Avian Radar Technologies: Wind Energy Project Applications

Presented by:
Gary W. Andrews
General Manager
DeTect, Inc.
1902 Wilson Avenue
Panama City, Florida 32405
USA
T 850.763.7200
F 850.763.0920
www.detect-inc.com

DeTect Overview

• US corporation headquartered in Panama City, Florida, USA
• Offices in US (Florida, Colorado & DC), Canada & Germany
  – Radar manufacturing facilities in Panama City, Florida & Longmont, Colorado USA
  – Service staff based in Alberta, Arizona, California, Kentucky, North Carolina, Poland, Spain & Texas
  – Representative offices in over 80 countries worldwide
• Company specialized in applied radar remote sensing systems & technologies
• Over 90 radar systems delivered worldwide to date
  – US, Canada, Europe, India, Kuwait, Africa & New Zealand
DeTect Avian Radar Technologies for Wind Energy Projects

DeTect Radar Technologies

- US & UK national birdstrike networks
- Aircraft Birdstrike Avoidance Radars
- Environmental avian radar systems
- Automated bird control radars
- Fixed-beam Vertical Profile Radars

REPRESENTATIVE PROJECTS

- Merlin SCADA Bird Mortality Risk Mitigation Radar System, McCullough Windfarm, Texas, USA
- Radar launch complex marine & airspace monitoring radar
- 449 MHz Radar Wind Profiler, US NOAA Next Generation National Profiler Network, USA

HARRIER

- Airspace monitoring radars
- Marine surveillance radars

RAPTOR

- Radar Wind Profilers
- Research weather radars

DeTect Inc.

detection technologies

Expertise Applied Radar Ornithology

- Relevant staff resources include radar ornithologists, radar engineers, biologists & scientists
- Expertise in radar bird detection & control in complex environments:
  - Former Chief of USAF BASH Team
  - Head of USAF Bird Control Europe
  - Civilian (USDA) & military wildlife/bird control officers
  - US FAA Qualified Wildlife Control Biologists
- Relevant experience at over 200 project sites worldwide
  - U.S., Canada, Asia, Australia, Europe, Central America, Middle East, China & Africa

REPRESENTATIVE PROJECTS

- Avian-Radar System & radar for migratory bird control program, Kentucky, USA
- Avian-Radar System for migratory bird control, Lethbridge, Canada, USA
- Avian Aircraft Strike Hazard Radar, USA Hogan-Afghan, Afghanistan

DeTect Inc.

detection technologies

* Bird Aircraft Strike Hazard

www.DeTect-inc.com
DeTect Avian Radar Technologies for Wind Energy Projects

The World Leader in Bird Radar Development

DeTect staff have led Bird Radar technology development with every major industry ‘first’:

- Dopplerized bird radar system (2010)
- Automatic radar-based mitigation of raptor mortality at a wind farm (2010, Torsa Renovables, El Pino wind farm, Spain)
- Automated, real-time birdstrike risk alerting system integrated with dynamic historic data predictive trending (2009, Duban IAP, S. Africa)
- Automatic radar-based mitigation of migratory bird mortality at wind farms (2009, Iberdrola Penãscal & Pattern Gulf Wind I wind farms, Texas USA)
- All weather solid-state bird radar system (2009)
- Automated birdstrike risk alerting system in a commercial airport control tower (2008, Durban IAP, S. Africa)
- Automated birdstrike risk alerting system (2006, USAF)
- Bird radar system at commercial airport (2003, Augusta Regional)
- Permanent offshore wind farm year-round bird survey & monitoring system (2003, Near Shore Wind Park, The Netherlands)
- On-airfield bird detection radar in control tower (2003, RAF Kinkloss)
- Biological target detection algorithm for a weather radar (2001)
- Automatic vertical scanning radar for bird detection (2000)
- Airport bird avoidance model (1997, USAF)
- Computer birdstrike mission planning model for pilots (1996, USAF)
- Year-round remote sensing studies of bird activity (1995, USAF)

The World Leader in Bird Radar Development

DeTect staff have led Bird Radar technology development with every major industry ‘first’:

- Dopplerized bird radar system (2010)
- Automatic radar-based mitigation of raptor mortality at a wind farm (2010, Torsa Renovables, El Pino wind farm, Spain)
- Automated, real-time birdstrike risk alerting system integrated with dynamic historic data predictive trending (2009, Duban IAP, S. Africa)
- Automatic radar-based mitigation of migratory bird mortality at wind farms (2009, Iberdrola Penãascal & Pattern Gulf Wind I wind farms, Texas USA)
- All weather solid-state bird radar system (2009)
- Automated birdstrike risk alerting system in a commercial airport control tower (2008, Durban IAP, S. Africa)
- Automated birdstrike risk alerting system (2006, USAF)
- Bird radar system at commercial airport (2003, Augusta Regional)
- Permanent offshore wind farm year-round bird survey & monitoring system (2003, Near Shore Wind Park, The Netherlands)
- On-airfield bird detection radar in control tower (2003, RAF Kinkloss)
- Biological target detection algorithm for a weather radar (2001)
- Automatic vertical scanning radar for bird detection (2000)
- Airport bird avoidance model (1997, USAF)
- Computer birdstrike mission planning model for pilots (1996, USAF)
- Year-round remote sensing studies of bird activity (1995, USAF)
Radar Ornithology - History

• Radar has been used since the 1950’s to study birds & bats
• Virtually any radar can detect birds to some degree
  – Birds are “bags” of salt water in the air
  – Wide range bird radar systems/networks
    • US NEXt GENeration weather radar network
    • C-band weather radars
  – Close range bird radar systems
    • “Marine” Radars
    • Aviation radars
      – Terminal Doppler Weather Radar (TDWR)
      – Air Surveillance Radars (ASR)

Radar Ornithology – Primary Sensors

1. US NEXt GENeration weather radar network (NEXRAD)
   – US national weather radar network
   – 148 sensors arrayed across CONUS
   – 128 nm range for weather

2. Standard marine radar
   – Fan & pencil beam antennas
   – X-band (9410 MHz frequency)
     • Magnetron systems with power ranges from 2 – 50 kilowatts
       – Radar cost: ~$2,000 to $40K
     • Low power density solid-state systems available late 2010
       – Will be expensive (~$100K+)
   – S-band (3050 MHz frequency)
     • Magnetron systems with power range from 30 – 60 kilowatts
       – Radar cost: ~$18K to $50K
     • Low power density solid-state systems on market since 2009
       – ~$50,000 K+ per sensor
**Wide Range - NEXRAD for Bird Detection**

- NEXRAD detects biological targets along with weather
  - First 64 nm used reliable bird detection
  - Insects, birds & bats
  - Reflectivity density for biological targets in dBz can analyzed
  - Correlated as ‘levels’ of activity
- Historically has been used for migratory studies
- Limitations:
  - Wide beam width
  - No altitude data
  - Point targets are suppression
  - Low resolution (1 sq km for Level III data; 5 dBz increments)
  - Slow update rate (6 minutes)
  - Data gaps & terrain shadowing/beam blocked

**NEXRAD - Bird Detection System**

**Avian Hazard Advisory System (AHAS)**

- National avian radar system originally developed for the US Air Force by DeTect staff
  - Automated, computer-based neural network operating since 1998
  - Currently covers the CONUS, Alaska, Hawaii & Guam
  - Used to provides aircraft-bird strike risk advisories for US military aircraft through Internet
- Near real time Level III NEXRAD data from 148 radars downloaded & processed every 6 minutes
  - GIS-based system includes natural resource (BBS, CBC, wetlands, refuges, etc.) & birdstrike databases
  - Over 10 years of archived radar density data for the CONUS totaling 80+ TB (1 sq km resolution)
• “Screening” assessment of candidate windfarm sites within an area

• Provides **comparative** siting assessment of proposed project areas using:
  - Current NEXRAD bird density data
  - Historical processed NEXRAD density data
  - 5+ years available for most US locations
  - Visibility, natural resource & other databases

• Ranks sites by seasonal & periodic activity
  - Site-to-site ranking of seasonal & periodic density
  - Comparison of relative activity to existing windfarms

---

**NEXRAD – Wind Energy Project Application**

• Limitations:
  - Measures bird density only
  - Not able to track point targets
  - Beam coverage depends on distance from beam (ground level to max height)
  - Data valid only for first 64 nm from the radar
  - Not available in all countries

• Technology improvements:
  - Level II data (increased resolution)
    - Available in late 2010
    - Order of magnitude increase in data resolution (0.5 dBz increments)
  - Dual polarization (insect filtering)
  - Real-time directional tracking of movements
  - Automated roost identification
Close Range – Small Avian Radars

• Originally low-power or surplus military radars used mostly for research
  – Commercial, engineered systems now available
• Typically single or dual marine radar based system
  – Magnetron radar sensor most widely used to date (kilowatt level power)
    • Fan-beam more common (larger airspace volume; ~20 degree beam width)
    • Pencil beam used mostly for individual target/focused area study (~3 degree beam)
  – Advanced solid state radars now available (low power density, but greater sensitivity)
• Application:
  – Pre-construction bird/bat survey & risk assessment
  – Operational monitoring
  – Operating windfarm mortality risk mitigation

Avian Radars – Manual Single Scan Configuration

For survey, radar used collect data for ~15 minutes in each position, then ‘flipped’ to alternate position - results in ‘data gaps’
Avian Radars – Dual Scan Configurations

- Dual radars scan simultaneously & continuously
- Vertical X-band & horizontal S-band
- No data gaps

Avian Radar – Data Collection & Analysis

Three main methodologies in use:

1. Manually interpreted -
   - Skilled radar ornithologist monitors radar screen, interprets data & 'counts' targets
   - Limitations include operator variability, fatigue, target loss in ground clutter & inability to physically count all birds in "target rich" environment

2. Semi-automatic analysis -
   - Radar screen recorded & played back for detailed manual analysis or image processing
   - Allows more accurate counts & improved QA/QC; still unable to resolve bird target in clutter

3. Fully automated (MERLIN) -
   - Radar signal electronically processed with specialized radar software developed specifically for bird detection
DeTect Avian Radar Technologies for Wind Energy Projects

10/15/10

www.DeTect-inc.com

MERLIN Avian Radars – State-of-the-Art

• Based on technology originally developed for USAF & NASA for aircraft-bird strike avoidance
• Simultaneous, dual radar scanning (solid state)
• Real time bird detection, tracking & data display
• Uses radar signal processing software specifically developed for biological targets
  – “Adapting ship tracking software for birds has proven difficult” (US FAA 2009)
• All target & track data continuously recorded for analysis & modeling
  – Includes software for quantitative modeling of wind farm avian mortality risk
• Durable, self-contained design supports 24-7 unattended operation with remote data/display access & system control for remote sites

MERLIN XS2530e Avian Radar System, Beatrice Wind Park, Scotland

MERLIN X2530e Avian Radar System, Generation 4, 2009 standard mobile model

MERLIN XS2530e Avian Radar System, Iberdrola Penãscal Wind Farm, Texas USA

MERLIN – Standard Mobile Configuration

Horizontally-scanning solid-state wide-beam S-band radar provides 360° surveillance around the windfarm site out to 2-4 nm

Vertically-scanning wide-beam X-band radar provides altitude measurement to 10,000 ft and coverage of the Rotor Sweep Zone

Operates on 110 vAC, 60 amp service with UPS backup; includes optional diesel generator power system

Self-contained mobile system designed for off-road use

Environmentally controlled cabin houses computer systems & ancillary equipment

Real-time remote user data display & control via fiber optic, wireless & satellite connectivity
MERLIN - Digital Signal Processing

Raw horizontal radar image from offshore platform survey

MERLIN digitally processed image of bird tracks with custom site underlay

MERLIN - Application to Wind Energy Projects

1. Pre-construction monitoring
   - Provides full area & height coverage of Wind Resource Area (WRA)
   - Used to assess & project mortality risks
   - Linked to post-construction data
   - Year-round 24-7 survey preferred over “snap shots” (e.g. spring & fall only)

2. Post-construction monitoring
   - Detects area activity WITH wind turbines
   - Monitors changes in target numbers or behavior

3. Operating wind farm mortality risk mitigation
   - Radar-activated turbine curtailment and/or deterrent activation
   - Custom risk control parameters based on pre- and/or post-construction data
   - Supports mitigation of risk to migratory birds, raptors, resident & protected species, bats
Why Use MERLIN for Wind Farms?

Advantages:
• Meets ‘best technology’ requirements
• Larger & more complete survey coverage over visual methods
• Detects & tracks birds 24-7, at night & in weather (S-band only)
• Provides most complete picture of activity over time & space
• Provides large, high-resolution datasets
• Provides more precise target count, direction, speed, and altitude
• Provides automated real-time risk mitigation
• Technology advancing rapidly improving performance
  – Solid state radars introduced 2009
  – Doppler systems now available

Preconstruction Avian Radar Survey

System is typically positioned with the vertical radar beam aligned a representative turbine row to create a “radar fence”
• Tracks & counts bird & bat targets passing through & along the radar beam recording information to internal system databases
• Sizes birds into classes (small, medium, large & flock)
• Provides altitude & passage rate data for modeling & risk assessment

Note: each target enumerated is not necessarily a unique individual bird or bat so system actually measures exposure
Radar Coverage & Range – Wind Energy

Horizontal radar provides bird detection out to 2-4 miles & up to 10,000 feet 360° around the windfarm site.

Vertical radar provides bird detection out to 0.75-1.5 miles & up to 10,000 along wind turbine rows.

Real-time Display of Data – Local & Remote

Real-time display of data for local and remote monitoring.
Quantitative Data Analysis

- All target track data written automatically to MS/SQL databases
  - 1-2 sec update rates typically
- Data can be analyzed with a variety of standard & custom queries
  - Also viewed, analyzed & modeled in GIS
- Outputs include tabular & graphical datasets
- Allows quantitative determination of mortality risk based on measured passage rates & other parameters under various models

Wind Farm Avian Risk Analysis – Migratory Birds

- Standard generally not available … “how many birds are too many”?
- Most accurate probability model is based developed by US Air Force for calculating aircraft-bird strike risk in airspace volume*
- Calculates risk of bird collision with object based on the frontal zone presented by birds passing through the Rotor Swept Zone (RSZ)

Mortality Risk Modeling – Data Normalization

Radar passage rate (\# of birds/time unit)
- Data normalized over 1 km front
- Radar scanned zone 0.5 km to either side of the radar

Discrete Pathways – Collision Risk

- # of Discrete Pathways results in a 1 in “x” chance that a target passing through the RSZ will have to change its flight path to avoid a component of the turbine structure.
- If the Passage Rate (number of bird targets/hour/1 km front) as measured by the radar does not exceed the number of discrete pathways, then statistically no single target crosses the probability “Risk Threshold” of having to see and avoid any turbine component.

\[
\text{Total Number of Discrete Pathways} = \frac{\text{Rotor Swept Zone}}{\text{Frontal Area}}
\]
Migratory Birds – Frontal Model

Assumptions:

• Frontal surface includes full Rotor Swept Area (not just the blade)
• Birds have excellent visual acuity & can avoid what they can “see”
• Significant risk exists under conditions of low visibility (<1/3 mile)
• Assumes NO avoidance of obstacles

Notes:

• Model is conservative in that:
  – Main risk is during low visibility at night*
  – Model assumes ‘solid’ Rotor Swept Area
  – Some avoidance likely exists even under low visibility
• Other models must be used for raptors, bats, etc.


MERLIN SCADA Radar-based Mortality Risk Mitigation

• New technology developed by DeTect - avian radar integrated with the windfarm SCADA system (Supervisory Control and Data Acquisition)
  • Radar applies custom ‘rule sets’
    – May include bird passage rate, size, mass, direction, altitude, weather, wind, etc. to identify risk in real-time & trigger a response action
  • Rule sets are specific to each wind farm
    – Ideally are developed from survey data at each site (may require 12+ months of preconstruction data)

• Mitigation response options:
  • Alerts to windfarm operators/control centers
  • Automated idling of turbine (curtailment - all or in groups) with automatic or manual turbine restart when risk abates
  • Activation of bird deterrent devices
• Real-time radar-based curtailment/deterrence optimizes energy production while minimizing bird mortality
**MERLIN SCADA – Migratory Birds, Texas USA**

- First wind farms in the world to implement radar-based mitigation:
  - Use DeTect MERLIN SCADA Avian Radar System

- Rule sets based on passage rate & visibility
  - Visibility data provided from wind farm meteorological sensors via SCADA network
  - Two radar units located at leading edge of each windfarm & linked by VPN to share data
  - Radars located on northern edge for fall migration & southern edge for spring migration

**MERLIN SCADA – User Interface**

- VB.NET MERLIN SCADA remote monitoring system (in development)
  - Provides real-time operational data & control to windfarm operators & biologists

- Live consolidated remote display of data from the MERLIN system

- Web-based system includes Google .api
  - Includes daily activity reports (passage rates, curtailment events, track & altitude data)
  - Allows remote user query for periodic & trend analysis
  - Allows operations center to forecast curtailments & restarts
MERLIN - Deterrent Technologies

Long Range Acoustic Device (LRAD):
- Military grade acoustic beam device
- Projects intense, focused beam of sound up to 160 dB with effective ranges out to 1500 meters
- Manual & automatic directed options
- Can be integrated with radar technology to automatically track & deter airborne birds

MERLIN detect & deter:
- Radar-directed deterrence with MERLIN Haze zone-control software
- In use for large-scale industrial bird control (mines, oil processing, power)
- Incorporates LRADs & custom programmable laser units

Raptor Mitigation – TORSA El Pino, Spain

- MERLIN radar system installed Sep 2009 to develop data for vulture mortality mitigation:
  - 24/7 survey for complete MERLIN SCADA design
  - Validate system ability to define & detect risk event
  - Test LRAD deterrence on vultures
  - Define operating triggers ‘rule sets’ & responses

- Status:
  - ~12 months MERLIN radar data collected to date
  - MERLIN SCADA vulture risk mitigation parameters have been modeled:
    (1) detection
    (2) wind direction
    (3) cloud ceiling height
  - “Turbine Centric” MERLIN SCADA Implementation in process
**MERLIN SCADA – Turbine Centric Model**

- Full radar coverage of all turbines
  - VSR for each turbine row
  - Radar provides full horizon-to-horizon sweep of turbine row
- Primary collision risk is driven by two values from VSR:
  1. Distance to the turbine, and
  2. Direction of flight relative to the turbine
- Risk assessment computed for every target in real time
  - All individual has an associated risk calculation relative to every turbine in the row

---

**Distance from Turbine**

- [Image showing distance from turbine with color gradient indicating risk]
Target Heading

Horizontal Radar Data Component

- The risk components from both the vertical and horizontal radars are both used
  - A “3D” risk assessment is developed
  - Position of tracks on the horizontal radar influence the overall risk outcome

- **Outcome:**
  - Radar activated idling of individual turbines based on risk for each target when the risk threshold is exceeded
  - Maximizes operation, minimizes mortality
Golden Eagle Risk Mitigation - Principle

- Simple premise – when eagles are detected on, or closing in on the site, curtail the turbines to prevent the eagles from encountering spinning blades
  - Challenges:
    - Refine system to minimize mortality & optimize energy production
    - Differential eagles from eagle-like targets
- Pattern Ocotillo development program

Eagle Risk Mitigation – Multi-Sensor Plan

- No single sensor can get this job done on its own
- Requires a suite of sensors in concert can provide a robust system for real time curtailment operations
  - Radar
  - Video
  - Tags
- Develops data to design operational mitigation system
- Requires 12+ months study with full-time field biologists to design full system & develop risk rules
Radar Tracking

- Cue on-site biologist to presence of large targets consistent with eagles at the site
- Determine the vulnerability of the track based on distance to EACH turbine (real time risk assessment)
- Real time alarms conditions
- Works for all large birds, even eagles without radio tags
- Detection range likely greater than 3 nm (maximum capability of the new solid state Doppler radar for eagles will be greater & is being determined)

Video Tracker

- Theoretical range for video tracking an eagle >5 miles and as much as 8 miles is possible (once target is acquired)
- Target acquisition is cued by radar and slewed in azimuth manual acquisition in elevation (semi automated)
- Once acquired target tracking is automatic until the target is lost from view
### Video Tracker

- Allows a single biologist to keep VISUAL track of multiple eagles on site at once, even when they go in different directions
- Visual target identification for mitigation decision
- Recording of activity for post event analysis
- Provides operational data to develop advanced software for auto-identification of eagles & for automatic curtailment in combination with other sensor data

### Radio Telemetry

- Capture & radio tag resident birds and offspring
- Breeding Adults represent a greater loss than unpaired floaters
- Telemetry can indicate activity, altitude & approach of known banded birds to the site.
- Act as a mini “transponder” for association of eagle with radar tracks
- Expand knowledge of when eagles utilize the site which is likely driven by wind and soaring conditions
**MERLIN - Radar-based Mortality Risk Mitigation**

**Implementation process:**
1. Pre-construction surveys used to define high strike risk conditions & mitigation parameters required for each site (requires up to 12 months of data)
2. Radar system programmed with rule set based on these conditions
3. Radar system detects & tracks bird/bat targets in real-time, & gathers weather & other data
4. When rule set is met, the radar system initiates pre-determined mitigation measures
5. Post-implementation data used to refine rule sets

**Qualifiers & Notes:**
- Level of study and implementation is unique by site
- Appropriate, long-term pre-construction studies needed
- Refine with post-construction operational studies (Adaptive Management principles)
- Mitigation technique minimizes both bird mortality & turbine downtime by targeting high risk periods in real time

---

**Questions?**

**US Headquarters**

DeTect, Inc.  
1902 Wilson Avenue  
Panama City, Florida 32405  
USA  

T 850.783.7200  
F 850.763.0620  
E inquiry@detect-inc.com

**International Projects**

DeTect International  
5801 Lee Highway  
Arlington, Virginia 22207  
USA  

T 703-533-8555 ext 588  
F 703.533.3190  
E detectintl@detect-inc.com

www.detect-inc.com