A320neo vs A320ceo: Effect of Latest and Quieter Engines on Bird Strikes Rates

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Rationale of the study:
engine noise levels vs bird strikes, available publications

References:

- Wildlife Strikes to Civil Aircraft in the United States, 1990–2019

  "*Another complicating factor is that birds are less able to detect and avoid modern jet aircraft with quieter turbofan engines (Chapter 3, International Civil Aviation Organization 1993) compared to older aircraft with noisier (Chapter 2) engines (Burger 1983, Kelly et al. 1999)"*

- Burger, J. 1983. Jet aircraft noise and bird strikes: why more birds are being hit. Environmental Pollution (Series A) 30:143–152.

  "For landing planes, the narrow-bodied planes were significantly louder than the wide-bodied planes at touchdown, only 600 m from the test site. Wide-bodied planes had significantly more bird strikes than the narrow-bodied aircraft. These results indicate that birds have less warning of an approaching wide-bodied aircraft than they have for narrow-bodied aircraft."

- **However:** EASA study "Bird population trends and their impact on Aviation safety 1999-2008"
  « *Some past studies have indicated that aircraft with low noise level engines have a greater risk of a bird strike because the low noise decreases the warning and reaction time of birds. No such relationship could be confirmed within the dataset used ».*

Introduction

Objectives of the study:

- To provide a factual and worldwide **data-based analysis** for Airbus SA fleet of the real **effect of engine noise levels** on birdstrike rates
- Explore birdstrike data extracted from **operator logbooks** worldwide (shared through Airbus platform **Skywise**)
- Build a **statistical model** to analyze **relationship** between **engine noise levels and birdstrike**
- Scope:
  - **A320 and A321** (CEO and NEO)
  - From **January 2019 to April 2022**

Results of the study:

- Mathematical **model and data do not support the hypothesis of a negative relationship between lower engine noise levels and bird strike rates**; in fact, data show **comparable birdstrike rates** on NEO at whole aircraft level.
- Other factors, such as operational conditions, have more significant effects on birdstrike rates.

Context 1: used datasets

Datasets:

- **FAA** Wildlife Strike database
- Airline **logbooks** shared to Airbus through Skywise
  → 13 airlines (5 North America, 1 South America, 4 Europe, 3 Asia) having CEO and NEO fleets
  → **14.2M movements** (68% CEO, 32% NEO)**, 17.1K birdstrikes**

Number of movements studied by country

Source: Airbus platform Skywise © Airbus

Enriching birdstrikes dataset:

- Flights list (FlightRadar24, Skywise) → **each strike is connected to one flight** using logbook entry and metadata
- **Flight data** → date, time, location, aircraft configuration, weather, …
- **Flight profiles** (FlightRadar24, ACMS, …) → takeoff weight, vertical path, …

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FAA Wildlife Strike database and logbooks: differences and limitations

FAA Wildlife Strike database limitations:

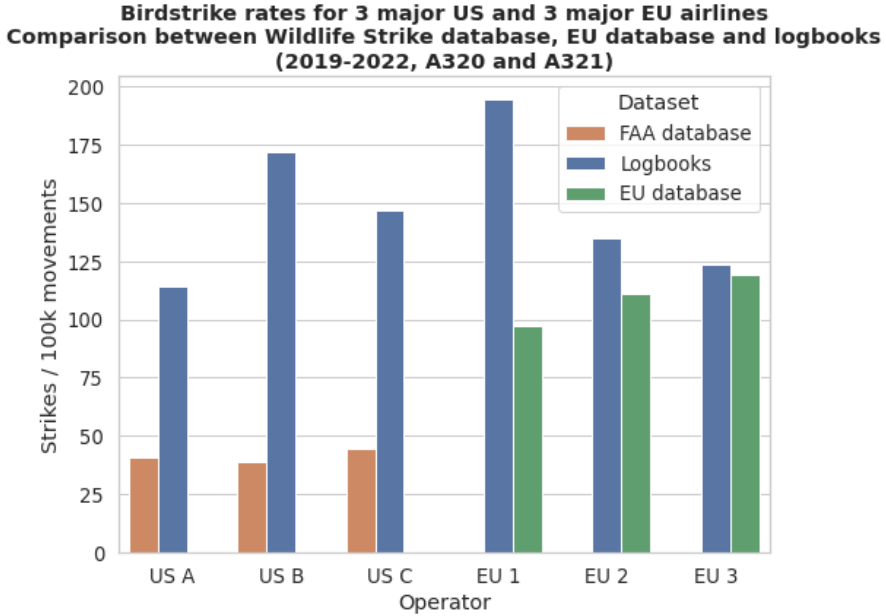
- Includes reported strikes for **17.1% of all A320/A321 flights**
- **Lower report rate** from operators. Majority of reports made by airports.
- Linked data **biases**: fleet operating in reporting airports seems to have higher birdstrike rates
- Geographical bias: **US flights only**

Logbooks dataset:

- Includes reported strikes for **29.3% of all A320/A321 flights → + 71% flights**
- **Most** of actual bird strikes are **reported by airlines**
- **Bounded biases**: airlines might slightly differ their reporting methods, but limited within one operator
- **Worldwide**

Very disparate rates depending on the dataset:

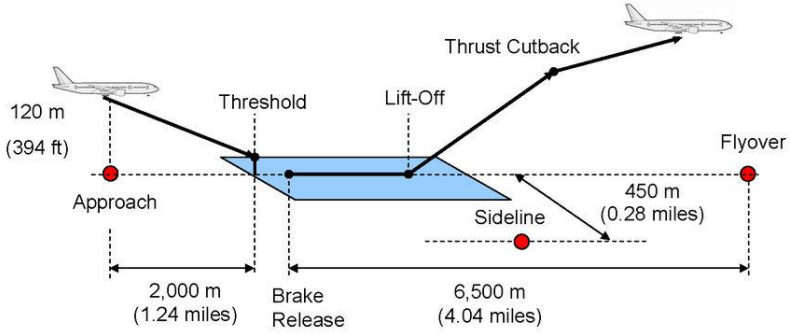
- **FAA** Wildlife Strike database (based on 3 major operators): **41.7 strike reports / 100k movements**
- **EU** database (based on 3 major operators): **104.9 strike reports / 100k movements**
- **Logbooks** dataset: **120.3 strike reports / 100k movements**



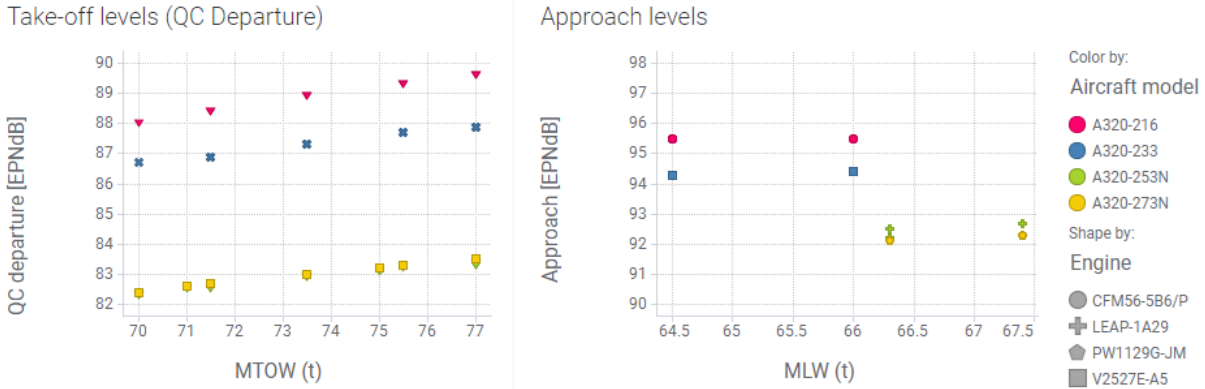
Source: FAA Wildlife Strike database, EU database and Airbus platform Skywise © Airbus

Context 2: engine noise levels

- Noise levels taken from Certification Levels.
- With NEO, noise benefit of 4dB at take-off and 2 dB at landing compared to CEO.
- Sharklets: incremental innovation that allows up to 1 dB in operational take-off conditions alongside the fuel efficiency performance.
- Note: noise level in real operations can be very different from certification noise levels, depending on the trajectory, weight, engine version, etc. Besides, there is no certification measurement point in front of the A/C, point of birds perspective.



Source: Multidisciplinary Design Optimization of low-noise transport aircraft, Researchgate - ICAO and FAR noise certification points.



Source: EASA website, Certification Noise Levels. Copyright EASA.

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Methods

Logbook = textual description of events → need of text mining to:

- **Filter entries** unrelated to birdstrikes, suspicions, duplicates, or multiple entries
- Extract **flight phase**
- Extract **struck parts** and identify damaged ones

Each filtered birdstrike occurrence is associated to a flight using

- **Logbook metadata** (operator, aircraft, date, time, location, flight number)
- **Extracted data** (phase of flight)
- **Probabilistic matching** (ex: occurrences occur more frequently during landing) when phase of flight is unknown

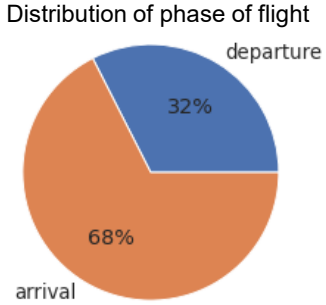
Causal inference techniques used:

- Linear and **logistic regression** to control for different confounding parameters (each parameter is isolated: all parameters fixed but one to isolate the effect of that one).

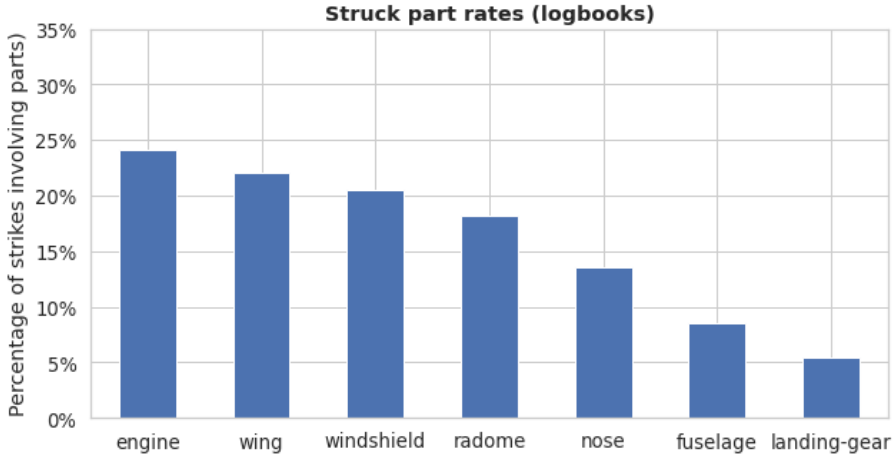
Text mining results

Text mining of logbook entries allow us to extract birdstrike information

- **2/3** of birdstrikes occur **at arrival**
- **Engines** are struck in around **24% of strikes** (21% for CEO, 31% for NEO)
- Textual description states damages in 1.5% of strikes



Source: Airbus platform Skywise



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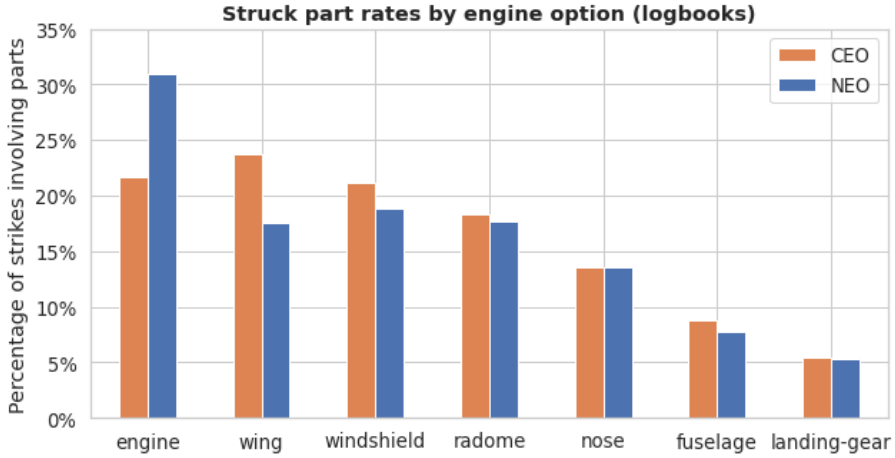

Source: Airbus platform Skywise © Airbus

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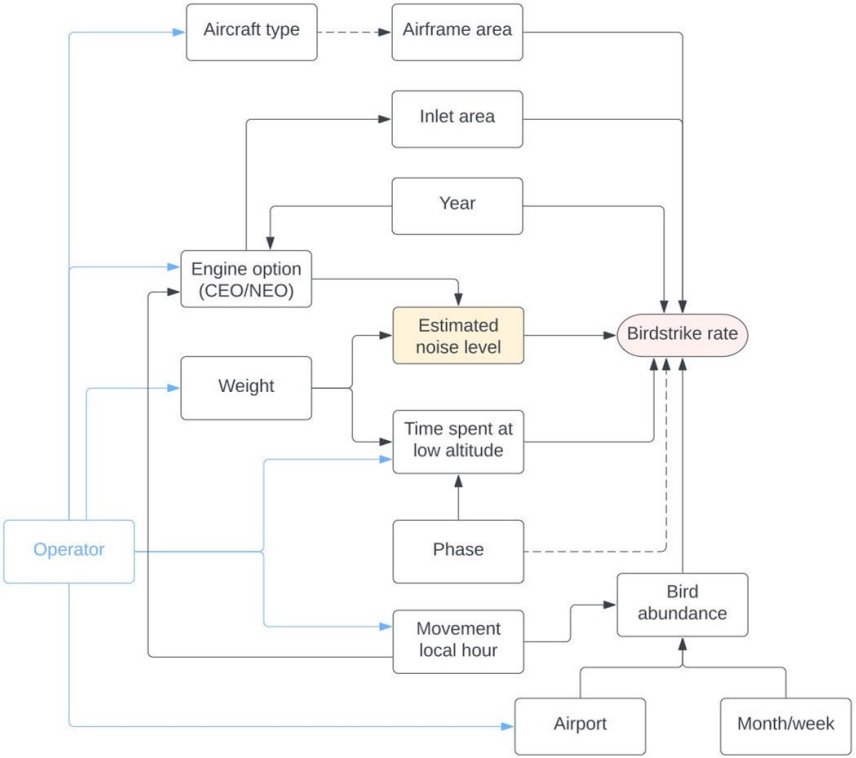
Statistical model

- Features taken into account, influencing birdstrikes:
  - **Operator**: reporting rate (methods, practices)
  - **Date**: week/month, Covid effect (increase of birdstrikes with air traffic recovery after Covid)
  - **Time**: local hour of movement
  - **Airport**: location (country, cluster, altitude, …), size
  - **Aircraft configuration**: aircraft type, engine, exposed surface
  - **Strike metadata**: phase of flight, struck part
  - **Engine noise levels** estimation: takeoff weight, engine model
  - **Flight path**: time spent at low altitude

- Each parameter is isolated for the regressions: all parameters fixed but one to isolate the effect of that one.

  → to cope with **confounding issues** and **biases** (including **operating differences**)

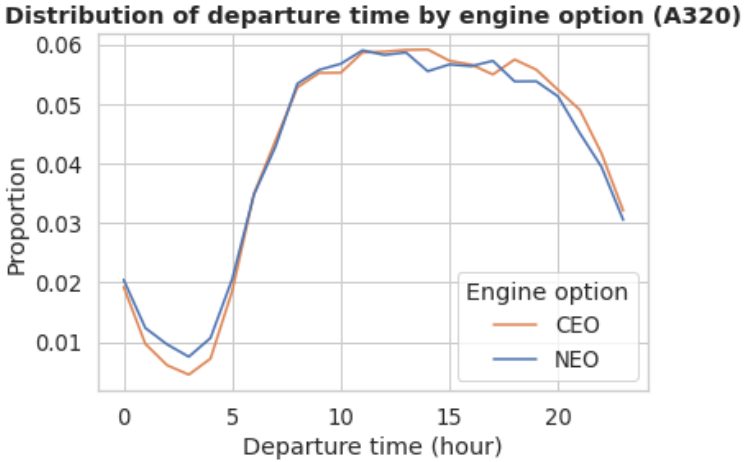


Operating differences between CEO and NEO – 1

Noticeable differences of operation observed between CEO and NEO fleets, for the 13 studied operators.

For instance:

- NEO are more used for flights around sunrise (time of higher bird activity)
- NEO have **higher takeoff weights** (on average, 62 100 kg for A320 CEO vs 65 300 kg for A320 NEO)



Source: Airbus platform Skywise © Airbus

Operating differences between CEO and NEO – 2

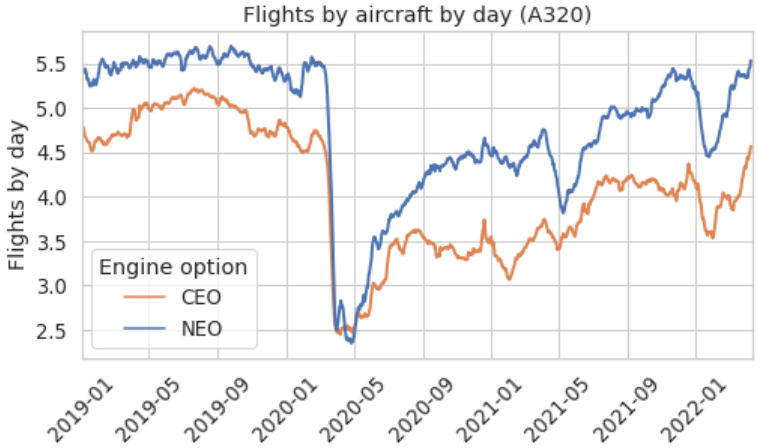
Noticeable differences of operation observed between CEO and NEO fleets, for the 13 studied operators.

For instance:

- **NEO have more flights per day** (5.5 flights/day for A320 before Covid) than CEO (4.9 flights/day)
- **NEO have more flights hours per day** (10.3 hours/day) than CEO (9.7 hours/day)

→ This explains the larger hour range for NEO

→ NEO is more used because more efficient



Source: Airbus platform Skywise © Airbus

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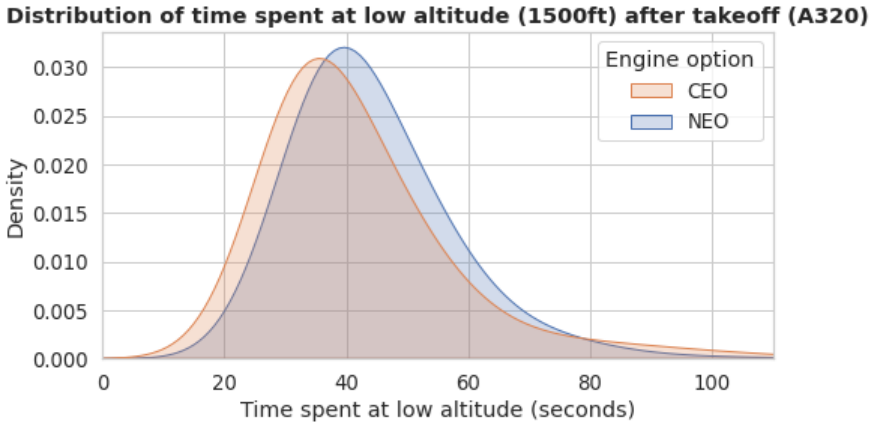
Operating differences between CEO and NEO – 3

Noticeable differences of operation observed between CEO and NEO fleets, for the 13 studied operators.

- On average, for A320 fleets, time spent under 1500ft is:
  - After takeoff: 41.5s for CEO vs 43.9s for NEO
  - Before landing: 128.0s for CEO vs 133.3s for NEO



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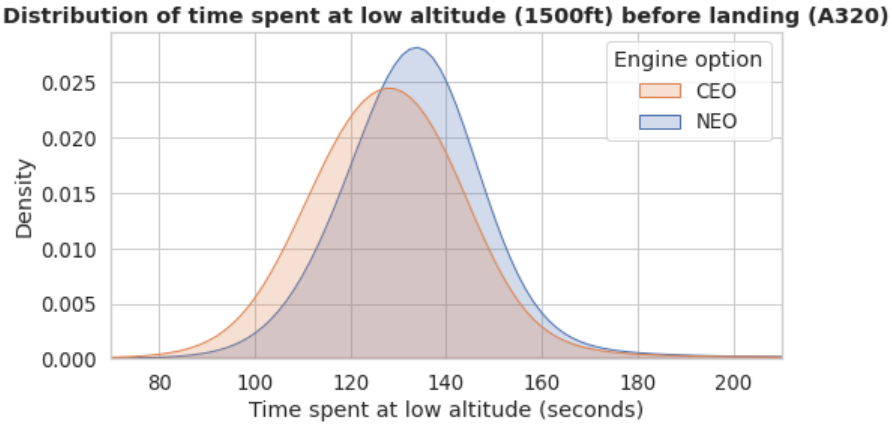

Source: Airbus platform Skywise © Airbus

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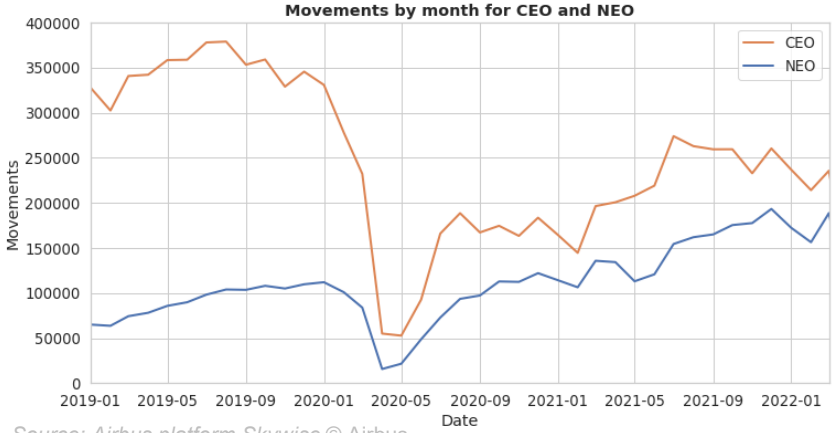
Operating differences between CEO and NEO – 4

Noticeable differences of operations observed between CEO and NEO fleets, for the 13 studied operators.

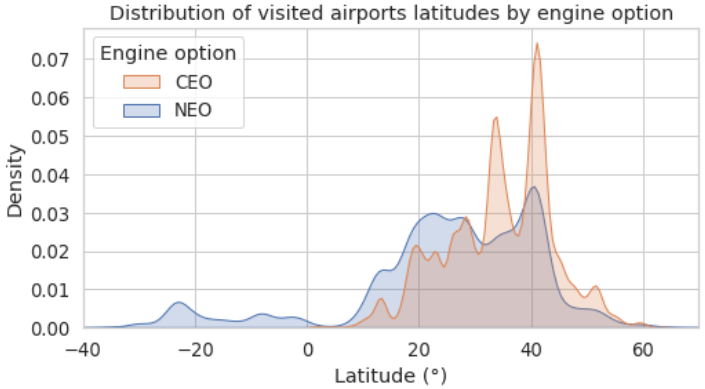
For instance:

- NEO are more around the equator
  (further explanation on following slides).
- Fleets are used differently depending on the time of year.

Even for same operator, CEO and NEO fleets can be used differently.



Source: Airbus platform Skywise © Airbus



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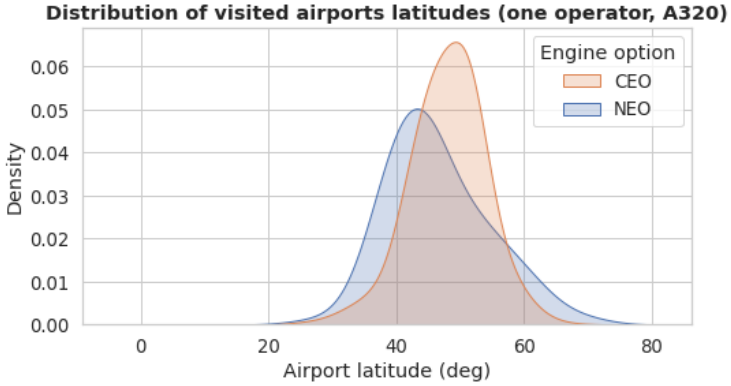

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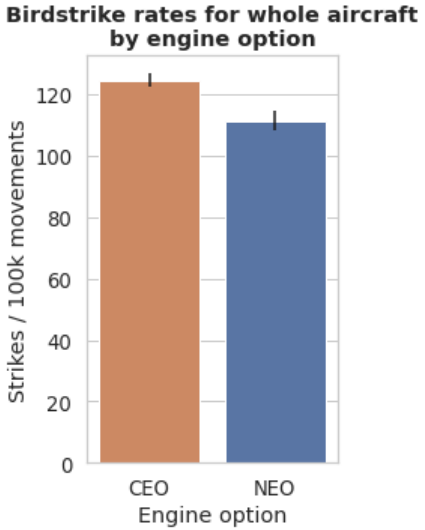
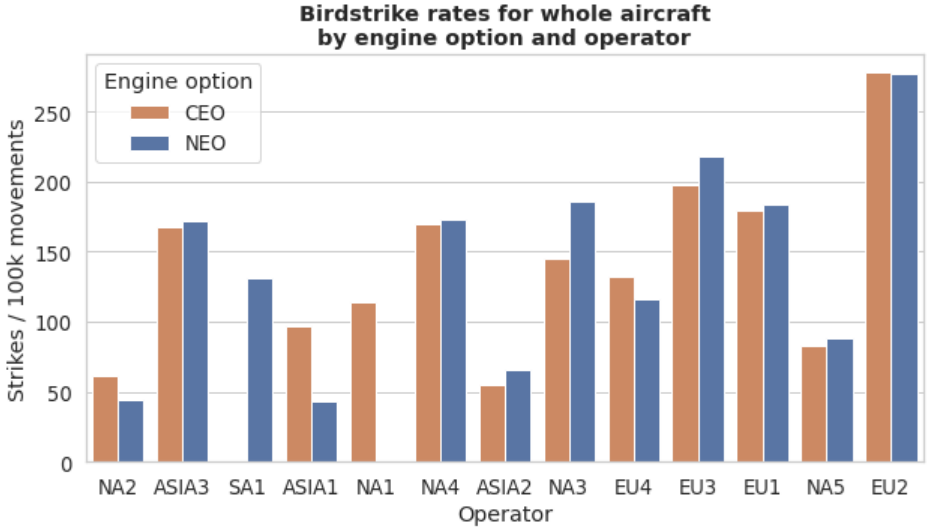
Birdstrikes on whole aircraft – 1st glance

- **Raw** birdstrike rates gives CEO to have higher rate than NEO



Source: Airbus platform Skywise © Airbus

- But **unclear tendency**: differs among operators.



Source: Airbus platform Skywise © Airbus

→ **Need to study the influence of all parameters and take operating differences into account**

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Birdstrikes on whole aircraft – other contributors

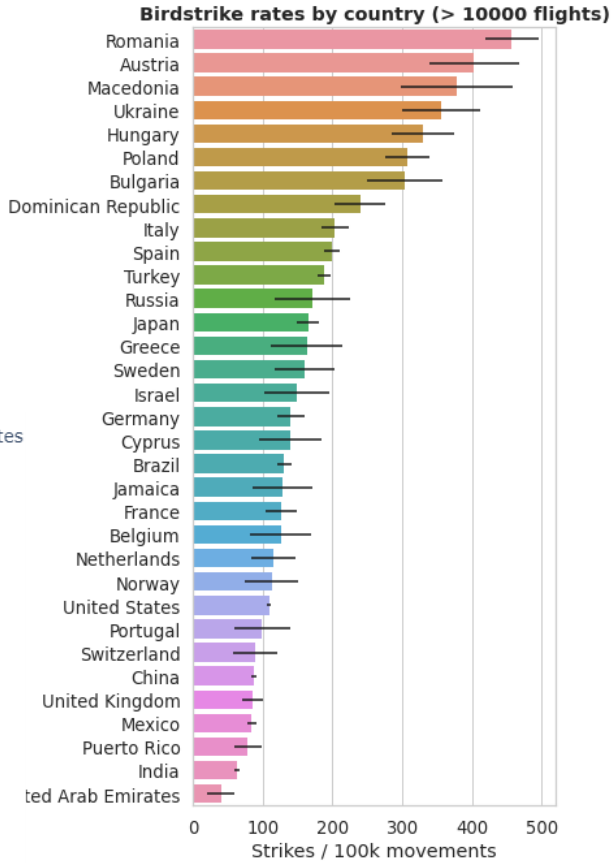
Regressions allow to identify several other contributors in the studied sample.

For instance:

- **Location**: **Eastern Europe** and **Middle East** have the highest birdstrike rates
- Note: Data in Eastern Europe limited to one operator - using small regional airports with limited wildlife prevention means - on main Europe migratory route from Scandinavia to Africa

Birdstrike rates (/ 100k movements) by country

Source: Airbus platform Skywise © Airbus



Source: Airbus platform Skywise © Airbus

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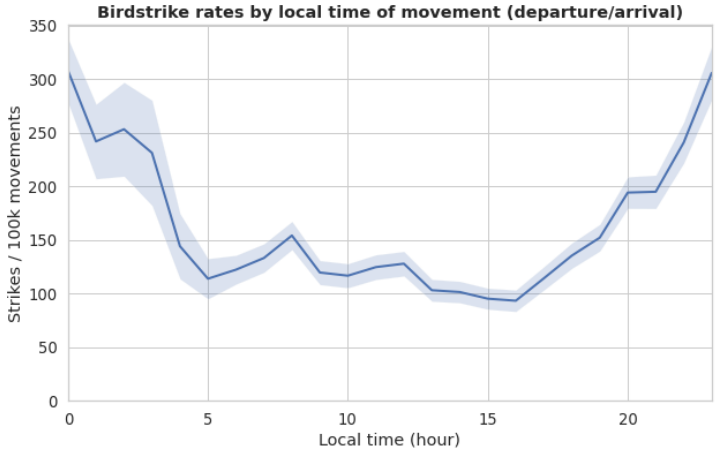
Birdstrikes on whole aircraft – other contributors

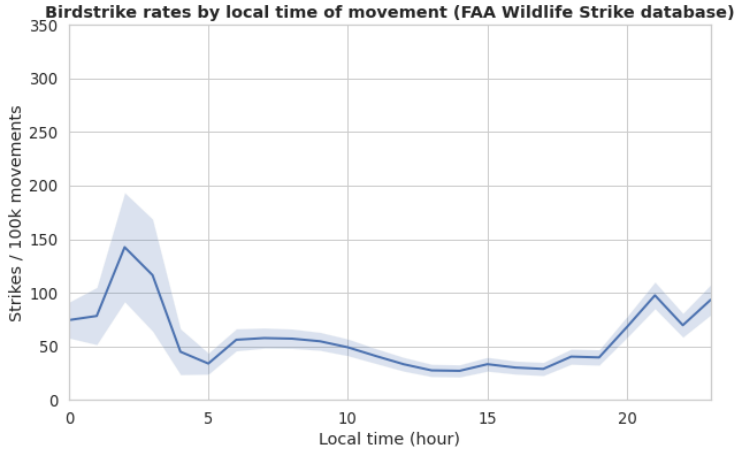
Regressions allow to identify several other contributors.

For instance:

- **Local time** of movement: strike rate is **higher during night times** than during the day (harder for birds to detect planes, less movements/activities around airports, lights perturbations, …).
- During the day, peaks can be observed during the **morning**.
- Also observed in the FAA Wildlife Strike database
  - Between 12 am and 4 am: 87.1 strikes / 100k movements
  - Between 12 pm and 4 pm: 30.3 strikes / 100k movement



Source: Airbus platform Skywise © Airbus



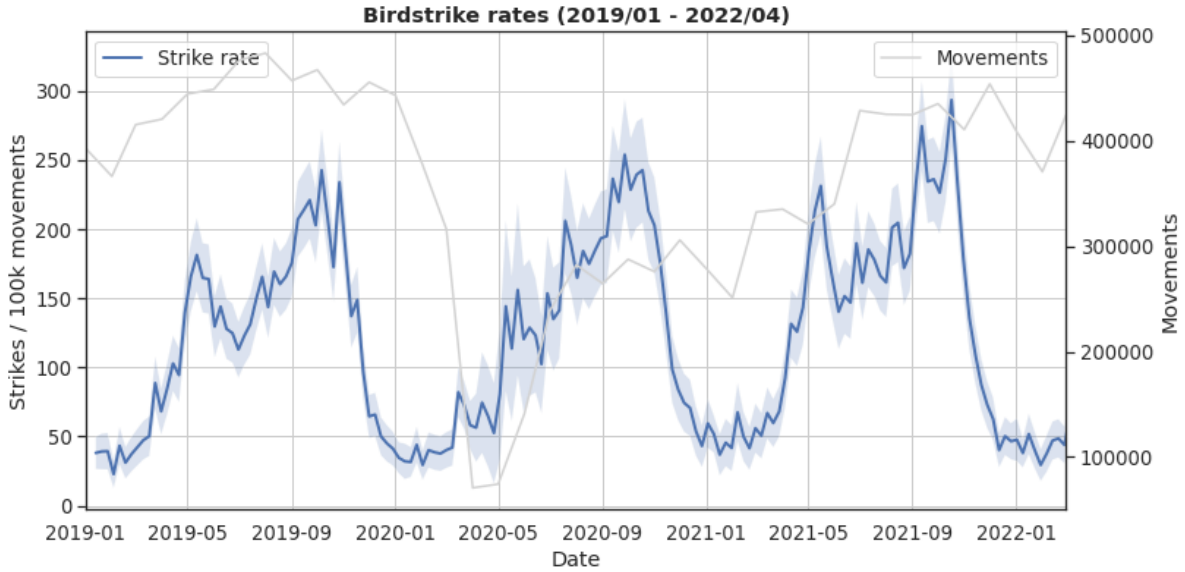
Source: FAA Wildlife strike database and Airbus platform Skywise © Airbus

Birdstrikes on whole aircraft – other contributors

Regressions allow to identify several other contributors.

For instance:

- **Date of year**: one of the main factor influencing birdstrike rates.



Source: Airbus platform Skywise © Airbus

*Note: Evolution of birdstrike rates over time is also a function of the **geographic region** (birds population and migratory routes).*

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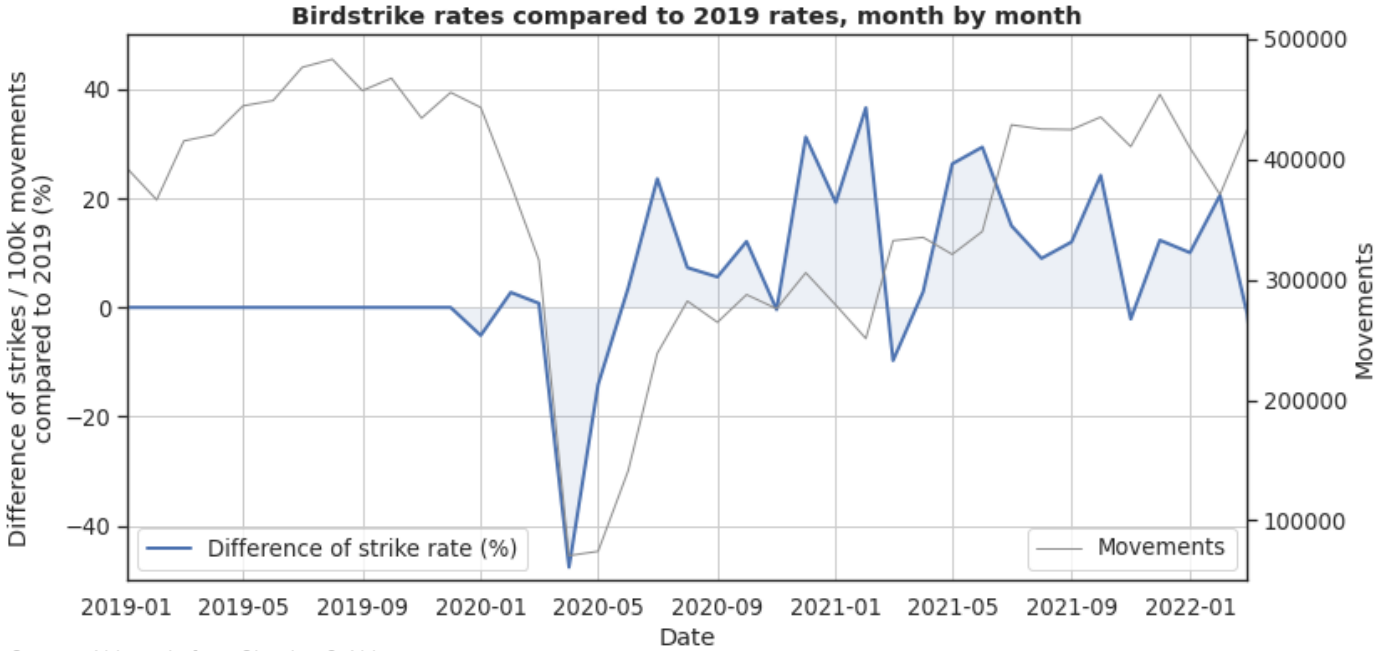
Birdstrikes on whole aircraft – other contributors

Regressions allow to identify several other contributors.

For instance:

- **Effect of Covid: increase of rates** while air traffic recovers.



Source: Airbus platform Skywise © Airbus

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Birdstrikes on whole aircraft – effects of engine noise levels

To estimate effect of engine noise levels on birdstrike rate, **all parameters fixed but noise level to isolate its effect**.
Extract of some coefficients results for logistic regression:

Variable	Coef	[0.025	0.975]	Std err	P-value	Odds ratio	[0.025	0.975]
Time spent at low altitude (< 1500ft)	0.0111	0.010	0.012	0.000	0.000	**1.12%**	1.01%	1.21%
Local hour (12pm – 4pm)	-1.0225	-1.125	-0.919	0.053	0.000	**-64.03%**	-67.5%	-60.11%
Year (2020)	0.1107	0.038	0.184	0.037	0.003	**11.71%**	3.9%	20.2%
Year (2021)	0.1278	0.066	0.190	0.032	0.000	**13.63%**	6.8%	20.92%
Noise level	0.0083	-0.010	0.027	0.009	**0.381**	**0.83%**	**-1%**	**2.74%**

Interpretation:

Based on this model and the collected data:

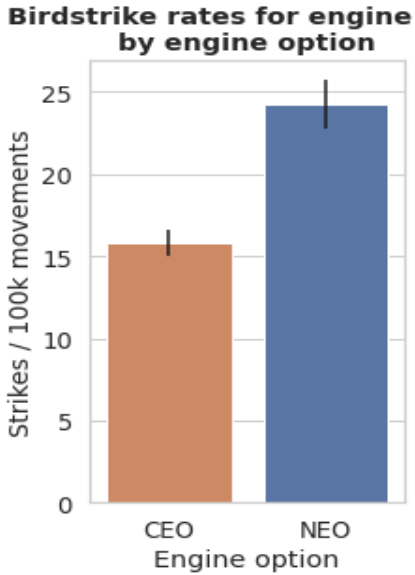
- Birdstrikes are **64% less likely to occur for movements in middle of day** (12pm – 4pm) **compared to night movements** (12am – 4am).
- Birdstrikes are **1.1% more likely by seconds spent at low altitude** (< 1500ft).
- Birdstrikes were **14% more likely in 2021 compared to 2019**, and 12% more likely in 2020 compared to 2019.
- Birdstrikes are 0.83% (confidence interval: [-1.0%, 2.7%]) more likely by increase of 1 dB in engine noise level (p-value = 0.38)
  → **model and data cannot support the hypothesis of a negative causal relationship between engine noise levels and birdstrike rates** (p-value > 0.05 □ coefficient found for noise level could be due to randomness or other factors not taken into account).

Birdstrikes on engine only – 1st glance

Airbus Amber

- **Higher raw birdstrike rate on NEO** compared to CEO (**+53%**)

- Main cause: **augmented engine inlet area**
  → +42% to +63% inlet area for NEO
  → Consistent with engine certification standards (bird size and number depending on inlet throat area)
  → NEO engines are certified to a higher standard than CEO engines



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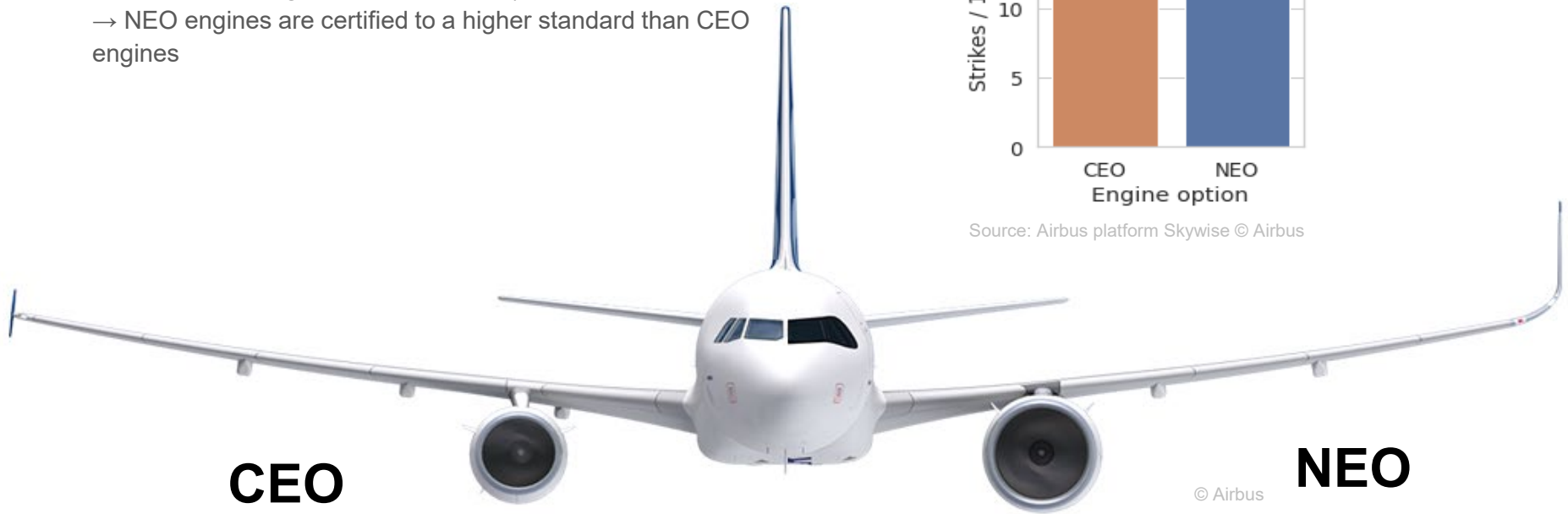

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Birdstrikes on engine only – effects of engine noise levels

To estimate effect of engine noise levels on birdstrike rate, **all parameters fixed but noise level to isolate its effect**.
Extract of some coefficients results for logistic regression:

Variable	Coef	[0.025	0.975]	Std err	P-value	Odds ratio	[0.025	0.975]
Inlet area	0.4812	0.296	0.666	0.094	0.000	**61.8%**	34.34%	94.64%
Noise level	-0.0044	-0.059	0.051	0.028	**0.877**	**-0.44%**	-5.7%	5.23%

Interpretation:

Based on this model and the collected data:

- Birdstrikes are approximately **62% more likely** to occur on NEO engine because of the **increase of inlet throat area**.
- Birdstrikes are 0.44% (confidence interval: [-5.7%, 5.2%]) less likely by increase of 1 dB in engine noise level (p-value = 0.88)
  → **model and data cannot support the hypothesis of a negative causal relationship between engine noise levels and birdstrike rates** (p-value > 0.05 □ coefficient found for noise level could be due to randomness or other factors not taken into account).

Conclusion of the study

- **Logbooks have been explored** for birdstrike occurrences
  - Systematic operator reporting → less biases

- **Several relevant factors** contributing to birdstrikes found in our data: date, location, time of the day, time spent at low altitude, typical route.

- Sample data showed **comparable or slightly lower birdstrike rates on NEO at whole aircraft level,** in spite of operational factors which have a mathematically proved influence on bird strike (higher time spent at low altitude per operation, earlier departure times, more operations per day).

- After fixing other factors to isolate the effect of engine noise levels: **model and data cannot support the hypothesis** of a negative relationship between engine noise levels and birdstrike rates.

Thank you

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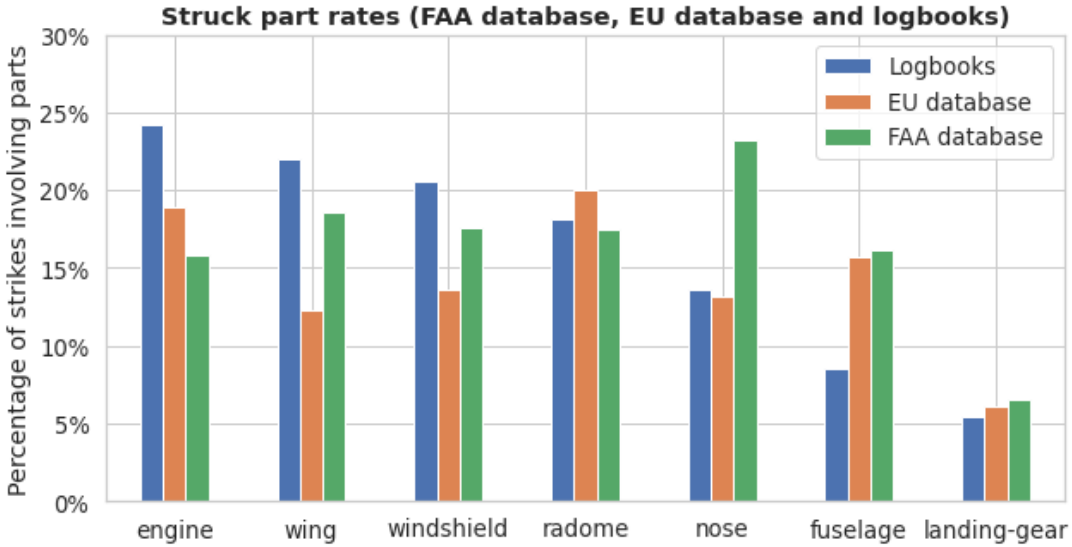
BACK UP SLIDES - Examples of logbook entries

Operator	Datetime	Aircraft registration	Flight number	Defect description
OP1	01-01-2022 11:00:00	XX-XXX	XXX	BIRDSTRIKE DURING T/O RUN (LOWER RADOME) RH SIDE
OP2	01-01-2022 11:00:00	XX-XXX	XXX	BIRD STRIKE AT LANDING
OP3	01-01-2022 11:00:00	XX-XXX	XXX	BIRD STRIKE. FULL INGESTION OF BIRD IN LEFT ENGINE. CHICKEN SMELL IN FLIGHT DECK WITH NORMAL ENGINE INDICATIONS, CARCUS FOUND ON RUNWAY.
OP4	01-01-2022 11:00:00	XX-XXX	XXX	SMALL BIRD STRIKE ON ENG #2

BACK UP SLIDES - Struck parts, results comparison

Struck parts distributions based on following datasets:

- FAA Wildlife Strike database
- EU Strike database
- Operator logbooks



Source: EU database (ECR), FAA Wildlife Strike database and Airbus platform Skywise © Airbus

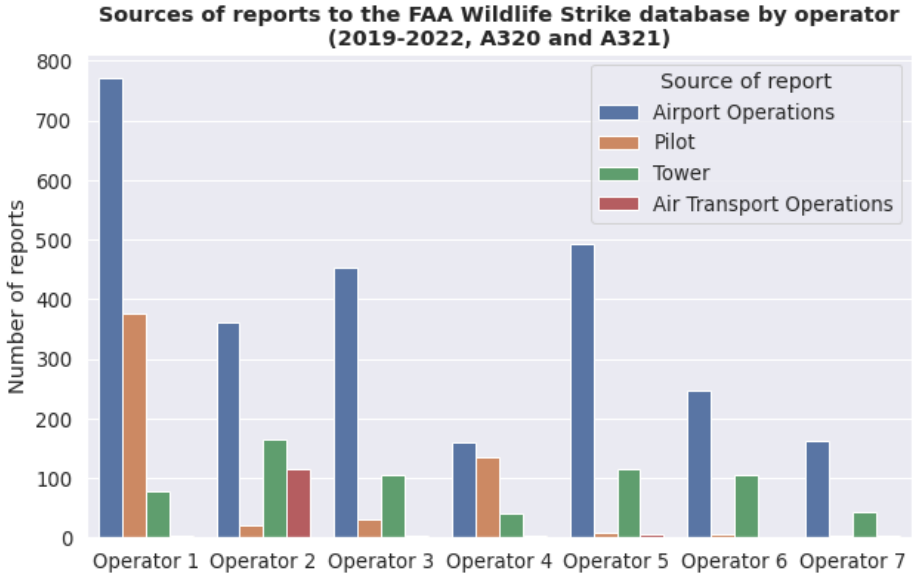
BACK UP SLIDES - FAA Wildlife Strike database and logbooks: differences and limitations

FAA Wildlife Strike database limitations:

- **Lower report rate** from operators. Majority of reports made by airports.
- Linked data **biases**: fleet operating in reporting airports seems to have higher birdstrike rates
- Geographical bias: **US flights only**

Logbooks dataset:

- **Most** of actual bird strikes are **reported by airlines**
- **Bounded biases**: airlines might slightly differ their reporting methods, but limited within one operator
- **Worldwide**



Source: FAA Wildlife Strike database and Airbus platform Skywise © Airbus

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BACK UP SLIDES - About logistic regression

Logistic regression models and estimates the probability of a birdstrike depending on selected parameters.

- Coefficients can be interpreted as: when all other parameters take mean value, an increase of the parameter by one leads on average to an increase by the coefficient of log odds of birdstrike.
  Odds ratios give that increase in percentage.

- P-value is used in hypothesis testing. For a variable coefficient, the p-value tests the null hypothesis that the variable has no correlation with birdstrike. It gives the probability of estimated such an extreme coefficient if the true coefficient was zero (null hypothesis).

  Then we can follow the rule:
  - If p-value > 0.05, we cannot refute the null hypothesis.
  - If p-value < 0.05, we can reject the null hypothesis and conclude it exists such a correlation between the variable and birdstrike probability.