Characterizing Bird Movement On, and Around, Airports Using Avian Radars System

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BACKGROUND

In 1999 the FAA asked the U of I Center of Excellence to assist them in wildlife issues at airports. I lead that effort and since 2002 have focused on technology performance assessments.

The stated purpose of this program is to use science-based assessment methods to assure the FAA and the public that use of new technologies at airports is *justified* based on proven performance, *does not compromise safety*, and is *compatible* with all aspects of airport operations.

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As part of the avian radar performance assessment program we have deployed avian radar systems to commercial and military airports for short and long term studies.

We have also acquired radar sensors and conducted studies on different radar manufacturers, bands, configurations, etc.

Systems Assessment Locations

- Seattle-Tacoma
  - Roof-top AR-2 (dual-dish)
  - Ground-based AR-1 (horizontal array)
- Chicago O'Hare
  - Ground-based AR-2 (dual-dish)
  - Ground-based AR-1 (horizontal array)
- JFK
  - Ground-based AR-2 (dual-dish)
  - Ground-based AR-1 (horizontal array)
- NAS Whidbey Island
  - eBirdRad (dish)
  - Ground-based AR-1 (horizontal array, dish)
  - AR-2 variously configured
- Dallas-Fort Worth
  - 2004 BIRDRAD testing
  - GMI MARS Avian Radar (horiz. and vert. spin)
  - SRC BSTAR Avian Radar (advanced tech.)
- Center of Excellence for Airport Technology
  - Operations center for entire radar network
- Cooperators
  - Vancouver, Canada
  - Schiphol, Netherlands
  - Cedar City, UT
  - Anacortes, WA
  - Portland, OR
  - IVAR
    - Edisto Island, SC
    - NAS Whidbey Island
    - NAS Pax River
    - MCAS Cherry Point
    - Elmendorf AFB

Sensor/System Testing Locations

- BIRDAR (USAF/FAA DUST - 2004)
  - DFW
  - Fermilab
- NAS Whidbey Island
  - JRC X-band and S-band
  - Kelvin Hughes X-band and S-band
  - X-band mobile radar no DRP
  - X-band mobile radar w/ DRP
  - Vertically spinning radar studies
  - Antenna power/beam distribution studies
  - UAS validation
  - Balloon w/ known RCS target validation
  - Long term validation studies
  - Migration analysis
  - S-band/X-band comparisons
  - L-band demonstration and development
- UIUC
  - Data Management
  - Remote ops testing
  - Systems support
  - O&M evaluations

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This testing has provided extensive experience in the deployment and use of avian radars and we have learned a lot!.

A major issue we faced throughout the program has been data analysis, and specifically in this presentation, understanding bird movement dynamics to enhance wildlife hazard management at airports!

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Radar is an excellent tool that can be used to better understand bird movement dynamics. Radars facilitate the characterization of:

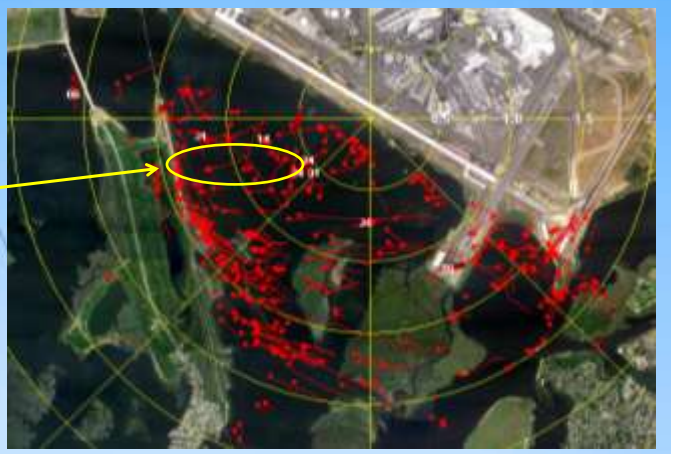
- General Activity
  - Assists in defining location, altitude, timing, and periodicity.
- Local Bird Movements
  - Assists in identifying feeding and loafing areas and supports the identification of local and regional patterns of movement.
- Night Movement
  - Radars supplement visual observations and provide information on activity 24/7.
- Migration
  - Long term records support identification of movement patterns, including migratory events

Before I provide examples of movement dynamics it is important to define some terms.

Detection/Plot - The basic display of a target where a detection may be a single bird or a group of birds plotted as a single target due to radar resolution.

Track – when multiple plots are related to define target movement. Tracks are assigned numbers and tracking allows development of heading and velocity information.

To illustrate plots and tracks, each square is a plot, lines indicate the target track.



Initial Track Observation (ITO) –

Because the radar beam does not provide horizon to horizon coverage, it is important to keep in mind the relationship of *target appearance on the radar in relation to beam characteristics and remember that appearance is not necessarily associated with a point of origin!*

In our analysis it is important to recognize that we are not assessing all birds present, only those detected and tracked by the radar. Using ITO analysis allows effective interpretation of target movement in relation to range and beam configuration, which define the volume of airspace interrogated by the radar.

To provide an example of ITOs, this figure shows tracks that were first observed near Subway Island and moved north east, towards runway on May 3rd 2010, 10:56 local.

ITO designation recognizes origin was not the island, rather this is when the birds entered the radar beam and were first tracked.

Movement – A large number of tracks or ITOs that exhibit similar behavior (heading, starting or ending point, etc). Movements typically include longer tracks with similar headings that are observed for several minutes. A movement can consist of many single tracks or ITOs. Movement patterns are best identified in track history plots.

Activity - Activity is the general characterization of all movements over a defined time period (hours to years). Specifically, activity is measured by counting tracks in defined time periods (dawn, daytime, evening, night, weeks, months, or seasons).

Example of a Movement at JFK

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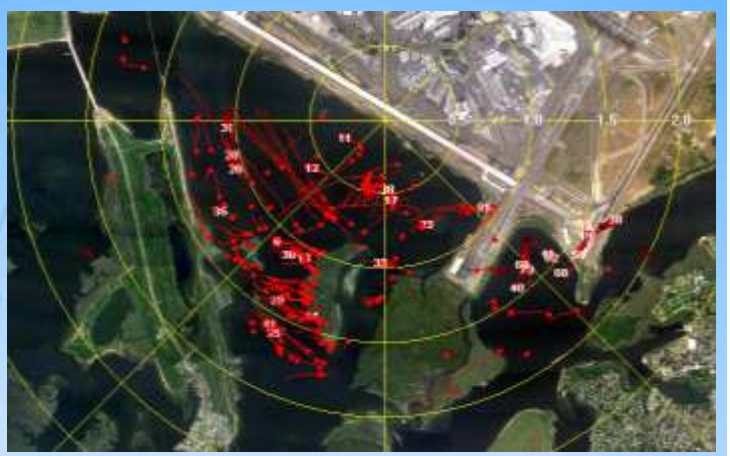
Example of a movement in a track history plot, where a group of targets are moving from the Northwest to the Southeast.



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Activity/Movement Examples

In our studies, we have observed and abundance of activity and a few have caught our attention particularly events where the duration of the movement is short, on the order of minutes, and if repeated, the repetition is daily or longer .

One, that I will share with your today was a regular movement that occurred in the morning each day.

The movement was first observed following our general review protocol where we select several days and simply watch movements. We observed a curious movement pattern and confirmed that this pattern occurred over several days. Consultation with the SEA wildlife biologist confirmed that the tracks were generated by starlings originating from a known roost in the parking garage at Seattle's airport.

Example of the Starling Movement

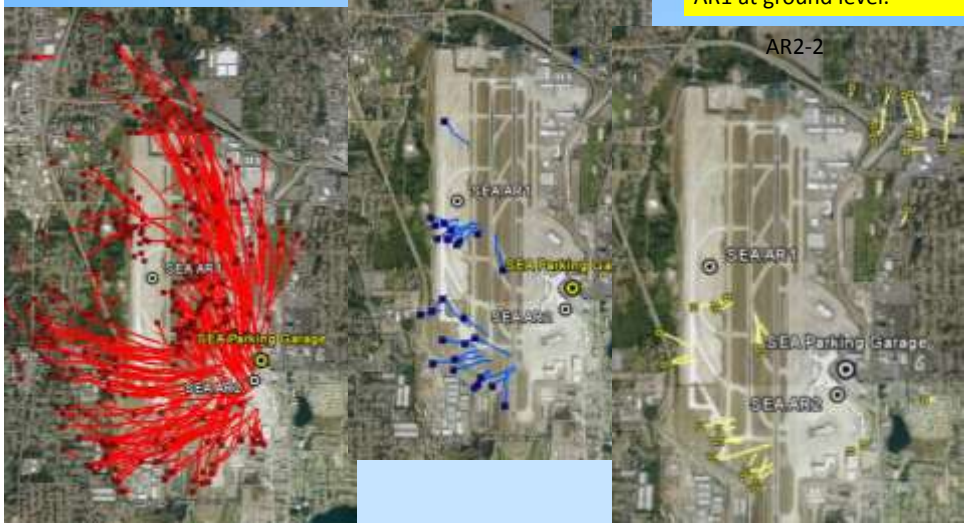
We have three radars operating at SEA, each covering a different altitude. The AR1-mid (array)provides the best coverage.

AR1-mid

AR2-1

AR2-2

Note the cause of the differences is the location of AR2 at 140ft AGL and AR1 at ground level.



We were able to analyze the roost evacuation in a number of ways and I will provide a few examples.

Roost Occupation and # of Dispersal Fronts Per Day

- The roost was occupied from mid-July to the end of October.
- The greatest number of dispersal fronts was 7 (Oct 15, 2009)
- The average number of dispersals per day was 3

	Average # Dispersals	Min # of Dispersals	Max # of Dispersals
July	1.5	1	3
August	2.6	1	6
September	3.6	1	6
October	3.8	1	7

Roost Evacuation Characteristics

- The shortest time between the beginning of the first and last frontal dispersal was
  - 1min, 15 sec
  - Oct.21 in light rain (2 total dispersals)
- The longest time between the first and last frontal dispersal was
  - 36min.
  - Sept. 3 in light rain (3 total dispersals)
- The average time between the first and last frontal dispersal varied with weather
  - All days: 15 min.
  - Overcast days: 20min.

This information provided important information for wildlife management and, potentially, ATC. A simple model that related dispersion fronts to sunrise provided a basis for recommending alerts to ATC.

In summary, observation of radar data alerted us to a characteristic signature in a radar. Follow-up provided a forensic analysis that focused management and supported better alerts for ATC.

We also observed a similar pattern at JFK!

What this experience revealed is that there are some distinctive patterns of movement that can be found at any airport. In this case, when roosting birds evacuate the roost, they create "ring angles," or dispersion fronts, that are distinctive and diagnostic.

Next I would like to deal with repetitious movements. These movements include movement that is generally consistent over time and space defining patterns that persist for many minutes up to hours.

Repetitious movements may show seasonal change with levels of activity increasing or decreasing related to time of day and the life history of the species present.

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It is important to understand that we don't just look at the radar, we study radar data to identify conditions that are important to airport safety. We operate under a Quality Assurance Plan (QAP) where one of the first steps in any deployment is definition of objectives.

These are some of the relevant objectives for JFK. Similar objectives were developed for each airport.

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- Collect and process data from the avian radar system to provide information that will support the identification of **general movement patterns** of birds on and around JFK. Particular attention should be paid to activity near **dawn and dusk**.

- In bird movement concentrate some effort on **night time analysis** of bird loafing/roosting locations, sources, and movement patterns.

- Collect and process data from the avian radar system to provide information that will support the identification of **origin and destination of birds tracked by the radar**. This will include on airport movements and off-airport movements particularly on the kilo extension and near the terminal buildings.

- Collect and process data from the avian radar system to provide information that will support the identification of the **dynamics of bird movement on and around** JFK.

- Collect and process data from the avian radar system to provide information that will support the identification of the **timing of local movements** of bird species on and around JFK. Particular attention should be dedicated to Thursten and Bergen basins

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We continue to conduct analyses throughout the deployment of the JFK radars, this example will provide a summary of findings from May and September 2010. Although the results are supported by quantitative analysis, I will provide a more descriptive summary.

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Spring and Fall at JFK

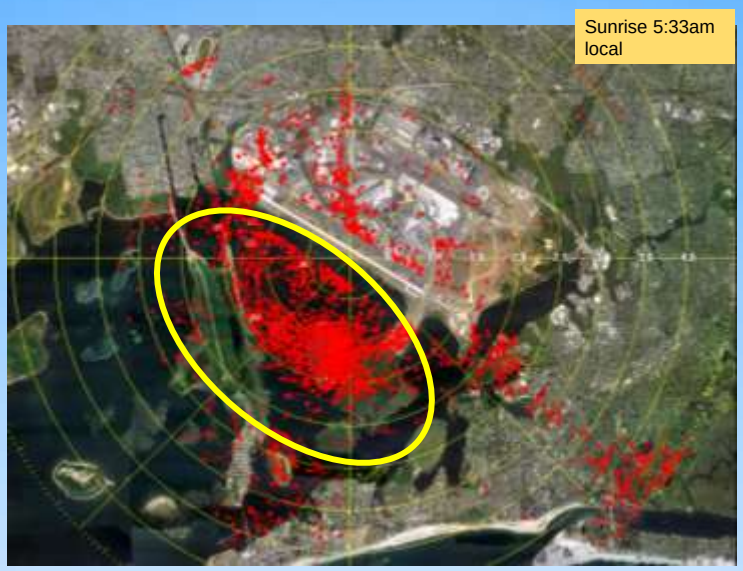
- Analysis has been completed for **May and September 2010** with a focus on:
  - Local movement patterns
  - Migration

- In May, sunrise occurred around, or after, 5:25 am local time and the sunset after 7:50 pm local time.
- Bird movements began around 6:00 am (local) and increased throughout the day with movement tapering off by 8:00 pm (local).

- ***Days with precipitation were not included in the analysis.***

AR2-L

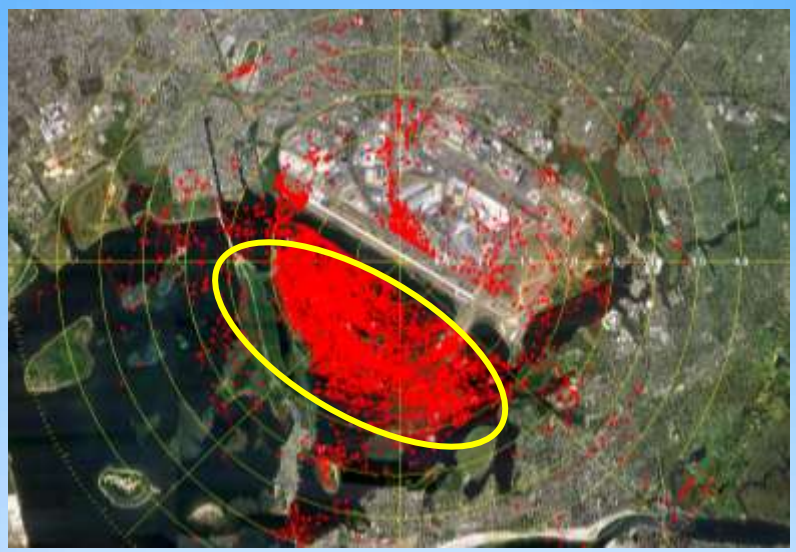
AR2-L track history with a mask for **May 20 2010 05:00:00am-5:30:01am**(Local Time)



The highlighted circle shows an area of dense tracks – elevated bird activity.

AR2-L

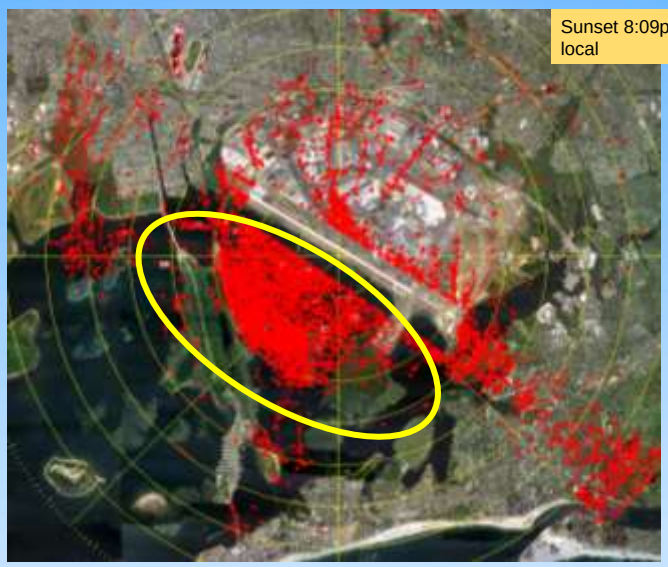
AR2-L track history with a mask for **May 20 2010**
1:00:01pm-1:30:00pm(Local Time)



Note high density of tracks at midday.

AR2-L

AR2-L track history with a mask for **May 20 2010**
8:00:01pm-8:30:01pm (Local Time)



Note reduced track density near dusk

Temporal Analysis Conclusions for May 2010

- Both Radars
  - Bird activity (as evidenced by the number of ITOs in the bay) started around 6 am (local) and increased throughout the day.
  - Most ITOs in daylight
- AR2-L
  - After the 1:00pm(local time) the overall activity increased significantly
    - Determining ITOs was difficult after 1pm
- AR2-H
  - The number of tracks increased through out day and began slowing down at 8 pm (local).
  - More ITOs at night than on the AR2-L

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Location Analysis for May 2010

- Most of activity, movements and ITOs observed in Jamaica Bay
- Targets are at different altitudes depending on the distance from the radar and uptilt of the radar

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Location Analysis of AR2-L in May 2010

- There are 3 main locations of ITOs (only 5% of observed ITOs were not in one of these locations):
  - JOCO Marsh (38%)
  - East High Meadow (30%)
  - Subway Island (27%)

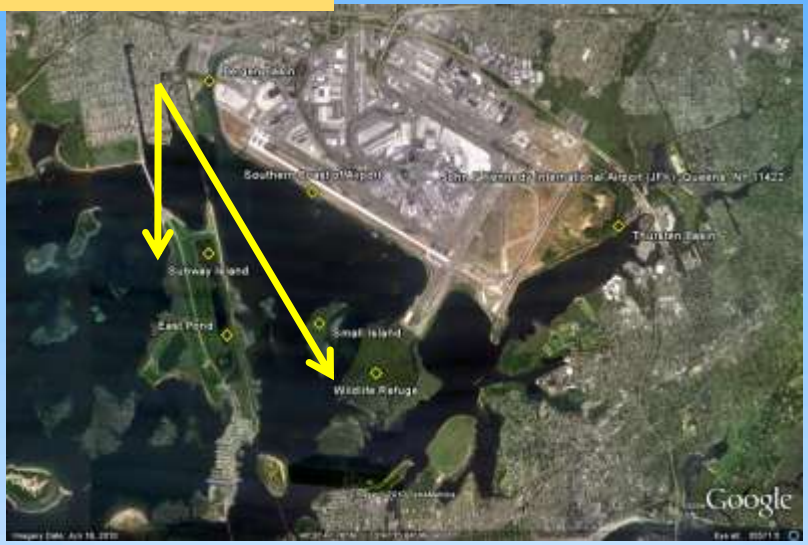
Location Analysis of AR2-H in May 2010

- In the first ½ of May, ITOs early in the day were more frequent than later in the month
- Highest numbers of ITOs began at the following locations
  - Subway Island - 27% - moved north or northeast towards shore, or east towards Thurston Basin
  - Bergen Basin -18% - moved towards the center of Jamaica Bay, Joco Marsh, or Subway Island
  - Southern Coast of the Airport. – 16% - same as Bergen Basin

Movement Direction in May 2010

Majority of ITOs related to Subway Island on the AR2-H moved north or northeast towards the shore, runway, or east towards East head of Bay

ITOs Direction in May 2010

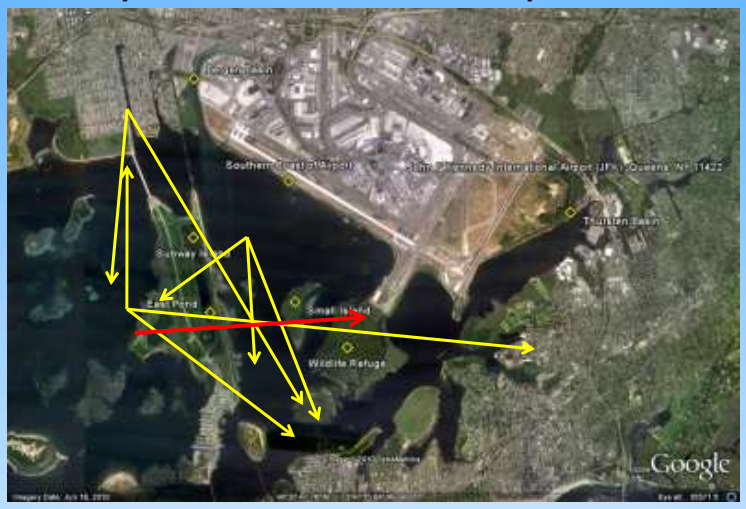


The ITOs related to Bergen Basin moved south or southeast towards Subway Island or Joco Marsh.

ITOs Direction in May 2010

The ITOs related to the South Coast of Airport moved towards East High Meadow, Joco Marsh and Subway Island.

Summary of Movements May 2010



Yellow = AR2-H
Red = AR2-L

September 2010

General Activity September 2010

- Analysis is focused more on movement direction than timing,
  - Large number of tracks or ITOs occur that exhibit similar behavior (heading, starting or ending point, etc).
  - Generally we observed long tracks, which were observed for several minutes
- Movements and ITOs associated with Subway Island (similar to May 2010)
- Morning and evening movements
  - Large
  - Eastbound and westbound through Jamaica Bay
- Daytime activity
  - Similar to morning and evening activity
  - Less intense than morning and evening

Morning Activity

- Two components of movements (in AR2-L):
  - Westbound movement
    - Starting at Joco Marsh towards Subway Island and Bergen Basin.
  - Eastbound movement
    - Starting at Subway Island heading towards airfield and Joco Marsh.
- Movement Timing
  - Begin within a half hour of sunrise with most activity in the fifteen minutes around sunrise
- AR2H similar to AR2L but with fewer targets
- Reminder AR2-L elevation
  - Targets are at lower elevations,
  - Typically within a few hundred feet of the surface (e.g. at 1.5 miles the top of the beam is at about 600 ft).
- AR2-H have altitudes at eastern shore Subway Island of between 550ft-740ft.

Summary of Movements for September 2010 - Morning

Yellow – AR2-L Red – AR2-H

Evening Activity

- Evening movements start about an hour before and continue through sunset
- Evening activity more extended than post-sunrise
- Eastbound and westbound movement is similar to morning movement.
  - Eastbound movement is towards Joco Marsh.
  - Westbound movement is towards Subway Island.
- Activity detected in the AR2-H, but with fewer targets.

Summary of Movements for September 2010 - Evening

Yellow – AR2-L Red – AR2-H

Night Activity

- Majority of activity is detected in Jamaica Bay with movement to the northwest in the AR2-L.
- The activity on both AR2 radars indicate a large number of targets at close range (within 1.5 miles).
- The AR2-H results are similar to the AR2-L - differences:
  - An area of strong southwestern movement beginning at the kilo extension and passing over Joco Marsh.
  - Long tracks that start from the north-northeast heading south-southwest.
- Long tracks observed in AR2H suggesting migratory movements.
  - The AR2-H beam coverage is at high elevation (greater than 700 feet).

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Summary of Movements for September 2010 - Night

Yellow – AR2-L Red – AR2-H

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Summary of September 2010

- The avian radar reveals high levels of bird activity in Jamaca Bay.
- Analysis of activity indicates changes during the day.
  - Eastbound and westbound movements dominate morning and evening.
  - Short range activity at night in both radars.
  - Long range detections may be migration or commuters at night in AR2-H.
- Radar suggests Subway Island may play a significant role in overall activity at JFK.

General Summary for JFK Radar Analysis

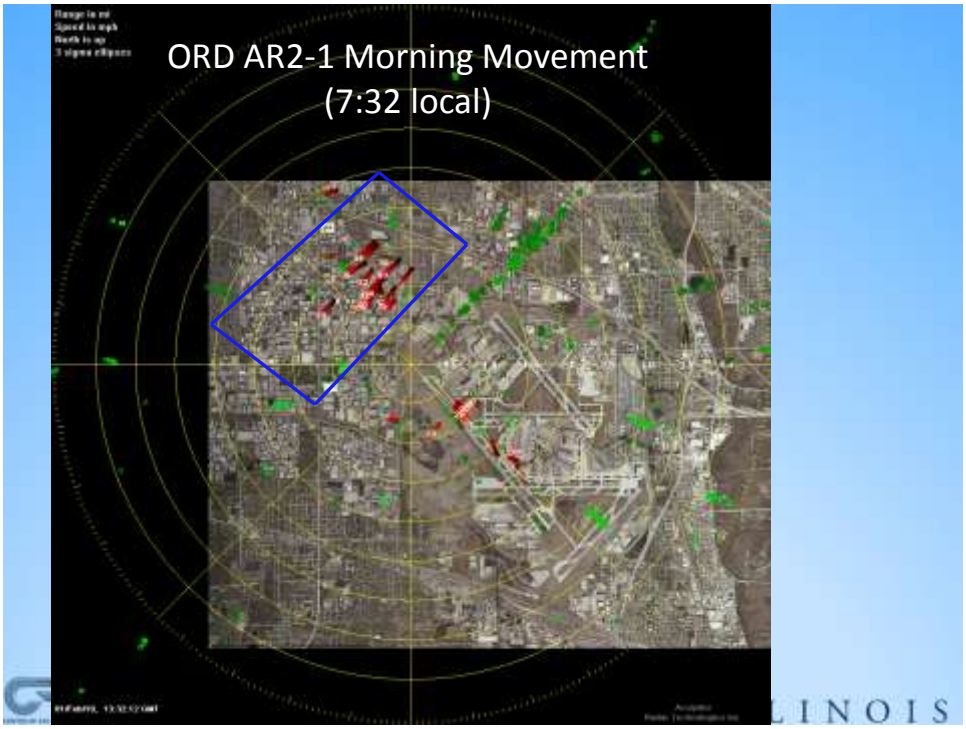
- Effective methodologies in historical radar analysis have been demonstrated
- Location Analysis
  - The avian radar reveals high levels of bird activity in Jamaica Bay.
  - Radar suggests Subway Island may play a significant role in overall activity at JFK.
- Timing –
  - Peak of activity in the 15 minutes surrounding sunrise.
  - Higher levels of activity in the afternoon and near sunset.
  - Least amount of activity at night

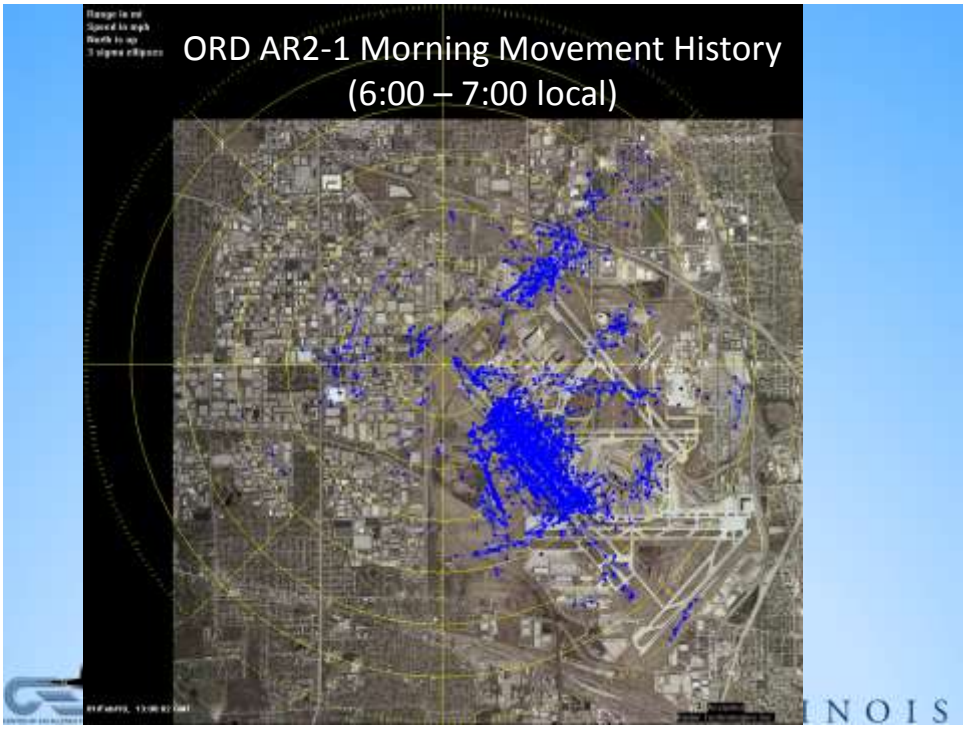
Next I will present an example of movement analysis for Chicago's ORD.

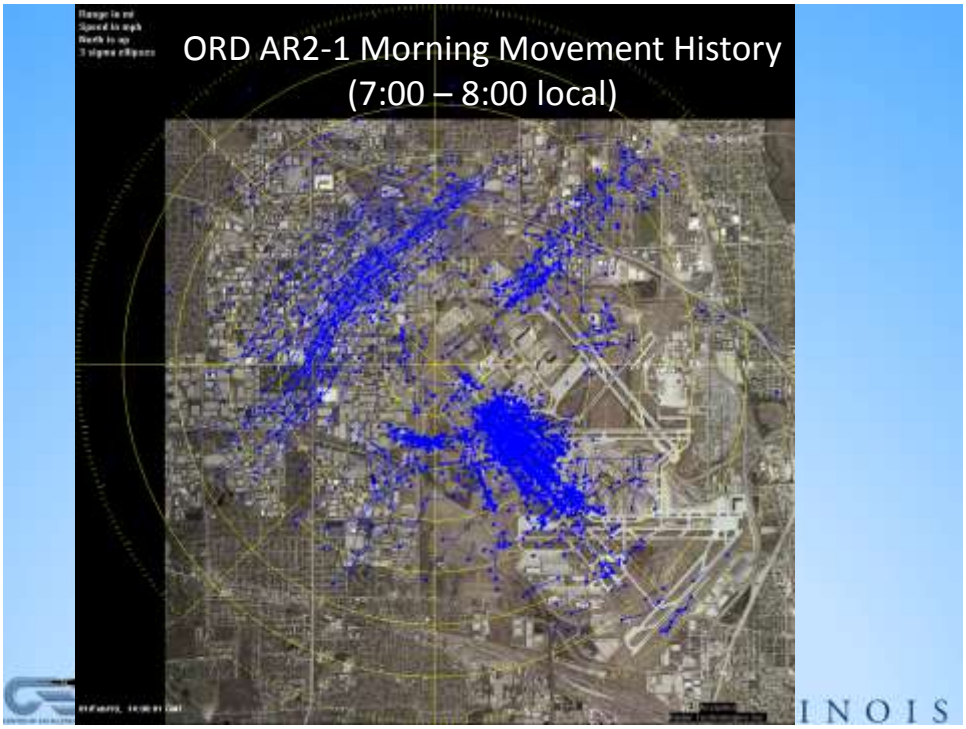
At ORD we are cooperating with USDA biologists in the assessment and working with them on radar validation and incorporation of radar data into their wildlife management efforts.

Bird Movement Summary

- Two movements of interest were observed at O'Hare, detected by AR2-1 (low angle) and the AR1 (slightly higher angle).
- South-westerly movements from north of the airfield were observed in the morning. These movements take place over the course of an hour.
- North-easterly afternoon movements take place over a few hours and are not as prominent as the morning movement.


ORD AR2-1 Morning Movement
(7:32 local)


ORD AR2-1 Morning Movement History
(6:00 – 7:00 local)


ORD AR2-1 Morning Movement History
(7:00 – 8:00 local)
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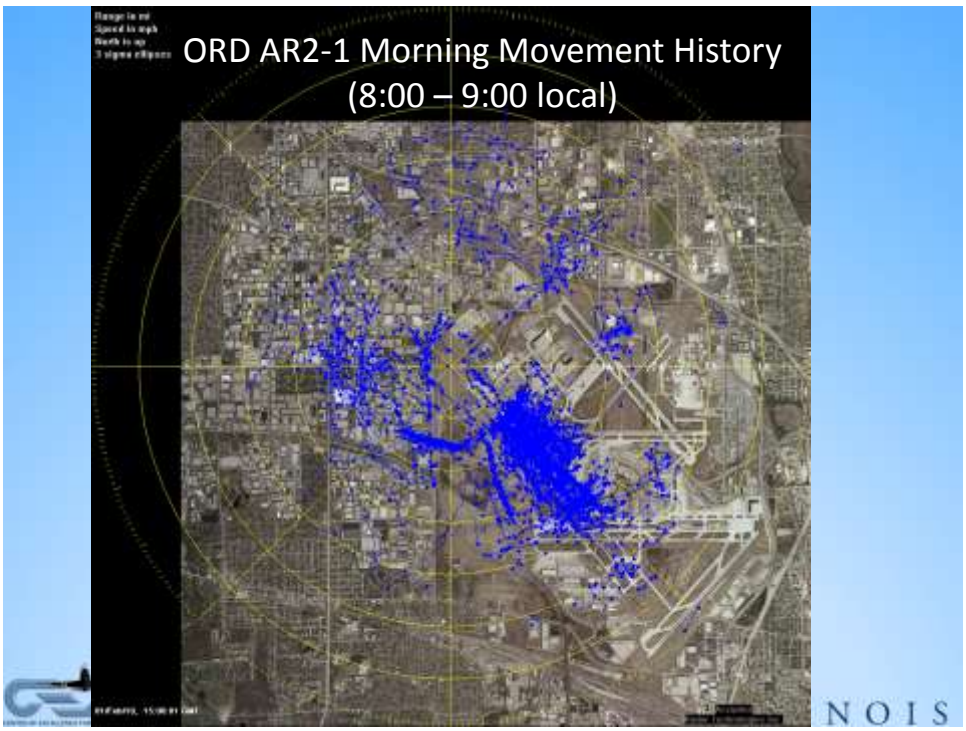
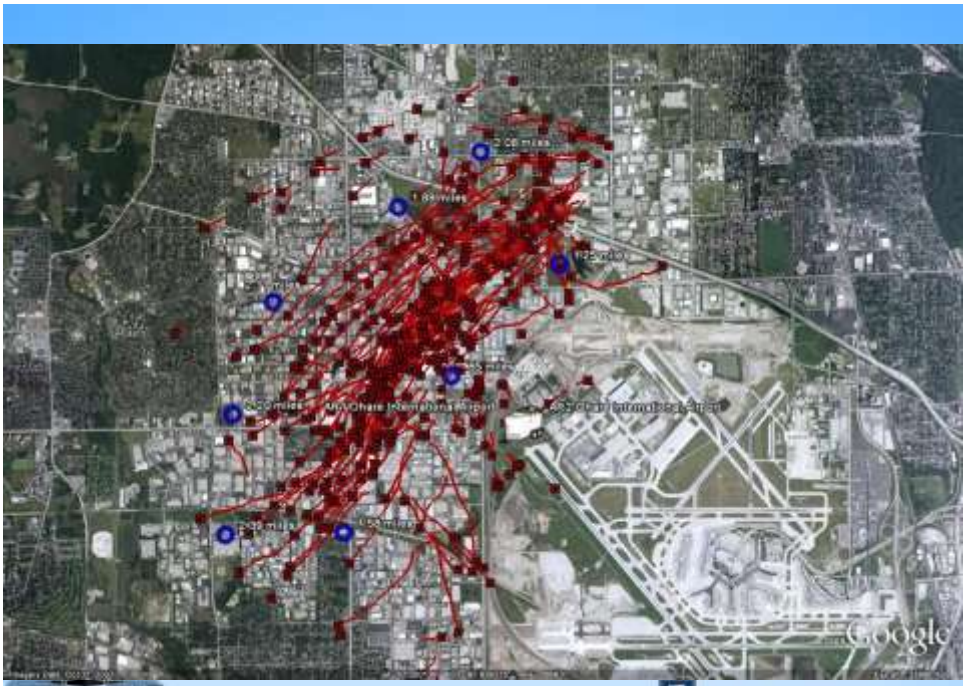

ORD AR2-1 Morning Movement History
(8:00 – 9:00 local)
NOIS

Morning Movement

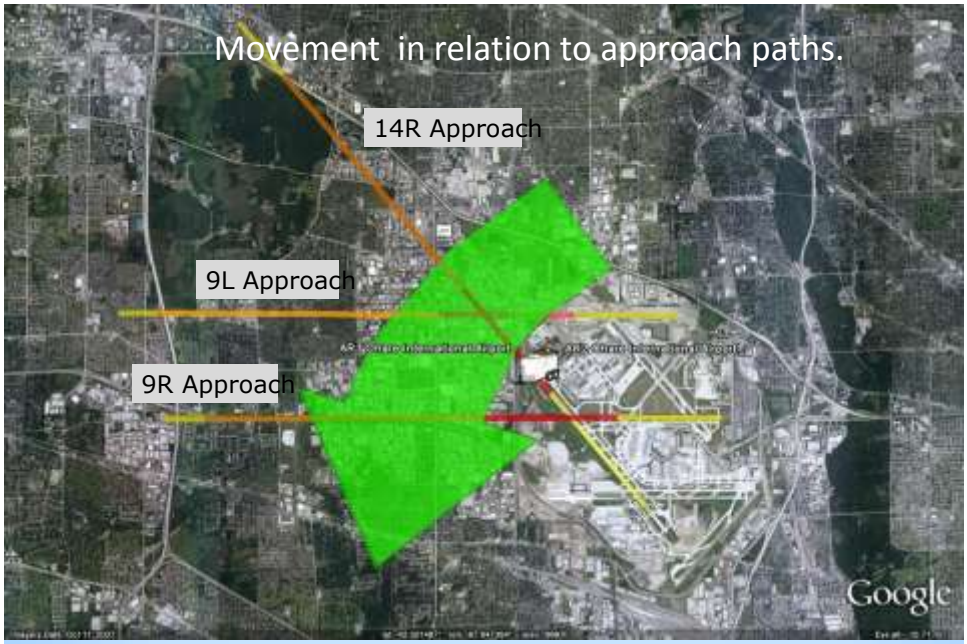
- From Feb 1st to 17th, this pattern occured on 9 days.
- Prominent movements occurred on 5 of the mornings. The other four were less obvious.
  - Did not occur on 6 of the days, with heavy snow on one of the days.
  - No data available on Feb 2nd and 3rd.
- On every day but one, movement took place during the 0700 hour (one day was during 0600 hour).

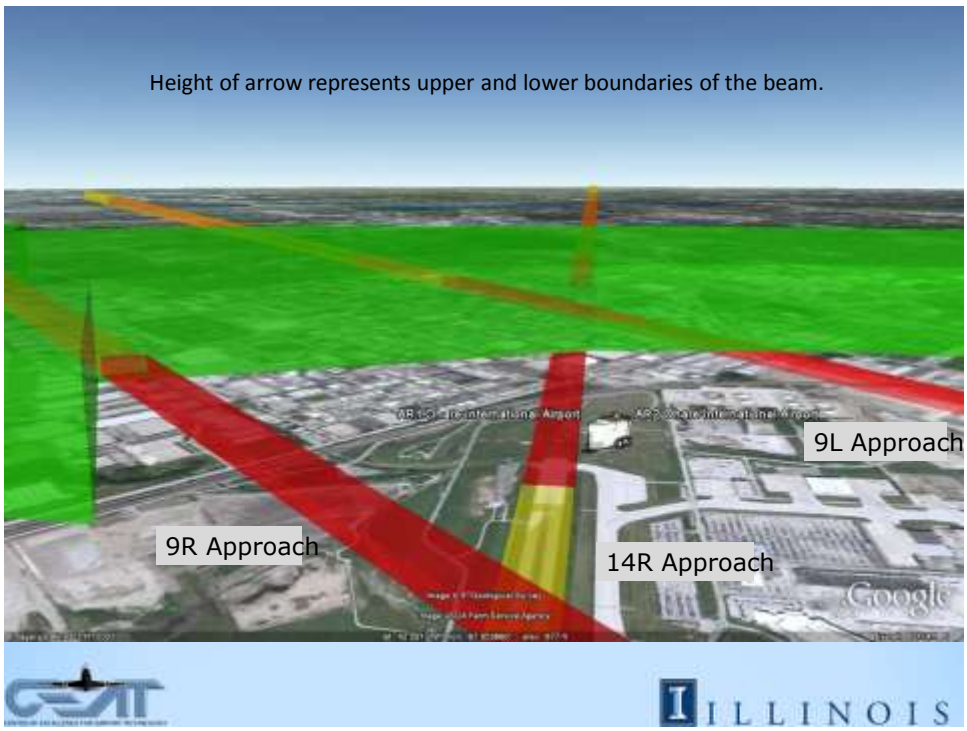
Morning Movement cont.

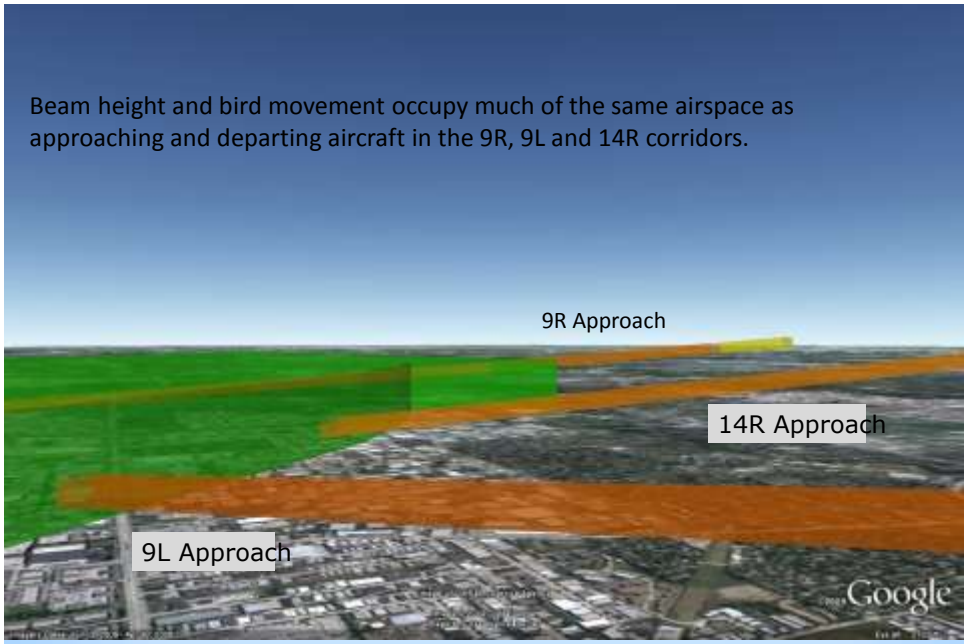
- Tracks appear mostly between 0.5 miles and 2.5 miles from radar. Highest concentration of tracks is between 1 mile to 1.5 miles.
- Beam center from closest tracks (.65 miles) to farthest (2.39 miles) climbs from 252ft to 895ft.
- With a 4° beam (and assuming no side lobe detections), the lowest extent of the beam climbs from 132ft to 490ft while the upper extent of the beam climbs from 373ft to 1339ft.
- The middle of the beam at the greatest concentration of tracks is about 493ft with a lower and upper extent of 252ft to 734ft.



The parabolic dish antenna used provides an estimate of ITO altitude. To provide a different visualization of these movements, efforts were made to present movement altitude with common flight paths to provide a better sense of hazard produced by these movements.


Movement in relation to approach paths.
14R Approach
9L Approach
9R Approach
Google


Height of arrow represents upper and lower boundaries of the beam.
9L Approach
9R Approach
14R Approach
Google



ORD Conclusions

- Radars will provide good tracking ability to the north, west and south.
- Multipath was present but not caused by every aircraft movement.
- Side lobe detections were an issue.
- Radars are detecting bird movements.

Although I could show you more examples, these three provide good examples of event and repetitious movements on, and around, airports.

The years of data are archived and are available to researchers who could benefit from data availability. Please look at our web site.

http://ceatasmp.cee.illinois.edu

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Questions?