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One 'near miss' too many? Drone safety issues and possible solutions: an airspace user view

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- Although remotely piloted aircraft systems (RPAS) or 'drones' have been in use for nearly one hundred years, recent advances in technology and miniaturisation has ushered a host of small and medium sized systems that stand to revolutionise many aspects of society.
- Larger systems have been largely the preserve of the military and in the last decade have been so successful operationally as to provoke a debate in the West about the ethics of their use. However smaller RPAS are becoming increasingly popular across a range of applications. Requiring minimal training to use, and for non-commercial uses such as hobbyists there is no regulatory requirement to receive training at all, so they are main source of concern for other airspace users.
- There should be no surprise therefore that the number of incidents of near-misses with other airspace users such as commercial air transport has risen substantially in the last few years.
- Data from the few actual collisions suggest that drones pose a relatively limited impact on aircraft, and scenario testing is surprisingly limited. However this masks a real risk even a relatively small drone can pose to certain types of aircraft such as helicopters, and to all aircraft depending on the stage of flight and the location and speed of impact.
- There are various methods of avoiding collisions in the first place. Sighting and evasion is perhaps the most difficult given that drones are so small, and evasion can be as dangerous as impact depending on the phase of flight. Geo-fencing to prevent drones from entering certain airspaces is feasible but needs to be sound. Registration might remove the highest risk drone users.
- One of the biggest challenges will be creating a regulatory regime that adequately captures the issues of drone public use and ensures some degree of accountability.

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CII Introduction: while the proliferation of drones has been heralded in revolutionising so many aspects of our everyday lives, there have also been warnings about the rising incidence of them conflicting with other airspace users such passenger aircraft near airports. This gives rise to concerns that a mass drone population in the UK and elsewhere will have profound implications on airspace use and safety, an issue of interest not just to aviation insurance. It provides yet another case study of regulation trying to keep up with rapid surges in new technology. In this first instalment in a series of three Thinkpieces on the insurance implications of drones, we have invited Captain Andy Brown of the British Air Line Pilots Assocation to set out some of the key airspace safety issues related to drones, from the perspective of the people who are increasingly having to share the sky with them.

Drones, also known as Remotely Piloted Aircraft Systems (RPAS), Unmanned Aircraft Systems (UAS) or Unmanned Aerial Vehicles (UAV) have been in operation for around 100 years, starting in the two great wars with limited success, and now used successfully by the military for 'dull, dirty and dangerous' missions. However, it is the recent advances in miniaturisation of GPS, stability systems and computers as well as advances in lightweight lithium battery technology that have heralded a revolution of small and medium sized RPAS. There are a plethora of applications and current uses of small and medium RPAS are border surveillance, agricultural crop monitoring, monitoring of infrastructure such as power facilities and pipelines, commercial photography, aerial mapping and charting, while proposed civil and commercial applications include security awareness, disaster response, event coverage, advertising and now parcel delivery by companies such as Google and Amazon.

RPAS operations

Large RPAS are almost entirely the preserve of the military. Both the United States Air Force and the Royal Air Force use qualified pilots to further train to operate RPAS. These pilots carry out the take-off and landing phases, while a weapons specialist will operate the system during the operational phase, often thousands of miles from the area of operations. The work stations for the operators are very similar to a flight deck, together with video screens so pilots can 'see' what is going on. Air traffic controllers say that they cannot tell the difference between RPAS and manned aircraft, and indeed RPAS aircraft are marshalled around aerodromes in the same way as manned aircraft. Large civilian RPAS however are far less numerous. In the UK the only system to have been trialled recently is the £62m Autonomous Systems Technology Related Airborne Evaluation and Assessment (ASTRAEA) project which saw a BAe Jetstream complete a 500 mile trip from Warton, Lancashire to Inverness in April 2013. This was flown by a ground-based pilot and trialled a cloud-sensing electronic eye, as well as a visual sense and avoid system. It also had two safety pilots on board. It is due to fly again shortly. It is considered that regular use of civilian large RPAS may take much longer, and would probably commence with cargo carrying operations over oceans and sparsely populated areas. Large RPAS are highly regulated and operated by professional and well-trained RPAS 'pilots' so may be considered relatively safe, particularly in respect to operating with other manned aircraft. Even so, the accident rate for the military in the past has been relatively high with over 400 crashes of large US military RPAS since September 2001.[1]

Reported RPAS/manned aircraft near-misses in the UK:

2013: 2 2014:4 2015 (to 9 Sept): 16

Source: UK Airprox Board

Due to the ability to take photographs in remote, inaccessible and 'overhead' locations, there has been an explosion in the numbers of small RPAS, especially the 'quadcopters' that can be bought for a few hundred pounds, including camera. These small quadcopters weigh around 1½kg. They are used by both professionals and hobbyists. It is these drones that have been the cause of near-collisions with airliners and other manned aircraft. Compared to the two or more years required to train a military pilot of large RPAS, the training required for a Civil Aviation Authority (CAA) Permit for Aerial Work for a small quadcopter, as required by anyone who wishes to use a drone commercially, is two to three days and costs around £1,500–£2,000. This is in accordance with the 'light touch regulation' espoused by the CAA. However, since these quadcopters are relatively easy to fly, there are many hobbyists who fly without training, and it is these that probably pose the greatest threat to passenger aircraft and other airspace users.

How many near misses?

There were two recorded near misses in the UK in 2013 and four in 2014; whereas in 2015 this total quadrupled to 16, and that is just to 9 September.[2] The majority were described as small quadcopters and many were catalogued by airliners during the approach to the airport. None of the owners of the drones were identified. In

[1] Source: The Washington Post

[2] Source: UK Airprox Board, Sep 2015.

addition, major airports such as Manchester and Gatwick have closed either part or all of their airspace when drones have been sighted, causing both flight delays and diversions at considerable cost and inconvenience to airlines and passengers.

Whilst there have admittedly been few actual collisions with drones, there have been hundreds of near misses reported world-wide. Given the increasing numbers of drones, it is a question of when, not if, a drone causes fatal damage to a manned aeroplane or helicopter.

What if they hit? Damage to aircraft

Relatively little is really known about how dangerous such a collision might be. Some argue that RPAS constitute no greater threat to manned aircraft than large birds. Others argue that the combination of weight and impact speed make them a serious threat.

To date there have been just two documented cases of drones striking manned aircraft. The first occurred in August 2011 between a US Air Force C-130 Hercules and an RQ-7 surveillance drone. It must be emphasised that the RQ-7 at 100–150kg is far heavier than a typical quadcopter which weighs around 2kg. The large, sturdy transport plane sustained damage to its wing leading edge and fuel tank, but managed to land safely. Recently, in September 2015, a small quadcopter hit a light aircraft on the landing gear in Norway. The damage was minimal, and again the aircraft landed safely.

C-130 Hercules following collision with RQ-7 drone. Photos: DefenseTech.org

Despite a call for a "risk-based approach to safety regulations for RPAS"[3], there has been very little computational testing, and it appears there has been no empirical testing of damage caused by small drones to airliners, light aircraft or helicopters. The University of Monash in Australia carried out computer simulations using the Monte Carlo method, as well as using evidence from bird-strikes[4] and came to a number of conclusions:

- 3 out of 4 collisions expected in airliner engines
- Loss of engine should be assumed, but aircraft expected to land safely;
- Commercial aircraft windscreen – penetration likely for drone heavier than 2kg;
- Light aircraft or helicopter canopy – penetration likely at max cruise velocity for small drone; and
- No empirical data exists for penetration of screen by solid object, with a recommendation to conduct this.

It would be very useful to carry out empirical testing of drones, or even drone parts, such as the relatively heavy and dense battery, onto aircraft components, such as windscreens. Since helicopters are particularly vulnerable at low level, especially Air Ambulance performing a rescue, it would also be useful to carry out actual impact testing against main rotors, rotor heads and tail rotors, in addition to canopies. BALPA has approached an engineering consultancy, and the cost of computational testing using Finite Element methods, followed by empirical testing to confirm the results, would cost in the order of £250,000–£300,000.

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Frangibility of Drones

If computational and empirical testing can be carried out, it would then be possible to examine the effects of designing drones to be more frangible, so that if they were to hit a critical component they may be less likely to cause fatal damage. For instance, the lithium battery is one of the densest and heaviest components of a drone, so it might be possible to connect several batteries in parallel or series rather than having one big battery. Frangibility would then become a design requirement for future drones. Also if there was a speed at which it was determined that less damage would be caused by a drone, helicopter pilots might be advised to reduce speed in areas in which drones might be operating.

Can the near-misses be avoided?

There are various methods of avoiding collisions, starting with the basic principle of 'see and avoid'. When an aircraft is on a collision course with a drone, the drone will appear in the same position on the windscreen of the aircraft. The human eye is very good at sensing relative movement, but poor when there is no relative movement.

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[3] House of Lords European Committee Report on Civilian Use of Drones in the EU 5 March 2015 p 67 para 6

[4] Monash University – Potential damage assessment of a mid-air collision with a small UAV 12/6/2013

Therefore the pilot is unlikely to see the drone until the last second when it suddenly gets bigger, and the eye senses the drone appearing to expand in size. However, since most quadcopters are relatively small, the human eye would only sense this at the last second, causing very little time to react. Even so, it may not be advisable to carry out evasive manoeuvres which could destabilise the approach and could cause greater danger if close to the ground. A helicopter might be able to slow down if a drone had been sighted in the landing area to give more time to see and react. However an airliner cannot slow down below around 150 miles per hour.

Geo-fencing

Geo-fencing is a technique whereby all major airports are stored in the data base of the navigation system of the drone. It provides a radius of around 5 miles from an airport whereby the drone either cannot start its motors if within the prohibited area, or will simply not enter the area if already airborne. Most large manufactures, such as DJI of China, have implemented this technology into all their drones. It is possible to include any area on the planet including sensitive areas such as nuclear power stations. It has probably been successful in limiting fewer drones into airport areas than would have happened if it did not exist. However, there are also many enthusiasts who construct their own drones, and presently there is no legal requirement for a home-made drone to adopt geo-fencing, and it could be disabled, as some YouTube footage of airliners proves. Also geo-fencing does not protect light aircraft or helicopters operating away from major airports, such as Air Ambulances. These situations can attract hobbyists and others wishing to photograph incidents such as road traffic accidents. It should be noted that the future King of England is now an Air Ambulance pilot, which itself might attract the interest of some drone owners, including a new breed of 'airborne paparazzi'.

Registration, Education, Public Perception

The CAA has encouraged the use of educational material and rules for drone owners to be included in all drones sold in the UK. Presently under consideration by ministers is the introduction of an online registration system, forcing owners to put their details on a database before they could fly a drone. Both of these mitigations will help sensible owners understand the dangers posed by drones, but may not help when owners wish to deliberately fly their drones near other aircraft. In terms of public perception "more than half of adults in Britain think that the most appropriate level of punishment for someone flying a drone that endangers an aircraft, but does not cause the aircraft to crash, is a prison sentence (52%) – more than any other option tested."[5]

Robert Goodwill, transport minister, has said in a parliamentary answer that "The government is in early discussions with international partners about a drone traffic management system".[6] This may work for drone users who are willing to participate, but again it does little to stop the hobbyists, or the 'idiotic' who chose not to participate in such systems. It should be noted that such systems are a long way from reality at this time.

Conclusion

There are growing numbers of drones and there are growing numbers of 'near misses'. Despite some mitigations in place, and some sensible planned mitigations, many consider it can only be a matter of time before a major accident occurs. A drone that brought down an Airbus 320-sized airliner would be both catastrophic and expensive for the industry (direct/indirect/induced impact up to £750 million),[7] but even a helicopter that crashed over a city would be just as tragic, as demonstrated in November 2013 when a police helicopter crashed into the Clutha pub in Glasgow (though it was not a drone that caused this helicopter to crash). Many pilots agree that it is probably light aircraft and helicopters that face the greatest risk from a drone strike. Industry needs to measure the risks, including potential damage to aircraft, and find ways to reduce those risks.

Captain Andy Brown is an airline pilot and chairs the Remotely Piloted Aircraft Systems Working Group for the pilots' union BALPA. He is a former fighter pilot in the Royal Air Force during the latter stages of the Cold War, and then took up civilian flying, initially with the charter company Air 2000 flying Boeing 757 and 767 around the world, and now with a major UK airline flying short-haul around Europe. Andy has been a union rep for BALPA for 16 years and now serves on the National Executive Committee. His current role as an RPAS expert has taken him both to the House of Lords and the European Parliament to represent BALPA at the report into 'Civilian Use of Drones in the EU'.

The **British Air Line Pilots Association (BALPA)** represents 10,000 flight-crew in 26 different companies, from legacy carrier to low cost, from charter to executive jets, from air ambulance to flying instructors, and uses all available resources to "Making Every Flight a Safe Flight" www.balpa.org.

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[5] Source ComRes Survey 13th Apr 2015

[6] The Times 28 Sep 2015

[7] Source DronSystems July 2015