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Clarity from above

PwC global report on the commercial applications of drone technology

pwc

Contents

How can drones take business to the sky?

The IT revolution that began in the 1980s completely transformed the modern economy by enabling companies in industry to re-engineer their operations. Today we are witnessing a comparable disruption, on a similar scale, as drone technologies upend business models and reshape industry landscapes ranging from agriculture to filmmaking. In the very near future, clients in all areas of the economy will begin to see the impact of drones on their operational processes – from the way they receive deliveries to how they interact with their insurers.

Clarity from above seeks to quantify that impact by examining commercial applications of drone technology across industry sectors. Of interest are not only the machines (drones), but their broader applications for business, such as in the ability to capture unprecedented levels of data. That is why we have decided to use the term 'drone powered solutions'.

Drone powered solutions are best suited to sectors that require both mobility and a high quality of data. Specifically, businesses that manage assets dispersed over large areas have a long history of issues that new drone powered solutions can address. Large scale capital projects, infrastructure maintenance and agriculture can benefit greatly from the integration of drones into day-to-day business. Insurance and mining will find potential process improvements as they gain new levels of data quality and accessibility. And the entire transport industry will surely change its concept of last-mile delivery.

Considering the breadth of potential applications, we wanted to understand what the future value of the global drone powered solutions market could be. This includes not only drones as tools, but also all related solutions and software to be used in the industries covered by this report. We estimate the addressable market value of drone powered solutions at over $127bn. This is the value of current business services and labour that have a high potential for replacement in the very near future by drone powered solutions.

But when discussing the constant development of new drone applications, it is important to consider the regulatory and technological perspectives. Airspace governing bodies are facing the crucial challenge of ensuring the safety and privacy of citizens without suppressing innovation and growth. In many countries, regulations are being implemented to require pilots to pass practical and theoretical tests and medical examinations, as well as receive permission to fly in particular areas and beyond visual line of sight (BVLOS). These regulations are accompanied by technological improvements in avoidance and air-traffic management systems. The lack of such solutions may constitute a barrier to the development of commercial drone applications in a given territory.

Drone Powered Solutions is also the name of a newly established PwC global centre of excellence focusing on the use of drone technology and data analytics in business. It was established in Poland – a country which in 2013 became the first in the world to introduce a complete legal framework and institutions regulating the commercial use of drones.

The creation of the PwC Drone Powered Solutions centre of excellence, and the preparation of our first global report on how drones are poised to impact a broad range of industries, were made possible thanks to a number of factors. These include PwC's deep global industry expertise, our strategy & operations consulting capabilities and, just as importantly, a passionate curiosity to explore innovative ways that emerging technologies such as drones can be used for data capture and analysis to solve business challenges.

Around the world, drones equipped with cameras and sensors are providing companies with clearer, more comprehensive views of their businesses, and the opportunities and threats that surround them.

We hope this report will do the same for you.

Michał Mazur
Partner,
Drone Powered Solutions

Adam Wiśniewski
Director,
Drone Powered Solutions

1. What are the key commercial applications of drones?

UAVs (Unmanned Aerial Vehicles) were used commercially for the first time in Japan at the beginning of the 1980s, when unmanned helicopters proved to be an efficient way of supplementing piloted helicopters to spray pesticides on rice fields. At that time, remote aircraft technology was expensive and cumbersome. Progress has surged forward in technological capabilities, regulations and investment support, providing many new possible applications, particularly in agriculture, infrastructure, security, transport, media & entertainment, telecommunications, mining and insurance.

The application of drone technologies in existing business processes is allowing companies from those industries to create new business and operating models. Each industry has diverse needs, and as a consequence requires different types of drone-powered solutions, and various drone functionalities. Some of them value flight speed and payload capacity, while others wish to concentrate on solutions delivering high-quality, real-time data in a cost-effective way.

Considering the breadth of potential applications, we wanted to understand what the future value of the global drone powered solutions market could be. As data sources regarding its current value are rather scarce, we decided to show the potential of addressable markets. To measure such markets we have indicated the cost of labour and services that have a high potential for replacement in the very near future by drone powered solutions. Our analysis was performed separately for each industry and based on data from 2015.

The total addressable value of drone powered solutions in all applicable industries is estimated by PwC at over $127bn. The industry with the best prospects for drone applications is infrastructure, with total addressable value of just over $45bn.

Figure 1. Value of drone powered solutions addressable industries – global view ($ bn)[1]

	2015
Infrastructure	45.2
Transport	13.0
Insurance	6.8
Media & Ent.	8.8
Telecommunication	6.3
Agriculture	32.4
Security	10.5
Mining	4.3
Total	**127.3**

[1] Values presented in this table correspond with the current (2015) value of businesses and labour in each industry that may be replaced by drone powered solutions, according to PwC research.
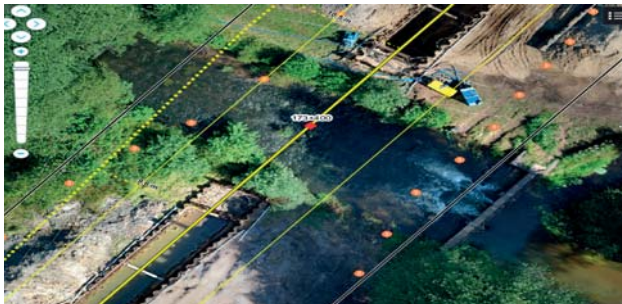
1.1 Infrastructure

Drones have only recently taken to the skies to assist in the management of various kinds of infrastructure, but they are here to stay. Not only can they perform hazardous work, but they also make it easier to acquire various data sets, doing so precisely and cost-effectively. Several infrastructure industries can benefit from drone technology more quickly than others: energy, roads, railways and oil & gas. Within these industries, companies operate extensive networks of complex assets, distributed over vast areas. Key drone applications in infrastructure are investment monitoring, maintenance and asset inventory. PwC estimates the addressable market of drone powered solutions in infrastructure at $45.2bn.
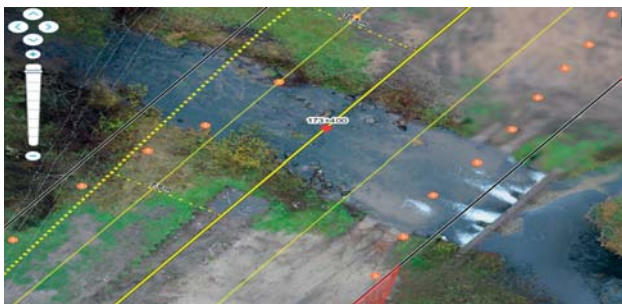
Investment monitoring

Real-time awareness and accuracy have always been challenges on construction sites, and even if we are only at the beginning of understanding what can be automated, it seems that drones are able to provide the data required at each phase of the construction process.

During the pre-construction phase, by providing better field data, drones can significantly improve the speed and quality of the design process. They are able to capture high-resolution videos and images, enabling 3D modelling and providing data about a site's initial status for investors and property owners before work begins. Data collected by drones can also enable the creation of Digital Terrain Models (DTMs), which ensure better contract valuation.

In the construction phase, drones are perfect for quick surveys of sites and for the precise gathering of data for progress reports. Investors can easily monitor progress by imposing overlays of plans onto photos of the actual state of construction, in addition to identifying discrepancies as small as 1 cm, and simultaneously verifying contractor reports. Furthermore, monitoring of construction sites by UAV helps check whether site borders have been crossed, and confirm that materials are being stored and handled correctly. Information from drones is processed automatically, and investors have swift access to complex data, enabling a fast reaction and an effective analysis of results. UAV technology allows investors to monitor contractor engagement and receive complete, trustworthy documentation that, if necessary, can be used as evidence to settle disputes in court.

On the construction site, contractors can use accurate data gathered by drones to perform precise work such as positioning steel slabs in concrete or measuring the depth of pipelines, preventing costly and dangerous construction errors. Drones further increase safety by performing hazardous work, and by monitoring construction areas for possible sources of risk and accidents.

In the last phase of the construction process, UAVs can be used for final work assessment, environmental impact verification and reporting. The data collected can be further used for maintenance and marketing purposes.

Maintenance

Maintenance is an inherent part of infrastructure management. Today, most such work is performed manually, based on in-person inspections, a slow and costly process that yields incomplete, poor-quality results. In some cases, rope access, scaffolding and elevated platforms are necessary, combined with the need to turn off the installation for the duration of the maintenance. This approach is not only time-consuming but also very costly. Of course, some inspections are required by law to be performed by certified personnel, but in many cases they can be performed by drones. To illustrate: a standard wind turbine inspection currently costs around $1,500 per tower; performing the same inspection using a drone cuts the cost by around 50%. Similar savings can be achieved on inspections of bridges and tunnels, where the costs of in-person inspections are even higher.

Before (initial state)

After

Today drones can not only locate defects faster and more thoroughly, but also more cheaply and safely. Due to advances in image processing, companies can analyse data much faster and more accurately. The software currently available for image processing allows extraction of much more valuable information and insights than ever before.

Asset inventory

Drones can be used in stocktaking and inventory management for infrastructure companies. Performing inventory assessments with UAVs allows companies to cut costs and accelerate the entire process, while providing more detailed information about the assets. It also increases workplace safety, as rotary-wing drones can fly into places that are difficult to reach without risking human lives. The best example may be inventory of telecommunication and broadcasting masts, and the devices installed on them. Ordinary stocktaking is dangerous, time-consuming and labour-intensive; using drones, enhanced by other new technologies such as optical barcodes and radio frequency tags (RFID), makes the process safer and much more efficient. And database integration makes the cataloguing process more detailed and more reliable.

What the future may hold

Drones are already changing the way we think about maintenance and monitoring services. We can expect to see drones not only diagnosing problems with crumbling infrastructure, such as cracks in tarmac, bridges and building facades, but also repairing them. In the future, 3D printing technology will be combined with drone technologies to maintain and repair infrastructure. Construction companies will be able to attach 3D printers to drones, to produce on-site replacement parts for damaged elements of infrastructure. The growth of 3D printing is already contributing to the drone sector: In 2014, the first flying 3D printer was created.

Monitoring and repair are not the only drone applications being developed within the infrastructure industry. Start-ups are testing drone technology to perform hazardous tasks at height, such as painting and window cleaning. Ultimately they will be able to perform most work at height, replacing humans in order to reduce the risk of death and injury, as well as increasing efficiency.

We also envisage the development of small autonomous drones for building internal infrastructure (e.g. ventilation systems). Thanks to more advanced capabilities and sensors, they will be able to navigate by themselves and perform tasks inside as well as outside buildings.

Drone application in capital projects as a vital step in designing, constructing, operating and maintaining infrastructure assets

Richard Abadie – PwC Global Capital Projects and Infrastructure Leader

Drone application in capital projects is an exciting growth area. As the price of drones continues to fall and new technology to exploit them becomes available, we expect their use will begin to pervade the entire lifecycle of capital projects, and filter down to even the smallest infrastructure projects.

Drones are being used in capital projects in a variety of ways. There are the obvious uses of taking photos or making aerial surveys of inaccessible locations, both to help scope a project and to monitor it. Taking this further, recent developments in photogrammetry allow the use of (relatively) cheap camera-only drones to create 3D representations of infrastructure assets that can then be imported into BIM systems to create scale models. Once a project is underway, these drones can also measure progress during construction work – a key piece of performance information from a project controls perspective. Still, one note of caution would be that while this can work well for the physically significant elements of projects, system installation and commissioning is more difficult to capture from a 'drone's eye' view.

How do we see this market developing? There are still some regulatory hurdles to overcome, which vary by country, but drone technology is developing quickly. In the near future we believe that drones will have increased automation to provide oversight, which will include health and safety monitoring, and on-going condition surveys. This data collection, combined with improvements in tailored data analytics, will enable predictive maintenance and other process improvements throughout each stage of a project's life cycle. In the distant future, we'd like to see drones actually undertake the construction of components on site: from a co-ordinated swarm of mini 3D-printing drones, to specialised drones undertaking specific hazardous tasks to achieve the ultimate in safe construction by removing the human operator from the site.

Drone applications will be a vital technology in the capital project of the future, and so we are advising project owners to place themselves at the leading edge of the innovation wave, to gain an optimum return on their investment.

1.2 Transport

The development prospects for drones in the transport industry are excellent, thanks largely to upcoming improvements in technology. Drones may play an important part in this technological shift. While initially the industry underestimated their utility, unmanned aerial vehicles are starting to be used in a wide spectrum of transport activities, from e-commerce package delivery, to transport of medicines, to fleet management and spare-parts delivery and even to same-day food delivery. Drones are certain to become an integral part of the transport industry very soon, offering both a method of delivery and services accompanying transport. The industry will turn to drones for their speed, accessibility and low operating costs compared with other forms of transport that require human labour. The addressable market for drone powered solutions in the transport industry is $13bn, according to our estimates.

Delivery of parcels

Within the e-commerce business, time of delivery is paramount when choosing a carrier. Drones enable fast delivery to a specific, predefined point, without much human action required. The convenience of sending packages to a client's doorstep will create an improved customer experience. Such concepts have already gained the attention of the largest players, such as Amazon and Google, who are in the testing phase for such solutions. Amazon has been running Amazon Prime Air, which seeks to automate last-mile delivery of packages using small drones, able to reach a destination in 30 minutes whilst carrying a small parcel. Sending a 2-kg package within a 10 km radius in the US by ground transport costs Amazon $2 to $8, compared with just 10 cents using a drone.[2] Google is also running a drone testing programme, Project Wing. The purpose is also last-mile delivery of goods, but the vehicle's construction is different from Amazon's. Google's drone is called a "tail sitter": Its take-off is vertical, then it moves into a horizontal position, which allows greater manoeuvrability and speed. Both established corporations and garage-based start-ups, and all kinds of companies in between, are involved in finding optimal ways of using drones in transport.

As a matter of fact, some logistics companies have actually put drones to real work. Swiss Post has been testing parcel deliveries by UAV since July 2015.[3] The drones fly autonomously, following previously defined paths drawn up by cloud software developed by Matternet (a US start-up), delivering payloads of up to 1 kilogram.[4] Last September, Posti, the Finnish national postal company, also tested delivery by drone for the first time in Europe in an inhabited urban environment. The drone flew 4 kilometres in Helsinki, from the mainland to the island of Suomenlinna, carrying a 3 kg parcel.[5]

As drones can quickly deliver packages to hard-to-reach areas, and offer flexibility of delivery points, other postal operators are following in Swiss Post and Posti's footsteps in testing drone technology.

Spare parts

In the area of goods delivery, another concept is also gaining popularity: delivery of spare parts. Maersk, which operates a large fleet of tankers, currently uses barges to deliver spare parts to its workers. As this process is expensive, the company has been searching for other options, and has also conducted drone delivery tests. Based on positive results, Maersk expects to be able to save $3,000 to $9,000 per ship annually using UAV technology.[6]

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[2] http://www.businessinsider.com/delivery-fee-for-amazon-prime-air-2015-4

[3] https://www.theguardian.com/technology/2015/jul/08/swiss-post-begins-testing-postal-delivery-by-unmanned-drone

[4] http://postandparcel.info/70443/news/matternet-and-swiss-post-to-start-payload-trials-with-drones/

[5] https://www.posti.com/english/current/2015/20150901_robotic_helicopters.html

[6] http://fortune.com/2016/03/09/maersk-drone-delivery-tanker/

Medical logistics

Another application for drones is in medical logistics. The two foremost studies in the field concern drug transport and using drones as flying defibrillators.

Last July, Flirtey (a US drone delivery start-up), NASA and Virginia Tech received special FAA approval to perform the first official drone delivery of medication in the United States. The vehicle carried medications from an airport to a nearby health clinic in a three-minute flight.[7] Delivering medical supplies in a remote rural area is the most likely application for drones in transport, because the need is high and the risk is low. Drones, unlike cars or motorcycles, are not subject to traffic delays, so samples can reach health-care workers much faster, making it easier to maintain ideal storage conditions.

Another potential medical application for drones is their use as flying defibrillators. A drone can be summoned by a patient with heart attack symptoms; the device can reach the patient, travelling at speeds of 100 km/h, locate and identify him or her and then perform an automatic defibrillation. By decreasing the time between identifying the first symptoms of a heart attack and the defibrillation drone's rapid response, the survival rate can increase from 8% to 80%.[8]

Food delivery

One of the most promising uses of drones in transport may be food delivery. Providing products such as frozen food, ready-to-eat dishes or even daily groceries from large chains may become be the next big thing in the food and restaurant industries. At first drones will be used to deliver such products to remote, difficult-to-access places that depend on external food supplies, such as oil rigs, research stations and isolated islands. Once proper regulations have been established, drones may perform the same tasks in residential areas, decreasing delivery times and increasing the efficiency of the entire transport value chain.

What the future may hold

Until now, helicopters have distinguished themselves from airplanes by their flight flexibility. Drones not only provide the same opportunities, but have the advantage of being smaller and eliminating the risk of losing a human operator. Another big advantage is their price, and therefore their extremely high availability. Thus, it is reasonable to forecast that drones will decrease the need for helicopters, and be able to conduct operations where the use of helicopters was too expensive or dangerous. On the other hand, if the two sectors merge, new opportunities may arise.

In the future, we may expect that airlines will start to deliver drone transportation services to their clients. This comes as no surprise, since airlines and drones are very much alike. Firstly, they both operate aerial vehicles that face similar levels of risk, a level that is clearly acceptable to the airlines. Furthermore, airlines already have experience and know-how in logistics, which gives them a natural competitive advantage in adopting drones in their service lines and diversifying their businesses. Since flying drones requires skill, and airlines already have their own training programmes to develop these skills, they can use their facilities to train future drone pilots, or even build their own drone crews.

[7] http://www.wsj.com/articles/drone-delivers-medicine-to-rural-virginia-clinic-1437155114
[8] http://www.tudelft.nl/en/current/latest-news/article/detail/ambulance-drone-tu-delft -vergroot-overlevingskans-bij-hartstilstand-drastisch/

Exploring new frontiers in Transport & Logistics

Julian Smith – Global Transport & Logistics Leader

In essence, every drone is an advanced version of a remote-controlled model aircraft. While many people had them as toys, most of us did not imagine their enormous potential. But today, like so many other technologies developed for military use, drones can be used to improve the efficiency of the transport and logistics industry. In addition to the technological advances, the drivers of this change include the high cost of operating and maintaining broad geographical networks, especially in remote areas. Drones offer the potential to save huge amounts of person and vehicle-hours through their mobility and flexibility.

Although the practical realities of drone implementation in Transport & Logistics will vary by industry and geography, there are several methods that will clearly have great impact. Postal operators are the first business sector to actively deploy drones. The ability to easily transport parcels to remote locations and define new delivery channels is definitely attractive. New delivery capacities for emergencies such as natural disasters also offer a key advantage. Secondly, companies such as online retailers, food delivery chains and infrastructure operators are constantly investigating solutions that can reduce costs, decrease reaction time and improve continuity of operations. As of now drones have great potential to deliver on all of those metrics.

The last category within the transport sector that can greatly benefit due to the speed of such solutions is medical logistics, where time is of the essence. Drones can quickly deliver lifesaving products or blood samples, and even someday work as flying defibrillators to save lives more directly. And it must be noted that developments in technology will only further accelerate real-life implementation.
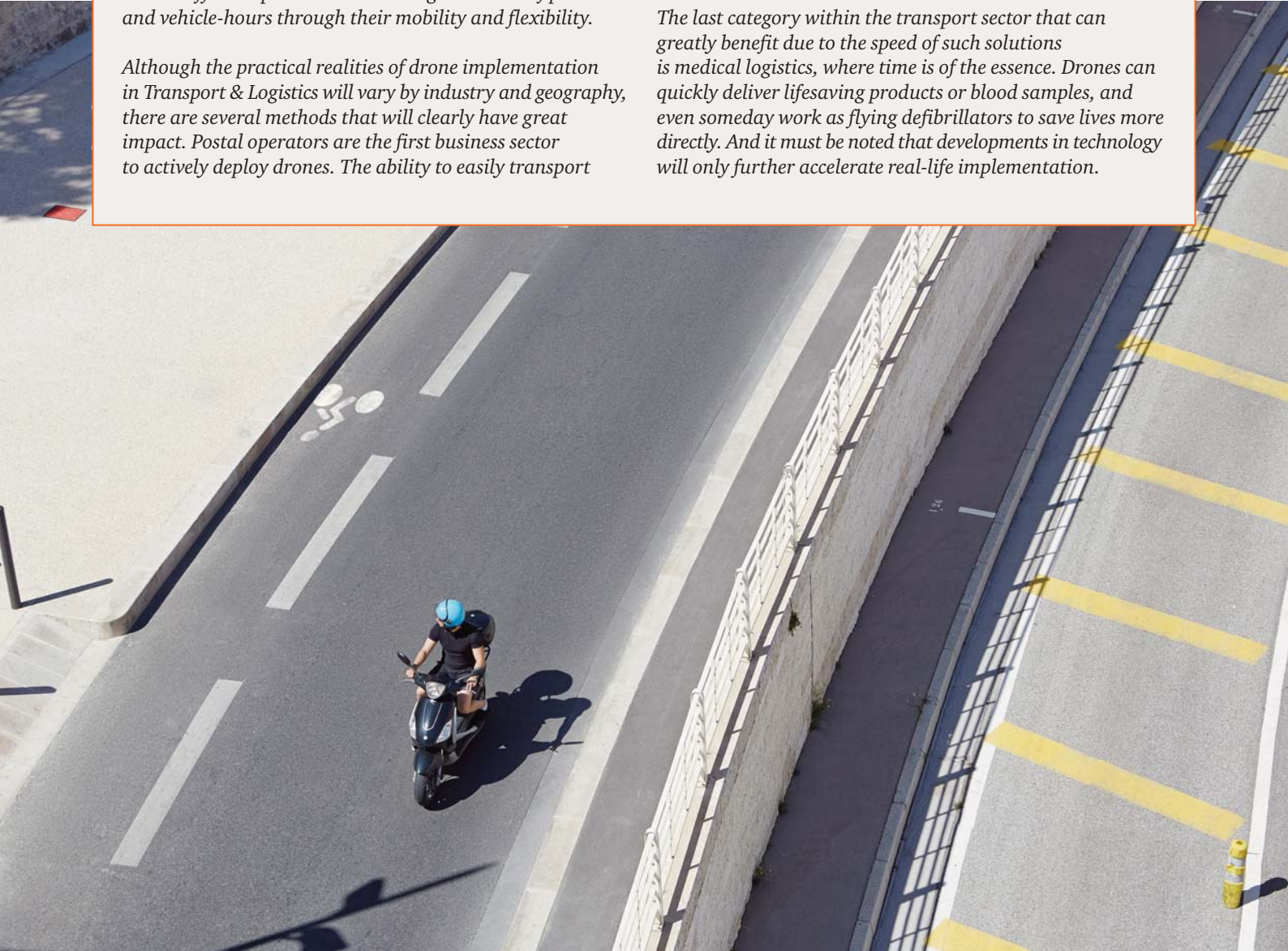
1.3 Insurance

Today's insurance sector faces two negative trends: increasing fraud, and increasing damage from natural disasters.

There are three areas where drone operations can enhance an insurer's procedures: risk monitoring, risk assessment and claims management (including fraud prevention). PwC estimates the addressable market of drone powered solutions in the insurance industry at $6.8bn.

Risk monitoring

An excellent example of drone applications in the insurance sector is their use in centres for monitoring areas exposed to natural disasters such as floods, droughts, volcanic eruptions or hurricanes. The average annual cost of insurance claims from natural disasters has increased eight-fold since 1970; the main reasons are economic growth resulting in rising property values, as well as growth of population density and insurance penetration in high risk areas – a trend that is compounded by the fast growth of certain Asian economies in disaster-prone regions.[9]

By monitoring threatened areas, national governments working with insurance companies can monitor the situation and alert local residents if an emergency arises. This allows insurers to prevent casualties and major damage, which obviously is extremely beneficial not only for them but also for re-insurers and the rest of society. Monitoring systems should consist of drones combined with a ground-level centre where the data they collect can be analysed. Such systems can help prevent or mitigate the economic consequences of natural disasters, benefiting the entire industry.

Risk assessment

Incorporating drones into insurance processes in assessing risk may have a beneficial effect on many of the aforementioned issues. First, more precise risk management thanks to data from drones can support underwriting processes such as calculating property and casualty premiums. Insurance companies can use drones to gather information about an object or site to capture its initial state before a policy is issued, or even decide to refuse to issue a policy. The information can be combined with data accumulated in more traditional ways for cross-sectional

analysis, which can increase efficiency and scoring model precision. Improved calculation of insurance premiums will also improve overall customer satisfaction, by tailoring costs more accurately.

Claims management & fraud prevention

According to the Insurance Information Institute, fraud comprises about 10% of property & casualty insurance losses and loss adjustment expenses every year, which means property-casualty fraud amounts to about $32 billion each year.[10] In addition, 57% of insurers predict an increase in this type of fraud by policy-holders.[11] Therefore, insurance companies are actively looking for new methods to reduce such losses by detecting fraud before claims are paid.

Data gathered by drones can be used to improve claims management by checking the initial state of a property and its condition after a reported incident. Drones can provide detailed, accurate data allowing for the creation of 3D models of a property / infrastructure, which can serve to assess possibly damaged areas faster, more cheaply and more precisely, as well as providing indisputable documentation to mitigate the risk of fraud. By using drones to assess damage, thus speeding up compensation, insurance companies can also improve customer satisfaction.

Drone operations can enable insurance companies to quickly and less expensively identify insured customers, and evaluate damage. UAVs can collect information on the condition of roads, railways, crops and other factors, and provide key information not only to enhance the process of damage evaluation but also to save lives. A prime example was Aviva's use of drones to assess flood damage in the UK in January 2016. While at that time the main use was to direct company employees on the ground, drones obviously could also provide a detailed assessment of damages.[12]

Future applications for drones in the insurance industry

In the future, by combining drones with other disruptive technologies such as machine learning, insurance companies will be able to improve predictions of damage. This will correlate premium calculation much more closely with real threats. By assessing risks better than ever before, insurance companies will be able to set premiums more accurately, ultimately increasing customer satisfaction.

[9]   http://www.agcs.allianz.com/insights/expert-risk-articles/natural-catastrophes-on-the-rise/

[10] http://www.iii.org/issue-update/insurance-fraud

[11] FICO Insurance Fraud Survey Highlights 2013

[12] http://www.ft.com/intl/cms/s/0/0df6980c-b628-11e5-8358-
      9a82b43f6b2f.html#axzz46Z3worgw

1.4 Media and Entertainment

One of the most popular fields for drone-powered solutions is in the media & entertainment industry. Companies in the industry have always been at the forefront of adopting new technologies, and thus it is hardly surprising that they are now. PwC estimates the addressable market of drone powered solutions in media & entertainment industry at $8.8bn.

Aerial photography and filming

The primary functionality of drones for the media and entertainment industry is aerial photography and filming. Drones can shoot commercials and movies; some prominent examples of the latter in which drones were used are Skyfall, The Wolf of Wall Street and Harry Potter. They can prove useful in reporting events by capturing footage for news broadcasts, the BBC being one company that has its own in-house drone team; at sports competitions, for which they were already used during such prestigious events as the 2014 Winter Olympics in Sochi; and for wildlife documentaries, including National Geographic's use of UAVs to film lions in Africa.[13] Drones can also be used to shoot private events: Many video and photography companies now offer drones to capture footage of special occasions.

Using drones can have numerous advantages over other methods of capturing images. One is their lower cost compared to planes or helicopters. Drones can also improve the quality of films and photos, in particular as the miniaturisation of technology makes it possible to place 4K cameras on these devices. Drones can take shots from very close, as they make little noise, for example approaching athletes during sporting events without distracting them. They can also take photos or videos at unique angles, operating at a greater height than a crane but lower than a helicopter. Finally, they can capture footage that would otherwise not be available, by reaching remote locations: for example, filming birds in the topmost branches of a tree for a wildlife documentary.

Advertising

Drones may also play a notable role in advertising and some of their uses in this area of exploring and testing drone-based solutions. They can do this indirectly, for example by intercepting cellular and Wi-Fi signals to determine users' locations and send advertising to their phones on that basis – e.g. ads of stores that the consumer is walking past. In 2015 AdNear, a Singapore-based location-marketing company, tested this solution by collecting data from consumers in the San Fernando Valley of Los Angeles.[14]

Drones can also be used in promotional activities more directly. They can carry banners with promotional messages, a solution used by the Russian agency Hungry Boys to advertise a Chinese takeaway restaurant in Moscow.[15] Furthermore, multiple drones can be used in skywriting. This concept is not new, having been employed, for example, by Paramount Pictures, which used drones glowing with LED lights to create the Star Trek Starfleet's logo over London's night sky, to promote the film Star Trek Into Darkness. In 2015 Intel organised a light show, featuring 100 drones whose movements where synchronised with the music of a live orchestra. The show used Intel software, and generated significant publicity by setting a Guinness World Record for the most drones simultaneously airborne. But in fact, Intel's objective was also to bring the creative applications of drones to the attention of those who perceive them only as weapons. The show demonstrates that drone technology can be used to organise air shows aimed purely at entertainment.[16]

Furthermore technical capabilities in this area are constantly improving: In 2015 another record was broken when a team of students at the Naval Postgraduate School in Monterey, California, launched 50 drones controlled by a single operator. Drones could also potentially be used to project advertisements onto various surfaces.

Entertainment shows and special effects

The potential of drones in entertainment is not yet fully utilised, and diverse new uses for these devices are appearing. Drones can take part in races or entertainment shows.

Drone racing, although not an entirely new concept, is about to become more prominent due to the recent emergence of the Drone Racing League. The organisation has raised more than $8m in funds, from such investors as Stephen Ross (owner of the Miami Dolphins, an American football team), and will host a series of races this year ending in a World Championship.[17] The races are to take place in unique, exciting locations – for example, a pre-season event in July 2015 was held in an old factory in New York, while venues for upcoming races include the abandoned Hawthorne Shopping Mall in Hollywood. Another large drone racing event, the World Drone Prix, took place for the first time in March 2016 in Dubai, with $1m in total prizes. It was organised at an illuminated science-fiction-like outdoor track, and could be viewed both by a live audience and by others over an online stream.

Drone racing has the potential to become mainstream, with some even believing that the sport can achieve similar popularity to Formula One auto races, and is expected to develop in a similar way to eSports (competitive video gaming). Drone racing is already gaining fans across the world. For participants, the thrill comes with the speed, the integration of reality with a computer game and the risk of a crash. For spectators, the appeal is mainly a function of the spectacular settings. Further development of drone technology should increase their agility and speed, making the races more exciting for an even wider audience.

Drones can also serve as a tool for creating special effects. This can be done on screen, as in the case of the short film "Sparked", created by Cirque du Soleil in collaboration with ETH Zurich and Verity Studios, which features quadcopters resembling lamps flying around to music. It can also prove useful during live events such as theatre performances. Disney seems to have noticed this potential, and is planning to start using drones as part of the evening entertainment at its theme parks. Specifically, the company intends to use drones to control large marionettes, possibly allowing the giant puppets to fly through the air, and others to serve as 'flixels' (flying pixels) – a fleet of drones flying in formation, each carrying a screen that displays an image, and together creating a larger display.

[13] http://www.wired.co.uk/news/archive/2014-02/12/bbc-drone-journalism

[14] http://www.forbes.com/sites/frankbi/2015/02/23/drones-are-already-intercepting-cell-phone-signals-in-l-a/#1787e55b6ee3

[15] http://dronelife.com/2014/08/13/new-advertising-drone/

[16] http://iq.intel.com/100-dancing-drones-set-world-record/

[17] http://www.digitaltrends.com/cool-tech/competitive-drone-racing-league-launches-2016-season/

1.5 Telecommunication

Drones can help companies in the telecom industry to address some of their most pressing challenges. These include issues related to their infrastructure – specifically maintenance, optimisation and further development in order to cover white spots – as well as pressure to reduce costs. Drones can also become a part of the infrastructure, by playing a role in broadcasting telecommunications signals. PwC estimates the addressable market of drone powered solutions in telecommunication industry at $6.3bn.

Maintenance enhancement

One area of drone technology that telecom operators are beginning to exploit is maintenance. Drones can carry out routine inspections of antennas by taking videos, pictures, readings and measurements. There are numerous advantages of using these devices instead of employees, mainly in the area of safety: Workers climbing towers risk injury or even loss of life, especially in bad weather. Another advantage is lower cost and higher speed. It is quicker to fly a drone than to set up equipment for an employee to climb a tower. T-Mobile demonstrated this when it used drones to conduct a pilot test of antenna masts at a stadium in Utrecht, which took 15 min as opposed to the week that it would have taken with traditional methods.[18] Furthermore, the qualitative data gathered by a drone is sent to the network carrier automatically, allowing instant analysis.

The potential applications of drones in network maintenance significantly exceed those commonly used today. The vehicles' tasks could be extended beyond routine inspections to include emergency missions – for example, flying over a network to assess damage after a natural disaster. Drones could also play a more active role in maintenance. British Telecom (BT) is investigating the possibility of drones carrying out repairs themselves, or delivering parts to engineers.

Future application: Investment planning and network optimisation

Drones may be used in radio-planning and line-of-sight (LoS) testing between radio towers, for example to identify obstructions (such as trees or buildings) and determine power needs. These findings can then be used, for example, to avoid a certain frequency affected by trees, or to select an appropriate antenna height and site location. Nokia Networks and "du" (the UAE telecom operator) have already tested using drones this way in Dubai. Drones can also analyse the quality and reach of a carrier's network: Nokia and du used drones carrying smartphones with network testing applications to examine the operator's network.[19] Finally, drones can be used to visualise electromagnetic fields originating from facilities such as mobile phone base stations.

Future application: Broadcasting telecommunication signals

It can also be expected that, in the future, drones will be used for broadcasting telecommunication signals, such as radio, television and internet, both permanently and in temporary roles. For example, drones can be a part of Cell on Wheels (COW) technology, a portable mobile cellular site that provides temporary network and wireless coverage to locations where cellular coverage is minimal or compromised. COWs are used to provide expanded cellular coverage and/or capacity to meet short-term demand, such as at major public events or during natural disasters.

As part of its initiative to provide affordable access to basic Internet services across the world, Facebook is working on creating a linked network of drones beaming internet signals to the earth in large rural areas that lack the infrastructure necessary for connectivity. The devices to be used are Aquila drones which, despite a wingspan equivalent to that of a Boeing 737, will be relatively light (400 kg), solar-powered and able to fly continuously for 3-6 months at an altitude far above that of commercial airplanes, thus avoiding the effects of weather. Facebook merely wants to develop the physical infrastructure required for this project and, subsequently, pass on its operations to traditional network carriers.[20] The company is expected to run trials using a full-size drone later this year, although it has already been testing prototypes. BT is planning to use similar technology to provide temporary broadband and mobile network access when its existing network is disrupted.[21]

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[18] http://www.aerialtronics.com/t-mobile-used-drone/

[19] http://company.nokia.com/en/news/press-releases/2015/07/07/nokia-networks-du-first -in-uae-to-use-telco-drones-for-better-network-planning-faster-optimization

[20] https://www.theguardian.com/technology/2015/jul/31/facebook-finishes-aquila-solar -powered-internet-drone-with-span-of-a-boeing-737

[21] http://www.telecomstechnews.com/news/2015/jul/07/drones-begin-their-shift-telecoms-industry/

Drones unlock new revenue generation and cost optimisation opportunities for the Technology, Information, Communication and Entertainment (TICE) sector

Vicki Huff – Global Technology, Entertainment, Media & Communications Leader

As with many digital technologies, the TICE sector is leading in experimentation with and adoption of drone applications, especially in the Communications and Entertainment sectors. As drone software and hardware capabilities continue to grow, companies big and small are finding fascinating ways to incorporate drones into their business models. This is a trend we expect to continue accelerating over the next five years.

Communications companies are exploring the use of drones for new methods of service deployment (e.g., as Cells on Wheels (COW), providing short-term capacity augmentation at big public events), improving their service performance (e.g. urban radio spectrum planning), and increasing their Operations and Maintenance (O&M) efficiency (e.g. remote inspection of cellular towers and base stations).

From allowing directors to create scenes and capture footage in ways that were simply not possible before, to being new real-time 'eyes in the skies' for the news channels (especially in times of disasters and emergencies), the entertainment sector is a natural space for drone applications.

San Francisco and New York now play host to drone film festivals, with the 2016 New York City Drone Film Festival receiving 350 film submissions from 45 countries. Finally, the technology companies are the innovators, manufacturers and, increasingly, the consumers of this emerging tech platform.

Of course, adoption challenges remain, ranging from liability concerns, to regulatory, security and privacy ones. Drone applications are proliferating, and we believe they will continue to do so over the next 5-10 years. Consumers and enterprises alike will continue to push creative drone applications, forcing governments, regulators and security companies to try and keep pace.

We recommend that TICE companies proactively explore drone applications and evaluate how drones will impact their operating models. We also remind you that an appropriate strategy needs to be developed and aligned in order to take advantage of the opportunities created. Finally, drone applications are still being shaped in how they're used and regulated in the broader business environment. TICE companies should be working with governments, regulators, each other and the public to help set the course.

1.6 Agriculture

Agricultural production has drastically increased in recent years, and studies predict that aggregate agricultural consumption will increase by 69% from 2010 to 2050. This increase will be mostly stimulated by population growth from 7 billion to 9 billion by 2050.[22]

In order to keep up with increasing demand, agriculture will have to revolutionise the way it produces food and become much more productive. Furthermore, production should be kept sustainable and help to prevent environmental damage. Moreover, other obstacles such as climate change make it harder to grow crops, due to an increasing number of unexpected weather events all over the world. So to satisfy world demand for food, close collaboration between governments, technology and industry has to be reinforced. PwC estimates the addressable market of drone powered solutions in agriculture industry at $32.4bn.

Crop supervision

Until now, the main obstacle in farming has been the large area of farmed land and low efficiency in crop monitoring. This problem is exacerbated by increasingly unpredictable weather conditions, which increase farming risk and field maintenance costs. Until recently, the most advanced form of monitoring used satellite imagery. The main limitation was that images had to be ordered in advance, could be taken only once a day and were not very precise. In addition, the services were extremely expensive and gave no guarantee of quality, which could easily drop on a cloudy day.

Today, drone technology offers a large variety of crop monitoring possibilities at a lower cost. Furthermore, drones can be integrated at every stage of the crop lifecycle, from soil analysis and seed planting to choosing the right moment for harvesting.

Soil and field analyses

The first stage of any agricultural cycle is to analyse the soil. Drones are able to produce precise 3D maps allowing early soil analysis, which can be used to plan seed planting patterns. Various start-ups have been able to create drone planting systems that not only achieve an uptake rate of 75%, but also decrease planting costs by 85%.[23] These systems shoot pods with seeds and plant nutrients into the soil, giving the plant all the nutrients necessary to stay alive. Furthermore, the analysis provides data for irrigation and nitrogen level management. Drones with hyperspectral, multispectral or thermal sensors are able to tell exactly which parts of a field lack water or need improvements. Additionally, once the crop is growing, they allow the calculation of the vegetation index, show the heat signature and allow crop planting.

Health assessment

Once the later stage of a crop life cycle is reached, the farmer's main objective turns to keeping the plants alive and healthy, which requires constant field monitoring. Drone monitoring possibilities are constantly being enhanced, providing the opportunity to reduce risk in the industry.

One of the latest developments helps to assess a plant's health and spot bacteria or fungal infections on trees. Scanning a crop using visible light (VIS) and near-infrared (NIR) light shows which plants reflect different amounts of green light and NIR light. This information can produce multi-spectral images that spot changes in plants and indicate their health. A fast reaction is usually crucial, because it can save a whole orchard from dying. In addition, as soon as a sickness is spotted, a more precise remedy can be applied and monitored. These two possibilities increase a plant's chance to overcome disease. Furthermore, in the case of crop failure, the farmer will be able to document losses for insurance claims much faster.

Crop spraying is another area of drone applications in agriculture. Drones can scan the ground, and maintain the right distance from the crops to spray the correct amount of liquid, modulating spraying in real time for even coverage. This will increase the efficiency of spraying, reducing the amount of excess chemicals penetrating into groundwater. Experts estimate that aerial spraying can be done as much as five times faster than with traditional machinery such as tractors.

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[22] Philip G. Pardey, Jason M. Beddow, Terrance M. Hurley, Timothy K.M. Beatty and Vernon R. Eidman, "A Bounds Analysis of World Food Futures: Global Agriculture Through to 2050", 2014, Australian Journal of Agricultural and Resource Economics, 58, pp. 571–589

[23] Mikhailova S., "Using Ex-military Drones to Plant Trees", http://www.huffingtonpost.com/pro-journo/using-ex-military-drones_b_8414532.html

The future

Drones will allow farming to become a highly data-driven industry, which eventually will lead to an increase in productivity and yields. Due to their ease of use and low cost, drones can be used for producing time series animations showing the precise development of a crop. Such analysis could reveal production inefficiencies and lead to better crop management. With those possibilities in mind, it can be assumed that this technology will transform agriculture into a high-tech industry for the first time, with decisions being based on real gathering and processing of data. Thus, agriculture's prime concern is not the drone's speed or flexibility, but the type and quality of data it can obtain. So the industry will primarily push for more sophisticated sensors and cameras. Another objective will be to obtain drones that will require a minimal level of training and be highly automated.

1.7 Security

While technology has always supported security firms with advanced electronics, sensors and video, many tasks still require a large amount of human involvement. Drones are changing the status quo thanks to their speed, size, manoeuvrability and applied technologies: they are the perfect supplement for ground security teams seeking to perform monitoring tasks more quickly and efficiently.

Drones can quickly cover large and difficult-to-reach areas, reducing staff numbers and costs, and do not require much space for their operators. As drones are manoeuvred by small pilot stations, operators can be gathered in one place, as with traditional video monitoring.

In security applications, areas need to be monitored constantly, requiring drones to be sturdy and able to operate in different weather conditions and at night. As operational time for security applications needs to be long in order to ensure continual surveillance, UAVs need higher-capacity, lighter batteries. In certain circumstances, batteries and electronic motors might be unsuitable for the tasks required, and may be replaced by fuel-burning engines enabling longer flights. To further overcome battery capacity issues, new concepts are being developed, such as wired drones connected by cable to an additional source of energy, which can be attached high above the ground to minimize the chance of breaking the connection.

PwC estimates the addressable market of drone powered solutions in security industry at $10.5bn.

Monitoring lines and sites

Because different parts of the security industry have differing requirements, we distinguish between two types of approach: monitoring lines and monitoring sites. In line monitoring, fixed-wing UAVs are used to perform highway, coastal and border surveillance. They can watch for cases of illegal border crossing, smuggling or wild animal traffic. In terms of monitoring sites, multi-rotors are used more frequently, as they provide higher manoeuvrability and can hover more easily. UAVs can provide live streaming of detailed data, follow objects or intruders from a safe distance and quickly cover a large area, but also record images that can identify whether part of a forest or a slag heap is missing. Drones have a competitive edge over stationary cameras, as intruders can't easily step out of sight, and they can cover areas that are normally out of reach. UAVs can also perform remote reconnaissance and rapid accident assessments to ensure

that an area is safe for a response team to enter, and to ensure a prompt reaction to security alarms; this can significantly impact the success ratio of response groups.

Drones have expanded their function beyond basic monitoring and can also ensure the safety of key sites or infrastructure, such as ports and airports. In Abu Dhabi, ADPC – the company that manages all the city's ports – decided to supplement its security system with drones. UAVs are also used for monitoring and assessing the scale of accidents. This information enables port authorities to delegate personnel more efficiently. UAVs have found other applications in industrial plants: reducing the costs of asset theft, in addition to monitoring and verifying the quality of employee work.

Proactive reaction

Drones do not need to be limited to repetitive tasks. During sporting events such as the 2014 World Cup in Brazil and the 2014 Sochi Winter Olympics, UAVs were used to ensure safety. Their main task was to track crowds in high-traffic areas and provide vast amounts of real-time data for security teams in the event of any disturbances. This enabled response teams to gauge a problem before it escalated. The Red Cross has also tested other uses of drones during such events – for example, identifying injuries to immediately dispatch medical help.

In addition to monitoring and rapid reaction, UAVs can provide detailed pictures and documentation of premises, enabling effective data analysis, identification of risks and security planning.

Future applications for drones in the security industry

In the future we envisage that the data gathered by UAVs will be instantly processed in the cloud, providing complete scene recognition supplementing human supervision. Thanks to machine learning software, drones will not only recognize unauthorised entry to a site, but also identify precisely who the intruder is, thanks to motion sensing and biometrics-based behaviour analysis, as well as facial recognition. UAVs will create systems enabling mass surveillance, where potential threats can be identified and data is immediately transmitted to response teams.

In addition to commercial use, drones could also be used in the future of personal security to perform autonomous sentinel duty. In general we can expect UAV security applications to further develop into a full portfolio; however, some aspects, such as the ability to fly beyond the visual line of sight, need to be clearly regulated.

1.8 Mining

The mining industry is one of the sectors where drone usage has untapped potential to deliver significant value for businesses. The commercial applications for drones in the mining industry are not so obvious at first sight; however, they can replace human in dangerous and monotonous jobs. Moreover, they are more cost-effective and versatile than helicopters; they are also faster, easier to navigate and emit less pollution than mining vehicles.

Drones are currently being tested and implemented mostly in open-cast mining, where they are replacing labour-intensive methods of inspection, mapping and surveying, as well as ensuring safety on the extraction site. We are also observing further developments in underground mining.

In open-cast mining we identify four main areas of drone applications: planning, extraction support, environmental protection and reporting. To assess the addressable market of drone powered solution in this industry PwC looked at particular cost categories and estimates the value at $4.3bn.

Planning

Open-cast mines usually cover several square kilometres, on varying surface levels, which translates into long routes for land vehicles and crew. Drones can be used to quickly map the area, optimise hauling routes and provide control information. They enable mine operators to communicate their plans, make reports, receive updates on work progress and manage pit and dump areas. They can easily assess and monitor potential storm damage; provide geotechnical and hydrological data; assist in the design of haul roads, dumps and pits; map steep, inaccessible inclines; and monitor surface stability.

Exploration

Drone applications in mining exploration range from providing data enabling resource calculation, through mapping a mining area, to management. UAVs can be equipped with special features to supply spare parts or take soil samples for deposit analysis. They are able to transport tools and lubricants required for maintenance or repair work. They can respond to emergency situations faster than people or other vehicles; transport medicines and rescue equipment; monitor the health of injured people until help arrives; and automatically react to various events.

For example, to meet the specific needs of the mining industry, Insitu built the GeoRanger drone, equipped with a magnetometer to store and interpret data related to the earth's surface. Data from the sensor can be stored on board or sent to a ground control station.

Environment

Drones are able to detect erosion, track changes in vegetation and search for defects in mining infrastructure that may endanger the environment, more easily, and definitely faster, than people on foot or manned aircraft can. Some countries use drones for surveillance. In combating air pollution, China has deployed a number of drones to track illegal night-time emissions produced by open-cast mines.

Reporting

Drones can also be used to monitor the production process in open pit mines and for early detection of deviations and threats. By creating a digital model of an open-pit mine's current state of work progress and detecting changes in the structure of the mine (landslides, damages to infrastructure), mine owners can increase safety and decrease costs of controlling processes. Early detection of irregularities and correct assessment of the open pit allows for quick response and better planning of work. It would also boost automatization of the whole extraction process which will result in decreased extraction costs.

The future

Drones typically use GPS technology to pinpoint their locations, which is not possible underground. However, a group of researchers seems to have overcome this limitation, using 3D scanning technology to create digital maps of underground spaces. Maps can be uploaded to the drones, allowing them to move smoothly through passages below the earth's surface. Drones underground can use laser scanners to measure mine drifts. It is worth mentioning that Clickmox, in co-operation with Glencore, has produced a small drone especially designed to clear boreholes of rocks blocking the way from the surface to a mine's lower levels.

2. What are the drivers and barriers to drone powered solutions?

The global civilian drone industry is in its early days, presenting a set of new legal, technical and social opportunities and challenges, due to the diversity of products and their possible applications. This chapter will present the main drivers and barriers, as well as how they might affect the pace of integrating drone powered solutions into business processes.

2.1 Drivers & enablers

PwC has identified three main factors which in our opinion are going to drive the use of commercial drone powered solutions in business. The following drivers will lead to the adoption of commercial applications of drone technologies.

Developed and implemented regulatory frameworks

The regulatory aspect of commercial drone operations is currently one of the most important factors affecting the pace of drone powered solutions' adoption by businesses and government entities. Today many organisations are considering testing and using drones in their business operations, but are wondering about the legal aspects. They see the benefits of using drones, but they need transparent rules on how and where they can use them, what they should do to guarantee the safety and efficiency of drone operations, and the grounds on which authorities

issue licenses or permits for commercial drone applications. National and international aviation authorities have started developing regulatory frameworks to guarantee that drones will be used in secure and business-friendly ways. PwC predicts that responsible, judicious regulations will boost the popularity of drone powered solutions among businesses from various industries. Moreover, insurance companies will have a significant role to play in that process by offering policies to protect drone operators and companies against physical losses and third-party liabilities. Once the regulatory framework is established, many companies now hesitating about using drones will decide to adopt them, to get ahead of the competition. We provide a more detailed discussion in chapter 3.1 of the evolution of the regulatory framework and how it affects drone users, manufacturers and providers of services.

The table below presents how the regulatory framework looks today in 15 countries, on five continents. Many countries have yet to develop regulations to guarantee a business-friendly legal environment.

Figure 2. Regulations by country

Territory	Possibility of commercial flights	License required to fly	Possibility to perform BVLOS flights	License required for BVLOS flights	Insurance required for commercial flights	Training required for pilots in order to obtain licenses
Poland	✓	✓	✓	✓	✓	✓
UK	✓	✓	✓	✓	✓	✓
China	✓	✓	✓	✗	✓	✓
Canada	✓	✓	✓	✗	✓	✗
Germany	✓	✓	✗	✗	✓	✓
France	✓	✓	✓	✗	✗	✓
South Africa	✓	✓	✓	✗	✗	✓
Indonesia	✓	✓	✗	✗	✓	✓
Australia	✓	✓	✗	✗	✓	✓
Brasil	✓	✓	✓	✗	✗	✗
Mexico	✓	✓	✗	✗	✗	✓
USA	✓	✓	✗	✗	✗	✗
Japan	✓	✗	✗	✗	✗	✗
Russia	✗	✗	✗	✗	✗	✓
Argentina	✗	✗	✗	✗	✗	✗

Based on PwC research (as of 31 March 2016).

Growing demand for high quality data

Companies have been using satellites, planes and helicopters to gather photogrammetry and geospatial data for many years. Both fields belong to the broader category of science known as geo-informatics, which deals with the structure and nature of spatial information used for urban planning, agriculture, infrastructure development, mining and many other applications. Applying photogrammetry and geospatial analysis gives companies access to valuable information regarding topography, hydrography, vegetation structure, soil types, land development and other characteristics to enhance their business operations. However, aerial images collected in the traditional way are still very expensive, and may not provide the necessary level of detail due to usually low quality of those images. Drones are much more cost-effective and guarantee high data quality. That's why growing demand for data will increase the use of drones for commercial purposes. Drones are becoming direct competitors with manned aviation and satellites. PwC believes the lower costs of gathering high quality data and greater versatility allow UAVs to be the primary tool for companies applying photogrammetry and geospatial analyses in their business processes.

Enhancing data processing & accessibility

Data acquired during drone operations has to be processed in order to deliver substantial value for businesses. The insights and recommendations based on that information have to be provided as fast as possible in an understandable, cohesive and comprehensive way. Customers expect the data to be available on every type of device (mobile or desktop), anytime, anywhere in the world. Therefore, PwC believes data accessibility is going to be one of the key drivers fuelling further adoption of drone technologies in business processes. This is also connected with the trend of simplifying and automating the use of drones, for instance by allowing control via mobile devices such as smartphones or tablets, rather than the dedicated controllers used today. Another example may be the development of autonomous flight control systems enabling businesses to safely operate a fleet of drones on various missions. Such trends will boost implementation of drone technologies by companies from various sectors.

New technological opportunities

Drones consist of many technologically advanced parts, which affects their efficiency, safety and reliability. Constant improvements in hardware solutions and decreasing prices will contribute to the rising number of possible drone applications, as well as encouraging people to invest in this new, more innovative and accessible technology. Technological breakthroughs, especially in the area of hardware, software and data processing, will fuel the growth of drone-powered solutions in the very near future.

The development of new types of power sources, engines and structural materials will impact the drone market's potential. For instance, manufacturers are developing hydrogen fuel cells, which are more efficient than the electric batteries that are currently used. This should reduce weight and increase flight time.

Another field of technological improvements will be in software and data processing. Drone manufacturers are working to implement autonomous avoidance systems – processing data obtained by the drone's sensors to avoid collisions or allow for automatic take-off and landing. This technology is currently used in a small number of devices and is constantly being improved.

Poland is making it possible for every company to be a drone technology enabled company

Adam Krasoń – CEO, PwC Poland

Technology is a great enabler. If applied in good settings, the results can be simply great. In Poland we have the exact mix of technology, local conditions and talent that has produced unparalleled progress in drone technology applications.

Initially, most industries perceived drones to be an unknown new tool; very few recognised their potential impact on operations. But this attitude has been rapidly changing, as the realisation spreads that drone technology can support various industries on a large scale, solving problems that they didn't even know existed.

This trend has been particularly noticeable in Poland, thanks to the country's long history of radio controlled model airplane societies, its high quality technical education and the aviation authorities' open approach. This framework has encouraged multinational corporations to locate the development of drone services and pilot programs in Poland. In addition, full liability insurance coverage has been developed to cover operators, drones and entities rendering drone related services.

Some of the most rapid acceptance of drone solutions has been in the aviation industry, where opportunities and synergies arise due to similar functions, risks and knowledge requirements. In particular, we observe that disruptive start-ups are increasingly working with established aviation players, combining their technology and knowledge with the aviation companies' networks and infrastructure to scale their concepts and achieve outstanding results.

Furthermore, to ensure aircraft safety, manufacturers are developing counter-measures such as jamming systems to prevent drones from colliding with other objects. We expect the development of control systems, using similar ground infrastructure to that used for airplanes, in the near future.

Poland is paving the way, and we encourage regulatory bodies and industries in other countries to take a closer look at the drone industry as a potential source of growth and synergies, enabling business to expand into new segments and markets.

2.2 Barriers

As in every other market, the drone industry is also exposed to various factors that can block rapid adoption.

Safety of drone operations

The most urgent challenge that national aviation authorities and the private sector have to face is ensuring secure supervision of recreational and commercial drone operations. One part of a secure supervision system will be mandatory drone registration, allowing authorities to identify drone pilots who break the law.

Another part of a safe supervision system is to develop a complex air-traffic management system for UAVs to prevent collisions with other flying objects. Such systems have to allow UAVs to see and avoid other aerial vehicles and potential obstacles, as well as communicating with air traffic controllers of manned vehicles. In addition, those systems have to be integrated with national air traffic management systems for manned aviation, to ensure the flow of information.

Moreover, drones have to possess auto-fail functions, preventing an uncontrolled fall from the air to the ground. Leading manufacturers are now implementing such functions in most models, sometimes even coupling them with autonomous obstacle detection systems.

PwC believes that these solutions will become the industry standard, and over time national and international authorities will create a unified system for air traffic control of drone operations.

Privacy issues

When drone operators perform flights over certain types of sites, they collect vast amounts of data, sometimes including confidential or sensitive information about private property or private behaviour. Due to a very broad definition of personal data, it isn't clear how companies should store these data, what types of data shouldn't be collected, or how individuals and companies can defend their privacy rights. However, this is a broader problem, concerning not only drone powered solutions, but also internet and telecommunication services. Several national authorities have been working on this issue, but thus far almost no decisions have been made, or solutions proposed. Market growth increases the pressure to regulate this area, though it will take time to prepare and pass proper legislation. This shouldn't be a major factor preventing further adoption of drone technologies, just as it wasn't in the case of telecommunication, internet and mobile technologies.

Insurance coverage availability

In most countries, aircraft users are obliged by regulators to have insurance to meet their liabilities in the case of an accident. The laws on UAV operators are still evolving, and insurance will become part of the complex regulatory framework. It is expected that insurance will be one of the main factors influencing risk management frameworks for drone technologies, in order to provide coverage for risks of physical losses or liabilities during and after drone operations. Physical losses include the drone itself, the equipment it is carrying and ground stations. Liability concerns potential property damage or injuries to third parties.

As the market expands, drone users will need more composite and high-value risk exposure insurance. Such policies are already being offered by insurers. In addition, drone manufacturers such as DJI are starting to offer their own insurance services, enabling customers to overcome one of the barriers to commercial use.

3. Who are the stakeholders of commercial drone applications?

3.1 Regulators

National airspace governing bodies are responsible for creating regulatory frameworks and overseeing their functioning. Such frameworks are still changing, and current structures vary widely. However, as a rule of thumb, to perform commercial flights it is necessary to pass state practical and theoretical tests and medical examinations, and to receive permission for flights in particular areas.

Evolution of the regulatory framework

National and international legislators are struggling to keep pace with advances in UAV technology. Drone regulations have changed in recent years from being treated as a niche hobby, to becoming part of regular aviation operations, to a point where national authorities have started developing special regulatory frameworks to address the most urgent issues. The first country to implement all necessary sets of regulations was Poland in 2013. Thanks to the combined efforts of the civilian aviation authorities, the UAV community and insurance companies, Poland allows commercial drone operations both VLOS (Visual-line-of-sight) & BVLOS (Beyond-visual-line-of-sight) in a secure and user-friendly way.

At the global level, the International Civil Aviation Organization (ICAO), a specialised agency of the United Nations, prepares standards and recommended practices for national and international air navigation to ensure safe and orderly growth. Of the 191 ICAO members, 63 have some regulations for drones already in place; nine states have pending regulations and five have temporarily banned the use of drones.[24]

Drone operation legislation

Flights by drones, called 'drone operations', are governed by manned and unmanned aviation laws determining the ground rules for operating drones in airspace. Most countries' regulations distinguish between recreational and commercial flights; however, a fully developed regulatory framework takes into account UAV weight, flight area, time of day and altitude. Mostly, the types of areas where flying drones is prohibited are very similar worldwide. Permission is always required to fly near and over airports, military infrastructure, key public infrastructure (e.g. government offices), densely-populated areas or other restricted areas. Some countries require UAV registration prior to use.

Generally, recreational flights performed by the smallest drones do not need aviation authority permission or a license. But in the US, for example, recreational drones weighing more than 250 grams but less than 25 kilograms have to be registered before their first flight.

Commercial flights in most countries have to be performed by certified pilots, and there are more specific restrictions regarding their use, especially in populated areas. In the majority of countries, drone operators have to obtain licenses, as well as special permission to perform commercial flights. Such permission can be issued case by case (as in the United States), depending on where and for what application the drone is to be used, or it can be granted more generally for all types of drone applications nationwide. Some countries (Russia) require the provision of technical details concerning the drones to be used, and a flight plan with a detailed description of how the drone operator will ensure safety and conduct an emergency landing if needed. It may also be required to appoint a pilot, a commander responsible for flight safety and an observer, especially during BVLOS flights.

Requirements for pilots

The next area of regulation encompasses the rules and requirements for personnel involved in UAV operations. This includes all types of obligatory or recommended training courses, certificates or permits necessary to perform drone operations. We can divide requirements for pilots in the same way as drone operation regulations: for recreational and commercial drone operators. In most countries, drone enthusiasts don't need any type of license or special training to fly their own light UAVs, for non-commercial purposes. Nevertheless, almost all territorial authorities require special types of pilot's licenses, certificates or permits for commercial flights. To obtain them, drone operators have to pass theoretical and practical tests, medical examinations and sometimes even possess a minimum amount of recent drone flying experience.

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[24] http://www.thenational.ae/world/southeast-asia/iata-call-for-regulation-as-drones-become-real-and-growing-threat

Figure 3. Drone registration requirements by country

Country	Airspace governing body	UAV registration
Argentina	Civil Aviation National Administration	✓
Australia	Civil Aviation Safety Authority	✗
Brazil	Department of Airspace Control	✗
Canada	Transport Canada	✗
China	Civil Aviation Administration of China	✓
France	Ministry of Ecology	✗
Germany	Federal Aviation Office	✗
Indonesia	Director General of Air Transportation	✓
Japan	Japan Civil Aviation Bureau	✗
Mexico	Mexico's Directorate General of Civil Aeronautics	✗
Poland	Polish Air Navigation Services Agency	✗
Russia	Federal Air Transport Agency	✓
South Africa	South African Civil Aviation Authority	✗
Turkey	Directorate General Of Civil Aviation Turkey (DCGA)	✓
UK	Civil Aviation Authority	✗
USA	Federal Aviation Administration (FAA)	✓

Based on PwC research (as of 31 March 2016).

For instance, in Poland, drone operators have to take theoretical and practical exams organised by the Civil Aviation Authority, as well as be in a possession of a valid medical examination and civil liability insurance. Drone operators can obtain two type of licence:

- Unmanned Aerial Vehicles Operator for Visual-Line-Of-Sight flights (UAVO VLOS)
- Unmanned Aerial Vehicles Operator for Beyond-Visual-Line-Of-Sight flights (UAVO BVLOS)

At the moment, training sessions are required only for the BVLOS license, but the CAA is currently working to impose this as a condition for taking the VLOS exam already this year. The training courses usually last from four to 10 days.

Insurance regulations

The last area of regulation relates to insurance guidelines and the rules governing mandatory or voluntary insurance coverage. Drone users should carry insurance policies covering physical loss, as well as liability for third-party damage and product liability. Third-party liability insurance (e.g. for injuries or property damage) is mandatory for drone operations in several countries (Canada, China, Germany, Poland and the UK). The latter two types of insurance protect drone users from liability for injuries to third parties and property damage caused by drone malfunctions or uncontrolled descent.

Future of the drone regulatory framework

For UAV operations to be commercially viable, national and international aviation laws may need to be overhauled, and a set of international regulations developed, to take UAV use into account in a consistent way. The ICAO is currently working on guidance for UAV operations, but the process is expected to take some time. The organisation plans to complete its standards and recommended practices by 2020, with a clear goal being a regulatory infrastructure for air-traffic management and sense-and-avoid technology. It is also expected that a manual for UAV operations will be published in 2018, ahead of the standards.

Another important aspect in regulating drone usage is the issue of privacy. While performing drone operations over populated areas, companies and governments can collect vast amounts of information, including data about private property, behaviour and other sensitive data. It is the responsibility of UAV operators and system providers to secure this information and to prevent misuse or theft. The core expertise of aviation regulatory agencies is safety, not privacy, and at least in Canada, Australia, and the US, aviation authorities don't engage in the regulation of privacy issues. The US Congress has already begun work on legislation to prohibit drone operators from capturing data in ways that would violate a reasonable expectation of privacy. Other proposed legislation would require drone operators to submit a "data collection statement" to the FAA, delineating information including what data will be collected, how it will be used and retained and whether the data will be sold to third parties. It is far from clear how other countries will try to manage this issue.

Drones as a driver for aviation industry development

Stefan Stroh – EMEA Transport & Logistics Leader

The 20th century was truly challenging for all regulatory authorities. With significant technological advancements in practically all areas of life, the law has had to play catch-up. The last 25 years have been jam-packed with new issues, such the increasing role of the internet, and computing and mobile enabled possibilities; even today, new lines are being drawn in the development of services and applications where creative business owners are endeavouring to push the envelope even further.

The response of aviation authorities to the emergence of drones as a commercial solution, not just a hobby, perfectly exemplifies these trends. The decreasing size and low cost of drones, combined with improved stabilisation and camera technology, has meant that they can now provide a commercially viable solution to many

longstanding problems. As a result, regulatory authorities have had to balance the need to address additional drone safety, security and privacy concerns without throttling the fledgling industry.

Such a balance can be achieved if the aviation sector keeps an open attitude and proactively sets down a clear and detailed legislative framework from the start, allowing the drone industry to thrive. Several countries, Poland in particular, have taken such an open approach, providing a full and detailed legal framework for both drone operators (requirements, training and licensing) and drone operations, including BVLOS.

Now, more than ever, every company has to be technologically aware and enabled. The aviation industry and its regulatory bodies are no different.

3.2 Manufacturers

In the emerging drone industry there are several key manufacturers from Asia, Europe and North America, competing for both individual and business customers. As the market continues to grow rapidly, many new players are expected to grow in this area. In 2015 the global market of manufacturing civilian drones was valued at $1.4bn, based on revenues of the biggest commercial drone producers.

In the recreational and commercial UAV industry, Parrot, DJI, 3D Robotics and Aeryon are some of the biggest suppliers; however, they face fierce competition from other manufacturers of high-end UAVs: Ehang, Walkera, Squadrone System, Xiro and Yuneec, as well as producers of low-end drones such as Cheerson, Syma, Hubsan, Blade, Hobbico and JJRC. It is also worth noting that some of the most important players in the military UAV sector, such as AeroVironment, BAE Systems, Elbit, Israel Aerospace Industries and Lockheed Martin, are also entering the commercial market by producing UAVs purely for business use.

The most popular manufacturers of commercial UAVs

DJI

The emerging industry of commercial UAVs already has a few key players trying to dominate this space. The best-known and undoubtedly the biggest manufacturer in terms of number of drones sold is DJI Innovations. DJI was founded in 2006 in Shenzhen, China, and from the beginning it has focused on delivering high-end, ready-to-fly UAVs for both commercial and recreational purposes. In the last three years DJI's revenue CAGR was 97.4%, fuelled by the release of models from the Phantom series, with the Phantom 3 being the most popular drone in the world today. The popularity of those series was driven by their ability to shoot stabilised aerial video and their unique design, while remaining affordable for recreational users. DJI's products are mostly used for aerial photography and commercial applications, such as: fire scene inspections, real estate surveys and 3-D mapping of landscapes. DJI also recently launched an octocopter, the DJI Agras MG-1, designed specifically for use in agriculture.

3D Robotics

3D Robotics' headquarters are located in Berkeley, California. It produces UAVs in Tijuana, Mexico, and its engineering department is based in San Diego. 3D's best-selling product is the Iris Plus, and it released the Solo, a semi-autonomous UAV, in late 2015, which has been very well received by drone enthusiasts. This model is designed with computer-assisted smart shots and push-button flight to get professional aerial photos and videos. The company's drones are used in agriculture, infrastructure, surveying, and mapping. The company has received equity funding of $99 million from various investors for commercial and consumer drone deployment.[25]

SenseFly/Parrot

Founded in 2009, SenseFly is a spin-off of the Swiss Federal Institute of Technology (EPFL). The company makes lightweight,safe, user-friendly fixed-wing drones used in agriculture, surveying, geographic information systems (GIS), mining, industrial inspection and data collection. SenseFly's most popular product is the eBee, a sensor-based commercial drone capable of various applications such as precision farming (eBee AG) or monitoring quarries and mines (eBee RTK). Since 2012, 62% of the company belongs to Parrot, a French manufacturer of recreational drones and wireless devices for mobile phones and cars (e.g. Bluetooth hands-free kits).[26] Parrot seized a large part of the recreational UAV market with its AR.drone series and their successor, the Bebop Drone, a mid-range drone with an integrated FPV (First-Person-View) system controlled by a smartphone or tablet. In 2015, drones became the company's biggest sellers, generating $199.15 million (56% of Parrot's revenue).[27] The company achieved a 121% year on year increase in revenue from drones.

Aeryon

Aeryon is a Canadian company based in Waterloo, Ontario, and founded in 2007. The company develops, designs and manufactures advanced micro UAVs. It serves civilian businesses, governments and military customers in Canada and across the world. The company has secured a $60 million investment from a global growth equity firm, Summit Partners. Its most popular product, the Aeryon SkyRanger, is designed to be a platform for both civilian and military operations. Aeryon is now partnering with Microsoft on its new Microsoft Advanced Patrol Platform (MAPP) vehicle; Microsoft has chosen the SkyRanger to demonstrate aerial image and data capture for MAPP. The most common uses of the SkyRanger are surveying, mapping and public safety monitoring. The company is a classic example of a manufacturer integrating both civilian and military applications in its range of products and services.

[25] Crunchbase, Available at 03.10.2016
[26] Parrot Annual Report 2012
[27] Parrot Annual Report 2015

Drivers of supply

In 2015, there were more than 200 commercial UAV manufacturers globally.[28] The growing demand for drones for commercial and recreational applications is undeniable, and it is shaping the drone manufacturing landscape. Ten years ago, companies that made UAVs mostly produced exclusively for military purposes. Today they make UAVs specially designed for commercial purposes such as public safety, wildlife and environmental monitoring, and infrastructure management. The reasons behind this transformation are not only growing interest in drones for commercial use but also rapid technological innovation in several key areas.

Advances in three major technology areas (miniaturisation, microelectronics & sensors, and power systems) have made it possible to produce more complex and versatile UAVs. Drones rely on electronics for navigation and remote or autonomous operations. Inertial devices such as the IMU (Inertial Measurement Unit) have now become extremely reliable, accurate, and affordable due to continual development. Furthermore, the miniaturization of electronics and their rapid innovation has played an important role in reducing a vehicle's overall weight and size. It has improved flexibility, portability, and overall survivability in the field. And of course, flights wouldn't be possible without a power system for the vehicle's engines and electronic systems. Thanks to the development of lithium-ion and lithium polymer battery capacities, manufacturers have been able to create UAVs with longer range.

Commercial off-the-shelf (COTS) components are playing an increasing role in the supply of UAVs because of rapid design and innovation in this field. COTS refers to all types of standardised products such as cameras, gimbals, sensors and microprocessors built and delivered by third party vendors to a UAV creator. The growing utilisation of COTS components produced by specialised suppliers helps push down the cost of production, while enhancing computing capability and making compact design possible.

Types of drones

UAVs can be divided into three categories based on their drive mechanisms: multirotor, fixed-wing or a hybrid version, the tilt-wing. Multirotor UAVs are controlled by varying rotor thrust and torque. They are capable of hovering in a fixed position and flying in any direction, which means they can carry out manoeuvres more quickly and efficiently than fixed-wing UAVs. They can also get airborne without a runway. Multirotor UAVs may have four, six or eight rotors. A greater number (6 or 8) enables the drone to stay in the air even if one of the engines fails. On the other hand, multirotor drones have slower maximum speeds, and shorter flight times, than fixed wing drones. In 2015, rotary-wing drones dominated the market, with a 77% share.[29]

The second type of UAV, fixed-wing drones, have a simpler structure, similar to an airplane. They have longer flight duration, at higher speeds, and thus can be used to survey larger areas. They are able to carry heavier payloads, for longer distances, by using less power. As a result, they can carry bigger and better sensors and cameras. In contrast to multirotor drones, fixed-wing drones cannot hover, since they require air moving over their wings to generate lift, and so must stay in constant forward motion. They also need a runway or launcher for taking off and landing. Those features make them unfit for work where they must operate in smaller areas, such as inspections or surveillance.

The hybrid model (tilt-wing) is a drone able to hover as needed, but which can also transition to faster and more efficient fixed-wing flight. It captures some of the best features of the other two types: it can fly longer distances but doesn't need a runway; it can hover, and also achieve higher flight speed. The number of tilt-wing drones on the market is low at the moment, but companies including Amazon are working on new models, particularly for transport applications.

[28] Global Small UAV Market 2016-2020; Technavio, p.18
[29] Global Commercial-Purpose Drones Market 2015-2019; Technavio

3.3 Research and Development

The drone sector is on the verge of becoming a mass industry, with enormous potential to disrupt various types of business. But unceasing work on research and product development must be done in order to fuel further growth of commercial applications. There are three main groups researching and developing new technologies connected to drones: universities, start-ups & large enterprises. All of them focus on several key research topics.

Artificial intelligence

The most promising R&D activities in the field of drones are those connected with incorporating artificial intelligence into UAVs, especially the use of machine learning software. AI software uses an algorithm that learns how to solve complex tasks by using a form of training similar to the way the human brain operates. Research teams from ETH University, the University of Sheffield and the University of Sussex are focusing on implementing solutions based on incorporating AI into drones to boost their operational capabilities. One of the most recent pieces of AI research related to drones was a project conducted by a team of scientists from ETH University in Zurich. The objective was to investigate and develop methods and techniques for robotic aerial construction. The team from ETH managed to build a suspension bridge using an autonomous swarm of UAVs, which allowed the team to cross various types of obstacles.
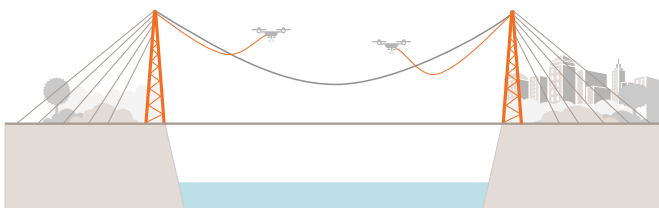
Drone detection and avoidance technology

One of the most important areas being investigated in R&D is certainly that of ensuring safety by developing see-and-avoid technology, and integrating it with existing air traffic control systems. The proposed solutions also have to be aligned with each country's specific UAV regulations. There are several companies trying to solve this issue, for example Airware

and PixiePath. Both provide autonomous flight control systems and ground control software, helping businesses to safely operate a variety of drone aircraft. Furthermore, leading drone manufacturers are incorporating autonomous obstacle detection systems into their newest products.

Control and communications

Another key challenge that drone manufacturers face today is enhancing the ability to control drones autonomously, and allowing them to communicate instantly with other airborne vehicles over long distances. Intel is making a big bet on the future of drones by investing in Airware and Yuneec (a UAV manufacturer), acquiring Ascending Technologies (a drone maker specialising in collision-avoidance technology) and a partnership with AT&T. Intel is working with AT&T to understand how LTE networks (4G) can enable drone business applications. 4G networks can be used to control UAVs as well as transfer information, images and videos collected during flights. Continued challenges include high energy consumption and the limited transmission range of LTE networks.

Image processing

Other rapidly developing solutions lie in the areas of aerial data processing and analytics. Such research is primarily focused on solving two main challenges: precision of deliverable products and reducing processing time. A typical example is Pix4D and its solution for producing flexible, continuous, on-demand surveys and 3D mapping. This product converts thousands of aerial and oblique images taken by UAVs into geo-referenced 2D orthomosaics, 3D surface models and point clouds. Pix4D is a spin-off of EPFL (the Swiss Federal Institute of Technology), and the team continues collaborating with academic scientists to further improve its deliverables.

Battery capacity

Battery weight is a major limitation on a drone's flight time, and thus a key challenge for manufacturers. The most common drone battery is the lithium-ion polymer (LiPo) type, which allows for 40-50 minutes of flight. Constraints of LiPo batteries include limited capacity, low potential to increase performance and susceptibility to changes in ambient temperature, which affects durability. To overcome those challenges, researchers are looking for new types of batteries. In late April 2015 Kokam, a South Korean battery maker, announced a product dedicated to drones with energy density around 50% higher than the typical UAV battery. Research also continues into new types of power source such as hydrogen fuel cells.

We expect a rapid pace of innovation in drone technology to continue expanding the breadth of possible commercial applications

Piotr Romanowski – CEE Advisory Leader

Drone technology is only now entering commercial use beyond recreational or experimental applications. This is driven by a combination of technological development, creation of regulatory frameworks and growing awareness and readiness of companies to adopt drone powered solutions in their daily operations. The range of potential use cases across industries is broad and their economics compelling.

There is no doubt that the learnings from the first commercial applications of the technology will spark even faster progress in expanding their range and adapting functionalities for each of the specific use cases. As in other new technologies, progress is achieved through the combined effort of academic institutions, start-ups and large corporations.

As with every emerging technology, the drone industry will also create its winners. The largest drone producers are approaching $1bn in revenues and a number of other drone-focused companies are expected to pass the unicorn threshold (valuation of $1bn) soon. The combination

of drone technology with artificial intelligence solutions appears particularly exciting – for example, enabling drones to build various types of structures autonomously.

At PwC, we strive to stay at the forefront of innovation to remain relevant as advisors that can help our clients solve important issues in their business. Given the expected scale and breadth of the drone revolution, we have launched a dedicated center of excellence – PwC Drone Powered Solutions – that focuses exclusively on commercial applications of drone technology to create value for our clients. We see our main role in translating the wealth of data captured by drones into value creating business insights. To achieve this we apply recent innovations in high-performance computing, image processing and artificial intelligence, and combine it with our deep business knowledge of specific industries.

It is fascinating to see how the combination of drone technology with deep analytical capabilities is reshaping the business world.
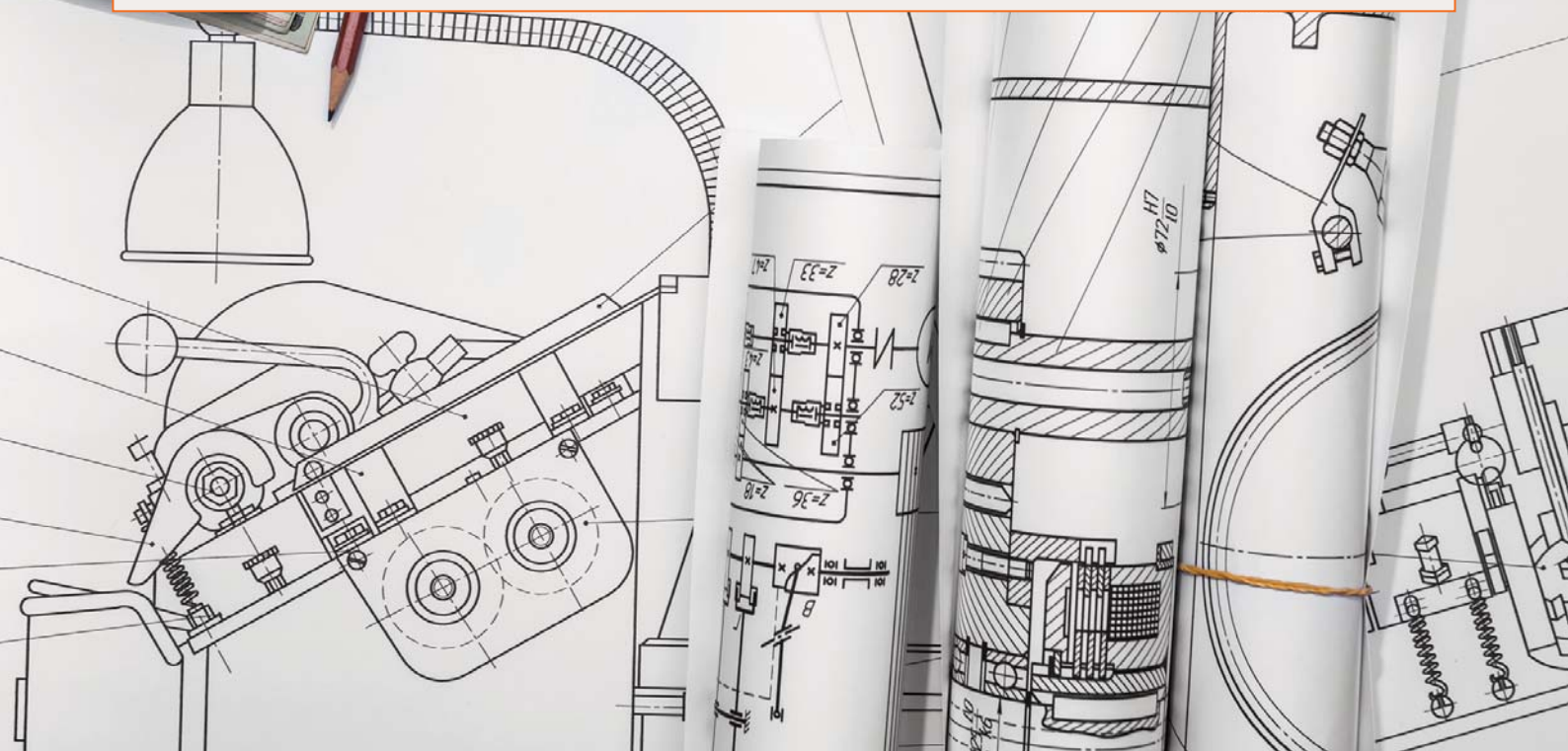
4. Who we are

Drone Powered Solutions (DPS) is PwC's first global centre of excellence focusing on the commercial use of drone technology. The team helps clients from various industries to maximise the potential offered by UAVs.

Established in Poland in early 2015, DPS is the world's first professional services consulting team dedicated to industrial and business applications of drone technology, and its location in Poland is no accident: Poland is one of the first countries worldwide to have adopted detailed laws regulating the industrial use of drones (as early as 2013).

In its short life, DPS has already worked with clients from various industries on testing applications of drone technology in their operations. We have developed end-to-end drone powered solutions for capital projects monitoring, infrastructure maintenance, insurance claims assessment and last mile transport.

Thanks to PwC's rich experience in strategic planning and operational transformation, DPS helps companies not only to select the appropriate solution but also to implement it in their daily operations. The scope of our competences includes strategy, process transformation, IT customisation, image data processing and analytics. These competencies enable DPS to deliver end-to-end services to clients. DPS has also developed its own proprietary delivery software, the PwC Geospatial.App, allowing for integration, presentation and management of comprehensive data sets. Thanks to its wide spectrum of functionalities, the tool enables easy, instant decision making.

The DPS team already has unique experience, proprietary solutions and methodologies, but we are not stopping here. We are constantly focused on developing new ideas and technology (e.g. machine learning), to efficiently support clients in the new drone reality.

Drone Powered Solution (DPS) – the world's first professional services consulting team dedicated to industrial and business applications of drone technology
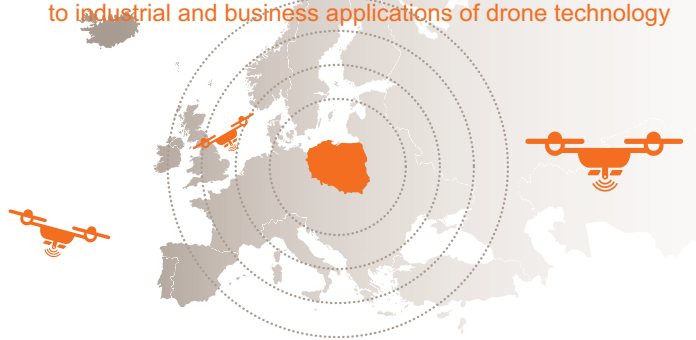
Wide scope of competences:
• visual data processing and analytics
• process transformation
• IT customization
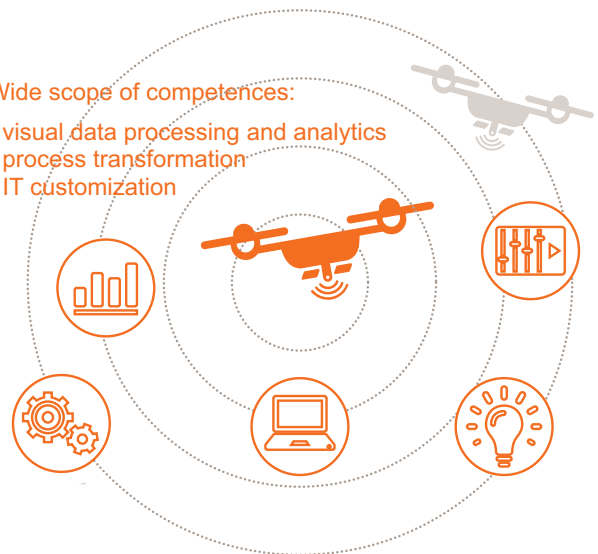
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