Hype Cycle for Drones and Mobile Robots, 2020

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By Analyst(s): Bill Ray

Initiatives: Technology Innovation

Drones and mobile robots are deployed to sense and manipulate data in remote areas that are hard for humans to reach. They can also provide improved safety, superior proficiency and lower costs.

Analysis

What You Need to Know

Drones and mobile robots have become a common tool in numerous industrial, commercial and consumer workspaces, as well as military applications. These devices are being used for site inspection, mapping, security, asset and inventory tracking, data collection, and other purposes. While monitoring (using cameras and/or environmental sensors) remains the most popular application, we are also seeing drones being used to clean buildings, spray crops and a wide number of other applications. These and other tasks can be performed in the air, on the ground or in water.

This Hype Cycle includes technologies used to enable the use of drones, mobile robots and even android robots, which could be semiautomated or fully automated. This year we have added autonomous trucks, as industry interest is growing in the concept, and we have split light-cargo delivery vehicles into those that fly (drones) and those with wheels (robots), as the development and deployment schedule are diverging.

End-user organizations that want to harness the value of robots or drones and vendors looking to develop or sell robot and drone services must review the innovation profiles in this Hype Cycle to understand their service roadmap and substantiate their business model.

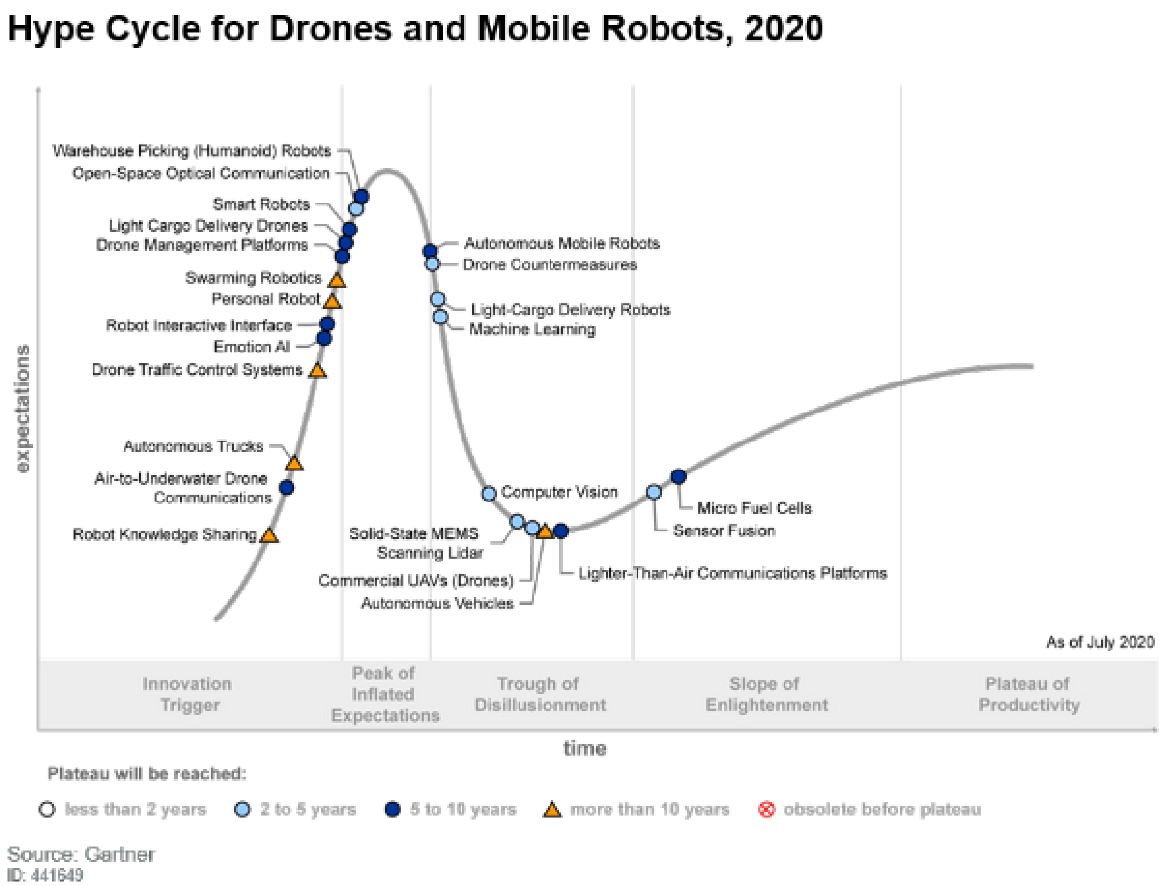
The Hype Cycle

Drones and mobile robots are becoming more powerful and practical with the progress of artificial intelligence (AI) and improvements in semiconductor technology. This evolution not only reduces the price and simplifies the use of autonomous technology, but it is also opening up new use cases as the lift capacity and range of the platforms extend.

Gartner is seeing increased demand for drones, and several countries have removed uncertainty around their use with new regulations and operator requirements. Despite that, the nascent nature of the industry means that (with one notable exception) all the profiles covered in this Hype Cycle remain more than two years ahead of widespread adoption. Many of the platforms, technologies and components (such as semiconductors, sensors, motors/actuators, networks, software/algorithms and materials) that will improve performance, costs and capabilities in these systems leverage development in other end markets.

Drone and mobile robots are being used more widely every day. However, there are still many challenges in making them better including limited autonomy, operational life between charging and fleet management. The innovation profiles listed in this document will show how the industry will overcome these challenges.

Figure 1. Hype Cycle for Drones and Mobile Robots, 2020



The Priority Matrix

The Priority Matrix combines positions on the Hype Cycle, benefit rating, and, most importantly, time to mainstream adoption of each innovation profile. Seven technologies have been rated transformational this year, including one (machine learning) that is expected to hit mainstream adoption within the next five years. Autonomous vehicles, including trucks, will also be transformational, but will not see widespread adoption for at least a decade.

A number of technologies with “high” impact will also mature within the next few years, creating an accelerating market for increasingly capable drones and mobile robots. Lidar is a particularly interesting technology that is finding its way into a host of applications (not the least being the latest Apple iPad). Increased production is driving down costs, accelerating adoption into drones and mobile robots.

Alongside these developments, we continues to see considerable development in drone countermeasures, as airports, municipalities and countries wrestle with a threat that has hitherto been the preserve of the military. Better drone countermeasures will be critical to public acceptance, which may be as significant a barrier to adoption as the technologies themselves.

Figure 2. Priority Matrix for Drones and Mobile Robots, 2020

Priority Matrix for Drones and Mobile Robots, 2020

benefit	years to mainstream adoption			
	less than two years	two to five years	five to 10 years	more than 10 years
transformational		Machine Learning	Autonomous Mobile Robots Emotion AI Warehouse Picking (Humanoid) Robots	Autonomous Trucks Autonomous Vehicles Personal Robot
high		Commercial UAVs (Drones) Computer Vision Open-Space Optical Communication Sensor Fusion Solid-State MEMS Scanning Lidar	Drone Management Platforms Light Cargo Delivery Drones Robot Interactive Interface Smart Robots	Drone Traffic Control Systems Robot Knowledge Sharing
moderate		Drone Countermeasures	Lighter-Than-Air Communications Platforms Micro Fuel Cells	Swarming Robotics
low		Light-Cargo Delivery Robots	Air-to-Underwater Drone Communications	

As of July 2020

Source: Gartner
ID: 441649

Off the Hype Cycle

This year, a few technologies have been dropped from the Hype Cycle to focus more on technologies specifically related to drones and mobile robots. Thus, we have removed several battery technologies, though updates on these technologies can be found in our “Hype Cycle for Power and Energy, 2020.”

On the Rise

Robot Knowledge Sharing

Analysis By: Annette Jump

Definition: Robot knowledge sharing describes the ability for robots to exchange knowledge and learned skills with other robots. Robot knowledge sharing enables a robot or multiple robots to be trained to perform a specific task or action via machine learning algorithms. This learned behavior is stored in a central or cloud location and then made available for other robots.

Position and Adoption Speed Justification: The term “robot” encompasses a wide range of systems from a simple automatic vacuum cleaner to complex devices such as personal assistant robots (PAR) and industrial robots. The time required to program a robot hinges on important factors such as the machine learning technique used (deep learning versus shallow learning) and the tasks the robot is intended to perform (simple versus complex or informational tasks versus physical tasks or a mixture of them).

There are different techniques to teach robots new tasks or make existing capabilities correctly work in unfamiliar situations. This is where robot knowledge sharing can help, as it is aimed at finding ways for robots to share skills and learned tasks in a useful way. Currently, researchers are experimenting with three ways to advance robot knowledge sharing:

- Cloud robotics (reinforcement learning, learning based on predictive models)
- Knowledge transfer robotics
- Human guidance robotics

Researchers from Robotics at Google are experimenting with using visual transfer learning for robotic manipulation, this method is similar as those used for computer vision tasks. It includes visual pretraining to improve learning efficiency applied for robot grasping tasks. MIT researchers and researchers at the RoboEarth project are working on creating a shared language for robots and an online repository to share knowledge about specific tasks over the internet. But there are still challenges linked to the ability to quickly share a lot of data via cloud (faster internet, 5G and increase in cloud capacity will help with that), as well as the need to create a robot community for knowledge sharing. Also, MIT researchers are experimenting with a new approach to transfer knowledge — they train robots by combining motion planning and learning demonstrated by other robots ("C-LEARN"). This approach can help teach robots to perform complex multistep tasks in manufacturing, assembling or maintenance.

Other projects include, Robo Brain that works with PlanIt and Tell Me Dave through which volunteers can help to train robots perform different tasks. Robot knowledge sharing and cloud robotics can provide robots with rapidly available intelligence and skills, but there are still a lot of technical challenges ahead and there has been only limited progress in 2019/early 2020. Therefore, the technology position on Hype Cycle has only slightly moved up on the Innovation trigger curve since 2019.

User Advice: Robot knowledge sharing is currently in the research stage, though successful knowledge transfer has been demonstrated with robots learning new, but very simple, skills (such as lifting and placing an object) via the knowledge database. This is the technology that will make swarming in robotics a possibility (this is the approach for coordinating multirobot systems that consist of mostly simple physical robots).

- Users deploying personal assistant robots in healthcare, public assistance or smart robots in industrial settings should be aware of robot knowledge sharing and robot training, especially when relying on systems that need to perform tasks with high precision. Robot knowledge sharing will originally be used in more complex, high-end robots and at a later stage be available for mainstream or basic robots.
- Utilizing common programming language, like ROS, will be helpful to help drive cross-robot learning in the future.

Business Impact: The robot knowledge sharing technology is still in adolescent and embryonic maturity state and it is important to keep that in mind when considering any business applications of this technology. One benefit of robot knowledge sharing is to bring scale to systems such as Learn C Tutorial that teaches robots new skills. The knowledge database can be used to export/transfer skills from one place and robot to multiple others. Once robot knowledge sharing moves from the research stage to successful commercialization, the impact will be felt by organizations who deploy robots performing tasks that cannot easily be conducted by humans. Robot “fleet management” will be also an important consideration in the future, as organizations will have hundreds or thousands of robots deployed. Ability to quickly providing latest software and knowledge updates will become critical.

Examples are finding and rescuing people in war zones and natural disasters, disabling bombs, as well as everyday day life — such as aid for the elderly or disabled.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Alphabet; Alphabet (DeepMind); Robo Brain; Tell Me Dave

Recommended Reading: “Top 10 Strategic Technology Trends for 2020: Autonomous Things”

“Forecast: IoT Enterprise Robots by Use Case, Worldwide, 2018-2028”

“Preparing for a Future When Your Next Manufacturing Employee Will Be a Robot”

Air-to-Underwater Drone Communications

Analysis By: Bill Ray

Definition: Air-to-underwater drone communication is a wireless connection between an aircraft and an unmanned survey vehicle or autonomous submarine. These vessels currently use a cable (or tether) to bypass the limitations imposed by the conductivity of saline seawater, which blocks most radio communications.

Position and Adoption Speed Justification: Communicating with submarine equipment is important for both military and civilian operations, but seawater is very opaque to radio signals (thanks to its high conductivity) while sonar is useful only in water. While the focus has been on maintaining contact with manned naval submarines, there is an increasing demand for communications with unmanned survey vehicles and autonomous submarines used in construction, port management and environmental monitoring.

Extremely low frequency (ELF) radio waves will travel through water, but the antenna needed to generate such waves (below 30Hz) is tens of kilometers in length, making it impractical for submarine or aircraft. These frequencies have been used by military forces to send orders to submarines in the field, but all communication is unidirectional.

A recent alternative uses a combination of sonar and radar to create a channel from an underwater vehicle to a flying aircraft. Sonar is used to transmit through the water, and as the sonar signal hits the surface, it creates a vibration that can be detected by a highly sensitive radar system some distance above the surface. Researchers at MIT have demonstrated such a system, but commercial development is progressing very slowly.

However, there is clear demand from the oil and gas industry, as well as search and rescue operations. For this reason, the technology for air-to-deep-sea communications has moved up the Hype Cycle and will likely be available within 10 years.

User Advice: Direct communication between aloft aircraft and a submarine drone or manned vehicle remains some way off, requiring significant technical developments. Potential users are advised to seek alternative channels, such as tethers, timed surfacing, or a towed buoy with a mounted antenna, until the new technology can be proven in the field.

Business Impact: Being able to communicate directly with submerged equipment would have a significant impact on submarine drones used to monitor, or even repair, undersea pipelines and cables. The technology would also be suitable for locating wrecked ships and aircraft (assuming a black box fitted with a sonar transmitter).

Benefit Rating: Low

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Massachusetts Institute of Technology; The VLF ELF Radio Research Institute

Recommended Reading: “Forecast: IoT Enterprise Drones by Use Case, Worldwide, 2018-2028”

“Top 10 Strategic Technology Trends for 2020: Autonomous Things”

Autonomous Trucks

Analysis By: Bart De Muynck

Definition: Autonomous trucks are commercial trucks that use a combination of lidar, radar, sensors and cameras as well as machine learning to drive autonomously, meaning without the assistance of a driver. There are several scenarios planned in which trucks can have drivers in the cabs while being autonomous. They can be fully autonomous vehicles without drivers or participate in truck platooning, where the lead vehicle has a driver and the following vehicles follow the lead truck fully autonomously.

Position and Adoption Speed Justification: The logistics industry sees autonomous trucks as an opportunity to improve safety and operational efficiencies. Autonomous trucks could also help lessen the challenges around shortage of drivers. Estimates for deploying autonomous trucks vary, with rollouts estimated to occur as quickly as three to five years in China. The U.S., by comparison, is closer to a decade away. In most cases, amending existing regulations will determine which regions adopt first.

User Advice: Although the current market for autonomous vehicles is quite limited, many companies with truck fleets should begin to look into autonomous vehicles to understand if, where and how this technology might impact their supply chains. Companies should look for parts of the world where regulations favor autonomous innovation, but today very few regions support this. Risk-tolerant companies should allocate a small, technically competent team to research and evaluate government regulations and emerging autonomous capabilities being added to current vehicles. Shippers should also talk to their third-party logistics providers to see how they are embracing autonomous vehicles. Some firms may want to partner with shippers initially to pilot the new capability while sharing some risks.

Business Impact: Autonomous driving technology is maturing rapidly but adoption will be constrained by other factors such as regulatory restrictions. Several successful pilots have shown the technology to be nearly ready for the open road. The trucking industry's appetite to embrace autonomous vehicles is fueled by the belief that early adopters will gain market share and secure a more profitable operating model. However, despite having the potential for addressing industry's most severe challenges, growth will be delayed by long-running and sometimes contentious regulatory debates and low public acceptance as well as due to economic factors such as the current COVID-19 crisis. Driver pay is one of the largest operating costs for fleets associated with a commercial truck. Safety regulations limit the amount of time a driver can operate behind the wheel. Together with the current driver shortage, autonomous trucks will provide additional capability on top of the current trucking capacity. Autonomous vehicles also reduce transit time substantially which affects the decreasing lead times customers put on orders and also reduces the need to have the inventory placed within close proximity to the end customer markets.

Autonomous trucks have already been used successfully in closed environments within vertical industries like mining and agriculture. They will be further tested on the road in the U.S., Europe and Asia/Pacific.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Alphabet (Waymo); Daimler Group; Einride; Embark; Google; Peloton; Pronto; Tesla Semi; TuSimple; Volvo Trucks

Recommended Reading: "Momentum and Demand Build for Autonomous Trucking"

"Top 10 Strategic Technology Trends for 2020: Autonomous Things"

Drone Traffic Control Systems

Analysis By: Aapo Markkanen

Definition: Drone traffic control systems are systems deployed to track, control and manage aerial drones that are operating in an airspace. The concept is also known as Unmanned Aircraft System Traffic Management, or UTM. These systems interface with both the organization(s) managing the airspace and the person or entity that is operating the drone or, in the case of autonomous devices, responsible for the drone.

Position and Adoption Speed Justification: Drone traffic control systems are in the emerging stage of maturity in the Hype Cycle, as aviation authorities and air navigation services continue to trial different vendor solutions. The most high-profile project is the Low Altitude Authorization and Notification Capability (LAANC) framework in the U.S. that was launched in 2018. In its current scope, LAANC provides instant authorization decisions on requests to fly in the restricted airspace. Parallel to LAANC, another major milestone was reached in December 2019, when the Federal Aviation Administration (FAA) submitted its proposal on remote identification of drones for public consultation. In effect, a remote ID system allows aviation and law enforcement authorities to identify violators of airspace restrictions and thereby enforce air traffic control. While the remote ID regulation is unlikely be finalized in 2020, it is such as a critical building block for the long-term management of drone traffic that already reaching the formal proposal stage should be seen as an important step forward.

In Europe, UTM trials are taking place under a set of services known as U-space, which is part of the wider Single European Sky initiative to consolidate Europe's air traffic management. U-space has seen demonstrations or trials taking place in, for example, Switzerland, Finland, Estonia and France. Elsewhere, there are similar UTM activities in, for example, Australia, New Zealand, Japan and Singapore.

While the technical progress on the UTM solutions has been steady, there are still many obstacles to their widespread adoption. Importantly, most of the questions about the commercial and operational models for the provision of UTM services remain unaddressed. For instance, it is still not yet clear how the systems will be funded and how many systems will need to be deployed per country. It is also not clear how they will be integrated into the existing air traffic control systems. It is likely that different aviation authorities will take different approaches to deployment. As with a number of other drone technologies, it is possible that the current COVID-19 crisis will somewhat accelerate UTM deployments.

User Advice: At this stage, organizations that use drones in countries where UTM systems are being trialed should investigate whether joining a trial project as an end user would be beneficial for their operations. For example, in the U.S., the use of a UTM platform that is part of LAANC allows drone operators to receive instant approvals on to fly within a five-mile radius of an airport. Without LAANC, a traditional waive process is required and can take several weeks. Meanwhile, in Switzerland, participating in the local UTM program has allowed enterprises to fly beyond visual line of sight (BVLOS) and, thus, conduct advanced trials on autonomous drone deliveries.

The organizations that are able to start developing such advanced drone capabilities, which otherwise would not be permitted by regulators, already now can gain a long-term advantage over their counterparts that continue to leverage solely more rudimentary capabilities. From the operator's perspective, access to a UTM system can be enabled as a feature of a more comprehensive drone management platform. Thus, it is advisable that end users investigating relevant product offerings evaluate them in the context of their overall drone management requirements.

Business Impact: Due to the high number of active drones that are expected to operate in the future, the processing of the interactions between the traffic controllers and the drone operators must be highly automated. Serving as platforms accessed by both sides, the UTM systems aim to enable such a high level of automation. Drone traffic control systems will have a positive impact on all industries that use drones, as it will allow organizations to conduct more complex operations. In particular, the deployment of these systems will facilitate use cases that involve BVLOS or autonomous flights or flying in restricted airspaces, such as near airports or in densely populated areas. Furthermore, UTM implementations will also benefit parties that require drone countermeasures, by providing a new layer through which to detect and potentially control the drones entering a particular airspace.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: AirMap; Altitude Angel; Amazon; DJI; GE; Kittyhawk; NTT DATA; Thales; Unifly; Verizon

Recommended Reading: "Why Autonomous Flying Drones Must Be on the Radar of Mobility Sector CIOs"

"Prepare for Drone Incursions With a Multilayered Countermeasures' Strategy"

"Top 10 Strategic Technology Trends for 2020: Autonomous Things"

"Forecast Analysis: IoT Enterprise Drone Shipments, Worldwide"

Emotion AI

Analysis By: Annette Zimmermann

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

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

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

Several new commercial deployments occurred in 2019 for emotion AI and new vendors entered the market. At the same time, we did not see any evidence for great advancements in technological capabilities. Therefore, the position of this profile on the Hype Cycle was stagnant.

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

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

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

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

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

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

- Insurance companies are using audio-based emotion AI for fraud detection.
- In call centers, voice-based emotion AI can be used for intelligent routing for a better customer experience.
- Software exists that helps physicians with diagnosing depression and dementia.
- Dubai's Road and Transport Authority (RTA) announced the use of CV-based emotion recognition in four of its "customer happiness centers." When the "happiness level" among visitors drops below a certain threshold (maybe due to long queues) employees are notified and can act upon it.
- Inside the car, audio and CV-based emotion AI helps to understand what is going on and detects whether passengers are emotionally distracted.
- In retail, stores are adopting camera-based facial and emotional recognition to understand demographics and moods of visitors, enhancing the retail experience. Similar trends are emerging in the hospitality industry (in hotel lobbies) where cameras are used to recognize frequent guests and recognize their emotions.
- In education, we have seen prototypes of learning software that adapts to the user's emotional state. Another opportunity is in training and workshops, where emotions of the training participants are captured to see how they are experiencing the training.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: audEERING; Affectiva; Behavioral Signals; Eyeris; Google; Intelligent Voice; Microsoft; Voicesense

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

"Competitive Landscape: Customer Analytics"

Robot Interactive Interface

Analysis By: Annette Zimmermann

Definition: The robot interactive interface is composed of the various input mechanisms (audio, visual, gesture and tactile) to communicate with a personal assistant robot as well as the various types of feedback about its state and its responses to human input.

Position and Adoption Speed Justification: The user interface is an essential part of the robot design. The most common UI currently is via natural language as virtual personal assistant (VPA) systems proliferate. Other input methods, including gesture, tactile and general visual inputs, are being integrated as well. The future will see robots with multimodal input/output variations, as the more input data is available, the better and more desired the response will be. We have moved this profile one step further in the Hype Cycle as we have seen some more commercial products coming recently to market. At the same time, some ventures and products were discontinued such as Jibo.

Vendors have started to apply technology from market research to add another dimension to the interface: human emotions. This is done by conducting audio analysis, using computer vision and analyzing biometric data to determine a user's emotional state. Facial expressions, gestures and intonation are analyzed to determine if the user feels sad, angry or indifferent. Toyota's Kirobo Mini aims to apply this capability via a camera for making motions/conversations with consideration to how the person is feeling. CloudMinds' deep learning platform enables their service robots to recognize emotions as well as to conduct grasping with high precision based on computer-vision.

Another area where we start to see interest is the emotion expression and detection technology used in chat-bots and service avatars. Here, the bot may detect the user sentiments in a service situation and more importantly — respond to it with a more human emotional expression. Vendors like DAVI and Soul Machines have invested in this technology to enable a more human-like experience with a service bot. The vendor DAVI s has conducted interesting testing around specific capabilities of regulated emotion expression and pilots for service avatars/bots have been completed for a tourist information setting in France.

Multiple challenges exist around hardware capabilities, software, communication networks and data analytics to ensure that (1) the input is captured, (2) the input is processed correctly without much delay, and (3) the input creates a meaningful response. Since there are no hardware standards for capturing audio or visual input, there is a wide variety of camera and audio systems deployed in the different products. For example, each vendor in this space can have a very different technology approach toward capturing images by implementing two, four or however many different cameras/lenses in a robot.

In addition, vendors may also use multiple operating systems in one product; for example, Sanbot Innovation uses Android (for the screen interface), robot operating system (ROS), and Linux for the camera (depth sensing). This will not make it easy for developers to develop apps across different products.

User Advice: We recommend:

- Vendors should integrate multimodal input and output mechanisms to support more use cases, as this is where the market is headed.
- Apply machine learning techniques to analyze human emotional states via facial expressions and voice analysis.
- Provide a more humanized experience by incorporating both emotion detection and emotional responses in service bots and robots.

Business Impact: Personal assistant robots used in healthcare, customer support/aid in public or commercial areas as well as in the connected home will need a good interactive interface to provide a good user experience. A robot that has highly fine-motoric capabilities could assist in a hospital, for example, to take blood samples. This helps nurses to focus on other important tasks.

Another area where a good Human Machine Interface (HMI) supports a use case is Catalia Health's nurse bot. the little bot communicates with older patients to discuss their well-being during a long-term treatment and to remind them about their medication. The bot uses and adapts its humor to the individual patient and makes the experience conversational to replicate a nurse that may call up the patient in their home every day to check on them.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Affectiva; Catalia Health; CloudMinds; DAVI; Sanbot Innovation; SoftBank Robotics; Soul Machines; Toyota

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

Personal Robot

Analysis By: Annette Jump

Definition: Personal robot is a robot that has been designed and created to be used by an individual. It will assist the user in their daily life and tasks, help in family life, do some repetitive tasks around the house or, in some cases, become a daily companion. Personal robots will perform tasks autonomously based on given rules or algorithms.

Position and Adoption Speed Justification: During the last three years, personal robots have gained attention at various tradeshows. Some of the recent introductions to the market include Walker from UBTECH, temi robot, Mykie from Bosch, LIKU from TOROOC, Buddy from Vivatech and many others, as well as some robot-building kits aimed at children. The look, product features and target users vary greatly between different products. Most of the personal robots will be able to recognize users; some will also be able to have a conversation, recognize or show emotions and offer a branded personality. They will be able to interact with the environment around them, often move autonomously, and recognize and react to sounds. The cost for personal robots will also vary greatly from $200 for basic models to several thousands of dollars for more-complex robots. Many personal robots are enhanced by machine learning and AI-based technologies in various areas around delivering value through VPAs, improving user interfacing (e.g., NLP), traveling (pattern recognition), SLAM, etc. They are also designed with humanoid features and mimicking facial expressions to add to the perception of them displaying emotions.

However, there are many limitations in the types of domestic tasks robots can accomplish. For example, robots struggle with many simple tasks such as washing dishes, sticking a bandage on a cut finger, dusting fragile ornaments, making a bed, brushing the cat, turning off the water when a pipe bursts. Therefore, special-purpose robots will also be around for many years and be more effective than general-purpose ones. Also, there is a lot of player churn in the market, as companies struggle to provide enough value for users and due to technology limitations. The recent failure of Anki, a toy robot company and Jibo, a social robot, serves to demonstrate the nascent nature of the market. Also, most of the personal robots are and will be cloud reliant, which can also be a significant disadvantage if the technology providers goes bankrupt.

The lack of advancements and the struggle to identify appropriate use cases for personal robots in 2019 and early 2020 have unchanged position of “personal robots” on the Innovation Trigger curve. The development of personal robots will continue to evolve very fast over the next five to 10 years, especially with rapid advancement in AI and biotech for robotics.

User Advice: For organizations delivering services, solutions or products for verticals such as healthcare, elderly care, telemedicine, home security, home monitoring, connected home and housing developers/designers, the personal robot could be a new channel to deliver enhanced services to the target customer group. At the customer-facing workplace the personal robot could, for example, work as a customer service assistant to identify customer inquiry, to instruct form fulfillment prior to communicating with a human staff, or to guide visitors in the public area.

While some enterprises might want to use it in a customer-facing area to enhance the innovative image of the company, it is important to seek the real value of effectiveness by providing capabilities such as informational or physical support, working on behalf of customers or employees, or handling tasks that humans either cannot or do not want to do. However, to avoid disappointing customers/employees, enterprises need to carefully take measure of the value the personal robot can deliver.

Due to limitations in terms of what personal robots can do, many consumers will not see clear value in them for the next three to five years. In use cases where there is value for users, only a small proportion of innovators or early adopters will pay extra money for them. For now, personal robots are a much more discussed topic in Japan and Asia with a greater variety of personal robots available in the market. This is due to cultural perceptions and lack of distinction — due to “shintoism” — between animate and inanimate objects. Additionally, robots have been used for automation in Japan for many years and are not seen as a threat in the workplace. Enterprises and technology providers aiming to deliver customer value through personal robots should build a monetizing model with a revenue stream from third parties, enterprise partners or government, but not directly from end customers.

Business Impact: The impact of personal robots to business can be transformational when the technology is ready. There are multiple stakeholders for the value of personal robots, users, technology providers and enterprises. The biggest impact is to enterprise users as the technology provides a new channel to interact, reach their customers and create a new business model. An example is retail, which can cut the middle channel and get orders directly from customers through a personal robot at home, saving tremendous channel costs and creating a much closer relationship with customers. Every consumer-facing vertical will be impacted by new digital channel personal robots at home. Enterprises should join the personal robot providers' ecosystem and learn from the technologies, but set realistic expectations given that it is still at application and market experimental stage in the short term. It will take at least two years to pass through the learning curve to improve both user experiences and technologies.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: ASUS; Fujisoft; LG; Sharp Electronics; SoftBank Robotics; Sony; TOROOC; UBTECH Robotics

Recommended Reading: "Top 10 Strategic Technology Trends for 2020: Autonomous Things"

"Forecast: IoT Enterprise Robots by Use Case, Worldwide, 2018-2028"

"Preparing for a Future When Your Next Manufacturing Employee Will Be a Robot"

Swarming Robotics

Analysis By: Ivar Berntz

Definition: Swarming robotics is an attempt to control both physically and behaviorally a set of communicating robots, e.g., drones, creating a feedback loop between them. With that, self-propelled individual robots aggregate together to move as a group and modify their movements to attain the goal of multirobot coverage or exploration of an area or situation. This can be done for commercial and military uses.

Position and Adoption Speed Justification: In 2020, swarming progressed closer to the peak. The innovation is approaching its adolescence. While several use cases still need to be extensively tested/developed/expanded upon before they can mature, others, like warehousing and drone swarms have progressed considerably. While there is still a need to simplify the individual robot communication, in an effort to isolate and understand swarm behavior and intelligence, group sizes of up to a thousand are increasingly being field tested, instead of only simulated on computers. More recent, emerging use cases, involve autonomous vehicles and human-robot coordination. We should thus expect continued evolution for swarming robotics.

User Advice: Swarming was initially focused on miniaturization and principally on the idea that for certain types of problems, many small, low-cost robots would yield similar if not better results performing a task than a larger more expensive robot. The advantage relied on the age-old truism of strength in numbers: A swarm can take on casualties and failures, and just keep going.

Emerging and developing use cases include:

- Military, the swarming technology benefits are intuitive. The idea of using a set of affordable, replaceable devices appeals to a number of applications, e.g., having a swarm of drones protect a group of soldiers. Several vendors are active in this market.
- Warehouse logistics, vehicle platoons and even multiplatoons can work collaboratively to alleviate congestion, increase throughput and reduce accidents. This is already in development by several vendors and clients.
- Entertainment, several large-scale demonstrations using dancing robots or drones have been done by various vendors.
- Social media bot swarms might evolve to simulate societal mood swings in order to drive voting or even broader societal outcomes, with considerable ethical implications.
- Healthcare, swarms of nanobots might one day perform preventative surgery without an incision made to the body, or repair physical damage. This requires working with universities in order to direct research.
- Maintenance areas, microbots could work inside machinery, monitoring and correcting eventual deviations, but this needs to be further developed.

- Farmers interested in covering wide swaths 24/7 can start getting acquainted with autonomous vehicles and unmanned aerial vehicles for mowing and harvesting, or crop protection.
- IT, server, storage and even AI farms that adapt themselves to nonprogrammed use cases. Several announcements have been made in the area of edge computing. Test where appropriate.
- Autonomous vehicle communication, with a moving grid of available slots to fit into or move to, could allow for different makes and sizes to share roads with regular vehicles in the future.

Business Impact: The most immediate business impact is at this moment being developed and tested in warehousing, entertainment and warfare contexts. Outside of these, it is still at an experimental level and thus more difficult to assess.

In principle, swarming complements aerial, naval, terrestrial and micro/nanotechnology autonomous thing technologies, as an assigned task could be done in less time, and for lesser cost, if a set of robots is deployed to the task or tasks.

In contrast to biological swarms, the digital embodiment has the advantage that the program of individual swarm members can be quickly updated based on information gathered by individual members. The whole swarm can learn from the mistakes of individual members.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Apium; China Electronics Technology Group; DJI; EHang; Intel; Kronstadt; Northrop Grumman; Raytheon Technologies; Siemens

Recommended Reading: “Hype Cycle for Drones and Mobile Robots, 2019”

“Top 10 Strategic Technology Trends for 2020: Autonomous Things”

“Deploy Leaner AI at the Edge: Comparing Three Architecture Patterns to Enable Edge AI”

At the Peak

Drone Management Platforms

Analysis By: Aapo Markkanen

Definition: Drone management platforms refer to software by which organizations manage fleets of unmanned aerial vehicles (UAVs) — that is, drones. Features include flight planning, waypoint, airspace notification and approval, vehicle registration and identification, staffing, training, and other aspects of fleet management. They can be offered both on a commercial basis to drone users and as outsourced air traffic management to aviation authorities. The air traffic management element is also known as Unmanned Aircraft System Traffic Management (UTM).

Position and Adoption Speed Justification: Two main factors have triggered the innovation on drone management platforms. First, aviation authorities in an increasing number of countries are starting to adapt their regulations to the needs of UAVs. The regulatory changes will create demand for technologies that can enable, for instance, operations in otherwise restricted airspace or electronic identification of the aircraft for other airspace users. Second, the end-user organizations that are relatively advanced in terms of their drone adoption are starting to require tools that allow them to manage their fleets in a more systematic and structured manner. Consequently, product features fall under basically two elements: the ones that enable compliance with new regulations (through UTM) and then the ones that enable fleet management independent of regulations. The first — the regulatory element — remains a significant product feature, and consequently, many of the leading drone management platforms put emphasis on their UTM capabilities. However, platforms that focus only on fleet and workflow management are also available. Data acquisition and data management are other relevant features addressed by vendors.

Kittyhawk and Verizon's Skyward are examples of integrated platforms that cover both UTM and fleet management, while DJI's FlightHub and PrecisionHawk's PrecisionFlight Pro focus on fleet management without UTM. For comparison, AirMap and Unifly are vendors that started off as UTM specialists and have more recently been adding features associated with fleet management. It is clear that the two initially distinct sides of the market are converging with each other.

As a technology domain, drone management platforms remain at an emergent stage, as relatively few enterprises using drones have reached an operational scale that would justify investment in a dedicated platform. The market, however, continues to progress as expected: its current status is largely where it was expected to be a year ago. Consequently, the technology has moved further along the Peak of Inflated Expectations.

User Advice: End users and third-party providers that have comparatively large fleets of drones (say, dozens of routinely deployed vehicles) should use drone management platforms to make their operations safer and more efficient. Similarly, any organization that would benefit from the less restrictive drone regulations being implemented within their geographical footprint should also assess the platforms with compatible UTM capabilities, when access to such capabilities is prerequisite for taking advantage of the changes. For this reason, a technical evaluation of shortlisted platforms should also extend to cover their capabilities in facilitating regulatory compliance.

Business Impact: Commercial UAVs can deliver significant business value already without a drone management platform, but scaling the operations can become highly challenging without purposely designed software tools. Essentially, these tools allow organizations to conduct more extensive drone operations with fewer resources. Additionally, taking advantage of the new, less restrictive regulations will, in most cases, necessitate a platform that can interface with the air traffic control. In particular, operating drones beyond visual line of sight (BVLOS) or autonomously in a routine manner will, in most countries, likely require similar UTM-enabled compliance. Consequently, in order to exploit such transformative operational capabilities, the end users or their third-party providers must eventually have a suitable platform in place.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: AirMap; Altitude Angel; DJI; DroneDeploy; DroneInch; Kittyhawk; NTT DATA; PrecisionHawk; Unifly; Verizon

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

"Forecast Analysis: IoT Enterprise Drone Shipments, Worldwide"

"Why Autonomous Flying Drones Must Be on the Radar of Mobility Sector CIOs"

Light Cargo Delivery Drones

Analysis By: Aapo Markkanen; Bill Ray

Definition: Light cargo delivery drones are flying, autonomous vehicles used to deliver small packages of food, medical supplies or other suitably sized goods. Autonomy may be supplemented by remote operation when needed. The maximum weight of cargo depends on the flown distance, the size of the drone and the applicable regulations, among other factors. Currently, for example, delivery drones used by JD.com in China include a battery-powered model being able to carry 10 kg over 100 km per charge and a gasoline-powered one being capable of 30 kg over 30 km.

Position and Adoption Speed Justification: Many high-profile companies, including Alphabet, Amazon and JD.com, have invested in development of delivery drones. The concepts are based either on dropping deliveries from midair or landing the drone at the delivery address. These services are still at an early stage, owing to the cost of the devices, the complexity of operation and regulatory restrictions. However, most of the vendors are hoping that the loosening regulations and the economies of scale will eventually make large-scale operations viable. With its relatively established medical delivery operations across Eastern Africa, Zipline is currently the best example of how the technology is being applied in the field.

Regulations are still developing, with aviation authorities and policymakers evaluating, in particular, how fleets of aerial delivery drones can be accommodated into the airspace. For urban operations, integration with smart city infrastructure is another area that requires significant progress. Ensuring physical safety, in terms of both people and property, is the key consideration, so vendors working on delivery drones are also paying particular attention to parachutes, redundant systems and other safety measures. Once the safety aspect has been adequately addressed, privacy is likely to become an issue that the vendors will have to tackle next.

The core technology behind the light cargo delivery drones is becoming increasingly advanced, but due to the regulatory constraints and certain technical challenges, they remain in the commercial sense an unproven concept. Therefore, in the Hype Cycle, they are still climbing the Peak of Inflated Expectations. However, the next 12 to 18 months may accelerate the progress to a certain extent, as the COVID-19 crisis strengthens the case for deliveries with no physical human contact — also from the regulators' point of view.

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

While this analysis should drive long-term investment in, and scaling of, delivery drones, trials and other small-scale commercial deployments should be considered even when there is unlikely to be near-term ROI, if the technology stands to have a strategic impact on the company's business. As they mature, emerging technologies, such as delivery drones, typically give the greatest competitive advantage to organizations that have gained experience with them from relatively early on.

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

Business Impact: The impact of low-cost deliveries will be extremely broad. Initially, they will disrupt postal and courier services. As the cost of delivery drops, wider and long-lasting changes in behavior among consumers and businesses will result. For example, in the retail and hospitality sectors, customers expecting 24-hour product availability to the door will be less likely to shop at local, late-night stores, while the number of dark kitchens (restaurants without a physical customer-facing presence) will increase. Healthcare organizations whose operational footprint covers congested or remote locations can benefit hugely from using drones to carry time-sensitive medical deliveries faster than what is otherwise possible.

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

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Alphabet; Amazon; Flytrex; JD.com; Matternet; Skycart; Wingcopter; Zipline

Recommended Reading: "Top 10 Strategic Technology Trends for 2020: Autonomous Things"

"Forecast Analysis: IoT Enterprise Drone Shipments, Worldwide"

"Why Autonomous Flying Drones Must Be on the Radar of Mobility Sector CIOs"

"Innovation Insight for Drones in Healthcare and Retail Last-Mile Delivery"

Smart Robots

Analysis By: Annette Jump

Definition: Smart robots are electromechanical form factors 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, recognize and solve problems. Some can interact with humans using voice language, while some have a specialized function, like delivery or warehouse robots. Due to advanced sensory capabilities, smart robots may work alongside humans.

Position and Adoption Speed Justification: Smart robots have had significantly less adoption to date compared with 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. In the last 12 months, many of the established robot providers expanding their product line and new companies entering the market. Here are few examples:

- Whiz robot from SoftBank Robotics that will be sold under robot-as-a service (RaaS) model and originally be available only in Japan.
- Furhat Robot from a Swedish startup (Furhat Robotics) developing social robots.

- Smart Robotics that has introduced a robot valet for parking cars in France (Lyon).
- Temi robot from temi that will target home assistance for elderly and will incorporate Amazon's Alexa.

The market is becoming more dynamic though the cost of entry and user tech sophistication are still high. Also, the time lag between product announcements and launch dates remain quite long at six to 12 months. Some products are killed before they reach broad availability. Recent market examples of slow adoption and withdrawals are Rethink Robotics, very low rate on renewal contracts for SoftBank Robotics' Pepper three-year contracts and decision of Henn na Hotel, a Japanese hotel, the first hotel chain to replace smart robots with humans. Specialization also is very important to success, as no smart robot can address all industry specific use cases. Despite some advancements in AI, product and material experimentation in 2019 and early 2020, the progress is still slow, as companies are still trying to identify business valuable use cases. Therefore, the position of "smart robots" has not changed versus 2019 and still remains on the Innovation Trigger curve. 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 explore new technologies, like reinforcement learning to drive continuous loop of learning for robots.

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 quality control (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:

- Logistics and warehousing: Product picking and packing, e-commerce order fulfillment, locating and moving goods

- Medical/Healthcare: Patient care, medical materials handling, prescription filling
- Customer care
- Goods delivery due to social distancing and quarantine with COVID-19
- Manufacturing: Product assembly, stock replenishment, support of remote operations
- Delivery of packages and food
- Reception/Concierge in hospitality, retail, hospitals, airports, etc.
- Other: Disposal of hazardous wastes

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

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

Recommended Reading: “Top 10 Strategic Technology Trends for 2020: Autonomous Things”

“Forecast: IoT Enterprise Robots by Use Case, Worldwide, 2018-2028”

“Preparing for a Future When Your Next Manufacturing Employee Will Be a Robot”

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

Open-Space Optical Communication

Analysis By: Bill Ray

Definition: Open-space optical communication (also known as free-space optical communication, or FSOC) involves encoding data into a laser beam that is directed at a receiving detector and decoder. Communication operates over line of sight, and the laser’s path is not protected in any way, operating in a similar fashion to a highly directional radio transmission.

Position and Adoption Speed Justification: Open-space optical communication can achieve throughput of 20 Gbps, at a range of up to 20 km, without the need for a radio license or expensive infrastructure, though implementation remains a considerable challenge.

Light (as created by a laser) offers a huge amount of bandwidth, and encoding technologies are well-understood, having been developed for use over optical fiber. Deployment is inexpensive, as no trenches must be dug, and frequencies of light are not regulated in the way that radio bands are, so spectrum licenses are not needed. However, fog and mist can form an impenetrable barrier, and heavy rain, wind-swept haze or smoke can reduce throughput enormously. The transmission power is limited by safety issues — lasers can quickly damage human eyes, resulting in limited range. Several companies have tried to address these issues, using power-adjustment techniques or hybrid approaches, but with limited success.

Optical communication systems have also been deployed within data centers, and it is easy to envision a directional laser providing high-speed communications with a moving robot.

Open-space optical communication is used most effectively where there are few people, and limited atmospheric interference. X (a sibling of Google) has had success deploying FSOC in India to provide backhaul links. Several satellite companies plan on using FSOC for intra-constellation communications over the next few years. In 2020 Sony demonstrated the practicality of earth-to-orbit communications with a 100 Mbps link from the International Space Station to a receiver on Earth.

Increased demand from orbital communications (both within orbit, and ground links) is driving greater innovation, and an increasing number of commercial (terrestrial) deployments, mean that this profile has been moved toward the Peak of Inflated Expectations.

User Advice: Without a significant breakthrough in technology or technique, open-space communication will have limited appeal in terrestrial markets. Links can be deployed at altitude (atop skyscrapers), for temporary events (where weather is expected to be good), and hybrid deployments (which fall back on radio connections in inclement weather) can provide useful peak bandwidth. High-bandwidth links to drones, or free-floating platforms, can also be established where atmospheric conditions permit. Applications include temporary deployments and providing a backup connection to fiber optic connections for enterprise network access — but in most environments, open-space optical is a technology to watch, not use.

Business Impact: Once the atmospheric challenges can be addressed, open-space optical communication offers a huge amount of point-to-point bandwidth without the expense of spectrum licensing or laying fiber optic cables. Tens of thousands of microwave links could be upgraded to open-space optical communications mounted on existing towers, boosting the capacity of the link by an order of magnitude.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Adolescent

Sample Vendors: fSONA; LightPointe Communications; Sony; Wireless Excellence; X

Recommended Reading: "Market Trends: Thousands of New Satellites Will Provide New Services to Disrupt the CSP Industry"

Warehouse Picking (Humanoid) Robots

Analysis By: Dwight Klappich

Definition: Warehouse picking robots are more humanlike robots that can pick up, handle and move goods using some form of reticulated arms and grippers. These systems employ advanced AI and vision systems to recognize and pick up items that are not in consistent places and orientations, and are not the same sizes and shapes.

Position and Adoption Speed Justification: While industrial robotic arms are mainstream in manufacturing, they remain nascent in warehousing except for some very specific applications such as palletizing. Industrial robots, are normally large, immobile and fit for one task. Given the varying types of work required in warehouses, this architecture is too limiting. Warehouse picking robots must address repeatable tasks with minimal variance from activity to activity and item to item, across dimensions and weights. Variability makes creating universal picking solutions technically very difficult, and it will be years before picking solutions match the flexibility, dexterity and speed of humans. Warehouse (humanoid) robots will evolve during the next five to 10 years to address the needs for better cost, flexibility, adaptability, scalability, utility and intelligence. Humanoidlike robots, similar to humans, will combine multiple technologies (such as AI-enabled vision systems, reticulated arms that can move in multiple planes, and various forms of gripping technology) to enable the robot to identify, locate, pick up and handle goods.

User Advice: There are a limited number of use cases where humanoid robots are viable today. There are stationary robotic arms that fit very specific use cases where the product size, weight and shape are consistent, where the location of product is consistent and where the operation to be performed is consistent (e.g., palletizing robotic arms for picking cases). If companies have these conditions, then exploring robotic arms is worthwhile. However, if companies are in less structured and consistent environments, then they must use caution and pilot extensively. Furthermore, companies should evaluate the realistic speed because, today, humans typically outperform robotic arms in all but the most select use cases.

Business Impact: Warehouse humanoid robots will transform warehouse operations over the coming decades as the costs and complexities come down, which will open up the market to more companies. Labor availability and labor costs seem to be the most likely drivers, but improvements in overall throughput and productivity will be the primary value, regardless of whether labor is reduced.

Consider the following impact areas:

- **Risk: High** — Robots are rapidly emerging, but remain unproven for all use cases. The long payback and high upfront capital outlay place more emphasis on an effective selection process.
- **Technology intensity: High** — Replacing people with robots places significant emphasis on getting technology right.
- **Strategic policy change: Moderate** — Shifting from people-centric organizations to robotics-driven environments has a significant impact on an organization's strategy and culture at all levels.
- **Organization change: Moderate** — Management techniques and organizational design must evolve with robots in mind.
- **Culture change: Moderate** — Cultural changes must be top of mind because some employees will feel threatened by robots, and this could negatively impact projects.
- **Process change: High** — When moving from people-driven to automated activities, processes must be redesigned to benefit from robotic advantages.
- **Competitive value: Moderate** — Primary competitive value comes from achieving best-in-class operational performance.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Berkshire Grey; IAMRobotics; Kindred; KUKA; RightHand Robotics (RHR)

Autonomous Mobile Robots

Analysis By: Dwight Klappich

Definition: Autonomous mobile robots (AMRs), formerly called smart automated guided vehicles (AGVs) in previous Gartner Supply Chain Execution Hype Cycles, add intelligence, guidance and sensory awareness to conventional AGVs, allowing them to operate independently and around humans. These new types of AGVs address the historic limitations of traditional AGVs, making them better suited to, and more cost-effective for, complex warehouses and collaborative activities.

Position and Adoption Speed Justification: AMRs will continue to gain traction in complex distribution centers and AMRs will increasingly develop to take over functions historically performed by humans on lift trucks such as product put-away or forward-picking replenishment with little to no human intervention. As computing power has multiplied and the cost of sensors has declined, the power, flexibility and use cases for AMRs have grown while prices have come down leading to significant AMR market demand growth. However, while customer demand strengthens, resource availability to deploy AMRs is poised to become a barrier to growth. Gartner tracks over 50 AMR vendors that perform various warehouse tasks from simple transport moving goods from point A to B to more complex and sophisticated collaborative picking robots where the AMR supplement human labor. Market penetration is low overall with under 20,000 AMRs deployed commercially today, which when contrasted to the well over a million of lift trucks is a small market so far.

User Advice: Next-generation AMRs have become more autonomous and intelligent. They will transform warehouse operations over the coming decades. Costs and complexities will also come down, which will open up the market to more companies. Labor reductions seem the most likely drivers, but improvements in overall throughput and productivity will be the primary value, regardless of whether labor is reduced or not. Warehouse operations with a high volume of bulk (i.e., palette) product moves should consider some of the current generations of AMRs as an alternative or to supplement existing automation. Companies looking to build new automated facilities also should explore the potential value of these smart machines.

Business Impact: AMRs will continue to gain traction in complex distribution centers. The same technologies will emerge and also have applications outside warehouses as the technology matures. For example, in retail stores there is the potential that an AMR could unload trucks and deliver palettes of goods to specific departments in a store without human intervention. Smart AGVs will increasingly develop to take over functions such as product put-away or forward-picking replenishment with little to no human intervention. AMRs could also have a positive environmental impact as they reduce costs such as lighting, heating and air conditioning, because robots don't need any of that.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: 6 River Systems; Clearpath Robotics; Fetch Robotics; GreyOrange; Locus Technologies; Seegrid; Vecna

Recommended Reading: "Predicts 2020: Supply Chain Technology"

"Cool Vendors in Supply Chain"

"Innovation Insight for Autonomous Mobile Robots"

Drone Countermeasures

Analysis By: Nick Ingelbrecht

Definition: Drone countermeasures are systems and devices designed to detect, neutralize or retaliate against incursions from trespassing drones.

Position and Adoption Speed Justification: Drone countermeasures constitute a fast-growing market of technologies to address the problem of intrusive, illegal or dangerous drone threats. Such countermeasures include electronic jamming, guns, nets and high-power lasers or microwaves to disable or destroy UAVs, as well as disruption systems and underwater countermeasures for submersible drones. The adoption of drone countermeasures has been accelerated by the proliferation of low-cost-drone activity and a recognition that ground-based security perimeters can easily be circumvented. The multiplicity of different solutions on offer, lack of industry standards and competing vendor claims have kept drone countermeasures near the peak of the Hype Cycle. Countermeasures may be ineffective against small, fast-moving drones in dense urban environments, where advanced detection is impaired by buildings. Swarm attacks pose a significant emerging threat vector. Security officials responsible for protecting major events, and sensitive locations (including prisons, critical infrastructure, police, airfields and mobile military units) are paying increased attention to drone threat assessments and countermeasures in their risk analysis and security planning. Mainstream adoption is accelerating fast as drone countermeasures evolve into a basic security requirement.

User Advice: Infrastructure and operations leaders seeking to build dependable physical security solutions should:

- Get ahead of the problem by including a threat analysis of illicit drone activity in your risk assessment and prioritize the need for drone countermeasures and anticipating the threat posed by counter drone-countermeasures. Countermeasures need to be contextually appropriate to the environment (e.g., military versus civilian; potential target value and attack vectors).
- Specify multisensor, multilayered approaches (including radar tracking and thermal, acoustic, video and RF/microwave sensors) capable of identifying tell-tale drone signatures since these increase the chance of a successful detection.
- Validate vendor claims via proofs of concept, vendor shootouts or demonstrations in your locale in different weather and lighting conditions. Test against a wide variety of different drone threats.
- Evaluate the emerging threat of drone swarms that could overwhelm standard countermeasures and run scenarios of different types of attacks.

- Evaluate the legal and physical risk of injury to people or property loss/damage resulting from drone countermeasures, due to uncontrolled descent or fragmentation of target drones or collateral damage caused by countermeasure weapons such as lasers, conventional munitions or microwave disruptors. Signal-jamming solutions need to be fully automated to be effective, whether “kill” type jammers or “return home” systems.
- Explore the processes and workflows for countermeasure responses and evaluate the need for nuisance alarm suppression analytics to facilitate monitoring and prioritize alerts.

Business Impact: Drone countermeasures will be broadly applicable across all industries and public agencies with a public safety/security remit. In the first instance, drone countermeasures will need to be instituted to protect sensitive locations, critical infrastructure, transportation hubs (especially airports) and major public gatherings. Longer term, demand for drone countermeasure products will evolve in response to illicit surveillance activities related to criminal activity, stalking, and transportation of drugs and contraband.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Aaronia; Advanced Protection Systems; Airspace Systems; Arcarithm; Black Sage; DJI; DroneShield; Raytheon Technologies; RAFAEL Advanced Defense Systems; SRC

Recommended Reading: “Emerging Technologies: Top Use Cases for Future-State Physical Security Infrastructure”

“Best Practices in Implementing Video Surveillance, Analytics and Response Systems in Physical Security”

“Video Analytics Functionality Spectrum: Competitive Advantage Lies in Basic Performance and Unique Features”

“Best Practices in Procurement for Video Surveillance, Analytics and Response Systems in Physical Security”

“Hype Cycle for Physical Security, 2018”

“Best Practices for Video Surveillance RFP: Setting the Strategy”

Sliding Into the Trough

Light-Cargo Delivery Robots

Analysis By: Bill Ray

Definition: Light-cargo delivery robots are wheeled autonomous vehicles used to deliver packages, including groceries and shopping. Size can vary from a small car (able to carry 200 kg) down to a shopping trolley (carrying 10 kg), while speed is usually restricted to a walking pace. Autonomy may be supplemented by remote operation when needed.

Position and Adoption Speed Justification: Many companies, from retail giant Amazon to specialist food companies like Domino's, have deployed delivery robots commercially, if at a small scale. Many of these services are still at an experimental stage, but market leader Starship Technologies recently celebrated 100,000 commercial deliveries across its deployments in Milton Keynes and London (both in the U.K.).

The limiting factor for deployments has been legislation, but the outbreak of COVID-19 has enabled municipalities to fast-track changes on public health grounds. Several U.S. cities have passed legislation permitting the use of delivery robots, and the increased interest in robot deliveries means that growth is only limited by production speed.

Therefore, we have placed this technology just before the Trough of Disillusionment with a time of less than two years to plateau.

User Advice: In the short term, delivery robots may be useful in preventing the spread of COVID-19, but for most businesses, light-cargo delivery via robots will be a cost reduction mechanism. For others, it will be a way to scale time-sensitive last-mile deliveries, which will, over time, become increasingly challenging for fully manual supply chains to handle. The decision on adoption must be a process of conducting a cost-benefit analysis. Enterprises should identify types of light cargo that might be suitable, and then identify the terrain over which the deliveries will take place. Wheeled robots generally need wide pathways, which may not be found in all cities or residential areas.

This estimate should then be compared with the cost of other, more traditional means of delivery, such as trucks or humans on bicycles. Light-cargo delivery robots will eventually become commonplace, reflecting the accelerating legislation and low cost of operation. Every business involved with the logistics of relevant goods should be planning how to take advantage of the technology as it matures. At this point, a recommended approach is to engage with pioneering vendors and relevant regulators in order to trial the technology.

Business Impact: The impact of low-cost deliveries will be extremely broad. Initially, they will be used for food deliveries in urban areas where the receiving individual is likely to be at home. As the cost of delivery drops, wider changes in behavior among consumers and businesses will result. For example, in the retail and hospitality sectors, customers expecting 24-hour product availability to the door will be less likely to shop at local, late-night stores, while the number of dark kitchens (restaurants without a physical customer-facing presence) will increase.

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

Benefit Rating: Low

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Amazon Robotics; Nuro; Starship Technologies

Recommended Reading: "Market Guide for Smart Robots in Retail"

"Why Autonomous Flying Drones Must Be on the Radar of Mobility Sector CIOs"

Machine Learning

Analysis By: Pieter den Hamer; Carlie Idoine; Shubhangi Vashisth

Definition: Machine learning is an AI discipline that solves business problems by utilizing mathematical models to extract knowledge and patterns from data. There are three major approaches that 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 still a popular concept, given its extensive range of impacts on business. The triggers of its massive growth and adoption have been growing volumes of data, advancements in compute infrastructure and the complexities that conventional engineering approaches are unable to handle. As organizations continue to adopt these technologies, we recently see focus on aspects that relate to ML explainability and operationalization. Augmentation and automation (of parts) of the ML development process improve productivity of data scientists and enable citizen data scientists in making ML pervasive across the enterprise. In addition, pretrained ML models are increasingly available through cloud service APIs, often focused on specific domains or industries. New frontiers are being explored in synthetic data, new algorithms (e.g., deep learning variations) and new types of learning. These include federated/collaborative, generative adversarial, transfer, adaptive and self-supervised learning, all aiming to broaden ML adoption.

User Advice: For data and analytics leaders:

- Focus on the business problem. Start with simple business problems for which there is consensus about the expected outcomes, and gradually move toward complex business scenarios.
- 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.
- Utilize packaged applications, if you find one that suits your use case requirements. These often can provide superb cost-time-risk trade-offs and significantly lower the skills barrier.
- Nurture the required talent for machine learning. Partner with universities and thought leaders to keep up to date with the rapid pace of advances in data science. Create an environment conducive to continuous education, and set explicit expectations that this is a learning process and mistakes will be made.
- Provide guidelines and monitor compliance with respect to security, privacy, bias and explainability.
- Leverage the augmentation and automation of ML activities, avoiding unnecessary low level coding and alleviating labor intensive tasks for expert data scientists, while making ML accessible for citizen data scientists.

- Explicitly manage "MLops" for deploying, integrating and monitoring ML models, not underestimating time and complexity. To be successful, early involvement is required of both business stakeholders and IT for integration and operations.
- Focus on data as the fuel for machine learning by adjusting your data management and information governance strategies to enable your ML team. Data is your unique competitive differentiator and adequate data quality, such as the representativeness of historical data for current market conditions, is critical for the success of ML.

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

- Automation
- Drug research
- Customer engagement
- Supply chain optimization
- Predictive maintenance
- Operational effectiveness
- Workforce effectiveness
- Fraud detection
- 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; Databricks; Dataiku; DataRobot; H2O.ai; IBM; MathWorks; Microsoft; SAS; TIBCO Software

Recommended Reading: "Magic Quadrant for Data Science and Machine Learning Platforms"

"Critical Capabilities for Data Science and Machine Learning Platforms"

"Toolkit: RFP for Data Science and Machine Learning Platforms"

"3 Types of Machine Learning for the Enterprise"

"Top Organizational Pitfalls of Machine Learning Initiatives"

Computer Vision

Analysis By: Nick Ingelbrecht

Definition: Computer vision is a process that involves capturing, processing and analyzing real-world images and videos to allow machines to extract meaningful, contextual information from the physical world.

Position and Adoption Speed Justification: Computer vision capabilities have advanced through the Hype Cycle as a result of improvements in the application of machine learning methods including deep neural networks, the availability of tooling and services as well as greater processing efficiencies. Enterprises everywhere face the challenge of how to exploit their visual information assets and automate the analysis of exponential volumes of image data. However, they face difficulties activating computer vision models in business processes, along with security and privacy concerns that impact their ability to realize business value. Gartner anticipates early mainstream adoption in the 2023-2025 time frame. Computer vision has progressed through the Hype Cycle in line with the growing maturity of machine learning solutions, including advances in optical character recognition products and object/behavior recognition models. Computer vision has broad applicability across numerous domains including automotive, retail, robotics, security, healthcare, manufacturing and many IoT applications, both in the visible and nonvisible spectrum including thermographic systems for remote fever and vital signs detection and facial recognition.

User Advice: Use computer vision to augment your organization's workforce capabilities by automating the processing of image and video data. Audit your organization's image/video assets and engage with business stakeholders to discover how computer vision applications can alleviate operational pain points, improve productivity and create new business opportunities. Ensure business stakeholders clearly articulate the tangible business benefits they are expecting from the computer vision assets to be developed.

In addition, we recommend:

- Focus initially on a few small projects, use fail-fast approaches and scale the most promising systems into production using cross-disciplinary teams. Do this by ensuring that sufficient software engineering resources are available to activate AI models in business processes and that governance and maintenance costs of image-based machine learning models are properly accounted for in ROI estimates.
- Critically assess change management impacts of implementing advanced analytics on the organization and its people as this has high potential to derail computer vision projects.
- Test production systems early in the real-world environment since lighting, color, object disposition and movement can break computer vision solutions that worked well in the development cycle.
- Build internal computer vision competencies and processes for exploiting image and video assets. This will enable the organization to make better procurement choices and lay the groundwork for more advanced innovation and product development opportunities.
- Exploit third-party computer vision tooling and services to accelerate data preparation and time to value by deploying early production systems.
- Evaluate legal, commercial and reputational risks associated with deploying computer vision solutions at the outset of customer/employee experience improvement projects.
- Be warned that the fast-evolving regulatory environment may derail computer vision projects due to privacy concerns.

Business Impact: The ability of organizations to capture value and generate insight from their own video/image data assets will become a question of competitiveness and ultimately survival. Key impacts of computer vision include:

- Greater levels of automation by reducing the demands on human monitoring staff and resulting in improved quality, speed and reliability of monitoring camera surveillance feeds.
- Improved decision support via event correlation, alarm management/prioritization and policy and rule engines for predetermined workflows.
- Enhanced customer experience in features such as queue monitoring and management, enhanced customer service and technical support.
- Reduced costs due to the ability to scale video systems without requiring greater human monitoring resources or manual processes.

Data is viewed as potentially one of the most important and unique strategic business assets that organizations control. Gartner estimates around 80% of these dark data assets — including uneventful surveillance video, video meetings and unsearchable text and graphics — are composed of image or video data which typically gets discarded because it has no apparent value. Key use cases today include the use of advanced analytics for video surveillance automation, health and safety compliance (PPE detection, COVID-19 mitigation, etc.), visual search, shopper and shelf analysis, automotive applications, OCR and quality assurance/production line automation in manufacturing. Increasingly, in the future, organizations that are unable to value and leverage their computer vision assets strategically will become uncompetitive.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Amazon Web Services; Another Brain; Baidu; Clarifai; Deepomatic; Google; Matroid; Microsoft; Nyris; Tencent

Recommended Reading: “Venture Capital Growth Insights: Computer Vision”

“Competitive Landscape: Computer Vision Platform Service Providers”

“Survey Analysis: Computer Vision Drives Enterprise Adoption of Artificial Intelligence”

"Market Trends: Facial Recognition for Enhanced Physical Security — Differentiating the Good, the Bad and the Ugly"

"Market Trends: Machine Vision Will Be the Game Changer Across Markets"

"Innovation Insight for Video/Image Analytics"

"Emerging Technologies: Top Advanced Computer Vision Use Cases for Retail"

"Critical Steps to Cash In on the Computer Vision Gold Rush"

Solid-State MEMS Scanning Lidar

Analysis By: Masatsune Yamaji

Definition: A solid-state micro-electromechanical system (MEMS)-based scanning lidar replaces moving parts with silicon-based hardware and integrates an application-specific integrated circuit (ASIC) to reduce the size of the entire module. The lidar creates a 3D map of its surroundings by emitting millions of laser dots per second and measuring the time it takes for the laser to bounce back.

Position and Adoption Speed Justification: Solid-state MEMS-based scanning lidar is designed to replace mechanical spinning lidar. With little or even no moving parts, solid-state MEMS-based scanning lidar is cheaper and more reliable. The size is also smaller through the use of fully integrated chips. Although the field of view is limited, the cost benefit of MEMS allows one vehicle to use multiple solid-state MEMS-based scanning lidars. In the long run, almost all electronic semiconductor components, including the laser beam, control circuitry, MEMS mirror, detectors and computing application-specific integrated circuit (ASIC), will run on a single chip. This will lead to even lower cost when it achieves mass production. The major application is in automotive.

Solid-state MEMS-based scanning lidar is moved ahead a few steps in the Hype Cycle position this year. Various technologies for lidars are competing each other today, but we believe that it will climb to the enlightenment stage soon. This is because an increasing number of vendors have released new versions of solid-state MEMS-based lidars with better performance and lower cost over the past year.

User Advice: For lidars deployed for automotive use cases, there are various lidar solutions that are competing with each other, and autonomous vehicle makers must work with solution providers to evaluate the quality and cost. In addition, building information modeling (BIM) software vendors must develop new algorithms to analyze the point cloud collected by solid-state lidar.

Autonomous things developers, such as service robot OEMs, should start the evaluation of solid-state MEMS scanning lidar for future product planning.

Business Impact: Solid-state MEMS-based scanning lidar can be used as simultaneous localization and mapping (SLAM) technology to create 3D modeling. It can be applied in industrial automation, security and surveillance, logistics, automotive, 3D mapping, and drone flight management.

Unlike current mechanical lidar placed on the roof of automotive, the solid-state lidar is very small and embedded in the surface of the automotive technology, which means that vehicle designs are not negatively impacted by the incorporation of these sensors.

The other major application area for solid-state lidar is drones. Mechanical lidar was used for BIM to create 3D point for high-resolution modeling. However, since the payload of drone is limited, it's hard to use mechanical lidar in drone. With solid-state lidar, drone can be very useful in inspection to provide real-time construction quality control. Also, it can be used for obstacle avoidance for intelligent flight operations.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Blickfeld; Innoviz; LeddarTech; Luminar Technologies; MicroVision; RoboSense

Recommended Reading: "Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide"

"Top 10 Strategic Technology Trends for 2020: Autonomous Things"

Autonomous Vehicles

Analysis By: Jonathan Davenport

Definition: Autonomous vehicles use various onboard sensing and localization technologies, such as lidar, radar, cameras, GPS and map data, in combination with AI-based decision making, to drive without human intervention. This Innovation Profile does not cover ADAS features that require humans to supervise vehicle operations. While self-driving cars are getting most of the attention at present, the technology can also be applied to nonpassenger vehicles for transportation of goods.

Position and Adoption Speed Justification: There have been a number of signs of autonomous driving moving into the Trough of Disillusionment during the past year. Drive.ai and Starsky Robotics failed, Cruise cut 8% of its workforce, and Zoox is looking for a buyer, Continental has delayed AV investments after Q120 earnings plummeted and Audi has abandoned its plans to introduce the Level 3 traffic jam pilot feature into its A8 vehicles, which it had originally announced back in 2017. Likewise, Ford Motor Company made the decision to shift the launch of its self-driving services to 2022 to evaluate the long-term impact of COVID-19 on customer behaviors.

But there has been increased investment too. For example, Intel’s Mobileye has acquired Moovit and is developing an autonomous mobility as a service (MaaS) solution for the emerging robotaxi market. This plan shifts Intel from being a supplier of chips and self-driving systems for the automotive industry and places it in direct competition with automakers’ own mobility ambitions and the likes of Waymo, Baidu and Yandex. Likewise, autonomous vehicle pilots and trials have continued to be undertaken, though most continue to be supported by safety drivers. To overcome regulatory issues, many autonomous shuttle buses have been demonstrated on private road networks, such as at airports.

The efforts of automobile manufacturers and technology companies to develop autonomous vehicles have been prominently featured by mainstream media, leading to unrealistic and inflated expectations for the technology. Artificial intelligence (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 and industrialization. However, the challenges increasingly include regulatory, legal and societal considerations, such as permits for operation, liability, insurance and the effects of human interaction.

Continued advancements in sensing, positioning, imaging, guidance, mapping and communications technologies, combined with AI algorithms and high-performance computing capabilities, are converging to bring the autonomous vehicle closer to reality. However, in 2020, complexity and cost challenges remain high, which is impacting reliability and affordability requirements, as well as hindering the ability for companies to get regulatory approval.

User Advice: The adoption of autonomous vehicle technology will require increasing levels of technical sophistication and reliability that rely less and 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, consumer education is critical to ensure that demand meets expectations once autonomous vehicle technology is ready for broad deployment. Specific focus must be applied to the transitional phase, where autonomous or semiautonomous vehicles will coexist with an older fleet of nonautonomous vehicles.

Look for use cases, such as mining, agriculture or airports, where autonomous vehicles can operate in restricted areas safely without regulatory restrictions. Use these implementations to drive early revenue and gather data and insights to improve the performance of self-driving systems.

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 who will be affected by automation to other roles.

Business Impact: The main implications of self-driving vehicles will be in the 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 being an option to reduce vehicle fuel consumption and improve traffic management. The interest of nonmobility companies (such as Intel, Waymo, Apple and Baidu) highlights the opportunity to turn self-driving cars into mobile computing systems. These systems 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.

When autonomous driving enters the Trough of Disillusionment, it might be a good opportunity for new market entrants.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Audi; AutoX; Daimler Group; General Motors; Mobileye; Pony.ai; Tesla; Uber; Waymo

Recommended Reading: “Market Trends: Monetizing Connected and Autonomous Vehicle Data”

“Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide”

“Utilize Partnerships to Secure a Winning Position in the Autonomous Driving Ecosystem”

“Market Insight: Use Situationally Aware Platforms to Enable Safe Autonomous Vehicle Handovers”

“Maverick* Research: Autonomous Mobile Structures Will Fuel the Sharing Economy”

Commercial UAVs (Drones)

Analysis By: Aapo Markkanen

Definition: Commercial unmanned aerial vehicles (UAVs, also known as drones) are small helicopters, fixed-wing airplanes, multirotors and hybrid aircrafts that have no human pilot on board. They are either remotely controlled by human pilots on the ground or outfitted for autonomous navigation. This analysis relates to UAVs used for commercial purposes — excluding consumer and military drones.

Position and Adoption Speed Justification: In 2020, commercial UAVs have nearly reached the bottom of the Trough of Disillusionment. In the technical sense, drones are a relatively mature technology and capable of increasingly sophisticated tasks. However, their wider adoption is often held back by national regulations that restrict or even outright prevent many use cases. In particular, flying drones beyond visual line of sight (BVLOS), above people or in restricted airspace, such as close to airports, are types of operations that are heavily regulated, if not entirely unpermitted, in most countries. Additionally, the scarcity of trained and licensed drone pilots, as well as the high cost of vertically specialized end-to-end drone solutions — which cover the devices, the supporting software and the flight operations — hold back large-scale adoption among end users. Autonomous flights would represent a major boost to the market, but their enablement for routine usage requires both further regulatory changes and technology advancements.

User Advice: Overall, a corporate drone program should have both short-term and long-term objectives. This is because commercial UAVs can deliver major operational benefits on a routine basis already today, but future technological or regulatory developments can significantly increase their applicability. For instance, once a major market introduces less restrictive regulation on BVLOS flights, the potential of drones in its territory can shoot up practically overnight. Meanwhile, permitting routine BVLOS operations will trigger substantial near-term investment and innovation among the affected technology and service providers. Organizations considering drones, therefore, should not solely plan on the basis of available technology, but also factor in the local regulatory outlook. It makes sense to proactively identify relevant regulatory and technological changes and take advantage of them as early as possible.

The Low Altitude Authorization and Notification Capability (LAANC) initiative in the U.S., facilitating flights in restricted airspace, is one such example users should be aware of. Today, the leading use cases include aerial photography, mapping and surveying, volume measurement, and remote inspection. All of these can be considerably enhanced by the right analytics, so as part of their UAV planning, the adopters should also take into account how they can exploit the captured data in the best possible way. Use cases involving physical tasks — such as delivering cargo or repairing assets — are currently largely in their nascency, but they can be expected to become gradually more viable over the medium term. However, benefits of commercial UAVs in applications that rely on completion of physical tasks will take longer to materialize than in the ones that focus on data capture and analysis.

Business Impact: Most of all, commercial UAVs represent a technology to enhance the capabilities of the roles such as land surveyors, insurance inspectors, and camera operators who traditionally perform labor-intensive tasks in potentially unsafe conditions. As such, drones offer productivity improvements by reducing and/or redeploying headcount, while enabling real-time data capture and improving employee safety. Examples of industry verticals where commercial UAVs can particularly add value include agriculture, construction, emergency services, extractive industries, media and entertainment, as well as utilities. In most of the verticals, the value of commercial UAVs is in reducing operating expenditure and improving safety, but there are also revenue-generating opportunities in industries such as cinematography, surveying and logistics. In 2020, the COVID-19 crisis is set to speed up drone adoption across various use cases such as public safety and traffic monitoring. Also, use of autonomous delivery drones may accelerate during the crisis.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Cyberhawk; Delair; DJI; DroneDeploy; Kespry; Nightingale Security; PrecisionHawk; Sky-Futures; Unmanned Life; Zipline

Recommended Reading: “Top 10 Strategic Technology Trends for 2020: Autonomous Things”

“Forecast Analysis: IoT Enterprise Drone Shipments, Worldwide”

Lighter-Than-Air Communications Platforms

Analysis By: Bill Ray

Definition: A lighter-than-air communications platform is an autonomous drone that floats using a lifting gas or surfaces such as wings. Such platforms offer the advantages of satellite communications at a fraction of the cost and with negligible latency in transmission. Supported by a balloon of lighter-than-air gas, some platforms are free-floating, while others are tethered by a cable.

Position and Adoption Speed Justification: In rural areas, network coverage is expensive. Here, high-altitude platforms can quickly and inexpensively provide communications over a wide area without having to negotiate land access or rental, while tethered deployments can provide instant cover for events or during emergencies.

There is significant interest in the technology, despite the imminent competition from LEO satellite constellations. The presence of such competition and the higher-than-expected costs of balloon-based platforms have pushed this profile into the Trough of Disillusionment.

If the wind direction is predictable at a specific altitude, then simple balloons can be launched regularly to provide consistent coverage (an approach pioneered by Space Data in 2001). By adding intelligence to the balloon, it should be possible to change altitude and catch prevailing winds to progress in a specific direction. This is the approach being pursued by Google's Project Loon, but reliability and the difficultly in recovering balloons have increased the cost of operation.

Tethered aerostats, such as a Helikite or the recently developed Airpup, provide an alternative more suitable for special events or disaster recovery. Combining a helium balloon with a kite enables the platform to stay aloft for days or weeks over a specific location to provide communications and/or observation. A radio deployed to an altitude of 1 kilometer can provide coverage over 50,000 square kilometers at very little cost. Tethered solutions also avoid battery life issues (as power can be delivered over the tether), which limits the utility of free-floating platforms. While solar power can provide some respite, power still remains a limiting factor in the deployment of free-floating platforms.

Lighter-than-air communications platforms provide continuous communications — relaying signals back down to the ground over a second radio connection, with minimal onboard processing. A connected ground station within the same footprint is required to route communications onto the internet or elsewhere.

User Advice: Helikites and high-altitude balloons are immediately available to anyone seeking radio coverage across a specific area for an event (such as a music festival) or emergency cover. Both need radio frequencies in which to operate, but both technologies are flight-proven and operational. For wide-area coverage over a long period, LEO satellites may provide a more-comprehensive solution, though such services will not be commercial until late 2020 at best.

Business Impact: Project Loon has been experimenting with LTE, enabling the Loon balloons to communicate directly with LTE handsets without any ground-based infrastructure, but LEO satellites have also demonstrated some capabilities in this area. Mobile network sites, used in emergencies or for temporally dense coverage (such as during a music festival) can effectively be complemented, or replaced, by tethered solutions.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Allsopp Helikites; Google X; Lockheed Martin; Thales Group

Recommended Reading: "Market Trends: Thousands of New Satellites Will Provide New Services to Disrupt the CSP Industry"

Climbing the Slope

Sensor Fusion

Analysis By: Amy Teng

Definition: Sensor fusion is a process that aggregates and "fuses" many disparate sensor inputs to increase sensor data accuracy and/or sensing coverage for the system to develop insights and decisions. A sensor fusion solution usually includes a set of sensors, a hardware sensor hub, a fusion engine and a software sensor fusion stack.

Position and Adoption Speed Justification: Sensor fusion for automotive and industrial systems has been prevalent for decades. Sensor fusion also exists in smartphones and tablets where the sensor data has been interpreted by OS allowing app developers access through APIs.

During the past few years, sensor fusion has evolved to include lidar, radar and visual sensing for autonomous cars, SLAM (simultaneous localization and mapping) for drones and robots, and six degrees of freedom (6DoF) visual and 3D audio immersion for (head mounted displays) HMDs.

Technology evolution of autonomous things and Internet of Things (IoT) will keep on pushing the number and the diversity of sensor and sensing technology to a higher level, driving continuous enhancement of sensor fusion technology. Sensor fusion algorithms' development has been benefited by the growing leverages of artificial intelligence/machine learning (AI/ML) technology. When this combined with improved sensor accuracy and advanced computational power of sensor engine, sensor fusion can analyze faster and better than before. Therefore, we moved its position a bit forward

User Advice: Sensor fusion software stacks can be derived from three resources: open source, sensor companies and software companies who focus on serving customers who have sensor fusion requirement. Sensor fusion software can be ported to a variety of different hardware platforms, ranging from application processors, general purpose microprocessors and microcontrollers, programmable logic, integrated combo sensors, and purpose-built devices like Microsoft's customized holographic processing unit (HPU) for HoloLens. Consider discrete, low-power sensor hub solution to offload the process of main processor when designing for power constraint and long battery life applications.

Build a central platform to manage sensor fusion algorithms across different products and applications to gain reuse efficiency. For example, a smartwatch and wristband can share same algorithm for detecting a wearer's gesture and posture, the two devices can also share the same voice actuated algorithm with smart speakers.

Leverage AI/ML to accelerate the pattern recognition of sensor signals and shorten sensor fusion development time.

Sensor fusion can also offer reduced size and weight, which is particularly important in drone applications.

Business Impact: Sensor fusion technology is a key element of enabling real-time contextual analysis because it comprehends the status of a system. Additionally, leverages AI/ML and clever manipulation of different types of input sensors to train model will explore new algorithms, resulting in new insights or new applications unseen before. For example, fusion of sound waves and surface vibration of sound source can create a new type of noise-cancellation device.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: CEVA (Hillcrest Labs); CyweeMotion; Kionix; Knowles; NXP; Qualcomm; QuickLogic; Renesas; STMicroelectronics; TDK (InvenSense)

Recommended Reading: "Cool Vendors in Novel Sensors"

"Cool Vendors in Novel Sensors"

"Market Trends: Supplying Intelligent Sensors for the IoT Takes Cooperation, Integration and Software"

Micro Fuel Cells

Analysis By: Jon Erensen

Definition: Micro fuel cells (MFCs) provide an alternative to batteries in mobile devices. They may be small enough for integration inside the device or a little larger for use as external power supplies. Most fuel cells use hydrogen as the base fuel, but MFCs usually operate from a hydrogen-rich liquid such as methanol or butane. MFCs can provide up to 10 times the energy storage capacity of a lithium battery but are not as good at delivering bursts of high power. This makes them more useful for battery charging than for primary power roles.

Position and Adoption Speed Justification: This technology stays in the same position on the Hype Cycle this year as we have not seen a material change in adoption. The only major application for MFCs has been in drones and certain robots because it has a higher power-to-weight ratio than traditional lithium ion batteries, allowing devices to operate for longer periods of time or over longer distances. But there has been little progress in addressing the many challenges associated with MFCs which include the lack of a global fuel supply infrastructure, stability issues and high costs. MFCs that are truly portable and could be incorporated into devices such as smartphones and other compact electronics are still limited to the concept and prototype stages. Fuel cells used as chargers for mobile devices remain stalled, because solutions based on rechargeable lithium ion batteries are less expensive and widely available. The availability of solar-powered chargers is another alternative for users in remote locations.

User Advice: Vendors of equipment such as drones, where the higher power-to-weight ratio is critical, should establish relationships with MFC companies and design MFC solutions into special models for their products. But it is important to understand the limitations of the technology, including distribution challenges and cost.

Emergency responders should consider MFC-based chargers as part of emergency preparations to allow smartphones and other mobile electronics to be used in situations where traditional power supplies will be unavailable for extended periods.

Business Impact: As an alternative power source, MFCs can be attractive and enable longer working times in certain mobile devices and applications.

MFCs have the potential to enable mobile devices with smaller footprints because of their higher power-to-weight ratio.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Aquafairy; Hitachi; Horizon Fuel Cell Technologies; Intelligent Energy; LG Electronics; NEC; SFC Energy; Sony

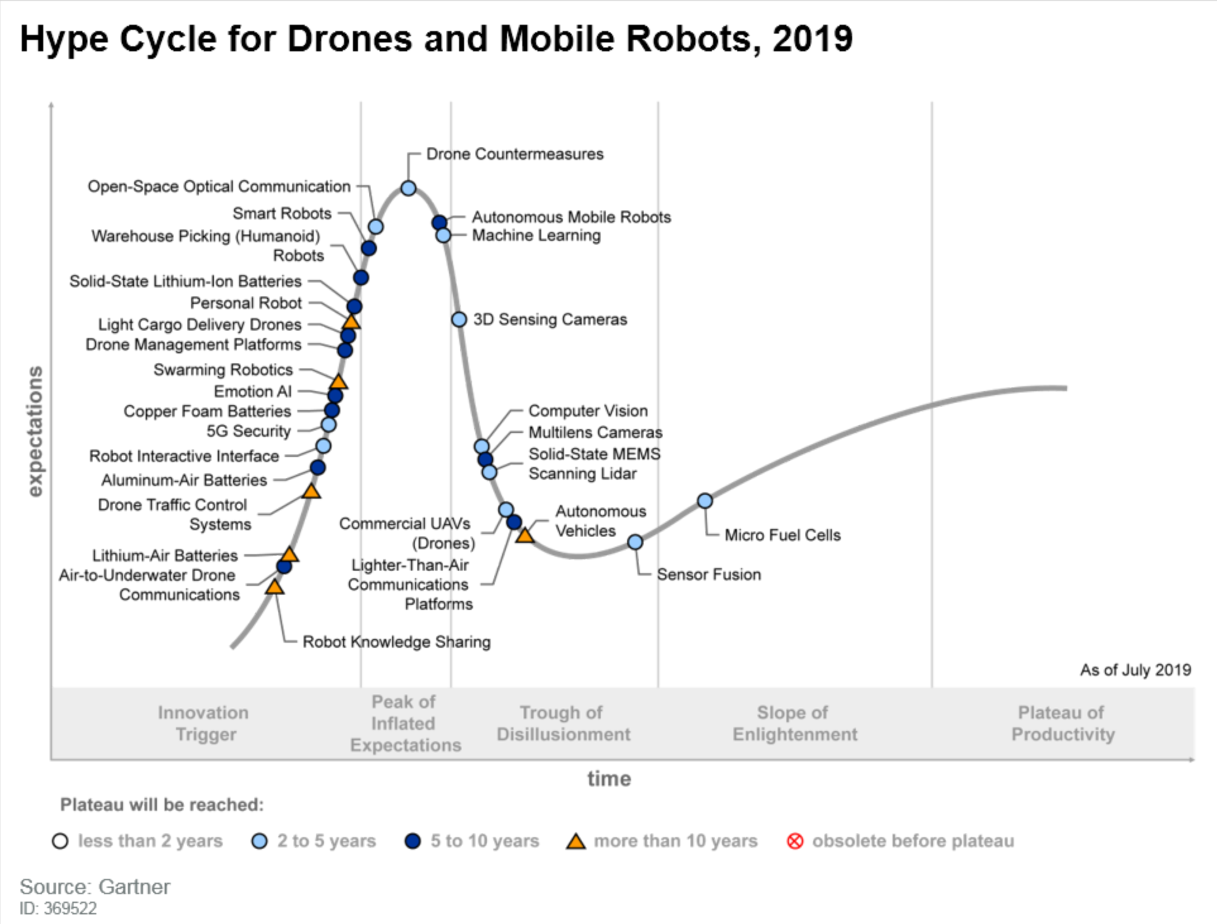
Recommended Reading: "Government Policies Will Drive Further Electric and Plug-In Hybrid Vehicle Market Growth in China"

"Forecast Overview: Industrial Electronics and Semiconductors, Worldwide, 2017 Update"

"Utility CIOs Must Get Ready for the Digital Grid"

Appendixes

Figure 3. Hype Cycle for Drones and Mobile Robots, 2019



Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 1: Hype Cycle Phases

(Enlarged table in Appendix)

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 2020)

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 2020)

Table 3: Maturity Levels

(Enlarged table in Appendix)

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 2020)

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Hype Cycle for Drones and Mobile Robots, 2018 - 18 July 2018

Hype Cycle for Drones and Mobile Robots, 2017 - 28 July 2017

Recommended by the Author

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Understanding Gartner's Hype Cycles

Forecast: IoT Enterprise Drones by Use Case, Worldwide, 2018-2028

Innovation Insight for Drones in Healthcare and Retail Last-Mile Delivery

Top 10 Strategic Technology Trends for 2020: Autonomous Things

Hype Cycle for Enabling Power and Energy Electronics, 2020

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.

Gartner

Source: Gartner (July 2020)

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 2020)

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

Maturity Level	Status	Products/Vendors
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 2020)