REGULATORY HORIZONS COUNCIL

The Regulation of Drones

An exploratory study

The Regulatory Horizons Council

November 2021

Contents

Foreword

This is an exciting time for the UK's drone sector. The last 18 months have seen many great examples of 'drones for good' in our society reinforcing quite publicly the significant role that drones can play in saving lives and solving problems, as well as boosting our economy. We know from various UK and global drone market studies there is a big prize if we can drive new technology and business uptake, overcoming safety challenges and engaging end-users. For example, PWC forecast a potential £42 billion positive impact on the UK economy by 2030 if we get this right.

Industry has been working closely with Government to help identify the barriers to realising this opportunity, and to determine the steps to overcome them.

Through my role as Chair of the Drone Industry Action Group, I know the drone sector will warmly welcome this timely review from the Regulatory Horizons Council (RHC). We have been grateful for the opportunity to provide inputs and evidence to this report. Drone technology, powered by advances in robotics, battery power and artificial intelligence, is 'on the cusp' of delivering new breakthrough capabilities, and is seeing increasing levels of investment in the UK and overseas. A forward-looking regulatory regime will be critical to ensuring the UK can compete and succeed in this global opportunity.

Businesses across the UK are developing and demonstrating new uses for drones, and it is good to see some examples included in this report. This reinforces the need to tackle the remaining barriers to realising the full extent of the business economic and social opportunities.

Drone application opportunities exist across the globe. There is a real opportunity for the UK to assume a global technology lead on drones but more significantly, by leveraging the reputation and renowned expertise of our own Civil Aviation Authority (CAA), we can put the right regulatory framework in place that becomes the standard across the world. My own belief is we need to get this right for drones, or we will never reap the benefits of autonomous freight and passenger flight. We need to build on Government support from UKRI's Future Flight, Connected Places Catapult's Pathfinder and CAA's sandbox programmes. And to grow the scale and scope of business-led demonstrators like the National Beyond Visual Line of Sight Experimentation Corridor. This report highlights tangible steps where the sector and Government can work together. It is in all our interests to ensure continued confidence in UK airspace safety and for the UK to harness this new technology to reap the multiple benefits from use of commercial drones.

I welcome these recommendations which outline a clear set of challenges and avenues to follow. Let us all come together to build the right environment and solutions for drone innovation to flourish.

Professor Iain Gray, Chair of the Drones Industry Action Group

1. Executive summary

- The Regulatory Horizons Council set out to examine how to improve aviation regulation for drones. We consulted the drone industry operating in the UK and elsewhere in the world, regulators in the UK, Ireland, USA, Switzerland, and Singapore; and other stakeholders.

- Drones promise to transform, and to disrupt, numerous industries, including medical supplies, consumer deliveries, infrastructure inspection, agricultural surveying, and environmental monitoring. Like most new technologies, they also bring risks, and for drones this includes risks of accidents, collisions, intrusion, noise, terrorism, and crime.

- The Government should recognise when assessing the risks of drones that there are also potential benefits missed in *not* developing drones. For example, the use of helicopters to inspect power lines and offshore oil and gas sites and the risks associated with this though relatively low can be reduced by deploying drones. By easing the path to drone deployment, regulators may be decreasing rather than increasing risks to human life.

- We generated five future possible scenarios for the future of drones, ranging from '*Luddite'* to '*Libertarian*'. These highlighted the importance of regulation, standards, geographical differentiation, accountability of operators, public engagement, security, and prioritisation of use cases.

- Drones are developing within a framework of detailed existing regulations for manned aircraft, some of which are ill-suited to the new technology. This will require adaptation for both manned aircraft and drones.

- The UK has congested airspace, making commercial experiments with drones difficult, but also has remote and marine areas that can be used more for trials. In our view, the UK drone industry (particularly for flights beyond the visual line of sight) is still mostly in an experimental phase of technology development rather than commercial deployment. Other countries have progressed further in the commercial deployment of drones, but we found no single compelling and clear foreign example of advanced regulation to emulate. This presents the UK with an opportunity.

- Some drone operating firms consider regulation to be a significant barrier to entry in the UK, very largely focused on the difficulties in securing, and renewing, the requisite clearances from the Civil Aviation Authority (CAA). This is due to a combination of: the pace of technological development, the capacity of the regulator to handle a growing number of applications; and in some cases, submissions for clearances lacking

necessary or complete details - simpler regulation, backed by robust safety and quality (foundation) standards, would bring cost-reduction and new growth opportunities.

- Success in pioneering commercial deployment in countries as diverse and unrelated as Rwanda, Singapore, Switzerland, and Ukraine, suggests that commercial viability requires faster and simpler permitting of beyond-visual-line-of-sight (BVLOS) flights and licensing of multiple vehicles per operator as well as automated approvals of flight plans along pre-approved routes. This could be supported in the UK by more realistic 'sandbox' opportunities for testing commercial uses of technology though we recognise that there are some existing legal constraints on the CAA on what it can do in this space.

- We recommend designating zones and times to facilitate the development of commercially realistic or market proving operations – expanding the purposes of the sandbox scheme beyond pure technology capability proof of concept; and the establishment of a 'scalebox' to provide supervisory support to companies in their growth phase.

- The Government should recognise that the public will value some use cases more highly than others. There is evidence[1] that learning about the range of potential use cases of drones has a positive impact overall on acceptance across the public. The delivery of *medical supplies, search and rescue services* are perceived as most beneficial to society and least concerning to the public.

- We recommend that the UK should review the funding model of the CAA with a view to finding a way for it to have a greater interest in supporting disruptive innovation. It should report to Government on how it is fulfilling this in ways that are measurable. We also recommend a change in emphasis in the CAA's drone-approval focus, towards direct engagement with drone operators to prove the commercial uses of the technology, as distinct from supporting the development of the technology.

- Innovations, such as flexible AI-based path planning and improved detect-and-avoid technology, promise to bring unexpected challenges and opportunities in the current decade. Future proofing can be achieved by flexible and 'soft' regulation, in the form of industry codes, guidelines and standards. We recommend that the UK increases its engagement with the development of national and international standards.

- The current approach to regulating drones is based on segregation of airspace between drones and manned aircraft. In the long run this cannot continue. We recommend that the Government and CAA set out a progressive and timebound roadmap to safely agreeing the shared use of airspace between different users to enable drones to fulfil their potential.

- A significant hurdle in the deployment of drones in shared airspace is the lack of mandatory electronic transponders on all users of airspace including private aircraft. In the short term we recommend the introduction of mandatory transponder zones for areas that explicitly prioritise drones; and that the Government sets out plans to bring in mandatory electronic conspicuity by 2025, if not sooner.

- We recommend that the Competition & Markets Authority (CMA), in collaboration with the Civil Aviation Authority, examine the digital platform and data issues in the emerging market in Unmanned Traffic Management (UTM) systems and the potential for these to result in persistent market power. This should build on the CMA's work on digital markets, to be taken up by the relevant regulators today to prevent this from occurring.

- It is imperative that the Government sets out a compelling and short vision statement and regulatory principles for drones that acts as a signal to the industry and the public over the next ten years.

- Another issue that needs to be tackled but that was beyond our capacity to consider in detail in the time available is the constraint created by the allocation of scarce electromagnetic spectrum for drones. The potential prize for the UK getting this right merits Government working with Ofcom, businesses, and other end users to outline a way forward.

Acknowledgements

This report would not have been possible without the help of our stakeholders, colleagues, and the wider community.

Many thanks go to our stakeholders, both domestic and international who offered their expertise to participate in workshops, interviews, and bilateral meetings.

2. Introduction

The Regulatory Horizons Council (RHC) is an independent expert committee that identifies the implications of technological innovation, and provides Government with impartial, expert advice on the regulatory reform required to support its rapid and safe introduction. It conducted horizon scanning and prioritisation exercises to derive a shortlist of priority areas, and then selected four initial areas to focus on: drones, fusion energy regulation, medical devices regulation and genetic technologies.

This report represents views from across the RHC and was led by Matt Ridley with support from Parag Vyas.[1] Our recommendations have been based on an extensive programme of stakeholder engagement and evidence gathering. Over the last 12 months, we have met with representatives from industry, academia, and policy officials both in the UK and internationally. These activities have provided a broad range of innovative ideas on the regulation of drones. This report would not have been possible without the help of our stakeholders and colleagues in the UK and internationally who kindly offered their time and expertise to us whether that is through bilateral meetings, or workshops.

What are drones?

For the purposes of this report, drones are defined in the broadest sense as "any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board".[2] Land or maritime based drones are explicitly out of scope. These systems may also be referred to as unmanned aircraft, unmanned aerial systems (UAS), remotely piloted aircraft systems (RPAS), unmanned aerial vehicles (UAVs), model aircraft, or radio-controlled aircraft.[3] We recognise that some stakeholders within the community feel that 'drones' is an overly simplistic term that fails to capture the multiple uses of the technology and the degree of sophistication, but we have chosen to retain the term as a shorthand. The report will primarily focus on the commercial uses of the technology and exclude military applications.

[1] RHC membership details are here: https://www.gov.uk/government/groups/regulatory-horizons-council-rhc#membership

[2] https://www.caa.co.uk/Consumers/Unmanned-aircraft/General-guidance/Information-for-the-public-about-UAS-and-drones/#:~:text=An%20unmanned%20aircraft%20(UA)%20is,)%202018%2F1139%20%E2%80%93%20Basic%20Regulation

[3] https://www.caa.co.uk/Consumers/Unmanned-aircraft/Our-role/An-introduction-to-unmanned-aircraft-systems/

2.1 Background

Drones: "Born in Captivity"?
In the words of economist Adam Thierer, drones were "born in captivity"[4] in that their development arrived in a world where strict regulations for manned aircraft exist. This potentially leads to significant drawbacks for the commercial development of the technology.

Drones have distinct features that are fundamentally different from manned aircraft: they do not (currently) carry passengers, so do not run the risk of causing fatalities to those on board but can cause risks to others; drones generally return to base after a flight, rather than going from point to point; and drones are often very lightweight. In addition, much of the improvement in drone performance will come in the form of iterative software updates, or small augmentations to bring new features, rather than basic redesigns. Yet the operations of drones are generally considered within the regulatory sphere of manned aircraft operation.

Secondly, drones are entering skies in which manned aircraft have evolved to become extremely safe, which makes it harder for them. The tolerance of the public or regulators for occasional accidents was much higher in the early days of manned flight. Regulations for the safe deployment of aircraft were introduced in a vacuum, starting in the 1920s. An accident simply led to new attempts at safer practices, whereas a drone accident that causes damage or a fatality would now understandably be a setback for the entire industry that might take many years to overcome.

That drones are sharing airspace with piloted aircraft despite having distinct features and are having to adapt to a regulatory regime with an understandably very low tolerance for risk has partially contributed towards drones' faltering commercial deployment. However, we cannot ignore successful lessons that can be learnt from a century of piloted flight regulation. Some of the experience of regulating piloted aircraft to some extent can provide a useful foundation for the regulation of drones, with respect to airspace management, airworthiness, and pilot qualification.

Aviation safety is a spectacular and unmatched success story. On average, a person would have to travel by air every day for 16,581 years to experience a fatal accident[5]. This improvement has been achieved partly by a culture of recording (with black boxes) and sharing lessons from accidents throughout the industry, including internationally, and it is critical that these sentiments are embraced by drone operators as they will be vital for

[4] Adam Thierer in his book "Evasive Entrepreneurs and the Future of Governance - How Innovation Improves Economies and Governments" makes the argument that "Evasive techniques are obviously more likely to succeed for technologies and sectors that are "born free" as opposed to "born captive." Technologies that are "born free" are not confronted with old laws and regulatory regimes that require permission before new products and services are offered.

[5] https://www.iata.org/en/youandiata/travelers/aviation-safety/

aiding the development of drones commercially, improving public acceptability, and ultimately moving to a world where manned aircraft and drones can co-exist.

2.2 Why drones?

Drones not only have the potential to be a significant growth industry, but can also help to improve productivity, efficiency and accessibility across multiple industries and applications. It cannot be taken for granted that these benefits will materialise. Providing the appropriate pro-innovation regulatory environment will be a critical enabler for turning this promise into reality.

Benefits

There have been several studies that have attempted to encapsulate the economic benefits of drones in the UK and one of the most cited reports is a PWC study in May 2018[6]. It suggested that by 2030, assuming several actions are put in place, such as the evolution of regulation to permit more use cases, the drone industry could employ up 628,000 people and forecast to increase UK gross domestic product (GDP) by £42 billion.[7]

The PWC figure includes jobs that may potentially become part of the drone economy. Based on assumptions and subsequent modelling in a 2019 consultation, the Department for Transport suggests that the number of commercial operators in 2050 could range from 20,000 to 60,000 and the number of drones could range from 200,000 to 900,000[8]. While the studies have focused on the macro-economic benefits of drones to the economy, there is an argument that suggests that the most significant impact could be cost savings and productivity improvements for existing industries both in the public and private sector.

In 2021, research by PWC for the Future Flight Challenge (an ongoing £125m Government investment to advance the next generation of aviation solutions)[9] illustrates potential benefits and costs from switching to drone use, with cost savings of roughly 20%-50% for some use cases, except for rural and urban air taxi services where costs may increase. For example, costs for inspection type activities may fall by around 34% and last mile delivery may save about 20% when using drones. It is worth noting that this research makes a key assumption that the regulatory environment poses no barrier to the operation of the case studies chosen - this does not reflect today's realities. Furthermore, PWC and Nesta estimated that the use of drones over the next 15 years to support delivery of public

[6] Our understanding is that this report is currently being updated.

[7] PwC, "Skies without limits: Drones - taking the UK's economy to new heights", 2018

[8] Chart 1 and Chart 2 in https://assets.publishing.service.gov.uk/Government/uploads/system/uploads/attachment_data/file/937275/future-of-drones-in-uk-consultation-response-web.pdf

[9] https://www.pwc.co.uk/issues/intelligent-digital/drones/pwc-helping-shape-uk-aviation-future.html

services in urban areas (e.g., transport of urgent medical products like blood) in the UK could lead to £1.1 billion in cost savings and £6.9 billion increase in GDP[10].

In other parts of the world, drones are increasingly used to deliver urgent medical supplies and samples, including blood. In Rwanda, Zipline now averages one medical delivery every four minutes by fixed-wing drone, mostly of blood to rural clinics that are hard to reach by vehicle in hilly terrain. Zipline estimates that 10% of these deliveries are life-saving, and claims its drones are saving four lives per hour. In the UK, congested roads lead to significant delays in the delivery of medical supplies, so there is an opportunity for similar benefits. Cranfield University has investigated the possible advantages of transporting time-critical blood supplies and medical samples between different hospitals in Oxford, a journey that can take 40 minutes or more by van. A glider can legally fly over the city of Oxford with no radio, transponder, or special permit, but this is not the case for drones.

It is important to attempt to measure the economic impact of drones in the UK, particularly as the Government is investing millions of pounds of taxpayers' money on funding research and development. We would, however, emphasise the point that the economic figures cited above remain estimates and therefore there is always a limit on how much confidence can be placed on them. There is little doubt though that drones in certain cases can provide not only cost savings for organisations but also lead to wider societal benefits - as the examples below illustrate.

Case Studies

Using drones to maintain railway tracks

Network Rail oversee about 1,000 flights per year, of which approximately 35% are flown by its own pilots, of which 35% are training flights to stay current and 65% are for operational requirements. The drones can gather data, videos, and images of the railway and this is particularly valuable for areas that are difficult or dangerous to access, ensuring that engineers are kept safe[11] [12].

[10] https://www.nesta.org.uk/blog/report-how-drones-can-save-the-public-sector-1bn/

[11] It is worth noting that in 2021 Network Rail was the subject of investigation by the Air Accident Investigation Board after a drone crashed near a built-up area. The report concluded that the 1.4 kg drone landed in an unoccupied garden, and that nobody has been harmed by a drone in the UK but recommended that the CAA should keep a log of failure rates per flying hour. Network Rail, which aims to reduce the accident rate for manned track monitoring, has since moved to using sub-250 g drones for this work.https://assets.publishing.service.gov.uk/media/609cf2d98fa8f56a39f36210/DJI_Phantom_4_RTK_UAS_reg_N-A_06-21.pdf

[12] https://www.networkrail.co.uk/running-the-railway/looking-after-the-railway/our-fleet-machines-and-vehicles/air-operations/drones-or-unmanned-aircraft-systems-uas/

Using drones to deliver medical supplies to hospitals

Drones were used to deliver medical supplies such as COVID test kits and personal protective equipment to a Scottish island. As part of a two-week trial, the supplies were flown from Lorn and Islands District General Hospital in Oban on Scotland's west coast to the Mull and Iona Community Hospital in Craignure on the Isle of Mull - about 12 miles (19km) over sea[13]. Currently, the supplies are mainly delivered via road and a 45-minute ferry crossing; drone flights take approximately 15 minutes. Flying beyond visual line of sight, these operations were granted authorisation from the Civil Aviation Authority following a safety case assessment.

Drones may also bring benefits for the environment. Addressing the risks associated with climate change has risen up the policy agenda and the UK Government has a commitment to reach net zero greenhouse gas emissions by 2050. It is difficult to say definitively at this stage whether the development of drones will overall aid or hinder this goal.

The academic literature has mostly focused on the use of drones in the delivery/e-commerce sector when assessing the environmental credentials of the technology, even though drones have multiple applications that could provide associated benefits for the environment. For example, drones are highly effective in environmental monitoring such as "*measuring pollution issues, habitat or soil quality and carbon uptake or ice flow and whale movement in the Arctic or even collecting whale spray for analysis.*"[14] A further example from Imperial College London is the use of drones to monitor environmental and ecological changes in forests which in turn can help to detect and monitor forest fires and collate other valuable data[15]. On drone use for package delivery specifically, there is some emerging evidence in the academic literature that small drones tend to consume less energy on average than delivery trucks and therefore could reduce emissions, but the extent of emissions reduction will depend on how the technology is used and deployed[16].

Risks

Although drones present huge potential benefits to the UK's economy, society, and environment they also present risks. This section does not attempt to be exhaustive. For example, we have not explored the risks posed by illegal and malicious use of drones to facilitate criminal activity and terrorist attacks or disrupt critical national infrastructure, though we note that the police have been given increased powers in the Air Traffic

[13] https://www.improvementservice.org.uk/case-studies/argyll-and-bute-council/oban-airport-supports-drone-trial-for-medical-supplies

[14] PwC, "Skies without limits: Drones - taking the UK's economy to new heights", 2018

[15] https://www.imperial.ac.uk/news/207653/drones-that-patrol-forests-could-monitor/#:~:text=Imperial%20researchers%20have%20created%20drones,and%20insects%20through%20their%20habitat.

[16] https://www.nature.com/articles/s41467-017-02411-5

Management and Unmanned Aircraft Act 2021 to address some of these threats. Instead, we will briefly touch on three of the common risks, namely privacy, safety, and noise.

There are disputes between stakeholders in the drone community on whether some of the risks explored below are real and significant or based on public misconceptions. To some extent this may be immaterial as public perception or lack of trust, even if misguided, can be sufficient to stifle the progress of technological innovation.

Privacy

One of the prevalent concerns is that drones can be used either deliberately or inadvertently to collect data on individuals without their knowledge or consent. For commercial drone operators, the Information Commissioner's Office (ICO) have outlined that personal data, such as location or personal images, are protected by the Data Protection Act 2018 and GDPR[17], which therefore apply to drone use.

In addition, there are specific provisions in the Air Navigation Order 2016 which restricts a small surveillance drone from being flown over or within 150m of congested areas, an organised open-air assembly of more than 1000 people, or within 50m of any vessels, vehicle, structure, or people. Furthermore, the Royal Academy of Engineering and Royal Aeronautical Society have suggested that the threat to privacy from drones is no greater than mobile phones or other recording device[18]. While the relevant legislation seems to be in place to address issues around privacy for commercial drone use, there may be wider public concerns around privacy infringements particularly from recreational users of drones which could be mitigated by education on drone safety and public campaigns. For example, a respondent to a public engagement study described drones as "*a needless use of technology whose only purpose seems to be spying and interfering with aircraft*"[19].

Safety

In addition to the risk to people and property on the ground, a further risk often discussed is the risk that drones can potentially pose to piloted aircraft. The CAA published a report in 2018[20] suggesting that though were only seven confirmed cases of direct in flight contact between drones and civil or military manned aircraft worldwide at that time, the number of occasions where UK pilots have reported suspected drones near their aircraft is increasing.

[17] https://ico.org.uk/your-data-matters/drones/; https://publications.parliament.uk/pa/cm201719/cmselect/cmsctech/2021/202102.htm

[18] https://publications.parliament.uk/pa/cm201719/cmselect/cmsctech/2021/202102.htm

[19] https://www.pwc.co.uk/issues/intelligent-digital/drones-and-trust.html

[20] https://publicapps.caa.co.uk/docs/33/CAP1627_Jan2018.pdf

The British Airline Pilots Association (BALPA) reaffirm this view that the risks of a catastrophic collision of a drone with an aircraft are increasing. The UK Airprox Board, the official body which collates airprox ('near miss') reports from pilots highlights 125 incidents between piloted aircraft and drones in 2019, an increase from 71 incidents in 2016. Although the British Model Flying Association and the Flight Safety Board argue that these numbers are based on self-reported data from pilots, the increased usage of drones for commercial and leisure purposes has increased the unintentional or intentional risks of collision and or disruption of a manned aircraft.

In the spirit of transparency that is key to aviation safety, pilots want to ensure that with greater positional conspicuity, unknown objects become known objects in the aviation industry, so all users are sharing communal information and have the right to be there. It is therefore imperative that drone safety data be captured and shared as widely as possible if progress is to be made and secondly continued informational campaigns and messaging will be needed to inform drone operators on flying responsibly[21].

Noise

There is a range of opinions among stakeholders with respect to the degree of nuisance that drone noise represents now and in the future. These expectations regarding noise and disturbance, are influenced by issues such as the level of understanding on drones, the type of drones likely to be operating and whether it is in an urban/rural location. In urban settings, most small drones are now difficult to hear against background noise, but there have been cases where drones have been unpopular in residential settings because of noise. This is especially likely to be an issue with consumer deliveries which have yet to be trialled at scale in urban areas. As the following quote highlights, there may be a gap concerning noise regulation. "*Noise from civil aircraft is not a statutory nuisance in the UK, and neither the Environmental Protection Act (1990), nor the Noise Act 1996, offer any protection. Ordinarily, that would leave civil action in the county courts as an option, but the aviation industry enjoys a special exemption by way of the Civil Aviation Act (1982)*"[22]

In forthcoming research to be published by Connected Places Catapult on the public perceptions of drones, there is evidence that the prospect of more drones in the sky causes relatively little concern currently in terms of noise, but a better understanding can help to foster public acceptance not just for noise but drone operations generally. For example, around two thirds of respondents (65%) with a 'good understanding' of drones felt comfortable or moderately comfortable with seeing increased drones in the sky compared to less than half of respondents (43%) who had 'little understanding' of drones.

[21] https://publications.parliament.uk/pa/cm201719/cmselect/cmsctech/2021/202102.htm
[22] https://www.aef.org.uk/guides/understanding-aircraft-noise/

Overall, the RHC's view is that while the UK ought to be cognisant of current and emerging risks, drones represent a key technological innovation in which the UK should continue to invest to ensure that it grasps opportunities to grow the economy, benefit society and improve the environment. In addition, we believe that regulation is a critical underpinning factor that will determine the extent to which these opportunities manifest now and in the future.

Indeed, we would go further and point out that when assessing the risks of drones there are also risks in not fostering the commercial use of drones. For example, the inherent risks in the use of helicopters to inspect power lines or oil and gas sites, or the risks of working at height in general can be greatly reduced by replacing people with drones. Therefore, risk assessment calculations need to consider the "unseen" risk (opportunity cost) of not proceeding with drone innovation and commercialisation – the latent risk of current practices, which although low could be lower[23] – as well as the "seen" risks of proceeding. However, measuring unseen, avoided risks of this kind is not straightforward.

[23] According to the **International Helicopter Safety Foundation (IHSF)**, in Europe, there were 43 accidents in 2017, 11 of which were fatal. In 2016 there were 52 accidents (12 fatal), and in 2015 there were 84 accidents (17 fatal).

3. Exam question and approach

The RHC takes a multidisciplinary and agile approach to developing its recommendations. It conducted its investigations by asking the following question, which we developed and sense-checked with stakeholders across industry and Government actors including the Department for Transport and the Civil Aviation Authority.

Exam question

"To examine how to optimise aviation regulation for unmanned aircraft in ten years' time. Particular attention to be paid to:

-The Operating Safety Case (including Beyond Visual Line of Sight operations);
- Air-Worthiness and certification;
- Airspace Management; and
- Air Traffic Management."

Approach

- We consulted the Department for Transport, the Civil Aviation Authority, and external stakeholders to understand the current regulation of the drone industry.
- We spoke with industry, both domestically and internationally, to understand their experiences of regulation in practice, the challenges they faced and to explore potential solutions. A list of stakeholders is outlined in **Annex E**.
- We conducted a futures exercise to understand the factors that would affect possible developments in the industry and generate a variety of possible futures. **(Annex C)**
- We undertook light touch desk-based research to review how, on drone regulation, the UK compares to a selection of other countries. **(Annex D)**

4. Stakeholder perspectives

Key Findings

In responding to the overarching exam question, the stakeholder engagement exercises highlighted several common findings set out below.

The status of commercial drone operations in the UK is largely experimental

The UK drone industry, particularly for operations beyond the visual line of sight is almost entirely still in an experimental phase of technology development rather than commercial deployment. Some examples of projects that have been running trials but are not yet commercial are set out below.

- The UKRI Future Flight Challenge running between 2021 and 2024 aims to bring together technologies in electrification, aviation systems and autonomy to create new modes of air travel and capability. This includes encouraging trials with technologies including drones. In total, there are 48 entries of which around half involve drones.
- Windracers has been conducting delivery trials in the Solent, initially delivering up to 40kg payloads to St Mary's Hospital on the Isle of Wight from Southampton General Hospital.
- Flylogix is using fixed-wing, petrol-engined drones to visit offshore oil and gas installations in the North Sea with a view to sensing methane emissions. Flights are restricted to weekends and require the filing of a separate Temporary Danger Area (TDA) for each flight.
- Sees.AI is exploring the remote operation of drones in industrial environments, from a central control room.
- Callen Lenz is exploring the convergence of military and civil drone usage from a base in Salisbury.
- Cranfield University is using its airfield to encourage experimental use of drones at certain times in the Cranfield experimental corridor.

There is an urgent need to bridge the gap in the UK between technology and commercial business development. There are examples of operators who have successfully pioneered

potentially commercial applications in Ukraine, Brazil, and Ireland and are seeking to expand their use of drones in the UK for agricultural surveying and drone delivery services. The Phoenix Programme is focusing on the commercialisation of drone operation services from the outset. With a launch in early 2021, the programme is still relatively new.[24]

Short-term regulatory opportunities for the UK exist

Our survey of industry insiders and observers identified some key difficulties in securing regulatory clearances:

Our findings suggest there is a strong willingness on the part of the CAA to engage with the drone industry, but an acute and existing problem is a lack of capacity to handle the ever-growing number of applications under the current regime. The CAA have highlighted to us that extensive time is already spent on airspace applications for drones and delays can be due to submissions lacking necessary or incomplete details with guidance then being provided to sponsors.

We recommend a review which explicitly seeks to change the appraisal of the requisite clearances required for drone operations, to speed it up via automation so that the CAA can focus their manual efforts on complex cases. To become commercially viable, logging individual flights with regulators will soon need to give way to a more automated approvals process, e.g., along pre-approved routes. This is particularly desirable for repeated operations of a very similar nature where only a small change has occurred.

Ghana's CAA has already instituted such a system for Zipline's medical deliveries and other regulators around the world are considering such systems. It seems clear that aspects of the Operating Safety Case (OSC) approval process could also be automated, allowing the UK's CAA to bring greater regulatory scrutiny to a subset of applications for regulatory clearance.

Recommendation 1a

The Government should undertake a review of the capacity of the CAA to cope with increasing applications for drone use. This should include a review of the approach to providing the requisite clearances required to undertake drone operations, particularly the appraisal of Operating Safety Cases and renewals.

Linked to this capacity/process issue, some stakeholders voiced concerns about the current funding model of the CAA and the perverse incentives it may lead to. The CAA are largely required to cover the cost of their regulatory activities through charges on the industry. This is funded by subscription from airlines and other operators of aircraft. The

[24] https://www.dronemajorgroup.com/phoenix-programme

funding it receives to devote time and expertise to both the regulatory policy development and conduct of oversight for drone operations is largely based on a small, time-bound grant from central Government. The challenges this represents are recognised by other parts of Government, with UKRI specifically creating a mechanism to provide funding to CAA to enable timely regulatory clearances to be granted for its Future Flight programme.

Section 70 of the Transport Act 2000 requires that the CAA treat all airspace users equally. But recognising the user pays principle on which the CAA is funded where new entrants tend not to pay charges to CAA while existing incumbents do, there is a risk (whether real or perceived) that the CAA, with finite resource is understandably inclined to focus on its charge payers. We found no evidence that the CAA actively resists new entrants, but the risk remains, nonetheless. Therefore, the UK Government should review the funding model of the UK CAA with a view to finding a way for it to have a greater interest in supporting innovation that may undermine or affect the business model of existing incumbents. For the drone sector, CAA and DfT should consider how a move towards regulated self-assurance can be underpinned in the long-term by full cost-recovery for regulatory activity.

Recommendation 1b

The Government should undertake a review of the funding model of the CAA to recognise the need to encourage new technology while regulating the safety of existing technology.

Difficulty in gaining regulatory clearance for either i) beyond visual line of sight (BVLOS) operations; or ii) multiple vehicles per operator.

The UK does not ban the conduct of BVLOS drone operations, but consistent feedback from stakeholders suggests that gaining permission from the CAA for such flights can be difficult in practice. The onus is upon the operator to demonstrate and provide evidence that what is proposed will be safe. The CAA setting out what it regards as safe and operators then working towards achieving that could potentially be too prescriptive as an approach and inadvertently restrict the type of operations considered by industry.

However, some guidance by the regulator and/or the provision of exemplar applications (without compromising commercial sensitivity and permission from operators) could limit the onerous costs for small innovators and increase the likelihood that applications are ‘right first time’ and not unnecessarily delayed due to insufficient information. One suggestion from stakeholders was that CAA may want to explore delegating a third-party

body (akin) to the British Gliding Association (BGA) with very specific domain level expertise to approve BVLOS operations.

This perceived ability to obtain regulatory clearances has commercial impacts. For example, one stakeholder explained that the costs of using drones to survey crops in the UK is significantly higher than in Ukraine, partly because of the higher per-day cost of drone pilots, exacerbated by the difficulty in securing regulatory approvals.

As such, there is clearly a need for the UK to find a way to develop simpler licensing of more BVLOS operations in at least some areas and applications, even if only for a subset of applications or airframes. For agricultural surveys lack of BVLOS can mean having to land a drone in one field and move to the next one to relaunch rather than surveying several fields during one flight. For payload delivery it can mean short-distance flights or operators being present at landing as well as take-off sites. The CAA needs persuading that drones BVLOS can be as safely piloted as other forms of aviation. In future, it is likely that drones will be able to navigate autonomously, as tractors and combine harvesters can already do, using GPS or cellular triangulation.

A separate issue is that of the operation of multiple vehicles per operator. One of the main benefits of innovation comes not when a technology is invented but when it dramatically comes down in cost. Delivering packages by drone is currently expensive. If, however, one operator can pilot 20 drones at once, then the cost would be dramatically reduced. Zipline, in Rwanda, has moved gradually from three drones per operator to six, then 12, now 20 and plans to move to 24, using pre-programmed flight plans with manual override. It has had no accidents in Rwanda so far, but there has been at least one crash of its drone in Ghana, albeit with no casualties. We recognise that there may be lower population density and limited entities in the airspace in remote parts of Ghana or Rwanda; however there remain parts of the UK that have low population density.

Recommendation 2

The CAA should find ways to approve a) BVLOS operations more rapidly; and b) multiple drones per operator. This could involve delegating such approvals to a body with specialised expertise.

Based on our stakeholder engagement, there was a broadly positive view towards the Future Flight programme and the Innovation Team advising drone operators within the CAA, however, the current implementation of sandboxing efforts was seen as having some drawbacks.

Several elements of this repeatedly surfaced in conversations with stakeholders:

Testing environments are largely limited to technology capability proof of concept

The focus in the UK from the CAA appears to be wait for the technology to mature to a point where drones can slot into the existing usage structures without affecting other airspace users to any great extent. Current sandboxing efforts are therefore designed to test technological innovation, not regulatory, or wider, innovation. For example, a particular stakeholder expressed that they found themselves excluded from subsequent rounds of Future Flight sandboxing programmes because the innovations it wanted to test were no longer technical and were practical or commercial in nature.

Direct dialogue to facilitate business case use developed by industry

We have talked to drone service providers that operate abroad which provide services aimed at proving commercial uses of technology. They spoke of CAAs in other countries for example Ireland, Switzerland & Rwanda which take a view that can be described as, **'what can we do today and how do we make that fit?'** In such situations, the decision maker in the regulator is in direct dialogue with industry. We also spoke to regulators including Switzerland, Ireland, USA, Singapore. The regulators in each case are directly engaged with the companies, and there appears to be a collaborative approach to implementing regulations and in some cases facilitating business use cases developed by the industry without compromising their regulatory independence.

Testing environments are insufficient for testing business models and commercialisation

Critical to commercialising the technology is the ability to test it at scale. Many companies highlighted this problem globally, and no less so in the UK. For example, one stakeholder stated "The Sandbox is a highly controlled operation, so you are not learning new things. You can't build a business in a sandbox; you must be able to scale." As such, we recommend the establishment of scaleboxes – a CAA service which explicitly seeks to provide regulatory clearance at an expedited rate and scale to support companies in their growth phase, with a focus on ensuring that regulation is proportionate to the nature and size of the business in question and previous safety evidence gathers, as well as any novel risks involved. This should specifically address the limitations on commercialisation that the current 90 day limited Temporary Danger Areas policy produces. This should also include designating zones and times for standardised drone operations to facilitate the development of commercially realistic or market proving operations.

The sandbox offer is not clear

Some stakeholders perceived the CAA Innovation Team and/or sandbox offer to be a 'front door to a CAA reception room', i.e., that there is no 'sandbox' as such - no constrained environment to operate, test, enhance and prove effectiveness. (We recognise that definitions of precisely what constitutes a 'sandbox' vary significantly between regulators, and that the term originates in the very different field of software.)

The CAA Innovation Team is plugged into Future Flight and is supportive of industry but there is a concern that this team which liaises directly with innovative drone operators does not have the necessary authority to give regulatory clearance or make policy decisions to permit regulatory easements. We are conscious that the Government is currently consulting on how regulators can be more empowered to implement sandboxes, therefore this may change. The CAA highlighted to us that they are not legally allowed to operate as the sponsor of an airspace change and the Innovation Hub seeks to work with participants to identify an appropriate volume of airspace within which to test their innovative operation or novel technology while ensuring the safety of other airspace users and the public. Furthermore, there are existing 'permanent danger areas' across the country which innovators can access – if they deem it appropriate for the operation or technology they wish to demonstrate.

Recommendation 3

Recognising the existing legal constraints that exists on the CAA, we would recommend that the Government does what it can to unlock the full potential of its sandboxing offer, including:

a. empowering suitably qualified individuals to make regulatory easements for drones whilst overseeing an iterated sandboxing offer, thereby facilitating a greater range of innovation – included but not limited to regulatory innovation and business model innovation; and

b. the establishment of a 'scalebox' to provide regulatory clearance at an expedited rate and scale to support commercialisation initiatives and companies in their growth phase, including by designating zones and times to facilitate the development of commercially realistic or market proving operations.

In the medium to long term, the commercialisation of drones will depend on the development of Unmanned Aircraft System Traffic Management or UTM. The United States has established a Research Transition Team between the Federal Aviation Administration (FAA), NASA, and industry to coordinate its UTM initiative[25]. This will focus on "use case development, data exchange and information architecture, communications and navigation, and sense and avoid".

In the UK there is an initiative coordinated by the Connected Places Catapult (CPC) to develop the Open Access UTM Framework, and this is being used by several Future Flight projects. We also note that a few large technology industry companies who have expertise in the commercial exploitation of data are involved in UTM development, such as Alphabet (the parent company of Google) and Amazon. For example, we understand that Wing will develop the framework that will allow airspace authorities to share data digitally and automatically with drone operators through verified third party applications, known as UTM Service Providers (UTMSPs).[26]

UTM systems are essentially digital platforms - operating systems that enable multiple devices, in this case drones, to connect to each other and potentially to some central controller, enabling sharing of information, communication and coordination to manage drone traffic. They can also collect, store, and generate insight from data, using this data to improve the efficacy of the UTM.

As noted in the 2019 Furman review[27], the digital economy has the potential to create substantial benefits, but digital markets are subject to 'tipping' in which a winner can take most of the market. Although there may be market benefits to this, it is possible that substantial costs can also arise from 'market tipping' and 'winner-takes-most'. As the report states: 'Government and regulators can be at an enormous informational disadvantage relative to technology companies….' and 'Regulators may be captured by the companies they are regulating.' Following on from the Furman Review, the Competition and Markets Authority in 2020 completed a market study on online platforms and digital advertising, noting the existence of network effects and economies of scale and 'unmatchable access to data' in these markets, conferring substantial market power on incumbents and weakening competition[28]. In our view, the nature of UTMs means that the issues identified by the Furman review and the CMA's online platforms and digital advertising study could apply to them.

UTMs will likely have powerful network effects, such that the value of the network itself will increase as the number of connections to the network increases. Put simply, a UTM that

[25] https://www.faa.gov/uas/research_development/traffic_management/
[26] https://wing.com/resource-hub/articles/uk-selects-wing/
[27] Furman Review (2019), Unlocking digital competition
[28] Competition and Markets Authority (2020), Online platforms and digital advertising

can connect with many drones and many controllers will be more useful than one that can connect a small number of drones and a small number of controllers. Such network effects create powerful economies of scale and will create incentives for any UTM to grow scale quickly. Drone manufacturers will also have incentives to ensure that their drones will work effectively with all major UTMs to widen the potential areas of their operation, and therefore their markets, as far as possible. So, if the number of UTMs a given drone can connect with is limited, those UTMs that gain scale quickly will quickly capture the market. In such circumstances, it will be very difficult for a new UTM to break into the UTM market; the market may 'tip' quickly from there being several competing UTMs to one dominant UTM.

These scale economies and network effects may be compounded by data issues. As a UTM connects drones, it will capture data about their flight, their interactions with each other and interactions with a controller. This data will be valuable, in part because it will improve the capacity of the UTM to optimise air space use over time. Thus, a UTM that quickly grows scale could gain a significant first mover advantage through access to such data, and this could become a barrier to entry or expansion of smaller, competitor UTMs, unless open access is mandated to this data from the outset and unless a common protocol is established for collection of and access to such data to support interoperability. We consider that these digital platform and data issues created make the UTM market susceptible to monopoly or persistent market in the future. This in turn could limit the potential for innovation in this market in future, as incumbents seek to protect their position, and as regulators inevitably struggle retrospectively to create the conditions of contestability that challengers would need to succeed.

A further issue is the barrier to market entry represented by the need to accumulate hours of data through operations to provide evidence for certification. The need to establish confidence in a new technology is entirely appropriate and the CAA can be fully expected to assess requirements and identify what is appropriate. A scenario is that a drone technology is the first to gain sufficient operating hours and achieve certification, and is therefore succeeds in the market, where it gains further operating hours. A question to address is whether the need to acquire operational data presents a barrier to other drone technology developers and reduce the opportunity for competition in the market. The sharing of data and establishing industry standards could be considered as options in this context.

Recommendation 4

We recommend that the Competition & Markets Authority (CMA), in collaboration with the Civil Aviation Authority, and the relevant government and industry stakeholders explore the digital platform and data issues that could arise in the emerging market of Unmanned Traffic Management (UTM) systems and the potential for these to result in persistent market power. This should build on the CMA's work and expertise on digital markets, to be taken up by the relevant regulators today to prevent this from occurring.

Electronic conspicuity

A significant hurdle in the deployment of drones is the lack of mandatory electronic transponders on all users of airspace including private aircraft. This means that gliders or private aircraft are not necessarily electronically conspicuous to a drone or its operator, leading to a risk of collision if airspace is shared. Despite CAA supported grants for their purchase, there is reluctance on the part of general aviation to move to mandatory electronic conspicuity (EC). This may be because of libertarian concerns over tracking and the associated increased oversight. There are though safety benefits in increased take-up of EC devices, including general aviation.

The ADS-B system used in civil aviation is highly accurate and transmits precise location information in a fast enough manner to be useful for air-traffic controllers and all other air users, except for some fast military jets. Although it is mostly affordable compared with the cost of aircraft, it is not mandatory for private aircraft. ADS-B is the system most likely to be used by drones. However, there is significant concern that the ADS-B system has limited bandwidth and will be rapidly saturated in congested areas. This suggests that initial deployment could be confined to rural and remote areas with less congested airspace. In the future, the issue of screen clutter in air-traffic control suggests that multiple technologies will be needed for electronic conspicuity.

The Civil Aviation Authority states that electronic conspicuity “is seen as the means for all aircraft to be able to identify and respond to one another. EC can help to reduce the number of mid-air collisions by increasing the situational awareness of pilots and remote pilots[29].” In the long run, airspace needs to be considered as a resource for multiple beneficiaries and not just general aviation. Unlike the FAA in the United States, the CAA has not committed to bringing in mandatory electronic conspicuity but states that “The development of EC solutions for UAS will be an evolutionary process and may take several years for individual EC technologies to reach maturity. EC solutions refer to

[29] https://www.caa.co.uk/Consumers/Unmanned-aircraft/Electronic-Conspicuity

devices, systems, and infrastructure that bring these technologies together to market and ensure that they are interoperable."

Recommendation 5a

The Government should set out a plan for the acceleration of the universal adoption of electronic conspicuity by all aircraft, with a mandatory date of 1 Jan 2025 imposed, if not sooner.

Ending segregation

Airspace is a shared national resource, and there ought to be a recognition that there are existing incumbent users but that as technologies develops, they will need to share it with other users for economic and societal gains. The current approach to regulating drones is based on segregation of airspace. Testing drones in segregated airspace will have to be replaced progressively by testing in shared airspace. Drones are restricted to below 400 feet and further restricted in certain zones such as defined proximity to airports. (Other aircraft are also restricted in various areas, such as prisons and nuclear sites.) Drones are permitted to have exclusive use of airspace via the designation of exclusion zones - no piloted aircraft at certain times or in certain zones when airspace is segregated. There is consensus both from industry and Government that this is something that will have to change. Opposition from, for example, the pilots' union BALPA and from general aviation (private planes and gliders), is however significant.

One reason for ending segregation by height is that certain risks of low flying are greater than for high flying. In urban areas, for example, flying below 100 metres or 300 feet carries risks of collision with buildings and of accidents caused by downdrafts or the short reaction time required to rescue a drone that is mistakenly flown too low. One-size-fits-all regulation is plainly inappropriate: congested, urban airspace presents very different issues from remote, rural landscapes.

However, for drones to share the same airspace as piloted aircraft, gaining the confidence of pilots will be helped by the development of "detect and avoid" systems. This technology has been in development for more than a decade, for example the ASTRAEA programme, which commenced in 2006. This culminated in 2013 with a live test flight demonstration, where a BAE Systems Jetstream 31 acting as a 'surrogate' UAV, was flown between Preston and Inverness[30]. Nonetheless, the technology is not fully mature, but it is likely to be improved in the coming years. In the long run, however, there is no alternative to the ending of airspace segregation, and no half-way house. Elsewhere in the world, the best

[30] https://www.adsadvance.co.uk/look-no-hands---first-unmanned-flight-over-british-airspace.html?play=1

example of fully shared airspace we came across was Zipline's operations in Africa, where drone flight plans are filed with air-traffic control and receive clearance for take-off integrated with other air traffic. Admittedly, the level of airspace congestion is demonstrably lower than UK population centres.

A pathway to ending segregation, and allowing drones to share airspace with piloted aircraft, is vital. However, this confronts the usual "chicken-egg" dilemma that pilots of manned aircraft cannot gain confidence in sharing airspace with drones unless there is a large body of data to support the safety of shared airspace, and that data cannot be gathered unless airspace is shared.

One option for gaining that experience is that new forms of segregation, other than by altitude, are tried in semi-permanent or routine experimental zones, especially those with less congested airspace. This would include days of the weeks or times of day reserved for drones. We welcome the fact that these kind of flexible airspace constructs are already being explored within the CAA's Regulatory Sandbox and by other innovators. Given successful results from drones sharing airspace with each other under such conditions, the next phase could be for limited numbers of drones to start sharing airspace with limited numbers of manned aircraft in daylight conditions in good weather in relatively unpopulated areas. Piloted aircraft would have to use transponders in such experiments.

Furthermore, the UK has some unexploited geographical advantages for the commercialisation of drones. As a relatively small country with congested airspace, the UK could be considered not to be the ideal place to pioneer drone operations. Countries with less congested airspace and more remote areas may leap-frog more developed countries such as the UK. However, the UK does have two geographical features that promise to aid the growth of the industry. It has less populated regions, especially in the Highlands and Islands of Scotland and it has a long coastline so that drones can fly over the sea on many routes, a feature it shares with Singapore. These features present opportunities for building up experience of safe flying that can then be used for commercial operations.

The UK has an opportunity to use the Hebrides, or Orkney and Shetland, or the Isle of Man, as a testbed for some drone delivery operations. For example, with medical supplies, as the recent Mull experiment during Covid showed, and for future aviation more broadly as with the creation of the UK's first operationally based, low-carbon aviation test centre at Kirkwall Airport in the Orkney Islands. This would capture the public imagination as well as delivering real value for the residents of island communities. If the flights were almost exclusively over the sea, the risks would be kept to a minimum, and the flights could be segregated by time of day if not by height. Such an experiment would not in itself be profitable but if officially encouraged and subsidised, it could attract several ambitious companies to take part. The experiment would satisfy those firms that complain that proper experimentation of the kind needed to prove viability is currently difficult in the UK. It's also

clear that such a move would align with the Government's levelling up and freeports agenda.

Finally, whilst segregation continues, there is an opportunity to consider creating a segregated block of low-level airspace where piloted aircraft do not operate, emergency services and emergency landings aside. Within this, drones could be the exclusive airspace user. As well as providing airspace for trials, this will also enable federated UTM solutions to be tested before they can be considered for other airspace constructs, at higher altitudes.

Recommendations 5b, 5c & 5d

5. The Government and CAA should set out a time-bound and progressive roadmap to agreeing the shared use of airspace between different users to enable drones to fulfil their potential. For the development of drones, this should be supported by:

b) the introduction of permanent - or initially regularly scheduled semi-permanent - mandatory transponder zones for areas that explicitly prioritise drones. Remote and marine areas could be chosen;

c) a geographically constrained segregated block of low-level airspace where piloted aircraft do not routinely operate; and

d) diligent tracking of improvements in drone detect-and-avoid capabilities.

Future-proofing drone regulation may require soft law

All contributors to this project agreed that there are significant uncertainties about how drones will evolve, and how they will be used in the future. This makes it essential that regulation allows for unexpected developments and is not tied to specific technologies of today. We expect swarming, collision-avoidance and automated "safe least cost path planning" to be features of drones within the next decade. This will create challenges for regulators. For instance, flexible AI-based path planning (already being used experimentally in indoor applications) may be incompatible with regulation that requires the filing of flight plans in advance. But we also expect technological developments that are currently unknown, bringing new opportunities for drones but new challenges for regulators.

It is therefore important for drone regulation to be as open-ended and general as possible with the flexibility available for the regulator to amend easily. Simple rules such as "do no

harm" can be interpreted by future regulators more usefully than detailed prescriptions, such as "stay beneath 400 feet".

One way in which regulators can encourage innovation, or at least avoid discouraging it, is by nudging industries into agreeing "soft regulations", such as standards and guidelines, which can be updated more flexibly and rapidly as technology changes and to develop appropriate skills. In theory this can also help to tackle the "pacing problem" – that developments in technology outpace developments in regulation. "Hard regulation" can result in a "regulate and forget" approach, rather than a process of continuous updating of regulations to suit changing technology. A recent review of soft-law methods listed the following examples[31]:

- Multistakeholder processes
- Codes of conduct
- Standards
- Private certifications
- Agency workshops and guidance documents
- Informal negotiations
- Education and awareness efforts

If the drone industry develops its own rules, codes, certifications, and guidance, this will go a long way to reassuring both Government and the public that it can operate safely. However, small start-ups rarely have the time or budget to engage with such processes effectively, so this is a case where the regulator could "herd" the industry in the right direction. In the case of standards, there was some feedback from stakeholders that the UK Government could do more to engage with the British Standards Institute and the International Standards Organisation to help develop global standards for drones. ASTM International (formerly the American Society for Testing and Materials) is another key body.

[31] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3118539

Recommendation 6

Standards play a significant role in the development of regulatory framework for drones. We understand that the CAA already contributes to specific standards setting exercises including the RTCA and ASTM International (formerly the American Society for Testing and Materials). The increasing importance of international standards to shape the future of drones means that we would recommend increasing UK support and engagement with the relevant bodies (including the British Standards Institute and International Standards Organisation) so the UK can be better placed to influence the direction of travel for these international standards.

Privacy and noise

Regulation will undoubtedly play a role in deciding public acceptance of drones as they fly over people's property. Firms that we spoke to that are flying deliveries over people's houses have been able to reassure people that no downward-looking cameras are on the drones. However, once commercial operations begin over a wider area, this reassurance may be harder to provide. Regulations prohibiting drones from filming below themselves except in certain cases may be necessary.

No standard or regulation exists today for noise a drone can produce. While most drones are now quiet, and the noise problem has not yet loomed large, noise is universally disliked, and it cannot be assumed that this will not be an issue in public acceptance. Google's delivery trials in Australia were halted in 2019 due to noise complaints[32]. Drones fly much lower than aircraft so even if relatively quiet they can give the impression of causing a nuisance. Furthermore, it is not simply the volume of the noise that is important, the pitch is also important with one interviewee highlighting how quieter but higher pitched noises were often perceived as particularly annoying.

In addition, "noise from civil aircraft is not a statutory nuisance in the UK, and neither the Environmental Protection Act (1990), nor the Noise Act 1996, offer any protection. Ordinarily, that would leave civil action in the county courts as an option, but the aviation industry enjoys a special exemption by way of the Civil Aviation Act (1982)"

Recommendation 7

Utilising public engagement, the Government should track privacy and noise considerations around increased drone use.

[32] https://www.abc.net.au/news/2019-11-21/google-affiliated-drone-delivery-company-clashes-with-Government/11722380

The need for a strategic vision for drones

There are multiple ongoing initiatives related to drones within Government – primarily with the Department for Transport, Department for Business, Energy and Industrial Strategy, Home Office, the Civil Aviation Authority, Ofcom, Connected Places Catapult, and UK Research and Innovation (UKRI). This list is not meant to be exhaustive and the £125m Future Flight Challenge and the Drones Pathfinder Programme are just two examples. Historically, there have been numerous policy and operational initiatives related to drones including two substantive consultations[33], the development of the Counter Drones Strategy and more recently, the Air Traffic Management and Unmanned Aircraft Act 2021.

Though the above initiatives have varying objectives, there was a strong sentiment from external stakeholders that these disparate activities would benefit from a strategic anchor in the form of a vision statement for the drone industry. This would enable these initiatives to demonstrate how they dock into a single policy and provide an articulation of ambition for drones for the country. We found widespread acknowledgement of the benefits of drones for society and industry and similarly widespread recognition of the risks. But as far as we are aware, the closest document that explicitly attempted to set out a coherent and pithy vision in one place is the Counter Drones Strategy.

However, the scope of this strategy is limited as it naturally focuses on reducing the risk posed by malicious or illegal use of drones. A vision for drones ought to be all-encompassing and focus on both mitigating risks and enabling innovation and opportunities. Our conclusion on the need for a vision is not new. In 2019, the House of Commons Science and Technology Committee published its report into the commercial and recreational drone use in the UK[34]. One of its recommendations (No.24) was that the Government should produce a White Paper by Summer 2020 that outlines the vision for how drones will be integrated into UK communities over the coming years. Furthermore, in 2020 the Drone Delivery Group, concluded that 'despite the very best intentioned efforts, the overall Government landscape is fractured….with no clear national strategy'.

In addition, from time to time the Government should update its remit letters from the responsible minister sent to the CAA. These letters are critical to providing political steers to, and top cover for, decision makers within CAA. We note and welcome the exchange between the CAA and the Secretary of State[35] which included an emphasis from the Transport Secretary of State on the CAA 'supporting innovation and new business models and other innovations that have the potential to drive significant economic growth in UK aviation while achieving our net zero by 2050 ambitions'. Going forward, these should more greatly emphasise innovation and commercial deployment of drones at scale. We

[33] '*Unlocking the UK's High-Tech Economy: Consultation on the Safe Use of drones in the UK' (2016-2017); Taking Flight: The Future of Drones in the UK' (2018-2019)*

[34] *Commercial and recreational drone use in the UK*

[35] https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=9890

suggest this could include a requirement for the CAA to report on the number of approvals it is achieving, broken down to explain how many support technological innovation, and how many support business model innovation. Further, the CAA should report to Parliament and Government on how it is fulfilling that remit letter, in a regular fashion.

Recommendation 8

The UK cannot wait for the future of drones, in whatever form, to arrive and hope to mitigate undesirable outcomes, so it is imperative that the **Government sets out a short, compelling vision statement for drones that acts as a signal to the industry and the public.**

The Regulatory Horizons Council does not have the full co-ordinating power and/or authority of Government and industry, nor do we have the resources to conduct an extensive testing and engagement exercise. But we have outlined some preliminary thoughts on what a draft vision statement and accompanying regulatory principles for iteration and consideration by Government could look like (**Annex A**). This is intended to be a starting point and was tested with a limited set of stakeholders.

Recommendation 9

We welcome the recent exchange of letters between the CAA and the Transport Secretary of State[36]. **The Government should, where appropriate, make greater use of remit letters to impart political direction and vision to the CAA. In doing so, the Government may wish to recognise that the public will value some use cases more highly than others.** Future remit letters should more keenly emphasise innovation, particularly commercialisation of innovative business models. Further, the CAA should report to Government on how it is fulfilling that remit letter in ways that are measurable.

[36] https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=9890

5. Future scenarios

To complement our engagement with stakeholders through the traditional medium of interviews, we used a workshop with representatives from across industry, Government, and regulators to develop an outline of five possible futures and consider some of the implications for the regulation of drones looking out to 2030 (attendees listed at **Annex E**). Recognising the uncertainties that are inherent when thinking about the development of regulation of a future technology, as a tool, scenario development can help ensure that policies, regulations etc are resilient across a range of possible futures. These futures will explore how changes emerging today might result in contrasting future environments in which designs and uses of drones might evolve.

The workshop consisted of the following key activities:

1. **Sketching a systems map** of the current state of play in the aviation sector – main components, major actors, and interconnections, especially as relevant to drones.

2. **Identifying change and possible change** – what current trends or emerging signals of change are there that will/may significantly affect the aviation sector for the evolving use of drones.

3. **Assessing change,** such that we reached a group consensus on what was low/high importance mapped against low/high certainty. This allowed us to identify four groups – i) respond: highly important and highly certain; ii) ignore: low importance and low certainty; iii) monitor: low importance, high certainty; and iv) explore: low certainty and high importance. It was this final group – the critical uncertainties - that was used as the primary basis for the futures scenario exercise.

4. **Specifying possible outcomes of critical uncertainties**, identify contrasting potential outcomes for identified high importance, low certainty change that, if realised, would drive different possible future environments.

5. **Combining different possible outcomes of the critical uncertainties to build difference future scenarios out to 2030**. These imagined futures were envisioned as being distinct from the present, structurally defendable in terms of presenting a coherent story (logical) and useful for considering how regulation and drones' usage might change.

6. **Building potential futures** – utilising the preliminary scenario, build out the details of possible futures and explore **what the conditions of each future might mean for regulation**.

This report will focus on the discussions on a) critical uncertainties that are likely to transform or disrupt the aviation sector, b) the potential futures formulated, and c) the implications for regulation.

Critical Uncertainties

Based on a group discussion, the top three critical uncertainties identified were

1. the degree of public acceptance of drones, including privacy/intrusion, noise and sight pollution and the degree to which drones are accommodated by existing air users;
2. the governance and dominance of big tech with regards to drones; and
3. the extent of advances in artificial intelligence and autonomy and their public reception.

These are explored in greater detail in **Annex B.**

Future Scenarios

The workshop produced five substantively different scenarios, labelled as Egalitarian, NIMBY, Libertarian, Luddite, and Meritocratic; to represent their core character or spirit.

These are briefly described below, and more detail is included in **Annex C.**

Egalitarian

Characteristics: The public are ambivalent towards drones with a plurality of local attitudes which dictate local policy, resulting in disparities in uptake and outcomes across localities. AI and automation make modest advances. The UK makes a determined and rapid transition to combat climate change. Big tech expands its dominance generally but specifically into drones and aviation, achieving sovereignty in a way only previously exercised by states.

Novel outcomes: The UK has less agency and ability to shape its regulatory environment – we would likely adhere to global standards, conventions, and approaches. The UK aviation industry has become a subset of the tech industry. The importance of local perspectives suggests there could be more of a need for nuance in the distinction between local/regional/national regulation – both of airspace and traffic management. The vexed questions of how to assure AI use and the integration of ‘system of systems’ looms large.

Polity reaches to hold external, likely foreign, actors to account and struggles to do so – the public clamour for accountability. ‘Drones that do’ likely to play key role in operational matters, such as law enforcement or mitigation of the climate emergency – e.g., farming applications such as planting seeds, spraying crops etc. Public attitudes demand, and therefore lead to, quieter and less visually conspicuous drones.

NIMBY

Characteristics: NIMBY attitudes prevail – the public are okay with the underlying concept but concerned about frequency and proximity which limits the scale of use near population centres. AI and automation make modest advances. The UK makes a slow adaptation to climate change. Competition law globally curtails dominance of big tech firms, allowing smaller firms to flourish.

Novel outcomes: huge opportunity cost in terms of forgone use cases from lack of use of drones at scale and across different sectors. Increased compliance activity by law enforcement and oversight bodies due to public concerns. Local councils control issuing of licences. National aviation market remains relatively stable over the ten-year horizon. Drones replacing noisy helicopters is seen as better than delivery drones which are ruled out. Airspace may become monetised. Limited acceptance of drones stimulates innovation only within a subset of acceptable use cases e.g., emergency services or farming applications. Airspace segregation continues but is more geographically defined. Anti-trust and competition powers increasingly used and politicised. Lack of public acceptance limits the ability to experiment, test and commercialise in the UK. Use cases around replacing hazardous or laborious work particularly developed.

Luddite

Characteristics: The public do not accept drones and actively resist their deployment and operation. AI and automation make modest advances with some decision making but draconian, publicly demanded restrictions prevent value from being realised. The UK makes a slow adaptation to climate change. The luddite movement rejects big tech and loss of local control. Globally, big tech expands its dominance over other sectors, and they become world leaders politically.

Novel outcomes: Investment goes elsewhere. Huge economic opportunity cost. Sensitivity to accidents heightens concerns around malicious actors. Increased political support for controlling regulations and legal structures. Petitioning for bans/curtailment. Anti-science and distrust of authorities makes it difficult to change attitudes or behaviours.

Libertarian

Characteristics: There is complete public acceptance of drones, and they are prioritised over and above other airspace users. AI achieves partial knowledge refinement and some

decision making and there is some ‘broad’ AI with meta-cognition. There is ubiquitous planned automation. The UK makes a slow adaptation to climate change. Big tech expands its dominance over other sectors, but this is effectively managed to ensure competition and Governments maintain sovereignty. Global corporations become world leaders politically.

Novel outcomes: The legal and regulatory environment is highly supportive of new drone innovations. Public services benefit from cheaper, easier, faster, and more efficient delivery mechanisms. Huge increase in tech advances in UK. Drones used for a plethora of purposes, including a big role in climate monitoring and mitigation of the climate emergency via clean-up. Lots of downward pressure on piloted aviation. Regulators must change methods of monitoring and certifying to keep-up with demand – perhaps individual accountability via an airframe.

Meritocratic

Characteristics: The public supports limited use cases for drone operations which are routine in some areas, predominantly where those are socially beneficial. Narrow static AI achieves partial expertise with some decision making. Some automation achieved within narrow boundaries but only with human oversight. The UK makes a fast, early, and proactive response to the adaptation required of the climate emergency. Markets continue to be fair and open with big tech effectively managed by competition law and practice.

Novel outcomes: Economic opportunity cost of forgone development and employment opportunities for the UK. Regulatory and legal frameworks strike a balance between public concerns, climate change reform demands and a sustainable economy. More regional airports grow as piloted and unpiloted aircraft meet existing and new demand. Rural communities more connected. Emergency services may introduce new opportunities for small businesses to provide new ‘blue light’ services, e.g., facilitating greater speed of access to health services in rural communities. Public attitudes very sensitive to any disruption or collateral resulting from accidents.

Possible implications for Regulation

Utilising the scenarios that were generated, the below possible implications for regulation were identified. More detail is provided in **Annex B**.

A differentiated approach with regards to regulation, perhaps based on geography or population density, could enable progress on drones to be made under a variety of scenarios.

There will continue to be a need to coordinate internationally on the governance of big tech, particularly given possible ambitions around universal traffic management (UTM).

There will be a need to outline the approach to traffic and airspace management in the longer-term, for example it could be a federated, local, or alternatively a national approach.

Demands for accountability, both for operations and for the employment of increasingly sophisticated AI and autonomy, will have a bearing on how the technology develops and scales for drones.

There could be a need to track the development of local regulations, particularly permitting or control of e.g., movement corridors, landing areas or noise pollution as well as considering what could or should be devolved.

Public engagement to understand the preferences and attitudes of the public (around noise and sight pollution in particular) will be required to inform policy and product development.

There could be a need to consider the balance between the clear commercial value of trial data and the regulatory approval process.

Use cases that represent the replacement of hazardous or laborious work would likely be endorsed more readily by the public.

Successful integration and uptake of drones will be dependent upon adequate security to minimise the risk of nefarious actors successfully conducting malicious activity.

6. Recommendations

1. **The Government should undertake a review of the capacity of the CAA to cope with increasing applications for drone use**. This should include:

a. reviewing the approach to providing the requisite clearances required to undertake drone operations, particularly the appraisal of Operating Safety Cases and renewals.

b. the Government should undertake a review of the funding model of the CAA to recognise the need to encourage new technology while regulating the safety of existing technology.

2. **The CAA should find ways to approve: a) BVLOS operations more rapidly; and b) multiple drones per operator**. This could involve delegating such approvals to a body with specialised expertise.

3. Recognising the existing legal constraints that exists on the CAA, **we would recommend that the Government does what it can to unlock the full potential of its sandboxing offer**, including:

a. empowering suitably qualified individuals to make regulatory easements for drones whilst overseeing an iterated sandboxing offer, thereby facilitating a greater range of innovation – included but not limited to regulatory innovation and business model innovation; and

b. the establishment of a 'scalebox' to provide regulatory clearance at an expedited rate and scale to support commercialisation initiatives and companies in their growth phase, including by designating zones and times to facilitate the development of commercially realistic or market proving operations.

4. **The Competition & Markets Authority (CMA), in collaboration with the Civil Aviation Authority, and the relevant government and industry stakeholders should explore the digital platform and data issues that could arise in the emerging market of Unmanned Traffic Management (UTM) systems and the potential for these to result in persistent market power.** This should build on the CMA's work and expertise on digital markets, to be taken up by the relevant regulators today to prevent this from occurring.

5. a) The Government should **set out a plan for the acceleration of the universal adoption of electronic conspicuity by all aircraft, with a mandatory date of 1 Jan 2025 imposed, if not sooner.**

The Government and CAA should **set out a time-bound and progressive roadmap to agreeing the shared use of airspace between different users to enable drones to fulfil their potential**. For the development of drones, this should be supported by:

b) the introduction of permanent - or initially regularly scheduled semi-permanent - mandatory transponder zones for areas that explicitly prioritise drones. Remote and marine areas could be chosen;

c) a geographically constrained segregated block of low-level airspace where piloted aircraft do not routinely operate; and

d) diligent tracking of improvements in drone detect-and-avoid capabilities.

6. Standards play a significant role in the development of regulatory framework for drones. We understand that the CAA already contributes to specific standards setting exercises including the RTCA and ASTM International (formerly the American Society for Testing and Materials). The increasing importance of international standards to shape the future of drones means that we **would recommend increasing UK support and engagement with the relevant bodies (including the British Standards Institute and International Standards Organisation) so the UK can be better placed to influence the direction of travel for these international standards.**

7. Utilising public engagement, the **Government should track privacy and noise considerations around increased drone use**.

8. The UK cannot wait for the future of drones, in whatever form, to arrive and hope to mitigate undesirable outcomes, so it is imperative that the **Government sets out a short, compelling vision statement for drones that acts as a signal to the industry and the public.**

9. We welcome the recent exchange of letters between the CAA and the Transport Secretary of State[37]. **The Government should, where appropriate, make greater use of remit letters to impart political direction and vision to the CAA. In doing so, the Government may wish to recognise that the public will value some use cases more highly than others.** Future remit letters should more keenly emphasise innovation, particularly commercialisation of innovative business models. Further, the CAA should report to Government on how it is fulfilling that remit letter in ways that are measurable.

[37] https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=9890

Annexes

Annex A: Draft vision statement and principles for regulation

By 2030, the UK has commercially deployed remotely piloted aircraft systems rapidly and safely and this deployment enables better outcomes for the economy, society, and the environment.

Key Features

- The vision ought to be for a specific time-period. We chose 2030 for our scenarios exercise as it was far enough in the future to have meaningful discussions but not too far ahead that it would be impossible to forecast developments.

- The scope of the vision should primarily focus on the commercial use of drones but will have to include recreational use. Military applications of drones should be out of scope.

- The choice of rapid *and* safe is deliberate. We recognise that there may be tensions between these two sentiments not just with drones but broadly in innovation generally, but we think it is a false dichotomy to assume that moving slowly is always safe, while moving rapidly is necessarily reckless. With the right incremental approach to testing, experimenting, and scaling up, faster development can also be safer development.

- The Government should not remain neutral on this issue as it has already invested hundreds of millions of taxpayer pounds in facilitating drone technology and mitigating the risks. Therefore, we would anticipate that the Government would want to be explicit about harnessing the technology for good.

- Making this vision come to life should not be placed solely on the shoulders of government. Industry has a critical role and responsibility in making this vision come to life and in particular embracing some of the ethos behind responsible innovation; namely recognising that public engagement and acceptability are important factors

Key Regulatory Principles

Recognising that the Council's remit is around the regulation of innovation, we here set out prospective regulatory principles that can act as guardrails on the journey to 2030.

The ambition for the UK should be to have a vibrant world-leading industry/environment for drones, attracting investment, and to be one of the best places in the world to test, develop and deploy the technology.

Based on the Regulation of the Fourth Industrial Revolution, key regulatory principles include:

- ***To ensure regulation balances risks and benefits.*** *Innovation brings new hazards, but it also brings new benefits, and removes old hazards. While the precautionary principle suggests considering all possible future risks of encouraging the use of drones, however uncertain, balancing the innovation principle also suggests considering all possible future benefits of using them, however uncertain.*

- ***To foster a regulatory system that is sufficiently flexible to be future proof.*** *The unexpected can be expected to occur in rapidly changing technologies. Prescriptive legislation or rules can provide clarity for businesses today but can lock in outdated approaches to achieving policy outcomes and hinder innovation. For drones, this should include adapting regulations for different local and regional contexts and ensuring that regulation is based on practicability and not theoretical possibility.*

- ***To recognise that deployment is a vital part of testing,*** *adapting to innovation requires more than testing under experimental conditions, but must allow scaling up and integrating new technologies for commercial deployment.*

- ***To establish a co-ordinated, effective, targeted, and transparent research and development programme****. It is critical that the learnings and implications for regulation or a regulatory approach are fed back and implemented where appropriate.*

- ***To establish a two-way dialogue with the public on how innovation should be regulated. Public acceptability of innovative technologies cannot be taken for granted.*** *Drone technology is advancing rapidly with the potential to perform critical services in everyday life – from transporting urgent medical supplies to bridge inspection. We acknowledge that Nesta have undertaken previous work with local stakeholders of the key factors critical for safe drone operation at scale in cities and there remain challenges on what is publicly acceptable in terms of noise, privacy, safety and other issues.*

- ***To engage and support innovators to navigate the regulatory landscape and comply with regulation.*** *We acknowledge that Nesta have undertaken previous work with local stakeholders of the key factors critical for safe drone operation at*

scale in cities and there remain challenges on what is publicly acceptable in terms of noise, privacy, safety and other issues.

- ***To work with partners across the globe to reduce regulatory barriers to trade in products and services associated with drone technologies.*** *Emerging technologies are increasingly trans-border in nature. This creates exciting frontiers for innovative businesses but creates new challenges for regulators.*

Annex B: Futures workshop - critical uncertainties, scenario hypothesis & implications

The following critical uncertainties were singled out by participants during the workshop, with possible implications drawn from the subsequent scenario development.

Critical uncertainty 1: the degree of public acceptance of drones, including privacy/intrusion, noise and sight pollution **and the degree to which drones are accommodated by existing air users**.

Possible implications? If NIMBY attitudes prevail, creative opportunities for the employment of drones will be limited and incumbent operating models will endure. **A differentiated approach, perhaps based on geography or population density, could enable progress to me made under a variety of scenarios.** Further, while industry might judge something to be entirely safe, public attitudes can result in considerable backlash, pushback, and political controversy. Something can be perfectly safe and still supremely annoying.

Critical uncertainty 2: the governance and dominance of big tech (WRT drones).

Possible implications? **There is a need to coordinate internationally on the governance of big tech, particularly given possible ambitions around universal traffic management (UTM).** The rising issue of state vs company sovereignty is paramount here**. The Government may wish to signal its preferred approach to traffic management in the longer-term, for example it could be a federated local or alternatively a national approach.** It will also need to monitor the competitive landscape as it evolves and work increasingly closely with the Governments of other jurisdictions.

Critical uncertainty 3: the extent of advances in AI and autonomy and their public reception.

Possible implications? **Demands for accountability, both for operations and for the**

employment of increasingly sophisticated AI and autonomy, could have a bearing on how the technology develops and scales. Autonomy and AI are issues being wrestled with in many domains. For drones, the read across of any considerations for assurance and insurance will be important.

Scenario hypothesis & implications

These hypotheses and their implications were generated from the imagined futures – the future scenarios – generated during the workshop.

Scenario hypothesis 1: the extent relevant powers to regulate drones are devolved. If local or regional decision makers are empowered, then divergences in local policy could be sufficiently substantive to the extent that it influences commercial decision making. A national jurisdiction which makes it easy to navigate these local differences will likely be more attractive to businesses overseas as well as making it easier for domestic companies to scale.

Possible implications? The Government may wish to track the development of local regulations, particularly permitting of e.g., movement corridors, landing areas or noise pollution as well as considering what *could* or *should* be devolved. This could support a deliberate policy of having certain areas designated for testing. However, establishing local policy could become extremely confusing for drone operators and possibly introduce additional cost. While different methods may be legitimate based on the location and airspace, we ought to consider the wider business implications.

Scenario hypothesis 2: the extent to which noise generated by drones can be minimised.

Possible implications? As a universally disliked phenomenon, if unsolved, noise from drones is going to be a critical and enduring issue of contention. If noise remains an issue, it is plausible that limits on their pervasiveness will be demanded by the public to the extent that they are not operating at revolutionary scale, particularly within urbanised areas. It is perhaps more likely that they will be employed via hubs on a more regionalised or geographically determined basis. Public engagement to understand the preferences and attitudes of the public (around noise and sight pollution in particular) will be required to inform policy and product development.

Scenario hypothesis 3: data sharing for the limited number of trials that are permitted could be vital in supporting SMEs and start-ups, if market dominance is to be prevented in the face of limited regulatory capacity to meet the demand from industry for experimental

licences and/or the limited capacity on testing airspace or geography or limited regulatory/political appetite for risk.

Possible implications? The Government may wish to consider the balance between the clear commercial value of trial data and the regulatory approval process. Arguably, the more that SMEs and a competitive market are favoured, the greater the extend that data-sharing should be a pre-requisite for trial approval.

Scenario hypothesis 4: It is likely that use cases that improve the environment by e.g., enabling a reduction in pollution or improving environmental monitoring OR that remove the need for humans to do hazardous or laborious work are likely to achieve broad support.

Possible implications? The Government may wish to signal which use cases they are particularly in favour of supporting (or accelerating) the regulatory clearance to enable.

Scenario hypothesis 5: If we become dependent on automated or autonomous drones, there is a considerable systemic or contagion risk that could arise.

Possible implications? Successful integration and **uptake of drones will be dependent upon adequate security** to minimise the risk of nefarious actors successfully conducting malicious activity.

Scenario hypothesis 6: An accident involving a drone could result in a dramatic undermining of public faith in the technology and therefore setbacks for its adoption.

Possible implications? Of course, the magnitude of any harm will have a critical bearing but the reasons a drone operation was being undertaken are likely to have a significant bearing on the reaction of the public. The Government may wish to prioritise consideration of certain use cases.

Possible implications? The Government may wish to explore opportunities for prioritising regulatory easements to enable new, specifically selected and socially beneficial, use cases, e.g., drones applied to pesticides or inspection taskings

Annex C: Future scenarios in detail

Characteristics/Scenario	'Egalitarian'	'NIMBY'	'Luddite'	'Libertarian'	'Meritocratic'
Defining characteristics – change variables					
Public acceptance	**Public ambivalent**	**NIMBY attitudes** prevail across the population	Public **do not accept** and actively resist	**Complete public acceptance**	**Limited, necessary use cases** supported by public
Status of AI and autonomy	'Narrow' AI achieves partial knowledge refinement with some decision making. Some automation achieved within narrow boundaries	'Narrow' AI achieves partial knowledge refinement with some decision making. Some automation achieved within narrow boundaries – but further limited by external (contrived) restrictions	'Narrow' AI achieves partial knowledge refinement with some decision making. Some automation possible within narrow boundaries – but not allowed to be realised due to draconian external (contrived) restrictions	'Narrow' AI achieves partial knowledge refinement with some decision making, some 'broad' AI with meta-cognition. Ubiquitous and planned automation	'Narrow' static AI achieves partial expertise with some decision making. Some automation achieved within narrow boundaries but only with human oversight due to large error rate
Climate change response	**Fast**, early, and proactive	**Slow** and late	**Slow** and late	**Slow** and late	**Fast**, early, and proactive
Dominance of' big tech' companies and/or of globalised solutions	**Big tech expands its dominance over other sectors**	**Competition law globally curtails dominance of big tech**	**Luddite movement rejects big tech companies and loss of control domestically**	**Governments maintain sovereignty**	**Fair and open markets, effectively managed by competition law**
Politics / policy	Some national decision making. Government will need to make decision about locus of decision making – likely to be pushed down and decentralised. Politics reaches to hold external, likely including foreign, actors to account and struggles. Key allies have Governments no longer aligned with UK policy; there is a greater reliance on international norms and suppliers. Operating more regularly in populated spaces, a small number of accidents can feed into conspiracy groups and drive opposition. Jobs losses - 'drones that do' replacing jobs. Civil liberty implications with private drones being used for policing / snooping – and data collected by 'drones that do' in normal work also being available to companies and Governments. Fringe actors may seek to disrupt or deny UA operations. Hacking/systemic/contagion risk due to level of integration and automated nature of processes.	Too challenging for single Governments to constrain big tech, so multilateral international cooperation is prioritised and achieved agreements negotiated, e.g., UK works with G7 to achieve successful regulation of big tech firms. Anti-trust/competition powers increasingly used and politicised. Politics reaches to hold external, likely including foreign, actors to account and struggles.	Drone accident in mid 2020s causes fatalities. This creates a strong anti-drone lobby before the technology is fully mature; rumours are that it was a rogue state, which raises security concerns.	Government regulation works to monitor big tech companies and maintain sovereignty. Government lags in implementing climate response in the face of business resistance.	Political pressure to respond to differentiated views of public for the limited areas of drone operations that are acceptable and for oversight of the use of AI and autonomy. Increasing innovation disparity between different parts of the world – countries that more openly 'allow' technological innovations to disrupt and enable leaps 'forward' as opposed to those with policy, regulatory, or legal constraints.

Characteristics/Scenario	'Egalitarian'	'NIMBY'	'Luddite'	'Libertarian'	'Meritocratic'
Misc.	this enhances the collection and importance of analysis of big data, with pervasive systemic effects. Realisation of drones at scale across a variety of use cases results in reduced cost to society, improved safety, improved environmental outcomes, increased flexibility, and choice Personal privacy further infringed, increased noise and visual pollution, short-term job losses from disruptive innovation and displacement activity.	Elements of status quo maintained. Humanity exposed to fewer hazards because of some dangerous human work being done by UA. Cost of aviation reduced by increasing use of UA delivering improved opportunity to poorest in society. Law enforcement and emergency services response improved. People can receive goods/ parcels quicker; environmental protection, meet net zero targets; faster communications Huge opportunity cost in terms of forgone use cases and employment at greater scale. Populations' transition to a reduced carbon and more autonomous word slowed. Noise pollution/ irritants; petitions against drone use (NIMBY); data protection risks; personal protection risks;	Leisure and pleasure use suffer public backlash. Opportunity cost of forgone use cases. Sensitivity to accidents heightens concerns around malicious actors. Investment goes elsewhere so UK doesn't benefit from being tech UA hub. Economic opportunity cost of forgone development and employment in the UK.	Noise pollution/ irritants. There will always be some persons/ groups who are not bought into the technology.	Remotely piloted aircraft are routine in certain circumstances but not pervasive, e.g., delivery drones are autonomous but not widely employed, operating out of hubs rather than doing door to door. Flying taxis are not the norm. Larger aircraft are never fully autonomous – AI is always partnered with humans. Some backlash from communities near distribution centres due to drones whizzing overhead – downside of extensive drone delivery services. Economic opportunity cost of forgone development and employment in the UK.
Law / regulatory	The UK has less agency and ability to shape its environment – we adhere to global standards. Tech companies dictating how sustainability starts to look, influencing Government targets. Less transparency about how decisions are made. Local/regional/national differentiation because of divergent needs and views. Increasing role for UA in operational matters in relation to the law. This could include compliance.	More international cooperation and linkage of regulatory and legal frameworks to exert more effective control on big firms (international regulatory cooperation increases) National regulations need to align / complement. International regulation of big tech giants creates more space for small innovative firms to grow, potentially resulting in greater diversity of solutions. Increased compliance activity by law enforcement and oversight bodies due to public concerns. Local councils are issuing licences for flying drones managed locally.	Increased political support for controlling regulations and legal structures. Petitioning for bans/curtailment. Safety prioritised over other considerations.	The legal and regulatory environment is highly supportive of new innovations transitioning to market.	Regulatory and legal frameworks negotiate balance between public concerns, climate change reform and a sustainable economy. Focus on instilling public confidence and building trust.

Changing markets	Widespread disruption to swathes of the aviation sector and wider economy. Quick adoption of new technology / drone delivery services. Air taxis (manned) in widespread use; some pilot projects using autonomous air taxis. Less ground level traffic / congestion. Air transport system increasingly integrated, and with trains, ground taxis, etc. Security drones used by both business and Government to defend countries / companies. Expansion of drone defence industry. Globalised nature of market and complexity involved leads to market concentration. Delivery of goods by UA increases; UA use in defence in a variety of roles expands; applications in agriculture are linked to sustainability and efficiency in use of resources; UA provide 'air taxis' Law and regulatory enforcement, pan-economy, supported by UA. 'Drones that do' are used to build infrastructure, spray crops, plant seeds, recycle, monitor, and enforce etc.	Relatively stable market as dominant models prevails but come under pressure from some iteration and diversification to delivery models. Drones replacing noisy helicopters is better / less controversial than drones delivering packages – noisier at your doorstep. Greater regulation of drones driven by demand. Pivot of some UA business to law enforcement. NIMBY won't change quickly – resistance to unmanned aviation. People may need to pay / get permission to enter airspace. Airspace is a limited resource. Air cargo could become more expensive due to fuel and emissions costs. Limited acceptance of UA stimulates innovation and new use cases for a smaller subset of uses and in a non-uniform way across the population, geography, and economy of the UK. E.g., there may be an increase in UA being used for shorter journeys – but still as a form of public rather than private transport - with an increase in associated 'take-off and landing sites and routes management. Transport of goods / people / cargo increases in more sparsely populated areas. Tool to share data, e.g., surveillance / monitoring; more environmental surveillance; data from multiple drones pooled to improve accuracy, granularity; share data across multiple industries Satellites – high-altitude drones act as communications relays Shopping and its evolution. Law enforcement and compliance uses particularly supported.	Limited benefits due to little or no uptake of drones/ UA. Socially, things stay the same. Ten-year period characterised by volatility. Strong market downturn after initial success; limited investment despite apparent opportunities and more pervasive uptake in other jurisdictions. Leisure uses of drones seen as anti-social, safety hazards. Strong security and safety concerns limit growth of use. Public aversion constrains new use cases BUT, in few cases, where slow development includes public consultation and transparency regarding safety measures, a market foothold could emerge – possibly in crisis response uses? Safety of humans prioritised. Use cases in segregated or remote areas develop, so too for roles where, on balance, the risk to humans is lower (e.g., infrastructure inspection/dangerous environments).	Huge social benefits as the population embraces the technology. Communications are quicker and easier, public services are more efficient, deliveries faster. Reduced pollution due to less fuelled vehicles needed. Huge increase in technology advances in the UK, the market is booming. The surge in demand means big companies are producing on mass UA and drones, regulators and standard agencies need to step up fast to monitor in the industries rapid growth and ensure products are safe. Drones used to monitor build-up of plastic pollution / local flooding / vehicle pollution. Drones manage and action environmental clean-up. Massive uptick in drone delivery services. Rapid and constant innovation results in drones being replaced by other technological devices. More pressure on manned aviation. Public demand unmanned aircraft due to safety concerns to adopt autonomy.	Safety of population is prioritised. Society benefits from reduced cost of certain services and the reemployment of capital in more useful ways. Pace of change is managed effectively due to constraints, helping to ensure buy-in of population is maintained. More regional airports for manned air transport, with growth of renewable-powered aircraft, regional airports also hydrogen fuel cell refuelling points. New markets for energy distribution – small, remote airports – greater access for rural communities with these regional airports and the airport experience will be very different: only a short interval in the airport, not the airport as destination. Carriage of dangerous goods restricted to manned aircraft only, cannot be taken by drone. Emergency services will introduce new opportunities for small businesses to provide new 'blue light' services – allowing greater health access to rural areas. Different companies providing alternative / zero-carbon solutions will emerge – new opportunities in systems equipment, propulsion, re-optimized air traffic management solutions and ground operations, that are all eco-friendly. Due to lack of true AI autonomy, the full business potential is not fulfilled. Industry fails in further innovation and gets stuck due to lack of support and funding. Very sensitive to any disruption arising from a singular event / accident (see Scenario 3) as tech is still on the edge of acceptance. Any catastrophic accident could drive major public backlash which would in turn inhibit investment.

Characteristics/Scenario	'Egalitarian'	'NIMBY'	'Luddite'	'Libertarian'	'Meritocratic'
		Possible disruption because of cyber activity of hostile actors and/or misuse by third parties. Use cases around replacing hazardous or laborious work by humans particularly developed.			
Changes to regulations, e.g., Operational safety, BVLOS flying, airworthiness and certification, licencing, airspace management, air-traffic management.	Light touch regulation: businesses create their own standards and requirements. Regulation is used more as an insurance based / liability product. Companies make the decisions as to what is and isn't allowed in terms of operational safety. Regulations exist concerning how different companies interact in the integrated system. Local concerns drive geographic restrictions on the use of UA. Regulation develops ways to assure AI use and integration of 'system of systems. Competition law/ anti-trust increasingly used to hold international or large actors to account, and endeavour to minimise barriers to entry. Local attitudes reflected by local regulation. Possibly suggests there is a need for more nuanced distinction between local/regional/national regulation of airspace and air traffic management Environmental standards increase. BVLOS operations would need a practical way of being signed off – this would require airspace management and air traffic management to be reformed. AI & autonomy advances would require a pathway to demonstrate compliance.	Operational safety requires human oversight as understanding and use of AI/autonomous systems improves. BVLOS enabled for a wide use of cases but only with human pilot providing oversight. Airspace segregation continues but is more geographically defined and prescriptive and begins to be managed, in part, at a national level even at lower altitudes. Break-up of monolithic firms after tighter international regulation of big firms. Sharing of some data become a pre-requisite of regulatory approval	Given events envisaged in the scenario, by the end of the period, regulation has reverted to a similar state as to how it was in 2020, with a large emphasis on demonstrable safety assurance. Perhaps some differentiation based on geographical characteristics or population densities. Regulation and regulators must embrace more transparency in their process, focus on building reputation and on public engagement, erring on the side of caution. Changes are more incremental, more stringent on innovators to 'prove' safety or usefulness of their tech	Self-regulated by industry; aviation shifts to regulation by aircraft rather than as a whole – individual aircraft have personal responsibility (like MOTs for cars); regulators are as agile as possible due to huge change – or the regulators are embedded within the industry itself.	Basically, down to the perception of risk by the public – expectation should start from the point of safety, i.e., over-regulation which can be followed by gradual de-regulation. Regulators prioritise growing public confidence and do so via regulation – limits fully autonomous flight but expands BVLOS capability in limited areas. Human oversight and focus on explainability. Geographic zoning. Local regulations. Enabling of routes to commercial employment for some use cases.

Annex D: Fact finding exercise

This annex sets out a very brief fact-finding exercise that we initially undertook to provide a snapshot of the state of play of drone regulation at a high level in the UK, U.S., Singapore, and Switzerland. This was done to aid our understanding before we delved into a more detailed and technical engagement with stakeholders in the UK and abroad. We focused on countries:

1. like the UK in terms of population density, urbanisation, economic wealth, comparative social/public attitudes;

2. Countries with vastly different regional environments who are taking a regional approach to regulation; and

3. Countries that are perceived to be advanced in getting regulation of drones 'right'.

The United Kingdom

Who is the regulator?

The Civil Aviation Authority (CAA) regulate and enforce civilian drone operations and within an airspace context also regulate military operations.

Regulatory Approach

The UK has drone regulations on both a national and local level. On a national level, drones are primarily regulated through the **UAS IR** and **UAS DR** which was amended in 2018 to introduce:

- A height restriction of 400ft for all small drones;
- A 1km restriction on all small drone flights around protected aerodromes;
- A registration scheme for operators of small drones of a mass between 250g and 20kg inclusive; and
- Competence requirements for remote pilots of small drones of a mass between 250g and 20kg inclusive

On a local level, authorities have limited powers which can be imposed via by-laws, for example Leicester City Council prohibits the use of drones of recreational and commercial purposes on council lands due to concerns of liability over legal action. [38]

The CAA has three categories for flying drones, the open category which means the user will not need authorisation to fly; the specific category which requires authorisation as the

[38] Law Library of Congress, Regulation of Drones, April 2016, p119

operation presents a greater risk and the certified category that need to be treated in the same way as piloted aircraft (aircraft certification, operator certification, pilot licensing). The requirements for flying in the open category involve registering as an operator, keeping the drone in direct line of sight, keeping below 400ft and using a system that weighs less than 25kg. The specific category covers operations that present a greater risk, and the key requirement is for the operator to gain an operational authorisation issued by the CAA.

United States

Who is the regulator?

The Federal Aviation Authority (FAA) is the national regulator; however, states and local authorities can produce specific regulations.

Regulatory Approach

National Drone Regulations

In 2016 the FAA presented rules on drones under 25 kg conducting non-leisure and non-Government operations, these rules stipulate flights can only occur during daylight and the drone must stay within the operator's visual line of sight, drones cannot be flown over people or in airport flight paths, this also included processes for certification and registration.[39] All drones, regardless of use, must be registered and drone operators must notify air traffic control in advance if they plan to fly devices within 8km of an airport. To fly commercially, users must hold a remote pilot certification, UAV's must weigh less than 25 kg and kept within visual line of sight, flown below 400ft, under 100mph.

Examples of current use cases

Residential drone deliveries are beginning trials in California with the company Dive Delivery securing permission from the FAA to deliver to addresses in San Mateo and Contra Consta counties. The drones will be used to deliver essential lightweight items, such as face masks, and will be conducted within the visual line of sight. Drones will be used, equipped with drop mechanisms, and operated by a certified remote drone pilot. The drone mission planning, airspace authorization and flight execution will be handled by an iOS app from airspace and flight management technology company Avision. Drones will take off from a predefined location, fly to the customer location via automated waypoints, lower into the marked location, automatically release the package and return to the launch

[39] FAA press notice, "DOT and FAA Propose New Rules for Small Unmanned Aircraft Systems", 15 February 2015 and FAA, Unmanned Aircraft Systems [accessed 12 October 2016]

location. Customers will be notified before and immediately after the operation to ensure they do not walk under the drone at any time.

Switzerland

Who is the regulator?

The Federal Office of Civil Aviation (FOCA) is a division of the Federal Department of Environment, Transport, Energy and Communications and is responsible for the regulation and oversight of civil aviation.

Regulatory Approach

There are general rules for flying a drone in Switzerland. They are categorised in a similar way to other countries, roughly three categories based on weight: recreational, less than 500g; model, 500g to 30kg; or professional, 30kg+. If the pilot always has direct line of sight with the drone, if they weigh less than 500g they may operate without a permit. An automated flight (i.e., autonomous operation of a drone) within the direct line of sight of the pilot is permitted, provided that the pilot can intervene to control of the drone at any time if required.

A permit from the FOCA and insurance is always required for drones weighing over 0.5 kg. This also applies to BVLOS operations. Drones may not be flown within 5km of an airport. Drones and model aircraft must not be operated above crowds or without direct line of sight. In exceptional cases, however, the FOCA can grant approval for such flights if users submit an application.[40]

Examples of current use cases

Crop spraying: In 2019 Switzerland were the first country in Europe to allow the use of drones to spray phytosanitary products on plants and crops.[41] The authorisation was requested by the Agroscope institute– a Government agricultural research body – and granted by the Federal Office for Civil Aviation (FOCA).

Many farms in Switzerland have steep land plots which present a challenge for cultivation. For over sixty years helicopters have been used to farm these plots, although there is only one firm which is authorized to conduct such operations. Drone technologies, however, have emerged as a low-ecological impact and highly accurate way to spray plants and

[40] https://www.bazl.admin.ch/bazl/de/home/gutzuwissen/drohnen-und-flugmodelle/allgemeine-fragen-zu-drohnen.html

[41] https://www.eu-startups.com/2020/11/how-are-drones-are-changing-the-face-of-agriculture/

crops. Drones can fly lower and with more precision thus avoiding wastage or misdirected spray. The FOCA has authorised drones only if they can be shown to follow an automatic flight trajectory over a certain distance with maximum variations of 50cm.[42]

Singapore

Who is the regulator?

The Civil Aviation Authority of Singapore (CAAS) is a Statutory Board under the Ministry of Transport.

Regulatory Approach

CAAS operates a 'low/medium/high' categorisation system for drone regulation. Segregation is used to achieve deconfliction and manage airspace. A permit is not required to fly a drone that weighs 7kg or less that is being flown 200 feet or below. If flying a drone heavier than 7 kilograms or above 200 feet, a permit is required.

Drones cannot be flown over people or crowds and may only be flown during daylight hours. Drone pilots must always maintain a visual line of sight with their drone. Singapore requires drone pilots to obtain a permit to fly under conditions of flights above 200 feet, flights in restricted airspace, for all flights conducted for business purposes (i.e., commercial flights). [43]

From Feb 2021, CAAS implemented a Drones Basic Training Certificate (UABTC) to promote and educate recreational users of drones above 1.5kg but below 7kg. Similarly, they implemented a Drones Pilot Licences (UAPL) to ensure the minimum pilot competency is achieved for drones about 7KG, with an accompanying digital licence.

Any drone with a total weight of above 250 grams must be registered before it can be operated in Singapore[44] For business purposes: users must register the drone if the total weight exceeds 250g and need to obtain a drone Pilot Licence, Operator Permit and Class 1 Activity Permit.

Similarly, to the UK CAA, they currently get additional funding from their HM Treasury equivalent to cover their Drone regulatory work. They have a 'first come, first served' basis for regulatory processing. Their main experimental sandbox is over the maritime estate, allowing 'ship to shore' operations.

[42] https://www.swissinfo.ch/eng/innovation_crop-spraying-drones-to-be-authorised-/45121230
[43] https://www.caas.gov.sg/public-passengers/unmanned-aircraft/permitted-flying-areas-and-no-fly-zones
[44] https://www.caas.gov.sg/public-passengers/unmanned-aircraft/ua-regulatory-requirements/ua-registration

Examples of current use cases

Water Quality

Singapore's national water agency has deployed autonomous drones at six of the country's reservoirs to monitor water quality. The beyond visual line of sight drones are fitted with remote sensing systems and cameras than analyse the water for turbidity and algae concentration. The use of the drones saves 5,000 man-hours of monitoring as the drones can survey a large area. The drones will fly according to pre-programmed flight paths, staying clear of residential areas.[45]

Ship Drone Delivery

Start-up company F-drones announced the first commercial beyond-visual-line-of-sight drone delivery in Singapore. The company recently obtained the first ever authorization in Singapore for flight beyond the pilot's visual line of sight (BVLOS) to perform drone deliveries to ships.[46] The trips take less than 15 minutes on average, offering a greener and faster way of transferring supplies in busy ports. Diesel-powered launch boats are currently used for such deliveries, of which there can be more than 100 a day in Singapore. It can take more than two hours for the boats to make trips of a similar distance and choppy seas can cause delays. While these vessels can carry up to two tonnes of cargo, around 15 per cent to 20 per cent of deliveries in ports around the world are for payloads of under 100kg. This highlights the appeal for drone deliveries, and as the drones are flown over water, they cause less disturbance to the city population. [47]

[45] https://www.computerweekly.com/news/252501476/Singapore-deploys-drones-to-monitor-reservoir-water-quality

[46] https://dronelife.com/2020/04/29/drone-delivery-to-ships/

[47] https://www.straitstimes.com/tech/singapores-first-drone-delivery-service-takes-flight

Annex E: List of stakeholders

Futures workshop

- Officials from: the Department for Business, Energy, and Industrial Strategy (BEIS), the Department for Transport (DfT), the Civil Aviation Authority (CAA), Home Office, The Connected Places Catapult (CPC), Ofcom, the Department for Digital, Culture, Media, and Sport (DCMS), the British Standards Institute (BSI), the National Physical Laboratory (NPL), the UK Accreditation Service (UKAS)
- National Air Traffic Services - Adrian Clark
- Hummingbird Tech - Hendrik Knyphausen
- Windracers – Charles Scales and German Moreno
- Skypoint - Aleks Kowalski
- Altitude Angel – Michael Gadd
- Network Rail, Drone Operations – Paul Lindup
- British Telecom – Dave Pankhurst
- Frazer-Nash consultancy – Luke Bonnett and Will Barnes
- AddleShaw Goddard LLP - Lauren Payne
- Cranfield University - Iain Gray
- Southampton University - James Scanlan

Bilaterals and multilaterals

- Officials across Whitehall, CAA and UKRI
- Representatives from the Drones Industry Action Group
- Singapore CAA – Tan Kah Han, Chung Wei, M Maran, Jonathan Tan & Wesley Lee

- Swiss Federal Office of Civil Aviation (FOCA) - Francine Zimmerman
- U.S. Federal Aviation Authority's Assure programme – Billy Klauser & Steve Lux
- The City of Los Angeles's Mayor's Office – Julia Thayne
- The City of Los Angeles's Urban Air Mobility Fellow - Clint Harper
- Harper Adams University – John Gill
- Cranfield University – Alex Williamson
- Zipline – Harrison Wolf
- Manna – Bobby Healy & Ralph James
- Callen Lenz - Adrian Eves
- See.AI – John McKenna
- Flylogix – Ed Clay
- Drone Major Group – Robert Garbett
- Frazer-Nash consultancy - Luke Bonnett
- Altitude Angel – Mike Gadd
- Skyports – Simon Whalley
- Hummingbird – Will Wells
- Airwards – Richard Nichols

Annex F: RHC reflection

The Regulatory Horizons Council is a relatively new body and the drones' study is one of the first it has undertaken. Lessons learned from this work will be used to inform future projects and they include the following:

- The RHC is charged with looking ‘round corners’ to understand what may happen in the future and how future technologies should be regulated. It was therefore vital not to confine our work to existing technologies, but to consider potential developments and not to seek certainty. Hence our commissioning of a Futures workshop to explore many different futures.

- Unlike the work on genetic technologies and fusion, this project was not commissioned by government. But we quickly agreed that there was a vital need for such work because of the rapid development of the technology and a widespread view that the UK had not decided upon a clear vision of how to regulate it.

- The project involved an industry with multiple stakeholders of widely different kinds, operating in agriculture, surveying, delivery, and other areas. Issues raised by drones are many and various and involve the public as well as firms and regulators. This made it essential to interview as wide a spectrum of stakeholders as possible, but not to try to cover every aspect of the issue lest we never reach a conclusion.

- It quickly became apparent that the views of UK government agencies and industry differed markedly with respect to what should be and was in practice permitted. We felt it important to reflect but not to resolve these differences.

- It also emerged that both drones themselves and their regulation differed markedly in different parts of the world and that one service we could perform was to speak to agencies and firms operating in various other countries to learn valuable lessons from them.