inmarsat
AVIATION

UNLOCKING THE FULL POTENTIAL OF ADVANCED AIR MOBILITY

CONTENTS

FOREWORD

This report is an updated version of the 'UAVs: Unlocking Positive Transformation in the World' report released in October 2021 in partnership with Cranfield University.

Over the following pages you will read a lot about how commercial uncrewed aerial vehicles[1] – UAVs – have the potential to transform our world. This is not hyperbole. The positive possibilities UAVs can help bring to life are only constrained by one's imagination.

In the coming years – and all the projections and predictions point to an exponential rise in market size and value this decade, as this report will show – the adoption of UAVs will empower an inspiring array of industries.

Indeed, the broad spectrum of sectors that will be positively impacted is astounding, as there are few new technologies that have such wide applicability. Emergency services, disaster relief, urban air transport, commercial and industrial cargo deliveries, environmental inspection and monitoring are just a few of the industries that will benefit.

Collaboration key to overcoming challenges

But potential, possibilities and projections are nothing without action. And this action has to come from all the stakeholders and actors in this burgeoning ecosystem. Collaboration is critical.

It's beholden on all of us – OEMs (Original Equipment Manufacturers), satcom terminal manufacturers, connectivity partners, software solution providers, regulators, Air Navigation Service Providers (ANSPs) and end users – to work together and safely overcome the challenges that currently hinder the sector.

In turn, as a collective ecosystem, we will be able to demonstrate the practical solutions this sector will usher in and, perhaps most importantly, its safety.

UAVs as a force for good

One of our immediate challenges is one of perception. Mention UAVs – or, more likely, drones – to most people and they start raising concerns about privacy while in their garden and joke about having their coffee or pizza delivered to their door, or they point to the use of drones in a military context.

Since our last review in 2021, a lot has moved on in the world of advanced air mobility. Commercial use cases have begun to be widely tested and investment has spurred new innovations. Agriculture, an early adopter of UAVs has seen significant progress. For example Israel's Tevel has refined fruit-picking quadcopters able to identify fruit at the correct level of ripeness which are then plucked and lowered to the ground, and in Chile, farmers are using multi-spectral imagers to pick grapes at the right time.

Additionally, what was once seen as science fiction, is becoming reality. Urban Air Mobility companies have seen huge levels of investment and interest and a healthy order book has followed. This has culminated in the announcement by Archer Aviation and United Airlines[2] that they are seeking to launch the first commercial electric air taxi route in Chicago in 2025.

As an industry we need to highlight the incredible sustainability benefits UAVs can support. Widespread delivery of cargo along regulated corridors with electric Vertical Take Off and Landing (eVTOL) vehicles will radically reduce emissions as we firstly take cargo, and eventually people, off the roads and rail.

UAVs will facilitate a step change across the industry. They will ensure safe passage for maritime vessels, assist in surveying remote lighthouse and channel marker buoys after bad weather, and conduct platform and pipeline inspections.

There are numerous humanitarian gains, too. They can play a critical role in accelerating blue-light service responses by enabling a video feed to be deployed quickly at the scene of an incident – thus highlighting additional services that may be required. This automation saves time, saves money and saves lives.

Anthony Spouncer, Inmarsat

In short, UAVs create a world of exciting opportunities.

Connectivity critical to answering regulatory questions

Of course, there are challenges. Today, commercial air transportation is heavily regulated, with processes promoting continual safety, learning and enforcement. With good reason. Aviation without safety is nothing. As such, we need to take the best from commercial air transport regulation into this new uncrewed flying world.

Therefore, we all need to work with regulators and policy makers to ensure the UAV space is as safe as possible. Collaboration will help expedite this. Inmarsat has been in the aviation communication, navigation and surveillance space for 30 years, but we are only one part of the solution. UAVs will require diverse, trusted and resilient communication links, just like commercial air transport, for their undoubted potential to come to fruition.

It's projected that there will be 32 million commercial UAVs expected by 2031, according to Teal Report 2022/2023. Of these, an estimated 600,000 will be flying beyond visual line of sight (BVLOS).

UAVs create a world of exciting opportunities

1 Also referred to as UAS – uncrewed aerial systems
2 https://investors.archer.com/news/news-details/2023/United-Airlines-and-Archer-Announce-First-Commercial-Electric-Air-Taxi-Route-in-Chicago/default.aspx

To fly safe, BVLOS certified, operations and integrate with other air traffic, UAVs will need reliable and secure methods for control that enable identification, segregation, Detect, Sense and Avoid capabilities. Because the aviation industry won't be doubling its air traffic controller workforce anytime soon, there will need to be a way to exchange real-time information between stakeholders, and this will require secure and resilient multi-layered connectivity capabilities. The need is clear: fast, trusted, reliable communication between controllers and operators/pilots, between operators and UAVs, and between operators and service providers.

In commercial aviation today, voice communications are the primary method for Air Traffic Control (ATC) to communicate with pilots on board the aircraft. In the future, with the integration of UAVs, this limited method of communication simply does not scale. Commercial aviation regulators recognise this limitation and are integrating new capabilities, such as the FAA Data Comm[3] program, to exchange and streamline ATC and pilot communications. However, none of this is planned for the UAV industry. Pilots of remote and autonomous UAV operations must be able to control multiple UAVs BVLOS and this can only be achieved through integrated automation. As an industry we have to embrace digitalisation, utilise machine learning, and incorporate AI, in a controlled manner, where it makes sense. This will allow BVLOS and other UAV operations to establish flight corridors where they are required and enable free flight navigation where practical. All stakeholders in the UAV ecosystem will need to learn, evolve and build while working together with regulators to guarantee we achieve safe BVLOS operations.

Commercial UAVs have the potential to positively transform how we live. UAVs are a powerful force for good, but work is required, alongside trusted, resilient and reliable space-based connectivity that works independently or seamlessly with ground-based solutions, to ensure the limitless possibilities of UAVs are realised – for all of our benefit.

Anthony Spouncer, Inmarsat Aviation's Senior Director of UAVs and Uncrewed Traffic Management (UTM)

3 https://www.faa.gov/newsroom/data-communications-data-comm-0?newsId=21994

INTRODUCTION

The near exponential future growth of the use of Uncrewed Aerial Vehicles (UAVs) for the autonomous movement of goods and people has been widely predicted. A recent study[4] estimates that the overall advanced air mobility market is expected to be valued at $16.81 billion in 2025, and reach $110.02 billion in 2035, registering a CAGR of 21.7 %. It is clear that air transportation is about to undergo the most significant transformation since the introduction of the jet engine and the growth of the global commercial passenger market.

What has been remarkable is that the growth and demand for Advanced Air Mobility actually accelerated during the COVID-19 pandemic. At a time where commercial aviation was facing a very uncertain future, investment flooded in to support and accelerate the development of prototypes and technologies, across every region of the world.

The term UAV or drone encompasses an incredibly broad range of vehicles which are entirely pilotless (similar to the emerging self-drive cars) or are controlled by a ground based human pilot. Similarly, the range of sizes and technologies is equally broad, extending from the smallest quad rotor copters that are typically less than 50 cm in size to very large UAVs which have aerostructures that are similar to conventional aircraft. These larger UAVs can be in the form of converted conventional aircraft flying on autonomous cargo delivery routes or new electrically powered vertical take-off and landing (eVTOL) platforms or even futuristic concept aircraft potentially capable of launching satellites into low earth orbit[5]. Because the majority of new generation UAVs use electrical propulsion systems they represent a new class of sustainable air transport for the movement of goods, and indeed people, that have the undoubted potential to contribute positively to the global climate challenge.

Not surprisingly the potential range of applications of UAVs is equally broad and consequently so are the benefits to commerce and society. Aerial photography and surveillance activities were seen as the early applications for UAVs, however firefighting, remote medical emergency missions, high precision agriculture, search and rescue and even personal air mobility are all now under development across the globe. The most significant driver for this technology is however, the opportunity to redefine the way we move goods by air. UAVs are instrumental in creating so called "Smart Logistics" that can potentially provide significant productivity and efficiency savings whether it be for 24/7 last mile delivery from warehouses to consumers within urban environments or for the movement of cargo between commercial hubs and warehouses.

BVLOS FLIGHT

Perhaps the biggest challenge to realising the opportunities that UAVs are presenting lies in their control once they are beyond the visual line of sight of their ground controller, so called BVLOS flight. These challenges are different for low altitude flights (below 400 ft) to those at higher altitudes where UAVs would operate alongside conventional aircraft in controlled commercial airspace, but in both cases the UAVs at all times need to be electronically "visible" to other airspace users and airspace management systems to enable both manned and uncrewed flights to occur within the same airspace and to ensure flight safety for all. For low altitude BVLOS flights, therefore, UAVs must be able to operate under the guidance of automated airspace management systems often referred to as Uncrewed aircraft system Traffic Management (UTMs). For flights in controlled airspace, this means the UTM systems must also interface alongside existing air traffic management systems. UTMs are highly dependent on resilient data connectivity, in order to exchange information and accurately identify and track aircraft, whether across ground

based (LTE 4/5G, C-Band) or satellite networks, and have to be approved by national and international regulatory authorities to enable conventional aircraft to operate safely in the same airspace as the UAVs. This problem is not just one isolated to a single country or geographical area, as the community evolves, the regulations need to have global acceptance and are able to both support innovative digital technologies and clearly define the roles and responsibilities of all stakeholders within the overarching uncrewed aerial system (UAS).

This short paper briefly looks at the role of UAVs in how they might change the nature of commerce as we know it today and also how they can have direct benefit to our society by providing both humanitarian and medical services. The paper also considers one of the principal barriers facing this emerging sector; harmonised methods for trusted and resilient information exchange for all parts of the ecosystem (globally and regionally) and standards for BVLOS operations approval.

First though, the paper considers what is often overlooked; the commercial advantages of UAVs and the fact that UAVs can have a positive impact on our environment through the roll out of the electrically powered propulsion system.

4 https://www.alliedmarketresearch.com/advanced-aerial-mobility-market-A12516
5 https://www.aviationtoday.com/2020/12/14/aevums-ravn-x-drone-offer-rapid-launches-low-earth-orbit/

CREATING COMMERCIAL ADVANTAGE

When adopted by global markets, UAVs are expected to provide significant commercial advantage to those organisations who are willing to embrace the technology and adopt new operational methods. A significant enabler to commercial growth will be the enablement of robust, secure and regulated data connectivity, whether via satellite networks having global reach or local terrestrial networks (or more likely a combination of both) enabling routine BVLOS flights. Once networks are established, overall supply chain/business efficiency is expected to grow through reduced cost and time of operations by virtue of scalability.

Current estimates are for a net overall cost saving of £16bn by 2030 across multiple sectors (ranging from telecoms, construction, to transport and agriculture to mention but a few)[6]. Although a negative impact on jobs might be expected, UAVs will help achieve some of the global sustainability goals (e.g. tackling congestion, inefficient operations, health and safety issues).

Within the UK, an analysis of the potential multi-factor productivity impact generated through the use of UAVs for commercial purposes shows that, by 2030, the major beneficiaries are expected to be the technology/telecoms sector (providers of UAVs and UAV services) and the transport and logistics sector, so called Smart Logistics[7] **(Figure 1)**.

TECHNOLOGY AND TELECOMS

The realisation that UAVs, in all their forms, have the potential to enable significant growth in a variety of global markets has itself created new technology markets for UAV platforms and flight management systems as well as providing new opportunities for existing ground and satellite communication providers. Global sales of commerical UAVs are expected to rise from 1.1m units in 2022 to 1.8m in 2025 and upwards of 2.8m by 2030,[8] with the retail sector leading the way. Rapidly expanding companies such as DJI, UVify, Hubsan, Parrot and many others are now providing small and medium size platforms for both hobbyists and commercial users alike. At the other end of the scale, global giants Honeywell Aerospace have developed a lightweight UAV satellite communications system that has recently been chosen for Pipistrel's Nuuva V300 UAV platform, having a payload of 460 kg and flight range of 300 km[9].

The Telcos also see that there is opportunity in the UAV marketplace. By leverage their existing cloud infrastructure and network capacity, new "Drone Powered Solutions", such as live data streaming and data insight analysis by the Telcos to their customers, can be brought online, as well using drone services themselves as part of their physical infrastructure inspection operations[10].

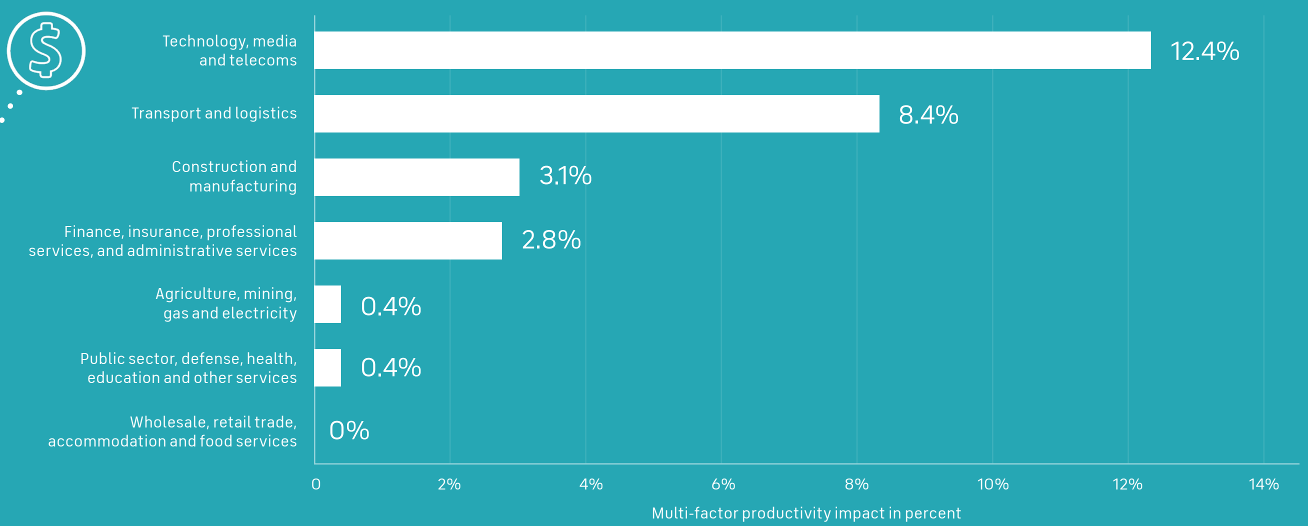

Figure 1: Commercial Drone Multi-Factor Productivity Impact by Economic Sector

6 https://www.pwc.co.uk/issues/intelligent-digital/the-impact-of-drones-on-the-uk-economy.html
7 https://www.statista.com/statistics/866236/commercial-drones-productivity-impact-on-economic-sectors/
8 https://www.researchandmarkets.com/reports/5406415/global-drone-market-report-2021-2026
9 https://www.honeywell.com/us/en/press/2021/08/pipistrel-selects-honeywells-revolutionary-small-uav-satcom-system-for-all-uncrewed-aircraft-platforms
10 https://www.telecomreview.com/index.php/articles/reports-and-coverage/4190-how-drones-are-revolutionizing-the-telecom-industry

The current package delivery UAV market is expected to accelerate to $4.40 billion in 2025

SMART LOGISTICS

UAVs have a future role in both the short-range delivery of packages to consumers and the movement of heavier cargo between commercial hubs and warehouses.

The current package delivery UAV market is estimated at being worth $0.99 billion but is expected to accelerate to $4.40 billion in 2025[11]. Even prior to the pandemic the major e-commerce and delivery companies have been experimenting with the use of UAVs as part of their Smart Logistics solutions and consequently there is a plethora of systems being trialled or under development through both national initiatives (such as the UK's Future Flight programme) or direct entrepreneurial commercial activity supported in some instances by a regulatory sandbox service from a country's aviation authority. Examples include:

- UPS Flight Forward™ Drone Delivery (certified from the US Federal Aviation Administration) is operating commercial drone deliveries beyond the visual line of sight. Based on Matternet's M2 drone system, Flight Forward provides fast delivery for time-sensitive medicines.
- Alphabet Project Wing from Google X labs is an initiative to create, fly and use UAVs for last mile delivery of consumer packages (even coffee) of up to 1.2kg and distances of 12 miles.

While the potential for commercial UAV enabled package delivery services to grow significantly exists, current technical and regulatory challenges are initially restricting this growth only to specific niche markets (such as medical deliveries) or in sparsely populated regions. As a consequence, some major logistics organisations, such as DHL and Amazon, have recently scaled back their "last mile" UAV delivery programmes to focus their efforts elsewhere.

The autonomous movement of freight or cargo between commercial hubs and warehouses by large UAVs is considered as potentially the first large scale commercial opportunity that will be realised within the logistics sector. The development of zero emission electric or hydrogen powered commercial cargo aircraft (e.g. Eviation's Alice, Anavia's HT-100, Xmobots's Drargo 150) potentially provides a new class of regional fixed wing and rotor aircraft that will have the capability to operate initially with a single pilot, and then autonomously under the guidance of a ground controller, delivering cargo between warehouses via transcontinental or transoceanic flights. UPS' commitment to purchase Beta Technologies eVTOL aircraft for example is a clear indication that the major logistics companies are considering short range electric aircraft as a stepping stone towards autonomous flight services[12].

With such significant investment and leadership by the global logistics companies, and many others, the logistics sector is expected to eventually be heavily driven by UAV applications. Early predictions are that up to 80% of deliveries will be made by autonomous vehicles, including UAVs[13], by 2026. At the time these predictions appeared to be over optimistic but with such a dynamic and fast moving market they may be closer to being a reality than originally thought.

Early predictions are that up to 80% of deliveries will be made by autonomous vehicles, including UAVs, by 2026

11 https://www.thebusinessresearchcompany.com/report/drone-package-delivery-global-market-report
12 https://about.ups.com/us/en/newsroom/press-releases/innovation-driven/ups-flight-forward-adds-new-aircraft.html
13 https://www.mckinsey.com/~/media/mckinsey/industries/travel%20transport%20and%20logistics/our%20insights/how%20customer%20demands%20are%20reshaping%20last%20mile%20delivery/parcel_delivery_the_future_of_last_mile.ashx

Drones for agriculture and livestock management [15]

SMART FARMING

While not expected to have the same net commercial impact as the much larger logistics sector, the agriculture sector is already using smart technologies, including UAVs, for multiple tasks that have a direct impact on the planning and resilience of a nation's food supply. Smart agriculture is being driven by the ever-growing demand for food production and lack of available labour along with the technological advances and affordability of UAVs themselves. Forecasts predict that the agricultural UAV market size will be worth almost $2.5 billion with in excess of 300,000 units being shipped by 2025[14].

Ranging from monitoring fields for efficient irrigation, spraying fertilizers where required and monitoring potential illness or security threats in livestock, the benefits of UAVs are not just for farmers, but also for governments and development agencies who need accurate, up-to-date information regarding crops grown for funding (budget allocation) and insurance purposes. Perhaps what is most exciting about this area of UAV application is how existing satellite ground observation techniques, already commonly used for growth and ground stress measurements, can be integrated with low altitude UAV flight data – with each technique providing different spatial, spectral and temporal resolution to provide a new level of insight.

Clearly, the prospects of using UAVs for smart farming are potentially significant. However, the cost and the regulatory ease in operating UAVs for various farming operations might play a critical role in motivating farmers to adopt UAVs.

14 Teal Report 2022/23
15 https://jaguzafarm.com/drone-and-ai/

SUPPORTING SUSTAINABILITY

Environmental sustainability is one of the most pressing issues confronting modern society.

Cities are responsible for a significant portion of environmental impacts, with medium and heavy-duty freight transport accounting for approximately 24% of pollutant gas emissions in the USA[15]. In the EU this figure is 22%, with cars and vans representing 16% of the total Greenhouse Gas emissions[16]. Similarly, the rapid growth of e-commerce and package delivery means that the increased traffic congestion in our urban areas and the deterioration of our roads necessitates new technological and operational solutions to meet customers' demand for faster, more reliable, more environmentally conscious and cheaper delivery systems.

Electrification and ultimately automation of both cargo and consumer delivery fleets are a common objective of all major retailers and logistics service providers in order to achieve overall low-carbon targets.

Electric vehicle fleets are being deployed in many cities to reduce both carbon dioxide (CO_2) and other airborne pollutants. While undoubtably such initiatives have positive benefits in themselves they do not address the growing challenge of inner-city road network congestion which at times can have significant impact on delivery times and CO_2 production per journey. UAVs have the potential to significantly reduce the negative environmental impact currently produced by urban road transport operations. By assigning parts of the cargo or consumer delivery journey to UAVs there is the opportunity to reduce both the levels of CO_2 emissions per delivery and also to reduce urban road network congestion so providing further emissions reduction benefit.

QUANTIFYING THE GREEN IMPACT

Using electrically powered UAVs as part of an autonomous cargo (B2B) and last mile delivery solution is greener and cheaper. A study of drone deliveries in North America[17] estimated that a small package, when delivered over short distances, has significant UAV efficiency advantages compared to diesel powered truck deliveries, with the UAV emitting 0.42 kg of greenhouse gases per small package compared to 0.92 kg truck emissions – less than half. The study further estimates that UAV deliveries within California might reduce transport related greenhouse gas emissions by 54% compared to trucks whereas in the State of Missouri, due to alternative energy sources, the reductions are estimated to be a more moderate (but still impressive) 23% (**Figures 2 and 3**).

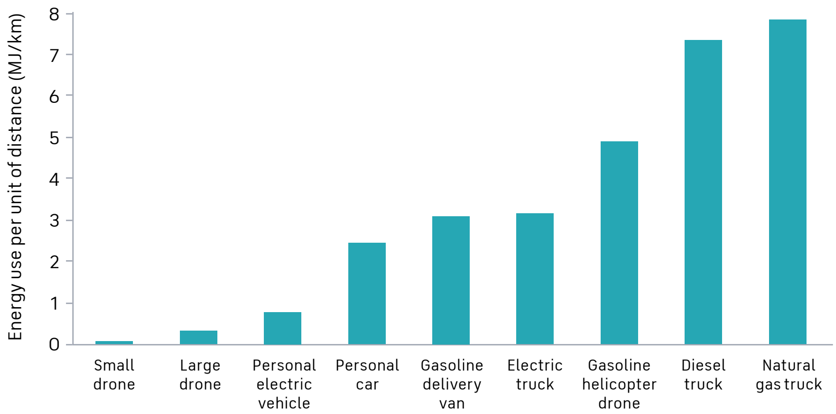

Figure 2: Energy use and life cycle greenhouse gas emissions of UAVs for commercial package delivery [16]

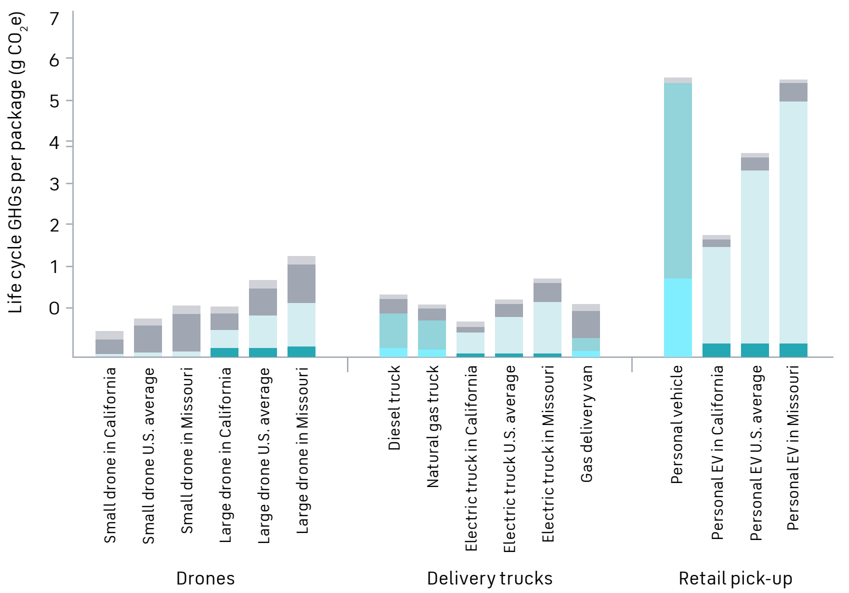

Figure 3: Energy use and life cycle greenhouse gas emissions of UAVs for commercial package delivery [16]

Battery production
Transportation fuels combustion
Transportation electricity
Upstream transportation fuels
Warehouse electricity
Warehouse gas

16 https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions
17 European Environment Agency, 2020
18 Stolaroff et al., 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5811440

Using its own modelling and primary data resources, Cranfield University has also predicted significant greenhouse emission reductions, through modelling typical last mile delivery assignments and different urban scenarios. A small light commercial vehicle (LCV) delivering 10 similar size packages per 8-hour shift over a 5 km delivery radius from a central warehouse was considered. The LCV was assumed to follow regular delivery protocols of consecutive deliveries via an optimised route plan. Under this scenario the estimated carbon dioxide emissions of the LCV per 24 hours (3 shifts) is estimated as 3,394 grams.

In the first instance a medium-sized UAV with a range of 36 km, carrying a payload of 5 kgs was considered. Because of the payload limit, the UAV would have to make separate individual journeys from the central warehouse rather than making consecutive deliveries. Even under this less-than-optimal operating pattern the estimated carbon dioxide emissions from the UAV per 24 hours (3 shifts) would be 2,160 grams, representing a significant 36% reduction when compared with the equivalent LCV road transport.

In another scenario a much larger UAV with a 50 Kgs payload was arranged to operate in the same "one-to-many" delivery protocol as the LCV. This scenario produces 1,800 grams of emissions per 24 hours representing an even more significant reduction of 47% (**Figure 4**).

Our analysis has shown that the potential to decrease emissions is based on a specific case, however when the routes and order delivery schedules are optimised (for example similar neighbouring deliveries grouped together), we expect to see reductions higher than the above. The benefits to those living within urban environments are particularly significant. With over 3.8 billion parcel deliveries in the UK alone[19] during pre-pandemic 2019, almost all involving diesel powered road vehicles, UAVs have a real potential to replace a proportion of this traffic within urban and city areas; thereby reducing road congestion and environmental pollution.

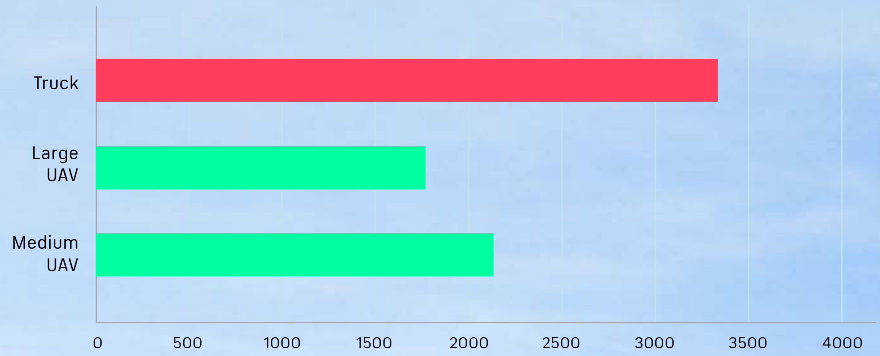

Figure 4a: Carbon Dioxide Emissions (grams equivalent) per 24 hours; Cranfield University

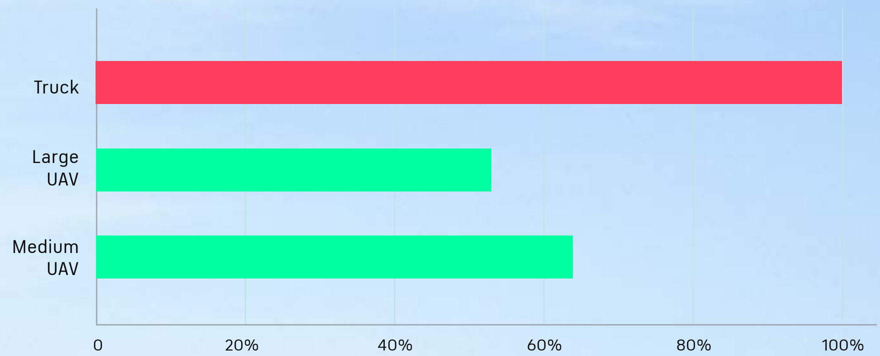

Figure 4b: Carbon Dioxide Emissions (% normalised) per 24 hours; Cranfield University

19 https://www.pitneybowes.com/us/shipping-index.html#

DELIVERING SOCIETAL BENEFIT

UAVs are already delivering benefits to communities across the globe that extend well beyond those driven by commercial gain.

UAV applications within ecology are now common place, particularly for species population estimates. Within the wildlife and forestry sectors, for example, the surveillance of wild animals by UAVs has successfully facilitated the protection of endangered animals from poachers as well as monitoring forests for illegal deforestation or mining operations[20]. More recently UAVs have been used to plant seeds in open forest areas and monitor their growth; as well as for proactively identifying and managing fire incidences. Environmental hazard detection (flood and fire) is also another effective application of UAVs with the growth of incidences associated with climate change.

UAVs are mobile eyes in the sky with the capability to scan large areas in a very short time for finding missing persons, filming crime scenes, and providing live updates direct from major incidents (e.g. protests and large events).

The regular inspection of critical national infrastructure is an essential component of making sure that societies are able to function. Rail and energy companies are already using UAVs within visual line of sight for inspection and maintenance operations of their large assets along with their network infrastructures. Routine beyond visual line of sight (BVLOS) enabled by reliable and global connectivity solutions will allow such companies to accumulate more data and be in a position to make more informed decisions on the condition of their assets. Even within the aviation sector the use of UAVs to inspect aircraft[22] and airports[23] are now being actively considered to improve the operational safety and efficiency.

Figure 5: Drone for environmental hazard detection [21]

Figure 6: Drones for delivering medical supplies

Figure 7: Drones for aircraft [23] and rail infrastructure inspection [24]

20 https://www.equinoxsdrones.com/blog/how-drone-technology-is-becoming-essential-for-forestry
21 https://theconversation.com/drones-help-track-wildfires-count-wildlife-and-map-plants-12511
22 https://aviationweek.com/top-4-uses-drones-aircraft-maintenance
23 https://www.cranfield.ac.uk/press/news-2020/drones-used-to-conduct-automated-inspections-at-cranfield-airport
24 https://www.railtech.com/policy/2019/07/17/drones-become-new-rail-workers/

HUMANITARIAN AND MEDICAL AID – EARLY ADOPTERS

The medical and humanitarian aid sectors are embracing the advancement of UAV technologies and see themselves firmly as one of the market's early adopters. UAVs operating in remote search and rescue operations have, for a number of years, already helped to save hundreds of lives and now hospitals and pharmacies in both urban and rural locations are beginning to see that there is real potential for efficiency benefits for themselves. One such benefit is the significant reduction of lost time. Most medical supply transportation today is undertaken by specialist couriers, "blue lights" or ambulances via road networks, which are significantly impacted by traffic congestions, especially in busy urban environments. UAVs can bring essential improvements in such cases.

The operation of UAVs in remote areas and under emergency conditions has faced significantly less regulatory challenges and so have provided ideal operational test beds as well as providing direct and immediate benefits. One of the pioneers in this area is the California based company, Zipline, who are specialising in humanitarian deliveries, such as the delivery of blood and medical supplies to remote locations by BVLOS flights. The company is operating commercially in Rwanda and Ghana. As of April 2022, its drones have made 275,000 commercial deliveries covering over 20 million flight miles, delivering blood products via UAV (**Figure 8**).

Within Europe, UAVs have been trialed as part of an emergency response by TU Delft aiming to prevent deaths and accelerate recovery efforts (**Figure 9**) through the provision of fast delivery of first aid items. These include Automated Defibrillators (AED) and two-way video communication between the first aiders and emergency services. Elsewhere, Google's Project Wing has been testing UAV operations in Australia aiming for disaster relief by delivering aid, including water and medical supplies to affected areas (**Figure 10**).

Figure 8: Blood deliveries in Rwanda by Zipline 2016 [25]

Figure 9: Ambulance Drone by TU Delft, 2014 [26]

Figure 10: Project Wing by Alphabet [27] *UAV for disaster relief for delivering aid to isolated areas*

25 https://www.cnbc.com/2023/03/15/zipline-unveils-p2-delivery-drones-that-dock-and-recharge-autonomously.html
26 https://www.tudelft.nl/en/ide/research/research-labs/applied-labs/ambulance-drone
27 Image credit: https://doctorpreneurs.com/latest-medical-drones-startups

The development of an efficient UAV-based transport network between hospitals makes logistical and financial sense as well as providing a real opportunity to improve both patient wellbeing and also reduce greenhouse gas emissions

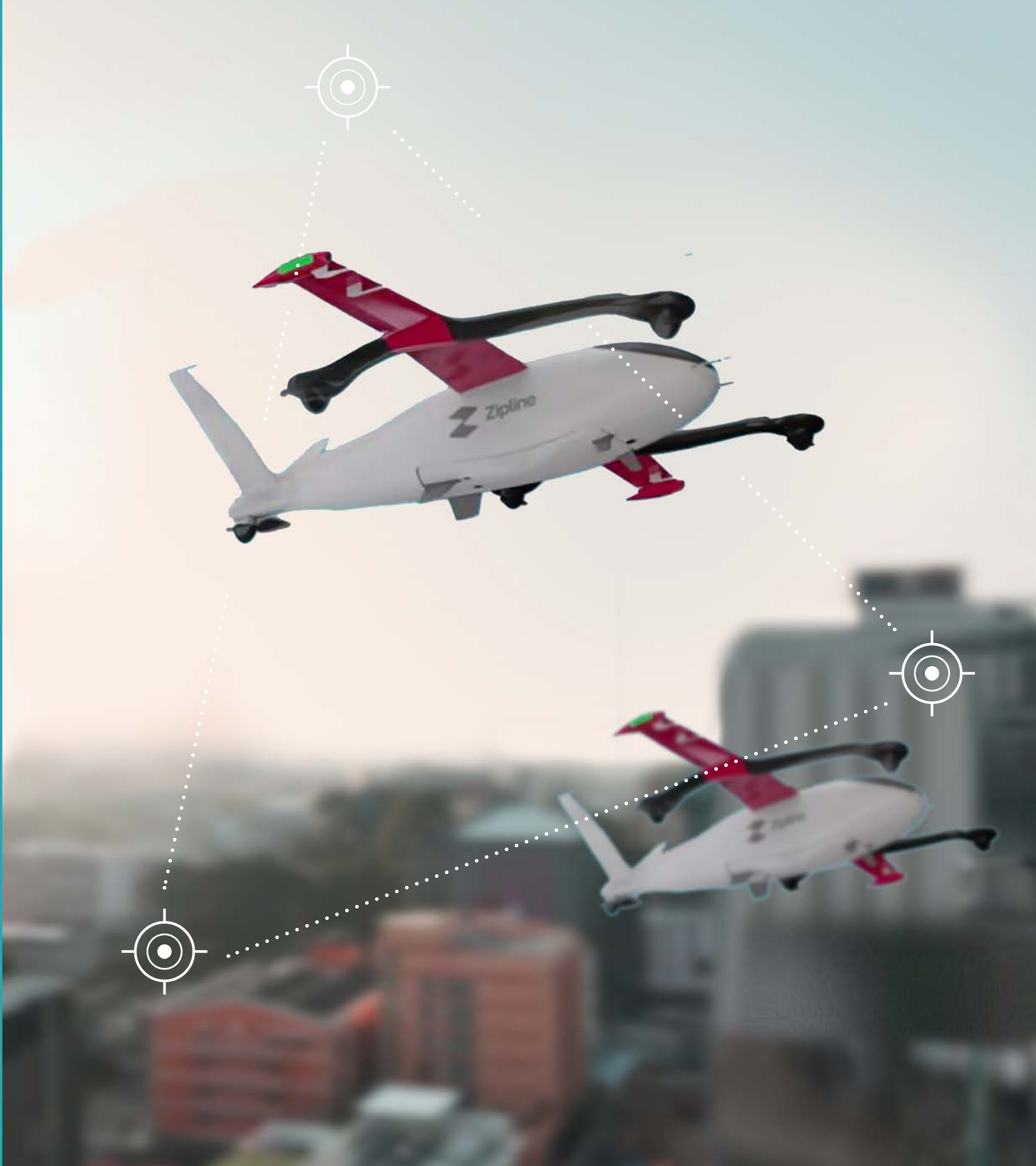

Figure 11: Apian conducting hospital-to-hospital medical drone deliveries between two hospitals across the Solent, 2022[30]

Meanwhile the impact of the COVID-19 crisis created new unforeseen opportunities for the use of UAV services beyond ongoing search and rescue services. For example, the pandemic exacerbated the need for hospitals to significantly improve the efficiency and speed of their inter-site medical distribution services, while limiting staff exposure to health risks and avoiding cross-contamination.

As medical supply movements are mostly undertaken by specialist couriers via road networks the delivery times are heavily impacted by traffic conditions. As a typical example, it takes approximately two hours to complete a time-critical "blue light" shipment, e.g. by ambulance, between a city hospital and their blood bank with a representative 40 miles distance between them. This time includes the delivery time itself plus the processing time for the hospital staff, which are almost equally split. It is evident that, from a point of commissioning to receipt, each medical delivery journey can consume significant amounts of valuable time and resource which would have otherwise been used to support the hospital's frontline services.

With an estimated 2.5 million movements (medical supplies, biological samples and other items) between hospitals and associated sites within the UK alone[28], the development of an efficient UAV-based transport network between hospitals makes logistical and financial sense as well as providing a real opportunity to improve both patient wellbeing and also reduce greenhouse gas emissions. During the COVID-19 pandemic, there had been significant additional operational demands on regulators with respect to the adoption of UAS transporting medical supplies. The UK CAA has had to develop new approval policies[29] that detail requirements and guidance for the approval of BVLOS UAV flight authorisations in an effective and efficient manner in order to respond to the surge in market interest. Although there is limited data around the potential UAV medical delivery market, an extrapolation of the current market indicates a size of approximately $1.3bn by 2030, representing almost 5% of the total predicted UAV global market.

Early medical movement trials showed impressive results. Last year, Apian, partnered with the NHS, completed a 3 month demonstration project for UAV deliveries of medical supplies, specifically chemotherapy medication between the pharmacy at Portsmouth Hospitals University NHS Trust to St Mary's Hospital on the Isle of Wight, where staff collected them before distributing it to hospital teams and patients. By using UAV services, the scheme made it possible to cut delivery times to the island from four hours to 30 minutes, with one flight replacing two car journeys and one hovercraft or ferry journey per delivery. Due to the short shelf life of chemotherapy, reducing the transport time of the medication can play a significant role towards minimising wastage and treatment delays.

28 https://www.businessweekly.co.uk/news/biomedtech/first-flying-doctor-now-medical-supplies-drone
29 CAP1915_NHSCovid19(01052020).pdf (caa.co.uk) - First edition of CAP 1915, 1 May 2020
30 https://apian.aero/solent.html

While these proof-of-concepts tend to be milestones in both the development and proof of reliability of single UAV platforms to service the needs of hospitals and communities in remote areas they are still restrictive since they require onsite teams with skilled pilots, tied to the UAV provider, with open spaces required for launch and receipt. In many cases the UAV is launched via catapult, and the payload is delivered via parachute which is caught in a large net. For major hospitals in dense city and urban environments, these restrictions significantly limit their ability to take advantage of the opportunity that UAVs can provide.

Projects are now ongoing in the UK and elsewhere to find UAV service solutions that can be routinely adopted by hospitals that are located in major cities. Partners on the AIRESPONSE[31] and INMED[32] projects are working in close collaboration with hospital stakeholders to address the UAV delivery technical and operational challenges of working in city environments and with non-specialist operators. Detect And Avoid (DAA) capabilities similar to autonomous automobile vision systems (**Figure 12**) will be key to overcoming the operational challenges, such as collision risks, protecting critical national infrastructure, low accuracy of UAV navigation and lost connectivity. As a part of the required holistic solution the projects are also addressing the logistical requirements of hospital campuses, the integration of the physical and digital logistical infrastructures as well as the incorporation of resilient approved packaging.

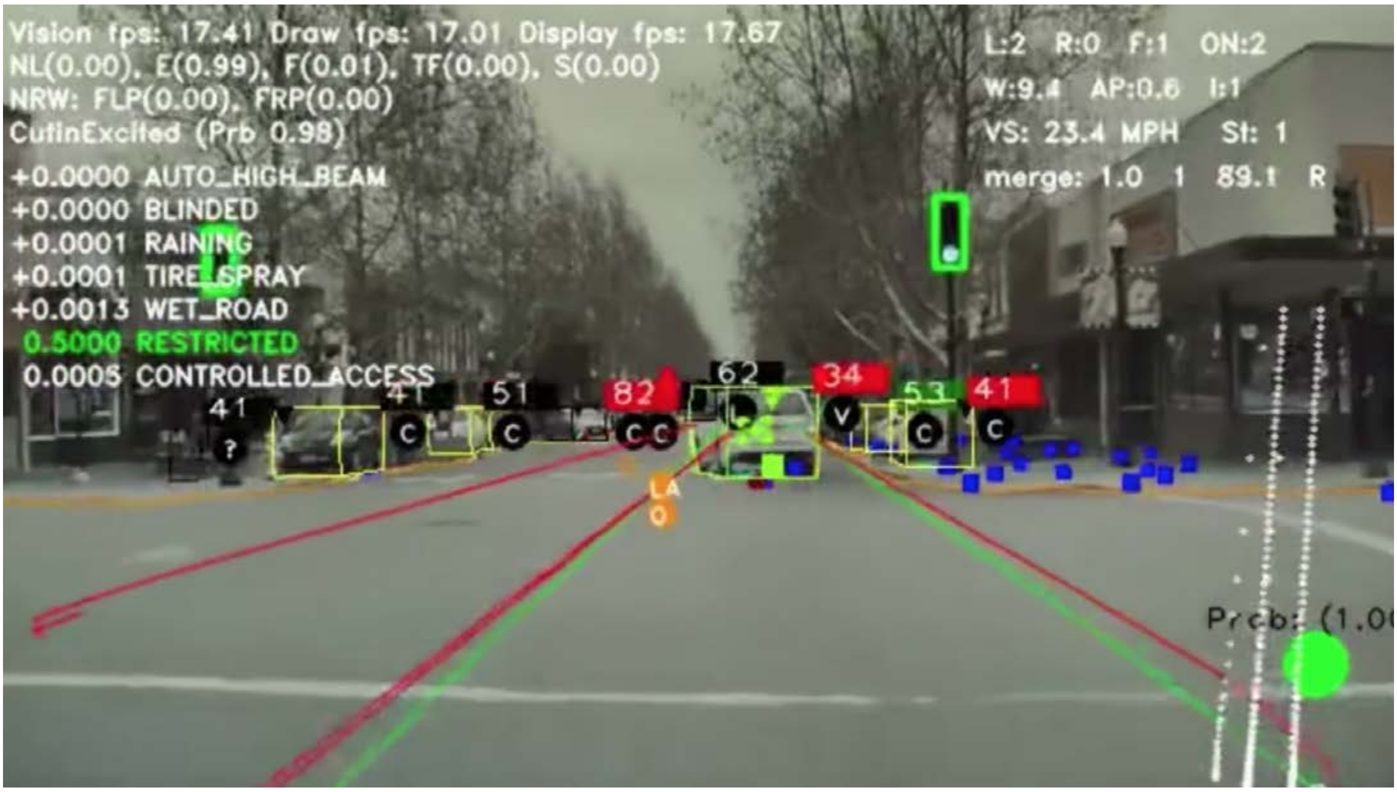

Figure 12 Tesla's autopilot system at work. The system perceives real-world objects using machine vision and then classifies them (e.g. car, stop sign, etc.) using machine learning.[33]

Projects are now ongoing in the UK and elsewhere to find UAV service solutions that can be routinely adopted by hospitals that are located in major cities

31 https://intelsius.com/airesponse/
32 https://gtr.ukri.org/projects?ref=75259
33 https://nerdist.com/article/teslas-autopilot-vision-terminator-hud/

AIRSPACE AND SAFETY MANAGEMENT – MEETING THE REGULATORY CHALLENGE

Perhaps the greatest barrier to global integration of UAS is the development and implementation of airspace management regulations that are relevant to this new form of air transportation and the expected order of magnitude increase in the number of airborne vehicles, daily operational tempo, and operational scenarios (or use cases).

Well-structured and relevant regulation for all elements of uncrewed aircraft systems (UAS), i.e. not only the UAV itself but the supporting ground infrastructure, the voice and datalink communications and command and control (C2) link, etc., is absolutely essential in defining roles and responsibilities for all stakeholders that utilise both controlled and uncontrolled airspace and flight corridors; which to date has been responsible for ensuring remarkably safe air travel.

Developing UAS regulations continues to be a complex task in all regions of the world, with regulators facing the combined challenges of framing a regulatory structure capable of safely accommodating a large variety of new vehicles without negatively impacting access or efficiency for current airspace users, a rate of innovation and change not seen since the introduction of the jet engine, and unprecedented anticipated operational demand within the rapidly emerging and evolving Advanced Air Mobility (AAM) sector (Figure 13).

These challenges are widely recognized and acknowledged; however the lack of comprehensive legislation that truly reflects current technological capabilities has resulted in a continued barrier to entry for UAS operators who intend to fly BVLOS, fly above 400′, or whose vehicles or intended operations don't fit into the lowest risk categories. For the near-term, most regulators have opted to allow limited BVLOS or higher risk flights on a case-by-case or waiver basis, or have set aside segregated UA airspace or corridors. For example the UK's position echoes that of many other nation states, in that BVLOS flights "must be conducted either within segregated airspace, or using a "Detect and Avoid" system, or the operation is such that it poses no additional risk to aviation."

For farther-term, full BVLOS integration, most regulators are actively working with industry in order to gather sufficient test flight data to inform development of the missing regulations and standards; either directly, through collaboration in industry forums such as the recent US BVLOS Aviation Rulemaking Committee (ARC)[34] , or through sandbox and testing environment initiatives such as the UK's CAA Sandbox and in the US across their various UAS Test Sites.

The issue of regulatory harmonisation across international boundaries is also critical, potentially limiting transnational flight operations within internationally controlled airspace. The International Civil Aviation Organization (ICAO) is addressing this challenge through its Remote Piloted Aircraft System Panel (RPASP), and the newly formed Advanced Air Mobility Study Group.

The collective learned experiences from all of these initiatives are vital, and the data gathered will help inform development of the next level of international and State-specific aviation standards and UAS regulations. Two example case studies of major activities are discussed below: evolution of the European U-Space model, and US work on developing UTM capabilities.

Regulators will face significant challenges in the next few years. The key common challenges relate to three broad themes:

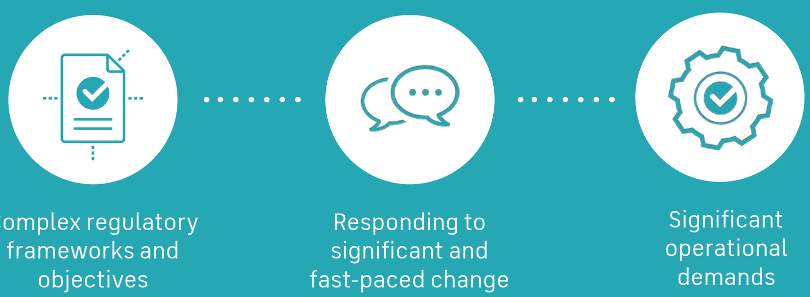

Figure 13: Regulatory challenges [34]

34 https://www.faa.gov/regulations_policies/rulemaking/committees/documents/index.cfm/document/information?documentID=5424

EUROPE U-SPACE

The European Union's U-space vision encompasses the phased introduction of a set of services and procedures which are designed to support the safe, efficient, and secure access to airspace for a large number of UAS. These services rely on a high level of digitalisation and automation, both onboard the UAV and as part of the supporting infrastructure, either terrestrial or space-based. The U-Space maturity model outlines a set of technical capabilities and services which will be needed to fully integrate UAS into European airspace, starting with foundation services (U1) and progressing to initial services (U2), advanced services (U3) and finally full services (U4) (see Figure 14)[35].

Between 2020 and 2022, many SESAR3 JU projects carried out tests and trialled solutions at almost 70 locations across Europe, demonstrating the readiness of U-space services to support a broad range of UAS operations, and the interaction between UA (uncrewed aircraft) and uncrewed aviation. These demonstrations ranged from parcel deliveries between urban areas, to medical emergencies and police interventions, to air taxi trials in controlled airspace around airports.[36] An important output of this research was an updated and consolidated concept of operations (ConOps) for U-space[37], now including urban air mobility (UAM).

In order to support the deployment and implementation of U-space, a U-Space regulatory package was approved by the European Union Aviation Safety Agency (EASA) Committee in February 2021. The European Commission (EC) subsequently adopted and published the policy package regulating U-space in April of 2021; whose provision became applicable as of January 2023. The U-Space regulatory package consists of:

- Commission Implementing Regulation (EU) 2021/664, which regulates the technical and operational requirements for the U-space system.
- Amendments to two Implementing Regulations (EU) 2021/665 and (EU)

U1 – Foundation services
- e-identification
- e-registration
- geo-awareness

U3 – Intial services
- Flight planning and approval
- Tracking

U2 – Enhanced services
- Dynamic capacity managment
- Tactical conflict resolution

U4 – Full services
- Collaboration interface with ATC
- Additional new services

Figure 14: Regulatory challenges [35]

35 SESAR Innovation Pipeline 2021: Air traffic management research and innovation
36 https://www.sesarju.eu/U-space_everyday_benefits
37 https://www.sesarju.eu/node/3411

2021/666

UNITED STATES UTM R&D

Within the USA the Federal Aviation Authority (FAA), with the support of its multi-stakeholder Advanced Aviation Advisory Committee (AAAC) and others, has several ongoing national trials and demonstration programmes leading towards UAS flight integration within controlled airspace underpinned by federated UTM services.

The UAS Civil Integration Roadmap highlights the progress made to date (Figure 15) including the Integrated Pilot Program that evaluated multiple operational concepts, and the issuing of final rulings for both Remote Identification and Operating Over People.

The roadmap also recognises the many technical and operational challenges that still need to be addressed ranging from Detect & Avoid, Command and Control (C2), Human Factors and Safety Risk Management to Counter UAS. As these challenges are being gradually addressed by their stakeholders they will inform policy and ultimately subsequent regulation.

Future UAS operations also feature as a key part of the FAA's ambitious overall air traffic modernisation programme; "Next Generation Air Transportation System" (NextGen). The NextGen programme is seeking to adopt "a spiral development of UTM, starting with low complexity operations and building, module by module, higher complexity operational concept requirements". The goal for an initial UTM implementation is to minimise deployment and development time by utilising current industry-provided technologies and capabilities for operations (e.g. existing ground and satellite communications infrastructures) capable of meeting appropriate performance requirements for safety, security (cyber security, resilience, failure modes, redundancy), and efficiency while minimising

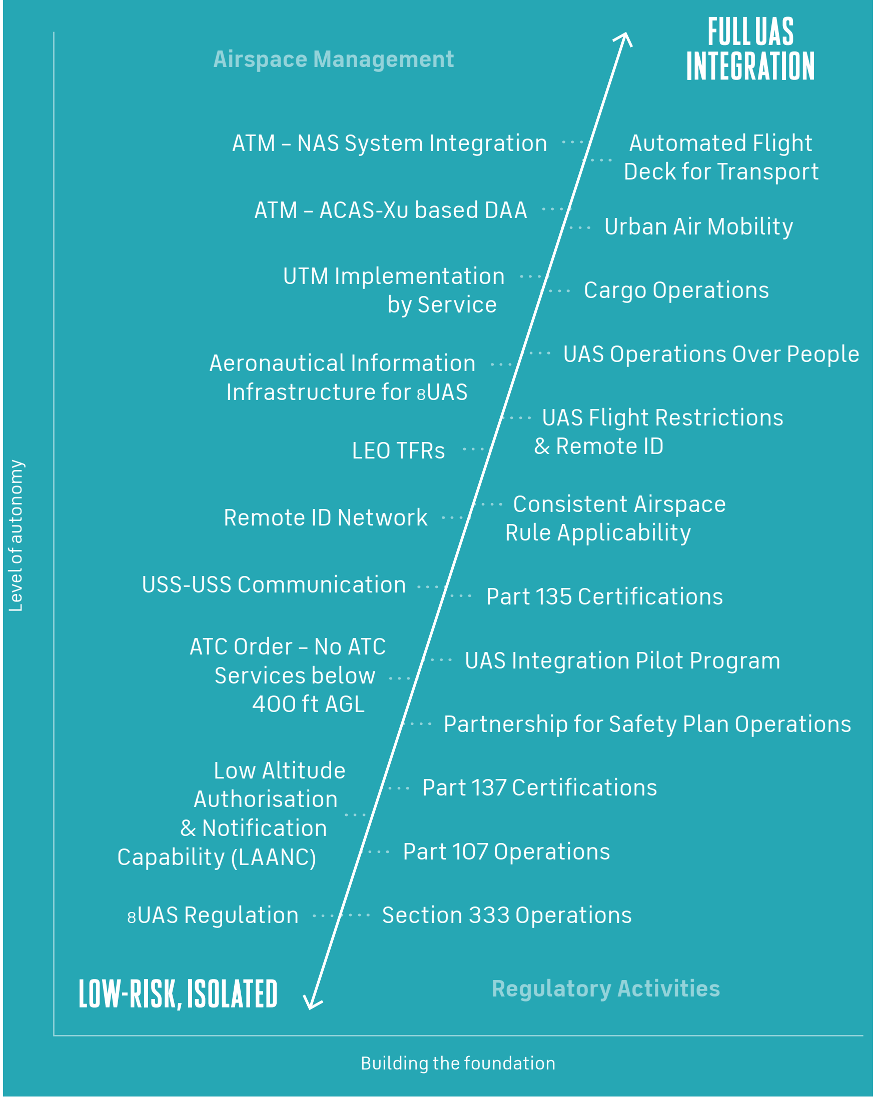

Figure 15: UAS Civil Integration Roadmap

environmental impacts and respecting privacy and safety of citizens.

The FAA released its latest UTM Concept of Operations (ConOps) version 2.0 in 2020 designed to provide regulatory support for low altitude (below 400 feet) UAV flights by reaffirming that it will adopt "a set of federated services and an all-encompassing framework for managing multiple UAS operations". Version 2.0 starts to consider more complex environments including BVLOS flights in controlled airspace(Class B,C,D & E) through the introduction of new concepts such as airspace authorisation, remote identification of UAS operators, and further standards development in support of enabling UTM operations.

In support of the FAA's approach, NASA has been engaged in technology capability assessment studies (Technology Capability Level), the latest being the TCL Level 4 flight trials that focused on the performance of UTMs within urban and suburban environments. The trials demonstrated the ability of UTMs to support BVLOS flights and provide operators with good situational awareness of their own UAVs. However, the trials also highlighted the need for improved data connectivity to provide information about flights other than those under their direct control and for "clear procedural guidelines and clear information displays".

The Level 4 trials echo a common theme amongst all the aviation regulators; namely that there is a need to provide platforms that exchange essential data through timely, resilient, and diverse connectivity pathways between all of the stakeholders operating in low level airspace. Not unsurprisingly in seeking to achieve the desired high levels of data connectivity there is a need also to consider how the data is protected and what the data liability challenges might be.

38 Uncrewed Aircraft System (UAS) Traffic Management (UTM) (faa.gov)
39 UTM: Air Traffic Management for Low-Altitude Drones (nasa.gov)
40 https://www4.icao.int/ganpportal/trustframework

RPAS BVLOS Ecosystem

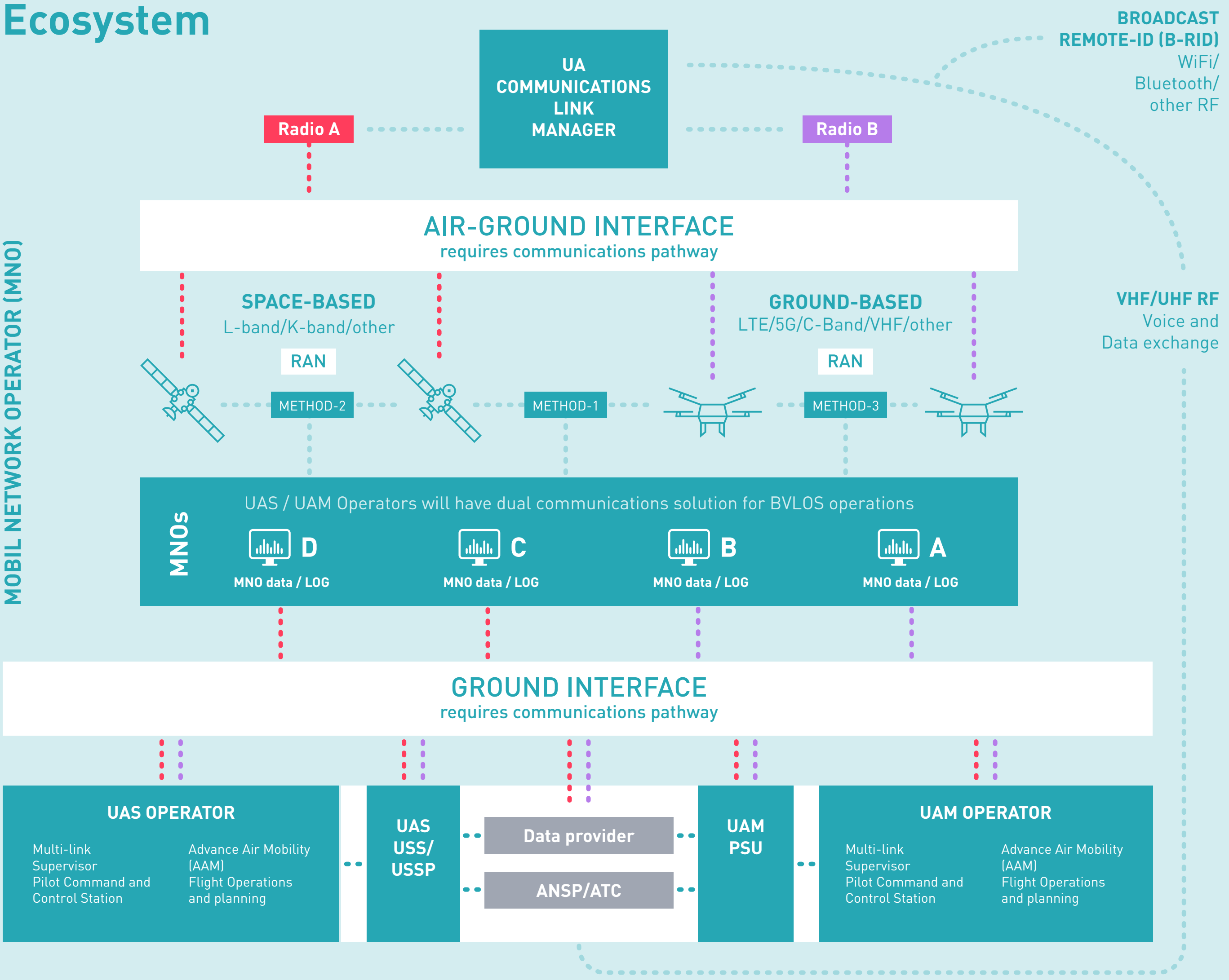

Figure 16: BVLOS potential communications pathways

TRUSTED AND RESILIENT INFORMATION EXCHANGE

Both the European Union and the USA have recognised that creating new networks of UTMs, potentially within federated structures, will introduce a number of unique challenges. All stakeholders will be highly dependent on trusted interconnectivity and integration with stakeholder assets being connected through diverse communication solutions (satellite and/or ground-based pathways) leading to complex communications solutions between the UAV and the pilot control station (**Figure 16**).

Additionally as the ecosystem evolves the communications pathways between the pilot and the UAS Service providers, the regulators and Air Traffic Control infrastructure all present new risk that does not exist in the commercial aviation industry. These create both new safety and cybersecurity risk, whether unintended or malicious, that may have an impact on safety.

Users of the UTM networks must have the confidence that the networks have the capabilities to provide trusted and resilient communications to facilitate information exchanges in a manner that is not complex and complies with the appropriate policies, regulations and laws. Mutual Trust is partly provided by the regulation itself that should harmonise both the safety and security framework to be implemented. The second part of mutual trust supported by regulation is that it not only mandates the requirements for the ecosystem but is also identifies methods for validation developed by the regulator through competent enforcement. As this ecosystem grows, ensuring that there is a harmonised framework to follow, such as that proposed by the UK's Open Access initiative and others, becomes a critical attribute for the community.

To help aid the aviation community as a whole, The International Civil Aviation Organization (ICAO) has responded to the global need for trusted and resilient communications needs that enable safe and secure information exchange.

ICAO has established a Study Group (SG) known as the International Aviation Trust Framework (IATF). Under the study group the IATF remit is to develop a framework that enables global mutual digital identity (DI) trust. Additionally the IATF has also developed a framework for global trusted and resilient information exchange that provides a policy framework known as the Global Resilient Aviation Information Network (GRAIN)[41]. The GRAIN framework identifies policies to establish identity trust along with a framework to establish operational trust between interconnected users by establishing a scalable risk based approach for organizations to implement for managing the software, hardware, systems and networks that would be used to exchange information. This ensures each interconnected user will be at a known level of technical trust to enable safe and secure information exchange. ICAO are in a position of setting out harmonised rules for the aviation community to help reduce the complexity of information exchange using such frameworks, as they have done for many decades for crewed aviation, although the enforcement will be through national instruments. The implementation of the DI framework will ideally become common globally and provides a harmonised framework to mutually trust the communications pathways. The GRAIN framework is advisory and not planned to be mandatory, but it does provide a structure to establish a higher level of trust with a large volume of interconnected users. On a regional/ geographical level, especially those that support the UAV community, these frameworks present opportunities to implement regional versions of these frameworks, customized to meet the needs of all stakeholders.

At a minimum, the framework to establish identity trust between parts of the ecosystem should be considered as this would significantly reduce the level of complexity of establishing trusted interfaces for information exchange. Implementing a common framework for identity trust would enable Mobile Network Operators, Service Providers, the regulator and UAV operators to implement a identity framework that is interoperable for all ground communications and goes a long way towards reducing the complexity of establishing connectivity and mutual identity trust.

Supporting safety and security, there are many questions about the evolution of the IATF and the benefits that can be realised by the UAV ecosystem. This is especially true since the UAV community does not necessarily require global interconnectivity. Following a harmonised framework like those provided by the IATF, even at a regional level, provides many safety and security benefits for implementing harmonised interoperability standards where it makes sense. UAS service supplier, Mobile Network Operators and others will have to provide real time and near real time accurate data continuously. The performance of these systems will be both the operator and most likely based upon the mandated regulation that identify minimum performance levels for services. Regardless of the frameworks implemented, all providers have to deliver a capability and implement frameworks that enable all aspects of the ecosystem.

The commercial aviation community working together often drive new changes and work collaboratively with the regulators. This is no different for the UAV community if we all work together. We have to keep in mind that it's not just the commercial industry that is impacted. We have to keep in mind that the implementation of these capabilities must also be supported by the regulator and its capacity to also implement these changes.

CONCLUSION

This brief paper has been produced to highlight some of the impacts and challenges of the emerging UAV sector as it undergoes what is projected to be unprecedented growth that some consider is on a par with the introduction of the jet engine and the global commercial market.

While popular representation of UAVs focusses largely on the prospect of deliveries into the back gardens of those living in urban environments, the more immediate benefits are likely to be elsewhere. The humanitarian relief, infrastructure inspection, broadcasting and farming sectors to name but a few are already today benefiting from the regular use of UAVs. What is surprising is as a direct result of the COVID-19 pandemic another early adopter of UAVs is emerging in the form of medical deliveries to and from hospitals. Deliveries between inner city hospitals are currently regularly and significantly delayed by road congestion adding critical minutes to journey times. With an estimated 2.5 million medical delivery movements per year in the UK alone this represents a real operational concern. Multiple and extremely promising demonstration trials are now in progress that are accessing the true benefits of new UAV enabled delivery services that can be integrated seamlessly into routine hospital procedures.

The early adopter sectors such as medical delivery will pave the way for market entry by the global commercial logistics organisations. Driven by significant potential cost saving benefits and greater delivery network resilience autonomous vehicles, including UAVs, are now be trialled. The initial focus is on providing autonomous B2B services (i.e. deliveries to and from logistics centres) and then to B2C services. With the prospect of 80% of all deliveries being made by autonomous vehicles by 2026 and the introduction of so-called Smart Logistics this represents potentially a dynamic shift in the way modern societies work.

Commercial UAVs need to be able to fly safely in both controlled and uncontrolled airspace under the guidance of Uncrewed Traffic Management (UTM) systems and beyond the line of sight of any ground-based operators

As number of operational UAV flights escalate so they are able to contribute significantly to the reduction in global environmental airborne pollution and green-house emissions. Road freight traffic can currently account for between 22% and 25% of urban airborne pollutants and with the rapid growth of e-commerce and package delivery this is likely to increase. However, UAVs are almost universally powered by electric propulsion systems that can be recharged from renewable energy sources so not adding to the environmental burden. Modelling by Cranfield University, and corroborated other sources, suggests that UAVs when used instead of conventional diesel-powered vehicles for "last mile" deliveries can potentially reduce urban transport greenhouse emissions by up 47%.

The regulatory enablement of safe, low altitude UAV flights alongside conventional aircraft, particularly within urban airspace, is now considered to be the greatest challenge to the growth of the UAV market. Commercial UAVs need to be able to fly safely in both controlled and uncontrolled airspace under the guidance of Uncrewed Traffic Management (UTM) systems and beyond the line of sight of any ground-based operators.
Major initiatives in Europe, USA and elsewhere are focusing on developing regulatory frameworks that will enable multiple UTMs to operate concurrently within (typically) federated structures to provide the same safe airspace management infrastructure that we currently use for conventional aircraft. Unpinning the UTMs will need to be trusted, resilient, secure and diverse data communication systems without which BVLOS operations and management would not be possible and the full potential of UAVs will not be realised.

HOW INMARSAT IS WORKING TO UNLOCK THE SKIES

This is where Inmarsat comes in. To get to the point where you have UAVs successfully operating beyond visual line of sight, we have to first unlock the sky. Alongside our comprehensive and expert ecosystem of partners we can achieve that by demonstrating that reliable and secure connectivity works on small UAVs. Safe and robust communications is unquestionably the catalyst - the key – to unlocking the skies.

At Inmarsat, we have over 30 years' experience enabling air traffic management and aviation safety. Communication, navigation, surveillance and mobile connectivity is at the heart of what we do.

We also have extensive UAV experience working with civil and military governments worldwide. These utilise our market-leading, award-winning, secure and ultra-reliable L-band network, ELERA, which already safely guides tens of thousands of business and commercial aircraft across the globe every day.

While our L-band network represents communication, navigation, surveillance, air traffic control, separation standards – safety in other words – it's clear that we are only one link in a very important chain. We are collaborating with other communication technologies - LTE for instance - to provide multilink communication capabilities. However, parts of the ecosystem will have their limitations; LTE for example suffers from cross talk from other masts at around 1000ft. So it is incumbent upon us, as a global satellite provider of ubiquitous connectivity, to work with all in the industry to establish multi-channel communications that will allow everyone to put safety at the heart the future of UAVs.

With the recent launch of our latest network, ORCHESTRA, we are redefining what a communications network does and can be, as ORCHESTRA seamlessly integrates GEO, LEO, terrestrial 5G and dynamic mesh technologies. This is also complemented by Inmarsat Velaris, our bespoke connectivity solution for the UAV sector. Inmarsat Velaris is a global, reliable and totally scalable Command and Control (C2) service enabling everything from simple tracking and identification for small drones to full aero safety services for UAVs operating in controlled airspace.

Inmarsat believes in the unlimited world of possibilities that UAVs offer. Working alongside regulators to demonstrate the value and safety of UAVs, and consequently opening up this airspace, is our next task.

This will only be achieved with the assistance of our dedicated partner network and our wider innovative UAV ecosystem. We welcome contact from potential partners and developers who are interested in integrating our UAV connectivity solutions into its programmes or joining our growing UAV ecosystem.

inmarsat
AVIATION

AUTHORS

COORDINATING AUTHOR

Alex Holt

Marketing Business Partner

Inmarsat Aviation

CONTRIBUTING AUTHORS

Dr Adrian Cole
FIMechE, FRAeS, CEng

Programme Manager – Digital Aviation Research & Technology Centre

Cranfield University

Dr Abhijeet Ghadge

Associate Professor of Logistics and Supply Chain Management

Cranfield University

Dr Ivan Petrunin
MInstNDT, MIEEE

Lecturer in Digital Signal Processing for Autonomous Systems

Cranfield University

Dr Ioannis Koliousis
FCMI, FCILT

Associate Professor of Logistics and Supply Chain Management

Cranfield University

Richard Ryan, barrister
LL.B(Hons), LL.M, M.A.

Part-time Phd Student

Cranfield University

Kristen Mineck

Manager, Aviation Standards and Requirements

Inmarsat Aviation