# Hype Cycle for Emerging Technologies, 2019

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The 2019 Hype Cycle highlights the emerging technologies with significant impact on business, society and people over the next five to 10 years. This year includes technologies that promise to deliver a global low-latency internet, create a virtual map of the real world and mimic human creativity.

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## What You Need to Know

Technology innovation leaders, CTOs and CIOs must continually stay abreast of emerging technologies to determine the impact on their industries and the opportunities for their organizations. This year brings exciting new opportunities for organizations to explore in their search for technology-enabled business transformation. Early adopters can leverage this Hype Cycle as a starting point to:

- Understand the technologies they need to watch over the five- to 10-year planning horizon
- Explore ideas around potential opportunities
- Start making plans to exploit these technologies as they become commercially viable

This year, five trends have evolved and emerged as follows:

- Sensing and mobility
- Augmented humans
- Postclassical compute and comms
- Digital ecosystems
- Advanced AI and analytics

Technology innovation has become the key to competitive differentiation and is responsible for transforming many industries. The pace of change in technology continues to accelerate as breakthrough technologies are continually introduced challenging even the most innovative business and technology decision makers to keep up, yet they must. Technology innovation leaders focused on digital business transformation recognize the need to cut through the hype and determine the potential business impact of emerging technologies. The innovation profiles highlighted in this research provide decision makers with specific guidance on the business impact of emerging technologies and recommendations for how to proceed (or not) to leverage these technologies to drive competitive differentiation.

## The Hype Cycle

The Hype Cycle for emerging technologies is unique among most Gartner Hype Cycles because it distills insights from more than 2,000 technologies that Gartner profiles into a succinct set of must-know emerging technologies and trends. With a focus on emerging tech, this Hype Cycle is heavily weighted on those trends appearing in the first half of the cycle. This year, we are refocusing the Hype Cycle to shift toward introducing new technologies that have not been previously highlighted in past iterations of this Hype Cycle. Of course this necessitates retiring most of the technologies that were highlighted in the 2018 version of this research. It does not mean that technologies that are retired from this Hype Cycle have ceased to be important; rather, we believe it is best to inform you on the newest technologies and trends.

### Emerging Technologies Trends

The 2019 Hype Cycle for emerging technologies highlights five distinct trends that create and enable new experiences, leveraging artificial intelligence (AI) and other constructs that enable organizations to take advantage of emerging digital ecosystems. CIOs, CTOs, enterprise architects, technology innovation leaders and other IT leaders should track the following five emerging technology trends:

- **Sensing and Mobility.** By combining sensor technologies with artificial intelligence, machines are gaining a better understanding of the world around them, enabling mobility and manipulation of objects. Sensing technologies are a core component of the Internet of Things (IoT) and the vast amounts of data collected. Utilizing intelligence enables the ability to gain many types of insights that can be applied to many scenarios.

  Enterprises that are seeking leverage sensing and mobility capabilities should consider the following technologies: 3D sensing cameras, AR cloud, light-cargo delivery drones, flying autonomous vehicles and autonomous driving Levels 4 and 5.

- **Augmented Human.** Technology is increasingly being developed to provide seamless interactions and to help humans become healthier, stronger and more insightful. Augmented human advances enable creation of cognitive and physical improvements as an integral part of the human body. An example of this is the ability to provide superhuman capabilities such as the creation of limb prosthetics with characteristics that can exceed the highest natural human performance.

  Extending humans includes biochips, personification, augmented intelligence, emotion AI, immersive workspaces and biotech (cultured or artificial tissue).

- **Postclassical Compute and Comms.** For decades, classical core computing, communication and integration technologies have made significant advances largely through improvements in traditional architectures — faster CPUs, denser memory and increasing throughput as predicted by Moore's Law. The next generations of these technologies adopt entirely new architectures. This category includes not only entirely new approaches, but also incremental improvements that have potentially dramatic impacts.

  Specific examples include 5G, next-generation memory, low-earth-orbit satellite systems and nanoscale 3D printing.

- **Digital Ecosystems.** The automation of business ecosystems is advancing rapidly to reduce friction and enable dynamic connections. Digital ecosystems leverage an interdependent group of actors (enterprises, people and things) sharing digital platforms to achieve a mutually beneficial purpose. Different ecosystems can coexist if separated by geography, market or category. Digitalization has facilitated the deconstruction of classical value chains, leading to stronger, more flexible and resilient webs of value delivery that are constantly morphing to create new improved products and services. Given the restless nature of digital ecosystems, CIOs must factor them into future planning.

  Critical technologies to be considered include: DigitalOps, knowledge graphs, synthetic data, decentralized web and decentralized autonomous organizations.

- **Advanced AI and Analytics.** The frontier of AI technology is changing rapidly as new classes of algorithms and data structures enable entirely new capabilities. AI is advancing in multiple directions as the concepts are applied to more and broader scenarios. Advanced analytics comprises the autonomous or semiautonomous examination of data or content using sophisticated techniques and tools, typically beyond those of traditional business intelligence (BI). Advanced analytics are used to discover deeper insights, make predictions or generate recommendations; thus, organizations can supercharge their efforts in taking advantage of intelligence.

  The technologies to track include adaptive machine learning (ML), edge AI, edge analytics, explainable AI, AI PaaS, transfer learning, generative adversarial networks, and graph analytics.

### Major Hype Cycle Changes

Understanding the new emerging technologies that are being introduced on the Hype Cycle for the first time in 2019 provides business and technology leaders with the leading indicators of early technology trends that will mature in the next decade. This year, we introduce the following new technologies to the Hype Cycle for emerging technologies:

- 3D sensing cameras — This technology has a wide variety of use cases including augmented reality (AR) applications, driving assistance systems, gesture recognition, factory automation and authentication. The opportunities for 3D sensing cameras are promising and, hence, will require powerful processing power and advanced software and algorithms for better recognition and reaction.
- Adaptive ML — This technology provides the capability to frequently retrain ML models when they're online in their runtime environment, rather than only training ML models when they're offline in their development and test environment. It provides the opportunity for ML models to respond to changes in the environment, which is particularly useful for autonomous systems such as self-driving vehicles and smart robots.
- AR cloud — This innovation is a persistent, digital content layer mapped to objects and locations in the physical world. Once it becomes more developed, it will provide a digital twin of the physical world that can be augmented with information and virtual objects.
- Augmented Intelligence — Augmented intelligence is a human-centric partnership between people and AI to enhance people's cognitive performance and minimize the impact of errors made by AI algorithms alone. It has the potential to accelerate human performance in cognitive tasks.
- Decentralized autonomous organization (DAO) — This type of organization is a digital entity that can engage in business interactions with other digital agents and corporate entities without conventional human management. Constructed on blockchain technologies, DAOs rely on smart contracts to engage with other entities for the exchange of value across a business ecosystem.
- Decentralized web — This is a new stack of technologies for the development of decentralized web applications that enable users to control their own identity and data. Decentralized web

promises to enable true peer-to-peer interactions and transactions with no reliance on centralized platforms and intermediaries.

- DigitalOps — This innovation enables the rapid development and adaptation of dynamic, real-time, scalable business products and applications, facilitating the emergence of a digital business technology platform. It is an evolution of the automation aspects of business process management (BPM) that incorporates decision management and event processing with agile methodologies for continuous delivery of business improvement in applications to deliver a step-change improvement in business agility.
- Edge analytics — This technology enables decision making closer to where the data is generated in distributed devices, servers or gateways located away from corporate data centers or cloud servers. This provides opportunities to reduce latency/determinism and data/bandwidth, increase privacy/security, and enable local interactivity or some limited autonomy.
- Emotion AI — Emotion AI uses AI to analyze the emotional state of a user (via computer vision, audio/voice input, sensors and/or software logic). It can make technology more sympathetic to users' emotional states and take on anthropomorphic qualities. There are a broad range of use cases including market research, fraud detection, medical diagnoses and adapting learning.
- Explainable AI — Explainable AI is a set of capabilities that describes an AI model, highlights its strengths and weaknesses, predicts its likely behavior, and identifies any potential biases. While not every AI output needs to be explained, those models that are guiding consequential decision making affecting people will require transparency.
- Generative adversarial networks (GANs) — These networks leverage AI models to create original simulations of objects such as videos, images, music and text (poetry, stories, marketing copy) that replicate authentic objects or their pattern, style or essence with varying degrees of quality or realism. The powerful idea is that deep neural network (DNN) classifiers can be modified to generate realistic objects of the same type, including generating pharmaceutical compounds, creating simulated environments for training autonomous vehicles and robots, and generating synthetic data to train neural networks and to protect privacy.
- Graph analytics — This innovation enables the exploration of relationships between entities such as organizations, people or transactions. Nodes are connected explicitly or implicitly, indicating levels of influence, frequency of interaction, or probability. Graph analytics is highly effective at both assessing risk and responding to it to analyze fraud, route optimization, clustering, outlier detection, Markov chains, discrete-event simulation and more.
- Immersive workspaces — Immersive workspaces are collaborative work environments that convey a sense of real-world presence through the use of visual (virtual reality [VR], augmented reality [AR], and mixed reality [MR]), auditory, haptic and other sensory elements. They will facilitate richer and more natural collaboration, knowledge sharing, onboarding and training.
- Light-cargo delivery drones — These are flying, or wheeled, autonomous vehicles used to deliver small packages (about 10 kg), including food or medical supplies. Light-cargo delivery via drones will reduce costs and scale time-sensitive last-mile deliveries. The core technology behind the light delivery drones is becoming increasingly advanced, but the drones are constrained by regulation and certain technical challenges.

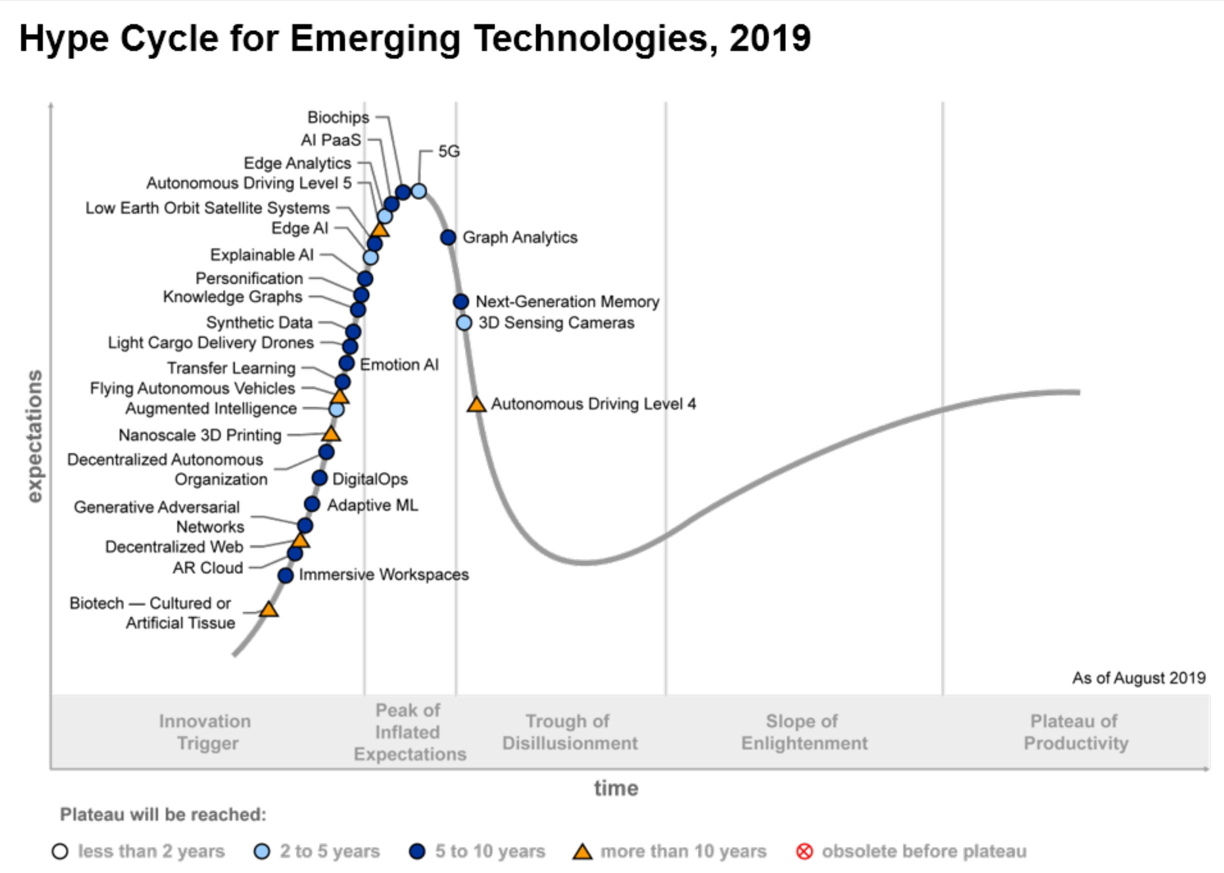
- Low-earth-orbit satellite systems — These systems can provide low-latency, high-speed global broadband or narrowband voice and data network services, including to regions with little or no existing terrestrial or satcom coverage. This will extend coverage to the 48% of homes currently without internet access and provide connectivity for devices (connected cars, remote drilling and drones) anywhere in the world.
- Nanoscale 3D printing — This innovation uses specialized additive manufacturing technology and related processes to create minute, intricate structures and/or features that are measured in micrometers. While still in the lab, it could be leveraged for miniaturization efforts, developing new medicines, in vivo medical devices, espionage tools, microsensors, artwork, microrobotics and printable electronics.
- Next-generation memory — Technologies such as storage-class memory (SCM) will fundamentally change the performance of emerging applications. These represent a new class of memory technology providing nonvolatile memory (byte or block addressable) with access speeds close to those of traditional DRAM-based memory modules but at a substantially lower cost. This will be compelling for the very highest performance application workloads such as big data analytics for real-time analytic processing, in-memory databases, AI/ML workloads and other workloads where performance premiums can be justified.
- Personification — This innovation delivers the relevance and marketing value of personalization without processing personal data that is subject to regulatory restrictions. By shifting reliance from personalization to nonpersonal data, personification has the potential to restore value lost to marketers through regulation of personal data.
- Synthetic data — Synthetic data is a class of data that is artificially generated, rather than obtained from direct sources. Synthetic data addresses the problem of volume and variety for sparse, nonexistent or difficult to get data used to train AI models, thus leveling the field for smaller AI developers. It can also reduce the regulatory risk of managing personal information by replacing it with synthetic versions.
- Transfer learning — Transfer learning is the reuse of previously trained ML models as an advanced starting point for new purposes in order to reduce the learning time required to attain acceptable performance. It has the potential to overcome the barriers to broad AI adoption, provided that there are sufficient numbers of applicable models available, the tools to reuse the data are in place, and there is enough subsequent retraining on new data to attain successful use.

In addition, technology innovation leaders should play close attention to the technologies that have moved forward along the Hype Cycle since 2018:

- AI PaaS — AI cloud service offerings are primarily focused on the three key areas of machine learning, natural language processing and computer vision. AI applications utilizing cloud services have continued to gain traction and acceptance in the market both by data scientists and developers alike. The promise of using cloud services to more quickly and easily build and deploy AI solutions will push this technology to the Peak of Inflated Expectations.

- Biotech (cultured or artificial tissue) — Biotech or biorobotics is artificial/cultured biologically inspired tissue, muscles or robots that could emulate some human response due to external stimulators. While the technology is still very much in the lab/experimental stage, advances are being made with sensors and soft actuators to enable robots to safely interact with humans and the environment.
- Edge AI — Edge AI refers to the use of AI techniques embedded in IoT endpoints, gateways and edge devices. Adoption of edge AI is increasing for applications that are latency-sensitive (e.g., autonomous navigation), subject to network interruptions (e.g., remote monitoring, NLP, facial recognition) and/or are data-intensive (e.g., video analytics).
- Knowledge graphs — Knowledge graphs are data structures in which disparate data about entities (including people, companies and digital assets) is codified as a graph. While large companies like Microsoft and Google have demonstrated the value of knowledge graphs, adoption has made slow progress in enterprises.
- 5G — 5G is the next-generation cellular standard after 4G, and the official International Telecommunication Union (ITU) specification targets maximum downlink and uplink throughputs of 20 Gbps and 10 Gbps, respectively; latency below 5 milliseconds; and massive scalability. 5G is still an emerging technology in development, with fragmented global coverage and use cases being explored.
- Biochips — Biochips relate to several technologies that combine semiconductor and biological sciences and are used to analyze biological elements, such as DNA, ions, ribonucleic acid and proteins, in addition to certain chemicals. A significant rise in the adoption of personalized medicine and the increasing focus on technological advancements are the key factors that are projected to encourage the development of the global biochips market.
- Autonomous driving Level 4 — Despite huge leaps forward in Level 4 autonomous driving, large-scale commercial solutions are still a number of years away. Governments are continuing to issue permits to allow on-road testing of Level 4 vehicles. In China, a new 62-mile-long highway with dedicated lanes for autonomous vehicles has been announced.
- Autonomous driving Level 5 — Level 5 or “full” automation is a definition established by SAE International that refers to self-driving vehicles that can operate without human intervention in every situation and condition. Technology advancements necessary for Level 4 vehicles will be developed further for Level 5 use cases.
- Flying autonomous vehicles — More than a dozen companies are working on new aircraft that are piloted by artificial intelligence and designed to create a more agile, less expensive and quicker way to execute air travel, primarily in congested areas. While there are a number of use-case opportunities, technical challenges and regulation will delay broad deployment for many years.

Figure 1. Hype Cycle for Emerging Technologies, 2019




Source: Gartner
ID: 370466

## The Priority Matrix

Emerging technologies are disruptive by nature, but the competitive advantage they provide is not yet well known or proven in the market. Most will take more than five years, and some more than 10 years, to reach the Plateau of Productivity. These examples illustrate the impact of key emerging technologies in the near term and the longer term.

Technology innovation leaders must address the two near-term technologies with transformational impact (augmented intelligence and edge AI). Specifically they must:

- Use augmented intelligence as a design approach. Implement AI to focus human attention where it is most needed, in order to accelerate organizational competencies that fulfill your vision for digital transformation. Work with HR to upskill employees and maximize the effects of AI-augmented roles and decisions via ongoing education, experience labs, AI-enabled just-in-time training and other methods. Approach augmented intelligence through three time horizons:

    - In the short term, scale volume, reduce errors and automate routine tasks.
    - In the medium term, scale quality, amplify human talents, further improve business efficiencies, and create new products and experiences.
    - In the long term, build personalized products and services at scale, reinvent your business, industry and society, and maximize customer convenience.
- Evaluate when to consider AI at the edge versus a centralized solution. Applications that have high communications costs, are sensitive to latency or ingest high volumes of data at the edge are good candidates for AI at the edge.
- Determine whether the new AI developments in deep learning (DL) are applicable to their IoT deployments, or whether traditional data analytics and AI methodologies are adequate. In the case of DL, investigate automated development environments first to minimize the learning curve and accelerate prototyping.
- Deploy analytics across the key IoT system elements — IoT edge, IoT platform and enterprise — so that the processing is closer to the data source, the communications overhead is reduced, and meaningful insights are extracted more quickly. It will be key for some deployments of data aggregation and transformation, as well as event-based architecture.
- Use the IoT gateway as the aggregation and filtering point to perform most of the edge analytics functions. Make an exception for compute-intensive endpoints, where AI-based analytics can be performed on the devices themselves.
- Assess the risk associated with the nondeterministic nature of many AI techniques, where it may not be possible to control or replicate the analysis results.

Figure 2. Priority Matrix for Emerging Technologies, 2019

**Priority Matrix for Emerging Technologies, 2019**

| benefit | years to mainstream adoption: less than 2 years | 2 to 5 years | 5 to 10 years | more than 10 years |
|---|---|---|---|---|
| transformational | | **Augmented Intelligence**<br>**Edge AI** | AR Cloud<br>Decentralized Autonomous Organization<br>DigitalOps<br>Emotion AI<br>Generative Adversarial Networks<br>Immersive Workspaces<br>Low Earth Orbit Satellite Systems<br>Next-Generation Memory | Autonomous Driving Level 4<br>Autonomous Driving Level 5<br>Biotech — Cultured or Artificial Tissue<br>Decentralized Web |
| high | | 3D Sensing Cameras<br>5G<br>Edge Analytics | Adaptive ML<br>AI PaaS<br>Biochips<br>Explainable AI<br>Graph Analytics<br>Knowledge Graphs<br>Light Cargo Delivery Drones<br>Personification<br>Synthetic Data | Nanoscale 3D Printing |
| moderate | | | Transfer Learning | Flying Autonomous Vehicles |
| low | | | | |

**As of August 2019**

Source: Gartner
ID: 370466

## Off the Hype Cycle

Because this Hype Cycle pulls from such a broad spectrum of topics and is intended to be dynamic, many technologies are featured in a specific year or two, but are not tracked over a longer period of time. This is not intended to imply that they are unimportant — quite the opposite. In some cases, these technologies are no longer "emerging," but rather are becoming more integral to business and IT. In other cases, technologies that have been highlighted in this Hype Cycle for three years have been removed from the Hype Cycle in order to highlight other new emerging technologies.

Technology planners can refer to Gartner's broader collection of Hype Cycles for items of ongoing interest. Some of the technologies that appeared in the 2018 version of the Hype Cycle for emerging technologies, but do not appear in this year's report, are:

- Deep neural networks (deep learning) — This is a foundational technology for many of the applied AI technologies highlighted in this Hype Cycle. While still important, it was removed to highlight other technologies.
- Deep neural network application-specific integrated circuits (ASICs) — While market penetration is still low, we expect this market to mature quickly. The benefits of DNN ASICs in performance and energy consumption are significant, but widespread use of DNN ASICs will require the standardization of neural network architectures. DNN ASICs are often used in edge AI applications.
- Blockchain — Blockchain has been on this Hype Cycle for the past three years. While blockchain remains an important technology trend, it was removed to make space to highlight other trends such as decentralized web and decentralized autonomous organization, which are built upon blockchain technology and represent the leading edge of blockchain's development.
- IoT platform — This technology has been on this Hype Cycle for the past three years and is rapidly approaching a much more mature state, which moves it off the emerging technology class of innovation profiles.
- Conversational AI platform — While continuing to be an important technology, the conversational AI platform is rapidly approaching a much more mature state, which moves it off the emerging technology class of innovation profiles.
- Digital twin — While continuing to be an important technology, digital twin is rapidly approaching a much more mature state, which moves it off the emerging technology class of innovation profiles.
- Mixed reality — While continuing to be an important technology and still emerging, mixed reality was removed to make space to highlight other trends.
- Silicon anode batteries — While continuing to be an important technology and still emerging, silicon anode batteries was removed to make space to highlight other trends.
- Augmented reality — While continuing to be an important technology, augmented reality is rapidly approaching a much more mature state, which moves it off the emerging technology class of innovation profiles.
- Smart robots — This technology has appeared on this Hype Cycle for the past three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.
- Self-healing system technology — While continuing to be an important technology and still emerging, self-healing system technology was removed to make space to highlight other trends.
- Neuromorphic hardware — Neuromorphic hardware has appeared on this Hype Cycle for the past three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.

- Virtual assistants — VA has appeared on this Hype Cycle for the past three years. While continuing to be an important technology, it is rapidly approaching a much more mature state, which moves it off the emerging technology class of innovation profiles.
- Autonomous mobile robots — While continuing to be an important technology and still emerging, autonomous mobile robots was removed to make space to highlight other trends.
- Smart fabrics — While continuing to be an important technology and still emerging, smart fabrics was removed to make space to highlight other trends.
- 4D printing — 4D printing has appeared on this Hype Cycle for three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.
- Blockchain for data security — While continuing to be an important technology and still emerging, blockchain for data security was removed to make space to highlight other trends.
- Artificial general intelligence — Artificial general intelligence has appeared on this Hype Cycle for three years. This technology will not be mature for decades; therefore, it was removed to make space to highlight other trends.
- Connected home — Connected home has appeared on this Hype Cycle for three years. While continuing to be an important technology, it is rapidly approaching a much more mature state, which moves it off the emerging technology class of innovation profiles.
- Exoskeleton — While continuing to be an important technology and still emerging, exoskeleton was removed to make space to highlight other trends.
- Carbon nanotube — Carbon nanotube has appeared on this Hype Cycle for the past three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.
- Smart workspace — Smart workspace has appeared on this Hype Cycle for the past three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.
- Brain-computer interface — Brain-computer interface has appeared on this Hype Cycle for the past three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.
- Volumetric displays — Volumetric displays has appeared on this Hype Cycle for the past three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.
- Smart dust — Smart dust has appeared on this Hype Cycle for the past three years. While continuing to be an important technology and still emerging, it was removed to make space to highlight other trends.

- Quantum computing — Quantum computing has appeared on this Hype Cycle for more than three years. It continues to be an important technology and is still emerging, but it was removed to make space to highlight other trends.

Even though these profiled technologies were removed from the emerging technologies Hype Cycle, it doesn't mean that they are not going to have a high or transformative impact on your organization. This Hype Cycle identifies the 30 or so technologies poised to have significant impact over the next decade. To broaden the number of trends that can be highlighted in this Hype Cycle and to make it more dynamic, technologies are removed to make space to highlight new emerging technologies. Every year, this will evolve to give clients the latest market movements and technology shifts. Expect that this Hype Cycle will change materially every year.

## On the Rise

### Biotech — Cultured or Artificial Tissue

***Analysis By:*** Annette Jump

***Definition:*** Biotech or biorobotics covers the use of artificial/cultured biological tissue harnessed by robots to emulate human response to external stimulation. Trigger stimulation examples include, current, pressure, temperature or voltage. Biotech tends to have greater mobility, flexibility and often can include some sensory abilities.

***Position and Adoption Speed Justification:*** Biotechnology is still at the lab development stage, however, in the last year advances were made with sensors and soft actuators enabling robots to safely interact with humans and the environment. Biotech is based on multiple streams of knowledge such as mechanical engineering, electronics, bioengineering and information engineering, and positioned at the cross-section between robotics, neural engineering and medicine. Biotechnology includes a variety of different future applications and could be used to make biologically inspired robots or highly advanced prosthetics as well as medical treatments. In robotics some research is being focused around developing artificially sensing skin, others on artificial muscles. Artificial sensing skin, via tactile sensors, will be able to detect pressure as contact is made with an object. This can help robots sense objects around them. Artificial muscle (often called actuator) is used in soft robots, but it tends to respond slowly and it is difficult to control the properties of biomuscles. Recently Harvard University published a breakthrough in developing a dielectric elastomer with a broad range of motion that requires relatively low voltage and no rigid components. This could help address two main technical challenges in biotech, as many current robots rely on conventional electromagnetic rotary motors.

The ultimate goal of soft robotics is to create skin and tissue over the robot exterior. In addition, tissues could be grown to simulate muscles that might be used in propulsion of the robot and, in the case of nanobots and microsized robots, insect biology could be mimicked.

However, there is a lot of caution and skepticism about how quickly biotech and artificial muscle will develop in the coming years. The biggest challenge in this technology innovation is around electroactive polymers that enable creation of actuators. Ongoing challenges in this area led us to keep the position of this Innovation Profile unchanged on the Hype Cycle.

***User Advice:*** We are at least 10 years away from biorobots playing a part in our society. Therefore, for companies interested in biotech, it is worth getting in touch with specific universities and research labs to learn more about this technology and identify potential future usage scenarios.

***Business Impact:*** This technology is still in very early development, but it could potentially be used in future in soft robots or artificial muscle for more complex robots, medicine, medical treatment, welfare equipment, military, toys and smart structures.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Recommended Reading:*** “Top 10 Strategic Technology Trends for 2019”

“Top 10 AI and Sensing Technology Capabilities for Personal Assistant Robots in 2020”

## Immersive Workspaces

***Analysis By:*** Marty Resnick

***Definition:*** Immersive workspaces are collaborative work environments that convey a sense of real-world presence through the use of visual, auditory, haptic and other sensory elements. They principally employ virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies and techniques, and are delivered to users through head-mounted displays.

***Position and Adoption Speed Justification:*** Immersive workspaces will provide enhanced opportunities for meeting solutions and telecommuting by delivering environments designed for deeper collaboration. They will facilitate richer and more natural collaboration, knowledge sharing, onboarding, and training, facilitated by the use of immersive technologies and sensory elements.

Immersive workspaces are continuing to appear and mature within VR platforms, such as those of Oculus, but developments have also moved toward MR. Immersive workspaces have the ability to create 3D virtual offices and desktops in a VR world. Also emerging is the ability, using MR, to place digital objects (such as images of monitors) on walls in virtual representations of the physical world, which offers new collaboration, interactivity, visualization and productivity opportunities.

Immersive workspaces are at a very early stage of development with limited functionality, but they are developing quickly. They are deployed in pilots and proofs of concept (POCs). However, large enterprises are investigating new and innovative ways to enhance collaboration and communication through the use of immersive technologies.

***User Advice:*** Organizations looking to use immersive workspaces to enhance communication and collaboration among members of an increasingly remote workforce and with business partners should:

- Evaluate the market and experience virtual desktop applications through VR ecosystems, such as those of HTC (Vive) and Facebook (Oculus), as well as MR ecosystems such as Microsoft (HoloLens 2).
- Give their employees the opportunity to test immersive technologies.
- Review unified communications vendors' roadmaps and plans for immersive workspaces.
- Start small with a POC — for VR conferencing, for example. Then, plan specific use cases for a wider rollout, taking account of requirements for networks, hardware and software.

Currently, the use of 3D-enabled applications in immersive workspaces is limited, and availability of these applications will need to grow to meet the true value of immersive workspaces.

***Business Impact:*** Immersive workspaces could offer organizations opportunities to reduce travel expenses by improving remote collaboration and to increase productivity through design visualizations. They also could provide enhanced analytics collaboration through immersive analytics. Immersive workspaces could improve connections and engagement between office-based workers and remote workers and suppliers. Providers of virtual meeting, conferencing and training solutions should be looking to add immersive workspace capabilities to their products.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Cisco; Facebook; Google; HTC; Microsoft; vSpatial

***Recommended Reading:*** "Maverick* Research: Throw Out Your Keyboards, Close Your Physical Workplace and Come to Your Senses"

"Smart Workspaces: Midterm Investments for Tech CEOs"

"Virtual Reality and Augmented Reality: Using Immersive Technologies for Digital Transformation, Customer Experience and Innovation"

"How Architecting for Next-Generation Experiences Helps to Deliver Customer and Business Outcomes"

## AR Cloud

***Analysis By:*** Tuong Nguyen; David Cearley

***Definition:*** The augmented reality (AR) cloud is the underlying, persistent, digital content layer mapped to objects and locations in the physical world. It provides a digital legend in the form of a point cloud to annotate (augment) objects and places in the physical world. It is a key infrastructure component that will be required to enable a ubiquitous, scalable, spatial web experience.

***Position and Adoption Speed Justification:*** Similar to AR, aspects of the AR cloud have existed for decades, but the emergence of the AR cloud as a concept has re-emerged as recently as 2017. Many startups (see vendor list below) are developing revolutionary platforms and systems to bring the AR cloud to fruition. A simple (but misleading) view is that this is a database that will "feed" AR and mixed reality (MR) experiences. The AR cloud is much more rich and complex than a simple database. Numerous, underlying elements will need to be created (such as edge networking, high bandwidth and low-latency communications, standardized tools and content types for publishing into the AR cloud, management and delivery of content, and interoperability to ensure seamless and ubiquitous [rather than siloed] experiences) to enable this shift in how we organize and interact with digital content. Traditionally, leading tech vendors have invested in distributed network infrastructure, but many of them (such as Amazon, Google, Facebook, Microsoft) are adapting to a new paradigm to support localized, persistent, collaborative, shared, multiuser interactions. Some of this infrastructure and requirements will be ushered in by the arrival of low-latency, wireless networking (5G will serve as an enabling tech), while others are still being developed.

***User Advice:*** In the next decade, the AR cloud could form the multilayer digital twin of the physical world. This will enable new interactions and in term new business models and ways to monetize the physical world. The AR cloud will change the way that enterprises think of physical assets, how they interact with customers and the associated risks.

***Business Impact:*** The AR cloud, let alone standards governing its infrastructure, is a work in progress. The best way to prepare is to evaluate potential areas of impact of business outcomes — areas that can be exploited or affected by the AR cloud. There are broad possibilities here. For example, in city management, this includes collaborative, dynamic and contextualized maps of cities to highlight details such as public restrooms, public transit locations, traffic issues, wayfinding as well as public utility maintenance records, log fix-it requests, and government office locations. Following are the areas that will be affected by the AR cloud:

- Privacy — defining what should be captured by sensors (image and others) and how it will be stored.
- Security — establishing hierarchies for data capture and protection.
- Compliance — the impact of massive physical data collection on regulations such as GDPR.
- Digital ethics — guidelines to manage and capture content as well as segregating data into public and private realms.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** 6D.ai; Amazon; Apple; Facebook; Google; Microsoft; Ubiquity6; Visualix; Xperiel

***Recommended Reading:*** "Market Guide for Augmented Reality"

## Decentralized Web

***Analysis By:*** Avivah Litan; Adrian Leow

***Definition:*** Decentralized web (or Web 3.0) is a new stack of technologies for the development of decentralized web applications that enables users to control their own identity and data. These technologies include blockchain as a trust verification mechanism, privacy-preserving and interoperability protocols, decentralized infrastructure and application platforms, and decentralized identity. These will eventually realize the vision of a decentralized web.

***Position and Adoption Speed Justification:*** Traditional web-enabled social media and electronic commerce have revolutionized social interactions, bringing suppliers and consumers of information, goods and services together in a peer-to-peer setup on a global scale. However, with Web 2.0, all these interactions and transactions require a digital platform (like those of eBay, Amazon, Alibaba Group, Facebook, Google and Uber) acting as trusted provider or broker between entities who do not know or trust each other. These platforms have created a valuable peer-to-peer economy, but they also define the relationship rules and host all of the participants' data. Decentralized web promises to enable true peer-to-peer interaction and transactions with no reliance on centralized platforms and intermediaries.

The Web 3.0 stack that will move Web 2.0 services into the Web 3.0 protocol has yet to be standardized. Other than platform-oriented specifications, all protocol standard initiatives are either at early stages of inception or under development. Examples of initiatives include the Web3 Foundation and ISO/TC 307 for blockchain and distributed ledger technologies. It is important to note that, although DApp architectures are more fault-tolerant and attack-resistant, they are currently slower than traditional systems. Although it is likely that the future of internet technologies will be more decentralized, this is unlikely to eliminate centralized authorities and systems from most enterprise B2B and B2C use cases. This is because they will play a key role in the governance and oversight of digital ecosystems.

***User Advice:*** Enterprise architecture and technology innovation leaders adopting blockchain technologies should monitor developments in Web 3.0 protocols and standards by monitoring the initiatives of the Web3 Foundation and ISO/TC 307 for blockchain and distributed-ledger technologies. Organizations that want to promote Web 3.0 concepts in their applications can further evaluate and pilot blockchain platforms that implement a Web 3.0 vision by giving end users control of their own identity data. These platforms include self-sovereign and distributed-identity blockchain-based applications, and emerging blockchain-based advertising platforms. Other blockchain applications in other domains will also emerge before Web 3.0 protocols and standards mature, and users may find it useful to work with these new applications as they come to market.

***Business Impact:*** Web 3.0 will implement the protocols that support the most revolutionary aspect of blockchain technology, which is that it embraces a peer-to-peer decentralized design that eliminates central authority. To support this vision, users must be able to control their own identities and data. This, in fact, was the promise of the web before the large internet gatekeepers assumed their central and powerful positions over the past couple of decades. Blockchain-based technology and Web 3.0 have the potential to take the web to where it was originally "supposed" to be — to a point where consumers and end users have control of their own identity and data. Service providers will have to adapt their business models to work within the new paradigm. Those that figure out the new formulas for adopting Web 3.0 technology soonest will emerge as the success stories of the next decade.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Algorand; Brave; Cosmos; Enigma; Lightning Network; MetaMask; Opera; Polkadot; Raiden; Sovrin Foundation

***Recommended Reading:*** "Guidance for Assessing Blockchain Platforms"

"Planning for Blockchain Solution Adoption"

## Generative Adversarial Networks

***Analysis By:*** Brian Burke

***Definition:*** Generative adversarial networks (GANs) are composed of two neural network models, a generator and a discriminator that work together to create original simulations of objects such as videos, images, music and text (poetry, stories, marketing copy) that replicate authentic objects or their pattern, style or essence with varying degrees of quality or realism.

***Position and Adoption Speed Justification:*** Originally proposed by Ian J. Goodfellow in 2014, this technology is in a nascent state, with the majority of applications coming from research labs. Commercial applications have just started being explored. The algorithms require a lot of manual tuning to make them perform in the desired manner, and development of the technology is constrained by the extremely limited resources that have knowledge in this area. As commercial applications become more commonplace, the technology will improve as the benefits are significant.

GANs are commonly used to create of images of people who don't exist, to create fake political videos, to compose music and poetry. In 2018, an image produced by a GAN was sold at an auction for $432,500. While these "novelty" applications are prominent, research is underway to apply these algorithms to far more valuable challenges such as generating marketing content, graphic designs, designing new parts (generative design), generating pharmaceutical compounds, creating simulated environments for training autonomous vehicles and robots and generating synthetic data to train neural networks and to protect privacy.

***User Advice:*** In a GAN, the generator is essentially a deep learning classifier running in reverse to create an object. It then presents it to the discriminator which predicts if the object is real or not, providing this information to the generator. This feedback loop provides guidance to the generator to adjust the objects it is creating to become more like what the discriminator predicts is real.

Through many iterations, the generated object becomes indistinguishable from a real object for the discriminator.

Technology innovation leaders in organizations that are technologically innovative should evaluate the potential for leveraging this technology today, and partner with universities to conduct proof of concepts where the potential benefits are significant. Tech innovation leaders should do their due diligence and consider the fact that while the core technologies are readily available in the public domain, the technology is brittle, resource hungry and requires significant (and rare) AI skills. They should also focus on other pressing issues such as explainability, as GANs are ‘black boxes’ and there is no way to prove the accuracy of the objects produced other than by subjective methods.

***Business Impact:*** Commercial implementations of GAN technology are limited to experimental uses today. The powerful idea is that deep neural network classifiers can be modified to generate realistic objects of the same type. GANs have the potential to impact many creative activities from content creation (art, music, poetry, stories, marketing materials) to many types of design (architecture, engineering, drug, fashion, graphic, industrial, interior, landscape, lighting, process). GANs might also be used to create simulations where actual data may be difficult to obtain (training data for machine learning) or pose a privacy risk (health data) or be costly to produce (video game backgrounds). GANs have the potential to augment humans’ talents for many creative tasks across many industries.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Amazon; Autodesk; DeepMind; Microsoft; Neuromation; NVIDIA

***Recommended Reading:*** “Market Insight: Creative AI — Assisted and Generative Content Creation”

“Embrace These 3 Key Trends in Content Marketing”

## Adaptive ML

***Analysis By:*** Pieter den Hamer; Erick Brethenoux

***Definition:*** Adaptive machine learning (ML) is the capability of frequently retraining ML models when they’re online in their runtime environment, rather than only training ML models when they’re offline in their development and test environment. This capability allows ML applications to adapt to changing or new real-world circumstances that were not foreseen or available during development. Based on user feedback or data about the quality of the ML output, e.g., prediction errors, the model parameters are updated while online.

***Position and Adoption Speed Justification:*** Adaptive ML is just emerging and in many cases still embryonic. It gets much closer to self-learning, or at least to more frequent learning, in contrast with current AI applications which after deployment only use static ML models that depend on infrequent redeployment of new model updates to improve themselves. Adaptive ML is technically challenging for a number of reasons, including:

- A closed loop between the output and input of the ML application is required, including a mechanism like user or expert feedback, or a quantitative measure to determine the quality of the ML output and the extent to which the ML model should be updated to enforce or improve current model parameter settings.
- Adaptive ML typically occurs frequently in its runtime environment — less frequent model updates can already be achieved by the current approach of offline training and periodic model update deployments. This implies that there is no time to fully retrain the model, using all available historical data and newly acquired closed loop data. Instead, the model must be retrained online and incrementally, using only new or most recent data, which requires incremental learning algorithms that are different from offline learning algorithms that typically rely on large batches of historical data.
- Adaptive ML must be tuned in terms of weighting new data versus older data that was used for earlier online or offline training and other challenges such as preventing overfitting and proper testing and validation, at least periodically.

Non-technical challenges include ethical, societal, reliability, liability, safety and security concerns that come with self-learning and autonomous systems.

***User Advice:*** Adaptive ML is a key enabler of autonomous systems such as self-driving vehicles or smart robots that should be able to operate in their ever changing contexts. Also, increasing pace and dynamics in business ecosystems will require more adaptive ML to power continuous intelligence, streaming analytics, decision automation and augmented intelligence in a myriad of industries and business areas.

Adaptive ML should not be considered by organizations to replace but to complement current ML. Most adaptive ML applications will start out with a model that was trained offline. The other way around, adaptive ML can be seen as a way to further improve, contextualize, personalize or fine-tune the quality of ML models, once online.

In addition, adaptive ML can be used to compensate for limited availability of historical or synthetic data, inhibiting offline training during development. Likewise, adaptive ML can be used to reduce the need for extensive simulations or trials for reinforcement learning, before deployment. In both cases, the adaptive ML application starts out with a minimal viable model that was pretrained offline, with the model then incrementally improved during the actual online usage.

Adaptive ML must be accompanied by a proper risk analysis and risk mitigation activities, if only to frequently monitor the quality and reliability of adaptive ML applications.

Adaptive ML relates to and works together with ML operations (MLops): apply MLops to deploy new ML models from their development and test environment to their runtime environment, after which adaptive ML is applied to continue learning. Once deployed MLops monitors quality and business relevance of the online adaptive ML application. If MLops detect that the adaptive ML application is no longer meeting quality or other criteria, MLops should take the adaptive ML application offline, overhaul it in a development environment, test and redeploy, after which adaptive ML takes over again and MLops returns to monitoring.

Organizations should actively monitor the potentially significant impact of adaptive of ML on talent, infrastructure and enabling technology. For example, adaptive ML is likely to be more demanding in terms of computing power in runtime environments and will require the development of knowledge about new (incremental learning) algorithms and tools.

***Business Impact:*** Adaptive ML will allow organizations to respond more quickly and effectively to changes in their business ecosystem by using more autonomous systems that are responsive to the dynamics. Adaptive ML will also help organizations to improve the quality of their ML applications by providing feedback after their deployment, thus implementing a more frequent “learning” mechanism. Adaptive ML is most relevant in areas in which context and conditions or in which the behaviour or preferences of actors change frequently. Example, application areas include gaming, organized crime fighting and anti-terrorism, fraud detection, cyber security, quality monitoring in manufacturing, virtual personal assistants, semi(autonomous) cars and smart robotics.

***Benefit Rating:*** High

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** Cogitai; IBM (Neural-Symbolic research); Microsoft; Tazi.ai

***Recommended Reading:*** “Artificial Intelligence Hype: Managing Business Leadership Expectation”

“Building Your Continuous Intelligence Capability for Digital Transformation”

“Preparing and Architecting for Machine Learning: 2018 Update”

### DigitalOps

***Analysis By:*** Derek Miers

***Definition:*** DigitalOps enables the rapid development and adaptation of dynamic, real-time and scalable business products and applications, facilitating the emergence of a digital business technology platform. It is an evolution of the automation aspects of BPM incorporating decision management and event processing with agile methodologies for continuous delivery of business improvement in applications to deliver a step change improvement in business agility.

***Position and Adoption Speed Justification:*** DigitalOps represents the “business” center of a digital business technology platform, coordinating and orchestrating systems and other resources that may sit outside the corporate firewall. Underpinning the orchestration and coordination, DigitalOps environments incorporate mechanisms for process modeling, sensing/analyzing (process mining, event detection and performance metrics) and responding (real-time operational decision models), and dynamic optimization (applying artificial intelligence and machine learning). A few vendors have some parts of the needed functionality:

- Most iBPMS vendors have a shot, but they have not embraced the event-driven mechanisms needed to scale.
- EBPA vendors have started to develop innovative ways of visualizing the operating model and linking that to performance reporting and continuous intelligence.
- APIs, multigrained services and RPA approaches have overcome most integration challenges.
- Process mining and machine learning algorithms have only a peripheral role today.

DigitalOps is still a nascent market with only leading and innovative organizations recognizing the opportunity it offers to allow them to scale their business operations. Like DevOps, DigitalOps is not a "system" to buy. DigitalOps environments are implemented by the business and IT working together to drive agility and continuous business change through the configuration and recombination of models rather than the development of code.

***User Advice:*** EA and technology innovation leaders should:

- Sell the benefits of using business-centric models and technologies in a layered approach (business, IT, third party) to drive digital transformation in operations to their executive team. With broader understanding of these benefits, it becomes much easier to develop business product offerings that leverage automation.
- Shorten the time needed to implement and evolve business product offerings by reconsidering their organization's approach to business processes, decision models and associated tooling. Identify how these types of models can help to automate interactions at scale on the digital technology platform.
- Identify where automated decision management fits by exploring Decision Model and Notation (DMN) with a view toward radically simplifying processes. With all the variation captured in an executable decision model, a process that had 70 to 100 steps may reduce to less than 10 steps.
- Engage product development teams to co-create their future services together. Make reusability a priority by helping them translate customer journey maps into phased value streams, looking for shared capabilities within each phase and then developing more granular product descriptions for the common aspects of these business capabilities. Identifying the right level of granularity in these common business capabilities will enable reuse across a wide set of product scenarios.
- Integrate external processes and engines, as well as legacy data and applications where needed, by developing configurable interfaces based on multigrained services, APIs or (as a last resort) RPA tools. With careful attention to data design and configuration, the interfaces can then support multiple processes and products.

- Ensure careful governance of all the different elements (processes, decision models, common integration components, configurations) over time. They will often have different and distinct life cycles, as well as a diverse set of stakeholders.

***Business Impact:*** DigitalOps provides the basis for an emergent approach to business operations. By applying a DigitalOps approach to better support execution within business operations, the organization can move from planning and definition of strategic goals to the clarification of that intent through to the orchestration of resources in the digital platform. Alternatively, the organization can focus on the industrialization of common components (complete with integrated engines and external services), which are then amenable to later configuration and extension to create new and innovative products for execution on the digital platform. DigitalOps:

- Enables the dynamic optimization and recombination of products and services through industrialized common process components, underpinning reuse of these elements and scaling new offerings in the market.
- Coordinates and balances customer expectations and corporate goals/objectives within each product offering, while driving the alignment of business operations.
- Ameliorates the first-mover advantages of digital disruptors by enabling a “fast-follower” business strategy, allowing both Mode 1 and Mode 2 operations to coexist and cross over.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Appian; Bizagi; MooD International; Pegasystems

***Recommended Reading:*** “DigitalOps Helps Connect Business Models to the Digital Business Platform”

“Beyond Automation: Digitalization Changes Business Process Design and Execution”

“Critical Capabilities for Intelligent Business Process Management Suites”

“The Future of BPM: From Prescribed Actions to Improvisational Interactions”

“Get Out of Strategic Limbo: How to Discover and Exploit the Business Moments That Drive Digital Transformation”

## Decentralized Autonomous Organization

***Analysis By:*** David Furlonger; Rajesh Kandaswamy

***Definition:*** A decentralized autonomous organization (DAO) is a digital entity that can engage in business interactions with other digital agents and corporate entities without conventional human management. They rely on smart contracts for interactions. As a DAO may be autonomous and span multiple geographic jurisdictions, it may be beyond legal reach — literally, an outlaw.

***Position and Adoption Speed Justification:*** In its early stage, current form, a DAO is an application-level solution constructed on a blockchain platform. DAOs are programmatically controlled via code that runs on the blockchain platform (a mechanism known as "smart contract"). The agents can send and receive payments; engage in other forms of value exchange and dynamic behavior, relying on tokens to validate value exchange; and interact with other DAOs, as well as conventional information systems (via APIs). They can also potentially spawn other digital entities and work in concert with these.

Although DAOs have faded into the background to some extent, related concepts may reenergize their evolution. Initial coin offerings (ICOs) are narrow-scope mechanisms that implement a small subset of the DAO vision, but are now being deployed within cryptocurrency communities (primarily Ethereum). Dapps are also a functionality relating to DAO, particularly in the context of money management.

The vision of the DAO concept includes different types of automated governance. Participants can initiate actions through various means (for example, voting rights based in proportion to value token holdings), as well as digital asset trading. In future versions, the DAOs will be able to evolve via artificial intelligence (AI) techniques and self-modifying code. DAO platforms, such as DAOstack, offer tools that help create and operate DAOs.

DAOs are still in the early stage of evolution. Many challenges and limitations that have yet to be overcome including developing aspects of the core technology to support the key aspects of an organization. The opportunity is for investors in DAOs to share in the development and future of the organization, negating the need for centralized control. The transparent and structured nature of the operational rules provides for more efficiency in how the DAO conducts business. The security of the code, lack of legal frameworks, need for better tokenization platforms, the risk in moving away from proven business models, vested interest of traditional companies and governments, and the underlying issues with cryptocurrencies provide for an uncertain future.

***User Advice:*** Track the emerging ecosystem of DAOs and Dapps ICO initiatives, which is primarily occurring outside traditional enterprises, and learn from its success or failure. In addition, follow other radically different approaches to management and organizational hierarchy — including those that are enabled by AI. AI is likely to strongly influence the functionality/capability of DAOs. As AI technology matures, its ability to shape and improve smart contracts use cases and therefore, the terms and conditions of doing business will be significant. Executives should also consider experimenting with aspects of computer-augmented decision making in limited-risk areas. Carefully measure lead and lag indicators, as well as the impacts on reporting lines, from staff morale through, to the amount of productivity and level of innovation achieved.

***Business Impact:*** DAOs will function autonomously, enabled by a blockchain-platform-based distributed and decentralized network to engage with a commercial ecosystem (for example, other DAOs, traditional companies and individuals) for undertaking transactions of a monetary and nonmonetary nature (using smart contracts). This trend will be applicable across all contexts, sizes of organizations and geographies. It is easier to implement in newer and smaller organizations, and in geographies and contexts where hierarchies of power are less embedded in the culture. However, even the largest hierarchical businesses can find areas to begin experimentation with a managementless organization. Potential benefits can be significant, including greater agility, productivity, speed of decision making, more-efficient business processes and expanded capabilities. Since a cultural change is required, there is also potential for competitive advantage, sustained for the midterm, for institutions that go on the journey earlier.

The legal status of a DAO is important. For most organizations, the DAO should be constructed such that it is within the reach of law, most likely through an independent entity that can manage and control its operation.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Colony; DAO IPCI; DAOstack; Ethereum

***Recommended Reading:*** “Use Gartner’s Blockchain Conceptual Model to Exploit the Full Range of Possibilities”

“Blockchain-Based Transformation: A Gartner Trend Insight Report”

“Blockchain Status 2018: Market Adoption Reality”

## Nanoscale 3D Printing

***Analysis By:*** Michael Shanler

***Definition:*** Nanoscale 3D printing (3DP) is the use of specialized additive manufacturing technology and related processes to create minute, intricate structures and/or features with high aspect ratios. Nanoscale objects are measured in micrometers (μm).

***Position and Adoption Speed Justification:*** The use of 3DP technology for micromanufacturing and nanomanufacturing is still in the R&D phase, with close collaboration between corporate development engineers and university researchers. However, the interest in technical partnerships and co-development efforts, and internal R&D projects by 3DP hardware providers is beginning

Today, nanoscale (also known as microscale printing) requires not only specialized 3DP equipment and optics, but also additional postprinting processing steps — both mechanical and chemical. R&D investigators are reporting that operating at this scale requires specialized approaches and new procedures for printing, processing and inspection. A variety of research and technical universities are also driving nanoscale 3DP activities including Jilin University (China), Rutgers, University of California — Irvine, University of Southern California, Penn State University, and Ohio University. Research institutes working on nanoscale 3DP include HRL Laboratories and the Metal Processing Research Center (Spain).

As of 2019, there are only a handful of companies selling 3DP software or equipment for manufacturing at the nanoscale level. One example is Nanofabrica launching the availability of micro-level resolution using their additive manufacturing technology

For this reason, the technology is positioned very early in the Hype Cycle, in the Innovation Trigger phase, and will still take more than 10 years to reach mainstream.

***User Advice:*** R&D engineers, technologists and new product development stakeholders should keep microscale 3DP on the watch list, as the technology could lead to new product innovations. This technology is currently buried deeply in university and corporate R&D. For example, many organizations would need to make a new investment or partnership to even explore focused electron beam induced deposition (FEBID). In many ways, this is a scientific curiosity that is looking for a "killer app" to come along. Keep in mind the technology itself may require extensive proof of concept (POC) tests.

Nanoscale work will be challenging to industrialize. We expect significant hurdles to keep the technology in academic labs for a few years, before a handful of companies begin to leverage 3DP into R&D or downstream supply chain. IT stakeholders with organizations investigating nanoscale 3DP should ensure that engineering, design and inspection platforms will have the suitable CAD or PLM plug-ins or capabilities for doing this type of work. Also, the data models and inspection techniques will require advanced imaging and image analysis.

Engineering and scientific leads interested in mitigating risks for nanoscale 3DP should seek out academic partners and collaborators to help refine the technology and run proofs of concept. PLM, CAD and 3DP process leaders should work with vendors to ensure realistic roadmaps can support internal workflows.

***Business Impact:*** Many engineering scientists believe that the next wave of innovations will happen at a scientific or material level, not necessarily at a design level. Nanoscale 3DP represents the intersection of 3DP, engineering design, science, physics and chemistry. Nanoscale 3DP has a strong potential relationship with 4D printing, where the fourth dimension represents an activity such as movement or a dynamic response of the printed item over time. Nanoscale 3DP could be leveraged for miniaturization efforts, developing new medicines, in vivo medical devices, espionage tools, microsensors, artwork, microrobotics and printable electronics, for example.

The benefit ratings could be extremely high and even potentially transformational. However, commercializing and scaling 3DP in a robust process is still a risky and likely resource-intensive endeavor, which cannot be ignored until there is more progress with POCs and R&D efforts.

***Benefit Rating:*** High

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** 3D Systems; Fraunhofer IMM; Nano Dimension; Nanoscribe; NanoScale Systems; Nanowerk; Stratasys; SwissLitho

***Recommended Reading:*** "Predicts 2019: 3D Printing Accelerates, While 4D Printing Is Getting Started"

"Cool Vendors in 3D Printing, 2017"

## Augmented Intelligence

***Analysis By:*** Svetlana Sicular; Dave Aron

***Definition:*** Augmented intelligence is a human-centered partnership model of people and artificial intelligence (AI) working together to enhance cognitive performance, including learning, decision making and new experiences.

Augmented intelligence is sometimes referred to as "Centaur intelligence." It is different from augmented analytics: augmented intelligence is about people taking advantage of AI; augmented analytics is about data and analytics technologies enhanced with AI.

***Position and Adoption Speed Justification:*** Increasingly, the approach to AI as the means of human augmentation outweighs the views on AI as the means of full automation. Augmented intelligence is quickly emerging as a design approach to get the most value from AI. It employs AI to compensate for human limitations and enables people to expand the possibilities for AI. Many early-adopter enterprises had thought initially that full automation was the way to use AI. Now, they have started to realize that full automation is very expensive and complex. They are taking a more realistic view, where augmented intelligence compensates automation's limitations with people's creativity, flexibility and adaptability. They treat AI as a human assistant, and humans as AI assistants.

Gartner's AI business value forecast highlights decision support/augmentation as the largest type of AI by business value-add (see "Forecast: The Business Value of Artificial Intelligence, Worldwide, 2017-2025"). Augmented intelligence already reduces mistakes and routine, positively reflecting on the customer service and transactions such as customer interactions, citizen services and patient care. The goal is to be more efficient with automation, while complementing AI with a human touch in order to keep things personal and with human common sense to manage the risks of AI automation.

Most AI vendors are also shifting their solutions and messaging to a combination of humans and AI, rather than to a purely machinistic view. In spring 2019, the first Human-Centered AI (HAI) Symposium took place in Stanford, California, U.S. At this symposium, leading AI scientists and practitioners also reaffirmed the role of AI as augmenting human capabilities.

***User Advice:*** CIOs, data and analytics leaders and IT leaders responsible for AI should use augmented intelligence as a design approach. Implement AI to focus human attention where it is most needed, in order to accelerate organizational competencies that fulfill your vision for digital transformation. Center on what you can do for people, not what to automate — this is how you achieve human touch at scale.

Plan application and user experience design to facilitate augmented intelligence. This design could be more abstract (software, services, digital) or also in the physical space (physical robots and the like).

Help people learn and improve, so the company, ecosystem and the entire society can take on more exceptional and forward-looking work. Approach augmented intelligence through three time horizons:

- In the short term, scale volume, reduce errors and automate routine tasks.
- In the medium term, scale quality, amplify human talents, further improve business efficiencies and create new products and experiences.
- In the long term, build personalized products and services at scale, reinvent your business, industry and society, and maximize customer convenience.

Add augmented intelligence to the workforce plan. Give people clarity about AI systems. Transform from episodic to continuous, multidisciplinary learning to sustain innovation. Work with HR to upskill employees. Maximize the effects of AI-augmented roles and decisions via ongoing education, experience labs, AI-enabled just-in-time training and other methods.

***Business Impact:*** Properly orchestrated, AI automation combined with human touch makes AI impactful. AI's mistakes are unavoidable, but people can fix them. The use of AI in areas of "life and death" presents tremendous risk — augmented intelligence mitigates this by adding humans to AI. While humans see and analyze the world in hours, minutes and seconds, augmented intelligence can react much faster. With algorithms being commoditized, implementation philosophy and ethics will be the greatest differentiators of AI solutions: AI philosophy and ethics require people who know how to get them right.

***Benefit Rating:*** Transformational

***Market Penetration:*** 5% to 20% of target audience

***Maturity:*** Emerging

***Recommended Reading:*** "Leverage Augmented Intelligence to Win With AI"

"Predicts 2019: AI and the Future of Work"

"Individuals, Groups and Society in the Loop of Artificial Intelligence Design and Development"

"From Digital Transformation to ContinuousNext: Key Insights From the 2018 Gartner Symposium/ ITxpo Keynote"

"How to Develop the Right Technical and Human Architectures for Digital Business"

### Flying Autonomous Vehicles

***Analysis By:*** Michael Ramsey

***Definition:*** Flying autonomous vehicles encompass self-operating aircraft that sometimes are referred to as "flying cars" or personal drones and are designed to operate without a human pilot either in the vehicle or remotely operating. These vehicles could include commercial delivery drones as well as air taxi services. They are distinguished by their ability to complete complex decision making in addition to handling normal vehicle operations as an "autopilot" function might do in a standard aircraft.

***Position and Adoption Speed Justification:*** More than a dozen companies are working on new aircraft that are piloted by artificial intelligence and designed to create a more agile, less expensive and quicker way to execute air travel, primarily in congested areas. The goals of the projects include:

- Faster travel in densely populated areas
- Speedy delivery of goods and services in a three-dimensional context
- Economical air travel over short distances
- Logistics too difficult to reach; rural locations with poor infrastructure

The ambitions around these vehicles have primarily expressed themselves in the form of advanced air taxis that would fly over congested megacities, reducing transit time. There are efforts underway by companies such as Airbus and Uber Technologies to develop self-flying vehicles. In most cases, the designs are multiple-rotor, vertical-takeoff-and-landing (VTOL) devices. They are similar in capability to traditional helicopters, but look similar to much smaller drones.

While the prospect of direct flights over congested areas is tantalizing, these vehicles face significant challenges to implementation. The technology is not currently validated by federal authorities and ensuring safety of such a system could take years. In addition, regulations are such that distances of a mile or more may be required between the vehicles over urban areas, limiting the usefulness. Infrastructure in cities is not currently available for landing areas to accommodate large numbers of vehicles and the vehicles produce significant noise. Finally, most versions of the vehicles are battery-powered, limiting their range significantly when compared with standard helicopters. All that said, the prospect of fast, economical and, ideally, safe flight, point-to-point, in urban areas is certain to attract significant interest and investment.

***User Advice:*** For CIOs in organizations dependent on transportation and logistics, add these vehicles to the long-term technologies that may need to be obtained or used in your processes. While it may be decades before these vehicles proliferate, they are nearly certain to grace the skies at some point. Assess what problems in logistics, both for moving people and for cargo, that might be solved by using these vehicles. Consider how systems might need to be altered internally to allow for use of the vehicles.

***Business Impact:*** The business impact of flying autonomous vehicles is likely to be moderate for most companies, though it could be quite high in a limited set of businesses around mobility services and logistics. For instance, if Amazon can use autonomous drones for package delivery at scale, it could reduce its costs and speed up delivery of packages. For most people, these vehicles will be an extra convenience and not the primary way they will travel. In the end, they are mostly going to be the equivalent of robot-piloted helicopters, which lowers the cost and perhaps increases the availability of a service that already exists. It is likely that special use cases in remote areas or difficult topography will lead to much faster adoption on a regional or special use basis, as helicopters already serve locations like this in special circumstances.

***Benefit Rating:*** Moderate

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Airbus; Bell; Lilium; Terrafugia; Uber; Volocopter

***Recommended Reading:*** "Changing Drone Regulations Are a Major Market Opportunity for Technology and Service Providers"

"Maverick* Research: Flying Autonomous Vehicles — The Next Big Thing That Isn't"

"Top 10 Strategic Technology Trends for 2019: Autonomous Things"

"The 2019 Top Supply Chain Technology Trends You Can't Ignore"

"Top 10 Strategic Technology Trends for Manufacturing Industries in 2019: Autonomous Things"

## Transfer Learning

***Analysis By:*** Stephen Emmott; Anthony Mullen

***Definition:*** Transfer learning is the reuse of previously trained machine learning (ML) models as an advanced starting point for new purposes in order to reduce the learning time required to attain acceptable performance. Learning can be transferred through unsupervised, inductive and transductive methods. Transfer learning is distinct from other approaches to reducing learning cycle time and improving performance, such as ensemble learning.

***Position and Adoption Speed Justification:*** The reuse of ML models is not new. The theory, techniques and tools behind transfer learning stretch back many years. However, despite the hype of AI touching all enterprises, only a minority have proactively deployed it beyond what is embedded in enterprise software products. Developing and training AI is challenging and risky, with the key barriers to adoption being the skills of staff, understanding benefits and use cases, and scope or quality of data. Given the investment required to succeed, enterprises are looking for ways to leverage existing models. This might be sourced from internal efforts (custom models trained on internal data) or external sources. These could include successful implementations of transfer learning in natural language processing (word2vec), audio/speech (ASR for English — used to accelerate development of other languages) and computer vision (Imagenet).

Transfer learning provides an approach to adoption that has the potential to overcome the barriers to adopting AI, provided that there are sufficient numbers of applicable models available, the tools to reuse the data are in place, and there is enough subsequent retraining on new data to attain successful use. Although challenging, early adopters and providers of AI are now starting to generate models and tools that make transfer learning viable for the majority.

***User Advice:*** Enterprises at all levels of AI maturity should start to use AI for new purposes after asking the question: "Which models can we leverage?" and seek to source these models both internally and externally. Those with a more mature level of AI adoption should additionally ask how their current models might be reused in related domains and similar tasks, and facilitate their use through their enterprises' AI center of excellence (CoE).

Making transfer learning habitual is a critical success factor to accelerating enterprisewide ML-based AI adoption. Aside from ensuring the mandate for transfer learning, IT leaders need to ensure the availability of models and tools to facilitate its use. Maintaining internal directories of AI models — with the help of your CoE — and external sources of models or products embedding models is also key.

The tools used to create and train models should be checked for their support of transfer learning, which should also be a requirement for any new tools. A mandate for transfer learning can help to organize approaches to AI into a hierarchy based on whether it is:

- Embedded in enterprise software
- Embedded in a point software application
- An external component integrated into software via APIs
- A custom solution sourced externally
- A custom solution sourced internally

At each level in the hierarchy, you should seek support for transferable learning commensurate with the level of customization required. For example, at the level of an "external component integrated into software via APIs" Google's AutoML facilitates additional training with customer data.

Transfer learning can be facilitated using both internal as well as third-party datasets, but this use is excluded without knowledge of their existence. Within your directory of models, include external datasets, and work with your data analytics leaders to utilize metadata management initiatives to identify internal datasets.

***Business Impact:*** Transfer learning will impact all use of ML, both in terms of how organizations apply this, and the technology they acquire with it embedded. Presently, the primary motivators for enterprises adoption of AI are the improvement of customer service and the automation of repetitive or manual tasks. Enterprises that are prioritizing the application of AI to improved customer experience are already benefiting from transfer learning through speech-to-text and translation services. The shift from symbolic to nonsymbolic and hybrid (a combination of both) techniques in the processing of natural language, combined with transfer learning, is enabling (and will continue to enable) the extraction of richer insights from text-based content, including more accurate sentiment analysis and understanding.

Transfer learning promises the possibility to attain acceptable task performance with less training data. Such capabilities will augment customer-facing staff, and elevate the performance of the bots that work alongside them. These capabilities will also lead to progressive automation of work in adjacent information-rich domains, accelerating automation in the enterprise. A consequence of this will be easing the burden of managing many and similar narrow models in the context of the slow arc to general artificial intelligence.

***Benefit Rating:*** Moderate

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** DeepMind; Google; Hyperscience; Indico; Leverton; Microsoft; NVIDIA

***Recommended Reading:*** "Clarify Strategy and Tactics for Artificial Intelligence by Separating Training and Machine Learning"

"Maverick* Research: Use Simulations to Give Machines Imagination"

## Emotion AI

***Analysis By:*** Annette Zimmermann

***Definition:*** Emotion artificial intelligence (AI) technologies (also called affective computing) use AI to analyze the emotional state of a user (via computer vision, audio/voice input, sensors and/or software logic). It can initiate responses by performing specific, personalized actions to fit the mood of the customer.

***Position and Adoption Speed Justification:*** One of the benefits of detecting emotions/states is for a system to act more sympathetically. It creates anthropomorphic qualities for personal assistant robots (PARs), making them appear more "human." This "emotional capability" is an important element in enhancing the communication and interaction between users and a PAR. People's daily behavior, communication and decisions are based on emotions — our nonverbal responses in a one-on-one communication are an inseparable element from our dialogues and need to be considered in the human-machine interface (HMI) concept.

The first step in detecting human emotions is to define the different types of emotions, from angry, sad, happy and insecure. AI is a critical part of some, although not all, emotion AI solutions. Computer vision (CV)-based emotion AI requires a collection of imaging/video data and preparing it to be fed into an artificial neural network (ANN). Vendors using CV technology to detect emotions primarily apply convolutional neural networks (CNNs), a deep-learning technique.

Several new commercial deployments occurred in 2018/2019 for emotion AI and new vendors entered the market, which led us to move the technology profile two positions up.

There are several vendors, including Beyond Verbal, audEERING and Intelligent Voice, which have developed emotion AI systems based on audio analysis. Phonetic attributes and the understanding of words do not play a primary role here, and the most sophisticated systems are completely language-agnostic, including tonal languages. Vendors have developed algorithms that attribute the different pieces of sound waves to emotional states. The main type of neural networks (NNs) used for audio-based emotion AI are recurrent neural networks (RNNs).

Data quality (lab-based versus real-life data) and machine learning (ML) techniques determine the reliability of the technology to detect emotions. The better the data and the more data there is, the higher the probability of detecting different nuances of human emotions. Combinations of CV-based, audio-based and sensor-supported technologies make sense in certain use cases, but is not always required to gain a better result.

***User Advice:*** As the market is currently very immature, most vendors are focused on two or three use cases in two or three industries. Hence, when selecting a vendor, it is important to review their capabilities and reference cases. As discussed above, the context and environment of the use case will determine the type of emotion AI to be used. Organizations should make lists of use cases that apply to them.

- Be use-case-driven. The use case will determine the emotion AI technology to be used and vendor selection.
- Appoint responsibility for data privacy in your organization, a chief data privacy officer or equivalent.
- Work with your vendor on change management in order to avoid user backlash due to sensitive data being collected.

At the same time, identifying and processing human emotion is currently a gray area, especially in the EU. The EU Commission has started an initiative to review the ethical aspects of AI technologies, and emotion AI will certainly be part of this debate.

***Business Impact:*** Emotion AI technologies have already been adopted by various business functions in different industries, including call centers, PARs and high-end cars. CV-based emotion AI has already been used for more than a decade in market research — testing how consumers react to products and commercials. For about two years, many vendors have moved into completely new industries and use cases such as automotive, robotics, medical diagnostics, education and the public sector:

- Insurance companies are using audio-based emotion AI for fraud detection.
- In call centers, voice-based emotion AI can be used for intelligent routing for a better customer experience.
- Software exists that helps physicians with diagnosing depression and dementia.
- Dubai's Road and Transport Authority (RTA) announced the use of CV-based emotion recognition in four of its "customer happiness centers." When the "happiness level" among

visitors drops below a certain threshold (maybe due to long queues) employees are notified and can act upon it.

- Inside the car, audio and CV-based emotion AI helps to understand what is going on and detects whether passengers are emotionally distracted.
- In retail, stores are adopting camera-based facial and emotional recognition to understand demographics and moods of visitors, enhancing the retail experience. Similar trends are emerging in the hospitality industry (in hotel lobbies) where cameras are used to recognize frequent guests and recognize their emotions.
- In education, we have seen prototypes of learning software that adapts to the user's emotional state. Another opportunity is in training and workshops, where emotions of the training participants are captured to see how they are experiencing the training.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** audEERING; Affectiva; Beyond Verbal; Eyeris; Google; Intelligent Voice; Microsoft; Voicesense

***Recommended Reading:*** "Competitive Landscape: Emotion AI Technologies, Worldwide, 2018"

### Light Cargo Delivery Drones

***Analysis By:*** Aapo Markkanen; Bill Ray

***Definition:*** Light cargo delivery drones are flying, or wheeled, autonomous vehicles used to deliver small packages (about 10 kg), including food or medical supplies. Autonomy may be supplemented by remote operation when needed.

***Position and Adoption Speed Justification:*** Many companies, including Alphabet and Amazon, have experimented with delivery drones. Commercial services exist in a small scale: Some use wheeled ground-based drones driving at low speeds on pedestrian pathways, while others use flying drones that either drop deliveries or land at the delivery address. These services are still at an experimental stage, owing to the cost of the devices and the complexity of operation. However, most of the vendors are hoping that the loosening regulations and the economies of scale will eventually make large-scale operations viable.

Regulations are still developing, with aviation authorities and policymakers evaluating, in particular, how fleets of aerial delivery drones can be accommodated into the airspace, as well as how autonomous delivery vehicles (aerial or ground-based) can be integrated with smart city infrastructure. Aerial drones attract most attention, but wheeled systems are less complex in terms of both technical implementation and regulation.

The core technology behind the light delivery drones are becoming increasingly advanced, but due to the regulatory constraints and certain technical challenges, they remain an unproven concept. Therefore, in the Hype Cycle, they are still at least a couple of years away from the Peak of Inflated Expectations.

***User Advice:*** For most businesses, light cargo delivery via drones will be a cost reduction mechanism. For some others, it will be a way to scale time-sensitive last-mile deliveries, which will, over time, become increasingly challenging for fully manual supply chains to handle. The decision on adoption must be a process of creating a cost-benefit analysis. Enterprises should identify types of light cargo that might be suitable for drone delivery, and then identify the terrain over which the deliveries will take place. The terrain will determine the method of locomotion — fixed wing flight, rotary flight, wheels or something more esoteric — which will, in turn, determine the cost of delivery and enable a cost estimate to be created. This estimate should then be compared with the cost of other, more traditional means of delivery, such as trucks. The process should be repeated annually, as the costs will change as the technology matures and the scale of deployments increases.

Light cargo delivery drones will eventually become commonplace. Every business involved with the logistics of relevant goods, and especially the ones with a dispersed base of end customers, should be planning how to take advantage of the technology as it matures. At this point, a recommended approach is to engage with pioneering vendors and relevant regulators in order to trial the technology.

***Business Impact:*** The impact of low-cost deliveries will be extremely broad. Initially, they will disrupt postal and courier services, as well as, for instance, the fleets of casual workers making food deliveries in urban areas. As the cost of delivery drops, wider changes in behavior among consumers and businesses will result. For example, in the retail and hospitality sectors, customers expecting 24-hour product availability to the door will be less likely to shop at local, late-night stores, while the number of dark kitchens (restaurants without a physical customer-facing presence) will increase.

The proliferation of autonomous vehicles may also increase public tolerance for (and trust in) the autonomy of all kinds, and as such, it may pave the way for greater acceptance of autonomously driven passenger vehicles.

***Benefit Rating:*** High

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** Alphabet; Amazon; Boxbot; Flytrex; Marble; Matternet; Nuro; Starship; Udelv; Zipline

***Recommended Reading:*** “How to View Drone Deployment in Distribution and Logistics”

“Top 10 Strategic Technology Trends for 2019: Autonomous Things”

## Synthetic Data

***Analysis By:*** Anthony Mullen; Alexander Linden

***Definition:*** Synthetic data is a class of data that is artificially generated, i.e., not obtained from direct measurements. Generation can use different methods such as statistically rigorous sampling from real data, semantic approaches, Generative Adversarial Networks (GANs) or by creating simulation scenarios where models and processes interact to create completely new datasets of events.

***Position and Adoption Speed Justification:*** One of the major problems with AI development today is the burden in obtaining real-world data and labelling it so that AI may be trained effectively. For example, retail environments contain endless combinations of product, store layout and observable shopper behavior. Also, autonomous vehicles require millions of hours of training data. Synthetic data addresses the problem of volume and variety for sparse, nonexistent or difficult to get data. There are three primary methods we see in the marketplace today:

1. Sampling to generate data according to some distribution
2. GAN architectures that mimic real data
3. Agent-based techniques in simulations

Synthetic data, today at least, is not a panacea — it can have bias problems, miss natural anomalies, be complicated to develop or may not contribute any new information to the existing real-world data. Data quality is tied to the model that developed it. Yet, Gartner believes, the pros outweigh the cons and the vendor landscape is rapidly expanding to meet the demand for more training and test data in AI. Increased adoption of simulation techniques will accelerate this trend.

***User Advice:***

- Identify areas in your organization where data is missing, incomplete or expensive to obtain, thus, currently blocking AI initiatives. In regulated industries, such as pharma or finance, exercise caution and adhere to rules.
- Where personal data is required but data privacy is a requirement consider synthetic variations of the original data or synthetic replacement of parts of it.
- Begin with the sampling approach and leverage data scientists to ensure statistical validity of the sample and distribution of the synthetic data.
- Mature toward the simulation-driven approach, emphasizing creating agents and processes within a simulation framework to generate permutations of interactions that result in synthetic data.
- Above all, leverage specialist vendors while the technology matures.

***Business Impact:*** Synthetic data promises to accelerate training data development, improve precision, reduce costs and cover more scenarios resulting in a more quickly developed and resilient AI solutions. Further, synthetic data can act as a democratizer for smaller players as they try to compete with data-laden tech heavyweights. Privacy restrictions are an additional major driver of this technology. As a result, we see the benefit as "high." Today, we see increased adoption of synthetic data approaches across industries in particular automotive, robotics, content generation, retail, fraud, finance, defense, and logistics along with early shoots of use in development of synthetic speech and natural language data for NLP applications. Enterprises should expect a rapid growth in the use of these techniques over the next three years.

***Benefit Rating:*** High

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** AiFi; Apprente; Archarithms; Bitext; Kinetic Vision; Mapillary; May Mobility; Neuromation; Simudyne; TwentyBN

***Recommended Reading:*** "Predicts 2019: The Democratization of AI"

"Maverick* Research: Use Simulations to Give Machines Imagination"

"Top 10 Strategic Technology Trends for 2019: AI-Driven Development"

"How to Develop the Right Technical and Human Architectures for Digital Business"

"Elevating Test Data Management for DevOps"

## Knowledge Graphs

***Analysis By:*** Stephen Emmott

***Definition:*** Knowledge graphs are data structures in which disparate data about entities (including people, companies, and digital assets) is codified as a graph — a network of nodes and links ("edges") — rather than tables of rows and columns. This enables information ("knowledge") to be located (knowledge graph as an index) or synthesized (knowledge graph as a data source) on demand.

***Position and Adoption Speed Justification:*** Google's Knowledge Graph (Google search) and the Microsoft Graph (Office 365) are evidence of the growing popularity of knowledge graphs due to their ability to encode and interrelate disparate data, whether structured or unstructured, at source. Both companies use knowledge graphs to enhance the relevance of search, and provide information "cards" that are synthesized directly from their graphs. This supports collaboration and sharing, search and discovery, and the extraction of insights through analysis (proactive recommendations of which documents to read or colleagues to consult, for example).

Specialist vendors offer graph-based capabilities that support the creation and management of knowledge graphs that can serve a range of use cases within the enterprise. Products in a variety of markets — such as text analytics and insight engines — also include the underlying graph technology upon which to build knowledge graphs and enhance functionality.

Knowledge graphs represent the application of graph technology and so have to be built by encoding content, sourced both within and external to the enterprise. Knowledge graphs within the enterprise remain a consideration for some — but a reality for few. Resistance to adoption is slowing or precluding their establishment for most enterprises, hence the steady ascendance to the Peak of Inflated Expectations coupled with a long time to the Plateau of Productivity.

***User Advice:*** Although available as stand-alone products from niche vendors, the knowledge graphs' benefits are typically realized through the wider platforms and applications they service. Application leaders should evaluate how vendors apply knowledge graph concepts to determine how vendor solutions could benefit their digital business platform. Enterprises should familiarize themselves with the graphs, and specifically knowledge graphs, that are already in play within their digital platforms. The knowledge graph may well be a subset of a wider graph, and embedded within various platforms and applications. Enterprises should seek to gain access to their knowledge graph(s) with a view to including them within their data governance and management. Related to this, the data needs to be accessible for inspection and moderation by subject-matter experts within the business. Beyond "received" knowledge graphs, you should identify use cases where there is a need for custom-made knowledge graphs and evaluate products that facilitate this.

Graphs are ideally suited to storing data extracted from the analysis of unstructured sources such as documents using natural language technologies, but are also capable of storing structured data, including metadata that implicitly provides structure and context. A defining aspects of knowledge graphs — and a distinguishing factor from graphs in general — is their "entity centricity." People, events and other data points can be identified through analysis of unstructured data prior to ingestion, and subsequent disambiguation within the knowledge graph once contextualized. Using graph analysis, organic and dynamic relationships between entities (digital assets and people, for example) and usage (interactions and processes) can be discovered and exploited automatically. Knowledge graphs require substantial domain expertise when you populate and maintain them current.

***Business Impact:*** Organizations can expect significant value from knowledge graphs in many areas — in fact, wherever immediate or proactive (recommendations) access to information is needed.

This might be in terms of supporting external constituencies (such as customers); in supporting self-help or purchase-related decision-making; suppliers or resellers seeking product information; or employees needing improved digital dexterity.

Within the enterprise, it might include

- **Collaboration/sharing:** Interrelated data is contextualized data, thereby aiding its discovery and findability via implicit and indirect connections (recommending relevant documents, for example).
- **Investigation and audit:** With the capability to capture and disambiguate entities that map to entities in the real world, relationships can be explored (for example, to identify fraud, supply-chain risks or patterns of collaboration).

- **Analysis/reporting:** Once structured in the form of a knowledge graph, unstructured data can be queried, thereby preprocessing it for analysis (extracting key topics from recent messaging, for example).
- **Interoperability and automation:** Autonomous reading and "understanding" of data supports integrating and operationalization of data for different enterprise applications (labelling data for use in machine learning, for example).
- **Data reuse/cross-industry collaboration:** Being linked conceptually "chunks" data and metadata, which can be shared more easily and hence foster reuse (importing pre-existing knowledge graphs such as DBpedia, in part or whole, for example).

***Benefit Rating:*** High

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** Attivio; Diffbot; Facebook; Intelligent Views; Maana; Neo4j; Semantic Web Company (PoolParty); Skelter Labs; Smartlogic; TopQuadrant

***Recommended Reading:*** "Magic Quadrant for Data Management Solutions for Analytics"

"Magic Quadrant for Insight Engines"

"Magic Quadrant for Operational Database Management Systems"

"Hype Cycle for Data Science and Machine Learning, 2018"

"Automate Knowledge Management With Data Science to Enable the Learning Organization"

"Digital Workplace Graphs Promise to Improve Productivity and Collaboration, but Risks Exist"

## Personification

***Analysis By:*** Andrew Frank

***Definition:*** Personification allows marketers to deliver targeted digital experiences to individuals based on their inferred membership in a characteristic customer segment rather than based on knowledge of their personal identity.

***Position and Adoption Speed Justification:*** Tension between personalization and privacy restrictions is generating innovative approaches to experience targeting that avoid personal data. Personification's goal is to deliver the relevance and marketing value of personalization without processing personal data that is subject to regulatory restrictions.

The precise boundaries around personal data vary by jurisdiction. But certain data available during a digital interaction, such as a subject's regional location, type of device being used and contextual factors such as the time of day and local weather are not sufficient to uniquely identify an individual. Similar clues, such as the type of content surrounding an advertisement, or clickstream behavior during the course of a site visit, are similarly anonymous as long as they are not associated with any unique or persistent identifier.

As legal and technical challenges to the unfettered use of personal data advance, marketers and solution providers seek opportunities to apply modeling and advanced analytics to extract more powerful inferences from contextual data to deliver on the promise of personification. Scaling these capabilities, however, will require changes to the cookie and device ID-based practices that underpin much of today's personalization and programmatic advertising markets, such as standard models to encode and express anonymous contextual and behavioral information.

Analytics firms, data-savvy marketers, and a few leading publishers, such as The New York Times, are spearheading advances in AI-driven insights that summarize and target audience interests and propensities using anonymized data. Although these approaches tend to be marketer- or publisher-specific, the technology is moving fast and the stakes are high, so expect continuing progress for the next four or five years. Meanwhile, marketers must reassess aggressive visions of one-to-one personalization at all stages of the customer journey, especially where consent or data are lacking.

***User Advice:*** Marketers must:

- Re-evaluate personalization strategies to focus on content designed to help consumers in ways that both encourage opt-in and require less personal data-driven guesswork to connect consumers with relevant content.
- Make a clear-eyed assessment of the degree and circumstances under which customers and prospects are likely to grant broad consent to tracking and profiling. Few brands can claim a fan base large and devoted enough to assume most interactions can be personalized with consent to use personal data. Assure that customers who decline consent still receive valuable experiences. Beware of tactics that use commercial incentives to gain consent as this can be easily revoked and may run afoul of regulations. Communicate a strong value proposition to customers about what they get for permission to use their data.
- Understand all applicable restrictions, both legal and technical, to the use of personal data in marketing. These include laws such as the EU's General Data Protection Regulation (GDPR) and the California Consumer Protection Act (CCPA). Also, understand the evolving privacy features of browsers such as Apple's Safari's Intelligent Tracking Prevention (ITP) and Google Chrome's new APIs.
- Seek ways to maximize the value of contextual data, such as weather, time, device characteristics, traffic source and observable user actions to define and identify personas.
- Use "atomic content" and experimental design to test and refine persona definitions and their associated content experiences.
- Regardless of regional laws, offer customers transparent ways to discover why they're receiving variable content and solicit feedback on your explanations. Work with IT and privacy counterparts to deploy solutions that allow people to manage their data and preferences.

- Separate personas for true consent-based personalization and personification. Personalization activity may inform personification models by extracting contextual data elements, but make sure that personified segments are free of personal data and can't be combined with other data to identify (or reidentify) an individual.

***Business Impact:*** Personification impacts three areas of marketing:

- Targeted advertising is strongly affected by new restrictions on the flow of personal data. By shifting reliance to nonpersonal data, personification has the potential to restore value lost to the digital advertising supply chain. This shift in reliance also avoids further consolidation of market power among platforms most likely to gain large-scale consent to ad targeting based on massive audience engagement (e.g., Google, Facebook and Amazon).
- Direct marketing (such as email and mobile messaging) is increasingly subject to consent restrictions under GDPR. Personification can reduce the extent of personal data required for profiling, reducing resistance to consent while continuing to optimize relevance and engagement.
- Many personalization solutions assume both presence and consent to use visitor data for personalization. Personification can be applied in a broader range of situations and content strategies with less risk.

Personification is an attractive area of research for machine learning because its goal is to make strong inferences from data that is harder to interpret than traditional demographic and behavioral datasets. Its utilization of publicly available data, including public posts and profiles on Twitter, LinkedIn, Instagram, etc., may expose new regional and generational disparities in privacy norms.

***Benefit Rating:*** High

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** Adobe; Adworthy; Amobee; Analytic Partners; BloomReach; Merkle; Nielsen; Oracle; Segment

***Recommended Reading:*** "Use Personification to Balance Personalized Marketing With Privacy and GDPR"

## Explainable AI

***Analysis By:*** Saniye Alaybeyi

***Definition:*** AI researchers define "explainable AI" as an ensemble of methods that make black-box AI algorithms' outputs sufficiently understandable. Gartner's definition of explainable AI is broader — a set of capabilities that describes a model, highlights its strengths and weaknesses, predicts its likely behavior, and identifies any potential biases. It can articulate the decisions of a descriptive, predictive or prescriptive model to enable accuracy, fairness, accountability, stability and transparency in algorithmic decision making.

***Position and Adoption Speed Justification:*** Not every decision an AI model makes needs to be explained. There is considerable hype that is associated with explainable AI today. Although some vendors have introduced early explainable AI capabilities, most are using it for marketing purposes. Therefore, we decided to put explainable AI at prepeak on the Hype Cycle. Gartner anticipates that organizations do and will continue to achieve a lot of fantastic results without the need for full explainability. Depending on the business context, however, privacy, security, algorithmic transparency and digital ethics may demand different levels of requirements for explainability. For example:

- AI that makes decisions about people, such as rejecting a loan application, may require explainability. By law, providers of algorithms must give the user a reason for the rejection.
- According to the EU's GDPR, which took effect in May 2018, users affected by an algorithmic decision may ask for an explanation.
- AI that makes decisions in a closed loop with important consequences, such as autonomous driving, also has a high need for explainability due to ethical and possibly legal reasons.
- The Financial Stability Board (FSB) identified the lack of interpretability of AI and machine learning methods as "a potential macrolevel risk." The same board indicated that a pervasive use of these AI models that lack explainability may result in unintended consequences.
- Explainable AI comes up often during Gartner end-user client inquires, as well as in the news and media. During Gartner vendor briefings, vendors are also starting to claim they have explainable AI available to their customers. The Defense Advanced Research Projects Agency (DARPA) now projects that explainable AI will emerge in transportation, security, medicine, finance, legal and military applications.

***User Advice:***

- Foster ongoing conversations with various line-of-business leaders, including legal and compliance, to gain an understanding of the AI model's interpretability requirements, challenges and opportunities from each business unit. Integrate these findings into the development of the enterprise information management strategy.
- Build partnerships with IT, in particular with application leaders, to explain how the AI model fits within the overall design and operation of the business solution, and to give stakeholders visibility into training data.
- Start with using AI to augment rather than replace human decision making. Having humans make the ultimate decision avoids some complexity of explainable AI. Data biases may still be questioned, but human-based decisions are likely to be more difficult to be challenged than machine-only decisions.
- Create data and algorithm policy review boards to track and perform periodic reviews of machine learning algorithms and data being used. Continue to explain AI outputs within changing security requirements, privacy needs, ethical values, societal expectations and cultural norms.

***Business Impact:*** End-user organizations may be able to utilize some future interpretability capabilities from vendors to be able to explain their AI outputs. But eventually, AI explainability is the end-user organization's responsibility. End users know the business context their organizations operate in, so they are better-positioned to explain their AI's decisions and outputs in human-understandable ways. The need for explainable AI has implications for how IT leaders operate, such as consulting with the line of business, asking the right questions specific to the business domain, and identifying transparency requirements for data sources and algorithms. The overarching goal is that models need to conform to regulatory requirements and take into account any issues or constraints that the line of business has highlighted. New policies around the inputs and boundary conditions on the inputs into the AI subsystem, how anomalies are handled, how models are trained and the frequency of training need to be incorporated into AI governance frameworks. Many questions about the suitability of the AI model will rely on a clear understanding of the goals of the application(s) being designed.

***Benefit Rating:*** High

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** H2O.ai; IBM; Microsoft; simMachines

***Recommended Reading:*** "Top 10 Data and Analytics Technology Trends That Will Change Your Business"

"Build Trust With Business Users by Moving Toward Explainable AI"

"Predicts 2019: Digital Ethics, Policy and Governance Are Key to Success With Artificial Intelligence"

## At the Peak

### Edge AI

***Analysis By:*** Erick Brethenoux; Martin Reynolds; Alan Priestley

***Definition:*** Edge AI refers to the use of AI techniques embedded in IoT endpoints, gateways and edge devices, in applications ranging from autonomous vehicles to streaming analytics. While predominantly focused on AI Inference, more sophisticated system may include a local training capability to provide in-situ optimization of the AI models.

***Position and Adoption Speed Justification:*** Edge AI will be implemented in a range of different ways, depending the application and design constraints of the equipment being deployed — form factor, power budget (i.e., battery powered vs. mains powered), data volume, decision latency, location, security requirements etc.:

- Data captured at an IoT endpoint and transferred to an AI system hosted within an edge computer, gateway or aggregation point: In this architecture, the IoT endpoint is a peripheral to the AI system. The endpoint acts as a data gatherer that feeds this data to the AI system. An example of this is environmental sensors deployed for a smart agriculture application.

- AI embedded in the IoT endpoint: In this architecture, the IoT endpoint is capable of running AI models to interpret data captured by the endpoint and drives some of the endpoints' functions. In this case the AI model (e.g., a machine learning model) is trained (and updated) on a central system and deployed to the IoT endpoint. An example is a medical wearable that leverages sensor data and AI to help visually impaired people navigate the world in their daily lives.

The applications that are starting to see increasing adoption of edge AI include those that are latency sensitive (e.g., autonomous navigation), network availability (e.g., remote monitoring), and data intensive (e.g., video analytics). While many of these applications are still in R&D or trial phases, and widespread adoption is at least a few years away, other such as video analytics (leveraging deep learning methods and deployed as deep learning models at the endpoints) are starting to see adoption — driven by the rapid growth in deployment of surveillance cameras and the need for real time interpretation of captured video streams.

***User Advice:*** Enterprise architecture and technology innovation leaders should:

- Evaluate when to consider AI at the edge vs. a centralized solution. Applications that have high-communications costs are sensitive to latency, or ingest high volumes of data at the edge are good candidates for AI at the edge.
- Determine whether the new AI developments in deep learning (DL) are applicable to their IoT deployments, or whether traditional data analytics and AI methodologies are adequate. In the case of DL, investigate automated development environments first to minimize the learning curve and accelerate prototyping.
- Deploy analytics across the key IoT system elements — IoT edge, IoT platform and enterprise — so that the processing is closer to the data source, the communications overhead is reduced, and meaningful insights are extracted more quickly. It will be key for some deployments of data aggregation and transformation, as well as event-based architecture.
- Use the IoT gateway as the aggregation and filtering point to perform most of the edge analytics functions. Make an exception for compute-intensive endpoints, where AI-based analytics can be performed on the devices themselves.
- Assess the risk associated with the non-deterministic nature of many AI techniques where it may not be possible to control or replicate the analysis results.

***Business Impact:*** By incorporating AI techniques at the edge, enterprises may be positively impacted as follows:

- Improved operational efficiency, such as enhanced visual inspection systems in a manufacturing setting.
- Enhanced customer experience, with faster execution time, performed at the edge.

- Reduced latency in decision-making, with the use of streaming analytics and migration to an event-based architecture,
- Communication cost reduction, with less data traffic between the edge and the cloud
- Increased availability even when the edge is disconnected from the network.
- Reduced storage demand through a more reactive exploitation of the data and a better estimate of its potential obsolescence

***Benefit Rating:*** Transformational

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** Amazon; Baidu; Google; Huawei; Intel; Matroid; Microsoft; Neurala; NVIDIA; Qualcomm

***Recommended Reading:*** "AI on the Edge: Fusing Artificial Intelligence and IoT Will Catalyze New Digital Value Creation"

"Innovation Insight for Artificial Intelligence of Things — Machine Learning in the IoT Era"

"Managing the Data Tsunami: How AI and Edge Computing Will Enhance IoT Analytics"

"Cool Vendors in AI Semiconductors"

### Low Earth Orbit Satellite Systems

***Analysis By:*** Bill Menezes

***Definition:*** Low earth orbit (LEO) communications satellites can provide global broadband or narrowband voice and data network services, including to regions with little or no existing terrestrial or satcom coverage. LEO systems operate at lower altitudes (1,200 miles or less) than predominant geostationary (GEO) systems (approx. 22,000 miles). Planned LEO broadband systems of up to thousands of satellites will provide connectivity at significantly lower latency and, depending on system technology, higher data speeds than GEO and current LEO systems.

***Position and Adoption Speed Justification:*** Demand for LEO services is well-defined, but Gartner rates newer and planned systems as embryonic given the lengthy time frames to plan and deploy such systems, plus availability of sufficient radio frequencies and inexpensive directional antennas. Only about 51.2% of households globally had internet access at YE18, according to the International Telecommunication Union. Lack of broadband access hinders economic growth, thereby limiting enterprise business potential in underserved regions. Over the next decade, one or more next-generation LEO systems will likely extend broadband to at least 60% of the world's population. However, as of 1Q19, most new systems proposed to address this need remained in the planning stages. One of the planned systems closest to commercial deployment — OneWeb's planned 600-satellite, low-earth orbit constellation — launched its first six satellites in February

2019, with a 2021 target for global commercial service. Further, not all currently tested or proposed systems likely will come to fruition.

***User Advice:*** Enterprises with current or planned business interests in remote or underserved global regions should closely follow LEO system development to align narrowband and broadband connectivity requirements with technology capabilities and service availability. Planned systems include:

- OneWeb, which reduced its planned global constellation to 600 inexpensive satellites from the original 900. The system targets downlink speeds of multiple Gbps at round-trip latency of 10 ms to 30 ms. Terminals for fixed and mobile applications would provide a broadband satellite connection plus 2G, 3G and 4G LTE device connections.
- SpaceX venture Starlink has outlined a plan to operate a 4,425-satcom LEO constellation to provide global broadband internet access. SpaceX launched the first two test satellites for its planned Starlink system in February 2018, but does not expect full commercial broadband coverage until 2024. The full constellation will require more than 100 successful launches.
- Telesat, which already operates a number of GEO satellites, plans a constellation of 117 or more LEO satcoms to provide global broadband connectivity. The Canadian company launched a test satellite in January 2018, targeting commercial service in 2022.
- Amazon's "Project Kuiper" is seeking regulatory permission for a LEO constellation of 3,236 satellites to provide broadband internet access to underserved areas. As of 2Q19, there was no announced service date.

Proposed broadband LEO systems have received the most attention, but planned or existing LEO services include those supporting narrowband data for IoT and digital imaging, or satellite phone and messaging services.

***Business Impact:*** Satellites can cover all remote or underserved geographies, providing the broadband connectivity critical to operating in those areas. In addition, planned LEO satellite constellations can provide low-latency backhaul for terrestrial technologies such as remote cellular towers and Wi-Fi hotspots, possibly spurring new development of those networks in areas where high costs have prevented wired WAN backhaul connections. Traditional service provider business models may be disrupted if providers such as Amazon launch systems relying on advertising-supported services, instead of subscription-supported legacy models, to address the large number of targeted users who may be unable to pay for services.

***Benefit Rating:*** Transformational

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** Amazon; Iridium; OneWeb; ORBCOMM; SpaceX; Telesat

***Recommended Reading:*** "Satellite Communications Strengthen Resilience Planning"

"Market Trends: New Satellite Constellations Will Provide Revolutionary Opportunities for Connecting the IoT"

## Autonomous Driving Level 5

***Analysis By:*** Jonathan Davenport

***Definition:*** Level 5 or "full" automation is a definition established by SAE International that refers to self-driving vehicles that can operate without human intervention in every situation and condition. As a result, there is no longer any requirement for a vehicle to be fitted with pedals, brakes or a steering wheel. The autonomous vehicle system controls all driving tasks.

***Position and Adoption Speed Justification:*** There is great excitement surrounding fully autonomous vehicles. However, achieving full autonomy is incredibly complex, with some believing that Level 5 autonomy is not possible and certainly won't be possible for a decade or more. Level 5 vehicles will further the reach of mobility as a service (MaaS). MaaS vehicles will no longer be limited to certain geofenced areas, and instead will be capable of taking passengers anywhere they want to go. They will have even farther-reaching consequences for the transport and logistics industries, which will no longer require human drivers.

Technology advancements necessary for Level 4 vehicles will be developed further for Level 5 use cases. For an autonomous vehicle, monitoring its environment is core to the technology that allows it to function independently. To gather situational data, vehicles such as those Waymo is developing are fitted with an array of sensors that provide a 360-degree field of view using lidar, camera, radar and other supplementary sensors. These sensors need to be capable of gathering data around the vehicle as it moves to create a 3D picture of the vehicle's surroundings. The ability for the artificial intelligence to understand what it sees through these sensors, along with lowering costs, is where a lot of the investment is being made.

This development needs to build effectively across a variety of conditions. Conditions include daytime, nighttime, and different weather and light conditions to identify dynamic and static objects, including pedestrians, cyclists, other vehicles, traffic lights, construction cones and other road features. So, the improvement between Levels 4 and 5 will be incremental, but nonetheless significant.

Disengagements identify where the vehicle is not capable of dealing with a situation on a road and requires a human to take control. While much testing is done in virtual simulations, a linear decline in disengagements is not necessarily expected, as the more challenging the testing, the higher the likelihood of a disengagement. However, over time, disengagements will decline to a point where companies can prove that their vehicle is safe to operate without human oversight in all conditions.

***User Advice:*** The design of Level 5 vehicles will need to differ from that of their Level 4 counterparts, which were typically focused on geofenced urban and suburban transportation. Level 5 vehicles must be capable of transporting people long distances, allowing the provision of intercity MaaS offerings for the first time.

Trucks should no longer be designed with a cab for a human occupant. Thought will need to be given as to how the change in design will impact aerodynamics and associated fuel economy.

Gartner assumes that, to deliver full autonomous driving functionality, Level 5 autonomous driving ECU must have:

- More than 100 TFLOPS of processing capability
- More than 128GB of DRAM
- More than 2TB of nonvolatile storage
- 1 Gbps or faster data link interface

***Business Impact:*** Fully autonomous vehicles have the potential to radically affect lives. Different activities can be undertaken while the vehicle is in motion, while road safety will improve. This may lead to a relaxation of certain safety laws, allowing the vehicle interior to be rethought. As a result, people will seek to utilize their time in a vehicle more productively. This will lead to the vehicle becoming the third living space, where people engage with family and friends, watch videos, play computer games, and work. There is even the potential for autonomous vehicles to lead to services such as haircuts or massages being delivered while in transit between locations, and workouts being undertaken in a vehicle as part of a daily commute.

Industries such as logistics will utilize fully autonomous fleets. This will radically change the distance that vehicles can travel in a single day (as they are no longer limited by driver safety hours). Trucks will look very different to how they do today as they start to be designed without a cab for the driver to sit in.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Apple; BMW; Bosch Group; nuTonomy; NVIDIA; Tesla; Uber; Waymo

***Recommended Reading:*** "Maverick* Research: Autonomous Mobile Structures Will Fuel the Sharing Economy"

"Automotive and Smart Mobility CIOs Must Play a Crucial Role in the Autonomous Driving Technology Stack"

"Market Insight: Autonomous Driving Creates Opportunities for AI-Enabled Personal Technologies"

## Edge Analytics

***Analysis By:*** Eric Hunter; W. Roy Schulte; Jim Hare

***Definition:*** "Analytics" is the discipline that applies logic (i.e., "rules") and mathematics ("algorithms") to data to provide insights for making better decisions. "Edge" analytics means that the analytics are executed in distributed devices, servers or gateways located away from corporate data centers or cloud servers closer to where data from "things" (commonly sensors) is being generated.

***Position and Adoption Speed Justification:*** Edge analytics moved further along the Hype Cycle toward the Peak of Inflated Expectations driven by increased expectations for edge analytics via machine learning and advances in the hybrid cloud. Five drivers for edge analytics use cases include latency/determinism, local interactivity, data/bandwidth considerations, privacy/security, or limited autonomy. Edge analytics offerings primarily support decentralized deployments of device-isolated insights. However, as connectivity advances and the demand for cross-device analytics increase, edge analytics will be tasked not only with providing edge-resident insights, but also to support conversion and compression to move data to hybrid cloud platforms for aggregation.

An increasing number of IoT platform and analytics vendors are adding the ability to deploy and run small-footprint analytics packages on edge devices — supporting both endpoints and aggregation devices like an IoT gateway. It reflects the shifting balance between edge and cloud computing. Public cloud providers are further accelerating this trend with announcements from Amazon Web Services (AWS Outposts), Microsoft (Azure Stack), Google (Anthos) and IBM (OpenShift). This trend is being driven by several factors including rightsizing connectivity to the edge, real-time analytics and data privacy considerations.

***User Advice:*** Analytics leaders should consider edge analytics across the following five imperatives:

- **Limited Autonomy.** An individual device, asset or even a larger distributed site must provide analytic insights even in the midst of disconnection from cloud or data center infrastructure and resources
- **Privacy/Security.** Regulations or data privacy laws require that data be kept within the location of origin or the organization deems the transfer of data to introduce too many security vulnerabilities
- **Latency/Determinism.** Network connectivity does not have the ability to support desired latency or stability requirements
- **Local Interactivity.** Cross-device interdependencies as part of a larger system require edge-resident analytics
- **Data/Bandwidth.** It would cost too much to upload the full volume or fidelity of generated data, and there is no benefit to moving device-level data to a central location for aggregated analysis. Another scenario includes edge analytics for support of centralized cloud or data center analytic strategies by converting/compressing edge-generated data alongside for network transmission

***Business Impact:*** Running analytics at the edge will become commonplace for both data and analytics and IoT architectures by the time it reaches the plateau.

Advantages include:

- **Faster response times.** Many sensors deliver digital and analog data at very low millisecond or sub millisecond intervals. When that data is sent to a central location for analysis, delays are introduced, and it loses its value for real-time requirements.
- **Reduced network bottlenecks.** Minimizes the risk of congesting device networks with full-fidelity or high-bandwidth data transmission (video, millisecond interval sensor reads and analog sensors).
- **Data filtering.** This reduces the data management and storage overhead by using edge analytics to look for just the actionable data. As a result, only the necessary data is analyzed or sent on for further analysis.
- **Reliability.** The remote location can remain in operation even if the network, cloud servers or data centers are unavailable.
- **Reduced communications cost.** Device-only edge analytics eliminate communication costs while edge device-based conversion and compression can dramatically lower costs versus sending raw analog or full-fidelity digital data to a central cloud or data center

Disadvantages include:

- **Increased complexity.** Remote, distributed analytics deployment and management make the deployment and management more complicated than for aggregated data in a single location — particularly when devices are heterogeneous in nature — lacking in standardization.
- **Reduced data granularity.** There is a potential loss of useful insight by discarding raw data stored locally as "data exhaust."
- **Lack of cross-device analytics.** Unless device data is transmitted to a consolidated location from the edge, leaders can lose the ability to deliver cross-device insights and analytics.
- **Device maintenance and technical currency.** Edge analytics will require more capable devices that increase demands for monitoring and maintenance of device health along with introducing demands for keeping devices up-to-date with both software and hardware revisions.

***Benefit Rating:*** High

***Market Penetration:*** 5% to 20% of target audience

***Maturity:*** Adolescent

***Sample Vendors:*** Amazon Web Services; Arundo; Element; FogHorn; Iguazio; Microsoft Azure; Particle; PTC (ThingWorx); SAS; Sisense

***Recommended Reading:*** "Top Strategic IoT Trends and Technologies Through 2023"

"Top 10 Strategic Technology Trends for 2019: Empowered Edge"

"The Edge Completes the Cloud: A Gartner Trend Insight Report"

"Deploying IoT Analytics, From Edge to Enterprise"

"4 Technology Sources for an AI-Enabled Enterprise"

"What Tech CEOs Must Know About Edge Computing in 2019"

## AI PaaS

***Analysis By:*** Bern Elliot

***Definition:*** Cloud artificial intelligence and machine learning platform services are known collectively as AI cloud services. These solutions provide AI model building tools, APIs and associated middleware that enable the building/training, deployment and consumption of machine learning models running on prebuilt infrastructure as cloud services. These cover vision, voice and general data classification and prediction models of any type.

***Position and Adoption Speed Justification:*** Hype around AI cloud services continues to increase, with the leading cloud service providers, including Alibaba, Amazon Web Services (AWS), Baidu, Google, IBM and Microsoft, clamoring to become the platform of choice. Over the past several years, AI applications utilizing cloud services have continued to gain traction and acceptance in the market both by data scientists and developers alike. The promise of using cloud services to more quickly and easily build and deploy AI solutions will push this technology to the Peak of Inflated Expectations. However, this will be followed by some level of disillusionment as organizations experience and understand the limitations of the offerings.

AI cloud service offerings are primarily focused on the three key areas of machine learning, natural-language processing and computer vision. The AI cloud approach is continuing to disrupt the more-established on-premises data science and machine learning platform market, especially as organizations experiment and build AI prototypes. The availability of specialized hardware instances with AI-optimized chips and large amounts of data storage makes the cloud an ideal environment for organizations to build and deploy AI applications without the risks, costs and delays of conventional on-premises procurement. Cloud service providers are also offering packaged APIs and tools that make it easier for developers to integrate AI capabilities into existing applications.

***User Advice:*** IT leaders responsible for AI-enabled applications should take these steps:

- Consider AI cloud services over on-premises options to reduce the overhead of developing and for easier deployment and elastic scalability.
- Improve the chances of success of your AI strategy by experimenting with different AI techniques and AI cloud services providers, using the exact same dataset, and then selecting one that best addresses your requirements. Consider using an A/B testing approach.
- Increase your organization's AI project success by selecting AI cloud services that addresses your data science, developer and infrastructure requirements and skill limitations. Pretrained AI cloud services often require no (or limited) data science expertise.

***Business Impact:*** AI cloud services offerings are focused on the three key AI services of machine learning (ML), natural-language processing and computer vision:

- Machine learning: Packaged ML services offered by the AI cloud service providers to unify the end-to-end ML workflow. Advanced solutions providing integrated access to all phases of the project — from data preparation to deployment in a managed training and execution environment accessible through APIs. Though many fail to deliver data preparation and augmentation capabilities.
- For technical professional teams with little to no data science expertise, features like automated algorithm selection and training-set creation will offload some of the complexity of the project and leverage existing expertise on operating cloud services.
- Natural-language processing: Organizations can use pretrained NLP systems to create cloud-based language solutions for a variety of use cases. Major AI cloud services vendors provide a language-processing catalog as part of their portfolio. This includes tools for developing and maintaining conversational and chatbot solutions, as would be used by simpler Q&A applications or by more-sophisticated conversational virtual assistants. Additional language services include transcription, translation, speech-to-text, text-to-speech and text analytics.
- Computer vision: This enables organizations to use pretrained visual models for generic images, though not for custom images. This may enable more rapid development of applications that process visual information. Major AI cloud services vendors provide a catalog of services for both images and video. A key capability is support for facial detection, recognition and analysis. Additional visual services include optical character recognition (OCR), handwriting recognition (HWR) label extraction, logo detection, and content moderation. Pretrained systems often require no data science expertise and allow developers to gain unique and new insight by invoking an API.

The combination of the above as cloud services will accelerate digital business technology platform viability in the short term.

***Benefit Rating:*** High

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Adolescent

***Sample Vendors:*** Alibaba Group; Amazon Web Services; Baidu Cloud; Google (Cloud AI); IBM (IBM Cloud); Microsoft (Azure AI Platform)

***Recommended Reading:*** “Market Guide for AI Portfolio Cloud Service Providers”

## Biochips

***Analysis By:*** Gaurav Gupta

***Definition:*** Biochips relate to several technologies that combine semiconductor and biological sciences. The most common form is based on an array of molecular sensors on the chip surface — typically referred to as “lab-on-chip.” The underlying mechanism utilizes microfluidic microelectromechanical systems (MEMS) technology. Biochips are used to analyze biological elements, such as DNA, ions, ribonucleic acid and proteins, in addition to certain chemicals.

***Position and Adoption Speed Justification:*** A significant rise in the adoption of personalized medicine and the increasing focus on technological advancements are the key factors that are projected to encourage the development of the global biochips market (a reason to move its position in Hype Cycle). But, factors such as high cost, lack of knowledge about it in emerging nations, and absence of common regulatory standards will be some of the issues that will delay market growth. Also, an alternative technology, i.e., next-generation sequencing (NGS) technology will create hurdles in the growth of biochips.

***User Advice:*** Key players in the market should emphasize on targeting the developing economies, which hold immense growth opportunities.

In addition, they should focus on:

- Using mergers and acquisitions as a way to gain access to technology and grow.
- Enhance market penetration by focusing on new products with this application.
- Collaborate with Government to get funding for technology development.
- Advertise other benefits of biochips. One such example is that it can replace animal testing that is considered unethical and is expensive.

***Business Impact:*** Private organizations along with the governments of many countries have increasingly become aware of the several benefits of biotechnology.

The products based on DNA microarrays, protein chips, lab-on-a-chip, and organ-on-a-chip technologies will alleviate existing issues associated with time and cost in their respective applicable fields.

Another impact will be seen in medical field for detecting diseases and in biotechnology to detect oxygen and pH.

***Benefit Rating:*** High

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Emerging

***Sample Vendors:*** Abbott; Agilent; Cellix Bio; GE Healthcare; imec; Illumina; Mitsubishi Chemical; Owlstone; PerkinElmer; Thermo Fisher Scientific

***Recommended Reading:*** "Biochips: Where Biology Meets Technology"

## 5G

***Analysis By:*** Sylvain Fabre

***Definition:*** 5G is the next-generation cellular standard after 4G (Long Term Evolution [LTE], LTE Advanced [LTE-A] and LTE-A Pro) defined in several standards — International Telecommunication Union (ITU), Third Generation Partnership Project (3GPP) and European Telecommunications Standards Institute (ETSI). The official ITU specification, IMT-2020 targets maximum downlink and uplink throughputs of 20 Gbps and 10 Gbps respectively, latency below 5 milliseconds and massive scalability. New system architecture includes core slicing as well as wireless edge.

***Position and Adoption Speed Justification:*** 5G core and edge topology also need to be added to realize the full benefits of 5G, but this may occur later toward 2022 to 2025.

Thirty-nine operators have announced 5G rollouts (Source Global mobile Suppliers Association [GSA], April 2019), just under 5% of mobile networks (excluding mobile virtual network operators [MVNOs] and subbrands). 15 have launched fixed wireless access (FWA).

3GPP Release 16 is scheduled to be frozen in March 2020.

The larger early communications service providers' (CSPs') 5G deployments so far include:

- In the U.S. by:
  - AT&T
  - Verizon
- In South Korea by:
  - kt
  - LG U+ (estimated >5,000 base stations)
  - SK Telecom
- In Australia by:
  - Telstra

Through 2022, organizations will mainly utilize 5G to support Internet of Things (IoT) communications, high-definition video.

Use of higher frequencies and massive capacity, will require very dense deployments with higher frequency reuse. Here we see regional differences, whereby mmWave will be leveraged in the U.S. but not elsewhere.

Gartner expects many 5G deployments to initially focus on islands of deployment, without continuous national coverage, typically reaching less than full parity with existing 4G geographical coverage by 2022 in developed nations.

Less than 45% of CSPs globally will have launched a commercial 5G network by 2025. Uncertainty about the nature of the use cases and business models that may drive 5G is currently a source of uncertainty for many CSPs, enterprises, and technology and service providers (TSPs).

***User Advice:*** TSP product managers should:

- Focus mobile infrastructure planning on LTE, LTE-A, LTE-A Pro, small cells and heterogeneous networks (HetNets), as part of a planned transition toward 5G.
- Ensure backward compatibility to preceding generation (LTE) devices and networks. This is necessary because initial 5G coverage may be limited, so new 5G devices need to be able to seamlessly transition to 4G infrastructure as a fallback. 3GPP is evaluating only 4G/5G interoperability; IP Multimedia Subsystem (IMS) will be required to handle additional intergeneration interwork for 5G.
- Focus on related architecture initiatives — such as software-defined network (SDN), network function virtualization (NFV), CSP edge computing and distributed cloud architectures, as well as end-to-end security in preparation for 5G. 4G mostly follows a traditional cellular network architecture, but 5G will prove more complicated and a heterogeneous network (HetNet) will be commonly adopted, with a denser grid in hot spots, so topology changes must be planned. Operations need further automation and orchestration at scale as well, so self-organizing network (SON) frameworks need to be in place.
- Provide solutions where new frequency allocations (preferably) should be used for the latest technology — 5G — to benefit from lower cost per byte, higher bandwidth and more capacity.
- Help CSPs in their new focus into vertical solutions (B2B) for 5G.
- Have a clear understanding of specific verticals and their use cases for more effective consultative selling of their 5G solutions.
- Build their ecosystem of partners to target verticals more effectively with 5G.

Enterprise business leaders should:

- Identify use cases that definitely require the high-end performance of 5G; these may be few or even nonexistent for many verticals.
- Evaluate the multiple alternatives currently available that may prove adequate and more cost-effective than 5G for many use cases (for example, low-power wide-area [LPWA] such as NarrowBand Internet of Things [NB-IoT], long-range [LoRa], Wireless Smart Ubiquitous Networks [Wi-SUN]).

***Business Impact:*** Gartner Enterprise 5G surveys indicate that vertical use cases with 5G would be first motivated by operational cost savings. In addition, the vertical users for 5G appear to value lower latency from ultrareliable and low-latency communications (URLLC) and expect 5G to outperform rivals in this area.

With Massive Machine-Type Communications (mMTC), scenarios of very dense deployments can occur, supported by the 5G target of 1 million connected sensors per square kilometer.

5G enables, principally, three technology deployment and business scenarios, which each support distinct new services, and possibly new business models (such as latency-as-a-service):

- Enhanced mobile broadband (eMBB) supports high-definition video.

- Massive Machine-Type Communications (mMTC) supports large sensor and IoT deployments.
- Ultrareliable and low-latency communications (URLLC) covers high availability and very low latency use cases, such as remote vehicle/drone operations.

URLLC and mMTC will be implemented after eMBB. Only eMBB addresses the traditional mobile handset requirement of ever higher throughput. URLLC addresses many existing industrial, medical, drone and transportation requirements — where reliability and latency requirements surpass bandwidth needs. Finally, mMTC addresses the scale requirements of IoT.

***Benefit Rating:*** High

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Adolescent

***Sample Vendors:*** Cisco; Ericsson; Huawei Technologies; NEC; Nokia; Samsung; ZTE

***Recommended Reading:*** "Market Guide for CSP Edge Computing Solutions"

"3 Requirements to Successfully Offer Commercial 5G Services"

"IT Market Clock for Communications Service Provider Infrastructure, 2018"

"Magic Quadrant for LTE Network Infrastructure"

## Graph Analytics

***Analysis By:*** Mark Beyer; Rita Sallam

***Definition:*** Graph analytic techniques allow for the exploration of relationships between entities such as organizations, people or transactions. Graph analytics consist of models that determine the "connectedness" across data points to describe nodes/clusters and demarcation points. Nodes are connected explicitly or implicitly, indicating levels of influence, frequency of interaction, or probability. Graph analytics are typically portrayed via multiperspective visualization for business user consumption.

***Position and Adoption Speed Justification:*** Graph analytics climbed slightly over the Peak of Inflated Expectations due to increased awareness in early 2019. The growing adoption of graph analytics is driven largely by the need to identify and explore insights into relationships for specific business use cases. This requires analysis across an exponentially larger amount of heterogeneous data, which is not well-suited to relational storage and analysis. These highly complex models are developed and used within machine learning with the output stored in graph databases. GraphDBs present an ideal framework for storing, manipulating and analyzing the widely varied perspectives in the graph model due to their graph-specific processing languages, capabilities and computational power. At the same time, established AI techniques (such as Bayesian networks) are increasing the power of knowledge graphs and the usefulness of graph analytics by introducing further nuance in representational power.

Graph analytics processing is a core technology underlying many other advanced technologies, such as virtual personal assistants, smart advisors and other smart machines. Various platforms also use graph analytics to identify important findings.

Analytics experts are beginning to claim specialization in graph analytics, and some traditional analytics vendors are offering capabilities that enable users to build interactive network graphs. Many providers are introducing graph engines embedded in their platforms, which means that some of the adoption curve will remain almost hidden. Importantly, the utilization of graph analytics is necessary in order to develop knowledge graphs — a highly useful output of graph analytics. Commercialization of graph analytics is still at quite an early stage, with a small number of emerging players. The method of storing and processing data within graph databases differs from traditional relational data, creating a demand for new skills related to graph-specific knowledge, which may limit growth in adoption. Examples of the new skills required include knowledge and experience with the Resource Description Framework (RDF), Property Graphs, SPARQL Protocol and RDF Query Language (SPARQL), and emerging languages such as Apache TinkerPop or the recently open-sourced Cypher.

***User Advice:*** Data and analytics leaders should evaluate opportunities to incorporate graph analytics into their analytics portfolio and strategy. This will enable them to address the high-value use cases that are less-suited to traditional SQL-based queries and visualizations (such as computing and visualizing the shortest path, or the relationship between, and influence of, two nodes or entities of interest in a network). They should also consider using graph analytics to enhance pattern analysis. In a more recent development, metadata analysis has shown graph analysis to be specifically high value.

The user can interact directly with the graph elements to find insights, and the analytic results and output can also be stored for repeated use in a graph database.

Relational analytics is typically ideal for structured, static data in columns and rows in tables. Graph analytics, by contrast, is a new kind of lens for exploring fluid and indirect relationships between entities across multistructured data. It can deliver the kind of insight that is difficult to reach with SQL-based relational analytics.

***Business Impact:*** Graph analytics is highly effective at both assessing risk and responding to it to analyze fraud, route optimization, clustering, outlier detection, Markov chains, discrete-event simulation and more. The engines used to expose fraud and corruption can also be used to identify similar issues within the organization and answer issues of liability in a proactive manner. They can also be used to identify peculiarly successful operating units within a larger organization to analyze if their patterns can be repeated. Once a graph process is completed, it can be visualized — using size, color, shape and direction — to represent relationship and node attributes.

A now classic example of identifying networks of relationships is the International Consortium of Investigative Journalists (ICIJ) research, which revealed the Panama Papers.

Graph analytics can extend the potential value of the data discovery capabilities in modern business intelligence and analytics platforms. Once a graph process is completed, it can be visualized — using size, color, shape and direction — to represent relationship and node attributes. Additionally, graph analytics enable causality and dependency analyses, therefore increasing transparency in predictive models.

Business situations in which graph analytics constitute an ideal framework for analysis and presentation include:

- Route optimization
- Market basket analysis
- Fraud detection
- Social network analysis
- CRM optimization
- Location intelligence
- Supply chain monitoring
- Load balancing
- Special forms of workforce analytics, such as enterprise social graphs and digital workplace graphs
- Recency, frequency, monetary (RFM) analysis of related networks of objects, assets and conditions

There are also more-specialized applications:

- Law enforcement investigation
- Epidemiology
- Genome research
- Detection of money laundering

***Benefit Rating:*** High

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Adolescent

***Sample Vendors:*** Cambridge Semantics; Centrifuge Systems; Databricks; Digital Reasoning; Emcien; Maana; Palantir; Symphony AyasdiAI; SynerScope

***Recommended Reading:*** "Combine Predictive and Prescriptive Analytics to Solve Business Problems"

"Best Practices for Designing Your Data Lake"

## Sliding Into the Trough

### Next-Generation Memory

***Analysis By:*** Martin Reynolds; Chirag Dekate

***Definition:*** Next-generation memory is a type of nonvolatile memory capable of replacing DRAM in servers. It will have the density and manufacturing cost of flash memory, but will be fast enough to augment, or even replace, DRAM.

***Position and Adoption Speed Justification:*** Phase-change memory is shipping in storage devices, and Intel is preparing to ship it as the main memory for server platforms in 2019. In the long term, Intel's PCM could replace DRAM and flash memory in many systems, including as embedded memory. As this technology evolves, it will be priced lower than DRAM server memory.

Next-generation memory techniques include Hewlett Packard Enterprise's (HPE's) ion migration memristor, Intel-Micron's 3D XPoint phase change and spin-transfer torque memory. Other technologies exist, but only these three can compete with flash density and DRAM performance. Of the three, Intel-Micron's 3D XPoint technology is the furthest along.

Intel is placing big bets on 3D XPoint, and will probably hold the competition off through 2020. Intel will control the integration of 3D XPoint into server platforms using proprietary controller IP. Therefore, Intel has a strong incentive to develop its markets and margins before competition enters the market. Although Samsung is bringing a competing small block, flash-based technology to market, it will take some time before Samsung can substitute this technology for main memory. Achieving this objective will require devices that work more like DRAM, which means a completely reliable, fast-write cycle, because Intel is unlikely to share its platform controller IP.

The 3D Xpoint memory cell technology is shipping in less demanding PCIe and NVMe solid-state storage devices, where memory management is far simpler. These devices exhibit high-transaction rates compared with flash-based solid-state drives (SSDs), because of their low-write latency. Fully exploiting these performance attributes requires changes to software and drivers. Reducing the cost of keeping data in the "main memory" and simplifying HA architecture can accelerate mainstream organization adoption of in-memory computing architectures.

***User Advice:*** Next-generation memory will enable servers with main memory of more than 6TB, and up to 60TB of fast, nonvolatile storage. The nonvolatile storage will be significantly faster than any SSD today. In 2019, server vendors released eight-socket systems supporting 32TB of main memory.

These servers bring a new price point to buyers for large-scale transaction processing and data analytics. Users should evaluate these products for in-memory database or analytics workloads that require larger capacity than available with DRAM, or workloads requiring high-speed persistent memory that can survive server power loss.

These systems are potentially transformational in businesses that have large-scale look-up, matching and analysis challenges, including banking, transportation and logistics. The combination of 36TB of lower-cost memory and eight advanced CPUs in a 2U chassis represents a compelling advantage in price, performance and rack space.

***Business Impact:*** These systems will enable a five to 10 times increase in fast, local storage capacity, enabling scale-up computing systems to perform faster or handle larger analytics workloads. Alternatively, these systems can provide greater consolidation, reducing costs by shrinking the data center space required. In addition to this, a key impact of this technology will be to accelerate adoption of in-memory computing architectures.

***Benefit Rating:*** Transformational

***Market Penetration:*** 1% to 5% of target audience

***Maturity:*** Adolescent

***Sample Vendors:*** Dell; Hewlett Packard Enterprise; Inspur; Intel; Lenovo; Supermicro

***Recommended Reading:*** “Predicts 2018: In-Memory Computing Technologies Remain Pervasive as Adoption Grows”

“Forecast: Mobile Memory, 2018”

## 3D Sensing Cameras

***Analysis By:*** Claire Wen

***Definition:*** 3D sensing cameras capture depth information of objects and surroundings. There are various solutions including stereo vision with two cameras, structured-light solution, and time-of-flight (TOF).

This profile was renamed from “3D camera” since 2018 to highlight the “sensing” capability that has complexity in system design, whereas 3D camera, often composed of two cameras, is more for creative photography such as the bokeh effect.

***Position and Adoption Speed Justification:*** 3D sensing cameras enable various use cases including gesture recognition as human-machine-interface, factory automation, automotive ADAS for safety, etc. Google and Apple also brought this technology into smartphones for augmented reality (AR) activities and authentication. Huawei, Xiaomi, and OPPO have adopted 3D sensing with the structured light solution for certain models for the past year, and other leading android based smartphone OEMs including Samsung Electronics and LG are planning to use with TOF this year. Meanwhile, Apple has adopted 3D sensing with structured light solution for all of its models launched last year.

Accuracy is the critical factor and it needs optimization of hardware (image sensors, light sources, processors, etc.) and software (algorithm, platform, APP etc.). Artificial-intelligence application processors will be needed for better imaging analysis. This issue is particularly important for mobile payment in smartphones where the third-party biometric verification is required. Therefore, the total cost of the combination of hardware and software for high-level accuracy will be the inhibitor for mainstream adoption in smartphones. Meanwhile, other innovative authentication methods (such as optical in-display fingerprint) for smartphones are improving with the cost and performance. That causes smartphone OEMs choose other authentication methods over 3D sensing cameras. As the result, the current use of 3D sensing cameras in smartphones are moving into AR activities from authentication. The product design and manufacturing of 3D sensing cameras for AR activities are less complex and have lower cost because the accuracy requirement is not as rigor as authentications.

We believe that 3D sensing cameras are sliding into trough because the cost of adoption is still high and the perceived value (accuracy) is still working in process.

***User Advice:*** The 3D sensing capability is improving. Electronics OEMs should build a multiphase feature roadmap by specifying incremental 3D features and corresponding 3D sensing solutions. The idea of 3D sensing camera is still new to end users and how much end users see the value will determine the adoption of 3D cameras.

Service providers should identify possible uses with 3D sensing camera and develop software applications and cloud services for targeted audience. A good software should be designed based on the specific use case, rather than a generic one.

Businesses, in general, should strive to use an optimized 3D sensing camera solution to improve workforce collaboration, communicate more quickly and identify suitable merchandise for customers.

***Business Impact:*** 3D sensing camera is a critical component for augmented reality and, thus, will increase AR-related business opportunities. IKEA has launched an AR app, with improved 3D sensing capability for consumers to encourage transactions. On the other hand, 3D sensing cameras for authentication will become more reliable, thus, will be competing with existing authentication solutions such as fingerprint. Therefore, the demand of 3D sensing camera is promising and hence, will require powerful processing power and advanced software and algorithm for better recognition and reaction.

While 3D sensing cameras in smartphones continue to influence consumers' behavior, industrial and automotive are now quickly evolved with 3D sensing cameras. Operation efficiency will be greatly improved as 3D sensing camera can detect unusual component parts in the production line so that operators can quickly notice. Driving will be easier and safer using advanced driver-assistance systems (ADAS) with 3D sensing camera due to the capability of gathering and analyzing information.

***Benefit Rating:*** High

***Market Penetration:*** 5% to 20% of target audience

***Maturity:*** Adolescent

***Sample Vendors:*** Apple; Google; Intel; Microsoft; Sony

## Autonomous Driving Level 4

***Analysis By:*** Jonathan Davenport

***Definition:*** A vehicle classified as Level 4 using the SAE International rating system must be capable of self-driving operation without the need for a human driver. However, Level 4 vehicles cannot drive in all conditions, such as driving during snow or heavy rain, nor will these vehicles be able to deal with all road types or junctions. It is expected that most Level 4 vehicles will operate as part of a mobility fleet in geofenced areas, without steering wheels or pedals.

***Position and Adoption Speed Justification:*** Despite huge leaps forward in Level 4 autonomous driving, large-scale commercial solutions are still a number of years away. Simulation is being used to test challenging maneuvers and situations, with companies like Waymo harnessing the equivalent of 25,000 vehicles to drive every hour of every day to refine the neural networks that underpin the autonomous vehicle perception models. Plus, governments are continuing to issue permits to allow on-road testing of Level 4 vehicles. In China, a new 62-mile-long highway with dedicated lanes for autonomous vehicles has been announced.

However, the challenges of creating autonomous vehicles should not be underestimated. High-profile accidents, such as the Uber vehicle that was involved in a fatal collision in Arizona in 2018, show the need for improved validation of the technology. This, coupled with the need for regulatory approval, highlights the challenges that the industry still faces to bring a mainstream Level 4 solution to market.

Despite these challenges, automotive manufacturers aim to commercialize the technology for consumer use early in the next decade. This leaves several years of hype between today and when a product is available for use by consumers.

***User Advice:*** It is expected that the economics of Level 4 automation will make private ownership cost-prohibitive, certainly to begin with. As a result, Level 4 autonomous vehicles need to be designed for mobility as a service (MaaS) fleets or other commercial purposes, such as logistics, material or cargo handling.

Many see the widespread adoption of MaaS to be driven by the emergence of Level 4 vehicles, coupled with other macroenvironmental trends, such as:

- Growing urbanization
- Increased use of public transportation, taxis and bikes by young people
- The growth in "as a service" solutions

Level 4 vehicles will not be able to handle all road conditions and situations. As a result, these fleets will likely operate in geofenced areas, where the operator is confident that the vehicles are capable of handling every situation they will encounter. In situations where the vehicle is unable to continue driving, it will need to initiate a "safety protocol." The safety protocol will require the AI system to be capable of assessing the least dangerous maneuver and bring the vehicle to a halt at the side of the road. In such situations, vehicles may be remotely piloted, utilizing teleoperation systems.

To see mass adoption of Level 4 vehicles, work is also needed to:

- Help the general public trust autonomous vehicles
- Ensure the right legal framework is put in place to support a smooth transition of these vehicles onto the world's roads

Level 4 vehicles would not require steering wheels, accelerator and brake pedals, or mirrors. But they may have them to overcome issues around regulation and to help drive the car in exceptional environmental conditions.

To deliver autonomous driving functionality, Gartner assumes Level 4 autonomous driving ECUs must have:

- More than 70 TFLOPS of processing capability
- More than 48GB of DRAM
- More than 512GB of nonvolatile storage
- 100 Mbps or faster data link interface

***Business Impact:*** Level 4 automation could lead to dramatic changes in how people move around and what activities they are able to engage in while in the vehicle. The introduction of Level 4 MaaS vehicles will start people's migration from owning their vehicle (automotive customers) to instead becoming consumers of transportation provided by third-party fleets. This will impact retention and significantly change the profile of automotive OEMs' customer base, especially in urban and suburban areas. Vehicle OEMs will increasingly sell to mobility providers, or they may become providers themselves, owning the fleet of cars they build.

The vehicles in autonomous fleets may become commoditized. To address this risk, the automotive industry needs to prepare for the migration to autonomous fleets and consider how customer relationships and brand loyalty should be nurtured.

People travelling in the vehicles will be able to shop online, work on a laptop, watch video content and engage with other passengers in a way that has never before been possible. This will transform time that was previously "wasted," such as on commutes into work, making people far more productive.

***Benefit Rating:*** Transformational

***Market Penetration:*** Less than 1% of target audience

***Maturity:*** Embryonic

***Sample Vendors:*** Alibaba Group; Aptiv; Baidu; Ford Motor; General Motors; Intel; Mercedes-Benz; NVIDIA; Volvo Cars; Waymo

***Recommended Reading:*** "Market Insight: Cracking the Semiautonomous Machine-Human Handover Problem"

“Market Insight: Autonomous Driving Creates Opportunities for AI-Enabled Personal Technologies”

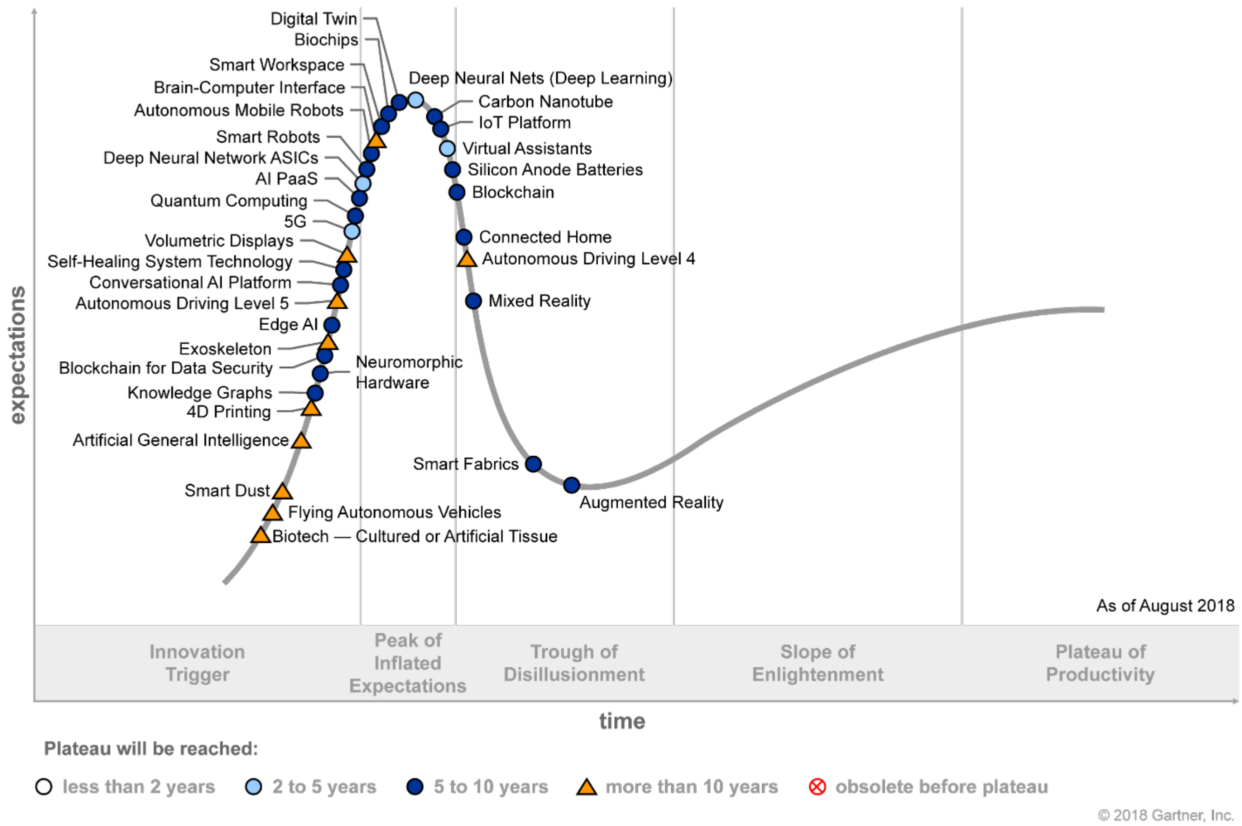
“Automotive and Smart Mobility CIOs Must Play a Crucial Role in the Autonomous Driving Technology Stack”

“Market Insight: Choosing the Right Technology Ecosystem Is Critical for Successful Autonomous Vehicle Products”

“Use Autonomous Vehicle Automation Levels and Usage Scenarios for Your Product Alignment Strategy”

## Appendixes

Figure 3. Hype Cycle for Emerging Technologies, 2018



## Hype Cycle Phases, Benefit Ratings and Maturity Levels

### Table 1. Hype Cycle Phases

| Phase | Definition |
|---|---|
| *Innovation Trigger* | A breakthrough, public demonstration, product launch or other event generates significant press and industry interest. |
| *Peak of Inflated Expectations* | During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the technology is pushed to its limits. The only enterprises making money are conference organizers and magazine publishers. |
| *Trough of Disillusionment* | Because the technology does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales. |
| *Slope of Enlightenment* | Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the technology's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process. |
| *Plateau of Productivity* | The real-world benefits of the technology are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase. |
| *Years to Mainstream Adoption* | The time required for the technology to reach the Plateau of Productivity. |

Source: Gartner (August 2019)

### Table 2. Benefit Ratings

| Benefit Rating | Definition |
|---|---|
| *Transformational* | Enables new ways of doing business across industries that will result in major shifts in industry dynamics |
| *High* | Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise |
| *Moderate* | Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise |
| *Low* | Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings |

Source: Gartner (August 2019)

Table 3. Maturity Levels

| Maturity Level | Status | Products/Vendors |
|---|---|---|
| *Embryonic* | ■ In labs | ■ None |
| *Emerging* | ■ Commercialization by vendors<br>■ Pilots and deployments by industry leaders | ■ First generation<br>■ High price<br>■ Much customization |
| *Adolescent* | ■ Maturing technology capabilities and process understanding<br>■ Uptake beyond early adopters | ■ Second generation<br>■ Less customization |
| *Early mainstream* | ■ Proven technology<br>■ Vendors, technology and adoption rapidly evolving | ■ Third generation<br>■ More out-of-box methodologies |
| *Mature mainstream* | ■ Robust technology<br>■ Not much evolution in vendors or technology | ■ Several dominant vendors |
| *Legacy* | ■ Not appropriate for new developments<br>■ Cost of migration constrains replacement | ■ Maintenance revenue focus |
| *Obsolete* | ■ Rarely used | ■ Used/resale market only |

Source: Gartner (August 2019)

## Gartner Recommended Reading

*Some documents may not be available as part of your current Gartner subscription.*

Understanding Gartner's Hype Cycles

Toolkit: Create Your Own Hype Cycle With Gartner's Innovation Database

### More on This Topic

This is part of two in-depth collections of research. See the collections:

- 2019 Hype Cycles: 5 Priorities Shape the Further Evolution of Digital Innovation: A Gartner Trend Insight Report
- Top 10 Strategic Technology Trends for 2020: A Gartner Trend Insight Report

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