An assessment of the threat to airliners from small drones in the United Kingdom

(Including the mitigating effects of SERA implementation)

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Summary

1. This report uses CAP1627 “Drone Safety Risks: an assessment” and the speed restrictions imposed by the implementation of the Standardised European Rules of the Air (SERA) as the basis for an assessment of the threat that small drones pose to airliners only (excluding consideration of the threat to smaller aeroplanes and helicopters). This assessment concludes that the most severe consequences of a collision between an airliner and a 2kg drone below 10,000ft are the shutting down of one engine or the obscuration of the view through one windscreen. Neither of these events would be a significant threat to the safety of the airliner.

2. This report also presents a basic analysis of the probability of occurrence of collisions between airliners and small drones. It is predicted that the general risk of collision with drones of up to 2kg when flying below 10,000ft altitude is that they will occur less frequently than 1 every 27 years on average. For the specific case of a drone operating within 500m of an airport runway the method predicts a collision frequency of one in every 2,700 take-offs/landings that take place whilst the drone is present.

3. This review concludes that the threat that small drones pose to airliners is economic damage to the operators, not a threat to flight crew or public safety. It is therefore suggested that the management of the drone risk could be delegated to aircraft operators. i.e. When the alleged presence of a drone is reported in airspace with the potential for proximity with airliners, rather than a blanket closure of that airspace being enforced, the information could be passed to the aircraft commanders who could react in accordance with the policies laid down by their airlines.

Introduction

4. In 2018 the UK Civil Aviation Authority (CAA) published CAP1627 – “Drone Safety Risks: an assessment”. That document presents information and analysis on the potential consequences of collisions between manned aircraft and small drones. Whilst the main body of CAP1627 identifies that the level of protection of light aircraft and helicopters against the effects of a drone collision is lower than for large aeroplanes (airliners), the conclusions and declared actions do not make that distinction. This is significant because the general application of the findings of CAP1627 for all categories of aircraft may mean that the measures taken to address the threat from drones are disproportionate for large aeroplanes. For example, is it appropriate to close an airport because of the presence of a small drone that may be a significant hazard to light aeroplanes and helicopters, but presents a much lower risk to the safety of an airliner?

A factor that is not mentioned in CAP1627 is that the implementation of the Standardised European Rules of the Air (SERA) imposes a speed limit of 250kts throughout the UK on all civilian aircraft when flying below 10,000ft. This restriction defines the maximum speed for any impact with a drone below 10,000ft.

This report reviews CAP1627 as it applies to large aeroplanes only. The objective is to provide a realistic assessment of the threat that irresponsible or reckless operation of small drones may pose to airline operations. As the threat is from those who are ignorant of the rules or will deliberately disregard them, the analysis takes no credit for airport Flight Restriction Zones nor the general prohibition on flying drones above 400ft.

The potential for small drones to cause damage to large aeroplanes (airliners)

5. Paragraph 2.33 of CAP1627 states:

> *"....these factors lead the CAA to consider that the likelihood of drone collision with other aircraft is highest in relation to small drones operated by recreational users. Given the cost and mass relationship in Figure 2, it is further considered likely that the majority of recreational small drones will be of less than 2kg mass. This is the category of drone covered by this assessment."*

6. The severity of the damage that may be caused by a collision with a bird, drone, or any other object is primarily dependent upon the kinetic energy of the impact, which is proportional to the mass of the object and to the square of the impact velocity.

   Documents issued by NATS concerning the implementation of the Standardised European Rules of the Air advise that the Class A airspace around Heathrow (and presumably any other airports) is being changed to Class D. When that change is made all lower level airspace in the UK will be Class D, E or G. This means that there will be a maximum speed limit throughout the UK of 250kts for all civilian aircraft flying below 10,000ft. CAP1627 says that 95% of drone related airprox reports are for altitudes below 10,000ft. It follows that the case that should be considered when assessing the risk of a drone collision is a drone mass of up to 2kg and a velocity not exceeding 250kts.

7. As part of the type certification process for large aeroplanes the aircraft design organisations must satisfy the regulators that their products can continue safe flight and landing following an impact with a bird, typically a 4lb (1.82kg) bird at a speed that is defined by the design cruise speed of the aeroplane (Vc). As noted in CAP1627 this 'bird impact speed' is typically 340kts.

8. For a given object mass, lowering the impact speed from 340kts to 250kts results in a large reduction in kinetic energy. The kinetic energy of a collision with an object with a mass of 2kg at 250kts will be only 60% of the kinetic energy of the 4lb bird impact design case. The conclusion to be drawn from this is that a collision with a 2kg drone would not be expected to inflict more than superficial damage to an airliner flying below 10,000ft in UK airspace. The change in kinetic energy level for the reduced maximum impact speed is so great that this conclusion is considered valid, even allowing for the statement in CAP1627 that:

> *"... the CAA recognises, and the recent FAA modelling work suggests, that the design and materials used in drone construction are likely to mean that drones cause more damage than birds for equivalent impact levels".*

9. The first conclusion of this assessment is that the most likely collision with a drone - up to 2kg and below 10,000ft - will be at a kinetic energy level that is less than 60% of the bird impact design case for airliners and so should not cause damage to the aircraft that would degrade its airworthiness. It is only collisions above an altitude of 10,000ft with a 2kg drone that may potentially cause damage that could degrade the structure or systems of an airliner.

The probability of a collision

10. Figure 5 in CAP1627 presents the probability of a sighting/conflict with a drone at speeds between 304kts and 340kts. CAP1627 summarises the analysis as follows:

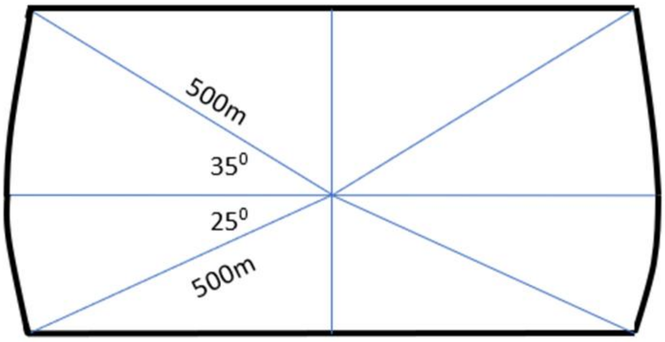
> *"....the probability of a passenger airliner experiencing a drone in proximity whilst above 340kt and at or below 12,000ft in the London TMA was about* $2x10^{-6}$ *per flight. This equates to a probability of two drone proximity incidents above the velocity to which airliner windscreens are certified per million aircraft flights".*
>
> *"A proximity incident is far more likely than a collision. Furthermore, proximity reports relate to all areas of the aircraft and not just the windscreen. It therefore follows that the estimated probability of a drone collision damaging an airliner windscreen, and causing immediate harm to the crew (resulting in subsequent harm to passengers or third parties) is, at present and based on this data, very much lower than the probability of a drone being in proximity of an aircraft".*

11. CAP1627 does not offer any estimate for the probability of a collision or of an airliner being in proximity with a drone below 10,000ft. A method based on pilot field of view and aircraft size has been developed by the author to provide estimates of the probability of proximity below 10,000ft and of the probability of collision below 12,000ft.

Method

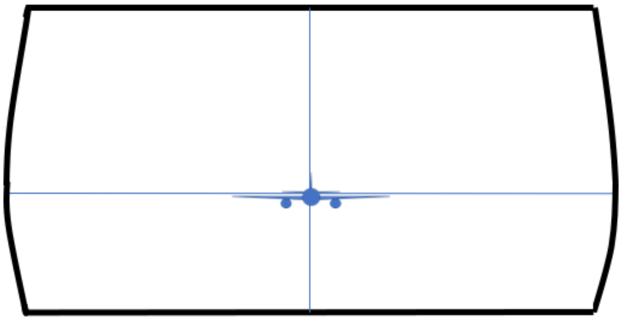
12. For this analysis it is assumed that the velocity of a drone is negligible compared with the velocity of the aircraft (as is assumed for bird impact) and that the maximum distance for the visual detection of a small drone is 500m (the limit applied by the CAA for Visual Line Of Sight operation of drones). It is further assumed that the words 'a drone in proximity' in CAP1627 mean a drone that comes within 500m of the aircraft and within the field of view of the flight crew.

13. Based upon the FAR 25 AC 25.773 "Pilot Compartment View, Design Considerations" and data obtained for a modern in-service airliner, the typical field of view from the cockpit for each pilot is up to 25^0 downwards, 35^0 upwards and 120^0 to each side. The area of sky ahead of the aircraft within which the pilots will be able to see a drone as the aircraft moves forward will be the forward projection of this cockpit field of view. See Sketch 1. This projected field of view has an area of $430{,}000m^2$; ($Area_{FoV}$)



Sketch 1
The area ahead of the aircraft within which a drone
will come into the view of either or both pilots

For a collision to occur a drone would have to be aligned with the frontal area ‘footprint’ of the aircraft; $\text{Area}_{A/C}$. See Sketch 2.



Sketch 2
For a collision the drone would have to be located within the aircraft outline.

The probability of a collision with the aircraft is then the probability of a drone being within the field of view area multiplied by the frontal area of the aircraft and divided by the projected field of view area.

i.e.
Collision probability = Probability of entering field of view area x ($\text{Area}_{A/C}$ / Area_{FoV})

If the probability of a drone entering the field of view area is known, this formula can be used to calculate the probability of a collision with:

- any part of the aircraft (by using the total frontal area of the aircraft);
- the cockpit area (by using the fuselage nose cross-section as the frontal area); or
- any engine (by using the sum of the nacelle intake areas of the engines as the frontal area).

According to the formula the likelihood of collision increases with aircraft size. Therefore, for this analysis, the frontal areas have been estimated for the largest airliner currently in service, the Airbus A380. The Field of View Area is 430,000m^2. See Table 1 for the ratios of frontal areas to Field of View Area.

	Frontal area - m^2	$\frac{Area_{A/C}}{Area_{FoV}}$	$\frac{Area_{FoV}}{Area_{A/C}}$
Complete Aircraft	158	0.00037	2,700
Cockpit (fuselage nose)	39	0.00009	11,000
4 Engines	50	0.00012	8,600

Table 1 – Area Ratios

Table 1 implies that only 1 in 2,700 drone encounters will result in a collision with any part of the A380 aircraft. For the cockpit area the figure is 1 collision in 11,000 encounters. For any of the four engines it is 1 collision every 8,600 encounters. As the A380 is the limiting case, these area ratios will be used as the basis for calculations in the remainder of this document; calculated collision frequencies for smaller aircraft will be correspondingly lower.

The probability of a collision at or above 340kts (between 10,000ft and 12,000ft)

14. In CAP1627, the CAA estimates that there will be two drone proximity incidents per million flights at airspeeds of 340kts or higher. CAP1595 “Aviation Safety Review 2016” states that there are 2.4 million flights per year in UK airspace. Combining these two figures implies 4.8 drone encounters per year at speeds of 340kts or higher. Using this encounter rate with the area ratio formula given above we should expect the collision rates to be:

0.0018 per year or 1 per 560 years for a collision with any part of the aircraft;
0.0004 per year or 1 per 2,300 years for a collision with the cockpit area; and
0.0006 per year or 1 per 1,700 years for a collision with any one of the 4 engines.

So, this method predicts that collisions at speeds that could cause damage that is comparable to a critical bird impact will occur at intervals of several hundred years. Even if this crude method is wrong by a factor of 10, we should still expect such collisions to occur no more frequently than 1 every 50 years.

In this context it is noteworthy that the Department for Transport publication “Aviation 2050” quotes a Fatal Accident Rate (due to all causes) of 0.2 per million flights for European airlines. According to CAP1595 “UK Aviation Safety Review for 2016”, UK airlines complete 1.2 million flights per year. Together these figures imply that the statistical level of safety for UK airline operations is a probability of one fatal accident every 4.2 years on average. The probability of collision with a drone at high speed is insignificant compared with the overall probability of a fatal accident involving a UK-registered airliner due to all causes.

The probability of a collision below 10,000ft at up to 250kts.

15. The number of UK airprox reports from all sources (commercial and general aviation) concerning objects that may be small drones has risen to a level of around 100 per year. Using an encounter rate of 100 per year with the area ratio method set out above gives expected collision rates of:

0.037 per year or 1 per 27 years for a collision with any part of the aircraft;
0.009 per year or 1 per 111 years for a collision with the cockpit area; and
0.012 per year or 1 per 83 years for a collision with any one of the 4 engines.

So, the collisions at speeds below 250kts (which should not cause harm to passengers in aeroplanes that are designed to withstand a 4lb bird impact at 340kts) are also predicted to be extremely rare.

Does this method give credible estimates?

16. There are about 100 UK airprox reports per year from all sources (commercial and general aviation) concerning objects that may be small drones. Combining an annual rate of 100 alleged drone reports with 2.4 million flights per year in the UK, gives a probability of encountering a drone below 10,000ft as 41 encounters per million flights. The total number of commercial flights worldwide is approximately 35 million per year. Combining those two figures suggests a worldwide drone encounter rate of 35 x 41 = 1,435 per year. Applying the area ratio method above to that figure gives a predicted rate of 0.53 collisions per year for impact with any part of a commercial aircraft. That implies that there will be one collision between a drone and an airliner somewhere in the world about once every 2 years.

Given that multi-rotor drones have been widely available to the public for about 5 years this method predicts the occurrence of between 2 and 3 collisions between drones and airliners worldwide in that time period. That estimate is consistent with the statement in CAP1627 that:

> *"At the time of writing there have been seven confirmed cases of direct in flight contact between drones and civil or military manned aircraft worldwide."*

(The 7 confirmed collisions will include all categories of civil aircraft, not just airliners, plus military aircraft).

The calculation method is sensitive to the assumptions of maximum visual range (500m) and the probability of encountering a drone. If we take a very conservative view and assume that pilots will first see a drone at a distance of only 300m and that they currently see and report only 1 in 5 of the drones that actually come within 300m of the aircraft, the calculations for an aircraft flying below 10,000ft would be based on a Field of View Area of 155,000m^2 and 500 drone encounters per year. Using these values, the predicted collision rates would be:

0.515 per year or 1 every 2 years for a collision with any part of the aircraft;
0.125 per year or 1 every 8 years for a collision with the cockpit area; and
0.167 per year or 1 every 6 years for a collision with any one of the 4 engines.

It is considered that these collision frequencies are still acceptable for impacts at only 60% of the kinetic energy of the bird strike design case; particularly when compared with the Fatal Accident Rate for commercial flights by European operators.

Alternatively, one could take the contrary view that the annual number of drone encounters in the UK is less than 100 because pilots may be mistakenly reporting airborne debris or distant manned aircraft as drones, and so are over-reporting. If that were the case then the predicted frequency of collisions would be proportionately lower than calculated in paragraph 15 above.

The probability of a collision at an airport

17. The estimates calculated above rely on the accuracy of the figure for the probability of a drone coming into the field of view of the flight crew. If we take the case of airliners operating from a runway at a time when a drone is being flown deliberately within 500m of that runway, the probability of the drone entering the field of view will be unity – i.e. it will always be there. For that scenario the method gives the following estimated collision rates:
    1 collision with any part of the aircraft every 2,700 take-offs/landings;
    1 collision with the cockpit area every 11,000 take-offs/landings; and
    1 collision with any 1 of 4 engines every 8,600 take-offs/landings – (for a twin-engine aircraft the rate is 1 collision with an engine every 17,200 take-offs/landings).

    This calculation assumes that the drone will be in a random position within 500m of the runway. This is consistent with it being operated irresponsibly, but without the intent of colliding with an airliner. Clearly, if the drone pilot is trying to cause a collision, the likelihood of impact will be greater, but the severity of such a collision will be very low because airliner speeds during final approach to land and initial climb after take-off are less than 200kts. The kinetic energy of any impact with a 2kg drone at 200kts or less will be less than 35% of the bird impact design condition and therefore no damage should result from any collision. The most severe consequence would be a ‘turn back’ and precautionary landing for a departing aircraft to inspect for damage – assuming that the collision was noticed by the crew.

What damage could a drone of up to 2kg mass cause in a collision at a velocity not exceeding 250kts?

18. Given the very significant mitigating effect of the 250kt speed limit it is considered worth reviewing the potential damage that could be caused to an airliner in a collision with a 2kg drone - as discussed in CAP1627 – with this speed restriction applied.

19. **Windscreen and fuselage nose.**
    Given that all airliner windscreens must comply with the bird impact certification requirements (1.82kg bird, circa 340kts) a 2kg drone would not be expected to rupture the windscreen of an airliner flying at 250kts. It is possible that a windscreen impact could cause damage that would make that particular screen unusable. But airliners have 6 windscreens and two of those screens (Direct Vision – DV – windows) can be opened below 200kts - to provide sufficient external reference (to be used in addition to the instruments) to land safely in the unlikely event that all 6 windscreens become opaque.

    There are many reasons why a single airliner windscreen may become opaque – such as failure of the anti-icing system for that screen or adhesion of debris from a non-critical bird impact. It is inherent in the design of airliners that loss of vision through a minority of the windscreens will have negligible effect on continued safe flight and landing.

    The nose radome could suffer localised damage from a drone impact, but this would not prejudice continued safe flight and landing.

20. **Engines**
    CAP1627 reports the expert opinion of a leading turbine engine manufacturer that it is unlikely that the ingestion of a drone would significantly affect the ability of an engine to produce thrust; and extremely unlikely that drone ingestion would compromise the

ability of the engine to shut down safely. So, the most severe consequence of a drone being ingested by an airliner engine would be the necessity to shut down the affected engine.

As is recognised in CAP1627, compliance with the Type Certification requirements for large aeroplanes assures continued safe flight and landing following sudden, complete and unrecoverable loss of thrust from any one of the engines at any point during a flight. Indeed, flights over the world's oceans by twin-engine aeroplanes are predicated on evidence that, following the failure of one engine, the aeroplane will continue to fly for at least 3 hours and land safely using the remaining engine.

21. **Wing and tailplane leading edges**
It is not credible to believe that a drone collision at up to 60% of the kinetic energy specified by the bird impact requirements would cause significant damage to the leading edges of the wing or horizontal / vertical tail surfaces of an airliner.

22. **Landing Gear**
Landing gear components are amongst the strongest parts of the aircraft structure as they must withstand vertical landing loads and longitudinal wheel braking forces. The landing gear systems, including hydraulic and electrical components and all associated routing and moving parts, are designed and segregated to maintain functionality after impacts from birds, tyre debris (if a tread separates or a tyre deflates at high speed on the runway) and water impingement during landings on contaminated runways. It is considered extremely unlikely that any part of the landing gear of an airliner would sustain significant damage from a collision with a drone.

23. **High Lift Devices**
High lift devices are fitted to the leading and trailing edges of the wings. Leading edge devices (slats, Krueger flaps or leading edge droop) and trailing edge devices (flaps) are certified to the same bird strike requirements as the rest of the aircraft in both the retracted and deployed positions. A drone impact might cause superficial localised damage or at worst, jam the operation of the leading edge devices, but would not prejudice continued safe flight and landing.

24. **Primary Flying controls including spoilers**
Primary flying controls (other than the spoilers) are fitted to the trailing edges of the wings and the horizontal / vertical tailplanes. Due to their location they would not be expected to suffer any more than an insignificant glancing blow from a drone impact. Spoilers hinged from the upper surface of the wing that can be operated in flight are certified to the same bird strike requirements as the rest of the aircraft and a potential drone impact would not be expected to cause anything other than superficial damage. Furthermore, it is a Type Certification requirement for large aeroplanes that losing the use of a single control surface shall not compromise continued safe flight and landing. All airliners have multiple control surfaces actuated independently of each other by multiple power systems. i.e. There is multiple redundancy of control surface function. The failure or jamming of any single moving surface would have negligible effect on the ability of the crew to control the aircraft.

Loss of control / passenger injury caused by manoeuvring to avoid a collision.

25. CAP1627 lists as a threat the possibility that pilots may lose control of their aircraft through manoeuvring to avoid a collision with a drone, or that such manoeuvring may cause injury to passengers. However, CAP1627 offers no analysis to support this.

26. Assuming that a conflicting small drone can first be seen at a distance of 500m, the pilot of an airliner flying at 150-250kts has between 4 and 6.5 seconds to:

    - see the drone;
    - recognise that it is not moving laterally or vertically relative to the airliner and so presents a collision risk;
    - take hold of the controls (as the aircraft will probably have the autopilot engaged); and
    - initiate an avoidance manoeuvre.

    This assumes that the pilot is looking directly forward with eyes focussed at infinity when the drone first comes within visual range.

    Human vision gives optimum performance for detecting movement when an image moves rapidly across the retina of the eye; it is least effective when the image is stationary on the retina. This is unfortunate because, when two aircraft are going to collide, the angle of approach is constant and so the aircraft do not move across the pilots' fields of view. In the context of avoiding a mid-air collision the most demanding case for human eyesight is a threat from directly ahead because the image does not move and the closing speed is greatest.

27. Given the small size of the drones being considered here and airliner operating speeds in the range 150-250kts, it is considered extremely unlikely that pilots will see a drone that will hit or pass very close to the aircraft in time to initiate any avoidance manoeuvre. This is confirmed by several of the airprox reports submitted by airline pilots which include statements to the effect that 'there was no time to react'.

    A comparison with the bird hazard is directly relevant here. Mid-size birds such as gulls are comparable in size to 2kg drones and are far more abundant; yet there is no history of loss of control or passenger injuries caused by pilots attempting to avoid colliding with them. Therefore, it is concluded that loss of control or injury arising from pilots manoeuvring the aircraft to avoid a collision with a drone is not a credible scenario and should be discounted.

Flight crew incapacitation

28. The analysis presented above justifies the conclusion that a 2kg drone collision at 250kts will not have sufficient kinetic energy to penetrate the windscreen of an airliner. The analysis also concludes that a drone impact in the region of the cockpit at 340kts (which could rupture a windscreen) will have a frequency of 1 every 11,000 years. However, as pilot incapacitation is highlighted in CAP1627, that issue is addressed here.

29. The first point to note is that, in addition to the windscreen strength requirements, the design certification requirements specify in CS/FAR 25.775(c) that:

    > *"Unless it can be shown by analysis or tests that the probability of occurrence of a critical windshield fragmentation condition is of a low order, the aeroplane must have a means to minimise the danger to the pilots from flying windshield fragments due to bird impact."*

Thus, the design certification requirements include a level of protection for pilots from debris following windscreen rupture.

30. The second point is that pilot incapacitation is a frequent event that has minimal effect on the safety of aircraft that have more than one pilot in the cockpit. The report "Pilot incapacitation occurrences 2010-2014" published by the Australian Transport Safety Bureau may be found here:
https://www.atsb.gov.au/media/5768970/ar-2015-096-final.pdf

The summary of this report states:

> *"In the past 5 years, there have been 23 pilot incapacitation occurrences reported per year on average.*
> *Nearly 75 per cent of the incapacitation occurrences happened in high capacity air transport operations (about 1 in every 34,000 flights), with the main cause being gastrointestinal illness, followed by laser strikes. In the majority of the occurrences reported, the incapacitation was severe enough for the pilot to be removed from duty for the remainder of the flight. With multi-pilot crews in high capacity operations, these occurrences usually had minimal effect on the flight.*

75% of 23 incapacitation occurrences is 17 events in airline operations every year, or one pilot incapacitation aboard Australian-registered airliners every 21 days on average. Within the body of the report, in the context of airline operations, it is further stated:

> *"In less than 10 per cent of flights, a return to the take-off airport or diversion to another airport en route was initiated due to the severity of the incapacitation".*

31. The third point is that we have already had the most severe windscreen-related accident – British Airways flight BA5390 on 10th June 1990 – and the aircraft landed safely. Due to a maintenance error the captain's primary windscreen was not properly installed and the complete windscreen departed the aircraft as it was climbing through 17,300ft pressure altitude. The captain, who had released his shoulder harness and loosened his lap strap, was pushed half way out of the windscreen aperture by the cabin air as the aircraft depressurised. The first officer, who initially believed the captain to be dead, took control of the aircraft, diverted and completed a safe landing. In the event the captain survived and later returned to commercial flying. One other crew member suffered minor injuries. There were no passenger injuries.
The AAIB report may be found here:
https://www.gov.uk/aaib-reports/1-1992-bac-one-eleven-g-bjrt-10-june-1990

Whilst no-one would argue that the occurrence of events of this kind is acceptable, this incident serves to demonstrate that continued safe flight and landing can follow loss of a windscreen combined with pilot incapacitation and aircraft de-pressurisation.

Conclusions

32. The implementation of SERA means that the assessment of the risk of a drone collision should focus on a drone mass of up to 2kg and a velocity not exceeding 250kts. Such a collision would have a kinetic energy of less than 60% of the bird impact design case that is applied to the Type Certification of airliners and would not the expected to cause damage to the aircraft that would degrade its airworthiness. It is only for collisions above an altitude of 10,000ft that there is the potential for a 2kg

drone to cause damage that could degrade the structure or systems of an airliner. The probability of a collision above 10,000ft is predicted to be less than 1 every 500 years.

33. This review has found that the most severe consequences of a collision with a 2kg drone below 10,000ft are the shutting down of one engine or the obscuration of view through one windscreen. Pilots are tested regularly on their ability to respond correctly to sudden engine failure. The obscuration of view through one windscreen can be dealt with by simply transferring control of the aircraft from one pilot to the other. Thus, neither of these events would be a significant threat to the safety of the aircraft. The frequency of drone collisions with windscreens or engines below 10,000ft is predicted to be less than 1 every 80 years on average.

34. This report also addresses the likelihood and severity of an impact with a drone that is operating within 500m of an airport runway. The probability of collision is calculated to be 1 per 2,700 take-offs/landings during the period that the drone is operating, but the severity of such a collision would be very low because airliner speeds during final approach to land and initial climb after take-off are less than 200kts. The kinetic energy of any impact with a 2kg drone at up to 200kts will be less than 35% of the bird impact design condition and therefore no appreciable damage should result from any collision close to a runway. The most severe effects would be minor damage to one windscreen or loss of thrust from one engine, which would not be a threat to safety.

35. The threat that small drones pose to airliners is of economic loss, not a threat to the safety of either flight crew or the general public. i.e. A collision may result in the affected aircraft having to turn back or divert and be taken out of service for inspection and repair. But that is no worse than any inflight engine shutdown, bird impact, Foreign Object Damage, collision with a ground service vehicle, or indeed the failure of a component or system that must be repaired before further flight. Airlines cope with such issues every day. They cost the operators money, but there is no threat to aircraft safety. It is therefore suggested that the management of the drone risk (which is of economic damage) could be delegated to aircraft operators.

36. It is suggested that if the possible presence of a drone is reported where it could come into proximity with airliners, an alternative to closing the airspace or airport could be to give the aircraft operators that information. Operators could then implement their own measures for responding to the threat to their aircraft, such as:
    (i) Suspending all departures and diverting all incoming aircraft.
    (ii) Suspending all departures but allowing incoming aircraft to continue to land.
    (iii) As (ii) but requiring the pilots of incoming aircraft to fly at less than 200kts in the vicinity of the airport to reduce the severity of any impact.
    (iv) Continue with all scheduled departures and arrivals but with a speed limit below 200kts in the vicinity of the airport to reduce the severity of any impact.
    (v) Continue with all scheduled departures and arrivals as normal.

    If an operator were to be very unlucky and a collision occurred the most severe outcome would be the return or diversion of a single aeroplane that would have to be taken out of service for inspection.

37. The overall conclusion is that the threat to the safety of the general public from the irresponsible operation of small drones causing conflict with airliners is negligible.

About the author:
Cliff Whittaker is an aeronautical engineer with 39 years of experience in aviation, comprising:

- 15 years working as an aerodynamicist and project engineer on the design and certification of airliners and business aircraft;
- 20 years working in civil aviation regulation, including rule-making and head of policy roles in design airworthiness and flight crew licensing;
- 4 years working on aircraft performance in a design research environment.
