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Influence of take-off power on bird ingestion threat

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Introduction

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

Airbus in service experience highlights risk of engine / multiple engines damage due to bird strike:

- 2009 - A320 Hudson
- 2019 - A321 Ural Airlines - Cornfield emergency landing
- 2021 - A320neo Bald Eagle ingestion / Fan blade failure / fire
- 2022 - A321 Swainson's hawk ingestion / engine damage / fire

- Most severe cases occurred around rotation / early climb
- In one case full derated Take-Off despite knowledge of bird presence at the end of the runway
- Another case occurred when a longer runway was requested by the crew to allow more derate

→ Increased power / shorter Take-Off distance / Steeper climb could have avoided those particular cases

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What can we do as an airframer?

Spending lower time at low altitude decreases the number of bird strikes:

- 2.7x more strikes reported in approach vs climb - consistent with amount of time spent below 5000 ft in both phases
- Airbus 2022 study on sample of A320 / A321 fleets, bird strikes increases by 1.1% per each second spent < 1500ft

→ Spending less time at low altitude could be a means to reduce bird strike risk

→ Airbus question:
Would Take-Off with increased power in case of known / increased risk of bird strike be a way to improve safety with respect to bird strikes?

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	Birds	
Phase of flight	33-year total	% of total known
Parked	110	<1
Taxi	547	<1
Take-off Run	28,149	17
Climb	26,038	16
Departure[4]	2,640	2
En Route	5,114	3
Arrival[4]	711	<1
Descent	2,211	1
Approach	71,471	43
Landing Roll	29,041	17
Local[4]	974	1
Total known	**167,006**	**100**

Source: FAA - Wildlife Strikes to Civil Aircraft in the United States, 1990–2022

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Why this study with Rolls-Royce?

Expected effects of taking off with more power:

- Anticipate reduction in number of strikes
- Within certification enveloppe for aircraft & engines
- If no increase of speed this will result in less aircraft damage
- Physics more complex for engine strike and drawbacks on engine operations (derate is used to increase time of wing / decrease engine maintenance)

→ **Need to involve Airbus' engine suppliers**

- Airbus initiative to contact our 3 main engines suppliers and launch sensitivity study
- Montecarlo approach selected to compare effect of changing part of the Take Off profile for a portion of the flights.
- Airbus worked with the engine suppliers to share data and ensure a level of consistency between studies
- Conclusion shared in Beatriz Angulo's presentation at this conference.

→ **Rolls-Royce analysis detailed in the next slides**

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Thank you

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Influence of take-off cycle on bird ingestion threat

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September 2023

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- Bird ingestion threat
- Typical flight cycle
- Flight cycles assessed & predicted bird ingestion rates
- Monte Carlo analysis to predict Fan damage for each cycle
- Conclusions

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Bird ingestion threat

- Bird strikes to civil aircraft cost an average of ~$200,000 per incident, in damage & service disruption [1].
- Example: Flock of birds, at least one appears to be ingested in right engine at ~800ft.

- Majority of encounters with birds happen at low altitude.
  - 74% < 500 ft
  - Less than 1% are > 10,000ft
  - Exceptional events at > 30,000ft happen, but they are rare.

1. FAA National Wildlife Strike Database, serial report number 28, June 2022

https://www.youtube.com/watch?v=AqcsjpdEJMQ
A330-900, departing Amsterdam
Approximately 800ft

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Typical take-off power

- Operators are motivated to use de-rated take-off power where possible
  - Reduces fuel burn
  - Reduces engine deterioration

- But, de-rated power in take-off & climb results in aircraft climbing more slowly & spending more time at low altitude.

Is the widespread use of de-rated take-offs increasing bird strike risk?

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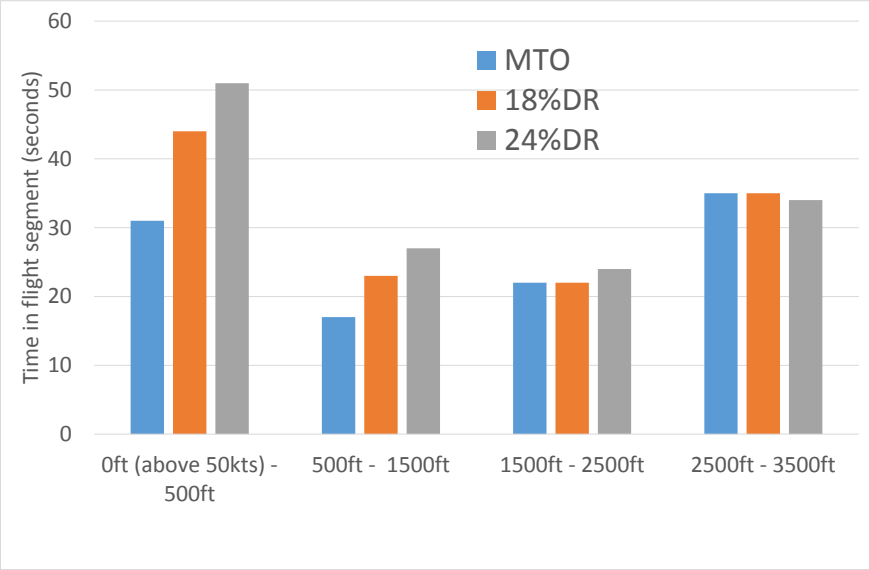
Flight cycles – predicted bird ingestion rates

Flight cycles assessed

- Joint study between Rolls-Royce and Airbus for a large civil engine to assess the bird ingestion risk, owing to the time spent at low altitude.
- 3 Flight cycles assessed:
  - MTO: Max take-off case
  - 18%DR – approx. 18% de-rated thrust
  - 24%DR – approx. 24% de-rated thrust
- Time spent in take-off segments:



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Number of bird strikes

Flight cycles – predicted bird ingestion rates

- Dolbeer study [2] shows that 0ft – 500ft altitude range dominates:
  - 74% of events happen <500 ft
  - 11% of events happen between 500ft and 1500ft
  - 15% happen >1500ft
- This work assumes that the split between Take-off and Approach for a particular altitude band is based on the time spent in flight.
- Predicted bird strike rate, normalised to typical operation (24%DR):

Typical de-rate in service →

Flight cycle	During Take-off & Climb	All flight phases
24%DR	1.00	1.00
18%DR	0.86	0.94
MTO	0.63	0.83

- So, wider use of MTO power could reduce the overall # bird strikes by ~17%, and those in the most vulnerable part of the flight by ~37% !

However, not all bird ingestion events are equally damaging…

2. Height Distribution of Birds Recorded by Collisions with Civil Aircraft, Richard Dolbeer, Feb 2006

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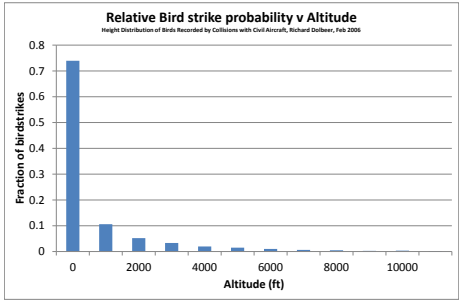
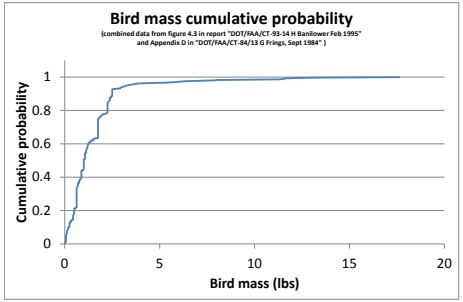
Monte Carlo Analysis





Monte Carlo Analysis

- Monte Carlo simulations are used to model the probability of different outcomes in a process that cannot easily be defined analytically.
- Bird strike Monte Carlo analysis developed to include the following variables:
  - Point in flight cycle, which determines:
    - Air speed
    - Fan rotor speed
  - Bird mass distribution (0.3oz -> 17 lbs)
  - Bird strike probability with altitude (lower altitudes much more likely)
  - Strike height on the Fan
- Although it is possible to damage other components in an engine including those in the core, the focus of this study is damage to the Fan (largest target) in Take-off and Climb (greatest loading on the fan).
- All Monte Carlo analyses were run to the same duration of exposure (not the same number of bird strike events).

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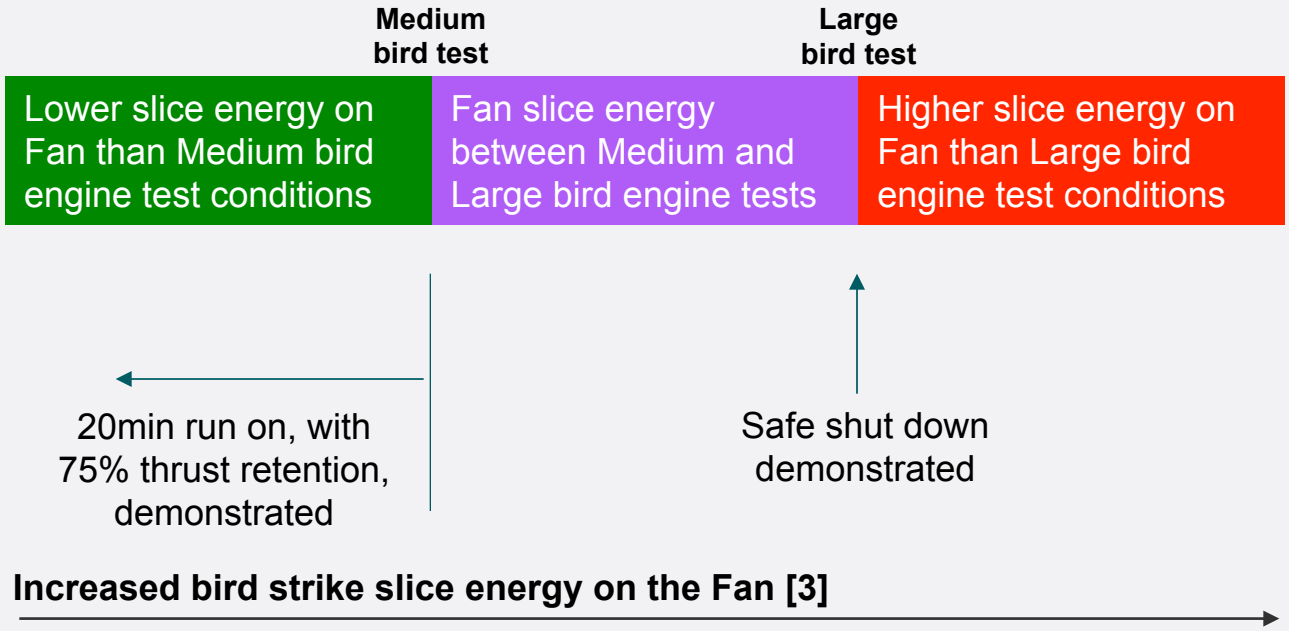
Monte Carlo Analysis

Fan Blade criteria

- Each ingestion event where a bird strikes the fan has been assessed relative to certification test (CS-E800 / FAR33.76) conditions:



3. Slice energy used in statistical simulations in Aerospace Industries Association Bird Ingestion Working Group Report, November 2012

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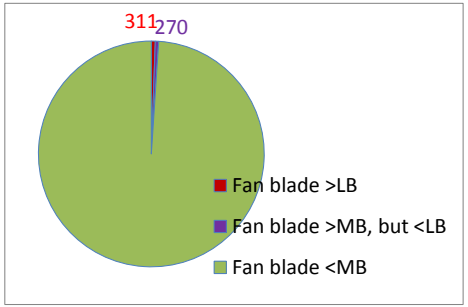
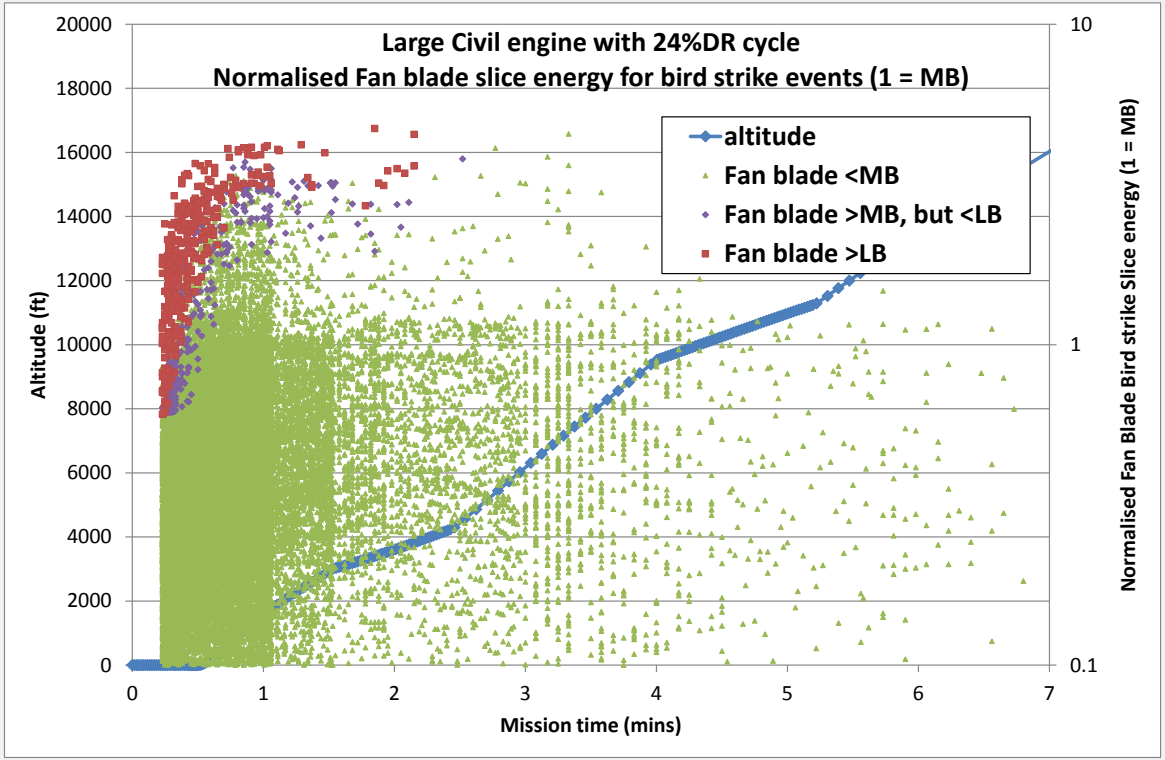
24%DR Results – Fan bird strike loading (Take-off & Climb)

24%DR Monte Carlo analysis results



Total number of ingestions = 100,000



- Majority of bird strikes occur at low altitude.
- Most damaging events occur during take-off & climb (low A/C speed; high fan speed).
- Only 0.58% of ingestion events predicted to cause more severe Fan loading than MB test conditions.

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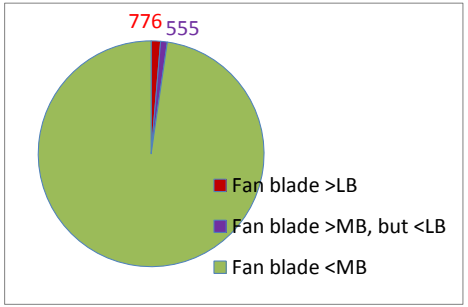
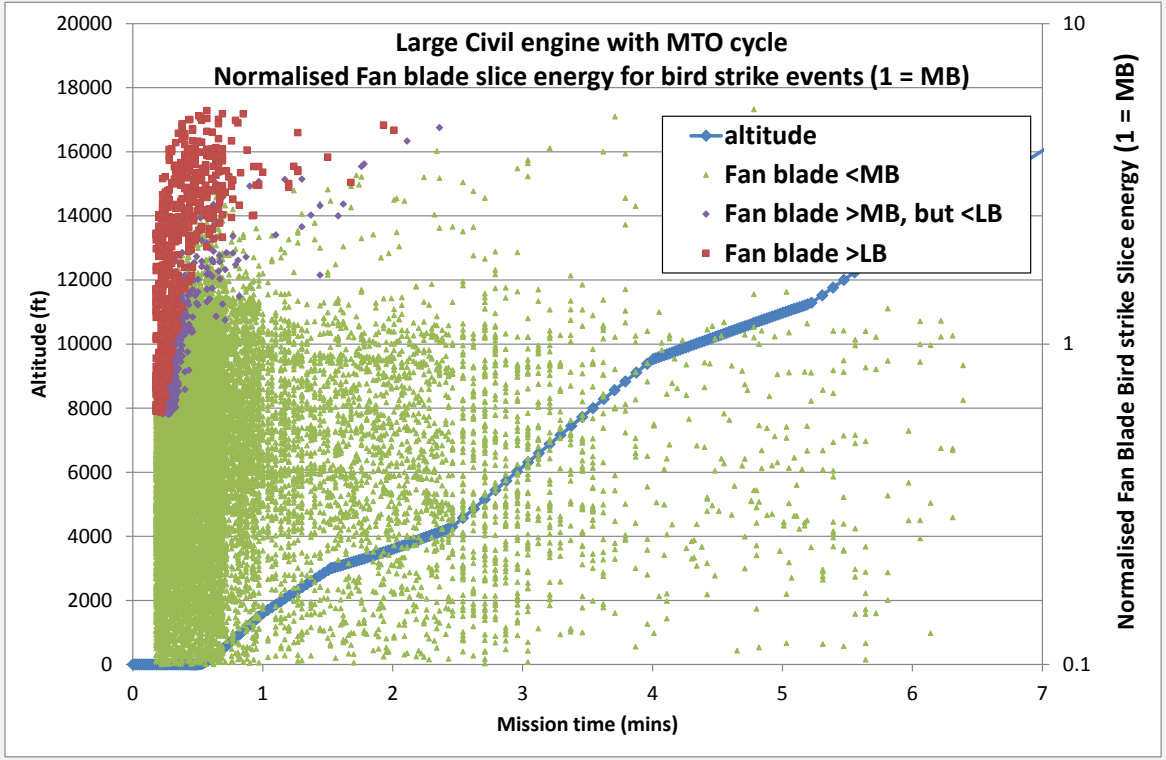
MTO Results – Fan bird strike loading (Take-off & Climb)

MTO Monte Carlo analysis results



Total number of ingestions = 84,933



- 15% fewer ingestions predicted (across whole flight cycle), consistent with hand calculations.
- 1.6% of ingestion events predicted to cause more severe Fan loading than MB test conditions.
- Therefore, can deduce that the practice of widespread use of MTO conditions could significantly increase the number of power loss events.

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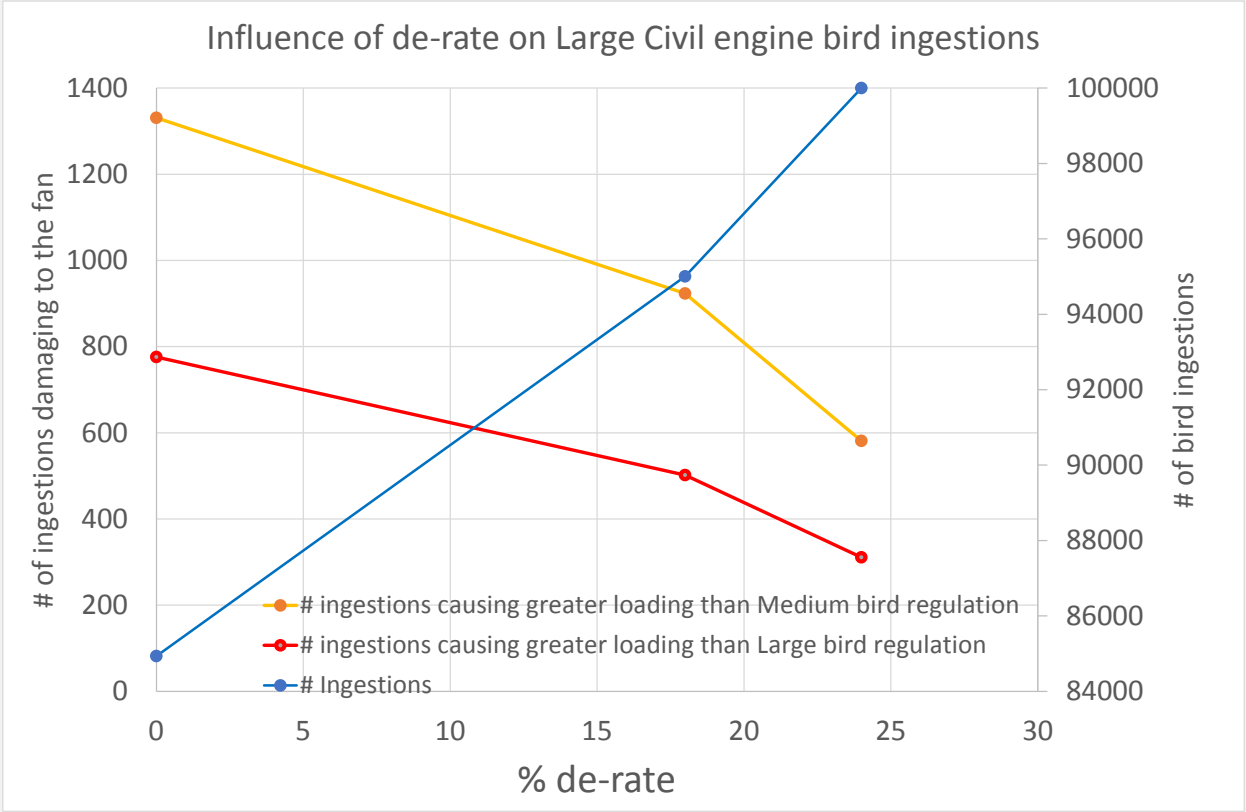
Summary

Results summary



- A move to use less de-rate would drop the number of ingestions, but those that remain would be more damaging.

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Conclusions

- Whilst less de-rate would reduce the number of bird ingestions, those that remain are predicted to be more damaging to engines.

- From an engine only perspective, de-rate is useful to reduce the number of damaging bird ingestions (and reduce fuel burn & deterioration).

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