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BIRD STRIKES TO AIRLINER TURBINE ENGINES

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Summary

Bird strikes reported during the years 1990 to 1994 world-wide to the engines of UK registered turbine powered airlines have been analysed. Birds of weight below 100g, such as the many single swift/swallow/martin reports have been excluded. Aircraft movement data has been used to obtain rates for 1462 aircraft strikes and the 367 engine strikes (25% of incidents affected the engine), together with damage rates. The term damaged has only been used where repair or replacement was necessary. The airports where the 94 cases of damage occurred and weight of bird species involved have been detailed. The results show that rear mounted engines are 4 to 5 times less likely to suffer a strike or damage than wing mounted engines. The engine strike rate does not appear to correlate with engine fan area. There is some evidence that the noisier engines have lower strike rates. The in-service abilities of engines to cope with birds shows considerable variation. More information from wider sources and research on engine forward noise/frequency spectrum may be useful.

Key Words: Statistics, Engineering, Civil Aviation, Engines, Reporting, Aircraft Appearance, Noise

1 INTRODUCTION

a A paper 'Bird Strikes to Transport Aircraft Jet Engines' was presented by the Author at the World Conference on Bird Hazards, Paris, October 1977 and was also published as CAA Paper 77021. It used selected European data from 1973 to 1976. Many of the engines in service at that time have now disappeared and new engine types designed to much more rigorous airworthiness standards are in widespread use. It was therefore felt appropriate to re-examine certain aspects of the problem.

b This paper is not directly comparable with the previous paper as the original paper used data from **all** bird strikes to engines, whereas this paper has **excluded** small birds, ie those below 100 gms. Thus swifts, swallows, martins, sparrows etc which are mostly single strikes and not a threat to jet engines, have been excluded. The use of this weight discriminant has also excluded starlings which can be a threat as they do form very dense flocks which are a hazard to engines. However, since most starling strikes are single birds, for simplicity's sake, they have also been excluded.

c The information contained in this paper is only as good as the standard of reporting. Furthermore, in some cases the sample sizes are small.

d Certain aircraft types and thus engines are used by only one airline and the record will be affected by that airline's route structure and reporting standard. Some aircraft/engine combinations are used by, or have been used by, many airlines and the data is thus more reliable.

e Although a larger sample size would be highly desirable, examination of the record of engine damage and engine movements provides an indication of the service capability of the engine to cope with real life bird ingestion compared with certification tests. The term 'damaged' has been confined to an event where repair or replacement of parts has been necessary. Cases of blade damage that is dressed out or carried over to a future opportunity, have not been counted as damage. In some cases a bird strike report form was only completed by the aircrew at which point the extent of the damage was not known. Subsequent enquiries to verify the extent of the damage have sometimes drawn a blank as the aircraft may have been sold or the operator ceased trading. These cases have **not** been classified as damaged, thus the rates are a minimum.

f There is considerable variation in the degree of damage and the amount of **usable** thrust available, however, in a number of cases power has to be reduced to keep engine vibration within limits. Furthermore, in many incidents the bird species and thus weight is not known.

g The airports where damage has occurred have been listed but will be dependent on the amount of use by UK airlines, which is difficult to quantify.

2 SOURCE OF INFORMATION

a The bird strike information has been extracted from bird strike forms (CA1282), occurrence reports and the BASIS system used by one of the airlines. The 5 year period from 1990 to 1994 has been used.

b Aircraft and hence engine movement data has been obtained from published Annual CAA Papers which include aircraft type and utilisation.

c In an attempt to obtain more comprehensive information on engine strikes, the UK now includes the items shown below on the UK Bird Strike Reporting Form.

	Engine Damage 1	2	3	4	Comments/Observations
Aircrew Indications:					
fire observed	☐	☐	☐	☐	
fire warning	☐	☐	☐	☐	
vibration	☐	☐	☐	☐	
temperature shift	☐	☐	☐	☐	
noise	☐	☐	☐	☐	
thrust loss	☐	☐	☐	☐	
(specify estimated %)					
other (specify)	☐	☐	☐	☐	
Aircrew Actions:					
shutdown	☐	☐	☐	☐	
power reduction	☐	☐	☐	☐	
nil or other (specify)	☐	☐	☐	☐	
Maintenance Findings:					
fire					
uncontained	☐	☐	☐	☐	
Nº. of fan blades replaced	☐	☐	☐	☐	
estimated Nº. of birds struck	☐	☐	☐	☐	
damage, other (specify)	☐	☐	☐	☐	

3 DISCUSSION

a It is suggested that the following factors influence the reporting of bird strikes, and the effects, on engines:

a) the reporting of a strike is dependent on
  - i) a strike taking place
  - ii) ease of detection
  - iii) operator's reporting standard

b) an engine strike is dependent on
  - i) engine location
  - ii) engine frontal area
  - iii) circumstances, ie route, time, of day, flight phase
  - iv) engine forward noise signature

c) engine damage depends upon
  - i) a strike
  - ii) weight of bird struck
  - iii) engine design and certification standard
  - iv) engine operating conditions.
  - v) airspeed

b Many of the above are inter-related and it is very difficult to separate the various factors. An attempt is made to separate the factors. The removal of small bird strikes, which are likely to pass unnoticed through large fan engines, factor a) ii) should be reduced. The data is from UK airlines operating world-wide on a variety of routes and in many cases the aircraft is used by several operators, thus reducing the effect of a) iii) operators reporting standard (see Table 1).

c In order to take appropriate account of the variation in the number of engines fitted to the aircraft, the paper, in the main, uses engine movements (ie a B747 makes 8 engine movements in one flight), the rates being per 100,000 engine movements.

d Twenty five percent of the incidents resulted in an engine strike.

4 RESULTS

a Aircraft Noise (see Tables 1 and 5)

Some limited work carried out in the USA indicates that very quiet aircraft may not provide the birds with enough aural alert to get out of the way in time. The 1995 fatal accident to the Boeing 707 based USAF AWACs aircraft, which is very noisy, may result in further work. Of the available noise measurements, the most useful are the sideline noise, take-off noise being measured when the aircraft is at 1000ft. However, the noise levels that would be most relevant are forward noise, which is not normally measured.

It could be expected that the noisier aircraft would have a lower strike rate than average. Examination of Table 1 shows that the aircraft with above average aircraft strike rates are Airbus A320-CFM56 and V2500, BAe 146, B727-JT8D, B757-RB211, B767-CF6, L1011 Tristar and McDonnell Douglas DC10-CF6. The quietest **aircraft** from a sideline noise point of view are BAe 146, Fokker F100, Airbus A320, B737-CFM56, B757-RB211, B767-RB211. The noisiest aircraft, Concorde, in this sample has a zero strike rate, if it were to have an average strike rate, six strikes could have been expected. (An Air France Concorde has suffered Canada goose strikes to the engines during this period.) There appears to be some correlation between sideline noise and aircraft strike rate. A larger data sample split into take-off and approach strikes, together with forward noise levels, may help to confirm the hypothesis. Frequency spectrum may also be a factor for investigation.

Field research on bird reaction may help to make the results more meaningful. It would underline the need for exemplary bird control at airports used by very quiet aircraft.

b Engine Location (see Tables 2 and 3)

It appears that wing mounted engines are between 3 and 4 times more likely to suffer a strike than the better protected aft mounted engines. The sample size of strikes to centre mounted engines is too small to be useful. Strikes on wing mounted engines are easier to detect than aft mounted engines. Where damage is concerned the ratio is 5.5:1. These results are similar to those from the earlier paper. It is fortunate that executive jet aircraft which often use smaller airports where little may be done about bird strikes, are all aft/centre engined.

c Engine Frontal Area (see Tables 2 and 5)

It could be expected that the larger the fan area (and aircraft) the more likely the engine would be expected to suffer a bird strike. These are plotted in Fig 1. There appears to be little or no correlation, thus it might be concluded that there are other highly influential factor. One possible factor is the low forward noise levels of the newer very quiet engines. This is discussed in para c.

d Engine Resistance to Birds (see Table 4)

The 93 cases of engine damage have been assessed. Incidents where nothing was known about the extent of the damage or remedial action have been excluded. The damage rates are thus a minimum. The engines which appear to suffer an above average percentage of damage and damage rate are the CF6 and the CFM56. The percentage of engine strikes which result in damage is above average on JT9D and RB211, but their damage rates are close to or on the mean for all engines. The engines with a good damage record are the JT8D, Alf502 and, particularly, the IAE V2500 and Spey. With some of the above engines the aft location of the engine provides considerable protection from being struck not generally enjoyed by wing mounted engines. However, it is odd that in this sample, in the event of a strike on an aft mounted JT8D engine, the probability of damage is more than 3 times that of a wing mounted JT8D engine. In some cases the sample sizes are small.

e Bird Species Struck (see Table 6)

From Table 6 it can be seen that few of the bird species that caused engine damage have a maximum weight of over 1.8kg (4 lbs). Gulls, as usual, accounted for over 50% of the damage cases where the bird species were known. Pigeons also feature significantly. The majority of birds are within the proposed future multiple mixed 1½ and 2½ lb test criteria. It is unfortunate that 'gull' has such a wide range of weight, but the larger black-backed species are relatively uncommon. The majority of birds struck are species which respond readily to airport measures. (An earlier sample of 7500 strikes reported by European airlines showed only 1.3% of identified species were over 4 lb.) It is disappointing that in 38% of engine damage cases, there is no idea of the bird species.

f Airports Where Damage Occurred (see Table 7)

Table 7 is affected by the number of flights by UK aircraft at the particular airport. Thus at UK airports the table shows that most of the damage events are at the busiest airports. There are several foreign airports where flights by UK aircraft are infrequent. Sadly it would be a very difficult task to obtain aircraft movement data from all UK airlines at foreign airports.

5 CONCLUSIONS

a As has been shown in other papers and reports, there is not enough information available on engine damage or else sample sizes are small. Further investigation should be carried out using data from European and other BSCE participants able to provide aircraft movement data. This will help to obviate any bias due to operator's reporting standards, routes used etc.

b Aft mounted engines are less likely to suffer detectable bird strikes than wing mounted engines by a factor of about 4. Where damage is concerned, the factor is about 5, although the JT8D, used in both locations, is about 1.5:1.

c Although, in some instances, there is as yet inadequate evidence, there are indications that the aircraft fitted with noisier engines have a lower bird strike rate than the quieter engines. Even at this early stage, the trends should not be ignored. It appears that two of the new generation of very quiet engines, the Alf502, V2500 and Tay have good in-service damage records.

d The correlation between engine fan area and engine strikes may suggest that either undetected strikes (even though small birds have been excluded) take place with the remains being ejected via the by-pass leaving no evidence or else there are other significant factors which have a major influence, eg forward noise spectrum.

e There is a wide range between the worst and the average rates for engine damage whilst some engines due to the protection from the aft location, have a very good record.

f Continued collection and analysis of bird strike data will help to verify some of the above and confirm the in-service durability of engines.

g Steps should be taken to obtain better information about bird species causing damage with greater emphasis on feather remains recovered from engines.

h Further research should be implemented on forward noise levels and frequency spectra, to show if these do result in sufficient audio alerting of birds in time for them to get out of the way in time.

TABLE 1 - BIRDS (over 100g) ALL STRIKES TO AIRCRAFT

Aircraft Type	Engine Type	Number of Operators*	Aircraft Movements	All Bird Strikes	Aircraft Strike Rate per 10,000
Airbus A300	CF6	2	34.640	7	2.0
Airbus A320	CFM56	3	175,848	58	3.3
Airbus A320	V2500	4	38,054	22	5.8
Airbus A340	CFM56	1	2,834	1	-
BAe Concorde	Olympus	1	18,424	0	0
BAe 146	ALF 502	11	423,080	129	3.0
BAe 1-11	Spey	8	424,836	110	2.6
Boeing 707	JT3D	3	5,490	1	-
Boeing 727	JT8D	2	50,688	19	3.7
Boeing 737	JT8D	7	847,992	247	2.9
Boeing 737	CFM56	13	954,888	250	2.6
Boeing 747	JT9D	2	123,832	34	2.7
Boeing 747	RB211	1	242,158	68	2.8
Boeing 747	CF6	1	2252	2	(8.9)
Boeing 757	RB211	9	948,910	281	3.0
Boeing 767	CF6	4	101,924	56	5.5
Boeing 767	RB211	1	167,746	34	2.0
Fokker F100	Tay	3	77,800	22	2.8
L1011 Tristar	RB211	1	51,548	20	3.9
McDonnell Douglas DC9/MD80	JT8D	2	385,586	80	2.1
McDonnell Douglas DC10	CF6	2	44,046	21	4.8
TOTAL/MEAN	-	-	5,122,576	1462	2.85

* Note: Re-named or amalgamated airline names counted as one operator.

TABLE 2 - BIRDS (over 100g) ENGINE STRIKES

Aircraft Type	Engine Type	Number of Engines/ Location*	Engine Movements	Engine Strikes	Strike Rate per 100,000 Engine Movements	Engine Damage	Damage Rate per 100,000 Engine Movements
Airbus A300	CF6	2W	69,280	3	4.3	2	2.90
Airbus A320	CFM56	2W	351,696	16	4.5	3	0.85
Airbus A320	V2500	2W	76,108	8	10.5	0	0
Airbus A340	CFM56	4W	11,336	1	(8.8)	1	-
BAe Concorde	Olympus	4W	73,696	0	0	0	0
BAe 146	ALF 502	4W	1,692,320	43	2.5	8	0.47
BAe 1-11	Spey	2A	849,672	10	1.2	0	0
Boeing 707	JT3D	4W	21.960	1	(4.5)	1	-
Boeing 727	JT8D	2A 1C	101,376 50,688	1 0	(1.0) -	0 0	0 0
Boeing 737	JT8D	2W	1,695,984	62	3.6	9	0.53
Boeing 737	CFM56	2W	1,909,776	101	5.3	31	1.62
Boeing 747	JT9D	4W	495,328	10	2.0	3	0.60
Boeing 747	RB211	4W	968,632	21	2.2	12	1.20
Boeing 747	CF6	4W	9008	2	2.2	1	-
Boeing 757	RB211	2W	1,897,820	55	2.9	11	0.58
Boeing 767	CF6	2W	203,848	14	6.9	4	1.96
Boeing 767	RB211	2W	335,492	6	1.8	3	0.89
Fokker F100	Tay	2A	155,600	2	1.2	0	0
L1011 Tristar	RB211	2W 1C	103,096 51,548	3 0	2.9 -	1 0	0 -
McDonnell Douglas DC9/MD80	JT8D	2A	771,172	5	(0.6)	3	0.39
McDonnell Douglas DC10	CF6	2W 1C	88,092 44,046	2 1	2.3 (2.3)	0 0	0 -
TOTAL/MEAN	-	-	12,027,574	367	3.0	93	0.77

* Note: W - Wing, A - Aft, C-Central

Damage ate per 100,000 Engine ements
2.90
0.85
0
-
0
0.47
0
-
0 0
0.53
1.62
0.60
1.20
-
.58
.96
.89
0
0 -
39
0 -
7

TABLE 3 - SUMMARY OF ENGINE POSITION

Engine Position	Engine Movements	All Strikes	Rate per 100,000	Damaging Strikes	Rate per 100,000
Wing Mounted	10,159,072	349	3.43	90	0.88
Aft Mounted	1,877,820	18	0.96	3	0.16
Centre Mounted	146,282	1	-	0	-

TABLE 4 - SUMMARY OF ENGINE DAMAGE

Engine		Engine Strikes	Strike Rate	Damaging Strikes	%	Engine Movements	Damage Rate per 100,000
CFM International	CFM56	118	5.2	35	30	2,272,808	1.54
General Electric	CF6	22	5.3	8	36	414,274	1.93
IAE	V2500	8	10.5	0	0	76,108	0
Pratt & Whitney	JT3D	1	-	1	-	21,960	-
	JT8D wing	62	3.6	9	15	1,695,984	0.53
	JT8D aft	6	0.7	3	50	923,236	0.32
	JT9D	10	2.0	3	30	495,328	0.60
Rolls Royce	Olympus	0	0	0	0	73,696	-
	RB211	85	2.5	26	30	3,356,588	0.77
	Spey	10	1.1	0	0	849,672	0
	Tay	2	1.3	0	-	155,600	0
Textron Lycoming	Alf 502	43	2.5	8	19	1,693,320	0.47
TOTALS		**368**	**3.06**	**93**	**25.2**	**12,027,574**	**0.77**

Notes: Some percentages and rates will be affected by the particular routes used and hence wieghts of birds encountered.

TABLE 6 - BIRDS CAUSING ENGINE DAMAGE

Common Name	Scientific Name	Weight	Number of Damage Cases
Heron	Areda sp	500g - 4.5kg	1
Black kite	Milvus migrams	780g	2
Buzzard	Buteo sp	260g - 1.3kg	1
Fish eagle	Haliaectus vocifer	2.8kg	1
Bird of prey	Falconiformes	105g - 1.3kg	2
Partridge	Perdix perdix	400g	1
Plover	Charadriiformes	140-200g	1
Golden plover	Pluvialis apricaria	185g	1
Lapwing	Vanellus vanellus	215g	2
Balck-headed gull	Larus ridibundus	275g	6
Common gull	Larus canus	420g	2
Herring gull	Larus argentatus	1.0kg	2
'Gull'	Larus sp	120g - 2kg	21
Pigeon	Columba sp	up to 465g	9
Woodpigeon	Columba palumbus	465g	2
Rook	Corvus frugilegus	430g	1
Crow	Corvus sp	up to 530g	3
Unknown			36
TOTAL			94

TABLE 7 - AIRPORT WHERE ENGINE DAMAGE OCCURRED

UK Airports			
Aberdeen	2	Liverpool	1
Belfast Int	3	Luton	4
Birmingham	2	Manchester	5
Cardiff	4	Newcastle	2
Edinburgh	2	Prestwick	1
Gatwick	4	Stansted	1
Glasgow	1	Teesside	1
Heathrow	10	TOTAL	43
Foreign Airports			
Amsterdam	4	Larnaca	2
Basle	1	Lusaka	1
Bangor	1	Lagos	1
Bombay	2	Monastir	1
Banjul	1	Montpellier	1
Boston	1	Mombassa	1
Budapest	2	Mauritius	1
Corfu	1	Nairobi	2
Delhi	1	Oporto	1
Entebbe	2	Orlando	1
Faro	2	Porto Santo	1
Frankfurt	1	Paris CDG	1
Funchal	1	Salzburg	1
Gibraltar	1	Shannon	1
Genoa	1	Tel Aviv	1
Islamabad	2	Zakinthos	1
Ibiza	2	TOTAL	44
En-route	6		

Note: The damage at UK airports is partly a reflection of UK operators movements at those airports. The same may not be true at certain non-UK airports.

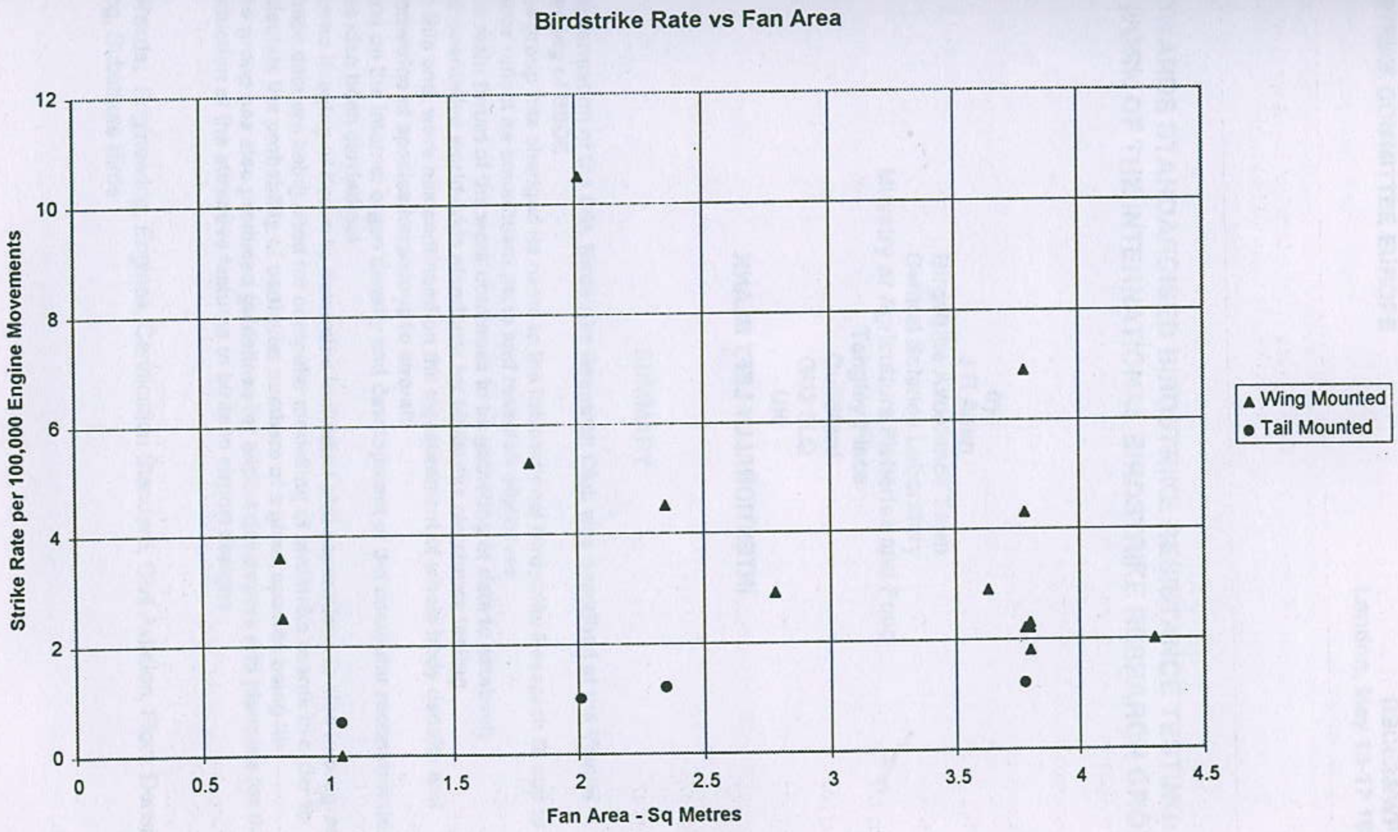
TABLE 5 - ENGINE FAN AREA AND NOISE LEVELS

Aircraft	Engine	Fan Area (sq metres) +	Sideline* (EPNL)	Approach*
Airbus A300	CF6	3.78	97.9	103.1
Airbus A320	CFM56	2.35	94.4	96.4
Airbus A320	V2500	2.01	92.8	96.6
Airbus A340	CFM56	2.66	N/A	
BAe Concorde	Olympus	1.05	112.0	117.0
BAe 146	Alf 502	0.82	87.6	96.0
BAe 1-11	Spey	0.54	103.4	101.7
Boeing 727	JT8D	0.81	104.7	106.3
Boeing 737	JT8D	0.81	104.4	015.3
Boeing 737	CFM56	1.81	93.2	100.2
Boeing 747	JT9D	4.30	103.5	107.8
Boeing 747	RB211	3.80	99.7	107.3
Boeing 747	CF6	3.78	101.8	107.0
Boeing 757	RB211	2.78	94.4	100.3
Boeing 767	CF6	3.78	97.2	101.7
Boeing 767	RB211	3.80	94.8	99.8
Fokker F100	Tay	1.02	91.7	93.0
L1011 Tristar	RB211	3.63	97.9	102.8
McDonnell Douglas DC9	JT8D	0.81	103.7	104.3
McDonnel Douglas DC10	CF6	3.8	98.5	106.6

* From FAA AC 36-1 F 'Noise Levels for US Certificated and Foreign Aircraft' of 5 June 1992, sideline noise at 450m (Concorde at 650m).

\+ From Janes All Worlds Aircraft, there is some variation depending upon aircraft series.

Fig 1


Birdstrike Rate vs Fan Area
Strike Rate per 100,000 Engine Movements
0
2
4
6
8
10
12
Fan Area - Sq Metres
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
▲ Wing Mounted
● Tail Mounted