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**HIGH SPEED FLIGHT AT LOW ALTITUDE: HAZARD TO COMMERCIAL AVIATION?**

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**ABSTRACT**

Commercial aircraft are capable of, and in fact, do, operate at high speed (>250 knots indicated airspeed [KIAS]) at low altitude (below 10,000' above ground level) worldwide. Design, construction and certification standards for these aircraft were developed over 40 years ago. Since the development of these standards populations of large flocking birds have increased dramatically in many parts of the world. Yet neither design/construction standards nor operational practice have changed to reflect the new threat. Subsequent serious damage resulting from recent collisions indicates change is necessary. Since 2003, flight rules in Canada and the United States have been amended, principally due to concern over bird strikes, to prohibit high-speed flight below 10,000'. As Mexico has already adopted such standard there is now no high-speed flight at low altitude in North America. Worldwide, however, various Flight Identification Regions (FIRs) have adopted a variety of speeds at low altitude to suit air traffic control (ATC) requirements. Most operators and regulators are unaware of the force imparted on airframes and engines by bird collisions, demonstrated by the equation: kinetic energy = (1/2 mass) times (velocity<sup>2</sup>). For example, a 20% increase in aircraft speed from 250 to 300 KIAS results in a 44% increase in impact energy during a bird strike. Clearly the speed of the aircraft and engine rotation speed are more important in a collision than the size of the bird and more controllable than the size of the bird. While hardening the aircraft structure is an effective mitigation strategy, a faster and cheaper solution to reducing impact energy on the aircraft is to adopt operating strategies and rules which limit exposure to damage during collisions. One such strategy/rule is to prohibit high-speed flight at low altitude by commercial aircraft.

**Key words:** commercial aircraft, speed, design standards, rules, operating practice, damage, bird, bird strike

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## **1. Introduction**

Conflict between aircraft and birds is a continuing and growing concern worldwide. The cost of bird collisions with air carrier aircraft can be US\$1.2 billion a year (Allan/Orosz, 2001). A variety of mitigation actions are available to airport operators to reduce the risk of birdstrikes by an aircraft on or near their airport (Cleary/Dolbeer, 2005). However, mitigation in the enroute portion of the flight has a limited number of options.

Technology, such as radar observations or computer predictions of hazard (BAM), is unavailable to civil aircraft and may never be available. There is virtually no training for flight crews regarding the hazard of bird collisions, nor is any required by regulators. Essentially the only mitigating factor in the enroute portion of a flight is the design/construction standards for commercial aircraft, which are outdated.

## **2. Certification Standards**

Both the U.S. FAA and the EU JAA have developed design/certification standards for commercial aircraft. Engine certification has been dealt with previously and will not be considered here, rather airframe and window standards will be examined.

Current standards for airworthiness address a single strike by a bird of certain weight. The weights vary depending on the portion of aircraft struck. For instance, survival of a 4-pound bird strike was previously considered sufficient until a Vickers Viscount turboprop was struck on its empennage by a tundra swan (12-17 pounds) over the eastern U.S. The resultant loss of the aircraft's tail and all aboard resulted in, in 1970, a change to the Federal Air Regulations (FARs). As this aircraft had struck a 12-17 pound bird, the certification standards for the empennage were raised to ensure aircraft could withstand an eight-pound bird impact.

Further, the introduction of the 'glass cockpit' aircraft with its emphasis on computer driven flight management systems and cathode ray tube displays opens another area of concern. In 1989 an A-320 aircraft, operating at 2,500' and 250 knots indicated airspeed (KIAS), collided with a vulture (~10 pound) just above the cockpit windscreen. Although the windows were not penetrated, sufficient energy was imparted onto the airframe to destroy 4 of the 6 cockpit display units (CRTs) and loosen a fire button, causing the shutdown of one engine.

Additionally, certification standards do not address nor do manufacturers have to demonstrate flight with multiple systems inoperative, such as the above situation. Further, certification standards require that the aircraft be able to survive a single strike by a four-pound bird at  $V_c$ , the design cruising speed of the aircraft at sea level. However, at sea level the design cruising speed is virtually equal to the true airspeed of the aircraft. As the aircraft ascends the same indicated airspeed will yield a higher true airspeed due to the reduced atmospheric pressure at altitude. Therefore a bird strike at the same indicated airspeed at a higher altitude will generate greater force on the aircraft. There is no comment on this speed change in the regulations.

## 2.1 Certification Metrics

Design/certification standards are based on a freedom from catastrophe of  $10^{-9}$ , or one catastrophe to every  $10^9$  operations. This standard is, of course, based upon obtaining the complete and correct data, a daunting task not only in birdstrike collision work but also certification work. Additionally, not only must the data be obtained, but it must also be applied in a manner to draw an accurate picture of the risk. For instance, during the FAA sponsored high-speed climb test at Houston, Texas in 1998, a Delta Air Lines B727 collided with a flock of snow geese (5-7 pounds) at 280 KIAS. The #1 engine was destroyed by bird ingestion, the #2 engine was damaged by ingestion of radome parts (radome and radar unit were knocked off the aircraft by collision with birds) and the #3 engine, while suffering no direct ingestion damage, was put at risk as two birds penetrated the pylon which holds the engine onto the airframe and contains both fuel lines and control cables. Obviously this was a serious event, but it was not recorded as a multiple bird ingestion event as the #2 engine was not damaged by *birds*, rather by airplane parts knocked off the airplane by birds. The #3 engine had no ingestion, so the pylon penetration was considered by the engine certification group as a structures matter. As the aircraft did not crash there was no reason to amend the standards.

This method of certification is reactive in nature, waiting for a catastrophe to affect the data. It is not proactive and does not allow for changes in the hazard level, i.e., dramatically increasing populations of large flocking birds which will inevitably lead to increasing number of collisions (Dolbeer/Eschenfelder, 2002).

However, both the FAA and JAA have been considering the proper standards for bird strike protection. Both of these regulatory bodies have developed positions for increased bird strike standards. Unfortunately, neither group agrees with the other group's position. Therefore the groups have 'agreed to disagree' on the level of bird strike protection that the structural portion of the aircraft requires. So there will be no harmonization of the bird strike protection standards between FAA and JAA (Kasowski, 2003).

## 3. Operational Considerations

Modern jet aircraft can operate routinely at a speed range between 320-340 KIAS at low altitude (less than 10,000'). These speeds are restricted in some states by regulation such as the U.S. FAA's FAR Part 91.117(a), limiting speeds to 250 KIAS below 10,000'. This rule was implemented as part of the 'see and avoid' concept to prevent mid-air collisions between aircraft. Mexico also maintains a speed limit below 10,000' of 250 KIAS. Canada has recently moved to amend CAR 602.32 to prohibit speeds greater than 250 KIAS below 10,000'. One of the driving factors of this rule change by Transport Canada was the concern of high-speed collisions between aircraft and large flocking birds.

### **3.1 Air Traffic Control Considerations**

Many Flight Identification Regions (FIRs), such as those at Singapore, Rome, Amsterdam, allow unlimited speeds at low altitude depending on air traffic requirements. In these FIRs the controller may simply issue a clearance to the pilot for “speed unrestricted”, which allows for high-speed flight at low altitude. Other FIRs, which have a lesser volume of traffic, have no restrictions on speed at low altitude (Jeppeson, 2005).

### **3.2 Migratory Bird Routes**

Migratory routes of various species of large flocking birds have been identified in several parts of the world. For example, it is readily obvious that large eastern European birds migrate to Africa annually, passing along the eastern shore of the Mediterranean Sea. Additional European-Africa routes are over the Iberian Peninsula and the Italian Peninsula to central, southern and eastern Africa. More information regarding migratory routes is becoming available from recent scientific contributions by eastern European states. Large air carrier airports underlying these routes can be readily identified. Unfortunately the beginning and ending dates of these annual migrations cannot be readily defined. Additionally, migratory flight altitudes are commonly between 5,000 and 7,000 feet, with some species flying at 11,500 feet (McKinnon, et al, 2001).

## **4. High Speed Flight at Low Altitude Safety Considerations**

In 1997 the FAA began a test at the Houston Intercontinental Airport, allowing for speeds in excess of 250 KIAS on departure. The stated object of the test was to increase capacity. A series of industry meetings were hosted by the FAA to obtain data and address concerns regarding this test. At no time during these meetings or during the test was any data collected demonstrating that this test was saving either fuel or cost. Other concerns were raised however, as the data showed that aircraft at high speed were exiting the side of the Class B airspace rather than climbing out the top of Class B airspace, an action which could increase the likelihood of mid-air collision. The reason the aircraft climb performance was lessened was that excess thrust previously used to increase climb rate was being transferred to increase acceleration (Lankford, et al, 2000). Additionally the above-cited Delta B727 collision with migratory snow geese in 1998 was a concern to some. Bird strikes were also a concern to the National Transportation Safety Board (NTSB). In 1999 the NTSB expressed their concern to the FAA regarding the safety of high-speed flight at low altitude due to the bird strike hazard (Hall, 1999).

Due to concerns regarding bird strike risk the FAA commissioned a study to assess the risk. When completed this study could not quantify the bird strike risk, therefore no risk analysis could be designed (Herricks, 2002). Since the test could not be proven to be as safe as the former procedure the FAA terminated the test. There is currently no high-speed flight at low altitude in the U.S.

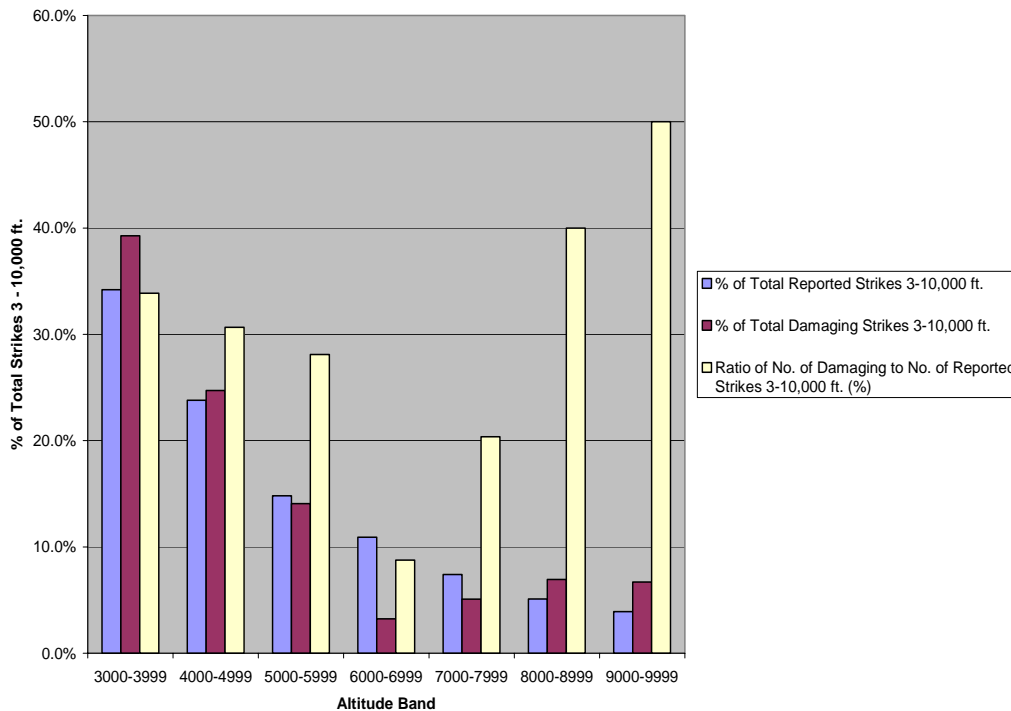
In Canada, Transport Canada had previously allowed high-speed flight at low altitude on departure in some FIRs. However, in 2002 Transport Canada published a Notice of Proposed Amendment (NPA) 2002-022 to CAR 602.32 to eliminate speeds in excess of 250 KIAS below 10,000 feet. In support of this NPA Transport Canada commissioned a risk analysis.

This analysis found, among other things, that "...populations of high-risk bird species are increasing". It further found that "...current airframe and engine certification standards do not reduce risks associated with strikes..."; and that "...any potential operating-cost savings that might be achieved through increased flight speeds would be more than offset by losses incurred through bird strikes" (Sowden/Kelly, 2002). Therefore Transport Canada moved to eliminate high-speed flight at low altitude.

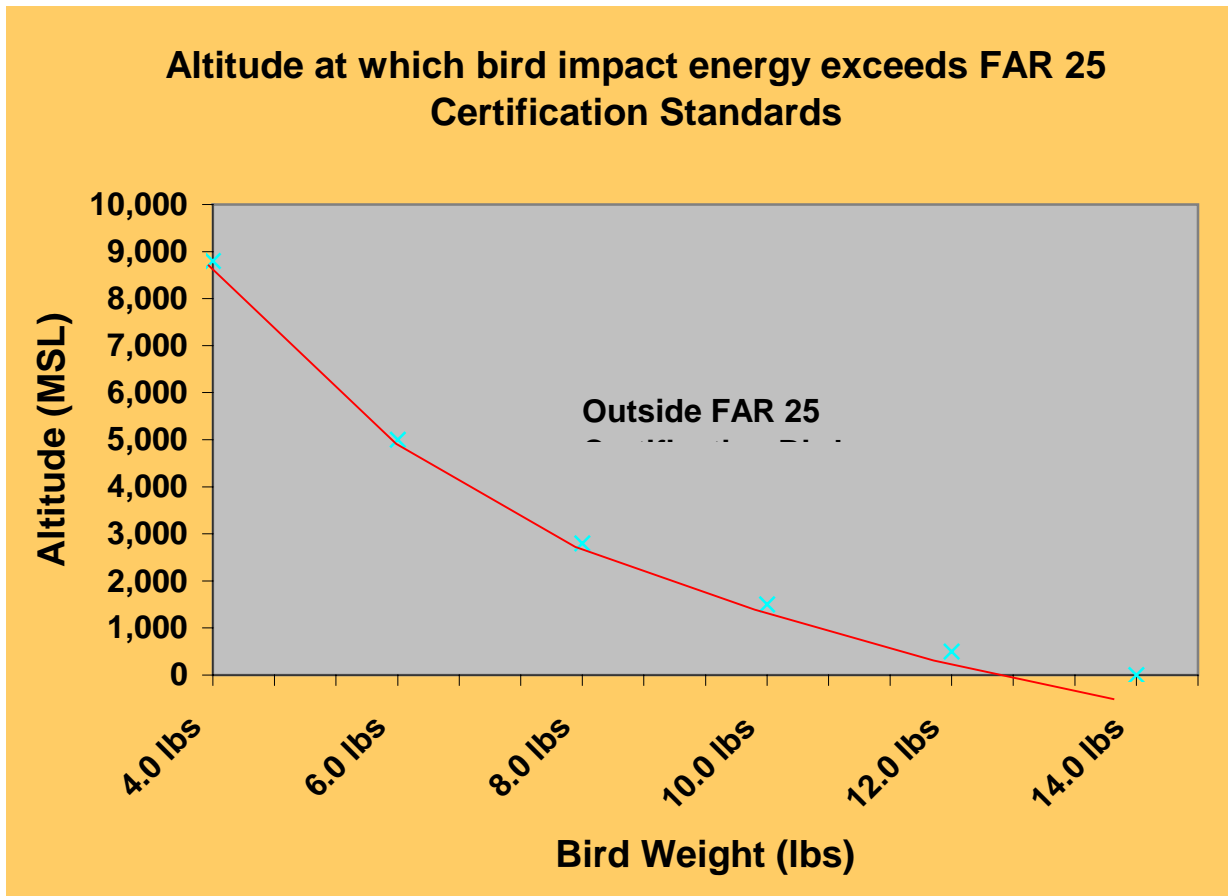
## 5. Discussion

The growth of large flocking bird populations is undeniable (Dolbeer/Eschenfelder, 2002/2003). Also undeniable is the growth in aviation worldwide. It is inevitable that conflict between aviation and wildlife will increase. Therefore effective mitigation to ensure the current level of safety must be implemented.

The enroute portion of the flight is relying on design standards which have been outdated by bird population growth. Not only are these design standards in need of revision but regulatory authorities cannot even decide on what the new standard should be. While an increase in altitude decreases the likelihood of a birdstrike, it also increases the risk, as the higher the altitude the more likely the strike will be a damaging one (figure 1).



Additionally, the equation  $KE = (\frac{1}{2} \text{ mass}) \times (\text{velocity squared})$ , where KE equals kinetic energy imparted on the aircraft in foot pounds per square inch, clearly reveals that the speed of the aircraft is much more important than the size of the bird. That is, an aircraft which strikes a 10-pound goose at 250 KIAS at 9,000 feet will have an impact force of 72,617 pounds. Increasing the speed by only 20%, to 300 KIAS, results in a 44% increase of impact force on the airframe to 104,500 pounds. Figure 2 demonstrates an aircraft at 280 KIAS.



The rationale for the limiting altitude to be 10,000 feet is one of simple expedience rather than pragmatic fact. The FAA established 10,000 feet as its speed limiting altitude due to mid-air collision avoidance. After modern jet aircraft were introduced into the civil fleets there were several mid-air collisions between general aviation aircraft and air carrier turbojets. Partial blame for these collisions was placed on high speed at low altitude, where the aircraft did not have enough time to “see and avoid” each other. Since most general aviation aircraft do not fly about 10,000 feet due to the required use of oxygen in unpressurized aircraft, the 10,000-foot altitude was adopted as a speed limit point. Subsequently this level was adopted by many states worldwide for the same purpose.

Likewise the speed of 250 KIAS was adopted, after industry meetings, as a ‘good enough’ speed in a compromise between safety and efficiency at lower altitudes.

There are certainly no hard and fast ‘cruising altitudes’ for migratory wildlife. However, as there is already a commonly accepted speed limit point for aircraft that seems to fit the upper limits of migratory altitudes, the 10,000-foot level could readily be adopted. Likewise, anecdotal information indicates that, generally, birds tend to bounce off aircraft below 250 KIAS but seem to penetrate above that speed.

Not all FIRs or airports suffer from migratory bird hazards. However, many do. Plus, some aircraft leaving areas of low threat may, in fact, be landing at airports with a high bird strike risk. Additionally, it is very difficult to pinpoint the beginning or end of the annual migration cycles due to varying climatic conditions annually and the desires of various bird species to migrate.

## **6. Conclusions**

1. The airframe, window and airspeed systems design standards on modern aircraft need to be updated. However, there is no consensus between regulatory authorities as to the proper level. Therefore it can be concluded that the design/certification standards are no longer adequate.
2. There is no training available to flight crews, nor any data upon which to base decisions, which will allow flight crews to take action which will mitigate bird strike risks in the enroute portion of their flight.
3. Regulators, aircraft owners/operators and flight crews have absolute control of the speed of aircraft. While a slower speed at lower latitudes may not prevent a bird strike, it will certainly lessen the impact on the aircraft, hence reducing the risk of a catastrophic event.
4. In areas where large flocking birds are present, aircraft airspeeds should be restricted to 250 KIAS below 10,000 feet.

## **7. Acknowledgments**

I would particularly like to acknowledge the large amount of background work accomplished on this subject by Bruce Mackinnon of Transport Canada and the technical analysis of Captain Richard Sowden. My thanks, also, to Dr. Richard Dolbeer for his critical analysis.

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