Connected Drones

A New Perspective On The Digital Economy

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Introduction

Today, the pervasive deployment of sensors provides a digital view of previously analog tasks, processes, and operations. The vast amounts of data produced by these sensors, combined with virtually limitless computing power, is transforming efficiency and creating new competitive frontiers.

Companies are shifting the value proposition from traditional hardware and equipment offerings, to insights based on data, analytics and advanced algorithms. Digital technology allows information to be communicated perfectly, over long distance, to huge numbers of users, at very low incremental cost. The internet of things enables companies to apply digital technology to improve the scalability of their operations, communicate simultaneously with separate communities, and combine previously distinct processes to transform existing business models and produce new opportunities.

Adapting to ubiquitous digital connectivity is now essential to competitiveness in most sectors of our economy. We have examined transformation across dozens of industries and companies – both traditional and born-digital. We have talked to hundreds of executives in our effort to understand how traditional modes of innovation and operational execution are changing. We have seen that digital transformation is no traditional disruption scenario: the paradigm is not displacement and replacement but connectivity and recombination. Transactions are being digitized, data is being generated and analyzed in new ways, and previously discrete objects, people, and activities are being connected. Incumbents can use their existing assets, dramatically increase their value, and defend against (or partner with) entrants.

The opportunity emerging around UAS technology highlights many of these principles. As with many new technology innovations, early use cases focused on UAS augmentation of human skills in traditionally labor-intensive applications: crop scouting or utility infrastructure inspection are typical examples where significant efficiency gains or safety improvements can be rapidly achieved through deployment of UAS-based video capture platforms.

Over time, UAS technology combined with innovation in other emerging areas like AI, computer vision, and remote sensing will enable new levels of automation and new types of analytic solutions that will have transformative impact across these verticals. For example, rather than live visual inspection of potential rotor blade damage on a wind turbine by a trained human UAS operator, imagine an autonomous UAS fleet deployed across a wind farm to continuously capture video data, AI/ML analytics at the edge to automate identification and classification of known damage patterns, and cloud based optimization solutions that predict potential turbine output losses in megawatts per year based on historical wind farm data and aggregate industry benchmarks.

In this white paper we explore the market opportunities for large scale UAS adoption, and the role(s) of the communication network operators in the value chain. We will examine the emerging ecosystem in the UAS market, and the predicted growth of the different opportunity areas. The connectivity provided by network operators is a foundational element of the UAS ecosystem. In order to support more complex use cases and occupy key roles in the ecosystem, operators can expand up the tech stack to capture value in data, analytics and platform offerings. Achieving large numbers of connected UASs across multiple industries will take effort in safety and regulation implementation; we present some of the key considerations that apply to developing these areas. Finally, in addition to a review of connectivity developments and requirements, we consider the benefits and drivers of adoption for UASs, diving deep on the value created by specific application use cases.

Karim R. Lakhani, Harvard Business School

Karim R. Lakhani is Professor of Business Administration in the Technology and Operation Management Unit at the Harvard Business School, where he is also the faculty co-founder of the Harvard Business School Digital Initiative and the Principal Investigator of Harvard's Crowd Innovation Lab. Professor Lakhani specializes in technology management and innovation, examining the digital transformation of companies and industries. His research has shown the importance of data and analytics as drivers of business and operating model transformation and source of competitive advantage. He regularly works with Keystone Strategy to develop digital transformation strategies for firms across broad industry contexts and has partnered with Huawei to study the challenges facing the telecommunications sector specifically and develop an innovation-based approach for driving growth.

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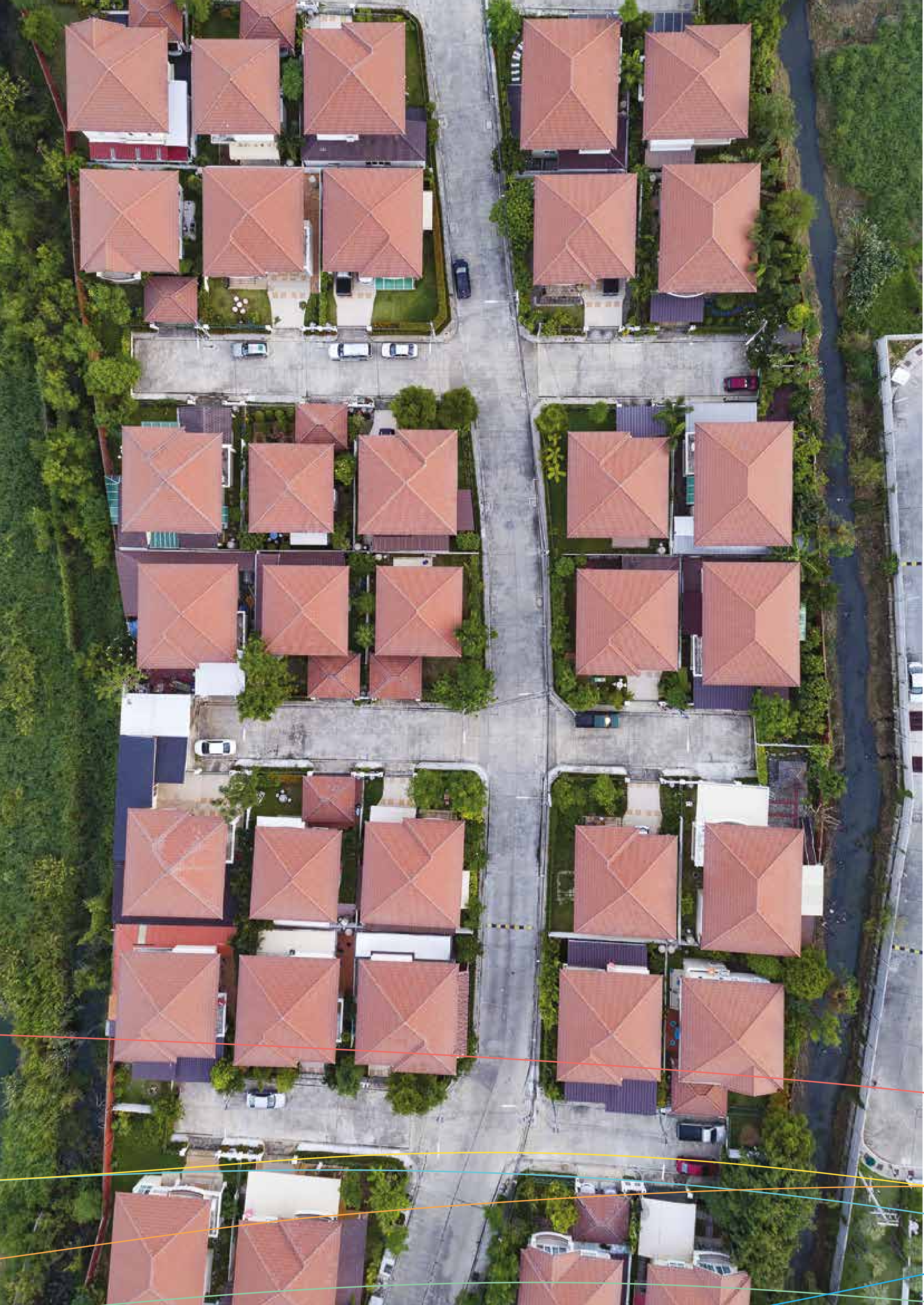

Market Overview

The global market for Unmanned Aircraft Systems (UAS) has grown significantly over the last decade, such that UASs are now established as viable delivery platforms for a diverse set of consumer, commercial and governmental applications.

> **There is an opportunity for the Communication network operators to be the trusted partner for secure communications and identity (based on global standards) to national regulators for UAS Traffic Management (UTM) initiatives.**

HUAWEI SPO LAB

Rapid technological development on the hardware side, initially driven by military applications, has resulted in robust and reliable aerial platforms now addressing a growing number of civil and industrial use cases, across a diverse set of verticals including agriculture, oil & gas, logistics, and many others.

A number of challenges still constrain widespread adoption of UAS technology in these commercial contexts, however. National aviation regulators must navigate supporting the industries that have emerged around nascent UAS technology, whilst at the same time assuring public safety and security as unmanned and manned vehicles share the skies. The public perception of UAS is an associated concern, as an increasing number of autonomous vehicles occupy the lower airspace surrounding densely populated towns and cities.

There is an opportunity for the Communication network operators to be the trusted partner for secure communications and identity (based on global standards) to national regulators for UAS Traffic Management (UTM) initiatives. Starting with telemetry and evolving towards control to enable Beyond Visual Line of Sight (BVLOS) operations is important to scale up the benefits from 'connected' UASs across different industries. Similarly, new perspectives on risk are influencing the legislative approach to liability and insurance, and driving mandatory certification and training for companies that wish to commercially exploit emerging UAS technology.

There are also broader ecosystem challenges that need to be addressed. UAS provides government agencies with a new set of tools to assure public safety and security. They also offer vertical solutions to secure assets (Oil & Gas), or increase productivity (Agricultural). The ability to securely control, collect, and analyze large datasets gathered from multiple autonomous, and potentially collaborative, aerial vehicles is fundamental to these endeavors. To fully achieve the promise and potential of UAS applications, the challenges of secure communications and assured identity will need to be addressed. Another challenge is winning the hearts and minds of a skeptical public, who have yet to be convinced of the value of UAS occupying the skies above their cities as they go about their everyday activities.

Martin Creaner, Huawei SPO Lab
Author of Delivering the Digital Economy

Market Landscape

Huawei's Wireless X Labs and SPO Lab divisions have engaged with our partner Keystone Strategy to analyze the UAS market, and the potential value capture mechanisms that may be employed by ecosystem companies. Keystone forecast the UAS technology market in 5+ years time at $12 - 33 billion in the U.S. and $41 – 114 billion globally.

The Huawei and Keystone approach identified and estimated value capture mechanisms across the nine layers of the UAS technology stack (as shown in the technology stack below), from connectivity to IaaS and Analytics.

> **"Value capture across the UAS technology stack will continue to accelerate, with profit pools likely emerging in the analytics and data platform domains."**

Keystone will organize the ecosystem around an offering / technology stack perspective to identify key platform business opportunities

Tech Stack	Elements	Technology Ecosystem / Relevant Players	
Insurance & Other	• Insurance • Training • Operations Mgmt.	Insurance: UAV Protect, AIG; Training: DARTDRONES; Operations Management: SkyWard, Kittyhawk	Full Stack Offerings Cross Vertical: PrecisionHawk, kespry, SkySpecs, Flyver
Drone Operator Marketplace	• Operators	Drone Operator Marketplace: Drone Base, airstoc, ArcadiaSky	
Analytics	• Analytics	Analytics: AgPixel, Agribotix, Airware, skyglyph	Real Estate: RectrixAS
Data Platform	• Processing • Storage • Collaboration	Data Processing & Storage: DroneDeploy, SKYCATCH, propeller	
IaaS	• IaaS	IaaS: amazon web services, Microsoft Azure, BT, Google Cloud Platform	Oil & Gas: Sky-Futures
Flight Planning / Management	• UTM • ATM • Drone Operations • OS / Autopilot	UTM: AIRMAP, Botlink; ATM; Drone Operations: SkyWard, Kittyhawk; OS / Autopilot: NAVSTIK LABS, PERCEPTO, SKYDIO	Agriculture: GAMAYA
Hardware	• Aircraft • On-board HW • Docking Stations • Ground Sensors	Aircraft: dji, YUNEEC; On-Board Hardware: swift, Quanergy, Intel RealSense, 3DR; Docking Stations: HIVE, SWARMX; Ground Sensors: DroneShield	Construction: Red Bird, DroneView
Connectivity	• Cellular Network • Private Network	Public Network: verizon, at&t, Globalstar, iridium, T-Mobile, Sprint; Private Network: ONRAMP, Silver Spring, CISCO, SEMTECH, SIGFOX, LinkLabs, nwave	

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Figure 1

Examples of value capture calculations include estimations of data storage / processing fees, pilot salaries from UAS data collection, autopilot software sales, UAS sales, and gains in connectivity from data transferred in flight. To create this market model, Keystone and Huawei accumulated research from 30+ secondary sources (e.g. FAA permit data, sizing reports), as well as a database of 130+ UAS companies and offerings, to define 50+ near term metrics and 20+ growth rates providing a short term and 5+ year projection for the U.S. and global UAS market.

Keystone and Huawei also conducted interviews with experts across the UAS industry – founders and technology officers at UAS startups – who provided feedback and validation for the market sizing estimates and methodology. Through this value capture exercise, Keystone has identified a large opportunity in provision of UAS data platforms, as well as a significant emerging IaaS workload. Huawei and Keystone validated this future state opportunity through additional interviews with UAS experts to capture their opinions on the future state of the UAS market, and develop a perspective on the ecosystem future state for each individual tech stack layer.

A significant amount of the market (25%+) is currently focused on data platform and analytics. As illustrated in the diagram below, this is forecasted to grow to 37% of the global market, with increasing value from drone data storage and processing services, and vertical-specific analytics.

Global Drone Market Size Ranges, 5+ Year Projection

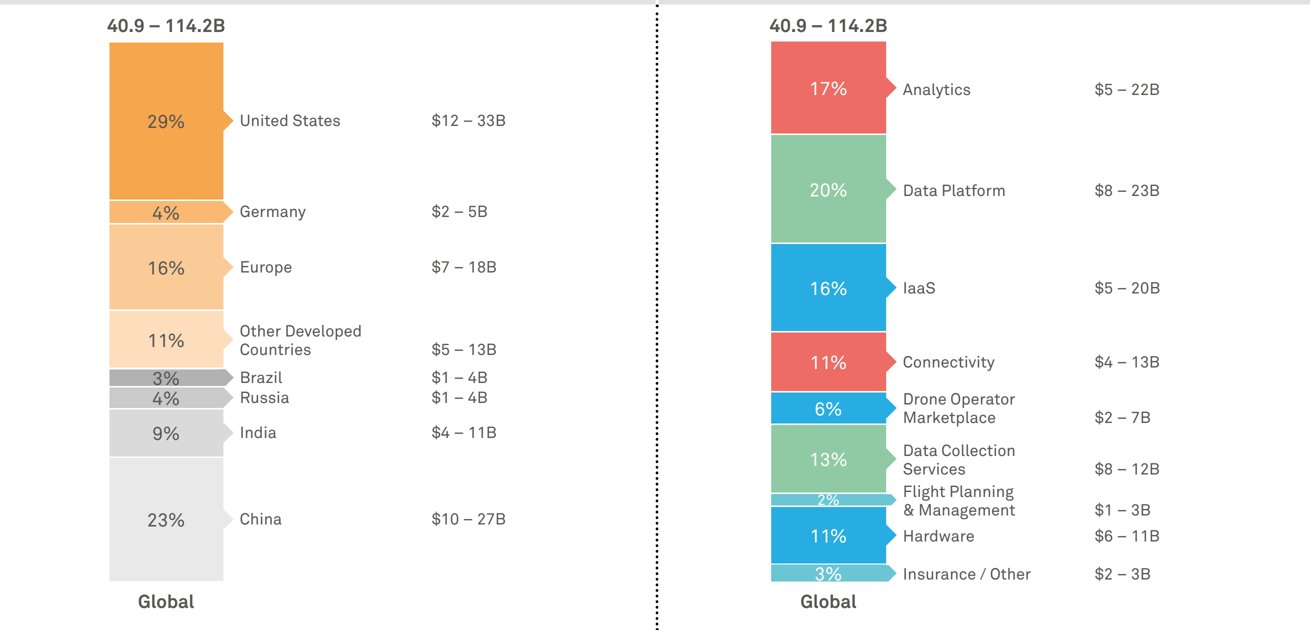
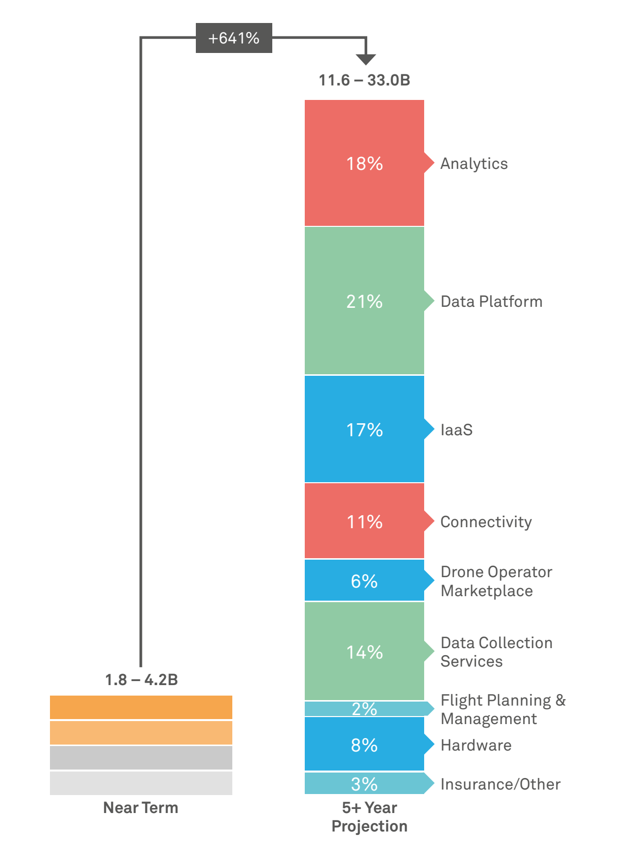


Figure 2

US UAS technology stack is estimated to grow 7x in 5+ years

Drone Stack, Near Term / 5 Year Projection



Stack Level	Near Term Size	5+ Year Projection
Overall	$1.8 – 4.2B	$11.6 – 33.0B
Analytics	$36 – 178M	$1.3 – 6.6B
Data Platform	$382 – 1,118M	$2.4 – 6.9B
IaaS	$247 – 1,027M	$1.6 – 5.9B
Connectivity	$12 – 43M	$1.1 – 3.9B
Drone Operator Marketplace	$19 – 96M	$0.5 – 2.0B
Data Collection Services	$535 – 801M	$2.5 – 3.7B
Flight Planning / Management	$10 – 27M	$0.2 – 0.7B
Hardware	$473 – 794M	$1.4 – 2.4B
Insurance / Office	$73 – 149M	$0.5 – 1.0B

Figure 3

Current gains from data transfer connectivity are small, but forecast to grow to 11% of the $41-114 billion global UAS market in 5 years' time, driven by a higher share of UAS leveraging cellular connectivity for data transfer and real time connectivity. Meanwhile, hardware will shift to occupy a smaller portion of the profit pool, as UAS hardware becomes increasingly commoditized. Lower cost UAS fleets with bundled autopilot capabilities and limited specialization will drive mass commercial UAS adoption.

Delving deeper, Huawei and Keystone assessed an array of application use cases across a broad set of verticals, a snapshot of which are presented in the table below.

Vertical	Use Cases
Agriculture	Continuous Crop Monitoring
	Nutrient Management / VRT Optimization
	Targeted Pesticide Applications
	Irrigation Management Efficiency
	Cattle Herding
Construction / Infrastructure	Construction Site Management
	Railway Safety / Inspection
	Bridge Maintenance / Inspection
Disaster Management	Flash Flood Recovery
	Lifeguard Assistance
	Search and Rescue
	Wildfire Mapping / Fighting
	Structural Integrity / Assessment
	High Rise Building Fire Fighting
	CBRNE Disaster Tracking
	Disaster Reconnaissance & Management
Energy / Utilities	Wind Turbine Inspection
	Power Line / Poles Surveys
	Substation Inspection
	Hydroelectric Facilities Inspection
	Risk Monitoring
Insurance	Risk Assessment
	Claim Adjustment / Validation
	Fraud Prevention
Media / Entertainment	Cinematography
	Journalism
	Targeted Ads / Promotional Vehicles
	Drone Racing / Entertainment
Mining	Open Cast Mine Planning
	Mining Exploration / Maintenance
Oil & Gas	Environmental Monitoring
	3D Underground Mapping
	Gas Flare Inspection
	Pipeline Leak Detection / Inspection
	Oil Spill Monitoring
	Oil Platform Inspection
Security	Aerial Photography
	Border Control
	Highway Traffic Surveillance
	Missing Persons Facial Recognition
	Law Enforcement
	Critical Site Monitoring
	Intruder Detection
Telecom Infrastructure	Infrastructure Inspection
	Infrastructure Maintenance / Optimization
	Infrastructure Expansion
Transport / Logistics	First Aid Delivery / Medical Logistics
	Organ Transplant Delivery
	Parcel Delivery
	Shipping Freight Delivery
	Food Delivery
Weather / Environment	Wildlife Conservation
	Climate Change Monitoring
	Shipping Emission Monitoring
	Reforestation
	Weather Monitoring
	Environmental Monitoring

Figure 4

Application use-cases may be segmented into near term opportunities that can be targeted today, as well as longer term opportunities and the evolution of near term opportunities. However, nearly all of the applications assessed present an opportunity for network providers to offer connectivity solutions for commercial UAS operations.

Analysis of the global UAS opportunity values the potential market at over $40.9 – 114.5 billion

Figure 5

Vertical prioritisation by Keystone and Huawei considering value capture opportunity and Communication network operators control points

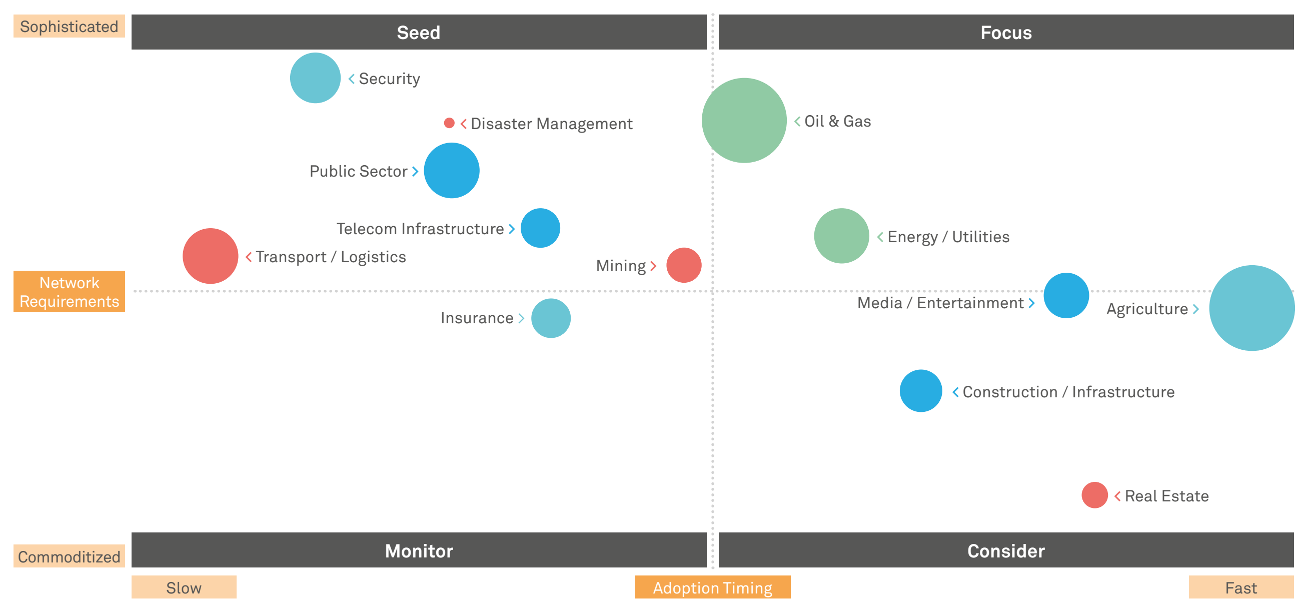


Figure 6

Once connectivity is established, opportunities for incremental revenue subsequently open up at the IaaS, Data Platform and Analytics layers of the stack. These layers of the stack become more critical as UAS technology and regulation evolve. More complex application use cases will require autonomous UAS operations, perhaps involving multiple aerial vehicles interworking with other land-based robotic units. These types of application use cases will demand advanced real-time analytics, and require massive data volumes to be transferred securely, stored and inspected.

Unmanned Aircraft System Traffic Management

One of the primary concerns occupying the minds of regulators, ecosystem companies and the public at large is how to manage the huge number of aerial vehicles that will jostle for the airspace above towns and cities, particularly as more commercial applications are brought to market.

Aspects such as vehicle airworthiness, certification, operator training, registration, insurance and privacy are top of mind as national regulators and civilian populations adapt to dense UAS operations above their parks, schools, workplaces and properties.

Unmanned aerial vehicle operations currently generally take place at low altitudes within airspace that is presently uncontrolled. However, this airspace is also heavily used for all manner of existing civil aviation activities, contains valuable infrastructure and is subject to transient conditions. General aviators within low-altitude airspace typically operate under Visual Flight Rules (VFR), as depicted in the diagram below. Under VFR, the onus is on each aviator to maintain separation from other aircraft and obstacles through constant observation of the vicinity and other users of the airspace.

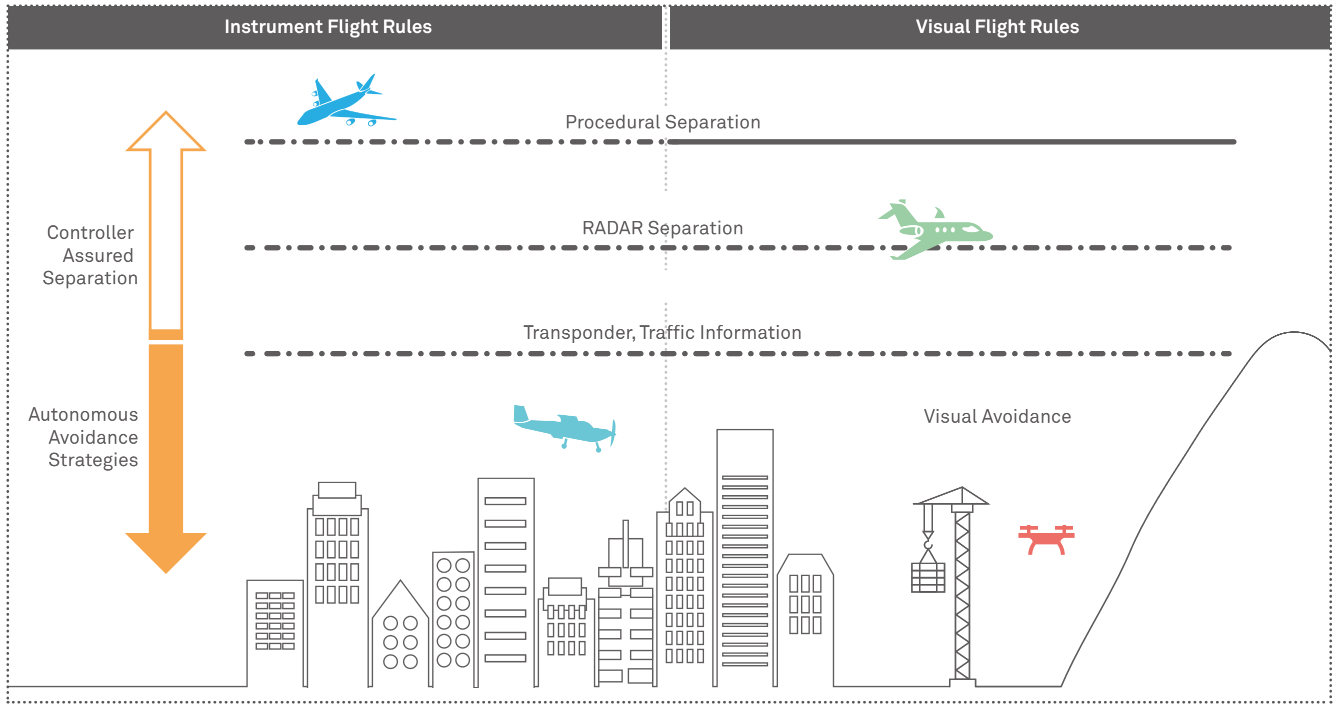


Figure 7

We have already witnessed incidents that demonstrate how human aviators struggle to cope when very small and fast moving objects occupy the same airspace. Visual separation techniques quickly become infeasible; if humans cannot see and predict the movement of other vehicles and objects in sufficient time to react, then it is apparent than observation is no longer a viable technique to maintain separation.

Even if there are no manned airframes and human aviators involved, there are significant risks associated with unmanned aerial vehicle activities within unclassified airspace. The potential for a bird-strike, a collision with a temporary fixture or another unmanned vehicle are key concerns for national airspace regulators. Collision avoidance systems can help protect unmanned aircraft, but they are not designed to deal with dense traffic patterns and handle the movements of multiple other airframes and objects within the vicinity.

A new paradigm is required to bring order to activities within low-altitude and unclassified airspace; a number of different organizations are discussing how we address the UTM challenge. See figure 7 for detail on the task facing regulatory bodies, and the action needed for a comprehensive UTM system.

Partner Perspective

DFS Deutsche Flugsicherung

> There are a number of organizations that are well positioned to address the UTM challenge, namely communication network operators and ANSPs, and, at best, both in collaboration

Ralf Heidger, DFS

CAAs and ANSPs

In some countries civil aviation authorities (CAAs) and air navigation service providers (ANSPs) are one body, such as the Federal Aviation Authority in the US. In many European countries these are separate entities, like in the UK (CAA and NATS) and Germany (BMVI plus LBA plus LLBs and DFS). Where they are separate bodies, CAAs address regulation and policy making; ANSPs address operational and technical services and infrastructure. Both entities must respond to the innovation driven by the UAS market, each in its respective role. ANSPs have a mandate to ensure air traffic safety. As a result, they are typically the first body to respond to UAS activities, and lead the push for CAAs to develop policies in response to the UAS activities.

UTM, ATM extension

The high growth rate in UASs, and emerging ecosystems around new commercial applications, affect all layers of airspace. The airspace layers are referred to according to their altitude, from Very Low Level (VLL), to controlled airspace, and Very High Level (VHL). ANSPs must ensure safe and fair integration of UAS in each of these layers. In controlled airspace and VHL, UASs are covered under the existing air traffic management (ATM) system and operations.

In VLL airspace, a new system is needed to manage UAS traffic, referred to as 'UTM', or UAS traffic management system. Under existing ATM regulations, all aircraft have to carry a transponder, demonstrate airworthiness, and follow certain procedures. UASs are similar to an aircraft in some regards, but operate with specific performance characteristics and properties. The International Civil Aviation Organization (ICAO) bears responsibility for extending the current set of procedures to incorporate UASs.

Safe and fair integration

In VLL airspace, where most UAS operations are expected to take place, the challenge is more complicated than in controlled airspace and VHL where ATM applies. A range of measures should be applied to integrate UASs fairly and safely:

- Regulative measures such as a requirement for labelling and identification, including electronic identification for cases where a physical label cannot be observed
- The registration of UASs and pilots or operators in a standardized national database
- The requirement of pilot qualification, preferably proportional to the risk of operations that are performed
- The requirement on the UAS operator or pilot to comply with risk-proportional safety measures, for example when operating the UAS beyond visual line of sight
- The requirement to submit missions for approval along with supporting safety documents (qualification, experience, UAS equipment with safety features, checklists, maintenance proofs, presence of quality assurance procedures, etc.)
- Requirement for mission validation and approval by the UTM, including validation against no-fly zones and restricted areas
- In-flight monitoring of the UAS to observe restrictions and no-fly zones, identify nearby aircraft (manned or unmanned), and generation of suitable warning to the pilot or operator in case of violation or emergency
- Structure VLL airspace for integration of UASs, and enhanced controlled airspace structures for UASs.

UTM systems are to be built on top of registration databases, need to implement the mentioned workflows and have to locate and track manned and unmanned aircraft in VLL.

Furthermore, they need accurate map data, weather information and forecast, and elaborate sensor tracking and flightplan processing. These capabilities need to fit in suitable airspace structures, following methods of airspace design. These are all predominant features of existing ATM systems.

With respect to technology and operations, ANSPs 'are in a pole position' to implement such systems and services. However, VLL surveillance does not exist today. Aircraft in VLL maneuver freely with responsibility to follow ICAO rules. To build up surveillance, GPS and mobile telecommunications are key, thus making communication network operators a natural partner. Surveillance in VLL can be established through a device using GPS for positioning (either attached or integrated on-board), and a mobile network to communicate the GPS position. Similar technology could be applied for manned aircraft flying according to VFR rules in VLL, e.g. carry-on-devices, FLARM or ADS-B, depending on what can achieve airworthiness.

UTM services will affect a broader range of stakeholders than ATM. These services will interface with more systems than ATM, and the payment principles will be different from current ATM schemes. SaaS and user pay principles will be key in the new arrangements. Self-governance, in place of air traffic controllers, will be the paradigm in UTM. Classical controller tasks will be limited to specific critical areas, e.g. around airports.

Beyond ATM stakeholders such as pilots, operators and controllers, police, community and approval authorities will play a key role in UTM; not only in the workflows, but also in contributing map data and rule sets with temporary zones, obstacles, events to be protected, etc. UTM will address and provide greater situational awareness, not only to the UAS pilots, but also to operation centres, airports, law enforcement, and pilots of manned aircraft. To serve this large, diverse group of parties, UTM should be scalable, web-based, support mobile applications, and leverage the scalability of cloud services.

UTM will interact and draw information from manifold adjacent systems:

- Map and GIS systems
- Weather data sources
- ATM systems for flight-plan and track exchange
- Operator systems
- Devices on and in the UAS itself
- The UAS remote pilot system
- Various types of human-machine interface clients.

Building this web of interconnected systems will take considerable effort, with the current state limited by factors such as the availability of detailed, accurate, recent map data, coverage of mobile communication, and means of redundancy. It is important to design a roadmap for full UTM implementation and integration, with the interacting layers built incrementally and connectedly. This approach is proposed and detailed in the U-Space blueprint of the European Commission.

> The upcoming UAS market represents another chance to use mobile networks to exploit the full potential of UAS based applications for the benefit in a multitude of use cases

Andreas Frisch, Deutsche Telekom AG

Communication network operators enabling UAS operations

Major contribution of mobile networks

Cellular mobile networks have already been proven as a major enabler in many industry verticals. The emerging UAS market represents an opportunity to use mobile networks to exploit the full potential of UAS based applications for the benefit of multiple use cases.

For good reason, mobile networks have already been considered for data communication needs in the context of UAS operations. Given their far extended aerial reach, their worldwide standardized technology, highly developed capacity and capabilities and established procedures for users, cellular networks are candidates for playing a significant part in setting up a controlled and reliable system for UAS operation.

In principle, there are three major needs for connecting UASs by means of a communications link:

Making UASs visible

Currently, most UASs are too small, fly too low, and are built from material not suited for radar reflection to be detected by air traffic control using existing technologies and systems. An alternative would be to make the UAS communicate basic data such as identity, position and brief status information by means of a continuous data link between the UAS and a ground station. Although this requires additional security to ensure data is correct, the UAS becomes visible to air traffic management.

Automated operation beyond visible line of sight (BVLOS)

In particular, for professional UAS use, the development of automated operations and/or use beyond the pilot's visible line of sight represent major factors in the efficient use of UASs in commercial operations. However, automated operation does not mean uncontrolled operation by merely relying on the UASs on-board system. Even in automated and/or BVLOS operation, full control by the operator has to be guaranteed by transferring all relevant flight and mission data to the operator and vice versa, thereby allowing the operator to step in and issue new commands during each phase of the flight. While current UAS remote control radio systems are based on specific radio links or WLAN with limited reach, mobile networks can deliver connectivity over long distances. In principle, worldwide or cross border reach is conceivable providing the UAS has mobile cellular coverage.

Payload data transmission

Some UAS use cases require an online data transmission to a ground station beyond the command and control data link. In such cases, data from sensors or video data from a camera is directly transmitted to the user to allow immediate processing and action depending on the data gathered.

For many generic applications, cellular mobile networks can provide a solution. Moreover, mobile network technologies can provide additional benefits. In particular, mobile network technologies provide a unique identity based on the SIM/eSIM and related verification process. Furthermore, location data verification is possible by using cell data to corroborate the GPS-position sent by the UAS. Finally, the use of dedicated radio spectrum ensures stable communication with the UAS compared to uncoordinated systems such as WLAN/Wi-Fi.

There is still a need for further research and development work on the use of mobile networks for UASs.

Although many aspects work in favor of the use of mobile networks for connecting UASs, further investigation is required. Currently mobile networks are designed and optimized to serve users at ground level. New and specific challenges of UASs operating as mobile terminals in airspace are expected to arise.

Coverage and capacity

Most mobile networks are currently designed to provide best coverage on terrestrial level and have been improved over time based on recognized usage requirements by the customers. In such networks, coverage in the airspace is mainly provided by side beams of antennas or reflections. Accordingly coverage in the lower airspace is not planned as it is on the terrestrial level, which makes more analysis necessary to predict coverage and related bandwidth. Furthermore, it is obvious that altitude of UAS operation is a crucial aspect for this, since terrestrial networks in current design can support terminals in the airspace only to a limited altitude.

However, since connectivity for UAS represents a new market, usage patterns as well as coverage and bandwidth demands by users, still have to be verified to set requirements towards the networks for any kind of iterations or optimizations.

Interference effects

It is well-known that a transmitter will influence other transmitters in range if they are not separated or coordinated. On ground level there is much experience in handling those effects while topography helps to limit range. Having mobile terminals in the sky with line of sight in relation to a number of surrounding cells, even kilometers away, may pose specific challenges since the signals sent out by these transmitters will affect the signal to noise ratio in all these surrounding cells.

These effects have to be thoroughly investigated and specific interference mitigation methods may have to be introduced to avoid negative impacts either for terrestrial usage or usage for a UAS connectivity and to ensure same level of mobile network performance as accustomed.

End-to-end perspective necessary

Cellular mobile networks can represent a major enabler, but they have to be integrated in the entire communication chain to achieve the far reaching objectives on the integration of UASs in the entire Air Traffic Management and enabling UASs as a safe and highly performing tool for all kind of use cases.

Starting in the device, manufacturers of UASs may have to build up expertise in integration of mobile communication modules in their devices to become part of the system. Although the modules are highly standardized there are even some requirements to meet in deployment and testing. Interaction with mobile network operators to share know-how and to ensure sound installation of module and antenna for best performance is highly recommended.

The fair and safe integration in air traffic, as outlined earlier in the document, represents a fundamental demand for connectivity of UASs. Given the benefits cellular mobile networks could offer it still has to be kept in mind that usually there is no guarantee of 100% availability, either in area coverage or operational availability. Accordingly mechanisms have to be developed in Air Traffic Management which are able to handle situations while a UAS has no connectivity via a cellular mobile network, either temporarily during operation or in a situation of operation outside the reach of an available network.

Similar to the UTM application, developers have to define requirements towards their need of mobile network resources, in particular bandwidth during all phases of operation. In particular a combination of different sensors and cameras with up to 4k video resolution, combined with request for online low latency transfer to a remote ground station represent specific challenges which have to be carefully planned to ensure full performance for the user. Clearly stated minimum demands could really help to understand the market needs and to design mobile networks according to the requests of users.

Vendors of mobile network and device technology are requested to anticipate the specific needs coming up from this new kind of operation as described above. Providing tailored solutions to overcome potential critical aspects would help to introduce soon a very powerful technological platform to boost UAS operation to its full extent.

Market Drivers

UASs offer a host of societal benefits. However, as we discussed previously, we must determine how we manage densely populated airspace, address public concerns and enable a smooth passage to commercialization for UAS operators.

Whilst public perception, regulation and UTM continue to evolve, likewise the UAS technology on offer is maturing and advancing rapidly – permitting automated UAS to carry-out more complex tasks and address an increasing number of application use cases. In this section we consider the key benefits of UAS platforms which are driving their adoption. Subsequently, we'll look at how technological advances are allowing these benefits to be realized across a range of new application use cases.

Operational Efficiencies

To date, the primary market driver for the majority of UAS application use cases has been a reduction in cost and an increase in efficiency. Emerging UAS technology enables the costs associated with traditional aerial operations to be dramatically reduced. In the majority of cases, the cost reduction is straightforward to quantify, qualify and hence a robust business case may be quickly established.

By way of example, Oil & Gas majors have demonstrated that UAS platforms can significantly reduce the costs associated with their asset lifecycle management and maintenance regime. Traditionally activities such as pipeline inspection involved high-cost helicopter or fixed-wing over flights, undertaken by highly skilled aviators who visually inspect pipeline corridors looking for evidence of intrusion or liquid chemical containment issues. The total cost per hour for inspection flights may be upwards of $3,000, however, inspections may now be undertaken by low-cost UASs, significantly reducing the costs involved. Similar savings may be realized across Oil & Gas asset management activities, such as flare inspection – see page 21 for more details.

Agriculture is another industry where huge opportunities present. Studies into the positive impacts of Precision Agriculture and UAS platforms have estimated that farmers may increase their crop yield by up to 5%, whilst also reducing their input costs by 5%. UAS technology may enable farmers to gain a better understanding of their crops through closer, more timely and more frequent inspections. Consequently, irrigation, pesticides and chemical fertilizers may be applied in a more targeted manner to address those crops that require and will benefit from the intervention. Low-cost UAS platforms help reduce the cost of inspection and chemical application, whilst also enabling farmers to continually monitor and tend to crops in a cost effective manner.

Whilst the focus presently is on the succession of manned airborne activities by unmanned vehicles, there is further potential to improve efficiencies through automation. For example, applying analytics to the video captured during a pipeline inspection overflight can automate the visual surveying. If achieved in real-time, the UAS may detect and subsequently opt to inspect defective aspects of the pipeline more closely - eliminating the costs associated with a follow-up inspection and leading to full automation of inspection activities.

Risk Reduction

One of the major concerns associated with manned aerial applications is the associated risks. Pilot training, flight duration, weather conditions and hazard restrictions are key considerations that must be taken into account when deploying a manned aircraft.

UAS technology enables us to place unmanned aircraft into situations where it is infeasible to place a human aviator due to the associated risks. We can also leverage UASs to glean greater insight in advance of human activities to help mitigate risks and reduce the time that humans spend in hazardous situations.

By way of example, utility and civil construction companies are embracing UAS technology to help mitigate the risks involved in infrastructure inspection. The vast majority of inspections rely on placing 'human eyes' on infrastructure to assess the condition of essential components and to determine if maintenance is required.

Leveraging low-cost UASs, maintenance teams can inspect infrastructure whilst keeping their feet firmly on the ground, hence eliminating risky and time consuming climbs. For example, let's consider how energy firms inspect key pylon infrastructure. Presently operators may choose to employ a helicopter inspection, or more often require a maintenance team to undertake a climb to visually inspect pylon infrastructure.

UAS enable maintenance teams to perform an initial inspection from the ground, eliminating risky climbs and reducing cost. A UAS inspection is typically quicker and requires less people than a climb, hence teams may inspect pylons at a greater frequency or with fewer dedicated personnel. If a defect is identified, the extent and impact may be assessed from the ground. A human climb may be required to resolve the issue, but before leaving the ground the maintenance team can ensure they have the replacement components, the appropriate tools and team to undertake and complete the repair.

Similar risk reduction and mitigation strategies may be employed across multiple verticals, removing humans from harsh environments or treacherous conditions and eliminating unnecessary activities.

Location, Accuracy and Precision

UAS technology may be employed to provide greater detail than current aerial surveillance solutions, hence enabling higher precision analysis and promoting accurate decision making.

Let's consider the example of an insurance assessment for a civil property as a result of storm damage, or a recent inspection of the Capitol building roofline in the USA. Traditionally this kind of activity would require human inspection involving ladders and scaffolding, a lengthy, risky and costly procedure. However, a UAS may be easily deployed and operated within centimeters of the roofline to provide a detailed assessment of the condition.
A pilot may be onsite operating the UAS whilst the survey assessor sits at their desk hundreds of miles away, directing the pilot and inspecting the images to survey the roof without them needing to leave their office.

The Agricultural industry also benefits significantly from the granular and accurate assessment provided by UAS platforms. Traditional crop inspection techniques rely on manned aircraft or satellite overflights, both of which are constrained in terms of flight frequency and the detail they can provide. Low-cost UASs provide a more detailed assessment than either of these techniques, enabling farmers to continually tend to their crops, potentially at the individual plant level rather than a granularity of square meters. Armed with a detailed assessment, farmers subsequently intervene in a timely and accurate manner, thereby reducing input costs and increasing yield by tending for crops at a far more granular level.

Failure To Communicate: Obstacles to UAS Technology Evolution

Contributed By: Sven Juerss, CEO, Microdrones GmbH

UASs, like all disruptive tech industries, must overcome shared challenges in order to drive market adoption of applications. To be commercially viable, UAS applications must be able to be deployed safely, effectively and efficiently.

UAS sensor, navigation and guidance technologies are constantly improving. Performance, size and affordability improvements continue to amaze. Unfortunately, market adoption is being choked off by a lack of adequate connectivity (networks). Networks are required to enable safe, mass use of UASs in the real world.

One of the major constraints today is connectivity to cooperative and non-cooperative members (cooperative members use trackers to reveal themselves to air traffic control; non-cooperative members do not) as well as the ability to connect with support services. When these two constraints are overcome, the industry can achieve quick upscaling of civil UAS operations.

One way of solving this could be by connecting UASs to an upscaling server or cloud service; this service could be used as a master brain for all global UAS operations related to UTM and Collision Avoidance. In such a scenario, each connected UAS would contribute data so that the whole system constantly learns and improves over time. With this in place, not every UAS would have its own 'brain' limited by payload capacity, but rather a cloud service could serve as a 'master brain'. This would enable professionals to upscale much quicker as compared to updating/upgrading every deployed UAS.

Connectivity: it's critical

No matter how good a UAS solution is in a test scenario, scalable adoption of the technology demands communication between unmanned aircraft and their shared monitoring/traffic management systems. To put it simply - connectivity is critical to market maturation.

Connectivity and Collision Avoidance

UAS traffic of the future can be efficiently and safely managed using cellular mobile networks. Multiple use cases have demonstrated how an easily-attachable 'Hook On Device' can be integrated into a professional UAS. Tighter integrations with connected UAS autopilots have also been shown to work.

Overall, UAS manufacturers and their customers seek an easy to integrate, cost effective connectivity solution that does not interfere with existing radio systems typically onboard current UASs. The solution should not limit range and should provide flexibility for planning flights and applications. High data throughput and bandwidth is helpful in enabling quick data transfer for mission specific software. Manufacturers and users will benefit from convenience and new features including maintenance and remote support. Establishing connectivity infrastructure will not only help the existing UAS market to mature, but it will open up completely new revenue streams in the form of services and support.

Unmanned Aerial Problem Solving

What happens when a UAS goes offline or flies into a dead zone? Several fail-safe ideas have been proposed, including special transmitters to reestablish 'emergency connectivity' that will keep basic UTM functions running. Longer term, you might envision instant coverage by relying on 'server-drones' to relay a signal for 'client-drones' that would otherwise fly into dead zone territory.

There are numerous ways to manage traffic for compliant operators and planned events. Of course, there will inevitably be non-compliant operators, obstacles, and unforeseen events. The industry is still seeking a robust collision avoidance system. One possibility for every UAS is to be able to sense its surroundings and/or to support acquisition of collision maps that can be redistributed to every nearby UAS in real time. Solving this will forge a path for professional UASs adoption globally.

New Technology, New Rules

You might say that many of today's UASs are overloaded with radio equipment and antennas. This equipment enables command and control features as well as exchange of mission critical data between operators and ground segments. Equipment varies widely depending on application and what country you are operating in. Establishing harmonized international rules for UTM will lead to more drones being connected by mobile broadband networks. Good, reasonable lawmaking will create demand for hardware, software and networking technologies that connect via established global standards.

Step one to establishing such a global standard is to open up all mobile networks for drone-usage, governing said usage under very clear rules and properly defined safety standards. As any UAS operation is very sensitive to losing signal it is important to consider allowing UASs a priority link on these networks.

Application Use Cases

Precision / Smart Agriculture

Precision Agriculture, or Smart Agriculture leverages advances in UAS and IoT technologies to improve operational efficiency and maximize yields, whilst minimizing the use of chemical pesticides and fertilizers.

There are immediate benefits for farm operators as input costs are reduced, and yields may be improved with greater insight and more targeted crop care. National agencies are also stakeholders with an interest in reducing detrimental environmental impact and wasteful irrigation.

Agriculture presents several interesting UAS application use cases, including crop health monitoring, nutrient management, fertilizer application, and irrigation management with a total value creation opportunity of $36 billion. UASs are relied upon in agriculture to take field 3D maps to show soil patterns, spray crops with water / fertilizer, shoot seeds into the soil, and utilize thermal and other IoT sensors to provide crop health updates to farmers.

Value Creation Example: $36.1billion global value creation potential for key agriculture use cases

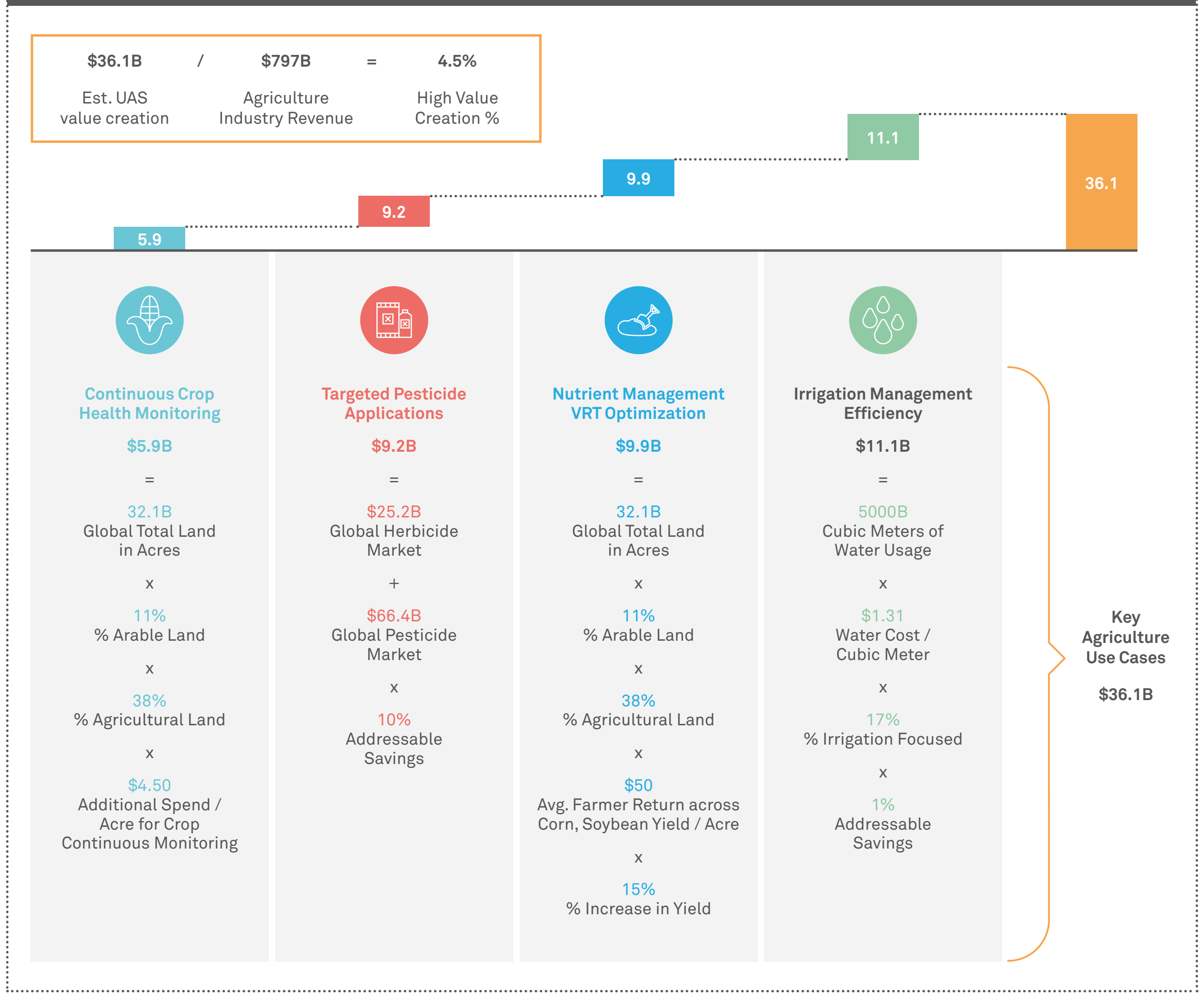


Figure 8

Oil & Gas

The Oil & Gas industry maintains one of the most complex and complete asset lifecycle management regimes, keenly aware of not only the impact of defects and failure on production but also their wider environmental responsibilities.

UAS platforms are primarily used for managing complex operations, monitoring equipment in remote areas (e.g. oil rigs and platforms) and detecting potential oil spills / pipeline leaks and other high risk issues. UAS solutions provide up-to-date, measurable geospatial information that Oil & Gas companies can leverage to detect problems early-on and perform necessary data analysis to minimize risks. The total value creation for UAS in Oil & Gas industry is estimated to be $31 billion.

Value creation example: $31.2 billion global value creation for key Oil & Gas use cases

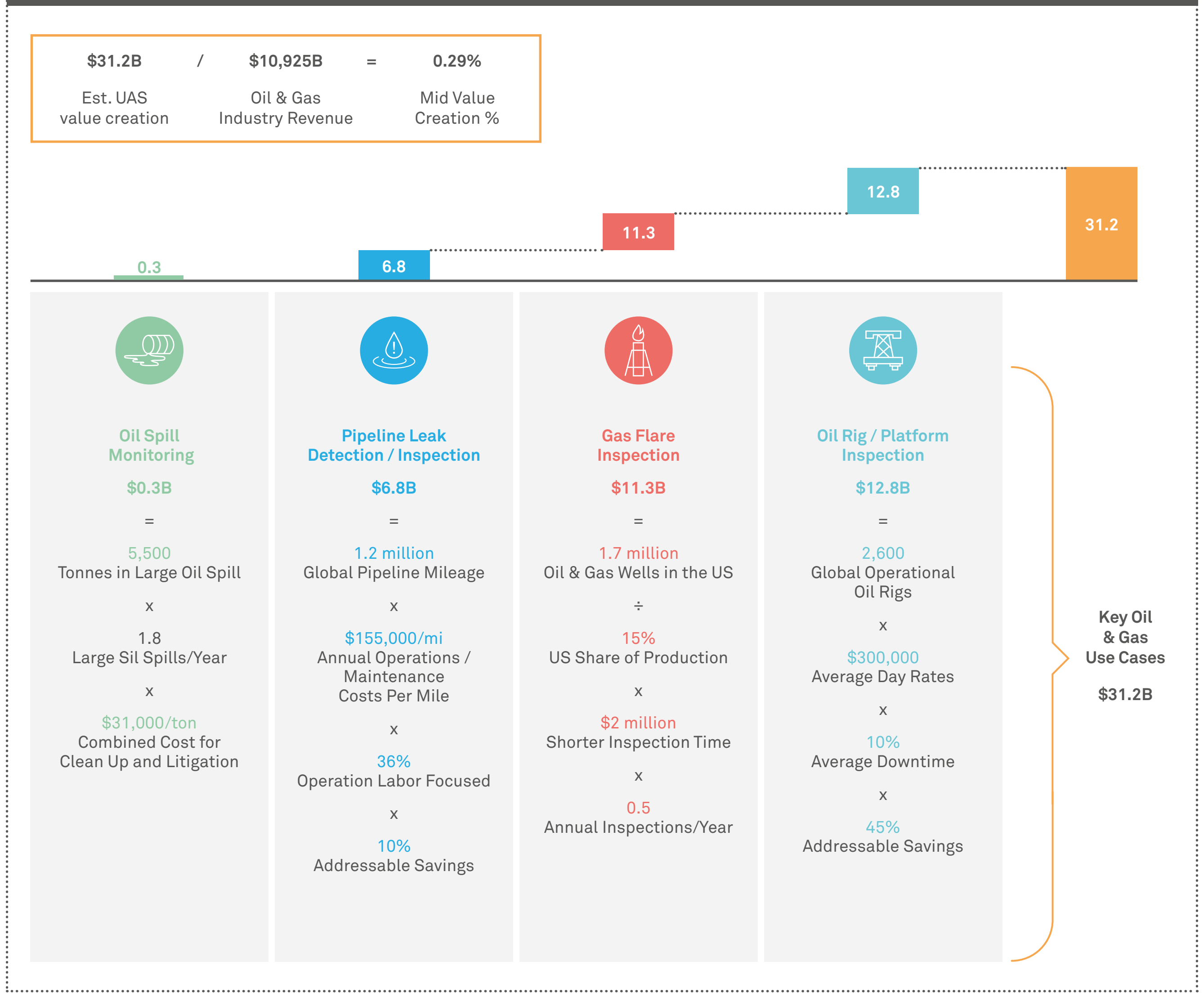


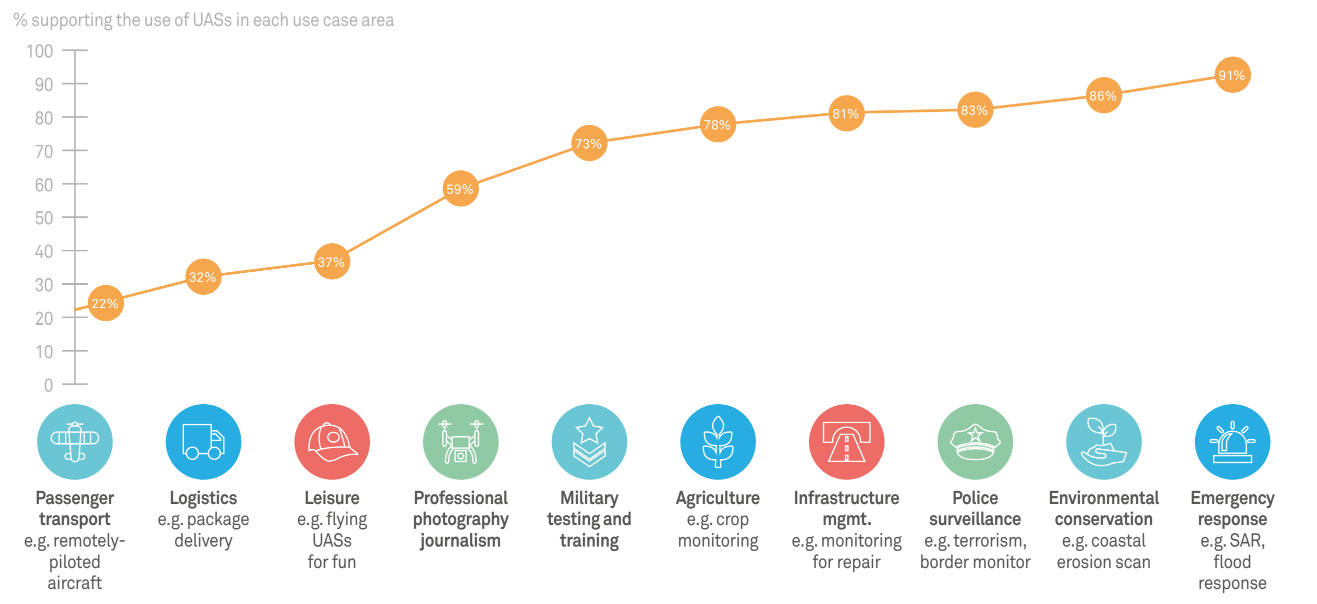
Figure 9

Public Safety

UAS technology is proving to offer impactful solutions to some of the most pressing situations facing the public.

The flexibility, timeliness and automated nature of UASs provides high value use cases in disaster response, emergency medical access, search and rescue, and environmental monitoring. Moreover, these applications of UASs have significant support among the public. In a 2016 ComRes poll of British adults, over 90% supported the use of UASs in emergency response.

Emergency response and environmental conservation have the highest public support for UAS use cases, amongst UK adults



ComRes survey of 2,043 British adults, May 2016, on behalf of the Royal Aeronautical Society
Data weighted to be representative of all British adults aged 18+
ComRes is a member of the British Polling Council and abides by its rules. Data tables are available on the ComRes website www.comresglobal.com

Figure 10

Emergency response

UASs can provide unique vantage points delivering real-time data feeds from emergency scenes to provide improved or earlier situational awareness for first-responders, fire fighters and police. In one such application, Deutsche Telekom and the Dortmund Fire Service rescue operations have demonstrated how UAS platforms may be leveraged to provide enhanced situational awareness. Under this initiative, once an alarm has been raised to prompt a rescue effort, a UAS flies to the area and begins an automated surveillance to find the victim. The UAS can guide the terrestrial rescue units directly to the location. Using UAS surveillance helps rescue teams to find a missed or injured person as soon as possible, minimizing search time and increasing the probability of a successful rescue. Crucial time can be saved, and rescue teams can focus on attending to the medical needs of the victim. This has been demonstrated in a joint proof of concept performed by Institute of Fire Service and Rescue Technology Dortmund, Deutsche Telekom, Deutsche Flugsicherung, Huawei and RWTH-Aachen.

Medical response

UAS platforms have also demonstrated great potential to assist with the transportation and distribution of drugs, medical aid and organ transplants. For example, in 2016, the Rwandan government teamed with Silicon Valley start-up Zipline to deliver medical supplies to five Rwandan hospitals; further plans will expand the program to almost half of the country's hospitals. In an application which demonstrates the reach and efficiency potential of UAS technology, a research paper published by Johns Hopkins Medical School suggests that using UAS to deliver vaccines in low and middle income countries can improve vaccine availability from 94% to 96%, whilst generating approximately 20% savings in transportation.

Conclusion

Conservative estimates forecast that over half a million UASs will occupy the skies delivering a range of commercial and governmental applications in the US by 2020, with a similar growth pattern in Europe.

Communication network operators are uniquely positioned to play a significant role in the emerging UAS ecosystem. Existing communication network operators, network infrastructure and distribution channels provide the ideal starting point to deliver required connectivity. Communication network operators which expand beyond connectivity services into data platform and analytics marketplace capabilities will stand to capture significant additional value as the industry develops.

Ecosystem and Value Chain

Demands for UAS registration and traceability are driving requirements for continual connectivity and assured identity. Operators are well-positioned as the trusted partner for national regulators to provide secure communications and assured identity for UTM initiatives.

Although connectivity provides the ideal entry point into UAS applications, a substantial opportunity for communication network operators can be found beyond increasingly commoditized connectivity services. Data platform services and analytics are predicted to represent the largest section of the future UAS market, with data collection services and IaaS the next biggest revenue drivers (see figure 2 on page 7). UAS operators and commercial users will exhibit significant demand for data management, analytics and platform support; communication network operators are well-placed to develop these services. By leveraging their unique capabilities, communication network operators may establish themselves as a key partner to UAS operators, initially addressing the needs of UTM and then expanding to address high-value use cases.

To understand the potential evolution of communication network operators' role in the UAS market, consider the progression of required capabilities. At present, communication network operators have existing technical capabilities which will allow them to deliver connectivity, device security and identity management, and integrate into UTM. Developing advanced networking and content delivery infrastructure will open up opportunities in network virtualization and increased use of unmanned flight vehicles. Further expansion through partnership, brand development and advanced technological capabilities will allow communication network operators to provide key services across the UAS market. This roadmap is illustrated in Figure 11.

Figure 11

The telecoms industry has key capabilities that bring unique advantages across emerging business segments, including UAS.

Leveraging these capabilities, communication network operators possess significant control points within the UAS Ecosystem.

Communication network operators have unique technical capabilities that enable UAS connectivity and UTM.

Advanced capabilities will be key to enabling emerging use cases and value-add services.

Partnerships, familiarity with regulated industries and trust-brand status positions communication network operators for future use cases.

The UAS ecosystem, depicted in figure 12, ranges from UAS hardware delivered by airframe and payload manufacturers, communication network operator connectivity, flight planning and management through to data platforms, analytics and cloud-based system integrators. By focusing on data processing and storage, collaborative solutions and advanced analytics, communication network operators can occupy significant control points in the UAS ecosystem.

Communication network operators value-added services within a data platform offering include secure cloud storage, APIs and data models, data processing algorithms and infrastructure, and provision of incentives such as bundled services for an existing enterprise customer base. Once a data platform offering matures, there will be potential to eventually unlock indirect monetization of UAS platform data (e.g. data sharing with third parties such as UAS manufacturers, insurance companies, etc.).

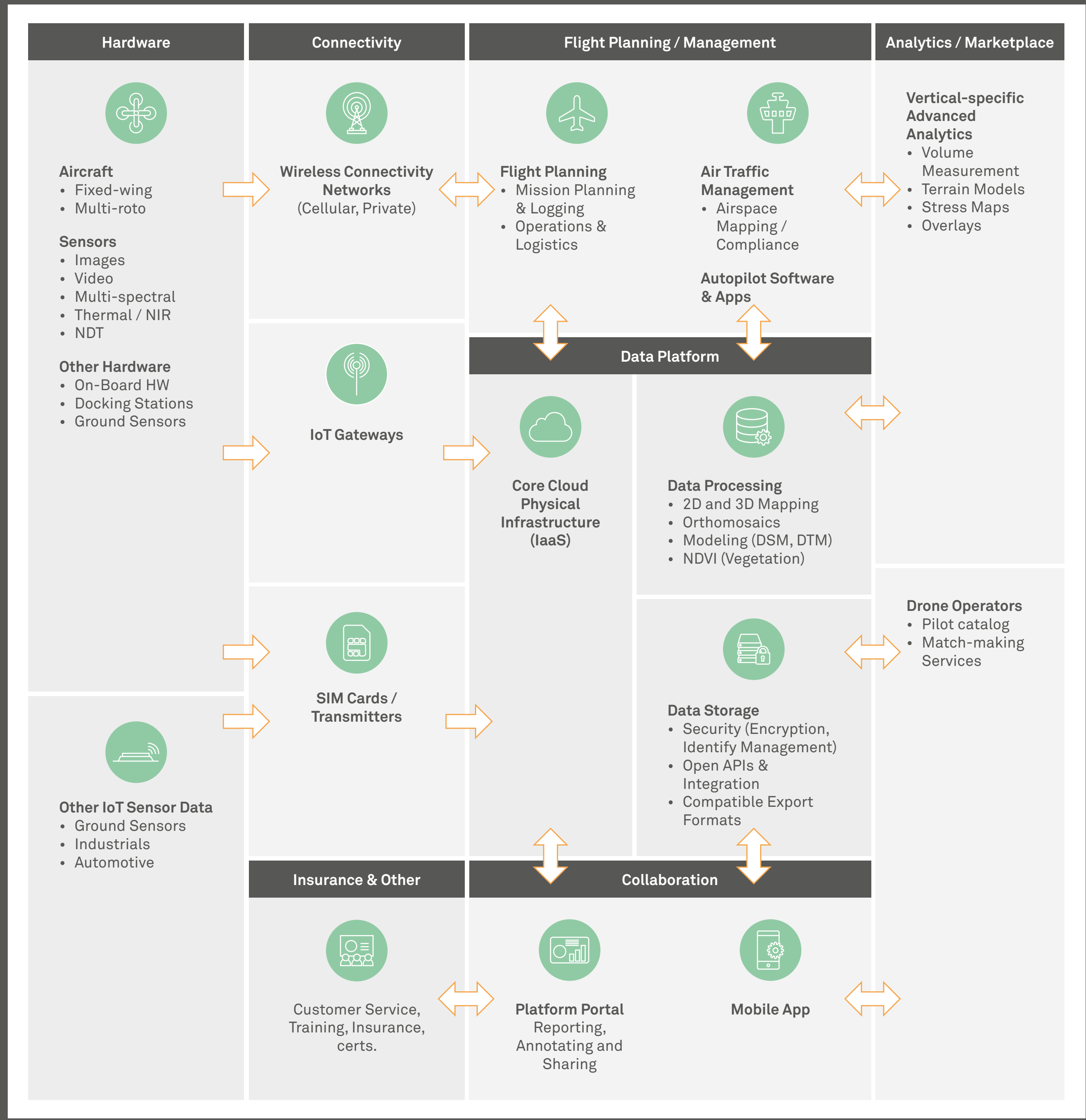


Figure 12

The UAS ecosystem and market is still in the early stages, and the current set of emerging use cases are initial steps towards a much broader range of applications. The vast majority of emerging use cases are centered on delivering new vantage points to augment human tasks – essentially surveillance and surveying use cases. As the UAS market matures, subsequent stages of evolution will demand autonomous flight capabilities, followed by autonomous missions, leading to UAS platforms that automate physical tasks rather than simply visually augmenting humans as they do presently. In time, humans will be completely removed from the loop for mundane, repetitive or hazardous situations. UASs will interact with the world around them, and with other robotic vehicles. Real-time and low-latency decision making will be essential to ensure operational integrity and safety, stimulating demand for computational and analytic capabilities in close proximity to operating environments.

To establish a keystone presence in the future UAS ecosystem, communication network operators should weigh current revenue opportunities against much larger potential revenues as a key service provider and partner. For example, a burdensome pain point for UAS operators at present is data ingestion. It takes significant resources to transfer, store and analyze the massive amount of data that UAS platforms collect. Communication network operators can address this pain point by offering data platform services, such as processing and transfer. Moreover, to gain this initial entry into a significant new area, it may be worthwhile subsidizing connectivity while monetizing data services.

As UAS use cases develops, UASs themselves will become part of extensive solutions-based ecosystems. With capabilities across infrastructure, data management and partnerships required for these broader applications, communication network operators are well-placed to grow with the range of possible uses for UASs. Figure 13 demonstrates a possible evolution of UAS applications.

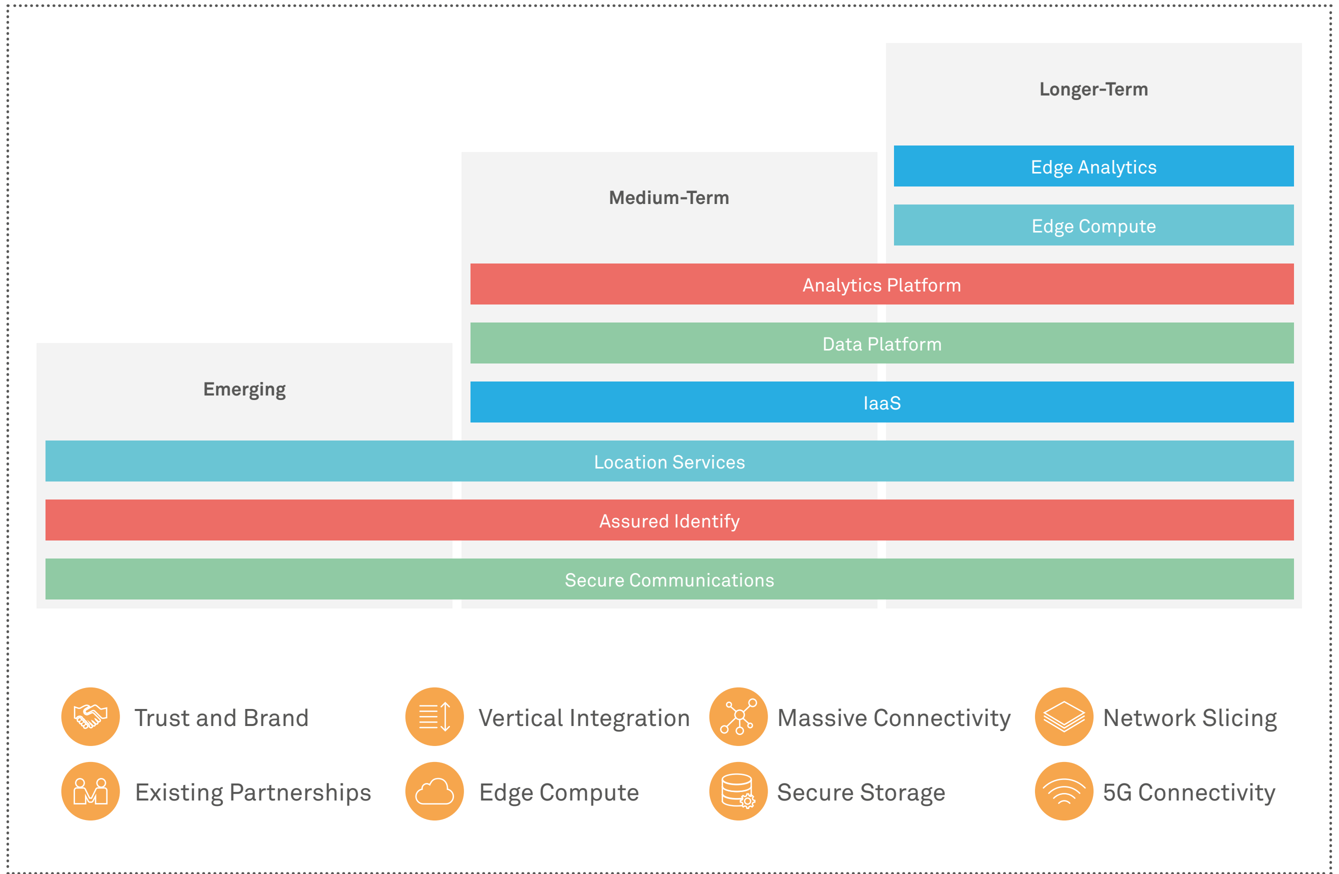


Figure 13

Communication network operator's current position and capabilities offer a compelling position from which to form a UAS platform strategy. The advantages of technical and commercial capabilities, long-established manufacturer relationships, and reputation as trusted partner to national agencies, regulators and multi-national companies, are difficult for new entrants to replicate quickly. Communication network operators will have the opportunity to develop technological capabilities and deliver value across the ecosystem, if they chose to pursue these opportunities beyond connectivity services.

Contributors

About Deutsche Telekom

Deutsche Telekom is one of the world's leading integrated telecommunications companies, with some 165 million mobile customers, 28.5 million fixed-network lines, and 18.5 million broadband lines. We provide fixed-network/broadband, mobile communications, Internet, and IPTV products and services for consumers, and information and communication technology (ICT) solutions for business and corporate customers. Deutsche Telekom is present in more than 50 countries. With a staff of some 218,300 employees throughout the world, we generated revenue of 73.1 billion Euros in the 2016 financial year, about 66 percent of it outside Germany.

So that we can continue to be successful, we are already evolving from a traditional telephone company into an entirely new kind of service company. Our core business, i.e., the operation and sale of networks and connections, remains the basis. But at the same time we are proactively committing to business areas that open up new growth opportunities for us.

About DFS Deutsche Flugsicherung GmbH

DFS Deutsche Flugsicherung GmbH is responsible for air traffic control in Germany and is headquartered in the town of Langen close to Frankfurt. It is a company organised under private law and 100% owned by the Federal Republic of Germany. Founded in 1993, DFS is the successor to the Federal Administration of Air Navigation Services (BFS), a government authority. The German Constitution and the German Aviation Act (LuftVG) had to be amended by the Bundestag to make this possible. In Germany, military and civil air traffic controllers work side by side. Since 1994, DFS has been responsible for the handling of both civil and military air traffic in peacetime. Only military aerodromes are exempted from this integration. Throughout Germany, DFS is represented at 16 international airports, and at nine regional airports by its subsidiary DFS Aviation Services GmbH. Controlling air traffic from the towers and control centres is the core business of the German air navigation service provider.

About Microdrones

Founded in Germany in 2005, Microdrones developed the world's first commercial quadcopter and the company still leads the industry with professional UAS solutions. By packaging robust drones with cutting-edge sensors, software and workflow, Microdrones delivers solutions that make it easy for businesses to start using UAS for surveying, mapping, construction, inspection, precision agriculture, utilities and mining. A heritage of quality German engineering, extra-long flight times, resistance to environmental challenges, and technology such as direct georeferencing make Microdrones solutions exceptionally safe, efficient, and cost-effective choices for commercial users. Microdrones serves markets around the globe. The Team from Microdrones is excited about the possibilities of a future global Unmanned Traffic Management standard; we will continue to develop and integrate our technology, and to contribute to best practices and knowledge building for the shared challenges of the industry.

About Keystone Strategy

Keystone Strategy, LLC is an innovative strategy and economics consulting firm delivering transformative ideas and novel solutions to global enterprises on leading-edge challenges in technology, business, and science. The firm's expertise in strategy, economics, product development, intellectual property and antitrust is ideally suited to developing bold strategies that have a far-reaching impact on business, consumers, and public policy. Keystone Strategy combines the strategic insights of leading experts from Harvard, Stanford, MIT, Wharton and other top universities with the practical industry expertise of its accomplished professionals to deliver extraordinary impact. Keystone Strategy applies the most advanced strategy, analytical and business management services while also using our entrepreneurial skills to drive innovation, business growth, and digital transformation. Our areas of expertise include Ecosystems, Innovation, R&D process, Antitrust, Intellectual Property, IoT, Search, Mobile, Cloud Computing, and other Emerging Technologies.

About Huawei

Huawei is a leading global ICT solutions provider. As a responsible and robust business player, innovative information society enabler, and cooperative industry contributor, Huawei is committed to building a Better Connected World. Through our dedication to customer-centric innovation and strong partnerships, we have established end-to-end capabilities and strengths across carrier, enterprise, consumer, and cloud computing domains. Huawei's 170,000 employees worldwide create maximum value for telecom operators, enterprises and consumers. Our innovative ICT solutions, products and services have been deployed in over 170 countries and regions, serving more than one-third of the world's population. Founded in 1987, Huawei is a private company that is fully owned by its employees. For more information, please visit Huawei online at www.huawei.com.

About Wireless X Labs

Wireless X Labs is a brand-new platform designed to get together telecom operators, technical vendors, and partners from vertical sectors to explore future mobile application scenarios, drive business and technical innovations, and build an open ecosystem. Wireless X Labs have set up three laboratories, which aim to explore three major areas: people-to-people connectivity, applications for vertical sectors, and applications in household.

About SPO Lab

The SPO Lab is Huawei's business research lab focused on developing a deep understanding of the next generation of digital services that are driving communication network operators digital transformation. The main focus of the SPO Lab is on the practical applications of a wide range of new digital services, the new business models that will underpin these services, and the digital transformation journey the communication network operators will need to undertake to exploit these new services.

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