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**Aviation Stakeholder Management Of Bird Strike Risks –  
Enhancing Communication Processes To Pilots And Air Traffic Controllers For  
Information Derived From Avian Radar**

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## Executive Summary

Avian radar has been validated, and guidance for its use in supplementing wildlife hazard management plans at civil airports to reduce avian threats was provided by the Federal Aviation Administration in late 2010. Efforts are underway to assess the efficacy of an automated, tactical, bird-threat alerting system for use by airport operations personnel. Thus, the time is opportune to engage pilots and air traffic service providers to develop additional strategic and tactical information products and communication processes suitable for bird-threat awareness and decision making.

In 2009, Captains Richard Sowden and Paul Eschenfelder proposed a practical framework for developing processes to maximize bird-strike risk mitigation, while ensuring that overall flight safety is maintained or enhanced. We build on that framework by considering the actors involved in risk management across the aviation enterprise, examining their existing processes as they relate to wind shear, severe weather, and bird hazards, and applying specific knowledge and experience gained by regulatory agencies, airport personnel, and avian radar developers with regards to environmental hazards.

The internationally-applicable, avian-threat information, tools, and their proposed integration into the aviation operating environment are the outcome of a small working group that included pilots, air traffic controllers, wildlife biologists, and radar developers. It is our hope that the proposed risk management approach and provided examples will help engage the broader aviation community by giving it a tangible starting point for discussion that will lead to a credible implementation plan respecting the industry's culture and operational and economic constraints.

## Acronyms

AGL	Above Ground Level
AIM	Aeronautical Information Manual
AIP	Aeronautical Information Publications
AIRAC	Aeronautical Information Regulation and Control
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATS	Air Traffic Service
BEZ	Bird Exclusion Zone
BHI	Bird Hazard Information
CFS	Canadian Flight Supplement
FAA	Federal Aviation Administration
IFALPA	International Federation of Airline Pilots' Associations
JFK	John F. Kennedy International Airport
NOTAM	Notice to Airmen
SEA	Seattle-Tacoma International Airport
TPI	Threat Probability Index or Threat Prediction Indicator
WHMP	Wildlife Hazard Management Plan
YYZ (CYYZ)	Toronto Pearson International Airport

## Introduction

Since U.S. Airways 1549's miracle landing on the Hudson in January 2009, bird strikes have almost become a household word. With increasing hazardous bird populations, damaging bird strikes continue in spite of the excellent efforts made by airports and wildlife specialists to make their aerodromes less attractive to problem species. To mitigate bird strikes further, other bird strike mitigation processes need to be developed and integrated into the aviation enterprise in a coordinated manner. If information for bird strike threats occurring on-airport as well as off-airport were available; and if this information was appropriately communicated to other actors<sup>1</sup> in the aviation enterprise, including pilots, air traffic controllers, airlines, and airport operators, just as we provide other environmental hazard information such as wind-shear and volcanic eruptions, couldn't we improve aviation safety further? Shouldn't we?

The authors believe the answer to these questions is yes. The intent of the paper is twofold: (1) to engage and stimulate an open, constructive discussion with people and organizations involved in aviation safety drawing on their expertise and their involvement to develop additional bird strike-risk mitigation layers; and (2) to illustrate how avian-radar-derived threat information can be integrated into the

<sup>1</sup> In the context of this white paper, a "stakeholder" is anyone with an interest in bird strike risk mitigation, while an "actor" is a person, organization, or system capable of making decisions or taking actions that affect such mitigation. Actors are always stakeholders, but not all stakeholders are actors. The flying public and the news media are two examples of stakeholders who have an interest in bird strikes, but who are not actors because they have no direct involvement in the processes affecting bird strikes and their mitigation.

aviation enterprise to provide threat awareness to these actors, respecting industry culture as well as operational and economic constraints. The ideas presented herein are offered as a starting point for discussion, and were developed by a small working group consisting of representatives of the following actors: pilots, air traffic services, wildlife biologists, and avian-radar developers.

Avian radar technology has matured and will continue to improve based on direct experience at airports. Avian radar has been validated, and guidance for its use in supplementing wildlife hazard management plans at civil airports to reduce avian threats was provided by the Federal Aviation Administration in late 2010 [1]. It was also certified for military airfields by United States Department of Defense's (DoD's) Environmental Security Technology Certification Program in 2011 [2]. Efforts are presently underway to assess the efficacy of an automated, tactical, bird-threat alerting system for use by airport operations personnel. Surveillance enhancements to support off-airport, localized, threat awareness have also recently been introduced to address the higher-altitude, damaging bird strikes that have been reported extensively by the media since US Airways 1549.

The time is opportune to engage pilots and air traffic service providers to develop additional strategic and tactical information products and communication processes suitable for bird-threat awareness and decision making.

In 2009, Captains Richard Sowden and Paul Eschenfelder proposed a practical framework, based on a foundation that emulates the mitigations and communication processes for other aviation environmental

risk, for developing such processes to maximize bird strike risk awareness, while ensuring overall flight safety is maintained or enhanced [3]. We build on that framework by considering the actors involved in risk management across the aviation enterprise, and examine their existing processes as they relate to severe environmental hazards such as wind shear, thunderstorms, or other severe weather conditions. We then apply the specific knowledge and experience of regulatory agencies, airport personnel, air traffic service providers, and avian radar developers to adapt existing processes to avian hazards. It should be noted that the methodology developed here is also applicable to other wildlife hazards.

It is our hope that the specific approaches and examples we present will help engage the broader aviation community and give it a tangible starting point for discussion that will lead to a credible implementation plan to be contributed to by all interested stakeholders.

The paper is organized as follows:

We begin with a discussion of a model of the aviation enterprise including its actors and existing transfer mechanisms to communicate hazards to pilots, and we summarize how bird threat information is used today. With this background, we propose an approach to the improved management of bird strike risk at civil (and military) airports that involves additional risk mitigation layers with the identified actors. Risk mitigation principles are established along with a high-level concept of operation where emphasis on pilots dominates. The actors involved, and the connections and information flows among them are proposed and discussed.



We then describe a system model to integrate the required avian-radar-derived information into the aviation enterprise model. The nature of avian radar information that is available today or will be in the near future for integration is considered, with attention to addressing on-airport and off-airport threats. Our synthesis of current aviation concepts for management of environmental risks and avian radar technology provides, for the first time, a starting point and roadmap for full-scale implementation of the proposed, bird strike risk mitigation strategy. Three bird threat situations are presented including migration; a regular, recurring event; and an irregular, unanticipated event. These situations are used to illustrate by way of example how bird threat information is communicated to pilots using existing transfer mechanisms including the AIP, NOTAMs, ATIS and ATS Communications.

We conclude the paper with an open discussion on where we go from here and an invitation to interested aviation industry stakeholders in the aviation industry to become engaged so that we can continue to improve aviation safety.

## The Aviation Enterprise

In this section, we consider the actors in the airport operational environment who can contribute to aviation safety with respect to bird strike risks. We then examine the information transfer mechanisms used to advise actors of hazards to aviation, such as severe weather, with a view towards adapting them for communicating bird-strike risks. Finally, we discuss the limited uses of avian threat information in practice today.

## The Airport Operational Environment

Through the efforts of the Federal Aviation Administration's (FAA) Center of Excellence for Airport Technology (CEAT), a model of the airport operational environment was developed that is useful for our purposes [4] (Figure 1).

This pyramid identifies key actors and processes involved in generation, delivery, and use of strategic and tactical information for aviation safety. At the base of the pyramid are technology developers and system vendors who develop and provide systems that generate and deliver situational awareness to stakeholders. Avian radar manufacturers are part of this group. Regulators and certification organizations play an important role in assessing, validating, developing standards for, providing guidance on, and certifying systems that can be safely deployed in the airport operational environment to meet certain safety objectives. Organizations like International Civil Aviation Organization (ICAO), the FAA, and Transport Canada are part of this group. Airport operations are naturally the hub for all arriving and departing activity at airports. They acquire

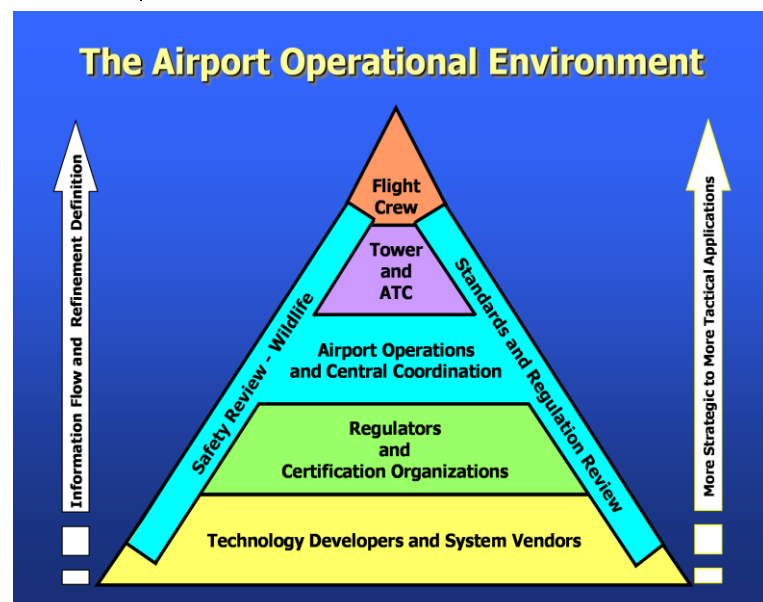


Figure 1: The airport operational environment pyramid.

awareness of hazards to aircraft on and around the airport and manage them to mitigate risk. This includes wildlife safety reviews, the creation and updating of an airport wildlife hazard management plan (WHMP), habitat management activities to make the aerodrome less attractive to problem birds, and a bird control program to harass birds that pose a risk to aircraft. The tower and Air Traffic Control (ATC) are responsible for managing aircraft to ensure safe separation (on the ground and in the air) and providing information to the flight crew to assist them in their role as the final layer of safety in keeping their passengers and aircraft safe. Tower controllers visually scan the aerodrome for hazards and report them to pilots. Airport controllers also regularly scan departure and approach ends of active runways. There is bi-directional voice communication between the tower and air operations related to hazards, including bird hazards. While not shown in Figure 1, the flight crew is also in communication with its airline.

While consistent threat information is needed across the aviation enterprise, the nature and level of detail required varies as it moves up the pyramid to the various actors. In order to mitigate information overload, and ensure understanding, threat advisories must be refined as they move up this pyramid and reach the flight crew. Whereas airport operations can receive and filter large data streams in airport-specific formats to provide actionable information to its trained ground personnel, pilots are limited by their need to manage multiple information sources and manage multiple risks.

Pilots manage multiple risks and have little opportunity to filter potentially distracting information. They require concise and precise information that is typically tactical

in nature for use in decision making. Furthermore, since flight operations is international in makeup, universally standardized language and formats must be used to convey understanding. Strategic information can benefit pilots during flight planning, and is typically managed by the airline.

Airport operations, on the other hand, can make full use of strategic and tactical information to guide planning and execution. Indeed, the WHMP is a strategic information resource and habitat management efforts are long-term activities designed to reduce bird presence. On the other hand, the bird control program responds to active threats that occur on any given day.

The regulators role is to publish Aeronautical Information Publications (AIP) and flight supplements that are strategic in nature.

Avian radar system developers typically capture additional, unrefined information generated by their systems to support assessment, certification, investigations, analysis, performance monitoring, and improvements to their systems.

### *Existing Aviation Industry Information Transfer Mechanisms*

Four existing information transfer mechanisms are available that convey information on hazardous environmental conditions to pilots; these mechanisms can be easily adapted to convey bird threat information to the flight crew as illustrated in Figure 2. Aeronautical Information Publications (AIP), Aeronautical Information Manual (AIM), and Flight Supplements are appropriate for long-term, strategic, high-level information, and are

updated on the Aeronautical Information Regulation And Control (AIRAC) cycle for use during flight planning. These are published by the State and updated regularly.

Notices to Airmen (NOTAMs) are a tactical tool that can be used for providing medium-term information. They are filled out by the airport operator and usually released only after human verification of the reported condition. Typically, NOTAMs are released 5 to 48 hours prior to an anticipated hazard condition. When the condition is concluded or reflected in Flight Supplements, the NOTAM is removed. The airport operator issues NOTAMs in a standard format and these are pushed to commercial pilots during flight planning after filtering by their airline dispatchers. General aviation pilots would typically read NOTAMs themselves. Flight crew access to NOTAMs is typically limited in flight.

Automatic Terminal Information Service (ATIS) messages are a shorter-term

tactical tool that are updated as conditions require and transmitted by voice radio and Aircraft Communications Addressing and Reporting System (ACARS). Typically, ATIS messages are updated by ATC hourly, but special messages can and are updated more frequently to reflect hazardous or rapidly changing weather conditions or critical runway condition information and navigation system failures. Pilots will typically check ATIS messages just prior to

commencing their descent, about 30 minutes out, so as not to be distracted from other tasks during subsequent critical phases of flight. ATIS messages are normally kept short and concise and with as much detail as a NOTAM.

Air traffic service (ATS) communications are the most short-term tactical tool, where controllers manage multiple aircraft and risks while prioritizing their actions in real-time. ATS provides pilots with the most up-to-date hazard information they require to safely navigate while en route, and during arrival and departure.

For illustration purposes, and without loss of generality, we characterize bird threat situations into three categories: migration events, regular recurring events, and

irregular unanticipated events. Migration events last months, typically in the spring and fall. Recurring events, such as daily commutes between night-time

roosts and daytime foraging and loafing sites are common and exhibited by many species. Both of these situations, because of their predictive and recurring nature, can be communicated using strategic mechanisms such as the AIP and Flight Supplements, as well as tactical mechanisms such as NOTAMs, ATIS messages, and ATS communications. Irregular situations cannot be anticipated and are therefore only appropriate for tactical NOTAMs, ATIS

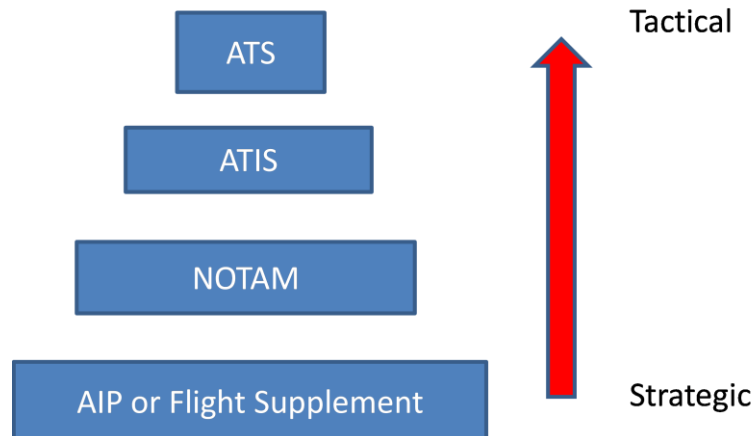


Figure 2: Aviation industry information transfer mechanisms

messages, and ATS communications. For universality, AIP, Flight Supplements, NOTAM, ATIS, and ATS communications are always provided in English using standardized terminology and message formats.

### *How is Bird Threat Information Integrated Today?*

Many States require airports to develop a WHMP to identify high-risk bird species and guide habitat management efforts to make their aerodromes less attractive to hazardous species. The WHMP also guides a local bird control program to further mitigate bird strikes by responding to detected or reported bird threats. In most cases, these efforts are concentrated within the airport perimeter where the risk of bird strikes is highest. The airport is responsible for these efforts.

In many States, air crews and aircraft maintenance crews also report bird strikes during or after a flight, and these reports further guide mitigation efforts. Wildlife specialists and regulators make use of this information to better understand bird threats, and airports use it to modify their WHMP accordingly.

The above measures are the primary means for mitigating bird strike risk today at civil airports.

Other secondary or limited sources of bird strike threat information include:

- Visual observations by tower controller or wildlife control personnel (typically limited in range to < 200 m, during daylight and fair weather conditions);
- Targets that bleed through airport surveillance radars (ASR) are often reported to pilots as “unknown target,

possibly birds” (height uncertainty of ASRs makes this information of little practical use); and

- NOTAMS that advise “bird activity in the vicinity of the airport”, which are largely ignored by flight crews (they are not localized in time or space, do not characterize the severity of the risk, and thus convey no useful information).

In short, at most civil airports the flight crew, airlines, tower and ATC are not actively engaged in a coordinated manner with the airport’s operations and wildlife control personnel to mitigate bird strike risk.

A handful of pioneering efforts at civil airports are pointing to the way new surveillance technology can cost-effectively assist in mitigating bird strike risk. For example, King Shaka International Airport in South Africa uses avian radar to alert the tower each day when more than a million Barn Swallows disperse from a protected roost less than 3 km away [5]. A thermal imaging system at Frankfurt International Airport monitors a small section of river used as a route by migrating birds and alerts air traffic controllers when birds are detected near the aircraft corridor [6].

In the United States, the FAA has assessed the improved bird awareness afforded by avian radars at Seattle-Tacoma International Airport (SEA), Chicago O’Hare (ORD), and New York’s John F. Kennedy (JFK) airports. Based on this assessment the FAA provided guidance [1] and funding for use in improving wildlife hazard management at airports. More recently, an avian-radar-derived, risk-based, tactical bird-threat alerting system is being assessed at SEA that will support the bird control program as well as the issuance of localized NOTAMs, voice communications between wildlife control and the tower, and ATIS and ATS communications between the tower and the



flight crew all around the airport. The stored, localized risk data generated by this system can also provide the basis for an airport avian threat advisory system that can support flight planning [4].

## **Approach to Improved Management of Bird Strike Risk**

State-of-the-art avian radar has the ability today to provide increased awareness of bird presence on and off the airport, and provide automated prediction and warning of bird strike threats to aircraft. We exploit these capabilities with a proposed risk management approach involving the design of multiple safety layers, consistently applied by various stakeholders across the aviation enterprise.

### *Risk Mitigation Principles*

A WHMP identifies hazardous birds at the airport and proposes measures to manage the risk. Large flocking birds tend to be particularly hazardous because of the damage they can cause to multiple engines, the airframe and aircraft systems simultaneously. Increased bird strike threat awareness provided by avian radar can be used by managers to better reduce bird populations, as well as to warn pilots when exposure to significant bird threats is high. Particular benefits that could be realized are:

- Improved development and amendment of airport wildlife hazard management plan;
- Improved daily planning and tactical on-site adjustment of bird control program;
- Strategic seasonal adjustment of departure and arrival flight patterns to reduce bird strike risk; and

- Minor tactical adjustment of departure and arrival flight patterns or times to reduce bird strike risk.

Tactical adjustment of departure and arrival flight patterns at the discretion of the pilot is intended to favour a profile whose total risk is reduced, not just the risk of a bird strike. Flight crews are required to manage many concurrent operational risks. Hence, bird strike threat information provided to pilots should be, by definition, advisory only, as advocated by the International Federation of Airline Pilots' Associations (IFALPA) [7]. This safety assessment requires global standards and training and must account for not only the nature of the bird strike threat, but the performance of the aircraft in question and its phase of flight.

By engaging the entire aviation enterprise in developing additional bird strike risk mitigation layers along with related standards and training, we believe that the operating culture can be aligned to reduce today's increasing bird strike risk, just as other environmental risks such as severe weather and wind shear risks have been mitigated.

The diversity of aircraft types and their respective air worthiness standards makes the development of these bird-strike risk mitigation layers challenging. Because of their large number of aircraft movements and higher potential severity of a bird strike event, we believe that the initial focus should be placed on air-carrier operations. Avian-radar-derived threat awareness information should be characterized using globally-consistent terms, structure, and format so that air carriers can develop aircraft-specific procedures to be used by the flight crew in response to particular threats.

The risk mitigation processes we considered can be organized into two classes: those

involving aircraft and those not involving aircraft. Processes can be proactive, meaning they are carried out before a bird strike, or reactive, meaning they are carried out after a bird strike. For risk mitigation processes involving aircraft, the critical phases and sub-phases of flight need to be considered to develop acceptable tactical responses to bird strike threats reported to pilots so as to ensure overall safety. Suitable tactical and strategic information products and tools derived from avian radar serve to inform aviation enterprise actors in a consistent manner, so that their actions will be aligned in accordance with a joint risk management strategy.

### *Processes Not Involving Aircraft*

Three risk mitigation processes designed to remove bird presence from the aerodrome and atmosphere are:

- Wildlife Hazard Management Plan WHMP (proactive/reactive)
- Habitat Management (proactive)
- Bird control program BCP (proactive)

Each of the above processes requires special consideration for on-airport and off-airport risk. Off-airport considerations are often neglected but are nevertheless extremely important.

The FAA, through the issuance of Advisory Circular No. 150/5220-25, has already validated and reported on the usefulness of avian radar in regard to the above processes [1]. Furthermore, it has authorized airports in the United States to use Airport Improvement Program funds to acquire avian radar. Avian radar's ability to capture bird movements 24 hours a day and to characterize their abundance, size, location, altitude, speed, heading direction, commonly used routes, and roosting and foraging sites over any time scale serves to

provide feedback on the efficacy of an airport's WHMP and supports the resulting Habitat Management and Bird Control Programs proactively. The WHMP benefits through consideration of reported bird strikes and reactive revisions to ensure high-risk species are being addressed effectively.

### *Processes Involving Aircraft*

A number of processes involving aircraft are worthy of consideration to mitigate bird strike risk. These include:

- Bird strike reporting (reactive);
- Flight Planning (proactive);
- Take-off and Initial Climb (proactive); and
- Initial Approach, Approach & Landing (proactive).

Bird strike reporting is already commonplace either on a voluntary or mandatory basis in many States. This is a reactive process that, with over two decades of quality data, has led to a good understanding of the threat of bird strike risk. While improvements in reporting frequency and report accuracy can and should be made, currently available data provide a scientifically sound sample for quantifying the significance of bird-strike risk and prioritizing efforts to mitigate risk even more. With geometrically growing large bird populations [8], including problem species, we must systematically add additional risk mitigation layers to protect aircraft and the travelling public. The large number of damaging strikes in recent years including loss of life is testimony to this fact. Because Wildlife Hazard Management Plans are reviewed regularly, they provide a proactive mechanism for adding these risk mitigation layers to monitor and analyze the success of bird-strike risk management practices.

For all practical purposes, flight planning today at civil airports does not account for bird strike risk. Neither are imminent bird strike threat warnings provided to pilots; hence aircraft flight profiles are not proactively adjusted to reduce risk. These are processes that could be developed and added as additional risk-mitigation layers in response to avian-radar-derived bird strike threat data.

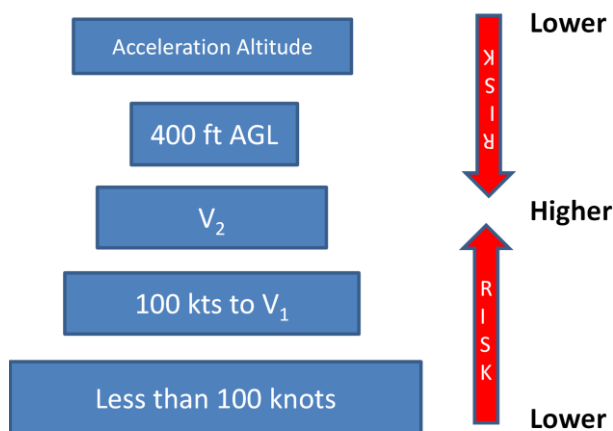


Figure 3: Take-off risk evaluation

If bird strike threat warnings were provided

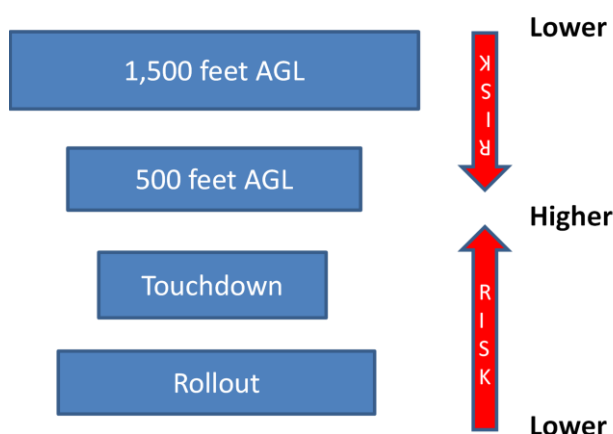


Figure 4: Landing risk evaluation

to pilots, response options would depend on the aircraft's phase of flight. Most bird strikes occur during takeoff or landing.

Takeoff is the highest risk phase of flight for bird strikes, but the risk is not constant. Evaluation of takeoff sub-phases reveals that crew and aircraft performances differ in criticality as illustrated in Figure 3:

- Initial takeoff roll to 100 knots – less critical
- 100 knots to  $V_1$  – criticality increases approaching  $V_1$
- $V_1$  to 400 ft AGL – critical
- 400 ft AGL to acceleration altitude – criticality reduces with acceleration altitude (varies from 400 ft AGL to 3,000 ft AGL)
- Above acceleration altitude – criticality reduces with flap/slat retraction

Landing phase is a high-risk phase of flight, but risk is not constant. Evaluation of landing sub phases reveals that crew and aircraft performances vary in criticality as illustrated in Figure 4:

- Initial approach – 3,000 feet AGL to ~1,500 feet AGL is less critical, but risk increases with flap/slat extension and lower altitude<sup>2</sup>
- ~1,500 feet AGL to 500 feet AGL – risk increases, ability to maneuver decreases, less performance margins
- 500 feet AGL to touchdown - critical, little ability to maneuver and lowest performance margins
- Rollout – lowest risk for phase of flight

### Concept of Operation

It is time for airports to embrace avian radar technology to improve risk mitigation efforts associated with their WHMP, habitat management, and bird control programs. It

<sup>2</sup>  $V_1$  is the speed used by the pilot that satisfies all industry aircraft performance requirements.

has been shown that above 500', bird strikes are seven times more likely at night [9], where current bird observation methods are ineffective and where avian radar excels.

Because it is difficult to obtain bird strike threat awareness off the airport, most airports concentrate their efforts within the fence. With the increase in off-airport damaging bird strikes reported in recent years, it is time to expand our bird strike mitigation efforts well beyond the airport fence. New scanning capabilities being introduced into avian radar will provide the required threat awareness to help there as well [10].

It is also time that localized bird strike threat warnings make their way to pilots so they can make safety adjustments to their departure and arrival flight patterns as they deem appropriate. Getting this information to pilots requires the integrated involvement of airports, airlines, and air traffic services.

Aeronautical Information Publications, Flight Supplements, NOTAMS, ATIS messages, and ATS communications should be used in a consistent manner to convey bird strike risk information to aviation enterprise actors. As shown below, avian radar can provide this risk information. Real-time awareness of bird-strike threats

can be generated by an avian radar threat alerting system, monitored centrally, and communicated by airport operations directly to bird-control program personnel to respond to and verify. Long-term threats (e.g., migration) could result in a NOTAM issued (once the seasonal period has started or is anticipated) by the airport. ATIS messages could be used to provide dynamic updates to a NOTAM (e.g., migration is occurring right now). Threats predicted to persist for several minutes or more could be communicated to ATS, by voice and/or a local bird strike threat display. To inform pilots of dynamic bird hazard information, ATC can issue an ATIS update or use ATS communications.

The pilot can make tactical adjustments to his flight pattern to mitigate bird strike risk if he deems the bird-strike threat high enough in relation to his particular aircraft and the criticality of the phase of flight. Some possible adjustments are detailed in Table 1.

In situations where bird strike threats persist off of a runway for extended periods of time (e.g., tens of minutes or longer), it is also possible for ATC to request departing aircraft to make an adjustment to their takeoff path to steer clear of the threat, much like they would do for weather.

Table 1: Possible tactical adjustments to flight pattern of aircraft in response to bird strike threat warning

TAKEOFF PHASE	POSSIBLE MITIGATIONS	LANDING PHASE	POSSIBLE MITIGATIONS
Ready for takeoff	Delay takeoff	10,000' down to 1500' AGL	Profile adjustment (vertical / lateral / runway change) Monitor situation
Less than 100 knots	Reject takeoff	1,500' down to 500' AGL	Missed approach Continuing as per AFM
100 knots to V <sub>1</sub>	Reject takeoff	500' AGL down to touchdown	Missed approach Continuing as per AFM
Less than 400' AGL	none	Touchdown / Rollout	Idle reverse thrust
Greater than 400' AGL	Profile adjustment (vertical / lateral)		
Acceleration Altitude	Profile adjustment (vertical / lateral)		



During flight planning, an online airport bird strike *threat advisory system* for both the departure airport and arrival airport could be checked against possible departure and arrival flight patterns, respectively, in addition to NOTAMs. This information could be used with a to-be-developed flight pattern risk calculator to provide pilots with awareness on the statistically lowest bird-strike risk departure and arrival flight patterns for a given airport at the respective departure and arrival times. Typically, this process would be carried out by the airline dispatch and provided to the pilot.

Runway selection is constrained at civil airports and throughput can change considerably by switching configurations. Nevertheless, there may be compelling safety reasons to make seasonal adjustments. The same online bird strike threat advisory system could be used by airport authorities, air traffic control, and the airlines for a given airport to make seasonal adjustments to the airport runway configurations to account for bird strike risk.

When bird strikes occur, the airport should quickly review its bird strike threat advisory system (strategic) and threat alerting system (tactical) to investigate if this was an isolated incident, a known threat, or a new recurring threat that requires immediate action. If a recurring threat exists, NOTAMs, ATIS, and ATS communications can be used to inform pilots and further mitigate risk. Property owners can be approached with convincing data for recurring off-airport threats. Every bird strike becomes a learning event to further improve aviation safety, but these events if used alone provide a very limited data set for analysis. Other sources of bird hazard information such as avian radar data are more extensive and map both actual strike

events as well as potential bird hazards; and they can be mined to more accurately identify bird hazard locations and movement patterns [12]. This additional hazard data can then be used to support a proactive risk management strategy in keeping with industry best practice use of Safety Management System processes.

Clearly, the entire aviation enterprise must be involved to implement these proposed bird strike risk mitigation measures, including the airport operator, airlines, air traffic services, pilots, and regulators. Avian radar information can be used to support these processes in tactical and strategic contexts. Our proposed approach to integration is provided in next section.

### **Available Avian Radar Information**

In the last ten years, avian radar technology has matured to the point that it can now: (1) provide coverage (i.e., through surveillance) of the aerosphere where aircraft operate, both on and off the airport; (2) acquire high-quality, trajectory information to characterize bird movements within the coverage volume; and (3) support a number of strategic and tactical tools (i.e., bird behaviour and threat prediction information products) derived from this information to support bird-strike risk mitigation efforts.

#### ***Coverage/Location***

Birds are small targets that are relatively challenging to detect and track; consequently, an avian radar needs to be relatively close to them. Most bird strikes occur for aircraft at 500' AGL and below [9], where aircraft are over the aerodrome or a short distance away. Installing avian radar on-airport near the runways being protected makes good sense for bird awareness there, in the arrival and departure corridors. Because radar coverage is the resource that

drives cost, radar designers have successfully matched their radar's coverage pattern to the confined arrival and departure corridors being protected. Recent advances to avian radar antennas [10] mean that birds above or below the corridors can now also be seen, leading to greater threat awareness around the aerodrome and early warning of birds moving towards the protected funnels.

Characterizing hazardous, off-airport bird movements and providing tactical bird threat alerts while aircraft are present at altitudes up to 10,000' AGL and out to 20 km from the airport places even greater coverage requirements on avian radar. The benefit of off-airport coverage is that because 98% of bird strikes occur below 10,000' (see Figure 5), bird awareness would be available virtually everywhere it is needed. Fortunately, as a result of technology advances in avian radar [10], it is now possible to characterize off-airport threats such as those faced by US Airways Flight 1549, and the numerous other off-airport damaging strikes before and since (see [11] for additional examples).

### Information Quality

Threat prediction is necessary in order to alert air crews before they are exposed to a threat. For off-airport threats where the coverage volume is especially large, birds must be tracked throughout the volume used by aircraft with the birds' trajectories resolved in latitude, longitude, and altitude (i.e., 3D coordinates) and with speed and heading resolved to generate reliable trajectories needed for threat alerts. Fan-beam antennas, whether oriented in a horizontal scanning or vertical scanning configuration, can only resolve in two dimensions. However, narrow-beam, scanning antennas (dish antennas and dual-axis scanning dish antennas [10]) can readily provide 3D information, even in large flock situations where multiple birds are present in the radar's resolution cell.

A biomass-related metric is needed to characterize the severity of a particular hazard for risk measures. This is available in the form of radar cross section (RCS) estimates [12].

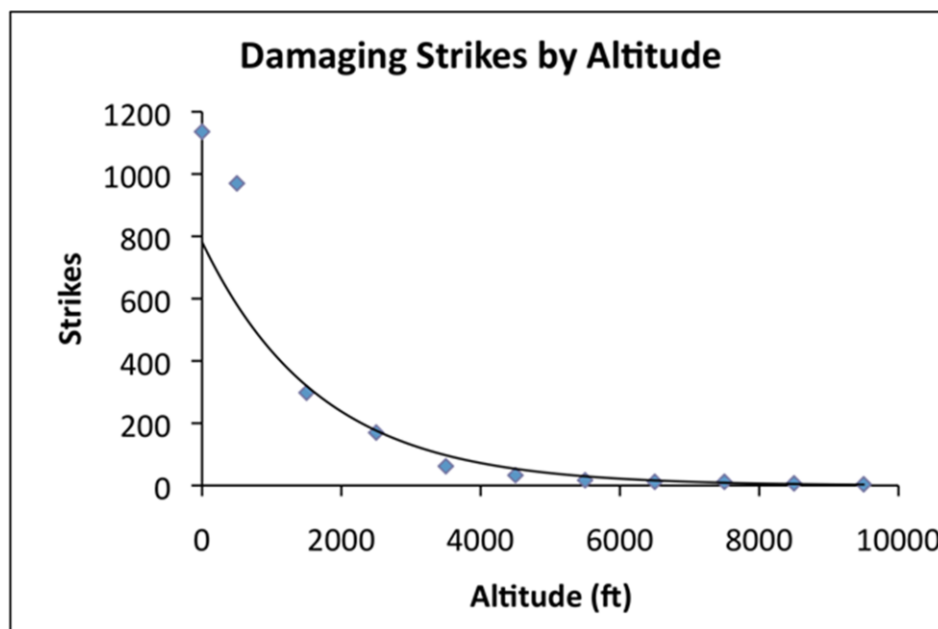


Figure 5. The altitudinal distribution of non-minor damaging bird strikes reported in the FAA database from January 1990 through March 2012

### *Tactical and Strategic Tools*

Bird trajectory information captured by avian radar can be analyzed by a number of tactical and strategic tools or information products for use by aviation actors for bird-strike risk mitigation. For the purposes of this paper, we have grouped available tools into two classes: hazard assessment and threat prediction. Hazard assessment tools are statistical in nature and characterize local bird populations. Threat prediction tools, on the other hand, characterize individual birds or groups of birds in localized areas and at particular times that pose a risk to aircraft.

#### **Hazard Assessment**

Bird abundance distributions are useful tools in wildlife assessment; they characterize the numbers and distribution of birds around the aerodrome.

On a temporal scale, bird presence varies seasonally with migration and daily differences in day- and night-time activities. Instantaneous abundance data can be averaged and displayed on time scales ranging from hourly to annual to quantify and compare bird presence. Such information can be particularly useful in scheduling flight operations.

Bird abundance distributions as a function of altitude can be useful for understanding concentrations of birds in the atmosphere. These distribution metrics, for day-time versus night-time and seasonal variation, and at different spatial locations around the

airport, can provide increased awareness of migration, soaring birds, commuter birds, and resident bird activity. Of course these abundance, altitude, and spatial distributions can be filtered against target attributes that characterize particular bird groups behaviors.

Real-time bird trajectories can be organized and stored permanently in a queryable information system that enables aviation actors to: (1) replay particular situations and (2) mine a rich source of avian data for bird strike risk mitigation [12,13]. Airports (wildlife control personnel and managers) and regulators will be the key users of this information.

An example of an avian-radar generated bird abundance chart is shown in Figure 6. Bird abundance is characterized in this example over the hours in a day, averaged over the entire month of April. During this particular month at JFK, relatively low night-time activity was observed, with a significant increase in bird activity at sunrise. Charts like this can be helpful in directing and scheduling bird control efforts to have the greatest impact on risk mitigation. By playing back radar tracks during this period, wildlife personnel can understand where the increased activity is occurring so they can respond to it. It is important to recognize that the environment is dynamic. While April may have relatively low activity during night-time, the amount of night-time activity may differ drastically in another month as a result of the arrival of migrants.

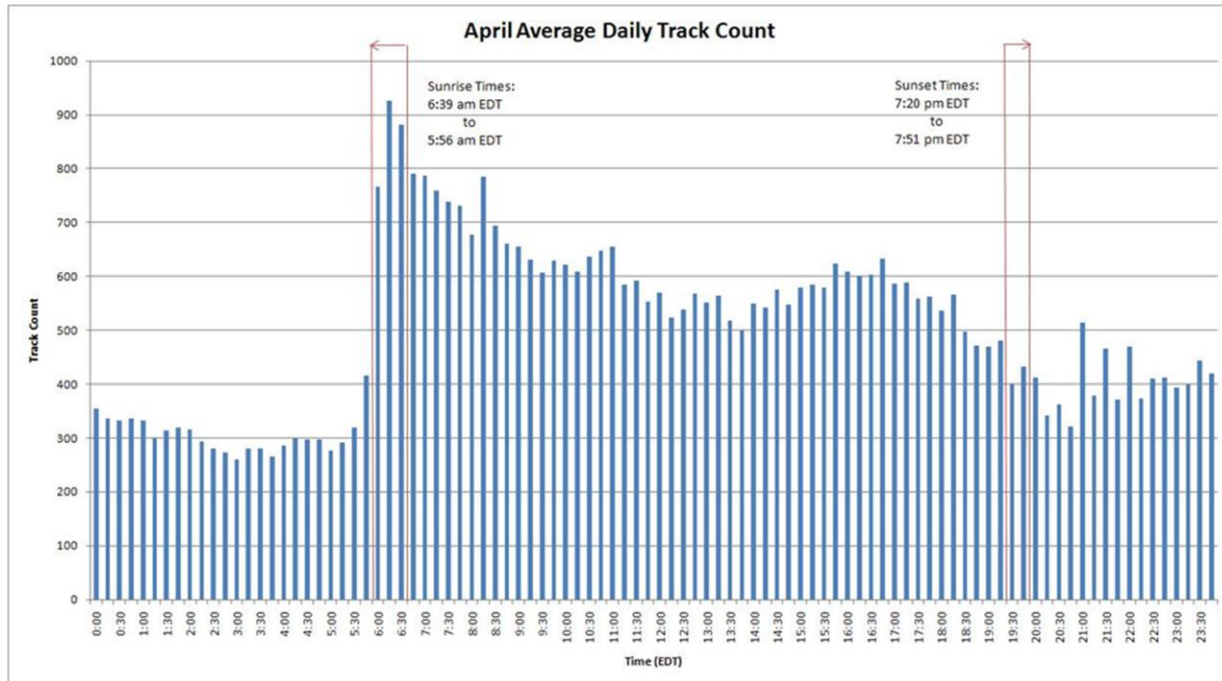


Figure 6 Daily Bird Abundance Chart for JFK Averaged for the month of April

### Threat prediction

Threat prediction tools can warn of risk to aircraft from local bird activity, especially for airport users who are not wildlife experts. These tools automatically calculate risk in a standardized manner that is understandable to all actors in the aviation enterprise. Furthermore, this focus leads to actionable threat alerts that are localized in time and space and mitigates information overload.

Risk can be computed as a function of the likelihood of an event (in this case, a bird strike) and the severity of the consequence of that event. The severity of the consequence of a bird strike in turn depends upon a number of factors, including the mass of birds struck and the aircraft's phase of flight and performance at the time.

We propose to categorize risk by defining three threat levels based on the aggregate biomass of birds in a defined space. A low

threat level might be associated with one or a few small birds (low biomass); a moderate threat level might be associated with a single larger bird or several small birds (moderate biomass); and a severe threat level might be associated with many small birds or several large birds (large amount of biomass). The heading direction, speed, and behavioural characteristics (e.g. circling versus passing through) of the birds could also be factored into the threat level definitions.

We localize threats by dividing the aerosphere around the aerodrome into a number of bird exclusion zones (BEZs) that take into account the airport configuration (Figure 7), labelled A through K in the example. Low threat levels are not shown on the display, moderate threat levels are shaded yellow (e.g., BEZ K), and severe threat levels are shaded red (e.g., BEZ A). Additional bird exclusion zones can easily be defined to cover off-airport threats.



In addition to the threat level, we must also measure the likelihood (probability) of encountering the particular threat. We propose to define this probability as the amount of time that each threat level is active in a given bird exclusion zone during a specified period of time (e.g. 15 minutes is used in Figure 7). We refer to this ratio as the threat probability index (TPI) or threat prediction indicator (discussed later). We then define a TPI threshold as the exposure level we will tolerate before an actionable alert is issued by the threat alerting system. In Figure 7, the TPI threshold is set at 20% and is re-calculated every minute, based on the previous 15-minutes. In this example, if a particular threat level appears for more than 180 seconds (20% of 15 minutes), the TPI threshold will be exceeded and the

corresponding threat alert will be issued for that bird exclusion zone.

Such a bird threat alerting system can generate tactical alerts for use by virtually all airport actors, including airport operations, ATC, and pilots. It is operating in the Airport Communications Center at SEA, where threat alerts are issued for dispatch to wildlife control personnel for response. The TPI threshold is based on a 15-minute time window at SEA because that was judged to be the maximum time it should take the response personnel to reach the offending bird exclusion zone. This approach makes these threat alerts actionable and is the subject of an ongoing FAA concept of operations study at SEA [4].

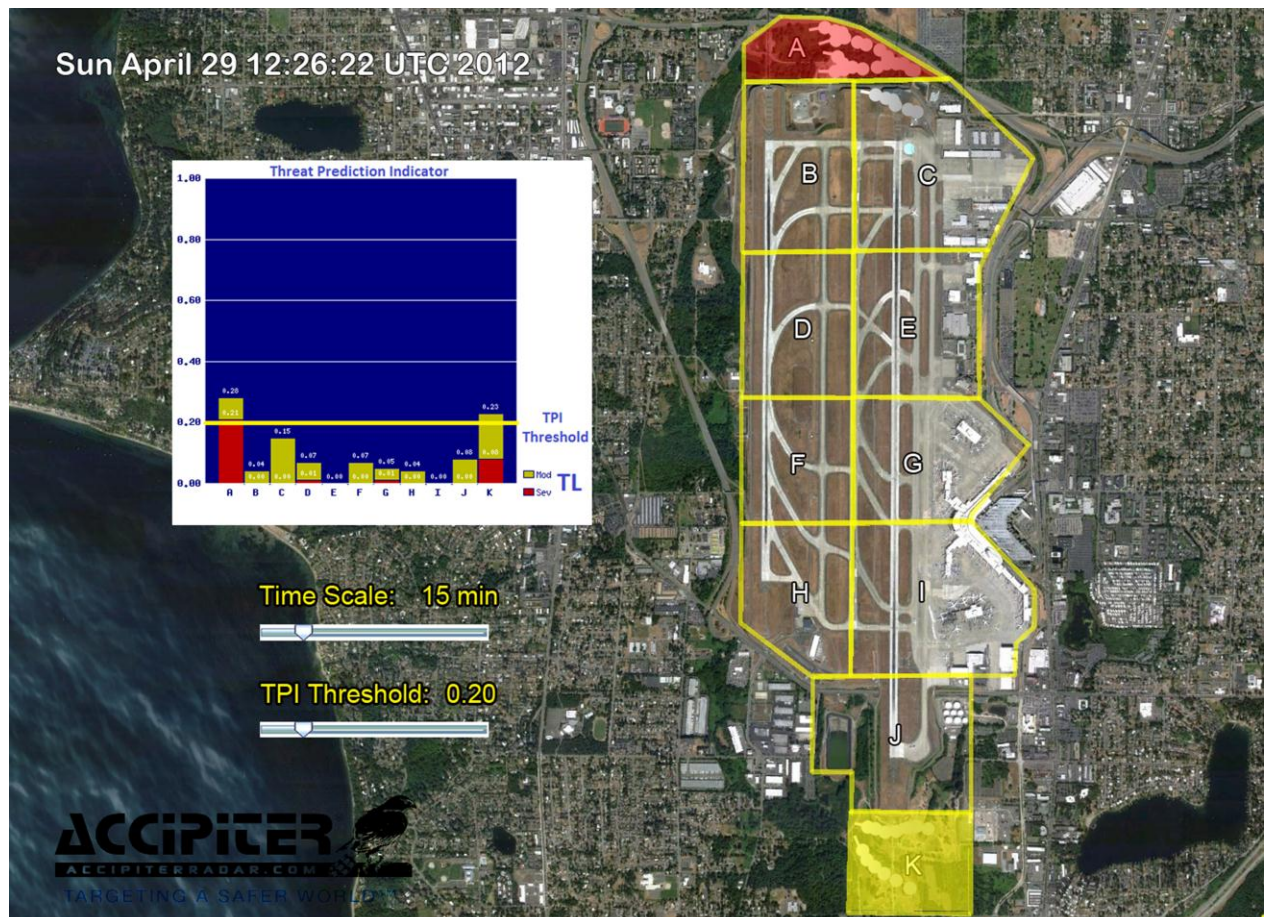


Figure 7: Actionable bird threat alerting system at Seattle-Tacoma International Airport  
(TL= threat level, TPI = threat prediction indicator)

The threat prediction approach described above has proven out in practice and is based on the following two principles: (1) greater persistence and/or higher recurrence rate of a bird threat level in a BEZ results in a higher TPI; and (2) a threat condition with a reasonably high TPI is likely to persist for at least one time period into the future. The first principle is simple mathematics; the second relates to bird traffic flow. Our threat prediction approach is patterned after overhead highway traffic signs that warn drivers to expect congestion a few kilometers ahead. This prediction is based on the current traffic situation a few kilometers ahead and the expectation that situation will continue for a short time into the future based on traffic flow dynamics. It is for this reason that we also define TPI to mean threat prediction indicator.

Bird threat alerts can be stored and analyzed in the form of an on-line bird strike threat advisory system for an airport. The threat alerts have attributes of date, time, location, threat level, and TPI. Figure 8 is an extract of a one-week advisory report generated from the threat advisory system for BEZ A severe. The TPI is provided for each of the 24 hours in the day, and high TPI values are color-coded to draw attention to problem areas. The severe-threat condition triggered on 29 April 2012 at 12:26 UTC in Figure 7

is also seen in the report in Figure 8. Note that in Figure 8, the TPI is shown as 0.08 for the hour in question because it was calculated on a one-hour time scale instead of the 15-minute time scale in Figure 7.

The threat advisory system illustrated by the weekly report in Figure 8 can be used by airport operations to quantitatively assess risk reduction and the effectiveness of habitat management programs by examining whether TPIs are increasing or decreasing from year to year. By including a flight pattern risk calculator, one could map particular flight patterns against the threat advisory system TPIs to calculate a cumulative bird strike risk metric. These could be compared and accumulated across all flight patterns for one airport configuration and compared against a second configuration. Large differences between total bird strike risk could favor seasonal changes to airport configurations that the airlines, airport operator, and ATC could consider. The same methodology could be applied to select a favored approach and/or departure flight pattern during flight planning, if options are available.

With bird strike threat alerting now available, it is necessary for the aviation industry to develop and standardize on

Date (dd/mm/yyyy)	Alert Name	Hour (UTC)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
		Hour (Local)	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
26/04/2012	A Severe		0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
27/04/2012	A Severe		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28/04/2012	A Severe		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29/04/2012	A Severe		0	0	0	0	0	0	0	0	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0
30/04/2012	A Severe		0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0
01/05/2012	A Severe		0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0
02/05/2012	A Severe		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26/04/2012	B Moderate		0	0	0.01	0	0	0	0	0	0	0	0	0	0.04	0	0.01	0	0	0.01	0	0.01	0	0	0.01	0.01
27/04/2012	B Moderate		0.01	0	0.03	0	0.04	0	0	0	0	0.01	0.01	0.01	0.03	0.02	0	0.01	0	0.01	0.01	0.01	0	0	0	0.01

Figure 8: An extract from a weekly threat advisory report showing TPI versus BEZ and time of day at SEA. This information would be provided by the airport bird strike threat advisory system.

uniformity in messaging bird threats, whether at the strategic or tactical level, and for departures and arrivals. Consistent language is necessary for flight planning, as well as for NOTAMs, ATIS messages, and ATS communications.

We propose to refer to these communications as bird hazard information (BHI) reports. In Table 2, a sample BHI report is proposed as a starting point towards a standard characterization of avian threats in support of strategic and tactical advisory messages. The BHI report sample in Table 2 begins by identifying the source of the report that could be the result of a forecast, an avian radar or a human observer. The threat type, if known, characterizes the nature of the threat. The date/time the report is issued is noted. The threat is characterized by a probability (which in the case of radar could be determined from the TPI) and severity (which in the case of radar could be derived from the threat level). The location of the threat is provided relative to a local reference point, and is specified by a bearing, distance and altitude. The heading direction and speed associated with the

threat are also provided. In the case of a forecast, the expected commencement and duration of the threat are also included in the BHI report.

## Integration of Avian Radar in to Aviation Enterprise

In Figure 9, a data flow diagram is shown that (1) captures our proposed risk management strategy, and (2) exploits the airport operational environment model presented in Figure 1. This system model provides, for the first time, a starting point and roadmap that could lead to full-scale implementation of the proposed bird strike risk mitigation strategy. The actors, avian radar-based data flows, and risk mitigation processes are illustrated and discussed. We conclude this section by using hypothetical bird threat examples to illustrate the nature of bird threat information that can be provided to flight crews to mitigate bird strike risk.

Table 2: Bird Hazard Information – a sample message is shown

<b>SOURCE</b> <i>Radar</i>	{FORECAST, RADAR, VISUAL}
<b>THREAT TYPE</b> <i>Migration</i>	{MIGRATION, SOARING, FLOCKING, ...}
<b>ISSUED AT TIME</b> <i>19 Aug 12, 1900</i>	{defines the date/time the report was made}
<b>EXPECTED COMMENCEMENT</b> 21 Aug 12, 1800	{DATE/TIME of threat}
<b>EXPECTED DURATION</b> <i>90 days</i>	{TIME HOURS or DAYS}
<b>PROBABILITY</b> <i>3</i>	{1=low, 2=medium, 3=high}
<b>SEVERITY</b> <i>2</i>	{1=low, 2=medium, 3=high}
<b>REF-POINT</b> <i>16R threshold</i>	{2D based on geographic reference point}
<b>BEARING</b> <i>67 deg</i>	{degrees relative to REF-POINT}
<b>DISTANCE</b> <i>4 mi</i>	{miles from REF-POINT}
<b>ALTITUDE</b> <i>1000 to 2000 feet</i>	{feet min to max AGL}
<b>HEADING</b> <i>SE</i>	{N, NE, E, SE, S, SW, W, NW – direction birds are heading}
<b>SPEED</b> <i>20 knots</i>	{GROUND SPEED of birds in knots}







Table 3: Avian Radar Information Usage

Avian Radar Information Receiver	Usage	Responsible Actor	Strategic/ Tactical
WHMP	WHMP development /amendment	Airport Operator	Strategic
BCP	Daily planning and tactical adjustment of BCP activities	Airport Operator	Both
ATS	Seasonal adjustment of runway configuration	Airline/Airport/ATS	Strategic
Standards and Training	Safety assessment, regulation, compliance	Regulator	Strategic
ATC	Adjustment of ATIS messages and tactical risk management information through direct communication	ATS Provider	Tactical
Flight Crew	Flight profile adjustment	Flight Crew	Tactical

Table 4: Flight Crew Avian Radar Information Products Summary

Flight Crew Information Source	Flight Phase Used	Information Source	Responsible Actor	Strategic/ Tactical	Refresh Schedule	Constraints
AIM/AIP & Threat Advisory System	Planning	WHMP / Threat Advisory System	Airport Operator	Strategic	AIRAC Cycle (28 days)	Distribution timeline
NOTAM	Planning/ In-flight	BCP	Airport Operator	Both	As needed	Distribution timeline and accessibility in-flight
ATIS	In-flight	BCP and/or ATS through Threat Alerting System	ATS Provider	Tactical	Normally hourly, but as needed	Message updates may conflict with flight crew workload
ATS Information	In-flight	BCP and/or Threat Alerting System	ATS Provider	Tactical	As needed	Requirement to risk manage multiple aircraft and risks

The avian radar generates and maintains the airport threat advisory system that can be directly accessed via the Internet by all stakeholders. Other hazard assessment information products are directly accessible to airport operations personnel, including the airport's wildlife biologist(s) for wildlife hazard assessment, habitat management, and bird control programs. Strategic avian hazard assessments and threat prediction information can be used to keep up-to-date aeronautical information publications with more detailed threat awareness, detailing seasonal variations and bird movement patterns. This information can also be used by airlines, the airport, and ATC to consider runway configuration changes on a seasonal basis that may significantly mitigate bird strike risk. In addition, flight dispatch can access the threat advisory system of the departure and arrival airports and determine, using a flight pattern risk calculator, the recommended departure and arrival flight profiles if runway selection is a possibility. This information is passed on to the flight crew. The threat advisory system can also support the development of flight crew procedures in response to particular avian threats, and the development and delivery of training programs for all actors.

Tactical threat alerts are provided by the threat alerting system and are available in real-time to airport operations personnel who can issue NOTAMs and notify the tower of threats. The tower can then notify the flight crew accordingly using ATIS updates or direct ATS communications. The flight crew can consider this threat information and decide whether it is advisable to adjust the flight profile of their aircraft in response. The tower may also have direct access to the threat alerting system so tower personnel can consult it directly when required. The benefit of providing the tower with direct access is to

protect against a missed or delayed threat communication from airport operations due to other pressing priorities. Furthermore, pilots can request an update from the tower as they approach the airport and ATC will be able to provide a timely response by glancing at the threat alerting system display.

Finally, some time in the future it is also possible for on-board aircraft avionics to receive threat alerts from avian radar directly. It is not clear at this time whether the benefits would justify the effort. On-board sensors might also be considered for en route aircraft.

### *Scenario-Based Flight Crew Examples*

We have developed three hypothetically contrived bird situations for an airport such as Toronto Pearson International Airport (YYZ) that is located near a large body of water. These situations illustrate how AIP, NOTAMs, ATIS and ATS communications can be used to convey bird strike threats to pilots. These examples relate to migration events (e.g. autumn migration), regular, recurring events (e.g. morning/evening movements to and from feeding areas), and irregular, unanticipated events (e.g. starlings swarming a runway to eat grasshoppers).

Contextual details along with message timing and formatting in accordance with Table 2 are provided for illustrative purposes.

#### **Migration Events**

AIM/AIP could be used to notify YYZ flight crews of migration events to be expected at YYZ as follows:

BIRD MIGRATION WILL TAKE PLACE OVER A BROAD AREA AROUND YYZ FROM MID-AUGUST THROUGH LATE NOVEMBER AND IS INFLUENCED BY WEATHER. SMALL

SONGBIRDS MIGRATE EARLIEST, FOLLOWED BY LARGE SONGBIRDS, SHOREBIRDS IN DENSE FLOCKS, AND FLOCKS OF SMALL DUCKS. LARGE DUCKS AND GEESE TYPICALLY MIGRATE THE LATEST IN THE SEASON. MOST MIGRATION TAKES PLACE AT NIGHT AND, CONSEQUENTLY, THE PROBABILITY OF A BIRD STRIKE ABOVE 500 FT AGL IS 7 TIMES GREATER AT NIGHT.

NOTAMs could be issued at the beginning of migration and updated as migration progresses. For example, consider the following situation:

Southward waterfowl (ducks and geese) migration is underway in the Toronto area. Waterfowl typically migrate in flocks, sometimes dense, producing multiple strikes. Birds are typically in the air from 1 hour after sunset until near dawn, but may continue flying after dawn, at altitudes to 5000' AGL.

A NOTAM could be issued as follows:

120001 NOTAM CYYZ TORONTO  
INTERNATIONAL  
CYYZ WATERFOWL MIGRATION UNDERWAY  
IN VICINITY OF AIRPORT ALTITUDE LESS  
THAN 5000' TYPICALLY BETWEEN 1 HOUR  
AFTER SUNSET TIL DAWN  
1209150000 TIL 1211302359

ATIS Messages could be posted as follows (issued in conjunction with the ATIS Timestamp):

1 hour before sunset:

WATERFOWL MIGRATION IN VICINITY OF  
AIRPORT MOVING S AT 35 KTS ALTITUDE  
LESS THAN 5000' TIL 0700Z.

ATS Communications could be provided to pilots as follows:

#### BIRD HAZARD ADVISORY

RADAR OBSERVES POSSIBLE MIGRATING WATERFOWL HAZARD THREAT LEVEL 3, SEVERITY 3 BEARING 350 DEGREES FROM RWY 16R THRESHOLD 5NM. HEADING SE AT 35 KTS. ALTITUDE 1000' TO 2000' AGL.

#### Regular Recurring Events

AIP/CFS could be used to notify YYZ flight crews of regularly occurring events as follows:

MANY SPECIES OF BIRDS EXHIBIT REGULAR, DAILY COMMUTES BETWEEN THEIR NIGHT-TIME ROOSTS AND DAYTIME FORAGING AND LOAFING SITES. GULLS, WATERFOWL, AND AQUATIC BIRDS SPEND THE NIGHTS ON LAKE ONTARIO AND MOVE ONTO SHORE SHORTLY AFTER DAWN. THESE FLIGHTS ARE TO PARKS, GOLF COURSES, AGRICULTURAL FIELDS, WASTE FACILITIES, AND PARKING LOTS AROUND YYZ. RETURN FLIGHTS TO THE LAKE TAKE PLACE ABOUT AN HOUR BEFORE SUNSET. THIS ACTIVITY IS HEAVIEST FROM LATE SUMMER THROUGH AUTUMN WHEN NEW JUVENILE BIRDS AND MIGRANTS AUGMENT LOCAL POPULATIONS. ALTITUDES ARE GENERALLY LESS THAN 1000' AGL AND HAZARDOUS MOVEMENTS ARE ADVERTISED BY CLASS I NOTAM, ATIS MESSAGE AND ATS COMMUNICATION WHERE AVAILABLE.

NOTAMs could be issued for specific groups of birds when their activity is expected to become hazardous to aviation, usually in mid-July, as follows:

120002 NOTAM CYYZ TORONTO  
INTERNATIONAL  
CYYZ INCREASED LOCAL BIRD ACTIVITY  
FROM LAKE ONTARIO SHORE TO  
CENTENNIAL PARK GOLF COURSE (3NM SE  
THRESHOLD RWY 33R) ALTITUDES LESS  
THAN 500' AGL  
1207010000 TIL 1207312359

ATIS messages could be posted as follows (issued in conjunction with the ATIS Timestamp):

1 hour before dawn:

HAZARDOUS FLOCKING GULL ACTIVITY EXPECTED FROM LAKE ONTARIO TO CENTENNIAL PARK GOLF COURSE (2NM BRG 135 DEGREES FROM RWY 33R THRESHOLD) ALTITUDES LESS THAN 500' MOVING NW AT 20 KTS

*expected from dawn until 1 hour after*

1 hour before sunset:

HAZARDOUS FLOCKING GULL ACTIVITY EXPECTED FROM CENTENNIAL PARK GOLF COURSE (2NM BRG 135 DEGREES FROM RWY 33R THRESHOLD) TO LAKE ONTARIO ALTITUDES LESS THAN 500' MOVING SE AT 20 KTS

*expected from now until sunset*

ATS Communications could be provided to pilots as follows:

BIRD HAZARD ADVISORY  
RADAR OBSERVES FLOCKING GULL HAZARD THREAT LEVEL 2, SEVERITY 2 BEARING 135 DEGREES FROM RWY 33R THRESHOLD 2NM. FLOCK HEADING SE AT 20 KTS. MAX ALTITUDE OBSERVED 500' AGL.

### **Irregular Unanticipated Events**

During dry months of the summer grasshopper populations increase to such numbers that they can invade the airfield, attracting thousands of birds to feed on them, especially flocks of European Starlings.

AIP/CFS would not be used because indicating that “*There are sometimes large flocks of birds on the airfield.*” would be of no use to anyone.

Because of the short lead times, it would not be possible to issue a NOTAM in advance of such events. A NOTAM could be issued reporting the presence of flocks after they arrived as follows:

120003 NOTAM CYYZ TORONTO INTERNATIONAL  
CYYZ LARGE FLOCKS OF STARLINGS PRESENT ON WEST SIDE OF AIRFIELD. FLOCKS ARE MOST NUMEROUS BETWEEN 1000Z AND 1200Z. BIRD CONTROL ACTIVITIES ARE UNDERWAY. BIRDS MAY BE PRESENT UNTIL 1207072359Z.  
1207021000Z TIL APPROX 1207072359Z

ATIS messages could be posted when the birds are reported on the airfield as follows (issued in conjunction with the ATIS Timestamp):

LARGE FLOCKS OF BIRDS REPORTED ACTIVE NEAR APPROACH END RWY 05 ALTITUDES UP TO 500' AGL.

ATS Communications could be provided to pilots as follows:

BIRD HAZARD ADVISORY  
RADAR OBSERVES BIRD THREAT-PROBABILITY 3 SEVERITY 3 NEAR RWY 05 THRESHOLD. ALTITUDE UP TO 500' AGL MOVING NE AT 15 KTS.

### **Summary and Next Steps**

We had a very specific goal in developing this paper; namely, to engage the broader aviation community in discussion on how to integrate avian-radar-derived, strategic and tactical bird awareness and bird-strike threat information into the aviation enterprise to better mitigate the risk of bird strikes, thereby improving aviation safety. The authors desire to jump-start this discussion by proposing a starting point that involves pilots, air traffic service providers, airlines,



airport operators, wildlife specialists, regulators, and radar developers.

The ideas we present are those of the authors and not necessarily the organizations they represent. The authors have collaborated over several months to develop this integrated starting point that hopefully will be critiqued, corrected, improved, and built-upon by our colleagues and appropriate aviation groups established for this purpose. It is our hope that the very basic analysis and synthesis we present can be exploited as a tangible starting point that leads to a credible implementation plan respecting the industry's culture and operational and economic constraints.

The authors would be most pleased to receive comments that can improve the ideas presented here; and look forward to working with the broader community to advance our common goal of more safely sharing the skies with birds.

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