European Union Aviation Safety Agency

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EASA Research project ‘Vulnerability of manned aircraft to drone strikes’

Final project presentation

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Background

Recommendation from the EASA drone – aircraft collision Task Force 2016:

The Task Force recommends that **further research should be conducted** to **establish hazard severity thresholds for collisions between drones and manned aircraft.**

- **Impact analyses should be performed** to determine the effects of a drone threat impacting aircraft critical components (…).
- To gain confidence in the model, **the method should be validated against tests on representative aircraft components** such as airframe parts, windshields and rotating elements (i.e. rotors, propellers and fan blades).

The Drones Strikes research project fully captures the recommendation

Link with the EASA Counter Drone Action Plan

#	Objective	Deliverable	Status
1	**Educate the public to prevent and reduce misuse of drones around aerodromes**	1. Safety promotion material to create public awareness and understanding of the existence and purpose of geographical zones. 2. AMC/GM defining a common unique digital format for UAS geographical zones.	Completed 2020 & **Ongoing** Completed Feb-22
2	Prepare aerodromes to mitigate risks from unauthorized drone use	EASA guidance material (in the form of a manual) describing the roles and responsibilities of the actors, and best practices on how to respond to unauthorized drones in the surroundings of an aerodrome.	Completed Mar-21
3	**Support the assessment of the safety risk of drones to manned aircraft**	**Preliminary paper (Input to Objective 2) addressing the consequences of drone collision with manned aircraft in aerodrome zone**	**Completed** Mar-21 & Oct-23
4	Ensure that C-UAS measures are swiftly considered and implemented from a global safety perspective	Contribution to the development of International Standards to support the safe and harmonised implementation of Counter-UAS Systems into airport environment and ATM/ANS systems.	**Ongoing**
5	Support adequate occurrence reporting	1. Define high-level criteria to classify airprox events. 2. Evaluate compatibility of existing occurrence reporting procedures for inclusion of occurrences involving UA. 3. Develop suitable action plan to integrate UA in common occurrence reporting procedures.	Partially completed Feb-23 **Ongoing**

Research results will now replace the paper providing complete and verified information agreed with stakeholders

Research project overview

This Horizon 2020 programme has been sponsored by the European Commission

<u>Key objectives:</u>

→ **to deepen understanding** - through experimental testing and simulation techniques — of the effects of collisions between mass market drones and manned aircraft;

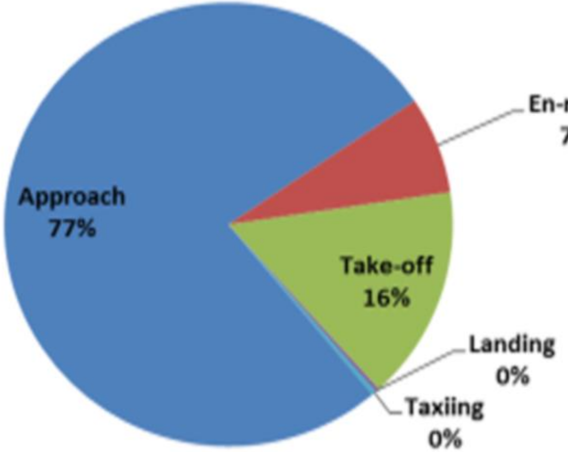
→ **to identify drone design strategies** aimed at containing the risk that drone-aircraft collision may induce on the aircraft and its occupants; and

→ **pending the research results, to define a draft design requirement and test standards** for future drones to be put on the market within the EU open category (CE marking).

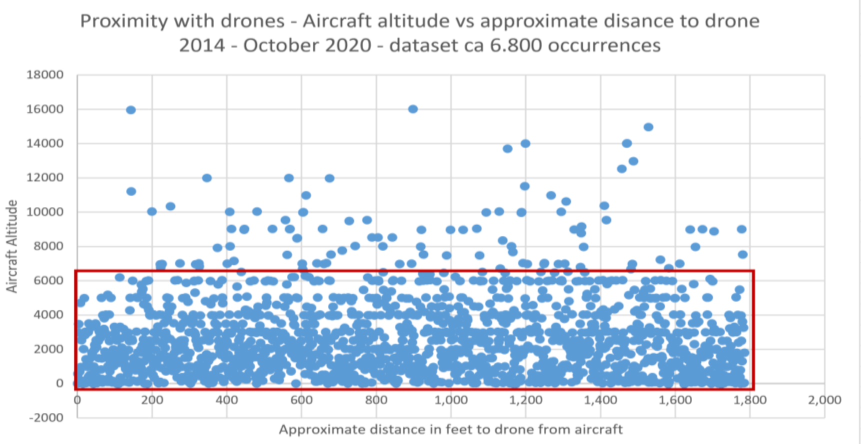
Observed near missed between drones and manned aircraft

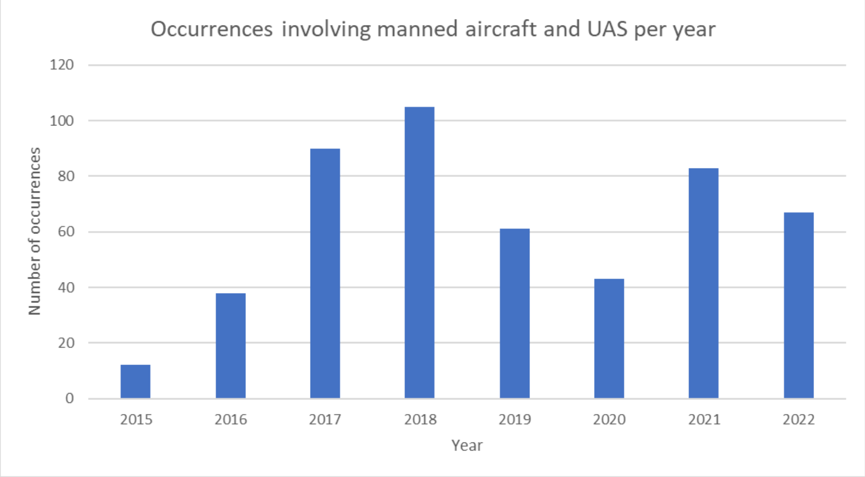
The vast majority of sightings of drones from aircraft occur:

- Below 6,000ft altitude
- During the Approach phase of flight



Phases of manned aircraft flight and drone detection (from EUROCONTROL voluntary ATM incident reporting by airlines (rotorcraft and GA not included)





Any type of occurrence involving manned aircraft AND UAS (source ECR database, UK excluded)

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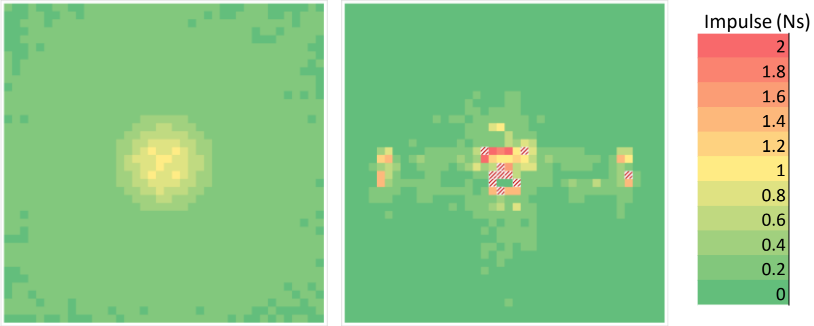
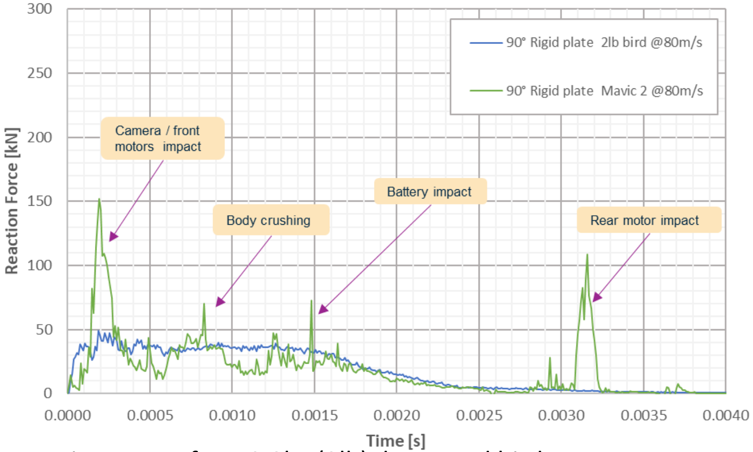
Bird strike comparison

- Drone impacts are more severe than collisions with birds of the same mass
  - Drone impact forces are concentrated at component locations
  - Greater peak forces in drone collisions
  - Bird can flow around a structure

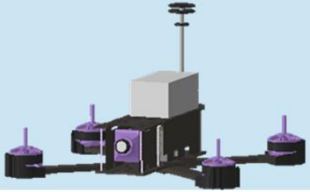


Distribution of impact forces (Impulse) on a flat plate target



Force-time curve for a 0.9kg (2lb) drone and bird

Drone ‘threats’ modelled within the programme

Name	Mass	Dimensions* (width x length x height)	Maximum speed (Sport mode)	Image of Threat Model
DJI Mavic Mini	0.249kg	202x159x55mm	13.0 ms^{-1}	
Eachine Wizard X220s	0.540kg	210x175x80mm	27.0 ms^{-1}	
DJI Mavic 2	0.905kg	322x242x84mm	20.0 ms^{-1}	
Delair UX11	1.365kg	1100x675x120mm	23.2 ms^{-1}	
DJI Inspire 2	3.426kg	520x465mm	26.1 ms^{-1}	

Vulnerability evaluation

Completion of approximately 1,500 collision simulations, evaluating impacts:

- Of **all drones** considered
- Against **all manned aircraft** considered
- On **critical impact locations**
- On a range of **realistic speeds**

Hazardous event: if estimated effect is HEC 1 or 2 (Hazardous Event Classification). does not mean that fatalities will necessarily occur

Data have been further elaborated for manned aircraft take-off/landing and approach/climb phases to provide a pragmatic result in terms of probability.

Severity Level	High — Hazardous event		Low — Undesirable event		
	HEC 1 (most severe)	HEC 2	HEC 3	HEC 4	HEC 5 (least severe)
Effect on A/C	Normally with hull loss	Large reduction in Functional capabilities or safety margins	Significant reduction in Functional capabilities or safety margins	Slight reduction in Functional capabilities or safety margins	No effect on operational capabilities or safety
Effect on Occupants (excluding. Flight Crew)	Multiple fatalities	Serious or fatal injury to a small number of passengers or cabin crew	Physical distress, possibly including injuries	Physical discomfort	Inconvenience
Effect on Flight Crew	Fatalities or incapacitation	Physical distress or excessive workload impairs ability to perform tasks	Physical discomfort or a significant increase in workload	Slight increase in workload	No effect on flight crew
Effect on Operations	Total loss of separation. Total loss of control, mid-air collision, flight into terrain or high speed surface movement collision.	Large reduction in separation or a total loss of air traffic control for a significant period of time	Significant reduction in separation or significant reduction in air traffic control capability.	Slight reduction in separation or slight reduction in air traffic control capability. Significant increase in air traffic controller workload.	Slight increase in air traffic controller workload.

Limitations and cautions

- The study has assessed collisions against traditional aluminium alloy airframes, rather than more-modern composite constructions

- Probabilities are derived from a simplified perfectly frontal collision
  - In particular for rotorcraft probabilities are referred to fuselage impacts only, addressing rotors separately

Role of cooperation

- Gaps of study strongly filled with international cooperation (ASSURE and other organizations)
  - Engine ingestion
  - Main rotor and tail rotor blades (specimens not available to cover all classes)

Recommendations for drones design

- **Excessively-heavy constructions and excessive maximum speeds**, that are not required to meet the legitimate operational use-case requirements of the product, should be **avoided.**

- **Multi-rotor drones**: frangible and/or folding motor arms are preferred to stiff/strong constructions;

- Where **major components**, including forward-mounted cameras, are assembled in close proximity and/or installed along the **body axis**, it is desirable to:

  → include gaps between them avoiding high stiffness which could cause them to act as a single projectile;

  → offset them vertically and/or laterally, rather than aligning them on common axis.

- **Fixed wing drones:** 'pusher prop' designs are greatly preferred, rather than 'puller-prop' configurations. Where **spinners** are used on horizontally-mounted motors, slender and / or pointed designs should be **avoided**, and the potential of energy-absorbing mechanisms considered.

- **Batteries:** batteries containing cylindrical steel-case cells should be **avoided**. Pouch-style batteries (in rolled or layered configurations), with cases that are not excessively strong are preferred.

Usability of research results

- Complementary data to inform **C-UAS risk assessments**
- No hazard for Large Aircraft and Business Jets align with **simplified rules for drones under 250 gr** (no registration; no DRI) -
- Recommendations and draft standards for **drone design**
- Recommendation and observation for **manned aircraft design**
- (By-product): **confirmation of JARUS crash area model**
- Inform the identified safety issue **Damage tolerance to UAS collisions (SI-4019)** and **Airborne conflict with an unmanned aircraft system (UAS) (SI-2014)** found in volume III of the EPAS
- Support EASA's efforts to understand the severity of drones strikes to manned aircraft. Through the **Safety Risk Management process**, this will then lead to **appropriate EPAS actions**

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