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An Advanced Avian Radar Display for Automated Bird Strike Risk Determination for Airports and Airfields

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Introduction

Over the past ten years, development of bird detection radars for use as real-time aircraft birdstrike avoidance systems has moved beyond research and development into active deployment of the technology as an operational tool in a BASH program (Kelly 2006). A key challenge in use of avian radars at both military and commercial airfields however has been integration of the greatly expanded level of risk information provided by avian radar technology into the current procedures and methods for setting bird strike risk conditions at airports and airfields. Over the past two years, much of the effort at DeTect, Inc. has been directed at operational deployment of modern avian radar technology and extensive "lessons learned" have resulted from deploying over 30 MERLIN™ Avian Radar Systems throughout the U.S., Canada and Europe.

This paper provides an overview of the MERLIN™ Air Traffic Control (MERLIN ATC) display, a new interface to DeTect's MERLIN Aircraft Birdstrike Avoidance Radar system that provides significantly improved situational awareness to controllers and airfield operators and presents bird activity information in an operationally usable, strike risk-based format. The MERLIN ATC includes automated determination and display of the current strike risk in real time for the approach and departure corridors, and was designed specifically to facilitate delivery of automated risk information in the Air Traffic Control (ATC) tower environment.

Background

Over the past ten years, development of bird detection radars for use as real time aircraft birdstrike avoidance sensor systems has been propelled forward by advances in low cost digital signal processors and computer power. Marine radar had been used by biologists for many years to study bird, bat and insect activity (Korschgen et al. 1984; Williams 1984; Williams et al. 1972). However, the ability to process the marine radar data in real time to remove clutter, extract plots (potential targets), and qualify and correlate the plots into tracks has simplified the resultant data making it easier for the layman to understand and interpret the results (Zakrajsek & Bissonette, 2001).

Operational Risk Management

The operational experience of the past decade has shown that this simplified data display is not the peak of performance of such displays. End users want a display that they can quickly assimilate to make operational risk management decisions and set the bird watch condition, without the cost of having a full-time operator continuously monitoring the radar display. Additionally, operational risk decisions often require additional data such as target size or other characteristics that add complexity to the data display and delay the risk determination. As a rule, the more complex the display, the slower the process to assimilate the data and reach an operational risk management decision. The design challenge to avian radar developers is to balance the data needs for decision making with the complexity of the display and timeliness of risk determination.

Air Traffic Control

The primary function of ATC at an airport or airfield is to keep aircraft in the operating area separated from each one another. Additional responsibilities include efficient and safe management of the airspace and dissemination of traffic instructions, conditional information, weather advisories and navigational instructions. To optimally manage birdstrike risk requires ATC to assume the additional task of separating aircraft and birds and necessitates more sophisticated tools, such as avian radars. Much discussion has occurred over the last decade between bird strike management specialists as to whether additional tasking is achievable given the existing heavy workload of most ATC centers and general resistance to change among controllers. This added role is likely achievable at many airfields and airports where:

- The operational tempo is not excessively high;
- The bird-aircraft strike risk is historically moderate to high -- justifying the need to manage the risk; and,
- There exists a willingness on the part of ATC and airfield management to more effectively address bird strike risk.

These factors all together can combine to overcome the inherent “resistance to change” within the organization and ensure effective integration of the new data provided by avian radar systems.

MERLIN Radar Display Output

MERLIN was originally designed to provide real-time detection and tracking of bird activity on and around airfields with the objectives of providing controllers and bird control units improved situational awareness to reduce birdstrikes. The standard MERLIN system consists of two wide-beam radars to provide maximum coverage of the airspace:

- A horizontally-operated radar scanning 360 degrees around the system location, and,
- A vertically-operated radar sweeping the radar beam from horizon-to-horizon in the using the industry standard vertical scanning method for ornithological radars (Harmata et al. 1999).

For aviation safety use, the MERLIN unit is typically installed at the mid-point of the runway with the vertically-scanning radar aligned with the runway so that the radar beam provides full coverage of the runway approach and departure corridors and the airspace above the airfield. The vertical radar provides altitude data (y-z) on bird targets passing through or along the radar beam with operating ranges out to 4 miles and allows controllers to monitor the critical approach and departure corridors and along the runway where the majority of airfield bird strikes occur. The horizontal radar provides positional data (x-y) on bird targets in the environment around the airfield out to 6 miles providing situational awareness on bird targets that may be approaching the runway on a course to cause strike risk.

The MERLIN operating software has essentially had one standard display package to deliver the information from these radars since it was first introduced to the market in 2003. The system software design does allows for distribution of displays via WWAN, WAN or LAN[1] to multiple users in real time with some flexibility if display options, however only a limited set of options were standard in the early generations of the system. Data from both radars is processed by the system software and presented to the user on two side-by-side monitors: one for the vertical-scanning radar (VSR) and one for the horizontal-scanning radar (HSR). In combination, this presentation provides complete information to the user on the current position of bird targets in relation to the runway and airfield. Standard industry aviation formats are used that includes various user selectable display options such as color-coded symbols, target trails and target tags.

The HSR bird tracks are displayed in real-time in a plan position indicator (PPI) display view providing the position of each target tracked by the system as a color-coded symbol. Radar range is indicated in one nautical mile (nm) increment “range rings”. Display options include the ability to view the processed data tracks in real-time with site specific underlay “maps” that include key site reference features such as runways, roads, special resource areas (wetlands,

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[1] WWAN (Wireless Wide Area Network) uses cellular network technologies for broad area data distribution and internet connectivity; WAN (Wide Area Network) is a computer network that covers a broad area; LAN (Local Area Network) is a computer network covering a small geographic area. WANs and LANs can be wired (Ethernet) or wireless. The defining characteristics of LANs, in contrast to WANs, include their much higher data transfer rates, smaller geographic range, and lack of a need for leased telecommunication lines. MERLIN systems are currently in operation with radar display and data distribution on all three types of systems.

woodlands, water bodies) and structures to allow the user to quickly place each target an intuitive, contextual manner for the airfield or airport. Users of standard commercial and military aircraft tracking radar systems will find the MERLIN display format very familiar.

The HSR display also includes two sidebar options that can be activated to the right of the screen: a Vertical Risk Bar, and (2) a Groundtruth Bar. The Vertical Risk Bar provides an automatic determination of the relative birdstrike risk for each altitude level “band” in 100 foot increments for the airspace above the runway based on the vertical distribution of bird targets as concurrently tracked by the VSR. The information is presented as a color-coded bar graph with the length of the bar reflecting the cumulative target count and the bar color indicating the current risk for that band (Green = LOW; Yellow = MODERATE; and, Red = SEVERE). The risk threshold levels are user programmable and are typically set for each airfield based on specific BASH program requirements and collected field data collected during the first six months after start-up of the system. The risk bar is designed to provide the user with a quick “at-a-glance” view situational awareness of bird activity around and above the airfield showing where and at what altitude bird activity is highest. The combination of the HSR PPI display with the Vertical risk Bar is referred to as the “MERLIN Range Display”.

The Groundtruth Bar option, when enabled, replaces the Vertical Risk Bar along the side of the screen and allows the user to record visual groundtruth observations directly into the MERLIN system database along with the standard data attributes automatically recorded for the specific target selected. This feature is typically used bird control staff and biologists for development of historic data for resource planning, modeling and management. Appended information can include species type, verification targets counts such as the number of birds in a flock. Notational data can selected from a pre-programmed, user customizable list within the software (e.g. a list of bird species common to the site) or the user can override the standard list and type in specific notes (e.g. new species observed, behavior notations, etc.).

In the original MERLIN software design, the VSR data was displayed on a second monitor with the left and right halves of the screen representing the vertical horizon-to-horizon “sweep” range of the radar with the radar position located in the lower center of the screen. Grid indicator increments showed the distance of each target from the radar location (y-position) and altitude axes shown in scaled increments to the maximum range set within the system by the user (z-position). Targets passing through the VSR radar beam or along the beam sweep can be observed and tracked in real-time on this display. As in the HSR display, the VSR display screen also can be set to display target tags and trails and includes the Groundtruth Bar feature.

The first deployment of the MERLIN system for aviation safety was at the US Air Force (USAF) Dare County Bombing Range in North Carolina in the fall of 2003.

This system used the Range Display and its effectiveness proven successful, with the range reporting zero Class A or B birdstrikes since it began using the system operationally in over four years ago. However, with additional deployments at airfields starting with Tyndall Air Force Base (AFB), Florida in 2004, installations at USAF Whiteman AFB, Missouri and Dover AFB, Delaware, testing at Dallas-Fort Worth (DFW) International Airport starting in 2005, and experience gained on delivering over 25 additional MERLIN systems in the U.S., Canada and Europe, it became clear from user input that additional automation would be required for effective use in the ATC environment.

Lessons Learned

While the original MERLIN design met the requirement to provide precise data on the altitude of both birds and aircraft -- particularly in the critical runway approach and departure corridors - - in most operational tower environments controllers simply have too many tasks already and, with tight budgets, additional personnel resources for staff to monitor a “bird radar” full time are not likely to be available. Subsequently, original airfield users of MERLIN provided feedback that the system needed to:

(1) Be self-monitoring, cueing them to high risk areas of the display with audible and/or visual alerts,

(2) Automatically determine the associated bird strike risk level, and,

(3) Independently monitor the risk for the approach and departure corridors.

Based on consultations with tower users, airfield managers, and bird control units, including USDA and other contract wildlife biologists, these high risk areas would be defined as locations where multiple birds had passed through the radar beam over a fixed period and that the level of sensitivity to quantity and size of bird targets would need to be “adjustable” for each airfield based on the types of birds historically present, the types of airframes in use, the requirements of the specific BASH program and other factors.

Anyone who has spent time on or near an airfield conducting bird control knows that some species will consistently cross an airfield in about the same location and at similar altitudes over a time period. Tracking these short term trends and cueing the observer to these locations helps in risk management decision making and can be used as an indicator for the risk algorithms. The ability to identify a high risk area is especially important if it occurs at a critical phase of flight such as rotation when the transition to powered flight first occurs. Similarly, the risk presented by the size of birds present varies depending on the airframes in use at the airfield -- a small to medium size bird presents a higher level of risk to an F-16 fighter than to a C-17 transport.

Accordingly, these and other variables must be factored into any risk determination algorithms in an automated risk-based avian radar system. In 2007, DeTect added new software display applications for automated hazing of birds at industrial sites and initiated development of a new MERLIN display -- MERLIN ATC (for Air Traffic Control) -- to meet these operational needs of users of the technology. The initial MERLIN ATC application is focused upon the vertical radar display as its genesis is discussed below.

MERLIN ATC

As described previously, the MERLIN vertical-scanning radar is typically located at mid-field on the primary runway and scans along the centerline of the runway out to 2 – 4 nm. The wide beam radar sensor used in MERLIN creates a hemisphere above the runway that extends either side of the runway centerline by 10-15 degrees. As the scan is in the vertical plane, the altitude measurement of each target is quite accurate and limited only by the error for slant range to a target at the side of the scan. This contrasts with collecting data from a pencil-beam radar tilted at an angle where the target altitude must be estimating from the range and angle of the centerline of the radar beam, resulting in greater uncertainty about the altitude of the bird within the beam width. This altitude error increases with the distance of the target from the pencil beam radar, especially if the beam width is estimated from antenna manufacturer data and not from calibration from targets with a radar cross section (RCS) comparable to a bird target.

Important MERLIN system technological developments for automation of the risk-based avian radar display resulted from DeTect’s delivery of a custom-built MERLIN system to NASA for the launch of Space Shuttle Atlantis (STS-121) in 2006 and have been incorporated in the MERLIN ATC display. During STS-114 in June 2005, the space shuttle suffered a Turkey Vulture strike to the external tank just seconds into lift-off. NASA management concluded that the likelihood of a similar event increased from “remote to infrequent” and posed significant safety risk (NASA report IFA-114-I-13 Bird Strike During Ascent). In early 2006, NASA tested avian radar systems evaluating both pencil beam and wide beam radar sensors and subsequently ordered a MERLIN system to provide bird detection and risk monitoring for all future shuttle launches.

The NASA MERLIN deployment required specific display, operational and safety modifications. For operational decision support a custom MERLIN display was programmed to allow NASA to monitor bird activity around the launch pad to ensure that the launch trajectory is clear of birds as the decision to initiate the launch is made at T minus 1 minute (the last point at which the launch sequence can be stopped). For NASA, both the horizontal and vertical radar displays were modified to place the shuttle in the center of the display screen with defined risk control rings. In the case of the horizontal display, the new display functions to track bird activity around the pad in the run up to the shuttle launch and, if all bird targets are outside of the control ring at T minus 1 minute, then no bird could theoretically be above the shuttle by the time the shuttle cleared the pad and the launch can safely proceed. The development of the NASA risk-based radar display is operationally analogous to the decision making process to launch an aircraft from a runway and is directly applicable to commercial and military airfield bird strike risk management. As the zone within which a strike could occur at an airfield in linear however, the risk is driven more by the vertical zone instead of the horizontal and must take into account the increased speed of the aircraft which the "shortens" the strike zone.

One of the NASA acceptance criteria for the NASA MERLIN Avian Radar System was to validate the ability of the radar to detect bird targets over the launch pad with a high degree of reliability and certainty and to calibrate the system for specific target size classes. Due to the proximity very sensitive electronics and large stores of explosive materials, NASA specified strict maximum power density limitations for the system and the NASA MERLIN is a much lower powered system than is typically used for airfield applications. With this power limitation, certainty that the radar could detect birds at the operational range was critical and NASA specified that the final MERLIN system delivered would have to meet strict acceptance criteria as demonstrated by field performance validation and system calibration. NASA also required use of only X-Band radar frequencies which increases sensitivity of the radar to small insect targets and the calibration further required demonstration that the probability of false alarms from insects would be very low. NASA and US Navy staff subsequently conducted detailed calibration and power density testing of the final NASA MERLIN at the Kennedy Space Center. The testing methodology developed and resultant data from NASA and the Navy (as well as from DeTect's internal system calibration over the past year) have provided important calibration information on the type and size of targets tracked by a MERLIN system that is used for automation of risk analysis decision making.

MERLIN ATC beta Deployment

Development of MERLIN ATC started in early 2007 with the first operational deployments on four existing MERLIN systems in August of 2007. MERLIN ATC beta includes advanced features to separately monitor bird activity within user-defined airfield approach and departure corridors based on specific glide slope and airframe types for each airfield. The system continually analyzes and automatically displays the current bird strike risk rating for the runway approach and departure corridors on the MERLIN radar display screen using risk determination algorithms (separate risks is determined for both the approach and departure corridors). The risk determination for each corridor is based on a range of site specific parameters that are input into the software setup screen specific to each airfield and includes airframes in use, target size sensitivity (small, medium, large or flock size birds), and target size weighting.

Enhancements to the display have also been incorporated to provide a more user intuitive display that include runway designators, glide slope indicators, and, a variable maximum altitude scale. The software also includes an auto alert feature to notify tower personnel when the risk level changes via audible and/or visual alerts or by text message to cellular phones or Blackberry devices, to radio pagers, and by email message. In addition, separate Vertical Risk Bar Graphs are also included for both the approach and departure corridors with the current risk level displayed and color-coded onto the radar screen as LOW (in green), MODERATE (in yellow), and, SEVERE (in red) to provide controllers the ability to quickly determine current risk with a glance at the radar monitor.

Conclusion

The MERLIN ATC display marks only the first step along a path to introduce more powerful tools to aid ATC, airfield managers and bird controllers in managing the risk of birdstrikes at airfields. On July 25, 2007 it was reported that a bird strike occurred at JFK. According to an FAA employee web site, the airport was operating without weather or others forms of delay when a single birdstrike caused multiple flight delays -- the bird hit a departing aircraft which caused runway 13R to close for six minutes. This single delay resulted in backed up traffic at JFK and often is all it takes at a congested airport. In this circumstance, when runway throughput is so critical, reconsideration of delays to manage birds more effectively may have a significant payoff to airport and airline operators. A radar-indicated hold of thirty seconds for a bird to clear the runway maybe more acceptable in terms of traffic management than a six minute delay when a strike has occurred, and tools such as the MERLIN ATC could provide much improved situational data to airport personnel to support sound decision making.