.
Top consumer AI VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

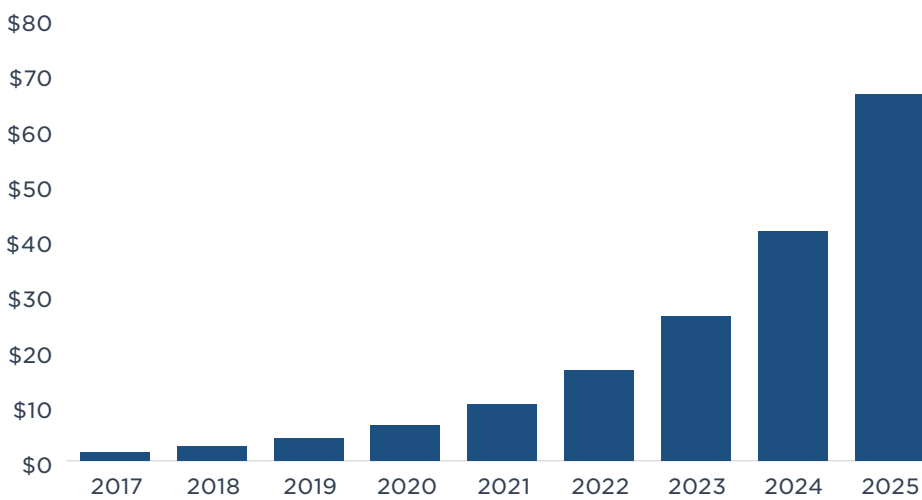
SEGMENT DEEP DIVE

Hardware



HARDWARE

Figure 24. MARKET SIZE (\$M)



Source: Tractica and PitchBook estimates. Represents estimated deep learning chip-set revenue.

APPLICATIONS

Attractive characteristics of businesses in the space include necessity for broader AI & ML implementation, TAM, and potential growth.

Companies in the space generate revenue by selling hardware solutions optimized for AI performance

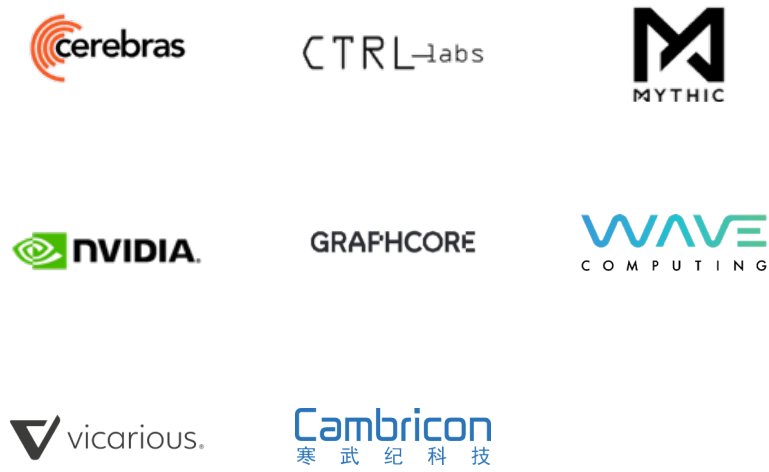
The main AI & ML applications in our dataset:

- Chips
- Robotics
- Wearables

KPIS

- Total processing power
- Energy efficiency
- Overall equipment effectiveness (OEE)
- R&D expenses as % of revenue
- Utilization

KEY PROVIDERS



NOTABLE DEALS



April 2019
\$150M Series B



September 2016
€392M M&A
Acquired by:
Intel

INDUSTRY DRIVERS

- Expansion of AI & ML applications driving demand for high-power compute infrastructure
- IoT and edge computing driving demand for advanced chips at the mobile device level
- Expansion of consumer and industrial devices, including smart speakers, wearables, robotics and driver-assist technologies



HARDWARE

Opportunities

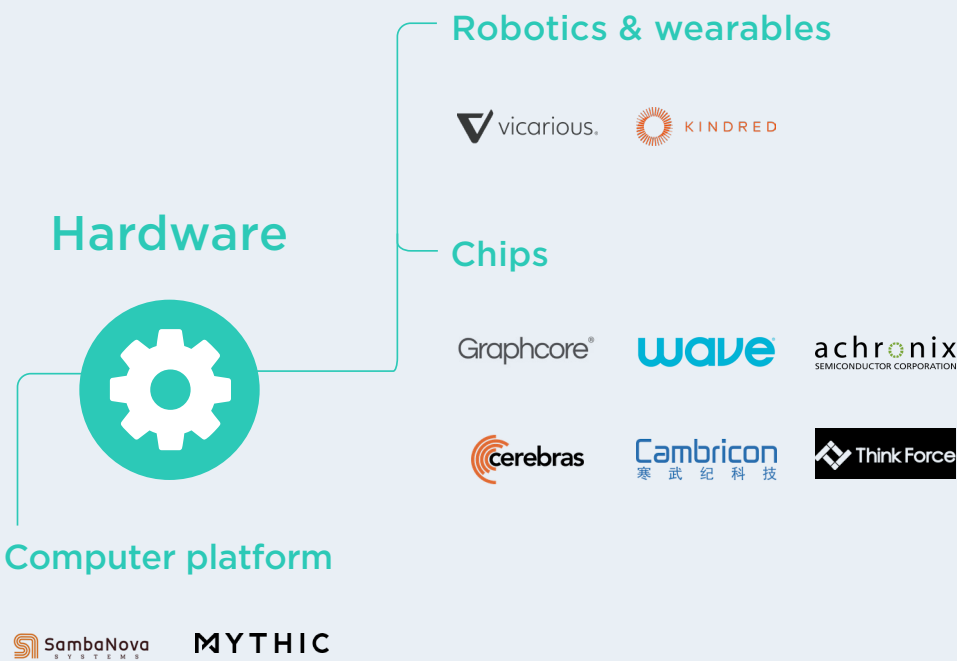
Improvements to computing power are critical to the success of AI & ML as a technology:

While much has been written about the applications of AI & ML software, equally important is the prevalence of hardware that is capable of powering it. Graphics processing units (GPUs) are the current chip of choice due to their memory bandwidth and parallelism, as the higher number of cores in a GPU relative to a CPU allows for the completion of more identical computations at the same time rather than completing them sequentially via a CPU. Because computations that rely on multitudes of independent calculations like large matrix multiplications are common in many AI & ML applications (especially neural networks) GPUs are well-suited to this task. Further, the market opportunity in the space is vast, with the market just for GPUs projected to be more than \$80 billion in the next five years.⁷

Proliferation of connected devices hinges on compatible hardware: The rise of IoT will require frequent interaction among countless connected machines. These machines will generate a continuous stream of real-time data necessary to drive ML models. As IoT ushers in a new era of edge computing, this will place more demand on chip providers to provide low-cost hardware capable of powering this distributed infrastructure.

Kneron has made edge computing a central piece of its chip products, with a dedicated AI processor called the neural processing unit (NPU) that has been optimized for performance on the edge.

7: “GPU Market Size Is Projected to Surpass USD 80 Billion by 2024,” Market Watch, February 13, 2019





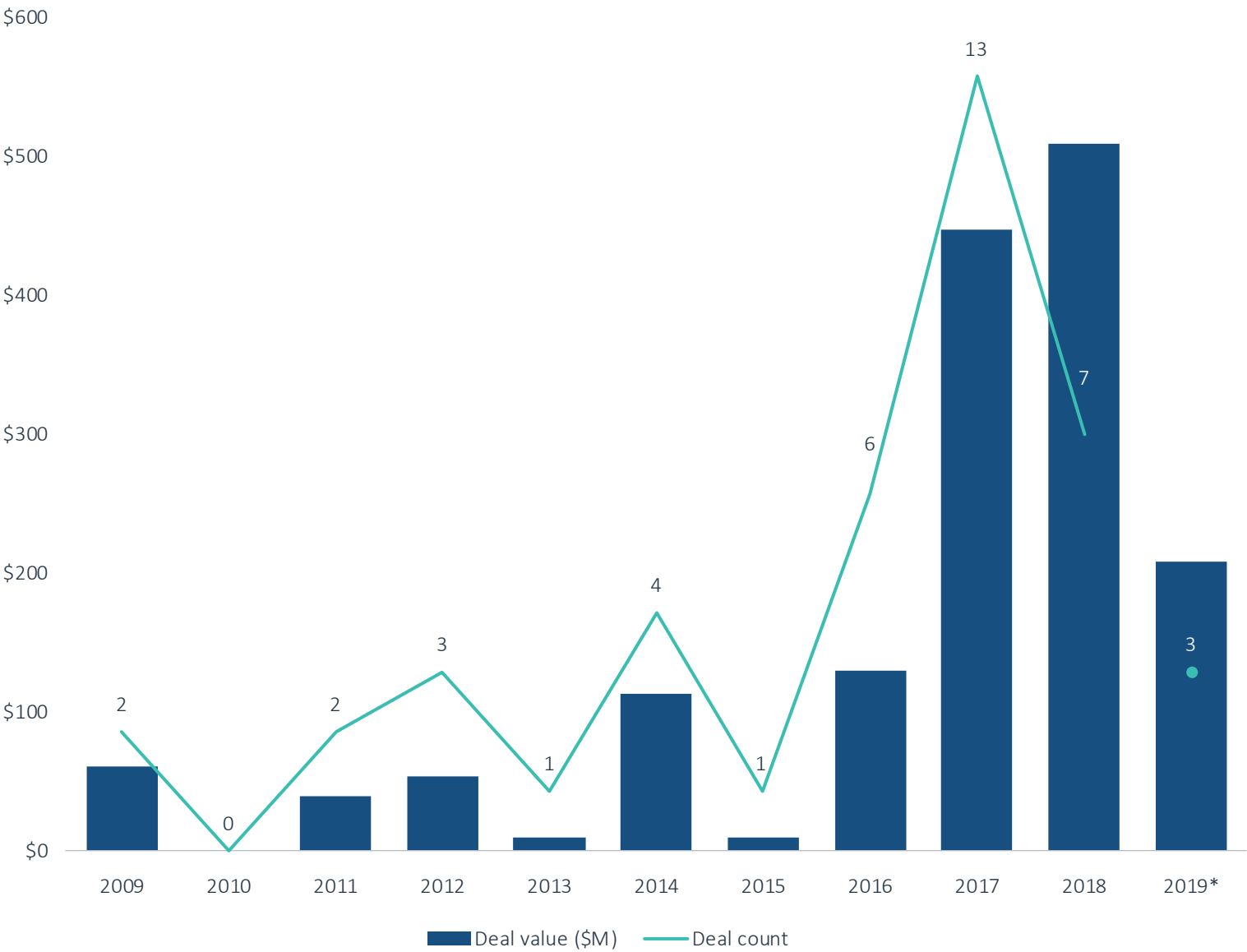
HARDWARE

Considerations

High capital intensity: Manufacturing requires significant capital to develop products that can quickly become commoditized. For this reason, we see high barriers to entry and expect most new products will come from incumbents. Nvidia and AMD spent \$2.4 billion and \$1.4 billion on R&D in 2018, representing 20.3% and 22.1% of revenue, respectively. The scale of these totals illustrate what startups are up against when trying to compete effectively in the space.

Large incumbents represent high barriers to entry: Even with a novel design and enough capital support, companies will face competition from large, established hardware manufacturers, including Nvidia’s GPUs and Intel’s field-programmable gate arrays (FPGAs). Other technology giants have also thrown their hats in the ring, with Google’s tensor processing units (TPUs) that are optimized to run functions on its Tensorflow framework. Tesla’s announced customized chip that will more efficiently run its cars, and Amazon’s growing line of in-home hardware devices. UK-based **Graphcore** is an example of a startup working to build a completely new processor specifically designed for AI & ML applications, dubbed IPU (intelligence processing unit); it successfully raised \$110 million in just over a year to bring this to reality.

Figure 25.
Hardware VC deal activity



Source: PitchBook | Geography: Global | *As of September 30, 2019



HARDWARE

Outlook

Hardware opportunity tracks broader adoption of AI & ML software: Increased implementation and deployment of AI & ML technologies is likely to drive greater demand for chips and other hardware devices. While incumbents can absorb some of this demand, AI & ML adoption will allow new providers to flourish with specialized or differentiated offerings.

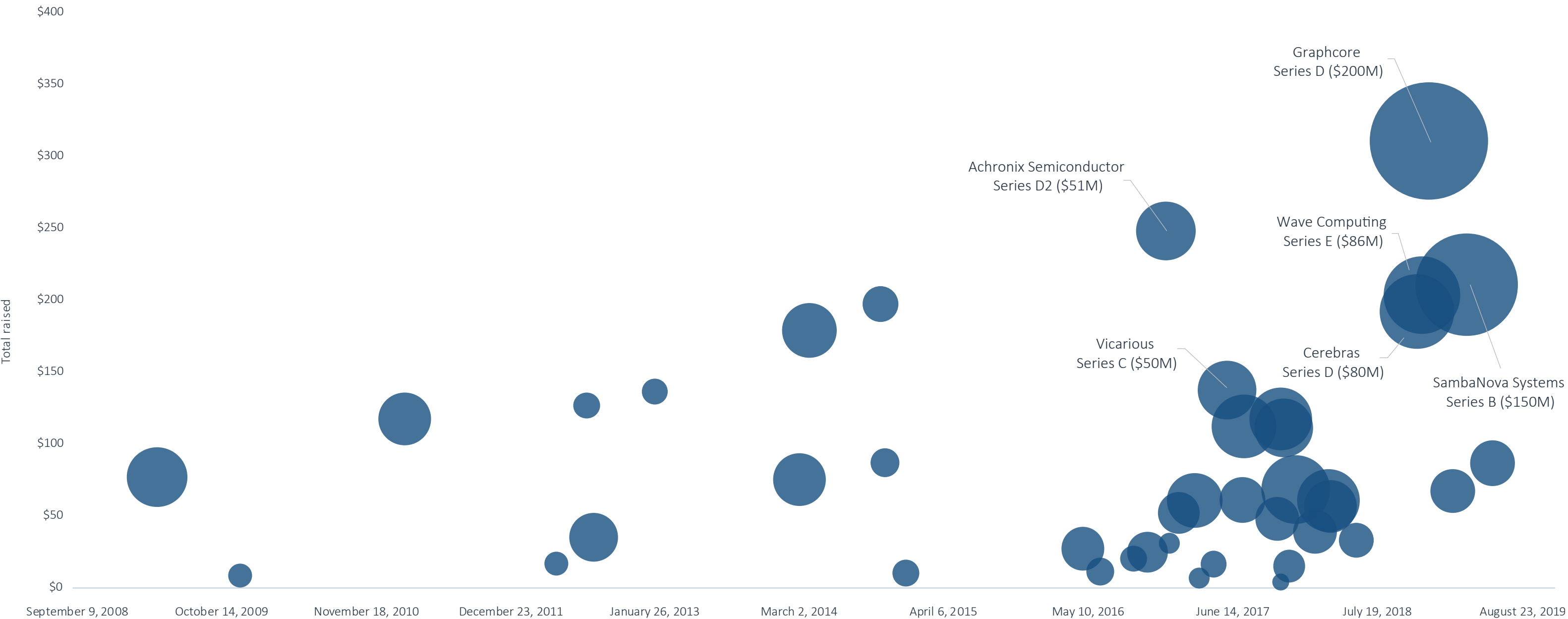
Optimized chips represent opportunity outside of GPUs: While GPUs remain a key component powering AI & ML technology, alternatives, such as field-programmable gate arrays (FPGAs), are also attracting investment. FPGAs are an enticing option due to their superior performance on certain datasets, energy efficiency and adaptability. This allows reconfiguration of existing chips for different purposes and drastically shortens implementation timelines. We expect to see continued diversity of processing infrastructure for AI & ML applications. The ability to customize hardware for a specific application (e.g. operating Tesla cars, TPUs for Tensorflow) seems to be picking up momentum as a way to reduce reliance on third parties in addition to improving speed and energy efficiency at the desired tasks.

Robotics and other devices will also drive growth: In addition to core chips, we expect the ecosystem for smart AI & ML hardware will continue to expand. These products include devices that can power autonomous or semi-autonomous driving capabilities, consumer wearables that can monitor movement and sound, and smart speakers or other video equipment for the home. Industrial use cases are also expanding, with coordinated, automated systems and robots running warehouses and factories.



HARDWARE

Figure 26.
Top hardware VC deals (\$M) by total capital raised



Source: PitchBook | Geography: Global | *As of September 30, 2019

Supplemental materials



Select company analysis

Z zymergen

Business overview

Zymergen is a biotechnology firm that researches, develops and manufactures commercial grade microbes. The companies applies AI & ML technology to make discoveries among the microbial genome that previously were not possible. The aim is to develop new kinds of industrial chemicals that are more sustainable and cheaper to produce.

400+ employees

Leadership

CEO, Co-founder: Joshua Hoffman
Co-founder & CSO: Zach Serber Ph.D
Co-founder & VP of Operations:
Jed Dean Ph.D
CTO: Aaron Kimball

Competitors

Ginkgo Bioworks, Arzeda, TeselaGen
Biotechnology, Qulab, Novozymes,
others

Financing history

Raised-to-date: \$592M over seven deals

Most recent round: \$406.5M Series C
(December 2018)

\$975M post-money valuation

First institutional round: \$2M (June 2013)

Ownership

SoftBank Investment Advisers, True Ventures,
Data Collective, Bioeconomy Capital,
Threshold Ventures, Obvious Ventures

GRAPHCORE

Business overview

Graphcore develops computer processors purpose-built for AI & ML applications. The company’s line of IPU’s (intelligence processing units) are designed to lower the cost of machine learning processing and improving efficiency by 10x-100x.

60+ employees

Leadership

Co-founder & CEO: Nigel Toon
Co-founder & CTO: Simon Knowles
CFO: Nick Davies

Competitors

Nvidia, Cerebras, Wave Computing,
Kneron, Thinkforce

Financing history

Raised-to-date: \$310M to date over six deals

Most recent round: \$200M Series D
(December 2018)

\$1.7B post-money valuation

First institutional round: \$24.7M (October
2016)

Ownership

Sequoia Capital, Atomico, Amadeus Capital
Partners, Dell Technologies Capital, Draper
Esprit, Foundation Capital



SUPPLEMENTAL MATERIALS

Select company analysis



Business overview

Narrative Science is an AI technology company developing a natural language generation engine. The product is designed to use data to generate reports that perfectly mimic the logic, language, analytics and formatting of reports authored by an analyst. The reports can provide automated data-driven insights for business leaders.

100+ employees

Leadership

CEO & Co-founder: Stuart Frankel JD
Chief Scientist & co-founder: Kristian Hammond Ph.D
CTO: Adam Kanouse
COO: Nick Beil

Competitors

Nugit, vPhrase, Forward Lane, Phrasee, AX Semantics

Financing history

Raised-to-date: \$43.4M over six deals.

Most recent round: \$11M Series D (April 2017)
\$137.5M post-money valuation

First institutional round: \$1.4M (April 2010)

Ownership

USAA Ventures, In-Q-Tel, Sapphire Ventures, Battery Ventures, SV Angel, Jump Capital



Business overview

Bowery operates an indoor farming business focused on organic produce that uses less water than traditional agriculture, requires no pesticides and is 100x more productive over the same land footprint as traditional farms. Produce currently includes lettuce, leafy greens and herbs.

65+ employees

Leadership

Co-founder & CEO: Irving Fain
Co-founder & Farm facilities: Brian Falther
CFO: Darren Thompson

Competitors

Competes with Plenty, Gotham Greens, BrightFarms, AeroFarms, TruLeaf

Financing history

Raised-to-date: \$187M over three deals

Most recent round: \$140M Series B (December 2018)

First institutional round: \$7.5M (October 2015)

Ownership

Clayton Capital Partners, Enterprise Rent-A-Car, Hyundai CRADLE, Thayer Ventures, Second Avenue Partners, Via ID, Idealab, GV, GGV Capital, General Catalyst, Temasek, First Round Capital, RRE Ventures, Dara Khosrowshahi



SUPPLEMENTAL MATERIALS

Additional VC data

Figure 27.
AI & ML VC deal activity

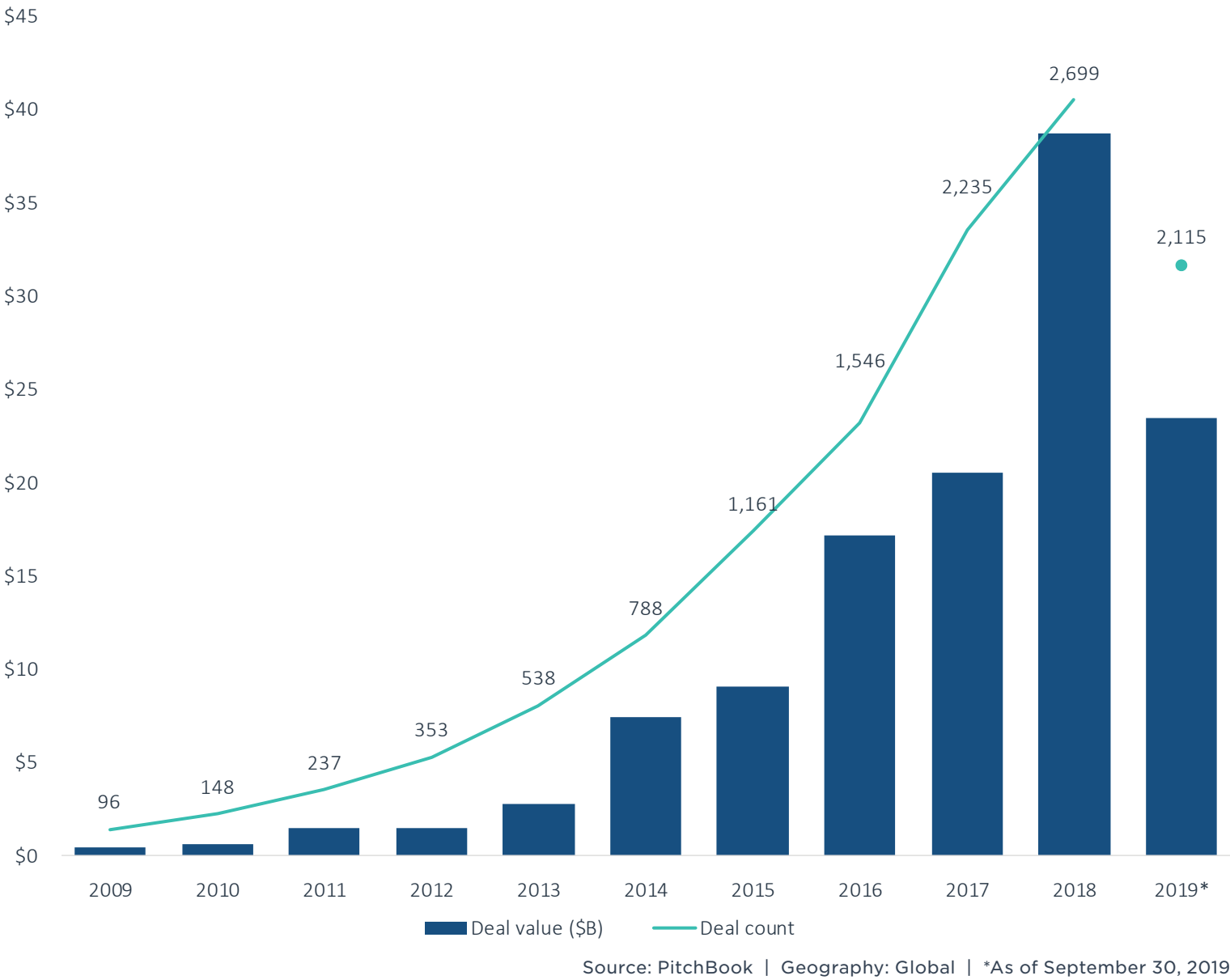


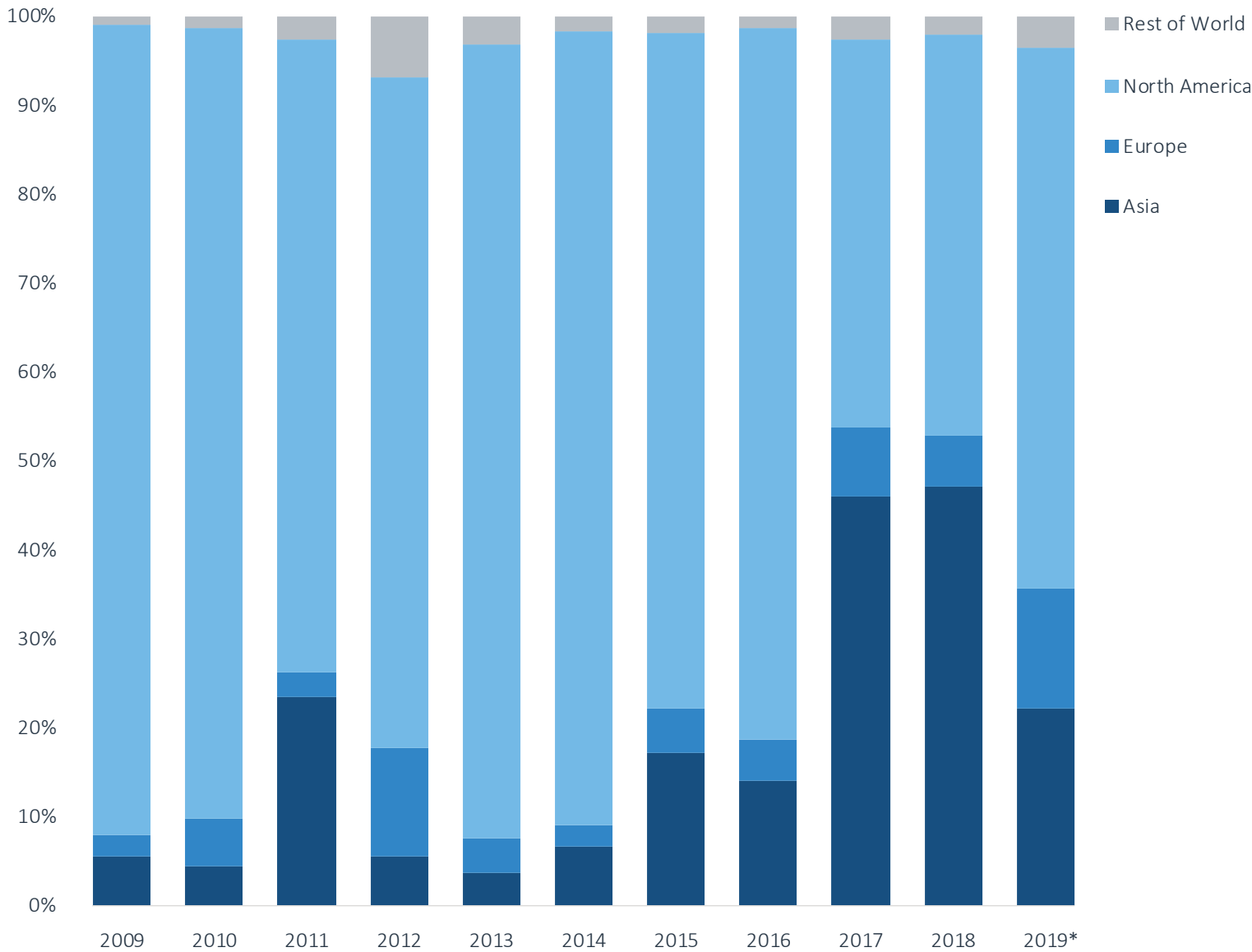
Figure 28. NOTABLE VC DEALS

 December 2018 \$407M Series C Investors: SoftBank, Two Sigma	 June 2018 \$200M Series E Investors: Accel, IVP, Gen Atlantic
 June 2018 \$392M Series E Investors: IVP, Cross Creek Adv	 September 2018 \$50M Series E Investors: KKR, Vitrivian Partners
 May 2016 \$5.6B Series G Investors: T. Rowe Price, Tiger Global	 January 2016 \$880M Series K Investors: VSL, Nautilus



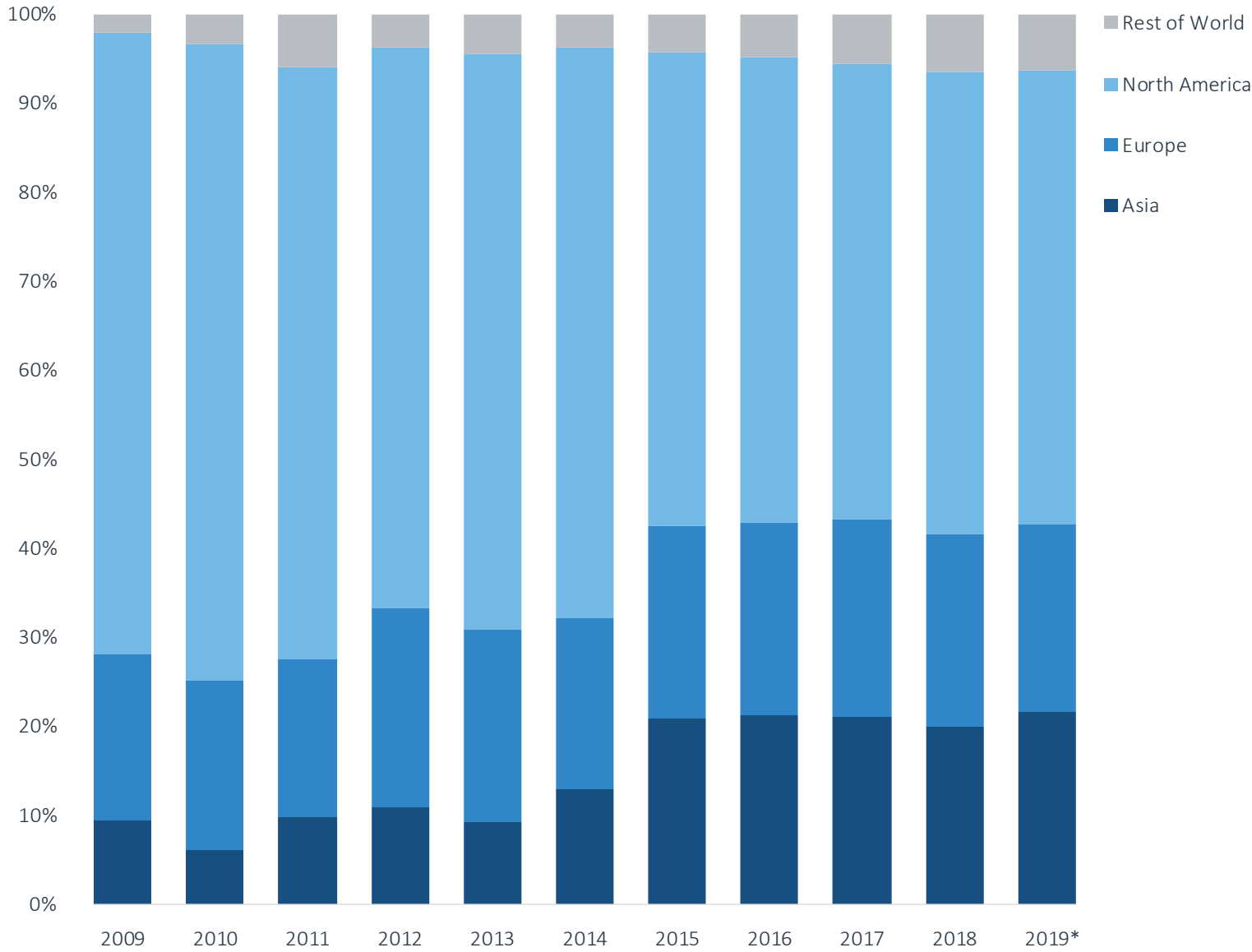
SUPPLEMENTAL MATERIALS

Figure 29.
AI & ML VC deals (\$) by region



Source: PitchBook | Geography: Global | *As of September 30, 2019

Figure 30.
AI & ML VC deals (#) by region



Source: PitchBook | Geography: Global | *As of September 30, 2019



SUPPLEMENTAL MATERIALS

Figure 31.
Median AI & ML VC deal size (\$M) by stage

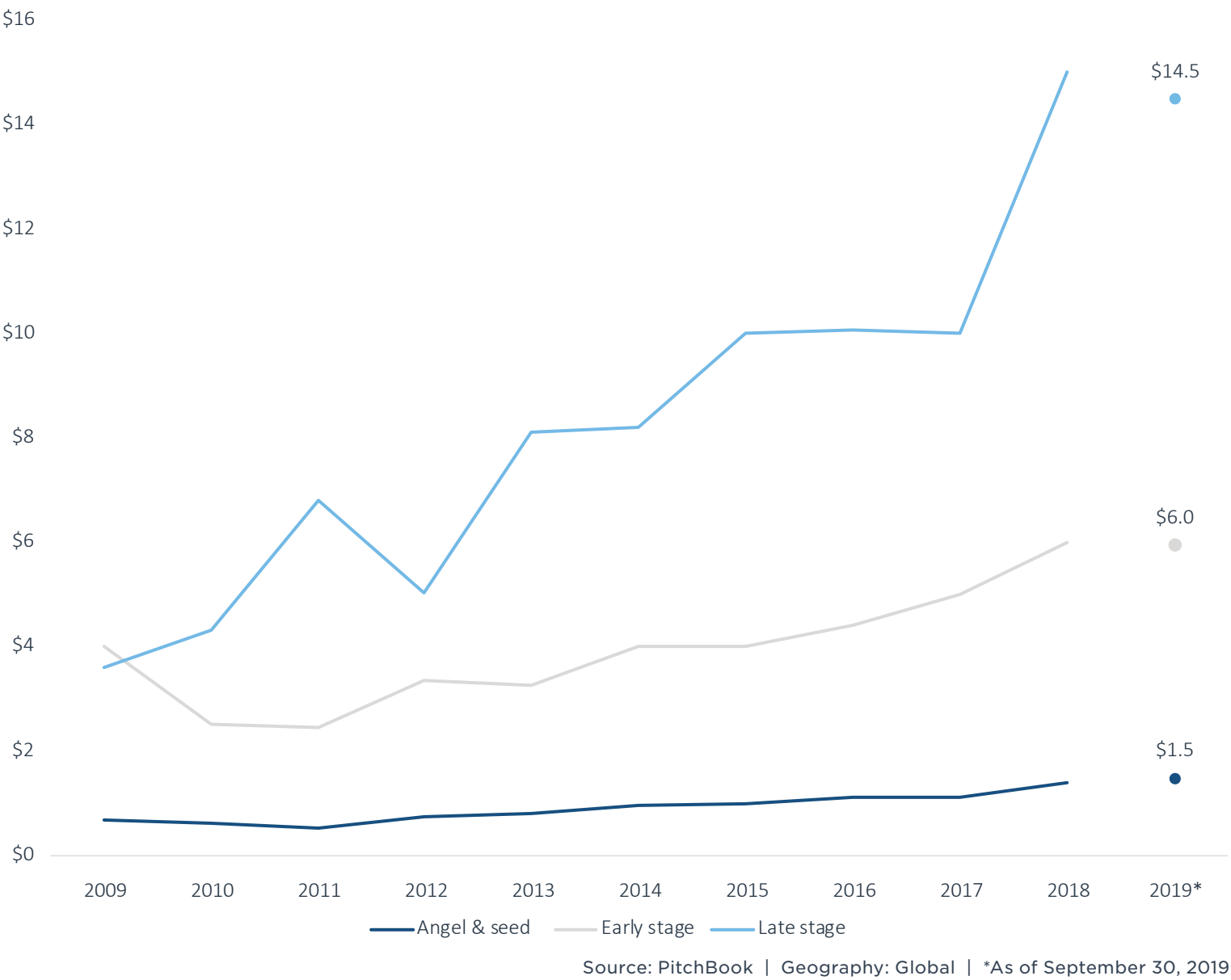
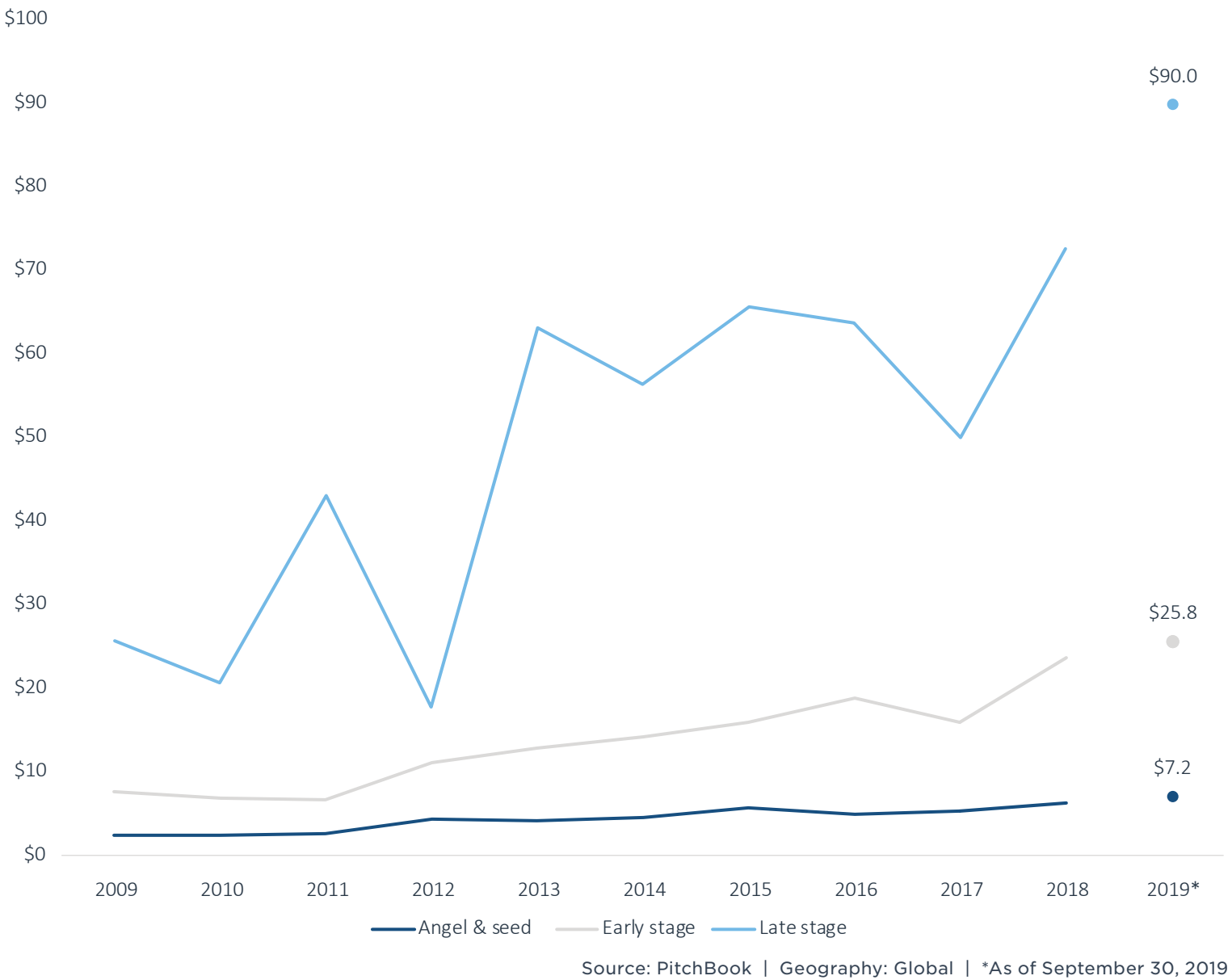


Figure 32.
Median AI & ML VC pre-money valuation (\$M) by stage





SUPPLEMENTAL MATERIALS

Figure 33.
AI & ML VC exit activity

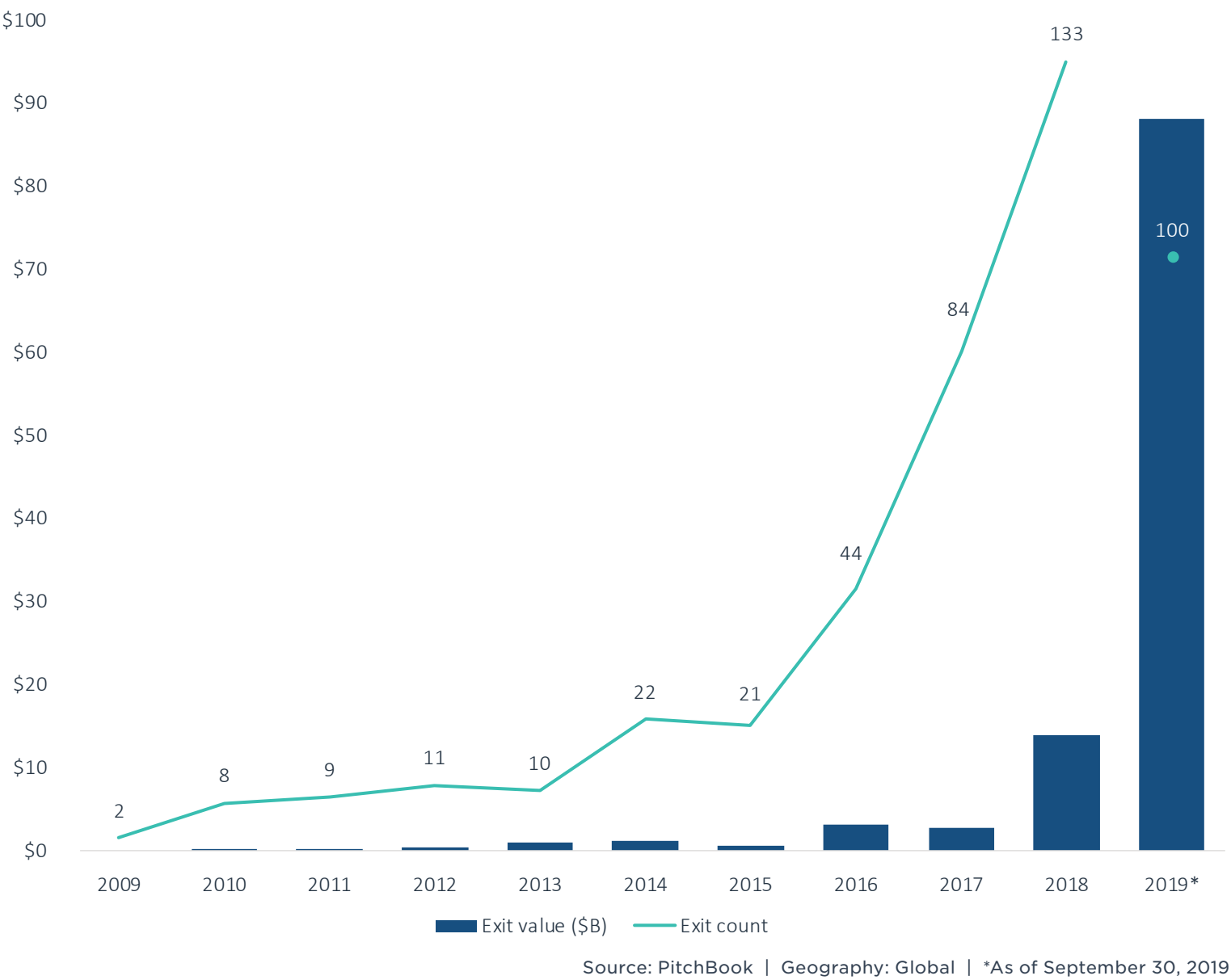


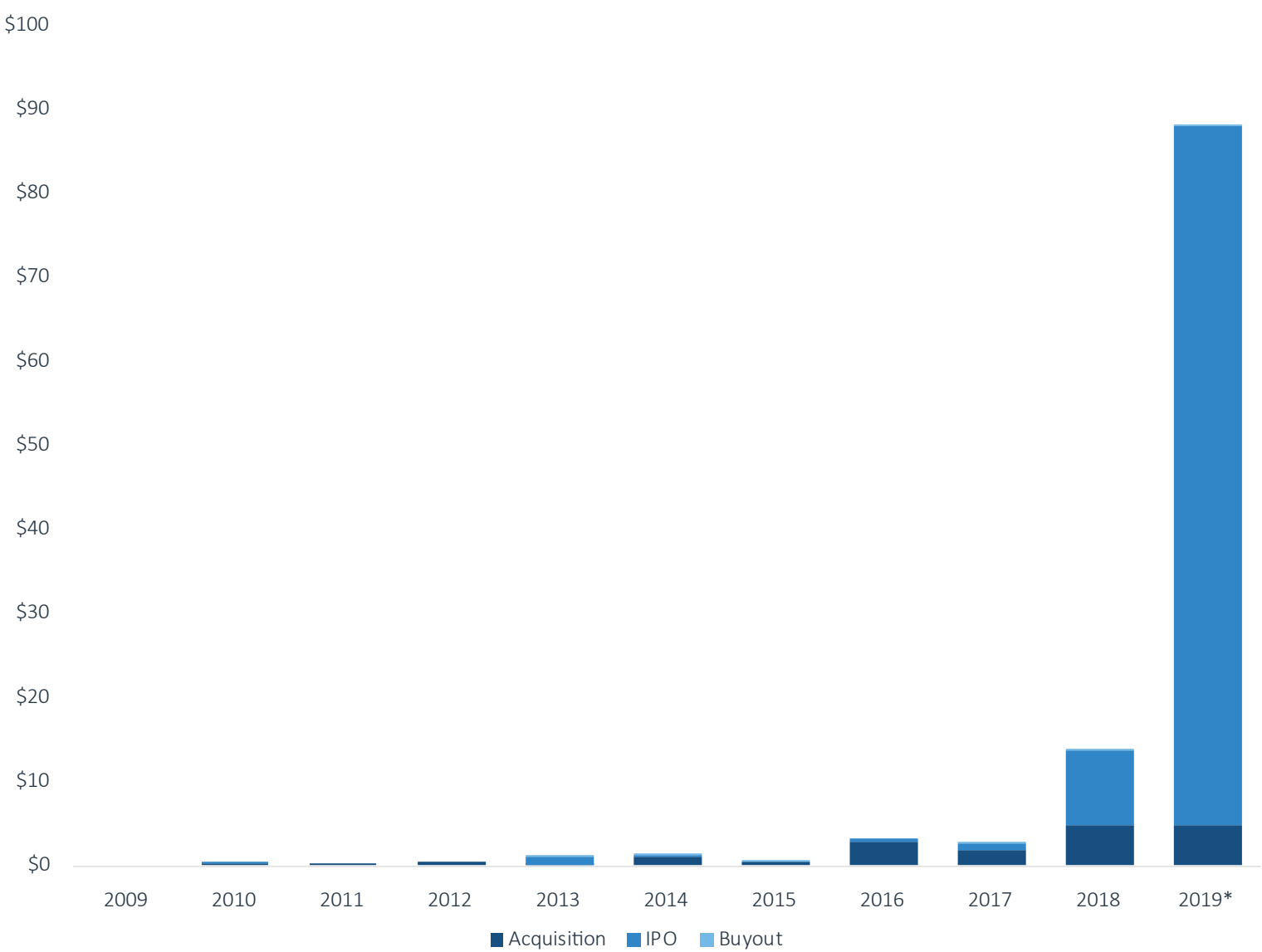
Figure 34. NOTABLE VC EXITS

 January 2019 \$200M Acquired by: 	 April 2018 \$1.9B Acquired by: 
 April 2018 \$550M Acquired by: 	 November 2017 \$454M Acquired by: 
 May 2016 \$1B Acquired by: 	 January 2014 \$650M Acquired by: 



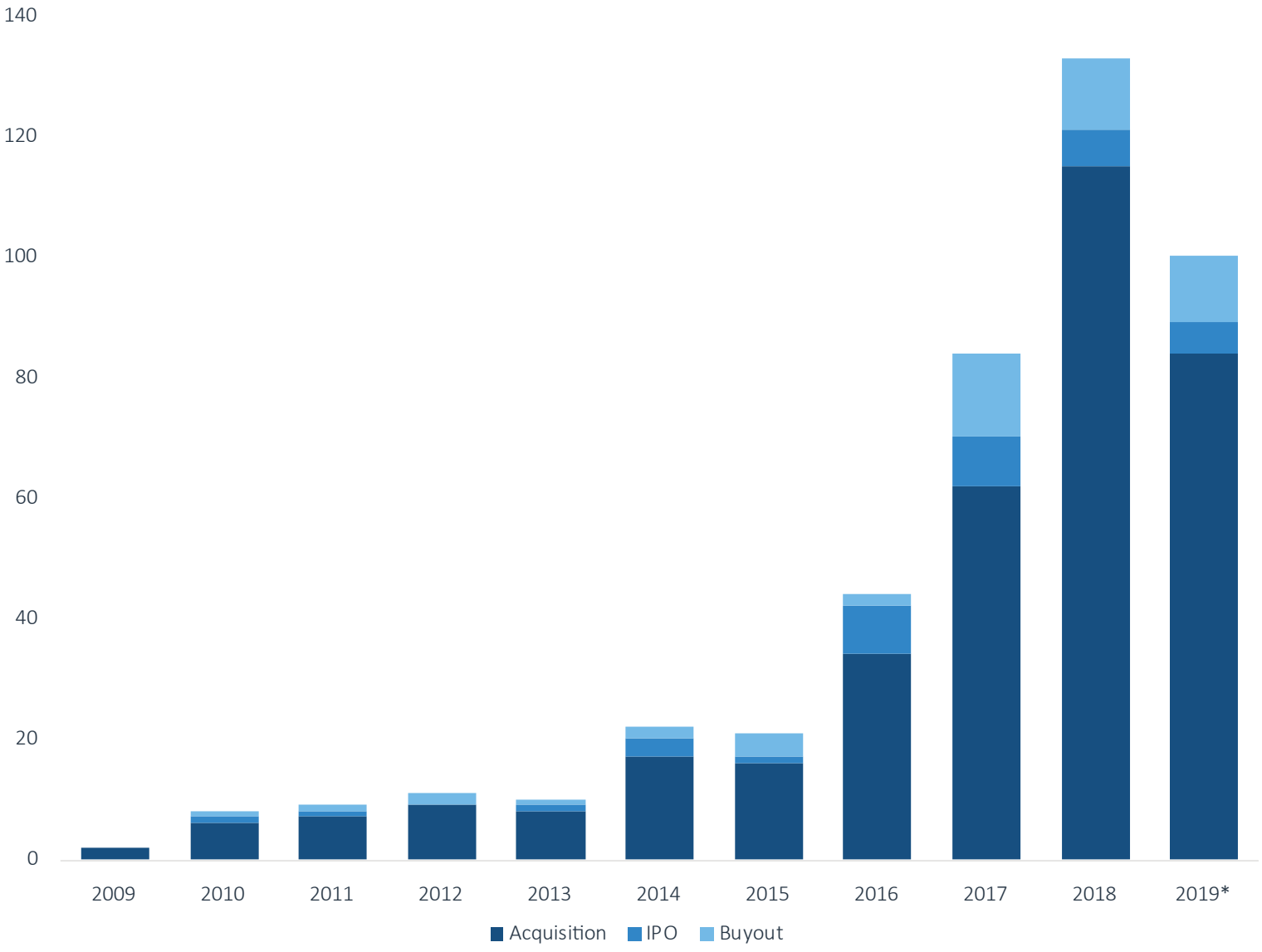
SUPPLEMENTAL MATERIALS

Figure 35.
AI & ML VC exits (\$B) by type



Source: PitchBook | Geography: Global | *As of September 30, 2019

Figure 36.
AI & ML VC exits (#) by type



Source: PitchBook | Geography: Global | *As of September 30, 2019



SUPPLEMENTAL MATERIALS

Figure 37.
Top VC-backed AI & ML companies by most recent post-valuation

COMPANY	SEGMENT	DEAL SIZE (\$M)	PRE-MONEY VALUATION (\$M)	POST-MONEY VALUATION (\$M)	COUNTRY
Bytedance	Consumer Products and Services (B2C)	\$3,000.0	\$72,000.0	\$75,000.0	China
Palantir Technologies	Information Technology	\$880.0	\$24,120.0	\$25,000.0	USA
Kuaishou	Information Technology	\$1,000.0	\$17,000.0	\$18,000.0	China
Bitmain	Information Technology	\$734.8	\$11,265.3	\$12,000.0	China
Ping An Medical and Healthcare Management	Healthcare	\$1,150.0	\$7,650.0	\$8,800.0	China
SenseTime	Information Technology	\$1,000.0	\$6,600.0	\$7,600.0	China
UiPath	Information Technology	\$568.0	\$6,532.0	\$7,100.0	USA
Samsara	Information Technology	\$300.0	\$6,000.0	\$6,300.0	USA
Ubtech	Consumer Products and Services (B2C)	\$820.0	\$4,180.0	\$5,000.0	China
Face++	Information Technology	\$750.0	\$3,500.0	\$4,000.0	China

Source: PitchBook | Geography: Global | *As of September 30, 2019



SUPPLEMENTAL MATERIALS

Figure 38.
Top investors in AI & ML by VC capital invested*

INVESTOR NAME	CAPITAL INVESTED (\$M)
New Enterprise Associates	\$8,521.9
Fort Ross Ventures	\$5,723.3
Sway Ventures	\$5,667.7
USAA Corporate Development	\$5,659.9
Caspian Venture Capital	\$5,607.6
Sequoia Capital China	\$4,814.6
Qiming Venture Partners	\$4,665.4
GV	\$4,076.2
Accel	\$3,884.8
GGV Capital	\$3,819.7

Source: PitchBook | Geography: Global | *As of September 30, 2019
Note: Capital invested (\$M) represents total deal value for the transactions these investors participated in, not individual contribution.

Figure 39.
Top investors in AI & ML by VC deal count

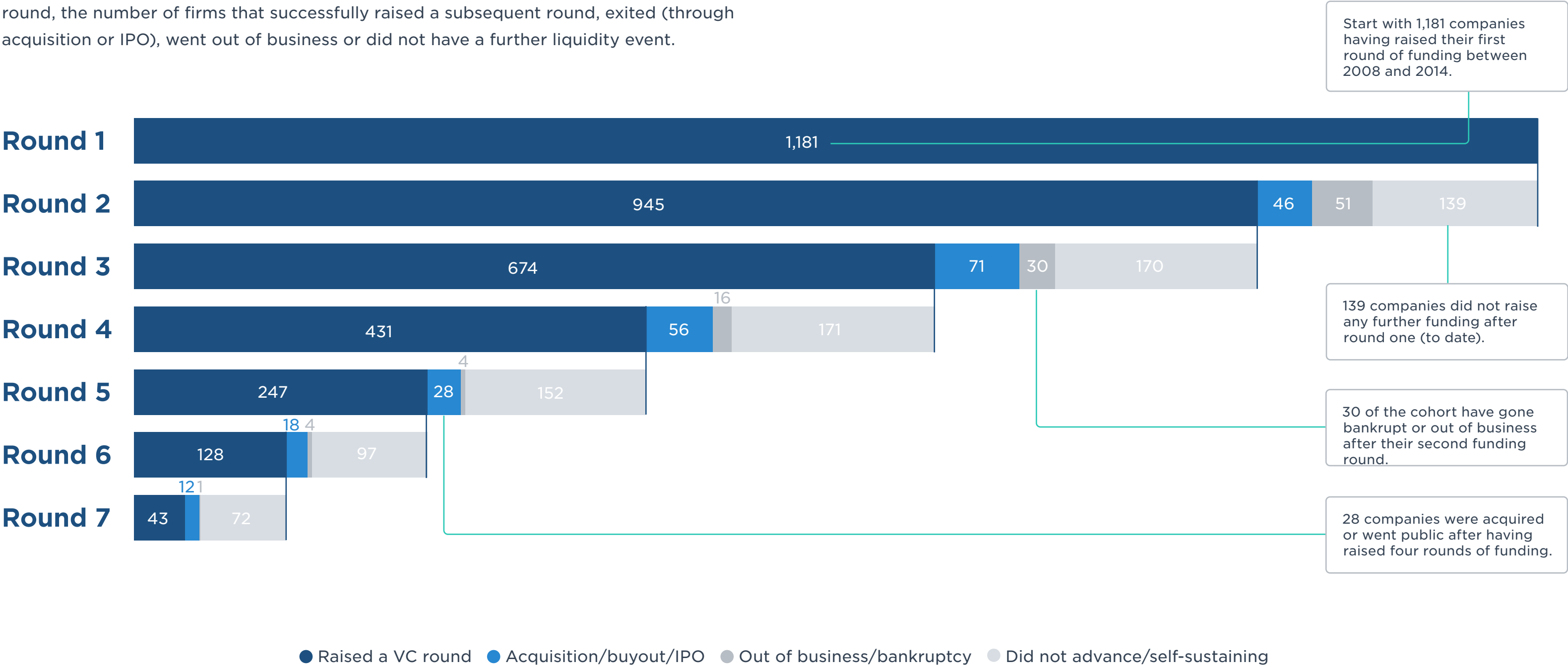
INVESTOR NAME	DEAL COUNT
Khosla Ventures	122
Right Side Capital Management	114
New Enterprise Associates	113
Accel	112
Intel Capital	100
Andreessen Horowitz	94
GV	92
Data Collective	89
First Round Capital	79
General Catalyst	74

Source: PitchBook | Geography: Global | *As of September 30, 2019



VC funnel

This VC funnel uses PitchBook data to analyze the VC funding life cycle by highlighting, by round, the number of firms that successfully raised a subsequent round, exited (through acquisition or IPO), went out of business or did not have a further liquidity event.





About PitchBook Emerging Tech Research

Independent, objective and timely market intel

As the private markets continue to grow in complexity and competition, it's essential for investors to understand the industries, sectors and companies driving the asset class.

Our Emerging Tech Research provides detailed analysis of nascent tech sectors so you can better navigate the changing markets you operate in—and pursue new opportunities with confidence.

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