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Misuse of civilian drones

Drones are increasingly used for photography, agriculture, delivery and emergency response. However, travel disruption at UK airports due to drone sightings has renewed debate about their use. This note looks at civilian drones and their applications, focusing on potential misuse and possible responses.

Overview

- Drone use for commercial and recreational purposes offers many potential social and economic benefits, including for aerial observation, transport and sport.
- Yet, drones pose potential challenges for safety, security, privacy and noise, and may facilitate crime.
- Technology can help detect, control, seize, disable or destroy drones that are being misused. However, this may be by-passed or inappropriate in some settings.
- Widespread commercial adoption would need further technological innovation and changes to legislation.

Background

Aerial drones, also known as unmanned aircraft, are flying systems that do not carry a pilot.[1–5] They may be controlled remotely by a pilot or fly with various levels of autonomy following pre-programmed flight plans.[3,4] Drones may be fully autonomous, meaning that a pilot is unable to intervene during flight.[1] Drones can have fixed wings, rotary blades or a combination.[6–9] They are one component of an unmanned aircraft system, comprising the drone, a controller and a communications system.[2–4]

Drones can have civilian or military uses. This note focuses on civilian uses. Drone use for recreational and commercial purposes is growing, as technology becomes cheaper and more sophisticated.[10] A 2018 survey found that 11% of adults in England had used a drone at least once.[11] The Civil Aviation Authority (CAA) reported that permissions obtained for commercial drone operators in the UK doubled to over 5,000 from February 2017 to May 2019.[12] A drone operator is a person or organisation who manages a drone but may not directly control it or be present during flight.[5] One projection suggests that more than 76,000 drones, operated by government and commercial organisations, may be in use in the UK by 2030,[13] increasing UK gross domestic product by around £42 bn in public services, construction and manufacturing. Publicly available data about the number of recreational drones in use in the UK are limited. Forecasts of the global market vary from £2.4–25.8 bn by 2025.[14] This compares with projections for the global commercial drone market of £1.2–6.9 bn by 2025.[14]

Greater drone use affords many potential social and economic benefits (covered more extensively in POSTnote 497). Drones can also present new challenges for safety and security. For example, reports of near-misses between aircraft and drones rose from 71 in 2016 to 125 in 2018.[15,16] However, these figures have been challenged by some in the industry as overestimates.[17,18] A 2016 study using laboratory tests and computer modelling found that mid-air collisions with drones could cause critical damage to manned aircraft.[19] The Commons Science and Technology Committee recently raised concerns about a lack of consensus in the aviation community on the likely consequences of a drone-aeroplane collision.[20]

In 2018, the Government introduced new limits on where drones can be flown and new registration and education requirements for drone operators and pilots (Box 1).[5,21] It also announced up to £125 m for a Future Flight Challenge to support the development of electric and autonomous aircraft by 2025.[22,23] Before the 2019 General Election, the Government published a strategy for tackling malicious drone use.[24] In January 2020, the new Government introduced a bill that included new police powers for enforcing aviation laws (Box 2).[25,26] The EU is standardising rules for drone operations across Member States and published a regulatory framework for drone use in 2019.[27,28]

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Box 1: Drones Policy and Regulation

Policy

The Department for Transport (DfT) has primary responsibility for drone policy and legislation. Other departments with specific responsibilities include the Home Office, responsible for drafting and implementing legislation relating to the malicious misuse of drones, and the Department for Business, Energy and Industrial Strategy which is jointly responsible with DfT for public investment and research into civilian drones.[29]

Regulation

Civilian drone operations are regulated and enforced by the Civil Aviation Authority (CAA) in the UK, and regulated by the European Aviation Safety Agency (EASA) at an EU level. The International Civil Aviation Organization (ICAO) is the UN agency working to establish agreement on global civil aviation standards and practices. It oversees the Chicago Convention on International Civil Aviation (1944), which applies to both manned and unmanned aircraft.[3,30]

Drone Technology

Drone Operation

Drones can be bought pre-assembled or constructed from component parts.[31] They are controlled remotely by a person using a joystick or a digital interface such as a phone, which communicates with the drone via radio signals.[32–34] Drones have two basic types of operation:

- **Manual** – the pilot steers the drone in real-time
- **Pre-programmed** – the drone follows pre-defined instructions, such as moving along a pre-set flightpath.[35,36]

Manual operation may involve a degree of automation, for instance to maintain a constant height. Satellite navigation (with a system such as GPS) can be used during both manual and pre-programmed flight. It is not always required, for example if a pilot can see the drone and steer it in real-time. Some drones have a return to home function that returns them to their launch site. This is activated by the pilot or automatically due to low battery or loss of communication between the drone and controller.[35,37]

Detection and Avoidance of Obstacles

High-end civilian drones are increasingly equipped with obstacle detection and collision avoidance systems.[37] These can help to avoid collisions with obstacles such as trees or buildings, but generally do not react quickly enough to avoid collisions with moving objects.[38] They usually have three aspects to their operation:[39]

- Continuous observing and sensing of the environment with sensors using radar (radio waves), lidar (light), ultrasound, or visible or infrared cameras.
- Data from the sensors are sent to collision detection software that calculates whether a collision is likely.
- A new path for the drone is generated by collision avoidance software.

Applications of Civilian Drones

Drones have the potential to reduce costs, improve efficiency and provide new services.[40] They usually perform one of two main functions: making observations of an area or transporting a payload.[41] Drones can be particularly useful in remote, inaccessible or dangerous settings.[42] In general, applications involving observations are more established than those involving transportation.[53] Future applications may be influenced by public perceptions (Box 3). Current uses include:

- **Photography and filming** for research, commercial or recreational purposes, e.g. filming movies[54]
- **Environmental monitoring,** e.g. tracking animals at risk from poachers or mapping radioactive contamination[55,56]
- **Agriculture**, e.g. collecting data about crop health and applying fertilisers or pesticides accordingly[57]
- **Inspecting infrastructure** for wear and damage, e.g. by operators such as National Grid[58] and Network Rail, and small-scale drone contractors such as CamFly Films[59,60]
- **Emergency response,** e.g. to aid search and rescue teams in the Lake District,[61] or provide 4G mobile coverage and live video surveillance in a disaster area[62]
- **Delivery,** e.g. of pizzas in New Zealand and China, groceries in Canberra, Australia, and Iceland, blood to hospitals in Rwanda and parcels in trials in Cambridgeshire.[63–68]
- **Sport,** e.g. drone racing competitions are held worldwide, with drones often being custom built or modified.[69–71]

Box 2: Drones Legislation

UK Legislation

Civilian drones must comply with existing civil aviation legislation. In the UK, this is primarily the Civil Aviation Act 1982 and the Air Navigation Order 2016 (ANO).[29] The ANO was amended in 2018 to introduce new restrictions for drones, including:[43–45]

- Prohibiting small drones (up to 20 kg) from flying over 400 feet, or within 1 km of airport boundaries, with penalties including a fine of up to £2500. This previously only applied to drones over 7 kg.
- Requiring operators of drones weighing 250 g or more to register with the CAA,[46] and pilots to pass an online competency test. Penalties for non-compliance include a fine of up to £1000.

The ANO was amended again in 2019.[47] This extended the flight restriction zone at protected aerodromes (including airports and airfields), within which permission is required to fly a drone. Aerodromes are usually surrounded by an aerodrome traffic zone (ATZ) with a radius of 4–5 km.[48] The amendment increased the flight restriction zone from 1 km around aerodrome boundaries to the ATZ, and added restricted zones (of typically 5 km by 1 km strips) to the ends of runways. Members of model aircraft flying associations recognised by the CAA are exempt from some drone regulations.[5] Other legislation may also apply. The Information Commissioner's Office has issued advice for drone users on complying with data protection laws such as the General Data Protection Regulation.[49,50]

The Government introduced an Air Traffic Management and Unmanned Aircraft Bill to Parliament in January 2020, to give the police the power to require a person to land a drone, issue a fixed penalty notice for certain drone offences, and introduce new stop and search powers where offences involving drones have been committed.[25,26]

EU Legislation

EU regulations for drones are set out in Regulation (EU) 2018/1139, which came into force in 2018.[51] The European Commission and EASA have since developed more detailed legislation (adopted in June 2019) to regulate the operation, certification and technical requirements for drones, and the registration of operators.[27,28] The new rules are due to become fully applicable in June 2022 (CBP 7734).[52]

Box 3: Public Perception of Drones

Public opinion is likely to influence how drones are used.[72]

- A 2017 survey of around 3,500 adults in England found that they were most familiar with leisure and military uses of drones (71% and 70% of participants, respectively), followed by policing (63%), photography (62%) and emergency response (48%). Most (79%) had at least one concern, with privacy (59%) the biggest, then use for criminal activity (28%) and risk of airspace collisions (25%).[11]
- A 2017 poll of 2,000 UK adults found that the user and use were the most decisive factors in how drones were perceived. Drone use by the emergency services was most positively received. Concerns about privacy and safety ranked over other issues such as noise.[73]
- A 2019 UK survey of 1,520 members of the public and 252 senior business leaders found 31% of the public felt positive about drones compared to 56% of the leaders. Uses with wider societal benefits, such as search and rescue, were most popular with the public.[74]
- Research by Coventry University suggests that the media has an influential role in shaping public attitudes towards drones.[75]

Misuse of Drones

Drone misuse can be accidental or deliberate. It may lead to risks to safety, to the security of both physical and virtual assets, and potential infringements of privacy (Box 4).[76]

Accidental Misuse

Drones may be unintentionally flown dangerously or into a restricted area, such as an airport, if users are unfamiliar with drone technology or the law.[76] Pilots may also lose control inadvertently due to human error or a technical failure. This may put other aircraft, as well as people, vehicles and infrastructure on the ground at risk.[77] The CAA has produced a Dronecode (publicised through the Dronesafe campaign) to provide guidance to the public on safe and legal drone use.[5,48] A study of 350 UK drone users and 2,000 UK adults found that awareness of the Dronecode rose from 11% in 2016 to 71% in 2018.[78]

Deliberate Misuse

The speed, low cost, and increasing flight range and capacity to carry items of drones can also make them attractive to people who may deliberately use them maliciously, recklessly, negligently or with criminal intent.[31,79] Examples include:[79,80]

- Causing disruption to other aircraft.
- Intrusion of privacy by filming people without permission.[81]
- Potential facilitation of cyber-attacks, e.g. using a drone carrying a radio transmitter to hijack a Bluetooth mouse.[82]
- Facilitation of physical attacks, e.g. by reconnaissance of critical infrastructure, or carrying explosives or other harmful materials in a terrorist attack.[83–85]
- Enabling other criminal activity, e.g. flying contraband into prisons or identifying vulnerable homes for burglaries.[86]

Addressing drone misuse

The May Government introduced new requirements for the pilots and operators of certain drones (Box 2). It intended to give the police new powers, with the aim of deterring illegal or dangerous flying.[5] In October 2019, the Commons Science and Technology Committee urged the Ministry of Defence to make malicious drone use a top intelligence priority.[20] Soon after, the Government published a strategy for reducing the risks of illegal drone use, including clarifying the roles of organisations in responding to illegal drone activity.[24] Besides policy approaches, there are technological ways of addressing drone misuse. They include those built into drones, and those that can detect, track, seize, disable or destroy drones posing a threat.[94]

Box 4: Examples of Drone-Related Disruptions

Disruption at Gatwick Airport, December 2018

Reports of drone sightings at Gatwick Airport in December 2018 grounded around 1,000 flights for almost 36 hours, affecting more than 140,000 passengers.[87,88] One estimate suggests the incident could have cost the airport and airlines £50-70 m.[89] Gatwick Airport has said that it has since spent £5 million to prevent future attacks.[88]

Smuggling Contraband into Prisons

Drones can be used to fly drugs and mobile phones into prisons. In one case, seven men were jailed for dropping an estimated £550,000 worth of drugs to inmates during 2016/17.[90,91] Few prisons have drone counter-measures.[92] For example, electronic fencing at Guernsey prison can disrupt the communication links of drones within 1 km.[92,93]

Drone Features

Restricting Movement via Geofencing

Geofencing involves the creation of virtual boundaries that limit where a drone can fly.[95,96] A distinction is sometimes drawn between geocaging (containment within an area) and geofencing (exclusion from an area). Geofencing software installed on a drone compares the drone's position to a map of prohibited areas. When the drone attempts to enter a prohibited area, the software alerts the drone pilot or automatically prevents the drone from entering.[97,98] For geofencing or geocaging to work, the drone must be able to establish its location, for example via GPS.[95,97]

Many manufacturers embed geofencing software into their drones by default,[99,5] and new EU legislation adopted in June 2019 will make geofencing mandatory for certain drones (Box 2). It has been suggested that geofencing is only likely to deter intrusions into restricted areas that are either accidental, or deliberate but made by unsophisticated pilots.[98,100,101] Skilled people with malicious intent may be able to build drones without geofencing, or to disable the geofencing software in commercially produced drones.[31,102]

Automatic Identification via Electronic Conspicuity (EC)

Drones equipped with EC can actively signal their presence to other airspace users and receive signals that alert their pilot to other aircraft in the vicinity. EC (alongside other technological developments) could help limit the number of mid-air collisions and airspace incursions, and enable greater sharing of airspace between different types of aircraft.[22] It could also help establish whether a drone poses a threat by providing access to information such as the name of the operator, and could provide authorities with the exact location of the drone's pilot. EC is seen by industry groups as a prerequisite to enabling future drone operations, such as flights in densely crowded areas and beyond visual line of sight operations (Box 5).[103] A product standard requiring all new drones coming onto the EU market to have EC is due to come into force in 2022 (Box 2).[5,22]

Counter-measures – Detection and Tracking

Detecting a drone's presence, and tracking its location, can be difficult. Drone surveillance systems can use one or more of a range of detection technologies; however, every system has limitations. For example:[31,102–104]

- **Radiofrequency** – detects radio signals sent between the drone and its controller by scanning frequencies used by drones. Systems can struggle if other devices (e.g. WiFi networks) are using the same frequencies, and some need direct sight of the drone.
- **Radar** – detects a drone by emitting radio waves, which reflect off the drone and are picked up by a sensor. They can struggle to detect small, low-flying civilian drones.
- **Video** – detects a drone using video images, usually with either visible light or infrared thermal imaging, which require direct sight of the drone.
- **Acoustic** – matches sounds generated by drone motors and propellers to a library of known drone sounds. Sensitive to ambient noise, they have a limited detection range that depends on drone type and test environment.

Counter-measures – Seize, Disable or Destroy

There are various interventions for dealing with drones once they have been detected and classified as a threat. These are divided into those that use physical means to intercept and sometimes destroy the drone, and non-physical measures that disrupt drone operation or remove control from the pilot.[103,105] An effective system will likely involve a range of methods.[106,107] The MoD has launched a £2 million competition to develop counter-drone technologies.[108,109] The Centre for the Protection of National Infrastructure has been working with industry to develop counter-drone technologies and standards against which they can be tested.[110–112]

Physical Interception

Counter-measures to physically seize or destroy a drone include firearms, projectiles, guns that fire a net, interceptor drones fitted with a net, and even birds of prey trained to seize small drones from the air.[105] Such systems may be dangerous if the drone or counter-drone projectile falls to the ground, and are likely to be more suitable for military use or operations in remote areas.[103] Some net-based systems use a parachute intended to lower the drone in a controlled manner. However, this may still have risks, for example, if it lands on a powerline or person. If a drone is successfully captured, a forensic analysis may reveal information about its origin.[103]

Non-Physical Measures

Radiofrequency jamming can disrupt the communications link between a drone and its pilot by swamping the drone with a stronger radio signal.[103] Jamming may also disrupt the drone's satellite navigation link. In such cases the drone usually automatically lands, hovers on the spot, or returns home. However, jamming can disrupt other communications links in the vicinity and is not effective against autonomous drones.[103] High-power electromagnetic weapons may damage a drone's circuitry, stopping it in mid-flight.[106]

A drone's navigation signal or communications link may be remotely hacked (manipulated) or spoofed (imitated) to take control of the drone and send it home, stop it in mid-flight, or instruct it to land.[105,106,113] However such systems are hard to build and implement. Drones' communications links may also be protected, for instance with encryption,[114,31,103]

Box 5: New Technologies

Unmanned Traffic Management

An unmanned traffic management (UTM) system, which would enable drones to operate safely and efficiently alongside other aircraft, is likely to underpin many future drone applications and technologies.[115] In November 2018, a UTM platform's ability to safely manage manned and unmanned aircraft in the same airspace was tested at Manchester Airport.[116] The EU is also developing new services and procedures ("U-space") to allow large numbers of drones to access airspace.[117,118]

Beyond Visual Line of Sight (BVLOS) Operations

In the UK, drones flown for non-commercial uses must stay within visual line of sight of their pilot.[115] Commercial drones can be flown in extended visual line of sight if an application is made to the CAA and they are operated with observers who can both see the drone and communicate with the pilot.[4] Although BVLOS flights are not permitted for non-commercial operators and limited for commercial operators, BVLOS technology is under development. This includes through the UK's Pathfinder Programme.[115,119,120] BVLOS flights will also require other technical developments, such as reliable collision avoidance.[121]

Future Directions

The widespread commercial adoption of drones would require developments in technology and the legislation governing their use. For example, unmanned traffic management systems would enable drones to share airspace with manned aircraft (Box 5). Beyond visual line of sight operations could greatly extend the range over which drones could be used, for tasks including search and rescue, border control and deliveries.[115,122]

Artificial intelligence (AI) could enable drones to make decisions usually taken by a human pilot, for example by analysing data gathered by sense and avoid systems to decide how a drone should respond to a possible collision.[39,115,123–125] AI may also enable systems to learn without being explicitly programmed.[126] AI, detect and avoid systems, and vertical take-off and landing technologies are all likely to support the development of drones for transporting people.[127–129]

Technologies are also being developed to coordinate the actions of multiple drones, known as swarming. Drone swarming can be used to assist the emergency services (e.g. in responding to wildfires), for entertainment (e.g. synchronised drone displays), or to aid military warfare.[130–134] However, drone swarms might also be used against civilian targets, for example in a terrorist attack.[83,135] Widespread drone use may also raise other challenges in the future, such as contributing to noise pollution,[136–138] which could become an issue if drone operations (such as delivery) become routine in urban areas.[139,140]

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