



Artificial Intelligence

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Executive Summary

AI is driving the next industrial revolution

For decades, artificial intelligence (AI) was the domain of university and corporate R&D labs. Recent progress in machine learning (ML) on the back of improved algorithms (e.g., Google's AlphaGo, OpenAI's GPT-3) and increasing computing power have enabled AI to solve real-life problems. GlobalData estimates the total AI market will be worth \$1 trillion by 2030, up from \$103 billion in 2023 at a compound annual growth rate of 39%. In the coming decade, the country that emerges on top in AI will lead the Fourth Industrial Revolution.

Artificial general intelligence is still a distant dream

Despite the hype, artificial general intelligence (AGI), or the ability of machines to do anything that a human can and possess consciousness, is still decades away. However, 'good enough' AI is already here, capable of human interaction, motion, and decision-making. For example, OpenAI's ChatGPT can write original prose and chat with human fluency, DeepMind's algorithms can beat the best human chess players, and Boston Dynamics' Atlas robots can somersault. If this evolution continues, it could upend the labor-based capitalist economic model.

Generative AI is emerging as a force of creative destruction

Generative AI is the most talked-about area of AI today. It could drive the next level of business process automation across many industries and cause creative destruction by dismantling old business models while creating new ones. Conversely, it also creates both sustainability and regulatory challenges.

AI is driving the escalation in US-China trade tensions

The most advanced AI technologies rely on powerful chips. As such, the ongoing US-China trade dispute, which has led to the US prohibiting exports to China of either AI chips or the tools to manufacture them, will disrupt the competitive landscape. China will lose its AI market dominance if it does not secure access to advanced chip manufacturing technology.

Leaders and challengers

This report focuses on four key types of advanced AI capabilities.

Human-AI interaction

- **Leaders:** Alibaba, Alphabet, Amazon, Baidu, Megvii, Microsoft.
- **Challengers:** AEye, Clarifai, Hugging Face, iFlytek, SenseTime.

Decision-making

- **Leaders:** Alibaba, Alphabet, Amazon, Baidu, IBM, Microsoft, Tesla.
- **Challengers:** ANYbotics, Brain Corp, C3.ai, H2O.ai, SparkCognition.

Motion

- **Leaders:** ABB, Amazon, Festo, iRobot, Midea, Festo, Robotiq.
- **Challengers:** Ecovacs, ElliQ, Hyundai (Boston Dynamics).

Creation (or generative AI)

- **Leaders:** Alphabet, Anthropic, Hugging Face, Meta, Mistral AI, OpenAI.
- **Challengers:** Aleph Alpha, Amazon, Baichuan, Cohere, Moonshot AI, xAI.

Inside

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Related reports

- [Global Data's AI Governance Framework](#)
- [Next-Generation Chips](#)
- [High-Performance Computing](#)
- [Executive AI Briefing – 3rd Edition](#)
- [Data Analytics](#)
- [Cloud Computing](#)
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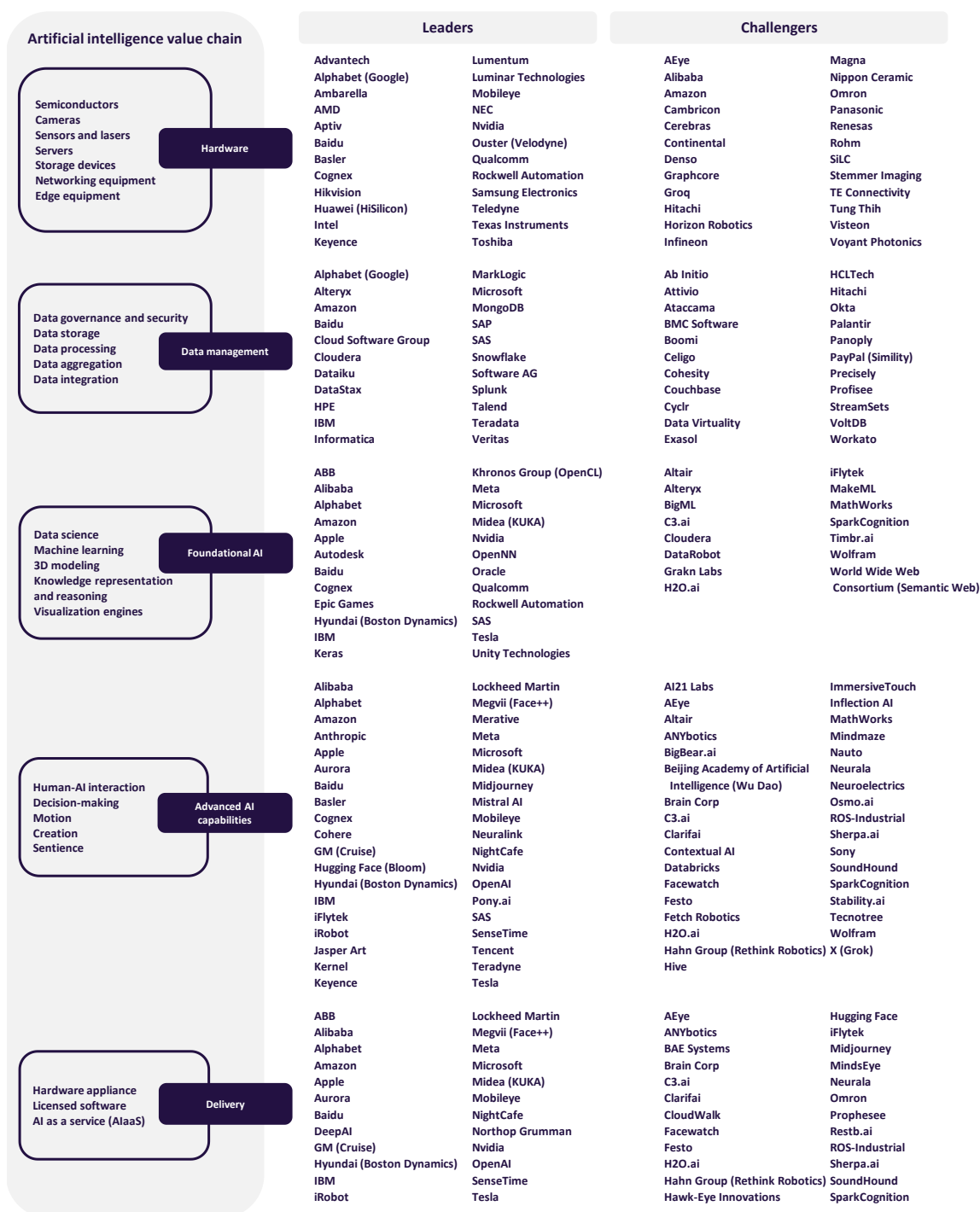
Report type

- Single theme
- Multi-theme
- Sector scorecard

Players

AI is still an immature market, but it contains a plethora of both big technology companies and disruptors. Technology players with large data sets and advanced AI chip capabilities are leading the pack, with US tech giants dominating each value chain segment and the Chinese players rapidly advancing. In the chart below, we identify the leaders and challengers in each segment.

Who are the leading players in the AI theme, and where do they sit in the value chain?



Source: GlobalData

Technology Briefing

What is AI?

Artificial intelligence (AI) refers to software-based systems that use data inputs to make decisions on their own.

AI has been a dream of humanity for centuries, but it was not until the invention of computers that we got closer to realizing it. The Greek poem *Argonautica*, written by Apollonius Rhodius in the third century BC, refers to a giant made of bronze called Talos, which very much fits the description of a robot with AI.

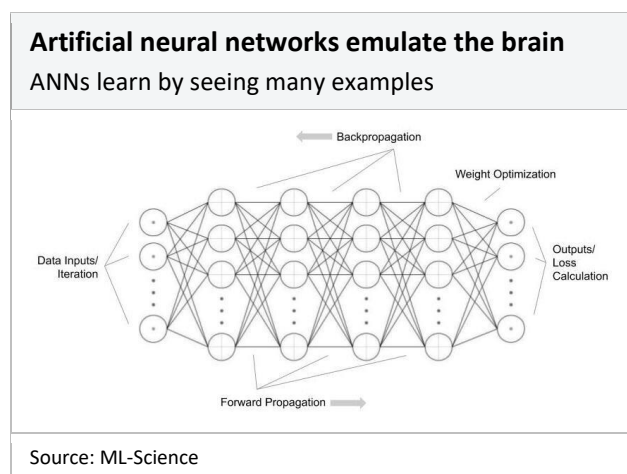
The meaning of AI has changed over the years. GlobalData's definition purposely leaves out any mention of whether the software-based systems actually 'think,' as this has been the subject of heated debate for decades. UK mathematician Alan Turing advocated back in 1950 that rather than considering whether machines can think, we should focus on whether or not machinery can show intelligent behavior.

Branches of AI

Depending on their ambition or scope, there are two main branches of AI: weak and strong.

Weak AI

Also known as artificial narrow intelligence (ANI), weak AI is an approach to AI that focuses on performing a specific task, such as answering questions based on user input, recognizing faces, or playing chess. Most importantly, it relies on human interference to define the parameters of its learning algorithms and provide the relevant training data.



Significant progress has been achieved in weak AI, with well-known examples including facial recognition algorithms, natural language models like OpenAI's GPT-n, virtual assistants like Siri or Alexa, Google subsidiary DeepMind's chess-playing program AlphaZero, and, to a certain extent, driverless cars.

The approach to achieving weak AI has typically revolved around using artificial neural networks (ANNs), systems inspired by the biological neural networks that make up animal brains. They learn to identify or categorize input data by seeing many examples.

Inspired by the brain's structure, ANNs are one of the main tools used in machine learning. An ANN has anywhere from

dozens to millions of artificial neurons - called units - arranged in a series of layers. The input layer receives various forms of information from the outside world. This is the data that the network aims to process or learn about. From the input unit, the data goes through one or more hidden units with the aim of transforming the input into something the output unit can use.

There are many neural network models suitable for different use cases and with various computational demands. The most popular types include ANNs, convolutional neural networks (CNNs), and recurrent neural networks (RNNs). ANNs are the simplest and easiest to use, although less powerful than CNNs, which are highly suitable for image recognition problems, or RNNs, typically used for text-to-speech conversions. This technology is also often called deep learning, a subset of machine learning.

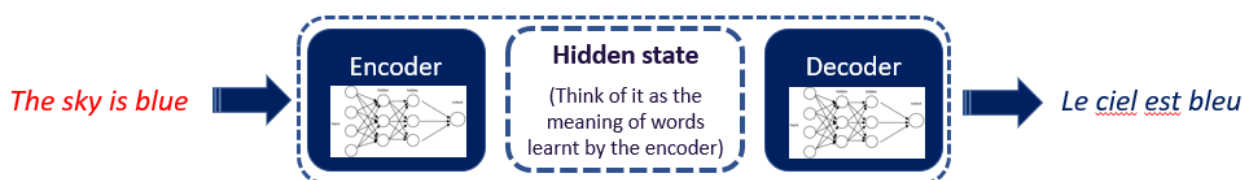
Large language models

Following Google researchers' introduction of the transformer architecture in 2017, a new type of neural network called large language models (LLMs) emerged. Their purpose is to either generate general-purpose language or perform other natural language processing (NLP) tasks such as classification or summarization.

LLMs are usually built using two neural networks, one acting as an encoder and the other as a decoder. They effectively translate text in the input language to the output language. This process is also called neural machine translation or sequence transduction. Interestingly, this approach works with any language, whether it be a human language like English, French, or Mandarin, a programming language like Python or JavaScript, sounds, pictures, video streams, or even protein structures. The public release of GPT-3 (2020) and then, most notably, ChatGPT (2022) by OpenAI brought LLMs to the mainstream. ChatGPT is a conversational LLM that translates questions into answers rather than translating between two different languages.

Large language models, in essence, translate between two languages

LLMs are built using two artificial neural networks



Source: GlobalData

The LLMs provided by the likes of OpenAI, Google, or Meta are called foundational models because they are trained on broad data such that these models can be applied across a wide range of use cases. As a result, they tend to have a very large number of neural network nodes, also called parameters. For instance, OpenAI GPT-3 had 175 billion parameters, which may seem like a lot, but Google's Gemini Ultra, launched in 2024, uses 1.56 trillion and OpenAI GPT-4 1.76 trillion. Training the models requires significant IT and financial resources, driven by the massive amounts of data involved and the high cost of the AI chips required.

However, for real-life use cases, the foundational pre-trained models must be further trained with proprietary data or process knowledge specific to a given company. For instance, a chatbot that automates customer support needs to learn about the company products and pricing plans.

Several training technologies are more suitable for certain types of additional knowledge or specific delivery models than others. There are currently three main ways to further train an LLM for real-life use cases, each with pros and cons:

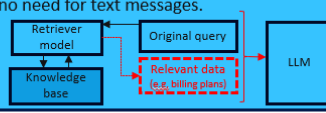
- **Prompt engineering.** This is the simplest form of training, based on passing along additional data to the LLM as part of the question. In the chatbot example, the additional data could be a table containing the company's pricing plans. In this case, costs are moderate in terms of IT skills, upfront development, and maintenance, yet the results are modest, and the solution is fragile, as it involves a lot of custom software development that is specific to a given question.
- **Retrieval augmented generation (RAG).** This is a framework, based on research from Meta, which aims to make LLMs more reliable and reduce hallucinations by automatically identifying relevant new information when an LLM is answering a question. A secondary retriever model uses semantic search to find data pertinent to the query in a separate knowledge base. This approach is less fragile than simple prompt engineering because it automatically incorporates proprietary and fresh data, yet it still provides limited domain process knowledge (that is, how things work rather than just factual data). For instance, including a product pricing list as part of a question to a foundational LLM does not mean that it suddenly understands what each product does, for which clients it is more suitable, or how to recommend it to a customer. However, the required skill set is more advanced, including data scientists and

experts in semantic search, and development costs are higher due to the need to develop and maintain a separate knowledge base and semantic search engine.

- **Full re-training.** Additional training data sets are prepared, and the full LLM is re-trained to learn additional facts and processes. While the quality of outputs is much better, it is significantly more expensive to develop and maintain, and because it takes time to curate training data sets and train the LLM, it cannot react as quickly to fresh new information as RAG does.

There are three main ways to further train a foundational AI model

Each approach has technical, financial, and organizational pros and cons

Training method	What is it?	Usage example	Who can implement?	Costs	Output quality
Prompt engineering	Passing additional data to the LLM as part of the question	Please recommend the best billing plan to a customer with four family members, and interests in video streaming and gaming but no need for text messages, using the billing plans table below. 	- Business users - Software developers	- Modest upfront development costs - Modest ongoing maintenance costs	- Incorporates limited proprietary data - No domain process knowledge - Fragile
Retrieval augmented generation (RAG)	An additional retriever model finds relevant content using semantic search and appends it to the prompt.	Please recommend the best billing plan to a customer with four family members, and interests in video streaming and gaming but no need for text messages. 	- AI software developers - Data scientists	- Significant upfront development costs - Material ongoing maintenance costs	- Automatically incorporates proprietary and fresh data - Limited domain process knowledge
Full re-training	Additional training data sets are prepared, and the full LLM retrained, so it learns additional facts and processes.	Please recommend the best billing plan to a customer with four family members, and interests in video streaming and gaming but no need for text messages. 	- GenAI or LLM engineers - Advanced AI software developers	- Very large upfront development costs - Very large ongoing maintenance costs	- Automatically incorporates proprietary and fresh data - Advanced domain process knowledge

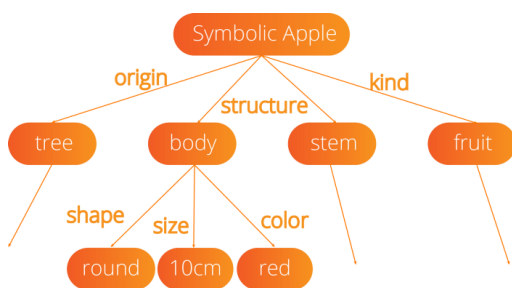
Source: GlobalData

The training of LLMs is becoming a complex and expensive activity. Infrastructure, financial, and organizational costs must be considered to choose the best LLM training approach. LLM training options like RAG or full re-training require the use of costly AI chips such as those of Nvidia and AMD or custom proprietary AI chips from the likes of Alphabet, Amazon, Baidu, or Microsoft.

Strong AI

Symbolic AI is the main type of strong AI

Internal symbolic representation of an apple



Source: Towards Data Science

Also known as artificial general intelligence (AGI) or general AI, strong AI is a theoretical form of AI whereby a machine would possess intelligence equal to humans. As such, it would be sentient and have a self-aware consciousness that could solve problems, learn, and plan for the future. This is the most ambitious definition of AI, the holy grail of AI, but it remains purely theoretical.

Historically, the approach to achieving strong AI has been around symbolic AI, whereby a machine forms an internal symbolic representation of the physical and abstract world. It, therefore, can apply rules or reasoning to learn further and make decisions. Examples of such approaches include expert systems that had moderate success in limited knowledge fields such as medical diagnosis, automated theorem provers in mathematics, and even

Sir Tim Berners-Lee's Semantic Web proposals, whereby integrated data and semantics in the World Wide Web would allow intelligent agents to resolve complex problems automatically.

While research continues in this field, it has had limited success in resolving real-life problems, as the internal or symbolic representations of the world quickly become unmanageable with scale.

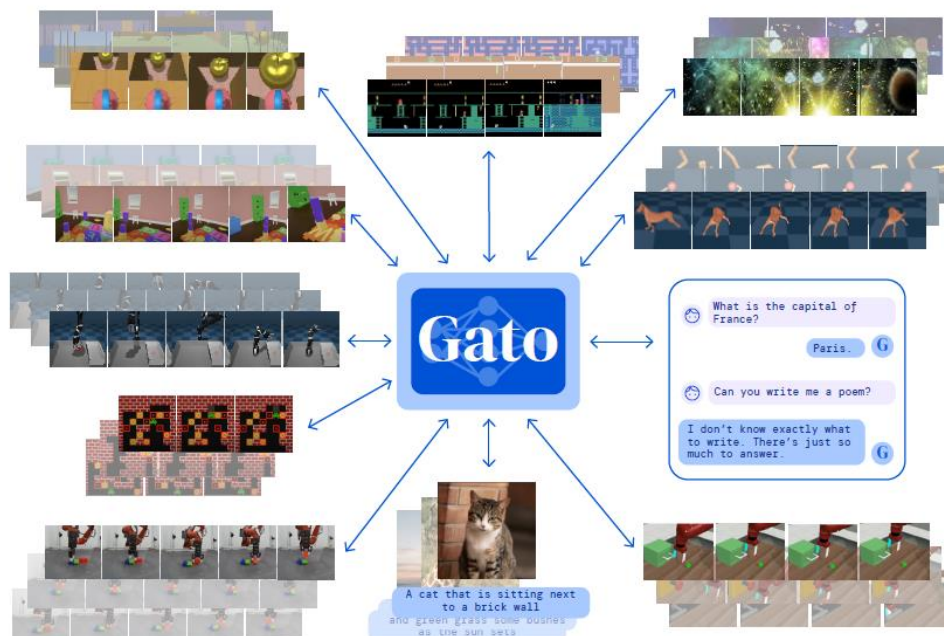
Within strong AI, there is a theoretical next level above AGI, which researchers call artificial super intelligence (ASI). This is where a machine possesses intelligence far surpassing that of the brightest and most gifted human minds. Some researchers believe that ASI will likely follow shortly after the development of AGI, not least because AGI would be capable of iteratively creating better AI algorithms until they became an improvement over human intelligence.

Interestingly, there have been claims from weak AI practitioners that, with enough scale, their machine learning models can achieve AGI, completely doing away with symbolic AI, yet the debate is still open. The belief is that, as very large neural network models are trained, they will eventually form the required symbolic representation and understanding of the world as represented by the values of the network nodes. By implication, this means such internal symbolic representations of the world are not directed or supervised by humans, posing some fundamental concerns about how controllable these systems would be in the long run. The results may even evoke the Frankenstein syndrome: the fear that machines will turn against their human creators.

As part of the pursuit of AGI using weak AI, particularly LLMs, researchers are developing models that can handle multimodality, or the ability to process and understand different sensory modes, such as text, audio, video, and even motion. As an early example, in May 2022, Google’s subsidiary, DeepMind, published a paper describing a generalist agent called Gato. It is capable of performing various tasks with the same underlying trained model. The current Gato version can play Atari, caption images, chat, or stack blocks with a real robot arm, among other activities. Many leading AI companies have now released multimodal models, including Google, OpenAI, Meta, Baidu, and Alibaba.

Google's Gato aims for general AI

Its capabilities include image recognition, chatting, playing an Atari game, or stacking blocks with a robot arm



Source: Google DeepMind

Arguably, there is a third branch of AI: neuro-symbolic AI. This combines neural networks and rule-based AI. While promising and conceptually sensible, as it seems closer to how our biological brains operate, it is still in its early stages.

The AI roadmap

Despite the recent progress in the use of AI in real-world situations, such as facial recognition, virtual assistants, and (to a certain extent) autonomous vehicles (AVs), we are still in the early stages of the AI roadmap.

To understand the different types of AI, it is worth considering the information that systems hold and rely upon to make decisions. This, in turn, defines the range of capabilities and, ultimately, the AI scope. There is a significant difference between a system with no knowledge of the past and no understanding of the world and a system with a memory of past events that has an internal representation of the world and even of other intelligent agents and their goals.

As a result, AI can be classified into four types based on memory and knowledge.

- **Reactive AI.** This type of intelligence acts predictably based on the input it receives. It does not rely on any internal concept of the world. It can neither form memories nor use past experiences to inform decisions. Examples include email spam filters, video streaming recommendation engines, or even IBM's Deep Blue, the chess-playing supercomputer that beat international grandmaster Garry Kasparov in the late 1990s.
- **Limited memory AI.** This type of intelligence can use past experiences incorporated into its internal representation of the world to inform future decisions. However, such past experiences are not stored for the long term. A good example is certain functionalities of AVs, which constantly observe other cars' speed and direction, adding them to their internal preprogrammed representations of the world. These representations also include lane markings, traffic lights, and other essential elements, like curves in the road. With this combination of static information and recent memories, the autonomous vehicle can decide whether to accelerate or slow down, change lanes, or turn.
- **Theory of mind AI.** This type of intelligence, which has not yet been successfully implemented, involves a more advanced internal representation of the world, including other intelligent agents or entities with their own goals that can affect their behavior. Following the prior example of the AV, to anticipate the intention of another driver to change lanes, they must hold an internal representation of the world that includes the other driver's state of mind. As complex as this may sound, experienced human drivers do precisely that, as they can anticipate, say, a pedestrian that may be about to cross the street suddenly or a distracted fellow driver that might abruptly change lanes without signaling.

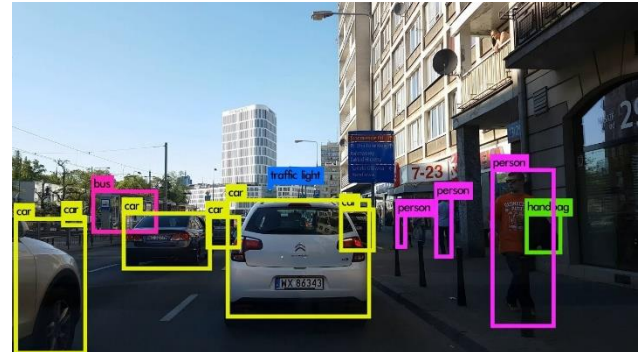
In psychology, a system that imputes mental states to other agents by making inferences about them is properly viewed as a theory and thus called a theory of mind because such states are not directly observable, yet the system can be used to predict the behavior of others. Only an AI system with a theory of mind could handle mental states such as purpose or intention, knowledge, belief, thinking, doubt, guessing, pretending, or liking, to name a few.

- **Self-aware AI.** This type of intelligence effectively improves the theory of mind, whereby its representation of the world and other agents also includes itself. Self-aware, conscious systems know about their internal states and can predict the feelings of others by inferring similar internal states to their own. If it sees a person crying, a self-aware AI system could infer that person is sad because that is how their internal state is when they cry.

Placing the various types of AI along a scope continuum is useful for understanding the overall AI landscape, as certain AI systems may fall between the theoretical categories defined above. For instance, it is unclear whether truly autonomous vehicles require a theory of mind to anticipate other drivers' behavior. Similarly, it may or may not be a requirement for fully autonomous mobile robots operating in a factory alongside humans, as they need to ensure they will not hurt them while operating heavy loads or machinery.

Limited memory AI keeps track of the world

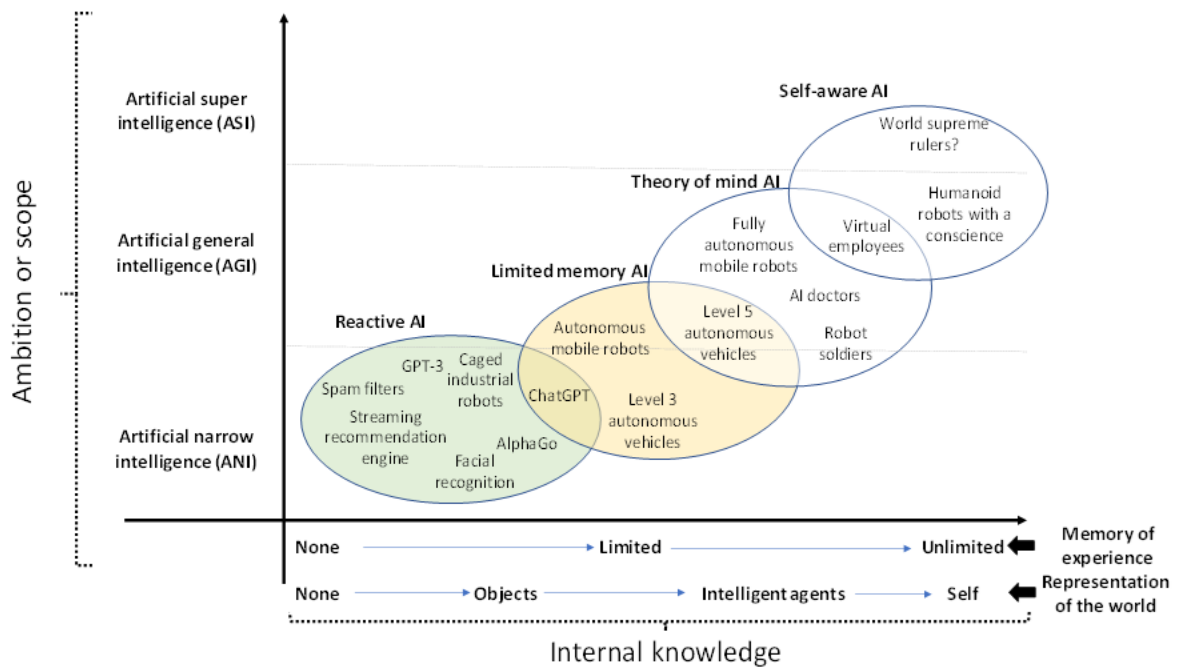
Other cars' speed and direction inform decisions



Source: Towards Data Science

We are at the early stages of the AI roadmap

Current AI systems have very limited memory and knowledge of the world



Source: GlobalData

So far, we have only been able to develop AI systems that fall into the reactive or limited memory categories. Achieving theory of mind or self-awareness might be decades away.

Advanced AI capabilities

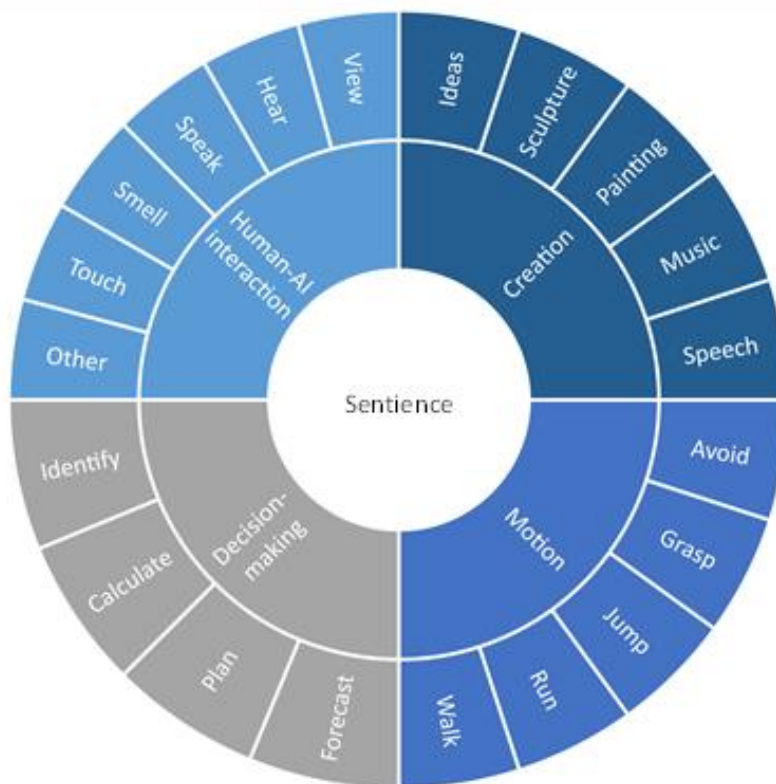
When building AI systems, a fundamental question is: what capabilities or behaviors make a system intelligent? The first step is to expand on our earlier definition and describe AI as any machine-based system that perceives its environment, pursues goals, adapts to feedback or change, provides information or takes action, and even has self-awareness and sentience.

Certainly, humans and animals in the higher layers of the evolutionary tree can interact with their environment, adapt to its changes, and take action to achieve their goals, such as individual and species survival. Whether animals have self-awareness or ethics is an open debate, but they have sentience.

This is relevant as even a weak AI approach can build systems that behave intelligently but are far from sentient.

There are five categories of advanced AI capabilities

They are human-AI interaction, decision-making, motion, creation, and sentience



Source: GlobalData

There are five categories of advanced AI capabilities:

- **Human-AI interaction:** This includes computer vision and conversational capabilities, as well as less developed artificial senses such as smell, taste, and touch. The latter, also known as haptics, consists of creating an experience of touch by applying forces, vibrations, or motions to the user, and it is crucial in robotics. In this category, we also include types of interactions, such as brain-machine interfaces, that do not typically exist in nature but are interactions between humans and AI.
- **Decision-making:** This includes capabilities that the average person will typically associate with intelligence, such as identifying, recognizing, classifying, analyzing, synthesizing, forecasting, problem-solving, and planning. An example could be a system capable of recognizing symptoms and vital signs for a human patient that can also identify the

patient's medical condition and develop a treatment plan. Both symbolic AI and neural networks can be used to perform these tasks, and it is likely that in the long run, a combination of the two will be required—if not new paradigms altogether.

- **Motion:** This includes the ability to move and interact with the world. Although underappreciated in the early years of AI research, it has become apparent that this is a complex capability that requires significant intelligence. For instance, an autonomous robot operating outdoors must be able to understand its position in three-dimensional space and move toward its destination. As it moves, it needs to analyze the feedback it receives from its sensors and adjust accordingly, as living things do. It has taken many years to build robots capable of walking on uneven terrain that can change as they step on it or grasping fragile objects like an egg or a human hand, something a five-year-old child can do without much effort. This is also intelligence, even if the average person might not appreciate it as such.
- **Creation:** This includes creation capabilities across multiple areas, including audio, video, and text. It is also known as generative AI, and one of the most renowned examples today is OpenAI's ChatGPT, which can write original prose and chat with human fluency. There is a relationship between intelligence and creativity, and it has been the subject of empirical research for decades. An intelligent system should be able to display creation capabilities in multiple areas. For instance, writing original text or music, drawing and painting, designing new structures or products, or even designing new AI systems. Allowing AI to make AI may sound like science fiction, yet researchers at OpenAI, Uber AI Labs, and various universities have worked on it for several years. They see it as a step on the road that one day leads to AGI or even ASI.
- **Sentience:** This includes the emergence of self-awareness or consciousness, which is the ultimate expression of intelligence in an artificial system. However, this is, at the moment, far from achievable. Many neuroscientists believe that consciousness is generated by the interoperation of various parts of the brain, called the neural correlates of consciousness (NCC), but there is no consensus on this view. NCC is the minimal set of neuronal events and mechanisms sufficient for a specific conscious percept. Self-awareness, the sense of belonging to a society, an ethical view of right and wrong, or the greater good are just a few examples of matters that would be dealt with at this AI capability level. While such debates may appear purely philosophical at this stage, they will become more important as intelligent autonomous robots take on more roles in our society, which might involve moral decisions.

AI researchers can become entranced with the development of AI with sentience and even a conscience. However, there is a much better business case for robots with effective interaction and motion capabilities and modest decision-making skills.

Trends

The main trends shaping the AI theme over the next 12 to 24 months are shown below. These trends are classified into three categories: technology trends, macroeconomic trends, and regulatory trends.

Technology trends

The table below highlights the key technology trends impacting the AI theme.

Trend	What's happening?
AI accelerators	AI accelerators are chips designed to perform AI tasks more efficiently, thereby reducing the time taken to, for example, process the large data sets associated with machine learning. Using neural networks for real-life use cases has put significant pressure on the capabilities of existing hardware. AI accelerators are emerging as the solution to this problem. Traditional central processing units (CPUs) lack the massive parallelism to compute AI models efficiently; they cannot simultaneously calculate the output of thousands of neurons in a layer. To overcome this limitation, AI data scientists often use graphics processing units (GPUs) optimized for graphics and typically used in video games because they support massive parallelism. However, they are not optimized from either a power consumption or price perspective. They are also not very good at handling inference workloads (the quick responses from a fully trained AI model). In recent years, large cloud service providers, from Google and Amazon to Alibaba and Baidu, have developed custom AI application-specific integrated circuits (ASICs) to act as AI accelerators. AI accelerators will increasingly specialize by use case and workload (e.g., training versus inference). As a result, our forecasts suggest AI chip revenue will reach approximately \$116 billion in 2030, recording a 21% compound annual growth rate (CAGR) between 2023 and 2030. Furthermore, while large cloud service providers have the scale to justify the cost of developing their own AI ASICs, this is not the case for many other organizations. Therefore, there will be a similar evolution in this area to that seen in the past with other specialized semiconductors. As the design matures and demand across the industry becomes more certain, semiconductor companies will likely step in and design standard special purpose logic (SPL) devices that will improve ASICs' performance and unit cost and eventually replace them. Start-ups like Biren Technology, Groq, Cambricon, Cerebras Systems, Graphcore, Horizon Robotics, SambaNova, TensTorrent, and Blaize are already pursuing this avenue. See AI Chips and Next-Generation Chips.

Trend	What's happening?
Generative AI	In its simplest definition, generative AI systems are self-learning algorithms, often called large language models or LLMs, that use existing data, such as text, audio, or images, to produce realistic new content. While generative AI became mainstream when OpenAI launched ChatGPT at the end of 2022, research and development (R&D) investments in this technology have been accelerating since 2017, following Google researchers' introduction of its transformer architecture and the availability of increasingly powerful AI chips, particularly those produced by Nvidia. LLMs' ability to either generate general-purpose language or perform other natural language processing (NLP) tasks, such as classification or summarization, has opened up a significant market opportunity for more advanced business process automation. From customer support chatbots and automatic generation of marketing collateral to contract drafting and clinical trial documentation preparation, most industries are exploring how they can use the technology. Generative AI has become the fastest-growing segment of the AI market. According to GlobalData forecasts, revenue will reach approximately \$33 billion in 2027, having grown at a CAGR of 91% between 2023 and 2027, which compares to the overall AI revenue growth of 32% over the same period. Leaders developing LLMs include Big Tech companies such as Alphabet, Meta, and Microsoft and smaller start-ups such as OpenAI, Anthropic, Mistral, Hugging Face, and Stability.ai, many of which have partnered with the former. Further, the vast compute and storage capacity required to train these models is driving extraordinary demand for AI chips, such as GPUs, FPGAs, and AI accelerators, from Nvidia and, to a lesser extent, AMD and Intel. See Artificial Intelligence – Executive Briefing (Third Edition).
The AGI debate	There are now many successful and popular AI models, such as GPT-4, Gemini, LLaMa 3, and Claude 3 (text generation), DALL-E 3 (image generation from text descriptions), PaLM (language reasoning), Flamingo (visual description), and Gato (generalist, multi-task AI). These models are all based on neural networks using deep learning algorithms. As a result, some in the AI community believe that artificial general intelligence (AGI), or the ability of machines to do anything that a human can and possess consciousness, can be achieved via sheer scaling (i.e., larger models, larger training datasets, and more computing power). This is important because it suggests that AI systems will soon be able to replace any human on any task, with huge implications for our economic systems and societies. However, other research teams prefer the less ambitious term human-level AI (HLAI). They believe there are still many problems to be resolved, and it is unclear whether sheer computational power will address them. Among these problems is the machine's ability to learn how the world works through observation, predict how to influence the world through actions, deal with the world's inherent unpredictability, and reason, plan, and predict effectively. Ultimately, the debate is whether this is achievable via gradient-based learning with our current artificial neural networks alone or whether many more breakthroughs are required.

Trend	What's happening?
Quantum neural networks	Quantum computers are built up from qubits (or quantum bits) that exist in a state of superposition, straddling both 'on' and 'off' states. It involves the phenomenon of quantum entanglement, under which separated particles in the same quantum state operate as one, with zero latency. Leading industry commentators estimated the quantum computing market's size in 2022 to be between \$500 million and \$1 billion, rising to \$10 billion between 2026 and 2030, representing a CAGR of between 30% and 50%. Quantum computing features, such as quantum parallelism or the effects of interference and entanglement, can be used as resources to compute neural network models exponentially faster. This would make them candidates for becoming the AI chips of the future. That said, quantum computing is still in its very early stages, and the existing quantum computers do not have enough qubits to handle even a demonstration neural network. Therefore, work is ongoing to be ready when enough processing capacity is available. For instance, Google has launched TensorFlow Quantum, a software framework for quantum machine learning that allows rapid prototyping of hybrid quantum-classical machine learning models. In 2019, Google claimed quantum supremacy, where a quantum device outperformed a classical one, albeit on a non-practical use case. IBM, also a leader in quantum computing, announced in July 2021 that it has found "mathematical proof" of a quantum advantage for quantum machine learning. In early 2024, it was D-Wave's turn to claim quantum supremacy, although its research is still being peer-reviewed. As innovation continues, quantum neural networks will become a promising route to achieving AGI. See Quantum Computing.
Neuromorphic computing	Neuromorphic computing consists of event-driven systems that ape the human cortex by tightly integrating memory and processing via neurons laid with synapses rather than separating them with a communication bus (a data highway to transfer data between components) in a clocked, sequential system. The neuro-synaptic approach promises to increase system performance by an order of magnitude while running on only a few watts. However, progress has been slower than in the machine learning camp, and chips like IBM's TrueNorth or Intel's Loihi I and Loihi II cannot resolve real-life problems (yet). Furthermore, an ecosystem of developers, development tools, companies, and applications has not yet emerged. That said, while neuromorphic computing is a long shot, it could address AI capabilities such as interaction (e.g., vision, hearing, and natural language processing) and motion (e.g., haptics) in the coming years if meaningful progress is made.
Edge AI	Edge AI refers to using AI systems that are located closer to users—at the edge of the network—to improve the speed and responsiveness of apps and services. Interestingly, the high power efficiency, low latency, and adaptability of neuromorphic chips make them good candidates for bringing a certain level of AI functionality to the edge. This is despite the fact that neuromorphic computing is still very immature, with a limited ecosystem of developers, tools, companies, and applications. Adding AI capabilities to connected devices on the network edge is an important area of convergence between disruptive themes of AI and the Internet of Things (IoT). Indeed, various start-ups are already working on this route, including BrainChip, SynSense, Innatera Nanosystems, GrAI Matter Labs, Eta Compute, and GyrFalcon. See Edge Computing and Internet of Things.

Trend	What's happening?
Explainable AI (XAI)	AI is increasingly involved in life-changing decisions like welfare payments, mortgage approvals, and medical diagnoses. Consequently, transparency and explainability have become essential. Controversies surrounding bias in AI models have received much attention, prompting companies to update their internal AI development guidelines to build trust. XAI is particularly important for this, as a model is only as good as the data on which it is trained. It should allow humans to understand and follow the path a model took to make a decision. XAI alone will not be enough to mitigate bias in the data, as it will only enable companies to identify potential discrimination. It will be up to businesses to correct their models as needed. However, the ability to fix a model before deployment at scale, avoiding a potential PR disaster, should appeal to most companies. XAI and responsible AI—which includes everything from compliance to governance and explainability—have emerged as a top priority for most companies involved with AI. Google introduced its own explainable AI tools and frameworks in 2019 to help developers fully understand the AI models they are deploying, make necessary adjustments, and build trust. In 2021, IBM partnered with Highmark Health to help predict at-risk patients, supporting preventative clinical intervention and outreach to avoid costly inpatient sepsis admissions. The platform used, IBM Cloud Pak for Data, includes an XAI and model monitoring module. In 2023, PathAI launched an AI-based breast cancer scoring algorithm using a technique called additive multiple instance learning (aMIL) heatmaps, which allows scores to be interpreted, explained, and confirmed by human doctors, reducing the black box concerns around using AI to analyze medical images.
Federated learning	Federated learning is a decentralized machine learning technique that uses multiple servers or edge devices (local nodes) to train an algorithm. This supports data privacy and access rights as, unlike traditional machine learning techniques, it does not centralize all local datasets on one server. It is a popular technique across sectors for security reasons, such as in healthcare-related models due to the sensitivity of the data. Federated learning is often called collaborative learning as it allows multiple actors to contribute to creating one machine learning model. Unlike in distributed learning, there is no assumption that the local datasets are independent and identically distributed.
Autonomous vehicles (AVs)	GlobalData predicts that vehicles with Level 4 autonomy (capable of self-driving under specific circumstances but limited by software geofencing) will start to operate on our roads sometime this decade. A geofence is a virtual geographic boundary, defined by global positioning system (GPS) or radio-frequency identification (RFID) technology, that enables software to trigger a response when a mobile device enters or leaves a particular area. In contrast, fully autonomous vehicles (Level 5) are not expected until 2035. The automotive and IT industries are investing heavily in developing AV software that uses sensor-fed machine learning algorithms. Companies like Alphabet's Waymo, Tesla, Aurora, Baidu, Aptiv, Nvidia, Intel, and GM are competing to be the leading players. Neural network-based machine learning will become a standard auto component and run on algorithm-specific AI. Fully autonomous vehicles will become the ultimate AI use case, as they need to identify moving objects, including other vehicles and pedestrians, predict their movement, and plan their actions accordingly. However, the path toward full vehicle autonomy is rockier than many predicted. Delays in technology development and several fatalities involving AVs over the last few years have highlighted the limitations in current machine learning systems, which learn from existing data only and struggle with situations they have never seen before. See Autonomous Vehicles and Computer Vision.

Trend	What's happening?
Smart cities	Surveillance technology, in the form of AI tools like computer vision (CV), is increasingly deployed in smart cities to improve efficiency. However, the level of surveillance can be more intrusive than needed to improve urban services. For example, CV is a mass surveillance tool in many autocratic and semi-autocratic countries. However, a 2022 report by the National Endowment for Democracy found that 52 of the 97 countries considered either liberal or electoral democracies also used AI-powered surveillance technologies, including the US, Brazil, Germany, India, and Singapore. Such widespread surveillance violates international standards for privacy (including the General Data Protection Regulation (GDPR) and the International Covenant on Civil and Political Rights). Both state that collection and use of biometric data should be limited to people found to be involved in wrongdoing and not from the mass population with no specific link to crime. See Smart Cities and Computer Vision.
Source: GlobalData	

Macroeconomic trends

The table below highlights the key macroeconomic trends impacting the AI theme.

Trend	What's happening?
AI talent	There is a significant shortage of AI talent, and demand continues to grow faster than supply. AI-related active job postings more than doubled in 2021 and 2022, at which point they appear to have stabilized, according to GlobalData's Job Analytics. The employees most in demand include data scientists, software engineers, technical leads and analysts, AI architects, and product managers. A lack of skilled talent is frequently cited as the main barrier to executing AI initiatives. Most companies have partnered with universities or recruited students straight out of university to meet their AI needs. However, a study by Chinese tech giant Tencent suggested that education is a bottleneck, at least in the short-term. Many universities have announced plans to start recruiting post-doctoral researchers and graduates, but it will take time before they become available. In the interim, companies are focusing on developing in-house expertise. For example, both Meta and Microsoft offer free AI training platforms for employees and the general public. Also, the number of self-taught AI experts has boomed as people use self-directed options, such as those offered by Coursera and Udacity. Companies are also developing tools and libraries that help non-specialists incorporate AI into their applications.
China	China aims to be the world leader in AI by 2030 and is investing heavily in making it happen. Given the government's efforts to identify and track its 1.4 billion people, Chinese facial recognition companies are in a powerful position. China's social credit system rates each citizen's trustworthiness based on a network of over 200 million surveillance cameras and ubiquitous facial recognition technology. The government shares its huge facial image database with Chinese technology companies, giving them an unparalleled advantage over non-Chinese CV firms. SenseTime and Megvii are the two best-funded start-ups in China's AI market and lead the way in facial recognition technology. The two companies have gained public attention due to the use of their technology by the Chinese police, raising concerns that their systems are being used as a tool of the authoritarian state. China's strengths in AI are mainly in applications that rely on vast troves of data to power algorithms. However, the country is still weak in other AI areas, including semiconductors. See China Tech.
The US	The US has long been the global leader in technology and, like China, sees AI at the center of the global technological revolution. This goes beyond just industrial policy and informs its foreign policy. The State Department is involved in the Organization for Economic Cooperation and Development (OECD) AI Policy Observatory, a platform established in February 2020 to facilitate dialogue between stakeholders and provide evidence-based policy analysis in the areas where AI has the most impact. The US is also a founding member of the Global Partnership on Artificial Intelligence (GPAI), a voluntary, multi-stakeholder initiative launched in June 2020 to advance AI in a manner consistent with democratic values and human rights. The US government has also passed several bills and regulations, such as technology export bans to China and industry subsidies, such as the CHIPS Act, which aim to improve its competitive standing against its main global competitor in AI. The US is also home to leading AI companies, from household names such as Alphabet, Meta, Microsoft, Amazon, IBM, and Nvidia to emerging start-ups such as OpenAI, C3.ai, H2O.ai, Hive, and Cerebras Systems.

Trend	What's happening?
Trade wars	The US regards China's efforts to become a dominant player in advanced technologies as a national security problem. The Trump administration believed the policies enshrined in the Made in China 2025 plan encouraged discriminatory treatment of foreign investment, forced technology transfers, intellectual property theft, and cyber espionage. In August 2019, the US imposed 15% tariffs on various Chinese goods, with China reciprocating with new duties. In October of the same year, the US Department of Commerce banned 28 Chinese companies involved in AI, surveillance, and security from buying products from US companies without government approval. Through diplomatic pressure, restrictions were applied in 2019 that stopped Europe's ASML from exporting its most advanced extreme ultraviolet (EUV) chip manufacturing equipment to China. The Biden administration has maintained the same stance and expanded restrictions on exporting advanced technology to China, particularly semiconductors. In October 2022, new measures were enacted to exclude China from using semiconductor chips made anywhere in the world with US tools. This effectively prohibits Nvidia and AMD from selling GPUs to China regardless of where they have been manufactured. In early 2024, the restrictions on ASML were expanded to include less advanced deep ultraviolet (DUV) machines after it emerged that China had managed to manufacture advanced chips using them. This will make it very challenging for Chinese AI companies to train and run their models. China has several advantages in AI compared to the US, including a large pool of software engineers and vast repositories of citizens' data. Despite China's reliance on the US for semiconductors—with US companies like Nvidia dominating the market for AI chips—the trade war is unlikely to prevent Beijing from pursuing its Made in China 2025 model. See AI Chips.
Taiwan	The People's Republic of China (PRC) officially holds the One China principle, which determines that there is only one sovereign state under China and the government of the PRC, and that Taiwan is a part of China. Taiwan opposes this view, holding that China and Taiwan form two separate countries. The status quo has been held for decades as the US has followed its own One China policy based on strategic ambiguity regarding Taiwan. As such, the US has formal relations with the PRC, recognizes the PRC as China's sole legal government, and maintains unofficial relations with Taiwan while not recognizing China's sovereignty over Taiwan. However, the trade wars between the US and China are fueling tensions around the Taiwan question, as the latter has a dominant position in the semiconductor industry, mainly via leading manufacturing vendor TSMC, as well as United Microelectronics, ASE, MediaTek, and Nanya. As recently as August 2022, the PRC published a white paper proposing annexation of Taiwan following the "one country, two systems" model already followed in Hong Kong, which Taiwan's foreign ministry quickly rejected. With the US banning the export of advanced semiconductor technology to China, there are increasing concerns that the PRC may decide to annex Taiwan by force, seizing control of TSMC's fabs and technology. While the outcome of escalating geopolitical conflicts is difficult to predict, such an annexation would significantly disrupt the global semiconductor and AI value chains yet would be unlikely to give China what it seeks. The most advanced TSMC chip manufacturing facilities, which produce the smallest chips required for AI, rely on manufacturing equipment from companies such as ASML, Applied Materials, KLA, and Lam Research. Such machinery cannot truly operate offline and without the support of engineers from those companies. As a result, it is doubtful that China could produce the advanced AI chips it needs. That said, the US and the rest of the world would take time to ramp up advanced chip manufacturing outside of Taiwan, although they would have access to all the advanced equipment and tools. In this situation, China's leadership in AI would fade away gradually.
Source: GlobalData	

Regulatory trends

The table below highlights the key regulatory trends impacting the AI theme.

Trend	What's happening?
Regulatory divergence	Both the US and Europe have taken steps to regulate AI, but there are notable differences in approach. Europe appears more optimistic about the benefits of regulation, while the US has warned of the dangers of overregulation. In early 2024, the European Parliament adopted the AI Act, which emphasizes safety and compliance with fundamental rights while providing regulatory clarity to encourage investment. Although the US has no equivalent federal law in place, in late 2023, President Biden issued an executive order on Safe, Secure, and Trustworthy Artificial Intelligence, which also seeks to protect citizens from the potential risks of AI. China continues to follow a government-first approach, although it released a list of AI guidelines in mid-2019, similar to the ethical frameworks laid out by Western governments and companies, suggesting that the Chinese state might be open to a dialogue about how it uses AI. In the past, China has been widely criticized for using AI technology to monitor citizens. In 2020, Tencent rolled out an AI-based credit scoring system to determine citizens' trust value, and the Chinese government installed surveillance cameras directly outside people's homes to monitor lockdowns imposed following the outbreak of COVID-19. Whether the US's tech industry-led efforts, China's government-first approach, or Europe's privacy and regulation-driven approach is the best way forward remains to be seen. See Tech Regulation and Splinternet.
Technology protectionism	After years of globalization and just-in-time supply chains, events like the COVID-19 pandemic, the trade dispute between the US and China, and the Russian invasion of Ukraine have driven a resurgence in industrial protectionism. This is particularly apparent in technology, where it is inspiring many regulatory measures and will likely continue to do so. For instance, the US has banned the use of specific foreign technology in its national infrastructure and advanced technology exports. Several cross-border M&A transactions have failed due, at least in part, to national strategy considerations (e.g., GlobalWafers' takeover of Siltronic, Nvidia's proposed purchase of Arm, and Wingtech's acquisition of Newport). The UK is also becoming more assertive in its industrial policy, even investing taxpayers' money into strategic industries (e.g., OneWeb). See Global M&A Deals in 2023 - Top Themes by Sector and Supply Chain Disruption.

Trend	What's happening?
AI ethics	Technologies such as AI are greatly improving governments' capabilities in surveillance and security, which they are embracing to different degrees. China openly uses facial recognition and drones to monitor its citizens, while in the US, the National Security Agency (NSA) and other enforcement agencies are also using this technology, with the assistance of companies like Palantir, Microsoft, and Amazon. The pendulum is still swinging between security and privacy and will likely settle at different positions in different jurisdictions. This could lead to regulatory frameworks setting limits for governments and the adoption of technologies like homomorphic encryption to enable AI to learn from data without giving away individual information. Homomorphic encryption permits users to perform computations on encrypted data without first decrypting it. This would be particularly useful in healthcare or insurance use cases, where AI systems could still learn from data without accessing personal information. Of course, police and government agencies are unlikely to find this technology sufficient for their aims as it does not allow the identification of individuals. In April 2021, the European Commission published its proposal for a regulation laying down harmonized rules on AI, which uses risk categories for uses of AI, ranging from minimal and limited to high and unacceptable. After a lengthy negotiation and approval at the country level, the European Parliament finally adopted the AI Act in early 2024. Companies using AI in the EU must now perform an ethical and data privacy risk assessment. See Global Data's AI Governance Framework, Tech Regulation, Computer Vision, and Splinternet.
Big Tech and obstruction of justice	Non-democratic and democratic regimes are moving towards increased surveillance in their own versions of the internet, though to different extents. China's New IP proposal is the most radical attempt, contemplating a system of centralized rule and absolute control over the internet. Western governments are also investigating the possibility of exerting more influence online, often in the name of national security. Regulators and policymakers are concerned that tech companies obstruct justice by using data privacy as a pretext to block federal agencies from accessing critical evidence on technology platforms. The US, UK, and Europe are debating introducing more regulatory power in this sphere and giving intelligence agencies greater access to users' personal data. Following terrorist attacks in the US and Europe in 2015 and 2016, national enforcement authorities identified encryption as a critical threat and serious impediment to investigating and prosecuting criminal activity. See Tech Regulation and Splinternet.
Source: GlobalData	

Industry Analysis

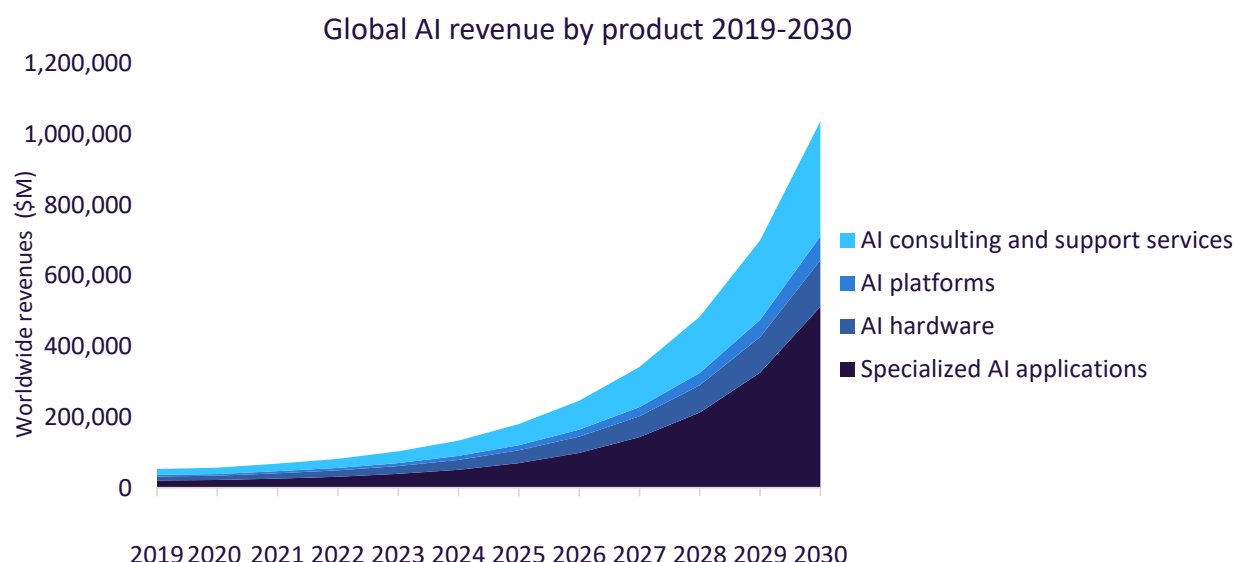
Our analysis focuses on AI technology: software-based systems that use data inputs to make decisions on their own. Developments in AI have been particularly enhanced by ML using neural networks and the widespread availability of computing power, data storage, and input devices such as smartphones and digital cameras.

Market size and growth forecasts

According to GlobalData forecasts, the total AI market, including software, hardware, and services, will be worth \$1,036.8 billion in 2030, having grown at a compound annual growth rate (CAGR) of 39.1% from \$103.0 billion in 2023. The specialized applications category is currently the largest market segment, but AI platforms are the fastest-growing. That said, it is important to understand that a significant proportion of AI hardware revenues and consulting and support services sales are driven by the sale of specialized AI applications, such as CV and conversational platforms.

The global market for specialized AI applications will be worth \$512 billion by 2030

Specialized AI applications pull through both AI hardware and consulting and support services

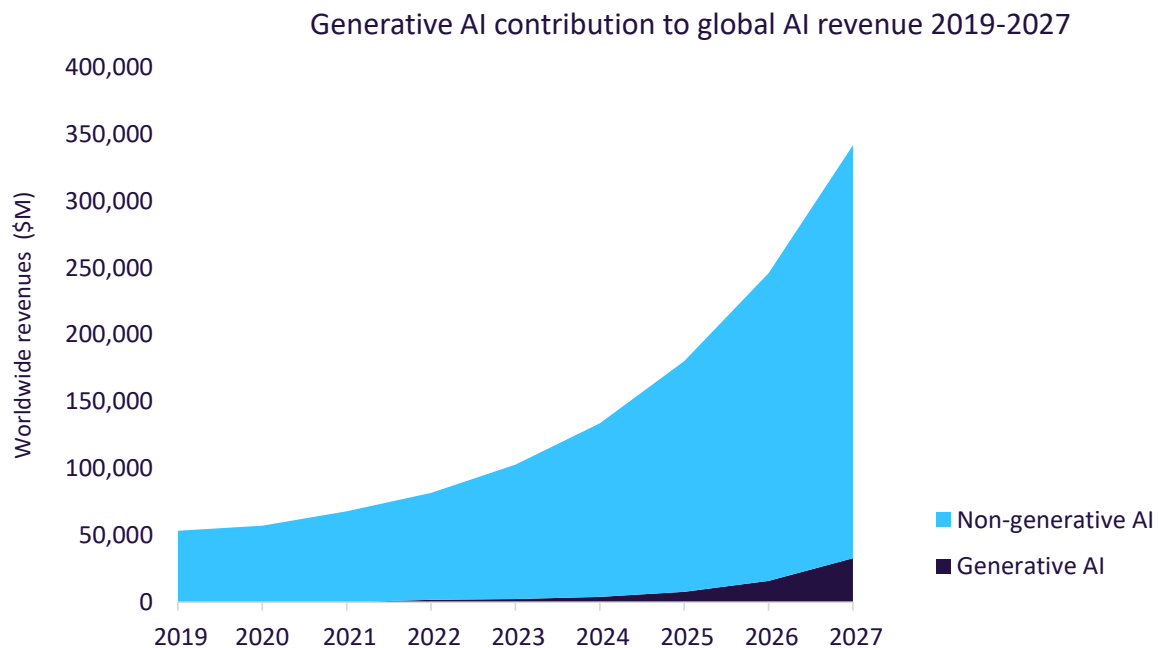


Source: GlobalData

Given the significant interest in generative AI, particularly since the launch of ChatGPT by OpenAI in late 2022, GlobalData also provides a separate view of the global AI market that shows the expected contribution of this novel technology to the mix. The generative AI portion of the AI market is expected to be worth \$33.0 billion in 2027, up from just \$1.8 billion in 2022 at a CAGR of 91.4%.

The global generative AI market will be worth \$33 billion by 2027

Generative AI will represent 10% of the overall AI market by 2027



Source: GlobalData

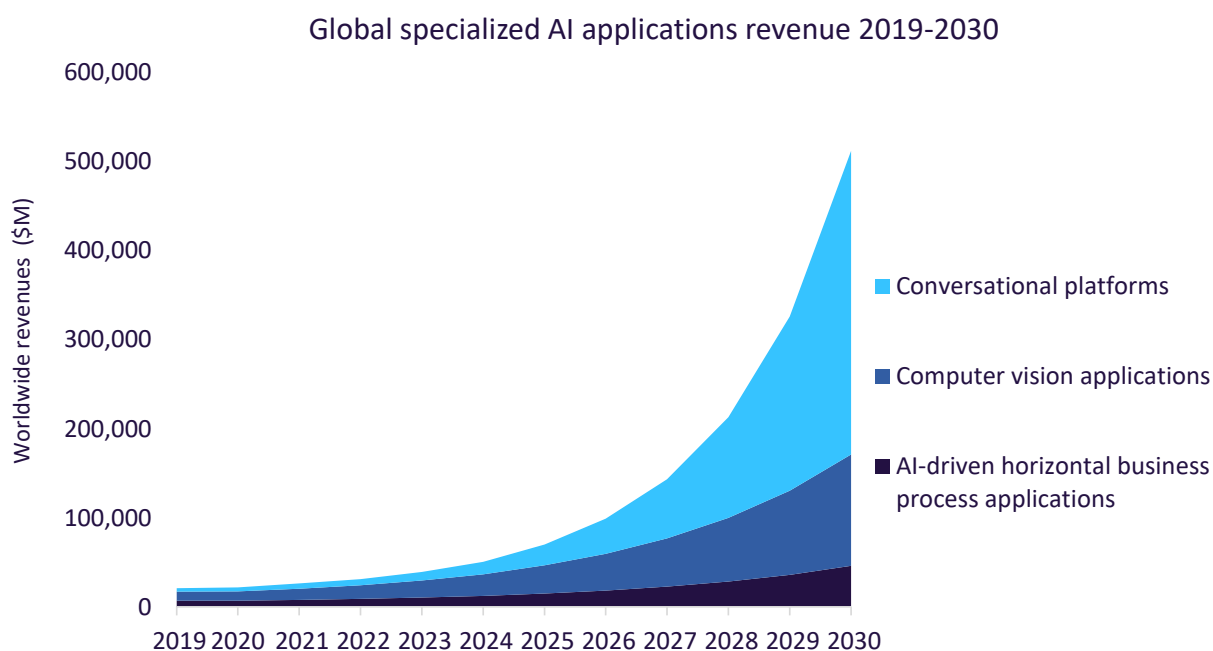
From a product or service perspective, the global specialized AI applications market will be worth \$512.1 billion in 2030, up from \$39.3 billion in 2023 at a CAGR of 44.3%. GlobalData breaks down its forecasts for this market into specific sub-categories, including conversational platforms, computer vision (CV), and horizontal applications embedded with AI-driven features such as image recognition, natural language processing, or sentiment analysis. CV is the largest sub-category, but conversational platforms is the fastest growing, so we expect its contribution to exceed CV's by 2027.

The global CV market will be worth \$125.1 billion in 2030, up from \$19.0 billion in 2023 at a CAGR of 30.9%. Several factors will drive this growth. Firstly, the huge number of digital images available will enable the extraction of ever more meaningful information from visual data, leading to the increased sophistication of CV algorithms. Countless images and videos from the built-in cameras of our mobile devices, alongside visual data collected by fixed cameras and even drones, will be used to train algorithms and deliver a higher level of recognition. Secondly, end-user demand across different industries—such as smart cities, healthcare, transport, and retail—will fuel growth.

The global conversational platforms market will be worth \$340.8 billion in 2030, up from \$9.6 billion in 2023 at a CAGR of 66.4%. This growth will partly be driven by the significant improvement in language models since the release of GPT-3 by OpenAI in 2020, which has broadened the capabilities and applications of conversational platforms.

The global specialized AI applications market will grow at a CAGR of 44%

CV applications and conversational platforms will drive demand for AI hardware, including AI chips



Source: GlobalData

The rapid growth in the volume of data is prompting demand for computing resources to analyze that data. AI applications will be boosted by the increased availability of AI chips capable of handling more complex processing, including cloud-based graphic processing units (GPUs) and custom AI accelerators based on application-specific integrated circuits (ASICs). These chips will be developed by established suppliers like Nvidia, AMD, and Intel and by the tech giants, which are increasingly designing their own. For example, in 2018, Alibaba entered the semiconductor industry by launching its PingTouGe subsidiary, which develops computer chips specifically designed for AI. Alibaba now uses its Yitian chips in its cloud business. Likewise, Baidu has been designing its own chips, branded Kunlun, since 2018, and in 2021, it also spun off its semis design business. Alphabet, Amazon, and Microsoft have all developed custom AI accelerators. Finally, advances in convolutional neural networks (CNNs) will also play a major role in developing AI applications, as will the availability of skilled analysts shifting from universities into industries.

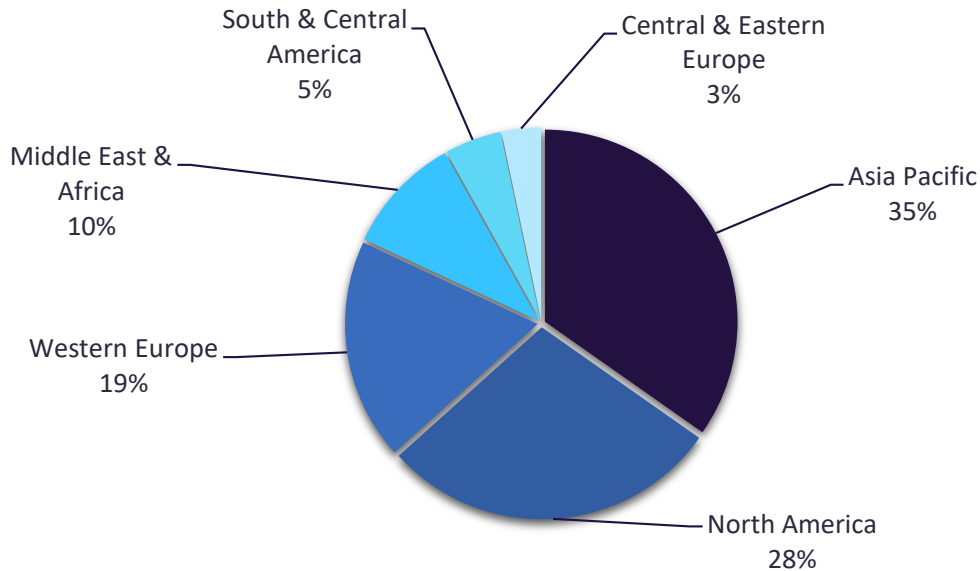
From a geographic perspective, North America had a 28% share of 2023 global AI revenues, with the Asia-Pacific region contributing 35%. Given the diverging regulatory posture around data privacy and the use of AI between regions, we expect Western Europe to lose market share to Asia Pacific over the next few years.

However, some inhibiting factors will hold back the growth of the global AI market. For instance, ethical concerns will result in new regulations, especially for the private use of surveillance technology. In addition, the ongoing trade dispute between the US and China will likely impact technological progress and adoption.

North America and Asia Pacific are the leading AI markets

AI regulation is likely to hold back adoption in Western Europe

Geographical split of global AI market 2023

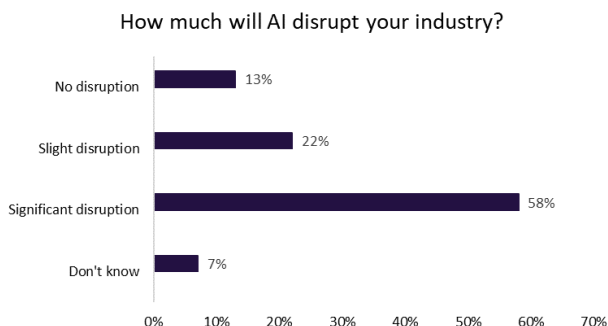


Source: GlobalData

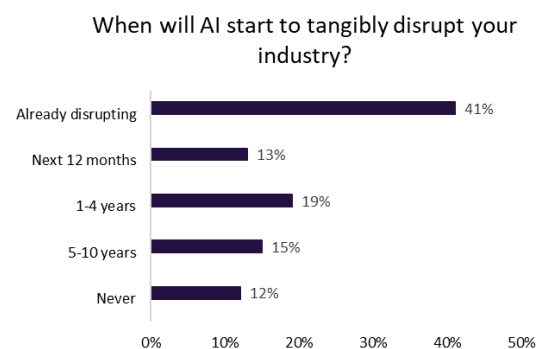
GlobalData's *Tech Sentiment Polls Q1 2024* illustrated the potential of AI technologies for business users. Well over half of the respondents felt that AI would cause significant disruption to their sectors, with only 13% believing there would be no disruption. Significantly, 41% of respondents said AI was already disrupting their business, up from 25% about a year ago. A further 32% believe it will cause tangible disruption within four years, even though the technology is only at an early stage of uptake and development.

Businesses all around the world view AI as a disruptive theme

Disruption intensity



Disruption timelines



Source: GlobalData Tech Sentiment Polls Q1 2024

Use cases

This section looks at AI applications across key verticals, namely automotive, healthcare, advertising, banking and finance, and power.

Automotive

As the automotive industry works towards delivering fully autonomous vehicles, it is relying on advanced AI capabilities, such as computer vision (CV), planning, motion, and, increasingly, conversational platforms. CV is a critical technology for advanced driver-assistance systems (ADASs) and autonomous vehicles (AVs) as it allows for the continuous processing of visual data, from road signs to vehicles and pedestrians on the road, and then helps to determine what action to take. The industry has deployed several technologies to turn vehicles into intelligent robots, including systems on chips (SoCs), GPS, analytic sensors, wireless communications, and deep learning.

Furthermore, an AV needs to have an internal three-dimensional representation of the world, an awareness of where it is standing, and a planning capability to understand moving objects and decide its next move based on visual feedback.

Most of the focus today is on LiDAR systems, but these currently cost as much as the rest of the parts of a self-driving vehicle combined. Until the cost comes down or cheaper alternatives are developed, self-driving will be the province of fleets run by ride-hailing and car-sharing companies. Silicon photonics technology—where data is transferred among computer chips by lasers rather than electrical conductors—can reduce the cost of LiDAR systems.

Mobileye is a leading provider of automotive CV
Its platform is used by many automotive companies



Source: Mobileye

Since 2020, the automotive industry has suffered significant disruption in its access to semiconductor components, initially due to global supply chain readjustments caused by the COVID-19 pandemic but more recently due to the ongoing trade dispute between the US and China. However, over the next couple of years, we expect demand for chips from the auto sector to continue to rise, especially for ADAS. By 2030, 80% of the value of a vehicle will reside in its software and content, with AI eating into the software's share and also enabling precision targeting and customizing of content.

See [Autonomous Vehicles](#).

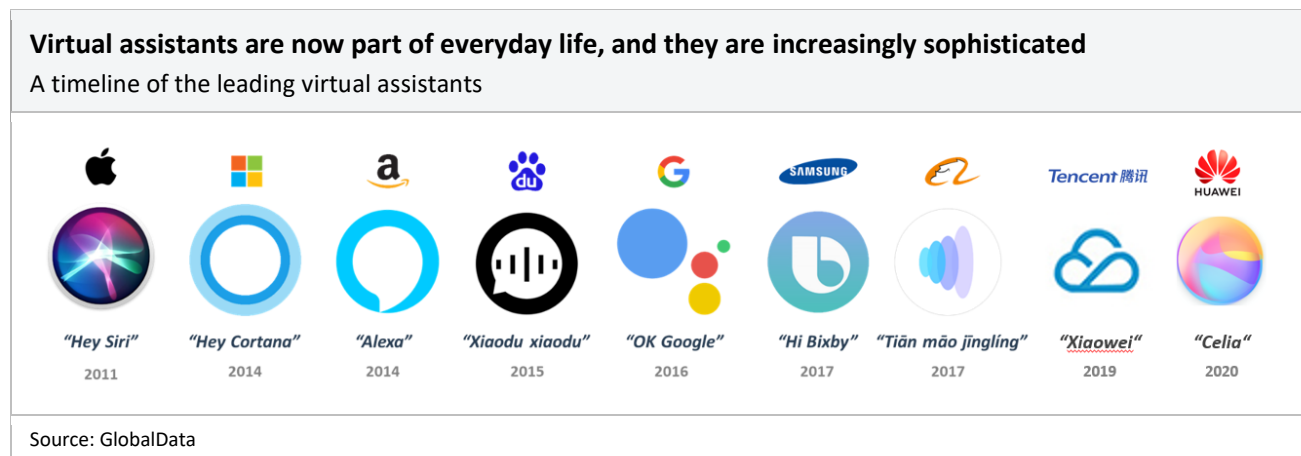
Leaders

Tesla, Alphabet (Waymo), Aurora, Mobileye, Geely, Mercedes-Benz, BMW, Baidu, Aptiv, GM.

Consumer electronics

Consumer electronics products are incorporating many features powered by AI technology, such as virtual assistants (e.g., Siri, Google Assistant, Alexa), authentication via facial recognition (e.g., Apple's FaceID), and advanced photo editing (e.g., Google's Magic Eraser).

Apple was the first to market with a virtual assistant, with Siri included in the iPhone 4S that launched in October 2011. Such was the popularity of the iPhone that, for a time, Siri was ubiquitous. The lack of credible alternatives from Microsoft and Google also gave Apple a distinct advantage. However, by 2020, most competitors had launched an alternative conversational platform. Below is a timeline of when some leading virtual assistants entered the market.



The emergence of LLMs with impressive conversational skills has raised expectations for virtual assistants embedded in consumer electronics. In 2023, OpenAI launched a ChatGPT app; in 2024, Microsoft launched a Copilot mobile app for Apple iOS and Android smartphones. Also in 2024, Apple announced a deal with OpenAI to add AI features to the iPhone, and a similar deal is also being pursued with Google to use its Gemini LLM.

As noted, CV is also a key feature adopted across many consumer electronics products. Apple first released Face ID in November 2017 on the iPhone X. It is now used across its range of iPhones and iPads. It is a facial recognition system that allows biometric authentication for unlocking a device, making payments, accessing sensitive data, and providing detailed facial expression tracking to enable Animoji (a custom 3D emoji that mirrors a user's facial expressions).

Google released the Magic Eraser feature in its Pixel 6 smartphone in 2021, though it had been talking about it since 2017. It allows the user to remove unwanted objects and people in their photos. It makes suggestions about removing objects but also lets the user choose. It relies on ML technology to automate what was previously a manual editing job in Photoshop.

See [Smart Speakers](#).

Leaders

Apple, Alibaba, Alphabet (Google), Amazon, Baidu, Microsoft, Samsung, Tencent.

AI can support advanced photo editing

Google Magic Eraser removes unwanted background objects



Source: Future

Cybersecurity

The cybersecurity industry has incorporated AI capabilities in several areas, including biometrics authentication (e.g., facial, fingerprint, and iris recognition), threat detection, and incident response. Often, the key AI capabilities are ML models trained to detect security breach patterns or determine the best remedial actions. For instance, the main product of security firm CrowdStrike, called Falcon, uses an AI-based user and entity behavior analytics (UEBA) engine. This detects threats by identifying activity that deviates from a normal baseline, such as unusual traffic patterns, unauthorized data access and movement, or suspicious or malicious activity on a computer network or endpoints. Likewise, UK-based Darktrace developed a product it calls an enterprise immune system (EIS). This uses AI methodologies and populates status rule bases through unsupervised machine learning.

AI is becoming particularly popular for incident response, given the increasing number of cyberattacks organizations must deal with every year. Automating incident response with AI makes it easier to resolve more incidents quickly, reducing the organization's downtime and resources required to deal with IT security.

See [Cybersecurity](#).

Leaders

CrowdStrike, Darktrace, Trellix, Palo Alto Networks, SentinelOne, Tanium.

Ecommerce and retail

Retail in general, and ecommerce specifically, were early adopters of AI in multiple areas of the business, including customer experience (e.g., purchasing recommendations, voice-enabled shopping assistants, personalized shopping experiences, facial recognition payments), fulfillment (e.g., warehouse robotics) and procurement (e.g., anti-counterfeit tools).

Amazon started using AI for its recommendation systems in 2003, using a novel algorithm called item-item collaborative filtering. Rather than recommending purchases that similar customers have made, it reviews recent purchase history and, for each purchase, pulls up a list of related items, giving them a weight based on how many times it appears in this process. Alibaba's recommender system is also considered state-of-the-art. Its transformer-based algorithm considers the sequence of a user's past actions, so, for instance, it will not recommend a phone case until after the user buys a new phone.

Warehouse automation was a necessity from the very early days of ecommerce, but with the increasing scale of the leading platforms, AI has been incorporated into the mix. For example, online grocer Ocado developed the Smart Platform to make consumption predictions for all its products and automatically order the right amounts to fill its warehouses while minimizing waste. Its AI algorithm considers parameters such as the day of the week, weather, season, or cultural events.

Independent providers such as 3PM Solutions (acquired by eBay in 2023), Digimarc, and BroutonLab have developed solutions to detect counterfeit products using computer vision and machine learning. The companies whose goods are being sold on ecommerce sites can take control of where counterfeits of their products are available.

See [Ecommerce](#) and [Frictionless Commerce](#).

Leaders

Amazon, Alibaba, eBay, Ocado.

AI underpins Amazon recommendations

It checks purchasers' correlations and user similarities



Source: Amazon

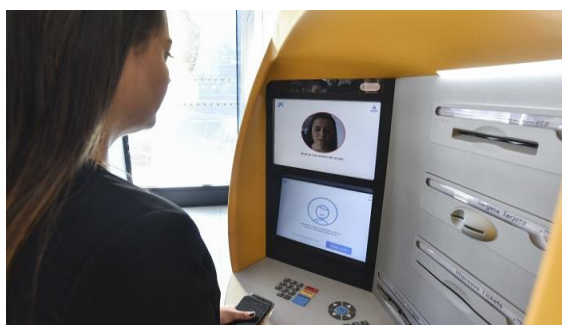
Financial services

Various analytics tasks at the core of the financial services industry, such as credit risk assessments, customer profiling, anti-money laundering, and fraud protection, can be improved using ML models. JP Morgan was an early adopter of AI in its business. In 2018, it launched a Contract Intelligence platform that used natural language processing to handle legal documents and extract essential data, improving how its back office reviewed commercial credit agreements. In 2019, it adopted ML to automate the hedging of some equity options. Three years later, it started building a deep hedging engine, also using ML, to work out how to hedge derivatives books from raw data, factoring in real-world market frictions such as transaction costs.

Another business area where financial services firms have been using AI is security, given the large volumes of hacking and fraud attempts. CV applications, particularly facial recognition (FR) technology, are relatively new to the financial services sector but could play a significant role. For example, FR can be a key element in multi-factor authentication for ATM withdrawals, mobile banking enrollment, mobile banking access, and online transactions.

CV can improve ATM security and usability

Bank customers can use an ATM without a PIN



Source: CaixaBank

In 2019, CaixaBank introduced FR to its ATMs, which customers can use without entering a PIN, while China's state-owned banks use FR software provided by start-ups CloudWalk and Yitu Technology. With that said, adoption has been modest so far, as there are still challenges regarding its accuracy, cost, security, and the need for customer education.

Significantly, Chinese authorities are signaling the need to take a tougher stance on FR technology in the face of increased data security and privacy concerns. Li Wei, director of the science and technology department at the People's Bank of China, has warned customers of risks related to biometric authentication. He argued that this technology could be less safe than a traditional password, as a person's face cannot be changed if and when their financial data is compromised.

Large financial institutions are using conversational platforms to reduce customer wait time, increase first-call resolution, and reduce call center costs. Bank of America's Erica uses predictive analytics and natural language processing to serve the 42 million users of the bank's mobile app.

Generative AI could potentially automate more sophisticated financial advisory services. However, the regulatory regime is still unclear, and early attempts still rely on a human financial advisor to review and interact with the customer. In 2023, JLL launched a GPT AI model for the commercial real estate industry, allowing its over 100,000 employees worldwide to provide commercial real estate insights to their clients. That same year, Bloomberg released a research paper disclosing its work on BloombergGPT, a 50 billion parameter language model trained on a wide range of financial data.

Services for individual investors, such as Wealthfront and Magnifi, are beginning to incorporate generative AI to assist in financial planning, portfolio construction, investment management, and personal banking.

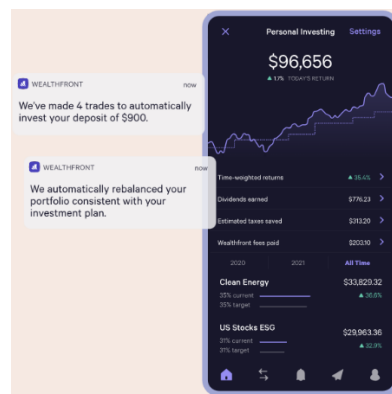
See [AI in Banking](#).

Leaders

Ant Financial, Baidu, Amazon, CloudWalk, FaceFirst, iProov, and Yitu Technology.

LLMs can act as financial advisors

Use cases include portfolio construction



Source: Wealthfront

Healthcare

The healthcare industry relies on high-level diagnostics provided by medical imaging. Demand is driven by aging populations in many nations and a desire to avoid unnecessary radiation exposure associated with other imaging technologies like X-rays and computerized tomography (CT) scans. CV software can help radiologists find abnormalities in patient scan images that could lead to a diagnosis when interpreted by a doctor. CV software can also help make some medical procedures safer and faster, including endoscopies.

AI provides clinical decision support

Deep learning algorithms learn key tumor features



Source: Merative

One of the most promising applications is automated image processing to detect tumors. Here, deep learning algorithms learn important features related to the disease from a collection of medical images and then make predictions based on that learning. Unfortunately, training these algorithms requires a vast amount of data, which is often unavailable. The scarcity of medical images is a challenge that needs to be overcome.

IBM was an early advocate of CV for healthcare but has suffered its fair share of disappointments. After acquiring Merge Healthcare in 2015, IBM had access to an extensive collection of medical images on which to train its Watson AI platform. However, despite the impressive data set, Watson struggled to live up to expectations.

In 2017, its relationship with the University of Texas MD Anderson Cancer Center collapsed after three years of work and more than \$60 million in spending. The following year, the press reported that Watson had made several “unsafe and incorrect recommendations” to cancer doctors, according to leaked internal documents. Nearly five years after the launch of IBM Watson Health, critics said that the tool was still only capable of performing routine tasks rather than delivering the promised AI-powered medical revolution. IBM eventually gave up and, in early 2022, sold the healthcare data and analytics assets from its Watson Health business to investment firm Francisco Partners, which subsequently renamed the business Merative. The company’s CV platform remains with IBM as part of its cognitive cloud offering.

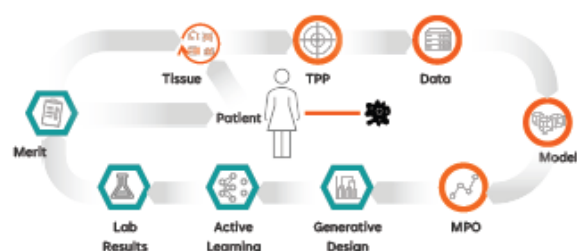
Despite these setbacks, the potential of CV and, more broadly, AI in the healthcare and pharma industries is enormous. In 2021, Alphabet’s subsidiary DeepMind launched AlphaFold, a protein structure prediction system that uses a deep learning model to predict the 3D structure of a protein from its amino acid sequence. AlphaFold has already been used to make significant advances in biology, such as predicting the structure of the SARS-CoV-2 spike protein, which the virus uses to enter cells. In 2022, Nvidia launched its BioNeMo Cloud service, which enables researchers to train and deploy LLMs for drug discovery. In 2023, another division within Alphabet launched Med-PaLM2, an LLM trained on a massive medical dataset, which can summarize insights from various medical texts and pass medical tests with acceptable results (e.g., 86.5% on the MedQA dataset). Meta is also involved in protein structure prediction, using its ESMFold model to build a database of over 700 million predicted protein structures, which it named the ESM Metagenomic Atlas.

Among the pharma start-ups, Exscientia was the first to report an AI-designed drug candidate to enter clinical trials in early 2020, a pivotal moment in AI drug discovery. The company has been working with Sumitomo Dainippon Pharma to create effective and selective molecules targeting complex biological challenges, such as Alzheimer’s disease psychosis.

The pharma industry is investing in AI

Generative AI can expedite the drug discovery process

Reinventing drug design by starting and ending with the patient
Enables a continuous learning loop



Source: Exscientia

In 2023, Insilico Medicine started working with DeepMind to develop drugs for liver cancer. It will use AI to expedite the drug discovery process, with a focus on developing a potential treatment for hepatocellular carcinoma (HCC), the most common form of primary liver cancer.

See [Artificial Intelligence in Healthcare](#), [Artificial Intelligence in Clinical Practice](#), [Artificial Intelligence in Drug Discovery](#), and [Generative AI in Pharma](#).

Leaders

Merative, Arterys, Philips Healthcare, GE Healthcare.

Timeline

AI is not a new concept. The idea of inanimate objects coming to life as intelligent beings goes back to Greek antiquity. In the first half of the 20th century, science fiction's golden age familiarized the world with the concept of artificially intelligent robots. In 1950, Alan Turing published the seminal paper *Computing Machinery and Intelligence*, in which he considered the question, "Can machines think?". Six years later, during a conference at Dartmouth College, the term 'artificial intelligence' was accepted as the name of the field of study into thinking machines.

The progress of AI has not been linear. There have been two significant periods of reduced funding and interest, known as AI winters. The first ran from 1974 to 1980, and the second from 1987 to 1993. Following the end of this second winter, interest slowly picked up, helped by IBM's chess-playing computer Deep Blue's landmark 1997 victory over grandmaster Garry Kasparov. Just over a decade later, Google built the first autonomous car, and OpenAI developed a language model that was able to write original prose with human-like fluency. The current AI boom was underway.

The major milestones in the journey of the AI theme are set out in the timeline below.

The AI story

How did this theme get here, and where is it going?

1642	Pascal invented the first digital calculating machine.
1854	George Boole invented Boolean algebra.
1913	Formal logic is revolutionized in <i>Principia Mathematica</i> by Whitehead and Russell.
1948	Von Neumann asserted that a general computer could simulate any effective procedure.
1950	Alan Turing developed the Turing Test to assess a machine's ability to exhibit intelligent (human-like) behavior.
1952	Arthur Samuel wrote the first game-playing program for draughts (checkers).
1956	The Dartmouth Summer Research Project on Artificial Intelligence was held, a foundational event for the field.
1959	John McCarthy and Marvin Minsky founded the MIT AI Lab.
1973	The Lighthill Report, heavily critical of AI research, set study of the area back in the UK and the US.
1997	World chess champion Garry Kasparov is defeated by IBM's Deep Blue.
2005	Tivo popularises recommendation technology based on tracking web activity and media usage.
2009	Google started its self-driving car project (later renamed Waymo), building its first autonomous car.
2011	IBM Watson beat human champions in the TV game show <i>Jeopardy!</i>
2011	Apple released the iPhone 4S, containing the natural language-based virtual assistant Siri.
2014	Tesla introduced AutoPilot, software that was later upgraded for fully autonomous driving.
2014	Amazon launched the Echo, an intelligent voice-activated speaker that included the Alexa virtual assistant.
2015	Baidu launched Duer, its intelligent assistant.
2016	Google DeepMind's AlphaGo algorithm beat the world Go champion Lee Sedol 4-1.
2017	Google Research team publishes the Transformer model ushering the generative AI revolution.
2017	Libratus, designed by Carnegie Mellon researchers, beat the top 4 players in no-limit Texas hold 'em poker.
2018	Alibaba's AI model scored better than humans in a Stanford University reading and comprehension test.
2019	The US added four of China's leading AI start-ups to a trade blacklist.
2020	COVID-19 accelerated investments in AI.
2020	OpenAI launched the language model GPT-3, which could write original prose with human-equivalent fluency.
2022	The US banned Nvidia and AMD from selling advanced AI chips, including GPUs, to China.
2030	GlobalData forecasts that spending on AI technology will be more than \$1,037 billion.
2035	Fully autonomous vehicles (Level 5) will be available to consumers.
2060	50% probability of full human-level AI, according to a poll of AI experts.
2120	75% probability of full human-level AI, according to a poll of AI experts.

Source: GlobalData

Signals

This section uses the over 180 million signals generated by GlobalData's thematic engine to predict how the AI theme will develop and identify the likely leaders. These signals are a useful source of competitor intelligence in the AI market.

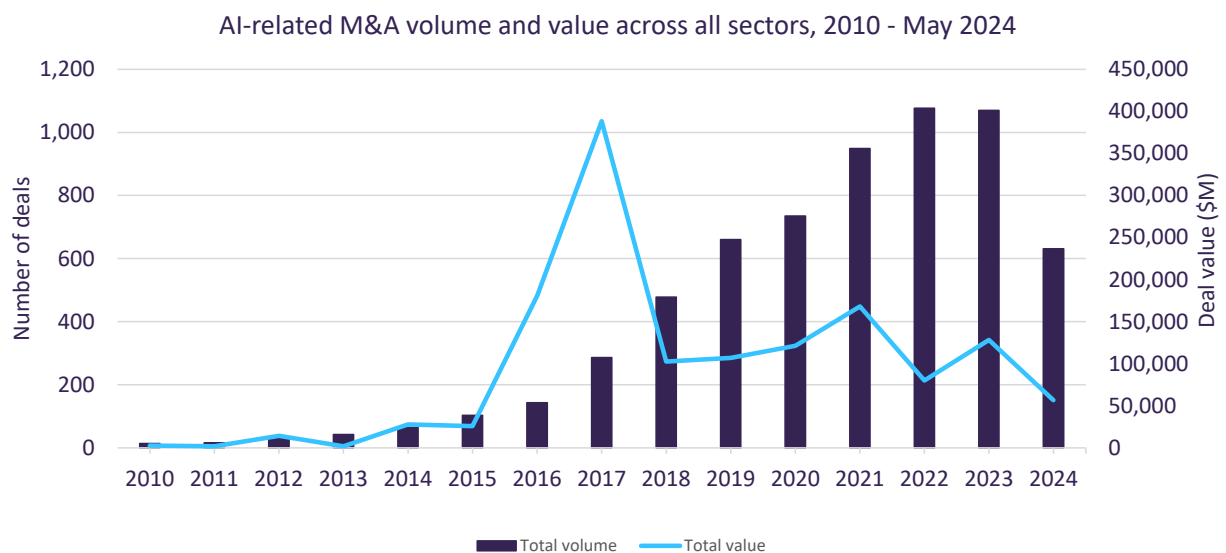
M&A trends

The COVID-19 pandemic, the resulting supply chain disruption, and the emergence of generative AI as an enterprise-ready technology have accelerated automation and digitalization across all industries. The potential of AI to enable both efficiency improvements and automation caused an upsurge in AI-related M&A activity across all sectors between 2019 and 2023.

Many AI-related acquisitions in the last two years have focused on generative AI and cloud AI infrastructure. Examples of the former include the minority stakes taken by Microsoft and Softbank in OpenAI and Amazon and Google in Anthropic and the outright acquisitions of MosaicML by Databricks and Light Year by Meituan. Examples of the latter include the acquisition of Run:AI and Excelero by Nvidia, Paperspace by DigitalOcean, and Databand.ai by IBM.

COVID-19 and generative AI have sparked increased AI adoption across all industries

M&A deal volumes have increased since 2015, while values have been more volatile



Source: GlobalData

The key M&A transactions associated with the AI theme since January 2022 are listed in the table below.

Date announced	Acquirer	Target	Value (\$M)	Target company description
May 2024	The9	Kuaijin Shidai	2,216	Operator of unmanned AI retail store platform.
May 2024	DocuSign	Lexion	165	Provider of AI-powered agreement management software.
May 2024	Aareon	Stonal	108	Provider of an AI-powered real estate data management platform.
Apr 2024	Thoma Bravo	Darktrace	5,300	Provider of AI-based cybersecurity software solutions and services.
Mar 2024	Amazon	Anthropic	2,750	Generative AI provider.
Mar 2024	The9	WM Therapeutics	1,409	Developer of AI-based precision medicine platforms for brain diseases.
Mar 2024	Nvidia	Run:AI	700	Provider of GPU orchestration software.
Feb 2024	Veradigm	ScienceIO	140	Provider of AI platforms and foundation models for healthcare.
Dec 2023	Burtech Acquisition ⁽¹⁾	Blaize	894	Provider of AI tools, including AI chips, for automotive and edge computing.
Dec 2023	Bayanat AI	Yahsat	2,290	Merger to create Space42, a provider of geospatial and mobility solutions.
Dec 2023	Lunit	Volpara Health Technologies	192	Provider of medical software for breast cancer screening using AI.
Dec 2023	LIG Nex1	Ghost Robotics	240	Developer of autonomous quadruped robots.
Oct 2023	Google	Anthropic	2,000	Generative AI provider.
Oct 2023	Nice	LiveVox Holdings	393	Cloud platform for customer engagement with AI capabilities.
Sep 2023	Amazon	Anthropic	4,000	Generative AI provider.
Sep 2023	Softbank	OpenAI	1,000	Generative AI provider.
Aug 2023	Parsons	Sealing Technologies	200	Provider of cybersecurity software and services with AI capabilities.
Aug 2023	AeroVironment	Tomahawk Robotics	120	Developer of AI-enabled control systems for the defense industry.

Date announced	Acquirer	Target	Value (\$M)	Target company description
Jul 2023	DoubleVerify Holdings	Scibids Technology	125	Provider of AI tools around advertisers' programmatic buying of digital campaigns.
Jul 2023	DigitalOcean Holdings	Paperspace	111	Cloud infrastructure provider for AI developers.
Jun 2023	Meituan	Beijing Light Year Beyond Technology	281	Generative AI provider.
Jun 2023	Databricks	Mosaic ML	1,300	Generative AI platform provider.
Jun 2023	Thomson Reuters	Casetext	650	Developer of an AI-powered assistant for law professionals.
Jun 2023	Kunlun Tech	Singularity AI	160	Generative AI provider.
May 2023	Philips Healthcare	DIA Imaging Analysis	100	Provider of AI ultrasound image examination tools for cardiac image acquisition.
Apr 2023	Rosecliff Acquisition Corp I ⁽¹⁾	Spectral AI	170	Provider of predictive AI solutions for medical diagnostics.
Mar 2023	CNH Industrial	Augmenta	110	Developer of AI-based field analyzer solutions.
Mar 2023	The Travelers Companies	Corvus Insurance Holdings	435	Cyber insurance company with a proprietary AI-driven cyber risk platform.
Mar 2023	Transcarent	98point6	100	Developer of an AI chatbot to assist medical doctors.
Feb 2023	Vahanna Tech Edge Acquisition I ⁽¹⁾	Roadzen	259	Provider of B2B AI solutions to the auto insurance market, primarily to automakers and fleet operators.
Feb 2023	indie Semiconductor	GEO Semiconductor	270	Developer of video-processing chips for automotive cameras.
Feb 2023	Google Cloud Platform	Anthropic	300	Generative AI provider.
Jan 2023	Microsoft	OpenAI	10,000	Generative AI provider.
Jan 2023	BioNTech	InstaDeep	608	AI consulting and services firm.
Dec 2022	Mozilla	Lentil AI	Not disclosed	AI and data analytics company focused on workplace productivity.

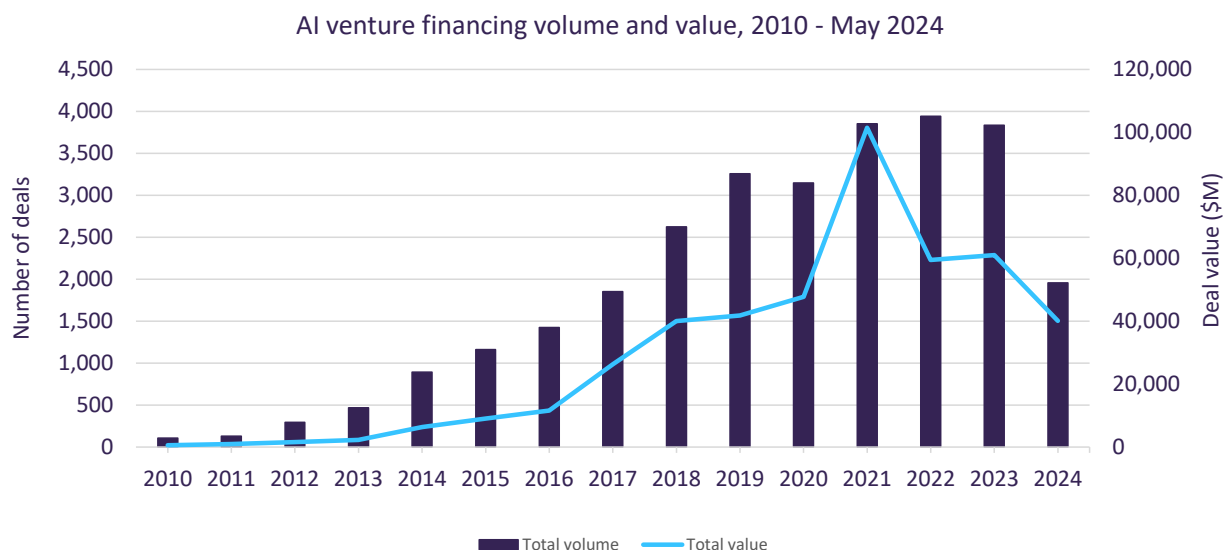
Date announced	Acquirer	Target	Value (\$M)	Target company description
Nov 2022	Accenture	Albert	Not disclosed	Consultancy firm providing AI and data solutions.
Nov 2022	Meta	Audio Analytic	Not disclosed	Audio recognition software provider.
Oct 2022	Telus International	WillowTree	1,225	Full-service digital product provider focused on end-user experiences.
Aug 2022	OneMeta AI	Metalanguage	Not disclosed	NLP applications and cognitive services company.
Jun 2022	IBM	Databand.ai	150	Data observability software provider.
Jun 2022	ReliaQuest	Digital Shadows	160	AI-powered threat intelligence and security services platform.
Mar 2022	Intel	Granulate Cloud Solutions	650	Automated optimization software provider.
Mar 2022	NielsenIQ	CiValue	Not disclosed	SaaS vendor that powers loyalty programs using an AI platform.
Mar 2022	Nvidia	Excelero	Not disclosed	High-performance block storage provider for AI and analytics workloads.
Feb 2022	Apple	AI Music Group	Not disclosed	AI-generated music tailored to consumer preferences.
Source: GlobalData (1) Special purpose acquisition company (SPAC) merger				

Venture financing trends

Venture financing activity in AI has been high over the last five years, particularly in AI chips and data analytics. Challenging macroeconomic conditions slowed venture financing activity in 2022, yet investment reaccelerated in 2023 and 2024 on the back of interest in generative AI. At the current run rate, 2024 will finish well above 2023 in terms of volume and value of deals.

Generative AI has driven a reacceleration in venture financing since early 2023

Venture financing deal value declined in 2022



Source: GlobalData

The key venture financing deals associated with the AI theme since January 2022 are listed in the table below.

Date announced	Company	Amount raised (\$M)	Company description
Jun 2024	Unisoc (Shanghai) Technologies	552	Chip designer across multiple fields, including AI, computing, and radio.
May 2024	Zhipu AI	400	Generative AI provider.
May 2024	X.AI	6,000	Generative AI provider.
May 2024	DeepL	300	AI translation provider.
May 2024	Scale AI	1,000	Provider of an enterprise data platform for generative AI development.
May 2024	Wayve Technologies	1,050	Autonomous driving platform provider.
May 2024	CoreWeave	1,100	Cloud infrastructure provider for AI developers.
Apr 2024	Xaira Therapeutics	1,000	AI drug discovery company.

Date announced	Company	Amount raised (\$M)	Company description
Mar 2024	Minimax AI	600	Generative AI provider.
Feb 2024	Figure AI	675	Humanoid form robots provider.
Feb 2024	Lambda	320	Cloud infrastructure provider for AI developers.
Feb 2024	Moonshot AI	1,000	Generative AI provider.
Jan 2024	Cohere	741	Generative AI provider.
Dec 2023	Anthropic	750	Generative AI provider.
Nov 2023	Aleph Alpha	500	Generative AI provider.
Oct 2023	Mistral AI	415	Generative AI provider.
Oct 2023	Beijing Baichuan Intelligent Technology	300	Generative AI provider.
Oct 2023	Metropolis Technologies	1,050	Computer vision provider.
Sep 2023	Databricks Inc	500	Data analytics and AI provider.
Sep 2023	Conigital	623	Autonomous driving platform provider.
Jun 2023	Inflection AI	1,300	Generative AI provider.
May 2023	Anthropic	450	Generative AI provider.
Apr 2023	OpenAI	300	Generative AI provider.
Mar 2023	Adept AI	350	Developer of AI work assistants.
Mar 2023	Anthropic	300	Generative AI provider.
Feb 2023	SandboxAQ	500	AI and quantum computing company.
Feb 2023	Anthropic	300	Generative AI company.
Jan 2023	OpenAI	10,000	Generative AI company.
Dec 2022	Moore Threads	215	Fabless semiconductor company focused on GPUs.
Dec 2022	Tredence	175	Data science solutions provider focused on AI workloads.
Dec 2022	Dataiku	200	AI and ML company.
Dec 2022	Snyk	197	Cybersecurity software company using AI for threat detection.

Date announced	Company	Amount raised (\$M)	Company description
Nov 2022	Locus Robotics	117	Warehouse robotics company specializing in autonomous robots.
Nov 2022	Astera Labs	150	Specialist provider of custom data and memory connectivity solutions.
Nov 2022	WEKA	135	AI-powered data management provider for next-generation workloads.
Nov 2022	AI Proteins	18.2	Biotech company focused on designing synthetic mini protein therapeutics.
Sep 2022	Arize AI	38	Platform that detects and eliminates ML model errors.
Aug 2022	Black Sesame Intelligent Technology	500	Chip maker for autonomous vehicles.
Jul 2022	Contentsquare	600	Digital experience analytics vendor using AI to extract insights.
Jun 2022	Beijing Megarobo Technology	300	AI and robotics company specializing in the fields of life sciences and clinical diagnosis.
Apr 2022	Anthropic	580	Generative AI provider.
Apr 2022	Viz.ai	100	AI-powered care coordination platform for medical specialists.
Mar 2022	Cresta Intelligence	80	Produces AI-powered customer service tools.
Feb 2022	Uniphore Technologies	400	Conversational automation technology company.
Feb 2022	Salt Security	140	Provides API security at enterprise scale.
Jan 2022	o9 Solutions	295	AI platform that digitalizes supply chains.
Jan 2022	SeekOut	115	AI-powered recruitment software.
Source: GlobalData			

Patent trends

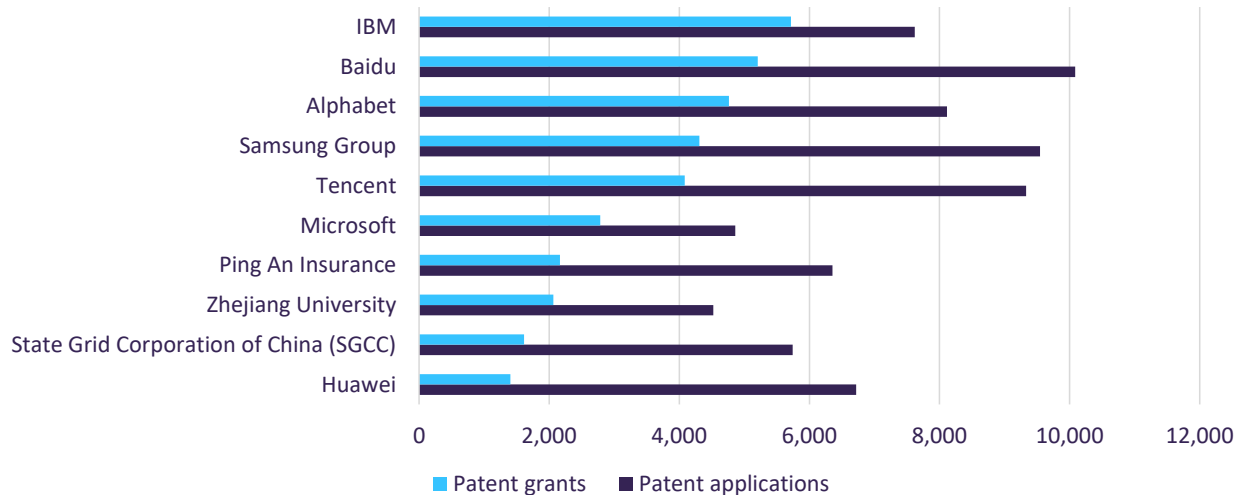
The number of patent filings for AI-related technologies has steadily increased in recent years, with more than nine times as many patents published in 2023 than in 2013.

The chart below shows the leading holders of granted AI patents between 2016 and May 2024. Unsurprisingly, AI innovation and adoption leaders like IBM, Alphabet, Samsung, and Microsoft are at the top half of the list. However, Chinese tech vendors such as Baidu, Tencent, and Huawei are increasing their ranking. In the last edition of this thematic report, Baidu and Tencent were ranked sixth and eighth, respectively, and Huawei did not even appear in the top 10.

IBM, Baidu, and Alphabet lead the way in AI-related patents

US and China lead in AI-related patent applications

Top 10 assignees of AI-related patents, 2020 - May 2024



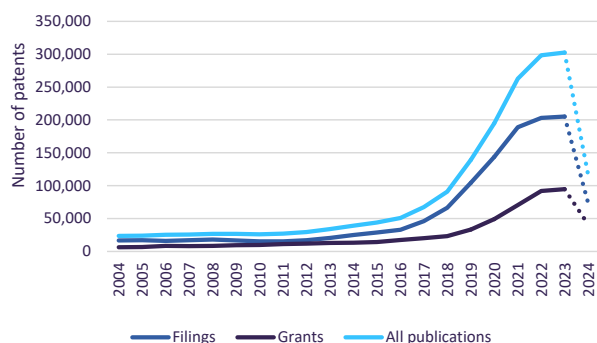
Source: GlobalData

From an overall trend perspective, there has been a significant acceleration in patent filings since 2017, not coincidentally the year Alphabet published the transformer model, which is the basis of most generative AI solutions.

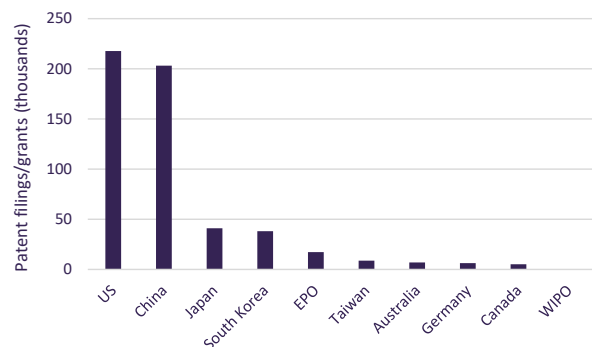
AI-related patent publications in the TMT sector have accelerated since 2018

AI technologies remain a playground for geopolitical competition between the US and China

AI-related patent trends 2004 - May 2024



Top 10 authorities publishing patents, 2016 - May 2024



Note: WIPO = World Intellectual Property Organization, EPO = European Patent Office

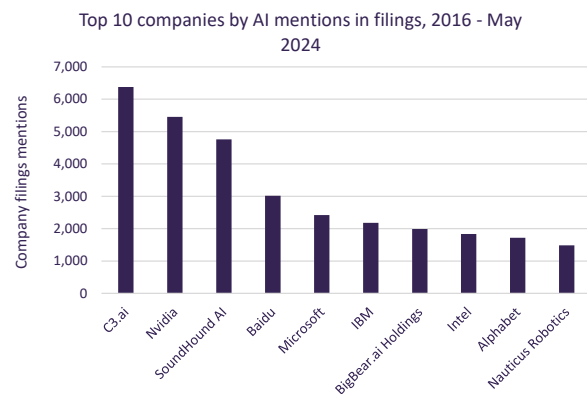
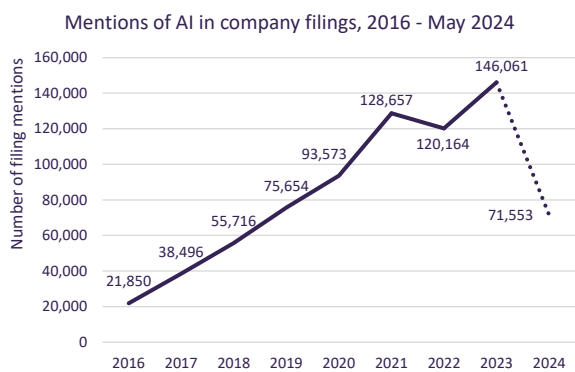
Source: GlobalData

Company filing trends

The left-hand chart below shows an increase in mentions of AI in company filings, which were seven times higher in 2023 than in 2016. There was a modest decrease in 2022 yet mentions quickly returned to trend in 2023 and year to date. However, with the increase in AI awareness due to the popularity of generative AI since OpenAI launched GPT-3 and ChatGPT at the end of 2022, mentions quickly rose again in 2023. Companies are taking advantage of these new capabilities, particularly in areas such as sales, marketing, and customer support, and discussing it in corporate filings. At the current run rate, 2024 will likely see a level of mentions similar to 2023, if not higher.

AI mentions in company filings in the TMT sector accelerated in 2020

The exponential growth in mentions correlates with the growing popularity of AI automation



Source: GlobalData

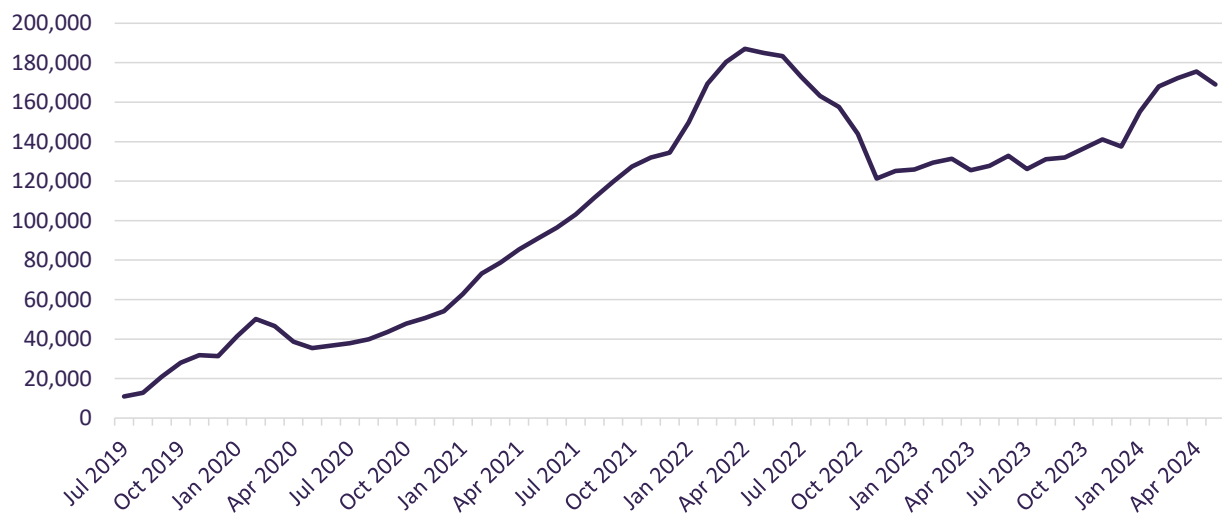
Hiring trends

GlobalData's Job Analytics indicates a growing trend in active job postings related to AI over the last five years, although, between May and November 2022, there was a decline, possibly related to a more uncertain global economic environment, particularly in the geopolitical sphere, with developments such as the war in Ukraine and the ongoing trade dispute between the US and China. That said, from early 2023, the upward trend modestly resumed, driven by all the investment in generative AI.

AI-related hiring peaked in April 2022

Hiring trends are volatile, but the decline in H2 2022 likely reflects the tech layoffs post-pandemic

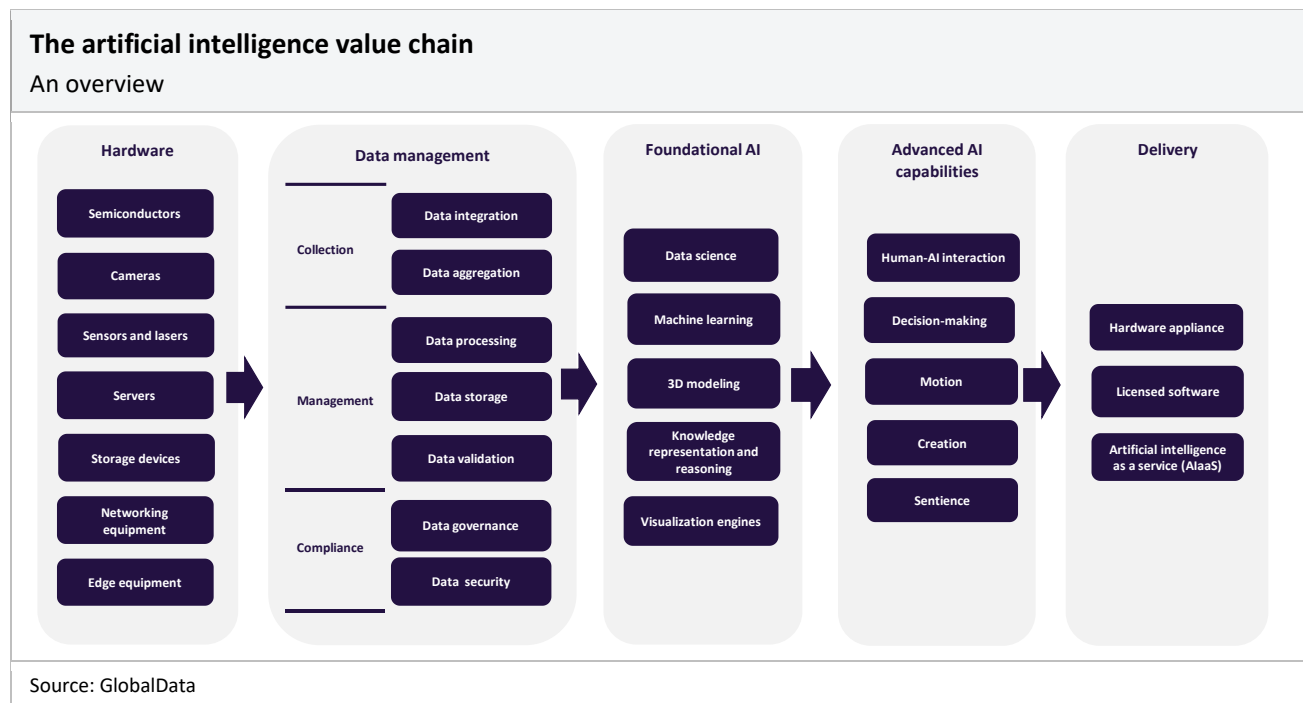
AI-related active jobs July 2019 - May 2024



Source: GlobalData

Value Chain

The graphic below shows our value chain for artificial intelligence (AI). It is split into five segments: hardware, data management, foundational AI, advanced AI capabilities, and delivery.



US and Chinese tech companies are tightly intertwined in the AI supply chain for components like cameras and AI chips. AI chips produced by the likes of Intel and Nvidia power the servers of both Chinese AI companies and public cloud vendors running AI workloads on behalf of their clients. In cases where Chinese vendors have developed their own AI chips (e.g., Alibaba, Baidu, Huawei), they are often manufactured in Taiwan using US technology. As such, the increasing restrictions imposed on them by the US government in the last three years are significantly disrupting the AI value chain. The US is now preventing Nvidia and AMD from selling advanced AI chips to China while at the same time banning the export of high-end semiconductor manufacturing tools that would enable China to manufacture its own AI chips.

Hardware

The AI hardware stack is not dissimilar from any IT system, although parts such as semiconductors, cameras, sensors, and edge equipment are very AI-specific. On the other hand, servers, storage, and networking equipment are standard and not designed specifically for AI use cases.

Semiconductors

The two main categories of semiconductors that benefit from being optimized for AI use cases are image processors to support computer vision (CV) and AI accelerators, both for the data center and the cloud edge.

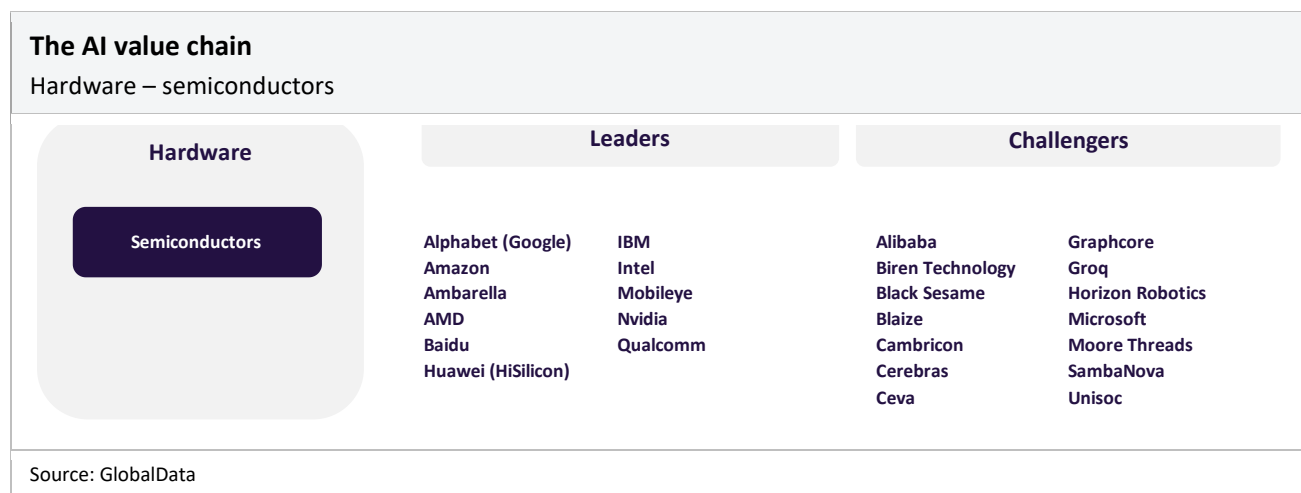


Image processors, also called image signal processors (ISPs), are a type of digital signal processor (DSP) used for image processing in digital cameras or other devices. Their primary function is to take the raw data derived from light sensors, adjust and enhance it, and convert it into video streams in digital formats that computers can understand. Ambarella and Qualcomm are leading vendors whose ISPs are used in CV applications such as video security, advanced driver assistance systems (ADASs), autonomous vehicles (AVs), and robotics.

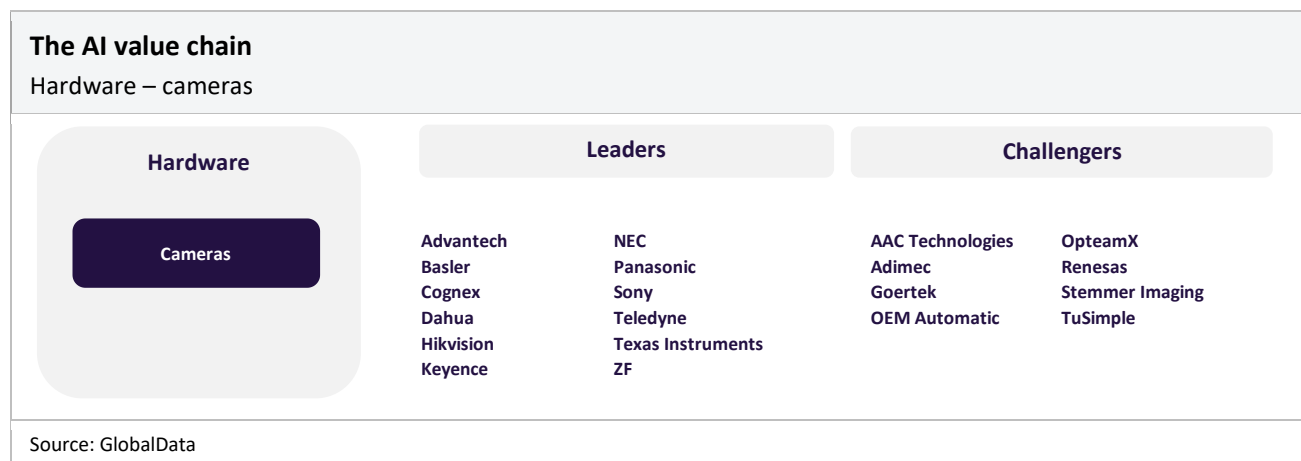
AI chips are semiconductors that are designed to perform AI tasks more efficiently. They are often referred to as AI accelerators and come in a variety of forms, including graphics processing units (GPUs), field programmable gate arrays (FPGAs), and application-specific integrated circuits (ASICs). As the volume of data for AI to interpret grows exponentially, the demand for AI chips, such as GPUs from Nvidia and AMD, increases. Moreover, AI chipmakers' biggest customers (tech companies like Alibaba, Amazon, Apple, Baidu, Google, Meta, and Microsoft) are increasingly designing their own specialist AI chips and sending them straight to foundries for manufacture. Google's tensor processing units (TPUs), Amazon's Inferentia and Trainium chips, and Microsoft's Maia 100 AI Accelerator now compete with merchant suppliers. Furthermore, new entrants, such as Biren Technology, Cambricon, Graphcore, Groq, and Horizon Robotics, use innovative chip architectures.

Edge cloud computing is also a promising area for AI. Users can achieve low latency and solve data privacy and bandwidth issues by performing analytics on edge devices (such as cameras, smartphones, and within vehicles) instead of relying on a connection to the cloud. Ambarella, HiSilicon (owned by Huawei), and Intel provide CV systems on a chip (SoCs) that contain video and AI processors in a single chip. These companies also offer chips and software for deep neural network AI applications. They specifically support inference (i.e., the AI component that applies logical rules to the training to deduce new information) at the edge instead of inference deployed in the data center or the on-premises server.

See [AI Chips](#) and [Next-Generation Chips](#).

Cameras

This segment includes suppliers of surveillance cameras and security products powered by AI. AI-powered cameras rely on powerful graphics and computer chips to analyze footage for image recognition, including facial recognition. Nvidia and AMD provide GPUs to train the AI algorithms used by computer vision systems, such as facial recognition tools, autonomous vehicles, and robots.



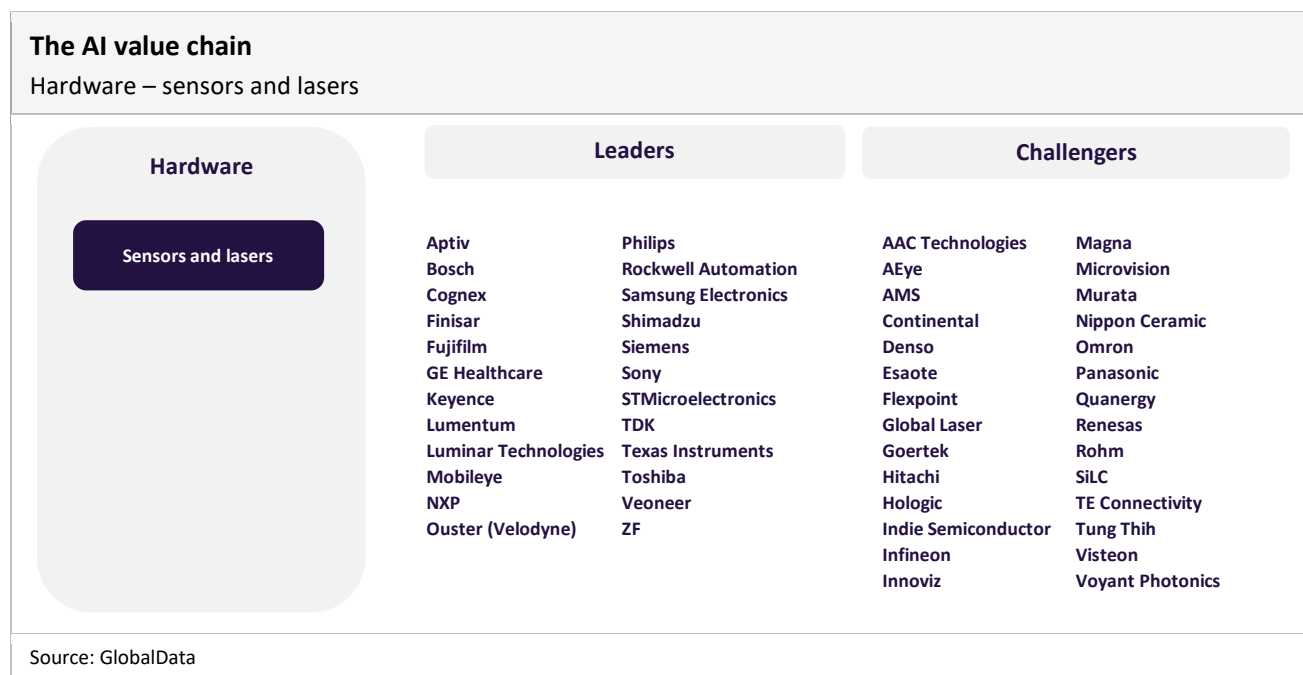
Facial recognition and surveillance are prominent AI use cases. They typically rely solely on cameras, unlike AVs and robots, which combine input from cameras, lasers, and other sensors to understand the world around them. Consequently, several vendors have developed AI-powered cameras that integrate some of the computer vision capabilities in the camera itself.

Hikvision, which is 42% owned by the Chinese government, has been selling surveillance equipment to the US since 2010 and quickly surpassed most of its competitors to become the world's largest supplier by 2016. The company's surveillance cameras can be found across the US, with most of its sales conducted through third-party vendors. In 2018, Hikvision and Dahua, the other major Chinese suppliers of surveillance cameras, were accused of exposing the US government to significant threats due to the use of their equipment by federal agencies. Hikvision has also faced international criticism for helping the Chinese authorities increase surveillance in the Muslim-majority Xinjiang region. Human rights groups and the UN have denounced the use of mass surveillance technology as part of a campaign of repression in the region.

In October 2019, the US government banned China's leading facial recognition companies like Hikvision, Dahua, Megvii, and SenseTime. This prevented them from buying US-made products, including x86 servers and GPUs, which enable the development of algorithms and deep learning training. In 2021, the US Congress passed the Secure Equipment Act, which banned a group of Chinese manufacturers, including Hikvision, Dahua, Huawei, Hytera, and ZTE, from selling equipment into the US market. The Chinese vendors remain global leaders in video surveillance systems, yet their access to Western markets has been significantly limited.

Sensors and lasers

Sensors and lasers are prerequisites in CV applications for AVs and robots.



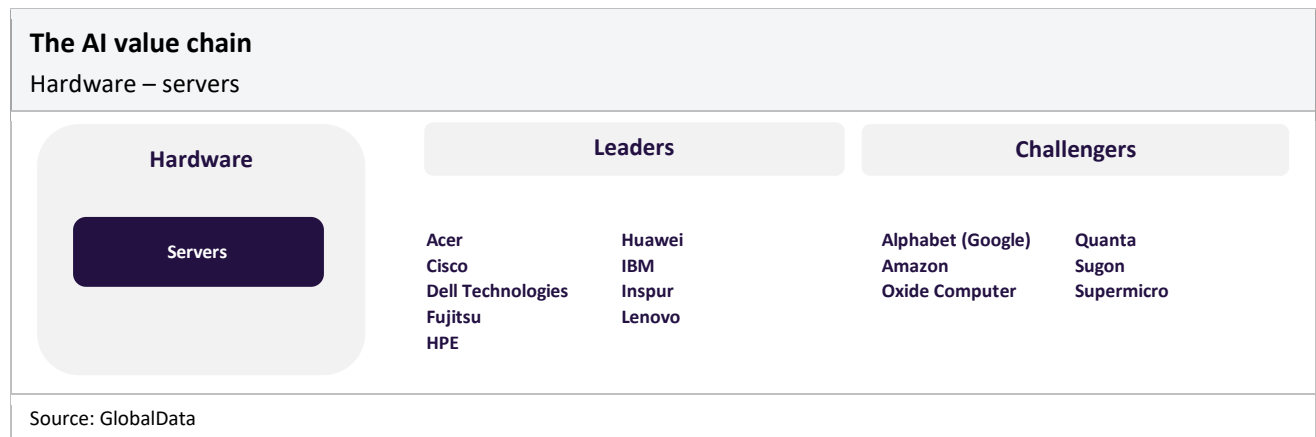
Within self-driving cars, Sony is the leader in image-sensing cameras, while Lumentum stands out as a supplier of laser-based 3D sensors. LiDAR is typically seen as a key ingredient in autonomous vehicles, but LiDAR systems can cost as much as the rest of the parts of a self-driving vehicle combined. The automotive industry is also being transformed by silicon photonics technology, where data is transferred among computer chips by lasers rather than electrical conductors, potentially reducing the cost of LiDAR systems. This could change the economics of self-driving cars, drones, and robots by dramatically reducing the cost and size of the CV systems they need to avoid collisions. Mobileye (owned by Intel), Finisar, Lumentum, Ouster (which merged with Velodyne Lidar in 2023), and IBM are leaders in silicon photonics.

In other use cases where CV requires positioning and navigation capabilities, such as industrial robotics, the take-up of sensors is driven by drastic reductions in their cost, which, in turn, helps to drive price competition as more manufacturers enter the market. In increasing demand are vision sensors, which use images captured by a camera to determine objects' orientation, presence, and accuracy. Also, lasers are used for triangulation, a popular 3D technique used on production and packing lines whereby the object to be measured passes through a line of laser light, and a camera delivers a 3D profile. Leaders include NXP, Sony, Cognex, and Keyence.

In the healthcare vertical, CV is increasingly used to assist in diagnostics. This is due to rising demand from an aging population and a desire to avoid the unnecessary radiation exposure associated with other imaging technologies like X-rays and computerized tomography (CT) scans. CV software can help radiologists find abnormalities in patient scan images that could lead to a diagnosis when interpreted by a doctor. CV can also help make some medical procedures safer and faster, including endoscopies. Leaders in this segment include GE Healthcare, Siemens, Philips, and Shimadzu.

Servers

AI systems need computing resources to run their underlying AI algorithms. This applies to the training phase, when many data samples are fed to the AI model, and the inference phase, when a trained model is run against a new sample.

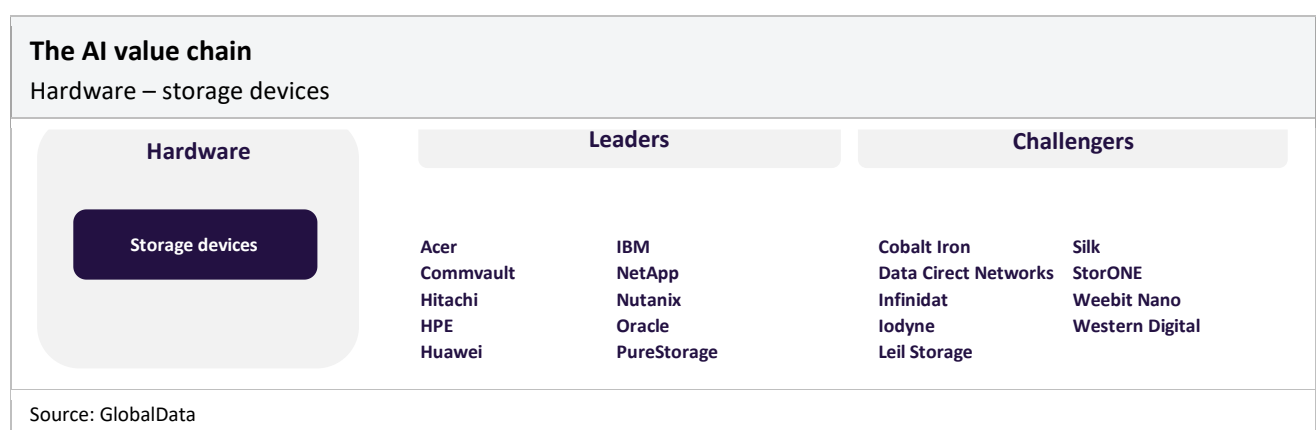


Industry-standard servers can be used for AI systems, although they will typically be equipped with AI chips, such as GPUs or AI accelerators. The leading server vendors include Dell Technologies, HPE, Inspur, Lenovo, and Huawei.

That said, when AI is hosted in the public cloud or delivered as a service (AlaaS), it is possible to use new servers developed by cloud vendors, usually including their own custom AI accelerators. For instance, with Amazon Web Services (AWS), customers can run their AI workloads either on servers with Nvidia or AMD GPUs or on custom servers featuring Graviton CPUs and Trainium or Inferentia AI accelerators. In 2023, Microsoft was the last large public cloud vendor to effectively enter the custom server market when it launched its Cobalt CPUs for general-purpose workloads and its Maia AI accelerators for AI workloads.

Storage devices

AI systems require significant storage resources, as they rely on very large datasets for training and applications such as image or video recognition, conversational platforms, and smart robots. Facial recognition, an important subset of image recognition, is trained on vast databases of known citizens.

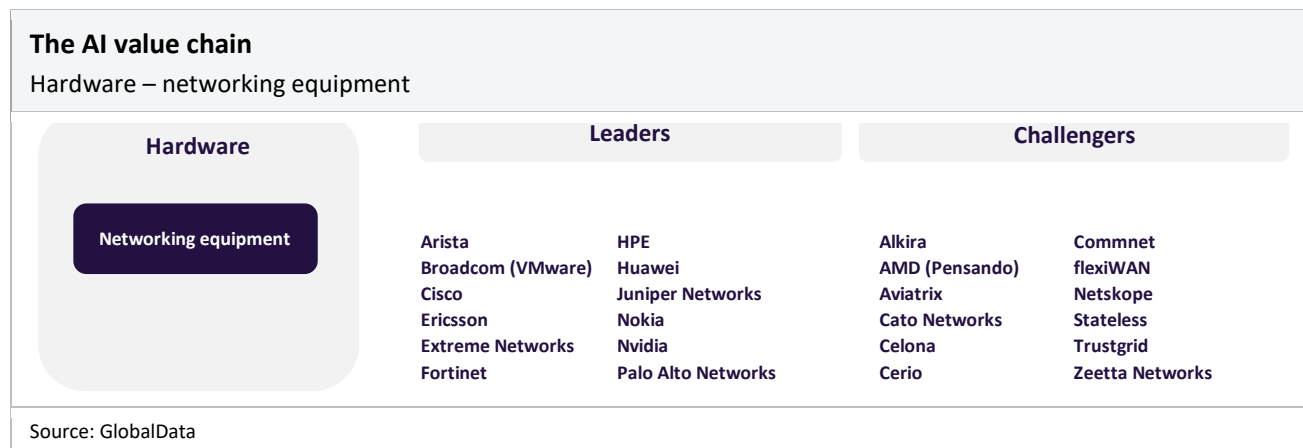


As with servers, no particular design or optimization is required for AI systems. The leading storage vendors include the traditional players: Dell Technologies, NetApp, HPE, IBM, Huawei, and Hitachi. When deployed in the private cloud, the hyperconverged infrastructure (HCI) leaders include Nutanix and PureStorage. HCI is a type of IT infrastructure system with a software-centric architecture that tightly integrates compute, storage, networking, and virtualization resources and other technologies from scratch in a commodity hardware box supported by a single vendor.

Networking equipment

AI systems require significant network resources, as cameras and sensors need to feed their data into the centralized storage devices, which the AI models then use within the servers.

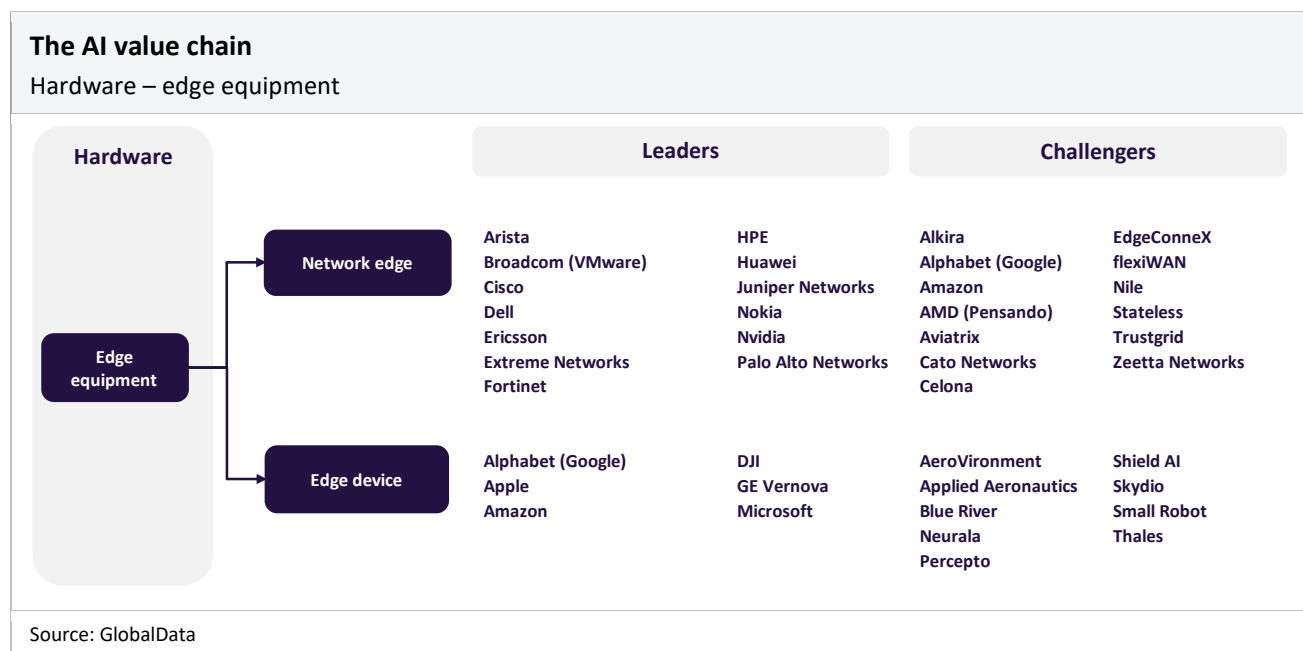
The case of AVs and autonomous mobile robots (AMRs) is singular, as all sensors and cameras are embedded within the vehicle or robot body. However, there is also a need for networking resources in these devices so that data from cameras, radars, and LiDAR reach their self-driving AI engines.



The leading networking equipment vendors include Cisco, Arista, HPE, and Juniper Networks (currently in the process of being acquired by HPE) for wireline or Wi-Fi connectivity. Regarding 4G and 5G connectivity, Ericsson, Nokia, and Huawei are leading vendors.

Edge equipment

For performance reasons, AI may often need to be deployed closer to the users, on edge equipment. This can either be on network equipment located nearby, which is usually referred to as network edge, or on devices such as smartphones, cameras, sensors, and drones. This is particularly useful when network connectivity is unstable or unavailable or when the required response times cannot be achieved by performing AI computations in the cloud.



Traditional networking equipment vendors like Cisco, Arista, HPE, and Juniper Networks dominate the network edge sector, but the device side offers more room for new entrants. Mobile device cameras and sensors are improving with each new model released. At the same time, AI-powered facial recognition capabilities are increasingly integrated into smartphones, enabling them to recognize their users and other objects and locations.

Google's Lens technology, which allows users to learn more about what is in a photo (like items they may want to buy), is embedded into many Android handsets and is available as an app in the Play Store. As people start shopping using Google's tools, the search company can beef up its advertising product to further capture users' interests and connect them with brands. Apple, on the other hand, leads in biometric security. Its Face ID technology, first introduced in 2017, allows users to unlock their iPhones with a glance at the screen.

AI also has innovative applications in certain drones, which use advanced cameras and neural networks to spot objects and people from a height. When used by the police to help find missing people, only a smartphone is required to use the recognition software. Skydio and Thales are among the companies developing this technology.

In 2019, Amazon launched a delivery drone that used various sensors and perception systems to avoid objects in the air and on the ground. However, progress has been slow. It was not until July 2022 that the company announced plans to roll out its Prime Air service to customers in Lockeford, California, and College Station, Texas. At the end of 2023, the company announced plans to start drone deliveries in the UK and Italy in 2024 and to bring its service to a third city in the US.

Data management

AI technology relies on large amounts of data, often called big data, and the various aspects of managing that data feature prominently in the AI value chain. However, data management is not exclusive to AI and can be considered a generic foundational layer. For instance, it also features in GlobalData's IoT, data analytics, and machine learning value chains.

Big data is produced by all forms of digital activity: phone calls, emails, sensors, payments, social media posts, and much more. It is also produced by machines, both hardware and software, in the form of machine-to-machine (M2M) data exchanges. It is typically managed in data centers, either in the public cloud, corporate data centers, or end devices. Broadly speaking, the objective of data management is to secure the data (through data governance and security technology) and manage the data (by applying storage, processing, aggregation, and integration techniques).

Our [Data Analytics](#) report provides a more detailed view of data management.

Data integration

The data integration category incorporates three functions: extract, transform, and load (ETL). ETL is used to copy data from multiple sources and place it into a destination system. Data is taken from one source (extracted), converted into a form that can be analyzed (transformed), and moved into a data warehouse or other system (loaded).

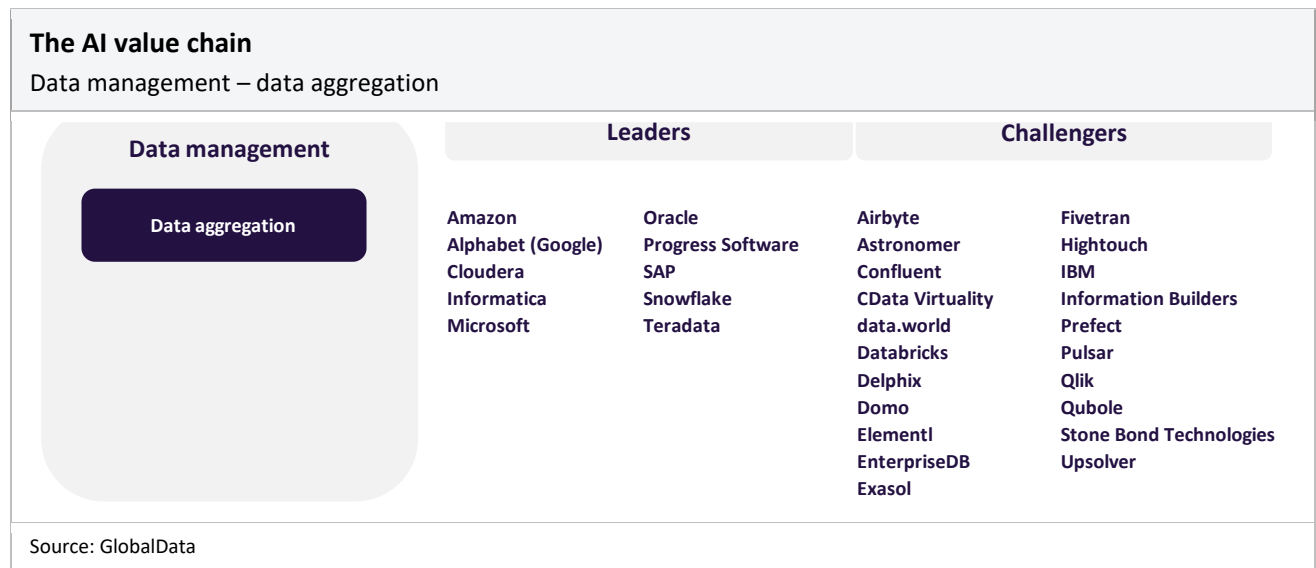
The AI value chain			
Data management – data integration			
Data management	Leaders		Challengers
	Data integration		
	Alteryx	Microsoft	Adeptia
	Cisco	Oracle	Alphabet (Google)
	Cloud Software Group	Qlik	Boomi
	Denodo Technologies	SAP	Broadcom (VMware)
	IBM	SAS	CData Virtuality
	Informatica	Software AG	Celigo
			Cyclr
			Databricks
			Dbt Labs
			Denodo
			HCLTech
			Hitachi
			Huawei
			Intenda
			InterSystems
			Jitterbit
			Keboola
			Make
			Matillion
			Precisely
			Salesforce
			Scale AI
			SnapLogici
			Stratio
			StreamSets
			Supermetrics
			Tray.io
			Workato

Source: GlobalData

Driven by the general shift towards cloud services, providers such as Informatica, IBM, and Oracle offer integration platform as a service (iPaaS) tools that connect software applications deployed in different environments.

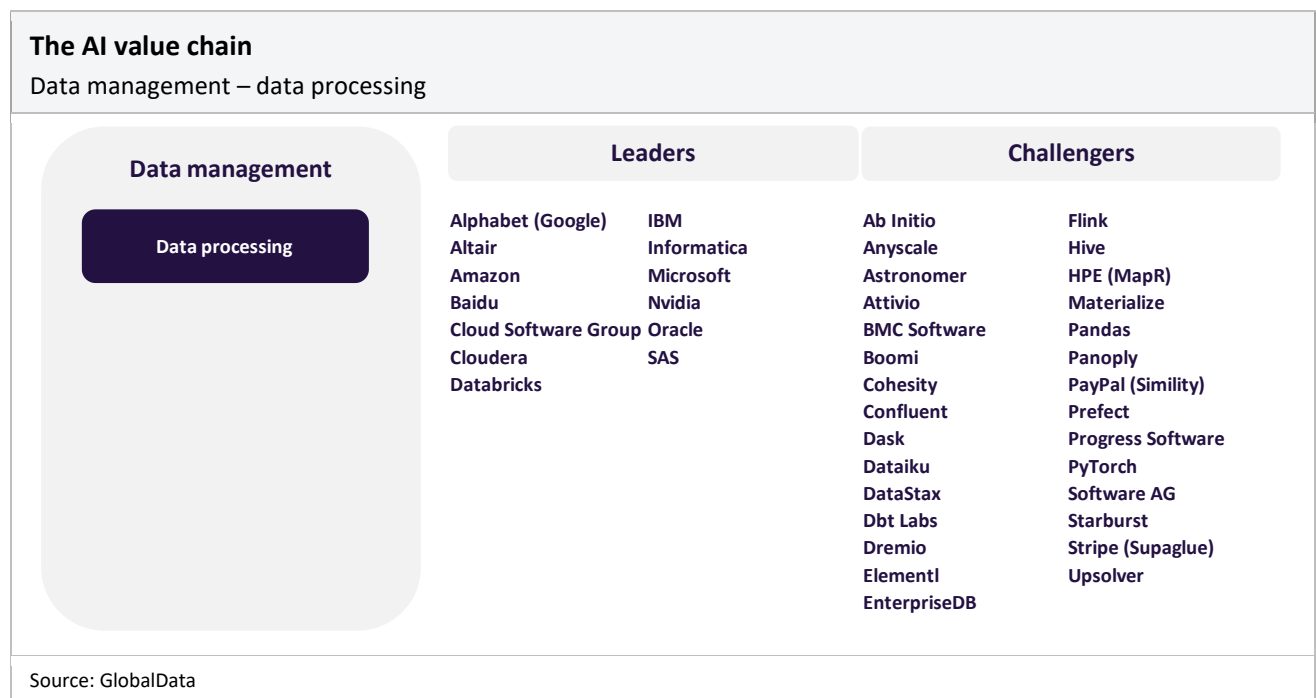
Data aggregation

Data aggregation involves compiling data in a format that can then be processed by statistical analysis tools or machine learning. The components of data aggregation are data warehousing and data replication. The former involves the construction of a data repository by searching and gathering data from disparate sources to support analysis-based decision-making, while the latter is the process where the data is stored in multiple locations to improve accessibility. Organizations use these solutions to eliminate data duplication and reveal hidden trends and insights.



Data processing

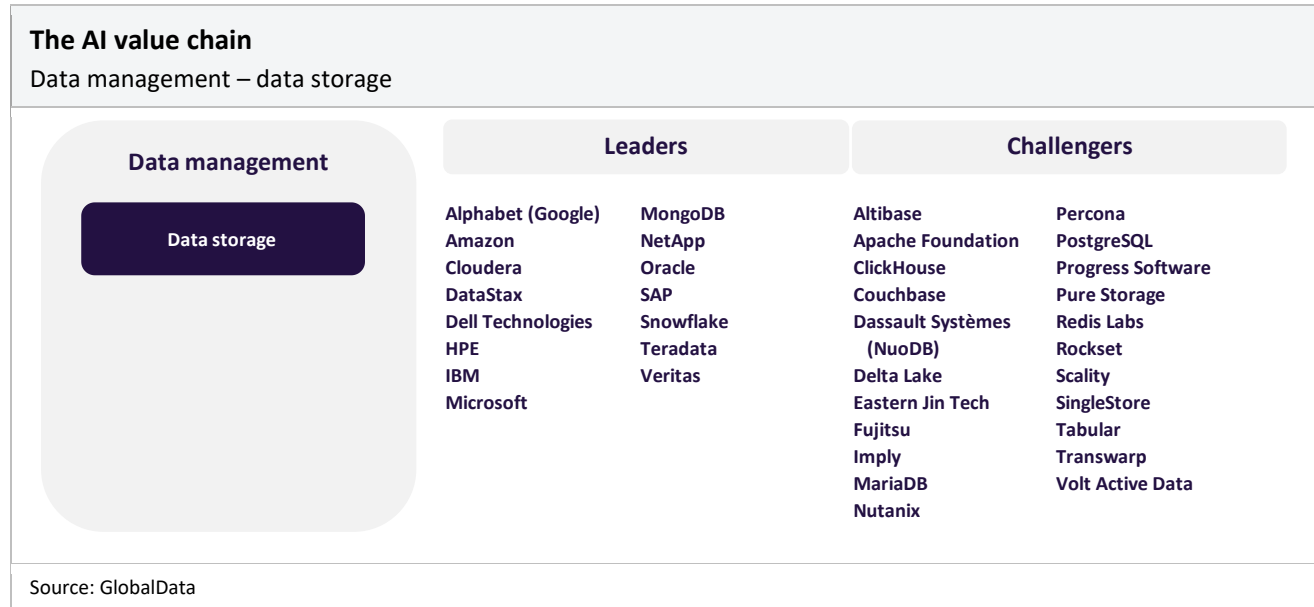
Data processing is the stage of data management where the raw data is transformed into useful information through batch or stream processing (batch processing deals with non-continuous data, while stream processing deals with continuous data).



It increasingly involves using machine learning algorithms that can automate the entire process to get the desired information in the form of graphs, charts, tables, images, and so on. Sequential query language (SQL) execution is also a widely used method in data processing, particularly to retrieve or alter existing data.

Data storage

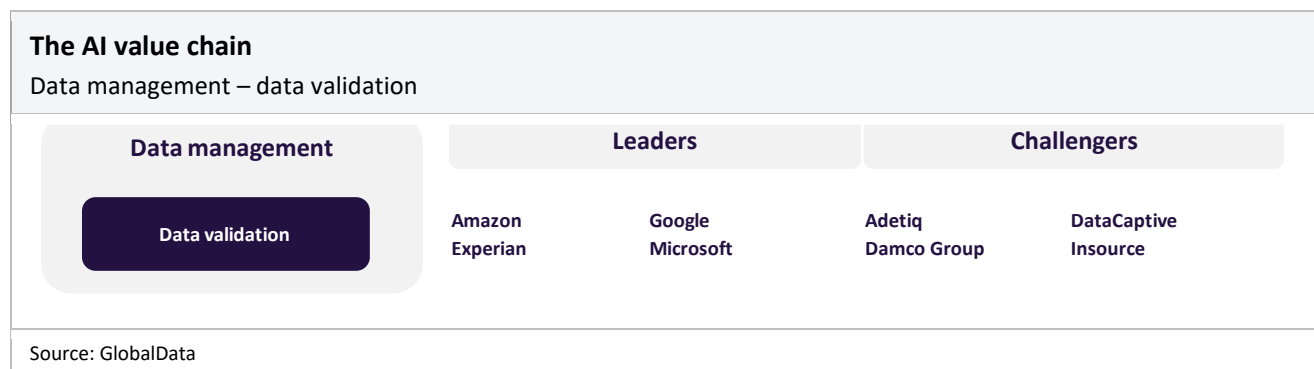
One of the key components of data management is collecting and managing large data sets to enable real-time consumption by AI algorithms, either for training or inference. The objective behind storing data in the cloud or on-premise is to structure data so that it can be easily retrieved and analyzed.



The data is generally stored in various forms, including distributed file systems, which store files in one or more servers while providing controlled access to users; relational databases, which store data in tabular form that depicts the relationship between data sets; and nonrelational databases, which store files without showing the linkage between data sets.

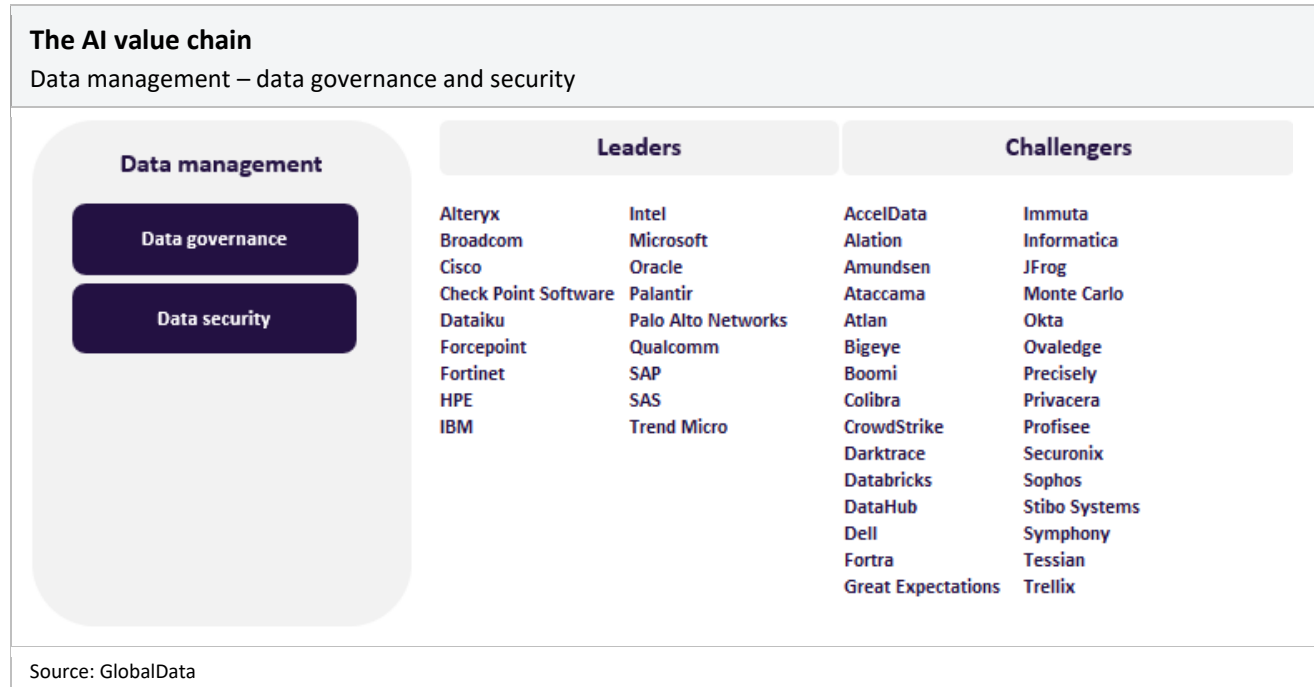
Data validation

Data validation is about ensuring that the data stored in central repositories, such as a data warehouse, data lake, or data lakehouse, remains up-to-date and accurate. This can be achieved with a combination of software and services, whereby data is monitored for errors and inconsistencies. The different types of validations performed on data ultimately depend on the analytical objectives and the data type.



Data governance and security

Data security is of paramount importance to businesses of all types, but particularly to AI, as the relevance of the decisions of AI systems is correlated to the quality of the input data. The data governance and security function covers data quality, availability, usability, and integrity.



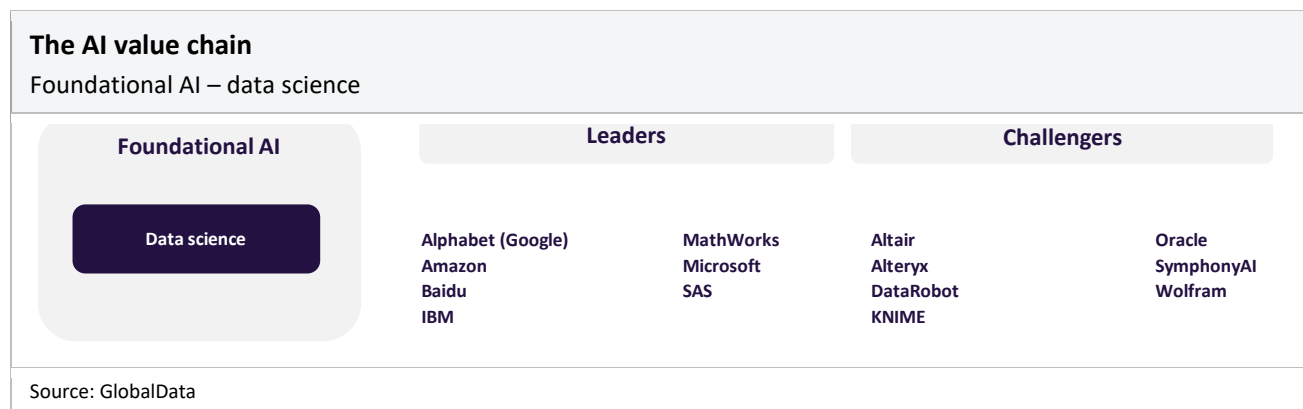
Master data management (MDM) refers to the effort made by an enterprise to create a single reference point for all critical business data. It aims to overcome challenges such as poor data governance, inconsistent data, and data manipulation.

Foundational AI

We define foundational AI as any technology that supports multiple advanced AI capabilities, such as computer vision, conversational platforms, discovery, or motion. For instance, machine learning (ML), which allows computer systems to learn and improve from data without being explicitly programmed, can be applied to visual data and identify human faces, to audio streams and identify spoken words, or to video streams and identify pedestrians. In this section, we describe several foundational AI technologies that are being used by many advanced AI capabilities.

Data science

Data science is an interdisciplinary field that uses scientific methods, processes, algorithms, and systems to extract knowledge and insights from structured and unstructured data. Interpreting and simplifying data to garner insights leading to competitive advantages drives the data science market.



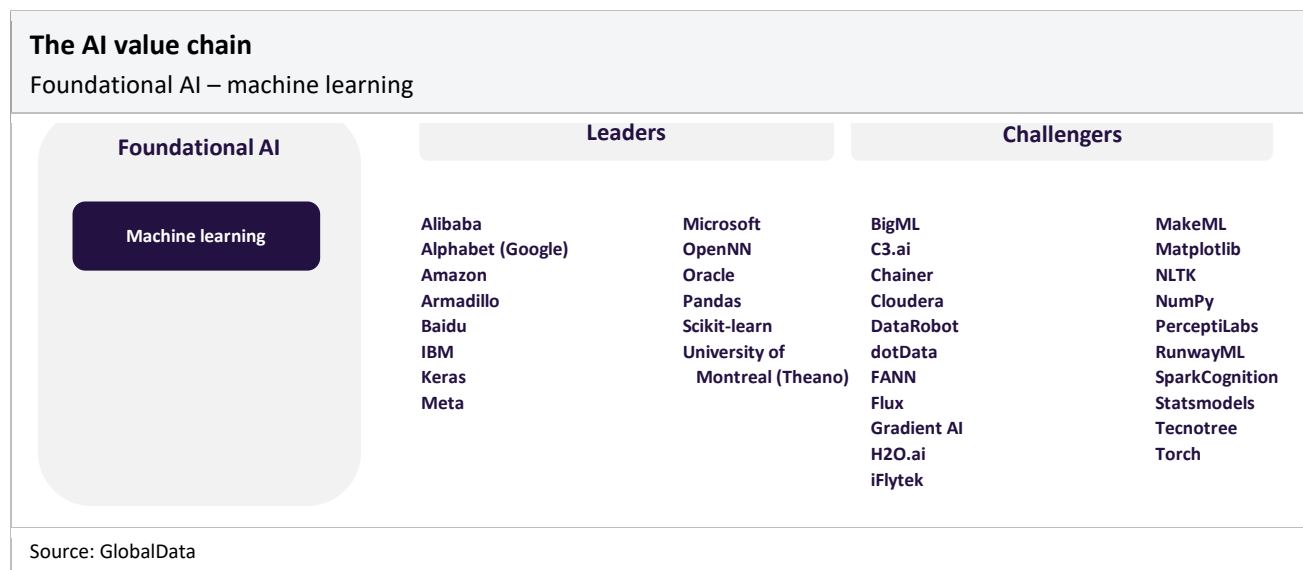
The market landscape for data science platforms is fragmented. Leading the way are providers of end-to-end solutions, such as IBM, SAS, and MathWorks (maker of MATLAB). Relative newcomers, such as Alteryx and DataRobot, are also well-positioned.

Machine learning

ML involves building models that learn and improve from data without being explicitly told what to do. Many companies use ML as part of predictive data models or software platforms that analyze behavioral data. Businesses have also applied ML to specific industry use cases, such as detecting bank fraud, assessing a person's creditworthiness, preventing cyberattacks, delivering personalized ads to consumers, and analyzing visual data. As such, while ML is a generic software tool, it is extensively used in AI to train models to enable advanced AI capabilities, such as computer vision, conversational platforms, or navigation.

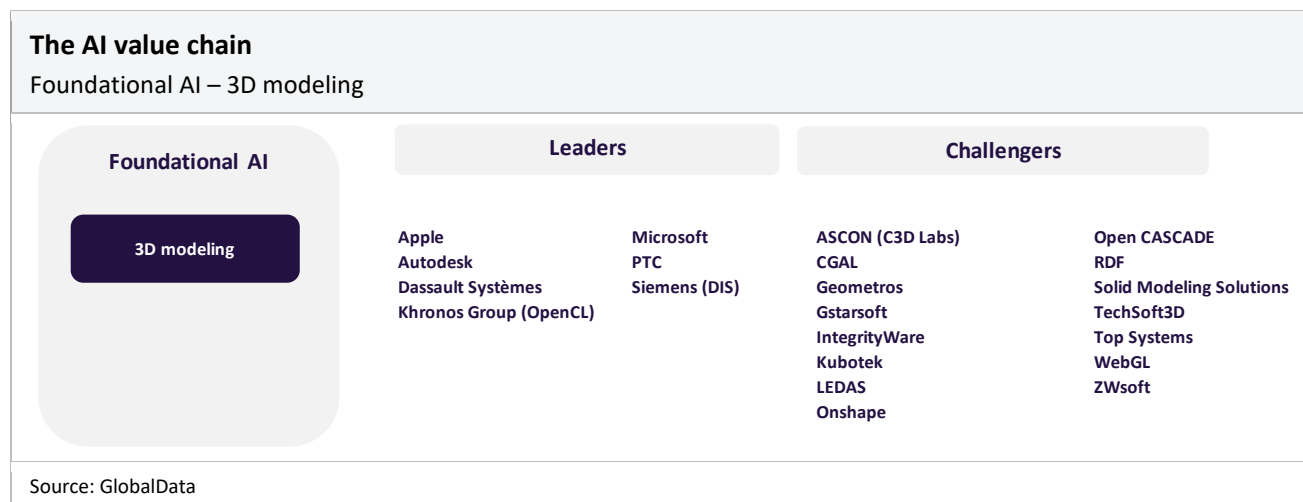
Despite the availability of open-source platforms, ML systems can be costly to create in-house, especially as there is a skills shortage, so many businesses prefer to rent ML and other AI services from the cloud. All the leading cloud service providers offer ML solutions that can support individual business needs. With demand growing, they are increasingly moving toward providing machine learning as a service (MLaaS). Cloud-based application programming interfaces (APIs) help to facilitate adoption and bypass some of the costs of developing models. Big Tech excels in this regard, particularly Amazon, Microsoft, Google, Baidu, and IBM.

Our [Machine Learning](#) report provides a more detailed view of machine learning.



3D modeling

For highly complex and interactive AI capabilities, systems need to understand the physical world, be aware of their position and movement, and be able to plan and make decisions to achieve their goals. As is often the case in software, several infrastructure software players have already addressed these fundamental needs for others to use in their application software.



While many AV and robotics companies choose to develop their own software solutions to implement an internal world representation, they can also use the infrastructure software tools developed by the computer-aided design (CAD) industry over the years, particularly geometric modeling kernels. Depending on the use case, an AI system may need a more or less accurate internal representation of the world. However, the more autonomous and critical a system, the greater the need for accurate 3D modeling.

Geometric (or 3D) modeling kernels are software components that provide the functionality to develop a mathematical coordinate-based representation of the world. This is needed by CAD software systems used to design cars and airplanes. It is also necessary for autonomous vehicles and robots, as they must be aware of their surroundings. They achieve this by representing each physical object using a collection of points in 3D space, connected by geometric entities such as triangles, lines, and curved surfaces.

The two leading kernels are ACIS and Parasolid, developed by Spatial (a subsidiary of Dassault Systèmes) and Siemens. Other leading vendors include Solid Modeling Solutions, PTC, and ASCON. Apple and Microsoft also provide 3D modeling libraries (e.g., Metal, Direct3D) to give advanced graphical capabilities to their operating systems for desktop computers.

Knowledge representation and reasoning

Knowledge representation and reasoning (KRR) is a field dedicated to representing information about the world in a form that a computer system can use to solve complex tasks using logic and reasoning. This is essential for AI systems supporting complex use cases, such as AVs and autonomous robots, which must understand the world and make decisions to achieve their goals.

Examples could be an AV following a plan to take you from your office to your home or an autonomous mobile robot (AMR) in a warehouse fulfilling several ecommerce orders by picking the products from the shelves. In both cases, it is necessary to have an internal knowledge representation (e.g., maps, addresses, products, orders, delivery routes) and the ability to figure out a plan of action based on assumptions and applied reasoning.



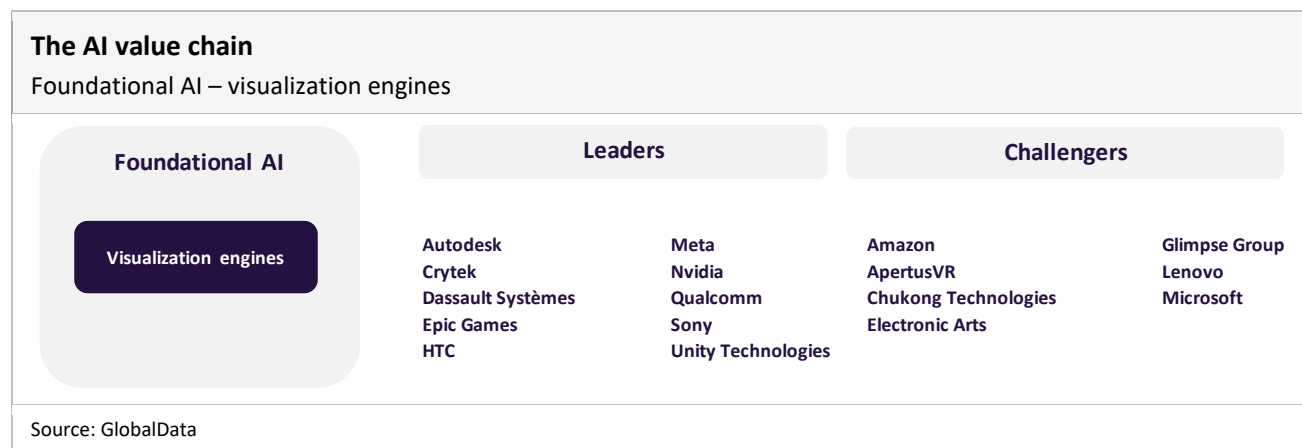
Robotics and AV companies have had to develop their own KRR solutions, so ABB, KUKA, Rockwell Automation, Baidu, Tesla, and Waymo are leading in this field. However, as KRR is a field of AI that goes beyond just robotics and AVs, there are also independent platforms such as openEASE and Cyc and the AI cloud services provided by Google and Microsoft.

Finally, the Semantic Web project of the World Wide Web Consortium also deserves special mention. Led by the web's inventor, Tim Berners-Lee, the goal is to make internet data machine-readable by enriching the web with an ontology that can describe concepts, relationships between entities, and categories of things. As a result, it would be possible to reason over data and for machines to do so on our behalf.

As the web stands today, a search for the tallest building in the world will return the correct answer only if someone has published a webpage listing the world's tallest buildings. However, the Semantic Web would allow an intelligent agent to find the data on buildings' heights across the web, reason which one is the tallest, and produce an answer. While still an unrealized dream, the Semantic Web could eventually become the primary knowledge source for AI agents.

Visualization engines

There are certain AI use cases where the ability to visualize an internal representation of the world is necessary to allow interaction, such as in the metaverse. In it, virtual environments gain intelligence to become more interactive. The avatars inhabiting the metaverse will usually be digital representations of real people but can also be entirely virtual, driven by AI.



Leading companies in this area tend to come from gaming (e.g., Epic Games, Unity Technologies) or CAD (e.g., Autodesk, Dassault Systèmes) backgrounds.

For a more detailed analysis, see our [Metaverse](#), [Augmented Reality](#), and [Digital Twins](#) reports.

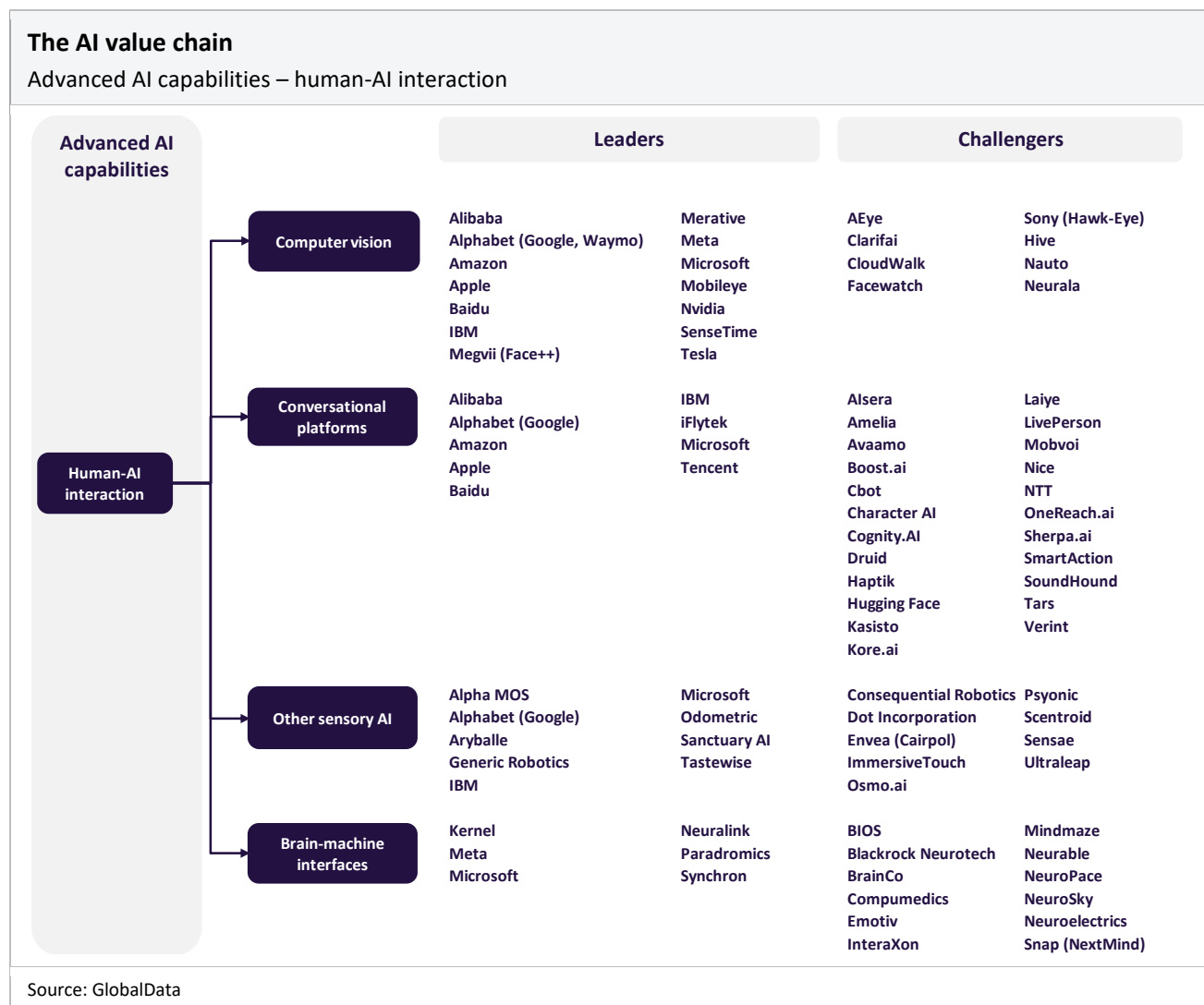
Advanced AI capabilities

We describe AI as software-based systems that use data inputs to make decisions on their own. However, a fundamental question when building AI systems is what capabilities or behaviors make a system intelligent. The first step is to expand on our earlier definition, identifying AI as any machine-based system that perceives its environment, pursues goals, adapts to feedback or change, provides information or takes action, and even has self-awareness and sentience, possibly ethics. As such, the ability to perceive and interact with the environment is a key advanced AI capability of any “intelligent” system.

We classify advanced AI capabilities into five categories: human-AI interaction, decision-making, motion, creation, and sentience.

Human-AI interaction

The most common and advanced human-AI interaction examples are computer vision and conversational platforms, but this category also includes less developed artificial senses, such as smell, taste, and touch, and some that do not exist in nature, such as brain-machine interfaces.



Computer vision

Computer vision (CV) is a key AI technology, which includes all technology that attempts to capture and interpret images or videos in a meaningful or useful way. There are four main categories of computer vision: image recognition, video recognition, object detection, and positioning and navigation.

The level of underlying intelligence required for computer vision varies significantly depending on the use case. For instance, a computer vision system that automates a warehouse must only read barcodes from items entering the warehouse, identify the product, and update an inventory database. There is no need for any further knowledge. On the other hand, the computer vision system of an autonomous robot or autonomous vehicle needs to have an internal three-dimensional representation of the world, an awareness of where it is standing, and the capability to understand moving objects and decide its next move based on visual feedback.

Companies that rely on large repositories of visual data to power algorithms are best positioned to provide CV solutions. These include Silicon Valley tech companies and Chinese AI companies that can access large amounts of citizens' visual data from the country's estimated 500 million surveillance cameras. Also, nimble start-ups with cutting-edge expertise developing innovative solutions will fuel CV's growth.

Many US software companies offer CV as part of a cloud-based ML platform for customer predictive analytics. Major tech players such as Google, Amazon, Microsoft, and IBM provide various types of image, video, speech, and text recognition through their cloud APIs. These are business-to-business (B2B) solutions where enterprises can get CV services quickly and without hiring ML experts (which are scarce and expensive).

The AI industry in China has been fueled by a combination of strong government backing, large data sets created by the vast population, and minimal privacy concerns. Video surveillance has gained momentum in the country, with a huge budget put aside for it at the government level. Its widespread use for surveillance has also raised concerns among human rights campaigners inside and outside the country. Leading Chinese vendors include Megvii, which develops the Face++ platform, SenseTime, Hikvision, and Dahua Technology.

For a more detailed analysis, see our [Computer Vision](#) report.

Conversational platforms

Conversational platforms use foundational AI capabilities such as ML and various other technologies—including speech recognition, natural language processing (NLP), and contextual awareness—to enable human-like interaction with computer systems. Voice is becoming the primary user interface for many consumer devices, including smartphones, automated home products (including smart speakers), and wearable tech.

Recent advances in speech recognition and NLP have improved the experience of talking to a computer, and smart speakers like the Amazon Echo and Google Nest have brought voice-enabled interaction into the home. Virtual assistants such as Apple's Siri or Amazon's Alexa are available in many products. Voice is also increasingly prevalent in cars, hotels, shops, and offices, playing various roles.

Virtual assistants' ability to understand varies greatly, depending on the sophistication of the underlying AI models. Virtual assistants enabling voice-activated control of products such as lights, locks, and thermostats or acting on commands in a smartphone require limited underlying intelligence. Simple machine learning models trained to catch the words uttered by the user are sufficient to provide a voice interface.

However, virtual assistants expected to respond to broad general questions and instructions, such as Siri, Alexa, Cortana, Google Assistant, Xiaodu, or AliGenie, require much more powerful AI models to interpret the instructions and figure out a way to obtain useful answers. This requires integrating other advanced AI capabilities, such as decision-making, within conversational platforms. In this scenario, the large cloud service providers with their AI-enabled services and huge amounts of data, like Amazon, Google, Microsoft, Alibaba, or Baidu, have an advantage over the likes of Samsung Electronics, Apple, or the specialist automated home appliance vendors.

The recent progress in the capabilities of large language models (LLMs), particularly since the launch of ChatGPT by OpenAI at the end of 2022, has led to significant interest and investment in enterprise conversational platforms built around an LLM. New companies have emerged and traditional chatbot developers have adopted the new technology, leading to a very dynamic competitive landscape that includes Alsera, Avaamo, Boost.ai, Cbot, Character AI, Cognition.AI, Kore.ai, OneReach.ai, Yellow.ai, to name a few.

See [Automated Home](#), [Smart Speakers](#), [Smartwatches](#), and [Wearable Tech](#).

Other sensory AI

Beyond the well-understood computer vision and conversational platforms, AI is also expanding into other less-developed senses, such as smell, taste, and touch.

By applying AI techniques to sensory data from chemical receptors such as those in our tongues and noses, it is possible to identify, categorize, and even re-design odors and tastes. This has applications in product design, customer targeting, and industrial safety, to name just a few.

The artificial sense of touch is also known as haptics. It involves creating an experience of touch by applying forces, vibrations, or motions to the user. It is very important in robotics and product simulation (e.g., flight simulators) and popular in gaming.

This field is very nascent, but early leading participants include large tech vendors such as Google, IBM, and Microsoft and start-ups such as Odometric, Tastewise, Generic Robotics, and Sanctuary AI.

Brain-machine interfaces

Brain-machine interfaces (BMIs), also called brain-computer interfaces (BCIs), are a direct communication pathway between the brain's electrical activity and an external device, such as a computer or a robotic limb. Nowadays, they mainly aim to augment or repair cognitive or sensory-motor functions of people who have suffered accidents or sustained injuries in conflict. However, the long-term aspiration is that they could expand the brain's capabilities and enable direct communication with the mind.

For instance, in the case of an artificial limb, the objective is to both read brain electrical activity to determine motor intent and pass sensor output from the artificial limb back to the brain as electrical pulses. Current BMIs are being trained using machine learning and lots of data to allow a level of mobility for artificial limbs.

This connection is typically achieved by getting electrodes close to the brain to 'listen' to its activity. The various BMI technologies can be classified into three categories depending on how close those electrodes are. Non-invasive approaches rely on superficial skin contact via gloves, helmets, or simple electrodes. Partially invasive BMI devices are implanted inside the skull but rest outside the brain rather than within the grey matter. Finally, invasive BMI solutions implant the electrodes under the scalp, directly communicating with the brain.

There have been early successes, largely in medical use cases, such as improving input and output capabilities for patients who are locked-in (e.g., tetraplegics) or restoring some mobility for patients who have lost limbs. For instance, Synchron announced in 2022 that its FDA-authorized Stentrode system had been implanted in the trial's first participant at Mount Sinai West Hospital in New York City. In early 2024, it was preparing to recruit patients for a large-scale clinical trial required to seek commercial approval for its device, having already received interest from about 120 clinical trial centers to help run the study.

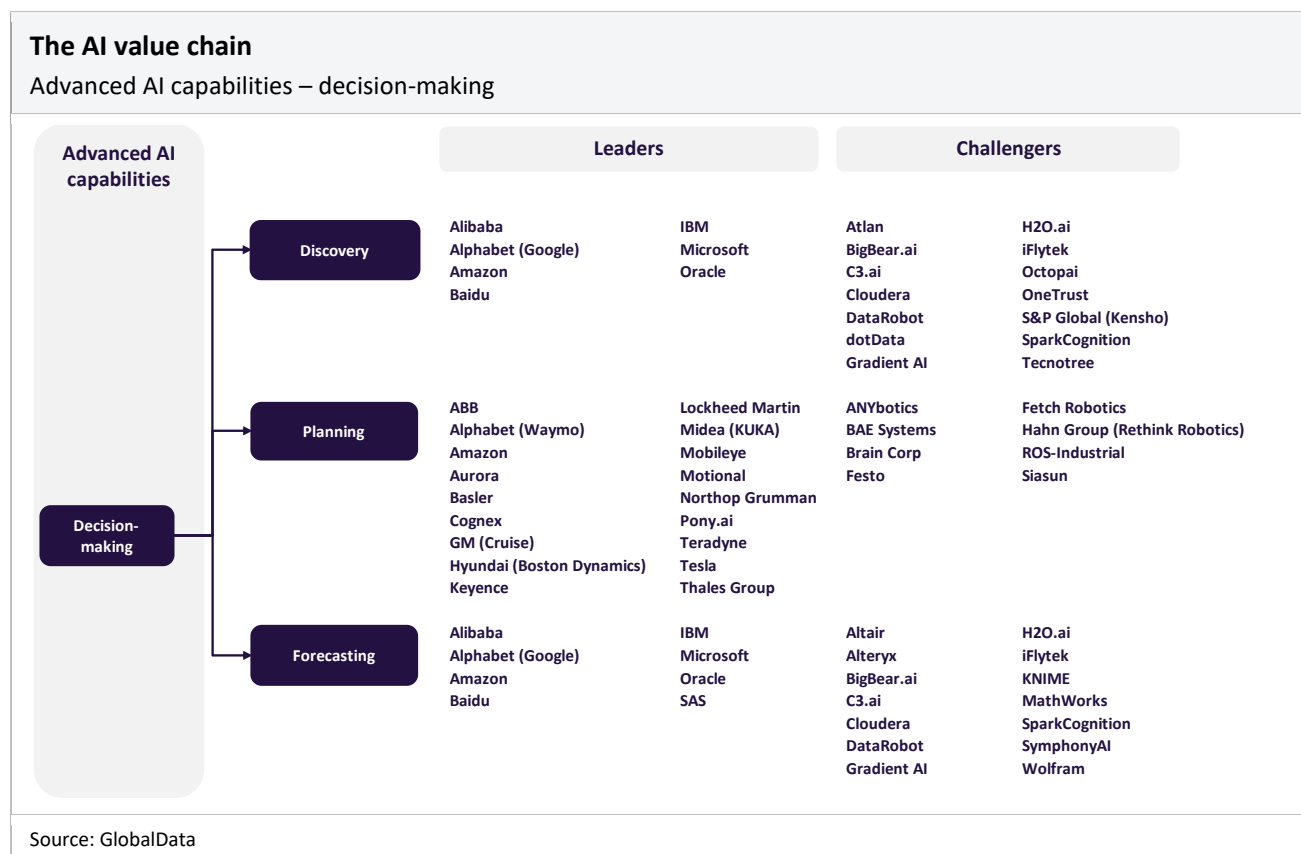
Other interesting research areas include keyboards without keys and talking without sound, which could allow direct communication with computers in the long run. For instance, in 2021, Neuralink released a video showing a monkey playing the video game *Pong* with its mind using one of its brain implants. In 2024, it ran a trial with a human patient who was paralyzed below the neck but could control a cursor on a screen.

However, not much progress has been achieved in expanding the brain's cognitive capabilities due to our lack of understanding of how our mind represents knowledge and operates. There is a huge difference between detecting

motion intent from brain waves and being able to read from or write to our brain's memory stores. For now, this remains the preserve of science fiction.

Decision-making

This category includes capabilities that the average person will typically associate with intelligence, such as identifying, recognizing, classifying, analyzing, synthesizing, forecasting, problem-solving, and planning. We group them into three main capabilities for convenience: discovery, planning, and forecasting.



Discovery

Discovery involves the analysis of large amounts of data to find patterns, logical relationships, similarities, groups, or dependencies. Example use cases include customer segmentation and anomaly (e.g., fraud) detection. Typically, discovery will rely on foundational AI capabilities, such as ML and knowledge representation and reasoning.

The leading cloud service providers have all developed discovery services, including the most common functionalities, such as segmentation and clustering, anomaly and outlier detection, correlation analysis, causal inference, and association analysis. A growing group of start-ups, such as C3.ai, DataRobot, H2O.ai, and SparkCognition, have developed vertical-specific discovery solutions covering financial services, government, insurance, health, manufacturing, marketing, retail, telecoms, and utilities.

Planning

Planning is about looking for optimal solutions to problems requiring long sequences of actions in complex environments where the search space is too vast for humans or even exact computer solutions. Examples of this capability include optimal routing for a delivery fleet or an individual autonomous vehicle, optimization of project plans, molecule search, and material design.

Planning capabilities are most valuable in robotics, autonomous driving, and industrial automation. Therefore, it is unsurprising that the leading vendors include the likes of Waymo, Aurora, Boston Dynamics, KUKA, Cognex, and Teradyne. In the case of autonomous driving and mobile robots, the planning capability needs to be closely integrated with computer vision and 3D modeling to give the system spatial awareness.

Forecasting

Forecasting is about finding complex patterns in data and using them to predict the future course of a time series or the likelihood of certain events happening. Examples include demand prediction, price prediction, and customer lifetime value estimation.

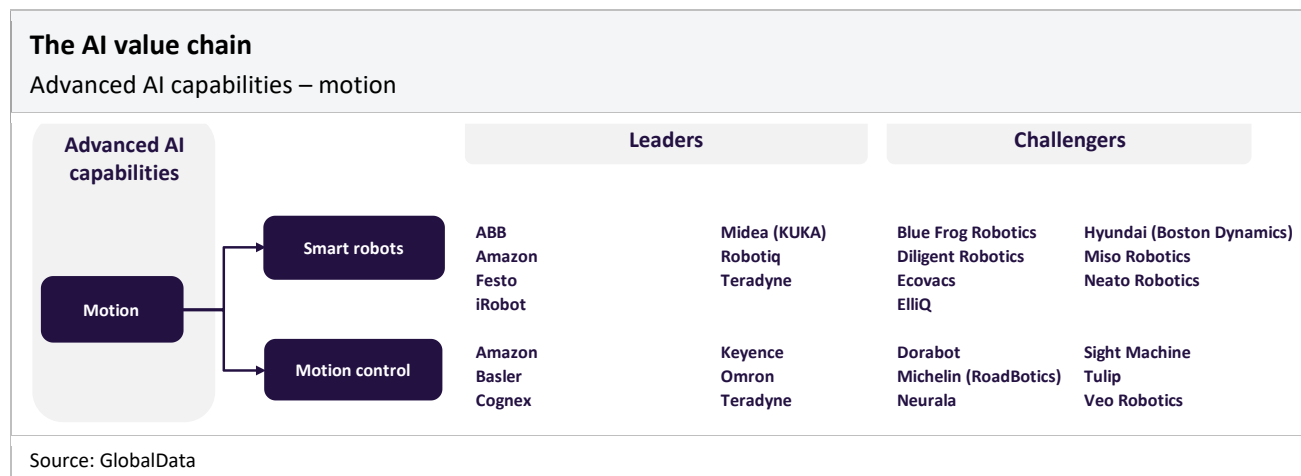
As forecasting is arguably an exceptional case of discovery, the leading vendors are largely the same, from the large public cloud vendors to emerging start-ups, such as C3.ai, DataRobot, H2O.ai, and SparkCognition.

Motion

This category includes capabilities related to moving in and interacting with the world. Use cases range in complexity from automatic inspection and process control in factories to fully autonomous vehicles or military robots.

Motion capabilities are interrelated with planning yet are more concerned with real-time feedback and interaction with the world. For instance, an autonomous robot needs to be capable of understanding its position in the three-dimensional world and devising a route to reach its destination without hitting any obstacles, such as walls, other robots, or people. However, as it moves, it needs to analyze the feedback it receives from its sensors and adjust, as living things do.

This distinction is similar to that between the conscious and the unconscious mind. For example, the conscious decision to walk around the table to grab a glass from the cupboard in the kitchen is different from the thousands of unconscious real-time micro-decisions taken by our cerebellum. These decisions get our legs moving and our arms and upper body balancing to adjust to the possibly uneven terrain and generate the proper grasp force in our fingers to open the cupboard and take the glass without crushing it.



Smart robots

Smart robots' capabilities include understanding their position in the three-dimensional world and the ability to move in and interact with it while dealing with real-time environment changes, such as other objects in motion or even changes to the landscape. Seemingly simple tasks such as grasping fragile objects without crushing them or walking in the forest are good examples of issues that smart robot capabilities address.

The leading players in smart robots include a mix of robotics incumbents such as ABB, KUKA, Amazon (Kiva), and Festo, industrial automation specialists such as Teradyne and Robotiq, and relatively new entrants such as iRobot (which remains independent after Amazon abandoned its takeover bid in early 2024).

For a more detailed analysis, see our [Robotics](#) and [Drones](#) reports.

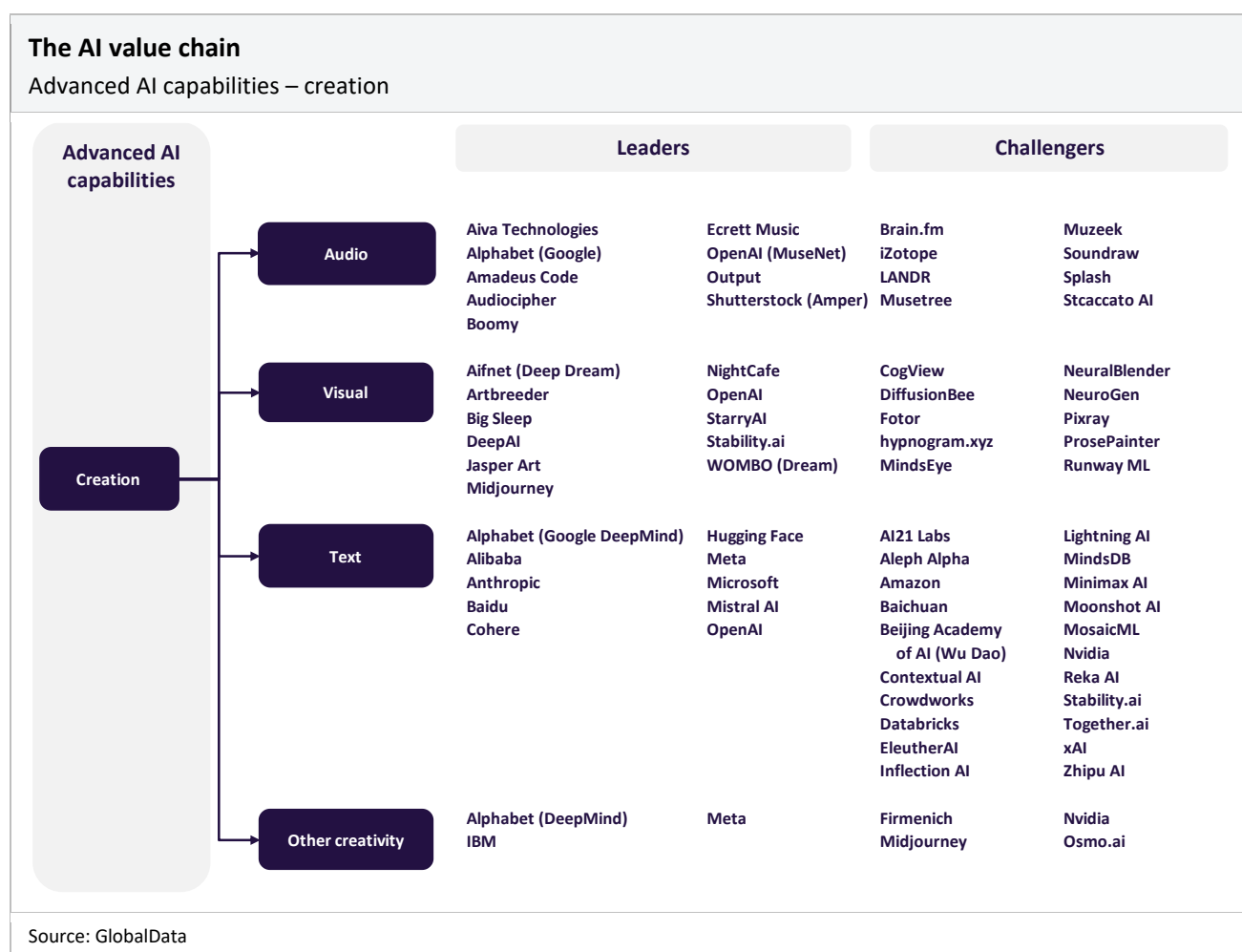
Motion control

Motion control deals with moving individual parts of a machine in a controlled manner, typically using real-time feedback from sensors such as cameras and lasers. This is especially helpful in applications such as production lines, where accuracy, power, and efficiency are very important. That said, unlike smart robots, motion control does not require an internal representation of the world or any self-awareness.

Leading companies in motion control include Basler, Cognex, Keyence, and Amazon, which operates one of the largest networks of fully automated warehouses to support its ecommerce business.

Creation

This category includes anything related to AI creating content in any shape or format, from writing original text or music, drawing and painting, designing new structures or products, or even designing new AI systems. The relationship between intelligence and creativity has been the subject of empirical research for decades. As such, an AI system should be expected to be able to display creation capabilities in multiple areas.



Audio

Music generation relies on deep learning to analyze hours of music and the associated metadata—such as the instruments involved, genre, and lyrics. Once fully trained, systems can create new musical pieces that may sound

somewhat like training pieces. For example, the Flow Machines software analyzed a vast database of songs before creating a melody and harmony in the style of The Beatles.

This has the potential to disrupt the music industry, particularly as it is unclear in many jurisdictions whether work generated solely by a machine has copyright protection.

This market is very nascent, but the current leading participants include small companies, such as Aiva Technologies, Shutterstock (which acquired Amper Music in 2020), Amadeus Code, and Boomy, and some large AI vendors, including Google and OpenAI.

Visual

Video and picture generation also relies on deep learning, although it is often integrated with NLP capabilities so that textual input describing the content to be generated can be provided.

This technology is disrupting the artistic world, blurring the lines between man and machine. In September 2022, artist Jason M. Allen won the Emerging Digital Artist prize at the Colorado State Fair with his painting *Théâtre D'opéra Spatial*, generated by the AI visual generator Midjourney. There have been several lawsuits related to copyright infringement by AI creation tools, but most are still ongoing, so the situation will likely remain unclear for the time being. For instance, DeviantArt, Midjourney, and Stability AI were sued in January 2023 in the US for copyright infringement. Although much of the case was thrown out by the court, a single direct copyright claim was allowed to stand against Stability AI. Further complicating the situation, the current stance of the US Copyright Office is that machines, including AI systems, cannot be considered authors. As these cases get resolved there will be more regulatory clarity around the use of generative AI for visual content creation.

The leading generators include Midjourney, NightCafe, OpenAI, Stability.ai, Aifnet (Deep Dream), Artbreeder, and DeepAI.

Text

The AI generation of original text took a significant step forward with the launch of a language model called Generative Pre-Trained Transformer 3 (GPT-3) by OpenAI in 2020, which could write original prose with fluency equivalent to that of a human. Advanced language models can create content such as blogs or tweets, generate code, or improve the customer experience by enhancing conversational platforms. That said, given that the underlying technology employed is deep learning models, it is unclear to what extent systems like GPT-3 understand what they are writing.

This emerging area has experienced significant growth in the last couple of years, attracting Big Tech players, including Google, Meta, Microsoft, Amazon, Alibaba, Baidu, and X, and a myriad of start-ups led by Open AI but closely followed by Anthropic, Cohere, Hugging Face, and Mistral AI. Further, companies operating in adjacent technology markets, such as hardware or data analytics, are entering the space, with examples including Nvidia and Databricks.

Other creativity

Similar principles to those used to generate audio, video, or text can also be directed to other areas, such as smells and flavors, but also more complex concepts, such as molecular structures or even algorithms.

In 2020, Alphabet's subsidiary DeepMind unveiled its AlphaFold AI model, which could determine a protein's 3D shape from its amino-acid sequence and has been able to predict protein structures accurately. The potential for life sciences and medicine is huge, from improving our understanding of how cells function to accelerating drug discovery. DeepMind launched AlphaFold 2 in 2021 and AlphaFold 3 in 2024, which can predict the structure and interactions of all of life's molecules. In 2022, Meta unveiled its own protein folding model based on a language learning model rather than a shape-and-sequence matching algorithm like DeepMind's. In a less cutting-edge field, IBM has been experimenting with its Watson platform to create novel cooking recipes.

AI can also be used to create original software code, which opens up exciting opportunities. For example, in 2022, DeepMind unveiled an AI, AlphaCode, capable of writing code to solve arbitrary problems. While the algorithm only finished in mid-table in a December 2022 coding challenge competition with both human developers and machines,

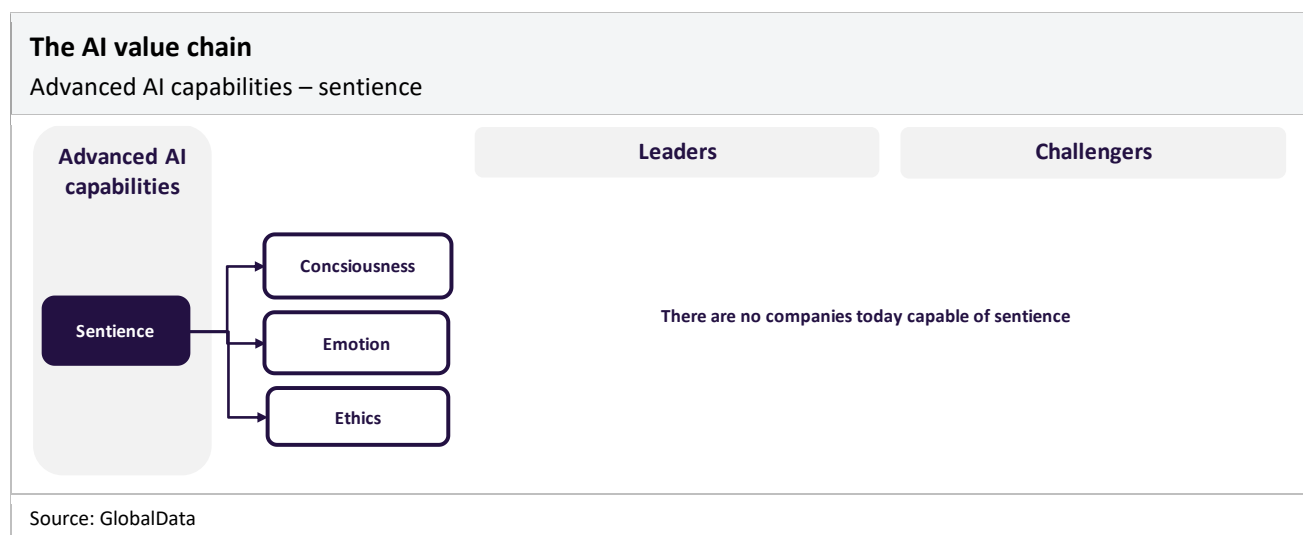
future versions will have improved capabilities. A year later, AlphaCode 2 was reported to perform better than 85% of participants, ranking just between the 'Expert' and 'Candidate Master' categories.

This is only one step away from allowing AI to make AI, which admittedly still sounds like science-fiction. However, researchers at OpenAI, Uber AI Labs, and various universities have been working on it for several years and see it as a step on the road that one day leads to artificial general intelligence (AGI) or even artificial super intelligence (ASI).

Sentience

This category includes the various AI capabilities associated with human intelligence (rather than other, less advanced life forms). Arguably, the ultimate expression of intelligence in an artificial system would be the emergence of self-awareness or consciousness. As a result of self-awareness and the understanding of others' consciousness, humans can have emotions and feelings and ultimately develop ethical principles and a conscience.

To be clear, this is, at the moment, far from achievable. However, this category has been included in the AI value chain for completeness. While AI research teams at universities may be exploring these concepts, no significant developments are coming from for-profit organizations.



Finally, it is worth noting that while having robots develop a conscience may feel like an exciting and worthy scientific challenge, it is not clear that there is a business case for it. Humans typically envision a future where humanoid robots do all the hard work for us until they break down and are replaced, while we are left to enjoy our leisure time. However, if those robots had sentience and even a conscience, there would be significant moral and ethical challenges to treating fully intelligent beings as slave labor.

Delivery

AI delivery models are similar to any IT system, although the AI specificities lead to a preference for either AI as a service (AlaaS) or hardware appliances.

The AI value chain				
Delivery				
Delivery	Leaders		Challengers	
Hardware appliance	ABB Alphabet (Waymo) Amazon Apple Aurora Baidu Canon GM (Cruise) Hyundai (Boston Dynamics) iRobot	Lockheed Martin Megvii (Face++) Midea (KUKA) Mobileye Northrop Grumman Nvidia Sony Tesla Thales Group	Aardvark Tactical AEye ANYbotics BAE Systems Coherix Diligent Robotics Ecovacs Festo	Hahn Group (Rethink Robotics) Sony (Hawk-Eye) iFlytek Nauto Neato Robotics Omron Prophesee
Licensed software	IBM Megvii (Face++) Microsoft	Nvidia OpenAI SenseTime	Brain Corp C3.ai Clarifai Facewatch Hugging Face iFlytek	Neurala ROS-Industrial Sherpa.ai SoundHound SparkCognition
Artificial intelligence as a service (AlaaS)	Aifnet Aiva Technologies Alibaba Alphabet (Google) Amazon Baidu DeepAI Ecrett Music	IBM Megvii (Face++) Meta Microsoft Midjourney OpenAI Shutterstock	Chocho AI Clarifai CloudWalk CoreWeave Crusoe DiffusionBee EleutherAI Facewatch Gradient AI H2O.ai Hugging Face	Lambda Labs LANDR MindsEye Muzeek Restb.ai SenseTime Stability.ai SoundHound ViSense Visionati
Source: GlobalData				

Hardware appliance

The hardware appliance model, whereby hardware equipment comes with preinstalled software, is the favorite approach for certain AI use cases, such as computer vision, autonomous mobile robots, and autonomous vehicles. Particularly in the last two cases, it is necessary as the AI software platform has to come embedded with either the robot or the car itself, which is still a proprietary hardware stack owned by a manufacturer.

In the long run, standards may eventually be widely adopted across the industry, allowing pure software vendors to market their AI solutions directly to end users. This would operate similarly to how PC users buy software from independent vendors such as Adobe and install it on their machines.

Licensed software

The software model, whereby clients license software and have to install it on their own hardware, is not too common in the AI sector as the large amounts of data required naturally lead to a cloud delivery model. However, several vendors are supporting the licensing model in areas such as computer vision (e.g., SenseTime, Megvii), industrial robotics (e.g., Neurala, Brain Corp), and autonomous vehicles (e.g., Baidu).

Artificial intelligence as a service

The emergence of a cloud delivery model, AI as a service (AIaaS), has been driven by the increasingly large volumes of data used by AI models, as it is more economical to store that data in the cloud. Thanks to open-source frameworks, toolkits, and hardware designed for deep learning, applications for AI are becoming increasingly widespread. ML has joined the cloud-based services market and opened up competition. Cloud developers like Google, Microsoft, and Amazon possess the platform for training models and deploying inference both in the cloud and at the edge.

AI APIs are B2B solutions where businesses can get AI services quickly, with no expertise in ML required and without the time and risk of establishing an in-house AI team. Cloud companies are offering AI as a part of a cloud-based ML platform, particularly for decision-making capabilities, including discovery, planning, and forecasting, boasting pre-trained models and development tools that AI programmers can use. The service provider's data centers handle the computation in these cases.

Companies

In this section, GlobalData highlights companies making their mark within the AI theme.

Public companies

The table below lists some leading listed players associated with this theme and summarizes their competitive position.

Company	Country	Competitive position in the artificial intelligence theme
Alibaba	China	Alibaba is a global technology leader thanks to its massive ecosystem, which spans entertainment, ecommerce, financial services, cloud services, and social media. The company has been front and center in China's drive to become the world leader in AI. Working closely with the government, Alibaba is a major backer of facial recognition leader SenseTime and neural network star Cambricon. It has launched the City Brain project at its home base in Hangzhou, and its smart city technology has been exported to Macau and Malaysia. In the AI chips theme, Alibaba has created the DAMO Academy to develop semiconductor technology. It has also designed the neural processing unit (NPU) chip Ali-NPU, acquired integrated circuit design company C-Sky, invested in core chip vendor Phytium, and launched its Arm-based server chip Yitian 710. Alibaba has the resources, reach, state support, and know-how to be a major force in AI. However, as a Chinese vendor, it will find it increasingly difficult to either access leading-edge node manufacturing foundries to make its own AI chips or acquire advanced AI chips from other vendors due to the ongoing China-US trade dispute.
Alphabet (parent company of Google, Waymo, and DeepMind)	US	Alphabet has been at the forefront of AI applications since 2012 when the Google Brain team built a system capable of identifying cats after analyzing around 10 million images. Alphabet benefits greatly from its diversification and scale. One of its biggest assets is the wealth of customer data provided by its search business and YouTube. The tech giant has been heavily involved in AI-related M&A activity, with its 2014 acquisition of ML pioneer DeepMind the most well-known. DeepMind has made significant progress in AI with programs like AlphaGo, which in 2016 beat human professional Go player Lee Sedol; AlphaZero, which beat the most powerful programs playing Go, chess, and shogi (Japanese chess); and AlphaFold, which started to predict protein structures in 2020. In early 2023, it also invested \$300 million in Anthropic, a generative AI start-up founded by former OpenAI employees just a couple of years before, while it also launched its own LLM, Bard (later renamed Gemini), to mixed reviews. On the hardware front, in 2016, Google unveiled its custom tensor processing unit (TPU), specifically designed to accelerate operations in ML neural networks. Further, its autonomous vehicle venture, Waymo, gives it the edge in the most advanced forms of CV, which require spatial awareness, planning, and reasoning capabilities. Finally, the tech giant is marketing its AI strategy through its cloud services business, Google Cloud Platform (GCP). It aims to democratize access to AI tools with pre-built models and easy-to-use services and give more advanced developers the tools to build custom models.

Company	Country	Competitive position in the artificial intelligence theme
Amazon	US	Amazon has been pushing AI, particularly CV technology, in different areas of its business for several years. The tech giant has faced pressure from civil liberties groups to stop selling its Rekognition software to police forces due to the potential for abuse by the authorities. Amazon's investment in ML and sensors and its advanced cloud operations illustrate its leadership in key technologies that enable AI. With Ring video doorbells and the Echo family of smart speakers, Amazon is also making inroads into the home. In 2019, the company announced that it would soon be able to operate a drone delivery service, employing CV and ML algorithms to detect and avoid people, animals, and even wires. However, progress has been slow, and it was not until 2022 that the company rolled out its Prime Air service to customers in Lockeford, California, and College Station, Texas. In 2020, Amazon entered the autonomous vehicle space by acquiring Zoox, which is developing AVs with full CV capabilities, spatial awareness, and navigational functionality. In June 2022, the company announced its first fully autonomous mobile robot (AMR), Proteus, for use in its ecommerce warehousing operations. Proteus is aware of its surroundings and can work safely alongside humans. In early 2023, the company started to get involved in generative AI with the preview launch of its Titan LLMs and Bedrock, a fully managed platform that offers a choice of LLMs from several AI companies. At the time of writing, the Bedrock platform includes LLMs from AI21 Labs, Anthropic, Cohere, Meta, Mistral AI, Stability AI, and Amazon itself. In early 2024, Amazon announced a \$4 billion investment in AI start-up Anthropic.
AMD	US	AMD is a semiconductor company that develops computer processors and related technologies for business and consumer markets. It has long been a direct competitor to Intel. However, unlike its main competitor, AMD is now a fabless semiconductor company, as it spun off its manufacturing capabilities into GlobalFoundries in 2009. The company is a significant force in AI semiconductors from various perspectives. Its acquisition of ATI in 2006 gave it a strong product portfolio of GPUs, branded Radeon, which it has continued to develop to compete with Nvidia. Most public cloud computing vendors offer a choice of either Nvidia or AMD GPUs for their compute instances. In 2016, the company launched a new line of GPUs, Instinct, designed to accelerate deep learning, artificial neural networks, high-performance computing (HPC), and general-purpose-on-GPU applications. In 2022, AMD acquired Xilinx, giving it access to FPGAs and SoCs. It gave AMD further market share in data center training workloads and vital expertise to develop AI-optimized semiconductor products. At the end of 2023, the company launched its Instinct MI300X for AI workloads and the MI300A for HPC, its response to the Nvidia H100, which dominates the data center AI market.

Company	Country	Competitive position in the artificial intelligence theme
Apple	US	Apple trails the leading players in AI. Both Google Assistant and Amazon Alexa regularly outperform Siri, and Apple was slow to enter the smart speaker race, resulting in its HomePod having a lot of ground to make up. However, Apple dominates the important wearables segment with its smartwatches and hearables, products that will help increase the use of Siri. In recent years, Apple has made a string of AI acquisitions to close the gap on its rivals. Significant investment has gone towards improving Siri, including purchasing several ML, voice tech, and edge computing start-ups. Apple entered the chip design business back in 2007 as it became apparent that Intel, the provider of the chips for its Mac computers, could not provide the low-power chips needed for the iPhone. By 2020, it had started using its own chips, the M series, for Mac products. Its A11 chip, used in the iPhone, incorporated a Neural Engine to enhance AI and machine learning processes. In 2020, the M1 Pro and M1 Max for Mac computers incorporated both GPU cores and Neural Engine cores. The chips will continue to evolve, with major new versions expected annually. They will likely enable augmented reality and medical apps involving heavy-duty machine learning. They were also expected to contribute to Apple's secret autonomous vehicle project. However, in early 2024, the project was reportedly wound down, with personnel reallocated to the AI division.
Baidu	China	With access to China's more than one billion internet users, Baidu's biggest asset in CV is its visual data set capable of fueling AI algorithms and constantly improving them. Baidu is also a rising star in autonomous driving technology, developing auto brains for car makers. Baidu's technology, Apollo, has been designated as the primary platform for autonomous driving by the Chinese authorities, which have granted the search company 50 municipal licenses to test autonomous vehicles on open roads. In 2021, the company released the sixth-generation mass-produced unmanned vehicle, Apollo RT6, with the first commercial product launched in May 2024. In early 2024, it was approved for robotaxi pilot operations on highways to Beijing Daxing Airport and a fully driverless service across the Yangtze River in Wuhan, effectively becoming China's first 24x7 robotaxi service. As a testament to its technology leadership, both VW and Tesla are reportedly in talks about using its driverless platform.
C3.ai	US	C3.ai has developed a platform for enterprise AI. It provides over 40 turnkey enterprise AI applications that span every sector. Some of its clients include Shell, the US Air Force, Philips, Baker Hughes, and Engie. Its products include ready-to-use enterprise AI applications, a set of deep-code, low-code, and no-code development tools, and its application platform. This provides all software services in one suite to develop, deploy, and manage enterprise AI applications.

Company	Country	Competitive position in the artificial intelligence theme
Cambricon Technologies	China	Cambricon was founded in 2016 by Professor Chen Tianshi, then a researcher at the Chinese Academy of Sciences' Institute of Computing Technology. Backed initially by the Chinese Academy of Sciences and Alibaba, it was listed on the Shanghai Stock Exchange's STAR Market in 2020. The company focuses on developing smart chips and processors with high performance and low power consumption for AI R&D. Its first-generation AI chip, Cambricon-1A, was a deep learning processor targeted at edge devices. Its derivative chips, Cambricon-1H and Cambricon-1M, power nearly 100 million smartphones and servers for clients, including Huawei and Alibaba. Its AI processor was the basis of the neural net component in the Huawei Kirin 970 processor and has been scaled for Lenovo and Sugon servers. In early 2021, it launched the Siyuan 290 smart chip and accelerator card and the Xuansi 1000 smart accelerator, manufactured using TSMC's 7nm process node. In late 2022, it announced the next generation of Siyuan 370 and 590 chips, which went into production in 2023. Cambricon will likely dominate the Chinese machine learning scene. However, it remains to be seen how the US-China trade dispute will affect it, particularly if it loses access to leading-edge node manufacturing.
Hyundai Motor Group (parent company of Boston Dynamics)	South Korea	Boston Dynamics is a US engineering and robotics design company founded in 1992 as a spin-off from the Massachusetts Institute of Technology (MIT). It was owned by Alphabet (2013-17) and Softbank (2017-20), but in June 2021, it was acquired by the Hyundai Motor Group. The company develops highly mobile robots, including BigDog, Spot, Stretch, Atlas, and Handle. Only Spot and Stretch are currently commercially available. Since 2019, Spot has been used by the power and utilities, construction, and manufacturing industries to automate routine inspection tasks and data capture safely, accurately, and frequently in remote or dangerous areas. In 2023, DHL started to use Stretch to unload trailers and containers in its warehouses. The company has historically close ties with the military. For instance, BigDog was a quadruped robot designed for the US military with funding from the Defense Advanced Research Projects Agency (DARPA). Boston Dynamics' most advanced robot is Atlas, a research platform designed to push the limits of whole-body mobility. It has a humanoid form, with two legs and two arms, and can perform leaps and somersaults, detect its surroundings, and predict how its motion will evolve and adjust accordingly. In 2024, the company retired the hydraulic version of its Atlas robots but will continue to develop the all-electric version.
IBM	US	IBM made an early move in AI with Watson, the computer system that in 2011 beat two human champions on the US quiz show <i>Jeopardy!</i> Since then, the company has invested heavily in bringing AI to businesses. The acquisition of Merge Healthcare in 2015 gave IBM access to an extensive collection of medical images on which to train its Watson AI platform. However, despite the impressive data set, Watson struggled to live up to expectations. In fact, the company came under scrutiny, particularly Watson for Oncology, for offering physician users inaccurate advice. IBM eventually gave up and, in early 2022, sold the healthcare data and analytics assets from its Watson Health business to investment firm Francisco Partners, which subsequently renamed the business Merative. The company's CV platform remains with IBM as part of its cognitive cloud offering. Despite these early setbacks, IBM remains a significant player in AI. That said, IBM's implementations are overly reliant on expensive consulting services at a time when competitors are providing plug-and-play APIs, which developers tend to prefer, at a much lower price.

Company	Country	Competitive position in the artificial intelligence theme
iFlytek	China	iFlytek is a partially state-owned Chinese IT company founded in 1999. It develops voice recognition software and various voice-based internet and mobile products covering education, communication, music, and toys. Having started in voice recognition, the company's ambitions in AI have expanded. Management believes cognitive intelligence comes from a mastery of language and how we express knowledge, allowing us to perform logical reasoning and complex decision-making. In 2014, the company launched the iFlytek Super Brain, an artificial neural network project similar to Google Brain, initially focusing on viewing, reading, and hearing capabilities but also aiming at decision-making. In 2022, the firm announced the Super Brain 2030 Plan, a series of strategic initiatives to advance the quality and availability of personal robots and AI to assist families and communities. In 2023, it launched its own LLM, SparkDesk, aiming to exceed OpenAI ChatGPT's capabilities in the Chinese language and achieve a similar level to its capabilities in English.
Intel	US	The semiconductor giant expanded its AI platform by acquiring AI processor makers Nervana, Movidius, Habana Labs, and CV chip maker Mobileye. Intel is also moving into the GPU market, currently dominated by Nvidia and Arm. In early 2021 the company launched its first Xe-based graphics card designed for mainstream PCs and small- and medium-sized businesses. Ultimately, the chip giant plans to combine GPUs with its CPUs to focus on AI applications, although its success has been modest. In the AI accelerator segment, it has continued to produce the Habana Gaudi product line, with Gaudi 2 launched in 2022 and Gaudi 3 in 2024. It listed Mobileye on the Nasdaq stock exchange in October 2022 but retains control of its autonomous vehicle unit through the higher voting rights of its Class B shares. This strategy is likely driven by the company's problems in its traditional business and its need to raise cash to fund its third-party semiconductor fabrication initiative.
Meta (formerly Facebook)	US	AI is an integral part of Meta's offering. Although the company initially stumbled (its virtual personal assistant M being the most notable flop), it appears to have found a unique strategic approach to AI. Unlike most of its largest peers, which are seeking to directly monetize generative AI technology, Meta has open-sourced its most advanced LLM, LLaMa 2, including its internal weights, causing significant disruption to the market. Meta believes AI could solve some of its biggest issues, including misinformation. In 2018, it acquired Bloomsbury AI, an NLP start-up, to help address fake news. In mid-2020, it released a database of 100,000 deepfakes, allowing anyone to test deepfake detection techniques. In addition to making its platforms safer, Meta uses AI to create new experiences. The image recognition system GrokNet identifies items for sale on Facebook Marketplace automatically. The company's pivot in 2021 to focus on the metaverse, including its name change, led to significant investment in AI technologies, such as object detection, AR and VR graphics, spatial awareness, and scene understanding. However, since 2023 the focus has shifted to generative AI, and in 2024 the company indicated that it plans to invest between \$35 and \$40 billion in its Reality Labs division.

Company	Country	Competitive position in the artificial intelligence theme
Microsoft	US	Microsoft was late to the AI party, but since Satya Nadella became CEO in 2014, AI has become a top priority. In 2018, Nadella stated that Microsoft would “infuse everything with AI.” It rapidly made up ground, helped by strategic acquisitions, such as Bonsai (ML), XOXCO, Semantic Machines and Nuance Communications (conversational platforms), Lobe (deep learning), and ADRM (data modeling). It also invests heavily in AI via its venture capital arm, M12. Adding AI functionality to its Azure cloud computing service is a priority, allowing customers to integrate AI into their applications. Microsoft Dynamics 365 AI was introduced at the beginning of 2019 to help customers predict future business outcomes. Like much of Microsoft’s AI portfolio, voice assistant Cortana, initially supposed to be a competitor to Siri and Alexa in the consumer market, became primarily a business tool. Microsoft is one of the leading providers of CV API platforms, and until 2020, it invested in facial recognition start-ups. However, after controversy around its funding of AnyVision, which was accused of involvement in a surveillance program in the West Bank, Microsoft decided to stop investing in facial recognition firms. In early 2023, Microsoft expanded its long-term partnership with OpenAI by investing a further \$10 billion. This allowed it to deploy OpenAI’s models, such as ChatGPT, across its consumer and enterprise products and introduce new categories of digital experiences built on OpenAI’s technology. Microsoft 365’s Copilot feature combines OpenAI’s LLMs with the data from Microsoft 365 apps to enhance productivity, from content creation to automated analytics. In November 2023, Microsoft was the last large public cloud vendor to effectively enter the custom AI chip market when it announced its Maia AI accelerators, which it is using to support services such as Microsoft Copilot or Azure OpenAI Service. In early 2024, Microsoft invested in generative AI entrant Mistral AI, although OpenAI remains its main AI partner.
Nvidia	US	Nvidia is the market leader in GPUs, which are very popular for AI workloads, particularly CV. However, it has become increasingly apparent that FPGAs and custom ASICs deliver better performance in inferencing workloads and that Nvidia GPUs are often too power-hungry and expensive for training workloads. Consequently, cloud service providers have developed training-optimized chips (e.g., Google TPU, Amazon Trainium, Microsoft Maia), and cheaper competitors have emerged (like Bitmain). Furthermore, several start-ups (e.g., Graphcore, Cambricon, Biren Technology, Groq, Cerebras Systems) are developing special-purpose logic AI chips, which could outperform even FPGAs and ASICs. That said, Nvidia is not standing still. In 2023, it launched its H100 AI accelerators. Boasting improved power performance, they became a de facto monopoly for data center AI workloads. In early 2024, just a few months after AMD had released its MI300X accelerators, Nvidia announced its successor accelerator, Blackwell B200, again taking over the market. Further, it has committed to an annual release of new AI accelerators, which will likely help it retain product leadership. Nvidia’s exposure to the Chinese market has been problematic on various fronts. In 2021, China’s crackdown on cryptocurrency mining impacted GPU sales. In addition, the US Department of Commerce’s decision to block leading Chinese CV companies also impacted sales. In 2022, the US government banned Nvidia and AMD from selling advanced AI chips, including GPUs, to China. While Nvidia has adapted by releasing products specifically tailored to the Chinese market, sales in China will continue declining as the US government updates those bans. That said, growth elsewhere continues to accelerate, offsetting such market losses.

Company	Country	Competitive position in the artificial intelligence theme
Tencent	China	Tencent opened an AI lab in 2016 with a vision to “Make AI Everywhere.” It has since pushed heavily on AI-related technologies and developing practical AI applications for business, particularly within social media, online gaming, cloud, and healthcare. Tencent is the Chinese government’s choice regarding AI for medical imaging and diagnosis. Arguably, its biggest strength is that it owns WeChat, China’s most popular social media app, with 1.3 billion users. It offers everything from messaging to money transfers and ride-hailing. WeChat also provides telehealth, health records management, chronic disease management, and much more, which is why Tencent has invested in and partnered with healthcare AI start-ups like iCarbonX, Babylon Health, Medopad, and Atomwise. Tencent also holds a prominent position in facial recognition, invests heavily in AVs, and has ramped up AI efforts within its cloud offering. In May 2020, the company announced it would invest \$70 billion into cloud computing, AI, and other technologies over the next five years. So far, the company has not launched an internal AI chip design program like its peers Alibaba and Baidu. However, in 2021, it invested in domestic semiconductor company Enflame, which is developing an AI training chip, DTU 1.0. The company now uses its Zixiao AI chips for internal workloads in its cloud services, although it does not sell them externally. In 2023, the company entered the generative AI space by releasing the foundational model Hunyuan, available via Tencent Cloud.
Tesla	US	Tesla is an automotive and clean energy company that designs and manufactures electric vehicles, battery energy storage, solar panels and roof tiles, and related products and services. The company has long been working towards making its electric vehicles autonomous, using large artificial neural networks trained on massive amounts of traffic data. Given the demanding workloads Tesla faces, it decided back in 2017 to develop its own custom AI ASICs. By 2019, it had started embedding its Full Self Driving (FSD) Chip in the Tesla Model S to deal with inference workloads more efficiently. In 2021, it announced the D1 Dojo chip, optimized for training workloads. However, by the end of 2023, management appeared to be deemphasizing its bet on in-house AI training chip development, admitting that its Nvidia GPU purchases could reach \$4 billion in 2024 and that its Texas gigafactory would host 50,000 Nvidia H100 chips for FSD training. As part of its self-driving efforts, Tesla has aggressively invested in CV solutions, which rely on a combination of cameras, LiDAR and radar, and neural net processing.
Source: GlobalData		

Private companies

The table below lists some interesting private companies associated with this theme and summarizes their competitive position.

Company	Country	Competitive position in the artificial intelligence theme
Anthropic	US	Anthropic is a US start-up with a family of LLMs named Claude, focusing on safety and reliability. It was founded in 2021 by seven former employees of OpenAI, in part due to concerns over the company's links with Microsoft. The team included siblings Daniela and Dario Amodei; the latter was OpenAI's vice president of research and is now Anthropic's CEO. In 2023, the company received a \$4 billion investment from Amazon, followed shortly after by a \$2 billion commitment from Google. Its first models, Claude and a smaller Claude Instant, went on limited release in March 2023, with Claude 2 released to the general public in July 2023. Claude 3 followed in March 2024 and came in three sizes: Opus, Sonnet, and Haiku. Consistent with its focus on safety, Anthropic has developed a framework called Constitutional AI, which aims to align AI systems with human values and ensure that they are helpful, harmless, and honest. This is achieved by humans providing a set of rules describing the desired behavior of the AI system, known as the constitution, and the system self-evaluating and adjusting its output against these rules.
Biren Technology	China	Biren is a Chinese fabless semiconductor design company focused on accelerators for AI and HPC workloads. It was founded in 2019 by a team of former Nvidia and Alibaba employees led by Lingjie Xu. The company has released two general-purpose GPUs so far: BR100 and BR104, the specifications of which are competitive with Nvidia's A100 and H100. There were plans for a Hong Kong IPO in 2023, but the company has struggled to achieve profitability, not helped by US export bans that have impacted its access to TSMC's advanced manufacturing. Eventually, the co-founder and CEO resigned in early January 2024, and the IPO plans appear to be on hold. However, given the strategic importance of the semiconductor sector, particularly AI chips, the company might eventually benefit from government support.
Brain Corp	US	Brain Corp is a US start-up developing core technology for the robotics industry across industries and applications. It was founded in 2009 and has raised \$161 million so far. The company's core product is BrainOS, an AI software platform for autonomous mobile robots (AMRs) operating in indoor public spaces. It allows them to navigate autonomously, avoid obstacles, adapt to changing environments, manage data, and seamlessly interact with end-users. Brain Corp's shelf-scanning robots help retailers manage inventory. Outfitted with computer vision, these robots capture and report key inventory details, such as availability, pricing accuracy, and location. In early 2024, the company disclosed operational metrics, such as reaching over 30,000 robots subscribed to BrainOS across autonomous floor scrubbing, autonomous vacuuming, and autonomous inventory scanning. It also announced the hiring of an industry veteran as chief revenue officer. Such steps may suggest the company is preparing for an IPO.

Company	Country	Competitive position in the artificial intelligence theme
Cerebras Systems	US	Cerebras Systems is an AI company that builds computer systems for complex deep learning applications, including semiconductor components. It has raised \$750 million so far, and at the November 2021 series F round of funding, it was valued at \$4 billion. Its systems are powered by the Cerebras Wafer Scale Engine (WSE), a single, wafer-scale integrated processor that includes computing, memory, and interconnected fabric. The company has embraced generative AI as a way to show the capabilities of its AI chips. In early 2023, it released a series of seven GPT-based LLMs for open use by the research community.
Graphcore	UK	Semiconductor company Graphcore develops AI accelerators, which it calls intelligence processing units (IPUs). They are designed to provide massive parallelism and to hold the complete machine-learning model inside the processor. The company has raised over \$710 million since 2016 from Dell, Bosch, BMW, Samsung, Microsoft, DeepMind co-founder Demis Hassabis (among others), and European VC Atomico. At its last funding round in December 2020, it was valued at \$2.7 billion. In 2019, Graphcore C2 IPUs were made available for preview on Microsoft Azure, although the only Tier 1 cloud partner currently offering its IPUs in the cloud is Tencent. Other cloud partners include Korea Telecom, NHN, Kingsoft Cloud, G-Core Labs, and Cirrascale. Graphcore expects computer systems using its IPU chips to be able to support AI models with 500 trillion parameters and calculate at more than 10 exaflops (10 billion floating point operations per second) per second.
H2O.ai	US	H2O.ai is an open-source machine learning platform that helps users build smart applications. It was founded in 2012 and has raised \$251 million in funding so far. Its Cloud AI platform offers automated machine learning (autoML) capabilities to simplify how AI is created and consumed. Various vertical-specific tools have been developed for financial services, government, health, insurance, manufacturing, marketing, retail, and telecommunications. In 2023, it launched H2OGPT and LLM Studio to help companies develop their own chatbots.
Hive	US	Hive is a US start-up that provides cloud-based enterprise AI solutions for intelligent automation. It was founded in 2013 and has raised \$121 million so far. The company offers a portfolio of deep-learning models built with consensus-validated training data sourced and annotated by a distributed workforce of more than two million registered contributors. Use cases include automated content moderation, contextual advertising, advertising and sponsorship measurement, and document parsing. With the emergence of generative AI, Hive has added AI-generated content detection services, which enhance its content moderation offering and cover text, images, video, and audio.

Company	Country	Competitive position in the artificial intelligence theme
Horizon Robotics	China	Horizon Robotics develops AI processors for robots and autonomous driving and software customized for those chips. The start-up was founded in 2015 by former Baidu Institute of Deep Learning (IDL) deputy director, Kai Yu. It has already launched several products, including the Journey 2, Journey 3, Journey 5, and Journey 6 automotive-grade AI processors. The Journey 6, launched in April 2024, is designed for Level 4 autonomous driving (meaning a car can drive by itself in most conditions without human involvement). The company has a strong ecosystem of over 24 original equipment manufacturers (OEMs) and 200 industry partners. Horizon Robotics has raised \$3.4 billion in funding over 11 rounds, with the latest taking place in September 2022.
Hugging Face	US	Hugging Face provides an open-source ML platform for AI developers. Founded in 2016 by French entrepreneurs Clément Delangue, Julien Chaumond, and Thomas Wolf, its initial goal was to develop a chatbot app targeted at teenagers. It later pivoted to become a platform for machine learning. In 2022, it launched Bloom, a multilingual LLM with 176 billion parameters. Hugging Face has raised \$400 million in funding. Its last round, in 2023, valued the company at \$4.5 billion and included investors such as Google, Amazon, Nvidia, AMD, Intel, and IBM.
Megvii	China	One of the most promising companies in China's AI landscape, Megvii filed a \$500 million IPO in August 2019 but did not win approval at a hearing with the Hong Kong Stock Exchange's Listing Committee. The filing was undermined by the US ban accusing Megvii and seven other Chinese technology giants of being involved in human rights violations against Muslim minorities in the Xinjiang region. In May 2022, the company resumed its plans to list publicly, this time registering with the Shanghai Stock Exchange, but again failed to succeed. Those plans were revived in July 2023, but the listing has not yet occurred. Its core product is Face++, a face-based identity verification system that can analyze 106 data points on a face and accurately confirm a person's identity. Face++ is an open platform and has become the biggest facial recognition platform in the world. The company claims to get most of its revenues from smart city applications that include facial recognition.
Mistral AI	France	Mistral AI provides open-source LLMs. It was founded in 2023 by former Meta Platforms and Google DeepMind employees Arthur Mensch, Guillaume Lample, and Timothée Lacroix. After less than a year of operation and with no products available, it raised EUR385 million (\$414 million) at a valuation of more than \$2 billion. The company offers both open-weight and API-only models, available on cloud platforms such as Microsoft Azure AI and AWS Bedrock.

Company	Country	Competitive position in the artificial intelligence theme
OpenAI	US	OpenAI is a nonprofit AI research laboratory with a for-profit subsidiary, OpenAI LP. Founded in 2015 by Elon Musk, Sam Altman, and others, it received a \$1 billion investment from Microsoft in 2019. In early 2023, Microsoft invested a further \$10 billion, which exacerbated internal tensions due to the conflict of interest between OpenAI's nonprofit origins and its investors' commercial goals. In 2021, a group of employees left to found Anthropic due to those concerns. In late 2023, the board fired CEO Sam Altman, claiming a loss of confidence in his ability to lead. After a negative reaction from employees and principal investor Microsoft, Altman was reinstated within a week, and the board was replaced. OpenAI is best known for its generative models, including GPT and DALL-E. In 2020, it released its GPT-3 language model. GPT-3 can answer natural language questions, translate between languages, and coherently generate improvised text. In 2021, it released DALL-E, which can generate realistic and accurate images, soon followed by DALL-E 2. In 2022, it released ChatGPT, a language model optimized for dialogue. This was followed in 2023 by GPT-4. Other notable models developed by OpenAI include Dactyl and Codex AI. Dactyl uses ML to train a human-like robot hand to manipulate physical objects. Codex is a descendant of GPT-3 that has additionally been trained on code from 54 million GitHub repositories. It can create working code in over a dozen programming languages, particularly Python.
Source: GlobalData		

Sector Scorecards

At GlobalData, we use a scorecard approach to predict tomorrow's leading companies within each sector. Our sector scorecards have three screens: a thematic screen, a valuation screen, and a risk screen.

Artificial intelligence is a theme that impacts many of the sectors we cover. In this section, we focus specifically on the application software, semiconductors, and consumer electronics sectors.

For a full explanation of thematic scoring, please refer to the methodology section at the back of this report.

Application software sector scorecard

Who's who

Who does what in the consumer electronics space?

Application software (60 companies)

Company	Ticker	Sector	MKT CAP (US\$ M)	Country	Description
Adobe	ADBE	Creativity applications	236,840	USA	Software conglomerate focusing on information management software
Alphabet	GOOGL	Internet ecosystems	2,280,758	USA	Internet ecosystem monetised by advertising, primarily through the Google search engine
Alteryx	Unlisted	Data management applications	Unlisted	USA	Developer of software for data storage, retrieval, management, reporting and analytics solutions.
Amazon	AMZN	Internet ecosystems	1,939,171	USA	Ecommerce giant and cloud infrastructure leader with a broad-ranging internet ecosystem that includes internet TV
Amdocs	DOX	Business Support Systems	9,080	USA	Provider of business support systems software and services
Ansys	ANSS	Computer aided design	28,051	USA	Developer of CAD-based engineering software
Apple	AAPL	Mobile phones	3,269,993	USA	Internet ecosystem monetised by the sale of proprietary hardware (smartphones and computers)
Autodesk	ADSK	Computer aided design	52,252	USA	CAD software developer
Automation Anywhere	Unlisted	Robotic Process Automation	Unlisted	USA	Robotic process automation software company
Baidu	BIDU	Internet ecosystems	30,925	China	Internet search engine with Chinese internet ecosystem
Bentley Systems	BSY	Decision management applications	14,952	USA	Infrastructure and engineering software
Blackbaud	BLKB	CRM software	3,885	USA	Provider of cloud based CRM services for charity and education sector
Blackline	BL	Accounting applications	2,916	USA	Provider of cloud-based software that automates and manages complex manual accounting processes.
Broadcom	AVGO	Wireless chips	735,839	USA	Fabless digital communications chip designer (Broadcom merged with Avago)
Cadence Design Systems	CDNS	Computer aided design	84,718	USA	CAD software developer with focus on chip design
Cloud Software Group	Unlisted	IT infrastructure software	Unlisted	USA	Cloud computing software services company formed by the merger of Citrix Systems and TIBCO
Cloudera	Unlisted	Cloud management platforms	Unlisted	USA	Developer of cloud software for business data, inc. storage, access, management, analysis, and security
Constellation Software	CSU	Enterprise applications	60,752	Canada	Enterprise software conglomerate which acquires vertical market software companies
Coupa	Unlisted	Supply chain applications	Unlisted	USA	Developer of procurement software
Dassault Systemes	DSY	Computer aided design	50,077	France	CAD software developer focused on 3D product life cycle management
Datadog	DDOG	Data Management Applications	41,207	USA	Big data analytics engine focused on IT observability or machine-to-machine (M2M) communications
DocuSign	DOCU	Decision management applications	10,567	USA	Provider of electronic signature solutions
Dynatrace	DT	Data Management Applications	12,916	USA	Big data analytics engine focused on IT observability or machine-to-machine (M2M) communications
Finastra	Unlisted	Core banking software	Unlisted	UK	Provider of enterprise software solutions for banks and financial services providers
Hivision	2415	Surveillance equipment	39,888	China	Provider of video surveillance equipment and software for civilian and military purposes.
Huawei	Unlisted	Mobile infrastructure equipment	Unlisted	China	Maker of telecom equipment, IT infrastructure, and semiconductors.
IBM	IBM	Software and hardware	156,943	USA	Technology conglomerate
iFlytek	2230	Voice platform	14,251	China	Developer of speech intelligence and artificial intelligence technology.
Infor	Unlisted	ERP Systems	Unlisted	USA	Software conglomerate focused on ERP systems and big data
Intuit	INTU	Accounting applications	178,206	USA	Software developer focused on accounting software for SMEs
Meta	META	Social networks	1,295,154	USA	Formerly Facebook. Internet ecosystem monetized via advertising on social networks
Microsoft	MSFT	Internet ecosystems	3,360,592	USA	Software conglomerate
Neusoft	600718	Business process outsourcing	1,396	China	Provider of IT services, software development and business process outsourcing
New Relic	Unlisted	Data management applications	Unlisted	USA	Provider of performance management tools for data center applications
Nfon	NFN	Collaborative Software	109	Germany	Provider of cloud-based telecoms services
OpenAI	Unlisted	Artificial intelligence	Unlisted	USA	AI software company focused on large language models for text, video, and code generation.
OpenText	OTEX	Decision management applications	8,123	Canada	Developer of knowledge management software for business
Oracle	ORCL	ERP systems	382,511	USA	Software conglomerate with focus on ERP databases
Palantir	PLTR	Security Software	56,162	USA	Software company focused on data analytics for cybersecurity
Progress Software	PRGS	Data management applications	2,374	USA	Software developer with focus on application development and data integration
PTC	Unlisted	Decision management applications	21,267	USA	Software developer focused on process lifecycle management
Quantinuum	Unlisted	Quantum software	Unlisted	UK	Quantum software and algorithm provider
RingCentral	RNG	Collaborative software	2,562	USA	Provider of cloud-based telecoms services.
Sage	SGE	Accounting applications	13,827	UK	Developer of accounting software
Salesforce	CRM	CRM software	245,012	USA	Cloud services company focused on web-based customer relationship management software
SAP	SAP	ERP systems	246,437	Germany	Software conglomerate focused on ERP systems and big data
SenseTime	20	Computer vision	6,000	China	Provider of computer vision and deep learning software with a particular focus on facial recognition.
ServiceNow	NOW	Cloud management platforms	158,697	USA	Provider of IT and cloud service management tools
Snowflake	SNOW	Data Management Applications	44,836	USA	Cloud-based data warehousing provider
Software AG	SOW	Enterprise applications	2,876	Germany	Enterprise software provider
SS&C	SSNC	Financial services applications	15,564	USA	Developer of financial services software
Sumo Logic	Unlisted	Data Management Applications	Unlisted	USA	Big data analytics engine focused on IT observability or machine-to-machine (M2M) communications
Temenos	TEMN	Financial services applications	5,180	Switzerland	Software developer focused on real-time banking software applications
UiPath	PATH	Robotic process automation	6,833	USA	Robotic process automation software company
Workday	WDAY	ERP systems	57,669	USA	Cloud based ERP systems provider
Workiva	WK	Data management applications	3,960	USA	Provider of cloud-based enterprise software to collect, manage, report and analyse real time business data.
Xero	XRO	Accounting applications	13,619	New Zealand	Online accounting software developer
Zapata Computing	Unlisted	Quantum software	Unlisted	USA	Quantum software and workflow developer
Zendesk	Unlisted	CRM software	Unlisted	USA	Developer of cloud-based customer service and help desk software
Zoom	ZM	Collaborative Software	17,796	USA	Provider of collaborative working tools

Source: GlobalData

Thematic screen

Our thematic screen ranks companies based on overall leadership in the 10 themes that matter most to their industry, generating a leading indicator of future performance

Application software (60 companies)				Thematic Screen											Thematic Ranking
Weighting				15%	15%	5%	10%	10%	5%	10%	10%	10%	10%	10%	
Company	MKT CAP (US\$ M)	Ticker	Country	Artificial Intelligence	Big Data	Blockchain	Cybersecurity	Internet of Things	ESG	Hybrid cloud	Multi-cloud management	Robotic Process Automation	Future of Work		
Microsoft	3,360,592	MSFT	USA	5	4	4	1	5	4	4	4	5	5	1	
Alphabet	2,280,758	GOOGL	USA	5	5	5	5	2	3	4	4	4	5	2	
Amazon	1,939,171	AMZN	USA	5	5	5	4	5	2	3	4	4	4	3	
IBM	156,943	IBM	USA	4	5	5	4	2	4	5	4	5	3	4	
Salesforce	245,012	CRM	USA	4	5	5	3	4	5	3	3	5	4	5	
Huawei	Unlisted	Unlisted	China	4	4	4	4	4	2	4	4	4	4	6	
SAP	246,437	SAP	Germany	4	4	4	3	4	5	4	3	4	4	7	
Apple	3,269,993	AAPL	USA	5	4	3	4	5	2	3	4	3	3	8	
UiPath	6,833	PATH	USA	5	4	3	2	3	4	3	3	5	5	9	
Infor	Unlisted	Unlisted	USA	4	4	4	3	4	4	4	3	4	4	10	
Cloudera	Unlisted	Unlisted	USA	4	5	2	4	4	3	4	3	3	4	11	
Cloud Software Group	Unlisted	Unlisted	USA	4	4	3	3	3	3	4	4	5	4	12	
Automation Anywhere	Unlisted	Unlisted	USA	5	4	3	3	3	2	3	3	5	5	13	
Alteryx	Unlisted	Unlisted	USA	4	5	2	4	4	3	4	3	4	3	14	
Broadcom	735,839	AVGO	USA	4	5	3	4	4	3	5	4	2	2	15	
Dynatrace	12,916	DT	USA	3	5	3	5	3	2	4	4	4	3	16	
OpenAI	Unlisted	Unlisted	USA	5	4	4	3	3	2	3	3	4	5	17	
Oracle	382,511	ORCL	USA	4	4	5	4	3	3	4	3	3	4	18	
Snowflake	44,836	SNOW	USA	4	5	2	4	4	3	3	3	4	3	19	
Datadog	41,207	DDOG	USA	3	5	3	5	3	2	4	4	3	3	20	
Sumo Logic	Unlisted	Unlisted	USA	3	5	3	5	3	2	4	4	3	3	21	
Adobe	236,840	ADBE	USA	5	4	3	2	3	4	4	3	3	4	22	
Baidu	30,925	BIDU	China	4	5	4	3	4	1	4	3	2	4	23	
iFlytek	14,251	2230	China	5	4	2	3	5	3	3	3	3	3	24	
Software AG	2,876	SOW	Germany	4	5	3	1	4	3	3	5	4	2	25	
Palantir	56,162	PLTR	USA	5	4	3	4	4	2	3	3	2	3	26	
OpenText	8,123	OTEX	Canada	3	5	3	3	3	3	3	4	4	3	27	
Meta	1,295,154	META	USA	4	5	3	2	4	1	3	3	3	4	28	
Zoom	17,796	ZM	USA	4	4	2	3	3	3	3	3	3	3	29	
Bentley Systems	14,952	BSY	USA	4	4	2	4	4	3	3	3	3	3	30	
ServiceNow	158,697	NOW	USA	3	4	2	2	3	3	4	3	5	4	31	
Hikvision	39,888	2415	China	4	3	3	4	5	1	3	3	3	3	32	
SenseTime	6,000	20	China	5	3	2	4	4	1	3	3	3	3	33	
Cadence Design Systems	84,718	CDNS	USA	4	3	3	3	4	3	4	3	3	2	34	
Autodesk	52,252	ADSK	USA	4	3	3	3	4	3	3	3	3	3	35	
Amdocs	9,080	DOX	USA	4	4	3	3	3	2	3	3	3	3	36	
Zapata Computing	Unlisted	Unlisted	USA	5	3	3	3	3	2	3	3	3	3	37	
Quantinuum	Unlisted	Unlisted	UK	5	3	3	3	3	2	3	3	3	3	38	
Workday	57,669	WDAY	USA	3	4	4	3	3	3	4	3	2	4	39	
PTC	21,267	PTC	USA	4	3	2	3	4	3	3	3	2	4	40	
SS&C	15,564	SSNC	USA	3	3	3	2	3	3	3	3	5	4	41	
Dassault Systemes	50,077	DSY	France	4	3	2	3	4	3	3	3	3	2	42	
RingCentral	2,562	RNG	USA	4	3	2	3	3	3	3	3	2	4	43	
Ansys	28,051	ANSS	USA	3	3	2	3	4	3	3	3	3	3	44	
DocuSign	10,567	DOCU	USA	3	2	3	4	3	3	3	3	4	3	45	
Temenos	5,180	TEMN	Switzerland	3	4	3	2	3	5	3	3	3	2	46	
Nifon	109	NFN	Germany	3	3	3	3	3	2	3	3	3	4	47	
Finestra	Unlisted	Unlisted	UK	3	4	3	2	3	3	3	3	4	2	48	
Blackbaud	3,885	BLKB	USA	3	4	4	2	3	3	3	3	2	3	49	
Zendesk	Unlisted	Unlisted	USA	4	3	2	2	3	3	3	3	3	3	50	
New Relic	Unlisted	Unlisted	USA	3	5	2	2	3	3	3	3	2	2	51	
Progress Software	2,374	PRGS	USA	3	4	2	2	3	3	4	3	2	2	52	
Workiva	3,960	WK	USA	2	4	2	3	3	3	3	3	2	3	53	
Coupa	Unlisted	Unlisted	USA	3	3	2	3	3	3	3	3	2	2	54	
Intuit	178,206	INTU	USA	3	3	3	2	2	3	3	3	3	2	55	
Xero	13,619	XRO	New Zealand	3	3	3	2	3	3	3	3	2	2	56	
Blackline	2,916	BL	USA	2	3	2	3	3	3	3	3	3	2	57	
Neusoft	1,396	600718	China	2	3	2	3	3	3	3	3	3	2	58	
Constellation Software	60,752	CSU	Canada	2	3	2	2	3	3	3	2	2	2	59	
Sage	13,827	SGE	UK	2	2	2	2	3	3	3	2	2	2	60	

Thematic leader



Thematic laggard

Key: 1 (red) implies this theme will have a negative impact on earnings over the next 12 months; 3 (amber) implies a neutral impact; and 5 (green) a positive impact. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Valuation screen

Our valuation screen ranks our universe of companies within a sector based on selected valuation metrics

Application software				Valuation Screen					Valuation Ranking
(60 companies)				25%	20%	15%	20%	100%	
Company	MKT CAP (US\$ M)	Ticker	Country	EV/EBITDA	EV/Sales	ROCE %	Net Debt (Cash)/ Market Value %	FCF yield %	
Baidu	30,925	BIDU	China	3.0	0.9	6.4	-84.4	11.2	1
Zoom	17,796	ZM	USA	17.3	2.4	6.4	-41.2	8.2	2
Hikvision	39,888	2415	China	15.6	3.0	17.0	-10.9	4.3	3
Amdocs	9,080	DOX	USA	10.6	1.8	12.9	-1.1	7.7	4
Neusoft	1,396	600718	China	31.5	0.8	0.9	-64.5	4.3	5
Alphabet	2,280,758	GOOGL	USA	22.7	7.1	26.3	-5.6	3.0	6
Meta	1,301,546	META	USA	21.6	9.3	23.7	-4.1	3.4	7
Progress Software	2,374	PRGS	USA	12.6	3.9	8.8	28.4	8.0	8
IBM	156,943	IBM	USA	15.4	3.3	8.6	26.2	7.6	9
Temenos	5,180	TEMN	Switzerland	17.5	5.8	14.4	10.8	4.6	10
SS&C	15,564	SSNC	USA	11.7	4.0	8.4	37.0	6.2	11
Apple	3,269,993	AAPL	USA	25.9	8.5	55.1	-1.6	3.1	12
OpenText	8,138	OTEX	Canada	13.5	3.5	3.7	92.0	8.1	13
DocuSign	10,567	DOCU	USA	75.0	3.4	2.4	-11.2	8.4	14
Salesforce	245,012	CRM	USA	27.1	6.6	6.2	-3.7	4.1	15
Sage	13,827	SGE	UK	25.6	5.2	11.5	5.1	3.4	16
Amazon	2,014,827	AMZN	USA	22.6	3.4	10.2	-0.4	1.7	17
Adobe	236,840	ADBE	USA	30.8	11.9	30.9	-1.8	2.9	18
Nfon	109	NFN	Germany	13.5	1.1	-0.9	-4.0	1.0	19
SAP	246,437	SAP	Germany	30.9	7.1	10.8	-3.6	2.5	20
Dassault Systemes	50,077	DSY	France	26.0	7.9	11.2		3.0	21
Oracle	386,317	ORCL	USA	21.4	8.7	14.0	19.9	3.1	22
Blackbaud	3,885	BLKB	USA	30.1	4.2	2.6	19.3	3.5	23
Software AG	2,876	SOW	Germany	26.8	2.6	1.9	-4.3	-0.4	24
RingCentral	2,562	RNG	USA	40.3	1.8	-10.2	52.7	12.9	25
Constellation Software	60,752	CSU	Canada	38.2	7.5	11.5	3.9	2.9	26
Workday	57,669	WDAY	USA	113.6	7.3	1.6	-8.8	3.3	27
Microsoft	3,360,592	MSFT	USA	32.3	15.6	28.7	-1.7	1.8	28
Dynatrace	12,916	DT	USA	65.9	8.4	6.0	-6.8	2.7	29
Autodesk	52,252	ADSK	USA	41.3	9.5	20.3	-0.4	2.4	30
Blackline	2,916	BL	USA	48.1	5.3	1.0	6.5	3.4	31
Ansys	28,051	ANSS	USA	37.2	12.4	9.7	-0.4	2.4	32
Intuit	178,206	INTU	USA	45.3	12.4	13.1	1.3	2.7	33
PTC	21,267	PTC	USA	40.1	10.8	9.9	6.6	2.8	34
UIPath	6,833	PATH	USA	-34.9	3.8	-7.3	-27.5	4.3	35
Broadcom	741,058	AVGO	USA	38.0	21.2	24.8	3.4	2.4	36
Xero	13,619	XRO	New Zealand	45.1	12.8	8.9	-1.4	1.5	37
Cadence Design Systems	84,718	CDNS	USA	60.7	20.7	30.7	-0.7	1.5	38
ServiceNow	158,697	NOW	USA	114.3	16.9	7.6	-4.3	1.7	39
Bentley Systems	14,952	BSY	USA	57.9	13.5	8.3	9.5	2.6	40
Palantir	56,162	PLTR	USA	333.3	23.0	3.2	-6.7	1.3	41
iFlytek	14,251	2230	China	50.5	5.6	1.7	3.6	-3.6	42
Snowflake	44,836	SNOW	USA	-38.6	13.5	-20.0	-12.0	1.8	43
Workiva	3,960	WK	USA	-47.0	6.2	-12.9	-0.9	1.7	44
Datadog	41,207	DDOG	USA	3455.0	17.9	-1.1	-4.6	1.5	45
SenseTime	6,000	20	China	-7.2	11.4	-22.5	-26.0	-10.9	46
Alteryx	Unlisted	Unlisted	USA						47
Automation Anywhere	Unlisted	Unlisted	USA						48
Cloud Software Group	Unlisted	Unlisted	USA						49
Cloudera	Unlisted	Unlisted	USA						50
Coupa	Unlisted	Unlisted	USA						51
Finastra	Unlisted	Unlisted	UK						52
Huawei	Unlisted	Unlisted	China						53
Infor	Unlisted	Unlisted	USA						54
New Relic	Unlisted	Unlisted	USA						55
OpenAI	Unlisted	Unlisted	USA						56
Quantinuum	Unlisted	Unlisted	UK						57
Sumo Logic	Unlisted	Unlisted	USA						58
Zapata Computing	Unlisted	Unlisted	USA						59
Zendesk	Unlisted	Unlisted	USA						60
Median				22.1	4.7	4.8	0.0	2.5	
Mean				84.6	6.2	6.8	-0.3	2.6	

Cheap



Expensive

Key: Green denotes that the company is cheap (15% more attractively priced than the median value for the sector) relative to its global peers; amber denotes it is within 15% of the sector median value; and red denotes that it is expensive relative to its global peers. Private companies are shown at the bottom of these rankings by default because they do not have a publicly listed market price. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Risk screen

Our risk screen ranks companies within a particular sector based on overall investment risk

Application software (60 companies)				Risk Screen				
			Weighting	40%	30%	15%	15%	100%
Company	MKT CAP (US\$ M)	Ticker	Country	Operational Risk	Financial Risk	Industry Risk	Country Risk	Risk Ranking
Intuit	178,206	INTU	USA	4	4	4	5	1
Meta	1,301,546	META	USA	4	4	3	4	2
Ansys	28,051	ANSS	USA	4	4	4	4	3
Amazon	2,014,827	AMZN	USA	4	4	3	5	4
Cadence Design Systems	84,718	CDNS	USA	4	4	3	4	5
Microsoft	3,360,592	MSFT	USA	4	4	3	4	6
SenseTime	6,000	20	China	3	4	4	5	7
Apple	3,269,993	AAPL	USA	5	3	3	4	8
Alphabet	2,280,758	GOOGL	USA	4	4	3	4	9
SAP	246,437	SAP	Germany	4	3	4	4	10
Dassault Systemes	50,077	DSY	France	4	3	4	4	11
iFlytek	14,251	2230	China	4	3	4	4	12
Adobe	236,840	ADBE	USA	4	3	3	4	13
Hikvision	39,888	2415	China	4	3	4	4	14
Broadcom	741,058	AVGO	USA	4	2	4	4	15
Cloud Software Group	Unlisted	Unlisted	USA	3	3	3	5	16
Amdocs	9,080	DOX	USA	3	3	4	4	17
Constellation Software	60,752	CSU	Canada	3	3	4	5	18
OpenText	8,138	OTEX	Canada	4	3	4	4	19
Autodesk	52,414	ADSK	USA	4	2	4	4	20
UiPath	7,263	PATH	USA	3	3	4	5	21
Software AG	2,876	SOW	Germany	3	3	3	4	22
Infor	Unlisted	Unlisted	USA	3	3	4	5	23
Sage	13,827	SGE	UK	3	3	4	4	24
OpenAI	Unlisted	Unlisted	USA	3	3	3	5	25
Cloudera	Unlisted	Unlisted	USA	2	3	4	5	26
Oracle	386,317	ORCL	USA	4	3	3	3	27
SS&C	15,564	SSNC	USA	3	2	3	5	28
ServiceNow	158,697	NOW	USA	3	3	3	4	29
Bentley Systems	14,952	BSY	USA	3	3	4	4	30
Temenos	5,180	TEMN	Switzerland	3	2	4	4	31
Blackbaud	3,885	BLKB	USA	3	2	4	5	32
Progress Software	2,374	PRGS	USA	3	2	3	4	33
IBM	156,943	IBM	USA	4	2	3	4	34
Snowflake	44,836	SNOW	USA	1	5	4	5	35
Finastra	Unlisted	Unlisted	UK	3	3	4	5	36
Datadog	41,207	DDOG	USA	2	3	4	4	37
Zoom	17,796	ZM	USA	2	4	4	3	38
Baidu	30,925	BIDU	China	3	2	4	4	39
Xero	13,619	XRO	New Zealand	2	3	4	4	40
Alteryx	Unlisted	Unlisted	USA	2	3	3	4	41
Salesforce	245,012	CRM	USA	3	3	3	3	42
Neusoft	1,396	600718	China	3	2	4	4	43
Workday	57,510	WDAY	USA	3	2	3	5	44
RingCentral	2,562	RNG	USA	3	2	3	5	45
PTC	21,267	PTC	USA	3	2	4	3	46
New Relic	Unlisted	Unlisted	USA	2	3	4	5	47
Automation Anywhere	Unlisted	Unlisted	USA	3	2	4	5	48
Palantir	56,162	PLTR	USA	3	2	4	4	49
Blackline	2,916	BL	USA	2	3	3	5	50
Zapata Computing	Unlisted	Unlisted	USA	2	2	4	5	51
Zendesk	Unlisted	Unlisted	USA	2	2	4	4	52
DocuSign	10,567	DOCU	USA	2	2	3	5	53
Coupa	Unlisted	Unlisted	USA	2	2	3	4	54
Quantinuum	Unlisted	Unlisted	UK	2	2	4	4	55
Sumo Logic	Unlisted	Unlisted	USA	1	2	4	5	56
Nfon	109	NFN	Germany	1	3	3	5	57
Dynatrace	12,916	DT	USA	2	2	4	4	58
Workiva	3,960	WK	USA	2	2	3	3	59
Huawei	Unlisted	Unlisted	China	2	2	4	4	60

Low risk

High risk

Key: Green denotes low risk; amber denotes medium risk; red denotes high risk. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Semiconductor sector scorecard

Who's who

Who does what in the semiconductor space?

Semiconductors (66 companies)

Company	Ticker	Sector	MKT CAP (US\$ M)	Country	Description
Aixtron	AKA	Chip equipment	2,201	Germany	Manufacturer of metal organic chemical vapour deposition (MOCVD) equipment
Alibaba	BABA	Internet ecosystems	174,951	China	China's leading ecommerce company
Alphabet	GOOGL	Internet ecosystems	2,280,758	USA	Internet ecosystem monetised by advertising, primarily through the Google search engine
Amazon	AMZN	Internet ecosystems	2,014,827	USA	Ecommerce giant and cloud infrastructure leader with a broad-ranging internet ecosystem that includes internet TV
Amberella	AMBA	Imaging chips	2,181	USA	Manufacturer of video compression and image processing semiconductors used in cameras and smartphones.
AMD	AMD	CPUs, GPUs and FPGAs	254,634	USA	Developer of x86 microprocessors and graphics chips
AMS	AMS	Foundry	1,330	Austria	Manufacturer of high-performance analogue chips, focusing on sensors, MEMS, NFC and ultra-low power.
Analog Devices	ADI	Mixed signal chips	114,299	USA	Designer of analogue, mixed-signal, and DSP integrated circuits
Apple	AAPL	Mobile phones	3,269,993	USA	Internet ecosystem monetised by the sale of proprietary hardware (smartphones and computers)
Applied Materials	AMAT	Chip equipment	192,231	USA	Manufacturer of wafer fabrication and semiconductor equipment
Arm	ARM	Chip design	172,599	UK	Designer of CPU cores and other IP blocks for smartphones, computer servers, and AI accelerators.
ASML	ASML	Chip equipment	410,532	Netherlands	Manufacturer of lithography equipment used to print circuits on silicon wafers to make chips.
Baidu	BIDU	Internet ecosystems	30,925	China	Internet search engine with Chinese internet ecosystem
Bitmain	Unlisted	AI chips	Unlisted	China	Designer and manufacturer of ASIC chips for bitcoin mining and AI workloads
BrainChip	BRN	AI chips	277	Australia	Designer of neuromorphic chips for AI workloads
Broadcom	AVGO	Wireless chips	74,058	USA	Fabless digital communications chip designer (Broadcom merged with Avago)
Cadence Design Systems	CDNS	Computer aided design	84,718	USA	CAD software developer with focus on chip design
Cambricon	688256	AI chips	11,645	China	Designer of AI chips
Cerebras	Unlisted	AI chips	Unlisted	USA	Designer of AI chips
Cirrus Logic	CRUS	Mixed signal chips	6,781	USA	Manufacturer of linear and mixed-signal processors
Diodes	DIOD	Power management chips	3,256	USA	Analogue chip designer for consumer electronics
GlobalFoundries	GFS	Foundry	28,130	USA	Chip foundry making silicon wafers for chipmakers that do not have their own fabs
Graphcore	Unlisted	AI chips	Unlisted	UK	Designer of AI chips
Groq	Unlisted	AI chips	Unlisted	USA	Designer of AI chips
Himax	HIMX	Imaging chips	1,447	Taiwan	Chip designer that focuses on touch controllers, TFT-LCD and AMOLED drivers
Horizon Robotics	Unlisted	AI Chips	Unlisted	China	Designer of AI chips for robots and autonomous vehicles
Huawei	Unlisted	Mobile infrastructure equipment	Unlisted	China	Maker of telecom equipment, IT infrastructure, and semiconductors.
IBM	IBM	Software and hardware	156,943	USA	Technology conglomerate
Infineon	IFX	Auto grade chips	47,514	Germany	Manufacturer of integrated mixed signal memory and logic chips for car, comms and industrial markets
Intel	INTC	Integrated design manufacturer	130,009	USA	World's largest integrated digital chip maker
IonQ	IONQ	Quantum computing	1,501	USA	Manufacturer of quantum computers and chips using trapped ytterbium ions
Lam Research	LRCX	Chip equipment	138,031	USA	Wafer fabrication equipment maker
Marvell	MVRL	Wireless chips	59,095	USA	Chip designer for digital broadband comms - IP and storage chips
MediaTek	2454	Wireless chips	68,922	Taiwan	Chip designer focused on low-end digital multi-media and wireless communications
Melexis	MELE	MEMS sensors	3,442	Belgium	Manufacturer of advanced chips and sensors for the autos industry
Microchip	MCHP	Microcontrollers	48,347	USA	Manufacturer of embedded microcontrollers
Micron	MU	Memory chips	157,645	USA	Manufacturer of integrated DRAM and flash memory
Microsoft	MSFT	Internet ecosystems	3,360,592	USA	Software conglomerate
Monolithic Power Systems	MPWR	Power management chips	39,738	USA	Fabless designer of analogue integrated circuits
Mythic	Unlisted	AI chips	Unlisted	USA	Designer of AI chips
Nanya Tech	2408	Memory chips	6,557	Taiwan	Manufacturer of DRAM memory
Nvidia	NVDA	GPUs	3,109,440	USA	Designer of digital graphics, video and multi-media processors
NXP	NXPI	Wireless chips	68,567	Netherlands	Designer of chips for mobile, consumer electronics. Spun out of Philip in 2006.
On Semiconductor	ON	Power management chips	29,329	USA	Power management chip designer
Qorvo	QRVO	Wireless chips	11,038	USA	Manufacturer of RF chips (formerly RF Micro Devices and Triquint Semi)
Qualcomm	QCOM	Wireless chips	220,615	USA	Manufacturer of chips and licensor of CDMA chip technology
Renesas	6723	Microcontrollers	35,067	Japan	A chip designer selling primarily to Japanese camakers.
Rigetti Computing	RGTI	Quantum computing	156	USA	Manufacturer of quantum computers and chips using superconducting circuits
Rohm	6963	MEMS sensors	5,420	Japan	Chip designer and foundry focused on MEMS sensors, analogue ICs, logic ICs, memory ICs and ASICs.
SambaNova	Unlisted	AI chips	Unlisted	USA	Provider of AI platform as a service which designs its own AI chips
Samsung Electronics	5930	Foundry	389,063	Korea	Integrated chip maker, smartphone maker and consumer electronics conglomerate
Silicon Labs	SLAB	Mixed signal chips	3,491	USA	Chip designer focused on analogue intensive mixed signal processors
Silicon Motion	SIMO	Memory chips	2,698	Hong Kong	Processors for NAND flash (63%), USB (20%) and graphics (15%)
SK Hynix	660	Memory chips	124,132	Korea	Memory chip maker focused on DRAM, SRAM, Flash, MCP
Skyworks	SWKS	Wireless chips	17,030	USA	Chip designer for mobile comms applications - digital and analogue
SMEE	Unlisted	Foundry	Unlisted	China	Manufacturer of wafer fabrication and semiconductor equipment
SMIC	981	Foundry	26,198	China	Chip foundry in China, run by Taiwanese
STMicroelectronics	STMPA	Mixed signal chips	36,406	Netherlands	Integrated analogue chip maker
Synopsys	SNPS	Computer aided design	91,703	USA	Design automation software for chip sector
SynSense	Unlisted	AI chips	Unlisted	Switzerland	Manufacturer of mixed-signal neuromorphic processors for AI workloads
Teradyne	TER	Chip equipment	22,928	USA	Manufacturer of automatic test systems (esp. for wireless chips). Also owns Universal Robots, a maker of co-bots
Tesla	TSLA	Car maker	626,262	USA	Manufacturer of electric cars
Texas Instruments	TXN	Mixed signal chips	175,814	USA	Integrated digital and analogue chip maker - also big in sensors and educational tools
Tokyo Electron	8035	Chip equipment	102,715	Japan	Semiconductor and flat panel production equipment
TSMC	2330	Foundry	769,134	Taiwan	World's largest chip foundry, making bespoke logic chips for companies that provide their own designs
UMC	2303	Foundry	21,829	Taiwan	Chip foundry

Source: GlobalData

Thematic screen

Our thematic screen ranks companies based on overall leadership in the 10 themes that matter most to their industry, generating a leading indicator of future performance

Semiconductors (66 companies)				Thematic Screen										Thematic Ranking
Company	MKT CAP (US\$ M)	Ticker	Country	Artificial Intelligence	Data Centers	5G	Internet of Things	Autonomous Vehicles	M&A	Geopolitics	Robotics	China Impact	AI Chips	
TSMC	789,134	2330	Taiwan	5	5	3	5	5	3	3	3	2	4	1
ASML	410,532	ASML	Netherlands	5	5	5	4	4	3	2	4	4	4	2
Samsung Electronics	389,063	5930	Korea	4	5	5	5	5	2	3	4	2	4	3
Alibaba	174,951	BABA	China	5	4	4	4	4	2	2	5	5	4	4
Nvidia	3,109,440	NVDA	USA	5	5	4	4	5	2	1	4	4	5	5
Microsoft	3,360,592	MSFT	USA	5	5	3	5	4	1	1	4	4	5	6
Amazon	2,014,827	AMZN	USA	5	5	3	5	4	1	1	5	3	5	7
Tesla	626,262	TSLA	USA	5	4	3	5	4	2	2	5	2	5	8
Silicon Motion	2,698	SIMO	Hong Kong	4	4	4	4	4	4	4	3	4	3	9
BrainChip	277	BRN	Australia	4	3	4	5	4	4	2	4	3	5	10
SynSense	Unlisted	Unlisted	Switzerland	4	3	4	5	4	4	2	4	3	5	11
Horizon Robotics	Unlisted	Unlisted	China	5	4	3	3	5	3	2	5	3	5	12
AMS	1,370	AMS	Austria	3	4	3	5	4	5	4	3	4	3	13
Cerebras	Unlisted	Unlisted	USA	5	5	3	4	4	4	2	4	3	5	14
SK Hynix	124,132	660	Korea	4	5	3	4	4	4	4	3	3	3	15
Groq	Unlisted	Unlisted	USA	5	5	3	4	4	5	1	3	3	5	16
Huawei	Unlisted	Unlisted	China	4	4	5	4	5	1	1	3	5	4	17
AMD	254,634	AMD	USA	5	5	3	4	3	3	1	3	3	5	18
Synopsys	91,703	SNPS	USA	4	4	4	4	4	3	1	4	4	4	19
Cambricon	11,645	688256	China	5	4	3	3	4	3	2	3	3	5	20
Himax	1,447	HIMX	Taiwan	4	2	3	4	4	4	3	3	4	4	21
Mythic	Unlisted	Unlisted	USA	4	5	4	4	3	5	1	3	3	4	22
Alphabet	2,280,758	GOOGL	USA	5	4	4	2	5	1	1	5	2	5	23
Arm	172,599	ARM	UK	4	4	4	4	4	4	2	3	2	4	24
Baidu	30,925	BIDU	China	4	3	3	4	4	3	1	4	5	4	25
SambaNova	Unlisted	Unlisted	USA	5	4	3	3	4	4	1	3	3	5	26
Apple	3,269,993	AAPL	USA	5	3	5	5	4	2	1	3	2	4	27
Nanya Tech	6,557	2408	Taiwan	3	4	4	4	4	4	2	3	4	3	28
Rohm	5,420	6963	Japan	3	3	3	5	5	4	3	4	2	3	29
Melexis	3,442	MELE	Belgium	4	3	3	4	5	4	3	3	3	3	30
Graphcore	Unlisted	Unlisted	UK	5	4	3	3	4	3	2	3	3	4	31
Qualcomm	220,615	QCOM	USA	4	4	5	5	4	2	1	4	2	3	32
Cadence Design Systems	84,718	CDNS	USA	4	4	4	4	4	3	1	3	3	4	33
MediaTek	68,922	2454	Taiwan	3	4	4	3	3	4	2	3	5	3	34
NXP	68,567	NXPI	Netherlands	4	3	3	5	5	4	2	4	2	3	35
STMicroelectronics	36,406	STMPA	Netherlands	4	3	3	5	5	4	2	4	2	3	36
SMIC	26,198	981	China	2	4	4	4	4	3	1	3	5	4	37
Aixtron	2,201	AXA	Germany	3	3	3	5	5	4	2	4	3	3	38
Applied Materials	192,231	AMAT	USA	4	4	4	4	4	3	1	3	4	3	39
IBM	156,943	IBM	USA	4	4	3	2	3	2	1	4	4	5	40
Infineon	47,505	IFX	Germany	4	3	3	5	5	3	2	4	2	3	41
Skyworks	17,030	SWKS	USA	3	3	3	5	5	4	1	3	3	3	42
IonQ	1,501	IONQ	USA	4	4	3	3	3	4	1	3	3	5	43
Rigetti Computing	156	RGTI	USA	4	4	3	3	3	4	1	3	3	5	44
Marvell	59,095	MRVL	USA	3	4	4	4	3	4	1	3	3	4	45
Renesas	35,067	6723	Japan	3	3	3	5	2	4	3	4	2	3	46
Teradyne	22,928	TER	USA	4	3	3	4	3	5	1	5	3	3	47
Ambarella	2,181	AMBA	USA	4	2	3	4	4	5	1	4	3	4	48
Bitmain	Unlisted	Unlisted	China	4	4	3	3	3	2	3	3	2	4	49
Lam Research	138,031	LRCX	USA	4	4	4	4	4	3	1	3	3	3	50
Intel	130,009	INTC	USA	5	4	2	4	5	2	1	3	4	3	51
Tokyo Electron	102,715	8035	Japan	3	4	3	4	4	3	3	3	2	3	52
On Semiconductor	29,329	ON	USA	3	4	3	4	5	4	1	4	3	3	53
SMEE	Unlisted	Unlisted	China	4	4	3	3	3	3	1	3	4	4	54
Broadcom	741,058	AVGO	USA	4	4	3	4	3	3	1	4	3	3	55
Micron	157,645	MU	USA	4	5	3	4	4	3	1	3	2	3	56
Monolithic Power Systems	39,738	MPWR	USA	4	4	3	4	3	4	1	3	3	3	57
UMC	21,829	2303	Taiwan	2	4	3	4	3	4	3	3	2	3	58
Texas Instruments	175,814	TXN	USA	4	4	3	4	4	2	1	4	2	3	59
Qorvo	11,038	QRVO	USA	4	3	4	4	3	5	1	3	2	3	60
Silicon Labs	3,491	SLAB	USA	3	3	3	5	5	3	1	3	3	3	61
Analog Devices	114,299	ADI	USA	3	4	3	4	4	3	1	4	2	3	62
GlobalFoundries	28,042	GFS	USA	2	3	3	5	3	4	1	3	4	3	63
Diodes	3,256	DIOD	USA	3	4	3	4	3	4	1	3	3	3	64
Microchip	48,347	MCHP	USA	3	4	3	4	3	3	1	3	3	3	65
Cirrus Logic	6,781	CRUS	USA	2	3	3	4	3	4	1	3	3	3	66

Thematic leader



Thematic laggard

Key: 1 (red) implies this theme will have a negative impact on earnings over the next 12 months; 3 (amber) implies a neutral impact; and 5 (green) a positive impact. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Valuation screen

Our valuation screen ranks our universe of companies within a sector based on selected valuation metrics

Semiconductors				Valuation Screen						Valuation Ranking
(66 companies)				25%	20%	15%	20%	20%	100%	
Company	MKT CAP (US\$ M)	Ticker	Country	EV/EBITDA	EV/Sales	Div yield %	Net Debt (Cash)/Market Value %	FCF yield %		
Alibaba	174,951	BABA	China	6.3	1.1	1.4	-64.9	11.8		1
STMicroelectronics	35,340	STMPA	Netherlands	5.0	1.9	0.6	-8.6	4.2		2
Baidu	30,925	BIDU	China	3.0	0.9		-84.6	11.3		3
MediaTek	68,922	2454	Taiwan	23.0	4.8	5.4	-14.2	7.0		4
UMC	21,829	2303	Taiwan	6.5	2.9	6.4	-19.7	-1.1		5
Skyworks	17,030	SWKS	USA	10.1	3.7	2.4	3.3	9.5		6
Diodes	3,256	DIOD	USA	7.9	1.8		-8.1	4.0		7
Rohm	5,420	6963	Japan	8.5	2.1	2.2	-31.8	-9.6		8
Samsung Electronics	389,063	5930	Korea	10.4	1.8	1.8	-18.6	-2.9		9
IBM	156,943	IBM	USA	15.3	3.2	3.8	26.4	7.7		10
Infineon	47,505	IFX	Germany	8.1	2.8	0.9	3.2	2.2		11
Himax	1,447	HIMX	Taiwan	28.4	1.9	5.8	18.8	8.9		12
Cirrus Logic	6,781	CRUS	USA	16.0	3.5		-10.3	5.7		13
Aixtron	2,201	AXXA	Germany	11.1	3.0	1.7	-8.8	-5.3		14
Silicon Motion	2,698	SIMO	Hong Kong	38.6	3.7	0.6	-12.3	3.7		15
Microchip	48,347	MCHP	USA	15.7	7.1	1.9	11.7	5.4		16
Renesas	35,067	6723	Japan	10.0	4.0		-0.8	6.6		17
Qualcomm	220,615	QCOM	USA	23.7	6.3	1.6	1.3	4.5		18
NXP	68,567	NXPI	Netherlands	15.9	5.7	1.5	10.1	3.7		19
Applied Materials	192,231	AMAT	USA	23.4	7.2	0.5	-1.8	4.0		20
Melexis	3,442	MELE	Belgium	11.0	3.5	4.4	4.6	-2.9		21
GlobalFoundries	28,042	GFS	USA	10.6	3.7		-4.6	1.1		22
Tokyo Electron	102,715	8035	Japan	31.3	8.7	1.2	-4.6	1.9		23
TSMC	769,134	2330	Taiwan	16.6	11.2	1.2	-3.6	1.2		24
Lam Research	138,031	LRCX	USA	25.0	7.9	0.7	-0.3	3.4		25
Analog Devices	113,058	ADI	USA	19.5	9.7	1.5	5.3	3.1		26
On Semiconductor	29,329	ON	USA	9.6	3.7		3.0	1.4		27
Apple	3,269,993	AAPL	USA	26.4	8.7	0.5	-1.5	3.0		28
Alphabet	2,280,758	GOOGL	USA	22.7	7.1		-5.6	3.0		29
Texas Instruments	175,814	TXN	USA	20.8	10.2	2.6	1.5	0.8		30
Teradyne	22,928	TER	USA	36.1	8.3	0.3	-4.1	1.9		31
Nanya Tech	6,528	2408	Taiwan	188.4	5.6	3.1	-23.3	-9.3		32
Intel	130,009	INTC	USA	16.4	2.9	2.4	14.2	-11.0		33
Qorvo	10,886	QRVO	USA	28.6	3.1		8.6	6.5		34
SMIC	26,199	981	China	11.6	6.0		-32.8	-16.3		35
Amazon	2,014,827	AMZN	USA	23.5	3.5		-0.4	1.6		36
Microsoft	3,360,592	MSFT	USA	32.4	15.6	0.6	-1.7	1.8		37
ASML	410,532	ASML	Netherlands	36.1	13.8	0.6	-0.8	0.9		38
Broadcom	741,058	AVGO	USA	38.2	21.4	1.0	3.4	2.4		39
Monolithic Power Systems	39,738	MPWR	USA	74.0	21.2	0.5	-2.8	1.5		40
Tesla	626,262	TSLA	USA	44.5	6.2		-3.8	0.7		41
Silicon Labs	3,491	SLAB	USA	115.0	4.0		-11.3	-1.5		42
SK Hynix	124,132	660	Korea	33.0	6.0	0.5	10.6	-2.6		43
Marvell	59,095	MRVL	USA	75.1	11.3	0.3	5.4	1.7		44
Synopsys	91,703	SNPS	USA	59.5	15.4		-1.7	1.3		45
Nvidia	3,109,440	NVDA	USA	89.7	50.8		-0.6	0.9		46
AMS	1,370	AMS	Austria	-3.2	0.8	2.9	112.0	-29.3		47
Cadence Design Systems	84,718	CDNS	USA	60.3	20.6		-0.7	1.5		48
AMD	254,634	AMD	USA	65.2	11.1		-1.3	0.4		49
Ambarella	2,181	AMBA	USA	-15.1	8.7		-10.1	0.3		50
Micron	157,645	MU	USA	80.2	10.4	0.3	1.7	-3.9		51
Arm	172,599	ARM	UK	621.5	52.5		-2.1	0.5		52
Rigetti Computing	156	RGTI	USA	-1.2	6.5		-50.0	-38.3		53
IonQ	1,501	IONQ	USA	-7.8	52.0		-30.4	-6.6		54
Cambricon	11,645	688256	China	-125.9	112.8		-5.8	-0.8		55
BrainChip	277	BRN	Australia	-9.4	1140.5		-4.6	-6.4		56
Bitmain	Unlisted	Unlisted	China							57
Cerebras	Unlisted	Unlisted	USA							58
Graphcore	Unlisted	Unlisted	UK							59
Groq	Unlisted	Unlisted	USA							60
Horizon Robotics	Unlisted	Unlisted	China							61
Huawei	Unlisted	Unlisted	China							62
Mythic	Unlisted	Unlisted	USA							63
SambaNova	Unlisted	Unlisted	USA							64
SMEE	Unlisted	Unlisted	China							65
SynSense	Unlisted	Unlisted	Switzerland							66
Median				15.8	4.4	0.3	-0.8	1.0		
Mean				31.0	26.6	1.0	-3.8	-0.1		

Cheap



Expensive

Key: Green denotes that the company is cheap (15% more attractively priced than the median value for the sector) relative to its global peers; amber denotes it is within 15% of the sector median value; and red denotes that it is expensive relative to its global peers. Private companies are shown at the bottom of these rankings by default because they do not have a publicly listed market price. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Risk screen

Our risk screen ranks companies within a particular sector based on overall investment risk

Semiconductors (66 companies)				Risk Screen				
		Weighting		40%	30%	15%	15%	100%
Company	MKT CAP (US\$ M)	Ticker	Country	Operational Risk	Financial Risk	Industry Risk	Country Risk	Risk Ranking
Nvidia	3,109,440	NVDA	USA	4	4	4	4	1
Tokyo Electron	102,715	8035	Japan	4	4	3	5	2
Amazon	2,014,827	AMZN	USA	4	4	3	5	3
AMD	254,634	AMD	USA	4	4	4	5	4
Lam Research	138,031	LRCX	USA	4	3	4	5	5
Cadence Design Systems	84,718	CDNS	USA	4	4	3	4	6
Microsoft	3,360,592	MSFT	USA	4	4	3	4	7
TSMC	769,134	2330	Taiwan	4	3	3	5	8
Alibaba	174,951	BABA	China	4	4	3	4	9
Synopsys	91,703	SNPS	USA	4	3	4	5	10
Teradyne	22,928	TER	USA	4	4	4	5	11
Apple	3,269,993	AAPL	USA	5	3	3	4	12
Nanya Tech	6,528	2408	Taiwan	3	4	4	4	13
Alphabet	2,280,758	GOOGL	USA	4	4	3	4	14
ASML	410,532	ASML	Netherlands	4	3	4	5	15
Texas Instruments	175,814	TXN	USA	4	3	3	3	16
Micron	157,645	MU	USA	4	3	4	5	17
Intel	130,009	INTC	USA	4	3	4	4	18
Skyworks	17,030	SWKS	USA	3	3	4	5	19
Applied Materials	192,231	AMAT	USA	4	3	3	5	20
STMicroelectronics	35,340	STMPA	Netherlands	3	3	4	5	21
Samsung Electronics	389,063	5930	Korea	4	4	3	4	22
Silicon Motion	2,698	SIMO	Hong Kong	3	4	4	4	23
Qualcomm	220,615	QCOM	USA	4	2	4	4	24
MediaTek	68,922	2454	Taiwan	4	4	4	3	25
Broadcom	741,058	AVGO	USA	4	2	4	4	26
SK Hynix	124,132	660	Korea	4	3	4	4	27
UMC	21,829	2303	Taiwan	3	3	4	5	28
Ambarella	2,181	AMBA	USA	2	5	4	5	29
Qorvo	10,886	QRVO	USA	3	3	4	4	30
Melexis	3,442	MELE	Belgium	3	4	4	4	31
Analog Devices	113,058	ADI	USA	4	2	4	4	32
Arm	172,599	ARM	UK	3	3	4	4	33
Cirrus Logic	6,781	CRUS	USA	3	4	4	4	34
Tesla	626,262	TSLA	USA	3	3	3	4	35
Monolithic Power Systems	39,738	MPWR	USA	3	4	3	4	36
NXP	68,567	NXPI	Netherlands	4	2	4	4	37
Aixtron	2,201	AIXA	Germany	3	4	4	3	38
Rohm	5,420	6963	Japan	2	4	4	4	39
On Semiconductor	29,329	ON	USA	3	2	4	5	40
IBM	156,943	IBM	USA	4	2	3	4	41
GlobalFoundries	28,042	GFS	USA	3	2	4	5	42
Himax	1,447	HIMX	Taiwan	3	3	4	4	43
Renesas	35,067	6723	Japan	3	2	4	4	44
SMIC	26,199	981	China	3	2	4	4	45
Baidu	30,925	BIDU	China	3	2	4	4	46
Marvell	59,095	MVVL	USA	3	2	4	4	47
Infineon	47,505	IFX	Germany	3	2	4	4	48
Diodes	3,256	DIOD	USA	2	3	4	4	49
BrainChip	277	BRN	Australia	2	3	4	5	50
Silicon Labs	3,491	SLAB	USA	3	2	4	4	51
Microchip	48,347	MCHP	USA	3	2	4	3	52
AMS	1,370	AMS	Austria	3	2	3	3	53
Rigetti Computing	156	RGTI	USA	2	2	4	5	54
IonQ	1,501	IONQ	USA	1	3	4	5	55
SambaNova	Unlisted	Unlisted	USA	2	2	4	5	56
Graphcore	Unlisted	Unlisted	UK	2	2	4	5	57
Cambricon	11,645	688256	China	2	3	4	4	58
SynSense	Unlisted	Unlisted	Switzerland	2	2	4	5	59
Mythic	Unlisted	Unlisted	USA	2	2	4	5	60
Bitmain	Unlisted	Unlisted	China	2	2	4	4	61
Cerebras	Unlisted	Unlisted	USA	2	2	4	5	62
Groq	Unlisted	Unlisted	USA	1	2	4	5	63
SMEEE	Unlisted	Unlisted	China	2	2	4	4	64
Huawei	Unlisted	Unlisted	China	2	2	4	4	65
Horizon Robotics	Unlisted	Unlisted	China	2	2	4	4	66

Low risk

High risk

Key: Green denotes low risk; amber denotes medium risk; red denotes high risk. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Consumer electronics sector scorecard

Who's who

Who does what in the consumer electronics space?

Consumer electronics (50 companies)

Company	Ticker	Sector	MKT CAP (US\$ M)	Country	Description
Acer	2353	Computers	4,421	Taiwan	Manufacturer of PCs, laptops, displays and computer peripherals
Alarm.com	ALRM	Surveillance equipment	3,091	USA	Provider of home security systems and automated home products
Alibaba	BABA	Internet ecosystems	174,951	China	China's leading ecommerce company
Alphabet	GOOGL	Internet ecosystems	2,280,758	USA	Internet ecosystem monetised by advertising, primarily through the Google search engine
Amazon	AMZN	Internet ecosystems	2,014,827	USA	Ecommerce giant and cloud infrastructure leader with a broad-ranging internet ecosystem that includes internet TV
Apple	AAPL	Mobile phones	3,269,993	USA	Internet ecosystem monetised by the sale of proprietary hardware (smartphones and computers)
Asus	2357	Computers	11,541	Taiwan	PC contractor - motherboards, graphic cards
Baidu	BIDU	Internet ecosystems	30,925	China	Internet search engine with Chinese internet ecosystem
Blackberry	BB	Mobile phones	1,447	Canada	Mobile handset manufacturer and corporate communications services provider
ByteDance	Unlisted	Internet ecosystems	Unlisted	China	Internet technology company, with products including video app TikTok
Canon	7751	Imaging equipment	36,526	Japan	Provider of digital imaging solutions
Compal	2324	Computers	4,738	Taiwan	Subcontractor for notebooks
Dell Technologies	DELL	Computers	98,898	USA	Provider of PCs, enterprise servers, monitors, printers, storage, software and networking equipment
DJI	Unlisted	Drones	Unlisted	China	Drone manufacturer
Garmin	GRMN	Wearable tech	31,119	Switzerland	Manufacturer of navigation and comms devices - esp. GPS
GoPro	GPRO	Wearable tech	200	USA	Developer of wearable and mountable cameras
Haier Smart Home	600690	Household appliances	36,125	China	Manufacturer of household appliances
Hikvision	2415	Surveillance equipment	39,888	China	Provider of video surveillance equipment and software for civilian and military purposes.
Honeywell	HON	Industrial automation	138,983	USA	An industrial automation software company
HP	HPQ	Computers	33,966	USA	Manufacturer of printers and PCs
HTC	2498	Mobile phones	1,181	Taiwan	Smart phone manufacturer
Huawei	Unlisted	Mobile infrastructure equipment	Unlisted	China	Maker of telecom equipment, IT infrastructure, and semiconductors.
Inventec	2356	Computers	6,162	Taiwan	PC subcontractor
iRobot	IRBT	Consumer robots	244	USA	Manufacturer of consumer and military robots
Lenovo	992	Computers	18,085	China	PC, server and smartphone manufacturer
LG Electronics	66570	Audio visual equipment	13,479	Korea	Manufacturer of consumer electronics and home appliances
Logitech	LOGN	PC peripherals	16,767	Switzerland	Manufacturer of personal interface products for PCs (mouse, web cameras, keyboards)
Magic Leap	Unlisted	Wearable tech	Unlisted	USA	Manufacturer of head-mounted wearable technology
Meta	META	Social networks	1,301,546	USA	Formerly Facebook. Internet ecosystem monetized via advertising on social networks
Microsoft	MSFT	Internet ecosystems	3,360,592	USA	Software conglomerate
Nikon	7731	Imaging equipment	3,567	Japan	Manufacturer of chip equipment, imaging solutions and microscopes
Ningbo Bird	600130	Mobile phones	335	China	Mobile handset manufacturer
Nintendo	7974	Games consoles	69,880	Japan	Gaming console manufacturer and games developer
Panasonic	6752	Audio visual equipment	20,174	Japan	Manufacturer of home appliances, audio video, PC peripherals, and telecom equipment
Parrot	PARRO	Drones	67	France	Manufacturer of infotainment solutions for cars, civil drones and connected objects
Philips	PHIA	MedTech	24,042	Netherlands	Manufacturer of medical systems and lighting products (sold its TV and consumer businesses in 2013)
Quanta Computer	2382	Computers	36,394	Taiwan	Biggest notebooks subcontractor
Ricoh	7752	Imaging equipment	5,209	Japan	Manufacturer of office automation equipment
Samsung Electronics	5930	Foundry	389,063	Korea	Integrated chip maker, smartphone maker and consumer electronics conglomerate
Seiko Epson	6724	Imaging equipment	5,943	Japan	Manufacturer of communications equipment, printers, scanners, LCD panels, semiconductors, watches and robots
Sharp	6753	Audio visual equipment	3,975	Japan	Manufacturer of consumer and industrial electronics
Sonos	SONO	Audio visual equipment	1,782	USA	Manufacturer of high-quality wireless speaker systems
Sony	6758	Audio visual equipment	105,725	Japan	Technology conglomerate with interests in TVs, smartphones, games, etc.
TomTom	TOM2	Navigation devices	742	Netherlands	GPS navigation product maker
Toshiba	Unlisted	Industrial conglomerate	Unlisted	Japan	Manufacturer of electronics, NAND flash, power generators and medical equipment
Vuzix	VUZI	Augmented reality	92	USA	Manufacturer of virtual reality and augmented reality eyeglasses
Wistron	3231	Computers	9,531	Taiwan	PC manufacturer
Xiaomi	1810	Mobile phones	57,103	China	A consumer electronics company that makes smartphones and a host of other consumer goods.
Yuneec	Unlisted	Drones	Unlisted	China	Drone manufacturer
ZTE	63	Mobile infrastructure equipment	16,878	China	Manufacturer of telecom equipment and smartphones

Source: GlobalData

Thematic screen

Our thematic screen ranks companies based on overall leadership in the 10 themes that matter most to their industry, generating a leading indicator of future performance

Consumer electronics (50 companies)				Thematic Screen											Thematic Ranking
Weighting				10%	15%	10%	10%	5%	10%	10%	10%	10%	10%		
Company	MKT CAP (US\$ M)	Ticker	Country	Artificial Intelligence	Digital Media	Automated Home	Wearable Tech	Autonomous Vehicles	Geopolitics	ESG	Virtual and Augmented Reality	Robotics	Regulation		
Sony	105,725	6758	Japan	4	4	4	4	4	3	4	5	5	3	1	
Alphabet	2,280,758	GOOGL	USA	5	5	5	4	5	1	3	4	5	1	2	
Honeywell	138,983	HON	USA	5	3	4	4	3	4	4	3	4	3	3	
Apple	3,269,993	AAPL	USA	5	5	5	4	4	1	2	5	3	2	4	
Samsung Electronics	389,063	5930	Korea	4	4	3	5	5	3	3	3	4	3	5	
Vuzix	92	VUZI	USA	4	3	4	4	3	4	3	5	3	3	6	
LG Electronics	13,479	66570	Korea	4	4	4	1	3	3	5	4	4	3	7	
Xiaomi	57,103	1810	China	3	4	4	5	4	3	1	4	4	3	8	
Sonos	1,782	SONO	USA	2	4	5	3	3	4	4	3	3	3	9	
Parrot	67	PARRO	France	4	3	3	3	4	5	3	3	4	3	10	
Huawei	Unlisted	Unlisted	China	4	4	4	4	5	1	2	4	3	4	11	
Alibaba	174,951	BABA	China	5	4	4	3	4	2	2	4	5	1	12	
iRobot	244	IRBT	USA	4	3	5	3	3	3	2	3	5	3	13	
Amazon	2,014,827	AMZN	USA	5	5	5	2	4	1	2	3	5	1	14	
Seiko Epson	5,943	6724	Japan	3	3	3	4	3	3	3	4	4	3	15	
HTC	1,181	2498	Taiwan	3	3	4	4	3	2	3	5	3	3	16	
ByteDance	Unlisted	Unlisted	China	5	5	3	4	3	1	2	5	3	1	17	
Lenovo	18,085	992	China	4	2	4	4	3	2	4	4	3	2	18	
Toshiba	Unlisted	Unlisted	Japan	4	2	4	4	3	3	2	4	4	3	19	
Meta	1,301,546	META	USA	4	5	4	4	3	1	1	5	3	1	20	
HP	33,966	HPQ	USA	4	3	3	3	3	3	4	3	3	3	21	
Alarm.com	3,091	ALRM	USA	4	3	5	3	3	2	3	2	4	3	22	
DJI	Unlisted	Unlisted	China	4	3	3	3	3	2	3	3	5	3	23	
Garmin	31,119	GRMN	Switzerland	1	3	4	5	4	3	3	3	3	3	24	
Microsoft	3,360,592	MSFT	USA	5	4	3	2	4	1	4	2	4	2	25	
Dell Technologies	98,898	DELL	USA	4	3	3	3	3	2	4	3	3	3	26	
Baidu	30,925	BIDU	China	4	4	4	3	4	1	1	4	4	2	27	
Philips	24,042	PHIA	Netherlands	4	2	4	3	4	2	4	3	3	3	28	
Wistron	9,531	3231	Taiwan	3	3	3	3	3	3	4	3	3	3	29	
Inventec	6,162	2356	Taiwan	4	3	3	3	3	3	3	3	3	3	30	
Canon	36,526	7751	Japan	4	3	3	3	2	4	3	3	2	3	31	
Nikon	3,567	7731	Japan	4	3	3	3	2	3	4	3	2	3	32	
Blackberry	1,447	BB	Canada	4	2	3	3	5	3	3	3	3	3	33	
Panasonic	20,174	6752	Japan	4	2	4	3	2	3	3	2	4	3	34	
TomTom	742	TOM2	Netherlands	3	3	3	3	3	3	3	3	3	3	35	
Yuneec	Unlisted	Unlisted	China	3	3	3	3	3	2	3	3	4	3	36	
Hikvision	39,888	2415	China	4	4	4	3	3	1	1	3	3	3	37	
ZTE	16,878	63	China	4	4	4	3	3	1	2	1	3	4	38	
Acer	4,421	2353	Taiwan	4	2	4	4	3	3	4	2	1	3	39	
Logitech	16,767	LOGN	Switzerland	3	3	4	3	3	2	3	4	1	3	40	
Ningbo Bird	335	600130	China	2	3	3	3	3	3	3	3	3	3	41	
Magic Leap	Unlisted	Unlisted	USA	3	3	3	4	3	2	3	4	1	3	42	
Sharp	3,975	6753	Japan	3	2	4	3	3	4	3	2	2	3	43	
GoPro	200	GPRO	USA	3	4	4	3	3	3	3	1	1	3	44	
Quanta Computer	36,394	2382	Taiwan	3	3	4	3	3	2	3	3	1	3	45	
Ricoh	5,209	7752	Japan	3	3	3	2	3	3	3	2	3	3	46	
Compal	4,738	2324	Taiwan	2	3	3	3	3	3	3	4	1	3	47	
Haier Smart Home	36,125	600690	China	3	2	5	2	3	3	2	2	3	3	48	
Nintendo	69,880	7974	Japan	2	4	3	2	3	3	2	2	2	3	49	
Asus	11,541	2357	Taiwan	3	2	4	2	3	3	3	2	2	3	50	

Thematic leader

Thematic laggard

Thematic leader



Thematic laggard

Key: 1 (red) implies this theme will have a negative impact on earnings over the next 12 months; 3 (amber) implies a neutral impact; and 5 (green) a positive impact. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Valuation screen

Our valuation screen ranks our universe of companies within a sector based on selected valuation metrics

Consumer electronics				Valuation Screen					
(50 companies)		Weighting		25%	20%	15%	20%	20%	100%
Company	MKT CAP (US\$ M)	Ticker	Country	EV/EBITDA	EV/Sales	Div yield %	P/E	FCF yield %	Valuation Ranking
Compal	4,738	2324	Taiwan	9.5	0.2	3.4	20.0	14.4	1
Panasonic	20,174	6752	Japan	4.8	0.4	2.4	7.3	6.8	2
Seiko Epson	5,943	6724	Japan	6.5	0.6	2.7	18.0	11.5	3
Lenovo	18,085	992	China	5.5	0.3	3.2	17.9	4.0	4
ZTE	16,878	63	China	8.0	0.9	3.5	13.1	10.9	5
HP	33,966	HPQ	USA	9.1	0.7	3.1	10.4	8.7	6
Ricoh	5,209	7752	Japan	5.8	0.4	2.6	18.8	4.5	7
LG Electronics	13,479	66570	Korea	4.3	0.3	1.3	26.2	9.5	8
Alibaba	174,951	BABA	China	6.3	1.1	1.4	15.9	11.8	9
Wistron	9,531	3231	Taiwan	9.7	0.4	2.4	26.9	11.2	10
Baidu	30,925	BIDU	China	3.0	0.9		11.5	11.3	11
Haier Smart Home	36,125	600690	China	13.2	1.0	2.8	15.8	5.9	12
Asus	11,541	2357	Taiwan	23.6	0.7	3.0	23.5	13.5	13
Acer	4,421	2353	Taiwan	18.0	0.4	3.1	29.0	8.2	14
Sony	105,725	6758	Japan	7.7	1.4	0.6	17.4	4.4	15
Nikon	3,567	7731	Japan	7.1	0.8	3.0	17.5	-4.3	16
Canon	36,526	7751	Japan	9.9	1.5	2.2	22.1	3.8	17
Hikvision	39,888	2415	China	15.6	3.0	2.4	20.5	4.3	18
Quanta Computer	36,394	2382	Taiwan	20.6	1.0	2.0	29.7	9.8	19
Inventec	6,162	2356	Taiwan	21.0	0.4	2.7	32.5	3.2	20
Dell Technologies	98,898	DELL	USA	13.7	1.3	1.1	30.8	6.0	21
Xiaomi	57,103	1810	China	13.6	1.2		23.7	8.4	22
Nintendo	69,880	7974	Japan	16.3	5.3	2.1	22.8	4.0	23
Honeywell	138,983	HON	USA	18.2	4.1	2.1	24.6	3.1	24
Logitech	16,767	LOGN	Switzerland	23.0	3.5	1.1	27.4	6.5	25
Garmin	31,119	GRMN	Switzerland	23.0	5.6	1.8	24.1	3.8	26
Samsung Electronics	389,063	5930	Korea	10.4	1.8	1.8	37.3	-2.9	27
Sharp	3,975	6753	Japan	-11.5	0.4		-4.2	11.3	28
Philips	24,042	PHIA	Netherlands	24.4	1.5		-48.3	7.2	29
TomTom	742	TOM2	Netherlands	18.0	0.7		-33.0	3.0	30
Apple	3,269,993	AAPL	USA	26.4	8.7	0.5	33.7	3.0	31
Alarm.com	3,091	ALRM	USA	29.4	3.3		38.1	3.9	32
Meta	1,301,546	META	USA	21.7	9.3		33.3	3.4	33
Alphabet	2,280,758	GOOGL	USA	22.7	7.1		30.9	3.0	34
Ningbo Bird	335	600130	China	66.9	4.0		174.5	2.9	35
Microsoft	3,360,592	MSFT	USA	32.4	15.6	0.6	46.4	1.8	36
Amazon	2,014,827	AMZN	USA	23.5	3.5		66.2	1.6	37
Sonos	1,782	SONO	USA	55.0	0.9		-173.5	2.8	38
GoPro	200	GPRO	USA	-0.7			-3.8	-17.2	39
iRobot	244	IRBT	USA	-1.1	0.3		-0.8	-48.3	40
Parrot	67	PARRO	France	-1.7	0.7		-1.9	-66.5	41
Blackberry	1,447	BB	Canada	-21.3	1.6		-11.1	-1.7	42
HTC	1,181	2498	Taiwan	-6.8	6.1		-11.3	-10.7	43
Vuzix	92	VUZI	USA	-1.4	5.4		-1.8	-46.6	44
ByteDance	Unlisted	Unlisted	China						45
DJI	Unlisted	Unlisted	China						46
Huawei	Unlisted	Unlisted	China						47
Magic Leap	Unlisted	Unlisted	USA						48
Toshiba	Unlisted	Unlisted	Japan						49
Yuneec	Unlisted	Unlisted	China						50
Median				9.6	0.9	0.6	18.0	3.8	
Mean				12.1	2.2	1.2	14.4	0.7	

Cheap

Expensive

Cheap



Expensive

Key: Green denotes that the company is cheap (15% more attractively priced than the median value for the sector) relative to its global peers; amber denotes it is within 15% of the sector median value; and red denotes that it is expensive relative to its global peers. Private companies are shown at the bottom of these rankings by default because they do not have a publicly listed market price. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Risk screen

Our risk screen ranks companies within a particular sector based on overall investment risk

Consumer electronics (50 companies)				Risk Screen					Risk Ranking
		Weighting		40%	30%	15%	15%	100%	
Company	MKT CAP (US\$ M)	Ticker	Country	Operational Risk	Financial Risk	Industry Risk	Country Risk		
Meta	1,301,546	META	USA	4	4	3	4		1
Nintendo	69,880	7974	Japan	4	5	3	4		2
Amazon	2,014,827	AMZN	USA	4	4	3	5		3
Sony	105,725	6758	Japan	4	3	3	5		4
Microsoft	3,360,592	MSFT	USA	4	4	3	4		5
Alibaba	174,951	BABA	China	4	4	3	4		6
Honeywell	138,983	HON	USA	4	4	3	4		7
Apple	3,269,993	AAPL	USA	5	3	3	4		8
Alphabet	2,280,758	GOOGL	USA	4	4	3	4		9
Alarm.com	3,091	ALRM	USA	3	4	4	5		10
Samsung Electronics	389,063	5930	Korea	4	4	3	4		11
Logitech	16,767	LOGN	Switzerland	4	4	3	3		12
Hikvision	39,888	2415	China	4	3	4	4		13
Asus	11,541	2357	Taiwan	3	4	3	5		14
Toshiba	Unlisted	Unlisted	Japan	3	3	3	4		15
Xiaomi	57,103	1810	China	4	3	3	4		16
Canon	36,526	7751	Japan	3	4	3	4		17
LG Electronics	13,479	66570	Korea	4	3	3	4		18
Philips	24,042	PHIA	Netherlands	3	3	4	4		19
Acer	4,421	2353	Taiwan	3	4	3	4		20
Ricoh	5,209	7752	Japan	3	3	4	4		21
iRobot	244	IRBT	USA	2	4	3	4		22
Dell Technologies	98,898	DELL	USA	4	2	3	4		23
Quanta Computer	36,394	2382	Taiwan	4	2	3	3		24
Lenovo	18,085	992	China	4	2	3	3		25
HP	33,966	HPQ	USA	4	3	3	3		26
Sharp	3,975	6753	Japan	4	2	3	4		27
Compal	4,738	2324	Taiwan	4	2	3	4		28
Panasonic	20,174	6752	Japan	3	3	3	4		29
Magic Leap	Unlisted	Unlisted	USA	3	3	3	5		30
Garmin	31,119	GRMN	Switzerland	3	4	3	3		31
Ningbo Bird	335	600130	China	3	3	3	4		32
ZTE	16,878	63	China	4	2	3	4		33
Inventec	6,162	2356	Taiwan	3	2	3	5		34
Baidu	30,925	BIDU	China	3	2	4	4		35
Blackberry	1,447	BB	Canada	3	2	3	4		36
Wistron	9,531	3231	Taiwan	3	2	3	4		37
Sonos	1,782	SONO	USA	2	4	3	3		38
Seiko Epson	5,943	6724	Japan	3	3	3	4		39
Haier Smart Home	36,125	600690	China	3	2	3	4		40
DJI	Unlisted	Unlisted	China	3	3	3	4		41
GoPro	200	GPRO	USA	3	3	3	3		42
Nikon	3,567	7731	Japan	2	2	3	4		43
TomTom	742	TOM2	Netherlands	2	3	3	4		44
Yuneec	Unlisted	Unlisted	China	3	2	3	4		45
Vuzix	92	VUZI	USA	1	4	3	5		46
Parrot	67	PARRO	France	2	3	4	4		47
ByteDance	Unlisted	Unlisted	China	2	2	4	4		48
Huawei	Unlisted	Unlisted	China	2	2	4	4		49
HTC	1,181	2498	Taiwan	1	2	3	5		50

Low risk

High risk

Key: Green denotes low risk; amber denotes medium risk; red denotes high risk. See the methodology section at the back of this report for an explanation of our research methodology.

Source: GlobalData

Glossary

Term	Definition
3D modeling	The process of developing a mathematical coordinate-based representation of the world. This is done by representing each physical object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, and curved surfaces.
AI chips	Refers to chips that are designed to perform AI tasks more efficiently, thereby reducing the time taken to, for example, process the large data sets associated with machine learning. They are often referred to as AI accelerators and come in a variety of forms, including graphics processing units (GPUs), field programmable gate arrays (FPGAs), and application-specific integrated circuits (ASICs).
AI model	A program or algorithm that utilizes a set of data that enables it to recognize certain patterns, often using machine learning techniques. It can be used to make predictions, recommendations, or decisions.
Algorithm	A finite sequence of well-defined, instructions implemented by a computer to solve a class of problems or to perform a computation.
Application programming interface (API)	A set of defined methods of communication between programs so that information can be exchanged without the need to access the core of either program.
Artificial general intelligence (AGI)	Also known as strong AI or general AI. A theoretical form of AI whereby a machine would require an intelligence equal to humans. As such, it would be sentient and have a self-aware consciousness that can solve problems, learn, and plan for the future. This is the most ambitious definition of AI, the holy grail of AI, but for now remains purely theoretical.
Artificial intelligence (AI)	Refers to software-based systems that use data inputs to make decisions on their own.
Artificial neural network (ANN)	Inspired by the structure of the brain, ANNs are one of the main tools used in machine learning. An artificial neural network has anywhere from dozens to millions of artificial neurons - called units - arranged in a series of layers. The input layer receives various forms of information from the outside world. This is the data that the network aims to process or learn about. From the input unit, the data goes through one or more hidden units with the aim of transforming the input into something the output unit can use. The term is often used to refer to the simplest type of neural network, also known as a feedforward neural network, as it processes inputs only in the forward direction. It can work with incomplete knowledge and is fault-tolerant, but it is less powerful than other types, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs).
Application-specific integrated circuits (ASICs)	Silicon chips designed to do a single specific task.
Augmented reality (AR)	Technology that allows the user to see the real world overlaid with a layer of digital content. This digital content layer can include sensor-based data, sound, video, graphics, or other datasets.
Automated home	The automation and control of household appliances—whether it be a fridge, TV, front door lock, kettle, or light bulb—via connection to the internet.

Term	Definition
Automated machine learning (AutoML)	The process of automating time-consuming, iterative tasks of machine learning model development.
Autonomous vehicle (AV)	Any vehicle that can drive itself without human intervention. There are five autonomous driving levels, of which the highest (Level 5) describes a vehicle that is fully autonomous under any conditions. This level is unlikely to be reached in the next 20 years.
Big data	Extremely large, diverse data sets that, when analyzed in aggregate, can reveal patterns, trends, and associations, especially relating to human behavior and interactions.
Bus	A communication bus is a data highway typically used to transfer data between components such as the central processing unit (CPU) and the dynamic memory within a computer system.
Business intelligence (BI)	Technologies, applications, and practices for the collection, integration, analysis, and presentation of business information.
Central processing unit (CPU)	The unit that performs most of the processing inside a computer. It carries out all the logical and arithmetical operations.
Collaborative robot (co-bot)	A robot that is designed to work alongside humans on specific tasks.
Computer vision	One of the key AI technologies, this category includes all technology that attempts to capture and interpret images or videos in a meaningful or useful way.
Context-aware computing	Refers to systems that adapt their behavior according to the physical environment in which they are operating. Contextual information can include location, orientation, temperature, light, pressure, and humidity.
Conversational platforms	Tools that employ a variety of technologies—including speech recognition, natural language processing (NLP), contextual awareness and machine learning—to enable human-like interaction with computer systems.
Convolutional neural network (CNN)	One of the most popular neural networks used today. It uses multiple layers of fully interconnected nodes, allowing it to automatically detect important features without any human supervision. These neural networks are suitable for image recognition problems but require lots of training data.
Computer vision as a service (CVaaS)	A type of software as a service (SaaS) hosted in the cloud that allows businesses to rent rather than build a computer vision platform.
Data center	A facility used to house computer systems and associated networking equipment to capture, store, analyze, and re-transmit data.
Deep learning	A field of ML that is built using artificial neural networks that model the way neurons in the human brain talk to each other.
Edge computing	Refers to a network architecture concept that enables cloud computing capabilities and an IT service environment at the edge of the network. By running applications and performing processing tasks closer to the customer, edge computing delivers superior performance with reduced latency.

Term	Definition
Emotion AI	Technology that aims to read a person's emotional responses by analyzing videos and photos and using predictive analytics to map these reactions.
Explainable artificial intelligence (XAI)	A set of tools and frameworks that help to develop interpretable and inclusive AI models.
Facial recognition	A software application capable of identifying or verifying a person by comparing and analyzing patterns based on the person's facial contours.
Field programmable gate array (FPGA)	Chips that can be configured by the user. They contain a large pool of logic gates that can be ordered and combined in an almost infinite number of designs. FPGAs can be programmed to run a specific algorithm for a particular task and then reprogrammed for another purpose once the task is complete.
Foundational AI models	A type of AI model designed to produce a wide and general variety of outputs rather than being very good at a very specific knowledge domain and type of content, such as text, audio, or video. It is also often called general purpose AI (GPAI).
Foundry	A factory that manufactures semiconductors and integrated circuits.
General Data Protection Regulation (GDPR)	A regulation that came into force across the EU in May 2018, giving consumers certain rights and protections over the data that organizations hold on them, including the right to data portability.
Geofence	A virtual geographic boundary, defined by global positioning system (GPS) or radio-frequency identification (RFID) technology, which enables software to trigger a response when a mobile device enters or leaves a particular area.
Geometric modeling kernel	Geometric (or 3D) modeling kernels are software components that provide the functionality to develop a mathematical coordinate-based representation of the world. This is needed by CAD software systems used to design cars and airplanes, but it is also required of autonomous vehicles and robots that need to be aware of their surroundings. These 3D modeling kernels achieve this by representing each physical object using a collection of points in 3D space, connected by geometric entities such as triangles, lines, and curved surfaces.
Graphics processing unit (GPU)	A programmable logic chip specialized for display functions. Modern GPUs can manipulate computer graphics and provide image processing very efficiently. They are also able to take large data sets and perform the same operation repeatedly and at high speed, which has made them fundamental to the development of artificial intelligence technologies.
Hallucination	In the artificial intelligence field, this refers to a response generated by AI that contains false or misleading information but is presented as fact. For instance, large language models are known to produce hallucinations when they are not able to find the right answer to a query.
Image recognition	An image recognition-enabled computer can look at an image and discern objects and features. A digital image is a binary representation of visual data that contains a grid of pixels with values that denote how bright and what color each pixel should be. Image recognition algorithms discern objects and features in an image by recognizing similar patterns in the grid of pixels by comparing them to a database of known images.

Term	Definition
Integrated circuit (IC)	An electronic circuit formed on a piece of semiconducting material that can be programmed to perform certain tasks such as computing or storing data.
Knowledge representation and reasoning (KRR)	A field of AI dedicated to representing information about the world in a form that a computer system can use to solve complex tasks using logic and reasoning. Such systems can be used to diagnose a medical condition, have a conversation using natural language, or decide the next move of a robotic arm.
Large language model (LLM)	A type of AI model that can perform various natural language processing tasks, including generating and classifying text, answering questions, and translating languages. A language model is considered large if it has over 100 billion internal parameters or internal nodes, which it updates as it learns. Examples of LLMs are OpenAI's GPT-4 and Google's Gemini.
Large language model (LLM) parameters or weights	The initial value of the nodes of the neural networks used to implement the large language model. Training a large language model consists of gradually adjusting these internal values as it is exposed to training data containing both the input and the expected output.
Latency	The time it takes a data packet to transit from point A to point B.
Light detection and ranging (LiDAR)	A remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system—generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.
Machine learning	An application of AI that gives computer systems the ability to learn and improve from data without being explicitly programmed.
Machine vision (MV)	This technology applies computer vision to industrial and manufacturing functions. It is a combination of software and hardware that provides operational control to devices to execute functions such as capturing and processing images and measuring various characteristics required for decision-making.
Neural networks (NNs)	Inspired by the structure of the brain, NNs are one of the main tools used in machine learning. An artificial neural network has anywhere from dozens to millions of artificial neurons—called units—arranged in a series of layers. The input layer receives various forms of information from the outside world. This is the data that the network aims to process or learn about. From the input unit, the data goes through one or more hidden units with the aim of transforming the input into something the output unit can use.
Neuromorphic computing	Event-driven computing that apes the human cortex by tightly integrating memory and processing via neurons laid with synapses, rather than separating them with a bus in a clocked, sequential system. The neuro-synaptic approach promises to increase system performance by an order of magnitude while running on only a few watts.
Object detection	This identifies real-world objects (such as humans, buildings, or cars) in digital images and videos. It is powered by algorithms that follow the same process of image classification described above.
Predictive maintenance	The asset management practice of repairing an asset or piece of equipment before it fails based on data received about it. The use of sensors to generate 'predictive maintenance' is one of the tenets at the heart of the Industrial Internet.

Term	Definition
Retrieval augmented generation (RAG)	A design approach that aims to make large language models more reliable by automatically retrieving document chunks from external knowledge bases that are relevant to the original question, typically using semantic search.
Retriever model	AI models which rank documents based on the probability that the document is relevant to the query.
Semantic search	The ability of search engines to consider the intent and contextual meaning of search phrases when serving content to users on the web.
Sensor	A device that detects or measures a physical property and then responds accordingly.
Silicon photonics	An emerging technology in which data is transferred between silicon chips by optical rays (i.e., laser light), which can carry far more data in less time than traditional electrical conductors.
Smart city	A city that uses connected sensors to enhance the quality and performance of urban services such as energy, transport, and utilities to make the city function more efficiently.
Smart speaker	A wireless speaker with an in-built voice-activated virtual assistant.
System on a chip (SoC)	A microchip that contains all the components required for a given electronic system, such as a computer, on a single integrated circuit. Its components usually include a graphics processing unit (GPU), a central processing unit (CPU), and system memory.
Video recognition	As a content analysis tool, video recognition technology dives deep into a video stream to identify useful information about the content. In most cases, video recognition software analyzes audio and video clips, compares them to a database of content, and determines if there is a match.
Virtual reality (VR)	Technology that aims to immerse the user in an entirely artificial world, which has the illusion of reality. It uses special equipment such as headsets or gloves fitted with sensors to simulate a user's physical presence in a 3D environment.
Source: GlobalData	

Further Reading

GlobalData reports

Publication date	Report title
May 2024	<u>GlobalData's AI Governance Framework</u>
May 2024	<u>Next-Generation Chips</u>
May 2024	<u>High-Performance Computing</u>
April 2024	<u>Executive AI Briefing – 3rd Edition</u>
February 2024	<u>Quantum Computing</u>
February 2024	<u>Cloud Computing</u>
January 2024	<u>Market Opportunity Forecasts to 2027: Artificial Intelligence</u>
January 2024	<u>Market Opportunity Forecasts to 2027: Generative AI</u>
December 2023	<u>Autonomous Vehicles</u>
December 2023	<u>Carbon Offsets</u>
December 2023	<u>Generative AI in Telecom</u>
October 2023	<u>AI Executive Briefing – 2nd Edition</u>
August 2023	<u>Tech Regulation</u>
August 2023	<u>Data Analytics</u>
July 2023	<u>Innovation Radar – Cognitive Revolution: Generative AI Meets Retail</u>
June 2023	<u>AI Executive Briefing - 1st Edition</u>
April 2023	<u>Innovation Radar – Generative AI Powerplay: What's in the Big Tech AI Playbook</u>
March 2023	<u>Innovation Radar – Text-to-X: how ChatGPT and Generative AI Can Transform the Future of Business</u>
February 2023	<u>Artificial Intelligence</u>
December 2022	<u>Tech, Media, & Telecom Themes 2023</u>

Publication date	Report title
December 2022	<u>Tech, Media, & Telecom Predictions 2023</u>
December 2022	<u>Machine Learning</u>
October 2022	<u>Computer Vision</u>
October 2022	<u>Global M&A Deals in Q3 2022 - Top Themes by Sector</u>
August 2022	<u>AI Chips</u>
July 2022	<u>China Tech</u>
June 2022	<u>AI in Drug Discovery</u>
May 2022	<u>Splinternet</u>
Source: GlobalData	

Our Thematic Research Methodology

Companies that invest in the right themes become success stories. Those that miss the important themes in their industry end up as failures.

Viewing the world's data by themes makes it easier to make important decisions

We define a theme as any issue that keeps a senior executive awake at night. GlobalData's thematic ecosystem is a single, integrated global research platform that provides an easy-to-use framework for tracking all themes across all companies in all sectors. It has a proven track record of identifying critical themes early, enabling companies to make the right investments ahead of the competition and secure that all-important competitive advantage.

Traditional research does a poor job of picking winners and losers

The difficulty in picking tomorrow's winners and losers in any industry arises from the sheer number of technology cycles—and other themes—that are in full swing right now. Companies are impacted by multiple themes that frequently conflict with one another. What is needed is an effective methodology that reflects, understands, and reconciles these conflicts.

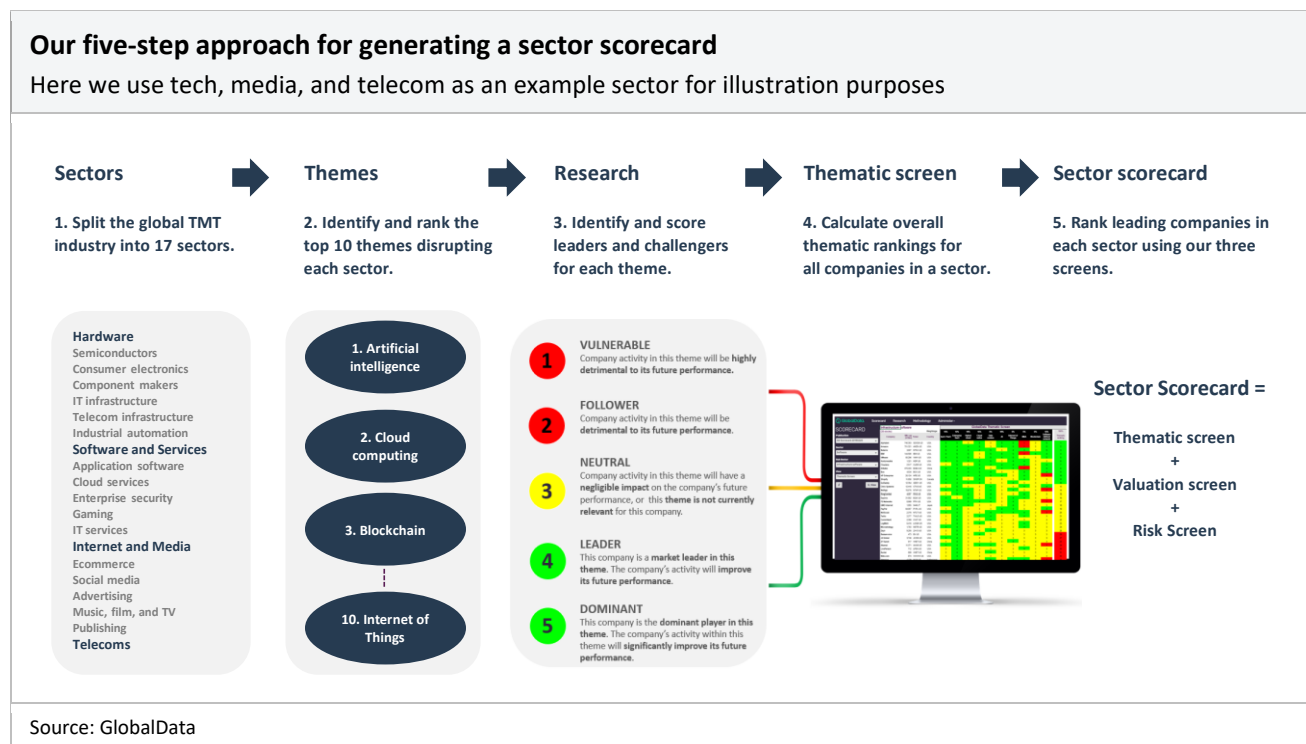
That is why we developed our thematic engine

At GlobalData, we have developed a unique thematic methodology for ranking all major companies in all major sectors based on their relative strength in the big themes that are impacting their industries.

Our thematic engine tags over 180 million data items across six alternative data sets—patents, jobs, deals, filings, social media, and news—to themes. The vast datasets within our thematic engine help our analysts to produce sector scorecards that identify the companies best placed to succeed in a future filled with multiple disruptive threats.

How do we create our sector scorecards?

First, we split each industry into sectors because a different set of themes drives each sector. Taking the TMT (technology, media, and telecom) industry as an example, we split this industry into the sectors shown in the graphic below.



Second, we identify and rank the top 10 themes for each sector (these can be technology themes, macroeconomic themes, or industry-specific themes). Third, we publish in-depth research on specific themes, identifying the winners and losers within each theme. The problem is that companies are exposed to multiple investment themes, and specific themes' relative importance can fluctuate. So, our fourth step is to create a thematic screen for each sector to calculate overall thematic leadership rankings after taking account of all themes impacting that sector. Finally, to give a crystal-clear picture, we combine this thematic screen with our valuation and risk screens to generate a sector scorecard used to help assess overall winners and losers.

What is in our sector scorecards?

Our sector scorecards help us determine which companies are best positioned for a future filled with disruptive threats. Each sector scorecard has three screens:

- **The thematic screen** tells us who are the overall leaders in the 10 themes that matter most, based on our thematic engine.
- **The valuation screen** tells us whether publicly listed players appear cheap or expensive relative to their peers based on consensus forecasts from investment analysts.
- **The risk screen** tells us who the riskiest players in each industry are, based on our assessment of four risk categories: operational risk, financial risk, industry risk, and country risk.

How do we score companies in our thematic screen?

Our thematic screen ranks companies within a sector based on overall leadership in the 10 themes that matter most to their industry, generating a leading indicator of future earnings growth.

Thematic scores predict the future, not the past. Our thematic scores are based on our analysts' assessment of their competitive position in relation to a theme, on a scale of 1 to 5:

1	Vulnerable	The company's activity in this theme will be highly detrimental to its future performance.
2	Follower	The company's activity in this theme will be detrimental to its future performance.
3	Neutral	The company's activity in this theme will have a negligible impact on the company's future performance, or this theme is not currently relevant for this company.
4	Leader	The company is a market leader in this theme. The company's activity in this theme will improve its future performance.
5	Dominant	The company is a dominant player in this theme. The company's activity in this theme will significantly improve its future performance.

How do our research reports fit into our overall thematic research ecosystem?

Our thematic research ecosystem is designed to assess the impact of all major themes on the leading companies in a sector. To do this, we produce three tiers of thematic reports:

- **Single theme:** These reports offer in-depth research into a specific theme (e.g., artificial intelligence). They identify winners and losers based on thematic leadership, market position, and other factors.
- **Multi-theme:** These reports cover all themes impacting a sector and the implications for the key players in that sector.
- **Sector scorecard:** These reports identify those companies most likely to succeed in a world filled with disruptive threats. They incorporate our thematic screen to show how conflicting themes interact with one another, as well as our valuation and risk screens.

About GlobalData

GlobalData is a leading provider of data, analytics, and insights on the world's largest industries. In an increasingly fast-moving, complex, and uncertain world, it has never been harder for organizations and decision makers to predict and navigate the future. This is why GlobalData's mission is to help our clients to decode the future and profit from faster, more informed decisions. As a leading information services company, thousands of clients rely on GlobalData for trusted, timely, and actionable intelligence. Our solutions are designed to provide a daily edge to professionals within corporations, financial institutions, professional services, and government agencies.

Unique Data

We continuously update and enrich 50+ terabytes of unique data to provide an unbiased, authoritative view of the sectors, markets, and companies offering growth opportunities across the world's largest industries.

Expert Analysis

We leverage the collective expertise of over 2,000 in-house industry analysts, data scientists, and journalists, as well as a global community of industry professionals, to provide decision-makers with timely, actionable insight.

Innovative Solutions

We help you work smarter and faster by giving you access to powerful analytics and customizable workflow tools tailored to your role, alongside direct access to our expert community of analysts.

One Platform

We have a single taxonomy across all of our data assets and integrate our capabilities into a single platform – giving you easy access to a complete, dynamic, and comparable view of the world's largest industries.



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