Airport Safety Management R&D in CEAT

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The Airport Safety Management efforts in CEAT were initiated in 1999 and through 2008 have developed into a major component of CEAT activities.

In addition to FAA elements this program now includes wildlife related R&D in the OMP, which is entering its 3\textsuperscript{rd} year.
The FAA effort includes the analysis and management of wildlife issues at airports, risk/hazard assessments, avian radar evaluations, FOD detection system evaluations, and visual guidance research support.
Specific Project Areas

**Early Projects**

- Review of BAM and AHAS and development of hazard/risk assessment foundations
- Application of GIS and other advanced technologies to improve airport safety – first prototype at DFW, now includes ORD, JFK, SEA
- Airframe risk assessment for bird collisions
- Bird radar evaluations at DFW
- FOD radar evaluation at JFK
Specific Project Areas

**Recent Projects**

- Avian Radar Deployment
  - SEA and NASWI March 2007
  - ORD & JFK Summer 2008
  - DFW Summer 2008

- FOD Detection System Performance Assessments
  - PVD – field work completed March 2008
  - BOS – field work beginning May 2008
  - ORD – mobile and intelligent vision system Summer 2008

- Visual guidance research initiated 2006
To provide a review of the program I will start with the GIS/Hazard Assessment efforts then review the major recent activities in avian radars and FOD detection.
The GIS/Hazard Assessment activities are fundamentally an effort in spatial analysis, the program has emphasized the use of geographic information sciences, in particular common GIS tools as a foundation for a 3-dimensional approach to hazard management.
Analysis of Local and Regional Data

Notice the impact of the Des Plaines River Corridor and analysis at various spatial scales.
New insights for flood management

Hydrography Near O'hare

Approximately 25-mile Radius of O'hare Airport
Transportation routes to use as a reference points for analysis.
Some of the detail has been lost in exporting this photo.

Notice the pond which already produces wildlife challenges.
Planning for wildlife hazard reduction generally starts with an existing set of conditions, which you modify. The trick is in knowing where to make the modifications.
Colors keyed to altitude (green >5000 ft)

Radar tracking provides a sense of where airplanes are!
There is also national scale information on likely bird hazards for 2 week periods for the US, which can be evaluated at airport scales.

BAM for Dec 17 to Dec 31, daytime, zoomed into a 25-mile radius around the airport. Pixels are 1 km² (See Table 4 for explanation of each risk level).
It is also possible to work more directly with information from a site in a GIS.
For example there is information on wildlife habitat from what is called the GAP assessment that provides a basis for connecting the species to land use and habitat!
This is GAP data for the DFW Airport area.
Areas of potential hazard may be topographic features or land use/habitat that is known to attract wildlife.

To provide species specific connections to habitat, we developed an autecology matrix for local bird species.

The matrix is updated with data from ongoing wildlife management programs.
For each species can identify habitat associations and support planning that will identify areas of greatest hazard for potential aircraft/wildlife collisions.

<table>
<thead>
<tr>
<th>Species</th>
<th>WATER</th>
<th>FOREST</th>
<th>WOODLAND</th>
<th>GRASSLAND</th>
<th>AGRICULT</th>
<th>URBAN</th>
<th>SHRUBLAND</th>
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<td>LAKE</td>
<td>PON</td>
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**ILLINOIS**
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

**CENTER OF EXCELLENCE FOR AIRPORT TECHNOLOGY**
This identifies “threat” areas where wildlife may occur.

This is the expected habitat for Mourning dove.

This is the expected habitat for the European starling.
This is the expected habitat for Eastern meadowlark.

This is the expected habitat for the Grackle.
When this analysis is combined with flight path data, a species specific hazard assessment can be completed to focus planning attention on critical areas.
The multidimensional capacity of the GIS allows identification of specific landscape features in a hazard/risk analysis, focusing management activities.
We have the capability to consider flight path hazards in three dimensions.
We can also refine the hazard assessment basis by considering reported abundance (left) or mass (right).
The GIS supports spatial analysis, and allows visualization of data in different ways, including 3d plots of data. These are examples of data displays for # of strikes per grid location.
Again, we have taken advantage of the flexibility of the GIS to assist in data analysis and create visual displays to assist in interpretation.
Total mass of birds from wildlife patrol reports, by grid.

We are also able to connect observations through the autecology matrix to expand our understanding of what we need to plan for! Here mass is related to report location.
Analyzing records for species differences is straightforward and useful in support of management analyses. Here the difference in blackbirds and hawks.
We have also been able to consider off-airport attractants to develop movement models that provide a basis for relating AOA problems to regional land use attributes.
We have also been able to assemble data to provide seasonal relationships to help local biologists understand what is happening on their airport.

Here is an example from Seattle-Tacoma International (SEA)
This is the base map of Seattle/Tacoma Airport including runway designation and the grid used to base all wildlife observations (strikes and patrol reports)
Spring Patrol Records
Summer Patrol Records
Fall Patrol Records

This includes the patrol records from September, October, and November from all years of data provided by SEA-TAC.
I think you can see that the assembly of data in a GIS context provides a foundation for the management that will improve airport safety.

The existing data was produced from daytime observations that were made once or twice a week.
Consider the improvement that could be achieved if we had the capability of observing 24/7 and establishing the movement dynamics in detail for daily, monthly, and seasonal changes.
This brings us to the avian radar program!

Initiated in 1994 with the development of a radar by the Air Force and the FAA, the avian radar program now has deployed commercial avian radars.

CEAT is in the process of making performance assessments.
Presently avian radars are operational at Seattle Tacoma International Airport (SEA) and the Naval Air Station Whidbey Island near Oak Harbor, WA.

Additional deployments are planned early to mid-2008 at Dallas-Fort Worth International (DFW) John F. Kennedy International (JFK) and O’Hare International (ORD).
The road to deployment has not been easy, we have had to come to grips with the fact that radar is a technology with technological limits. We have come to realize that radar is not a magic solution to all wildlife management problems!
The research program has several elements:

A focus on the **technology** – addressing issues such as calibration, limiting environmental conditions, and reliability.
A focus on the *birdstrike problem* – questions include: can the technology actually detect birds and then differentiate birds from other biological targets; can the radar do more than simply detect - can it track, can it provide a sense of mass/size, can it help in identifying species.
A focus on the **wildlife management problem** – can the technology actually add capabilities to existing wildlife management programs at airports – capabilities such as 24/7 surveillance, better movement pattern recognition, understanding variability in presence and movement, etc.
Thus there are research objectives at the program level, objectives for deployment locations, and objectives for wildlife management at the airports.
Through the initial radar testing, and now from the recent deployments, we have come to understand:

1. Radar is an important tool in our toolbox of technologies and practices intended to improve aerospace system safety.

2. We don’t know full capabilities, or limitations, of avian radars.

3. We need to complete performance evaluations to answer critical questions.

4. We need to have operating radars in the hands of airport folks to see how they will be used.
Under the topic, considering radar as a tool, let’s first talk about the radars CEAT has presently deployed, how the radars are working, and what the radars are telling us!
The two operational radars are located at NAS Whidbey Island, and SEA.
A FAA deployed AR1 at NASWI has a 20 degree array antenna.

Radar placement with view of Puget Sound.
The Navy BASH program has an eBirdRad at NASWI – 4° dish antenna w/ tilt.
The AR-1 radar has been operating continuously at NASWI since March, 2007 and the eBirdRad has been operating since August 2007.
An FAA AR-2 system is installed at SEA (on top of the Administration Building). The system has 2 separate radar units with 4° dish antennas with a 4° and 8° tilt.
The AR-2 system was initially tested in March 2007 for two weeks and came live with full time operation in July, 2007.
An obvious question you might ask is why three different configurations?

Let me answer that question with a brief review of antennas and few illustrations.
The array antenna sends out a signal that sweeps $\pm 10^\circ$ from horizontal. This antenna gives good horizontal coverage from the ground to 10 degrees above the horizon – a lot of energy goes into the ground!

The dish antenna provides a $4^\circ$ beam that can be adjusted in height. Two radars will cover $8^\circ$ with the height adjustment selected for range and clutter avoidance while providing altitude discrimination.
Note that in this visualization the detection area is a narrow and an tall rectangle. Any object in that rectangle will be indicated at a range, not an altitude!

In addition, the array antenna in the common marine radar configuration puts a fair amount of energy into the ground creating clutter problems.
• SUMMARY
  – Ultimate Goal
  – CEAT Jan07 Experiment
  – General Observation Concerning CEAT Jan07 Experiment
  – Ultimate Test Approach
• DETAILS
  – Test Protocols Used
  – Problems Encountered
  – Results Obtained
In this visualization, the $4^\circ$ cone is represented by a square with the diameter of the cone. The uptilt of the radar avoids ground clutter, and provides a greater range.

Note that detection will be anywhere in the cone at a given range. Because we can determine altitude from simple geometry we can get a better sense of altitude with range, but no exact measurement.
The AR2 at SEA thus gives us the opportunity to scan two altitude regions if we step the antennas appropriately (e.g. 4° and 8° tilt).

In addition the SEA installation is on the roof of the Admin Building (approximately 140 ft above the airfield) so that we are looking out with relatively low clutter. What we achieve is a coverage near the 10° of an array antenna, but with altitude descrimination.
What you saw in the last clip is a record of real time radar detections made at SEA!

Note the different colors of targets from different altitudes.

This is an example of what is available to us now – real time data streaming from the SEA radar in a Google Earth environment!
This now brings us to an important issue associated with radars.

Basically, a radar generates lots of data. What it detects may or may not be a hazardous target, in fact it may be something that slips through the analysis algorithms.

What I liken this to is drinking from a fire hose, and my research team has been spending a lot of time working with the data to develop ways to understand the data better.
Let me give you an example of these products.

First, I want to show you a movie of detections.

Note that this is simply an accelerated presentation of actual plots generated by the radar – you can see the time stamp in the lower center to get a sense of real time. Two time periods are provided, night and during the day.
Summary
CEAT Jan07 Experiment

• An initial step was taken towards developing a protocol for determining a particular avian radar's ability to:
  – Estimate RCS
  – Estimate position of birds-sized targets
  – Detect birds-sized targets at various distances
  – Detect birds-sized targets in clutter
  – Resolve closely-spaced targets in range and angle

• using a balloon and calibrated targets.
We have taken the track data and used the software to generate hourly summaries of tracks.

Here are examples of tracks for November 19 and 20 of this year showing the hourly track summaries.

This data summary assists in understanding movement timing and patterns, and location of activity in relation to aircraft movement.
Range in mi
Speed in mph
North is up
3 sigma clipses
Remember that different antennas detect in different portions of the airspace.

Since the eBirdRad is co-located at Whidbey, we can directly compare tracks, we can better understand altitude issues and track movement in areas where clutter prevents the AR1 from obtaining good information.

The first screen shot is eBirdrad, the second AR1 for the same time.
You may now be asking – OK, lots of pictures, but how can this help pilots or controllers.

Well, we are a long way from providing real time warnings from this data for you.

We are much closer to providing a hazard warning that will help in flight planning and safety awareness– Let me Illustrate!
What if we place a rectangle over a bit of airspace and count the number of tracks through the rectangle per unit time?
What I think we would have is a statistic that represents the hazard posed to aircraft that use that airspace.

With software automation we can develop statistics on trends so that we can convey to you a hazard condition that is much more accurate than your typical ATIS report.
We have also found that the radar has given us some very interesting views of bird/aircraft interactions.

What follows is a movie of the radar track of a large flock of Black bellied Plovers at NASWI.
These are roughly synchronized images from the AR-1 (low altitude) and the eBirdRad (high altitude) radars.
What we are working on is how to validate data and then use that data to provide good information to users!
In terms of capabilities, we are exploring capabilities of avian radars as we speak. The overall program will evaluate capabilities under different settings (SEA, ORD, JFK, & DFW), in different configurations, and conduct these evaluations while we also validate targets (e.g. we confirm that what the radar indicates is a bird, is!)
We flew a balloon with a radar target at SEA (on the new runway #3 that is under construction), and flew a RC helicopter as a target. Tests with a falcon were not successful.
Balloon with target and in flight at SEA 11/30.
Track of balloon along Runway #3 SEA
The RC helicopter used 12/2 at SEA.
Helicopter track recorded by GPS for 12/2 flight at SEA
The third element of the ASM program is a parallel performance evaluation for FOD detection systems.

FOD stands for Foreign Object Debris/Damage – junk around the airport!
FOD Detection Program History

- In FY-04, FAA R&D was tasked by FAA Headquarters to conduct a limited evaluation of a newly developed prototype FOD radar.

- Testing was conducted in January 2005 of the QinetiQ FOD Detection Radar.
FOD Detection Program History

- Through 2006 assisted in site selection and initiated a performance assessment program at PVD in June 2007
- In early 2007 other vendors asked to participate in performance evaluation program
FOD Detection Systems

- QinetiQ (UK) markets a 94 GHz radar (JFK & PVD)
- Xsight Systems (Israel) markets a hybrid video and radar system, testing will begin in late May 2008 at BOS
- Stratech (Singapore) markets an intelligent vision system – testing anticipated in November 2008
- Trex Enterprises (San Diego) markets a mobile radar (76 GHz) – testing in June 2008 at ORD
The Performance Assessment

• Objective is a technical report that will support development of requirements and standards.

• In this process CEAT is partnering with technology suppliers, coordinating local arrangements.
The performance assessment has four elements:

1. Calibration
2. Sensitivity Testing
3. Blind Testing
4. Operational Performance Analysis
Although technology for each system is different, a common evaluation procedure will be used for each system utilizing targets appropriate to the technology for calibration, targets of variable hazard for sensitivity testing, and actual FOD items for blind testing.
The basic approach is to deploy targets on transects and grids.
Calibration transects at PVD in relation to sensor location.
Inter-calibration, intended to verify performance between test periods, will use targets appropriate to the technology.
- 20 Dbs Cylinder used in radar testing

Contrasting color items used in visual detection systems
Use of runway is dictated by technology characteristics and experimental designs. At PVD, the entire runway is used with transects of targets placed at regular intervals.
Evaluation Protocol

Randomization occurs along runway and across width
Sensitivity testing is conducted with a fixed set of targets selected based on how commonly they occur on airports and relative hazard.
<table>
<thead>
<tr>
<th>FOD Item*</th>
<th>Expected Hazard</th>
<th>Frequency of Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Small piece of concrete</td>
<td>High</td>
<td>Common</td>
</tr>
<tr>
<td>2. Standard lug nut from service vehicle</td>
<td>High</td>
<td>Common</td>
</tr>
<tr>
<td>3. Roller bearing</td>
<td>High</td>
<td>Common</td>
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<tr>
<td>4. Chunk of Rubber</td>
<td>Low</td>
<td>Common</td>
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<tr>
<td>5. Mechanics wrench</td>
<td>High</td>
<td>Common</td>
</tr>
<tr>
<td>6. Fuel Cap</td>
<td>High</td>
<td>Common</td>
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<tr>
<td>7. Cotter key</td>
<td>Moderate</td>
<td>Common</td>
</tr>
<tr>
<td>8. Plastic bottle/bottle cap</td>
<td>Low</td>
<td>Common</td>
</tr>
<tr>
<td>9. Strapping material</td>
<td>Moderate</td>
<td>Common</td>
</tr>
<tr>
<td>10. Expansion joint material</td>
<td>Low</td>
<td>Common</td>
</tr>
<tr>
<td>11. Construction material – galvanized nails or sheetrock screws</td>
<td>Moderate</td>
<td>Based on construction activity</td>
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<tr>
<td>12. Runway infrastructure part – piece of runway light or signage</td>
<td>High</td>
<td>Uncommon</td>
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<tr>
<td>13. Small fasteners</td>
<td>Moderate</td>
<td>Common</td>
</tr>
<tr>
<td>14. Metal strip</td>
<td>High</td>
<td>Uncommon</td>
</tr>
<tr>
<td>15. Fiberglass door</td>
<td>Moderate</td>
<td>Common</td>
</tr>
<tr>
<td>16. Asphalt chunk</td>
<td>High</td>
<td>Common</td>
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</table>
* Items selected based on consultation with James Stephan of Delta Airlines based on his studies of FOD items common on runways.
Standard FOD Items
The sensitivity testing at PVD uses a grid of 23 items placed in relation to the six calibration transects.
FOD box with items for sensitivity testing
Example grids at PVD
Blind testing is conducted using randomly selected FOD items. These actual FOD items (or analogs) are randomly placed on the runway.
Typical collection of blind testing objects.
FOD items for blind testing
Typical FOD item placement in blind testing
Operational issues will be evaluated with the cooperation of airport personnel. A wide range of operational issues will be assessed.
Testing at PVD

Testing is conducted at PVD when Runway 5/23 is closed, so we had a window from about 12:30 am to 5 am for our testing.
PVD Operations Dept. provided escort and airfield transportation.
Teams deploy FOD items and document placement and timing
Once positioned teams vacate runway to allow time for detection and then rotate or retrieve items
We have completed the PVD testing with seven full assessment campaigns and three calibration tests during rain, ice, and snow.
Other Technology Assessments

In addition to the Tarsier™ radar at PVD, assessments are also planned for other technologies.
Xsight - FODetect™

Xsight is a company from Israel. They have developed a system that uses both video sensors and a millimeter radar. The Surface Detection Units replace runway edge lights.

This system is being evaluated at Boston’s Logan Airport (BOS).
SDU installed at BOS
System block diagram
Stratech - *iFerret™*

Stratech is a company from Singapore. They have developed a system that uses what they term “intelligent vision” with a high resolution video camera to detect FOD. Their system is being installed at Singapore’s Changi International Airport.

This system will be evaluated at Chicago’s O’Hare Airport (ORD).
Camera of iFerret™ system – engineering installation
Typical installation of multiple sensors scanning a runway surface.
Trex Enterprises – FOD Finder™

Trex is a US company located in San Diego, CA. They have developed a mobile FOD detection system that is coupled with a software package titled “Air Boss.” The detector uses a milimeter radar mounted on a truck.

This system will be evaluated at multiple airports with a focus on Chicago’s Midway (MDW).
FOD Finder™ radar system on Ford F-15 pick-up truck
User view showing detected FOD items and sweep line.