DOT/FAA/AR-09/61

Air Traffic Organization
NextGen & Operations Planning
Office of Research and
Technology Development
Washington, DC 20591

Deployment of Avian Radars at Civil Airports

February 2010

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-09/61		

4. Title and Subtitle	5. Report Date
DEPLOYMENT OF AVIAN RADARS AT CIVIL AIRPORTS	February 2010
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Edwin E. Herricks*, Elizabeth Woodworth*, and Ryan King**	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
*Center of Excellence for Airport Technology Department of Civil and Environmental Engineering University of Illinois at Urbana Champaign 205 N. Mathews, MC-250 Urbana, IL 61801 **Federal Aviation Administration William J. Hughes Technical Center Airport and Aircraft Safety Research and Development Group Airport Technology Research and Development Team Atlantic City International Airport, NJ 08405	
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Office of Airport Safety and Standards Washington, DC 20591	Final Report
	14. Sponsoring Agency Code
	AAS-300

15. Supplementary Notes

16. Abstract

As part of a multiple-year Federal Aviation Administration (FAA) Airport Safety Technology Research & Development Program, avian radar units were deployed at the Seattle-Tacoma International Airport and the Naval Air Station Whidbey Island, Oak Harbor, Washington, by the University of Illinois Center of Excellence in Airport Technology. The deployment activities included identification and selection of radar vendors and products, contracting for radar system deployment, site selection for radar placement, completion of FAA obstruction and frequency applications, installation, and operation of the radar systems. Although this document provides a general protocol for avian radar deployment and addresses a wide range of issues associated with radar use in the complex environment of a typical civil airport, the actual activities that must be completed for avian radar deployment will be site- and situation-specific.

17. Key Words	18. Distribution Statement
Avian radar, Airport safety management systems, Needs analysis, Operations, Maintenance	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	64	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ATIS	Automatic Terminal Information Service
CEAT	Center of Excellence in Airport Technology
DFW	Dallas-Fort Worth International Airport
DRP	Digital radar processor
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
GIS	Geographic Information System
ISP	Internet service provider
NASWI	Naval Air Station Whidbey Island
ORD	Chicago O'Hare International Airport
PPI	Plan position indicator
QAP	Quality Assurance Plan
RDBMS	Relational Database Management System
RF	Radio frequency
SEA	Seattle-Tacoma International Airport
SMS	Safety Management Systems
TDV	Track Data Viewer
TVW	Track Viewer Workstation
UPS	Uninterruptable power supply

EXECUTIVE SUMMARY

Radar technologies are commonly used at airports for the detection and tracking of aircraft, management of aircraft and vehicles in airport operations areas, and the detection of hazardous weather conditions. Unfortunately, none of these commonly used radars can be easily modified to provide information needed to manage wildlife on and around the airport. For this reason, specific radar-based detection systems have been developed to address the critical need for wildlife management and the assessment of wildlife threats to aircraft safety.

The deployment of avian radars at civil airports is a complex process. Costs associated with the acquisition and the operation and maintenance of these radars are high. Unlike other radars used at airports, avian radars are a new technology. As a result, few airport personnel have experience in the acquisition and use of avian radars. Successful deployment and use of avian radars requires a clear understanding of the system's capabilities and limitations as well as its physical, technological, and personnel requirements.

To support the earliest stages of the planning and deployment of avian radar systems at airports, this report has been prepared to list and comment on the critical path leading to the deployment of avian radar systems at civil airports. The intent of this report is to provide airport personnel with information on how to achieve a successful deployment by building on the experience gained by the Center of Excellence for Airport Technology in the selection, deployment, operation, and maintenance of avian radars at several airports.

1. INTRODUCTION.

At airports, avoiding collisions between birds and aircraft is the focus of both wildlife management and bird strike hazard warning systems [1]. In the past, the tools available to airport personnel were limited to human observation, which documented species and numbers, followed by scientific analysis. With the advent of radar technologies and the availability of relatively inexpensive radar systems, a new tool was introduced to airport safety management systems. Avian radar provides an opportunity to extend observational capabilities to around-the-clock operation and the ability to expand spatial coverage in both distance and altitude.

Radar technologies are commonly used at airports for the detection and tracking of aircraft, management of aircraft and vehicles in airport operations areas, and the detection of hazardous weather conditions. Unfortunately, none of the existing radar sensors at airports can be easily modified to provide needed information on wildlife movements on and around the airport [2]. For this reason, specific radar-based detection systems have been developed to address an airport's critical wildlife management and bird strike hazard warning requirements. The most common avian radar systems use readily available marine band radars (S-band and X-band) with scan configurations and digital processing of sensor data optimized for wildlife target detection and tracking. Unlike other radars used at airports, avian radars are a new addition to the technological capabilities of airports. As a result, few airport personnel have experience in the acquisition and use of this technology.

Over the past 10 years, as part of a Federal Aviation Administration Airport (FAA) Safety Technology Research and Development Program, research teams from the University of Illinois Center of Excellence for Airport Technology (CEAT) have deployed two avian radar systems at the Seattle-Tacoma International Airport (SEA) and the Naval Air Station Whidbey Island (NASWI), Oak Harbor, Washington. Each of the radar systems was operated for a year or more, providing avian radar performance data as well as information on bird movement dynamics. The comprehensive CEAT performance assessment program considered key issues, such as sensor location, radar testing with known targets, data acquisition and management, and data visualization. The insight and practical experiences gained by CEAT teams—from defining expectations to site selection and initial deployment to extracting and applying information from gathered data—informed the content of this report.

To support the earliest stages of the planning and deployment of avian radar systems at airports, this report lists and comments on the critical path leading to the deployment of avian radar systems at civil airports. It offers practical information to those interested in deployment and use of avian radars to meet wildlife management and hazard warning needs at civil airports by providing:

- information on how to begin the process of avian radar deployment.
- information on performance assessments.
- guidance on operation and maintenance of radar technologies.

- an overview of the acquisition and processing of data and information resources.

- strategies for integrating radar information into existing airport wildlife management and bird strike threat-reduction efforts.

2. AVIAN RADAR TECHNOLOGY.

Avian radar systems, designed specifically for the detection and tracking of bird targets, are a relatively new product that is marketed by several vendors. (Known vendors with their contact information are listed in appendix A.) The most common avian radar systems use readily available marine band radars. This report focuses on X-band radars operating at 9.4 GHz. However, the general principles apply to any avian radar technology use at civil airports.

Although marine radar technology was originally designed to detect and track large, slow-moving targets on a flat surface, it has benefited from advances in electronics and the availability of low-cost digital processing. In avian radar systems, scan configurations and digital processing of sensor data have been optimized for wildlife target detection and tracking to produce information on bird movement dynamics related to airport runways, runway orientation, and regional land use.

The use of marine radars as the basis for avian radar systems brings compromises in technological capabilities based on the cost and the availability of off-the-shelf sensors. Radars featuring improved resolution, tracking, Doppler measurement, or other advanced detection and capabilities exist, but these radars have high costs and are often specialized designs. Airports selecting more common and economical marine radars for their avian radar systems must be prepared to accommodate certain limitations in range, target size resolution, altitude determination, and sophistication in clutter management.

2.1 APPLICATIONS AND LIMITATIONS.

Although the avian radar systems that are currently available represent the cutting edge of technology for bird hazard identification and mitigation, avian radars are not yet sophisticated enough to meet all needs for all users. Today’s avian radar utility is primarily user-defined, based on:

- User needs
- Site conditions
- Technical factors
- Operational limitations
- Target dynamics
- A host of other factors

It is essential that airport management develop a sound concept of operations that is realistic and attainable.

2.1.1 Considering Avian Radar for Airport Use—Applications.

Currently, avian radars on civil airports are used primarily for wildlife management and support for bird strike prevention programs. Potential applications of avian radar run the gamut from straightforward to highly complex. For instance, using radar to track seasonal patterns of bird movements around an airport can be implemented relatively quickly and easily. Complex applications, such as sense-and-avoid use, are far more difficult to implement because technologies must be integrated with human dimensions. Effectively using radar in sense-and-avoid applications requires absolute certainty in target identification, movement direction, and speed, supported by a high-speed computation environment that conveys an alert to those individuals who control airspace and aircraft.

2.1.1.1 What are Some Wildlife Management Applications for Avian Radars?

Avian radars expand wildlife management personnel's observational capabilities to night and to distances exceeding the normal 500- to 1000-ft limits where visual capabilities, even with good binoculars, degrade. Radars provide new operational tools. The radar center provides an observer with a dynamic view of bird activity that is updated every few seconds, which can be carried into the field using readily available communications and computer technology, allowing wildlife officers a detailed view of bird activity on and around the airport. The ability to check for birds at distances beyond the capability of human sight or to determine that a new concentration of activity requires management attention can make wildlife management much more effective and efficient. (See section 3.4.2 for more on integrating harassment activities into airport operations.) The enhanced capabilities made possible by avian radar add a new dimension to airport wildlife management. This new dimension changes the perceived value of management programs and creates a new reality for wildlife management programs.

2.1.1.2 What are Some Airport Management/Hazard Warning Applications for Avian Radars?

The type of data provided by radar has multiple uses in airport safety management systems. As noted, an improved understanding of bird movement and the timing of the movement on and around the airport can lead to safety improvements. A better understanding of movement dynamics, particularly regular patterns of flight over areas of the airport, can focus attention on both management and observation. A directed management effort can reduce or eliminate the hazard. An improved observational effort can provide visual confirmation of threats that can be relayed to airport users. The continuous avian radar surveillance provides a data set that can be analyzed to update conditions based on a known history, particularly when trends in activity have been identified. For example, Automatic Terminal Information Service (ATIS) announcements can be made that are timely and accurate and change according to the presence and abundance of birds. This can avoid the habituation problem with pilots when the same warning is provided in ATIS summaries for weeks or months on end. The improvement of hazard warnings will make controllers and pilots more aware of potential threats.

As noted above, avian radar can also be used to direct harassment activities to areas of threatening bird concentrations. This capability makes mitigation activities more effective and provides controllers with a new operational capability that includes both a warning and the knowledge that control activities will be initiated rapidly to manage threats.

2.1.1.3 Where can Avian Radars be Used?

Avian radars offer flexibility of location. They can be used on or off airport property to provide information on bird movement and dynamics. Radars can have permanent locations with power and connectivity permanently installed or they can be portable, operating on generator power with modem-based connectivity.

A critical factor in maximizing the potential of avian radars is a clear set of requirements for data availability. In some settings, the radar can simply be operated using a trained observer to provide an assessment of bird activity. The radar can be operated in automatic mode, recording data that is periodically reviewed. The most powerful use of the radar occurs when a remote radar sensor is connected to an operational center where the flow of data is real-time. To achieve this level of connectivity to radar sensors, a high-speed connection is required. This high-speed connection may only reach the operations center but, if external connectivity can be provided, then remote operation, maintenance, and additional supporting systems (including centralized data processing or a centralized alert system) for multiple airports are possible.

2.1.1.4 When can Avian Radars be Used?

Avian radars are designed for around-the-clock operation. To optimize a radar's informational potential, wildlife management programs should be used full time or for extended operational periods.

2.1.2 Considering Avian Radar for Airport Use—Limitations.

Avian radar is a tool that can be used to improve safety at airports. However, radar as a technology is subject to technological, as well as physical, limitations. For example, avian radar technology alone is not yet sophisticated enough to improve airport safety by providing a sense-and-alert system that will warn of imminent bird/aircraft collision threats. To have realistic expectations and set realistic operational goals, potential users of this technology must understand and be willing to accommodate its limitations.

As a sensor, radar is limited and sometimes unpredictable. Terms such as "decibel drop" and "side lobes" are understood by radar engineers as characteristics of the technology and describe phenomena that create limitations for the radar user. For example, actual—rather than advertised—beam-width detection capability is related to the energy of the radar antenna's beam and the characteristics of the target. Large targets are sometimes detected well outside a radar antenna's expected beam geometry, and side-lobe energies sometimes create echos from unexpected places. Radars are subject to other interference. Movement of large aircraft on the ground at slow speeds can produce multiple echos (multipath interference) and potentially misleading track information. Thus, a radar operator must have a clear understanding of what the radar is "seeing" to distinguish bird tracks from tracks produced by insects, airport vehicles, and multiple echos. A lack of training and poor interpretation of the radar screen will result in the most severe limitation of any technology—bad data.

Avian radar has time limitations in terms of response times for target identification and tracking. Because the technology relies on a rotating beam and computer computations, there are lags between an echo return, detection, and eventual display. Users must be aware that a displayed target may no longer be in the location identified by the radar at that time. For example, the relative closing velocity of a bird and an aircraft is very rapid. A closing velocity of 250 mph covers a distance of over 350 ft, the length of a football field, in a second. If the antenna is rotating 24 times a minute, once every 2.5 seconds, and there is time needed for digital processing, a 3- or 4-second delay in target acquisition translates to a 1/4 mile of distance traveled by an aircraft. This is a critical issue that impedes the use of current avian radars as sense-and-alert systems, which are required to detect and process information very quickly to warn of imminent bird/aircraft collision threats.

2.1.2.1 Are Radar Capabilities Affected by Weather?

Radar performance is related to wavelength of transmission and moisture in the atmosphere. Rain, particularly heavy rainfall, can temporarily reduce the operational capabilities of some radars. Another weather factor is wind, particularly for marine radars operating over water. Wind can produce wave action that can fool the radar into interpreting wave movement for the movement of low-flying birds. In addition, the wave movement creates clutter, producing a variable clutter management requirement that will challenge the radar processor.

2.1.2.2 What are the Limitations to the use of Avian Radars for Sense-and-Alert Systems?

In addition to limitations in terms of response times for target identification and tracking described above, avian radars are largely untried in the complex operational environment of civil airports. Thus, at this time, avian radars should not be used, or even considered, for sense-and-alert systems. Existing avian radars are operating with a suboptimal sensor, not designed for avian targets. There is no published comprehensive validation of radar as an avian target sensor considering parameters typical of civil airports (e.g., application of avian radar data to real-time flight operations, which requires the highest level of reliability and safety).

2.1.3 Summary of Applications and Limitations.

The applications and limitations of avian radars are still being discovered. At this time, the advantage to understanding the movement dynamics of birds on and around the airport outweighs the limitations identified for this technology. A major finding about the deployment of avian radars is that much has been learned and much remains to be learned. In fact, the full potential of avian radars is yet untapped. These performance assessments have shown that radars can provide much needed information to wildlife management programs. Radars have revealed unexpected patterns of movement and have confirmed existing assumptions underlying wildlife management programs. Although not yet sophisticated enough for application as sense-and-alert systems to warn of imminent bird/aircraft collision threats, the radars are improving information resources on wildlife movement, leading to improvement in the quality of ATIS announcements and other threat condition information at airports. Most importantly, the deployments of avian radars are changing perceptions about wildlife movement and dynamics, as well as the future role that radars will play in wildlife management and airport operations.

2.2 HOW AVIAN RADAR WORKS.

The basic operation of avian radar is straightforward. A radio signal is generated and transmitted, and an echo from a target is captured and processed by the radar system, providing information about range to the target and the angle of that target from the radar. Avian radars provide only limited information beyond range, direction of movement, and velocity. It is the interpretation and application of that information to specific operational objectives that gives radar its value. The major components of any avian radar system are a radar unit, an antenna, a digital radar processor (DRP), and a visual display.

2.2.1 Radar Unit.

Radar units are often the least expensive part of an avian radar system. Cost-for-performance relationships are continually improving, although unit optimization remains focused on marine, rather than avian, applications.

The radar unit has two primary components: an operational console containing a plan position indicator (PPI) screen and a scanning unit containing the transceiver and antenna. The primary options available for commercially available marine radars include transmission power, control sophistication, display size and color, and antenna type (array or parabolic dish). As shown in figure 1, the console is used to adjust power/range settings, antenna rotation speed, and PPI display characteristics.

Figure 1. A Furuno® Radar PPI

2.2.2 Antenna.

The second component of the radar is the scanning unit and the antenna it rotates. Antenna selection is one of the most important decisions in avian radar deployment. Antenna type determines the operational characteristics of the radar (e.g., volume coverage) as well as the response of the system to clutter interference. For avian radars, there are two general antenna types—the slotted array antenna and the parabolic dish antenna.

An issue for both antenna types is extraneous energy that is emitted from the radar when the beam is generated. This extraneous side-lobe energy, as shown in figures 2 and 3, is inherent in all antennae, although some designs will minimize this problem. Side-lobe energies, as well as main lobes that strike the ground, enable spurious reflections from both stationary and moving reflectors. This produces echoes called "ground clutter" that clutter the screen and interfere with target detection.

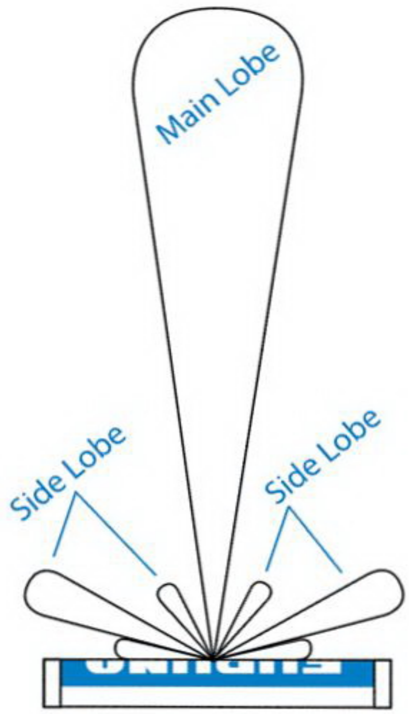

Figure 2. Example of Primary Beam (Main Lobe) and Secondary Beam (Side Lobe) Radiation Patterns for a Slotted Array Antenna (Source: Furuno® Product Documentation)

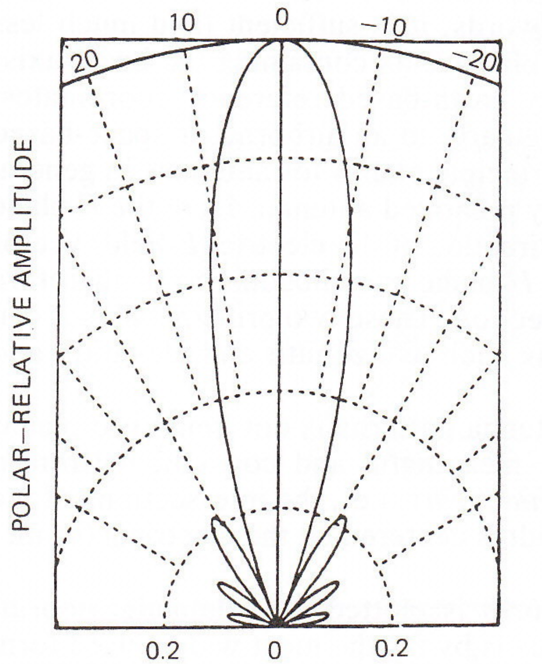

Figure 3. Plot of Beam Generated by a Parabolic Dish Antenna Showing Main Beam and Side Lobes [3]

2.2.2.1 Slotted Array Antenna.

Slotted array antennae provide excellent range and bearing information with no altitude discrimination. Figure 4 shows an example of a slotted array antenna. The detection volume of an array antenna spinning in a horizontal plane is defined by the antenna design, usually 1-2 degrees wide and 10 or more degrees up and down from horizontal. Because the lower part of the beam contacts the ground at short ranges as a function of antenna height above ground, the detection volume at a given range for the slotted array antenna depends on the upper part of the beam. At 3 miles, a 2- by 10-degree beam produces a volume of detection of approximately one-tenth of a mile wide and one-half a mile high. Any target in that volume, whether close to the ground or at altitude, will be shown on the PPI in the 3-mile range band. For this reason, slotted array antennae provide range and bearing, but no altitude information, when spinning in the horizontal plane. Further, the slotted array antenna radiates at approximately ±10 degrees, with approximately half of the radiated energy of this antenna producing high levels of clutter interference. When spinning in the vertical plane, azimuth and range can be converted to altitude and ground range; because of vertical rotation, the clutter interference is minimized. Figure 5 shows coverage of the array antennae in a vertical and horizontal rotation mode. In figure 5, the horizontal beam produces a 10-degree beam on either side of horizontal, producing an effective coverage of 10 degrees above the ground; the vertical antenna provides a 10-degree beam on either side of the antenna center line, producing a fan-shaped coverage of 20 degrees.

Figure 4. Slotted Array Antenna on CEAT Trailer Located at SEA

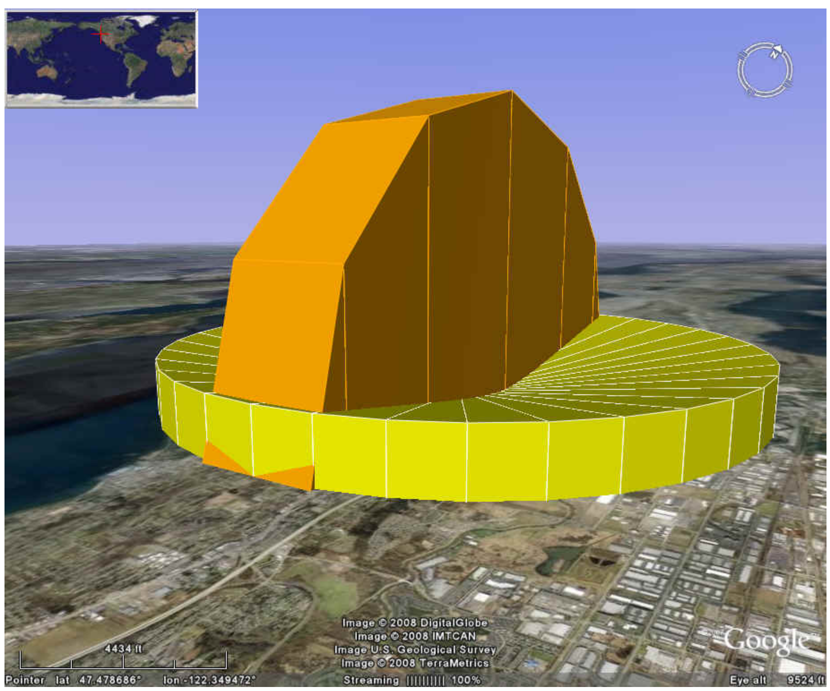

Figure 5. Coverage of the Array Antennae in Vertical and Horizontal Alignment

2.2.2.2 Parabolic Dish Antenna.

Parabolic dish antennae produce a defined conical beam projected from the antenna so simple geometric calculations, using beam characteristics and antenna uptilt, can be used to provide both range and altitude information. Figure 6 shows an example of parabolic dish antennae. These antennae may offer improved detection in high clutter situations because the energy in the beam is pointed into the air, avoiding ground clutter. The detection volume of the parabolic dish is defined as a conical beam projected from the antenna, usually with a beam width of 2 to 5 degrees. Figure 7 shows an antenna with a beam width of 4 degrees. The parabolic dish can be set at any angle between 0 and 90 degrees above the horizon. The adjustment of antenna angle enables target detection to be related the known height of the beam at a given range, providing an estimate of target altitude.

Figure 6. Parabolic Dish Antennae Mounted on the Administration Building at SEA

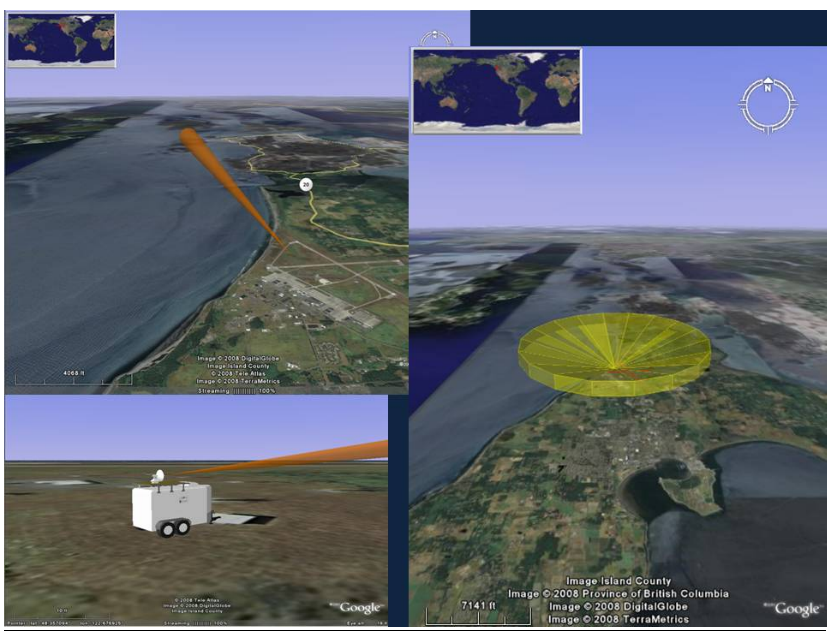

Figure 7. Representations of Dish Antenna Coverage as a Single Cone (Left) and the Full Volume Covered as the Dish Rotates (Right)

2.2.2.3 Actual Volume of Antenna Coverage.

The beam generated by the antenna provides an initial estimate of the volume of airspace covered by the radar system, i.e., the search volume. However, a manufacturer's specification of antenna beam characteristics uses simple geometry, rather than actual conditions, to define search volume. For accurate data analysis, a user must determine a system's actual search volume. For example, beam width is defined in terms of power distribution (attenuation of power) across the beam. However, a highly reflective target may be detected outside the expected beam width because sufficient reflective energy is available to produce a radar echo. This would produce a detection in an unexpected volume of coverage. Although this issue may not be important for all radar applications at airports, any use that requires estimates of numbers per volume may not be accurate. Further, expansion of beam width may lead to a situation where collision possibilities are overestimated because estimates of joint use of airspace by a bird and an aircraft are inaccurate.

The actual volume covered—the detection volume—of a radar may be very different from the search volume defined by beam geometry. For example, the presence of ground clutter in the circular area defined by the rotating antenna may interfere with target detection. The result is that only the fraction of the circular area that is free of clutter interference provides high-quality detection data. Clutter will often affect large areas in the search volume, producing a much reduced detection volume. Again, any use of radar data to provide numbers per volume must be adjusted to the actual detection volume.

2.2.3 Radar Signal Digital Processing.

The DRP is at the heart of the modern avian radar system. Components include a digitizing system for the analog data generated by the radar unit and a computer that uses the digitized data to reject clutter, and plot detections, and to assemble plotted detections into tracks. The capabilities of modern DRPs include control of system processing based on the digitized analog data from the radar transceiver. The DRP also performs clutter rejection functions and displays target plots and tracks with geographically referenced backgrounds on the computer screen. As shown in figure 8, the DRP is an alternate display to the radar PPI.

The flexible presentation of radar data achieved by the DRP eases the workload of operators in the analysis and interpretation of radar information. It is in the DRP that proprietary algorithms are used and where the selection of analytical methods and display procedures tend to separate avian radars among various vendors.

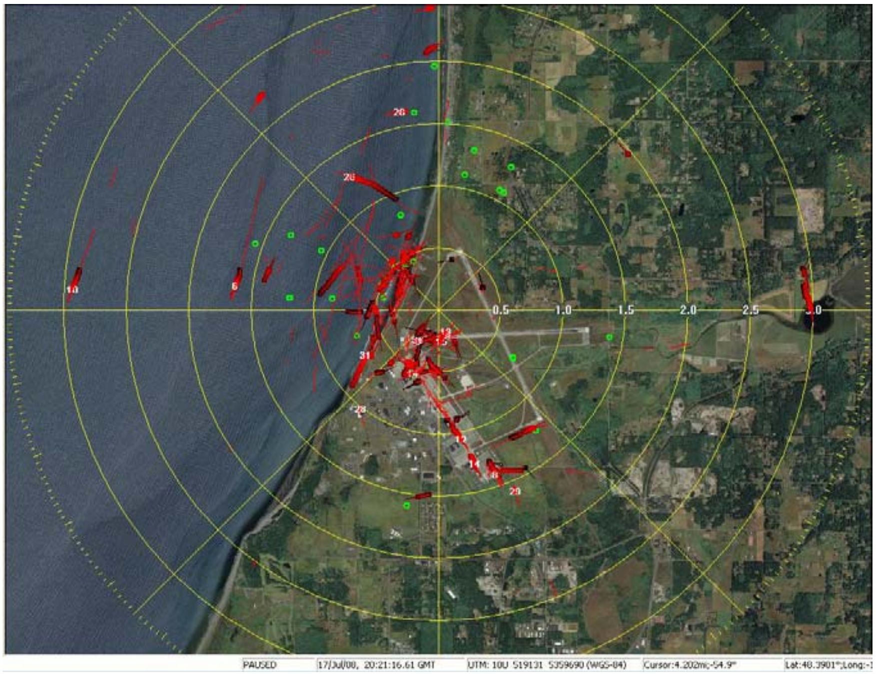

Figure 8. Radar DRP Showing Tracks (Red) and Plots (Green) of Detected Movements on a Geographically Referenced Screen

2.2.4 Visual Display.

In the modern avian radar, the PPI display of the radar is replaced with a computer screen that enables the display of maps with radar-tracking overlays and a synthesis of radar data, which can be selected by the user. Typical display options provide target tracking with system capabilities to count tracks, summarize data, and then display results in either real time or as historical summaries. Visual displays also reflect the experience of the vendor in presenting information useful to wildlife management or aircraft safety analysis. A wide range of options exists for the display of radar data.

The availability of DRP processing allows the development of specialized displays that can meet a range of user expectations. However, the PPI, which provides a raw image of sensor detections, is an important part of a quality-assurance process because it supports easy comparison of raw and processed images.

3. INITIATING THE PROJECT.

The deployment of avian radar systems at civil airports is a logical strategy for airport managers and wildlife management personnel to consider. Other radar systems are ubiquitous at airports and are an integral part of the air traffic control system and the monitoring of surface movements in the aircraft movement area. Avian radar technologies can be a viable next step in the assessment and management of wildlife threats to aircraft safety. Wildlife management personnel are well aware of the potential utility of radar in wildlife studies because of extensive scientific literature that addresses the use of radar for ornithological research. That literature covers a variety of radar systems, including portable marine radars, modified military radars, and NEXRAD (NEXt generation RADars) Doppler weather radars.

Although radar technologies are readily available, avian radars have had limited use at civil airports in the United States. The airport environment is complex. Any new radio frequency (RF) source must be accommodated in the already complicated RF environment of airports, which includes instrument landing systems, airport surveillance radars, and communications. In addition, safety zones are critical areas where obstructions to aircraft must be limited, making installation of radar equipment in preferred locations difficult. Finally, radar technologies are bound by physical laws that require line-of-site positioning and adjustment of radar RF characteristics to the airport environment where multiple permanent and mobile reflectors of RF energy challenge the interpretation of radar information.

In summary, the initiation of efforts leading to the installation and use of avian radars at airports is a complex undertaking that is related to the technology, the airport environment, and the expectations for performance from the radar.

3.1 ASSESSING NEEDS.

Avian radars at airports have two general applications: monitoring of bird movement in support of wildlife management programs and surveillance of airspace used by aircraft to identify threats to safe operation of aircraft. These two applications are interrelated. Proper management of wildlife can do much to reduce the risk of bird strikes, which damage planes and threaten the lives of passengers, air crews, and birds, including protected species.

The typical needs assessment will place a higher priority on the threat assessment, but currently available avian radars are more appropriately used to address the needs of wildlife management. As a component of the threat management system for aircraft operations, avian radars at civil airports cannot be expected, at this time, to contribute to improved safety by providing a sense-and-alert system that will warn of imminent bird/aircraft collision threats. However, avian radars can provide valuable real-time information to improve airport safety. For example, a real-time indication of the concentration of birds at a location can guide wildlife managers to the site to disperse these birds. Unfortunately, avian radars are largely untried in the complex operational environment of civil airports. Until sufficient testing and performance assessment activities are completed, they should not be used, or even considered, for sense-and-alert applications.

Avian radars can be used in a surveillance mode for providing coverage of approach and departure corridors. This surveillance will improve understanding of bird movement dynamics in critical corridors and help in assessing the real threat to aircraft safety posed by birds. Because avian radars significantly expand the capabilities of wildlife managers to observe bird movement and dynamics on and around the airport, avian radars can immediately meet the needs of wildlife management programs. Wildlife management may use avian radar systems to monitor the movement dynamics of wildlife on and around the airport, providing consistent information for trend assessments, identification of areas for focused management, and—

depending on airport communications capabilities—information about active wildlife management efforts at the airport.

Given the diversity of potential expectations for avian radar, a careful review of needs should be conducted by the airport as an essential step in the planning process. Identifying needs provides the foundation for integration of avian radar technology into airport safety management systems and for the establishment of deployment objectives for the radar technology. Typical needs that might be identified include:

- Developing a continuous surveillance program for aircraft approach and departure corridors.

- Improving a general understanding of bird movement and dynamics in relation to aircraft movement.

- Improving assessment of wildlife hazards considering issues such as potential altitudes of collisions or velocity and damage potential.

- Identifying bird movement periods and locations that can be used in planning departure times or departure paths.

- Developing an improved wildlife management program based on around-the-clock observations.

- Identifying management problem areas considering bird utilization of airport buildings or structures.

- Identifying management problem areas considering the origin, destination, and timing of transient birds.

- Providing real-time access of radar information to operations staff on the airport to improve response times to identified wildlife hazards.

3.2 INTEGRATING AIRPORT SAFETY MANAGEMENT SYSTEMS.

Avian radar used at an airport must be part of an integrated and well-managed safety program that has well-defined performance criteria based on a sound operational plan that is continuously improved by monitoring.

Airport Safety Management Systems (SMS) are the result of an approach to safety program development that links safety and efficiency with the objective of anticipating safety issues before they lead to accidents. As described by the FAA Advisory Circular (AC) 150/5200-37—Introduction to Safety Management Systems for Airport Operators and the International Civil Aviation Organization (ICAO), Doc 9859 Safety Management Manual, SMS development is now a regular part of Title 14 Code of Federal Regulations Part 139 requirements for airports.

The systematic assessment of safety issues in an SMS process provides an approach to proactively deal with safety issues, in particular, the integration of technologies such as avian radar in the complex operational environment of airports. Further, the four pillars of the SMS—policies and objectives, safety risk management, safety assurance, and safety promotion—require a needs assessment that clearly defines performance expectations and criteria, provides a clear operational plan that integrates any new technology in the airport environment, and assures a long-term commitment to monitoring to continually improve safety.

In SMS development, the hazards posed by wildlife are addressed by safety management activities that include the improvement of wildlife detection systems and procedures, the use of deterrent devices, development and implementation of wildlife management plans, and providing and managing wildlife attractants on and around the airport.

3.3 SETTING OBJECTIVES.

Setting objectives is the logical next step following a needs assessment and is the essential first step toward developing a Quality Assurance Plan (QAP). A clear statement of objectives refines the needs assessment, identifies the requirements for avian radar selection, defines operational characteristics and procedures, and identifies specific information products.

The following example of a general objective and more specific subobjectives are provided for the use of avian radar in wildlife management. A more specific example, based on safety program objectives for Chicago O'Hare International Airport (ORD), can be found in appendix B.

- Objective:

  Operate an avian radar system to support the management of wildlife at the airport, and evaluate the performance of the avian radar system in meeting the developing wildlife management needs at the airport. The avian radar system will be used to collect and process data to provide information that will support the accomplishment of the following subobjectives.

- Subobjectives:

  - Develop, conduct, and report on studies designed to characterize radar performance (defined as the ability to detect and track birds) in the airport environment.

  - Conduct tests to provide calibration data for radar technology.

  - Conduct tests to validate and verify radar performance considering both range and altitude of targets.

  - Identify the dynamics, timing, and trends of bird presence, movements, abundance, and behavior on and around the airport.

- Identify wildlife activity and use patterns on and around the airfield (i.e., loafing/roosting sites, location of source populations, movement patterns) with an emphasis on night hours.

- Identify the origin and destination of birds tracked by the radar outside the airfield.

- Identify target by bird category (e.g., single versus flock, small versus large).

- Determine relationships between habitat characteristics and bird activity at problematic locations.

- Reinforce wildlife hazard management recommendations made to airport officials by the wildlife biologists.

- Provide a foundation for a long-term regional analysis of avian presence on and near the airport.

- Provide information needed to develop management options for hazardous conditions that exist beyond the influence of common airport management techniques.

- Compare radar data and existing wildlife observational programs to identify hazards potentially undetected by traditional wildlife hazard management. Identify new wildlife hazards on the airport.

3.4 DEVELOPING AIRPORT COORDINATION.

A critical part of initial deployment considerations is developing a coordination plan for the effective use of the avian radar technology. The actual coordination plan will be specific to each airport, reflecting the organizational structure and the operational methods in place.

Although operational integration with air traffic and with wildlife management requires similar information from the radar, objectives will vary in the areas of airspace coverage, data validation, and speed of information transfer.

3.4.1 Operations Integration—Air Traffic.

The integration of avian radar information into air traffic control is a complex undertaking that must consider radar technology issues, air traffic, and methods to ensure information utility in the air traffic environment.

Radar technologies are limited in their capabilities, which are determined by the willingness of airports to invest in the technology. For example, existing avian radars that use relatively inexpensive off-the-shelf marine radar sensor technologies are limited in target-size discrimination at given ranges. The physics of the RF signal, the transmission characteristics of that signal, the antenna that sends and receives the signal, and the sensitivity of the receiver all influence detection capability and the tracking of targets. Further, there are inherent time delays in signal-to-display in existing avian radar systems due to the rotational speed of the antenna and the target-acquisition capabilities of the system. Thus, existing avian radars are not optimized for operation in an air traffic control environment where rapid verification of targets, position, and direction of movement are critical.

Although not optimized for air traffic use, avian radars can provide valuable information to air traffic control activities. At this time, the needs versus performance of avian radars in air traffic management must be carefully assessed. This assessment should clearly identify the limits of existing avian radars, but should also take advantage of the many benefits available from understanding the movement dynamics of birds in and around airports.

3.4.2 Operations Integration—Wildlife Management.

The operational integration of avian radars into wildlife management at airports can take advantage of the new information resources provided by radar systems. Although avian radar systems are bound by physical and technical limitations, the requirements of wildlife management can accommodate those limitations while still providing major benefits to airport safety. The primary benefit of avian radars is that they provide a means to continuously monitor the movement of targets, including birds, in the scan volume of the radar. This capability adds a new dimension to wildlife management by providing night-time surveillance of the airport, a permanent record of targets detected and tracked, and new options for the long-term monitoring of bird movement dynamics.

The integration of avian radars in operational aspects of wildlife management can provide information to various elements of wildlife management operations. For example, although there is a delay in the generation of target tracks on a radar display, the near-real-time tracking of target movement can provide an important adjunct to on-the-field wildlife management. In a typical situation where radar imagery can be transmitted to field vehicles, managers will be able to determine where their management activities are needed, which can contribute to the improved effectiveness of management options, such as harassment. For the near term, improved local and regional management can be achieved using daily or weekly summaries of bird movement activity with information on paths of movement supporting identification of the origin and destination of transitory birds. Further, this near-term information can be consolidated to provide a better picture of the threats of bird movement to aircraft, supporting the integration of updated information in airport ATIS announcements, or even Notice to Airmen, when unusual activity is observed. Finally, over the long term, the avian radar contributes to an archive of information, collected in a uniform manner, which can support detailed analysis of patterns and trends in bird movement.

The integration of avian radars in airport wildlife management will also be specific to the airport, reflecting the characteristics of the airport's wildlife management plan and operational procedures.

3.5 REVIEWING OBJECTIVES.

An important feature of the SMS approach to continuous improvement of airport safety is the on-going review of safety programs and issues. By implementing an SMS approach, the need for avian radars will be continuously assessed and clarified. This establishes a top-level requirement for a QAP and leads to a regular review of objectives.

The review of objectives is the point where the top-down safety strategies of SMS meet the bottom-up developments gained through operational experience. Objectives are initially set based on the needs and understandings available at the time the objectives are developed. As the interpretation of test results become available and as operational experience is gained, the objectives supporting an avian radar deployment must be reviewed and updated.

3.6 ESTABLISHING PLAN AND SCHEDULE.

The final step in initiating a radar deployment program is defining a specific plan of action and developing a realistic schedule for deployment. (The details of a plan of action will be provided in later sections.) Although issues that influence scheduling are also covered, particular attention should be given to developing a reasonable schedule when considering a radar deployment, particularly when a need for immediate action is required. The schedule should provide sufficient time for the following:

- Needs assessment and objective setting. These activities will require careful consideration and involve airport personnel, agency involvement, and possibly vendor participation to define technological capabilities.

- Procurement. The avian radar market does not support off-the-shelf solutions. Avian radars are often purpose-built with sensors and associated systems configured specifically for an airport. Sufficient time must be allowed in the planning schedule to develop specifications, meet procurement requirements such as bidding, and accommodate the manufacturing schedule of the vendor.

- Site Selection. The site selection process is a critical element of eventual avian radar performance. The process is complicated by approvals that are required prior to placement of the radar on the airport. Issues of possible obstructions and frequency interferences must be addressed in the FAA Form 7460 application. A possible conflict arises because it is necessary to conduct preliminary testing of radar at an airport before a site is selected and a Form 7460 application can be submitted. Further, the review process can be expected to take 60-90 days. Additional approvals may be needed, including Federal Communications Commission (FCC) licensing, which may take months to as much as a year.

- Installation. Following site selection, the avian radar must be installed. Although physical placement of the radar system may take only a few days, a complete installation will require set-up procedures adopted by the vendor and then acceptance testing by the airport. Once operational, performance criteria may require test and validation under a variety of weather conditions, producing an acceptance schedule that may extend for several months to a year.

The final planning and schedule should reflect a realistic assessment of the total time from the decision to acquire through operational stability characterized by meeting defined performance criteria.

4. CONTRACTING.

Following the needs assessment and objective setting, the next step in an avian radar deployment is the procurement of the radar system. The procurement process follows procedures established by the airport for any major purchase and must be based on a carefully defined set of requirements or specifications applicable to the radar technology, operational characteristics of the system, and information produced and used.

4.1 PROCUREMENT VERSUS DEMONSTRATION.

All options should be explored in the procurement of avian radar technologies. If airport personnel are confident that requirements and specifications can be developed for bidding or other procurement procedures, then they can proceed directly to procurement. If there is uncertainty about the actual requirements of specifications, then a demonstration of the technology at the airport should be considered. In the demonstration, the vendor will provide an operational radar system and work with airport personnel to establish how needs and objectives can be translated into tangible specifications for radar acquisition. In this situation, vendors can supply much needed technical information to airport personal who, in turn, will be able to assess how their needs can be met by a vendor’s product. The airport should be willing to offset some of the costs of the demonstration.

The experience gained during this study suggests that a demonstration of the avian radar technology on the airport is critical. There are a limited number of avian radars operating at U.S. airports, and the associated operational experience is also limited. Airports considering acquisition and deployment of avian radars should consult with those airports that have experience with avian radars and request a demonstration of any technology before procurement. Because each vendor can provide new insights into avian radar configuration and operation, it is also important to consider the demonstration of avian radar systems from different vendors.

4.2 DEVELOPING BIDDING SPECIFICATIONS.

The development of bidding specifications should consider technical and performance specifications provided in both numerical and narrative forms. Technical specifications should be sufficiently detailed to define range and coverage requirements of the radar sensor, but allow the vendor options on selection of the manufacturer of radar system components. Performance specifications should fully meet use objectives.

The development of a technical specification may include any or all of the following:

- Antenna
    - Manufacturer
    - Type
    - Horizontal and vertical beam width
    - Frequency of operation

- Radar Transmitter/Receiver
    - Manufacturer
    - Operating frequency
    - Peak power
    - Waveform characteristics
        - Pulse repetition frequency
        - Pulse width range settings with maximum range
    - Reliability (i.e., mean time to failure)
    - Operating environment (e.g., range of temperature, humidity, etc.)

- Digitizer
    - Manufacturer
    - Number of bits of digitization
    - Digitization speed
    - System capability
    - Operational mode
    - Dynamic range
    - Data type and acquisition by system

- Post-Processor
    - Computing platform
    - Radar signal processing
    - Clutter suppression

- Tracking
    - Options available for different targets
    - Position coordinates
    - Plot update speed
    - Track update speed
    - Heading update speed
    - Track history requirements

- Postprocessing requirements
- Maximum number of targets tracked per scan

- Display

  - Information provided on display
  - Display modes

    - Tools available on display (e.g. distance measures and heading)
    - Electronic range markers available

  - Units for on-screen measurements
  - Map importing capabilities
  - Documented output data formats

- Interfaces

  - Open (documented) interface to software components:

    - ANSI Standard Application Program Interface (API)
    - W3C-Compliant Web Services

  - Open standards (e.g., TCP/IP, SOAP, SQL)

- Networking

  - Network protocols (e.g., TCP/IP) supported
  - Wired versus wireless

- Notification

  - User-controlled parameters for setting alarms
  - Media (cell phone, email, etc.) for notifying personnel of an alarm

- Operation

  - Remote display options
  - Remote control options
  - Multiple-sensor integration

- Data Management

  - Storage
  - Data dictionary for all stored data
  - Metadata for all data stored
  - Specify what data must be stored, saved, and reused

- Replay of stored data

- Data Products

  - Data products available for storage (e.g., screen captures)
  - Support for on-screen captures of displays
  - Storage of detection data and availability
  - Storage of track data, replay options
  - Storage of raw digital data and reprocessing options
  - Validation of track performance

    - For detection and tracking, specify detection data associated with each track

    - Preservation of the association of detection with tracks as track histories

  - Data streaming
  - Data streaming requirements
  - Database engine for data streaming
  - Number of targets tracked in real time
  - Linkage of detection and track information in the data stream
  - Data streaming to/from remote sites in real time

4.3 OPERATIONS AND MAINTENANCE SPECIFICATIONS.

It is essential for airports to determine the level of support they need from a vendor and to develop specifications for operation and maintenance services consistent with the availability and responsibility of airport personnel. Specifications are contingent upon the capabilities of the airport and the level of vendor involvement required by the airport. Vendor involvement can range from generally independent management of the radar system by the airport to a turn-key operation with regular assistance provided by the vendor.

General operations and maintenance specifications should be developed to provide periodic servicing and repair of the radar system. The radar system typically includes an off-the-shelf radar unit that can be serviced by the manufacturer or the vendor, so airports may choose to assume maintenance responsibility for the radar unit. Other major hardware components of the radar system, such as the computer, displays, and communications links, may all include vendor products or proprietary elements. It is good practice to consider a service contract for such components.

Software operations and maintenance issues are complicated because they involve both radar system management and data management (addressed in the next section). Radar system management includes both the hardware and software associated with a digitizer and the DRP. The adjustment of detection algorithms and management of the DRP requires high levels of training that are specific to the vendor’s system. System management at this level should be addressed in a service contract.

Data from the DRP, usually in the form of tracks, is used to produce geo-referenced displays of radar data. In the radar system, a track-data analysis capability is usually coupled with options for display. Operation of the track-data analysis capability of the system usually requires intermediate-level training. Airports should plan to have staff trained to use track-data display systems, which will be the foundation for most data analysis. Usually training is offered as part of the radar system delivery, but airports should consider a contract with the vendor to provide regular training to airport personnel.

4.4 DATA AND DATA MANAGEMENT SPECIFICATIONS.

Specifications for data management should reflect the results of an airport's needs analysis and quality assurance program. Data specifications for wildlife management are likely to be somewhat different than specifications for real-time applications or for future sense-and-avoid applications.

The major focus of data specifications for any use must be on data quality, considering both precision and accuracy. After quality, factors such as data geographic references, the time interval between data generation, analysis, and reporting will be an important specification. Data management for wildlife management will require specifications for acquisition, processing, and archival storage. Data management specifications for real-time data use will require methods for data distribution to users. Data management specifications for sense-and-avoid warnings must include all the data quality specifications plus methods for providing alerts, including some definition of relative hazard that is developed based on criteria established by airport and regulatory personnel.

Because storage and retrieval of data is essential for comparative analysis of movement dynamics, the characteristics of the data archive are critical. Data from specified time periods, such as hourly or daily summaries of tracks, must be readily connected to provide comprehensive database searches. It should be noted that radars generate very large data sets and the data management tools that accommodate these large data sets must be available as a part of the data management system to facilitate data postprocessing. During postprocessing, other software, such as Geographic Information System (GIS) or statistical analysis programs, may be used to fully explore the information content of the radar data. Usually, the radar vendor has developed analytical methods for this level of analysis. Through the vendor, the analysis may be available as tools for use by airport personnel or as vendor services, which might include specialized data management packages based on the specific needs of the airport.

5. SITE SELECTION.

Determining the site for the avian radar on an airport is a complicated and time-consuming activity. Although the primary objective for radar deployment is effective detection and tracking of targets, issues such as safety zones, power availability, connectivity, and general access take precedence over optimal placement of radar. Placement of the radar on the airport invariably requires compromise in location.

5.1 ASSESSING NEEDS.

Finding an acceptable site for the radar requires prioritizing identified needs and then carefully analyzing competing issues. From a wildlife detection perspective, the most important criteria for site selection are providing good detection capabilities for known critical areas on the airport. Critical areas are those locations where observational data suggests a high hazard potential due to site attractants or the actual use of the area known from observations. From a radar operations perspective, the most critical criterion is minimizing clutter interference for critical areas. These two factors can generally be accommodated by several locations. The final location is then determined by considering infrastructure needs, such as the enclosures needed for the radar system (including towers or other structures required for the radar antenna), power supply, and the availability of high-speed connectivity.

The location of possible sites can be determined using the records of wildlife managers to analyze the airport's landscape and features to identify locations that may be attractive to birds. Such understanding of critical areas attractive to wildlife can be the basis for assessing needs and locating the radar to meet those needs. Several examples are described below.

Wildlife managers at SEA developed a grid for their airport. All personnel involved with wildlife management were tasked with coding activity types to grids to provide better location information for later analysis. The reports of patrol activities were then mapped on the airport grid map using a GIS. Figure 9 illustrates the areas of higher and lower levels of wildlife management activity by month. This geo-referenced data then provided the basis for analysis of wildlife activities by location and over time, providing an improved assessment of wildlife threats to aircraft safety.

Wildlife personnel at ORD conducted point counts of birds. A point count is simply observing and counting birds sited from a known location using a standard observational procedure. The point count provided coordinates that could be used in a GIS, enabling analysis of observational data in a geographic context. Changing numbers of birds observed were tallied for a year. Figure 10 shows seasonal changes wildlife numbers.

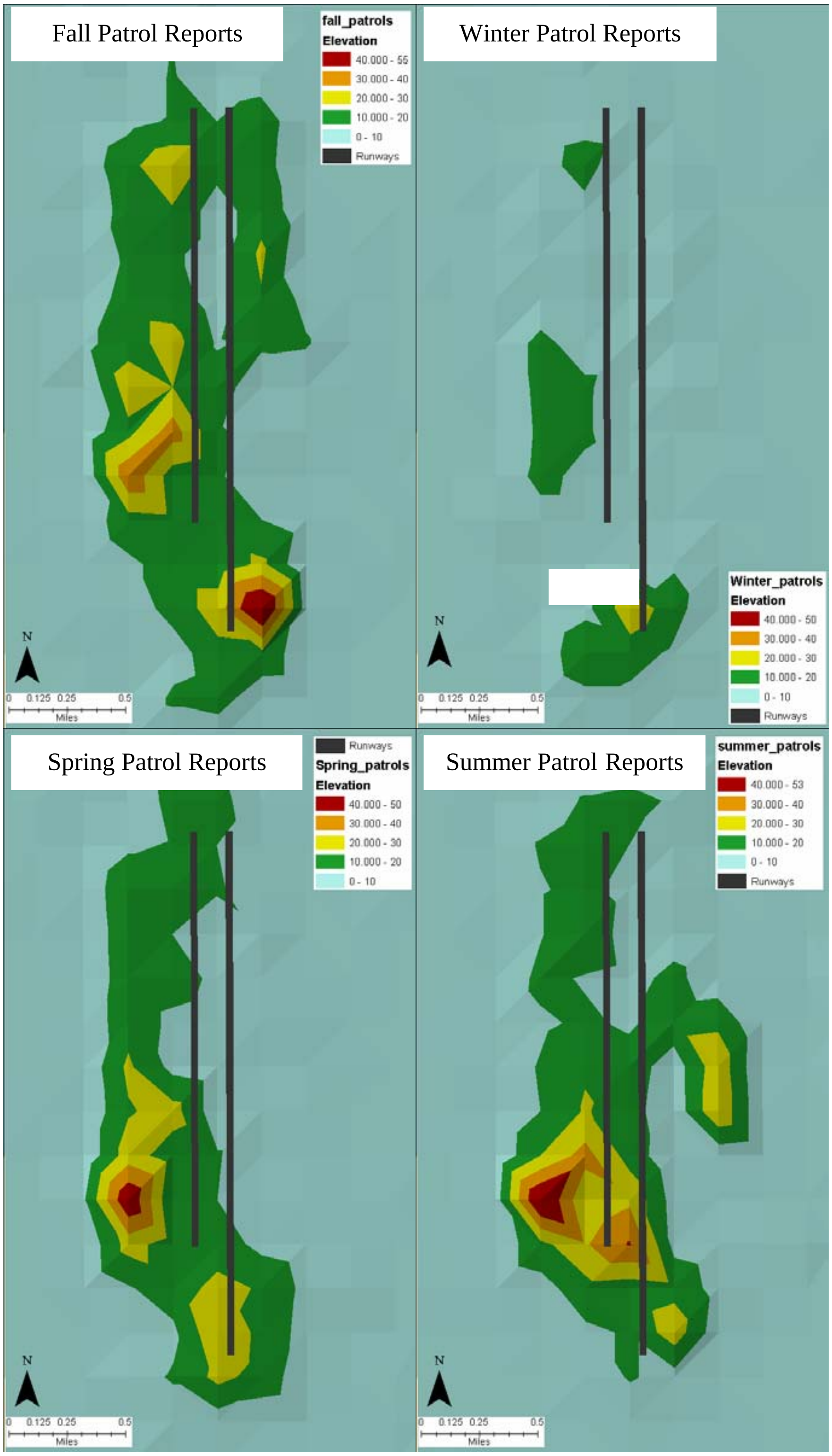

Figure 9. Areas of Higher and Lower Levels of Wildlife Management Activity by Month at SEA

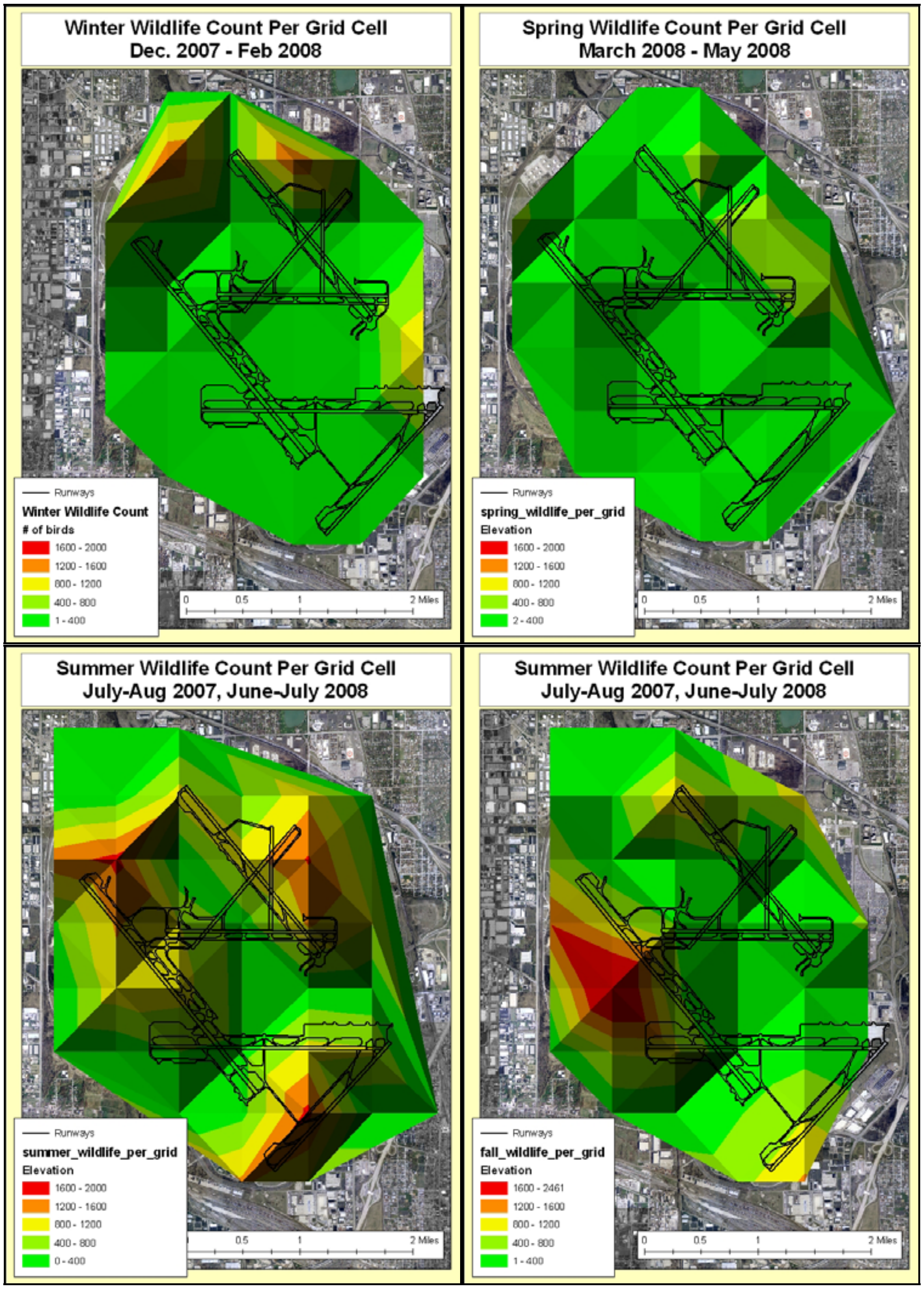

Figure 10. Seasonal Changes in Wildlife Numbers at ORD

To analyze the threat surrounding an airport on a larger regional scale, a GIS can be a helpful tool. Land cover data from the United States Geological Survey Gap Analysis Program were used to identify habitat conditions that could attract birds. By relating bird habitat preferences to the location of attractive habitat, CEAT developed in figures 11-14 for the area surrounding Dallas-Fort Worth International Airport (DFW).

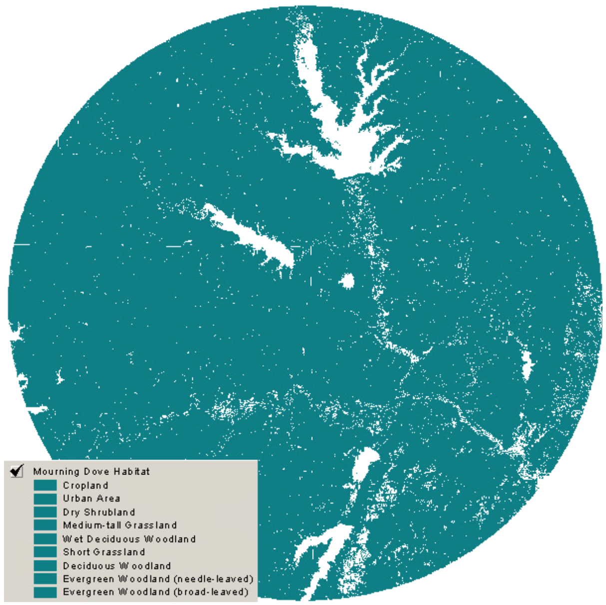

Figure 11. Land Cover Types That are Good Habitats for Mourning Doves (Teal)

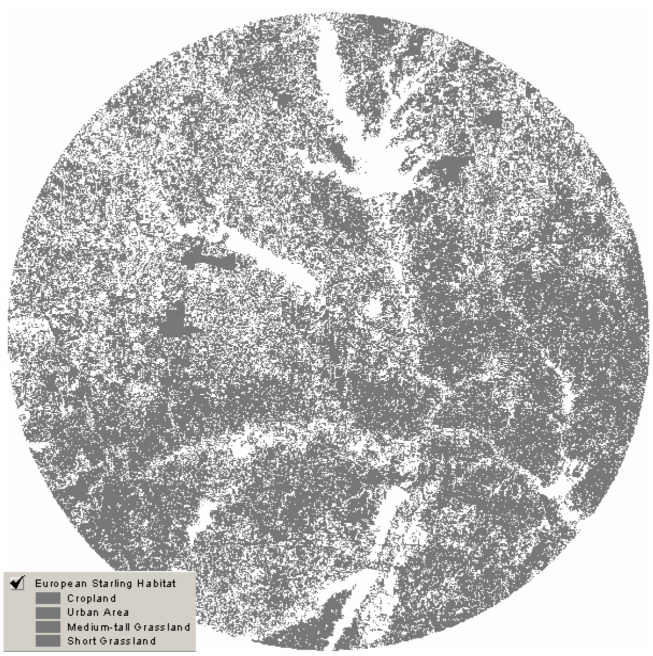

Figure 12. Land Cover Types That are Good Habitats for European Starlings (Grey)

Figure 13. Land Cover Types That are Good Habitats for European Meadowlarks (Yellow)

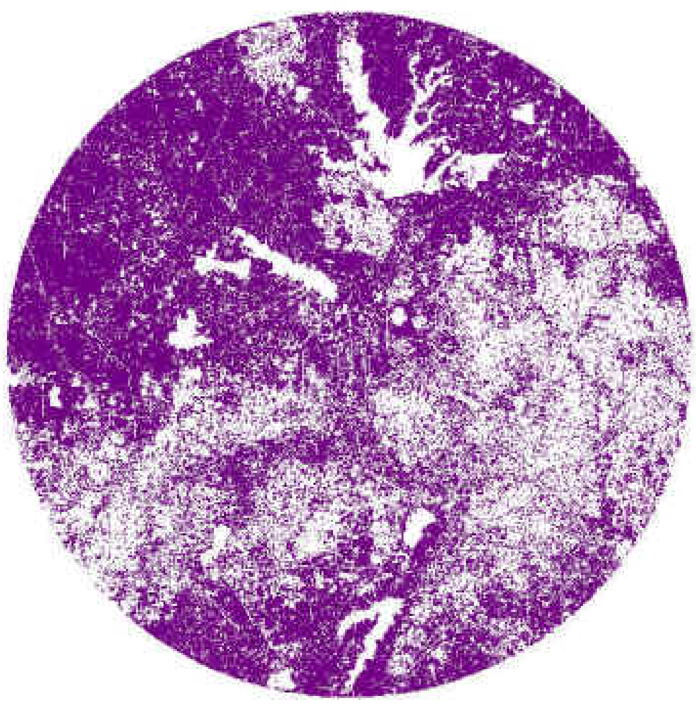

Figure 14. Land Cover Types That are Good Habitats for Grackles (Purple)

Using this approach, it is possible to identify areas of attractive habitat relative to the corridors typically used by airport traffic. Assessing issues such as expected altitude of aircraft and known characteristics of species flight behaviors, it is possible to develop a comprehensive assessment of avian hazards in the airport operational environment. In this hazard assessment, the hazard potential produced by both numbers of birds and the mass of individual birds can be determined.

Figures 15 and 16 show the relationship between attractive habitats and the threat posed by the quantity and mass of avian species. The red areas identify the highest threat; the blue and purple areas identify the lowest threat. Figure 15 illustrates the dispersed threat of birds on the landscape. A general assessment finds that the species include small birds that are dispersed across the landscape to feed or find shelter. In figure 16, when mass is taken into account, the water features on the landscape—particularly large reservoirs—present the highest threat because waterfowl tend to be bigger birds. These large-bird species move in flocks that present a particularly high hazard to aircraft.

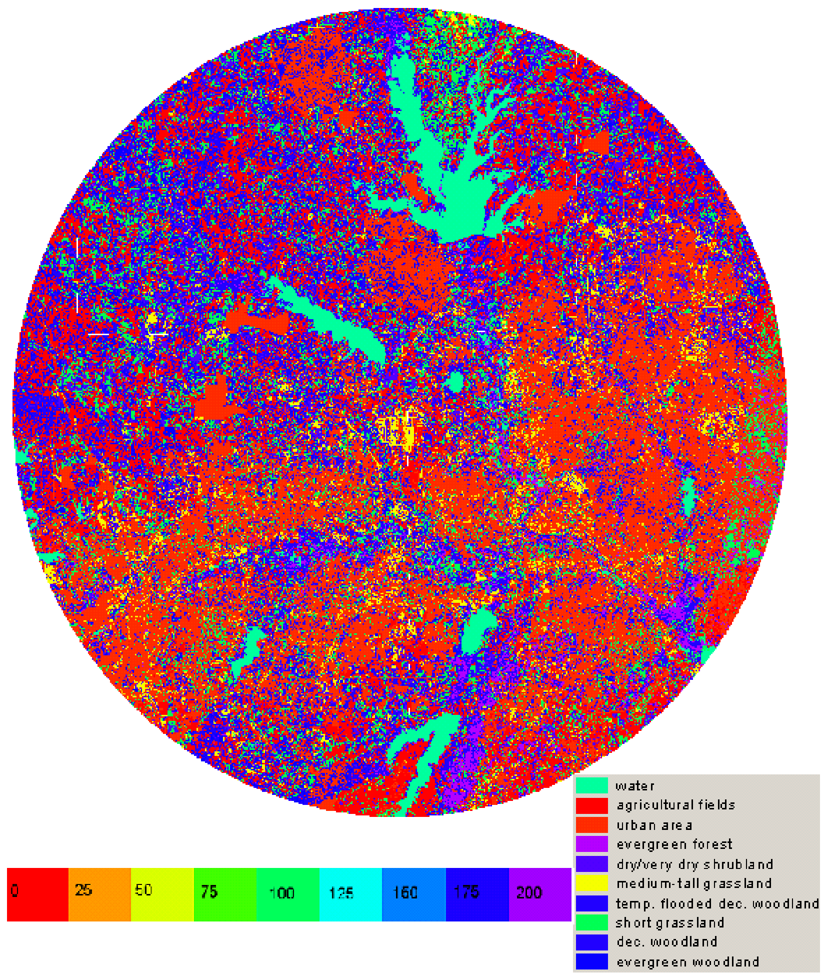

Figure 15. Attractive Habitats in the Vicinity of DFW Showing Threats Associated With Numbers of Birds

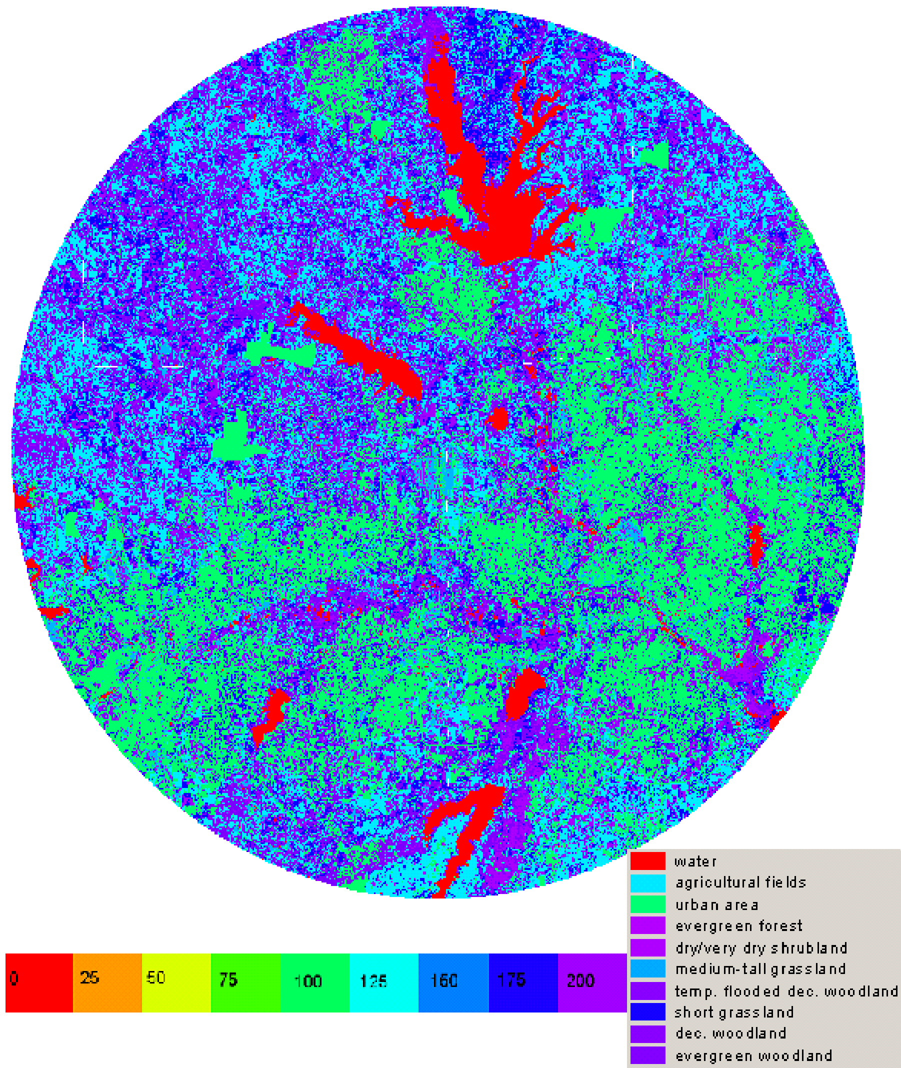

Figure 16. Attractive Habitats in the Vicinity of DFW Showing Threats Associated With the Mass of Birds

These types of analyses demonstrate that understanding the landscape, its features, and how attractive landscape features are to birds provide a basis for identifying where to "point" the radar, defining its coverage area by antenna characteristics and the existing clutter environment. Understanding the regional context for airport wildlife management should be a critical need of any airport wildlife management program.

5.2 INTEGRATING SMS.

A mechanism for the evaluation of needs and the corresponding optimization of radar location is an important part of the SMS process. In SMS, all interests on the airport are brought together to evaluate methods to improve safety. This group can most quickly consider alternatives and reach a consensus on possible locations.

5.3 SELECTING THE LOCATION.

The selection of the location for the radar in this performance assessment program is intended to meet two needs: surveillance in aircraft flight corridors and the highest quality wildlife management program possible.

5.3.1 Identification of Critical Areas.

The first step in selecting the location for avian radar is the identification of critical areas. This process includes two distinct approaches. The first approach is to define aircraft flight corridors. This is relatively simple. Reference can be made to instrument landing system documentation for approach and departure procedures. Empirical data is often available from radar track summaries, as shown in figure 17.

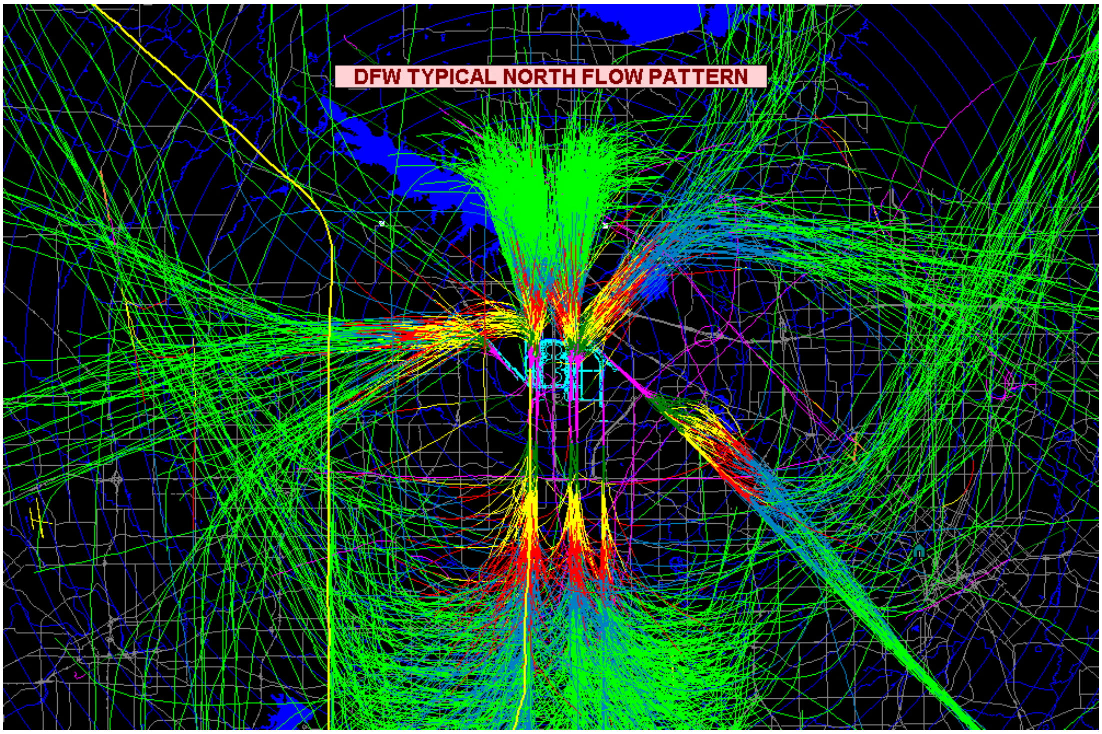

Figure 17. Radar Tracks Showing Expected Arrival and Departure Paths of Aircraft at DFW (Colors Indicate Altitude)

The second approach to locating the radar focuses on wildlife management needs. The starting point for this process is the wildlife management plan, including reference to regional analyses and any wildlife data available for the airport. A careful review of historical wildlife data is completed, assisted by display in a GIS to ease the visualization of the relationship of critical areas to possible locations of the radar. See section 5.1 for examples of this type of review.

5.3.2 Selecting the Radar.

Radar units are available from a number of manufacturers. Although an airport may simply accept the vendor selection of radar types, the airport operations personnel may wish to select the radar unit manufacturer based on experience or based on existing installations and trained staff who can maintain the radar. A component of this selection includes choices of radar transmission power and potential conflicts of radar RF emissions at the airport. Avian radar vendors can accommodate specific needs, but additional planning and cost may be associated with meeting such needs.

5.3.2.1 Selecting the Antenna.

The search volume and the detection volume for a radar system will be determined primarily by selection of the antenna. As described and illustrated in section 2.2.2, two general types of antenna are available for avian radar systems: the slotted array antenna (figure 4) and the parabolic dish antenna (figure 6). Each antenna has advantages and disadvantages, and each will provide different coverage and different clutter responses.

The slotted array antenna generates a beam of 20+ degrees vertical by 1-2 degrees horizontal. The beam generated is actually made up of two 10+ degree components above and below a horizontal line from the antenna. Since much of the lower portion of the beam reaches the ground a short distance from the antenna, the effective coverage of the antenna is limited to the top half of the beam. The coverage produced by the array antenna can be described as a triangular volume of revolution, reaching the altitude at a given range, as shown in table 1.

Table 1. Coverage of a 22-Degree Slotted Array Antenna and a 4-Degree Parabolic Dish With Dish Tilts of 0, 5, and 10 Degrees

	Distance From Antenna (mi)	0	0.5	1	2	3	4	5	6
Beam Height Array (ft)	Top of beam	0.0	513	1026	2053	3079	4105	5132	6158
	Bottom of beam	0.0	0	0	0	0	0	0	0
Beam Height Dish 0° (ft)	Top of beam	0.0	92	184	369	553	738	922	1106
	Bottom of beam	0.0	0	0	0	0	0	0	0
Beam Height Dish 5° (ft)	Top of beam	0.0	324	648	1297	1945	2593	3242	3890
	Bottom of beam	0.0	138	277	553	830	1107	1384	1660
Beam Height Dish 10° (ft)	Top of beam	0.0	561	1122	2245	3367	4489	5611	6734
	Bottom of beam	0.0	371	742	1484	2226	2968	3710	4452

Zero indicates ground level.

The beam generated by the parabolic dish is a cone with the diameter based on the number of degrees of a circle, usually 4 to 5 degrees. As shown in table 1, the distance between the top and bottom of the beam (diameter of the area in the beam) varies with range. Further, the up-tilt of the antenna (as indicated by 0°, 5°, and 10°) produces a minimum and a maximum altitude covered by the beam at any range. The slotted array antenna is limited to providing only the range and azimuth of a target, while the parabolic dish antenna can use simple geometry to also define the elevation (height) of a target (assumed to be at mid-beam).

The type of antenna should be selected by considering coverage needs and volumes of detection as constrained by clutter based on radar location. The importance of the availability of coarse altitude information for targets should also be considered.

5.3.2.2 Clutter Mapping.

The beam patterns of both slotted array and parabolic dish antenna types produce reflections from ground surfaces, buildings, and other fixed targets that interfere with target detection and tracking. This "clutter environment" decreases the radar's ability to detect and track avian targets. Thus, assessing the clutter environment when deploying radar is an important strategy for optimizing a radar's effectiveness. Although experienced individuals can suggest locations based on "eyeball" surveys, the only way clutter is fully revealed is by operating the radar. This produces a difficult situation in the radar deployment process. To use the radar on the airport will require completion and approval of an FAA Form 7460 for the exact locations of the radar unit(s). Unfortunately, it is not possible to select exact locations without using the radar on the airport to map the clutter environment.

A number of solutions have been found to this quandary. In some instances, temporary permission is granted for radar use during limited time periods. This facilitates the movement of the radar to multiple sites on the airport to provide actual data for possible alternative locations. After the temporary deployment of the radar, clutter mapping results can be reviewed and radar locations selected. The radar will then be inactivated while the FAA Form 7460 application is reviewed. If temporary permission is not available, then airport personnel should use their judgment to select a small number of locations and submit FAA Form 7460 applications for each location. Deployment will be delayed if these initial locations are unacceptable, requiring testing of other locations. However, it is likely that one of the selected locations will meet minimal needs and full deployment can occur immediately after clutter mapping has been completed.

5.3.3 Enclosures.

Avian radar systems have components that must be protected from the weather and temperature extremes. Although the radar head and antenna are designed for permanent exposure to the elements, the remainder of the radar unit, the DRP, and all other hardware supporting the radar must be protected. Options include housing these elements in a permanent purpose-build structure, a temporary structure (such as a trailer as shown in figures 18 and 19), or in an airport building. When determining enclosure type, consider the length of cable that will meet the manufacturer's requirements for connecting the radar controller with the rotating head and antenna. That distance, with the location that will provide the best coverage of critical areas, will determine enclosure type.

Figure 18. Slotted Array and Parabolic Dish Antennae Installed on a CEAT Trailer

Figure 19. Panoramic Views of the Interior of a CEAT Radar Trailer Equipped With an Accipiter® AR2 System With Two Radars

<u>5.3.4 Power</u>.

Power considerations are critical for any long-term deployment of the radar. It is possible to provide generator power, but maintaining fuel for the generator is usually the most critical operational parameter. The most essential technical parameter is conditioning the power to provide an acceptable source for uninterruptible power supplies (UPS), DRP computers, and communications equipment. Power supply voltage and amperage must be considered if heating or cooling is needed in the enclosure to maintain temperatures within a required range.

Although sometimes overlooked by non-electricians, the grounding of the system is particularly important in field applications. Typical trailers like the ones used in these performance assessments have a floating ground that may not provide the needed protection for people and critical electrical equipment during situations such as lightning strikes. Particular attention should be paid to grounding the trailer and assuring that all equipment in the trailer is properly grounded.

An important protection for the electronics in a radar system is a UPS. A high-quality UPS will not only maintain operation on battery power for short-term power interruptions, but will also condition power so that sensitive electronics are provided with reliable power, particularly if short-term operations require generator power.

5.3.5 Connectivity.

All avian radars provide the highest level of service when high-speed connectivity is provided among multiple units at an airport and a central router provides access to the Internet. Connectivity can range from physical transfer of archived data on portable storage media to connectivity using high-speed optical cable. Wireless connectivity can provide sufficient connection speeds to support remote radar operations. At NASWI, that wireless connection is provided by an Internet service provider (ISP) with the wireless connecting off-base to the ISP. At SEA, the mid-field radar unit is connected by a wireless system to a virtual private network provided by the Port of Seattle.

5.3.5.1 Security Issues.

All radars that are connected to the Internet are behind firewalls blocking all requests from the outside by default. For access to the radars, ports must be designated and open, based on the service needed. All services that run on ports exposed to the Internet should be password protected.

Data transfer is an important security issue. This security is associated with both the data channel and the security or limited access requirements developed, based on airport policies. In the CEAT systems, radar data is transferred using secure protocols and then is resident at a secure server in a remote location. Data is encrypted via secure sockets layer (ssl) when sent over the Internet. The data resides on this server until it can be accessed. Access is limited to accounts with varying levels of access privileges.

5.3.5.2 Bandwidth Issues.

Data can be retrieved in a number of ways, but the most efficient is to directly download the data from the radar. The method employed depends on the availability of an Internet connection as well as the bandwidth of that connection. Data can also be retrieved by attaching an external hard drive to the radar and manually downloading the data, although this procedure is not recommended.

Varying levels of connectivity can produce differing results. Wireless broadband is available in many areas. This access allows remote administration of the machines, limited live viewing, and very poor data transfer rates when compared to the bandwidth required for radar data transfer. The maximum bandwidth that currently can be obtained with this technology is 2 Mbit/s download with significantly less upload (500-700 kb/s).

Fiber-optical cable networks typically provide the highest speed connectivity currently available. Optical cable-based networks provide an ideal base for data transfer and management. Data accumulated during a day of operation can be transferred overnight, allowing the data to be available the next day. With this type of connection, the screen can also be viewed in near real time. Remote access is also improved with high-speed connectivity.

Depending on the source (cable, fiber, etc.), bandwidth will not be a limiting factor to radar utility. Modern networks are capable of transferring several gigabytes of data over the course of a few hours.

Another viable option exists for areas where a high-speed network is available, but there is no hard line to the trailer. As long as there is line-of-sight, a wireless bridge can be added to the system, linking it to the network. These high-speed wireless bridges can be used over several miles and have shown negligible impact on the transfer of data. Each link is directional and has full duplex capabilities. Wireless bridges employ wireless encryption protocols so the data cannot be easily intercepted.

6. LICENSING AND APPROVALS.

Radar uses radio frequencies as a basis for operation. Transmitting in the RF spectrum is controlled by the FCC, and the use of any RF emitter in the airport environment is a particular concern of the FAA.

6.1 FEDERAL COMMUNICATIONS COMMISSION.

Although no FCC license is required when marine radars are used on water, a basic issue facing any user of marine radars on land is the need for an FCC license. In land-based radar applications, an avian radar transmission frequency may conflict with existing airport radars, requiring additional test and verification of the spectrum fidelity of the marine radars used in the avian radar system. Because the FCC licensing process is technical and time-consuming, it may be best handled by consultants who specialize in this area.

6.2 FEDERAL AVIATION ADMINISTRATION.

At civil airports, the FAA requires review of both obstructions and possible frequency interference with other airport RF devices. The FAA review process is initiated with submission of FAA Form 7460, which provides notice of proposed construction or alteration on an airport.

FAA Form 7460 applications have both local and national elements. It is important to alert local or regional FAA officials and to determine their information needs. Although the FAA Form 7460 application process is handled by national coordinators, the process will be more efficient if local FAA personnel understand the project when they are asked to review the application.

6.3 OTHER APPROVALS.

FCC licensing and the FAA review process are just two steps in the deployment process. Deployment at civil airports also requires many levels of approvals, including airport-specific approvals for infrastructure and operations. The high-level coordination provided by the SMS plan will facilitate the multiple levels of approvals needed at each airport.

7. DELIVERY AND INSTALLATION.

The delivery of an avian radar requires access to the secure environment of the airport, which means planning access for equipment and personnel. Delivery requirements will be specified by the airport purchaser, but consideration should be given to the security clearances and escort requirements needed for installation technicians. In addition, avian radar systems may require a delivery/assembly area where the radar units are prepared for final deployment.

7.1 SETUP.

Delivery to final deployment locations may require the preparation of pads or buildings and the availability of power and connectivity. Temporary power and connectivity may need to be provided, depending on testing or other operational requirements.

7.2 INITIAL OPERATIONAL PERIOD.

The initial operational period may last from weeks to as much as a year. This potentially long timeframe is required to determine optimal configuration of radar settings to accommodate different weather conditions and seasonal patterns of bird movements that may improve detection of transient species.

In the initial operational period, the radar will be operated and settings adjusted to accommodate site-specific conditions not identified in clutter mapping.

7.2.1 Alternative Configurations.

The radar unit and the DRP in the radar system are interactive, and configurations of both must be optimized to provide the best site-specific radar operational performance. A range of settings is possible in both the radar and the DRP. Most of these settings are established as part of the vendor's development of the avian radar system, but other settings can produce site-specific configurations or configurations that address different conditions (e.g., rainfall). Alternative configurations include the antenna selected and operational settings of the radar unit (e.g., pulse length or rotational speed). If using a parabolic dish antenna, different angles are available in the configuration step. Additionally, it is possible to minimize clutter by placing the antenna close to the ground. Radar technologists also advise that clutter fences can be developed for some installations, but no clutter fencing has been attempted in the performance assessment program to date.

Aside from these physical configuration elements, the available options on the radar unit electronics (e.g., for internal clutter management systems) and the DRP allows an infinite number of settings for the radar system. The radar vendor limits the options for configuration changes based on an intimate understanding of the system and a desire to meet airport needs when the availability of trained staff may be limited. Vendors will typically provide a tuning service as part of the radar set-up and select a limited number of configurations that are most suitable to addressing identified objectives and meeting airport needs.

7.2.2 Selecting Optimal Configurations.

The radar unit and the radar system present the user with an unlimited number of possible adjustments to adapt performance to a site. Vendors of avian radars have experience in the use of their systems and usually have established radar unit and radar system configurations that have achieved advertised performance. Even though general configurations will produce adequate performance levels, there is usually a period of adjustment where the radar experts adjust the radar to site-specific conditions.

Airport operators should carefully review configurations with the radar vendor and expect the identification of alternative configurations to meet different needs and uses. For example, there may be a different configuration that will work more effectively during different seasonal weather patterns or for resident or migratory birds. The process of selecting alternative configurations is based, in part, on needs and objectives as well as experiences gained as the radar is used, developed, and analyzed for both validity and utility.

A second group of configuration issues are associated with detection volumes and displays. After determining critical areas for radar coverage, data should be reviewed to ensure that the radar beam actually covers critical areas. Such areas may shift, and adjusting the radar may be required as needs change. In addition, as actual radar data is assessed, it is essential to make sure that data is not contaminated by aircraft traffic or by traffic from nearby roads or highways on or off the airport property. Displays (color selection, trail length, speed values, distance values, screen extent, alarm zones, and useful maps) should also be configured to ease operations and enhance the radar's usefulness. Such settings will typically be developed by the radar vendor in consultation with the airport client.

7.3 PERIODIC REVIEW OF CONFIGURATIONS.

A QAP related to avian radars should include a regular review of radar operations and operational performance. A basic requirement is the periodic review of performance associated with the proper settings of the radar unit. As discussed above, the actual settings used for operation may change with season or target presence, thus a review of operational configurations may be scheduled based on seasonal or other time frames.

The review of configurations requires a baseline setting that is also associated with a baseline performance level. Another element of the clutter mapping procedure is to identify specific baseline settings and performance expectations for the radar. The results from the clutter mapping and from each review of configuration should be documented and archived.

8. OPERATIONS AND MAINTENANCE.

Avian radar systems consist of two major integrated components: the radar system and the digital processing system. Each system requires different technical skills to operate and maintain. Avian radar vendors may provide support for both systems. In cases where the radar system is not supported by the vendor, the airport facility will be required to identify a repair facility for the radar system. Deployed units will require periodic inspection and preventative maintenance to ensure that the system is operating within specifications and to prevent unnecessary downtime. Current radar technology uses components that have manufacturer-specified life expectancies. However, because there is little documentation of “real-world” life expectancies, possible replacement costs should be factored into the overall cost of maintenance for the system.

8.1 VENDOR RESPONSIBILITIES.

Although vendors will provide a wide range of services associated with the marketing and sale of an avian radar system, airport operators should establish a contractual relationship with the vendor to ensure that operational integrity is sustained over the life of the equipment. An initial requirement should be for technical support. If problems occur, it is essential to have immediate attention given to the problem and a solution provided in the shortest possible time. With appropriate connectivity, vendor technical staff can often work remotely to make necessary changes or to identify what repairs are needed.

Training is another issue of critical importance. Effective use of the radar system begins with understanding system operation and how to use the radar most effectively. This requires training. Airport operations personnel should expect initial training, advanced training, and recurrent training. A primary function of this training is to determine that the radar system is operating to specifications at all times. As part of the training, as well as an overall concept of operations, the vendor should provide a means to validate equipment function or maintenance schedule. The vendor should also assemble documentation and provide updated materials and software as appropriate.

8.2 AIRPORT RESPONSIBILITIES.

The primary responsibility of the airport is to secure all approvals for deployment, provide power and connectivity to field locations of the radar, and provide personnel (either staff or contractors) who will manage and use the radar. A critical issue that should not be overlooked is the review of needs and objectives throughout the acquisition and deployment phases of the radar installation. This is important because final tuning and adjustment of the radar should meet identified requirements that were clearly conveyed to the vendor at the time specifications were developed for the bidding process. Because site-specific adjustments will refine and define actual performance, airport operators should be responsible for leading the adjustment and tuning process to ensure that airport requirements are met.

Airport operators should identify how preventative maintenance will be performed and should locate sources for spares and other maintenance requirements. Airport operators should perform all recommended preventative maintenance and diagnostics or provide for a maintenance agreement for their completion on a schedule that will assure continuing operation of the radar. Airport operators should be responsible for all documentation related to radar system management.

9. DATA ACQUISITION AND ANALYSIS.

Radars produce extremely large data sets that must be processed and analyzed, then interpreted and archived. Although the DRP provides a reduction in the magnitude of the sensor data stream by converting the raw digital data signals to plots and track data for targets, retaining detection and plot data and generating moving target tracks still has the potential for producing large data sets that must be organized and archived. As an example, after approximately 15 months of operation with four radar sensors, the CEAT server storage exceeded 1 terabyte, primarily of processed data in plots-and-track files rather than raw data. Users should identify data output from their avian radar systems and be prepared to develop data-handling procedures appropriate to their system.

9.1 TYPES OF DATA.

Avian radar systems produce three types of data:

- Raw data, including digitized raw data
- Processed plot data
- Track data

The signals generated and received by the marine radars used in commercial avian radar systems are analog waveforms (i.e., radio waves). The first step in processing the received signals is to convert them from analog to digital form. This digitized but unprocessed data is referred to as “raw data.” Although raw data sets are extremely large, their retention allows maximum flexibility in postprocessing.

Processed data supports track development. This data usually consists of detections that have met processor criteria and are then aggregated into a plot of the position of each target in the current scan of the radar and the association of a plot with previous plots of that target to form a track of that target. At a minimum, the "plots-and-tracks" data include the spatial (e.g., longitude, latitude, and in some configurations, altitude) and temporal (i.e., date and time) coordinates of the targets of interest. Further processing of this data may use parameters such as velocity and heading to refine identification leading to the identification of avian targets, which are then tracked on the display. Retaining plot data allows the development of tracks using different selection criteria. Plots-and-tracks data sets are still large, but size reduction from raw data is significant.

Track data is most conveniently used when displayed in relation to geographic references. The analysis of individual tracks can lead to further refinement of target type and characteristics. The display of track data is the first product of the performance assessment. As figure 20 shows, tracks can be displayed for given time periods, such as hourly track summaries for the NASWI. Using track summaries, it is possible to identify daily timing and dynamics and to conduct analyses that relate bird activity to environmental conditions. Track data is also useful in identifying migratory events.

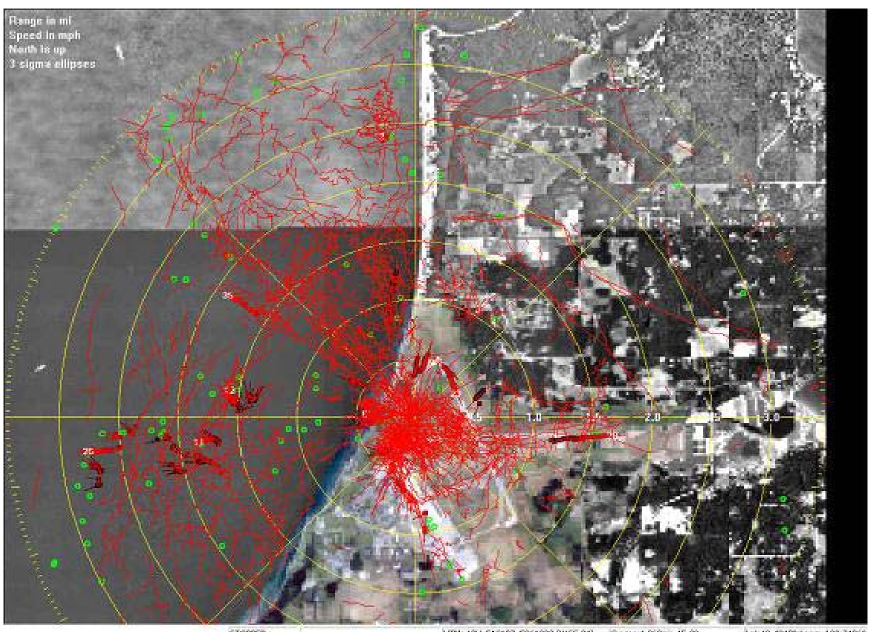

Figure 20. Example of an Hourly Track Summary at NASWI

The management problem for radar data grows with the number of radar systems in operation and the processing needs of airport users. During the study, the systems integration capabilities provided by Accipiter Radar Technologies, Inc., were used to postprocess daily radar plot-and-track data, producing several data visualization products. Although this process is currently manual, improvements are underway to complete basic postprocessing on a radar data server and complete initial steps for visualization of data resources automatically. In the CEAT system, all data types can be archived based on assessment program, study, or local needs. These data resources are available to the public and are intended to provide a long-term record of radar operation to assist in evaluating system robustness and reliability.

9.2 DATA PROCESSING.

Avian radar data processing generally includes two steps. As described above, the first step produces digital data by sampling the analog data stream from the radar sensor and then processing the digitized data to remove clutter and detect and track targets. The second step takes the digitized data, which are now in a form that can be processed by a computer, to display the tracks over maps of the area on the computer screen. This step can be done by different software, such as the Accipiter® DRP, TVW (Track Viewer Workstation), and TDV (Track Data Viewer). Plots, tracks, and other data are retained in archives. The archival data can be used in postprocessing that may use statistical, GIS, or other methods for data analysis. The general data processing process is illustrated in figure 21.

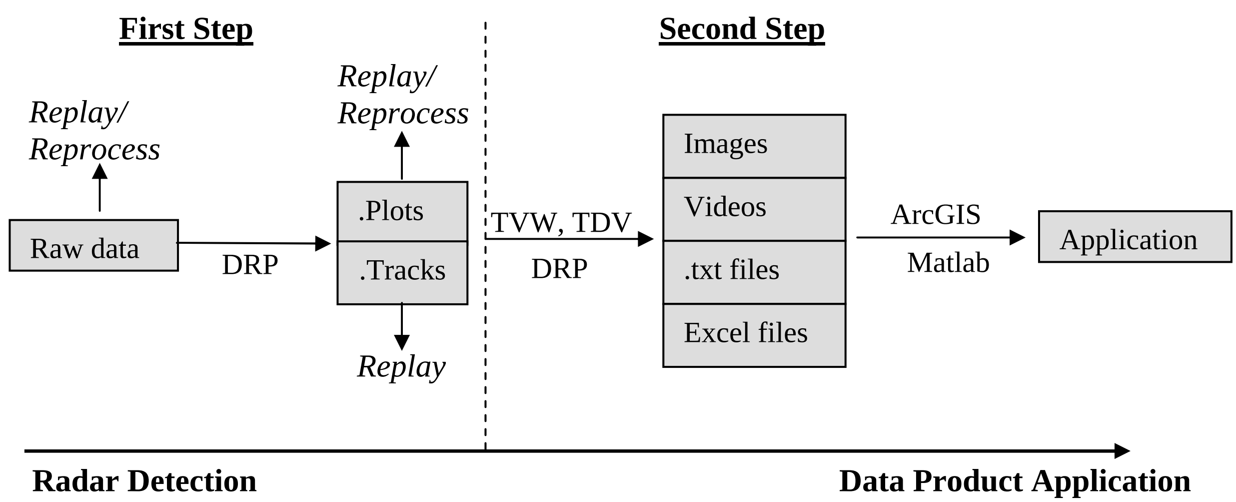

Figure 21. Flowchart of Radar Data Processing

9.2.1 Immediate Use.

Although avian radar systems support postprocessing by providing opportunities for data storage and management, the basic design of the radar supports immediate use of the data if experienced operators are available to observe the displays. The PPI provides an unaltered view of radar returns, typically showing clutter and targets. Most radar systems are capable of providing image history, which can be used as a simple tracking tool for targets. Some experience is needed to interpret PPI displays because the display has a radial context and the orientation of the screen may not match the preferred orientation of the observer. The PPI screen is an important adjunct to system utilization because it is free of extensive data processing and establishes a baseline for interpretation of any processed data.

On the computer monitor, the PPI displays processed data, usually over a map, or other geo-referenced display. The processed data is updated continuously and the data processor can show plots of targets that overlay geographic features, as well as tracks of targets over time. This display provides the operator with information that can be used immediately in support of wildlife management.

The general options for immediate use are illustrated in figure 22. The digitized data is processed by the computer. Depending on the vendor system, it is possible to specify display characteristics by adjusting parameters such as color, track history, and track length. It is also possible in some systems to immediately replay just observed conditions. Finally, data is recorded and transferred to archives for later review or postprocessing.

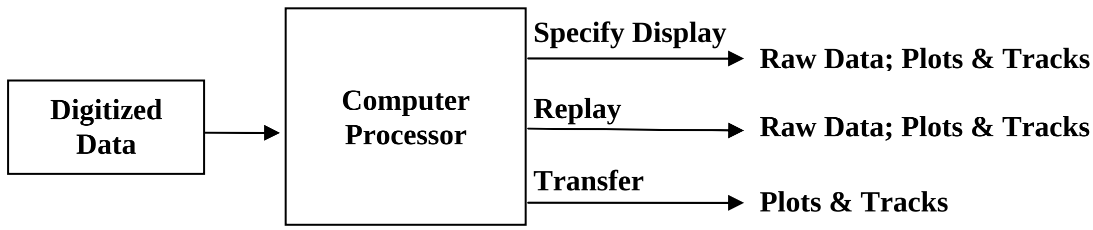

Figure 22. Flowchart of Radar Raw Data Processing With DRP

9.2.2 Intermediate Use.

The intermediate use of radar data takes recorded plots, track, or radar performance data and develops hourly, daily, or other summaries. Intermediate use of the data is dependent on the vendor system that defines the characteristics of the stored data and the postprocessing tools available to analyze the data. Some vendors provide specialized software to view tracks and analyze those tracks. For example, simple time-based histories of tracks will provide a sense of movement dynamics. Designating areas and counting tracks in those areas is the foundation for developing alerts to potential hazards. Intermediate use takes advantage of images, videos, and files for text generation or spreadsheet analysis, as shown in figure 23. The actual data files that, at a minimum, contain data such as time, ground velocity, heading, and target location (latitude and longitude) can be accessed for further analysis using data display or geographic information software.

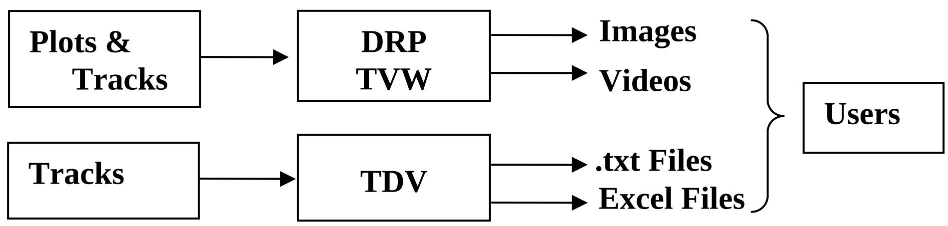

Figure 23. Flowchart of Data Product Generation

9.3 ARCHIVAL SYSTEM.

The data archiving system provided by the radar vendor is an important consideration of radar system acquisition and deployment. Archival systems have benefits and limits. For example, the use of common database systems, such as Microsoft® Access®, provides convenience and readily available training. However, the database engine is limited in terms of the number of records it can store, and it may be difficult to assemble sequential data sets for historical analysis. Full-function relational database management systems (RDBMS) that do not have these limitations are available as both proprietary and open-source products. Likewise, analysis software packages (e.g., GIS) are also available as proprietary and open-source products. Regardless of which products are chosen they should support open standard interfaces and languages (e.g., SQL for an RDBMS; GML or KML for GIS) to avoid being locked into a single vendor's products.

An important point to evaluate when considering avian radars is the efficiency with which the data is stored and the capabilities that exist for postprocessing. To provide maximum utility, raw data storage is needed. Raw data may originate from the radar unit, but often have large file sizes that limit the length of time data can be recorded. This raw data is valuable because it provides a data set that can be reprocessed as part of quality assurance programs, assess changes and improvements in the processing software, or to review incidents of interest with full reprocessing capability. The raw data resource may also be an intermediate product of the digitization process. This data is often subject to compression algorithms, and it is possible to archive raw data for reprocessing for long time periods.

In addition to raw data, processed data in the form of plots, tracks, and radar detection data should be archived in a form that allows ready retrieval and supports postprocessing.

9.3.1 Postprocessing.

The radar's tracking capabilities enable a day's worth of tracks to be visualized in different ways. Depending on the vendor solution, tracks may be stored as plot and track files or may be added to a database that contains additional data derived from the radar. Vendor solutions vary from a program that assembles and replays tracks from recorded data to external analytical engines, such as GIS programs, which assemble and process radar data. The data products from postprocessing are varied, may be different for different vendors, and may be developed to meet airport-specific needs.

9.3.2 Reprocessing.

Airport operators will find that there will be situations where it is important to reprocess data. Full reprocessing is only available if the raw data from the radar unit is recorded. This record is seldom available because of the massive size of the data sets generated by the radar. Alternatives exist in various approaches provided by different vendors. Raw data compression schemes reduce storage requirements, but storage of all radar data is still limited by size requirements. It is possible to develop storage systems that only retain data from a limited time and continuously roll over data sets. This approach would be suitable for event analysis.

Reprocessing can also take a form in which a processed data set is used by a program that allows a review of plot-and-track data. This review uses different criteria for track generation or the analysis of track density in relation to areas defined on a radar screen/area map overlay.

9.3.3 Metadata.

Metadata is data about data. It provides information that is not recorded with the primary measurement data, but which may be necessary to use and interpret the measurements. Metadata provides the context in which the measurements were made. For example, the track data output from an avian target (i.e., the primary measurement data) would typically include the spatial and temporal coordinates of the targets; it may not include the horizontal and vertical coordinates of the radar, the time zone of the date/time values (e.g., GMT versus local), the configuration of the radar (e.g., antenna type and angle, range setting), or how and when the radar was last calibrated. Depending on the avian radar system, some of this metadata may be recorded in a "configuration file" that is generated and used by the DRP.

Another common type of metadata is found in a data dictionary. A data dictionary is a human-readable document that names and describes the records and fields in the output data stream. A data dictionary provides details such as the type and length of each data element and the minimum and maximum values of numeric fields. If the output data is simply streamed into ASCII "flat" files, a single data dictionary may suffice. However, if the data is streamed into an RDBMS, a second data dictionary is also required that describes the tables, records, and fields in the database; the type and length of data elements; minimum and maximum values; and similar information. A document that maps the elements in the output data stream into the tables and elements of the database is also desirable.

The importance of metadata, including a data dictionary, cannot be overemphasized. Without it, the avian radar becomes, in a sense, a black-box that limits the users' ability to understand and interpret the data and to use the data for other, perhaps unforeseen, applications. As an example, avian radars can only directly measure the range and azimuth of a target. If the DRP computes the altitude of a target, the description of the altitude field in the data dictionary should detail how (including the formula) altitude is computed, the assumptions that go into that computation (e.g., a narrow-beam dish antenna was used), whether the altitude values are reported as integer or decimal numbers, the precision of the computed altitudes as a function of range (e.g., ±4 m at 1 km), and the units and datum in which the altitude values are recorded (e.g., meters above radar level). From this information and other metadata, the users can, for example, compute the height of a target above ground level.

Metadata needs to be tightly coupled with the primary measurement data. Both the data and metadata should be contained in the same data storage mechanism. When users retrieve measurement data, they should be able to easily find the accompanying metadata, and vice versa. Equally important, when the measurements data are moved from one RDBMS to another, the metadata should be moved.

9.4 DATA VISUALIZATION.

Data visualization is the element of the performance assessment program that is possibly the most complex and diverse. A review of objectives in section 3.3 reveals that there are many expectations for avian radars. There is clearly a need to provide hazard warnings, and these warnings must be supported by valid and timely data. There is a need to develop a sense of the location and timing of bird movement on and around the airport to assist in focusing wildlife management efforts. Thus, there is a need for immediate processing and analysis of radar data as well as for the development of archives to support historical analysis and trend reporting. The performance assessment of avian radars was initiated with a limited understanding of radar data, data types, and processing opportunities. As the performance assessment program has progressed, the availability of radar data and the definition of user needs has led to new data visualization efforts and corresponding products.

Different users require different data products, so a continuing challenge in data visualization is producing products that are useful to users. Unfortunately, users may have a sense of what they want or need, but may have little understanding of the data types needed. Thus, they are often unable to develop specifications for their desired products. Therefore, an effort was undertaken to develop pilot products, share these products with users, and then modify the products based on user comments. The CEAT web page at the University of Illinois (http://ceatasmp .cee.illinois.edu) provides examples of products developed by CEAT. The web page also provides examples of preliminary products that are intended to solicit user feedback. Thus, the data visualization elements in the avian radar performance assessment are evolutionary, building on pilot product, continually refining existing products and developing new products.

10. REVIEWING THE PROJECT.

Although not often associated with initial deployment of a technology, overall project review is an essential and continuing process in avian radar deployments. The project review is conducted at several levels using different schedules. For example, a basic review by airport operations and contracting personnel determines whether the vendor has met contract requirements for payment. An operations review is necessary to determine how the technology is operating. Periodic reviews by the SMS team determine if needs are being addressed and if the objectives established to guide the avian radar program are being met. These reviews may require formal reporting or may simply follow as a result of effective record keeping. The critical point is that, at the outset of the deployment, review elements and schedules should be set with identified performance criteria established as part of the needs assessment and objective setting process.

10.1 OPERATIONS REVIEW.

The operations review of avian radars can be set in normal airport operations, which typically employ a wide range of advanced technologies as a part of standard operations. This suggests that trained staff is available to develop, conduct, or review operational performance of the avian radars.

10.1.1 Monthly.

A fundamental element of any operations review is an assessment of the performance of the radar technology. Manufacturer or vendor guidance regarding maintenance schedules should be followed. The airport operations personnel may also wish to conduct performance assessments on a monthly basis to determine if bird movement dynamics are changing. Such a situation would require modified management procedures.

10.1.2 Annually.

An annual operational review should be conducted to provide a means to identify long-term issues in maintenance or operations that will require modification of standard operating procedures. For budgetary purposes, this review can also determine the actual cost of owning and operating the unit.

10.2 OBJECTIVES-BASED PERFORMANCE REVIEW.

As part of the QAP developed for the deployment of an avian radar at an airport, objectives were identified that were used to design and implement operational approaches, data acquisition and management, analysis procedures, data products, and the distribution of information to interested users. It is good practice to regularly review the QAP and, in particular, program objectives. In this review, an assessment should be made of success in meeting each objective. The result of this review should be elimination of objectives that have been met, with documentation provided for the record; restatement of objectives to better reflect the reality of the situation gained from experience; and the identification of new objectives.

10.3 USE-BASED PERFORMANCE REVIEW.

A use-based performance review is usually the most visible aspect of the avian radar deployment assessment. With initiation of the deployment, a wide range of stakeholders may have expressed expectations related to such issues as purpose, utility, problem identification, and problem solving. To address these expectations, the needs assessment established a base for expectation development, and the QAP was designed to offer a realistic path to meet expectations. Although the process of setting objectives is intended to bring expectations into line with reality, not all stakeholders will be satisfied, and many may retain unrealistic expectations of radar use. A use-based performance review, conducted on a regular basis with all stakeholders involved, is essential to identifying all stakeholders' expectations and then reviewing any new expectations and evolving requirements. Thus, it should be a continuing activity of the radar deployment.

11. CONCLUSIONS.

The deployment of the avian radar at a civil airport is a complex undertaking that includes preliminary site selection decisions, actual deployment, operations, maintenance, data analysis, management, and information dissemination. Although this document provides a general protocol for avian radar deployment and addresses a wide range of issues associated with radar use in the complex environment of a typical civil airport, the actual activities that must be completed for avian radar deployment will be site- and situation-specific.

12. REFERENCES.

1. Herricks, E.E. and Key, G., "Avian Radar Systems," *International Airport Review*, Vol. 6, 2007, pp. 56-59.

2. Gauthreaux, S.A., "Radar Ornithology—The Past, Present, and Future: A Personal Viewpoint," *Applying Radar Technology to Migratory Bird Conservation and Management: Strengthening and Expanding a Collaborative*, Ruth, J.M., ed., Open-File Report 2007–1361, 2007, pp. 50-54.

3. Skolnik, M. I., ed., *Radar Handbook*, Second Edition, McGraw-Hill, New York, 1990, pp. 6.8.

13. RELATED DOCUMENTS.

- Brand, M., "Integration and Validation of Networked Avian Radar (IVAR)," *Annual Meeting of the Bird Strike Committee USA/Canada*, Kingston, Ontario, Canada, 2006.

- Burger, Alan J., "Behavior and Numbers of Marbled Murrelets Measured With Radar," *Journal of Field Ornithology*, Vol. 68, No. 2, 1997, pp. 208-223.

- Eastwood, E., *Radar Ornithology*, Methuen and Co., London, United Kingdom, 1967.

- Gauthreaux, S.A. and Belser, C.G., "Overview: Radar Ornithology and Biological Conservation," *Auk*, Vol. 120, No. 2, 2003, pp. 266-277.

- Gauthreaux, S.A., Jr. and Livingston, J.W., "Monitoring Bird Migration With a Fixed-Beam Radar and a Thermal-Imaging Camera," *Journal of Field Ornithology*, Vol. 77, No.-3, 2006, pp. 319-328.

- Harmata, A.R., Podruzny, K.M., Zelenak, J.R., and Morrison, M.L., "Using Marine Surveillance Radar to Study Bird Movements and Impact Assessment," *Wildlife Society Bulletin*, Vol. 27, No. 1, 1999, pp. 44-52.

- Lack, D. and Varley, G.C., "Detection of Birds by Radar," *Nature*, Vol. 156, 1945, pp. 446.

- Larkin, R.P., "Radar Techniques for Wildlife," *Techniques for Wildlife Investigations and Management*, Sixth Edition, Braun, C.E., ed., The Wildlife Society, Bethesda, Maryland, 2005, pp. 448–464.

- Nohara, T.J., Weber, P., Premji, A., Krasnor, C., Gauthreaux, S., Brand, M., and Key, G., "Affordable Avian Radar Surveillance Systems for Natural Resource Management and BASH Applications," *Radar 2005 Conference*, IEEE International, Washington, DC, May 9-12, 2005.

- Nohara, T.J., Weber, P., Ukrainec, A., Premji, A., and Jones, G., "An Overview of Avian Radar Developments–Past, Present, and Future," *Annual Meeting of the Bird Strike Committee USA/Canada*, Kingston, Ontario, Canada, 2007.

- Ruth, J.M., ed., "Applying Radar Technology to Migratory Bird Conservation and Management: Strengthening and Expanding a Collaborative: Fort Collins, Colo.," U.S. Geological Survey, Biological Resources Discipline, Open-File Report 2007–1361, pp. 84, 2007.

APPENDIX A—AVIAN RADAR VENDORS

A list of avian radar vendors is necessarily fluid, reflecting the changes in business climate and the sense of urgency associated with bird strike hazards. The following list is not necessarily complete, but represents active vendors at the time this report was prepared.

- Accipiter Radar Technologies Incorporated (http://www.accipiterradar.com/home.html) (date last visited 4/24/09)

- DeTect, Inc. (http://www.detect-inc.com/) (date last visited 4/24/09)

- GeoMarine, Inc. (http://www.geo-marine.com/wrst/) (date last visited 4/24/09)

- TNO (Netherlands) http://www.tno.nl/content.cfm?context=markten&content=product&laag1=178&laag2=367&item_id=331&Taal=2 (date last visited 4/24/09)

APPENDIX B—SAMPLE OBJECTIVES

B.1 SAFETY PROGRAM OBJECTIVES FOR RADAR SENSOR EVALUATION.

B.1.1 OBJECTIVE.

Design and execute an avian radar performance evaluation program for civil airports to supply the technical information that will support the development of (1) requirements and standards for avian radars and (2) an advisory circular for avian radars.

B.1.2 SUBOBJECTIVES.

1. Compile technical data and develop an understanding of radar systems and radar system operation to support performance assessments of avian radars at civil airports.

2. Based on technical data, identify avian radar systems and avian radar system capabilities, which merit testing and evaluation in the operational environment of civil airports.

3. Deploy avian radars, and avian radar systems, representing different technologies, design approaches, and system characteristics at civil airports.

4. Operate avian radars and radar systems continuously for a sufficient time to account for environmental variability and avian target variability, while also assessing radar and radar system operational characteristics and general reliability.

5. Validate that the targets identified by the radar are birds, and investigate and validate the capability of the radar to track bird movement, providing data on both location and altitude of avian targets in the airport, and near airport, environment.

6. Identify the data characteristics and the information provided by avian radars and radar systems with the objective of developing a central avian radar data management capability that would provide national access to local data sets.

7. Demonstrate the fusion or integration of radar sensors at both the local and regional scale to support identification of wildlife movement on and around civil airports.

8. Verify the utility of radar supplied wildlife data to airport wildlife management programs.

9. Assess the utility of avian radar and radar systems in the reduction of the hazards of bird/aircraft collisions at civil airports.

10. Assess the utility of avian radars and radar systems in the management of wildlife at civil airports.

11. Prepare reports that will support the development of requirements and standards for the continuous use of avian radars at civil airports and the publication of an advisory circular on avian radar.

B.2 DEPLOYMENT OBJECTIVES FOR CHICAGO O'HARE INTERNATIONAL AIRPORT.

B.2.1 OBJECTIVE.

Deploy an avian radar system at Chicago O'Hare International Airport (ORD), operate the radar and radar system, test the radar and radar system, and report on the performance of the avian radar operations at ORD.

B.2.2 SITE AND TECHNOLOGY CHARACTERISTICS RELATED TO PROGRAM OBJECTIVES.

ORD is the second busiest airport in the world, which has a complex operational environment. Multiple runways are in constant use with some runways dedicated to arrivals, and some to departures. ORD has a long history of wildlife management, and recent bird strikes have encouraged the evaluation of advanced technologies to assist in the existing wildlife management program. Because of the size, complexity, and ongoing changes associated with the O'Hare Modernization Program, it is recognized that the initial radar deployment will only address a part of ORD avian radar needs. The selection of the Accipiter® radar systems for ORD provides the opportunity to evaluate the joint use of the Accipiter AR2 radar (two Accipiter radars operating from the same location with 4-degree parabolic dish antennae tilted at different angles), which provides improved altitude information for tracks, and the Accipiter AR1 radar (a single Accipiter radar deployed with an array antenna), which provides a 20-degree sweep (10 degrees above and below horizontal) that provides information on horizontal movement from the ground surface to 10-degrees above the horizon. This deployment will also take advantage of the strong support of the City of Chicago Department of Aviation and is coordinated with the U.S. Department of Agriculture Wildlife Services.

B.2.3 SUBOBJECTIVES.

1. Deploy an avian radar system that includes an Accipiter AR2 radar to provide tracking with improved altitude accuracy, and an Accipiter Radar Technologies, Inc. Accipiter AR1 radar to provide wide-area tracking.

2. Characterize actual radar coverage in relation to airport avian radar coverage needs to focus performance assessment activity as well as identify how the Accipiter AR series radars can address future deployment requirements.

3. Determine set-up, operation, and maintenance requirements for the avian radar at ORD.

4. Conduct validation studies to develop criteria for assessing radar performance in the detection and tracking of avian targets.

5. Conduct a series of ground-truthing campaigns to assess the performance of the avian radar based on identified criteria in subobjective 4.

6. Evaluate horizontal and vertical tracking of birds on the airport, in the airport exclusion zone, and to a range of approximately 6 nmi from the radar.

7. Develop the capability to identify hazards posed to aircraft from the movement of wildlife on and around the airport.

8. Develop and implement a hazard warning system for aircraft using ORD that reflects the capabilities and performance of the Accipiter AR radar.