BALPA

The Hazard of Drones to Commercial Aircraft Operations

ECAM 2018

Rob Hunter and Capt. Tim Pottage
British Airline Pilots' Association

MAKING EVERY FLIGHT A SAFE FLIGHT

British Airline Pilot's Association

Founded in 1937 in the context of safety concerns
Around 80% of all UK commercial pilots are members

Flight Safety Department

- Specialist in aviation medicine/pilot
- Scheduling specialists x 2
- Post Doc. Bio-mathematical modeller – (Forensic roster analytics)
- Ph.D. Cand. Human factors scientist – (How tired is too tired)
- *Health and Safety Specialist*
- Flight Safety Specialist
- PA

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Making every flight a safe flight

What might the next fatal airliner accident look like?

- Fatigue
- Commercial pressure
- Inadequate training, particularly in relation to the use of the autopilot
- Bad weather
- Maintenance/engineering issue/error
- Cargo Fire
- Terrorism/criminality/security
- Drone collision

“The first duty of an organisation is to survive”

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Drones

- Phenomenal utility
- Phenomenal technology
- Phenomenal business opportunity
- Commercial exploitation outpaces safety assurance

-> tension between productivity and safety

Military Aviation Authority

MAA

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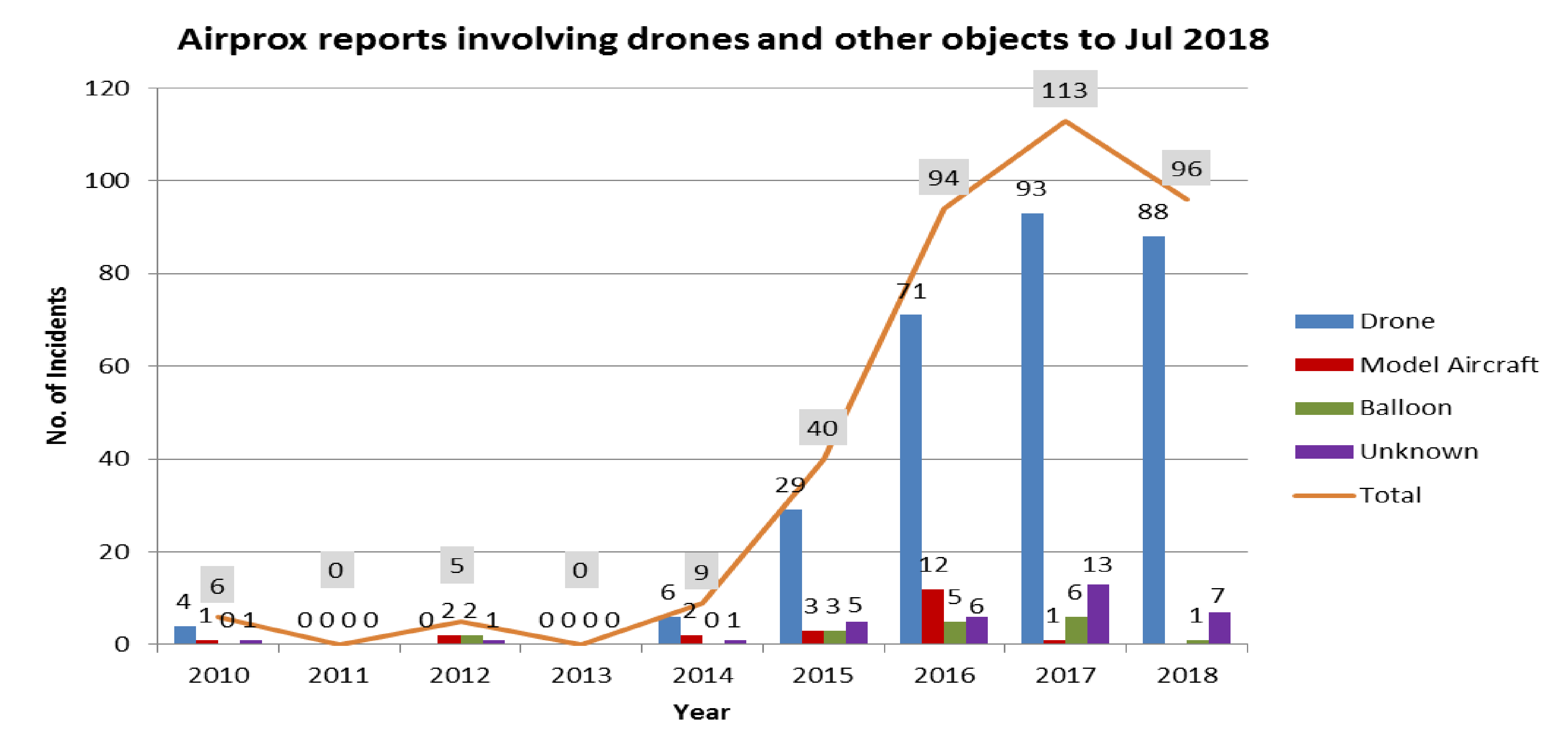
Department for Transport

Small Remotely Piloted Aircraft Systems (drones)

Mid-Air Collision Study

Context of our study: UK Airprox Board data



Context of our study:

- Risk of collision versus number of drones is likely non-linear
- Birds may not be designed to be crashworthy but they happen to be
- Drones are not designed to be crashworthy

-> crashworthiness is about reducing peaks in the forces experienced by colliding objects

Study partners

Sponsors -

- Military Aviation Authority
- Department for Transport
- BALPA

Organising and scoping -

- Ministry of Defence Unmanned Air Systems Capability Centre

Work undertaken by –

- QinetiQ
- Natural Impacts

Aircraft structures

- Helicopter windscreens (one birdstrike certified and one not).
- Helicopter tail rotors
- Large airliner windscreens; 2 ply and 3 ply

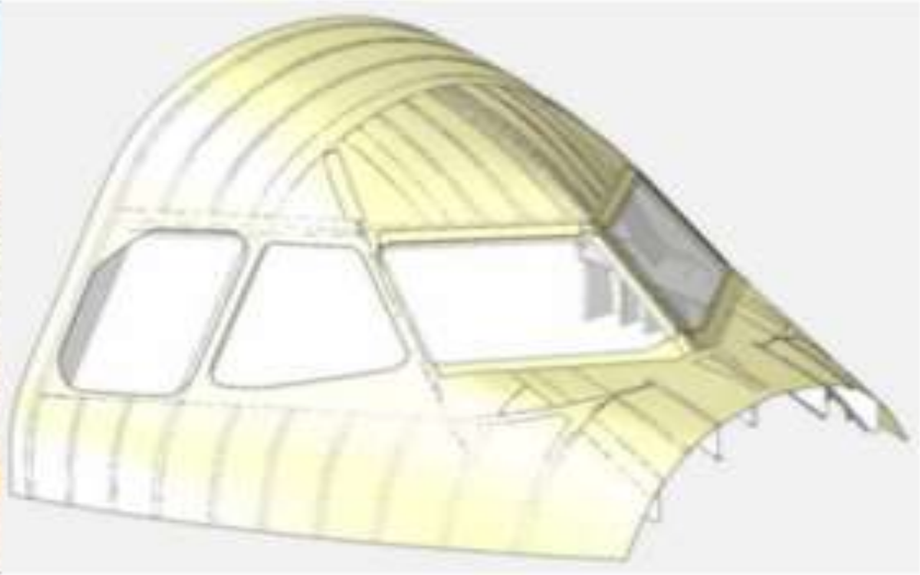
Drones

- 400 gram quadcopter; toys and hobbyists
- 1.2 kilogram quadcopter; hobbyist and smaller professional drones.
- 4 kilogram quadcopter; hobbyist and professional drones
- 3.5 kilogram fixed-wing (nose mounted propeller); professional long endurance and hobbyist drone types.

- Speeds – typical for low level
- Orientation – head on

Testing and Modelling

- Computer modelling; finite element analysis software
- Impact tests against genuine aircraft windscreens. Drones shot by a gas gun (barrel over 10m) toward the windscreen
- Calibration and validation of the computer model
- No live testing for helicopter tail rotors

Amongst other things, no account was taken for -

- Aerodynamic pressure on structures during flight
- Pressurisation of the cockpits
- Low temperatures

The challenges of using the gas gun -

- The 4 Kg drone and the fixed wing drone wouldn’t fit inside the gas gun barrel
- The acceleration from the gun “blows-up” the drone

Our experts felt that the most impactful case for the quadcopter was a strike along the axis of the rotors arms in which case the other two arms perpendicular to the impact axis would break off and may contribute little to the impact damage. Hence, for the 4 kg drone the object that was actually fired only weighed 2.1 kg

Similarly, for the fixed wing drone only the core battery, motor, propeller and spinner were fired.

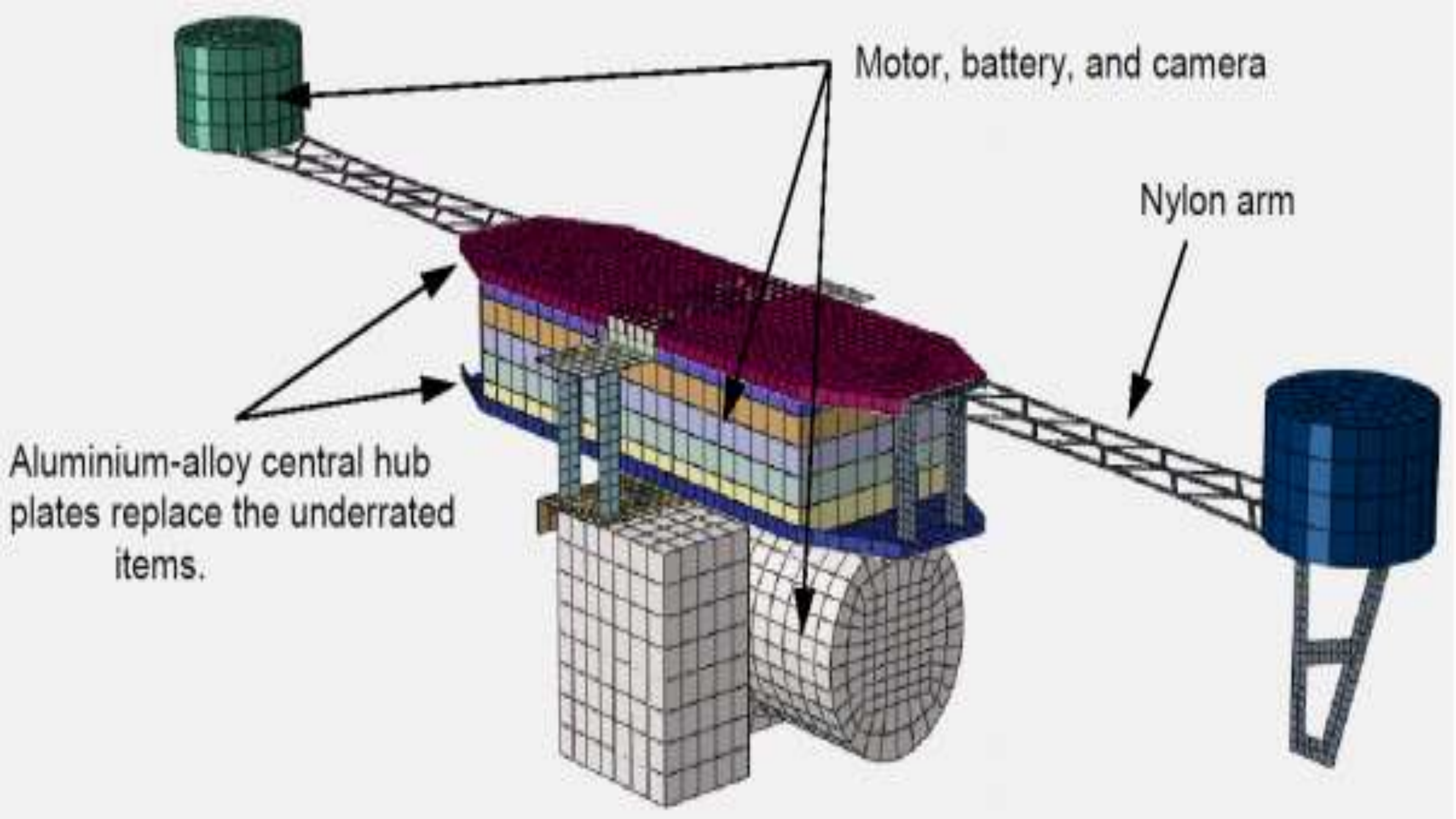
Also the “4 kg” drone glass fibre hub plates had to be replaced with aluminium

Battery
(14.8V 10,000mAh Li-Po)

Plastic arms with original central hub plates

Bridge camera

Motor (2-off)


Motor, battery, and camera
Nylon arm
Aluminium-alloy central hub
plates replace the underrated
items.

Calibration of the computer model

- Impact tests were conducted and results were filmed with high-speed cameras
- Results were compared with the finite element method modelled results
- Where necessary, the material properties included in the computer model were adjusted to better reflect the reality of the live tests - maximum adjustment to the material properties was 10%.
- Laboratory crush tests and impact tests were also performed to measure the strength and behaviour of the individual drone components, results were used to finesse the model.

- The calibrated model showed a strong correlation with the live tests, exception was the airliner windscreen, real-life tests showed less damage than predicted - ?due to the complexity of the windscreen construction

- A finessed calibrated model was then used to simulate the collisions covering the full range of impact speeds agreed by the stakeholders.

Results

<u>Non-birdstrike certificated helicopters</u>

- All classes of drone penetrated the windscreen at speeds well below the normal cruising speed of the helicopter
- The fixed wing drone penetrated when the helicopter was stationary
- General aviation aircraft windscreen results are expected to be similar

Birdstrike Certified Helicopter Windscreens

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- Quadcopter drones can penetrate these windscreens when the closing speed was similar to the helicopter's typical cruising speed.

- The speed the fixed-wing drone can itself reach meant that it could penetrate the windscreen if the helicopter was moving at a speed significantly below the normal cruising speed.

- When the helicopter was stationary a fixed-wing drone, when flying at its maximum speed, was unlikely to penetrate this windscreen

Helicopter Tail Rotors (modelled data only)

Critically damaged by an impact with any drone

Airliner Windscreens

- Windscreens are generally of a much tougher construction than those of helicopters.
- Windscreens, although substantially damaged, could retain integrity during impacts with drones up to speeds typically flown at during the aircraft landing and later stages of the approach.
- At higher altitudes and speeds, modelling and testing showed that severe damage to the 2 ply windscreen did not occur with the 1.2 kilogram class quadcopter components, but can occur during impacts with the 4 kilogram class quadcopter components.
- For the 3ply windscreen, at higher speeds and altitudes, the 3.5 kilogram class fixed-wing drone components penetrated the windscreen.

- fixed wing drones with metallic components can do significant damage to aircraft windscreens.
- drone construction plays a critical part in the severity of a collision.
- Components of drones do not behave in the same way as an equivalent mass bird under similar conditions.
- A simple plastic surround covering a drone motor had a notable effect in lowering the impact forces during component testing.
- The configuration of the drone, angle of collision, component masses and orientation of the motor shaft, all had a significant effect on the extent of the collision damage.

Recommendations

- Better understanding of likelihood of collision
- Special vulnerability of helicopters
- More testing
- Crashworthiness as part of the design requirement for civil and military drones

The BALPA perspective:
Drones are kryptonite to helicopters

- Very high speed of the rotor blade
- Retreating main rotor blade can direct drone parts into the tail rotor
- Loss of tail rotor function can be catastrophic
- Loss of main rotor integrity means there is no capacity to glide (autorotate)
- Rotor damage can lead to catastrophic vibration

Additional fixed wing considerations

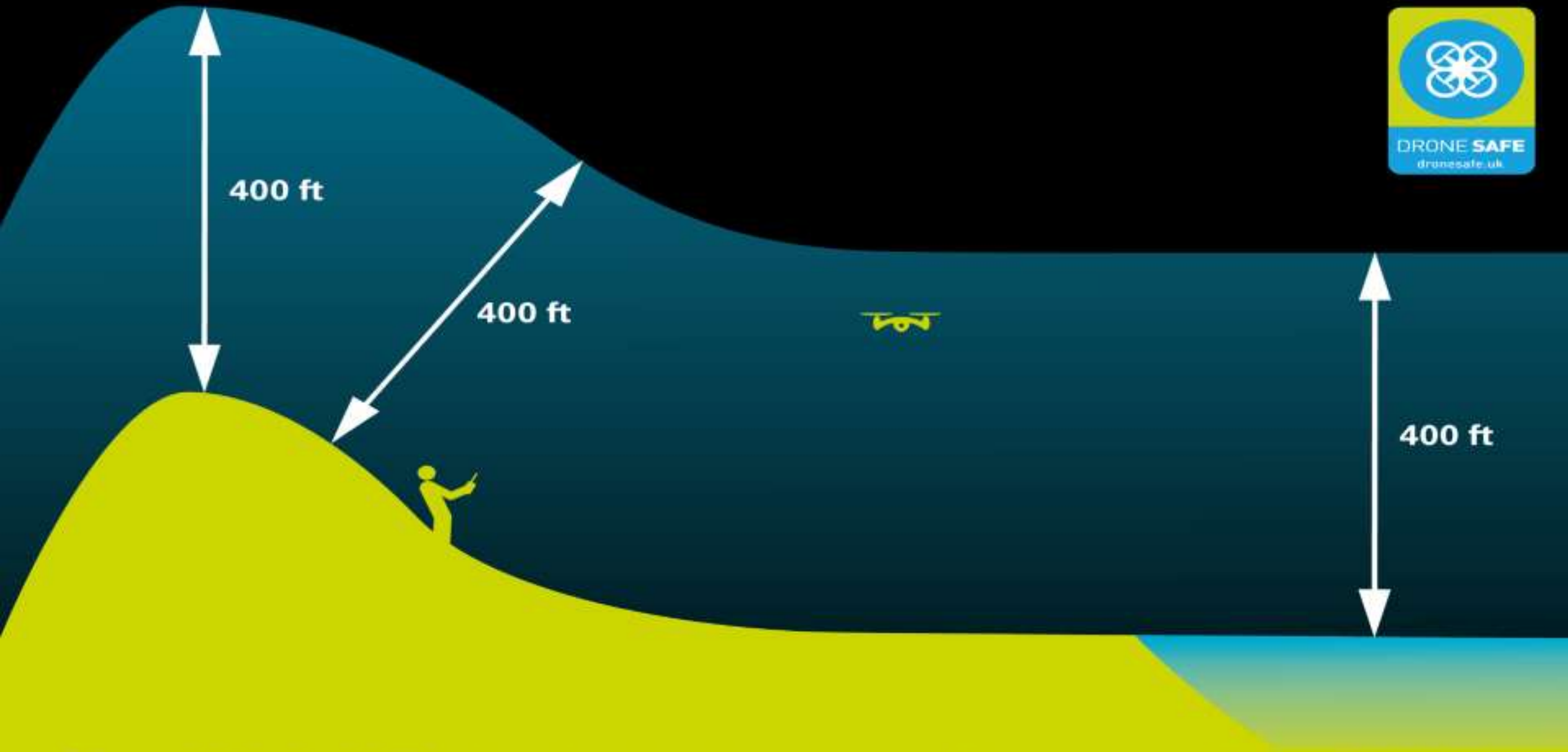
- Windscreen impact may not be the worse case scenario
- Turbofan engine failures should be contained – impacting objects may be directed by the fan away from the core
- ASSURE study – severe damage potential to vertical and horizontal stabilizers and wing leading edges

Concerns about damage affecting roll at low level -

Collision mitigation

- Registration
- Geo-fencing
- Sense and avoid/Transponders
- See and avoid
- Segregation

Current regulation in the UK since 30 July 2018

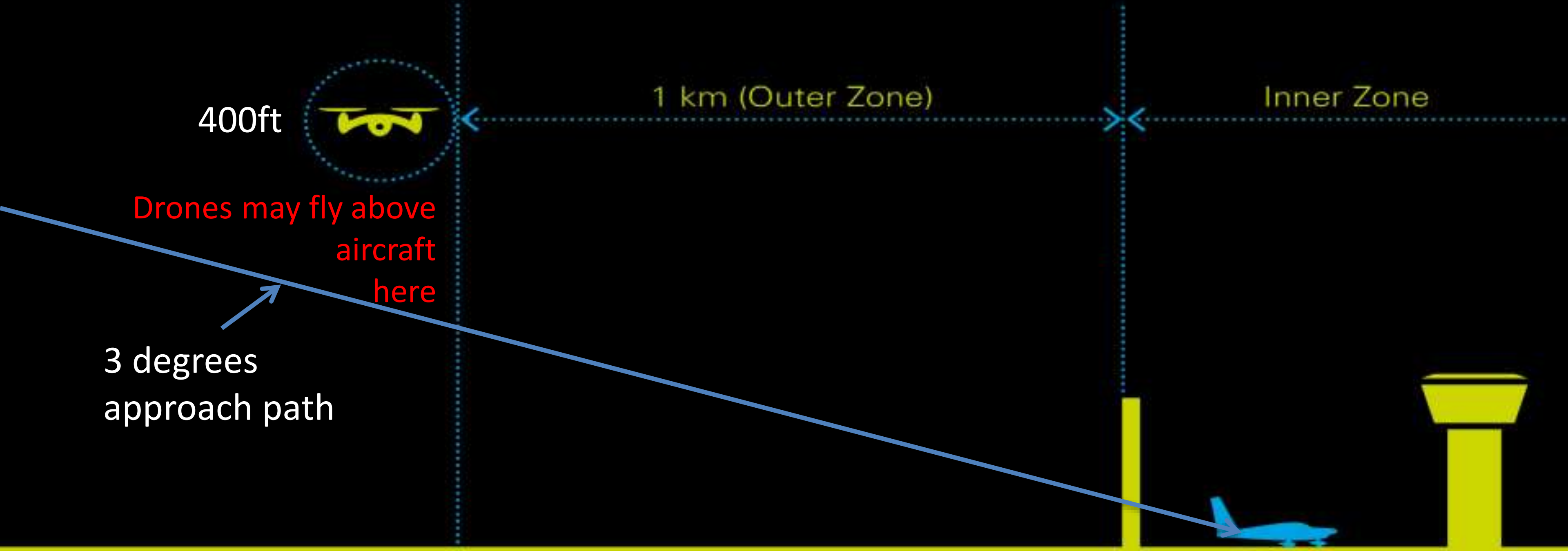


From **30 July 2018**, there is a legal maximum distance restriction of **400 feet** from the surface for the flight of any small unmanned aircraft

Keep out of the flight restriction zone of a protected aerodrome

Inner Zone – **the area over the aerodrome up to the boundary**
Outer Zone – **1 km from the aerodrome boundary**

Keep out of the flight restriction zone of a protected aerodrome



Inner Zone – **the area over the aerodrome up to the boundary**
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Article 94(2) The remote pilot is directly responsible for ensuring that the aircraft is flown safely

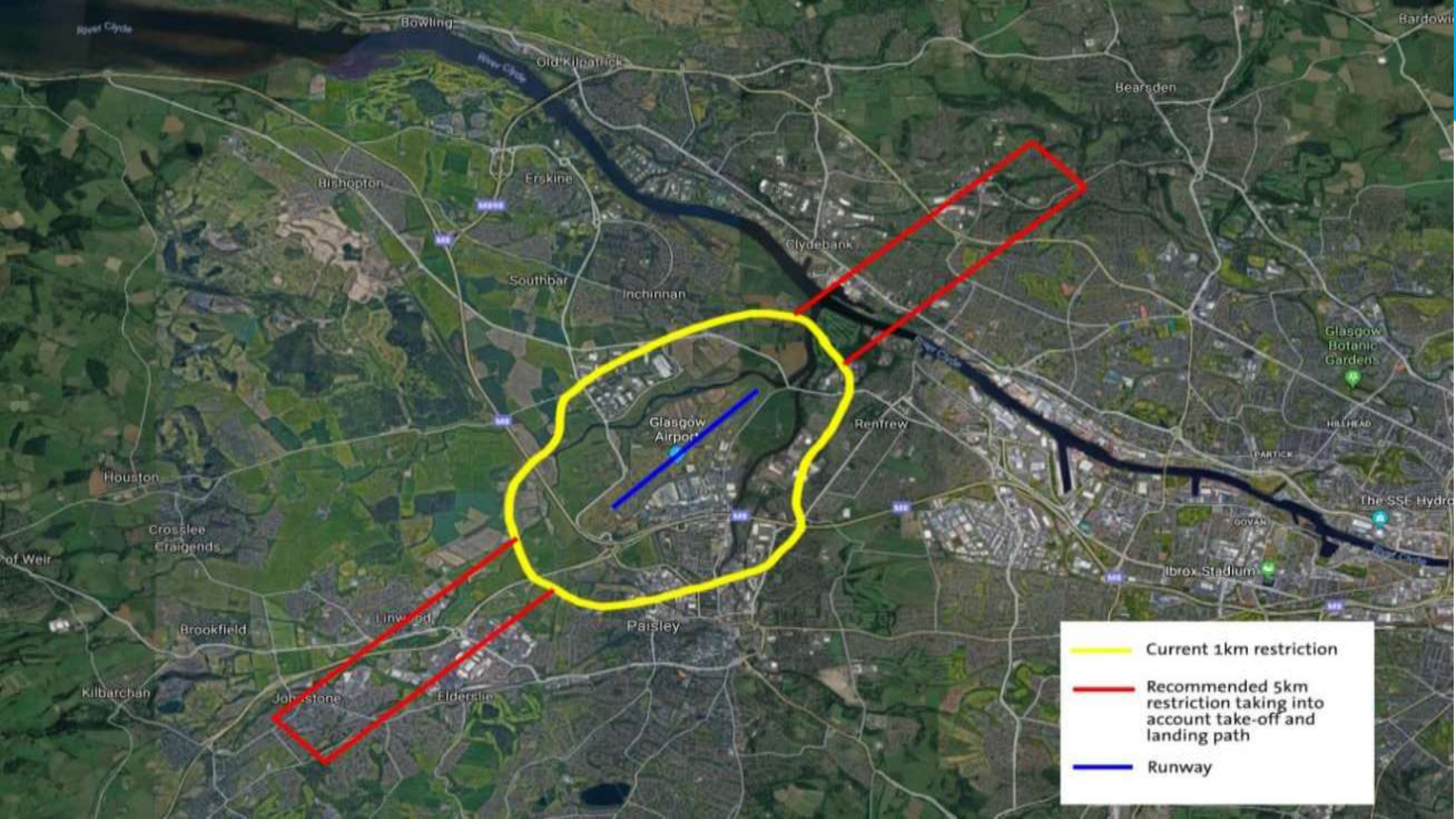
..but is it ever possible to fly safely so close to airliners on approach?

Article 94(3) The remote pilot must not fly the aircraft out of his/her sight, in order to ensure that collisions can be avoided

..but can a remote pilot really see and avoid airliners on approach?

..problems of depth perception and relative speed?

..how can we track two moving targets?



Bowling
River Clyde
Old Kilpatrick
Bardowie
Bearsden
Bishopton
Erskine
Clydebank
Southbar
Inchinnan
Glasgow Botanic Gardens
Glasgow Airport
Renfrew
Hillhead
Partick
Houston
The SSE Hydro
Govan
Crosslee
Craigends
Ibrox Stadium
Linwood
Brookfield
Paisley
Kilbarchan
Johnstone
Elderslie
Current 1km restriction
Recommended 5km restriction taking into account take-off and landing path
Runway

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Thank-you

robhunter@balpa.org

Making every flight a safe flight