Gartner

Hype Cycle for Emerging Technologies, 2017

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Our 2017 Hype Cycle reveals three distinct technology trends that profoundly create new experiences, with unrivaled intelligence, and offer platforms that propel organizations to connect with new business ecosystems in order to become competitive over the next five to 10 years.

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What You Need to Know

Organizations will continue to be faced with rapidly accelerating technology innovation that will profoundly impact the way they deal with their workforces, customers and partners. In particular, four emerging technologies are poised to be the highest priority: ecosystem-expanding technologies such as Blockchain; Brain-Computer Interface, which further entrenches humans into technology; Commercial UAVs (Drones), which challenge how goods and services are delivered; and intelligent API-driven Software-Defined Security, which enables a more secure digital world.

To survive and thrive in the digital economy, enterprise architecture (EA) and technology innovation leaders who are focused on mastering emerging and strategic trends must continue to work with their CIOs and business leaders to look for emerging technologies that can help create competitive advantage, generate value, overcome legal and regulatory hurdles, reduce operating costs, and enable transformational business models. This Hype Cycle provides a high-level view of important emerging trends that organizations must track, as well as the specific technologies that must be monitored.

This year, three trends stand out at a high level:

- AI Everywhere
- Transparently Immersive Experiences
- Digital Platforms

Enterprise architects who are focused on technology innovation must evaluate these high-level trends and the featured technologies, as well as the potential impact (value and risk) on their businesses. In addition to the potential impact on businesses, these trends provide a significant opportunity for EA leaders to help senior business and IT leaders respond to the digital business opportunities and threats by creating signature-ready actionable and diagnostic deliverables that guide investment decisions.

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 Gartner technologies into a succinct set of must-know emerging technologies and trends. This Hype Cycle specifically focuses on the set of technologies that is showing promise in delivering a high degree of competitive advantage over the next five to 10 years.

Megatrends Fueled by Emerging Technologies

The emerging technologies on the 2017 Hype Cycle reveal three distinct megatrends that profoundly create new experiences, with unrivaled intelligence, and offer platforms that allow organizations to connect with new business ecosystems. Those three megatrends are:

- **AI Everywhere:** Artificial intelligence (AI) technologies will be the most disruptive class of technologies over the next 10 years due to radical computational power, near-endless amounts of data, and unprecedented advances in deep neural networks; these will enable organizations with AI technologies to harness data in order to adapt to new situations and solve problems that no one has ever encountered previously.

  Enterprises that are seeking leverage in this theme should consider the following technologies: Deep Learning, Deep Reinforcement Learning, Artificial General Intelligence, Autonomous Vehicles, Cognitive Computing, Commercial UAVs (Drones), Conversational User Interfaces, Enterprise Taxonomy and Ontology Management, Machine Learning, Smart Dust, Smart Robots, and Smart Workspace.

- **Transparently Immersive Experiences:** Technology has and will continue to become more human-centric to the point where it will introduce transparency between people, businesses and things. This relationship will become much more entwined as the evolution of technology becomes more adaptive, contextual and fluid within the workplace, at home, and in interacting with businesses and other people.

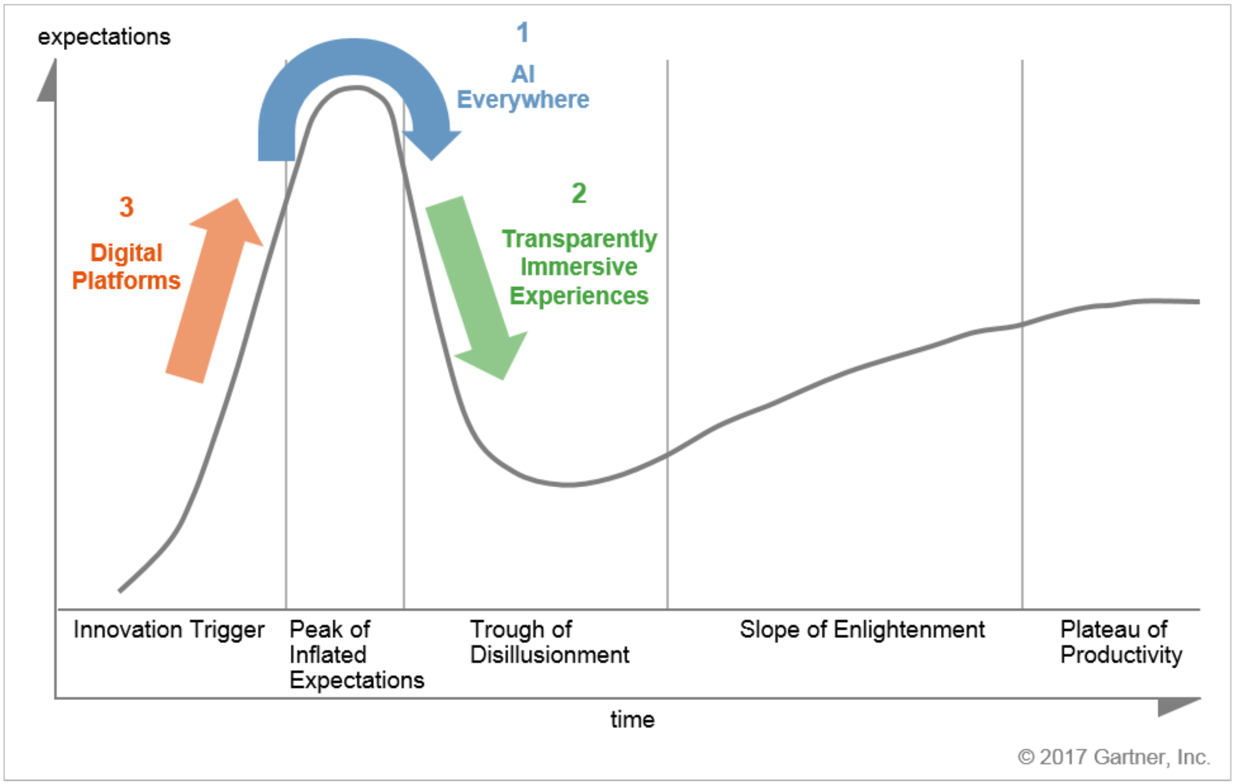
  Critical technologies to be considered include: 4D Printing, Augmented Reality, Brain-Computer Interface, Connected Home, Human Augmentation, Nanotube Electronics, Virtual Reality and Volumetric Displays.

- **Digital Platforms:** Emerging technologies require revolutionizing the enabling foundations that provide the volume of data needed, advanced compute power, and ubiquity-enabling ecosystems. The shift from compartmentalized technical infrastructure to ecosystem-enabling platforms is laying the foundations for entirely new business models that are forming the bridge between humans and technology. Within these dynamic ecosystems, organizations must proactively understand and redefine their strategy to create platform-based business models, and to exploit internal and external algorithms in order to generate value.

  Key platform-enabling technologies to track include: 5G, Digital Twin, Edge Computing, Blockchain, IoT Platform, Neuromorphic Hardware, Quantum Computing, Serverless PaaS and Software-Defined Security.

When we view these themes in aggregate, we can see how the human-centric enabling technologies within Transparently Immersive Experiences (such as Smart Workspace, Connected Home, Augmented Reality, Virtual Reality and the growing Brain-Computer Interface) are becoming the edge technologies that are pulling the other trends along the Hype Cycle (see Figure 1 [visible only in the noninteractive version of this research]).

Figure 1. How Emerging Technology Trends Move Along the Hype Cycle



Source: Gartner (July 2017)

AI Everywhere emerging technologies are moving rapidly through the Hype Cycle. These technologies are just crossing the peak, which shows that they are a key enabler of technologies that create transparent and immersive experiences.

Finally, Digital Platforms are rapidly moving up the Hype Cycle, illustrating the new IT realities that are possible by providing the underlining platforms that will fuel the future. Technologies like Quantum Computing and Blockchain are poised to create the most transformative and dramatic impacts in the next five to 10 years.

These megatrends illustrate that the more organizations are able to make technology an integral part of employees', partners' and customers' experiences, the more they will be able to connect their ecosystems to platforms in new and dynamic ways.

Major Hype Cycle Changes

Understanding the new emerging technologies that are being introduced on the Hype Cycle for the first time in 2017 provides enterprise architects with the leading indicators of what technology trends will be strategic in the coming years.

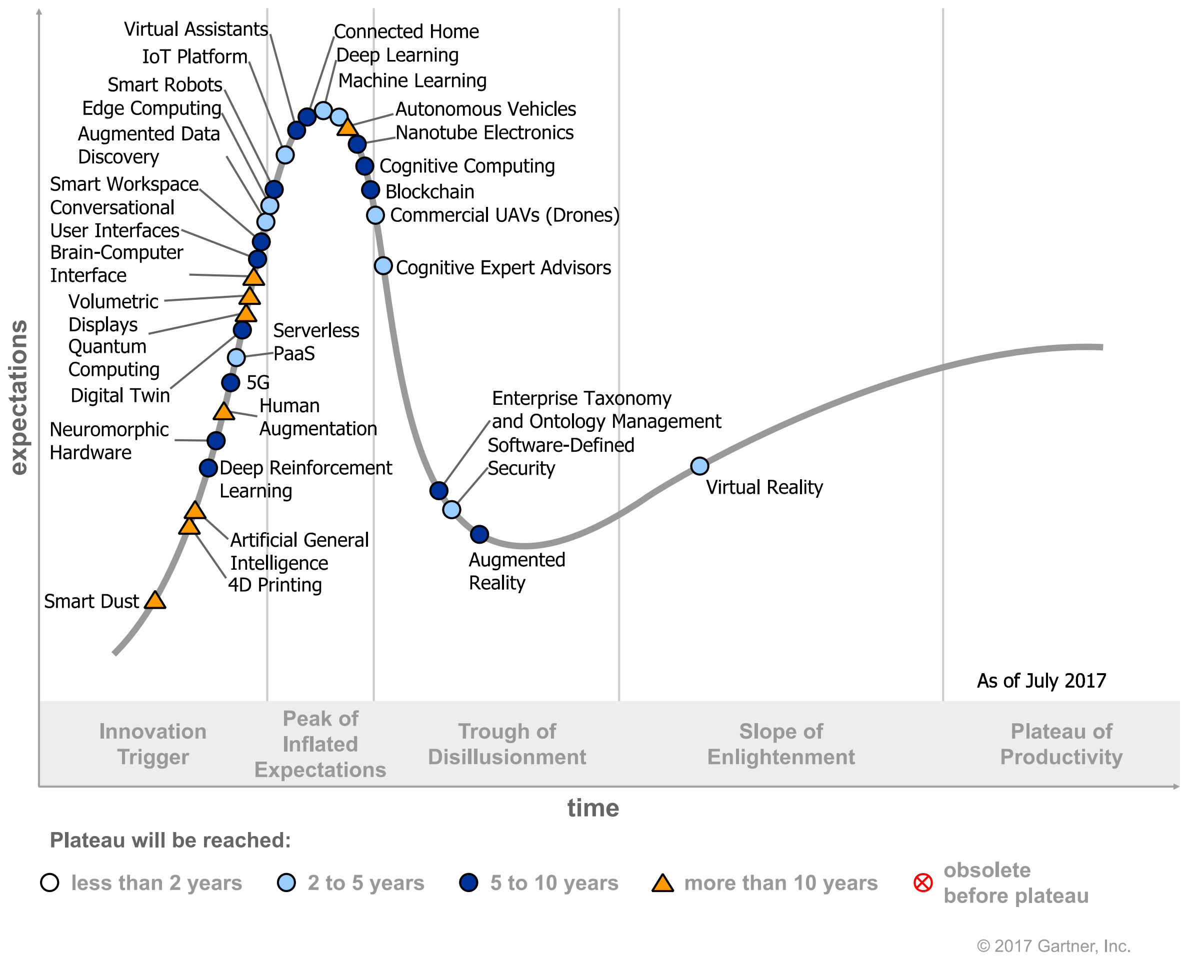
Also, understanding the eight new technologies below will support EA and technology innovation leaders in building on key themes of AI Everywhere, Transparently Immersive Experiences and Digital Platforms:

- 5G
- Artificial General Intelligence
- Deep Learning
- Deep Reinforcement Learning
- Digital Twin
- Edge Computing
- Serverless PaaS
- Cognitive Computing

In addition, EA and technology innovation leaders should evaluate the technologies that have moved significantly along the Hype Cycle since 2016:

1. **Blockchain:** This concept is gaining traction because it holds the promise of transforming industry operating models. Multiple business use cases are yet to be proved, and it is likely that — while the hype is around the financial services industry — manufacturing, government, healthcare and education will see more rapid evolution and acceptance.
2. **Commercial UAVs (Drones):** Major advances in AI hardware, miniaturization of computing power, and deep-learning algorithms that continue to be more useful are enabling drones to be used in industries like financial services, manufacturing, retail and automotive.
3. **Software-Defined Security (SDSec):** Security vendors continue to shift more of the policy management out of individual hardware elements and into a software-based management plane for flexibility in specifying security policy, regardless of location. As a result, SDSec will bring speed and agility to the enforcement of security policy, regardless of the location of the user, the information or the workload.
4. **Brain-Computer Interface:** As wearable technology advances to become miniaturized and more powerful, and also becomes pervasive in the commonplace, applications will benefit from hybrid techniques that combine brain, gaze and muscle tracking to offer hands-free interaction. Over the next five years, as virtual reality (VR) hardware develops, it is likely that noninvasive versions of this technology will be included in VR headset designs. Brain-Computer Interface has not only shown major progress, but also increased its impact in a transformational way.

Figure 2. Hype Cycle for Emerging Technologies, 2017



Source: Gartner (July 2017)

The Priority Matrix

Emerging technologies are disruptive by nature, but the competitive advantage they provide is not yet well-known or proved in the market. However, most will take more than five to 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.

Two to five years to mainstream adoption: The AI Everywhere trend is here, and the enabling, emerging technologies, such as Machine Learning, are already providing widespread and significant benefits, while Deep Learning and Commercial UAVs (Drones) are enabling Machine Learning algorithms for the masses. The full list of emerging technologies that are two to five years to mainstream adoption is:

- Augmented Data Discovery

- Cognitive Expert Advisors
- Deep Learning
- Edge Computing
- Commercial UAVs (Drones)
- IoT Platform
- Machine Learning
- Serverless PaaS
- Software-Defined Security
- Virtual Reality

Five to 10 years to mainstream adoption: Technologies indicate that the digital platforms are in full force. SDSec brings speed and agility to the enforcement of security policy, regardless of the location of the user, the information or the workload. Virtual Assistants provide unobtrusive, ubiquitous and contextually aware advisor-based solutions, while Blockchain will expand distributed ledger concepts that promise to transform industry operating models. The full list of emerging technologies that are five to 10 years to mainstream adoption is:

- 5G
- Deep Reinforcement Learning
- Digital Twin
- Augmented Reality
- Blockchain
- Cognitive Computing
- Connected Home
- Conversational User Interfaces
- Enterprise Taxonomy and Ontology Management
- Nanotube Electronics
- Neuromorphic Hardware
- Smart Robots
- Smart Workspace
- Virtual Assistants

More than 10 years to mainstream adoption: Quantum Computing provides unprecedented compute power. Artificial General Intelligence will drive ubiquity and AI as a service, which will ultimately be key factors in the convergence between AI Everywhere, Transparently Immersive Experiences and Digital Platforms. The full list of emerging technologies that are more than 10 years to mainstream adoption is:

- 4D Printing
- Artificial General Intelligence
- Autonomous Vehicles
- Brain-Computer Interface
- Human Augmentation
- Quantum Computing
- Smart Dust
- Volumetric Displays

Figure 3. Priority Matrix for Emerging Technologies, 2017

benefit	years to mainstream adoption			
	less than 2 years	2 to 5 years	5 to 10 years	more than 10 years
transformational		**Augmented Data Discovery** **Cognitive Expert Advisors** **Deep Learning** **Edge Computing** **IoT Platform** **Machine Learning** **Software-Defined Security**	Blockchain Cognitive Computing Conversational User Interfaces Deep Reinforcement Learning Digital Twin Nanotube Electronics Smart Workspace Virtual Assistants	4D Printing Artificial General Intelligence Autonomous Vehicles Brain-Computer Interface Human Augmentation Smart Dust
high		Commercial UAVs (Drones)	5G Augmented Reality Connected Home Neuromorphic Hardware Smart Robots	Quantum Computing
moderate		Serverless PaaS Virtual Reality	Enterprise Taxonomy and Ontology Management	Volumetric Displays
low				

As of July 2017

Source: Gartner (July 2017)

Off the Hype Cycle

Because this Hype Cycle pulls from such a broad spectrum of topics, many technologies are featured in a specific year because of their relative visibility, but are not tracked over a longer period of time. This is not intended to imply that they are unimportant — quite the opposite. In many cases, these technologies are no longer "emerging," but rather are becoming more integral to business and IT (such as big data and cloud computing). In other cases, technologies 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 "Hype Cycle for Emerging Technologies, 2016," but do not appear in this year's report, are:

- 802.11ax
- Affective Computing
- Context Brokering
- Gesture Control Devices
- Data Broker PaaS (dbrPaaS)
- Micro Data Centers
- Natural-Language Question Answering
- Personal Analytics
- Smart Data Discovery
- Virtual Personal Assistants

On the Rise

Smart Dust

Analysis By: Ganesh Ramamoorthy

Definition: Smart dust refers to motes, which are tiny wireless micro-electromechanical systems (MEMS), robots or other devices that can detect everything from light, temperature and pressure to vibration, magnetism and chemical composition. They run on a wireless computer network and are distributed over an area to perform tasks, usually sensing through RFID. As they do not use large antennas, these systems have ranges measured in just a few millimeters.

Position and Adoption Speed Justification: At present, much of the activity surrounding smart dust is concentrated in research laboratories, such as the U.S. Defense Advanced Research Projects Agency (DARPA)-funded project at the Robotics Research Laboratory at the University of Southern California and JLH Labs, and more recently the University of Stuttgart, have developed a new type of "smart dust" miniature camera smaller than the size of a grain of sand. The main purpose of the research is to make motes as small as possible, which involves both evolutionary and revolutionary advances in miniaturization, integration and energy management. They also aim to make motes available at as low a price as possible. Because a complete sensor/communication system integrated into a cubic-millimeter package is still a long way off, we have yet to see major commercial applications for smart dust. However, some reasonably small motes are commercially available for building controls, industrial monitoring and security applications. Recently, Amphenol Advanced Sensors announced the availability of a smart dust sensor designed to detect particulates that decrease air quality. Given its wide range of potential applications and benefits, this technology will, we believe, have a transformative effect on all areas of business and on people's lives in general. However, due to the lack of any major activity in terms of commercial implementations, smart dust remains in the same position.

User Advice: Smart dust that is available "off the shelf" can be configured with sensors that detect and measure a variety of properties, such as temperature, barometric pressure, humidity, light intensity, acceleration, vibration, magnetism, acoustic level and location (using GPS). The combination of these capabilities in a well-designed sensor network could create opportunities to deliver numerous services.

Business Impact: The potential benefits of smart dust are compelling and transformational. Given the embryonic stage of this technology's development, vendors should stake their claims via patent development for commercial applications, direct funding for research projects or equity funding for companies engaged in R&D. Smart dust will transform the way humans interact with their surroundings and create new ways for businesses to deliver services, while reducing costs in the process. This will have wide-ranging implications for businesses' technological, social, economic and legal practices across the globe.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Amphenol Advanced Sensors; Linear Technology; MEMSIC; Millennial Net; Moog

4D Printing

Analysis By: Michael Shanler; Miriam Burt

Definition: Four dimensional printing (4DP) is a technique where the materials are encoded with a dynamic capability — either function, confirmation or properties — that can change via the application of chemicals, electronics, particulates or nanomaterials. The printing technology has extra functionality to sequence, mix and place specific materials that will have a calculated effect.

Position and Adoption Speed Justification: 4DP is an emerging technology that remains in the embryonic stage, with more lab research and development continuing in the past 12 months. This technology aims to add another dimension to the 3D printing process by creating an object designed to change shape after it leaves the print bed, with most models relying on hydrogels to execute the process. The concept of this "shape shifting" technology was triggered a few years ago and is being developed through collaborative efforts between academia and technology firms.

While 4DP is on the radar for three-dimensional printing (3DP) technologists, smart materials have actually been around for several decades. Recent scientific advancements in biology, chemistry, electronics and 3D printing will accelerate the discipline. Over the next few years, 4DP research will generate interest and hype.

Challenges persist with bringing precision to objects' transformations after they've been printed. Material science research for 3DP is still an underserved market. Software is still a niche for both nanoscale and human-scale programmable materials with self-assembly characteristics. Modeling the geometries, determining interactions for changing states and calculating the energy (from heat, shaking, pneumatics, gravity, magnetics and so on) that impacts materials is no easy task. Engineering software vendors are just beginning to get interested.

In 2017, some exciting new advances in the newest frontier of using 4DP to grow tissues and organs in a laboratory setting have pushed this technology up the hype curve. These include the Harvard team's method to print transformable tissue engineering scaffolds that can support cell growth, as well as researchers from the Wake Forest Institute of Regenerative Medicine printing 3D-printed structures made of living cells that could replace human tissue, where the scaffolds change shape over time. Also, NASA engineers have leveraged 4DP to print "space chain mail." The Singapore Centre for 3D Printing and the Swiss Federal Institute of Technology in Zurich. Research has been put into the public domain that addresses the durability of 4D printed parts and its predictability as it relates to load-bearing of 4DP designs. It will still be over 10 years before this technology becomes adopted as mainstream.

User Advice: 4DP offers not only tremendous opportunities for engineers, but also for designers, as many new applications will arise. Smart materials will solve design/engineering problems, which often arise from the limitations of current materials.

Business and R&D IT leaders with science, technology and engineering responsibilities for new product innovation should explore the business and technical opportunities for 4D printing, and begin to educate peers on how 4D printing can add new functions. Building an internal 4D capability will present significant computer, scientific and engineering hurdles. Focus on strategic partnerships to advance the technique and develop proofs of concept to build the capabilities to run experiments and manage the entire laboratory infrastructure. The in-silico requirements can be shared. More engineering and modeling software vendors, academic laboratories and 3DP vendors will need to be included for sharing technical research. There are also opportunities for engaging via open innovation or consortium approaches.

R&D groups will need to focus on the evolving intellectual property landscape. Material science is a complicated space, and there are an immense number of scientific and formulation-based patents that may impact business cases. Explore relationships to further improve 4DP processes through R&D partnerships with material companies to develop and improve specifications for 4D-suitable materials.

Business Impact: 4DP is an opportunity to create future technology-based products that could disrupt your industry. Shape-shifting materials have already been leveraged in the automotive, aerospace, defense and medical industries. Dynamic and self-assembling materials have already begun to disrupt the way engineers think about designing components and delivering value.

Initially, the examples of "what's possible" will be technology-focused, but will have unclear revenue impacts. Shape-shifted materials that can reduce the drag coefficient of an airplane or vehicle during different environments might help optimize efficiency. The sole of an adaptive running shoe may adjust to wet versus dry pavements and improve grip. A self-assembling medical stent may reduce surgery times and improve patient outcomes. Implants will be able to change shape once they come into contact with body heat to conform with wound areas and lead to better surgical outcomes. A dynamic valve in an irrigation system could improve irrigation on a farm. A roof on a house could change form to facilitate draining, and walls could increase or decrease in thickness during the winter or summer to improve insulation values.

The business impacts for 4D are still murky, and most will be determined after 4D technology has been refined and scaled into businesses. Until then, don't be fooled by the anticipated hype, because the technology is still in its infancy. However, now is the time to evaluate whether it is worth exploring the technology to build into future product and service roadmaps.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Autodesk; Geosyntec Consultants; MIT; Stratasys

Recommended Reading: "Maverick* Research: Make Profits by Preparing Your Business for Global Climate Change"

"Lessons From Leaders: Insights on High Performance From 10 Years of the Supply Chain Top 25"

"What 3D Printing Means for Your Supply Chain"

Artificial General Intelligence

Analysis By: Tom Austin

Definition: Artificial general intelligence (AGI) — aka "strong AI" or "general-purpose machine intelligence" — would handle a very broad range of use cases if it existed. It does not. Special-purpose AI ("weak AI") is real and powerful, but limited to specific, narrower use cases. AGI exists only in science fiction and "what if" discussions. AI technologies do not deliver AGI. Despite appearing to have humanlike learning, reasoning, adapting and understanding, they lack common sense, intelligence and extensive methods for self-maintenance or reproduction.

Position and Adoption Speed Justification: Progress on AI has been limited to "weak AI." Position and adoption speed for AGI remain unchanged year over year. (In 2016, we labelled it "general-purpose machine intelligence." We changed it to "AGI" in 2017 to better reflect marketplace term popularity and usage.)

Today's AI technology cannot be proven to possess the equivalent of human intelligence (the lack of an agreed-to test is itself a problem). It may be possible to build a machine that approximates human cognitive capabilities, but we are likely decades away from having completed the necessary research and engineering.

AGI ("strong AI") is often entangled in cognitive computing discussions. Cognitive computing means different things to different people: a set of AI capabilities, a specialized type of hardware (as in neuromorphic or other highly parallel, short propagation path processors), or the use of information and communication technology (ICT) to enhance human cognition. This latter definition is what Gartner prefers for the term "cognitive computing."

User Advice: Focus on business results enabled by applications that exploit special-purpose (narrow use case) AI technologies, both leading-edge and older AI technologies.

The leading edge of AI is "amazing innovations," including deep-learning tools and related natural-language processing (NLP) capabilities. They do what we thought technology couldn't do. They are typically research-grade tooling, still emerging from research labs, undergoing turbulent changes in direction and not fully understood in terms of engineering principles. Over time, we learn their limits and develop workable engineering guidelines. As the amazement wears off and ennui sets in, we treat them as "aging innovations."

Look for business results enabled by applications exploiting either aging innovations (including expert systems and other symbolic AI approaches, as well as simpler forms of machine learning) or amazing innovations (typically more powerful and less well understood technologies) — or both.

Examples include autonomous transport, smart advisors and virtual assistants for customers (VCAs), employees and individuals, focused on various missions (e.g., wealth management) and responsibilities (e.g., sales or budget management). Most exploit a mix of amazing and aging innovations.

Special-purpose AI will have a huge and disruptive impact on business and personal life.

End-user organizations should ignore AGI until such time that AGI researchers and advocates demonstrate significant progress. Until then, ignore supplier allusions to their offerings' AGI or artificial human intelligence attributes — these are generally programmer-created illusions.

Business Impact: AGI will likely not emerge in the next 10 years. When it does, it will likely be the result of the combination of many special-purpose AI technologies.

We will see continued research in the next 10 years. In the long run, when AGI finally does appear, the benefits will likely be enormous. But some of the economic, social and political implications will be disruptive — and likely not all positive.

Because this is an embryonic area, there are no vendors selling systems exhibiting AGI. There is an active area of basic research, but it has not yet advanced to the point where there are real products.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Recommended Reading: "Smart Machines See Major Breakthroughs After Decades of Failure"

"How to Define and Use Smart Machine Terms Effectively"

Deep Reinforcement Learning

Analysis By: Alexander Linden; Martin Reynolds

Definition: Deep reinforcement learning is the application of deep neural networks to reinforcement learning. Reinforcement learning is a machine-learning technique where the objective is to acquire a mapping between situations and actions. Unlike supervised learning (where there is plenty of information for training), only sporadic rewards are available to influence a system's behavior. Positive rewards reinforce current behavior, and negative rewards punish current or previous behavior. The infrequency of feedback results in extended training times.

Position and Adoption Speed Justification: Reinforcement learning has been around for more than three decades. It can be considered a heuristic form of dynamic programming, which was introduced by Richard Bellman almost 60 years ago. The recent performance-driven success in computer-based game playing shown by, for example, AlphaGo (developed by Google DeepMind) and certain kinds of robot control, has driven renewed interest in a variant called deep reinforcement learning using deep learning systems. There are a few open-source frameworks that support the application of reinforcement learning (Google TensorFlow and those of OpenAI, for example), but almost all commercial data science workbenches currently lack this functionality.

User Advice:

- Don't put deep reinforcement learning on your development or deployment roadmaps unless your problem cannot be solved in any other way.
- Very few practical applications are available for reinforcement learning — search strategies, game playing, robotics and control engineering are examples.
- Deep reinforcement learning almost always requires deep expertise and, ideally, a simulation or controlled environment where the system can search for a range of policies that will ultimately yield the optimal evaluation.
- Deep reinforcement learning reduces the need for labeled data, but it typically requires a simulation, and finding good machine-learning models will require dramatically increased training time.

Business Impact: Deep reinforcement learning has potential primarily in the gaming and automation industries. It has the potential to deliver incremental efficiency improvements in complex automated processes. It may also lead to breakthroughs in robotics, including self-driving cars and humanoid robot chassis.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Google; Nvidia; OpenAI

Neuromorphic Hardware

Analysis By: Chirag Dekate; Martin Reynolds; Tom Austin

Definition: Neuromorphic computing can be defined as semiconductor-based processors that are conceptually inspired by neurobiological architectures. Neuromorphic chipsets feature non-von-Neumann architectures and often require execution models that are dramatically different from traditional processors.

Position and Adoption Speed Justification: Neuromorphic systems are at the very early prototype stage. IBM has delivered a TrueNorth-based system to Lawrence Livermore National Laboratory. BrainChip's Spiking Neuron Adaptive Processor (SNAP) technology enables fast and energy-efficient integration of unsupervised learning. Hewlett Packard Labs are developing DotMatrix, a neuromorphic engine designed to accelerate neural information processing. Micron's Automata Processor is designed to deliver extreme parallelism and performance for graph analytics, pattern matching and data analytics. There are three major barriers to the deployment of neuromorphic hardware:

- Accelerated computing technologies (e.g., GPUs) are more accessible and easily programmable than neuromorphic silicon.
- Knowledge gaps. Programming neuromorphic hardware will require new execution models and programming methodologies.
- Scalability. The large numbers of neurons and deep interconnect will challenge the ability of semiconductor manufacturers to create viable neuromorphic devices.

At the moment, these projects are not on the mainstream path for deep neural networks (DNNs), but that could change with a surprise breakthrough in programming techniques.

User Advice: Neuromorphic computing architectures can deliver extreme performance for use cases like deep learning, enabling real-time analytics while consuming very little energy. Furthermore, neuromorphic architectures can enable new class of applications that have very low temporal and spatial locality such as graph analytics. Most of the neuromorphic architectures today are not ready for mainstream adoption. I&O leaders can prepare for neuromorphic computing architectures by:

- Creating a roadmap plan by identifying key applications that will be impacted by neuromorphic computing.
- Partnering with key industry leaders in neuromorphic computing to develop testbeds using prototype processors and software.
- Developing applications for neuromorphic processor architectures will require new programming skillsets. Identify new skillsets that need to be nurtured for successful development of neuromorphic initiatives.

Business Impact: Neuromorphic hardware faces the largest barriers in advancing deep learning, but also may unlock the most powerful results. There are likely to be major leaps forward in hardware in the next decade, if not from neuromorphic hardware, then from other radically new hardware designs.

We are in the midst of a "big bang"-type change in smart machines, enabled by radically new hardware designs, suddenly practical deep neural network algorithms and huge amounts of big data used to train these systems. This big bang will result in machines being able to tag, contextualize and react to language, content and people's behavior; add substantial value to what people do; and improve on some things we used to think only people could do (drive automobiles, for example).

Every major industry will be ripe for disruption by these smart machines. Early adopters will have the best opportunity to drive their own destiny.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: BrainChip; Hewlett Packard Enterprise; IBM; Micron Technology

Recommended Reading: "Cool Vendors in Novel Semiconductors for Neural Networks, 2016"

"Market Guide for Compute Platforms"

"Three Elements of High-Performance Machine Learning Infrastructure Strategy"

Human Augmentation

Analysis By: Jackie Fenn

Definition: Human augmentation creates cognitive and physical improvements as an integral part of the human body to deliver performance that exceeds normal human limits. Augmentation examples include increased physical strength (for example, through exoskeletons), improved perception (for example, a hearing aid with a phone app to optimize directionality, or an implanted magnet that detects electrical current) and enhanced mental focus (for example, through medication or brain stimulation).

Position and Adoption Speed Justification: Organizations and society must confront a growing range of opportunities and challenges relating to employees who choose — or, in some cases, are required or are financially motivated — to enhance their bodies and minds though technology. Increasing specialization and job competition are demanding levels of performance that will drive more people to experiment with enhancing themselves, triggering a multibillion-dollar human augmentation market during the next quarter-century. Based on elective augmentation trends (in particular, the popularity of cosmetic surgery) and the growing range of augmentation opportunities available, we are positioning human augmentation midway between the trigger and the peak, even though it will be well over a decade before a significant number of organizations and individuals are affected. In the meantime, some organizations will contemplate offering their staff augmentation opportunities to increase performance, or will create policies to govern augmentation trends.

User Advice: Organizations aiming to be very early adopters of technology, particularly those whose employees are engaged in physically or mentally demanding work, should track lab advances and early commercialization in fields such as exoskeletons for strength, endurance and worker safety, and sensory enhancement or transference to improve information processing. Research advances are currently most rapid in the area of prosthetics, which are incorporating sensory feedback, and are becoming increasing flexible and fast for users to learn to use to through machine learning (see "Want a True Bionic Limb? Good Luck Without Machine Learning," Wired). Once developed, advances from medical research will rapidly become available as enhancement technologies. Cognitive enhancement through technology is already represented by the growing use of — and dependence on — instant mobile and voice access to information and community. Organizations must also continue to be ready for consumer- and employee-led adoption of the latest wearable or even implantable technologies.

Ethical controversies regarding human augmentation are emerging even before the technology becomes commonplace. Several states have already passed bills banning employers from requiring chip implants as a condition of employment. Future legislation will need to tackle topics such as whether a person has a right to certain types of augmentation as a medical service, and whether an employer is allowed to prefer a candidate with augmented capabilities over a "natural" one. Employers will need to weigh the value of human augmentation against the growing capabilities of robot workers, particularly as robots may involve fewer ethical and legal minefields than augmentation.

Business Impact: The impact of human augmentation — and the ethical and legal controversies surrounding it — will first be felt in industries and endeavors demanding extreme physical performance, such as the military, emergency services and sports, followed rapidly by those requiring intense mental focus and stamina, such as financial trading and high-stakes sales. Universities and some industries are already grappling with the use of nootropics, or cognitive-enhancing drugs, typically used off label to increase focus and mental performance.

Technology and talent management leaders will find themselves at the intersection of technology, biology and ethics as they support and manage people who are prepared or required to augment themselves. Highly competitive work environments and performance-based incentives may require new risk measurement and monitoring techniques to detect instances of covert augmentation — for example, by monitoring for anomalies in performance and achievements.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Recommended Reading: "Maverick* Research: The Future of Humans: Get Ready for Your Digitally, Chemically and Mechanically Enhanced Workforce"

"Technology Overview: Quantified Self"

5G

Analysis By: Sylvain Fabre; Mark Hung

Definition: 5G is the next-generation cellular standard after 4G (Long Term Evolution [LTE], LTE Advanced [LTE-A] and LTE-A Pro). It is currently being defined across several global standards bodies — International Telecommunication Union (ITU), Third Generation Partnership Project (3GPP) and European Telecommunications Standards Institute (ETSI). The official ITU specification, International Mobile Telecommunications-2020 (IMT-2020), targets maximum downlink and uplink throughputs of 20 and 1 Gbps, respectively, and latency below 5ms and massive scalability.

Position and Adoption Speed Justification: Gartner expects that by 2020, 3% of network-based mobile communications service providers (CSPs) will launch the 5G network commercially.

In addition to the global industry bodies that are working on the 5G specification, there are regional influencing groups (5G Forum, IMT-2020, Fifth Generation Mobile Communication Promotion Forum [5GMF], Mobile and wireless communications Enablers for Twenty-twenty [2020] Information Society [METIS], 5G Innovation Centre [5GIC], ETSI).

The 3GPP's Release 15 will most likely be finished in 2018. Therefore, commercial network infrastructure with early 5G-standard compliance could be achieved by 2019.

In addition to that, a recent proposal in 3GPP called 5G New Radio (NR) is looking at enabling mobile network operators (MNOs) to launch 5G in 2019, with only new radio access network (RAN) deployments, leaving the existing core intact.

Examples of early CSPs' 5G plans include:

- In 2017, Verizon will be launching fixed wireless access in network in select areas in the 28 gigahertz (GHz) spectrum (with previous trials in 15GHz, 28GHz, 39GHz, 64GHz).
- AT&T — on 3.5GHz, 15GHz, 28GHz. (In April 2017, AT&T also announced its plan for "5G Evolution." With these faster speeds possible, the latest devices will be in over 20 major U.S. metro areas by the end of 2017. However, this is based on LTE-A Pro.)

- Telstra (Australia) — 5G network for Gold Coast 2018 Commonwealth Games.
- In South Korea — kt will showcase 5G networks at the 2018 Winter Olympics in PyeongChang.
- T-Mobile USA — rollout expected to start in 2019 targeting national coverage in 2020 using 600MHz.
- Sprint USA — targeting 2019 deployment on 2.5GHz.
- NTT Docomo — showcasing deployment for 2020 Summer Olympics in Tokyo.

A driving factor for 5G adoption is the global competitive landscape of next-generation broadband access. For example, the EU's digital agenda has a target to realize 100% broadband coverage of 30 Mbps (at a minimum) by 2020 — that includes 50% of households having 100 Mbps available subscriptions or higher by 2020.

From 2018 through 2022, organizations will mainly utilize 5G to support IoT communications, high definition video and fixed wireless access. (See "Emerging Technology Analysis: 5G.")

Use of higher frequencies for spectrum, as well as massive capacity, will require very dense deployments with higher frequency reuse.

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

In addition to that, slower adoption of 5G by CSPs (compared to 4G) means less than 45% of CSPs globally will have launched a commercial 5G network by 2025.

User Advice: CSP technology business unit leaders should:

- Focus mobile infrastructure planning on LTE, LTE-A, LTE-A Pro, small cells and heterogeneous networks (HetNet), as part of a planned transition toward 5G. Standards-compliant commercial network equipment could be available by 2019, and commercial CSP rollouts occurring before 2019 are expected to leverage prestandard equipment.
- Clarify 5G's role within the Internet of Things (IoT) ecosystem before 5G's commercial launch.
- Ask vendors to indicate which standard they are building in order to address the risk of increased marketing hype around 5G, until a 5G standard is actually defined.
- Test backward compatibility to preceding generation (LTE) devices, especially with pre-5G networks. This is necessary because initial 5G coverage may be limited, so new devices need to be able to use at least the 4G infrastructure as a fallback.
- Act now to secure availability and cost for pre-5G/nonstandard devices, as this is most certainly going to be an issue, at least until 2020.
- Focus on related architecture initiatives — such as software-defined network (SDN), network function virtualization (NFV), wireless-edge computing, and distributed cloud architectures, as well as end-to-end security in preparation for 5G. 4G mainly adopts cellular network

architecture, but 5G will prove more complicated and a heterogeneous network (HetNet) will be commonly adopted, so topology changes must be planned.

Enterprise business leaders should:

- Evaluate the multiple alternatives available now that may be adequate and more cost-effective than 5G for many use cases (for example, low-power wide-areas [LPWAs] such as NarrowBand-Internet of Things [NB-IoT], long-range [LoRa], Sigfox, Random Phase Multiple Access [RPMA], Wireless Smart Ubiquitous Networks [Wi-SUN]).

Business Impact: 5G requirements cover primarily three technology aspects:

- Enhanced mobile broadband (eMBB)
- Massive Machine Type Communications (mMTC)
- Ultrareliable and low-latency communications (URLLC)

URLLC and mMTC will be implemented after eMBB.

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

5G targets up to 150,000 broadband users, or 200,000 mMTC low power IoT modules per square kilometer (Next Generation Mobile Networks [NGMN]).

5G's increased bandwidth incremental value on top of LTE and LTE-A, as well as a mature small cell layer and pervasive Wi-Fi, may be limited with respect to the deployment costs involved (as is the case with every new wireless network generation). Low latency is potentially a much more critical differentiator.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

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

Recommended Reading: "Emerging Technology Analysis: 5G"

"Market Guide for Proto-5G Infrastructure"

"Market Trends: Is 5G and IoT Hype or Opportunity?"

"IT Market Clock for Mobile Communications Service Provider Infrastructure, 2016"

"Magic Quadrant for LTE Network Infrastructure"

Serverless PaaS

Analysis By: Yefim V. Natis

Definition: A PaaS offering delivered with serverless characteristics is serverless PaaS. Serverless is a way of delivering an IT service where the underlying service-enabling resources are opaque to the customer, continuously available in required quantities — thus requiring no preprovisioning — and priced in terms of the engaged IT service, not the underlying consumed resources. Function PaaS (fPaaS) is a notable example with special constraints above the basic serverless characteristics. It is not the definition of an etalon of serverless PaaS.

Position and Adoption Speed Justification: Serverless delivery of IT services has gained broad notice after Amazon popularized its AWS Lambda function platform service. Although some associate the notion of serverless exclusively with fPaaS, the significance of serverless, as seen by the leading vendors (including Amazon, Google and Microsoft), extends beyond functions. All PaaS capabilities can be delivered with serverless characteristics; some are already and most will in the future. Serverless PaaS will augment, and in some cases replace, the traditional transparent model of delivery, such as the model of Salesforce (Heroku), AWS Elastic Beanstalk or IBM Bluemix Liberty for Java.

As the full scope of serverless delivery of PaaS capabilities rolls out, the definition will likely be refined: relaxed in some aspects and possibly further constrained in others. Note that serverless delivery principles also describe the common architecture of IaaS: the underlying hardware is hidden; pricing is set for virtual compute capacity (not hardware consumption); an open-ended number of compute units is continuously available and preprovisioning is optional. Serverless PaaS will likely support optional preprovisioning as well, offering lower costs to many applications with steady and predictable demand for resources. The constraints of fPaaS on time and resource consumption per instance will likely also not be retained for general serverless PaaS practices.

The current market dynamic already reflects these trends. Adoption of fPaaS is rapidly increasing in development of new applications, in new vendor renditions of fPaaS (including IBM, Google and Microsoft) and the emergence of several open-source serverless programming frameworks and platforms (Funktion, Apache OpenWhisk). The principles of serverless architecture are also increasingly applied beyond just the fPaaS: other cloud services from various providers are delivered serverless, including databases (SQlite, FaunaDB, DynamoDB) and other forms of cloud platform services. Most high-productivity application platform as a service (aPaaS) (like Salesforce [Force.com], Mendix or OutSystems) exhibit most of the characteristics of serverless delivery. So, too, do many other current xPaaS.

fPaaS experience will become the foundation for the more general serverless PaaS. As fPaaS evolves beyond hype — through the inevitable disappointments and toward the Plateau of Productivity — serverless PaaS will follow, building on the fPaaS lessons learned, but also creating its own hype and disappointments before maturity.

User Advice: CIOs, CTOs, IT leaders and planners:

- Use fPaaS offerings as representative of serverless PaaS to build in-house understanding of the trade-offs of the new platform delivery model, but with clear understanding that some of the constraints on design of functions (such as duration and size) are not attributes of the general serverless model. fPaaS is a special purpose example, but not the definition of serverless.
- When selecting platforms for cloud-native initiatives, look for platform services that closely approximate or match the serverless delivery model to achieve improved productivity, cost-efficiency and consistency of outcomes.
- Avoid the serverless model if the project requires advanced and direct forms of control over application infrastructure operations.
- Make the cloud platform selections with an effort to minimize vendor or service lock-in — the increasing adoption of serverless delivery model and other ongoing innovations may compel you to consider alternative options in platforms and vendors.

Business Impact: All PaaS should have been serverless from the start to reflect the fundamentals of design of both IaaS and SaaS, and most indeed is to some degree. Serverless PaaS represents the true cloud-style operations for cloud platform services. Adoption of a serverless PaaS delivery model will increase productivity and efficiency of PaaS, and help to streamline development, scale operations and reduce infrastructure costs. It will create a more consistent and manageable environment for cloud applications, but will require adjustments in the practices and strategies of planning, designing and operating the PaaS-based solutions, rendering some current applications legacy and requiring some new training and tooling.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Sample Vendors: Amazon Web Services; Google; IBM; Iron.io; Microsoft

Recommended Reading: "Platform as a Service: Definition, Taxonomy and Vendor Landscape, 2016"

"The Key Trends in PaaS, 2017"

"Adding Serverless Computing and fPaaS to Your Cloud-Native Architecture Toolbox"

Digital Twin

Analysis By: Marc Halpern; Alfonso Velosa; Simon F Jacobson

Definition: A digital twin is a virtual counterpart of a real object. As its purpose, a digital twin enables other software/systems to interact with it rather than the real object directly to improve maintenance, upgrades, repairs and operation of the actual object. The minimum elements of a digital twin include the model of the object, data from the object, a unique one-to-one correspondence to the object and the ability to monitor the object.

Position and Adoption Speed Justification: The idea of modeling many things including cars, buildings and consumer products, with functional behavior embedded in the virtual models is just emerging. Until now, not even 1% of such assets are modeled such that the models capture and mimic behavior. Digital twins today have gained tremendous mind share but remain the purview of relatively few professional communities in select manufacturing industries or utilities.

In high-value asset-intensive industry sectors (e.g., transportation and manufacturing) and mission-critical sectors (e.g., aerospace and defense), it is fairly common to instrument and model complex things (e.g., vehicles, aircraft, spacecraft, machines) but even so, digital twins are still rare. To date, Gartner estimates that only 5% of such complex assets are modeled.

In consumer-oriented industries such as consumer electronics, simple digital twins are beginning to proliferate to differentiate the products (e.g., stereo systems, smart lighting, etc.) among consumers. For example, a digital twin could be a model of a home sound system that enables a remote user to manipulate the physical system with virtual sliders and buttons on a mobile device. The features of digital twins can be criteria for selecting which consumer electronics brands to buy. Also, software updates intended to update user interfaces for millions of products could first be instantiated and validated on the digital twins. Gartner expects such simple digital twins to proliferate rapidly.

Increasingly, organizations will use more detailed digital twins to avert equipment failure and plan for equipment service, to plan manufacturing processes, to operate factories, to predict equipment failure or increase operational efficiency, and to perform enhanced product development (based on simulating the behavior of new products based on the digital twin insight from prior products, taking into consideration their cost, environment and performance). These more complicated digital twins will proliferate at a slower rate due to the difficulty and expense of creating them. But, over the next 10 years, they will be adopted by operations managers for assets where the cost-benefit analysis of risks in operations makes the case for digital twins compelling. It is also possible that organizations might invest in simple digital twins such as thermostats or relays that are a critical part of more complicated systems, which are not fully modeled as digital twins yet software interconnects exist between the digital twins, their actual counterparts, and the complicated systems they connect to.

User Advice: IT strategists whose companies must manage assets, products, or systems over multiple years should be identifying and prioritizing opportunities to enable digital twins that improve customer experiences and business operations. Early evidence suggests that customers delight in the convenient ability to monitor and control their consumer electronics remotely through relatively simple digital twins that exist on their mobile devices. Therefore, companies and entities with lower-value assets should consider whether simpler digital twins can be used, economically, to help improve the reliability and user experience of those assets. In industries such as manufacturing and utilities, the shift from preventative to predictive (condition-based) maintenance is a well-established, high-value use case for digital twins. Ideally, a digital twin implements one-for-one monitoring and control for each, distinct physical asset, and the digital twin counterpart can be queried or controlled with impact on the actual counterpart by authorized parties.

IT strategists do not have to choose between simple or complicated digital twins. Digital twins can range anywhere from simple to complicated. Or, simple digital twins can be systematically enhanced to duplicate increasingly complicated aspects of actual systems.

Digital twin planners must factor culture change as part of adopting digital twin strategies. For example, technicians, engineers and operations personnel who operate real-world things will increasingly need to work with data scientists and other IT professionals who have an expanding role in improving safety, reliability and performance by enabling digital twins.

When seeking the technology to adopt, IT strategists should look for IoT solutions, either IoT devices or IoT software, that provide digital twin templates that can be easily leveraged to create digital twins for your particular requirements and assets. They should also adopt IT that ensures all aspects of a digital twin — the sensors, metadata, data and analytics — are secure since digital twins are proxies for real-world systems.

Business Impact: Digital twins are transformational because hundreds of millions of things will most likely have digital twins within three to five years. They will compel business to operate differently. Benefits include superior asset utilization, service optimization and improved user experience across nearly all industries.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Amazon; Autodesk; Bosch Software Innovations; Dassault Systèmes; GE Digital; IBM; LogMeIn; Microsoft; PTC; Siemens PLM Software

Recommended Reading: "Innovation Insight for Digital Twins — Driving Better IoT-Fueled Decisions"

"Top 10 Strategic Technology Trends for 2017: A Gartner Trend Insight Report"

"Digital Business Is Transforming New Product Development Priorities"

"Enhance Business and Manage Risks With Appropriate Simulation and Computer-Aided Engineering Use"

Quantum Computing

Analysis By: Martin Reynolds; Matthew Brisse; Chirag Dekate

Definition: Quantum computing is a type of nonclassical computing that is based on the quantum state of subatomic particles. The state of the particles represents information, denoted in single elements known as qubits (quantum bits). A qubit can hold all possible results simultaneously until read, an attribute known as superposition. Qubits can also be linked with other qubits, a property known as entanglement. Quantum computers manipulate linked qubits to solve a problem, observing (reading) the final result in the qubits.

Position and Adoption Speed Justification: Quantum computers are not general-purpose computers. Rather, they are accelerators capable of running a limited number of algorithms with orders of magnitude of speedup over conventional computers. These problems fall into a broad category of search, where a traditional algorithm would take impossibly long to find a solution. Quantum computing is probabilistic. Grover's algorithm can complete a search with a 90% probability of a correct result in the square root of the time that a conventional computer takes. This example expresses the speedup, and also the care with which results must be handled.

Hardware based on quantum technology is unconventional, complex and leading-edge. To date, the largest demonstration of entanglement is about 17 qubits, which is little more than a lab curiosity. Even so, most researchers agree that hardware is not the core problem. Effective quantum computing will require the development of new quantum algorithms that will solve real-world problems, while operating in the quantum state. The lack of these algorithms is a significant problem. Researchers are trying to optimize new quantum algorithms to the specific design characteristics of quantum computers. IBM recently opened its quantum platform for external use, with the goal of raising awareness of quantum computing. Today, with 17 qubits, the system solves only trivial problems, but IBM expects to continue to increase its scale by increasing the number of qubits and decreasing the error rates.

Another emerging approach is that of trapped ions, instead of electrons. Ions are thousands of times more massive than electrons, which makes them less susceptible to noise, and easier to manage. Trapped ion advocates hope to achieve tens of linked cubits within the decade.

The technology continues to attract significant funding, and a great deal of research is underway at many university and corporate labs. D-Wave Systems, a manufacturer of annealing based quantum computers, currently leverages 2,000 qubits but does not rely on fully entangled qubits. Google, a user of a D-Wave quantum computer, believes that it might accelerate deep learning using the machine. Microsoft's Quantum Architectures and Computation Group (QuArC) is working on developing quantum algorithms as well as developing a software architecture for programming future algorithms.

User Advice: In the few known applications, quantum computers can operate exponentially faster than conventional computers. One example, noted above, is known as Grover's algorithm. However, Grover's algorithm is worthless for computers with a small qubit count.

Given the focus and achievements of research in quantum computing, our view is that general-purpose quantum computers will never be realized; they will instead be dedicated to a narrow class of use. This suggests architectures where traditional computers offload specific calculations to dedicated quantum acceleration engines. A lack of programming tools, such as compilers, is another factor restricting the broader potential of the technology. Specific applications include optimization, code breaking (as prime number factoring), image analysis and encryption.

If a quantum computer offering appears, check its usefulness across the range of applications that you require. It will probably be dedicated to a specific application and this is likely to be too narrow to justify a purchase. For those customers interested in quantum computing, Gartner recommends the use of quantum as a service (QaaS). QaaS providers such as IBM's Q cloud and Quantum Experience enable developers and programmers the ability to work with a quantum machine. Quantum code is even available on github.

Business Impact: Quantum computing could have a huge effect, especially in areas such as optimization, machine learning, cryptography, DNA and other forms of molecular modeling, large database access, encryption, stress analysis for mechanical systems, pattern matching, image analysis, and (possibly) weather forecasting. Analytics is likely to be a primary driver as the technology becomes useful, but this is outside the planning horizon of most enterprises.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: D-Wave Systems; Google; Harris Computer Systems; IBM; Microsoft

Volumetric Displays

Analysis By: Brian Blau

Definition: Volumetric displays create visual representations of objects in three dimensions, with a 360-degree spherical viewing angle in which the image changes as the viewer moves. Unlike most 3D planar displays, which create the illusion of depth through stereoscopic or autostereoscopic technique, volumetric displays create lifelike images in 3D space.

Position and Adoption Speed Justification: Volumetric displays have emerged from the laboratory but are often thought of as the iconic volumetric image of Princess Leia created by R2-D2 in the first Star Wars movie. Volumetric displays remain an elusive yet aspirational goal.

Volumetric displays fall into two categories: swept volume and static volume. Swept volume uses the persistence of human vision to recreate volumetric images from rapidly projected 2D "slices." Static volume displays rely on a 3D volume of active elements. Swept and static volumetric displays suffer from the significant dangers of rapidly moving parts or ionized particles in the vicinity of people, especially because the volumetric nature of the generated image convinces the brain that it is solid and "real" and, therefore, can be touched. In all cases, the physical volume of data required to generate a volumetric image is considerable, which will limits its overall advancement in the coming years.

User Advice: Outside of specialized areas where budgets are not significant constraints, with few exceptions, this technology remains firmly in lab rather than commercial applications. Current technologies limit the size of volumetric space that can be displayed, and the mechanical solutions create potentially dangerous, rapidly moving parts. Until alternative approaches can be delivered (which seems unlikely in the near future), volumetric displays will remain an extremely niche product, but eventually could be used as a product display, or to view objects or even people who are not at the same location.

Businesses interested in experimenting with volumetric displays should investigate Looking Glass Factory, a new entrant in the holographic display market. Its product produces a volumetric image inside a small desktop-based display device; it was announced in 2016, but has yet to ship.

Alternative devices, such as the HoloLamp, or even simple mirrors such as the ones used in the Tupac Shakur performance art display at Cochella 2012, could provide quality volumetric experiences using projectors compared to swept or static volume displays.

Business Impact: General applications are not well-developed for business use with volumetric displays. To date, simple applications in marketing have been deployed — usually targeted at high-end retail environments. There are some specialized applications for geospatial imaging to enhance 2D maps, and for use in architectural rendering. However, most of these can be achieved at much lower costs using other more commercialized technologies, such as 3D displays. Concurrently, the rapid growth and continuing development of head-mounted displays and light field displays threaten to overwhelm the continuing development of volumetric displays outside of specialized markets. Potential application areas include medical imaging, consumer entertainment, gaming and design, but costs will need to fall dramatically for these to be viable options for using true volumetric displays.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: HoloLamp; Leia; Looking Glass Factory; Musion; Realfiction; Voxiebox; Zebra Imaging

Recommended Reading: "Market Trends: Head-Mounted Displays for Virtual Reality and Augmented Reality"

Brain-Computer Interface

Analysis By: Anthony Mullen

Definition: A brain-computer interface (BCI) is a type of user interface whereby the user's distinct brain patterns are interpreted by a computer. Data is either passively observed for research or used as commands to control an application or device. There are three approaches:

1. Invasive, where electrodes directly connect to the brain.
2. Partially invasive, where the skull is penetrated, but the brain is not.
3. Noninvasive, where commercially available caps or headbands are worn to detect the signals from outside the skull.

Position and Adoption Speed Justification: Noninvasive methods cannot use higher-frequency signals as the skull blocks and disperses electromagnetic waves. A major challenge for this approach is obtaining sufficiently distinct brain patterns to perform a range of commands. While control today is not very smooth or continuous, it is possible to control virtual objects in multiple dimensions, play interactive games and control hardware. Notably, the world's first mind-controlled drone race was held by the University of Florida in 2016, showing a potential path for consumer robotics. Today there are still major issues of latency from thought to detection, making real-time control challenging.

Currently, the best neural interfaces are used for limb prosthetics, and use 100 channels to distill the neural signals of the brain. The Defense Advanced Research Projects Agency (DARPA) is investing $60 million over four years to improve this to a million channels with Neural Engineering System Design (NESD), which would see a one cubic centimeter device implanted in the human brain, which allows neurons to transfer data to electronics. This would be a transformational step for this technology with wide-reaching implications on not just more nuanced interfacing, but in deeply understanding the brain from a physical and psychological dimension. Initiatives such as the Obama administration's decade-long Brain Activity Map project will also drive forward knowledge benefiting this field.

While invasive techniques provide better results, it is expected that the noninvasive BCIs will grow at a quicker rate as the method has no issues with infection and discomfort, and can be more easily accommodated by institutions, patients and consumers. Noninvasive methods make up the majority of research; however, to date there is no large corpus of data available or standards between providers and hardware. As a result, determining accuracy of readings based on user characteristics such as demographic traits and state of mind and wider machine learning, has not flourished.

Brain-computer interfaces remain at an embryonic level of maturity, although we have positioned them at the prepeak point of the Hype Cycle in recognition of the gains made in prosthetics control, maturing open-source communities, new use cases such as drone control and increased usage for customer behavior research. Larger commercial investments by major technology investors such as Elon Musk (see "Elon Musk Launches Neuralink, a Venture to Merge the Human Brain With AI," The Verge) are trying their hand in this space as well while Facebook's Building 8 research group recently announced at their F8 developer conference a noninvasive project that allows users to interact and type just using thoughts with a goal of 100 words per minute.

User Advice: Today, outside the medical domain, speech recognition, gaze tracking or muscle-computer interfaces offer faster and more-flexible interaction than brain-computer interfaces. The need to wear a headband or cap to recognize the signals is also a serious limitation in most consumer or business contexts. As a result, there is no significant market for the use of these devices in mainstream business IT. Ultimately, most users outside of the medical and rehabilitation domain should treat brain-computer interfaces as a research activity and experiment with noninvasive tools. Undertaking these projects will require a considered investment of time and expertise. Open source communities for brain-computer interfaces and knowledge sharing are maturing with both OpenBCI and NeuroTechX building a much-needed international network for neurotechnology in 2015.

Hardware manufacturers developing drones, robotics, virtual reality headsets and professional sports devices should explore the benefits of noninvasive methods to improve performance and experience immersion.

Platform developers in the physical and mental wellness space should consider these devices as part of innovation programs to better understand contextual conditions that give rise to mind states such as attention, joy and frustration.

Marketers, customer experience professionals and interaction designers can use these devices now to add more quantitative signals on mind state to better understand how consumers use products and view messaging.

Business Impact: The BCI market is typically segmented into neurogaming, neuroprosthetics, defense and neuroanalysis (psychology). Neuroanalysis and neuroprosthetics are the largest commercial segments driven by hospitals and rehabilitation centers. Psychological research centers and military applications are next, with neurogaming is mostly nascent. These market sizes are likely to persist for five to 10 years.

As wearable technology becomes more commonplace, applications will benefit from hybrid techniques that combine brain, gaze and muscle tracking to offer hands-free interaction. Over the next five years, as virtual reality (VR) hardware develops, it is likely that noninvasive versions of this technology will be included in VR headset designs.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: ANT Neuro; Blackrock Microsystems; Emotiv; InteraXon; MindMaze; neurowear; NeuroSky; OpenBCI; Personal Neuro Devices

Recommended Reading: "The Future of Customer Feedback in Marketing"

"Supply Chain Brief: The Use of Wearable Technology in Transportation"

Conversational User Interfaces

Analysis By: Magnus Revang; Van L. Baker; Tom Austin

Definition: Conversational UI (CUI) is a high-level design model in which user and machine interactions primarily occur in the user's spoken or written natural language. Typically informal and bidirectional, these interactions range from simple utterances (like "Stop," "OK" or "What time is it?") through to highly complex interactions (for example, collecting oral testimony from crime witnesses) and highly complex results. As design models, CUI depends on implementation via applications or related services or on a conversational platform.

Position and Adoption Speed Justification: CUIs have seen an explosive growth in 2016/17 with chatbots, messaging platforms and virtual assistants, especially home speakers such as Amazon Echo and Google Home, all contributing to the increased hype. The promise of CUIs is a dramatic shift in responsibility between user and interface — where the responsibility shifts from the user having to learn the software, to the interface learning what the user wants. This promise warrants a transformational impact — even if current CUIs are far from living up to this promise.

Over the last year, there has been an explosion in the availability of conversational platforms used to implement CUI. These tools have made it a lot easier for developers to build CUIs. We have, as a consequence, also seen CUIs being implemented inside popular applications as an alternative to GUI, and even in application suites. We expect application suite vendors to bring to market CUIs in front of their business applications — which can quickly lead to hundreds of different chat interfaces being available to employees of a large enterprise — on multiple messaging platforms. The emerging pattern of chatbots acting as a guide or concierge in front of these conversational interfaces will likely gain a lot of traction over the next year.

Most CUI implementations are still primitive, and thus are not able to respond to complex queries. Increases in capabilities will, at first, largely come from improvements in natural-language understanding (NLU) and speech recognition, which will bring CUIs closer to the promise and hype. Additional capabilities around context handling, user identification and intent handling will likely arrive within the next year, but will still not be good enough to avoid a disillusionment phase in two-to-three years' time.

User Advice: CUIs shift the responsibility for learning from the user to the software, so the software learns what the user wants. The impact on training, onboarding and expansion of use cases is profound. The need for literacy-related training and tools will thus significantly diminish during the next decade. Plan on CUIs becoming the dominant model. By 2020, at least 40% of people working in new applications will primarily interact with CUIs there, removing much of the perceived need to invest further in improving "computer literacy."

Be wary, however, of committing to CUIs too deeply. Conversational interfaces can make machines smarter and improve the ability of people to handle novel situations (people and machines collaborating will be better than either working alone), but they also carry an extra burden. For well-developed, repetitive skills that can be performed almost effortlessly, injecting conversation can degrade performance — unless the technology is able to recognize the repetitive patterns and is able to invoke many steps of a routine process with a single, user-generated command.

Avoid retrofitting CUI front ends to existing applications unless this improves usability and user delight.

Business Impact: CUIs are the interaction pattern of many chatbots and virtual assistants — both will be significant contributors to the impact of CUIs.

Outside of this, CUIs will appear primarily in new applications. Enterprise IT leaders should be on the lookout for (and biased toward) CUIs to improve employee (and customer) effectiveness, as well as to cut operating expenses and time spent learning arcane computer semantics.

There will also be some retrofitting. Over the next five years, we do not expect large enterprises to invest heavily in retrofitting existing systems of record where the employee base is experienced and stable, and the feature set well-known to the user base. However, where there is high employee turnover or significant rapid changes in feature sets, or where enterprises face a continuing burden of providing computer literacy training, enterprise IT leaders need to consider creating people-literate front ends to make it easier for employees to adapt and excel.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Amazon; Baidu; Facebook; Google; IBM; IPsoft; Microsoft; Next IT; Salesforce

Recommended Reading: "Conversational AI to Shake Up Your Technical and Business Worlds"

"Architecture of Conversational Platforms"

"Market Insight: How to Collaborate and Compete in the Emerging VPA, VCA, VEA and Chatbot Ecosystems"

Smart Workspace

Analysis By: Mike Gotta; Carol Rozwell

Definition: A smart workspace exploits the growing digitalization of physical objects brought about by the Internet of Things (IoT) to deliver new ways of working, scheduling resources, coordinating facility services, sharing information and collaborating. The programmability of physical environments enables smart workspaces to work contextually with mobile devices, software applications, enterprise social graphs and smart machines to improve workforce efficiency and effectiveness. Any location where people work can be a smart workspace.

Position and Adoption Speed Justification: Smart workspaces primarily reflect advances in, and synergies between, six trends:

1. The IoT
2. Enterprise social graphs (and other types of graph)
3. Artificial-intelligence-related technologies
4. Digital signage/electronic whiteboards
5. Indoor mapping
6. Smart buildings (including trends in integrated workplace management systems)

A smart workspace is a key aspect of a digital workplace initiative, as it involves strategists involved in facilities and real estate as key stakeholders. It applies to physical environments such as:

- Building and campus environments, including in-building open spaces
- Office and desk spaces
- Conference rooms
- Huddle rooms (small spaces where people congregate)
- Retail and shop floors
- Manufacturing assembly lines

"Things" participate in a smart workspace. Examples include applications and devices such as electronic whiteboards, building interfaces (HVAC), large digital displays, smart badges, workstations, mobile devices and wearables.

Taking full advantage of a smart workspace will require organizations to revisit design strategies, to include methods for gaining a better understanding of how people participate in physical spaces.

Adoption rates will vary, based on organizations' requirements to support flexible work models that optimize the physical and interactive aspects of places and things (as well as employees' privacy concerns).

Technological advances in nonenterprise environments — in consumer electronics and appliances, as well as in homes, cities, transportation, fashion, security and so on — will influence smart workspace innovation. Conversely, a lack of advances in these areas will constrain progression of smart workspace technologies.

User Advice: Enterprise strategists focusing on a digital workplace strategy and digitalized business processes should follow smart workspace trends and look for deployment opportunities, such as meeting rooms, huddle rooms and in-building open spaces. Emerging applications will expand beyond traditional productivity scenarios to include situations that are more industry- and process-specific, such as an insurance professional using a digital pen that interacts directly with back-end processing systems, or a patient being remotely monitored via a wearable interface in their home that interfaces with diagnostic systems and advises healthcare professionals to improve care delivery. IT organizations will need to work much more closely with real-estate and facilities teams, and vice versa. Identity, access management, privacy and security teams will also play a critical role.

Additionally, electronic whiteboards are becoming integrated with traditional collaboration and content software systems, providing more opportunities for experimentation. Meeting artifacts can be better captured and connected to digital workplace graphs, to become more widely searchable. Beacons and sensors placed in key locations within a workplace can interact with mobile apps to deliver personalized information to workers, based on proximity. These can be used to improve employee learning, provide relevant information on products, or communicate safety procedures based on employee location.

The smart workspace will emerge at an uneven pace as organizations prioritize potential solutions independently of one another. For instance, building upgrades may take longer than expected, and some market sectors will be laggards in terms of smart workspace adoption. Localization needs will also influence smart workspace adoption.

Business Impact: The business impact of smart workspaces will be diverse, ranging from improved employee productivity and cultural perception of the workplace by workers, to improved customer experience as employees make better use of smart workspaces to serve clients. The results of these changes will often be a reduction in cost, because office utilization data will guide decisions about what types of workspace are most conducive to employee effectiveness.

The digitalization and programmatic evolution of places and things will impact IT methodologies related to system design, requiring new skills for design teams to understand how people use places and things. Smart workspaces will also have organizational impacts as traditional software teams now need to work with facilities management teams in ways not previously envisioned. The digitalization and programmability of the workplace will create new integration opportunities. For instance, smart workspace activities will signal information to digital workplace graphs and smart machines, and vice versa. Finally, adoption of smart workspaces will trigger a form of consumerization — "bring your own thing" (BYOx) — as employees add their own objects to smart workspace environments. Organizations will need to formulate and adjust BYOx policies accordingly.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: AgilQuest; Condeco; Estimote; MCS; Microsoft; Oblong; Planon; Prysm; Trimble

Recommended Reading: "Market Guide for Integrated Workplace Management Systems"

"Create a Catalog of Activity-Based Spaces in the Digital Workplace to Improve the Employee Experience"

"The Rebirth of Office Space: What Every CIO Needs to Know and Do"

At the Peak

Augmented Data Discovery

Analysis By: Rita L. Sallam; Cindi Howson; Carlie J. Idoine

Definition: Augmented data discovery (formerly smart data discovery), a key feature of next-generation modern BI and analytics platforms, enables business users and citizen data scientists to automatically find, visualize and narrate relevant findings, such as correlations, exceptions, clusters and predictions, without having to build models or write algorithms. Users explore data via visualizations, search and natural-language query technologies, supported by natural-language generated narration interpretation of results.

Position and Adoption Speed Justification: Over the past five years, visual-based data discovery tools have disrupted the traditional business intelligence (BI) and analytics market, as they are easy to use and enable users to assemble data rapidly, and explore hypotheses visually, to find new insights in data. Although visual-based data discovery has been transformative in the way it enables business users to explore data (in comparison with traditional BI technologies), many of the activities associated with preparing data, finding patterns in large, complex combinations of data, and sharing insights with others remain highly manual. Visual-based data discovery tools are easy to use, but since users analyze data manually by creating queries to investigate a hypothesis, it is not possible for them to explore every possible pattern combination, let alone determine whether their findings are the most relevant, significant and actionable.

Relying on business users to find patterns manually may result in users exploring their own biased hypotheses, missing key findings and drawing their own incorrect or incomplete conclusions, which may adversely affect decisions and outcomes.

Augmented data discovery can reduce time-consuming exploration and the false identification of less-relevant insights. Instead of an analyst manually testing all the combinations of data, algorithms for detecting correlations, segments, clusters, outliers and relationships are automatically applied to the data, with only the most statistically significant and relevant result presented to the user in smart visualizations and/or natural-language narration that are optimized based on the user's context. Applying a range of algorithms to the data in parallel and explaining actionable findings to users reduces the risk of missing important insights in the data versus manual exploration and optimizes the resulting action or decision.

Augmented data discovery capabilities will advance rapidly along the Hype Cycle to mainstream adoption, as a key feature of modern BI and analytics and data science platforms. More importantly, automated insights from augmented data discovery will also be embedded in enterprise applications — expanding its reach beyond the citizen data scientist to operational workers for greater business impact.

By 2018, augmented data discovery, which includes natural-language query and search, automated advanced analytics and visual-based data discovery capabilities, will be the most in-demand BI platform data discovery user experience paradigm, enabling mainstream business consumers to gain insights such as clusters, segments, predictions, outliers and anomalies from data.

User Advice: Data and analytics leaders should:

- Embrace augmented data discovery to deliver more advanced insights to a broader range of users — including citizen data scientists and, ultimately, operational workers — without expanding the use of data scientists.
- Monitor the augmented data discovery capabilities and roadmaps of modern BI and analytics, data science platforms, and of startups as they mature. They should do so particularly in terms of the upfront setup and data preparation required, the types of data that can be analyzed, the types and range of algorithms supported, and the accuracy of the findings.

- Explore opportunities to use augmented data discovery to complement existing modern BI and analytics, data science initiatives and embedded analytic applications where automating algorithms to detect patterns in data could reduce the exploration phase of analysis and improve highly skilled data science productivity. But recognize that citizen data scientists must collaborate with, and be coached by, specialist data scientists that still need to validate models, findings and applications.
- Start with a small list of specific business problems that cannot be solved with traditional BI and modern BI and analytics platforms (or are manually intensive), and launch a augmented data discovery pilot to assess the viability of augmented data discovery, prove its value and build trust in it.

Business Impact: Gartner predicts that, by 2019, due in large part to the automation of data science tasks, citizen data scientists will surpass data scientists in the amount of advanced analysis produced. This growth, enabled by augmented data discovery, will complement and extend existing modern BI and analytics and data science platforms, as well as enterprise applications, by putting insights from advanced analytics — once available only to data science specialists — into the hands of a broad range of business analysts, decision makers and operational workers across the enterprise, driving new sources of business value. Since data scientists will focus on only statistically significant findings for further analysis, and on creating enterprise grade models, only the most accurate and significant insights will be actioned and embedded in applications to optimize business impact. Expanded use of machine-learning automated and human-augmented models will also translate into less error from bias, which is inherent in manual exploration processes. It will also reduce the time users spend on exploring data, while giving them more time to act on the most relevant insights from data.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: DataRobot; DataRobot (Nutonian); IBM (Watson Analytics); Progress DataRPM; Salesforce (BeyondCore); SAS (Visual Analytics); SparkBeyond

Recommended Reading: "Magic Quadrant for Business Intelligence and Analytics Platforms"

"Magic Quadrant for Data Science Platforms"

"Citizen Data Science Augments Data Discovery and Simplifies Data Science"

"Pursue Citizen Data Science to Expand Analytics Use Cases"

"Augmented Analytics Is the Future of Data and Analytics"

Edge Computing

Analysis By: Bob Gill; Philip Dawson

Definition: Edge computing describes a computing topology in which information processing, and content collection and delivery are placed closer to the sources and sinks of this information. Drawing from the concepts of mesh networking and distributed data centers, edge computing looks to keep traffic and processing local and off the center of the network. The goals are to reduce latency, reduce unnecessary traffic, and establish a hub for interconnection between interested peers and for data thinning of complex media types or computational loads.

Position and Adoption Speed Justification: Most of the technology for creating the physical infrastructure of edge data centers is readily available, but widespread application of the topology and explicit application and networking architectures are not yet common. Synergies between edge computing as a physical implementation locus for IoT is increasing the concept's visibility dramatically. Systems and networking management platforms will need to be stretched to include edge locations and edge-function-specific technologies such as data thinning, video compression and analysis.

User Advice: We urge enterprises to begin using edge design patterns in their medium- to longer-term infrastructure architectures. Immediate actions might include simple trials using colocation and edge-specific networking capabilities or simply placing remote-location or branch office compute functions in a standardized enclosure (e.g., "data center in a box"). Some applications, such as client-facing web properties and branch office solutions, will be simpler to integrate and deploy, while data thinning and cloud interconnection will take more planning and experimentation to get right.

Business Impact: Edge computing solves many pressing issues such as high WAN costs and unacceptable latency. The edge computing topology will enable the specifics of digital business and IT solutions uniquely well in the near future.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Amazon; Apple; Google; Microsoft

Recommended Reading: "Colocation Networking: Connectivity Options to Drive Transformation and Enable Digital Business"

"The Edge Manifesto: Digital Business, Rich Media, Latency Sensitivity and the Use of Distributed Data Centers"

"2016 Strategic Roadmap for Data Center Infrastructure"

Smart Robots

Analysis By: Gerald Van Hoy; Kenneth F. Brant

Definition: Smart robots are an electromechanical form factor that work autonomously in the physical world, learning in short-term intervals from human-supervised training and demonstrations or by their supervised experiences on the job. They sense environmental conditions and recognize and solve problems. Some can interact with humans using voice language; some have a specialized functional form, like warehouse robots; others have general forms and/or humanoid appearances. Due to their advanced sensory capabilities, smart robots may work alongside humans.

Position and Adoption Speed Justification: Smart robots have had significantly less adoption to date as compared to their industrial counterparts (predefined, unchanged task) — but they received great hype in the marketplace, which is why smart robots are positioned climbing the Peak of Inflated Expectations. Hype and expectations will continue to build around smart robots during the next few years, as providers execute on their plans to expand their offerings and deliver solutions across the wider spectrum of industry-specific use cases and enterprise sizes. Hype is quickly building for smart robots as a result of several key vendors' actions during the past few years:

- Amazon Robotics (formerly Kiva Systems) plans to deploy 10,000 robots to fill customer orders.
- Google's acquisitions of multiple robotics technology companies.
- Rethink Robotics' launch of Baxter and Sawyer, which can work alongside human employees.
- SoftBank Robotics' introduction of the humanoid Pepper and creation of "Pepper for Biz" studios to expedite commercialization of business applications.
- In 2016, trials began in some Marriott, Hilton, Westin hotels for robot room service.

User Advice: Users in light manufacturing, distribution, retail, hospitality and healthcare facilities should consider smart robots as both substitutes and complements to their human workforce. Begin pilots designed to assess product capability and quantify benefits. Examine current business- and material-handling processes into which smart robots can be deployed; also, consider redesigning processes to take advantage of the benefits of smart robots with three- to five-year roadmaps for large-scale deployment. Smart robots could also be a QC check at the end of the process, rejecting product with faults and collecting data for analysis.

Business Impact: Smart robots will make their initial business impact across a wide spectrum of asset-centric, product-centric and service-centric industries. Their ability to do physical work, with greater reliability, lower costs, increased safety and higher productivity, is common across these industries. The ability for organizations to assist, replace or redeploy their human workers in more value-adding activities creates potentially high — and occasionally transformational — business benefits. Typical and potential use cases include medical materials handling, disposal of hazardous wastes, prescription filling and delivery, patient care, direct materials handling, stock replenishment, product assembly, finished goods movements, product pick and pack, e-commerce order fulfillment, package delivery, shopping assistance, customer care, concierge and disposal of hazardous materials.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Aethon; Amazon Robotics; ARxIUM; Google; iRobot; Panasonic; Rethink Robotics; Savioke; SoftBank Robotics; Symbotic

Recommended Reading: "Top 10 Strategic Technology Trends for 2017: Intelligent Things"

"Predicts 2017: Supply Chain Trends and Innovations"

"The Six Forces That Will Shape Business and Technology in 2030"

"Prepare for When AI Turns Skilled Practices Into Utilities"

IoT Platform

Analysis By: Alfonso Velosa; Yefim V. Natis

Definition: An Internet of Things (IoT) platform is software that facilitates operations involving IoT endpoints and enterprise resources such as analytics, cloud services and so forth. It is a suite of functional capabilities for interacting with IoT endpoints, near and far event stream analysis and decision making, integration of streams, context and enterprise systems, and other logic required in the end-to-end IoT solution — delivered as a combination of edge software platform and cloud IoT hub platform (IoT platform as a service).

Position and Adoption Speed Justification: Enterprises continue to engage with an increasingly diverse variety of IoT endpoints, seeking traditional benefits such as condition-based asset optimization, while discovering new business opportunities and new revenue models such as product subscriptions (product as a service). The sophistication, scale and business value of these interactions call for specialized technology resources. The IoT platform may be deployed in a hybrid fashion to meet the local autonomy or distributed computing requirements, and time and data constraints for enterprise business objectives. The hybrid elements cover the spectrum from cloud-based elements (either private or public) to on-premises software that is distributed between the endpoints and gateways. IoT endpoints are increasingly being represented locally and/or remotely by digital twins in an IoT platform.

Enterprises' increasing adoption of IoT and digital business amplifies the hype around IoT platforms, as well as propels vendor and user investments in IoT platforms and services. The increased deployment of IoT projects, with often-inflated time-to-deployment expectations and underestimated technical challenges (for example, for device provisioning, end-to-end solution integration and sufficient cybersecurity), is pushing IoT platforms closer to the Peak of Inflated Expectations, before the buildup of practical experience will eventually bring them to mainstream productivity and maturity. The year 2017 sees many of the megavendors bringing second-generation offerings to market, although their solutions, collectively, are still not yet fully complete or proven. This, plus new market entrants, continues to increase the marketing volume yet again.

User Advice: CIOs should:

- Establish or contribute to an IoT program management office or center of excellence (COE) composed of IT, operational technology and business personnel. This IoT COE can set objectives, coordinate planning and tactical vendor negotiations, collaborate, and share best practices, resources and people.
- IoT projects will require new capabilities for your organization; thus, budget for training and use the capabilities of IoT platforms. Start with smaller initiatives to build momentum, test business hypothesis and acquire implementation lessons, especially from "fast-fail" projects.
- Look for IoT platform offerings (software and/or services) that incorporate some support of:
  - Analytics
  - Application platform
  - Data management
  - Device management
  - Integration
  - Security
- Build a training program for your developers and business analysts based on existing IoT platform capabilities, as well as perform an assessment of the skill set within your organization. Plan to leverage a service partner to ramp up as you train internal resources.
- Understand that an IoT platform is a starting point. No IoT platform will work straight off the shelf. Customize the platform to build a solution for your unique circumstances (for example, adding third-party device support or analytics to meet special needs).
- Evaluate candidate IoT platforms in terms of their fit to your technology and business objectives, but expect roadmaps to evolve quickly in the fast-changing IoT market. A key criterion will be vendor capabilities to scale from proof-of-concept projects to operational-scale deployments.

Business Impact: There is a significant business opportunity to achieve greater value and make better decisions from the insights, information and data that are generated by instrumented devices, and to provide better control of things distributed across the enterprise and its external stakeholders. Unfortunately, this data has been largely locked in the devices — due mostly to lack of connectivity, but also lack of standards, systems and processes to obtain this data systematically. In some cases, it has been due to ignorance.

IoT platforms act as the intermediary between the "thing" and the well-established IT world and business processes. Therefore, they facilitate the introduction of a new potentially transformative wave of innovation to enterprises and consumer businesses in the pursuit of digital business, smart business decisions and intelligent business operations. IoT platforms provide the middleware foundation for companies to implement their IoT solutions — rather than investing in the middleware itself, companies should invest in the business solution. Most enterprises will need to experiment to determine their optimal IoT data and architectures, integration needs, cultural fit, and business models.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Amazon; Ayla Networks; Bsquare; Eurotech; IBM; Microsoft; Oracle; PTC; SAP; Siemens

Recommended Reading: "Market Guide for IoT Platforms"

"Use the IoT Platform Reference Model to Plan Your IoT Business Solutions"

"Maturity Model for the Internet of Things"

"Predicts 2017: Charting a Path to IoT Business Value"

"Platform as a Service: Definition, Taxonomy and Vendor Landscape, 2016"

Virtual Assistants

Analysis By: Van L. Baker; Tom Austin

Definition: VAs help users or enterprises with a set of tasks previously only possible by humans. VAs use AI and machine learning (e.g., NLP, prediction models, recommendations and personalization) to assist users or automate tasks. VAs listen and observe behaviors, build and maintain data models, and predict and recommend actions. They may act for the user, forming a relationship with the user over time. Virtual assistants shift responsibility for understanding the process from the user to the system by corresponding with the user.

Position and Adoption Speed Justification: The VA space is currently dominated by conversational interfaces such as Apple Siri, Google Assistant, Microsoft Cortana, IPsoft Amelia, Nuance Nina, Amazon Alexa, Kore.ai and SAP CoPilot. Increasingly, image recognition, behavior and event triggers will enhance VAs. Virtual assistants can be deployed in several use cases, including virtual personal assistants, virtual customer assistants and virtual employee assistants. VA adoption grows as users get more comfortable with them, technologies improve and the variety of implementations multiply:

- Unobtrusive, VA-like features, such as Gmail's Smart Inbox with recommended replies and Microsoft's Delve that finds unknown resources are embedded in existing products.
- Narrow-purpose VAs have also emerged (such as personal financial advisors, health and wellness coaches, and calendaring agents). (See the "Cognitive Expert Advisors" profile.)
- Virtual assistants are increasingly used to answer customer questions about products and services.
- VAs can act on behalf of consumers, employees and businesses, but the use cases are all based on the same AI technologies.

User Advice: Anticipate that VAs will proliferate as people and businesses move to conversational user interfaces. Individuals may use several different VAs while businesses migrate from one deployment to multiple VAs that have a common VA entry point for customers and employees:

- Businesses that haven't begun the process of deploying VAs to interact with customers and employees should start now due to rapid adoption of devices, including Amazon Echo and Google Home.
- Prepare for VAs in cloud office suites first, followed by commercial application suites like SAP, Oracle and Salesforce, and consumer application environments including Facebook.
- Look for opportunities to leverage VAs to make users more productive with business apps and mobile platforms.
- Carefully measure the impact of VAs on behavior and performance. Closely monitor use of VAs, especially in VCA use cases, and be prepared to hand off to human agents to ensure customer satisfaction.
- Utilize VAs in different use cases, including customer support and engagement, and employee support and enablement, as well as employee use of personal virtual assistants.

Business Impact:

- Understand that VAs have the potential to transform the nature of users, customers and employee service as well as the nature of work and the structure of the workplace.
- Realize that many providers of VAs exist, and the quality of VAs varies dramatically.
- VAs can be built, licensed from providers or created using professional services depending on the degree to which the implementation depends on domain-specific information.
- Security and the collection of personal information are still concerns, but users are growing comfortable interacting with VAs. VAs that are embedded in cloud office suites or deployed within enterprise-grade messaging platforms will gain traction in the enterprise as security concerns diminish.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Amazon; Apple; Google; IBM; IPsoft; Microsoft; Nuance; x.ai

Recommended Reading: "Market Guide for Virtual Customer Assistants"

"Seven Decision Points for Success With Virtual Customer Assistants"

"Architecture of Conversational Platforms"

"Conversational AI to Shake Up Your Technical and Business Worlds"

Connected Home

Analysis By: Fernando Elizalde

Definition: A connected home is networked to enable the interconnection and interoperability of multiple devices, services and apps, ranging from communications and entertainment to healthcare, security and home automation. These services and apps are delivered over numerous interlinked and integrated devices, sensors, tools and platforms. Contextual, real-time smart experiences are provided at the local or cloud level, enabling individuals and other connected services in the household to control and monitor the home remotely, as well as within it.

Position and Adoption Speed Justification: The connected home is a concept that overarches several technologies, devices, applications, services and industries. As such, it is defined in this technology profile to provide a framework for the Hype Cycle of the same name.

The concept has evolved has evolved to include, without being exhaustive:

- Media entertainment
- Home security
- Monitoring and automation
- Energy management products and services
- Health and fitness
- Education

Solutions have become less expensive, largely because of:

- The commoditization of components and the enablement of cloud integration, bringing down costs to technology providers
- The maturity of access technologies (such as broadband, Wi-Fi and 4G)
- The standardization of radio technologies, including low-energy networking standards (such as Bluetooth low energy [LE], ZigBee and Z-Wave), allowing for low-cost wireless connectivity in any device in the home
- The simplification of user interfaces

The connected home is evolving into the rendering of increasingly intelligent systems, which, by using smart learning algorithms and predictive analytics, deliver smart home experiences. Although adoption differs by regions and countries within regions, in the last 18 months the introduction of voice as interface has accelerated adoption. This is resulting in a rapid progress along the Hype Cycle. However, market fragmentation and dynamism in the market somewhat hinder faster consumer adoption. Among other things, consumers may be wary of spending on solutions that may soon become obsolete or whose value is not well-communicated by the vendors.

User Advice: The market is seeing a fast migration from closed and semiopen to open ecosystems and "certified" ecosystems through cloud integration and open API adoption. Open ecosystems are shaping up around Amazon's Echo and Alexa voice services, the Works with Nest program, Google Home and Apple's HomeKit. In view of these developments:

- Develop partnership strategies to build your existing expertise in devices, services and customer relationships. Provide a unified user experience and compelling integrated connected-home solutions across products, brands and platforms.
- Partner with software providers for a unified platform. Base your solutions on standardized protocols and home gateways to speed up market adoption.
- Open up APIs and make products work with market-leading connected home ecosystems in order to take advantage of the network effect that will happen.
- If you are a single solution vendor, don't lose focus on your own brand recognition while partnering with home ecosystems.
- Offer ease of use and reasonable hardware costs, differentiating the quality of experience on the services you have on offer by providing efficient support.
- Provide real value and disruptive solutions to the consumer, rather than a novelty or just aesthetics.
- Go beyond the programmable home and plan adding intelligence by using machine-learning capabilities that create and shape a "learning" home that will deliver the intelligent home.

Business Impact: Connected-home solutions affect a wide spectrum of manufacturers (of white goods, entertainment electronics and home automation, security, and fitness and health products), as well as providers of network infrastructure and services, ranging from energy utilities and surveillance to healthcare, insurance, communications and digital entertainment.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: ADT; Amazon; Apple; AT&T; Belkin; Deutsche Telekom; Google; Insteon; Samsung Electronics; Vivint

Recommended Reading: "Market Trends: The Connected Home, 2017"

"Cool Vendors in the Connected Home, 2017"

"Survey Analysis: Connected Home Solutions Remain in the Early Adopter Stage"

"Survey Analysis: Connected Home Solution Opportunities — Home Owners Versus Renters"

"Innovation Insight for Connected Homes for P&C Insurance"

"Google Home — What the Launch Means for Connected Home Providers"

Deep Learning

Analysis By: Alexander Linden; Svetlana Sicular; Nigel Shen

Definition: Deep learning expands standard machine learning by allowing intermediate representations to be discovered. These intermediate representations allow more complex problems to be tackled and others to be potentially solved with higher accuracy, fewer observations and less cumbersome manual fine-tuning.

Position and Adoption Speed Justification: Three factors have resulted in the swift rise of deep learning to the Peak of Inflated Expectations:

- Availability of unprecedented amounts of training data, including previously intractable data
- Refinements in models, algorithms and applications to make sense of the rapidly growing amount of data
- Hardware platforms for deep-learning models (with tens of thousands of clustered cores and supercomputer-class, GPU-based hardware architectures)

Thousands of vendors are exploring the applicability of deep learning to a range of fields, such as computer vision, conversational systems and bioinformatics. Researchers are steadily publishing surprising new papers on this topic. Heavyweights like Google, Apple, Microsoft, Facebook and Baidu are increasing their deep-learning R&D. For example, deep learning is behind Apple's Siri, Google's Google Now, Microsoft's Cortana and Amazon's Alexa. Hardware manufacturers are intensifying delivery of new, high-performance computing systems for training deep neural networks (DNNs). Deep-learning capabilities are becoming more accessible in data science platforms, and are expected to be a standard component in 80% of data scientists' tool boxes by 2018.

Commercialization is proceeding at full throttle. Startups are pursuing DNN-based opportunities and ideas, from toolkits and niche use cases to products and platforms, many of which are ready for experimentation and can deliver enterprises tactical wins. Cloud vendors view deep learning as one of the key attractions of their offerings — they are releasing and expanding DNN-centered APIs, frameworks and specialized computing capabilities. Deep-learning tools, mostly in the open-source arena (Caffe, TensorFlow, Theano and Deeplearning4j) are facilitating custom solutions.

To achieve consistently good results, deep learning requires experts and equipment. A wide range of techniques is needed to make DNN architectures work. However, computational resources for deep learning are uncommon, standard formulas are still partially undefined, and no single tool or system can currently meet all deep-learning needs.

User Advice: Data and analytics leaders of modernization initiatives should revisit previously intractable "cognitive" problems relating to text, images, video and speech analytics, as well as problems that involve complex data.

Accommodate rapid deep-learning evolution: Most successes have been achieved with the main DNN variations: convolutional neural networks for image and speech recognition; recurrent neural networks for natural-language processing and translation; and autoencoder artificial neural networks for bioinformatics.

Experiment with cloud-based services, such as facial recognition, language translation, conversational systems, speech search and hyperparameter tuning. Implement packaged applications that use DNNs trained in specific areas — for example, to ensure adherence to medical treatments.

Focus on data for deep learning as your long-term investment: This is within your field of competency, and the value of the right data will grow over time. Do not assume that DNNs will find insights from any type of data through unsupervised learning. So far, results have been achieved using supervised or semisupervised learning.

Acquire skills: Upskill your machine-learning experts through training. Engage academic teams. Use crowdsourcing providers like Kaggle, Algorithmia, TunedIT and Experfy.

Avoid using DNNs when laws or ethics require transparency, such as when you are subject to the EU's General Data Protection Regulation. In the U.S., the Defense Advanced Research Projects Agency (DARPA) is funding an Explainable Artificial Intelligence program to explain the computations of deep learning, but this will take several years.

Business Impact: Deep learning has transformational and disruptive potential for all industries. The challenge for those who want to realize this potential is to identify the right problems to solve with deep learning.

DNNs demonstrate superior accuracy to past state-of-the art algorithms in detecting fraud and other anomalies, making recommendations, discovering new drugs, making medical diagnoses, and solving problems that involve sequences (using, for example, video or time series analysis).

The basis of a DNN's potential is its ability to produce granular representations of highly dimensional and complex data. A DNN can, for example, give promising results when interpreting medical images in order to diagnose cancer early; to help improve the sight of visually impaired people; to enable self-driving vehicles; to colorize black-and-white photographs; to add missing elements to a photograph; and to recognize and understand a specific person's speech (which, in time, may make most devices conversational devices).

Completely new product categories in fields such as personal assistance, surveillance and even art should be expected.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Amazon; Arimo; deepsense.io; Google; H2O.ai; Intel; Kaggle; Microsoft; Psiori; Skymind

Recommended Reading: "Innovation Insight for Deep Learning"

"Cool Vendors in AI Core Technologies, 2017"

"Cool Vendors in Data Science and Machine Learning, 2017"

"Artificial Intelligence Primer for 2017"

"Predicts 2017: Analytics Strategy and Technology"

"Preparing and Architecting for Machine Learning"

"Magic Quadrant for Data Science Platforms"

Machine Learning

Analysis By: Alexander Linden; Peter Krensky; Carlie J. Idoine

Definition: Machine learning is a technical discipline that aims to extract certain kinds of knowledge and pattern from a series of observations. There are three major subdisciplines, which relate to the types of observation provided: supervised learning, where observations contain input/output pairs (also known as "labeled data"); unsupervised learning (where labels are omitted); and reinforcement learning (where evaluations are given of how good or bad a situation is).

Position and Adoption Speed Justification: Machine learning is one of the hottest concepts in technology at the moment, given its extensive range of effects on business. A sub-branch of machine learning, called deep learning, which involves deep neural nets, is receiving additional attention because it harnesses cognitive domains that were previously the exclusive territory of humans: image recognition, text understanding and audio recognition.

The drivers of continued massive growth and adoption are the growing volume of data and the complexities that conventional engineering approaches are increasingly unable to handle. In the future, advances in transportation, energy, medicine and manufacturing will be impossible without machine learning.

User Advice:

- Start with simple business problems for which there is consensus about the expected outcomes, and gradually move toward complex business scenarios.
- Nurture the required talent for machine learning, and partner with universities and thought leaders to keep up to date with the rapidly changing pace of advances in data science.

- Evaluate the capabilities of machine learning and its potential business impact across a wide range of use cases — from process improvement to the development of new services and products.
- Track what initiatives you already have underway that have a strong machine-learning component — for example, customer scoring, database marketing, churn management, quality control and predictive maintenance — to accelerate machine-learning maturation through cross-pollination of best practices. Monitor what other machine-learning initiatives you could be a part of and what your peers are doing.
- Assemble a (virtual) team that prioritizes machine-learning use cases, and establish a governance process to progress the most valuable use cases through to production.
- Focus on data as the fuel for machine learning by adjusting your data management and information governance for machine learning. Data is your unique competitive differentiator. Although the choice of machine-learning algorithms is fairly limited, data sources are abundant and a good long-term investment.

Business Impact: Machine learning drives improvements and new solutions to business problems across a vast array of business and social scenarios:

- Automation
- Drug research
- CRM
- Supply chain optimization
- Predictive maintenance
- Operational effectiveness
- Workforce effectiveness
- Fraud detection
- Automated vehicles
- Resource optimization

Machine-learning impacts can be explicit or implicit. Explicit impacts result from machine-learning initiatives. Implicit impacts result from products and solutions that you use without realizing they contain machine learning.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Alteryx; Dataiku; Domino Data Lab; H2O.ai; IBM; KNIME; Microsoft; RapidMiner; SAP; SAS

Recommended Reading: "Magic Quadrant for Data Science Platforms"

"Critical Capabilities for Data Science Platforms"

"Cool Vendors in Data Science and Machine Learning, 2017"

Autonomous Vehicles

Analysis By: James F. Hines

Definition: An autonomous vehicle is one that can move itself from a starting point to a predetermined destination without human intervention using various onboard sensing and localization technologies, such as lidar, radar, cameras, GPS and map data, in combination with AI-based decision-making capability. While self-driving cars are getting most of the attention at present, the technology can also be applied to nonpassenger vehicles and those that operate in the air and on water.

Position and Adoption Speed Justification: Through 2017, the efforts of automobile manufacturers and technology companies to develop self-driving passenger vehicles have been prominently featured by mainstream media, leading to unrealistic and inflated expectations for the technology. AI is a critical technology for enabling autonomous vehicles, and development of machine learning algorithms for autonomous vehicles has accelerated. Key challenges for the realization of autonomous vehicles continue to be centered on cost reductions for the technology, but they increasingly include legal and societal considerations, such as liability, insurance and the effects of human interaction.

Autonomous vehicle technology has a variety of potential applications in smart mobility, shipping and logistics, mining and agricultural operations, industrial, and security and military operations. Continued advancements in sensing, positioning, imaging, guidance, mapping and communications technologies, combined with artificial intelligence (AI) algorithms and high-performance computing capabilities, are converging to bring the autonomous vehicle closer to reality. However, in 2017, complexity and cost challenges remain high, which is impacting reliability and affordability requirements.

Several companies have made significant investments to assemble the portfolio of technologies needed to realize their autonomous vehicle plans. Intel is acquiring Mobileye for $15 billion, Ford motor company is investing $1 billion in Argo AI, Uber acquired Otto, and General Motors invested $500 million in Lyft for autonomous vehicle development and acquired Cruise Automation.

The pace of technology innovations and individual country, state and global legislation will likely initially result in specific, limited-use deployments of self-driving vehicles in the short term (for example, low-speed operations in a campus environment or designated area within a city, and high-speed operations on certified highways). Geofencing could be employed to limit autonomous operation to those permitted areas.

User Advice: The adoption of autonomous vehicle technology will develop in three distinct phases — automated driver assistance, semiautonomous and fully driverless vehicles. Each phase will require increasing levels of technical sophistication and reliability that rely less on human driving intervention. Automotive companies, service providers, governments and technology vendors (for example, software, hardware, sensor, map data and network providers) should collaborate on joint research and investments to advance the required technologies, as well as work on legislative frameworks for self-driving cars.

Furthermore, educate all constituencies of the benefits of self-driving vehicles. Consumer education is critical to ensure that demand meets expectations once autonomous vehicle technology is ready for broad deployment. For example, drivers will need to be educated on how to take over manually in case an autonomous vehicle disengages due to technical error or to changing environmental conditions. Specific focus must be applied to the transitional phase of implementing autonomous or partially autonomous vehicles with an existing older fleet of nonenabled vehicles. This will have implications for driver training, licensing and liability (as in insurance).

Autonomous vehicles will have a disruptive impact on some jobs, such as bus, taxi and truck drivers. Develop policies and programs to train and migrate employees that will be affected by automation to other roles.

Business Impact: The main implications of self-driving vehicles will be in economic, business and societal dimensions. Automotive and technology companies will be able to market autonomous vehicles as having innovative driver assistance, safety and convenience features, as well as an option to reduce vehicle fuel consumption and to improve traffic management. The interest of nonautomotive companies highlights the opportunity to turn self-driving cars into mobile computing systems that offer an ideal platform for the consumption and creation of digital content, including location-based services, vehicle-centric information and communications technologies.

Autonomous vehicles are also a part of mobility innovations and new transportation services that have the potential to disrupt established business models. For example, autonomous vehicles will eventually lead to new offerings that highlight mobility-on-demand access over vehicle ownership by having driverless vehicles pick up occupants when needed. Autonomous vehicles will deliver significant societal benefits, including reduced accidents, injuries and fatalities, as well as improved traffic management, which could impact other socioeconomic trends. For example, if people can use travel time for work or entertainment while being driven in an autonomous vehicle, living near a city center to be close to work won't be as critical, which could slow the process of urbanization.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Continental; Daimler Group; Delphi Automotive; General Motors; Mobileye; Nvidia; Robert Bosch; Uber; Waymo

Nanotube Electronics

Analysis By: Dean Freeman

Definition: Nanotubes are tiny cylinders of atoms that can be used for a wide variety of purposes. Properties can include high electrical conductivity, great mechanical strength, and insulator, semiconductor and conductor characteristics.

Position and Adoption Speed Justification: Carbon nanotubes with semiconductor properties offer the promise of small transistors with high switching speeds in future semiconductor devices. Carbon nanotubes with metallic (conducting) properties offer the promise of low electrical resistance that can be applied to the interconnections within integrated circuits. Other nanotube materials being evaluated include silicon and compound semiconductor materials. Silicon versions (often referred to as silicon nanowires) are actively being researched for use in silicon anode batteries.

Despite its high visibility, this technology is still working to gain traction as an electronics material outside of printing. Individual nanotubes can be readily fabricated, but problems remain with their interconnection and the fabrication of arrays of transistors. As a transistor gate material, nanotubes will look very promising — once the industry determines how to purify them and either grow them or place them on a substrate in quantities of several billion. Nanotubes will begin to appear when the technology nodes reach below five nanometers (nm); perhaps a generation sooner for interconnect technology if the challenges can be overcome. In 2013, IBM successfully built a 10,000-nanotube transistor device, and the company thinks it can have a production-worthy device in 2020, but the purification and cost challenges are still significant. There is discussion of gate all-around transistors at 7nm, however, it appears that conventional silicon technology may prevail another generation.

Interconnecting nanotube transistors present a different problem. There is the question of whether the nanotube bundles can support the required current densities. This is particularly critical in vias between layers. A 25nm-diameter via will hold approximately 21 nanotubes. Work on nanotubes as an interconnect appears to have dissipated as, in addition to all of the purity problems with CNT, the contact resistance between the materials in the interconnect region might be too big an issue to overcome.

Researchers are experimenting with new forms of, and new uses for, nanotubes. One team at the University of California, Berkeley, has developed a radio using a single nanotube; the 500nm length of the nanotube acts as the antenna, while other functions amplify and demodulate the signal.

With the challenges and the difficulties, CNT will not move forward on the Hype Cycle curve this year.

User Advice: Interested parties should monitor developments of this technology. Do not expect all advancements to occur during the same period. Pursue advances in energy-related applications first, such as batteries, solar cells and conducting materials in printed electronics. Semiconductor-related opportunity will take place beyond 5nm.

Business Impact: There is the potential for a huge impact, particularly when silicon devices reach their minimum size limits — expected during the next 10 to 15 years.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Globalfoundries; IBM; Imec; Intel; Samsung Electronics; TSMC

Recommended Reading: "Emerging Technology Analysis: Carbon Nanotubes Will Drive the Next Generation of Semiconductor Devices"

"Emerging Technology Analysis: Carbon Nanotubes and Graphene Are Indispensable for Future Electronic Products, So Act Now"

Cognitive Computing

Analysis By: Kenneth F. Brant

Definition: Cognitive computing is a class of technology, ranging from virtual assistants, cognitive expert advisors and intelligent augmented reality, enabling the improved performance of a human in cognitive tasks. We recognize "cognitive computing" as a promotional term in the marketplace, but do not believe these systems are truly capable of cognition; they mimic and/or extend the cognitive abilities of humans. They are interactive, iterative and stateful in dialogue, recalling previous interactions and adapting to changes in information and/or goals.

Position and Adoption Speed Justification: Cognitive computing rapidly climbed to the Peak of Inflated Expectations due to the pervasive promotion of the term by major vendors seeking differentiation in the latest generation of the AI marketplace. While some classes of AI like autonomous vehicles and virtual customer assistants may replace human workers, cognitive computing enhances them. Usability still suffers from difficulty in assembling the right bundles of technology matched to rich bodies of data, lack of skills to train rather than code systems and organizational and cultural acceptance. Thus, while the hype and expectations will continue to build, there is considerable disillusionment with cognitive computing still ahead. We expect these obstacles will be resolved for the mainstream adopters over the next five years, given the users' demands for making sense of patterns in the Internet of Things (IoT), digital business development and big data insights coupled with significant innovation of large and startup vendors.

User Advice: Realize that cognitive computing is a broad class of technologies, ranging from virtual assistants (VAs) that will assist with email and digital workplace issues to cognitive expert advisors (CEAs) that pair with knowledge workers to solve very narrow problems and make profound discoveries and computer vision (CV), augmented reality (AR) systems that enhances humans' sensory perception.

Establish clear, yet cross-functional, responsibilities to investigate and trial cognitive computing technologies, including VAs, CEAs and CV/AR.

Develop a mission statement and objectives for performance improvement via cognitive computing as part of a five-year technology adoption plan. Make sure to include employment policy considerations, impacts on workers, and sufficient time and resources to implement communication and change management programs.

Resist the temptation to select "winners" at this stage and make experimental trials involving many vendors.

Employ "Mode 2" development, cognitive ergonomics and design thinking to cognitive computing adoption plans.

Business Impact: Cognitive computing can impact the business in broad and deep dimensions. VAs, for example, will impact productivity horizontally and across many job categories, including performers of routine work. Meanwhile, CEAs will impact primarily vertical-specific use cases in the banking, insurance, healthcare and retail sectors, and in the narrow fields of nonroutine, knowledge work. CV/AR will enhance human perception, decision making and productivity in utilities, mining, construction, manufacturing and maintenance repair and overhaul functions.

Some of the business benefits you should seek to verify and quantify in cognitive-computing-based business models and trials include:

- Higher output per dollar of selling, general and administrative (SG&A) expenses
- Faster cycle times
- Improved productivity of field maintenance workers
- Reduced risk and opportunity costs due to poor/late decisions
- Greater return on R&D investments
- Improved employee safety and satisfaction

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Accenture; CognitiveScale; Deloitte; Digital Reasoning; Google; IBM; IPsoft; KPMG; Microsoft; Saffron (an Intel company)

Recommended Reading: "Digital Business Innovation With Smart Machines"

"Smart Agents Will Drive the Switch From Technology-Literate People, to People-Literate Technology"

"The IT Role in Helping High Impact Performers Thrive"

Blockchain

Analysis By: David Furlonger; Ray Valdes; Fabio Chesini

Definition: A blockchain is an expanding list of cryptographically signed, irrevocable transactional records shared by all participants in a network. Each record contains a time stamp and reference links to previous transactions. With this information, anyone with access rights can trace back a transactional event, at any point in its history, belonging to any participant. A blockchain, or public distributed ledger, provides open participation to anyone or any entity where access is not controlled by a central intermediary or a subset of participants.

Position and Adoption Speed Justification: Different types of public ledgers exist:

- Permissionless-public ledgers (e.g., the Bitcoin Blockchain and Ethereum) operate for any unknown or untrusted user with access to the ledger, and allow these users to participate in commercial transactions.
- Permissioned-public ledgers, (e.g., Ripple) operate on behalf of a community of interest, but access controls are owned/managed by rules (see "Understanding Blockchain Platform Architectures and Implementation Styles").

Largely, permissionless-public ledgers are inappropriate for most enterprise use-cases, where the ledger is deployed by an individual enterprise, or as part of an industry ecosystem or consortia. In many cases no token is used as part of the ledger platform. Enterprises "may" connect to permissionless ledger ecosystems (e.g., the Bitcoin Blockchain) for certain consumer-centric commercial activities — provided appropriate operational risk measures are in place.

Most distributed ledger initiatives are still in the early alpha or beta stage. Recent versions incorporate assets, data and executable programs allowing for customized applications to be developed on top of the ledger protocol. Significant positive hype remains about the value of ledgers, but concerns remain about the viability of the technologies, security (software and hardware), scalability, legality and interoperability. Unless and until more standards and enterprise scale capabilities are developed and adoptable in a mission-critical at scale context, acceptance of the technology and thence transformation of enterprise and industries will remain problematic.

During the next five to 10 years, convergence in architectural deployment styles (private and public) is likely, with all distributed ledgers having similar functional characteristics (e.g., ZK proofs, tokens, privacy controls, APIs and secure wallets). Market differentiation in public ledgers will lie in the inherent capabilities of consensus mechanisms (e.g., the efficiency of the distributed ledger), interoperability and UX.

User Advice: Use clear language and definitions for internal discussions about the nature of the technology and the type of ledger technology being developed. Ensure that nontechnical executives understand the differences in business outcomes (e.g., from both an operational risk and an ecosystem perspective) that each variety of ledger and its related application stack enables. Closely monitor distributed ledger developments and metacoin platforms, including related initiatives in areas such as consensus mechanism development, sharding, authentication and data management. If resources permit, consider distributed ledger for proof-of-concept (POC) development, but make sure your team has both the technical and business skills to understand the problem to be solved. Identify integration points with existing infrastructures (e.g., digital wallets) to determine future investment plans.

Business Impact: Public distributed ledgers continue to have high visibility, not least due to the wildly speculative volatility in the underlying tokens (e.g., Ether and bitcoin) over the last several months. However, enterprises remain cautious as to the future of public (permissionless) distributed ledger concepts due to issues such as scalability, risk, governance, etc. Multiple business use cases have yet to be proven and volatility in bitcoin persists. Presupposing the technical and business challenges of distributed ledgers can be overcome, in the short terms enterprises are most likely to use distributed ledger for operational efficiency gains, e.g., via the use of shared information and infrastructure. Long-term Gartner expects a complete reformation of whole industries and commercial activity as the programmable economy develops and ledgers contribute to the monetization of new ecosystems.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Bitcoin.org; Dash; Ethereum; Litecoin; Zcash

Recommended Reading: "The Future of Money Is the Programmable Economy, Not Just Bitcoin"

"Maverick* Research: In a Post-Bitcoin World, Metacoin Platforms Enable the Programmable Economy"

"Hype Cycle for the Future of Money, 2014"

"The Bitcoin Blockchain: The Magic and the Myths"

Commercial UAVs (Drones)

Analysis By: Gerald Van Hoy

Definition: Commercial unmanned aerial vehicles (UAVs) are small helicopters, fixed-wing airplanes, multirotors and hybrids remotely controlled by human pilots on the ground or outfitted for autonomous navigation. UAVs typically incorporate global navigation satellite system (GNSS), camera, and sensors guiding them in imaging, thermal and spectral analysis. Memory caches and communications links enable UAVs to collect datasets or transmit them for storage or processing to the cloud. Collision avoidance systems are increasingly included on these systems.

Position and Adoption Speed Justification: In 2017, commercial UAVs have now moved over the Peak of Inflated Expectations due to technology improvements and further demand. Commercial applications continue to emerge. Examples of commercial UAV applications include surveying for extractive industries, infrastructure inspection, pipeline inspection, disaster inspection, security inspection, and agriculture inspection. According to the U.S. Federal Aviation Administration (FAA) website, since establishing its Part 107 federal UAV regulations, commercial applications have strongly increased, and they are looking at an annual growth rate of 69.1%. China, Japan, the U.K. and the EU continue to test the application of UAVs in agricultural and parcel deliveries. All major e-retailers and package delivery companies continue to test drone delivery, particularly in rural areas and difficult terrain. The FAA's Nevada test site, Dubai, and Singapore began or will test drone taxi services in 2017. The oil and gas industry has continued to expand its use of drones in its operations, oil rig, pipeline, turbine inspections and surveying, as well as asset/inventory tracking. It is expected that such applications would be fairly commonplace within the next few years, and R&D continues to move further into autonomy.

Commercial UAV production is still somewhat hampered in areas of the world where countries have established regulations or recently amended their laws to accommodate UAVs. The FAA continues to accept waivers for particular rules, mostly the daylight operation rules which include Beyond Visual Line of Sight.

Given the increase in use cases, new technology investment, number of registrations and further regulations, Gartner moves the time to plateau as two to five years.

User Advice: Commercial and industrial firms in the oil and gas, agriculture, mining, construction, energy, transportation, news-gathering and film-making sectors should actively participate in this technology closely. Firms in these industries that have economic motivations to increase process uptime, improve workers' safety, and avoid catastrophic events and financial liabilities should do feasibility testing. These UAVs are especially attractive for autonomous inspections, used in sparsely populated environments where valuable assets are physically distributed and are costly and/or dangerous to inspect, such as the maintenance of solar and wind power generation equipment (which are highly sensitive to equipment misalignment and are difficult for humans to efficiently inspect), offshore rigs, oil and gas pipelines, power distribution lines, process manufacturing plants, and agricultural and construction work sites. U.S.-headquartered multinational firms in these sectors should be familiar with and adhere to the FAA Part 107 regulations regarding UAVs. Other country, state/province, county and city regulations may also affect testing and usage, and it would be advised that companies understand these jurisdictions first.

Business Impact: Commercial UAVs are replacements for human surveyors, inspectors, drivers and cameramen who previously had to perform costly jobs in unsafe conditions — so they offer productivity improvements by reducing and/or redeploying head count, while improving real-time data capture and workers' safety. The greater diagnostic capability of UAV payloads coupled with the increased availability/reliability of surveillance resources can reduce operating costs, missed opportunity costs and the risk of catastrophic events while improving project management and resource allocation. They can also generate revenue in the case of surveying.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: AirShip Technologies Group; Ascending Technologies; DJI; Flyability; PrecisionHawk; senseFly; Skycatch; Trimble

Recommended Reading: "Forecast: Personal and Commercial Drones, Worldwide, 2016"

"Market Trends: Multirotor Drone Evolution Will Demand Increased Semiconductor Content"

"Toolkit: Map Technologies to Insurance Business Priorities With Gartner's Value-Maturity-Velocity Model"

"Top 10 Trends Shaping the 2017 Utility Industry on the Road to Digital Business"

Sliding Into the Trough

Cognitive Expert Advisors

Analysis By: Kenneth F. Brant

Definition: Cognitive expert advisors (CEAs) are the most specialized form of "AI-enabled virtual assistants," developed using extremely deep and narrow training corpora. CEAs, at a minimum, incorporate specialized algorithms, as well as machine-learning and natural-language processing functions tuned specifically to a curated body of big data to answer questions, make discoveries, give recommendations, and aid decisions. They mimic the "cognitive" functions of human subject matter experts, extending the thoroughness, depth and timeliness of human insight.

Position and Adoption Speed Justification: CEAs quickly rose to the Peak of Inflated Expectations because of the prominence of IBM's Watson in popular culture (a question-answering prototype won Jeopardy) and the subsequent creation of the IBM Watson Group that heavily promoted the term "cognitive computing" in association with its expert advisor offerings. Many major vendors have now embraced the term "cognitive computing" with respect to their expert advisory platforms. The accuracy and productivity of these systems today are still being tested and proven. Even when initially successful, the systems can be fragile, requiring frequent troubleshooting, retraining and upkeep. We believe it will take considerable time (5 to 10 years) for these deployment and maintenance issues to become manageable and acceptable by the majority of enterprise users who want a dependable service level. This year's highly publicized retreat of MD Anderson regarding its initial CEA development program with IBM highlights the difficulty and risk involved in this class of AI. The issues are not strictly technological nor vendor-driven, but also involve a considerable amount of vision, risk-taking, leadership and commitment to change management on the part of enterprise champions. Furthermore, the skill sets and practices needed to be successful with this class of technology are not the same as those associated with the typical IT project, and they are not found in the typical line of business or strategic business unit leading the mission.

User Advice: Early adopters should begin trials of CEAs if they can identify a strong program champion who has visionary and change management leadership skills. These organizations should first verify that they are investigating applications that are suitable for CEAs and not for simpler technologies. Preliminary work should ensure that data/content is accessible (owned and/or acquired), and suitable for developing problem-specific "corpus." Do not select one company and move immediately to pilot. Given the complexity and wide range of results seen in the earliest trials to date, we advise a broad trial involving several providers to see which approaches produce the best results with your data, industry application and corporate culture. Be prepared to devote more time to each provider than you would for other types of software trial, as initial results may not be satisfactory, and the matching of algorithms with your curated content and training methods will require multiple assessments. Ensure that your internal personnel and service providers have the requisite skills and mindset to do the initial content curation, system training, experimentation and maintenance.

Business Impact: CEAs' business impacts to-date have been greatest in industries and applications where the presence of big, dynamic and largely unstructured data is compounded by the need for highly domain-specific and complex scientific inquiries, business decisions and customer recommendations.

Some of the key benefits promised by CEAs are:

- Faster scientific discoveries and accelerated time to market with new products and services (for example, in pharmaceutical and biotechnology research)
- More timely, accurate and beneficial problem identification and solution decision making (for example, in medical diagnosis and treatment)
- Lower costs, higher customer retention and brand equity in complex customer service situations (for example, in retail, insurance and investment customer care)

The cost and complexity of developing CEAs put them out of the direct reach of the large majority of consumers for the near future. We expect consumer usage of CEAs through 2018 will be via enterprises that have deployed them for premium-branded customer service offerings.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: CognitiveScale; IBM; Infosys; IPsoft; Saffron (an Intel company); Wipro

Enterprise Taxonomy and Ontology Management

Analysis By: Mark A. Beyer; Guido De Simoni

Definition: The management of the taxonomy (classification) and ontology (nature) of information consists of practices and implemented technology solutions. Ontology is a classification approach that groups similar items together based upon some affinity or parallel function. Taxonomy is the distinctive nature of particular concepts, physical things or even language structure. This definition is specific to data, rather than a general definition.

Position and Adoption Speed Justification: The ability to manage existing T&O pairs and to discover new, useful pairs is becoming increasingly important. T&O methods can be used to allow many different use cases to access and utilize information in a "data lake" or detailed layer of an enterprise data warehouse (EDW). Some T&O pairs or even overlapping layers can be specified (two taxonomies to one ontology or one taxonomy participating in two ontologies), others emerge dynamically from data discovery, data science modeling, business process evaluation or even content analytics (text, document, audio, image and video). As data is recombined by analysts, new affinity or sympathy between information assets is discovered and has the potential for benefits and reuse by other information systems.

Eventually, functionality will be reduced and the adoption will slow to a crawl as ontologies struggle for proof of value. We see the market developing less in the direction of general-purpose, cross-platform semantic modeling and more toward T&O management that will be used in specific cases and for specific projects. This "rationalization" process accelerated in the last 18 months with MDM, data quality and even data integration tools and platforms starting to assume these metadata driven capabilities. This raises the question of whether general-purpose T&O management will ever reach the Plateau of Productivity. Glossaries and other rudimentary T&O approaches have inflated expectations for significant introspection. The bulk of ontological work will remain human-driven, using tools that present metadata to human users who then develop personal ontology use cases. Some capabilities for enterprise taxonomy and ontology are diffusing, to some degree, into other platforms (catalogs, glossaries and so on), which has accelerated the demand for a more complete solution.

User Advice: Data administrators and information stewards should look for opportunities to federate the various metadata support efforts that are being established in different disciplines and begin to build a registry of shared taxonomies and ontologies. Metadata that catalogs the taxonomies and ontologies and (more importantly) ensures that they are shared, records the extent to which they are held in common, can support service-oriented deployments and could become a key component of context brokers.

Business glossaries encourage predominant definitions, they also allow for localized and domain-specific definitions and terminology management. Determine whether significant cross-purpose communication is taking place in your organization and consider using a glossary tool (one area of interest here is data catalogs).

Educate designated or selected business personnel in roles for the creation of information assets and in the importance of metadata as a precursor to introducing these T&O practices. Exercise extreme caution, however, end users should not be subjected to the rigor or terminology involved in metadata management. The focus here should be on ensuring the business understands the process, the benefits and the users' levels of commitment.

Business Impact: Enterprise T&O management will bring a faster, more agile mode of integration between business process changes and IT system changes. It will also enable better assessment (by business analysts) of the risks and benefits that accrue in the business regarding the maintenance and security of information assets. Ontologies are dynamic — they emerge as the business process is defined and as it changes or absorbs activity from adjacent processes. Taxonomy originates within a business process then expands as ontology concepts become better defined (see "Market Guide for Virtual Customer Assistants"). T&O capabilities become important as new forms of data architectures emerge, such as "governed" or "smart" data lakes, graph analysis, and so on (see "How Chief Data Officers Can Use an Information Catalog to Maximize Business Value From Information Assets").

Ontology implies how data can be used and often the same data can be used for many purposes. Taxonomy defines the components and relationships that are used in data to create a useful data object. All data points have dependency and reference to other data points and taxonomy explains both the components and their relationships to each other. It is possible for data to belong to multiple taxonomies and ontologies simultaneously.

The pursuit of T&O management will begin the process of aligning risk management with operations management, finally bridging the gap between compliance and margin management. In managing T&O resolution, data quality efforts will be easier to manage. Nonshared terms will be resolved to each other and sources will recognize common models for data quality resolution and master data management (MDM) support. New advances have been noted with regard to enterprise data management in the financial services and banking industry. From an ontology perspective it is almost mandatory that it remain within industry silos.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Adaptive; Digital Harbor; Global IDs; IBM; Mondeca; SAS; Smartlogic; TopQuadrant

Recommended Reading: "Innovation Insight: Leveraging Ontology to Exploit Business Value Hidden in Information"

"Market Guide for Virtual Customer Assistants"

"How Chief Data Officers Can Use an Information Catalog to Maximize Business Value From Information Assets"

Software-Defined Security

Analysis By: Neil MacDonald; Mike J. Walker

Definition: Software-defined security (SDSec) is an umbrella term covering a number of security processes and controls that benefit when the security policy management is abstracted from the underlying security policy enforcement points.

Position and Adoption Speed Justification: Information security infrastructure is too rigid and static to support the rapidly changing needs of digital business and to provide effective protection in a rapidly changing threat environment. Increasingly, security vendors are shifting more of the policy management out of individual hardware elements and into a software-based management plane for flexibility in specifying security policy, regardless of location. There are several areas within SDSec that are emerging — software-defined perimeters, software-defined segmentation (microsegmentation), software-defined data protection and cloud workload protection platforms.

User Advice:

- Look beyond the hype. There are several areas where organizations are finding value in SDSec use cases today.
- Don't make the mistake of assuming "software-defined" means software only. Security hardware will still be needed for deep inspection at demarcation points.
- Require all security platform vendors to open up via APIs for full programmability of their infrastructure.
- Pressure security platform vendors for their roadmaps to support OpenStack and other cloud management platforms.

Business Impact: Information security cannot be an inhibitor to the needs of digital business. SDSec will bring speed and agility to the enforcement of security policy regardless of the location of the user, the information or the workload.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Catbird; Certes Networks; CloudPassage; Fortinet; Illumio; Security First Corp.; Trend Micro; Unisys; vArmour; Vidder

Recommended Reading: "It's Time to Isolate Your Services From the Internet Cesspool"

"Market Guide for Cloud Workload Protection Platforms"

"What Is the Value of a Software-Defined Data Center?"

Augmented Reality

Analysis By: Tuong Huy Nguyen; Marty Resnick; Brian Blau

Definition: Augmented reality (AR) is the real-time use of information in the form of text, graphics, audio, and other virtual enhancements integrated with real-world objects and presented using a head-mounted-type (HMD) display or projected graphics overlays. It is this "real world" element that differentiates AR from virtual reality. AR aims to enhance users' interaction with the environment, rather than separating them from it.

Position and Adoption Speed Justification: Current technology is best-suited for purpose-built solutions. As such, position and adoption speed will vary by vertical and industry. This profile represents a homogenized view of AR implementations across market segments.

AR is currently struggling with mismatched expectations (vendors promising solutions beyond current capabilities), poor implementations (for example, solutions delivered without immersive development knowledge, workflow integration, or mapped-to-business value or need) and lack of standards (interoperability, content production, frameworks, etc.). Although Pokémon Go has significantly changed user behavior and acceptance of AR, B2C implementations are still struggling to show consumers value. Better and more transparent hardware, coupled with more compelling use cases, are needed before further progress can be made. Based on Gartner inquiry and industry news, B2B AR continues to gain traction as more enterprises are discovering and seeing the value of using AR in their workflow and other processes. HMD sales reflect the burgeoning pilot deployments.

Furthermore, developments and announcements for technology, hardware and platforms from leading IT vendors (such as Intel, Google, Facebook, Amazon and Microsoft) serve as a two-way steppingstone for AR development. For example, the role of social media and AR as discussed at Facebook's F8 conference. Advancements in HMD hardware will provide more compelling hands-free use cases for AR, as well.

User Advice: Decide on the audience for your AR solution. Internal- and external-facing solutions are not transposable. Restrict initial trials to a specific task or goal. Set benchmarks against unaugmented solutions to understand risks and benefits. Set the business goals, requirements and measurements for your AR implementation before choosing a provider. Rich and robust offerings can bring value only if you have a clear intention for the deployment. For external-facing implementations, use AR as an extension of your brand and experience. For internal-facing implementations, use AR as a tool that will enhance employee job function (for example, delivering context-specific information at the point of need for mobile workers, reduction of head count in plant and maintenance operations, or enhancing business processes via AR-based training and instruction).

Business Impact: By leveraging device sensors, AR acts as a digital extension of users' senses, and it serves as an interface for humans to the physical world. It provides a digital filter to enhance the user's surroundings with relevant, interesting and/or actionable information.

AR bridges the digital and physical world. This has an impact on both internal- and external-facing solutions. For example, internally, AR can provide value by enhancing training, maintenance and collaboration efforts. Externally, it offers brands, retailers and marketers the ability to seamlessly combine physical campaigns with their digital assets.

As such, AR is broadly applicable across many markets, including gaming, industrial design, digital commerce, marketing, mining, engineering, construction, energy and utility, automotive, logistics, manufacturing, healthcare, education, customer support, and field service.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Blippar; Catchoom; Daqri; Google; Kudan; Microsoft; Wikitude

Recommended Reading: "Market Guide for Augmented Reality"

"Competitive Landscape HMDs for Augmented Reality and Virtual Reality"

"Top 10 Strategic Technology Trends for 2017: Virtual Reality and Augmented Reality"

"The First Three Steps in Evaluating the Role of Head-Mounted Displays for Field Service"

"Immersive Technologies Offer Infinite Possibilities"

Climbing the Slope

Virtual Reality

Analysis By: Brian Blau

Definition: Virtual reality (VR) provides a computer-generated 3D environment that surrounds a user and responds to an individual's actions in a natural way, usually through immersive head-mounted displays (HMDs). Gesture recognition or handheld controllers provide hand and body tracking, and haptic (or touch-sensitive) feedback may be incorporated. Room-based systems provide a 3D experience while moving around large areas or can be used with multiple participants.

Position and Adoption Speed Justification: Immersive VR applications are more advanced than other types of graphical simulations, and the time to plateau of five to 10 years is consistent with awareness, exposure to the technology, and overall adoption with consumers and more traditional consumerlike usage for businesses.

VR experiences are typically used with HMDs. The well-known devices on the market today are the Oculus Rift, Sony PlayStation VR, Valve/HTC Vive, Samsung Gear VR and Google Cardboard. VR is mature enough for enterprise use, but caution is required as, while the devices are capable, the success of VR systems depends on the quality of the user experience or app. Most VR is being used by consumers to play video games or watch video, which can be 360-degree or spherical video content. VR is moving onto the plateau as VR HMD deployments are approaching 10 million (all combined), so there are a significant number of devices in the hands of users, but engagement or usage is still small and growing.

User Advice: Virtual reality can be used in a variety of business scenarios:

- Complex simulation and training applications
- Military simulation and training, such as flight simulators
- Telepresence in scenarios such as remote medicine
- Equipment operator training
- Entertainment and social experiences, such as video games or 360 surround video or interactive movies
- Product marketing to extend in the brand interaction or in product design
- Architectural walkthroughs and scientific visualization, such as genome mapping

- Modeling, such as geomodeling in the oil industry

While VR can be amazingly sophisticated and beneficial, the level of customization can come at a high cost. Recent advances in HMD technologies may help ease these obstacles, so developers should focus on building effective and quality experiences. Standards for artificial intelligence scripting, object metadata and social identity data are becoming more popular, due to increased use of personal and social networking technologies, which will help developers make VR more personalized and intelligent. Technologies such as cloud graphics processing and mobile video games, as well as the proliferation of broadband access, will allow application developers to integrate VR more easily into their products.

VR developers should consider targeting immersive video game development; interactive movies; and new storytelling experiences, live events and business-focused scenarios where using advanced visualization and HMDs can benefit the task or customer interaction point due to their ability to offer higher degrees of visual fidelity and personalization over what flat-screen-based systems can provide.

Business Impact: VR can support a wide variety of simulation and training applications, including rehearsals and response to events. VR can also shorten design cycles through immersive collaboration, and enhance the user interface experience for scientific visualization, education and entertainment. Businesses will benefit due to VR's immersive interfaces, helping create task efficiencies or reducing costs associated with new product design, or can enhance the understanding of information through advanced graphical visualization and simulation technologies.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: HTC; Mechdyne; NextVR; Oculus VR; Samsung; Sony; Valve; Virtual Heroes; WorldViz

Recommended Reading: "Market Trend: Head-Mounted Displays for Virtual Reality and Augmented Reality"

"Market Guide for Augmented Reality"

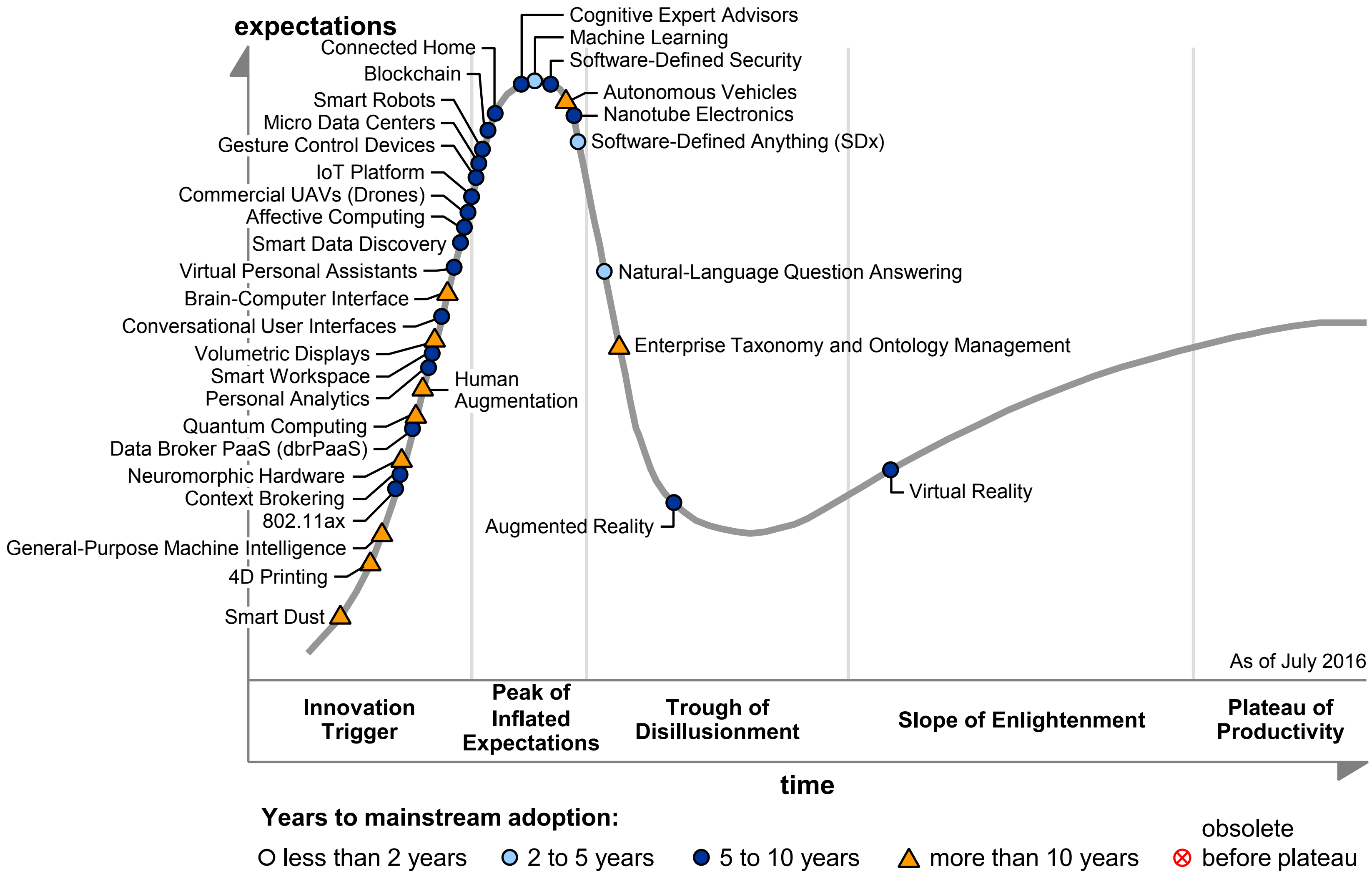
"Cool Vendors in Human-Machine Interface, 2017"

"Top 10 Strategic Technology Trends for 2017: Virtual Reality and Augmented Reality"

"Forecast: Wearable Electronic Devices, Worldwide, 2016"

Appendixes

Figure 4. Hype Cycle for Emerging Technologies, 2016



Source: Gartner (July 2016)

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 (July 2017)

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 (July 2017)

Table 3. Maturity Levels

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

Source: Gartner (July 2017)

Gartner Recommended Reading

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

"Understanding Gartner's Hype Cycles"

"Hype Cycle for Emerging Technologies, 2016"

"Toolkit: My Hype Cycle, 2016"

More on This Topic

This is part of an in-depth collection of research. See the collection:

- 2017 Hype Cycles Highlight Enterprise and Ecosystem Digital Disruptions: A Gartner Trend Insight Report

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