Bird Strike threat on jet airliners

Current protection and prevention techniques / Focus on Certification Requirements

North American Bird Strike Conference
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Beatriz Angulo-Ibanez
Antoine Pilon
Mohan Babu V

AIRBUS

Index: 360º around Bird Strike threat

Increased Bird Strike risk with regard to pre-covid rates (post-covid air traffic ramp-up, climate change aspects)

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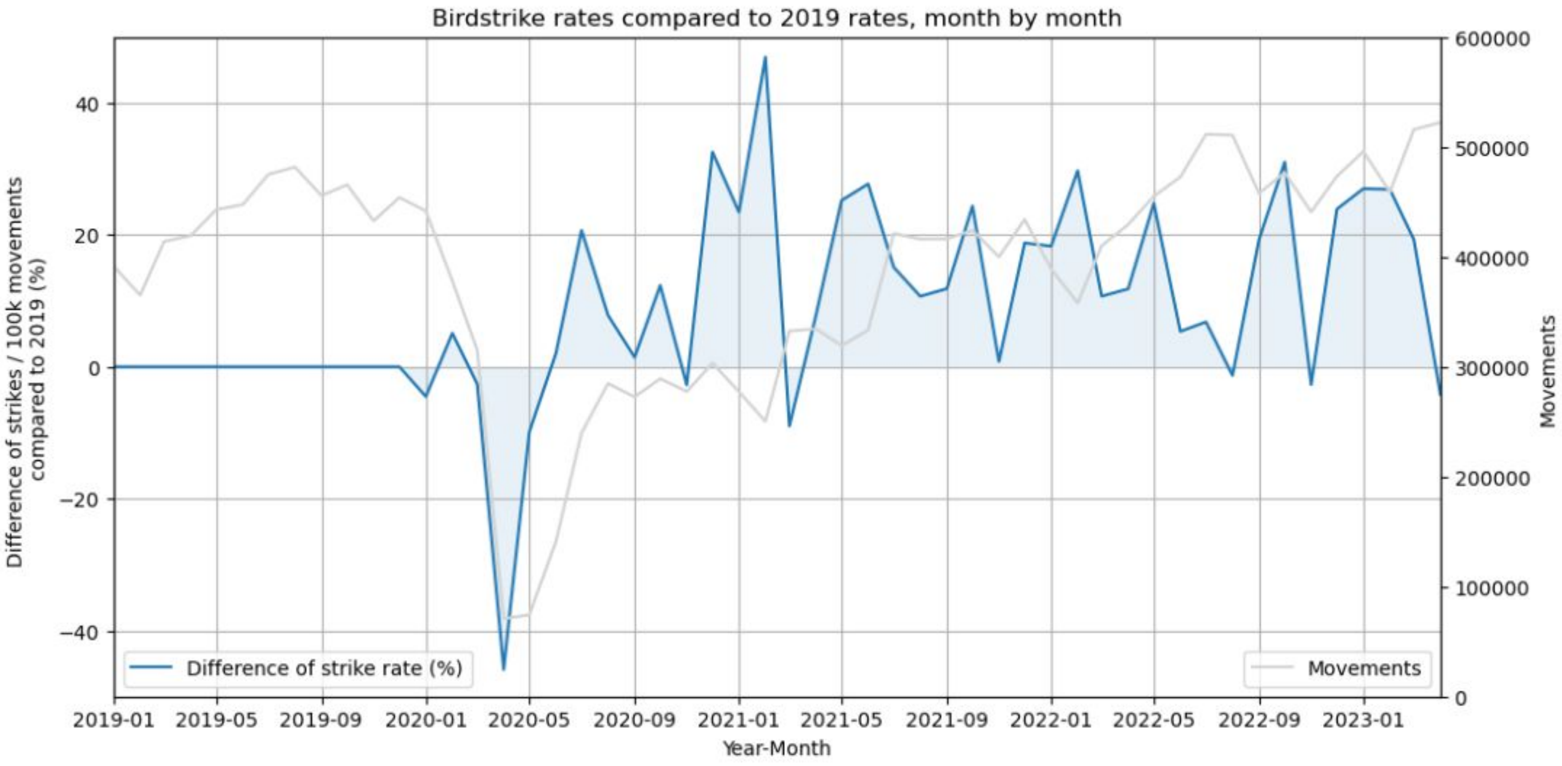
Bird Strike risk: the trends

Post-covid air traffic recovery: **measured rates** are **still higher than 2019** reference values.
Main possible influencing factors are further analysed on the following slides.

Graph refers to Airbus study conducted on A320 and A321 fleets for 13 worldwide operators from January 19 to May 23.

Bird strike rates compared to 2019, month by month

Difference of strikes / 100k movements compared to 2019 (%)



Source: Airbus platform Skywise © Airbus

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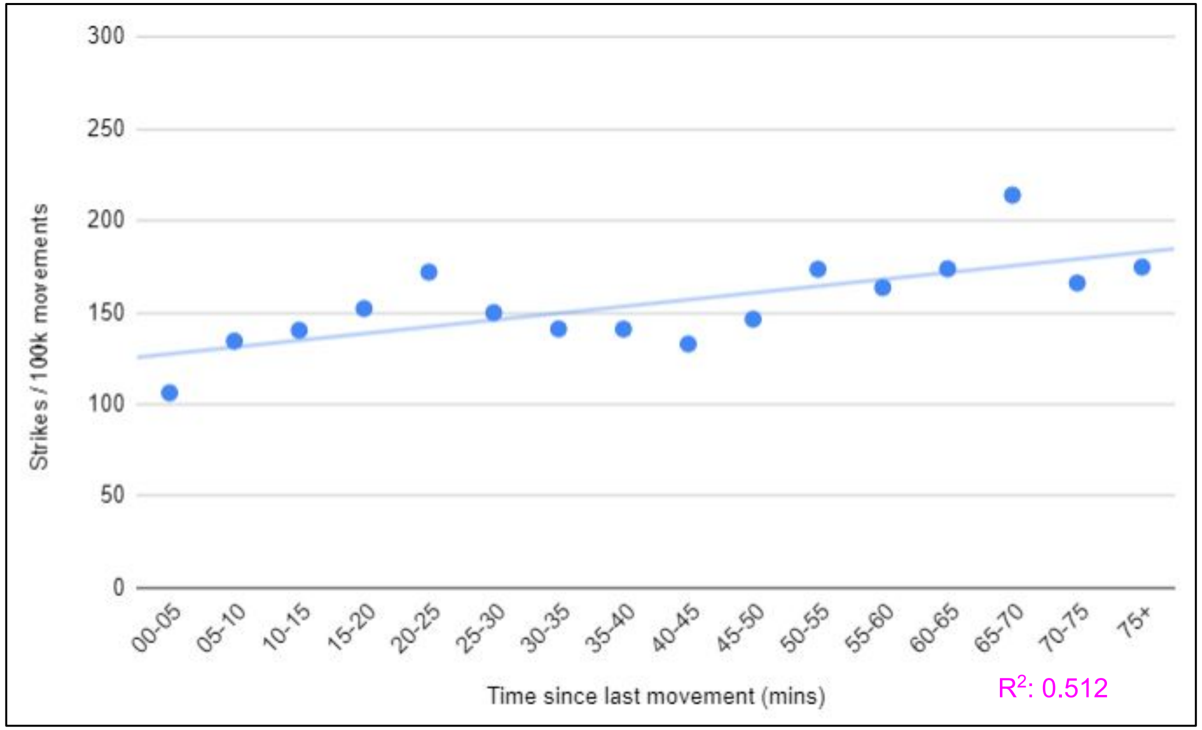
Bird Strike risk: effect of time since last movement

Post-covid air traffic recovery: **time since last runway movement** is a **measurable key risk factor**.
Reactivation of smaller regional airports with low density of movements + big airport hubs still not at full occupation of slots may contribute to this parameter.

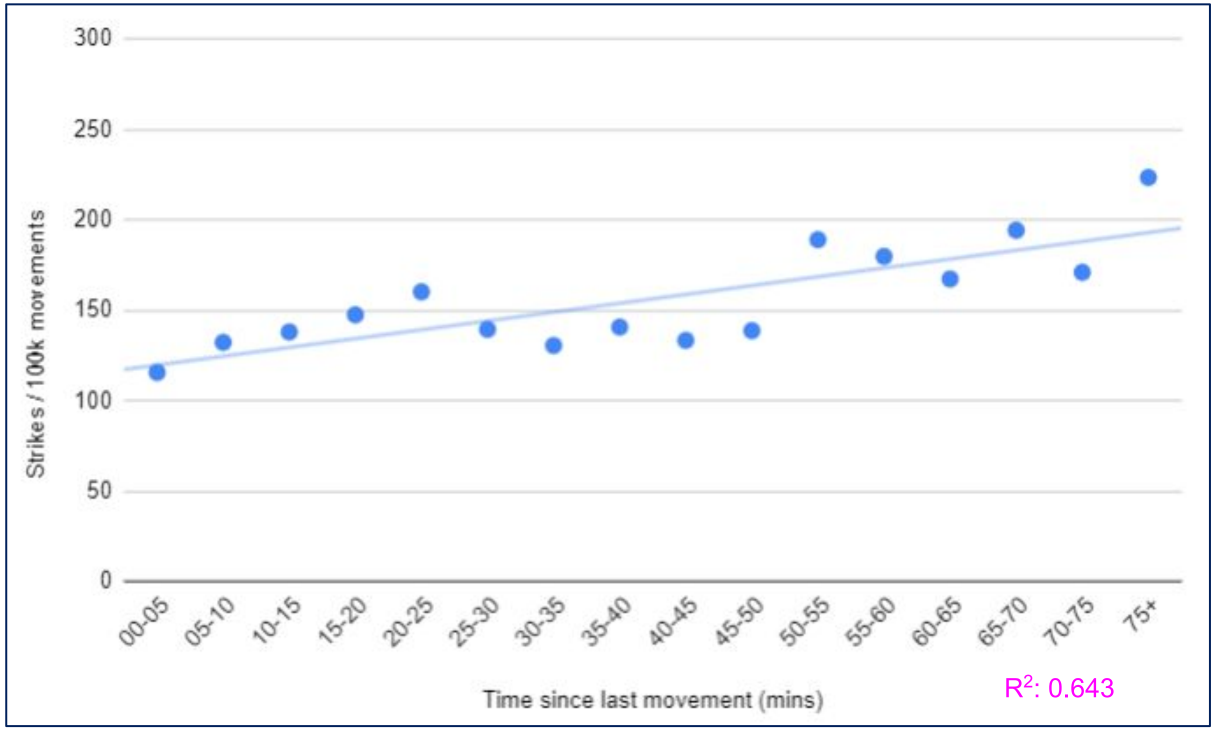
Graphs refer to Airbus study conducted on A320 and A321 fleets for 13 worldwide operators from Jan 19 to May 23.

Bird strike rates vs time since last **runway** movement



Source: Airbus platform Skywise © Airbus

Bird strike rates vs time since last **airport** movement

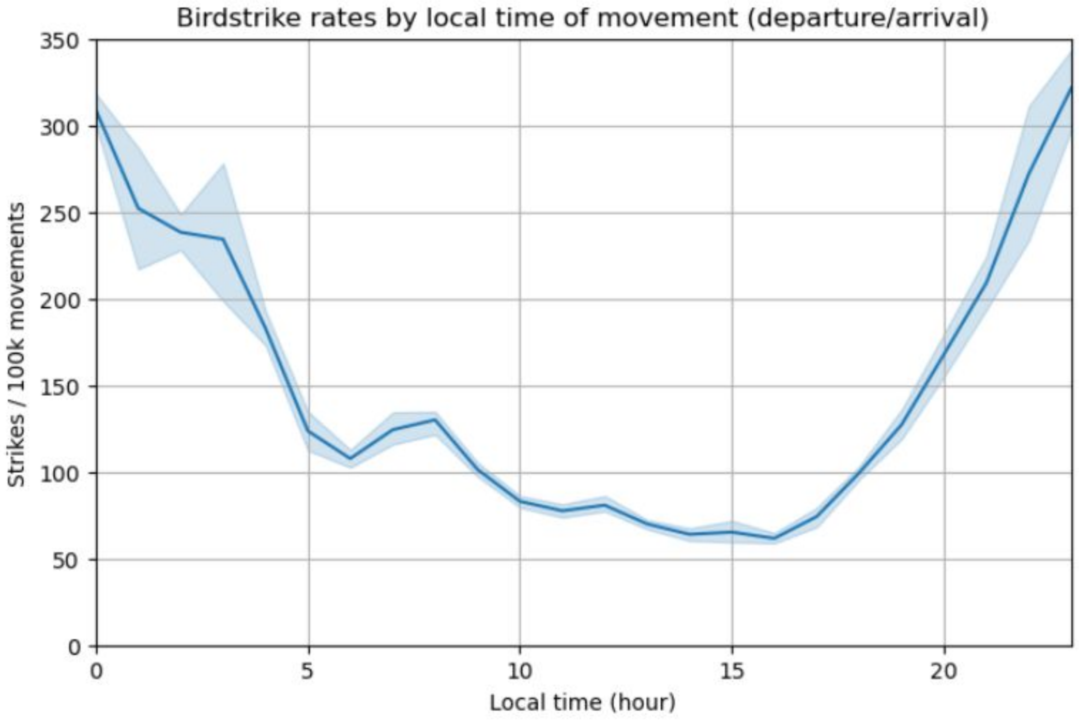


Source: Airbus platform Skywise © Airbus

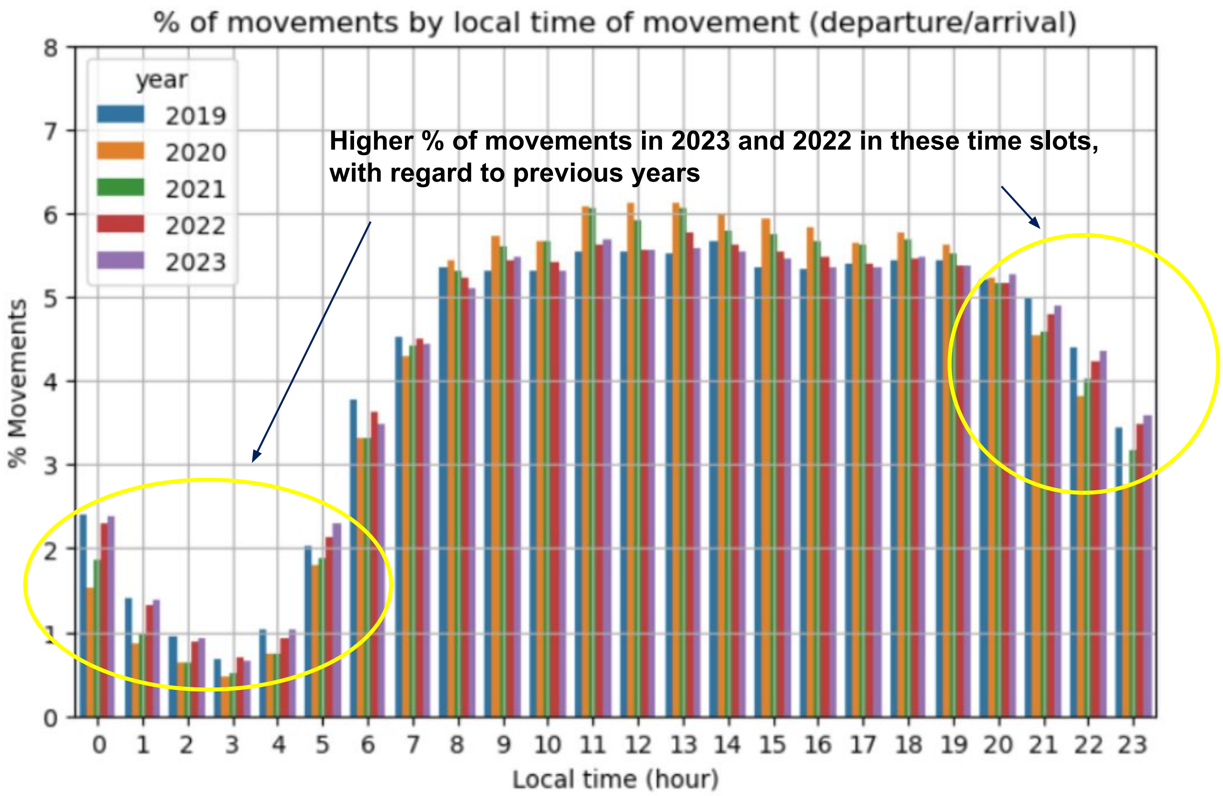
Bird Strike risk: effect of time of the day

Post-covid air traffic recovery: **time of the day** has also been identified as a **measurable key risk factor**.
Repopulation of airport slots after covid extends operations towards the sunrise/night slots, which have a higher risk of bird strike (less visibility / movement around airports, peak of birds activity just before sunrise).

Graphs refers to Airbus study conducted on A320 and A321 fleets for 13 worldwide operators from Jan 19 to May 23.



Source: Airbus platform Skywise © Airbus



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Bird Strike risk: climate change and migratory habitudes

[AIRBUS AMBER]

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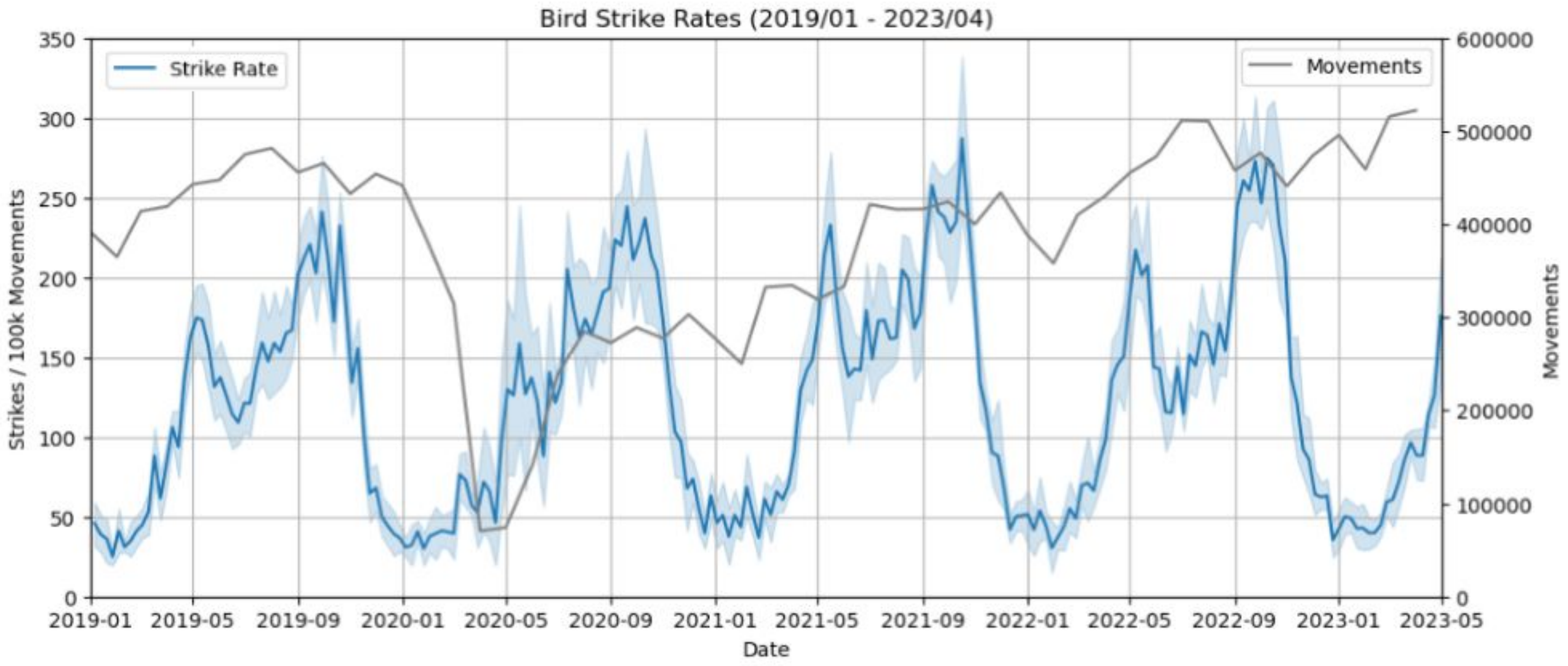
Climate change aspects: date of the year is **one of the main measurable factors** influencing bird strike rates.
Modification of migratory **habitudes** (moment of migration start) may expose to higher risk airports unprepared for it.

Graphs refer to Airbus study conducted on A320 and A321 fleets for 13 worldwide operators from Jan 19 to May 2023.



Source: Airbus platform Skywise © Airbus

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Bird Strike risk: climate change and aircraft exposure

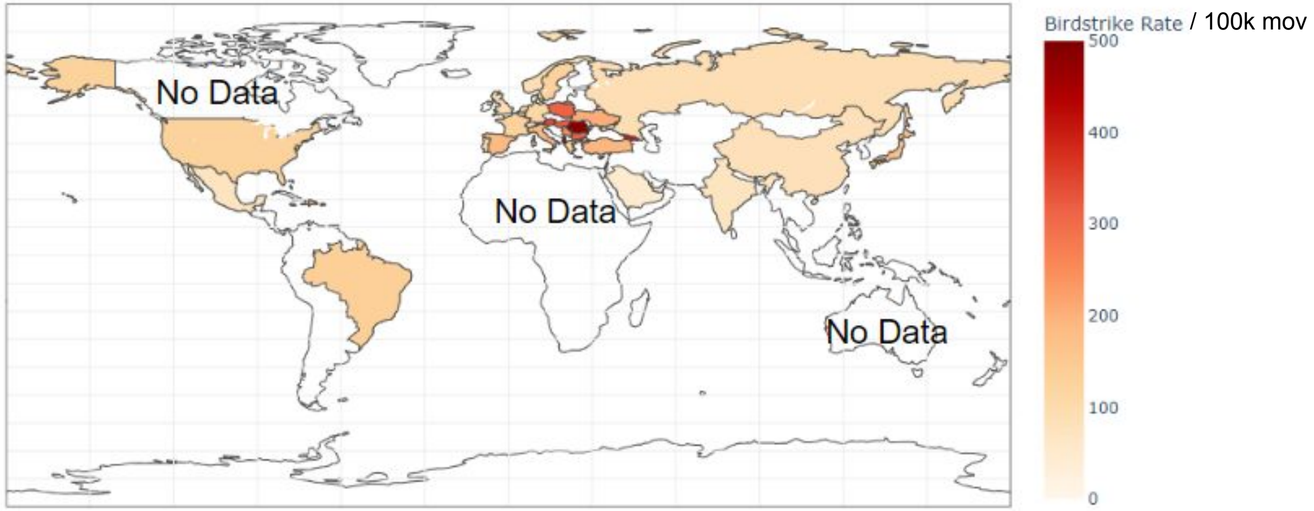
Climate change aspects: Aviar species of **bigger size** are in better position against climate challenge.

Graphs refer to Airbus study conducted on A320 and A321 fleets for 13 worldwide operators from Jan 19 to May 23.

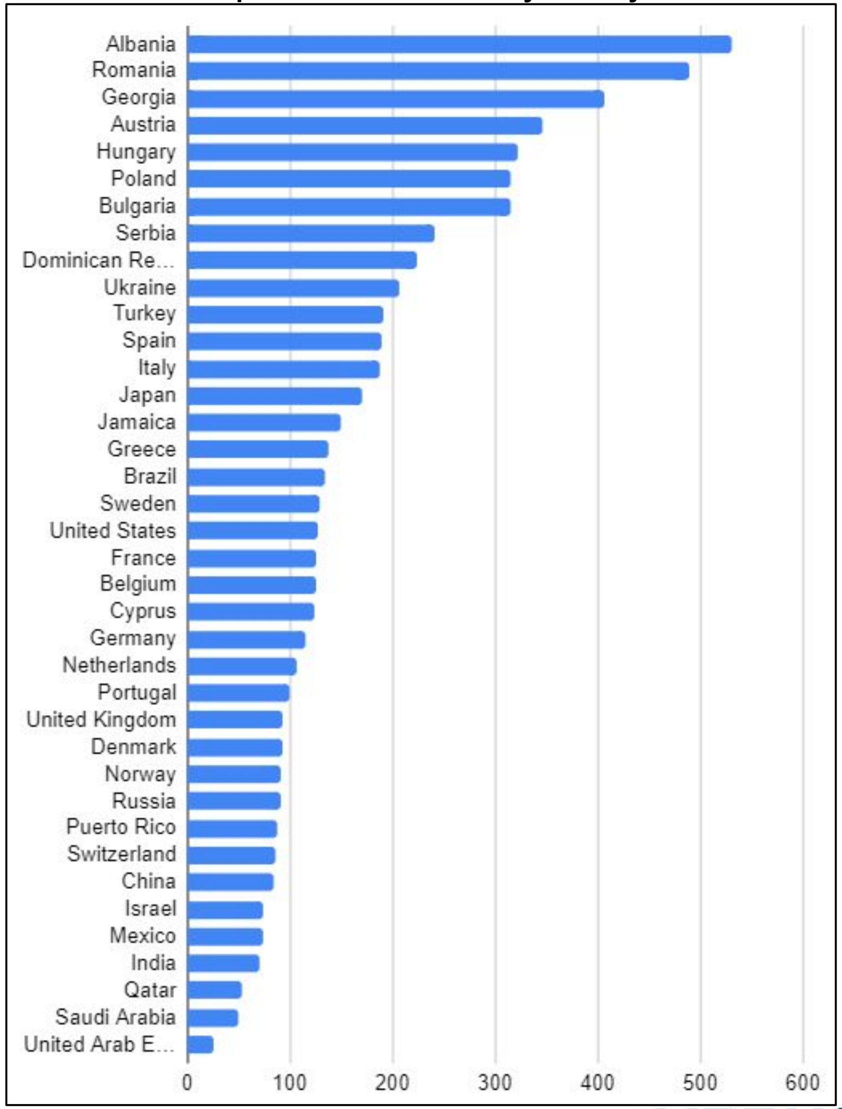
Geographical aspects: Eastern Europe, on one of the main migratory routes between Scandinavia and Africa, presents the highest strike rates.

Note: Data in Eastern Europe limited to one operator, using small regional airports with limited wildlife prevention means.

Source: Airbus platform Skywise © Airbus



Bird strike rates per 100k movements by country



Source: Airbus platform Skywise © Airbus

Bird Strike protection: regulation for Large Airplanes <u>CS 25 / FAR 25</u>

- CS 25.631 Bird Strike Damage

  "The aeroplane must be designed to assure capability of continued safe flight and landing of the aeroplane after impact with a **4 lb** (1,814 kg) bird when the velocity of the aeroplane (relative to the bird along the aeroplane's flight path) is equal to VC at sea-level or 0·85 VC at 2438 m (8000 ft), whichever is the more critical. Compliance may be shown by analysis only when based on tests carried out on sufficiently representative structures of similar design."

  AMC 25.631 draws the attention to consideration of the location and installation of items, systems and equipment in relation to bird strike.

- FAR 25.631 Bird Strike Damage

  *The **empennage structure** must be designed to assure capability of continued safe flight and landing of the airplane after impact with **an 8-pound bird** when the velocity of the airplane (relative to the bird along the airplane's flight path) is equal to **VC at sea level**, selected under § 25.335(a). Compliance with this section by provision of redundant structure and protected location of control system elements or protective devices such as splitter plates or energy absorbing material is acceptable. Where compliance is shown by analysis, tests, or both, use of data on airplanes having similar structural design is acceptable.*

- 25.775 (b)(c) Windshield

  (b)Windshield panes directly in front of the pilots in the normal conduct of their duties, and the supporting structures for these panes, must withstand, without penetration, the bird impact conditions specified in CS 25.631. **Note:** Airbus designs windshields to withstand **8-pounds bird.**

- 25.1323(j) Airspeed Indicating system (segregation requirement)

  Where duplicate airspeed indicators are required, their respective pitot tubes must be far enough apart to avoid damage to both tubes in a collision with a bird.

Note: first bird strike was recorded by the Wright brothers in 1905.

Requirements imply, depending on the aircraft component, **either demonstrating no penetration** in case of bird strike **or** providing a **redundant load path / system provision**, if there is penetration and damage.

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Bird Strike protection at airplane level: affected areas

No penetration + no critical systems installed behind (shock wave effect)**:**

- Windshields (transparencies, posts/sills) + upper and lower panels.

Penetration with **redundant load path / sufficient residual strength +** redundant **systems provision (segregation) behind:**

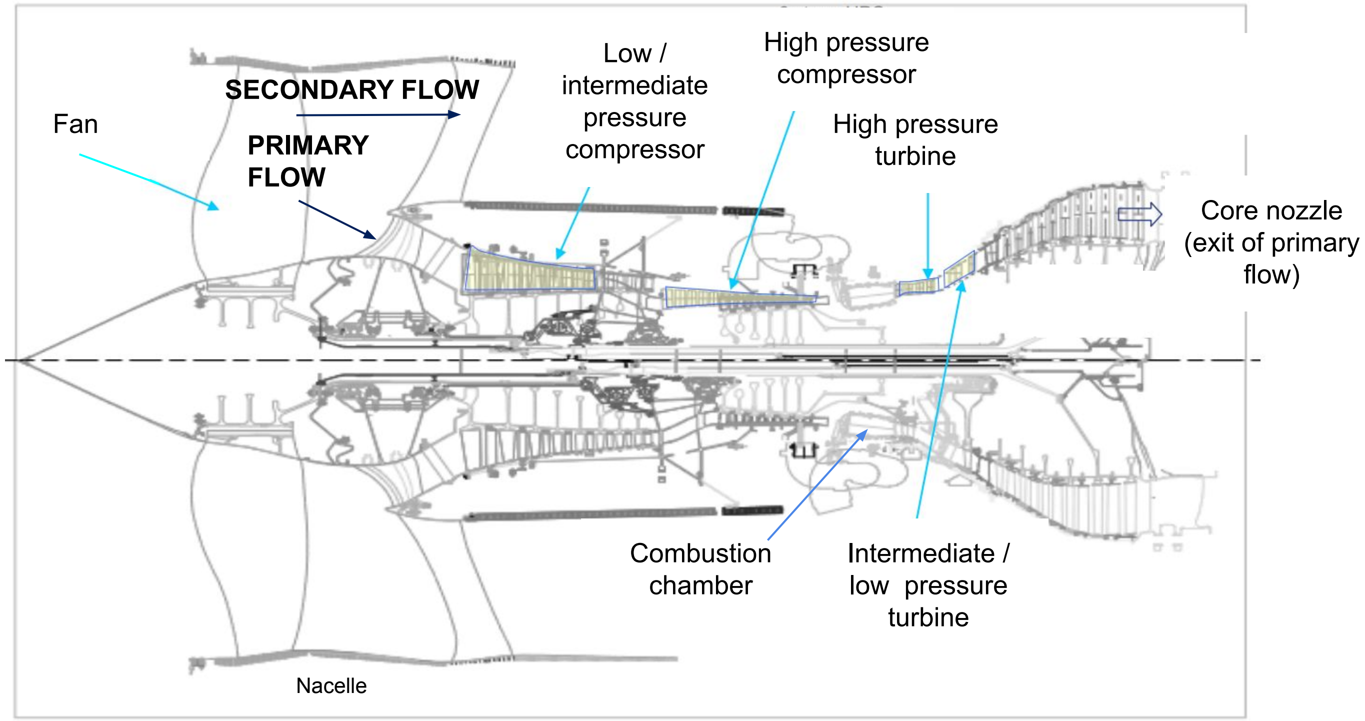
- Nose, Radome
- Forward pressure bulkhead
- Wings (Leading edge, slats, flaps) and winglets
- Pylons and nacelles
- Horizontal and vertical stabilizer (leading edges)
- Fairing (belly fairing, wing to fuselage..)
- Landing gears and landing gear doors
- Externally mounted devices (probes, antenna..)

Source: Airbus internal procedural documentation © Airbus

Specific normative for **Engines** (following slides).

Note: the ailerons, rudders, elevators and spoilers may be considered depending on exposure time (not requested by certification yet).

Bird Strike protection: Engine regulation CS-E 800 (E) / FAR 33.76
Focus on turbine / turbofan engines



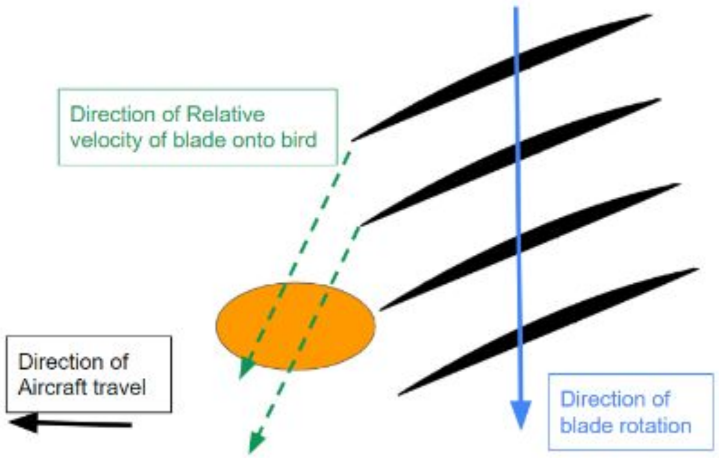
Source: Airbus Certification documentation © Airbus

In 1960, a Lockheed Electro L-188 crashed into the sea while attempting to take-off from Logan Airport in Boston, following a bird strike into 3 of its 4 engines. This accident, which was the first ever attributed to bird ingestion, led to the publication in **1965** of the first **Certification Requirements related to bird strike into engines.**

Since then, related normative has been updated 4 times, becoming **each time more demanding** through **in-service feedback** (notably the 1975 DC-10 runway excursion at JFK and the 2009 A320 Hudson River ditching).

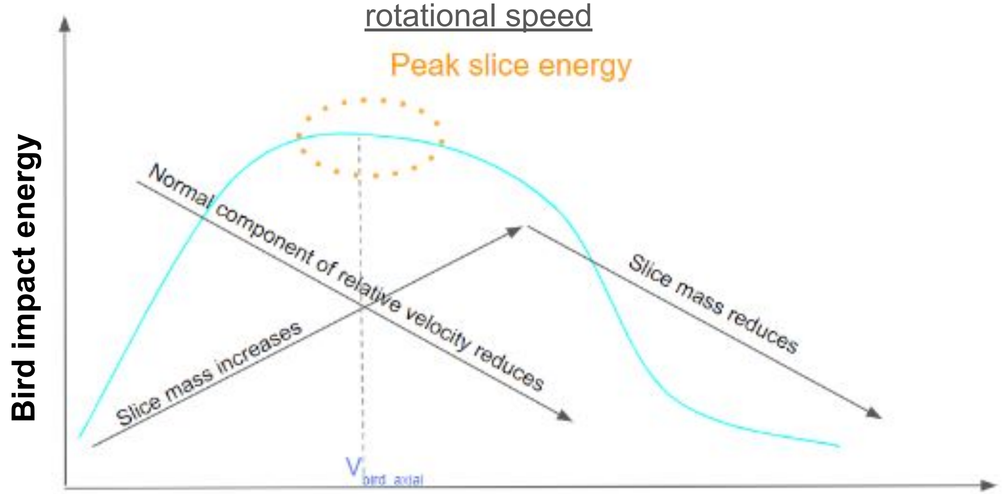
Bird Strike protection: Engine regulation CS-E 800 (E) / FAR 33.76
Focus on turbine / turbofan engines

View from above fan blades
(typical bird impact modelling)



Source: Airbus internal procedural documentation © Airbus

Impact Energy vs Aircraft Speed for a given bird mass at 100% Take Off power / 100 % fan rotational speed



Aircraft speed (equivalent to bird impact speed)

Source: Airbus internal procedural documentation © Airbus

The bird is **sliced** by the one or several **fan blades** that it can encounter. The **peak of slice energy at the tip of the fan blade**, for a given bird mass and Take Off power, takes place at an **aircraft speed around V1** (just before **aircraft rotation point**). Refer to graph on the right.

After the fan, the slice can follow the **primary flow into core** or being **centrifuged** to **secondary flow**. At bird ingestion, engine damage affects typically the **fan blades**, then -if in **primary** flow- also **compressor blades and combustion chamber.** The higher the fan rotational speed, the lower the possibility that the slices enter primary flow.

The moment of aircraft rotation at Take-Off, **around V1 speed**, is the **most critical impact condition** for engines and also the most critical moment for the **aircraft to lose one engine.**

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Bird Strike protection: Engine regulation CS-E 800 (E) / FAR 33.76

1) Single large bird ingestion tests:

-> The Engine operating conditions must be stabilised prior to ingestion at **not less than 100 % of the Take-off Power or Thrust** at the test day ambient conditions (**Note: 100% rotation speed** is the **most critical impact condition for fan blades**).
-> Bird speed 200 knots, or the maximum airspeed for normal flight operations.
-> Bird mass from 1,85 to 3,65 kg (4,08 to 8,05 lb) depending on inlet throat area.
-> **Typical consequence of fan blade damaged / lost** is fan imbalance and strong engine vibration, leading to **commanded idle thrust / shut down.**
-> **Test success criteria: safe shutdown.**

2) Large flocking bird ingestion tests (for inlet throat area **above 2,5m2**).

-> **"Flocking"** means that the aircraft is assumed to encounter a flock, and therefore to potentially surfer ingestion on **both engines at the same time** (therefore, requirement of **minimum remaining thrust** to pass the test).
-> **Not less than 90 % of the sea-level static Rated Take-off Thrust.**
-> Bird speed 200 knots.
-> Bird mass up to 2,5 kg (4,4 lb) depending on inlet throat area (**only one bird**).
-> **Test success criteria:** no sustained **reduction of thrust to less than 50 %** Rated Take-off Thrust or the Engine to shut down + 20 minutes minimum run-on time.

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Bird Strike protection: Engine regulation CS-E 800 (E) / FAR 33.76

3) Medium and small flocking birds ingestion tests:

-> Similar operating conditions of single large bird ingestion tests.
-> Small birds: one 85gr (0,18 lb) bird per 0,032m2 of inlet area, with a maximum of **16 birds.**
-> Medium: depending on inlet area, up to **7 birds** of 0,7 & 1,15kg (1,5 & 2,5 lb).
-> Test success criteria: no more than a sustained **25 % power or thrust loss** or the Engine to be shut down + 20 minutes minimum run-on time.

4) Core engine flocking bird ingestion tests
(recently updated by FAA as a result of the 2009 "Hudson Miracle"):

-> Operating condition at the **lowest necessary power or thrust** required to perform **climb from 3000 ft above ground level** in revenue service
(**Note**: equivalent to about **80% of max rotation speed, most critical condition for core = maximum slice mass ingested**).
-> Bird speed 250 knots, bird mass up to 1,15 kg (2,5lb) depending on inlet throat area.
-> **Typical worst consequence of bird ingestion into core** is **combustion chamber flame out / uncommanded shut down**.
-> Test success criteria: no sustained reduction of thrust to less than **50 %** Rated Take-off Thrust, or a sustained reduction in power or thrust to less than flight idle during the run-on segment of the test, or the Engine to shut down + 20 minutes minimum run-on time.


Courtesy: National Transportation Safety Board (source: NTSB report AAR-10/03 of.2009 "Hudson Miracle")

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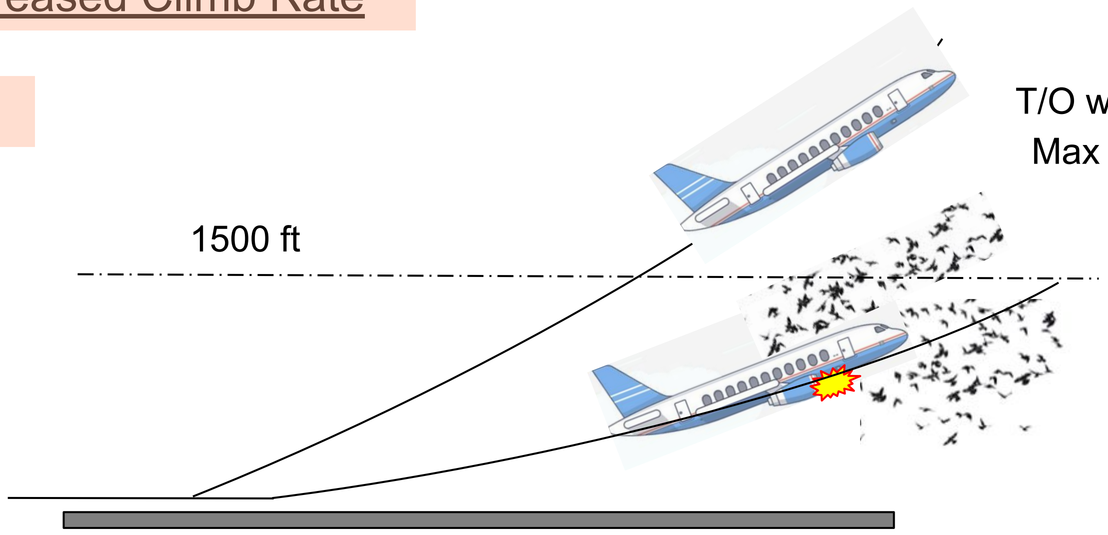
Bird Strike prevention: Operational Recommendations

1) Studies conducted about reduced Flex / increased Climb Rate

(subject of dedicated presentation by Rolls Royce)

- PROs of the operational recommendation:
  Reduction of bird strike risk exposure, by minimizing the time at low altitude.
  Potential reduction in damages to engine core (at higher power, bird slice is centrifuged and does not go into primary flow).

- CONs of the operational recommendation (trade-off)
  Maximum Take-Off power is the most critical condition for fan blades. Probability of Fan Blade damage is maximized.



Source: Airbus internal documentation © Airbus

However: analysis performed by 3 Engine Manufacturers does **not** support the intended Operational Recommendation.

T/O with reduced Flex / increased Climb Rate would **reduce the number of bird strikes**, but the remaining ones would be **more damaging to engines** (most critical operational condition for fan blades becoming standard and not occasional).

Bird Strike prevention: Operational Recommendations

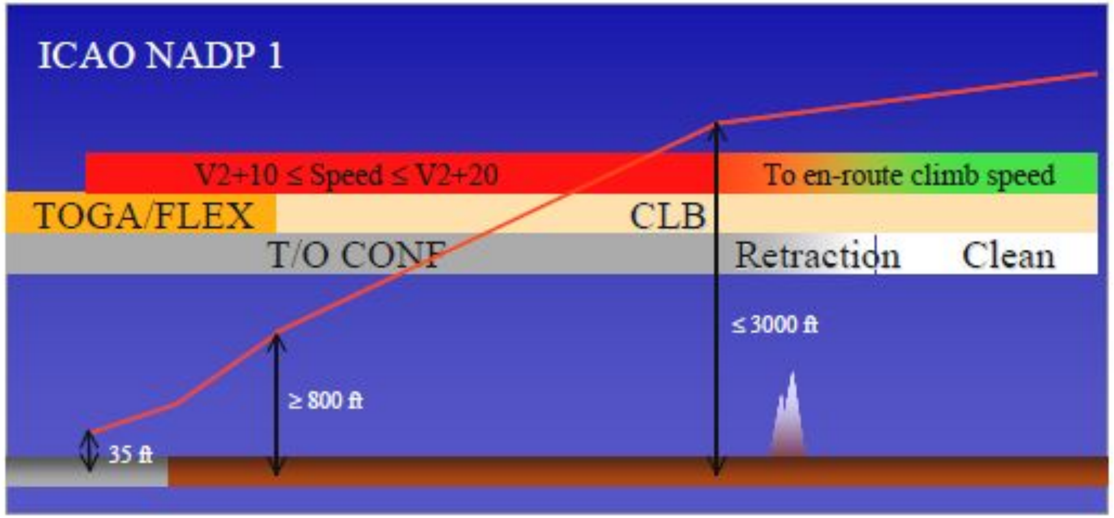
2) Noise Avoidance Departure Procedure / ICAO Vertical Noise Abatement profile "1":

-> Consists in **maximum Climb Rate without increase of Thrust.** Already recommended by **Air Line Pilots Association (ALPA).**

-> It involves a thrust cutback at or above a prescribed minimum altitude (800 ft) and delaying the flaps/slats retraction no later than the prescribed maximum altitude (3000 ft). At the prescribed maximum altitude, acceleration and flaps/slats retraction are performed according to standard schedule while maintaining a positive rate of climb and then completing the transition to normal en-route climb procedures.

-> The benefits are: low aircraft speed, which reduces impact force; rapid climb rate; and climb-out occurs as close to the airport boundary as possible, where bird activity is managed.

-> **APU-on** is also recommended whenever bird strike risk is perceived (to facilitate a quick engine restart attempt and provide electrical power).



Source: Airbus internal procedural documentation © Airbus

At landing:

-> It is recommended to proceed with landing, even if bird strike risk is perceived. **Go-around maneuver with thrust increase has got higher risk of engine damage** in case of strike. Statistically, about ⅔ of bird strikes happen during Arrival phase (and ⅓ at Departure).

Bird Strike prevention: Aircraft mounted devices

General limitation: it is **difficult to verify the real efficiency** of aircraft mounted devices,

- Some aviar species might be sensitive but others not -> possible influence of local bird population on in-service results, difficult to test devices during their development phase.
- Lack of exhaustive data from in-service experience endorsing (or not) existing devices.

a) With regard to **Pulsing Lights**:

➢ Alaska Airlines and Qantas, among other operators, have embodied this device on their non-Airbus fleets.

➢ **Any return of experience** that can be shared, regarding the efficiency of this device, is very interesting.

➢ Artificial intelligence and cloud technology might offer better solutions to study the efficiency of this kind of devices in the future.

Bird Strike prevention: Aircraft mounted devices

b) **FAA published on July 2022** promising **studies** regarding birds' vision **sensitivity to ultraviolet:**

- 300-400nm wavelength range, **pulsing ultraviolet LED lights replacing usual landing lights.**
- Test performed on an Air Tractor 802 (general aviation aircraft) during about 80h over several weeks.
- It was estimated that birds spotted the airplane from 166 yards (151,8m) away, versus 108 yards (98,7m) without the lights on.
- Research performed at the FAA's William J. Hughes Technical Center.

Ultraviolet lighting / reflective paint is **a very promising line of investigation** regarding aircraft mounted devices to avoid bird strike.

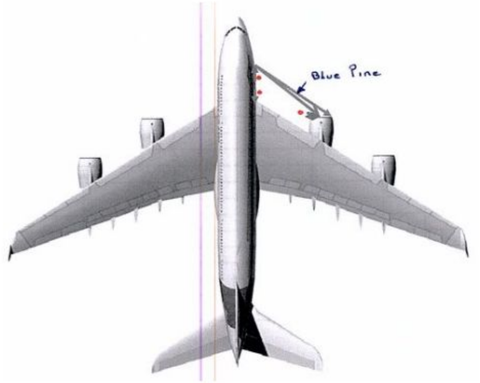
Bird Strike prevention: Wildlife management at airport level

Some initiatives tested by Airbus in the last years:

➢ ***Airbird Visual*** -based on LED screens of high visibility- proved not to generate habituation on **birds of prey** at Tarbes airport (south of France). However: very limited deployment.
Based on **knowledge about aviar vision, circular moving patterns on screen create a "looming" effect.**

These looming patterns were developed in the context of a previous Airbus project, the **<u>"Birdy" mounted device:</u>**

- Idea consisted in using the **engine fan as a screen** to project with laser the visual patterns.
- Project was stopped due to technical complexity: for instance, some engine models have an unusable fan screen due to black blades.



Source: Airbus internal documentation © Airbus

Source: "Test de Qualification du signal visuel AIR BIRD RAPACES developpé par Airbus", Service Technique de l'Aviation Civile, v1.2 dated 27/09/2017. Courtesy of Richard METZGER / DGAC – STAC.

KEY MESSAGES / CONCLUSIONS

- **Current bird strike rates are above pre-covid values.**
- Protection against bird strike is obtained through compliance to **Certification Requirements**, which are continuously evolving **(specially for engines) to become each time more demanding.**
- The moment of **aircraft rotation at Take-Off, around V1 speed**, is the **most critical bird strike condition for engines**, with the highest possibility of experiencing thrust loss. Also, it is the **most challenging condition** for the **aircraft if one engine is lost.**
- This makes especially critical the **wildlife management at airport level.**
- **High interest in exploring further means to reduce bird strike risk.**

AND… BIRDS ARE **NOT ONLY** A THREAT FOR AVIATION.

To be fair, birds are also a source of constant **inspiration** for us.

- In November 2021, Airbus successfully tested an **end-to-end new concept of operations** with **Fello'Fly:**
two A350 -one lead, one follower- together in a route Toulouse-Montreal, imitating the "V-shape" pattern of **migratory geese.**

- During commercial aircraft operations, air upwash enables a follower aircraft to benefit from free lift, resulting in **less engine thrust and, as a result, reduced fuel consumption.**
A technical solution developed by Airbus ensures aircraft remain safely positioned at a steady altitude throughout "paired" flight. The uplift from the wake has shown it can drive **at least a 5% reduction in CO_2 emissions per trip.**

Airbus is collaborating with Frenchbee,SAS Scandinavian Airlines, France's DSNA and DGAC, the UK's NATS, EUROCONTROL, NAVCANADA and the IAA (Irish Aviation Authority) to continue to demonstrate the operational feasibility of this project.

Source: Airbus website © Airbus

We pioneer sustainable aerospace for a safe and united world

Thank you

Bird Strike risk: some recent examples

- **Ural Airlines Flight 178** (A321ceo) from Moscow–Zhukovsky to Simferopol on **August 15th, 2019**. The flight suffered a bird strike (**flock of gulls**) after taking off and crash landed in a cornfield. **It was the first take-off of the day on that runway.** Both engines were stroken, with a complete loss of power on the left engine (not clear if a re-light procedure was properly attempted). **The proliferation of birds near Moscow–Zhukovsky airport has been attributed to illegal waste dumps.**

- **Spirit Airlines flight NK-3044** (A320neo) from Atlantic City, New Jersey, to Fort Lauderdale, Florida (**October 2nd, 2021**).
  Rejected Take-Off due to bird strike onto right engine. NTSB published report establishes that the strike eventually led to a failure of a fuel tube which ignited an engine fire.

  Analysis by the Smithsonian Institution identified the bird as a **Bald Eagle**, which is **heavier than the birds used on the FAA bird ingestion certification test**. During the certification test, the bird weight requirement was 2.75 kg (6.05 lb), and the eagle involved in the incident weighed 4.13 kg (9.1 lb).

Courtesy: National Transportation Safety Board (source: NTSB report ENG22LA002).

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Bird strike protection: Requirements to airframe and systems

- **No penetration**
  - **Structures in front of pilots**: windshield upper and lower cap (CS25.775). **Critical systems should not be installed behind** (shock wave effect).

- **Continued Safe Flight & Landing (CSF&L) in case of penetration**: applicable to **primary and secondary structures**. Up to Limit load to be sustained in non-detectable areas (for instance, leading edge/front spar of HTP) + **systems segregation** behind:

  - **Impact analysis:** Assessment of impact by Non Linear Finite Elements analysis supported by test.
  - **Residual strength analysis**: including also Air flow/dynamic pressure perturbation due to hole (in non pressurized area) and Rapid decompression effect due to hole (in pressurized area).

  - **Precautions versus non critical but heavy items (radome, belly fairing panels):** They shall not detach or, if detached, they shall not impact structures/systems essential for CSF&L.

"Fail safe" installation demonstration: attachment impacted by a single bird is considered lost, remaining attachments must ensure CSF&L.

  - **Specific Particular Risk Analysis scenarios to be excluded:**

    -Damage on flammable fluids pipes/containers on upstream path of heat sources (engine, brakes, bleed…) or damaged simultaneously with wiring.

    -Simultaneous impact on bleed and overheat detection system.

Bird Strike protection: systems installed on external fuselage

Specific segregation requirement on **pitot probes** (CS25.1323)

No hazardous consequences considering

- direct impact: loss of function.
- impact upfront the probes: may lead to perturbation with critical effects (consistent erroneous indication on two probes shall be avoided by specific monitoring function).

Ex: fuselage deformation, latch opening

- Part detachment consideration (antennas and/or antennas' radome).
- Depressurization consideration (effect of hole on fuselage).

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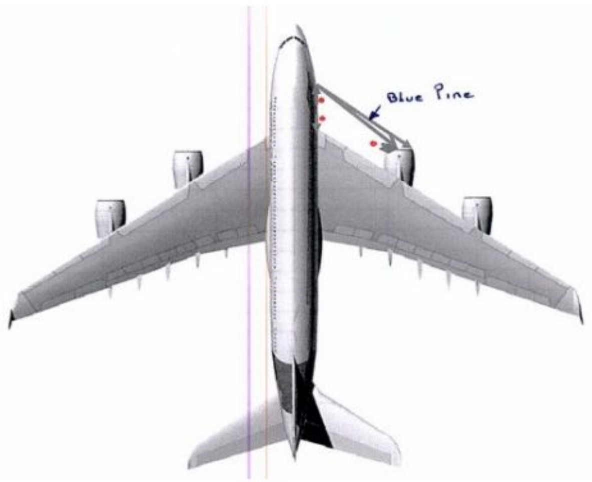
Bird Strike prevention: Aircraft mounted devices

One line of investigation explored in the past: **Airbus "Birdy" project.**

- Consisted in using the fan as a screen to project visual patterns.
- Project was stopped due to technical complexity: for instance, some engine models have an unusable fan screen due to black blades.
- Visual patterns developed were reused in the ***Airbird Visual*** project for airports (see next slide).

Airbus birdy project



Laser projection using engine fan as a screen

Also, **spirals** on engine spinner have been claimed to warn not only humans, but also **birds,** against rotating blades.

However: there are **no studies available** endorsing or discarding this theory.

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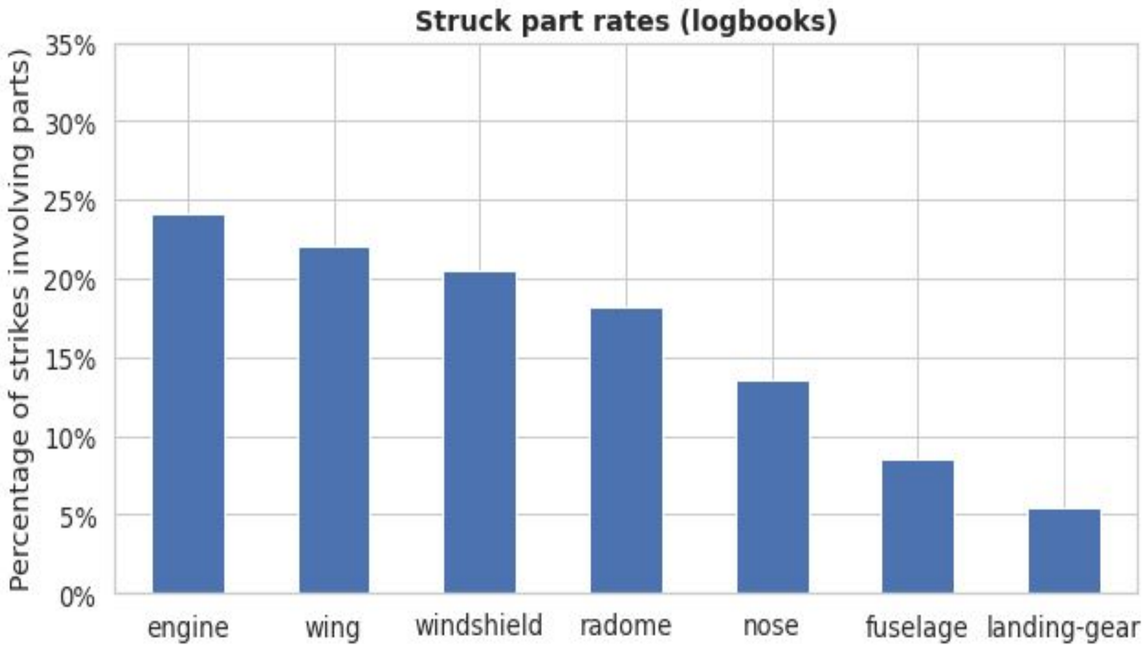
Annex– Statistical elements

- BS with damages: 1.4 10-5 / FH (2014) – 1,32 10-5/ FH (2018) [FAA]
- 9,3 % damaging BS / total BS on turbofan – 8,7 % on turbopropellers [EASA]
- 2,5 % of BS lead to substantial damage/destruction [FAA]
- Strikes with KE above current certification is 0,3%
  0,27% on turbojet A/C – 0,31% on turbopropeller A/C) [EASA]

- BS vs Altitude
  - 80% BS occur below 1500ft
    (airport environment / bird control measures)
  - 99% BS below 9500ft
  - Highest BS at 37000ft

- BS versus Aircraft part (see graph)

Graph refers to Airbus study conducted on A320 and A321 fleets for 13 worldwide operators from January 19 to April 22..

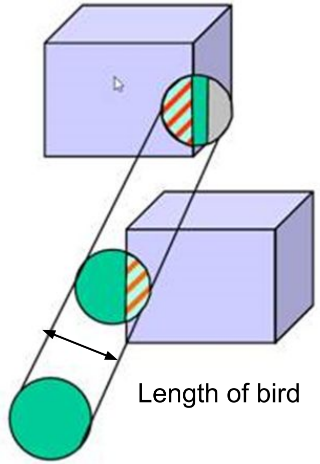


Source: Airbus platform Skywise © Airbus

Bird Strike protection: specific assumptions for systems in penetrated areas

- Shape and dimensions of the bird are considered unchanged after structure penetration.
- **Length of modelled bird** is considered as minimal distance for **system segregation** (plan normal to bird trajectory)
- After penetration, bird trajectory remain on the same axis (not realistic). *Deviated trajectories may be considered when relevant (ex: A380 test on pylon - trajectory deviated due to fairing support design)*
- If the bird is partially impacted when striking a structural part, the non impacted section may damage additional components (see sketch).
- Status considered for components in trajectory path:

Type of component	Failure mode to consider
Equipment (computer, power source, …)	Lost
Wiring	Cut open
Mechanical part	Broken or jammed
Pipe	Broken



Bird Strike protection: precautions for systems in non-penetrated areas

- **Precautions versus structure deformation area**

Critical systems shall not be installed in structure deformation area (Detailed Finite Elements Model analysis).

- **Precautions versus Shock Wave effect**

High acceleration levels may be transmitted to equipment installed directly on impacted structure, leading to system misbehavior and bracket failures.
(***ex: In 1989, an A320 was struck by a vulture hitting the top of the captain's panel of the windshield. This resulted in loss of information on 4 flight displays and fuel valve cutoff, causing one engine to shut down).***

<u>Best practice is to avoid as much as possible installing critical systems on impacted structures.</u>

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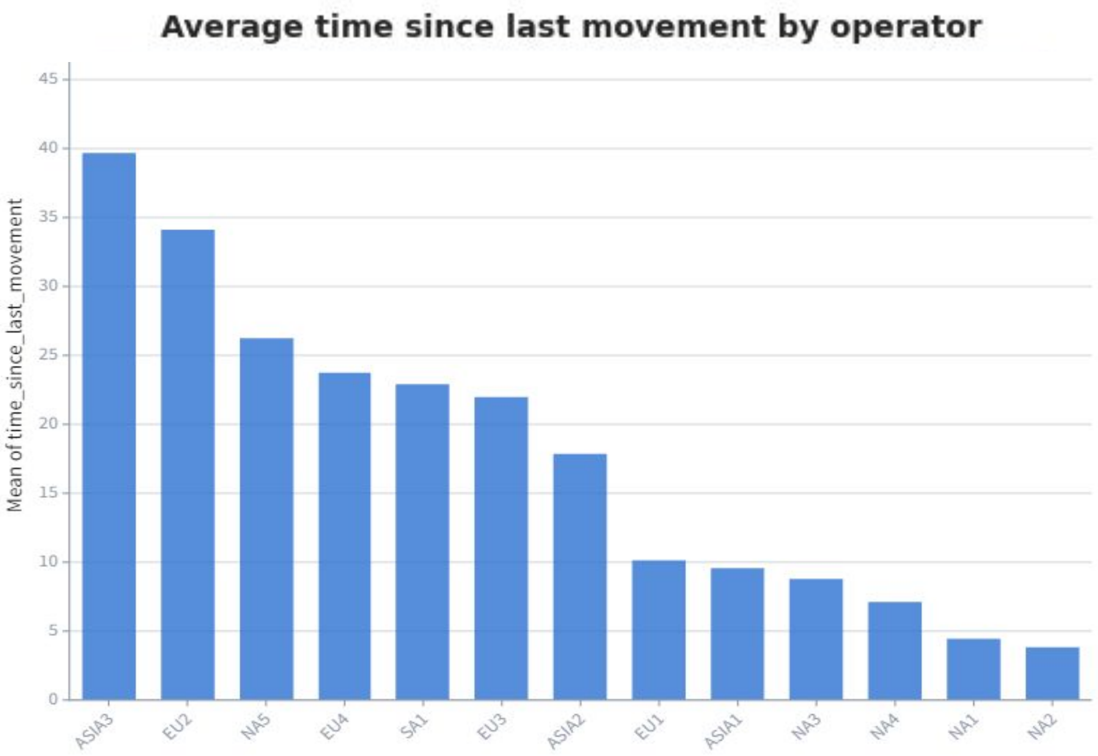
Bird Strike risk: effect of time since last movement

Post-covid air traffic recovery: **time since last runway movement** is a **key risk factor**. Reactivation of smaller regional airports with low density of movements + big airport hubs still not at full occupation of slots affect this parameter.

Graph refers to Airbus study conducted on A320 and A321 fleets for 13 worldwide operators from Jan 19 to May 23.



Source: Airbus platform Skywise © Airbus

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Bird Strike prevention: Operational Recommendations

1) Studies conducted about reduced Flex / increased Climb Rate

(subject of dedicated presentation by Rolls Royce)

- Joint initiative developed by Airbus and **3 Engine manufacturers** in the last 3 years.

- Scenario analysed: 10% of in-service Take-Offs performed with **reduced Flex / increased Climb Rate** (trade-off between Aircraft speed and Engine N1 on bird slice mass and centrifugal effect towards primary/secondary flow).

- Target is to **reduce the time spent at low altitude**, which has been identified as a key operational contributor (according to Airbus study on A320 / A321 fleets, for 13 analysed operators, bird strikes increases by 1.1% per each second spent < 1500ft).