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Abstract

Avian radar technology has matured to the point where robust data and analysis tools are now able to provide the aviation industry with high quality information to support bird strike risk mitigation activities. The aviation operating environment is dynamic and challenging with complex interactions between the primary bird strike risk mitigation stakeholders; airport operators, air traffic service providers and flight crews. The transfer of this proof of concept technology into a suite of tools that is integrated into the aviation industry requires the engagement and support of the user community in the next critical evolutionary step of this emerging technology. This paper examines the current and near-term future capabilities of avian radar technology and develops the fundamental framework for the practical, strategic and tactical use of the information to maximize strike risk mitigation while ensuring that overall flight safety is maintained or enhanced.

Introduction

From the early days of radar development over seventy years ago, researchers in various disciplines recognized that in addition to detecting man made moving objects such as ships or aircraft, that naturally occurring phenomena, birds or precipitation, could also be detected. The aviation industry has devoted considerable time and effort to very successfully refine ground and airborne weather radar detection technology into a suite of products, coupled with policies, procedures and guidance material for industry stakeholders to mitigate severe weather risks. Radar technology to detect birds, avian radar, has been developing, albeit until recently at a much slower pace, and has now matured to the point where it can be used to assist in bird strike risk mitigation. Avian radar development has reached the critical point where moving from the realm of scientific possibility, to integration into the industry operating environment as a valuable bird hazard risk mitigation tool, necessitates the development of policies procedures and guidance material by aviation industry stakeholders to introduce the technology and guide future research and development. Through an examination of avian radar capabilities, a review of similar aviation industry risk mitigation technology introduction experience and the application of accepted risk management strategies, this paper develops a suggested framework for wildlife management experts, radar technology developers and aviation industry stakeholders to integrate this technology in a safe and cost effective manner.

Avian Radar Technology

For many years wildlife biologists have recognized the value of radar as a tool to detect bird movements. In 1967 Eastwood published a book *Radar Ornithology*, and in 1976 Blokpoel in *Bird Hazards to Aircraft*, discusses extensively the value of radar detection as a bird strike mitigation tool. Wildlife biologists have struggled for many years to gain support to develop radar technology for bird detection. Radar technology has undergone dramatic hardware and software development to support military applications and this technology has now made its way into the civilian environment and has proven it can be adapted for bird detection. Avian radar research and development has matured to where production ready systems are, or will soon be available with the following capabilities:

- Automatic detection
- Remote and multiple operator displays
- Real time alerting systems
- High performance tracking in azimuth and altitude
- Radar data management
- Target classification
- Multi-radar networks and data integration with GIS displays
- Multi-sensor integration

Avian radar technology has now reached the point where valuable information from avian radar systems is available for use to support aircraft bird strike mitigation. To date, while there are a number of avian radar systems in use at both military and civilian airports, the installations are research or "proof of concept" systems and there has been no wide spread deployment of systems into the aviation industry. The fundamental reason for this lack of widespread deployment is the lack of an integrated, aviation industry supported and developed plan of how to use the technology safely and practically.

Aviation Industry Operating Culture

Due to concern over the potential for accidents, the aviation industry is very conservative and risk averse, consequently the introduction of new technology requires extensive in-depth validation by and consultation with, the entire user community before it receives regulatory approval and industry acceptance. This results in timelines that can span years, even decades. The aviation industry receives only very limited public funding and is further constrained by high costs, low profit margins and a need for tangible, near-term return on investment. Any incremental capital and operating costs created by the introduction of avian radar will be passed on to the travelling public. In the reality of today's struggling world economy, there is little industry appetite for increasing costs. While avian radar can and will result in a reduction in costs resulting from bird strikes and/or reduction in airport wildlife control costs, these costs savings will not occur in the near term and are difficult if not impossible to measure with any degree of accuracy that satisfies budget managers and will therefore be difficult to "sell" to the industry as a reason to advocate for the widespread adoption of avian radar technology.

It is vital to understand the aviation industry operating culture and the constraints this creates when introducing new technologies such as avian radar and build an implementation plan that works within the industry operating culture and constraints to minimize implementation timelines and cost, and, most importantly maximize industry acceptance or risk delaying deployment of this valuable bird strike risk mitigation tool.

Aviation Industry Severe Weather Risk Mitigation – Lessons Learned

Severe weather risk mitigation in the aviation industry can offer some excellent "lessons learned" when it comes to avian radar technology introduction. Why? Severe weather resulting from thunderstorms has caused numerous fatal accidents, and, since this is an environmental occurrence for which there is virtually no ability to modify the probability or severity of the risk, risk mitigation has focused on detection and avoidance of the hazard. Avian radar systems offer similar functionality – detection and warning of bird hazards, not bird behaviour modification.

The development of ground based and airborne weather radar and windshear detection and warning systems has resulted in dramatic reductions in the number of severe weather incidents and fatal accidents, but the path to reach the state we are at now, with sophisticated ground and aircraft thunderstorm and wind shear detection and warning systems has been long, arduous and costly. The length of the journey was partly a result of the pace of technology development, but more importantly the lack of an integrated industry process to manage the implementation of the technology into the operating environment. The critical area to focus on for lessons learned is the result, or current "end state" of the process, which is industry agreed:

- Hazard warning thresholds for airborne and ground based windshear detection systems based on aircraft performance limitations,
- Avoidance and recovery maneuvers tailored to aircraft specific performance limitations,
- Guidance documents for education and training of flight crews and air traffic service providers on severe weather risks and mitigations,
- Provision of hazard warning information to flight crews through structured messages from air traffic service providers and on-board systems,
- Development of an operating culture of avoiding severe weather encounters through proper flight planning routing and use of on-board weather radar systems through all phases of flight; and
- Decision making processes that retain the pilot-in-command authority to evaluate all the day-of-flight risks to determine the best overall risk mitigation strategy.

A Framework for Integrating Avian Radar Technology into the Aviation Operating Environment

Safety is an often misused term in many industries, including aviation. It implies a binary state; safe or unsafe. The correct terminology is risk management, or managing the exposure, probability and severity of, hazards to the lowest level reasonably practicable. This must be the overarching goal of any bird hazard risk mitigation strategy, ensuring that overall safety risk management is enhanced.

General Principles: The framework for integrating avian radar technology into the aviation operating environment must be based on the following principles:

1. *Reduce Bird Strike Risk Without Increasing Other Flight Safety Risks:* Aircraft flight is a complex multi-hazard event and risk management must always ensure that mitigating one risk does not create or increase another. For example, there is no value in proposing a bird avoidance maneuver that subsequently places the aircraft in danger of departing controlled flight or striking obstacles.

2. *Engage All the Industry Stakeholders in the Implementation Process:* Engagement of all the required industry stakeholders at the appropriate levels in the development of policies, processes and procedures prior to general implementation of avian radar is essential to cost effective implementation and user acceptance. Each segment of the aviation industry is a subject matter expert in their own right and it is only through collaborative decision making that uses these individual strengths that a safe, high quality, practical suite of tools can be developed and implemented.

Critical Elements for Implementation Success: Achieving a successful integration of avian radar into the aviation operating environment using the principles described above requires a plan that contains the following six elements:

1. *Multiple Layers of Risk Mitigation:*
   Successful risk mitigation relies on multiple activities to create layers of safety. Avian radar should not be used as a single source mitigation tool; rather it should be used as a critical element of the bird hazard risk management tool box. Avian radar systems have a suite of capabilities that promote the creation of these safety layers at two levels; strategic and tactical:

   Strategic: Data collected from avian radar systems on bird movements can be analyzed to determine vital information on bird species, numbers, lateral and vertical flight paths, seasonal and daily distributions at an airport. This information when combined with strike, wildlife control intervention, aircraft movement and wildlife survey data can be used to support development or amendment of:

   - Primary, Secondary and Special Bird hazard Zone using the Transport Canada Airport Bird Hazard Risk Assessment Process (ABRAP),
   - Airport Wildlife Management Plans,
   - Airport wildlife control procedures,
   - Airport departure and arrival routings,
   - Airport runway utilization schemes; and
   - State publications on airport bird hazards.

   Tactical: Data collected from avian radar systems on bird movements can be analyzed and using agreed hazard thresholds can provide:

   - More precise information on bird hazards for generation of NOTAMS. This functionality would support the development of an industry standard "Bird Hazard" NOTAM format, much like the VAAC messages and SNOWTAM format, which would ensure consistent information presentation throughout the world.
   - More precise information on bird hazards for generation of more accurate ATIS messages. This functionality would also support the development of an industry standard ATIS message format much like windshear alert information; and
   - Bird hazard warnings to flight crews through air traffic services or on-board systems.

2. *Detection System Hazard Warning Thresholds:*
   Development by aviation industry stakeholders of the bird hazard detection system warning thresholds based on aircraft specific airframe and engine certification standards

and accepted industry risk management standards for bird hazard determination by species and flocking behaviour.

3. *Bird Strike Avoidance Maneuvers:*
   Development by aviation industry stakeholders of any potential bird strike avoidance maneuver, that when initiated by the pilot-in-command, or commanded by on-board systems, is tailored to aircraft specific performance and maneuvering limitations by phase of flight.

4. *Common Standard for Aviation Industry Products & Procedures:*
   Aviation operations are global in nature, with different operating theaters and diverse aircraft types. To maximize safety and compatibility the aviation industry adopts common global standards for products and procedures thereby ensuring consistent safety outcomes. These industry standards are developed and maintained by industry associations and regulator such as ICAO, FAA, EASA, ARINC and the SAE. The standards define everything from display colors to inbound and outbound message formats to aircraft data busses and message structure and format for communication to flight crews. Any information, visual and verbal, and, standard operating procedures must be consistent no matter who builds the product and where it is operated. Failure to develop and adopt these common standards is not only detrimental to safety; it will result in deployment delays because users are afraid to select a product for fear it will not be compatible with other systems or become prematurely obsolete, like the Beta VCR.

5. *Operating Culture*
   Development of an industry operating culture that promotes effective bird hazard risk mitigation through the use of all available information, including avian radar data, when planning and operating a flight. This would require the development of policies and procedures for bird strike risk mitigation based on industry best practices and documented in the environmental section of a company Flight Operations Manual and/or Aircraft Operating Manual. The implementation of these policies and procedures would require the development of supporting guidance material, training modules and incorporation into the state mandated proficiency validation processes. Additionally, some air traffic service and airport operator bird strike mitigation processes, particularly those that consider delaying departures or arrivals would, due to the impact on fuel and time costs, require air operator consultation during development

6. *Decision Making Processes:*
   Flight crews operate in a very dynamic environment where they must manage multiple safety risks as well as the need to operate the aircraft economically to ensure the continued commercial success of the industry. These complex interactions result in the need to manage many risks during the course of any flight. The flight crew, specifically the pilot-in-command holds the ultimate legal responsibility for the safe conduct of the flight. Additionally, the flight crews are the only people who have the ability to assimilate all information available to them, and, more importantly, the ability to control the flight path of the aircraft safely, in consideration of all the risks.
   Given this complex risk equation, the difficulty in accurately predicting bird behaviour, and the legal responsibility of the pilot-in-command, any on-board systems, policies and procedures must always maintain the principle that the pilot-in-command has the ultimate authority to evaluate all the day-of-flight risks to determine the best overall risk mitigation strategy. The use of avian radar must never result in the development of

policies, procedures and products that remove the authority of the pilot-in-command to decide the best course of action, given the current conditions.

Engaging the Aviation Industry Stakeholders

The critical point has been reached where engaging the industry stakeholders in a meaningful and structured manner is required to ensure the timely and cost effective integration of avian radar technology into daily flight operations. It is only correct that the very industry that is going to pay for and use this tool plays a key part in the decision making processes for the implementation of the technology. The first critical decision will be who will oversee this stakeholder engagement process? Consideration of this question reveals that while there are four main groups of stakeholders; state regulators, radar manufacturer's, the aviation industry and wildlife experts, that since this ultimately affects aviation safety and operating cost that the avian radar implementation oversight should be jointly led by the regulatory authority and the aviation industry. This is not meant to diminish the critical role that the radar manufacturer's and wildlife experts play in this process; it merely reflects the current assignment of legal and fiscal responsibility for aviation safety activities.

This type of in-depth industry engagement should be structured to ensure that the correct subject matter experts for the various disciplines of the wildlife community, radar technology developers and aviation industry are engaged based on the five elements described above. It is clear that to ensure adherence to the fundamental general principle of enhancing overall flight safety that cross pollination of the various stakeholder working groups is required. Further, it is vital that stakeholder engagement is broad based, founded in recent experience in the aviation operating environment and includes representation from regulatory agencies, aircraft manufacturer's, air operators, industry trade associations, radar manufacturer's, military flight operations, airport operators, wildlife biologists and professional and general aviation pilot associations.

The stakeholders would be divided into two primary groups based on activity location; ground and airborne. Each of these two primary groups would then determine their own working groups and sub-committees to best manage the development and completion of their respective activities. Below is a suggested starting list for the members of the two primary groups:

Ground:

- Airport Operators (Military & Civilian)
- Commercial Air Operators Association(s)
- State Aviation Regulatory Body
- Radar Manufacturer(s)
- Wildlife Control Program Service Provider's
- Professional Pilot's Association(s)
- General Aviation Pilot's Association(s)
- Military Flight Operations
- Air Traffic Service Provider
- Air Traffic Controllers Association
- Wildlife biologists

Air:

- Commercial Air Operators Association
- State Aviation Regulator
- Radar Manufacturer(s)
- Aircraft Manufacturer(s)
- Professional Pilot's Association(s)
- General Aviation Pilot's Association(s)
- Military Flight Operations
- Air Traffic Service Provider
- Air Traffic Controllers Association
- Wildlife biologists

Note: The above lists use generic terminology for the identification of the various stakeholders.

The above groupings are representative of the stakeholders for a single state or group of states operating under a common regulatory structure. Given that the aviation industry is global in nature, consideration must also be given to establishing of an international working group, based on the same stakeholder demographics, to address development of common international standards.

Conclusion

Avian radar technology is a valuable tool in mitigating bird hazard risks that has reached a level that is mature enough to start the critical and complex process of integrating the technology into the aviation operating environment through a structured process of aviation industry stakeholder engagement.

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