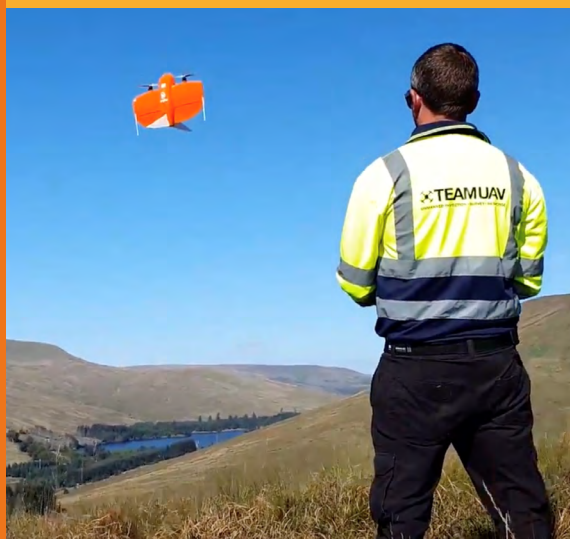
HM Government

Department for Business, Energy & Industrial Strategy

Department for Transport

Advancing airborne autonomy

Commercial drones saving money and saving lives in the UK



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Foreword

Rt Hon Kwasi Kwarteng
Secretary of State for Business
Energy and Industrial Strategy

Science and innovation underpin the productivity, potential and resilience of our economy. The Innovation Strategy emphasised our target for UK R&D to reach 2.4% of GDP in the next five years. We backed up this ambition by announcing record public support for R&D of nearly £40bn over the next three years. The UK has recognised research strengths in robotics and automation and is on track to be a world-leader in developing, testing and commercialising autonomous vehicles on the roads and drones in the air. This document outlines how we will continue to invest in the R&D capabilities, skills, clusters and regulatory frameworks that enable commercial drone innovation. We will support the UK's dynamic entrepreneurs to bring new solutions to market, for the benefit of us all.

Increasingly connected and automated systems, powered by AI, are already delivering new capabilities and better, safer jobs across the economy. I welcome PwC's updated forecasts outlining the massive UK opportunity in drone adoption, potentially worth up to £45bn by 2030. Public investment is helping unlock this potential, including through UKRI's Future Flight Challenge, where £70m of government funding is supporting new collaborations, ensuring the UK remains a leading destination for testing, demonstration and deployment of advanced robotics capabilities.

This report makes an important statement in outlining how consumers, including those who procure within government, can benefit from innovation in the drone sector. The growth of the drone sector requires end-user understanding and confidence. The examples outlined in this report show the tremendous commercial potential that drones can already deliver. Government is supporting practical, technological and regulatory enablers for commercial drones. I encourage business leaders across the UK to look hard at how drones can support new solutions and services, lowering carbon emissions and saving money, time and even lives.

Robert Courts
Minister for Aviation,
Maritime & Security

New aircraft such as drones present significant opportunities for low carbon local and regional air services. We want to work with industry to drive sustainable technological transformation through regulation and a systems approach to provide new and improved services for users.

We recently published the Flightpath to the Future that set out the key priorities to deliver our vision for a modern, innovative and efficient aviation sector over the next 10 years. This recognised the important role drones play and the potential from new aviation technology and its uses. We are committed to publishing a plan for the Future of Flight and will set up a Future of Flight Industry Group to work with industry and the CAA to develop and deliver it. The plan will include delivery of the necessary regulatory framework for aviation innovators to thrive. Government will also support the sector by delivering the Airspace Modernisation Strategy to achieve quicker, quieter, and cleaner flights and to ensure that all new and current airspace users can operate and coexist safely in UK airspace.

The CAA has a critical role to play in supporting delivery through its regulatory activities and working closely with innovators such as through its Innovation Hub. Government is providing additional funding to the CAA to scale up support for new aviation technology. Benefitting from new regulatory freedoms outside the EU, we will be one of the first countries in the world to routinely use new aircraft to provide new and improved low carbon services, and local and regional air mobility for goods and people.

Iain Gray
Chair
Drone Industry Action Group

This is an exciting time for the UK's drone sector. PwC's refreshed forecasts reiterate the enormous potential commercial drones have for public benefit and for cleaner growth and skilled jobs. Through my role as Chair of the Drone Industry Action Group, I see businesses across the UK developing and demonstrating new drone capabilities and helping make cutting-edge technology the norm not the new. I have welcomed working closely with Government to showcase what drones can do and to identify the barriers to realising their 2030 opportunity.

But for too many businesses this potential is obscured by regulation and end-users are unsure what is legal and what they should buy. My hope is that this report will help demystify drones – showing how they are already being used in a range of settings – and help give businesses the confidence to engage with the UK's drone innovators and to benefit from these new tools.

Drone opportunities exist across the globe. I know the UK can be a global player in drone services and solutions and help to set the global standards and frameworks for us to reap longer-term mobility and commercial benefits.

To achieve this potential will need collaboration. It is in all our interests to ensure continued confidence in UK airspace safety and for the UK to harness new technology to make existing aviation safer and to reap the multiple benefits from new drone services. This report shines a light on some of the more significant barriers to realising drone potential and recommends actions necessary to address them. The sector stands ready to work with UK government and regulatory authorities to overcome these.

Executive Summary

The commercial drone opportunity

Drones present a significant and exciting opportunity for the UK. They offer public and private organisations an opportunity to carry out tasks faster, safer, cheaper and with less impact on the environment than traditional methods. They will soon fulfil their promise of bringing deliveries by air (and eventually of carrying humans too) and will help save lives in the trained hands of our emergency services. They will also contribute to improving domestic connectivity and levelling up by providing better services to and from remote or isolated communities.

PwC's Skies without Limits v2.0 estimates that by 2030, assuming 'best-case' adoption:

- Drones could contribute up to £45 billion to the UK economy
- More than 900,000 drones could operate in the UK's skies
- £22 billion in net cost savings could be realised
- Carbon emissions could be reduced by 2.4 million tons
- 650,000 jobs could be associated with an economy that fully adopts drones

Enablers

The UK drone community has worked with government to identify priority enablers that will allow the UK to capitalise on the drone opportunity. These include

- ***Investing in state-of-the-art UK technology:*** Government will continue to support the UK's dynamic innovators, engineers and technicians driving the essential technology development, testing and integration that will make the UK a leader in drones and advanced robotics. This includes the recent £70m commitment from government into Phase 3 of the Future Flight Challenge to support the new technology testbeds and demonstrations that enable evidence-based safety frameworks to be built. Significant investment from the UK defence community is supporting UK manufacturing capability.
- ***Regulation that supports safe innovation:*** Government is committed to delivering an enabling regulatory framework that safely and efficiently supports the drone industry as it develops, while continuing to meet the UK's aviation safety goals. Government and the CAA are actively reviewing how new types of aircraft are regulated, what the future is for UK airspace and how it is managed. Government has committed record levels of funding to the CAA to ensure it has the capability and capacity to support the drone sector and provide guidance in key areas such as BVLOS flight and certified drones.
- ***Mainstreaming drone use in business:*** A range of government and sector bodies support effective drone adoption. The Connected Places Catapult's Pathfinder programme and drone sector bodies advise and support businesses to invest in drones with confidence. The Drone Industry Action Group acts as the primary collaborative forum between government and the drone sector
- ***Supporting drone sector dynamism:*** Government's business growth, funding and export support services help ensure the UK is the best place to start, grow and scale-up technology businesses. A wide range of national, local and university-led programmes complement the private incubation funding streams to support novel technologies and build thriving businesses.
- ***2030 skills:*** Fast growth of the drone sector will be led by the UK's dynamic entrepreneurs and necessitate a huge boost in the technicians and engineers to build, maintain and operate drone fleets. Similarly, effective trial, integration and use of drones by end users across the economy will need new skills and change programmes to make the most of potential new data and service solutions, including through new CPD programmes.
- ***Communications and connectivity:*** Communication technologies are essential to drones for control, authentication and authorisation, and data transmission and will be important components of efficient and safe future drone operations. Mobile network providers are investing in drone growth opportunities and working with Ofcom to develop and implement new spectrum bands, emission limits and equipment standards for this market.
- ***Drones for all:*** engaging public perceptions: Government, led by CAA, and the sector will continue to work together to inform and support public debate on drone use, ensuring end-users across the economy have the confidence to adopt drones and the public understand the important role commercial drones can play in our future society.

Call to Action

To maximise the impact of drones on the UK economy and society, we will build on our existing capabilities, to smooth the regulatory path and to support the UK's innovators to thrive. This Ambition Statement outlines core components for delivery, including:

- Government's Future of Flight Plan and Future of Flight Industry Group in developing a pathway to new uses and users of aviation and airspace
- Funding to ensure the UK supports and builds on the best of British drone technology, including through the Future Flight challenge, investing in and demonstrating new operating models and developing new frameworks to enable drone capabilities to thrive
- Implementation of sector-specific skills and CPD programmes to support effective end-user drone adoption and integration
- Supporting drone innovators in their ambitions to start-up and grow their businesses in the UK, and convening the Drone Industry Action Group to support collaboration between government and the drone community
- Wider regulatory support to enable routine drone operations, including a well-resourced CAA and refreshed Airspace Modernisation Strategy, and an Ofcom consultation to deliver robust drone communications and connectivity aiming to enable 4G and, in time, 5G for commercial use
- Active public outreach and communications underlining the positive potential uses for and benefits of commercial drones.

1 Vision

Enabling business growth through drone technology

Our vision is that by 2030 commercial drones[1] will be commonplace in the UK in a way that safely benefits the economy and wider society. Drones will deliver new capabilities, boost productivity and reduce emissions and risk to life, while sharing airspace equitably and safely with other users.

This is an exciting time for the UK's drone sector.

Drone technology innovators, powered by advances in robotics, battery power, imaging, communications, sensing and artificial intelligence, are on the cusp of delivering new breakthrough capabilities. Supported by increasing levels of investment, drones are safely flying further and more autonomously, improving productivity and unlocking new business models.

Updated evidence by PwC shows, with best-case adoption, UK public and private sector drone use could deliver a £45bn uplift to GDP by 2030. Drones are helping to keep our trains running, help inspect our roads, bridges and waterways and to ensure our power lines, wind turbines and oil & gas platforms are safe. PwC's analysis shows cost savings can be achieved across all sectors, and new sectors will emerge including drone delivery services. The largest commercial drone benefits come from:

- **Visual surveys and inspection:** drones used in construction, housing, infrastructure, agriculture and the emergency services across the UK
- **Delivery:** helping connect and serve remote communities, and building new business models – forecast to be worth £10bn to the UK economy by 2030

Drones also support critical public services. Coastguard, police and fire & rescue services are using drones to respond to emergencies safely and swiftly, to safeguard vulnerable people and to prevent and detect crime. As drone capabilities improve they will bring us entirely new services, including routine and emergency medical deliveries. They will reduce road congestion and carbon emissions. PwC estimates by 2030 they could save the equivalent of 1.7 million diesel cars as they increasingly replace helicopters and fixed wing aircraft and reduce the need for risky operations at height, offshore or in confined spaces.

In May 2022, Government published 'Flightpath to the future': a strategic framework for the aviation sector and vision for a modern, innovative and efficient sector over the next 10 years. The strategy set out a ten-point plan for the future of the aviation, establishing clear priorities to ensure the UK retains one of the strongest aviation sectors in the world. A key priority is to capture the potential from new technology and its uses, including drones. Benefitting from new regulatory freedoms outside the EU, Government's vision is for the UK to be one of the first in the world to routinely use new aircraft to provide new and improved low carbon local and regional air mobility for goods and people. Government announced it will convene a Future of Flight Industry Group to work alongside the Aviation and Jet Zero Councils to set out the forward path for aviation. A key output will be to develop and publish a Future of Flight Plan setting out the coordinated vision for new forms of aviation in the UK.

[1] **In this document, we define drones broadly to mean any aircraft without human pilot, crew or passengers operating under remote control by a human operator or with various degrees of autonomy.**

Government and the drone community have worked together to articulate this drone ambition and are committed to maximising the benefits to the UK of rapid adoption of drone capability. In this document we first set out the drone opportunity across different sectors and uses before outlining the enablers needed to deliver on this potential. We point to the key areas of Government activity where the UK drone community and end users are already driving UK capability and adoption forward. This includes technology commercialisation, business support, and regulation. We then outline how Government and the sector will work together in the years to come.

2 The drone opportunity

By 2030, new, proven technologies and established regulatory standards will enable drones capable of longer distance, autonomous flight and support drone deliveries and new business models. Recent years have laid the foundation for this acceleration, backed by Government support and increasing levels of private investment in the UK and overseas.

The consultancy Beauhurst reported UK investment of £10m in 2017, and over £30m in each of 2018, 2019 and 2020. As commercial drones become more autonomous and long-distance, they will become an embedded norm for efficient businesses and public institutions facing challenging commercial environments.

In the ***short-term***, we expect drones to see widespread adoption as the industry standard for inspecting the UK's buildings, power lines, offshore energy facilities, roads, railways and industrial facilities, to ensure they are safe, secure and efficient. Drones have been proven to save time and cost, improve accuracy, and be safer than traditional approaches using ladders, scaffolds, ropes, helicopters and airplanes.

In the ***medium-term***, we expect drone delivery services to see use cases scaling and new business models emerging, initially in emergency, high-value goods or remote area services. Building on existing hospital and international trials, we expect consumer delivery business models will grow in significance from 2025, benefiting both rural and urban communities. This capability will also be boosted by growing adoption of crop spraying drones for precision agriculture.

In the ***longer-term***, drones will be seamlessly integrated within many sectors, and new business models will emerge. Technology and engineering advances in heavy-lift, swarm, and communications and connectivity will drive improved supply chains, logistics and mobility. PwC forecast that at maximal adoption rates, this could increase UK GDP by £45bn, with some 900,000 drones providing essential services to power our economy. While we also anticipate passenger-focused air taxi and regional mobility services to emerge by 2030, we do not include this potential market in this report.

Drones reduce risk to humans: The UK's ageing infrastructure of railways, roads, buildings and utilities need regular inspection and maintenance to operate efficiently and safely. This is a hazardous process and every year, across the UK's infrastructure, inspection and security workers are hurt or killed undertaking work that can be assisted by drones. In hazardous, offshore or confined environments, the case is even more clear.

Drones can reduce environmental impact: PwC estimates that best-case drone use could deliver greenhouse gas savings equivalent to taking 1.7 million diesel cars off the road, through speed of data capture and reduced use of traditional aircraft. Inspection engineers, emergency workers and security guards will no longer need to drive long distances to remote locations at anti-social hours to make routine assessments or respond to incidents. There may be additional benefits such as reduced air pollutants, noise and congestion as drone delivery opportunities emerge and reduce conventional vehicle use.

Drones offer new services and connections: They can improve mail and logistics deliveries into isolated or remote communities and help reduce health inequalities by speeding medical response and delivery times.

3 Key use cases

Overview

For commercial operators the bottom-line and safety benefits of drones are critical. PwC's forecasts show the significant potential across the economy to reduce costs and improve jobs by 2030, as businesses and the public sector adopt new drone services. Drones are already commonplace in certain sectors, such as offshore energy, and in others their potential is only just becoming apparent.

Table 1: Potential annual cost savings from drone adoption in 2030, in 2021 prices

Sector	£bn	Example drone activity
Public and Defence, Health and Education services	4.6	Rapid response use by police and emergency services; defence solutions
Agriculture, Mining, Water, Gas and Electricity	4.4	Inspection/ survey and agriculture spraying
Transport and Logistics	4.2	Last mile and intra-depot delivery services
Wholesale, retail trade, accommodation and food services	3.7	Food delivery services and facilities inspection
Financial, Insurance, Professional and Administrative Services	3.0	Inspection and survey for audit and insurance
Construction and Manufacturing	1.6	Inspection, survey and monitoring
Technology, Media and Telecoms	0.9	Infrastructure inspection
Total	**22.4**	

Source: PwC Skies without Limits 2.0

Drones for public good

Drones are already delivering benefits for the public sector, across our national infrastructure through drone delivery, and by helping secure wider social and environmental benefits. The most valuable expected use cases are included here, with additional examples in the Annexe.

Emergency services, police and search and rescue

Drones are in regular use today in the UK by emergency services teams including firefighters, coastguard, ambulance and police. Drones help search in remote areas, on rooftops or bridges and in mountainous areas and monitor collision and crime scenes, floods and flood defences, wildfires, building collapse and unsafe structures.

Equipped with thermal imagery sensors, smaller quadcopter drones can quickly identify body heat, supporting operations in poor light or weather. Longer-distance drones can search expanses of sea at lower cost and for longer durations than manned flights. Drones assist intelligence-led response including reaching vulnerable persons, supporting policing with information and intelligence gathering, and are being deployed in novel uses such as in pop-up communications (tethered drones as cell towers), for forensic 3D photogrammetry capabilities and for delivery of life saving equipment (eg blood, drugs or defibrillators) to remote locations.

A crowd-sourced library has recorded over 500 rescue incidents involving drones globally, involving nearly 900 people (accurate as of 31 May 2022).

The UK **Maritime & Coastguard Agency** (MCA) recognises drones increase search effectiveness and lower risk to personnel. Uses ranges from persistent support of long-distance search operations to support of ground-based rescue teams throughout the UK's c. 2 million square mile Search and Rescue Region.

The MCA successfully trialled rotary wing drones together with helicopters on beach patrols in North Wales and found that combining crewed and uncrewed teams improved outcomes. The MCA operated from Aberporth runway at West Wales Airport and in adjacent segregated airspace.

Flood response: The UK has seen a number of major flooding events in recent years. February 2020 was the wettest ever recorded in England and economic losses across the UK were over £300m. Drones help to monitor flood defences and, through streamed video and photogrammetric processing of images, highlight the extent and magnitude of flooding.

Headquartered in Newport, South Wales, **RUAS** is contracted year-round by the Environment Agency to deliver live video feed within 6 hours of a flooding incident, operating from three different geographical locations. Images fed through to incident control rooms help to inform decision makers with real-time information, day or night. Drones provide RUAS *"confidence through observing what was actually happening rather than listening to what others thought was happening"*.

Asset inspection

Drones provide essential monitoring, survey and surveillance for the UK's national infrastructure and other asset owners, from building managers ensuring roofs and cladding are sound to industrial site owners ensuring emissions and operations are as expected, perimeters are secure and employees safe.

Sellafield: reducing risk to humans at the UK's most secure sites

Drones are a regular tool used at Sellafield, including in general site management as well as in more challenging environments with high radiation, helping keep risks as low as reasonably possible.

One recent use was to inspect a lagoon discharge line, along a 100m length, over 8m above ground. Where previously this would have required an extensive scaffold and taken up to 16 weeks, the drone survey was planned and completed, and the data processed by 2 people within 3 days. Estimated savings were £100k.

In 2021 Sellafield flew over 200 complex asset inspection missions with drones and supported MAGNOX and other UK nuclear sites in developing a standard Concept of Operations for use across the UK's critical national infrastructure, including NDA, MOD and prisons.

While estate agents have been using drones for years to capture property images, drones now provide high resolution digital data to help digitally map and maintain large and complex buildings and estates. Drone use is especially valuable for high-rise buildings and older properties, where traditional monitoring methods are expensive. Drones can assess weather damage, provide infrared mapping to inform eco-refurbishment, and check chimneys, aerials, solar panels, fencing, parking facilities or tree health.

Renfrewshire Council is using drones for regular façade and roof inspections of their social housing portfolio, which includes 14 high-rise towers.

Traditionally undertaken by scaffold or cherry picker, drones can inspect in a fraction of the time and tailor data insights for predictive maintenance.

Renfrewshire Council estimate using drone services to optimise their maintenance work programme saves them £4m per year across their portfolio. Scaled up nationally, this presents an enormous financial and safety benefit.

The digital information available from drones can be analysed and assessed using machine learning tools to help identify damage and suggest remedies. As part of building information modelling solutions, drones can help harness digital twin capability for optimisation of a wide range of properties and assets, from pre-construction, through life, to demolition.

By 2030, we expect BVLOS drone solutions will be ubiquitous for asset inspection, including energy infrastructure, road and rail, and to predominate in routine building and infrastructure inspections, with data automatically updating digital software analysis. This will include automated ‘drone-in-a-box’ solutions flying on pre-programmed routes on remote sites or responding to emergency needs. New ‘drones that do’ capabilities beyond imaging and sensing could include crack repairs, roof tiling, gutter cleaning, window washing and ‘live’ cable inspections.

Cranfield-based HeroTech8's drone-in-a-box solution enables single or multiple drones to be stored on site, charged and protected from the elements, ready for autonomous deployment on either a scheduled basis or when triggered by security system sensors. Drones detect anomalies or unexpected activity in real-time and relay images to a central security team or AI-powered depot.

Herotech8 is helping infrastructure clients in Europe achieve cost-savings of over 45% operating expenditure compared with medium-sized security teams, and these benefits rise with increased complexity (rooftops, stacks or masts).

While to date UK flights are supervised by an operator controlling the drone and observing the video feed, BVLOS capability is under development and offers the potential for further savings.

Drone delivery

Drone delivery to your door is an emerging capability with immense potential for economic growth and public benefit. While the clearest public benefit may emerge from quick, cheap deliveries of urgent medical supplies or parcels, there is a growing body of evidence of cost and carbon benefits and public support for more generic delivery services (takeaways, groceries) where these are in operation internationally, as well as agriculture use of new crop-spraying capabilities.

UK drone delivery trials have achieved notable successes including in healthcare logistics, enabling faster, cheaper transport of pharmacy, medicines, blood and lab specimens, as well as helping develop their business case. London-headquartered Skyports successfully completed hundreds of medical deliveries for NHS Scotland in 2021, principally along a 17km corridor between two hospitals in the Scottish Highlands. Skyports intends to expand into wider drone delivery services in Europe, the Americas and Asia. To demonstrate this potential, Government's Future Flight programme has supported trials with NHS partners, including in remote locations such as Scotland, Hampshire (Isle of Wight) and Cornwall (Isles of Scilly), proving drones can be faster and cheaper than helicopters and ambulances.

However, in all jurisdictions, the regulatory and safety structures and business models are still evolving. The UK has seen a number of successful trials, but ongoing engagement will be needed to ensure positive public appetite for autonomous delivery services of the future.

Windracers, headquartered in London, is enabling efficient postal and medical deliveries to remote communities. Able to fly in weather conditions too dangerous for crewed aviation, their fixed wing drone can carry 100kg up to 1000km, helping to connect remote communities reliably and affordably, with an estimated 30%+ reduction in carbon emissions over traditional routes.

In 2021 Windracers successfully trialled an uncrewed regular postal service in conjunction with Royal Mail to remote communities in the Orkney Islands. This builds on earlier trials in the Isles of Scilly and Isle of Mull. They are continuing to support Royal Mail's ambition to develop permanent, reliable, lower emission delivery solutions for remote communities.

Ship-to-shore deliveries were trialled in the UK during the pandemic to transport lateral flow test kits to ships without them having to come into harbour, saving fuel and the need for human to human contact. The UK's significant offshore experience puts us in a strong position to lead on this.

Drone delivery capability is already showing tremendous potential internationally, including for remote deliveries, and humanitarian aid. US-headquartered Zipline has made over 400,000 deliveries in Africa since its first flight in 2013, with daily drone deliveries for rural hospitals and health facilities in Rwanda and Ghana. Having raised over $480m to date, Zipline is expanding into new regions in Africa, and initiating new services in Japan and the USA.

By 2030, drones will be delivering a wide range of products in countries across the world, for both emergency and commercial customers, without raising road congestion and emissions.

Town centre businesses will find new sales outlets through drone delivery. Ireland-based **Manna**'s drone delivery service in Balbriggan has become a normal part of community life, with over 75,000 flights to 17,000 customers since 2019.

Using Manna's drone deliveries, local merchants reach the 13,000 homes, across a 30 square mile catchment area, with average flight times of 3 minutes. Within the first year, Manna had delivered to 40% of town residents, with a significant repeat customer cohort receiving over 50 deliveries each. Manna's operating costs are lower than road-based delivery and provide a quieter and emission-free solution. In 2021, Manna raised $25m to support scale-up at home and overseas, and has partnerships with retailers and brands including Tesco, Just Eat and Samsung.

Safety and Environmental benefits

Drones save lives. Used appropriately, drones have immense potential for good. Working with sector standards bodies, our ambition is for drone adoption wherever drones materially reduce risk to human health, such as where humans operate at dangerous heights, in remote locations or in confined spaces, and for dangerous operations in place of crewed helicopters, aircraft or vehicles.

Getting 'boots off ballast' is an aspiration at **Network Rail** to improve safety. The company strives for better ways to fulfil its obligations to inspect and maintain their 20,000 miles of track and 30,000 tunnels, bridges and viaducts.

Network Rail is a drone trailblazer, establishing operational frameworks and industry standards, managing more than 3,500 drone flights over the rail infrastructure in 2021, training staff and working with other critical national infrastructure owners to put its passengers and freight users first.

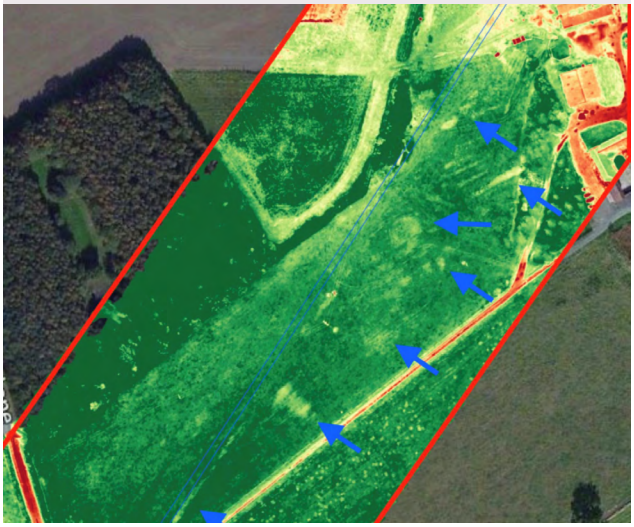
Drones are expected to play an important role in the future by conducting various services including close-up inspections in difficult to access areas, such as building roofs, bridges, coastal areas, overhead electricity lines, communication masts and in red zones areas. The high-quality images and data collection help keep engineers off tracks while still providing the accuracy and certainty to enable lines to operate safely and re-open quickly after maintenance works and/or incidents.

Drones deliver clear environmental benefits, including in agriculture, emissions monitoring, flooding and waste management.

FlyLogix: methane emission monitoring

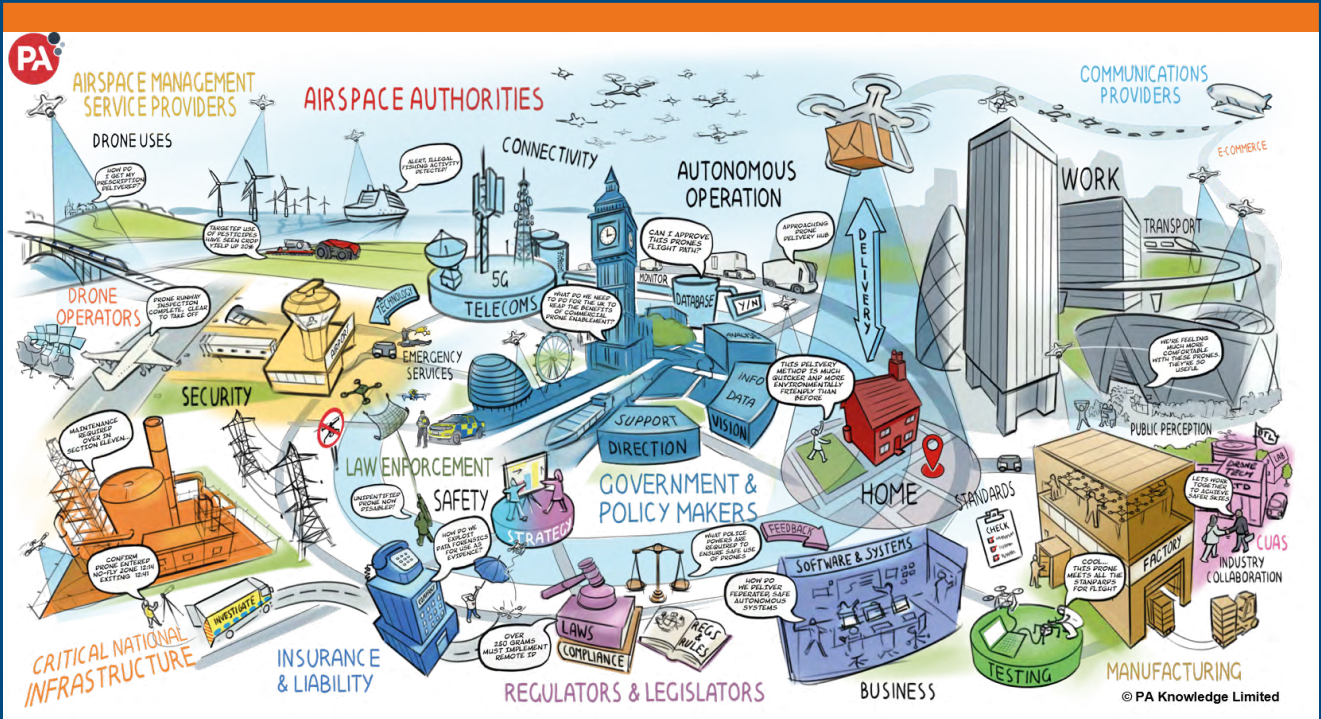
Drones are helping the UK's Oil & Gas industry to be cleaner and greener. **FlyLogix**, headquartered in Fareham, Hampshire, operates BVLOS flights to monitor methane emissions from ships and oil platforms. Drones built on a low-cost electronics platform fly for up to 500km. Operations are piloted from shore and provide real-time images and methane records from offshore platforms and vessels, ensuring improved environmental outcomes, at affordable rates, and with no danger to pilots.

A novel drone use is in **underground leak detection**, where the UK loses circa 3 billion litres of water per day. Thermal and multispectral imagery can detect and pinpoint the location of leaks from overhead for ground crew to investigate by measuring variations in ground temperature or spectral profile. **TeamUAV**, based in Worcestershire, is a pioneer of this approach: *"Our leak detection method using drones has a 75% accuracy rate and increases efficiency by a factor of ten. As the industry grows and as BVLOS regulation develops, this efficiency will grow further."* They have also used drones to map and create 3D models of pump station networks for large UK water companies.



4 Enablers

Core enablers and actions



Core enablers:

a. Investing in state-of-the-art UK technology
b. Regulation that supports safe innovation
c. Mainstreaming drone use in business
d. Supporting drone sector dynamism
e. 2030 skills
f. Connectivity and communications
g. Drones for all: engaging public perception

4a: Investing in state-of-the-art UK technology

By 2030, new technology capabilities will underpin new drone flight and communication capabilities, improving reliability, endurance and safety. These technology breakthroughs require continued research excellence, support for manufacturing and commercialisation, and an active market of early adopters to sell into and integrate new business models.

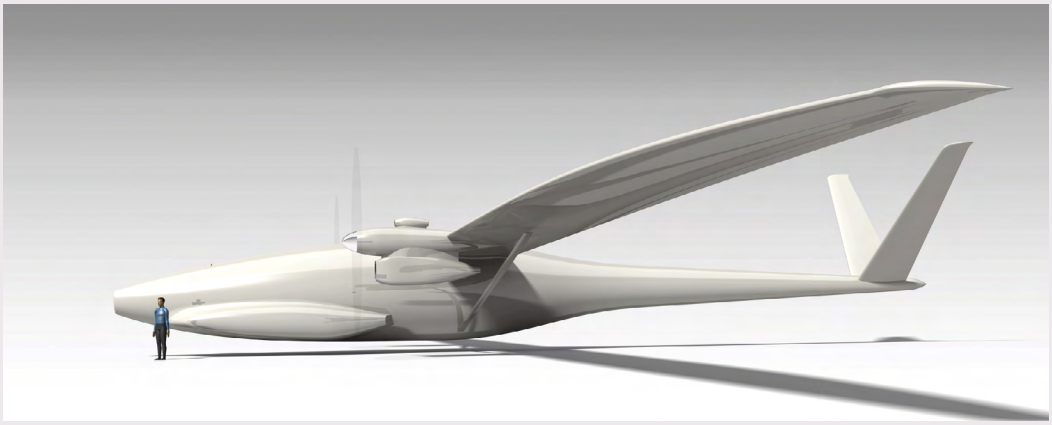
Technology frontiers: supporting UK manufacturing capability

While drones are already capable of long-distance autonomous flight, technology advances are powering new capabilities. The following is a summary of some 'frontier' challenges UK academics and businesses are investing in. Advances are also being made in payloads, including transportation of medical goods, pesticides and wide-area broadband communication systems.

Aircraft construction – Innovation in materials, propulsion systems, manufacturing and design will improve drone performance. Custom-built drones with lightweight metallic alloys are already in construction and looking longer-term novel lightweight materials like graphene and additive manufacturing techniques could bring in a new generation of ultra-long endurance drones. While likely to remain dominated by multi-rotor designs, improvements to materials and airframe design, including 3-D printing, will minimise weight and improve strength, while advances to drone power systems, computing and components continue.

Power and propulsion – Currently, most commercial drones run on batteries and electricity for propulsion and onboard sensor and processing capability, which limits flight time to 20-40 minutes. Across transport, huge investment is lowering cost and improving battery capability, including battery density (for speed/ acceleration), energy density and battery size (for longer flight range) and cycle life (for greater longevity until replacement). Solid-state, lithium-sulphur and lithium-air batteries technologies may deliver significant longer-term gains.

Longer duration or higher-altitude flights use internal combustion engines, hydrogen fuel cells or solar power, or hybrid systems. Local needs could be served by tethered drones attached by a power cable (including datalink).



Situational Awareness (including Detect & Avoid) – With increasingly capable sensors such as infrared, LIDAR and RGB (red, green, blue) and onboard processing capabilities powered by artificial intelligence, drones will be able to autonomously sense, understand and formulate actions in response to their surroundings. Autonomous flight control and electronic conspicuity will enable inter-operation with ground-based receivers and inform new traffic control systems designed to inform and integrate uncrewed and crewed aircraft. These capabilities are a critical enabler for safe BVLOS flight in unsegregated airspace and could underpin new services in GPS-denied or unmapped environments. UKRI's world-leading Trustworthy Autonomous Systems programme will support confidence in these capabilities.

Navigation / communications – Small, light, low power, robust, accurate navigation and positioning is essential for effective drone flight as we move to safe BVLOS in unsegregated airspace. Currently drones typically use GNSS (Global Navigation Satellite Systems) supported by onboard sensors to increase location accuracy and reliability as well as managing stability and drift. Telecoms network providers including BT and Vodafone are actively looking to support drone flight with 4G/ 5G mobile technology, including with CGI's 5G PNT (Positioning, Navigation and Timing) work. In 2021 Inmarsat announced investment into satellite communications for drones using L-Band (1-2 GHz, prized for its robustness in fog, rain and storm conditions), but this frequency potentially interferes with manned air traffic control.

Drone Swarms – Drone swarms are groups of drones in active communication with each other able to adapt their behaviour based on the behaviour of others. Emerging capabilities include semi-autonomous flocking drone technology. They could improve speed and effectiveness of drone delivery and agricultural uses, as well as inspection services. However, numerous challenges remain in communication protocols, network layers and battery capabilities.

Note: current drone lightshow 'fireworks' displays are centrally choreographed rather than true swarm technology.

The power of data: Maximising drone benefits requires an efficient conversion of drone-captured data into actionable management information that meets precise organisational requirements. The drone flight simply captures collects data. Effective corporate implementation requires a disciplined focus throughout the process to capture quality data, process it into actionable information that exceeds current capabilities, share it across relevant stakeholders and integrate it seamlessly.

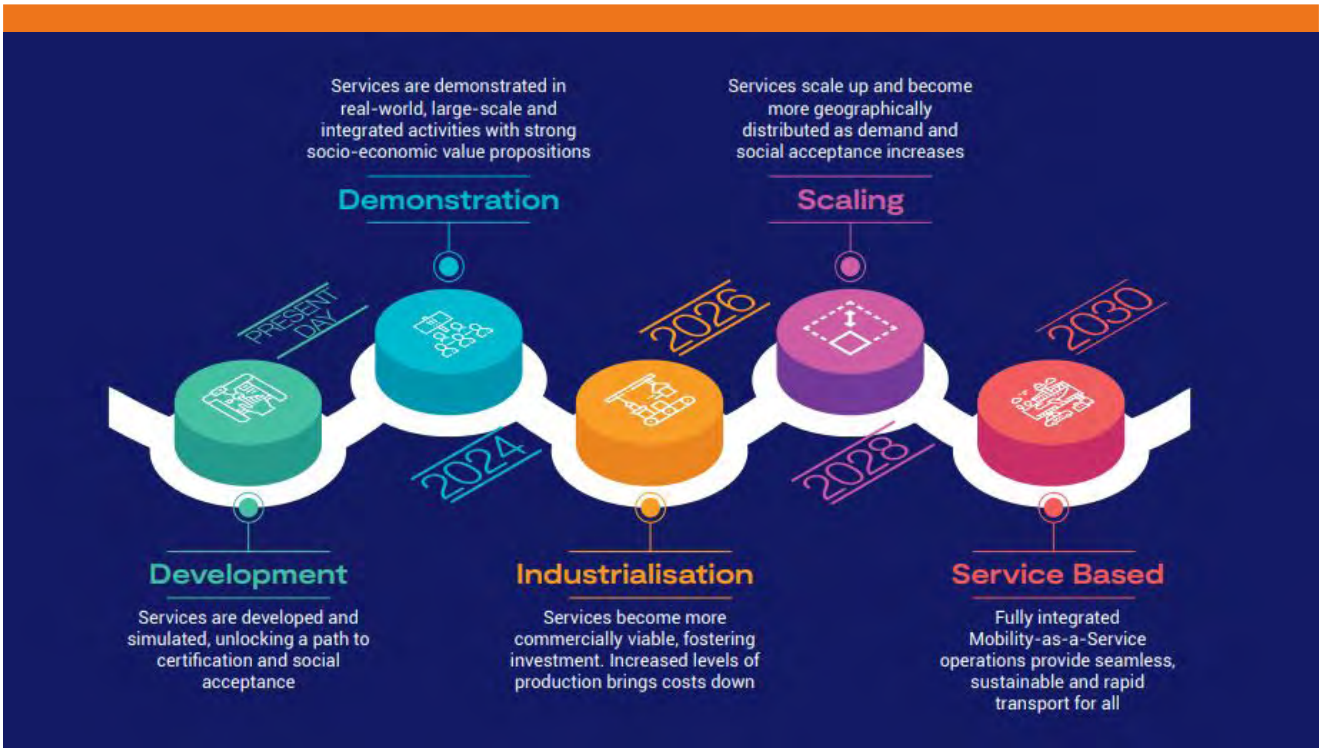
Cyberhawk, based in Edinburgh, has been providing drone inspections for utilities and energy companies since 2008.

Cyberhawk's "iHawk" software turns drone-captured and legacy helicopter or ground patrol data into usable management information and simple map-based interfaces for engineers. This helps Scottish & Southern Electricity Networks monitor 11,000 transmission towers and 150 substations, for integrity and compliance, and revealing opportunities for improvement. Cyberhawk is expanding rapidly in the UK and overseas, working with leading utility companies in Europe, North America and Asia.

ProDroneWorx provides close inspection services for buildings, using AI analysis on high-definition images to determine the type and severity of damage to buildings, dams and bridges. Their self-learning software platform has been trained on tens of thousands of human annotated images and accurately categorises a range of defects. These are timestamped to show deterioration and helps to provide a prioritised maintenance list for effective remediation to improve safety and avoid more costly future work.

Government support for drone technology

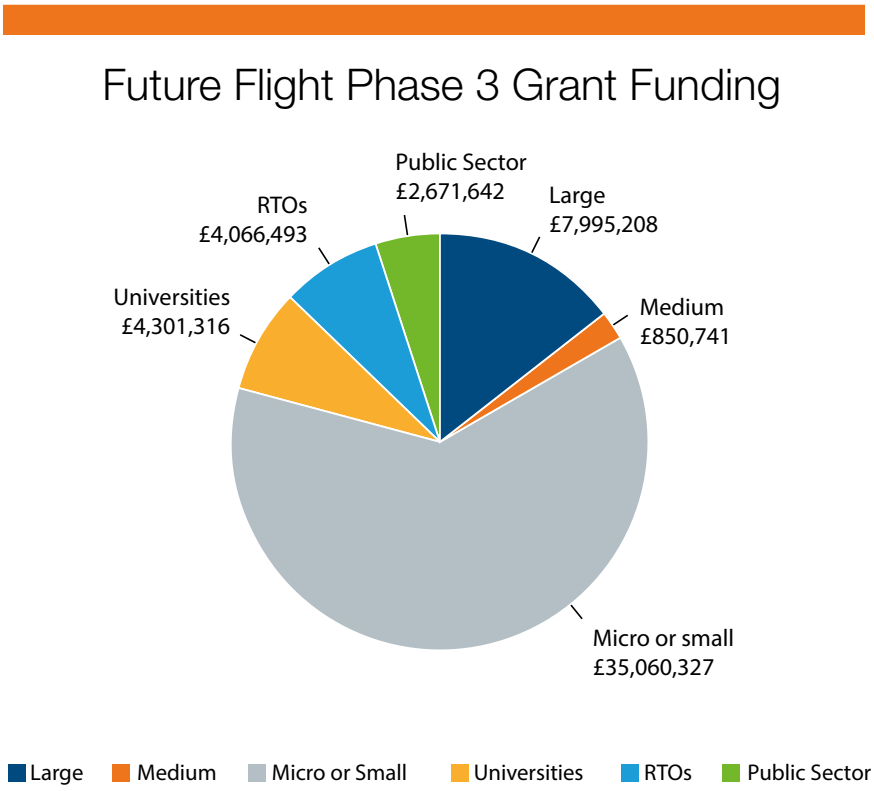
Government, through UK Research & Innovation (UKRI), provides core funding and coordination for UK R&D, including through innovation competitions and a Catapult network for emerging technologies.



Future Flight challenge

UKRI's Future Flight challenge aims to make the UK a global leader in drones and advanced aviation solutions. By 2030 the challenge forecasts a global market for drones worth $38 billion, enabled by a range of increasingly affordable technologies.

Future Flight will provide £125 million of Government grants between 2020 and 2024, matched by £175 million from industry partners collaborating in new electrification, flight and automation services.



From 2020 to 2022, grants worth £34 million supported innovative projects including Covid drone response, hospital logistics solutions, offshore/onshore oil & gas drone capabilities and a range of UK drug and parcel delivery 'firsts'. In 2022, a further £53 million in Phase 3 grants were announced for 14 drone-related R&D projects supporting more complex collaborations of aviation systems and new vehicle technologies. This is in addition to further funding that is dedicated to developing greener ways to fly, such as all-electric aircraft and advanced air mobility.

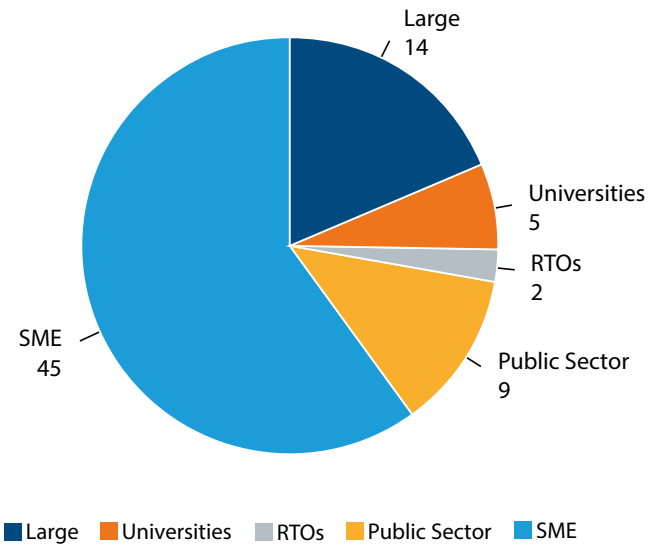
Future Flight positions the UK as a global leader in new aviation products and markets, harnessing the talents of UK SMEs, multinationals and world-class academic and research organisations. Funding is underpinned by a technology roadmap for drones and advanced aviation which forecasts new, affordable flight solutions, strong consumer demand and public sector adoption. Additional elements include:

- cost appraisals of these new capabilities
- studies to understand social acceptance
- an aviation safety framework

- support from Innovate UK's Knowledge Transfer Network to inform and connect researchers, digital innovators, entrepreneurs, drone companies, local authorities, potential end users and wider advisors.

The programme is helping connect industry with the public sector end-users and building strong cross-sector partnerships. Projects have involved local councils and healthcare providers, ensuring outputs are supported by local population groups. Trials have taken place across the UK, from Cornwall to the Orkney Islands, and already improved access to medical treatment for people in remote communities and helped remove people from potential harm inspecting fallen powerlines.

Future Flight Phase 3 Participants



These projects will accelerate the UK's drone capabilities, combining state-of-the-art vehicles with new enabling technologies and engaged end-users to demonstrate the utility of drones in addressing relevant and compelling use cases. Engagement with significant stakeholders across the public and private sector will position businesses to build services that will deliver economic and social benefits over the next 10 years and support wider Government objectives around NetZero and Levelling Up.

These projects have strong regional links and will engage local authorities and LEPs and support the creation of high-tech jobs. They will work with local communities to ensure public acceptance, highlighting the benefits of improved services and deliveries such as mail and vital medicines to regions of the UK with limited transport infrastructure.

Future Flight Phase 3 projects

Care & Equity - Logistics UAS Scotland (CAELUS2)

CAELUS2 aims to demonstrate the operation of a national network of drones for the distribution of healthcare products and medicines across Scotland. 16 partners including service providers, airport operators and NHS Scotland will demonstrate simulated and live flights to prove that networks of drones can integrate safely with other airspace users. Key workstreams will include:

- Developing new approaches to integrate drones with other aircraft in Scotland
- Demonstrating multiple drone deliveries by multiple operators within an innovative digital twin model that optimises medical logistics and flight integration
- Demonstrating innovative new ways of proactively engaging with communities, airspace users and potential customers.

Intelligent Drones for Ports and Highways Technology (InDePTH)

Drones will be used to repeatedly survey infrastructure estates, including Associated British Ports and Kier (highways construction) assets, to obtain detailed near real-time insights into these dynamic environments. In partnership with BT and RoboK, the project will enhance connectivity using 5G and fibre, and deliver new AI analytics using machine learning to optimise image processing and develop 3D digital twins. A drone-in-a-box solution will use onboard sensing, data and image processing equipment for run three use cases to improve:

- inventory management for ABP ports, focusing on vehicle inventory
- offshore surveillance and maritime operations
- highways assessment, to assure ground surface quality of highways, for Kier.

Protecting the environment

- A consortium including UK SME Windracers, the British Antarctic Survey and Lancashire Fire & Rescue will use drone swarms and detect and tackle natural disasters like wildfires in the UK and operating from British Antarctic sites aim to conduct scientific survey missions including studying changing wildlife, ice accumulation and weather conditions. Windracers 'ULTRA' platform can travel over 1000km and carry 100kg payloads.
- Project SeaWatch will provide low-cost maritime search and rescue and environmental and piracy monitoring using an autonomous drone with AI-enabled 3D cameras. Led by UAVAid and Archangel Imaging, SeaWatch will efficiently monitor vast areas of the sea or coastline and report anomalies and identify craft, with data transferred at near real-time speed.

Connecting this complex community is the interactive Future Flight Landscape map, developed by the Innovate UK Knowledge Transfer Network. This networking tool maps UK capability across digital and physical capabilities to support future flight solutions.

Future Flight also supports the CAA to ensure its projects can collaborate at an early stage of development, to ensuring projects test in safe environments and to help accelerate development of new policies and regulations by anticipating regulatory challenges in emerging areas of innovation.

CPC Drone Pathfinder

Government has also supported the Drone Pathfinder Programme delivered by the Connected Places Catapult (CPC). The recent Catalyst programme completed in March 2022 and helped accelerate commercial drone adoption, deepen understanding of the public perception of drones and tackled technological challenges through Drones Transport Research and Innovation Grants (TRIG: Drones)

The Catalyst helped demonstrate how current drone capabilities in different sectors can deliver new services while addressing safety challenges, including with:

- **Network Rail** to demonstrate how drones minimise the risk of trackside working and reduce network outages
- **Yorkshire Housing** to demonstrate how drones can reduce the overall cost of planned and preventative maintenance
- **Buxton Mountain Rescue** to demonstrate how drones designed for inclement weather can save lives in search and rescue operations
- The **Environment Agency** to understand how drones can monitor the UK's changing coastlines that are increasingly under threat due to climate change
- **AGRI-EPI** and a broad range of stakeholders to demonstrate how drones can increase farming yield and reduce the use of fertilisers and pesticides through more targeted application
- **Herotech8** and **IDIPIOYER** to demonstrate how drone-in-a-box solutions can deliver greater efficiencies and unlock new applications through increased automation

CPC developed a Drone Readiness Assessment; a high-level approach for adopting and scaling drone use within organisations. This enables industries and public sector to assess and understand how drone technologies and services can deliver productivity, efficiency and safety benefits. The programme collaborated with public authorities and businesses and included an awareness and education campaign with the UK's drone trade association, ARPAS-UK.

In addition, research into the public acceptance of drones was delivered through engagement and focus groups with the public through CPC's market research and insight partner, Trinity McQueen.

Through TRIG: Drones, the Pathfinder enabled six SMEs to deliver early-stage research and development studies helping integrate of drones into UK airspace. Next, the Pathfinder will develop test and deliver a new open-access, live test operational environment across the UK for drones.

UK drone testing capability

The UK research base continues to develop new capabilities and support the essential technology testing and support facilities. Some leading UK facilities include:

- Cranfield University's dedicated drone innovation hub
- University of Southampton's drone design and manufacturing research facilities
- Liverpool John Moores University's expertise in design, development and usage of drone systems including a simulator facility
- University of Exeter's drone consultancy services including training courses

For new drone technology with agricultural applications, DEFRA's Farming Innovation Programme supports innovation and R&D targeting the agricultural sector.

The European Space Agency actively supports innovative uses of satellite data, including novel drone services. For example, London-based Skyports received ESA funding for their medical delivery trials with NHS Scotland. Businesses can receive grant funding up to 50% of costs, and additional free support from knowledgeable UK-based 'ambassadors' to complete their applications.

The National Space Strategy supports the use of space-based technologies to modernise and transform transport, including drones, by enabling satellite positioning, navigation and timing for safe autonomous flight.

Llanbedr airport, located in Cardigan Bay / Snowdonia in North Wales, has a designated permanent danger area which enables year-round flying and welcomes testing of next generation drone, electric air mobility and space vehicles. This facility has supported numerous drone trials, including Snowdonia Aerospace's testing of advanced, long-distance communication, detect-and-avoid (DAA) and traffic management (UTM) technologies, to help enable safe beyond visual line of sight flights.

Supporting high-value manufacturing: defence applications

Advanced robotics, including drones, are helping our armed forces monitor their environment, improve communications, assess risks and respond to threats. Autonomous systems can augment existing military capability and enable soldiers to be redeployed to the tasks that only humans can do. While technology on its own will not transform security or warfare, and these tools will always be under meaningful human control, the sector is an active developer and procurer of cutting-edge technologies. By 2030 up to 80% of military air capability could be uncrewed, as remotely piloted or autonomous drone swarm and small aircraft enhance traditional piloted aircraft, taking on many of the surveillance and support roles.

UK-based manufacturers are helping deliver new drone solutions and capabilities. Capabilities are being trialled such as ship-to-ship cargo transportation, last-mile resupply, ultra-manoeuvrability in urban environments, swarm surveillance and logistics, heavy-lift support and high-altitude platform communications. MOD's Project Theseus is supporting 'last-mile' capability, including using uncrewed drones to deliver and resupply materials, food, fuel and ammunition. Together with the Nano Unmanned Air Systems (nUAS) projects, MOD is looking to create operational advantage for UK armed forces. All defence opportunities can be accessed via the Defence Sourcing Portal.

More broadly, the Defence Science and Technology Laboratory uses science and technology to help solve defence and security issues, working with industry, academia and internationally. This includes the Defence and Security Accelerator which helps translate innovative ideas into security products and services. MOD's Future Capabilities Group seeks complete robotic and drone systems to buy, scale and operate. The annual DSEI Conference is the showcase event for emerging technology.

4b. Regulation that supports safe innovation

The UK has a long and successful history in aviation and has developed a robust and world leading regulatory structure that has allowed the UK to take a leading position in the aviation sector. Regulation is of critical importance in the aviation sector providing the public with confidence in the aviation market while also providing robust frameworks that allow for open and equitable access to airspace. The shared goal for the sector and government is to enable the drones sector to achieve the necessary technologies and standards to enable safe and equitable integration into existing airspace.

We are at a critical time for the aviation industry as we are dealing with not only significant innovation, but also significant challenges both from the impact of the pandemic and the need to rapidly decarbonise.

The significant and exciting progress being made in drones is challenging traditional regulatory approaches all over the world. No country has developed comprehensive strategies and there is still a significant amount of work to be done on the global stage to understand what the shared principles will be for wider adoption of autonomous flight systems.

Government has been working with the CAA to develop the regulatory framework through building on existing legislation and developing the capability and capacity to develop new regulation and legislation that is fit for purpose for the UK and the growing, innovative drones sector. To support this Government has provided CAA with an additional £2.6 million to drive the development of Future of Flight, including drones, to continue developing the UK regulatory frameworks and provide more guidance to operators as they innovate. This work will enable the CAA and Government to ensure the aviation regulatory framework continues to develop and provides viable options for future traffic management, responsive to the demands from industry and the public and less reliant on Temporary Danger Areas.

Government consulted on The Future of Transport Regulatory Review in 2021 and a response is due to be published by the end of Summer 2022. The consultation covered issues of current regulatory frameworks for new aviation technology and aims to identify legislative gaps around new aviation technology, such as beyond visual line of sight drones, advanced air mobility and air traffic management. CAA continues to engage with the community and as part of a recent consultation has recommended to Government changes to existing legislation to make it fit for purpose for the UK.

Government will now help drive the sector forward by supporting collaboration and co-creation of new solutions for the sector. It will deliver a Future of Flight Plan (FoF Plan), building on existing work within the Connected Places Catapult, UKRI's Future Flight Challenge, CAA, Home Office and Ministry of Defence, along with other organisations from the Future of Flight ecosystem. This will set specific milestones addressing key challenges over the coming years. Recognising that we need multiple perspectives to deliver a coordinated, effective approach, and adapt to the changing technology and innovation landscape, government has announced a new governance structure – the Future of Flight Industry Group (FFIG) that will sponsor and help develop this plan.

It will be supported by officials from across government to provide strategic view across the public sector and deliver the Future of Flight vision.

Government will build on its response to the regulatory review consultation and develop and publish a FoF Plan to provide a clear direction on key milestones, to help businesses understand where to focus their resources and investment. As part of the FoF Plan, government will aim to set milestones and targets for:

- developing licensing, data and insurance requirements for Unified Traffic Management (UTM) systems to support the introduction of increased numbers of aircraft
- establishing airspace requirements for testing certifiable drones and advanced air mobility vehicles
- developing horizon-scanning capabilities to ensure that government and regulators are up to date with fast-moving developments in the aviation sector
- Understanding the impact of new aviation on the public to ensure that benefits and disbenefits are appropriately balanced for the public good
- developing 'use cases' to show businesses how new technology can be used, for example, a greater use of unmanned aircraft and advanced air mobility vehicles for regional travel or last-mile delivery services

The CAA will shortly publish the refreshed Airspace Modernisation Strategy (AMS) as a focal point for CAA's broader airspace policy, including drone integration, out to 2040. Government will also support the sector in delivering the AMS to ensure that all new and current airspace users can operate and coexist safely in UK airspace.

CAA operations and remit

The CAA defines the rules and principles for all drone operators and pilots, regardless of the type or size of drone they fly, whether they are a hobbyist or flying drones for commercial gain, or whether they aim to fly locally or beyond visual line of sight. CAA has published the core UK operating categories and principles for drones, including airworthiness, airspace, communications and carriage of dangerous goods. CAA Publication (CAP) 722 (including sub-documents A-F) provides the latest guidance. Since 2019, the CAA Innovation Hub has supported development and testing of ideas and products by establishing three new capabilities:

- ***Innovation Gateway:*** to make it easier for aviation innovators to work with the CAA, providing a single hub of information and point of contact (innovation@caa.co.uk) for them, while coordinating with the right parts of the CAA.
- ***Regulatory Sandbox:*** Helping innovators maximise regulatory readiness for the demonstration of their aviation systems by testing them in safe environments and learning how they address regulatory challenge.
- ***Regulatory Lab:*** Accelerating the development of new policies and regulations by anticipating regulatory challenges in areas of innovation, then defining the requirements for new policies and regulations.

The Innovation Gateway draws on expertise from industry and government to generate thought leadership on challenges including airspace integration, traffic management, advanced air mobility and carriage of dangerous goods. The flexible working methodology of the Innovation Hub allows lessons to be learnt and shared across these areas, to inform future policy and regulation. Working with Future Flight Challenge, CAA is supporting R&D projects tackling specific concepts and challenges including carriage of Dangerous Goods and BVLOS.

The UK aspires to a leading position for modern and safe regulatory systems and in recent years has made significant investment into the CAA. Government has provided significantly enhanced funding to the CAA to enable the development of a drones ecosystem plan focussed on use cases, as well as developing the CAA's capability as a regulator to be able to deliver the regulatory functions for these new and growing technologies.

The drones ecosystem plan will include deliverables focussed on aircraft and systems (airworthiness and certification); people (licensing, training, competency); technology infrastructure (identity and data management, CAA systems); safety; operations; and aviation infrastructure (traffic management/UTM, detect and avoid systems, airspace modernisation).

The CAA's Innovation Hub is currently investigating the challenges for operating BVLOS in non-segregated airspace, and Sandbox testing is underway with current projects exploring the use of detect and avoid systems and procedures, as well as the use of transponders and conspicuity to test airspace integration. A detect and avoid capability is central to removing reliance on temporary danger areas (TDA) for routine BVLOS flight outside of segregated airspace. The BVLOS sandbox aims to enable innovators to test solutions that detect non-cooperative aircraft and to improve conspicuity and traffic management (codified in CAP1861), and integrate with Future Flight's Aviation safety framework.

Government and the CAA have been working closely on assessing the current landscape for electronic conspicuity and considering what the future approach should be, including the possibility of using Transponder Mandatory Zones (TMZ) to integrate all airspace users. The CAA will shortly publish the refreshed Airspace Modernisation Strategy as a focal point for CAA's broader airspace policy, including drone integration.

The drone sector is playing its part in driving innovation and supporting integration. In 2021 a sector-led 'BVLOS Operations Forum' of major drone operators and users was convened by NATS to share experience and perspectives, and to develop collaborative solutions for long-term sector growth and sustainability. Intelligence sharing and collective working has helped traditional airspace operators develop the robust safety culture that exists today. Bringing the same approach to new airspace users will help develop and implement workable solutions with the same confidence in regulation and safety.

Looking ahead: Regulating BVLOS operations

As technologies and capabilities advance at pace, and new BVLOS solutions look to come to market, government will aim to develop better structures around implementation of the certified category, where operators are granted permission to operate within clear boundaries.

Segregated airspace, through Temporary Danger Areas or Permanent Danger Areas (typically military test sites), currently ensures safe separation between crewed and uncrewed aircraft to enable trials, testing and demonstration of new aircraft. The CAA is considering how Transponder Mandatory Zones or new designations of airspace (for example close to infrastructure such as rail track or power lines) may offer new opportunities for commercial drones and evolutionary steps towards more integrated airspace. The long-term intention is for all types of aircraft user and operation to have equal, unrestricted access to the skies.

The CAA is also considering how new technology can deliver a safer and more comprehensive air traffic management system. A centralised or federated service would capture all operations in any given piece of airspace and share this information so that crewed and uncrewed aircraft can operate safely in the same airspace. This would enable multiple service providers to operate, while ensuring they provide safe and secure information to their customers. The CAA will set the criteria for airspace to be managed in their forthcoming Airspace Modernisation Strategy, working with the sector to deliver an effective system for the UK.

UTM / fleet management software case study

Network Rail wanted to scale their drone flight operations but time-consuming, manual processes for flight planning, compliance and fleet management constrained their capacity. London-based **Dronecloud** transformed their working practices over 18 months, increasing flights by five times to over 3000 flights per year and reduced the average flight approval times from 14 days to under one hour.

Dronecloud said: *"Our platform helps bridge the gap between drone flight management tools (fleet management, logging) and UTM systems and services to provide users with the ability to deploy large scale operations safely. Using our platform, customers have grown from single-use, low-volume operations to more complex BVLOS advanced operations, deployed at scale."*

CAA resourcing and Air Traffic Control

For years the aviation sector has funded the CAA through a 'user pays' model. The pandemic underlined the challenges of this model, with revenues falling as aircraft were grounded. Significant investment will be needed into traffic management infrastructure and services. CAA support for drones has to date been funded through DfT and BEIS (including indirectly via Innovate UK) sponsorship. CAA and DfT are developing approaches to ensure that the CAA has a scheme of charges that will enable it to support and develop the industry into the future.

Currently NATS provides drone operators with access to all types of UK air traffic service information both inside and outside controlled airspace, including for a wide range of drone trials and regular operations. This activity generates additional cost that is currently supported by commercial airline fees. Elsewhere, such as in Spain and Australia, national air navigation service providers are integrating new infrastructure and services to enable UAS integration.

4c. Mainstreaming drone use within UK business

The end-users of drones need the knowledge, confidence and capability to buy and integrate them effectively. A 2019 PwC survey found that business leaders felt drone use cases were poorly articulated, service providers lacked credibility and bottom-line benefits were not clear. At recent workshops, end users shared their challenges: they lack awareness of state-of-the-art drone capabilities, how and where to procure them and how best to integrate drone solutions into their business models. While leaders in like-minded organisations are working together to share knowledge and approaches, among SMEs uptake is still limited.

Effective development and adoption of new technology relies on a web of human networks and relationships to share insights and manage risk. The drone ecosystem is still nascent, with technology innovators, academics, entrepreneurs, manufacturers and customers actively seek new approaches. Investors (public and private) are looking to back winners, and regulators and policy makers are creating the essential new frameworks of operation. At the fringes, local government, software developers, consultants and service integrators, students, recreational drone users, the media and members of the general public look to engage to varying degrees.

The UK ecosystem has a range of players supporting companies in improving awareness of drones and encouraging their effective adoption.

Connected Places Catapult (CPC) supports collaborative R&D opportunities, including for Future Flight, and is advancing work to enable BVLOS trials, drone traffic management and sustainable aviation in the UK and internationally. CPC's main drone-related programmes include

- Drone Pathfinder Programme helps tackle technical, operational, and commercial barriers facing drone operators and provides a platform for innovators to engage with government to learn from and share information. In 2022, CPC published a public perception study and supported SME innovation through Transport Research Innovation Grants
- Future of Air Mobility Accelerator, in partnership with Future Flight, supporting SMEs to develop solutions for Data Driven Aviation, Smart Airports and Advanced Air Mobility
- Open Access UTM Framework Programme to develop air traffic management solutions, frameworks and regulation.

Sector bodies provide trusted information and events for their members, including on skills and training, safe working practices, insurance and regulation. They also lobby government on challenges and barriers and to articulate drone sector's opportunities and needs.

- ARPAS-UK is a not-for-profit, member-funded trade body with a staffed information library, regular news updates and seminars on operational and policy issues.
- Drone Delivery Group has a wider scope across autonomy and develops white papers to raise awareness of commercial opportunities and regulatory and practical challenges.

Drone Industry Action Group: Established in 2016 by government, with Professor Iain Gray of Cranfield University as Chair, to operate as the primary collaborative forum between Government and leaders from drone businesses, academia, regulators and end users to share understanding of the barriers to autonomous flight and drive action.

Airwards is a global drone awards programme identifying, recognising and championing positive drone use cases. Established as a UK-based charity in 2020, Airwards is expanding its reach with community events to support uptake of drone use in business and to raise awareness among the wider public.

BVLOS Operations Forum, convened by NATS in 2021, brings together UK commercial drone operators and industry stakeholders aspiring for safe, reliable BVLOS operations. The Forum aims to facilitate collaboration on safety, to define and deliver implementable solutions as we move to autonomous, longer distance flight.

COMIT2drones delivers tangible projects for infrastructure and construction companies operating drone technology, for example demonstrating how drones can best be used for aerial survey, and how to optimise usable data.

Numerous informal collaborations are springing up across sectors as users look to share their experience, including in police and emergency services, energy (including nuclear) and national infrastructure (rail, road, etc) and local government.

Action

In the Flightpath to the Future, published May 2022, Government committed to set out the steps the Government and the regulator will take over the next three to five years to facilitate bringing these new air mobility services to market. It will provide a clear direction on key Government work which will help businesses understand where to focus their resources and investment. Government committed to set milestones and targets for achieving routine BVLOS drone operations and to establish a **Future of Flight Industry Group**, bringing together stakeholders from across these different technologies to address shared challenges in a coordinated way.

The Drone Industry Action Group will lead coordination with drone service providers and deliver practical outputs for end-users. A primary goal will be to support uptake of 'best-in-class' approaches, techniques or technologies that reduce risks to humans. The group will help coordinate and facilitate specialised application-oriented or sector-focused working groups that aim to address specific issues or support adoption. Focus areas will be agreed by the group, and may include: shared operating standards, frameworks or 'toolkits'; airspace notification; operator training standards; procurement of next generation drone capability; and business mainstreaming.

Recognising the real potential of drone delivery for the health sector and the significant appetite for adoption amongst NHS Trusts, BEIS, UKRI and DHSC will convene key stakeholders in the NHS and regulators to develop a framework to enable the introduction of drones within NHS supply chain, bringing together R&D activities already planned under Future Flight Phase 3 and developing the necessary regulatory frameworks to enable routine medical deliveries by drone.

4d. Supporting drone sector dynamism

Beyond the R&D dedicated to drones, a range of Government programmes support business leaders and academics to fulfil their potential. Outlined in Government's Innovation Strategy, this includes the ambition for the UK to be the best place in the world to start, scale up and grow a business. Drone innovators can access support through a range of programmes.

Business support services

Innovate UK EDGE provides expert advice, access to funding and a dedicated scale-up programme for technology innovators, as well as links to private-sector capability.

At local level, 38 **growth hubs in England** provide businesses information, advice and guidance to support growth. One example is Solent Transport Partnership aiming to reduce environmental and social impacts of freight and cars in the region and supported Windracers drone delivery trials. Support from Scotland's Business Gateway, Business Wales Smart Cymru programme and helpline, and Invest Northern Ireland helpline can all be found via GOV.UK.

Example: The Sheffield growth hub provided specialist support to develop business and marketing strategies to support the growth of local firm, Drone Defence. The business also received grant funding to support commercial research and develop new products for market. In 2021, it launched a new remote ID device, Aeroping, that can be fitted to any aircraft to broadcast location and track flights.

Technology entrepreneurs can access local peer networks to share experience and access business advice, coaching and mentoring. Vocational training and skills initiatives include apprenticeships and traineeships.

Growth funding

The British Business Bank and its British Patient Capital subsidiary help ensure technology investors are able to support longer term 'venture' growth and scale up finance. Drone companies can refer to the Better Business Finance directory of approved financial advice providers, and apply for innovation loans to support commercialisation of late-stage R&D. The BBB.

UK investor Britbots is dedicated to UK robotics, AI and automation. Britbots invests at pre-seed, scale-up and venture stages in entrepreneurs looking to drive productivity through hardware or software automation. Its portfolio includes drone companies Marble and Tethered Drone Solutions.

Exports

Drone companies can access free export advice from government, including accessing trade events and match funded exporting grants. Comprehensive digital advice helps firms to start exporting or increase overseas sales and includes an online tool to search for current export opportunities. Note: providers of high technology goods or services, including drones, should ensure they comply with guidance on exporting dual use technologies with the Export Control Organisation.

4e. 2030 skills

The UK's drone companies invest heavily in staff training, equipment and processes. The CAA requires all drone operators to be tested and registered, with extra certification needed for more complex flights. ARPAS-UK provides a database of registered training providers and their sector specialisms. However, to be confident of service quality, some end-users seek clearer qualifications or sector operating standards against which to assess operator skills and validate capabilities.

Looking ahead, to achieve our 2030 vision, the UK will need to continue to invest in businesses and people, both within the drone sector and to support effective adoption in end-user organisations

Drone sector leaders and innovators: Within the drone sector, UK entrepreneurs, technology innovators and physical and digital engineers need to harness technology into effective, affordable, reliable systems. This will need an increasing flow of qualified operators and technicians.

End-user capabilities: To optimise the benefits of drones, end-users need the confidence to procure services that are affordable and fit-for-purpose. End users want assurance of drone operator competence, validated by a third party, and tailored training programmes.

In response to these needs, sector-specific efforts have emerged, including from the Engineering and Construction Training Board, Sellafield, Network Rail and the police. The Chartered Institute of Civil Engineering Surveyors (CICES) is working to establish recognised standards of competence. Bespoke training and support programmes may also be available at regional, local or sectoral level. The ECITB's 2019 programme failed as it lacked sufficient end-user specification and validation.

Under the governance of National Police (and Fire) Chief Constables (NPCC and NFCC), individual drone units have established minimum standards for pilot competence in line with current regulatory requirements. The NPCC and the National Police Air Service are working together to introduce oversight of drone procurement, training and operational standards for policing and to develop Standard Operating Procedures and training materials, including compliance and safety management. Significant investments and budget allocations are being made to support these activities.

Data integration: Companies need informed procurement specialists, technical integrators, and leaders of digital change processes to drive adoption within their organisations. To maximise the benefits of using drones, data needs to be seamlessly integrated into the digital architectures that organisations use and into the standard operating and contractual practices they adopt. For many larger organisations, inspection, maintenance and repair services are sub-contracted and procurement processes follow time-honoured approaches with long-established relationships that can be hard to alter.

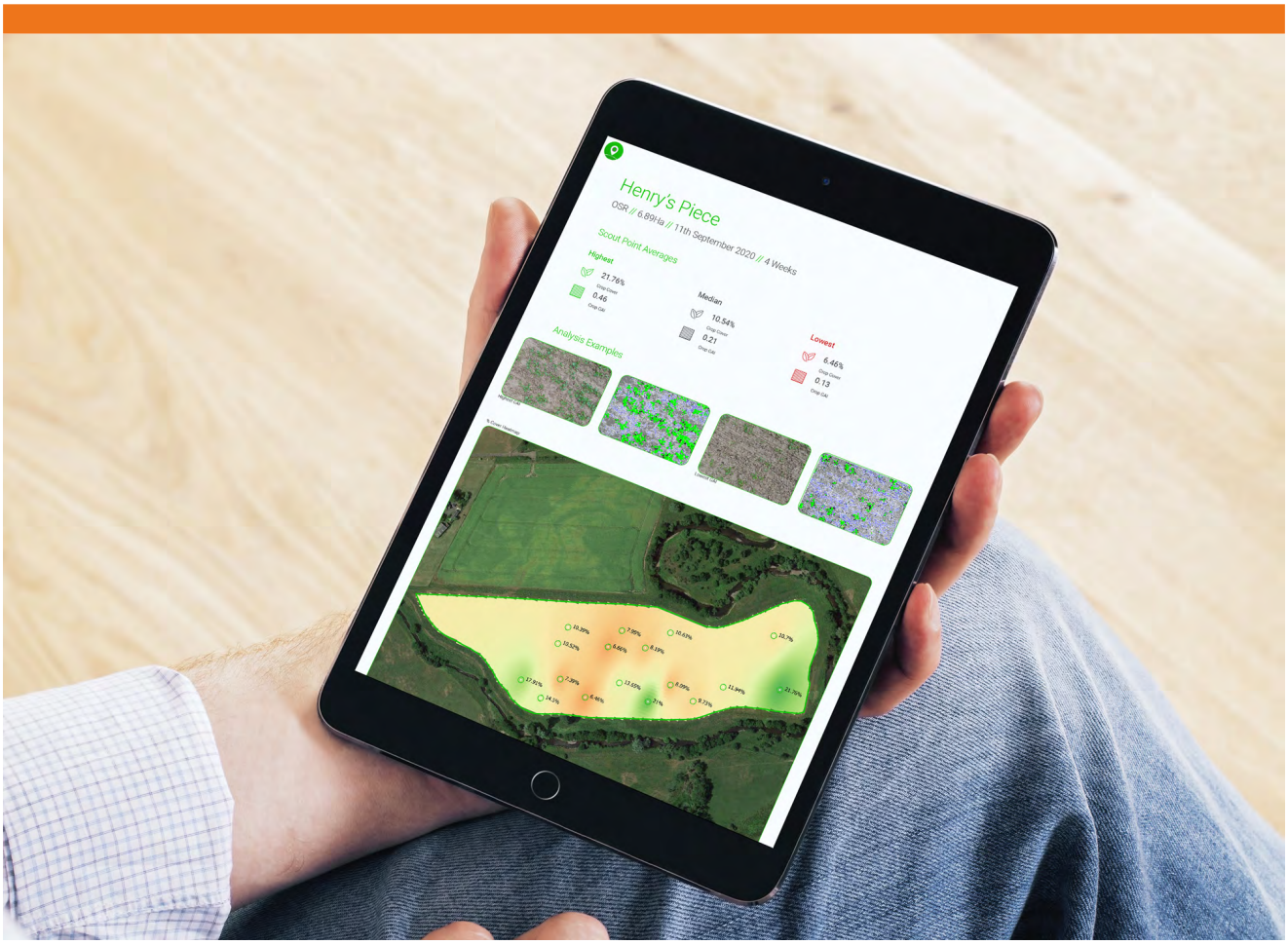
Action

ARPAS-UK and the Connected Places Catapult are working with relevant sector bodies, industry institutes and professional associations across the economy to deliver targeted drone training CPD (continuing professional development) courses.

This includes a series of pragmatic modules aims to support surveyors and engineers across a range of disciplines. Developed with input from professional bodies including Royal Institution of Chartered Surveyors, Chartered Institution of Civil Engineering Surveyors, The Survey Association and the Institution of Civil Engineers, these will upskill operators about drone capabilities (such as accuracy, speed and safety) and how to deliver services and derive the benefits and financial returns for their businesses, tailored to sectoral contexts. A series of CPD sessions will be rolled out for these users, marketed actively by partner bodies. With additional funding these sessions are expanded in content and across more and more industries and segments.

4f. Drone connectivity and communications

Communication technologies are essential to drones for control, authentication and authorisation, and data transmission. The vast majority of drones operate within stable coverage of existing cellular networks. Cellular and SIM card technologies have a thirty-year track record of safe and secure communications, with networks kept constantly updated yet built on global operational standards. Adoption of current and new mobile phone technology could complement other radio technologies to enhance drone capabilities, including flight control, situational awareness and conspicuity, payload management and data exchange.



In the UK today, commercial drone operators are not permitted to use SIM cards due to problems that drone communications could cause to the host mobile networks as well as other spectrum users, such as Air Traffic Control radar at the lower 2.6GHz frequency. Ofcom is working with industry and the CAA, including through UKRI's Future Flight Challenge, to develop technical parameters and an authorisation solution to permit drone operation using cellular technologies. While this work is ongoing, a number of drone companies have been granted trial and research licences by Ofcom to test and demonstrate 4G-enabled capabilities, working closely with network operators.

Internationally, Ofcom leads the UK's efforts to develop harmonised technical parameters for airborne mobile use with European regulators and international technical standards bodies.

Action

Government aims to enable safe use of cellular communications for commercial drones. Ofcom and the CAA will work with mobile network operators, equipment manufacturers and drone users to develop effective commercial licencing arrangements to deliver new capabilities for drone operators, while assuring network security and efficiency.

By the end of 2022, we anticipate use of mobile spectrum for commercial drone use, enabled by:

- Agreements between drone companies and mobile network operator(s), with drone users committing to stay within pre-agreed parameters of use which prevents the SIM from connecting to the 2.6 GHz band
- Approval from Ofcom and the CAA that use of mobile network is critical to drone command and control
- Continued investment from network providers to support this emerging opportunity

To ensure effective implementation, in June 2022 Ofcom launched a formal consultation seeking input on appropriate spectrum bands, emission limits and equipment standards. The development and evolution of 5G standards will also help identify drones on the network and enable centimetre-order positional accuracy.

4g. Drones for all: engaging public perceptions

While public sentiment is not seen as a key driver or limiter of drone adoption and sector growth, drone business leaders live in fear that a major safety or security incident involving a drone will result in public outcry and draconian restrictions. The Gatwick incident in 2018 was a blow to the sector (and drove investment and innovation towards counter-drone capabilities) and affirmed public concerns at the time about privacy and surveillance, safety and mis-use. But as understanding of their carefully regulated use increases, the public is increasingly pro-drone, especially as regards the benefits they can bring to safety and public good.

A 2021 study found over two thirds (68%) of the British public believe drones will have a positive impact on their life in the future. Greatest support exists where they benefit society for good, including in **firefighting** (76% positive), inspecting infrastructure (70%) or investigating crime scenes (73%).

Future Flight further evidenced this in UK-based public dialogue in 2022. Despite high overall levels of apprehension, there were participants who felt excited and optimistic about drones and Advanced Air Mobility. Participants were very accepting of emergency services utilising all future flight technologies for example in natural disaster response, terrorism incident response, search and rescue, healthcare and providing humanitarian aid. However, many of the participants who supported emergency usage of future flight technologies explicitly stated that they perceived these uses as the only acceptable ones.

While drone delivery services have historically been considered less popular, international evidence shows strong public support where these services are in place. Manna in Ireland, Aha in Iceland and Wing in the USA have been operating local drone grocery delivery operations since 2018/19 with strong public support. A Virginia Tech, USA survey in 2021 adjacent to Wing's delivery operations in 2021 showed 87% positive responses, with over 50% liking drone deliveries 'a great deal'. This was despite only 16% having used the service. The Virginia study concluded the direct personal opportunity to use drone delivery services and active local communications were key factors. However, these trials have been taking place within locations that have a significantly lower population density than many towns or cities in the UK. The Future Flight public dialogue highlighted significant concerns about drone deliveries in urban or higher population density areas. There was broader conditional support for the potential to increase access to goods or services for communities in remote, rural or lower population density locations within the UK. It concluded that carefully monitored UK based trials in lower population density locations that will benefit communities with poor access to goods or services could be an first step towards possible more widespread drone delivery. Throughout, the study noted it should not be seen as representative of UK-wide populations and further trials would be needed in different areas to test these services social or economic viability.

While there may never be universal appreciation of any technology, another recent market research by Trinity McQueen, sponsored by Government, found that key factors of acceptance were awareness of the extensive training, regulation and supervisory systems that already exist, and the public's confidence in the CAA.

Action

CAA is committed to disseminating drone information and engaging with the public to ensure clear understanding of drone regulations, including through their website and regular newsletters and CAA publications.

The Drone Industry Action Group and partners will continue to collate and disseminate trusted 'drones for good' materials and media including case studies and videos, including working with sector bodies to raise awareness of drone potential within relevant industries.

Future Flight will be undertaking a robust programme of social research and community engagement to build better insight into UK public awareness of drone governance and regulation, alongside wider expectations or concerns in drones and Advanced Air Mobility.

Annexe

FURTHER USE CASES

Agriculture

For centuries, farmers have walked their fields monitoring the health of their crops or livestock. Drones cover areas more quickly, offer real-time insights, are more precise than traditional methods, and are non-evasive to crops.

They offer farmers new tools to build a richer picture of their fields, with airborne sensors monitoring crop health with multispectral cameras, measuring soil temperatures and moisture, mapping elevations, helping plan irrigation and water flow management and helping farmers anticipate crop maturity and final yield for harvest planning. They can monitor livestock and help locate lost animals, using familiar pre-recorded dog barks to herd them. For insurance, they can report field and farm-level impacts of adverse weather or disease.

Crop-spraying drones are already delivering targeted treatments of fertilizer, pesticide or fungicide, which are more cost-effective and environmentally friendly than bulk spraying. The UK's Health & Safety Executive regulates aerial spraying, providing guidance that permission will be granted where spraying does not cause harm to human health or have unacceptable effects on the environment. The HSE is working with drone operators and sector leaders to develop a shared understanding of the risks to ensure drone spraying can be done safely.

By 2030, we expect crop assessment to be enhanced by heavy-lift crop-spraying with larger capacity, new drone swarm capabilities and novel uses such as aerial planting. Drones can access hard to reach locations and drop biodegradable pods filled with seed and nutrients into target locations. Examples include UN-sponsored mangrove replanting trials in Panama and Oxford-based Dendra which has raised over £9m for its ambitious plan to plant over 1bn trees per year to tackle industrial scale deforestation.

Northumberland-based DroneAg provides crop scouting, spraying and field mapping solutions for farmers. Their 'Skippy Scout' app controls a standard, off-the-shelf drone, autonomously inspecting crops at plant-level. Photos are uploaded and analysed using custom AI and field health reports available within minutes of a completed flight Farmers receive actionable metrics on crop health including location-specific metrics that can enable "variable rate" application of chemicals & fertiliser, saving money and benefiting the environment.

Drone Ag estimates it saved their first 100 UK users over 785 hours of labour last season. It now operates 18 countries in over 500 farms and the company is completing testing of a revised algorithm that will double data processing speeds.

AutoSpray Systems, based in Stoke-on-Trent offers farmers drone and ground-based spray systems to assess crop health and apply nitrogen, where little and often helps to minimise waste and optimise crop growth.

Oil & Gas

Over the past five years, drones have become commonplace in the North Sea, and are now routinely deployed by upstream energy operators to survey and inspect offshore rigs and pipelines, to monitor for methane emissions and to detect faults or leaks. Traditional helicopter and human inspections and maintenance were costly, often requiring facilities to close for extended periods. This interrupted revenue streams and presented significant risks to the skilled climbers using ropes, harnesses and rappelling equipment to reach hard-to-access areas, often in proximity to harmful chemicals and very high-temperature materials. Drones now deliver this essential data quickly and safely, with little or no interruption to business.

2030 opportunity: Incremental improvements in drone capability will build on 2022 near-universal adoption. There is some extension of capability to adjacent use cases and applications, but realistically there is less potential for a step change in cost savings within this sector.

Chichester-based **sees.ai** works with a number of the oil majors in the North Sea. They are among the first UK drone operators to be granted CAA permission to fly routine BVLOS flights in unsegregated airspace without pre-authorisation for each flight. Their BVLOS drones use advanced onboard autonomy and real-time 3D mapping to enable accurate flight control, with pilots operating from the Chichester control centre.

High-definition sensors capture similar resolution data to conventional, close-up, human or VLOS drone operations, but at ***savings of 30-60%***, depending on complexity of operations, hazards and access.

Remote operations pave the way for an exciting growth in **BVLOS** drone operations to 2030, where they could be located remotely, ready to respond to meet routine inspection schedules or emergency alerts.

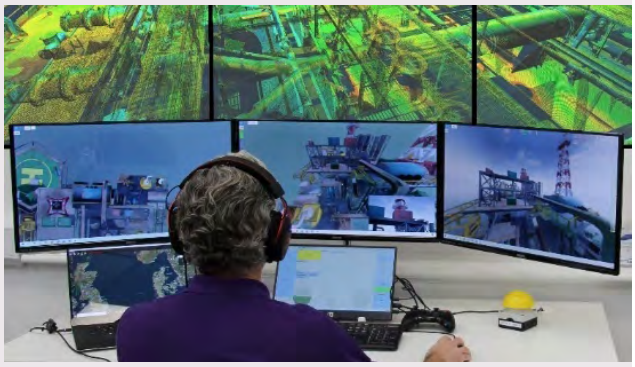


Image: Sees.ai operator, based in Chichester, looking at real time (top displays) and modelled (bottom displays) images of a North Sea asset

Financial, Insurance, Professional and Administrative services

Current use of drones by professional and business services organisations is still nascent, with some early adopters in infrastructure inspection and security and for insurance and auditing using drones to image and assess assets and stockpiles, and to provide data to support insurance assessments, such as imaging of collisions.

Extension of adoption to BVLOS solutions, and significant investment in warehouse and logistics automation will drive further automation of stock-taking and audit. Supported by digital twin technology, drone services will enhance warehouse management systems, improving audit speed and accuracy.

Digitally enabled inventory testing improves accuracy as drones can collect vast numbers of data points from a single flight. They enhance health and safety as data can be collected safely without surveyors climbing over unstable heaps. And they are less disruptive to clients as operations can continue on the site. These surveying software packages and data models can be assessed and shared anywhere in the world.

Drones carrying specialised cameras, coupled with computational and display capability have been producing 3D photogram imagery for a number of years, including for crash investigation, infrastructure monitoring and emergency response. PwC has used drones for stockpile audit since 2018. In their words: *"using drones on the first-year audit of a large mining client with multiple sites across the UK gave us accurate volume measurements of inventory in a quick and safe manner, avoiding the need to have people climbing over stockpiles... drones are certainly going to be an integral part of our inventory audit approach in future years."*