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Drones

Drones are on their way

Unmanned aerial vehicles – UAVs or, more commonly, drones – have been a regular feature in military applications, especially surveillance, for some time. However, over the past three to four years, the rapid proliferation of consumer electronics, the emergence of cloud technologies, the declining cost of server and bandwidth usage, the improving price-to-performance ratio of hardware components, and a dramatic rise in demand for a "bird's-eye" view of the earth have steadily opened up the market for the civilian use of drones both as recreational devices, and in commercial applications.

Drones will find a place at the heart of the IoT ecosystem

The ongoing development of the Internet of Things (IoT) combined with rising demand for drones among enthusiasts and enterprises – in addition to military organizations – is driving innovation in, and adoption of, drone technology. As the capabilities of drone technology improve on one hand, while the cost declines on the other, drones will become increasingly ubiquitous – playing an important role in the burgeoning IoT ecosystem.

Drone adoption is being held back by regulation

The enthusiastic adoption of drone technology by both individuals and enterprises faces regulatory barriers in many countries, driven by a combination of security and safety concerns. However, compelled by industrial demand, several governments are gradually undertaking regulatory reforms relating to the use of drones in commercial airspaces. This, in turn, is fueling investment for technological improvements and business prospects.

As regulations mature, drones as a service (DaaS) providers are poised to take advantage of opportunities to offer industry-specific solutions, with interest in drone adoption growing in a number of key domains including drone delivery, drone-based internet services, disaster response, and medical assistance. As adoption grows, the market is becoming increasingly intense and competitive, with several leaders already emerging.

Who is at the forefront in the drones industry?

DJI is the dominant force in the civilian drones sector, both in commercial and consumer markets.

The nearest competitors to DJI include Parrot and Yuneec, which are driving technological improvements to their offerings, but are struggling to compete with DJI's aggressive pricing strategies.

In the government sector, General Atomics and Northrop Grumman are well positioned, with Aviation Corporation of China (AVIC) progressing steadily worldwide. Aerovironment, Elbit Systems and Insitu (Boeing) are also key players competing in both the civilian and government sectors.

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Players

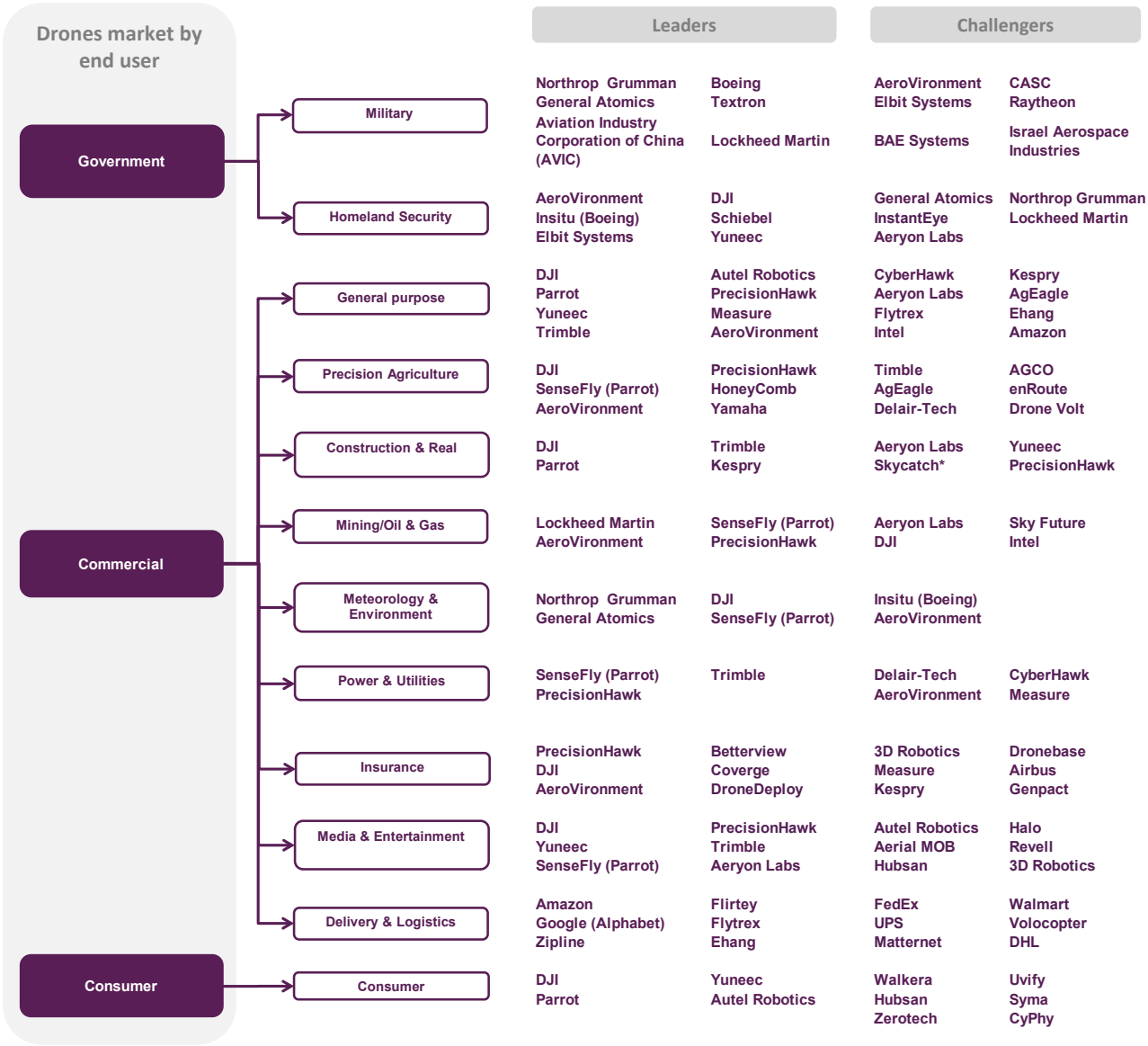
The government sector (including the military) is the primary market for drones, followed by the consumer segment. Commercial applications of drones are gradually increasing, and many enterprises are seeking regulatory permits for full-scale deployment of drones in their day-to-day operations. This optimistic outlook for drones is driving intense competition in the market with many companies, both established players and start-ups, vying for a share in a market that is set to enjoy strong growth over the next five years

Technology giants such as Amazon, Google, Microsoft, Intel and Facebook are strengthening their focus on drone technologies as they look to cash in on the potential for drones to drive the transformation of traditional industrial operational systems and pave the way for Industry 4.0.

The chart below identifies some of the leaders and challengers in the drones industry.

Who are the big players in the drones industry by end user market?

DJI is the most dominant player in the commercial and consumer drones industry, while General Atomics and AVIC command strong positions in the government segment.



Source: GlobalData

Trends

The main trends in the drones industry over the next 12 to 24 months are shown below. We classify these trends into three categories: technology trends, macroeconomic trends and regulatory trends.

Technology trends

The table below highlights the key technology trends impacting the drones industry.

Trend	What's happening?
Scaling up and down	To improve flight performance and expand the capabilities of their drones, drone manufacturers are working on scaling drone technology up on one hand, to deliver greater carrying capacity and endurance, and down on the other to deliver low cost, small footprint drones for surveillance. The miniaturization of sensors helps to cut down the overall size and weight of drones and reduce their power requirements. Size, weight and power consumption (SWaP) metrics are especially critical for military UAVs to support effective intelligence, surveillance and reconnaissance missions. Some prospective drone application areas – including search and rescue, offshore natural resource explorations and utilities inspection, among others – demand bigger drones to support larger payloads (especially battery and propulsion systems) so they can deliver longer endurance and greater carrying capacity. This factor is also driving the miniaturization of electronic components to ensure they take up less of the available space and weight capacity of the drone. For instance, Bosch is investing in development of single sensors which can perform multiple tasks and be thus controlled with integrated microprocessors.
Processor chips are enabling more capabilities	Microprocessors serve as the control centers for drones, providing a platform for control and communications software that integrates with collision avoidance sensors, high definition cameras and other sensors. Advances in chip design, driven in large measure by the mobile phone industry, are leading to smaller chips with higher performance and lower cost, which in turn helps to drive down the manufacturing cost of drones. Chip manufacturers are expanding the capabilities of system on a chip (SoC) components to combine multiple sensing and processing elements on a single chip. ARM-based processors from companies such as NXP Semiconductors and STMicroelectronics are among the most powerful in the market, with a major emphasis on low power/low cost. Presently, the market for drone processor chips is actively pursued by the major industrial players, with Intel and Qualcomm thriving in the market. Nvidia is proving to be a key challenger in this space, but still lags behind the leaders.
Growth in the application of 3D technologies	The ability of 3D modelling technologies to consume drone data in the form of imagery and radar/lidar data and convert it into complete topological models makes it possible to survey and monitor the landscape and the objects within it. Whether the application is the surveying of structures like bridges, buildings, factories or oil rigs, or the monitoring of farmland or forestry, drones are increasingly being integrated with improved sensors, high definition cameras and computer algorithms that can condense the images into 3D virtual images and enable easy assessment of anomalies. Industries which require frequent inspection and surveillance of pipelines, tracks and fields are using drones that can follow preset trajectories and simultaneously provide data to the user. Drones integrated with 3D technologies are beginning to be used to carry out maintenance and repair operations, particularly in inaccessible or dangerous environments.

Trend	What's happening?
Artificial intelligence (AI) and drones	The growing volume of data gathered by drones will create demand for increasingly sophisticated analysis of that data. To effectively process incoming sensor data and draw meaningful conclusions from it drone solutions need to make use of the latest data analytics technologies. For example, BNSF Railways, the US's largest railway company, operates Insitu drones to inspect railway tracks. About 300 GB of images are captured at two shots per second and these images are then overlapped in real time by AI techniques to enable detection of more than 30 instances of damage at once. Additionally, AI enables 'continued learning' for drones through techniques like machine learning, in order to enable complex capabilities like autonomous flying and obstacle recognition and avoidance. While the industrial sector is already proving to be a significant market for drones with AI capabilities, service sector companies are also vying for AI-enabled drones to develop new business models (e.g. drone deliveries). Against this backdrop, the leading AI players are gearing up to establish themselves in the drones market. Microsoft, which is one of the world's biggest investors in AI technology alongside the likes of IBM, Google, Alibaba, Intel, and Amazon, has partnered with DJI, the largest drone manufacturer, to use the Microsoft Azure IoT platform and AI tools for offerings targeted at the construction, law enforcement, agriculture areas, among others. Similarly, other leading players are focusing on development of their own AI powered drones for future applications. Nvidia and Neurala are among the key challengers and are increasingly offering AI integration to drone manufacturers.
Drone swarms	The need to manage and control multiple drones in close proximity will become more acute as the number of active drones grows. Cisco is promoting the concept of connected drones that can be controlled via a cloud-based infrastructure. The company argues that the ability to manage multiple drones simultaneously will enable faster data collection over vast areas, coupled with simultaneous data processing to deliver timely and accurate data. Presently most of the data generated by drones is transferred to cloud systems for users to access and analyze, often not in real-time. Microsoft's Azure Cloud, Amazon Web Services (AWS) and IBM Cloud (among others) are key cloud platforms currently being used by drone companies. Vertically integrated solutions are being offered by drone companies such as Kespry, PrecisionHawk and Airware, with their own cloud systems developed either in-house or in collaboration with other firms. For instance, SAP offers its Cloud Platform for Kespry to deliver aerial intelligence for industries such as construction and mining.
Augmented reality (AR) and drones	As the capabilities of AR technologies improve, drone makers are increasingly incorporating AR functionality into their products to enhance the user experience and make the application of drone technology more effective. The European Space Agency (ESA) has backed a French start-up, Sysveo, to integrate user made AR into a drone's video streams. This integration is intended to enable the real-time analysis of gathered data to improve operational efficiency and also provide enhanced anti-collision measures. Drone manufacturers are directly reaching out to homeland security agencies, gamers, firefighters, surveyors and construction engineers. Intel is the most notable established company providing AR technologies for drones.
Anti-collision technologies	While the relatively small scale of today's commercial drone deployments means that there is currently little risk of collision between drones, the widespread application of drone technology will require effective anti-collision systems to ensure that they can be operated safely in public places. Different sensor payloads are being developed to establish improved management and control of drones, in order to satisfy regulators and insurers that drones can be operated safely and autonomously. The European Union (EU) has a U-Space program under the Single European Sky Air Traffic Management Research (SESAR) project and the US's NextGen programs are aiding the development of anti-collision measures and also validating the feasibilities of high demanding beyond visual line of sight (BVLOS) operations.

Trend	What's happening?
Battery technologies	Most of today's drones are powered by lithium polymer (LiPo) batteries, which are known to deliver sufficient energy required to perform standard drone flights. However, the ability to transport increasingly heavy payloads and to conduct more demanding operations in varied environments, is constrained by the fact that present-day drones are limited in terms of their endurance. Growing demand for longer flight times and greater carrying capacity is driving drone manufacturers to explore alternative technologies such as hydrogen cells, gasoline powered solutions, solar batteries, gas-electric hybrid solutions and laser solutions among others.
Edge and fog computation – to improve data processing	Fog computing is a computing model which permits collected data to be analyzed within the drone itself (the edge), prior to interacting with the central point of control. As the volume of data that is gathered and analyzed by drones increases, the ability to perform this analysis at the point of collection will grow in importance. The cost, complexity, and latency involved in transmitting large volumes of sensor data from drones to a central point for analysis means that there can be a significant delay between an event being sensed and action taken as a result of it. A range of industry participants, including sensor suppliers, chip manufacturers, data connectivity providers, and integrators, are working on technology that allows a greater proportion of the data analysis and processing to take place at the edge of the system – on board the drone itself. Although Schneider's presence in the drone sector is presently limited today, the company is investing by using edge computing technology in the oil and gas industry. The use of fog computing will enable drone operators to reduce latency and limit the amount of data that needs to be transmitted from the drone to the controlling application. Other technologies like adaptive video streaming, parallel successive refinement-based streaming, and networked camera drones will become more common in future thanks to the increasing processing power that is deployed at the edge. Moreover, fog nodes will provide additional layers of security in terms of perimeter defense against hackers without adding complex firewalls and surplus cost. Upcoming drone delivery systems will make use of fog computing for autonomous or semi-autonomous flight, collision avoidance and real-time tracking. The Open Fog Consortium – formed as an association among Cisco, Intel, Microsoft, Princeton University, Dell and ARM Holdings – is working in line with future industrial requirements, including drones, and investing in network technology enhancements to improve data security and simplify computation systems. Tech giants like Intel, Microsoft, IBM, Amazon, SAP and Cisco (among others) are looking to be "first movers" in the drone fog computing market, banking on their established industrial connections.
Drones as a service (DaaS)	Over the next two years a number of specialist service companies will emerge, offering a turnkey solution for drone-based surveying, monitoring, and delivery. So rather than having to develop drone capabilities in-house, organizations will be able to rent drone services on an as-needed basis.
Unmanned aircraft system traffic management (UTM)	As the adoption and application of drone technology becomes more widespread, the need for autonomous UTM system, which can ensure safety, security and control of drones in low-altitude airspaces, will grow significantly. In addition, the need for UTM is identified as a key enabler for future autonomous passenger drones, vertical take-off and landing (VTOL) air systems and BVLOS operations. Taking cues from the established air traffic management (ATM) system, UTM initiatives are primarily focused around three parameters – communications, navigation, and surveillance. Some of the notable initiatives underway currently for development of UTM are being led by NASA, the European Aviation Safety Agency (EASA) and the Civil Aviation Administration of China (CAAC). In addition, some companies are also working on their own initiatives. For example, Cisco has initiated development of an autonomous drone traffic management system and is steadily supporting the NASA's UTM program. Also, AirMap, a start-up firm from the US, has joined forces with the Swiss air traffic control firm Skyguide and implemented the EU's U-Space vision in the Swiss Alps in Q1 2018. The Swiss-American joint effort was carried out to evaluate the standards set out in the EU's SESAR joint undertaking (JU).

Trend	What's happening?
Drone delivery	Drone delivery is the most anticipated, and hyped, commercial application of drone technology. Encouraged by Amazon's vision of drone powered package deliveries, the global drone community has shown great interest in this new model of distribution. With numerous initiatives currently in pilot testing worldwide, proponents promise that it will cause significant disruption to existing industrial distribution channels. Looking further out, some companies are looking at hyper-local / hyper-personal drone delivery by applying AI, 3D and AR. For instance, IBM's drones can recognize a person's need for coffee using inputs from his/her wearable gadget and deliver the same from a nearby coffee counter. Moreover, companies such as Volocopter and Ehang have demonstrated the capabilities of passenger delivery via drone, suggesting a new, cost effective mode of transport. Uber has also expressed interest in such technologies and has initiated the Uber Elevate program to evaluate the feasibilities of deploying passenger-carrying VTOL drones.

Source: GlobalData

Macroeconomic trends

The table below highlights the key macroeconomic trends impacting the drones industry.

Trend	What's happening?
The military – key demand generator	Accounting for more than 70% of the global drones market, the government segment, comprising of military and law enforcement agencies, was the key demand generator for drones in 2018. Ranging in size from Flir's Black Hornet UAV, which is just a few centimeters in length, to Northrop Grumman's 40-meter winged Global Hawk, military forces have been using drones in reconnaissance and to perform operational tasks for over a decade. Primarily used to conduct intelligence, surveillance and reconnaissance (ISR) activities, military UAVs are presently being developed for a wide range of uses such as electronic attack (EA), strike missions, suppression/destruction of enemy air defenses (SEAD), network nodes, communication relays and combat search and rescue (CSAR). Demand for UAVs from military forces will continue to grow as the number of potential applications of drone technologies increases.
Industrial prospects	Drone technology will be adopted in industrial markets in the following domains: aerial inspection and monitoring; payload delivery; media and entertainment; and security. These applications will demand the integration of a range of technologies such as 3D, laser, acoustics, AR, computer vision and cognitive tools. However the growth of drone applications in commercial spaces will continue to be restricted by existing regulations and public concerns around safety, security, and privacy. Industries which are set to exploit drones and associated technologies within the next 12 to 24 months include construction and real estate, oil and gas and mining, power and utilities, agriculture, and media and entertainment. Subsequently, surge in drone-related investments will also be noted across the telecoms, insurance, retail and logistics industries over the next two to four years.
Surging competition	The global drones market is exceptionally competitive, with varied solutions and services being offered by numerous companies. Although full-scale application of drones in commercial airspaces is restricted mostly by regulatory frameworks and lack of effective traffic management systems, the potential market valuation from recreation and business operations is attracting companies from all ICT fields.

Trend	What's happening?
Collaboration – to drive technology innovation and regulatory reform	Drone manufacturers, component suppliers, software integrators, and prospective enterprise users all share a vested interest in collaboration in order to promote the adoption of drone technology. The commercial deployment of drones beyond pilot studies and proof-of-concept projects is held back by the sluggish pace at which regulations are being defined and adapted. This creates a common cause for multiple organizations to work together to influence the pace and direction of public policy with respect to drone technology. For instance, Sharper Shape has partnered with the Edison Electric Institute (EEI) to develop and demonstrate commercial drones BVLOS flights for electric companies. Meanwhile, Boeing's acquisition of Near Earth Autonomy and Aurora Flight Sciences for autonomous UAV development and AirMap's collaboration with IBM's The Weather Company to provide hyperlocal weather information to drone pilots show the importance, and value, of collaboration and partnership. In the US, under the leadership of NASA, technology leaders such as Verizon, Google, Amazon and Harris are working on a $2.8 billion UTM project intending to harmonize drone traffic in US airspaces and which, in turn, will push for relaxing the regulatory framework and enable commercial application of drones in the country. Thus, collaboration is being viewed to not only facilitate better business solutions in future, but also to build swifter market penetration portfolios in compliance with regulatory reform.
Operating drones beyond visual line of sight	In order to be truly effective, drones must be capable of operating at long distances from the controller. The ability to operate BVLOS is currently the most demanding challenge faced by commercial drone applications worldwide. Under its ongoing UTM program, which focusses on the control and management of unmanned aircraft, NASA is endeavoring to develop an efficient "detect and avoid" solution for drones, which will take advantage of onboard sensors and computers to safely avoid nearby traffic. Supported by NASA, a drone software integrator, Simulyze, has demonstrated its BVLOS and collision avoidance capabilities in its Mission Insight platform. BVLOS operations are gradually gaining ground, with regulatory authorities granting approval in special use cases, albeit most often for experimental purposes at this point in time. For example, Switzerland and Sweden have permitted full scale BVLOS operations for SenseFly and Heliscope/Scopito respectively. Poland has also opened up its airspace for enterprises to explore BVLOS operations. Japan is experimenting with Amazon drone delivery BVLOS systems under a special exemption in the city of Chiba. Similarly, Google's Project Wing has also been approved for testing of drone delivery BVLOS operations in Australia. Such initiatives by national regulatory bodies are encouraging drone industry participants to continue exploring BVLOS technologies and enabling development of an efficient drone management system. Other countries such as Canada, China, Denmark, Germany, New Zealand, South Africa, the UK and the US are currently backing BVLOS by approving experimental operational permissions from different organizations.

Trend	What's happening?
China factor	China is currently the dominant country in the commercial drone market and is set to play a key role in reforming the industrial trends and regulations in the coming years. China is continuously investing in development of drone capabilities for both military and commercial applications. The country's latest development – Caihong 5 (CH-5) Rainbow – is being compared to the US Reaper and Israeli Heron TP, which are recognized to be the most advanced strike-capable military drones currently in service worldwide. Although China has demonstrated strike capable drones, deployments have so far been limited to non-combat zones. Additionally, several Chinese law enforcement agencies (LEAs) operate drones on a regular basis to monitor borders and conduct general surveillance missions. In terms of overall military UAV exports, China lags behind the US and Israel in the ISR segment. However, in the strike capable drone segment, China has steadily surpassed its peers over the past few years. Taking advantage of the increasing demand for drones among militaries worldwide and the US's legal restriction on foreign sales of armed drones under the Missile Technology Control Regime (MTCR), China has successfully tapped into a fast-growing market. For instance, in 2017, China announced plans to build a manufacturing unit in Saudi Arabia for local production of CH-4 military strike drones. Chinese drones are also significantly less expensive than their US and Israeli counterparts, enabling China to expand in countries with limited military budgets. For example, Iraq's strike drones (CH-4) recently deployed to neutralize ISIS locations, were procured from China because of their low unit costs as compared to the equally capable US Predators. According to Iraq's national media, the CH-4s deployed against ISIS have delivered near 100% strike rates. This factor also counters the perception of Chinese drone technologies as inferior to their Western counterparts. In the non-military segment, Chinese manufacturers account for approximately 80% of the market. China has delivered faster development of superior drones for enterprise applications. Major Chinese firms dominating the global civilian drones segment include DJI, Yuneec, and Autel Robotics. These companies benefit from China's low-cost manufacturing base and have established a strong price/performance advantage over their Western competitors. American firms such as 3D Robotics, Lily, GoPro and others have been severely hit by Chinese competition, resulting in staff reductions and even, in some cases, the shutting down of entire operations. As commercial demand for drones grows the leading Chinese players are working to develop their ability to sell into, and provide services and support for, international markets. To maintain their market hold in Western countries, Chinese firms are rapidly investing in technologies which are set to drive regulatory reforms for drone applications in commercial airspaces. For instance, recognizing the increasing importance of integration with air traffic control systems, Chinese firms are supporting automatic dependent surveillance - broadcast (ADS-B) in which aircraft broadcast their position on a standard frequency. DJI has rapidly adapted to the evolving regulatory norms and introduced the DJI AirSense on Matrice 200. This willingness to be a first mover has enabled the company to gain approval from the US Federal Aviation Administration (FAA) to perform Low Altitude Authorization and Notification Capability (LAANC) services for professional drone pilots in controlled airspace around US airports. In order to promote R&D in Chinese drone technology, the country is also exploring relaxing its domestic airspace restrictions. According to the latest announcements by the Chinese Ministry of Industry and Information Technology (MIIT), the Chinese domestic drones market is set to be valued at 180 billion yuan ($25 billion) by 2025. The MIIT has released guidelines to promote unified management systems for the domestic drones industry, strengthen competitive edge in the international market, and foster the leading Chinese manufacturers. These guidelines represent a strong signal that the country is determined to challenge globally and enable its home-grown firms to solidify their market positions in future.

Source: GlobalData

Regulatory trends

Unlike other technologies where commercial adoption, followed by operational vulnerabilities, has led to regulatory reforms, drones have been regulated from the outset because of the safety and security concerns associated with them and as a result of pre-existing regulations relating to radio-controlled aircraft. Most countries limit the deployment of drones in commercial or public spaces. Meanwhile, hobbyists and non-commercial consumers enjoy a degree of freedom to experiment, provided they remain within the limits imposed by existing regulations. As a result enthusiasts are successfully pushing innovation in drone technology. Driven by such advances and fueled by commercial demand, several countries are currently re-evaluating their drone legislation. However, safety and security concerns mean that the regulatory process is likely to be slow.

Regulators face huge challenges when it comes to developing appropriate drone regulation. Regulators have to balance a duty to enforce security and safety rules on one hand, with promoting the use of drones and innovation in drone technology on the other.

Regulatory authorities worldwide are struggling to adapt to drones in every aspect. Advances in technology, operational capabilities, application areas and surging demand from commercial participants have all combined to create pressure for change while also raising new concerns. Broadly, drone regulations for commercial applications include four elements: pilot's license, aircraft registration, restricted operational zones, and insurance.

- **Pilot's license:** Standard across the majority of countries for commercial purposes. However, the procedure to obtain a license varies from one country to another.
- **Aircraft registration:** Authorities intend to have detailed knowledge of the drone such as mass, maximum altitude capabilities, and operational purpose.
- **Airspace Restrictions:** A common parameter which states that it is illegal to fly drones for recreational and commercial purposes in proximity to airports and national critical infrastructure, including military facilities.
- **Drone insurance:** A standard requirement across the EU, although not mandated in other regions.

The different regulatory approaches can be outlined in five categories – outright ban, effective ban, requirement for constant visual line of sight (VLOS), experimental uses of BVLOS, and permissive.

- **Outright ban:** Drone deployment for commercial use is illegal.
- **Effective ban:** Drone use requires a license, but meeting regulatory requirements is either impossible or no approvals have been passed so far.
- **VLOS requirement:** Drone pilots must operate within visual line of sight.
- **Experimental BVLOS:** Where drones are operated beyond visual line of sight (BVLOS), permission must be sought from the regulator.
- **Permissive:** Drone use is relatively unrestricted for commercial applications, but subject to minimum safety standards.

Several countries have banned commercial drones for security reasons, particularly in countries where drones have been used by anti-national organizations to harm citizens, military and governments. For instance, Egypt refuses to permit drone operation owing to the threat of attacks from insurgent groups. Similarly, India has also prohibited drone use (except for military and experimental purposes) owing to the threat from cross-border terrorist organizations, while Iran has enacted a ban on individual drone operations for recreational or commercial purposes.

Current limitations on the ability to manage drone traffic and control the airspace that drones use make it hard for regulators to relax existing limitations. The evolution of drone traffic management technology will help in this regard, but most initiatives are still in their early stages. For example, Belgium, cited drone accidents as the key factor for its absolute ban on drone flying till 2017. However, since relaxation of regulations to permit VLOS applications, the country is presently investing in specialized training of operators, designing strict standard operating procedures (SOP) for flying in commercial airspaces, and drafting guidelines for drone operations among other measures.

Several technologically proactive countries are taking initial steps to facilitate the use of drones in their respective commercial sectors without compromising on security and safety. As such, regulations are being re-evaluated and re-drafted to balance national interest and economic progress.

Many countries have already introduced some kind of drone legislation. Many others, who currently prohibit drone use, are likely to follow.

The chart below identifies a number of countries and their differing regulatory approaches. The potential impact of such regulations on the drone industry's revenue growth over the next decade is also provided. Green shading in the table below indicates a positive impact and red a negative impact.

Different countries apply different approaches to regulating drones

Regulation type	Description	Countries		Impact on drone industry revenues		
				2018-2020	2021-2024	2025-2028
Outright ban	Drone use is illegal.	Argentina	Kuwait			
		Barbados	Kyrgyzstan			
		Belize	Madagascar			
		Brunei	Morocco			
		Côte d'Ivoire	North Korea			
		Cuba	Saudi Arabia			
		Ethiopia	Senegal			
		Fiji	Slovenia			
		India	Syria			
		Iran	Uzbekistan			
		Iraq	Zambia			
Effective ban	Drone use requires a license, but meeting regulatory requirements is either impossible or no approvals have been passed so far.	Algeria	Egypt			
		Belarus	Kenya			
		Chile	Nicaragua			
		Colombia	Nigeria			
VLOS required	Drone pilots must operate within Visual Line of Sight (VLOS).	Belgium	Luxembourg			
		Bermuda	Mexico			
		Bhutan	Nepal			
		Botswana	Netherlands			
		Croatia	Slovakia			
		Ecuador	South Africa			
		Jamaica	South Korea			
		Latvia	Switzerland			
		Lithuania	Thailand			
Experimental BVLOS	Where drones are operated beyond visual line of sight (BVLOS), permission must be sought from the regulator.	Australia	Japan			
		Austria	New Zealand			
		Brazil	Panama			
		Canada	Poland			
		China	Rwanda			
		Czech Republic	Singapore			
		Denmark	South Africa			
		Finland	Sri Lanka			
		France	Russia			
		Germany	Trinidad & Tobago			
		Greece	Uganda			
		Guyana	United Kingdom			
		Ireland	United States			
Permissive	Drone use is relatively unrestricted for commercial applications.	Costa Rica				
		Iceland				
		Italy				
		Norway				
		Sweden				
		United Arab Emirates				

Key:

Neutral impact on drone industry revenues

Positive impact on drone industry revenues

Negative impact on drone industry revenues

Source: RAND Corporation, GlobalData

The table below highlights the key regulatory trends poised to impact the drones industry within the next three to four years.

Trend	What's happening?
US FAA regulation	Historically, the US has been reluctant to relax regulations covering commercial drones, citing security and safety concerns. However by 2017 the FAA had announced exemptions to some companies permitting them to operate drones beyond visual line of sight. In the same year, the President Trump announced the launch of Unmanned Aircraft System (UAS) Integration Pilot Program (IPP), which is intended to foster collaboration between federal agencies and enterprises. Such initiatives indicate that the US, being the largest drone consumer currently, is making efforts to move beyond recreational markets and establish a framework that allows the use of drones in commercial applications. The country's transformed outlook on drone regulations has been triggered by developments in countries such as Japan, China, Australia, Singapore, Poland and the UK, which are attracting commercial opportunities by steadily evaluating and permitting drone applications. Moreover, the FAA's LAANC services have been initiated across 300 air traffic facilities in the country, under which the partner industrial organizations – Aeronyde, Airbus, AiRXOS, Altitude Angel, Converge, DJI, KittyHawk, UASidekick Unifly, AirMap, Harris Corp, Project Wing, Skyward and Thales – are involved in ensuring safe drone operations at night and BVLOS in specific locations. The LAANC program is thus serving as a foundational initiative for integrating drones alongside manned aircraft in the US's domestic airspace program NextGen. These programs are sure to drive regulatory reforms in next three to four years.
Europe U-Space Program	In October 2018, a €9.5 billion ($10.8 billion) program was announced under the SESAR JU U-Space blueprint to conduct tests of a wide range of drone operations and their interactions with manned aviation across Europe. The program has outlined nine projects, which include drone deliveries, medical emergencies and police interventions, maritime search and rescue missions, and forest inspections. The program was scheduled to begin demonstrations by January 2019. These projects will enable collaboration among drone operators, administration regulators, LEAs, and product developers – along with the latest technological systems – in a single environment to draft future drone legislation. With the rapid expansion in demand for drones in the European commercial and defense sectors, SESAR JU drafted the U-Space blueprint for integration drones in European skies alongside manned aircraft. Drones flying between 500 feet to 60,000 feet are expected to be integrated into conventional air traffic management using instrument flight rules (IFR). To spur swift growth of drone applications and balancing the same with safety and security measures, the U-Space program has identified three services: e-registration; e-identification; and geo-fencing. E-registration is applicable for all drones bearing above 250 grams, whereas e-identification will enable tracking of commercial drones in compliance with law enforcement procedures. Geo-fencing will ensure safe operation of drones without violating restricted flying zone norms. Post completion of the nine projects funded under SESAR JU, the U-Space program will be merged with the European Master Plan, which will take on the allocation of additional resources for the development and application of drones in all kinds of operational environments. Under the U-Space program, standards and recommended practices (SARPs) are currently being drafted by the International Civil Aviation Organization (ICAO), which will be finalized in 2020 and lead to initiating operations by 2023. The program is integrating technologies such as AI, IoT, big data, and 5G to ensure cybersecurity defense against drones. The U-Space program is intended to facilitate implementing a common set of drone legislation across the EU and benefit drones for military and civil users.

Trend	What's happening?
Drones and illegal activity	Over the 2018 Christmas period, one of the UK's busiest airports was bought to a standstill for three days as a result of a reported incursion by an unauthorized drone. The airport authorities were obliged to close the runways until the threat posed by the rogue drone (or drones) had been dealt with. In August 2018 drones were reportedly used in an attempt on the life of Venezuelan president Nicolas Maduro, with Venezuelan authorities claiming that two drones carrying nearly two kilograms of explosives were used in the assassination attempt. While the government's narrative subject to considerable dispute, the incident highlights the potential of drone technology in attacks of this kind. These incidents raise two primary concerns. The first relates to the regulation and management of drones, while the second concerns the ability of the authorities to intercept and capture or disable rogue drones. The fact that a single individual could use a relatively inexpensive device to close an airport represents a significant economic threat. The low cost and ease of use of drones makes them attractive for use in criminal activities ranging from illegal surveillance (snooping), to drug smuggling or terrorism. Drones are regularly used to smuggle contraband (including drugs and weapons) into prisons, and their use on a larger scale by drug cartels and dissident organizations will inevitably increase.
Anti-drone technology emerging as a market	In the light of the security concerns relating to drones, and the significant disruption that can be inadvertently or maliciously caused by drones and their operators, a new technology category in the form of anti-drone technology has emerged. Anti-drone technology is still relatively nascent, with current products applying one (or a combination of) the following techniques: radio jamming (to disrupt the control signals send by the controller), take-over (taking control of the drone by interfering with and replacing the control signals being sent by the operator), destructive attacks (using projectiles or high powered lasers to damage and disable the drone), and capture attacks (using grapples or nets to capture the drone).

Source: GlobalData

Industry analysis

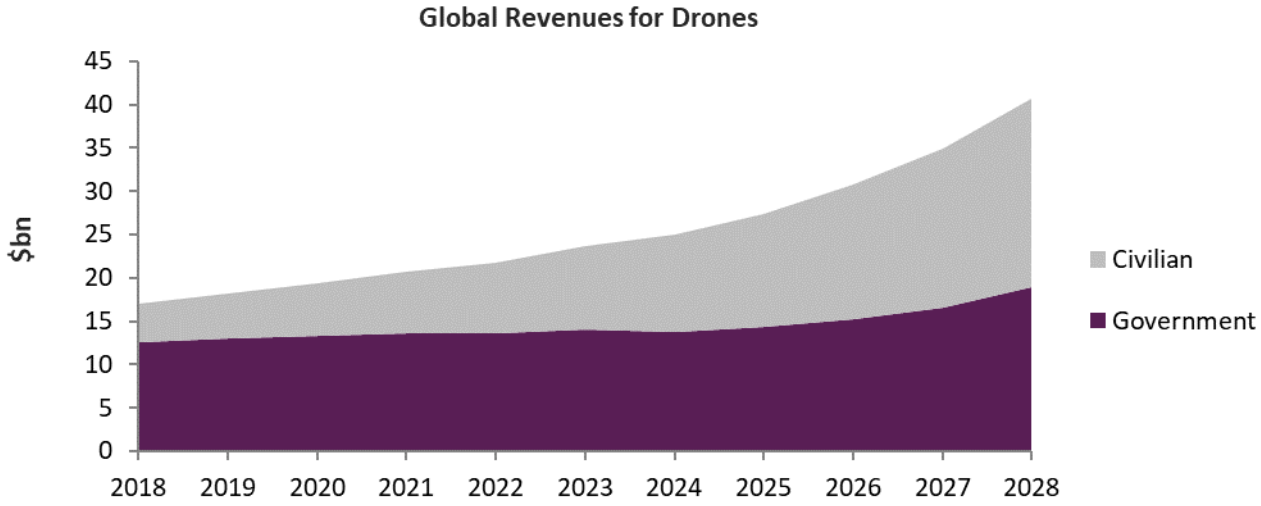
The speed of the transition of drones from war zones to retail stores has been phenomenal, especially given the negative associations and misconceptions surrounding them. The ability to collate sensor-generated data with powerful analytic tools presents a wide range of potential commercial and industrial applications, ranging from optimizing work processes to reducing expenditure on tedious manual tasks. At the consumer level, drones are becoming smarter and industries such as drone racing are becoming increasingly prominent worldwide. Enthusiasm surrounding drones is on the rise across the world.

Market size and growth forecasts

Estimates of the drones market vary significantly, with considerable differences in market definitions. The problem is also exacerbated by the lack of appropriate sales figures. The major drone manufacturers are all privately listed Chinese companies that do not reveal exact sales figures in public forums. However, drawing upon data from various sources, GlobalData estimates the global drones market, as of October 2018, at $17.0 billion. We forecast that it will grow to $40.7 billion by 2028, implying a compound annual growth rate of 9.1% over the next decade.

At $17bn, the global drones market is forecast to grow at 9.1% CAGR between 2018 and 2028…

…with growth likely to be significantly higher if drone regulation is relaxed

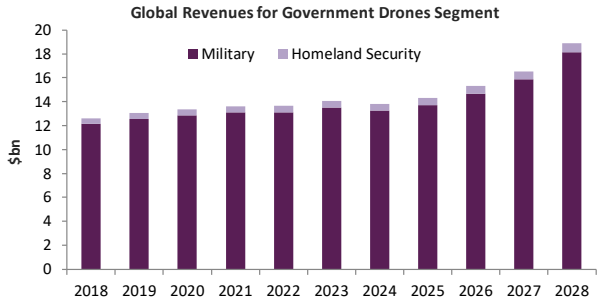


Source: GlobalData

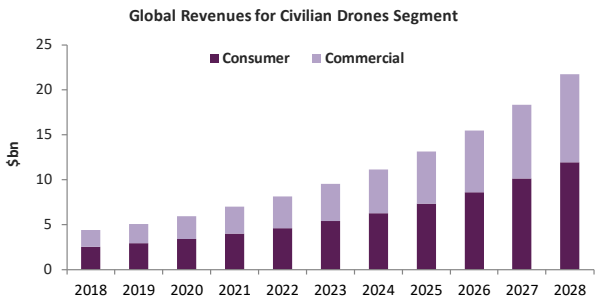
Accounting for a share of around 75%, governments currently comprise the largest end user segment for the global drones market: in 2018, the government drone market was worth $12.6bn and the civilian market $4.4bn.

In 2018, the government drone market was worth $12.6bn and the civilian market $4.4bn

Homeland security is the key driver for the government drone market.



Civilian drones are driven equally by commercial and consumer drone applications.



Source: GlobalData

Military demand will continue to drive market growth

Within the government segment, military expenditure on drones accounts for around 95% of the total, with the remaining share attributable to LEAs. Militaries worldwide are extensively using UAVs in a range of mission types, with several countries – notably those with limited resources – emerging as potential markets for low cost UAVs. Competition among defense contractors is gradually intensifying to tap the demand in these countries. Geopolitics and national policies are often seen as hindrances for military UAV manufacturers to market their products in these countries. They, therefore, rely heavily on domestic government contracts and foreign military sales contracts, which serve as the key growth generators for these firms as well the overall market.

LEAs see a number of potential applications for drone technology including surveillance, search and rescue, firefighting, crowd monitoring, traffic collision reconstructions, crime scene analysis, and suspect apprehension among others. Drone manufacturers are exploring opportunities for growth by collaborating with LEAs. For instance, DJI collaborated with law enforcement technologies provider Axon. Under the Axon Air program, Axon will supply camera-equipped DJI drones to LEAs worldwide. Established military UAV manufacturer General Atomics is also pursuing approval from the US FAA to equip federal LEAs with a modified autonomous version of the Reaper UAV as a replacement for helicopters. Similar to General Atomics, other military suppliers such as Aerovironment, Elbit Systems, Insitu (Boeing), and Schiebel are expected to tap into the LEA market for drones as and when regulations evolve.

Drone gaming segment to exhibit faster growth rate

The consumer sub-segment is still the largest demand generator in the civilian market, representing approximately 58% of overall spending. This share is expected to decline over the next 10 years, due to the growth of drone operations in the commercial arena.

The consumer drones segment is comprised of hobbyists, drone gamers and professionals who use drone technology as part of their professional work (referred to as prosumers). Fueled by the thrill of aerial photography and the ability to view the neighborhood from a bird’s eye, the hobbyist subset is comprised of "early majority" shoppers, who generate the majority demand for drones in the consumer market presently. Albeit the hobbyist segment will witness a decline in its market share over the years, the segment will maintain its dominant position in the consumer market during the next decade. The shrink in market share is attributed both to the increased adoption of drones in commercial applications, and regulations which may make it harder for the casual user to own and operate a drone. Investments in the hobbyist segment will largely emphasize camera packages, editing software and other tools, with features like increased time-of-flight (ToF) capabilities being seen as differentiators. The segment will witness the rise of some smaller players, while some leading companies will make a significant shift towards garnering revenue from commercial businesses.

Drone gaming is currently the most rapidly evolving trend among consumer drone enthusiasts. As this segment is driven predominantly by people aged between 15 and 35 – early adopters – it will undergo a significant transformation in terms of demand over the forecast period. Also, this segment will play an important role in leveraging the latest accessible commercial-off-the-shelf (COTS) technologies. Autonomous drones will come into play within the next five years, and drone gaming will convert into a more competitive and lucrative area of business worldwide.

The prosumers segment currently accounts for the smallest share of the consumer segment, but it will continue to be a constant demand generator in the market. This segment is anticipated to grow till 2020-2021 at a steady pace, following which, when commercial applications take off at larger scales, the segment will experience a downfall in its growth rate, which will reflect in its shrinking market share.

Construction and real estate, along with precision agriculture, to lead the market

The commercial use of drones will increase significantly over the next 10 years. The precision agriculture sector will see steady growth till 2020 but, after that, sectors such as delivery and logistics, media and entertainment, power utilities, and insurance will grow more quickly. Most developed and developing nations will consider application of drones for precision agriculture, with technological improvements in terms of software and sensor capabilities impacting adoption rates. In developing countries, product pricing will certainly have a key impact on the adoption rate and subscription models for DaaS could be successful.

The construction and real estate segment is one of the first industries to recognize the potential of drones to aid virtual design and construction (VDC), which provides architects and engineers with a new method of visualizing and analyzing structural requirements from different perspectives. Several industrial firms in the construction segment, most notably Komatsu and Hensel Phelps, are already deploying drones within VLOS for their daily operations. Although this sector accounts for the largest share of the market as of now, the construction and real estate segment will see a decline in its market share when other sectors begin maturing.

BVLOS is currently a key challenge for optimal implementation of drones in this sector. As it is anticipated that the restrictions in terms of BVLOS will continue to be imposed for security purposes, the flexibility of drone applications in the construction and real estate segment will remain limited.

The mining and oil and gas sectors are ready to begin adopting drone technology. However, regulatory restrictions currently present a significant barrier to adoption. As regulations become more lenient, the application rates are expected to grow steadily. Similarly, the meteorology and environment sector is yet to find significant traction, with only limited adoption seen thus far (e.g. NASA's use of military drones to study hurricanes and other environmental conditions.

The power and utilities segment includes electricity and water management companies operating in production, transmission and distribution of energy. This is a key sector which intends to use drones for inspection purposes. As the regulatory environment evolves, adoption will speed up in North America and Europe, whereas adoption will be slower elsewhere. Software, sensors and battery capabilities will be key investment areas.

Media and entertainment is one of the most demanding drone application sectors, hampered as it is by regulatory restrictions. As regulations relax, the sector will drive significant demand for drones.

The most eagerly-anticipated commercial application of drones is the delivery and logistics sector, spanning medical, food and mail supplies in remote locations, package deliveries in urban areas, and eventually human transportation. While much of the hype is overblown, drone technology will disrupt traditional distribution and logistics models. Once more, this sector will depend on the effective development of control and management technology as well as regulatory approval.

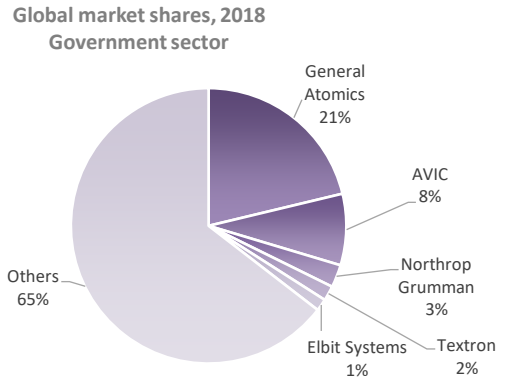
Competitive analysis

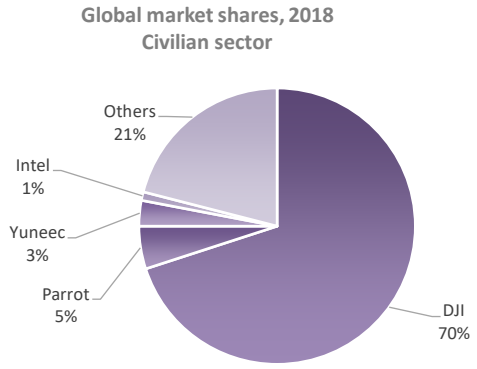
As noted earlier in this report, we divide the drones market into two sectors: government and civilian. Our estimates of the market shares of the leading players are illustrated below.

Chinese firms are in a strong position in both the government and civilian sectors

General Atomics leads the government sector, with China's AVIC its nearest competitor

DJI's dominance is being contested by Parrot, Yuneec and Intel in the civilian sector





Source: Government Budgets, Company Reports, GlobalData

In the government sector the leading UAV manufacturing countries include the US and Israel, with China demonstrating steady growth. Chinese UAV manufacturers are actively seeking to exploit the market gaps left unaddressed by the US and Israeli firms by offering technologically equivalent or even advanced alternatives at significantly lower cost.

A combination of geopolitics and intense competition means that the leaders vary from one region to another. For instance, General Atomics, Northrop Grumman and Textron – the US military UAV giants – generate revenues primarily from the US and its allies across Europe, the Middle East and Asia Pacific; they are largely absent in the expanding Chinese market. Similarly Israeli companies, particularly Elbit Systems, are strong in the domestic and US allied markets, but have failed to penetrate neighboring Arab markets.

AVIC's strength is primarily attributed to its strong grip on the domestic Chinese market. However, the company is also experiencing demand from other militaries who intend to procure advanced UAVs at cost-effective prices. Meanwhile, established government UAV contractors such as Aerovironment and Insitu, maintain strong holds in the North American and European regions and are also pursuing expansion in civilian markets with their distinctive technological offerings. Similar interests have also been demonstrated by larger firms such as General Atomics, Elbit Systems, Lockheed Martin and others. Such strategic moves are boosting the competitiveness of military UAV contractors as well resulting in reducing the gap between the government and civilian drone sectors.

Despite being restricted by regulations in the civilian sector, drone original equipment manufacturers (OEMs) are having to compete fiercely as a result of the rapidly evolving industrial demand for drone operations. DJI currently dominates the market with 70% market share globally, a result of aggressive pricing and continued innovation. Companies such as Intel and Yuneec (also supported by Intel) are trying to differentiate by investing heavily in integration of multiple technologies to improve their drone offerings, while others such as Parrot and Autel Robotics are trying to find a well-defined niche to make their own.

Timeline

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

The story of drones so far…

Timeline

1782	France: The Montgolfier brothers demonstrated unmanned balloons
1806	France: Scattered propaganda pamphlets all over parts of the country by using Kites from the HMS Pallas
1848	Austrians launched surprise attack on Venice using bombs on 200 unmanned balloons
1862	US: First patent filing for a flying machine which can hold bombs was filed in Massachusetts
1898	American Armed forces use a kite with a camera attached to it for reconnaissance during the Spanish-American war
1911	Libya was attacked by Italy using drones
1940s	US developed the GB-1 Glide Bomb, which was intended to bypass German air defenses during World War II
1960	Lightning bug and Ryan Firebee used as remote combat aircraft
1960s	Vietnam witnessed over 3500 Lightning bugs deployed by the US Armed Forces
1974	The Predator UAV was developed by Abe Karem
1985	The development of Pioneer UAV initiated in the US
1986	Israel and American military start using the Pioneer
1990	Miniature micro UAVs entered military services
1991	At least one UAV was airborne at all times
1993	Meteorology and Environment studies using UAVs begin
1999	Kosovo, Afghanistan and other war zones witnessed extensive application of the Predator UAVs
2007	Iraq and Afghanistan witnessed the use of the Reaper UAV by the US
2010	Consumer application of drones initiate in part of Europe and North America
2013	Google conceived the idea of using unmanned balloons to stream internet services in rural areas - Project Loon initia
2014	Consumer drones popularity exploded - for recreational purposes; the US approved military budget of ~$24Bn
2016	Consumer drones popularity reached all time high
2012	The US introduced the Section 333 of the FAA Modernization and Reform Act of 2012
2014	Amazon proposed the idea of using drones to deliver packages at doorsteps
2016	The US introduced the Code of Federal Regulations Title 14, Part 107; Facebook's Aquila set its first test flight
2017	Legalities and ethics in the foreground as drones keep getting popular
2018	SESAR JU's U-Space program allocated €9.5bn to study commercial drone application across the region
2019	BVLOS operations to expand across the US, Europe, China and other countries as regulators relax laws
2020	Regulatory framework evolves towards integration of manned and unmanned aerial vehicles in several countries
2025	Drone applications in the commercial sector become widespread
2028	More countries adopt drones for commercial and military purposes, drones become omnipresent in human activities

Source: GlobalData

Value chain

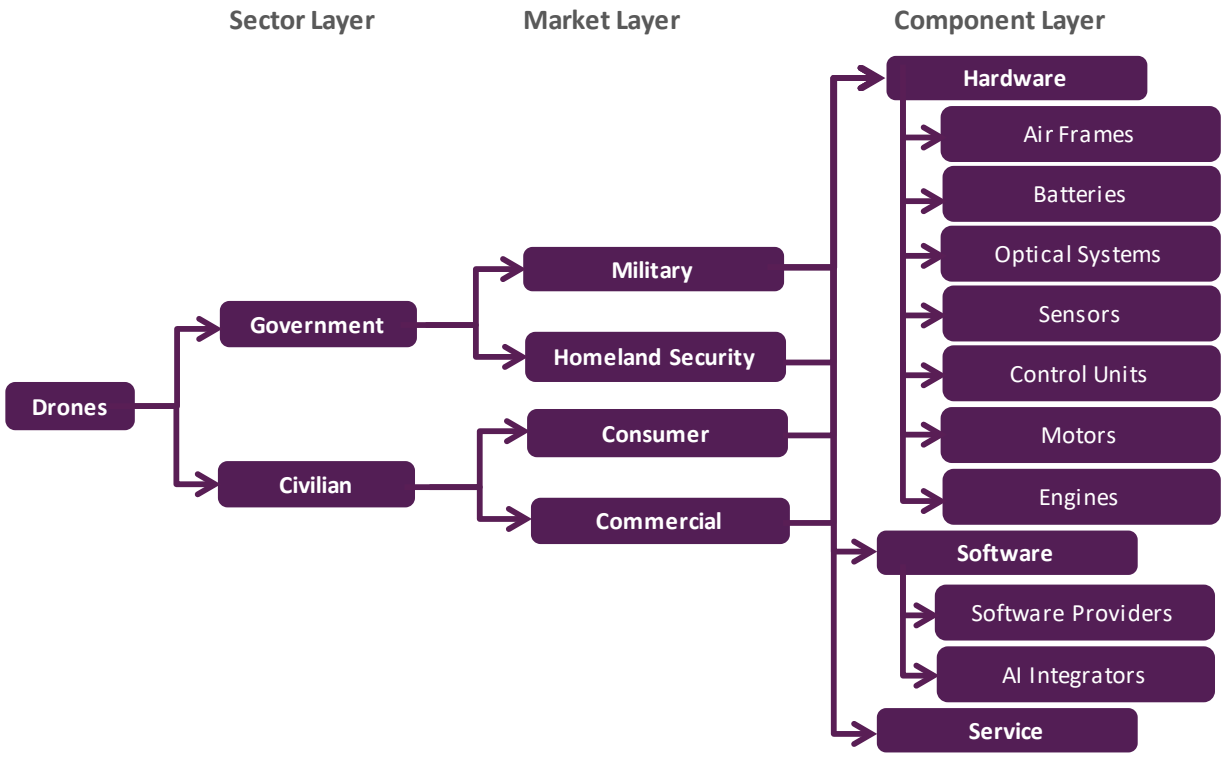
We divide the drones market into three layers: the sector layer, market layer and component layer.

The sector layer is categorized into government and civilian sectors, which further break down into the market layers. The government sector includes the military and homeland security drone markets, whereas the civilian sector is made up of the commercial and consumer drone markets. These markets are then further categorized into three broader component layers:

- **Hardware**. Recognizes the major companies supplying core drone components, including air frames, batteries, optical systems, sensors, control units, motors, and engines.
- **Software**. Identifies the top drone software providers and AI integrators, which are developing the drone brains and expanding their application possibilities.
- **Services**. Includes the leading DaaS providers, who have recently barged into the drone value chain.

The drones value chain

DaaS providers are gaining traction thanks to evolving regulatory frameworks…



Source: GlobalData

Until recently, when drones still catered to the government and consumer markets, the value chain had no services component. However, the services component is currently muscling in thanks to the increasing demand for drones in commercial airspaces. It is certain that, over a period of time, DaaS will gradually surpass the hardware and software components in terms of revenue generation.

On the following pages, we look at the leaders and challengers in each component layer by aligning them to their relevant sector. It is also worth noting that commercial drones and miniature military UAVs operate on motors powered by on-board LiPo batteries, whereas large military UAVs typically use engine propulsion for long endurance capabilities.

The hardware layer is a fundamental component in the drone value chain

The drone market is evolving rapidly, with two separate sectors – recreational drones and military drones - meeting in the middle to spawn the market for commercial drones. Military drone technologies are way ahead of consumer and commercial drone technologies, due to decades of operational history. Lightweight, stealthier drones with improved payload capabilities are currently being demanded by defense forces worldwide which, in turn, is attracting interest from carbon composite manufacturers. The established players like BAE Systems, Northrop Grumman, L3 Technologies and FLIR Systems are innovating at the component layer by repurposing military aircraft equipment and technology. Additionally, the traditional military aircraft engine supplier market is also witnessing intense competition among players in order to cater to the present military UAV market. The need for fuel efficient, long endurance UAV engines from the military has driven demand for more R&D from these players.

Drones value chain: Hardware layer

Hardware Layer	Civlian Sector		Government Sector	
	Leaders	Challengers	Leaders	Challengers
Air Frame	DJI Yuneec Parrot	Autel Robotics Kespry	Northrop Grumman Elbit Systems General Atomics	Insitu (Boeing) AeroVironment Lockheed Martin
Optical Systems	DJI FLIR Systems Sony Aeryon Labs	Yuneec Lumenera (Roper Technologies) GoPro Mobious	BAE Systems Northrop Grumman L3 Technologies FLIR Systems	Lockheed Martin Elbit Systems Israel Aerospace Industries Leonardo
Sensors	InvenSense Bosch Sensortec FLIR Systems Velodyne	ST Microelectronics TE Connectivity Sentera PrecisionHawk	General Atomics UTC Aerospace Insitu (Boeing) Raytheon	FLIR Systems Lockheed Martin Elbit Systems Textron
Control Units	Intel Qualcomm NVIDIA Ambarella	ST Microelectronics Texas Instruments Inc. Xilinx Inc. Microchip Technology Inc.	Intel Qualcomm NXP NVIDIA	Curtiss-Wright BAE Systems General Electric
Engines*			Rotax Honeywell Rolls-Royce	Safran Protonex (Ballard) 3W International GmbH

Source: GlobalData
* Engines are only used in large military UAVs.

In the consumer drones market – the second largest demand generator for drones – the emphasis is on modular platforms, which will enable operators to use drones for a variety of applications and payloads. Drone manufacturers are also prioritizing the demand. For instance, DJI's introduction of the Zenmuse camera series is intended to capture a particular part of the market. Optical systems are increasingly gaining emphasis from both manufacturers and drone operators. The rising demand for high resolution cameras has managed to attract several traditional vision tech companies such as Sony and FLIR Systems. DJI, which aims to be a complete drone component provider (despite having partnerships with FLIR Systems, Hasselblad and other camera suppliers), has undertaken an in-house initiative to improve its proprietary camera offerings.

In terms of control units – microprocessors – Intel has laid the foundation by taking the plunge into the drones industry. The company has already become a common name in the drones industry alongside DJI and Parrot. Along with its increasing investments in drone start-ups, Intel has also successfully demonstrated its in-house drones in several industrial profiles. Recognizing the growing importance of drones in industries, Qualcomm and Nvidia have also made forays in the market and are focusing on developing "drone brains" using their chip technologies.

The software layer is getting increasingly crowded

The tech giants are developing futuristic drone-human co-existential industrial environments.

In addition to improved hardware functionality, drones are increasingly dependent on modern software capabilities. Drone software not only optimizes drones' flight, but also facilitates communication with the operator. Additionally, with the introduction of AI tools, drones are becoming smarter, in terms of computation, and will be able to perform an increasing number of tasks autonomously.

Modern drone software includes three sub-layers: firmware, which functions from the machine code to processor, thereby leading to memory access; middleware, which– is responsible for conducting flight control, navigation and telecommunication; and the operating system (OS), which performs optic flow monitoring and collision avoidance while the Simultaneous Localization and Mapping (SLAM) system provides immediate responses to the information obtained from all the associated payloads and middleware.

Drones value chain: Software layer

Software Layer	Civlian Sector		Government Sector	
	Leaders	Challengers	Leaders	Challengers
Software Providers	DJI 3D Robotics Insitu (Boeing) Precision Hawk	DroneDeploy Aeryon Labs Pix4D Skydio	General Atomics L3 Technologies Curtiss-Wright Insitu (Boeing)	Harris Corporation Plex Systems Aeryon Labs Duke Robotics
AI Integrators	Microsoft Movidius (Intel) IBM	Neurala NVIDIA Avitas Systems (General Electric) PilotAI	Google	Amazon Microsoft IBM Neurala

Source: GlobalData

Companies such as DJI, 3D Robotics, PrecisionHawk and Insitu have gained market leading positions in the consumer and commercial software markets. Other companies – DroneDeploy, Aeryon Labs, Pix4D and Skydio – are challenging the leaders by offering industry-specific solutions to prospective drone operators. At the same time, the government drones software sector is witnessing immense competition among the leaders, such as General Atomics, L3 Technologies, Curtiss-Wright, and Insitu. Other prominent defense contractors such as Harris Corp, Plex Systems, Aeryon Labs, and Duke Robotics are actively pursuing opportunities in the military and homeland security drones software market.

In the AI sphere, Microsoft, Movidius (Intel) and IBM are investing heavily with specific focus on paving the way for future drone-based industrial applications. Neurala, Nvidia and Avitas Systems (among others) are also offering specific AI tools to drone manufacturers and software providers in order to challenge the market penetration of established tech stalwarts. On the government side, Google is the only contractor working on the US military's Project Maven, an AI project that studies imagery and could eventually be used to improve drone strikes in the battlefield. Google's participation in this project has caused internal unrest, with google employees expressing their concerns about the use of drone-based AI technologies in battle zones to the point that the company announced its decision not to extend its involvement beyond the current phase. Similar issues encountered by other AI providers – Amazon, IBM, Microsoft and Neurala – have also compelled them to opt out of military drone AI programs.

DaaS providers are the new entrants in the industry

Drones as a service refers to the concept of renting drone services on an as-needed basis, rather than having to develop drone capabilities in-house.

DaaS is a broad spectrum encompassing several service industries, of which the most anticipated and rapidly proliferating application area is delivery services. Stimulated by Amazon's vision of a drone-powered delivery network, several companies have entered the market in order to prove the concept and roll it out. In 2015, an American company, Flirtey, successfully demonstrated a drone based medical delivery system, which marked the commercial initiation of a new business opportunity. Following its success between 2016 and 2018, the US FAA approved Flirtey as a partner in the experimental study of drone delivery services in Reno, Nevada.

Drones value chain: Service layer

Service Layer	Civlian Sector		Government Sector	
	Leaders	Challengers	Leaders	Challengers
Services	Zipline Flirtey AirMap Flytrex Measure CyberHawk	Amazon Google (Alphabet) FedEx Uber Matternet Facebook	General Atomics Raytheon Northrop Grumman Aerovironment	L3 Technologies Lockheed Martin BAE Systems Airbus SE

Source: GlobalData
Note: Services in the government sector refers to ground control stations; which are not considered as a separate revenue channel

Gradually, companies such as Zipline (operating in Rwanda) and Flytrex (operating in Iceland) have witnessed significant success in the domain. Similarly other DaaS providers such as Measure, CyberHawk, Airmap, etc., are targeting enterprises which intend to cut down on operating expenses associated with management of assets that are difficult and dangerous to reach.

This growth in interest for drones in the commercial sector has prompted the tech giants to undertake in-house initiatives for development of futuristic services. For instance, Facebook and Google are exploring drone-based internet services in remote locations, Uber is working on developing a drone-driven human transportation system as a replacement of helicopters, FedEx and UPS are working on drone-powered courier services, Dominos is planning to launch a pizza delivery service using drones. Adjacent propositions are also emerging, for example cyber security is a major concern for drone operators and manufacturers, so start-up companies such as DeDrone, Sharper Shape, DroneShield, DroneDefense, SkySafe and others are offering software-based drone protection against hackers.

In the government sector, more specifically in the military markets, General Atomics, Raytheon, Northrop Grumman and Aerovironment have already established themselves to be leaders in ground control stations (GCS). Other defense contractors – including L3 Technologies, Lockheed Martin, BAE Systems and Airbus– are striving to grab a share of the pie by providing improved GCS services.

Companies section

In this section, we highlight the listed companies and private companies that are making their mark within the drones theme.

Public companies

The table below lists some of the leading listed players impacted by this theme and summaries their competitive position in the theme.

Company	Country	Competitive position in the drones theme
Aerovironment	US	Aerovironment manufactures drones for tactical purposes as well as video surveillance. The company registers around 85% of its revenue from drone sales to both military and enterprises. It entered the commercial market for drones with the launch of Quantix, which can scout up to 400 acres in just 45 minutes, making it a good choice for agriculture and energy sector applications. The company has also collaborated with Drone Nerds, the largest drone distributor in the US, to grow its market penetration. Additionally, Aerovironment has partnered with digital drone insurance portal DroneInsurance.com, highlighting the growing importance of drone insurance to commercial operators. In January 2018, Aerovironment announced the formation of a joint venture (JV) with HAPSMobile (a subsidiary of Softbank) to develop solar-powered high-altitude long-endurance UAVs for commercial operations with a total investment of $65 million.
Amazon	US	Amazon introduced the concept of drone delivery systems in 2013, before bringing it to reality with the launch of Amazon Prime Air in 2016. The first delivery was demonstrated in the UK, following which the company received approval to operate in Japan, under certain restrictions. In order to gain regulatory approvals in major countries, the company is currently plowing billions of dollars into development of its own transportation and logistics network, which encompasses concerns such as safety and data transmission vulnerabilities. The company is also rolling out improvements on AWS to combine with drone technologies, intended to facilitate overcoming bandwidth vulnerabilities.
BAE Systems	UK	Working across air, maritime, land and cyber domains, BAE one of the largest defense contractors in the world. The company has established itself in the global military UAV sector by developing systems such as Taranis, Mantis and HERTI (high endurance rapid technology insertion). BAE Systems also develop Next Generation Sense and Avoid Transponders, precision kill weapon systems, multifunctional UAV payloads and signals intelligence (SIGINT) payloads for military UAVs. As of 2018, the company is engaged in three key programs: PHASA-35, for development of a solar-electric powered UAV which will be capable of flying for up to a year before requiring maintenance; Magma, which will utilize an unique blown-air system to improve its stealth capabilities; and Adaptable UAV, which can alternate between fixed and rotary wings to suit mission requirements and environmental conditions.
Cisco	US	Cisco sees an opportunity in providing commercial drone deployments with a combination of secure and reliable communications, a platform that provides drone management services and the data analysis tools necessary to analyze and act upon the data gathered by drones. The company recently made an investment in Kespry, an industrial drone start-up targeting the oil and gas sector. Cisco envisions developing a package of connected individual "complete-drone-solutions" into a single platform for future industrial needs.

Company	Country	Competitive position in the drones theme
Elbit Systems	Israel	Elbit Systems offers a range of UAVs to military forces worldwide. The company focusses on a number of domains within the drone sector: aerial vehicle and mission systems, sensor and other payloads, communication systems, simulation systems, integration, and program management capabilities. The company has also announced its entry into the commercial UAVs segment with the launch of a 1.6 ton UAV – StarLiner – which is a modified version of the Hermes 900. Elbit is targeting law enforcement applications with the StarLiner, which can reach an altitude of 30,000 feet to capture photographs of an 80 square kilometer (31 square mile) area. The StarLiner can be equipped with additional features – radar, video cameras, and SIGINT equipment. Elbit is setting out to compete with the likes of General Atomics in the military and homeland security UAVs markets.
Facebook	US	Facebook has demonstrated aggressive investment to challenge Google's Project Wing with its in-house Aquila program. However, in October 2018 the company announced that it was halting the program and would seek partnerships with aviation companies to pursue development of high-altitude internet delivery systems. It has partnered with Airbus to develop improved versions of high-altitude platform stations, or HAPS, for internet streaming.
Google (Alphabet)	US	Google has been investing in autonomous vehicles and drone technology for some time. Two key projects are Project Wing (drone delivery), and Project Loon (the application of balloon technology to provide internet connectivity). The company has also made investments in several start-ups including Airware, Abundant Robotics and Carbon to develop drone technologies. Google's recent announcement of a $550 million investment in Chinese retail giant – JD.com – is also indicative of its support for JD's drone-based delivery systems across China.
IBM	US	IBM markets its IoT and cloud platforms to drone manufacturers and service companies. For instance Aerialtronics, a Dutch drone manufacturer, in 2016 introduced its commercial drones which are powered with cognitive computing capabilities based on the IBM Watson IoT platform and IBM Cloud. The drones are capable of carrying out industrial surveys and inspection across a wide range of industries. Similarly, Matternet, an emerging drone service company across North America and Europe, makes extensive use of the IBM Watson and Cloud products in developing solutions for its clients. IBM is also doing its own drone R&D and has recently patented an AI-powered coffee-delivery drone.
Insitu (Boeing)	US	As one of the largest aircraft manufacturers in the world, Boeing applies its experience and technology research to develop large UAVs for military applications. The company also caters to civilian markets with non-weaponized drones, which are used predominantly for aerial surveying and inspection. In September 2018, the Boeing subsidiary Insitu introduced the Integrator Extended Range UAV which, it claims, will cover a 200-nautical mile radius with 10 hours on station, or 300 miles with six hours on station. The company is also publicizing the benefits of deploying its ScanEagle drone (currently used primarily by military forces) for monitoring forest fires and helping firefighters.

Company	Country	Competitive position in the drones theme
Intel	USA	Intel, the largest microprocessor manufacturer in the world, was quick to recognize the potential of drones as an extension to the rapidly growing IoT segment. Over the years, the company has invested in several drone start-ups – 3D Robotics, Yuneec, Volocopter, PrecisionHawk, Airware, Ascending Technologies, Cyber Hawk, and DelAir – to develop camera, AR and cloud technologies. Intel's acquisition of 18% of Cloudera is an indication of its focus on merging drone technologies with data analytics platforms (Hadoop in this case). Intel is also developing its in-house drone, Falcon, which is being demonstrated across several enterprise and recreational applications worldwide. The company's acquisition of Movidius bolstered its existing research into the application of AI technology at the edge to deliver functions like advanced image recognition, competing with Microsoft, IBM, Nvidia and Neurala among others.
InvenSense (TDK)	Japan	InvenSense, now owned by TDK, provides micro-electro-mechanical systems (MEMS) inertial sensors for drones which are required for flight control engines, navigation, and imaging subsystems. Its six-axis sensors have been extremely successful in the consumer drones segment. Subsequently, in January 2018, the company launched its InvenSense ICM-20789, pioneering the first seven-axis motion and pressure sensor, suitable for wide range of IoT platforms, including drones. Presently, the company also offers nine-axis motion and pressure sensors to drone manufacturers.
Lockheed Martin	US	Lockheed Martin – the largest defense contractor in the world – has steadily invested in development of military UAV technologies and countermeasures. In 2018, Lockheed Martin also unveiled its VCSi software which enables militaries to control multiple drones from one platform, ushering in the concept of deploying drone swarms in a more intuitive and manageable way. Lockheed also collaborates with commercial industry entities to drive innovation in the drones market. For instance, in collaboration with Drone Racing League and supported by Nvidia's Jetson platform, Lockheed Martin launched the AlphaPilot program, which is intended to foster prosumer technologies to develop AI-powered racing drones. The company also offers its Indago quadrotor UAS for firefighting and inspection applications. As well as marketing drone technology, the company's ATHENA laser weapon is one of the most effective counter-drone technologies currently in use.
Microsoft	US	Gaining success in several industries with its AI capabilities, Microsoft is keen to pursue the opportunity for AI within the drone segment. It has partnered with the largest drone manufacturer – DJI – to provide its Azure Platform and Windows 10 to commercial drone operators across agriculture, construction and public safety. The company has also partnered with Qualcomm to create an AI developer kit for computer vision in cameras used on drones and in smart homes. Microsoft envisions large enterprises integrating drones into industrial operations, which will drive increasing demand for real time mapping. As a result, in 2017 the company completed a $26 million Series B investment in AirMap in association with Qualcomm, Airbus, Sony and Yuneec, among others. AirMap will utilize Microsoft AI tools and cloud infrastructures to develop intelligent drone traffic management systems for future industries. Microsoft has also developed AirSim, a tool that can be used to simulate the flight of drones around the world. The simulator is built on the Unreal Engine and Microsoft plans to add support for other industrial robots and autonomous vehicles. Presently, AirSim can simulate the flight of MAVLink and DJI drones and supports Pixhawk controllers and integrates with the Unity 3D rendering platform.

Company	Country	Competitive position in the drones theme
Northrop Grumman	US	As one of the leading aerospace companies and prime contractors to the US Armed Forces, Northrop Grumman has made a big investment in the development of military UAVs. The company's Autonomous Systems wing conducts R&D in military UAV sensors and processing equipment – which define the potential of most advanced UAVs. In common with most military UAV vendors Northrop Grumman is focused on improving SIGINT, sensor payloads, and time-of-flight.
Nvidia	US	Nvidia is progressively strengthening its position in the drones AI and control units segments. The company's latest offering – Jetson TX2, a credit card-sized system on chip computing platform - is designed to enable drones to take advantage of edge computing by providing enough local pressing power to run sophisticated AI applications. JD.com's drones and the General Electric company, Avitas, are using this AI platform to enhance the computing power of their drones. Moreover, in partnership with DJI, Nvidia is working on introducing AI capabilities to Komatsu's construction business. Nvidia's Tegra processors are used by DJI in the Manifold drone, a premium market offering.
Parrot	France	Parrot is the nearest competitor to the dominant DJI in the global drones market. The company is focused on offering drone-based business solutions across agriculture, construction and security. Its portfolio comprises hardware, software, and services for drone applications. Parrot plans to expand its drone operations in 2019 – to cement its apex position in the European drones market.
Qualcomm	US	Qualcomm, with is continued emphasis on drone technologies and experience in chip manufacturing, is currently competing with Intel, Ambarella and Nvidia in the drone microprocessor segment. The company claims that its modified drone chips can reduce the retail cost of 4K cameras and enhance drone battery run time substantially. Also, it markets a drone development platform – Snapdragon Flight – which targets drone developers.
SAP	Germany	SAP is primarily focused on enhancing its core enterprise resource planning (ERP) solutions, but sees a significant opportunity to sell commercial drone and IoT solutions to its large base of clients. SAP is keen to partner with start-ups through its innovation program which offers start-ups access to SAP technology, and its sales channel.
Schneider	France	Schneider is investing in the drone sector by leveraging edge computing technologies. The company recognizes drones as a major disruptor to industries and is poised to combine technological advancements to facilitate gathering, processing, analyzing data at the edge points. Although Schneider's involvement in the drone sector is presently limited, it has demonstrated significant drone capabilities in the oil and gas industry.
Siemens	Germany	Siemens is developing inspection systems that use drones and 3D image analysis to monitor pipelines, large industrial facilities, and pylons in high-voltage electrical distribution systems. The company is working with start-ups (e.g. Skyspecs) to bring a complete proposition to market. Siemens has extensive experience in delivering industrial infrastructure from factories to power distribution systems, so is well placed to sell industrial drone technology into its customer base.

Company	Country	Competitive position in the drones theme
Skyward (Verizon)	US	Skyward, a Verizon subsidiary, offers operational management solutions to enterprises for commercial drone applications. Verizon has launched an Airborne LTE Operations (ALO) initiative, which is a new service to simply aerial data generation and scale wireless connectivity of drones for enterprises. Skyward's technologies make up a platform that supports mission planning, complex workflow, restricted airspace information and pilot credentialing, FAA compliance support, drone registration, and provisioning rate plans for drones on Verizon's network. The technologies facilitate enterprises in creating and managing a broad spectrum of services backed by Verizon's mobile network, secure cloud interconnect and data analytics capabilities. Presently, Skyward is operating as an approved partner in the US FAA's LAANC services in Cincinnati, Reno, Lincoln and San Jose airports among others. In addition, the company is also involved with NASA in the development of UTM.
STMicro	US	STMicroelectronics designs and manufactures a wide range of hardware components, including microprocessors, sensors, motor control, precision amplifiers, battery management systems, and connectivity solutions. Serving the IoT and telecommunications market as well as targeting the drone segment, the company focuses on small foot-print, low-power devices. The company's flagship process of family is based around the ARM specification, and is compatible with most of the open source firmware for both Electronic Speed Controllers (ESC) and Flight Control Units (FCU) in the market. Additionally, the sensors provide flight stabilization, altitude control, obstacle avoidance and autonomous navigation for drones.
Textron	US	Textron is a leading military UAV manufacturer and has registered more than one million hours of flight in a wide range of hostile environments worldwide. Along with its military UAVs, the company also offers a civil variant of the Aerosonde drone, which is made available as a product or as a service to commercial enterprises and is suitable for aerial surveying, geospatial analysis, disaster response and critical infrastructure security. Launch of this civil variant reflected the company's determination to carry its military UAV reputation in the upcoming commercial drones market.

Source: Company data, GlobalData

Private companies

The table below lists some of the interesting private companies associated with this theme and summarise their competitive position in the theme.

Company	Country	Competitive position in the drones theme
Bosch	Germany	Bosch is working to develop industrial grade sensors which can simplify and expand drone applications in future. The company's current offering includes an array of drone sensors, which can significantly improve the performance of industrial drones. Some of its products have also been recognized as the most accurate ones in their respective classes. Additionally, to simplify a drone sensor anatomy, Bosch is emphasizing the use of single sensors which can perform multiple tasks and be controlled with an integrated microprocessor.
DJI	China	Dà-Jiāng Innovations dominates the global drone market with around 70% of the market. The company‘s success is down to its “design and build” business model. DJI maintains a facility in Shenzhen, China, where it employs over 1,500 people in research and development. This factor has enabled the company to vertically integrate development of sensors, software, camera and various other drone components. With a wide range of drones and components, the company experiences nominal competition from its peers, who struggle to match its ability to invest in R&D. DJI has an extensive network or partners. As of 2018 it has partnered with drone mission planning companies (AirMap, KittyHawk DroneDeploy, etc.), data acquisition companies (Flyability, PrecisionHawk, FLIR Systems, Leica, Aibotix, Slantrange, etc.), data processing companies (DroneDeploy, Seagate, Propeller, PrecisionHawk, etc.), data analysis providers (SkyCatch, DroneDeploy, Datumate, 3D Robotics, Propeller , PrecisionHawk, etc.), data presentation companies (SkyCatch, DroneDeploy, Datumate, Propeller, Facebook, Periscope, etc.) In 2018 DJI took the important step of introducing the Matrice series of drones, which are designed to enable enthusiasts and developers to easily add customized payloads such as sensors and communication systems. Developers can also reprogram the in-flight-control software to suit desired functions and synchronize the payloads. This benefits the company in identifying a steady stream of system developments for DJI drones driven by its prosumer community. DJI’s investment in Dronebase, a start-up which provides enterprises with drones and pilots for aerial photography, is a step closer to fulfillment of its vision that many enterprises would want to exploit drone technologies without owning one by them.
Ehang	China	Developed by the Beijing Yi-Hang Creation Science & Technology Co., Ltd., Ehang UAVs came into the spotlight in 2016 when it demonstrated the 184-passenger drone at the Consumer Electronics Show (CES). The company has announced plans to launch autonomous passenger taxi drone services in Dubai, but has yet to officially announce a launch date. It will compete with Uber Elevate, Lilium, Airbus Vahana, Volocopter and others in the drone taxi services market.

Company	Country	Competitive position in the drones theme
Flirtey	US	Founded in 2013, Flirtey was the first company to get US FAA approval to trial drone delivery. In 2016, the company demonstrated the first autonomous commercial drone delivery in urban areas. Currently the company is involved with NASA in the development of drone air traffic control software, under the UTM program. The company has also piloted a delivery service for medical supplies using drones in partnership with the Regional Emergency Medical Services Authority in the US. In 2018, Flirtey was selected as a partner in the FAA's Drone Integration Pilot Program, where it is working with FedEx and Domino's to deliver packages and pizza to customer by drones using AirMap software. The company's success in proving the concept of drone delivery makes it a strong challenger to Amazon's plans for its drone delivery service, Prime Air.
General Atomics	US	General Atomics is one of the largest UAV manufacturers, selling the Reaper and Predator UAV to the US and allies worldwide. To meet growing military demands for accurate ISR and strike capabilities, the company's focus is on providing long-endurance, mission capable UAVs quipped with integrated sensors and data link systems. The company's UAVs are supported by the Claw Mission Management Software, which serves as a complete multi-sensor platform and brings precision to the battlefield through task automation and intuitive map-based displays. Recognizing the growing demand for commercial drone applications, the company is pursuing approval from the US FAA to equip federal LEAs with a modified non-weaponized version of the Reaper UAV, which will eventually reduce dependence on helicopters.
Israel Aerospace Industries (IAI)	Israel	IAI manufactures the Heron family of military UAVs, which account for a significant proportion of its revenues. Other military UAVs offered by the company include Pioneer, RQ-5 Hunter, Harpy, Bird-Eye, Panther, Ranger, Scout, and Ghost. The company is an Israeli state-owned organization and limits its developments to military markets. With over 40 years of UAV experience and 1,600,000 operational flight hours on ISR missions, IAI is one of the major military drone exporters in terms of volume globally. With its established place in the market, combined with its focus on R&D in aerial automation, sensor technologies, and communication systems IAI is well positioned to drive substantial innovation in UAVs over the coming years.
Measure	US	Measure offers drone-based aerial inspection and surveying services and claims to be the largest drone intelligence company in the US. The company is actively promoting the modernization of drone regulations by introducing safe drone operation techniques, which are complaint with the US FAA regulations. Backed by IT services company Cognizant, Measure uses drone technology from a number of suppliers (including DJI, Aerialtronics, Aibotix, and Sensefly) and software providers (Skyward and DroneDeploy).
Yuneec	China	A Chinese giant, backed by Intel's technology and funding, which is striving to challenge DJI's market dominance. While the company has struggled against DJI and Parrot it has retained its position as the third largest non-military drone vendor.
Zipline	US	Zipline, a California based drone start-up, uses fixed winged drones to deliver medical and blood supplies to remote places in Rwanda. The company claims to deliver its packages with 100% accuracy and is currently focusing on enhancing the speed of delivery. As of April 2018, the company recorded a total of 300,000 kilometers drone coverage in over 4,000 flights since its service started in October 2016. Zipline has expanded its operations to Tanzania, and we expect it to launch in other sub-Saharan countries in the coming years. Zipline's practical experience of operating under tough environmental conditions means that it is well positioned to complete with likes of Amazon and Google's delivery services over the next few years.

Source: Company data, GlobalData

Technology briefing

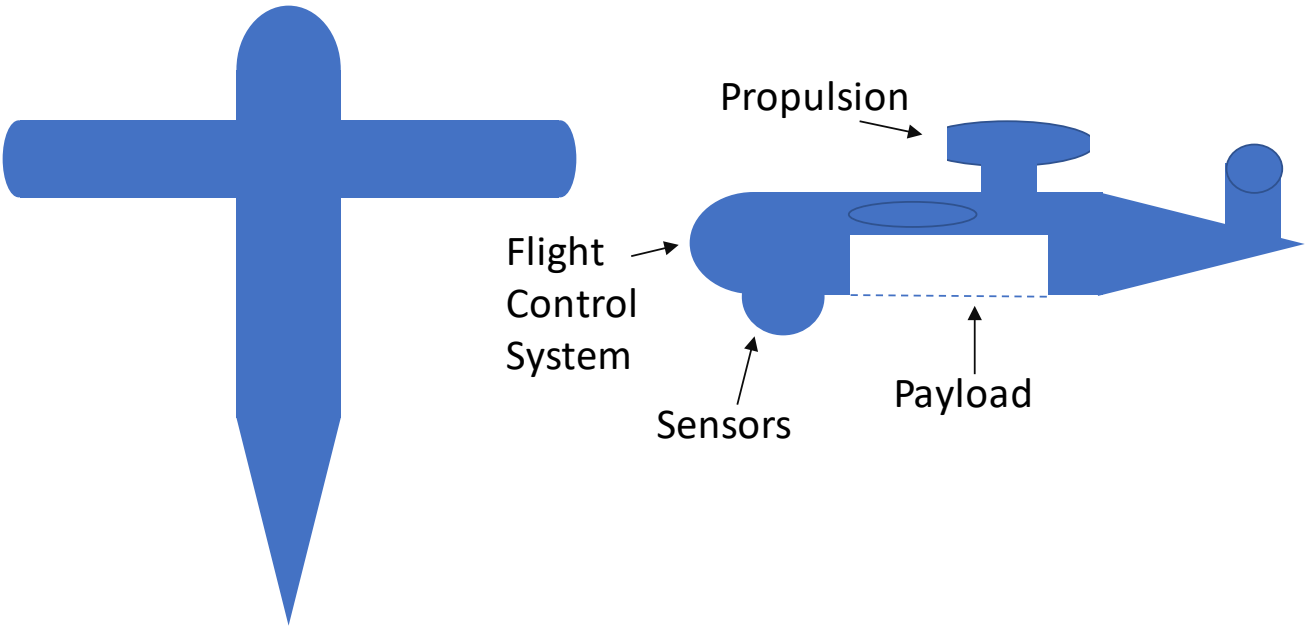
The focus of this report is aerial drones or UAVs.

Anatomy of a drone

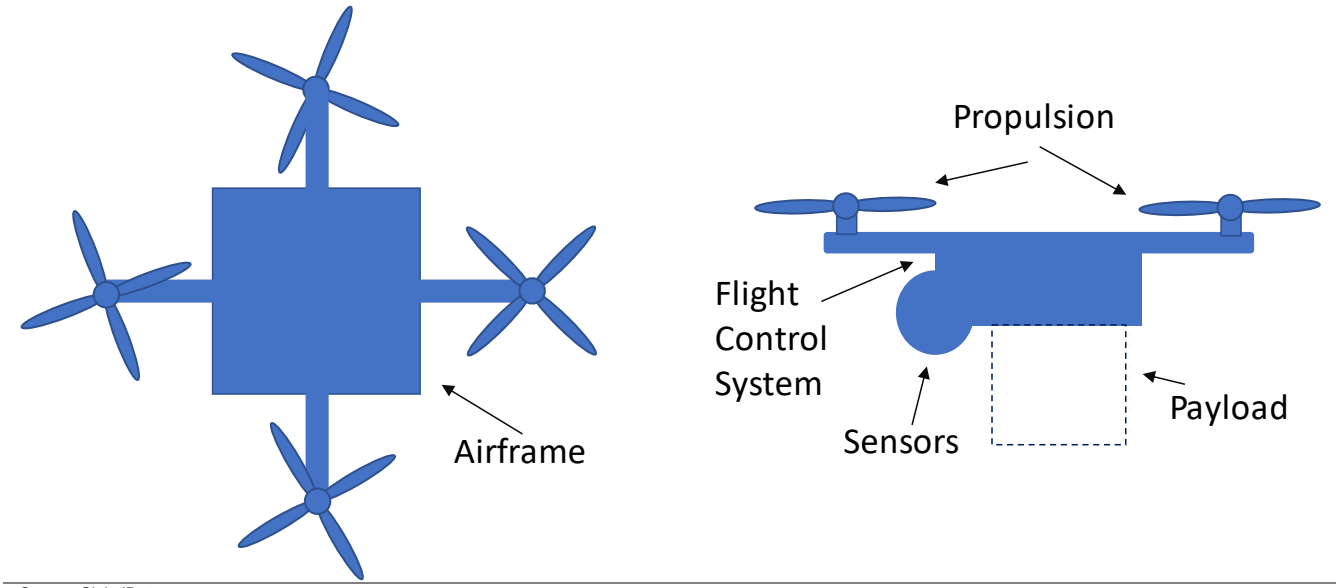
Broadly speaking, UAVs fall into two categories: conventional drones, which use wings to stay aloft, and 'copter drones, which typically use four, six, or eight vertically mounted rotors to fly (for the purpose of this section we will refer to these drones as quadcopters regardless of the number of rotors they carry).

While the flight characteristics of the two types of drone differ a lot, they both share a common set of core components.

Anatomy of a conventional drone



Anatomy of a quadcopter drone



Source: GlobalData

Both types of drone are comprised of the following:

- **The airframe.** The structure that carries all of the elements of the drone, along with any additional payload.
- **Propulsion system.** A means of propelling the drone through the air combined with the necessary fuel storage capacity (in the form of batteries or conventional aircraft fuel).
- **Flight control system**. The combination of sensors and microprocessors required to control the drone in flight. This includes gyroscopes, GPS modules, radio modules, and flight management software.
- **Sensors**. Sensors that support the gathering of information for transmission back to the controller. These sensors may take the form of one or more cameras in simple cases or may include sophisticated radar/lidar sensors that provide 3D information to support mapping and surveying.
- **Payload capacity.** While smaller drones may not have the ability to carry any additional payload beyond the sensors that are connected to them, many drones are designed to be able to carry additional payloads, either as a way to deliver that payload to an intended recipient, or as a means to add additional functionality to the drone. For example, a drone may carry more sophisticated surveying equipment for particular applications/missions.

The airframe

On conventional drones the airframe often resembles a conventional aeroplane, albeit without the need to set aside space for the human pilot/s. As drones increase in size, they make more and more use of conventional aircraft technology, which is one of the reasons that the leading manufacturers of larger drones often come from a defense or aviation background.

With quadcopters the airframe tends to be much simpler. While a conventional drone relies on aerodynamics and control surfaces to fly and change direction, quadcopters are controlled by varying the speed on individual rotors in order to adjust the attitude of the drone.

In both cases, designers focus on weight and strength. The airframes of both classes of drone are often made with modern composite materials (like carbon fiber) in order to keep weight to a minimum without sacrificing durability or toughness.

The propulsion system

The key goal of a drone propulsion system is to optimize speed, carrying capacity, and endurance. This is a key area of R&D for drone manufacturers and one where we expect to see a great deal of innovation and competition.

Larger drones often use propulsion systems that are already found in general aviation or scaled down versions of the same technologies. Lightweight petrol engines and small jet engines are often used on these drones as these conventional technologies currently offer the greatest speed, capacity, and endurance. Some large-scale drones can stay aloft for over 12 hours and fly over 1,000 miles on a mission, while carrying payloads of over 1.5 metric tons.

Most small conventional drones, and nearly all quadcopters, use electric motors for propulsion and lithium batteries to store their electrical charge. This limits their endurance significantly with the result that most quadcopters have a maximum flight time of less than an hour.

Several companies are researching solar-powered drones, typically for surveillance or communications applications. The goal is to build a solar powered drone that can fly continuously over a given area. This is an area where a great deal of research is taking place. In August 2018 Airbus flew one of its Zephyr HAPS (High Altitude Pseudo Satellite) solar powered drones non-stop for 25 days and 23 hours.

The flight control system

The flight control system is responsible for controlling the components associated with propulsion and direction. The simplest systems simply take commands from a remote controller and apply them to the motors and control surfaces but most flight control systems do significantly more, by providing features that support stabilization (allowing the controller to simply “drive the drone”, leaving the complex challenge of keeping it stable to the flight control system), navigation (where the controller simply tells the drone to navigate to a given point, or follow a specified route), collision avoidance (where the controller uses sensors to scan the space around it in order to avoid obstacles), or autonomous operation (where the controller is given a “mission” which it undertakes without any additional intervention).

Flight control systems are built around microprocessors which run flight control software and integrate with external sensors like GPD modules (for navigation), accelerometers (silicon gyroscopes used for stabilization), as well as proximity sensors and cameras which are used in collision avoidance.

Many drones have flight control systems which also include features designed to prevent the drone entering zones where the airspace is regulated, like airports. Features that help in regulating and managing the movement of drones will become more advanced and more prevalent over the coming years.

Sensors

In addition to the sensors that are required by the flight control system, drones can carry other sensors designed to support a specific application. The most common sensors are cameras, ranging from video cameras designed (and priced) for use by hobbyists to ultra-high definition cameras designed for surveying and image recognition. Other sensors may include radar or lidar to enable 3D mapping or environmental sensors for the detection and measurement of pollution.

Payload

The ability of drones to carry additional payloads varies, necessarily, according to the type and size of the drone. Small battery-powered quadcopters have a relatively modest payload capacity, while larger military drones can carry payloads weighing over a ton.

The payloads carried by drones can be passive or active. Passive payloads are simply carried in order to transport them from one place to another, as in the case of the application of drones for parcel delivery, while active payloads may contain their own control and communication systems. In the case of military drones these may take the form of guided missiles or smart bombs.

Key technologies within a drone

Below, we look at the key technology components within a drone and identify some of the leading players within each technology.

The microprocessor segment is dominated by Intel and Qualcomm

Supported by software and sensor packages Intel's in-house drone, Falcon 8+, which is designed to operate in oil and gas refineries, agricultural fields and construction sites, uses its on-board chips to store the data it captures, process it, and present it in structured formats. Currently, several initiatives are being undertaken by chip makers to develop superior performing chips which will also aid in driving down the retail price of drones. Qualcomm, for example, claims that its modified Snapdragon Flight chips can significantly lower the average cost of 4K camera drones by one-third and extend battery life by up to three times. The Snapdragon Flight Drone platform is a suite of hardware and software tools which combines communication, photography and navigation technologies on a single integrated circuit (IC). This SWaP measure enables the company to claim longer battery life on drones. Other chip makers striving to challenge the dominance of Intel and Qualcomm in the commercial drone microprocessor segment include Nvidia, Ambarella and ST Microelectronics. In the military segment Nvidia, Curtiss-Wright, BAE Systems and General Electric are looking to gain market share.

In addition to the chip makers, researchers are also striving to engineer microchips that can operate with low power and yet deliver improved outputs. For instance, researchers at the Massachusetts Institute of Technology (MIT) have developed a Lego minifigure-sized customizable chip named Navion, which consumes 24 milliwatts of power and is capable of processing real-time camera images at 171 frames per second. The chip also stores inertial measurements which, along with the camera images, can be used to track the drone's flight. Such engineering programs are clear indicators that the industry will persistently demand and witness miniaturization of payloads and processing chips, eventually leading to the development of powerful, robust, miniature drones. Investment on enhancing the capabilities of processor chips will be a constant area of focus, in order to develop smarter commercial drones for future applications.

AI is the next frontier for drones

As drones generate huge volumes of data, AI technologies are facilitating simultaneous processing to aid deployment of prompt solutions. For instance Intel, which is making aggressive efforts to combine cognitive technologies with drones for modern industries, successfully demonstrated its AI capabilities, deploying its Falcon 8+ drone to collect over 10,000 high resolution images and create a 3D map of the Great Wall of China. The drone uses AI technology to instantly analyse images, recognize damaged portions in the structure, and create a digital restoration plan along with calculated estimates of material requirements and project costs. Additionally, surging demand for drone powered enterprise solutions is fueling business synergies among OEMs and for AI integrators. Drone maker DJI, for example, collaborated with Microsoft in 2018, using Microsoft's Azure IoT Edge and AI capabilities to upgrade their drones for use in construction, law enforcement, agriculture and other applications.

Competing with Amazon, UPS, Dominos and other prospective drone delivery companies, IBM has also looked to use its AI competencies as a differentiator. The company recently patented an AI powered coffee delivery drone which can not only fly autonomously in crowded places but also understand when to deliver a coffee to a person. The drones are equipped with improved sensors and cameras with facial recognition that can "recognize certain physical characteristics of a human being associated with sleepiness or grogginess." After gathering data such as biometrics and pupil dilation from wearable tech gadgets such as Fitbit and Jawbone, the drone can deliver hot coffee. Also, the company believes that, with an increased number of advanced sensors and better camera images, the drones will be able to better leverage AI techniques to build internal maps constantly, ensuring safe operation in complex and crowded offices.

Commercial drone operators will use cloud technologies for swift industrial data management, protection and innovation

In today's world, drone-generated data is continuously streamed onto cloud data stores, where it is computed to draw business information. Tech giants such as Microsoft, Amazon and IBM are actively pursuing collaborations with drone manufacturers to provide improved cloud connectivity to their clients. However, the drone cloud technologies segment is increasingly getting crowded as several drone manufacturers (including Kespry, PrecisionHawk and others) are vertically integrating development of their own cloud infrastructures. This, approach enables the manufacturers to offer complete in-house drone application solutions to their industrial clientele.

While connecting cloud to drones is a challenging job for tech professionals, some companies are working to break the codes. For example, in 2017, a California based start-up, FlytBase, introduced the Internet of Drones platform where the FlytBase Cloud used protocols to efficiently connect drones to cloud based business applications in real time. In contrast to other cloud platforms on the market, the FlytBase Cloud platform also enables the users to build customized applications for operating a fleet of autonomous drones. The company collaborated with Salesforce, YouTube, Box, Cisco, Dropbox, Twilio, Spark, Zendesk, Nest, and Slack to provide ready integration of drones with numerous business apps, which facilitate building easy automated workflows and leverages drones solutions without depending on complex codes.

With the commercial drones market ready to take off on a significant scale, industries will demand connected drones which can not only provide information to a specific cloud infrastructure, but also communicate with all devices simultaneously in the network. Cisco is exploring options to provide drone powered decision-making information to its clients and is utilizing technologies such as cloud, fog computing, 3D modelling and others. The company is emphasizing the concept of connected drones, which can be controlled from a single cloud. Cisco envisions that such as connected system will then operate as a unique IoT system, collecting and gathering data at a faster pace over vast areas and simultaneously processing the same to draw analytical results. The current programs underway in Cisco labs involve integration of internet service with edge and fog computation solutions and cloud technologies.

3D technologies are gaining traction or industrial planning, operating and repair activities

Technological advancements achieved in areas of sensors, camera, software and computer aided design (CAD) systems have elevated the demand for 3D technologies across industries. As industries moved from subtractive manufacturing to additive manufacturing, the demand for 3D models have become a common approach to assess anomalies as well as drive efficiency. Drones generate environmental data captured by sensors and high-resolution cameras, which are solidified under computer controls to create 3D objects. Industries such as oil and gas, construction and real estate, forestry, agriculture, railways, and homeland security, where regular operations necessitate frequent inspection and survey, are opting for drones which are loaded with 3D models of the examining objects. This enables the operators to set the drones in specific flight trajectories, which scan the objects using lasers from multiple angles and detect anomalies.

Moreover, with the proliferation of drone technologies, 3D printing and 3D modelling are also being applied in the maintenance, repair and overhaul (MRO) sector. For instance, researchers at the University of Leeds and University College London have demonstrated a six-rotor hybrid aerial-ground drone which can scan stretches of a road, detect potholes and land to fill asphalt with one-millimeter accuracy. The entire process demonstrated a fusion of drone technologies with aerial image recognition and 3D printing. Although this technology prototype is some way from commercial adoption, it has the potential to be part of the self-repairing city of the future. Similar repair work is also being envisioned for railway tracks, buildings and bridges.

AR is becoming a reality in drones, supported by drone OEMs and tech giants

Intel's acquisition of 3D company Replay Technologies in 2016 was a step towards the development of AR drones. In the same year, the acquired company launched an AR venture called XTend Reality Expansion, which is presently working on merging elements of computer graphics, computer vision and cinematography to gamify real-life actions in drones. Additionally, Intel has launched the Intel Studio, which is enthusiastically progressing towards production of virtual reality (VR) and AR content for drones. In line with the increasing trend for AR, drones are being integrated in the stream for improved customer experience. Investments for development of AR drones has grown from 2015-2016 and several drone manufacturers are currently exploring AR capabilities on their products. DroneBase, a start-up company from the US, which connects enterprises with drone pilots for capturing aerial photos and videos for specific industrial work, raised $12 million in a series B funding in the first quarter of 2018.

Supported by Nvidia and MIT Lincoln Laboratory, researchers at MIT have developed a drone AR system – Flight Goggles, that can substantially minimize drone crashes during training sessions. The system serves as a virtual test bed for industrial drones which can later be operated in a wide range of environmental conditions. Exploiting a motion capture system along with image rendering program and enhanced electronics, Flight Goggles can quickly process images and transmit the same to the drone. Virtual images are at a rate of 90 frames per second (fps) can be fed to the drones using a custom-built circuit board which integrates a powerful embedded microprocessor along with an inertial measurement unit (IMU) and camera.

Anti-collision technologies are an essential element for future commercial drone applications

Anti-collision technologies ensure safer skies when drones are used in public places and also benefit autonomous navigation in restricted areas. Different types of sensors such as stereo vision, sonar, lidar, infrared, monocular vision and time-of-flight (ToF) are used on drones to avoid obstacles and navigate safely. These sensors can be used individually or in combination with one another depending on the application format. Leading drone manufacturers are also using these sensors for improved crash control measures. For example, DJI drones are equipped with stereo vision sensors at the front and sonar (ultrasonic) at the bottom. Similarly, Walkera Vitus operates ToF sensors at the front to detect and avoid obstacles en route. Kespy launched drones that utilize lidar sensors to ensure anti-collision, while Parrot AR 2.0 drones are loaded with dual monocular cameras for the same purpose.

Most drones in the market are equipped with sonar sensors at the bottom to evaluate the altitude. The DJI Mavic 2, introduced in August 2018, features six-directional anti-collision sensors on it. The drone uses Omnidirectional Obstacle Sensing to enable all-round obstacle detection. Although drone manufacturers have demonstrated substantial improvements in technologies that can ensure safer flights, regulatory authorities in most countries are still wary of permitting full scale commercial application, collision being one the major concerns. Researchers are striving to develop effective "sense and avoid" technologies that can provide improved anti-collision assurance for commercial and public applications of drones in future.

Moreover, the impact of the ongoing initiatives for safer and connected skies in the US and Europe, namely, NextGen and SESAR respectively, are compelling drone manufacturers and component suppliers to focus on ADS-B systems. Using ADS-B information from nearby aerial platforms, both manned and unmanned aircraft can avoid collision without the need for ground-level human assistance. DJI has been steadfast in adapting to the evolving regulatory norms by launching the DJI AirSense – a built-in ADS-B receiver on Matrice 200. The DJI AirSense provides information to the drone operator regarding aerial position, altitude, speed and velocity of nearby manned aircraft equipped with ADS-B transmitters. ADS-B mandates are gradually being laid out worldwide by aviation authorities to ensure autonomous communication among aerial platforms, which will facilitate management of air traffic in the coming years.

Following the increasing importance and legislations for ADS-B integration, new products with enhanced capabilities are being introduced in the market. For example, uAvionix, a US-based firm, has introduced a 1090MHz ADS-B single chip solution to ensure ADS-B transceivers and detect and avoid (DAA) applications on military UAVs and drones. The company claims that these are the smallest, lightest and most affordable ADS-B transceivers and transponders in the world presently. It also states that the low power consuming chip is capable of transmitting ADS-B information at a range of 0.01-0.25W, which translates to roughly one to 10 miles. Similarly, Aerobotics, a Polish company, has also introduced a high-speed, miniaturized drone (dimensions 23.0x18.0x2.5mm) ADS-B module which can effectively detect and avoid obstacles when equipped on small UAVs. Using high-speed on-chip processing technology, the company claims that the module is capable of reception range of over 200 miles and can process thousands of ADS-B signals per second from nearby aircraft. Drone manufacturers are anticipated to take advantage of such technological

upgrades, in order to push regulatory authorities for commercial permits and ensure effective traffic management systems in future.

UTM to drive regulatory evolution for enabling commercial drone applications

Widespread commercial drone applications are anticipated to begin over the next two to three years. This will elevate the need for effective management of the numerous aerial drones to ensure safety to human lives and critical infrastructure. Recognizing the wide range of prospective applications of drones and growing expectation of industrial entities, researchers are striving to develop autonomous unmanned traffic management systems (UTMs), which will ensure safety, security and control of drones in low-altitude airspaces. Development of an effective UTM within a period of 1-2 years is a herculean challenge to the researchers. Thus, association of all identified drone UTM stakeholders (such as operators, communication providers, data service companies and regulatory authorities) are being formed to drive collaborative programs for faster development of efficient systems. In the US, several tech companies, led by NASA, are working on a $2.8 billion program towards integration of drones in commercial space in near-term by development of an operative UTM system. The US FAA has also stepped up its initiative - LAANC – which is being developed in coordination with NASA's UTM. Similarly, the EASA and the CAAC are focusing on harmonizing drone traffic in their respective airspaces. Based on the development of these UTM systems, regulatory legislations in several countries and regions are anticipated to undergo significant modification, which will permit commercial application of drones. However, the effectiveness of preliminary UTMs will also continue to evolve in line with improved drone capabilities.

BVLOS is demanded by commercial drone operators

The Balloon Bombs from World War II are the most primitive human-developed BVLOS unmanned aerial platforms. However, they lacked communication and data relaying systems onboard. Presently, with the increasing deployment of drones for military ISR missions, BVLOS-capable drones are more of a necessity than an experimental project. From Black Hornet Nano to Reaper, military drones are potent BVLOS UAVs and are extensively used by armed forces worldwide. However, the commercial deployment of drones to operate BVLOS is much more critical owing to safety concerns. Most regulatory bodies worldwide are thus taking cautious steps in enabling commercial BVLOS operations. As a result, nominal, yet significant initiatives have been initiated, to evaluate the feasibilities of commercial BVLOS operation of drones.

In the anticipated wake of rapid regulatory reforms permitting commercial BVLOS operations, mostly in North America and Europe, several industries such as oil and gas, insurance, construction and real estate, power utilities and delivery services will witness a boom in their business opportunities within the next three to four years. Moreover, enthused by the benefits of drone based BVLOS technologies, LEAs worldwide will also generate significant demand to carry out more effective search and rescue, firefighting, border patrol, conservation management and other operations. Also, BVLOS drone operations will lead to reduced reliance on helicopters for aerial surveillance in several industries.

Following the increasing importance of BVLOS, the demand for fixed-wing vertical take-off and landing (VTOL) drones is also gaining momentum. Owing to their efficient forward flying capabilities coupled with long endurance ranges, the fixed wing VTOL drones are certain to dominate in the commercial sector within the next few years, especially in areas such as terrain mapping, surveying and long-distance sorties, among others. For example, Zipline utilizes fixed wing drones to deliver medical supplies in rural areas in Rwanda. In September 2018 Xcel Energy, the largest utility company in Colorado, initiated their BVLOS drone operations by signing a Safety Partnership Program with the US FAA. Under the testing phase, fixed wing VTOL drones are being deployed to collect data on the condition of transmission towers and power lines along a 50-mile route.

Counter drone technologies are a booming opportunity for drone service providers

As drones make their way into the commercial landscape, concerns over their use for unethical practices are also on the rise, which necessitate effective counter-drone technologies. Across the globe, there have been several instances where drones have been used for anti-social activities, especially against LEAs and military troops. Alarmed by such instances the US Department of Defense (DoD), which considers drones to be military assets critical for warfare of the future, has initiated 90 different programs to develop counter-unmanned aerial systems with a budgetary allocation of $1.5 billion in FY2019. Similarly MyDefence, a Danish drone service company, initiated a $425,000 program supported by the Innovation Fund, Denmark to develop anti-drone technologies for the Danish Armed Forces.

Even commercial end-users, including industrial conglomerates, universities, utilities, sports organizations, private security agencies, etc., are being exposed to malicious drone interference, compelling them to explore drone mitigation solutions. Against this backdrop, the focus of drone manufacturers has shifted to malicious

drone detection and counter-measure systems. Technologies based on radar, radio wave receivers, audio sensors and optical sensors are being utilized to develop detection systems. Meanwhile, jammers, spoofers (for GPS signal), sonic waves, lasers, electromagnetic pulses, high power microwaves and snagger nets etc. are some of the countermeasure alternatives used to annihilate detected malicious drones. Additionally, biological countermeasures, such as use of eagles to detect and neutralize rogue drones in restricted airspaces are being explored. Although the pioneering program for drone countermeasures using eagles was grounded by the Netherlands LEAs in 2017, citing ambiguous results, the UK is currently evaluating feasibility of the same. The French Air Force also runs a similar program where eagles are trained to take down unauthorized drones in the country's airspaces.

Seeking opportunity in the industry, several start-up firms are investing in development of counter-drone technologies. DroneShield, Dedrone, ApolloShield and Department 13 (Kunene Resources) are currently the most promising companies in the counter-drone technologies market. Some of the close challengers to these companies include Citadel Defense Company, SkyDroner, and OpenWorks Engineering. Additionally, industrial stalwarts are seeking synergies with start-ups to establish drone security. For instance, AT&T has partnered with Dedrone to identify potential rogue drones in the airspace as part of a pilot program for the company's smart city project. Defense contractor Lockheed Martin, also demonstrated their Advanced Test High Energy Asset (ATHENA) system, a 30kW laser weapon which can take down drones. The company is presently developing a 120kW version of the same for the US Army to restrict large military drones. Also, DJI's introduction of the Aeroscope platform, which enables a drone to detect, identify and track other drones flying overhead, is a move towards development of its own counter-drone technology.

Counter-drone technologies will continue to gain industrial importance and seek expansion on par with mainstream drone technologies. However, regulations prohibiting deployment of electronic mitigation techniques will also simultaneously require substantial reformations. As military regulations for deployment of electronic counter-drone technologies is often swiftly amended, in order to enhance security measures, similar improvements will also be demanded at the commercial level. Over the following years, several of the aforementioned counter-drone techniques will become obsolete, leading drone-operating enterprises to demand enhanced disruptive technologies. Technology leaders will thus gain opportunities to drive new business channels from these grey areas in the market.

Glossary

Term	Definition
Augmented reality	Augmented reality refers to the application of data to real-world images in order to augment the experience.
Automatic Dependent Surveillance – Broadcast (ADS-B)	Automatic Dependent Surveillance – Broadcast is a technology which broadcasts accurate position data for aircraft that can be used by air traffic control authorities, and by other aircraft in traffic management and collision avoidance.
Beyond Visual Line of Sight (BVLOS)	Beyond Visual Line of Sight refers to the concept that a drone may fly beyond the visual line of sight of the operator. This may impact the ability of the operator to safely handle the drone and is an inflexion point for many regulators.
Drones as a service (DaaS)	Drones as a service refers to the concept of renting drone services on an as-needed basis, rather than having to develop drone capabilities in-house.
Fog Computing	Fog computing is an architectural model in which a proportion of the data processing and analysis is done on the device that collects the data (the edge device) before transmitting data to the center.
Intelligence, surveillance and reconnaissance (ISR)	Intelligence, surveillance and reconnaissance is a military term that refers to the practice of linking several battlefield functions together in order to assist a combat force in its intelligence gathering and communications operations.
Law Enforcement Agency (LEA)	A Law Enforcement Agency is a government agency responsible for enforcement of the law.
Light detection and ranging (Lidar)	Lidar makes use of laser technology to calculate distances, analogous to radar (from which the term derives) lidar is used in navigation and as a way to survey the landscape to create a 3d model by measuring the disruption to a laser beam which is pointed towards the target object.
Ministry of Industry and Information Technology (MIIT)	MIIT is the Chinese Ministry of Industry and Information Technology.
Suppression of Enemy Defenses (SEAD)	Suppression of Enemy Defenses is a military term that refers to a range of combat tactics to ensure battlefield superiority.
SWaP	SWaP refers to Size, Weight, and Power consumption – three key factors in drone design.
Unmanned aerial vehicle (UAV)	An unmanned aerial vehicle is an aircraft that is piloted by remote control or an aircraft that flies autonomously, using onboard computers.
Unmanned aircraft system traffic management (UTM)	Unmanned aircraft system traffic management is a project run by NASA in the USA to develop standards and processes related to the management and control of drones and UAVs.
Vertical take-off and landing (VTOL)	A vertical take-off and landing aircraft is an aircraft that can hover, take off and land vertically, without the need for a runway.
Visual line of sight (VLOS)	Visual Line of Sight refers to the ability of a drone operator to safely control a drone by keeping it within his or her direct line of sight.

Source: GlobalData

Appendix: Our "Thematic" research methodology

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

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

GlobalData's thematic research ecosystem is a single, integrated global research platform that provides an easy-to-use framework for tracking all themes across all companies in all sectors. It has a proven track record of identifying the important themes early, enabling companies to make the right investments ahead of the competition, and secure that all-important competitive advantage.

Traditional research does a poor job of picking winners and losers

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

That is why we developed our "thematic engine"

At GlobalData, we have developed a unique thematic methodology for ranking technology, media and telecom (TMT) companies based on their relative strength in the big investment themes that are impacting their industries. Our thematic engine identifies which companies are best placed to succeed in a future filled with multiple disruptive threats.

To do this, we rate the performance of the top 600 TMT companies against the 50 most important themes impacting those companies, generating 30,000 thematic scores. The algorithms in GlobalData's thematic engine help to identify the longer-term winners and losers within the TMT sector.

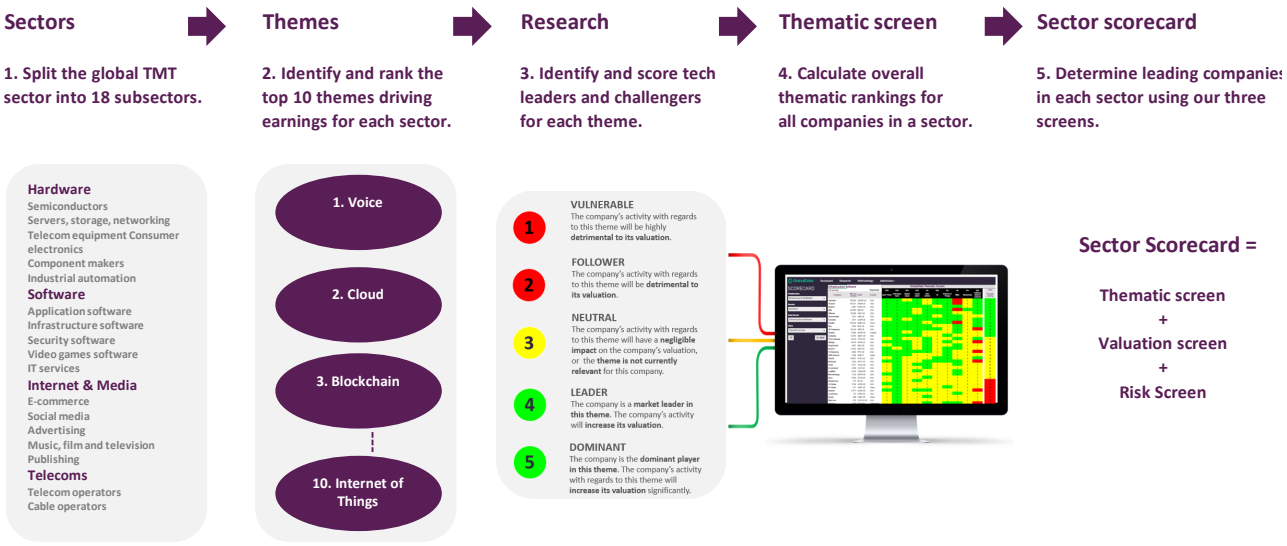
How do we create our sector scorecards?

First, we split the global TMT industry into 15 sectors. Second, we identify and rank the top 10 themes for each sector (these can be technology themes, macroeconomic themes or regulatory themes). Third, we publish in-depth research on specific themes, identifying the winners and losers. The problem is that companies are exposed to multiple investment themes and the relative importance of specific themes can fluctuate.

So, our fourth step is to create a thematic screen for each sector to calculate overall leadership rankings after taking account of all themes impacting that sector.

Finally, to give a crystal-clear picture, we combine this thematic screen with valuation and risk screens to generate a sector scorecard used to help assess overall winners and losers.

Our five-step approach for generating a sector scorecard



Source: GlobalData

What is in our sector scorecards?

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

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

How do we score companies in our thematic screen?

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

Thematic scores predict the future, not the past.

Our thematic scores are based on our analysts' assessment of their competitive position in relation to a theme, on a scale of 1 to 5:

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

How our research reports fit into our overall thematic research ecosystem

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

- **Single Theme:** These reports offer in-depth research into a specific theme (e.g. artificial intelligence). They identify winners and losers based on technology leadership, market position and other factors.
- **Multi-Theme:** These reports cover all companies and all themes within the TMT sector. There are two types: one is organized by sector; the other is organized by theme.
- **Sector Scorecard:** These reports identify those companies most likely to succeed in a world filled with disruptive threats. They incorporate our thematic screen to show how conflicting themes interact with one another, as a well as our valuation and risk screens.

About GlobalData

4,000 of the world's largest companies make better and more timely decisions thanks to our unique data, expert analysis and innovative solutions delivered through a single platform.

GlobalData is one of the world's leading providers of company operational data and strategic analysis, providing detailed information on tens of thousands of companies globally. Our highly qualified team of Analysts, Researchers, and Solution Consultants use proprietary data sources and various tools and techniques to gather, analyze and represent the latest and the most reliable information essential for businesses to sustain a competitive edge. Data is continuously updated and revised by large teams of research experts, so that it always reflects the latest events and information. With a large dedicated research and analysis capability, GlobalData employs rigorous primary and secondary research techniques in developing unique data sets and research material for this series and its other reports. GlobalData offers comprehensive geographic coverage across world's most important sectors, focusing particularly on energy and healthcare.

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