Safety Regulation Group

Civil Aviation Authority

Large Flocking Birds

An International Conflict Between Conservation and Air Safety

A significant international aviation safety issue has been identified arising from the combination of a dramatic increase in the worldwide population of large flocking birds and the long-term growth of air traffic. Growth in the geese population, and especially the increase in non-migratory geese near urban centres, is causing considerable air safety concern.

An encounter with a flock of these geese could cause multiple engine failures resulting in a catastrophic air accident. In some areas of North America, the risk of such an encounter may be approaching a critical level.

This document describes the manner in which the risk has been identified, its significance and possible remedial actions.

It is concluded that raising the certification standard for future engines will not address the large fleet of current engines which will remain in service for many years to come.

The problem must also be addressed with environmental initiatives. Worldwide action by, and co-operation with, groups from beyond the aviation community is required to reduce the risk of catastrophic accidents due to large bird encounters.

Figure 1: Bird patrol unit. (source CSL).

Bird Strikes

From the beginning of aviation history, aircraft have faced the hazard of bird strikes. The first known bird strike was in 1908. In 1912 the first fatality was caused by a bird strike when collision with a gull caused the death of the pilot of a Wright Flyer 1.

The hazard has become more severe as aircraft speed has increased. This is because though birds are relatively small in comparison to modern aircraft, the impact energy in collisions increases with the square of the relative impact speed.

Although not the main topic of this review, the effects of bird strikes on airframes are significant and have been fatal in the past. The threats posed by single and flocking birds in relation to existing requirements are currently being reviewed by an international panel and are the subject of a research programme in the USA. However it should be noted that simultaneous strikes on various parts of the airframe can normally be assessed independently of each other, with the effects of strikes being unrelated. This is not the case when considering multiple engine strikes.

Birdstrikes on turbine engines are more serious because they experience even higher impact energies than airframes. This is due to the high rotational speed of their fans and compressors (particularly when meeting the high thrust demands for take-off).

Figure 2: Typical engine fan blade damage.

Traditional Risk Reduction

Traditionally a dual approach has been taken to reduce the risk of catastrophic bird strikes:

1) Employ airport bird control measures to minimise the number of birds on the airport and in the immediate vicinity. The prime objective should be to maintain a bird free airfield 2.

2) Impose certification requirements on new aircraft and engines such that they are tolerant of the most hazardous types of probable bird strikes.

The first element of the approach depends on the use of adequately trained and resourced airport bird control organisations. It recognises that modern jet aircraft cruise at altitudes far higher than most birds, so the risk becomes significant when an aircraft is in the initial and final portions of its flight (i.e. take-off, climb, approach and landing).

Habitat management is necessary to provide an airport environment that discourages birds nesting, roosting or feeding. Regular bird patrols are also necessary using bird scaring and dispersal techniques. As a last resort, when the safety hazard becomes unacceptable, culling may be necessary.

Major liability issues can encourage effective bird control. It is reported that one airport authority reached a $5.3 million pre-trial settlement with one airline after an airliner was struck in 1995 by at least one Canada Goose at their airport 3.

Unfortunately the efforts of airport operators can be compromised by actions beyond the airport boundaries that encourage either the congregation of birds nearby, or their transit over the airfield. One study has shown that while 85% of bird strikes involved aircraft below 800ft (i.e. in the airport vicinity), 15% have occurred remote from the airfield 4, and another analysis has shown that as many as 40% actually occur beyond the airport perimeter 5.

Past Certification Requirements

Certification requirements provide the last line of defence against bird strikes. The Design and Production Standards Division of UK CAA's Safety Regulation Group, and its predecessor the Air Registration Board, have led the way internationally in the introduction of bird strike requirements.

Engine requirements recognise two categories of strike, both at the worst case between take-off and 250 knots (the highest speed likely at low altitude in an airport's vicinity):

One case (first introduced to British Civil Airworthiness Requirements (BCARs) in 1956 6 is an encounter with a single large bird. Here the engine must be capable of a safe shut down, without the discharge of debris that may damage the rest of the aircraft.

The other case (first introduced in to BCARs in 1964 [7]) is where a flock of birds is encountered on take-off affecting several engines (i.e. a common mode failure). The requirement is that the thrust must not drop below 75%, and that the engine can continue to operate long enough for the aircraft to land back at the airport. This ensures that even a four-engined aircraft, with all engines hit, can retain the same adequate performance as it would have with a single engine failure.

Traditionally this flocking bird requirement has assumed a smaller bird than the single impact requirement, as smaller birds are typically more likely to form flocks as a defence from predators. A number of these smaller birds are assumed to strike each engine simultaneously.

In both cases certification is based primarily on test results. Little credence has been given to analytical techniques as these have proven to be relatively poor at modelling in-service incidents.

The flocking bird requirement has developed over time as perception of the hazard has changed. It was introduced in response to an accident on 4 October 1960 when a Lockheed Electra turboprop powered aircraft hit a flock of starlings on take-off at Boston, Massachusetts. The number 1 engine lost all power, and engines 2 and 4 lost some power. The aircraft stalled and crashed into the harbour just beyond the runway, killing 62 [8].

Following an incident, involving a Vickers Vanguard turboprop at Edinburgh, UK on 11 Sept 1962 [9], the requirement was enhanced to introduce 1.5lb (0.7kg) birds, in order to cover gulls. In this incident the number 4 engine failed almost immediately. The other three engines all lost power with the number 2 engine shutting down as the aircraft manoeuvred. The aircraft was however able to make a safe landing on the remaining two engines.

While rig tests have been used for the large bird test, the run-on aspect of the flocking bird requirement necessitates that bird carcasses be fired from compressed air cannons at an engine running on a test bed.

Figure 3: Multi-barrelled birdgun in place in front of an engine. (Source Rolls-Royce)

The large bird requirement is currently for a single bird up to 8lb (3.6kg) in weight. The size was selected to address the majority of historically recorded bird strikes. It is not technically viable to protect engines from worst-case impacts from the largest, but relatively rare, bird species.

Geese – The Emerging Threat

During the last decade a new and serious threat has become apparent, namely the increasing numbers of large geese. The main threats in terms of body weight and population size are Canada Geese and Snow Geese. They are found in large numbers in North America. Canada Geese are also found in Europe in smaller, but increasing numbers. Additionally there is a smaller European threat from Greylag Geese.

Figure 4: Canada Geese (Source: CSL)

The mass of adult Canada and Snow Geese ranges from 5lbs (2.3kg) to 16lbs (7.3kg), averaging 8lbs (3.6kg). Geese are traditionally migratory birds. Whilst they usually fly at altitudes below 5,000ft they have been encountered at altitudes up to 20,000ft. Geese fly in v-shaped 'skeins', diagonal formations, with birds spaced about 10 to 12 feet (about 3 to 3.5m) apart. Thus they must be considered as flocking birds since the same skein could strike multiple engines. While traditionally migratory, an increasing percentage of geese are now non-migratory, inhabiting sites near population centres and hence airports. This threat brings the validity of the current requirements into question.

In the 1970s and 1980s the population of geese was such that goose strikes were rare. Hence the probability of a multiple engine incident was considered extremely remote. However the Canada Goose population in North America has increased from 2 million in 1990 to 5.7 million today [10], and the trend continues.

In 1953 the then small, and previously stable, UK population of about 3,000 geese began to increase at an average rate of about 8% per year. The UK goose population was over 73,000 by 1991 and has now reached around 130,000 [11].

It is likely that by 2010 the goose population will have doubled in size again. It is unclear when natural factors (such as availability of food or breeding sites) will begin to slow this growth [12].

Until the terrorist attacks of 11 September 2001 there had been a steady rise in the number of world passenger flights. Currently North America and Europe (which account for an estimated 70% of worldwide passenger movements) generate 20.8 million transport flights per annum. By 2010, assuming the likely recovery in growth, this is predicted to reach 28.2 million (36% more than today).

The combination of traffic growth and the expanding population of large flocking birds means that, unless positive action is taken, the risk of an airliner colliding with large flocking birds will rise by more than 2.5 times during this decade (and around 6 times higher in 2010 than in 1990).

Canada Geese have already caused one major aviation accident. In September 1996 a US Air Force E-3A AWACS aircraft (which uses the airframe of the civil Boeing 707) crashed after two engines were seriously damaged by a flock of Canada Geese at take-off. The crew of 24 perished.

Other more recent civil events show the potential for damage, and especially multiple engine damage, from geese:

1) On 9 January 1998 a Boeing 727 struck a flock of migrating Snow Geese while climbing after take-off from Houston, Texas. All three engines were extensively damaged, as were the leading edge slats, radome and airspeed pitot tube [13]. The aircraft was however able to make a safe landing.

2) On 1 September 1998 a Boeing 767 struck a flock of geese when the aircraft was about to touchdown at London Heathrow [14]. This caused extensive damage to the radome and the left wing leading edge and slats. The left engine had evidence of bird ingestion. Whilst a borescope inspection did not show evidence of damage to the engine core (probably as the bird strikes occurred when the engines were at idle power), all the fan blades had to be replaced. There was also evidence of bird strikes on the left and nose landing gears, left wing trailing edge flaps and the left stabiliser.

3) On 19 November 1998 a Boeing 747 encountered a flock of approximately 40 Snow Geese beyond the airport boundary while executing a missed approach at Montreal Airport, Canada. The number 4 engine was shutdown, and a safe landing was made. The number 3 engine controls jammed at idle during taxy. Subsequent examination revealed damage to the number 4 engine, the nacelle of the number 3 engine, the radome, landing gear, both wing leading edges and external lights. The number 2 and 4 engines were removed after this incident, though only the number 4 engine is believed to have had bird damage. The span wise distance between the nose and the outboard engine on a 747 is comparable with the engine spacing on the largest twin engined transport aircraft in service.

Figure 5: Boeing 747 (Source: CSL)

4) In March 1999 a McDonnell Douglas DC-9-15 encountered a flock of Snow Geese while on final approach at Kansas City International Airport. Several birds were ingested into both engines, resulting in severe engine power loss. The left engine suffered

repeated compressor stalls and the other went to a sub-idle condition. The captain reduced the power on the left engine just enough to lessen the surge/stall condition and allow enough thrust to maintain the approach. The aircraft landed successfully. There were no injuries 15.

Each of these cases has been confirmed as involving geese. If any feathers are recovered it is possible to identify the bird species by microscopic examination of the feather structure. Alternatively DNA techniques can be used to identify the species.

It is significant that only one of these incidents occurred within the boundary of an airport.

The US National Transportation Safety Board and the UK Air Accident Investigation Branch have both made recommendations after these incidents 16 17.

Current Certification Requirement Development Activity

The CAA has played a leading role in developing enhanced engine certification requirements and the NTSB and AAIB recommendations have served further to emphasise the need for such activity. This work has been conducted in co-operation with other safety regulators (the US Federal Aviation Administration, Transport Canada and other European Joint Aviation Authorities) and the aero engine industry.

The initial aim was to enhance the engine requirements in one step to include a test with an 8lb (3.6kg) bird at take-off conditions followed by a period of continued operation (run-on). It has now been established during experimental tests that the current best technology is unable to provide an engine capable of producing sufficient levels of thrust following such an encounter.

A large improvement in safety would however be demonstrated by a run-on test following ingestion of up to a 5.5 lb (2.5kg) bird (dependent on engine size). It is therefore currently proposed that this requirement be introduced internationally and that further research continues into enhancing engine bird strike resistance.

Once the new requirement is in force, it will only apply to new types of engines. Currently certified engines will continue in production. Since commercial aircraft have a lifetime of around 25 years or more, the improved standard will take time to be introduced into the civil aircraft fleet in significant numbers.

Figure 6: Typical Turbofan
(Source: CSL)

Enhancing the engine certification requirements will provide significant mitigation but will not in itself be capable of eliminating the risk of a catastrophic multi engine bird strike event. The shortfall needs to be filled by more vigorous bird control measures.

Airport Bird Control Risk Mitigation Measures

As noted previously, a significant proportion of strikes occur near airfields during take-off, initial climb, approach and landing. There is much that can be done to reduce bird populations in the vicinity of airfields in areas under the control of the airport operator. The prime objective should be to maintain a bird free airfield. This is a realistic goal if an adequately trained and resourced bird control organisation is in place 18 19.

While many airports in the UK and elsewhere have effective on-airfield bird control programmes, these need to become standard worldwide, integrated into an airport operator's Safety Management System. The CAA has enthusiastically promoted this activity and has published relevant guidance in CAP680.

Habitat management is necessary to provide an airfield environment that discourages all birds 20. One aspect involves netting ponds and lakes. Where this is impractical, steepening banks and introduction of other obstacles at the water's edge can encourage geese to move to sites with easier access between water and land 12.

Figure 7: Bird Netting Over Drainage Ditch (Source: CSL)

Low fences can actually be effective in open ground, as geese tend to prefer to walk between feeding and roosting sites (tending to only take-off and land from water). Appropriate management of grassed areas and vegetation can also effectively discourage birds [18]. It is also important to eliminate any nesting sites within the airport boundary.

Figure 8: Tall Grass to Discourage Birds Landing (Source: CSL)

These measures must be backed up with frequent bird patrols and the use of bird scaring and dispersal techniques. As a last resort culling may become necessary.

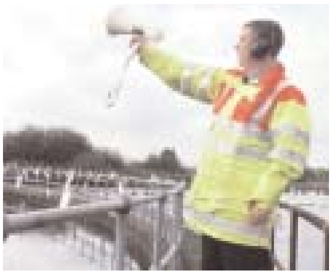


Figure 9: Acoustic Dispersal and Bird Deterrents Devices (Source: CSL)

National environmental agencies must acknowledge the air safety role of bird control units when considering any regulations that may affect the control of the bird strike risk.

Wider Environmental Risk Mitigation Measures

There are current laws in the U.S. protecting migratory birds that initiated from conservation acts as early as 1917. National legislation and EU Directives have a similar effect in Europe. The growth in Canada Geese and Snow Geese is largely due to increased protection and a better understanding of the conservation of the species.

The change of ecology, particularly of Canada Geese, that results in fast growing populations of more non-migratory birds is significant. Non-migratory geese tend to inhabit areas of open parkland, golf courses and areas with both natural and man-made water features. They have also adapted to feed on open farmland [21]. Geese are thus increasingly found near airports.

In order to manage the large flocking bird hazard, bird control techniques must be applied to extend to areas considerably beyond the airfield boundary. CAA sponsored research by the Central Science Laboratory of the UK Department for Environment, Food and Rural Affairs, has shown that large flocks of geese nesting in areas remote from the airfield can transit across airports and the adjacent airways while enroute to feeding grounds.

Direct control of the hazard cannot therefore rest solely in the hands of the aviation community. A wider range of environmental stakeholders are involved. In order to tackle the air safety hazard it is necessary for airport operators to develop a safety management strategy that involves local landowners and other agencies. Depending on circumstances this may affect zones 10 miles (16km), and perhaps more, from an airport's boundary.

Some of these stakeholders have not traditionally needed to consider air safety. Their commitment is however key to achieving a significant risk reduction. However provision for enforcing bird control measures may be necessary in some cases. Interestingly, while landowners in the UK have traditionally been required by environmental regulations to control 'pests' such as rats on their property, birds that threaten air safety are not similarly categorised.

It is clear that robust habitat management and active bird control measures employed within airports need to be used beyond the airport boundary.
Planning authorities must consider air safety when reviewing applications in close proximity to airports. Farmers need to carefully consider the air safety

impact that particular land use choices may have. National environmental agencies with the power to create protected areas for birds must similarly consider the risk of bird strikes when establishing such protected areas. They must also review the appropriateness of zones currently in place. Additionally developments that actively favour geese on an even wider radius must be avoided where possible.

Figure 10: Land Fill Site Without Netting (Source: CSL)

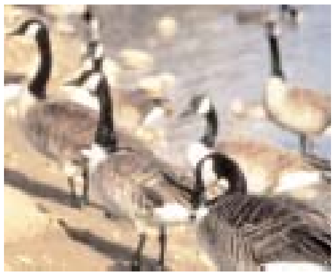
Figure 11: Netting in Place (Source: CSL)

Physical relocation of geese is an option. This is best achieved during the mating season when the birds are temporarily flightless. This though is an expensive option that merely moves the problem elsewhere 12. It may however be useful when small and distinct groups of geese pose an identifiable safety hazard.

In proximity to airports these measures may need to be supplemented by reproductive controls at geese sites resistant to other measures. While chemical contraception may be conceptually attractive as a humane population control there are so many practical difficulties that this technique is not yet available. Of particular concern is how to deliver the chemical in a selective manner without affecting other species.

Humane egg treatment is the most practical and proven technique for reproductive control of geese 20. One method pierces the eggs that are then left in the nest (stopping embryo growth while discouraging the female from laying more eggs). Another method removes the eggs and replaces them with dummy eggs. While such an action would stunt the population growth rate, Canada Geese are long-lived birds 12, and such reproductive controls alone are unlikely to have a major effect on the total population and thus the aviation hazard in an acceptable time scale. Hence in some extreme cases of non-migratory birds it may be necessary to resort to culling.

Figure 12: Canada Geese (Source: CSL)



Operational Risk Mitigation Measures

CAA sponsored research has shown that many bird formations (including geese) cross airport boundaries at altitudes as low at 50ft. This means that even daytime visual detection is difficult, especially where buildings and trees obscure the observer's view. Hence it is not practical to rely on warnings from bird control units or the air traffic control tower.

In order to gather improved data, trials with a bird detecting radar are being considered.

However the ability of commercial aircraft to manoeuvre to avoid birds while in close proximity to an airport is limited. In practice, once the take-off roll has commenced the only option is to reject the take-off. On approach the only option is to commence a missed approach. As the B747 case in Montreal shows, even this may result in a bird strike. Similarly the ability to direct aircraft around birds during the initial climb or while on approach will be limited and would result in the undesirable side effect of raising pilot workload and increasing the risk of eroding aircraft to aircraft separations.

Hence any warning that such systems could give is unlikely to be of practical use in the majority of cases and so cannot be assumed to make any significant impression in reducing the risk of a bird strike.

The primary objective of a bird detecting radar programme should be to gather better bird control intelligence. This would aid the planning of on-airfield bird control. It would also identify local bird sites responsible for the majority of incursions, helping to target off-airfield control activities.

There are other risk mitigations that could potentially reduce the risk of a bird strike, such as more lengthy use of landing lights [22], the use of weather radar or ultra-violet paint. All are postulated as increasing the ability of birds detecting and thus avoiding aircraft. There is no scientific evidence for their effectiveness however. Collectively these measures are not expected to have a major impact on the risk.

Figure 14: Bird Patrol (Source: CSL)

AIA Study

The Aerospace Industries Association (AIA) has recently conducted a study on bird control measures in order to advise the JAA and FAA. They made five recommendations, all of which the CAA support:

Recommendation 1: ICAO and national regulators should establish regulations that require airports to develop and implement a bird control plan that includes control of the numbers of flocking bird species both on and adjacent to their property. National laws should be provided by the countries concerned to enable airports to carry out these activities.

Recommendation 2: National regulators should prevent the establishment of sites that are attractive to birds on, or in the vicinity of, airports.

Recommendation 3: Incentives need to be strengthened for airport operators and local authorities to take the necessary actions to reduce/eliminate hazardous wildlife and hazardous wildlife attractants on or near their airport.

Recommendation 4: Aviation safety regulators need to lead an effort to inform the public of the hazard to commercial air safety caused by wildlife.

Recommendation 5: Countries should establish mechanisms to review populations of flocking bird species over 4 lbs (1.8kg) and then to manage populations in consultation with conservation and other interests to levels consistent with acceptable flight safety standards.

Conclusions

A significant aviation safety issue has been identified arising from the combination of a dramatic increase in the population of large flocking birds, in particular Canada Geese, and the forecast growth of the large civil transport fleet.

The risk of a catastrophic accident owing to multiple engine thrust loss after a bird strike encounter with a flock of geese is rising dramatically. The risk of such a strike will be approximately 2.5 times higher in 2010 than 2000, and around 6 times higher than 1990. There are no natural forces acting to limit this population growth.

A number of serious incidents have already occurred and the overall level of risk is now such that urgent international action is required.

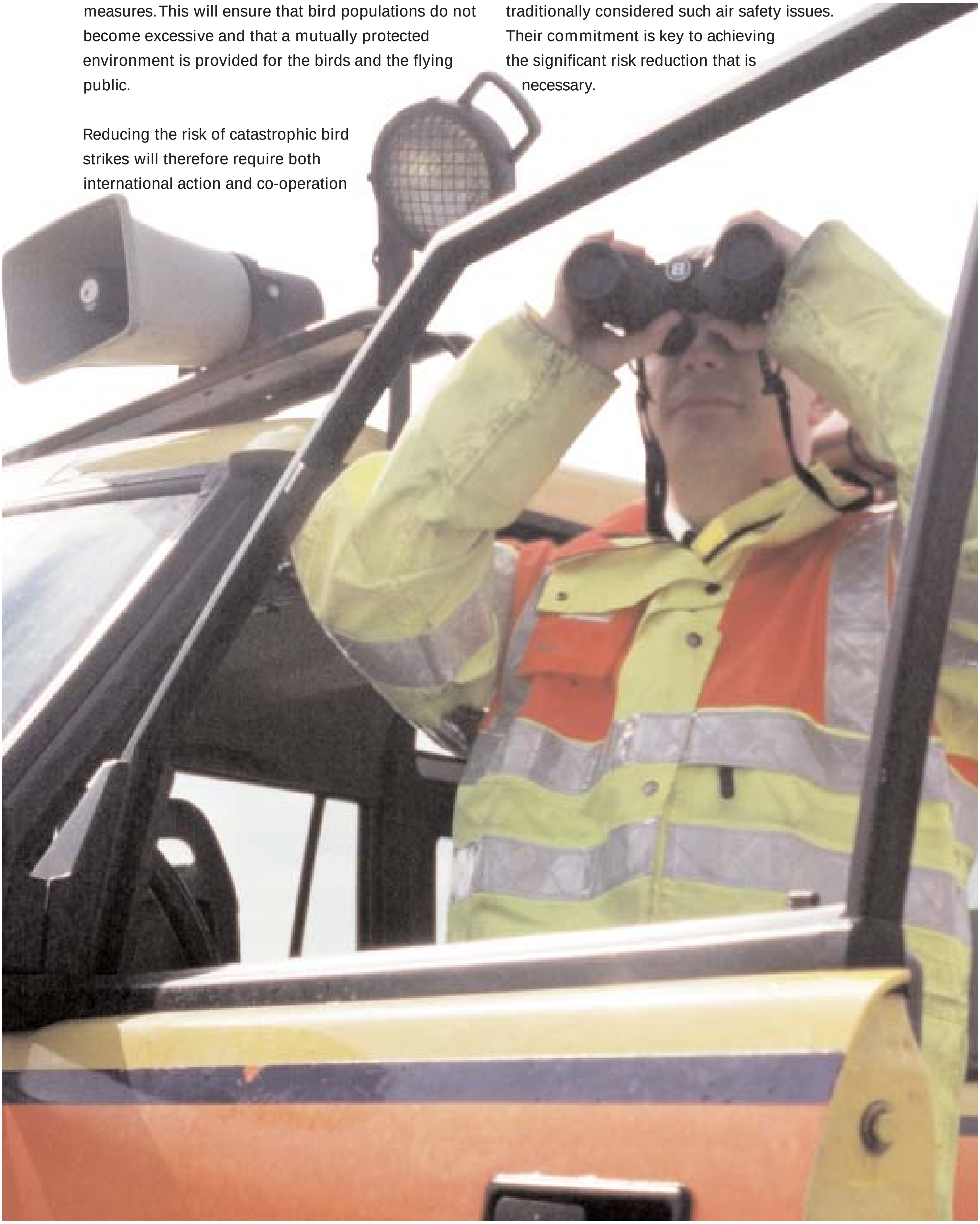
The last line of defence is the bird strike tolerance of aero engines. Improving the certification standard for future engines will not in itself be sufficient, owing to the bird strike tolerance that can be achieved with latest technology, and the timescale for introduction of improved engines into the civil fleet.

While UK bird control provisions are mature and are being further enhanced, it is essential that tighter standards for bird control be adopted internationally. On-airport bird control measures are the prime risk mitigation measure, but it has also been established that robust measures are necessary beyond the airport boundary, especially in North America where the goose population is much higher.

Local authorities and environmental agencies need to empower (and if necessary enforce) such wider bird control programmes. Landowners near airports need to take measures to minimise the use of their land by geese.

It is recommended that conservation laws be updated to reflect the need to balance control of hazardous populations of certain birds with sensible conservation measures. This will ensure that bird populations do not become excessive and that a mutually protected environment is provided for the birds and the flying public.

Reducing the risk of catastrophic bird strikes will therefore require both international action and co-operation from beyond the aviation community. This will include landowners, local authorities, environmental agencies and national governments that may not have traditionally considered such air safety issues. Their commitment is key to achieving the significant risk reduction that is necessary.



References

1 Thorpe, J (1996), 'Fatalities and Destroyed Civil Aircraft Due to Birds Strikes 1912-1995', The International Bird Strike Committee's 23rd Conference, 13-17 May, London, p18

2 Civil Aviation Authority, (1998), 'Aerodrome Bird Control', UK Civil Aviation Authority, CAP680, p2-1

3 MacKinnon, E et al (Ed.), (2001), 'Sharing the Skies', Transport Canada, p11

4 Thorpe, J (1987), 'Civil Aviation Birds Record', Royal Aeronautical Society Bird Hazards in Aviation Conference, 14 October, London, p5

5 Riddington, R (2000), 'The Large Flocking Bird Hazard', Flight Safety Foundation / International Federation of Airworthiness / International Air Transport Association, International Air Safety Seminar, New Orleans, November

6 Air Registration Board, (1956), 'BCAR Section C, Paper 271', UK Air Registration Board, November

7 Air Registration Board, (1964), 'BCAR Section C, Paper 406', UK Air Registration Board, September

8 Civil Aeronautics Board, (1962), 'Aircraft Accident Report: Eastern Air Lines Inc, Lockheed Electra L-188, N5533, Logan International Airport, Boston, Oct 4 1960', US Civil Aeronautics Board, July 31

9 Civil Aviation Authority, (1974), 'World Airliner Accident Summary', UK Civil Aviation Authority, CAP479

10 Fish and Wildlife Service, (2000), 'Waterfowl Population Status 2000', US Fish and Wildlife Service, 30 June

11 Austin, G E et al (2001), 'Updating the Canada Goose Population Estimate for Great Britain', British Trust for Ornithology

12 Allan, J R, Kirby, J S & Freare, C J, (1995), 'The Biology of Canada Geese Branta Canadensis in Relation to the Management of Feral Populations', Wildlife Biology, Volume 1 Issue 3, p129-143

13 MacKinnon, E et al (Ed.), (2001), 'Sharing the Skies', Transport Canada, p123

14 Air Accidents Investigation Branch, (2001), 'AAIB Bulletin 4/2001', UK Air Accidents Investigation Branch, April

15 Hall, J (1999), 'Safety Recommendations A-99-86 through –94', US National Transportation Safety Board, 19 November

16 Air Accidents Investigation Branch, (2001), 'AAIB Bulletin 4/2001', UK Air Accidents Investigation Branch, April

17 Hall, J (1999), 'Safety Recommendations A-99-86 through –94', US National Transportation Safety Board, 19 November

18 Civil Aviation Authority, (1998), 'Aerodrome Bird Control', UK Civil Aviation Authority, CAP680

19 Allan, J (1999). 'The Management of Problems Caused by Canada Geese: A Guide to Best Practice', DEFRA European Wildlife Division, Bristol

20 Watola, W, Allan, J R & Freare, C J, (1996), 'Problems and Management of Naturalised Introduced Canada Geese Branta Canadensis in Britain', published in Holmes, J S and Simons J R (Ed.), 'The Introduction and Naturalisation of Birds', HMSO

21 MacKinnon, E et al (Ed.), (2001), 'Sharing the Skies', Transport Canada, p41

22 MacKinnon, E et al (Ed.), (2001), 'Sharing the Skies', Transport Canada, p177-188

For further information please contact:

Safety Regulation Group
Civil Aviation Authority
Aviation House
Gatwick Airport South
West Sussex RH6 0YR

Tel: 01293 567171
Fax: 01293 573999

www.caa.co.uk