State of the Science: Technologies and Approaches for Monitoring Bird and Bat Collisions Offshore

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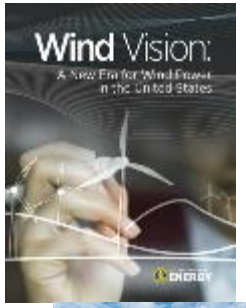
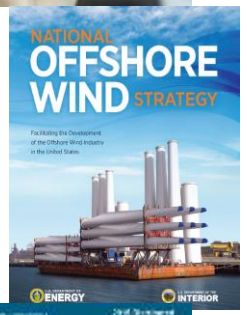
November 13, 2018

DOE Wind Energy Technologies Office

- The Wind Energy Technologies Office invests in early-stage applied energy science research, development, and validation activities for U.S. **land-based, offshore and distributed wind power** generation, manufacturing, and market barriers to lower wind energy costs, increase capacity, accelerate reliable and safe energy production, and address environmental and human use considerations.

- The Wind Energy Technologies Office supports wind as a sustainable domestic power source that currently **provides 6.3% of generation, employs more than 105,000 Americans across all 50 states,** enables a robust domestic turbine component manufacturing sector, and has expansive potential for delivering affordable, reliable power across the nation.





Wind Energy Programmatic Priorities

- Cost Reduction and Performance Improvement
- Technology Transfer Acceleration
- Market Barrier Reduction

Mitigating Environmental Barriers

Objective: Facilitate and disseminate research to understand and mitigate the impacts of wind energy on wildlife.

Data Collection and Experimentation	**Conduct research to better understand species' exposure and the factors that drive risk** in order to inform siting and mitigation solutions
Monitoring and Mitigation	**Advance technologies or methods to measure or reduce impacts** at wind energy facilities in an affordable manner
Information Synthesis and Sharing	**Coordinate information synthesis and dissemination** through collaboratives and information to reduce redundancy, make sense of disparate studies, and catalyze solution development.

Potential Offshore Wind Effects on Birds

1. Changes in habitat use (attraction or displacement)

2. Barrier effect

3. Collision

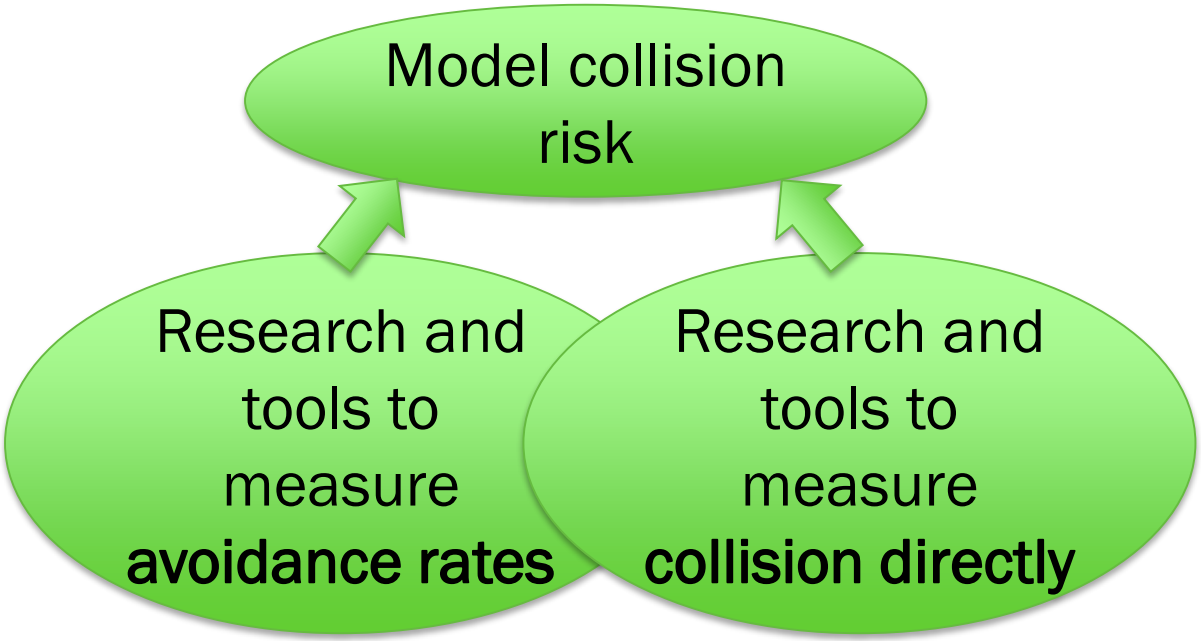

Photo credit: Jonathan Fiely

Quantifying Collision Risk Offshore

Tools to Measure or Estimate Collision Risk

- **Land-based techniques not transferrable**

General Approaches:



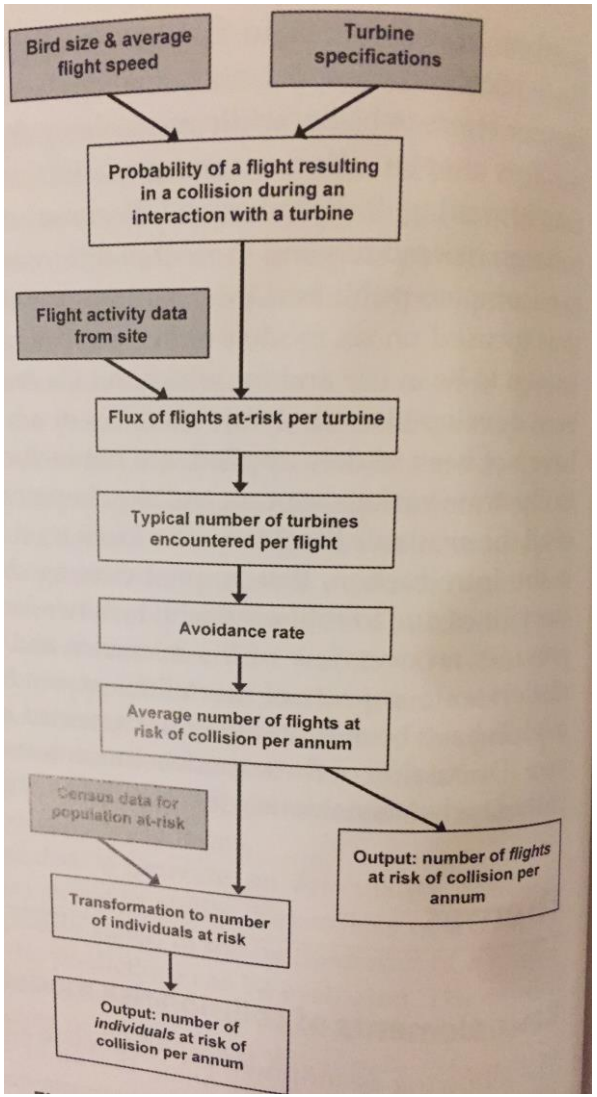
Collision Risk Modeling

Species and turbine specific data

Number of bird flights

Avoidance rates

Scaling up of ind. collisions for input to population level assessment



Source: Smales 2017

Avoidance

Macro

Meso
(horizontal and vertical)

Micro

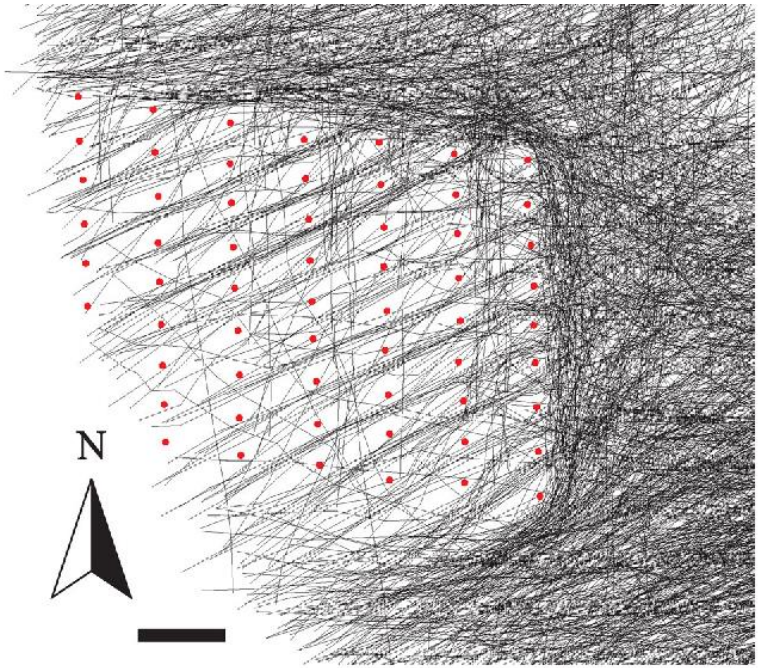
Radar

Visual observations

GPS tags

Camera systems

Source: Smales 2017



Source: Desholm and Kahlert 2005

Much of what is known about collision risk at offshore wind farms comes from large-scale, intensive research programs aimed at measuring avoidance rates and in some cases collision events as well.

ORJIP (Offshore Renewables Joint Industry Programme)

- **Bird Collisions Avoidance Study (2014 – 2017) – Published April 2018**
  - Goal: Measure avoidance behavior to refine estimates used in collision risk modeling
  - Thanet Offshore Wind Farm - 12 km off Margate, Kent (UK)
    - Equipment for monitoring included:
      - Range Finder (RF)
      - Local Area Weather Radar (LAWR)
      - High performance Naval Surveillance Radar (SCANTER)
      - Thermal Animal Detection System cameras- automated tracking (TADS)
  - Findings:
    - Birds of interest exhibited avoidance of offshore wind turbines
    - Behaviors reduced risk of collisions

	Northern Gannet	Black-legged Kittiwake	Herring Gull	Great Black-backed Gull	Lesser Black-backed Gull	All large gulls
Overall Macro EAR	0.999	0.998	0.998	0.998	0.999	0.996
SD	0.0003	0.001	0.0009	0.0009	0.0007	0.0019

Source: Svov et al. 2018

Collision Detection Technology – Components

- **Technology Characteristics:**
  - Coverage/range: Farm, turbine, portion of rotor swept zone, blade etc. (varies by technology)
  - Operational conditions: Day/night, inclement weather
  - Capabilities: Detection (false positives, false negatives), tracking, species identification, strike detection, real-time vs. post-processing,

- **System Components**
  - Target Detection/Identification: Camera (visual, thermal, and near IR), radar, acoustic monitors
  - Strike Detection: Accelerometers, microphones, cameras
  - Software: Automate analysis of data, select data to save
  - Data management: Remote connectivity vs. hard drive
  - Other Hardware: Housing, cabling, power, etc.

Technology Readiness Levels (TRLs)

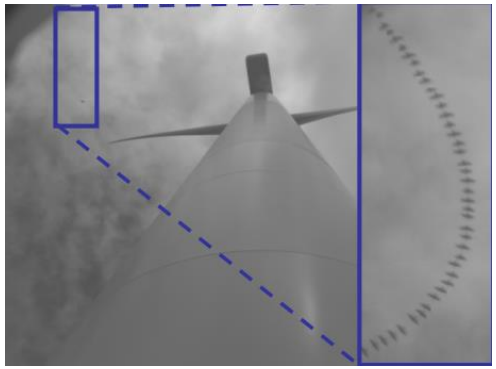
TRL 1	**Basic Research:** Initial scientific research has been conducted. Principles are qualitatively postulated and observed. Focus is on new discovery rather than applications.
TRL 2	**Applied Research:** Initial practical applications are identified. Potential of material or process to solve a problem, satisfy a need, or find application is confirmed.
TRL 3	**Critical Function or Proof of Concept Established**: Applied research advances and early stage development begins. Studies and laboratory measurements validate analytical predictions of separate elements of the technology.
TRL 4	**Lab Testing/Validation of Alpha Prototype Component/Process:** Design, development and lab testing of components/processes. Results provide evidence that performance targets may be attainable based on projected or modeled systems.
TRL 5	**Laboratory Testing of Integrated/Semi-Integrated System**: System Component and/or process validation is achieved in a relevant environment.
TRL 6	**Prototype System Verified**: System/process prototype demonstration in an operational environment (beta prototype system level).
TRL 7	**Integrated Pilot System Demonstrated**: System/process prototype demonstration in an operational environment (integrated pilot system level).
TRL 8	**System Incorporated in Commercial Design**: Actual system/process completed and qualified through test and demonstration (pre-commercial demonstration).
TRL 9	**System Proven and Ready for Full Commercial Deployment**: Actual system proven through successful operations in operating environment, and ready for full commercial deployment.

System: Accelerometers + Cameras

The remainder of this presentation relies heavily on Dirksen 2017. For more information regarding technologies for monitoring collisions offshore please see the full report here: https://tethys.pnnl.gov/sites/default/files/publications/Dirksen-2017.pdf

WT Bird– *ECN, The Netherlands*

- Components: Accelerometer, microphones, video camera
- Advertised Capabilities: Collision detection – larger birds
- Validation: History of testing of accelerometer system, camera a newer addition with some field validation
- TRL Range: High



Soura.lgi-conrce: https://eesulting.org/ecm/showcase/JP_EERAJPWIND_2082_ECN_-_WT_bird__a_bird_collision_monitoring_system

System: Cameras + Radar

Thermal Animal Detection System (TADS) & Multi-Sensor Bird Detection System (MUSE) – *DHI*

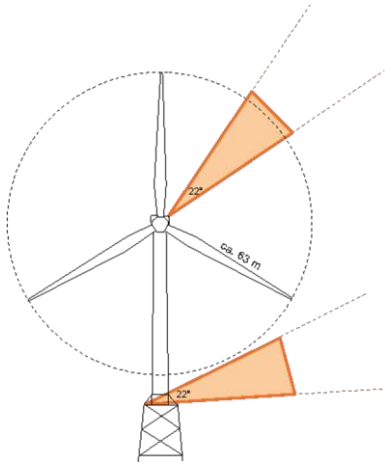
- Components: Two thermal cameras and daylight/low light camera, coupled with radar system
- Advertised Capabilities: Collision detection, meso and micro-scale avoidance monitoring
- Validation: Developed, tested, and used offshore. Research on-going to reduce false positives when used with radar system. Skov *et. al* 2018 -Thanet Offshore Wind Farm (UK).
- TRL Range: High

https://www.dhigroup.com/global/news/2017/02/automated-bird-monitoring-system-lands-on-pioneer-us-wind-farm

Cameras

Visual Automatic Recording System (VARS) – *IfAÖ*

- Components: Motion-controlled, infrared camera system
- Advertised Capabilities: Day or night detection and recording of birds and bats, collision monitoring. Designed to look at successful passage through rotor-swept zone and estimate collision.
- Validation: Testing on offshore environment since 2007. Deployed at German Offshore wind farm Alpha Ventus '10-'13. (Shultz, et. al. 2014)
- TRL Range: High

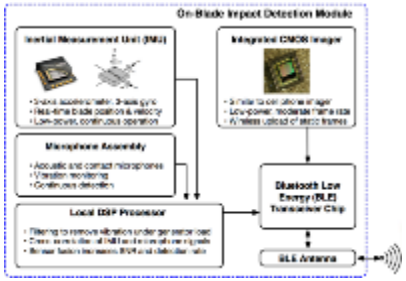


Source: Dirksen 2017

System: Accelerometer, Camera, Microphones

Avian and Bat Collision Monitoring System- Oregon State University *(DOE Funded)*

- Components: Visual 360˚ cameras, accelerometers, and contact microphones.
- Advertised Capabilities: Real-time, time-stamped detection of blade strike, and species identification, can also trigger visual deterrent
- Validation: Not yet tested offshore. 2013 individual component proof of concept testing. 2016, developing integrated system for applicability in eagle detection, deterrence, and strike detection.
- TRL Range: Mid



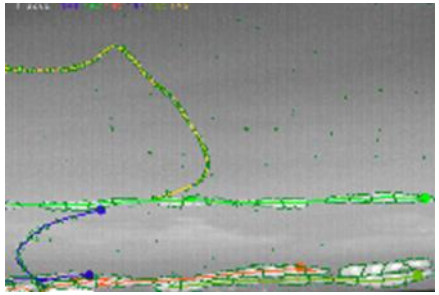
System: Cameras

Aerofauna Collision Avoidance Monitoring System – Hi Def and *BRI* *(DOE Funded)*

- Components: 2 HD visual cameras, and 2 thermal cameras operating in stereo
- Advertised Capabilities: Wildlife monitoring, day or night, in 3D to assess behavior and interactions with wind turbines.
- Validation: 2015 Proof of concept (not real time) tested on-shore with raptors to develop and validate software for analyzing video. Hardware successfully tested offshore in 2013 to demonstrate ruggedness.
- TRL Range: Mid

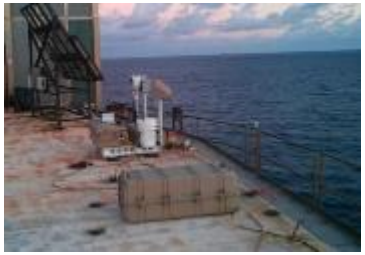
ThermalTracker Software – *Pacific Northwest National Lab* *(DOE Funded)*

- Components: Software for thermal camera systems
- Advertised Capabilities: Automated bird flight tracking, behavior analysis, and object identification,
- Validation: Under development since 2011, ThermalTracker has been evolving steadily. Not yet tested at an offshore wind farm, PNNL is conducting validation research in near-shore environment.
- TRL Range: Mid



System: Cameras + Microphones

ATOM (Acoustic & Thermographic Offshore Monitoring) - *Normandeau Associates*



- Components: Infrared camera, auditory & ultrasound microphones
- Advertised Capabilities: Day and night monitoring, species identification. Not real time. Data collected on hard-drive for later analysis.
- Validation Results: 2014 BOEM-funded design and development study. Tested offshore but not with turbines. Power issues with solar chargers.
- TRL Range: Mid

Bat Observation Technology - *Wageningen Marine Research*

- Components: Stereo Camera & Ultrasound detection
- Advertised Capabilities: Tracking 3D flight paths of bats offshore
- Validation Results: Lagerveld, et. al 2017 - study focused on proof of concept tracking (manual video processing) & acoustic bat ID. Not tested in marine environment.
- TRL Range: Low

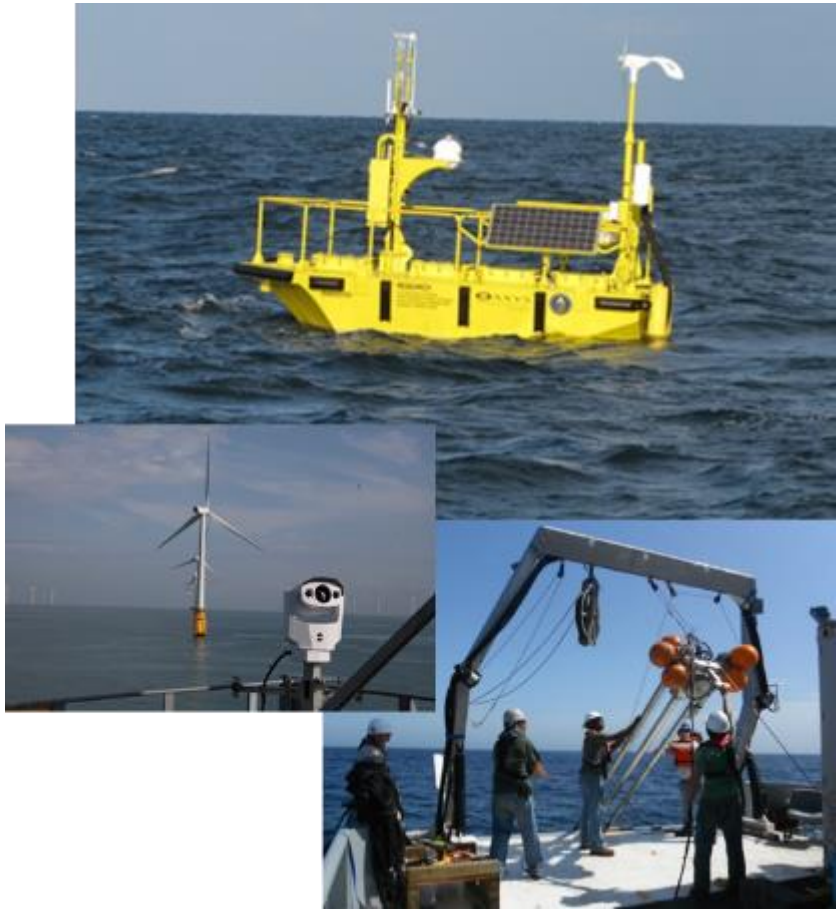
Impact Minimization Technologies

- **Cost/benefit relationship important to understand prior to application**
- **Bird technology developed for land-based contexts**

  e.g., DTBird - *Liquin Consultoría Ambiental* *(DOE Funding Land-Based Validation for Use on Eagles)*
  - Components: 360˚ camera coverage (visual and thermal), auditory deterrent, SCADA informed turbine curtailment
  - Advertised Capabilities: Automated day or night monitoring and fatality minimization.
  - Validation: Tested at numerous onshore farms and in the offshore environment in Europe. Limited publically available 3rd party assessments. Currently testing in US under DOE grant re: eagle detection/deterrence.
  - TRL Range: Mid/High
- **Bat deterrents** *(DOE Funded - Land-Based)*
  - Need to better understand risk offshore
  - Deterrent technology under development
  - Some promising results for ultrasonic acoustic deterrents, but species coverage gaps, need for additional testing to validate
  - Developed for land-based settings, not marinized
  - Potential challenges around ultra-sound attenuation with large turbines offshore

FY18 FOA: Advanced Wind R&D to Reduce Costs and Environmental Impacts

- **Topic Area 3:**
  - Support the research, development and validation of instrumentation to be used for the measurement and/or mitigation of key environmental concerns that drive permitting and monitoring processes/costs for offshore wind
  - Areas of focus:
    - Monitoring and mitigation technologies associated with noise impacts
    - Collision monitoring systems



Challenges Around Measuring Collision Risk Offshore

- **Scale of coverage**
- **Collisions are likely rare events**
  - Challenging to capture, as well as validate technology
- **State of technological readiness respective to the questions that drive regulation**
  - Species ID
  - Impacts during low visibility conditions
- **Data quantity**
- **O&M**
- **Cost**
- **Collision data alone doesn't provide much predictive value**
- **Important to remember all collision monitoring is essentially sampling with the intent inform questions of risk to populations**

Thank You

Information Sharing and Additional Resources:

- Tethys Wind-Environmental Information Database
  - https://tethys.pnnl.gov/wind-energy

Systems designed to measure passage through and around wind farms

The remainder of this presentation relies heavily on research published in Dirksen 2017. For more information regarding Technologies for Monitoring and Mitigating Impacts Offshore please see the full report here: https://tethys.pnnl.gov/sites/default/files/publications/Dirksen-2017.pdf

RADAR SYSTEMS

BirdScan MR1 - *Swiss BirdRadar Solution AG*

Components: Compact, vertically directed conical aperture radar

Advertised Capabilities: Bird and bat detection – height, wing flap pattern, direction and speed, target volume, target shape – up to 2km, depending on size.

3D-Flex - *Robin Radar*

Components: Horizontal S-Band Radar, FM Continuous Wave Radar.

Advertised Capabilities: Detect height, size, direction, and number of birds up to 10km. Data are stored and analyzed later.

Merlin Bird and Bat Radar - DeTect Inc.

Components: Doppler S-Band Horizontal Radar, and X-Band Vertical Scanning Radar

Advertised Capabilities: Detection and tracking of avian targets, can initiate curtailment of turbines through SCADA interface

BirdTrack - *Strix*

Components: Horizontal S-band & Vertical X-band radar, mobile or fixed housing.

Advertised Capabilities: Automatic detection and tracking of birds and bats (trajectory, speed, altitude); classification by species group. Birdtrack software claims to track and classify targets.

DHI Bird Detection System w/ Scanter 5000 - *Terma/DHI*

Components: Solid State Radar + DHI Bird Tracking Software

Advertised Capabilities: Flexible frequency selection, enhanced capacity to suppress interference/clutter from slow moving/stationary objects.

DHI Bird Detection System w/ LWAR 25 - *DHI*

Components: Fan beam and magnetron-based radar

Advertised Capabilities: Vertical and horizontal positioning. Coupled with bespoke software for signal processing (bird tracking)

System: Radar Systems

BirdScan MR1 - *Swiss BirdRadar Solution AG*

- Components: Compact, vertically directed conical aperture radar
- Advertised Capabilities: Bird and bat detection – height, wing flap pattern, direction and speed, target volume, target shape – up to 2km, depending on size.
- Validation Results: Has been tested and deployed offshore, but still has clutter issues if blades or sea surface are in the measurement range.
- TRL Range: Mid/High

3D-Flex - *Robin Radar*

- Components: Horizontal S-Band Radar, FM Continuous Wave Radar.
- Advertised Capabilities: Detect height, size, direction, and number of birds up to 10km. Data are stored and analyzed later.
- Validation Results: While tested, no publicly available results are available to verify claims.
- TRL Range: Mid/High

Merlin Bird and Bat Radar - DeTect Inc.

- Components: Doppler S-Band Horizontal Radar, and X-Band Vertical Scanning Radar
- Advertised Capabilities: Detection and tracking of avian targets, can initiate curtailment of turbines through SCADA interface
- Validation Results: Has been deployed onshore and offshore, constantly under development to improve hardware and data processing software. Data have resulted in understanding of wildlife movement patterns. Reports available relating to Dutch Offshore Wind Farm OWEZ (2005, 2011, 2012, 2015)
- TRL Range: Mid/High

System: Radar Systems

BirdTrack - *Strix*

- Components: Horizontal S-band & Vertical X-band radar, mobile or fixed housing.
- Advertised Capabilities: Automatic detection and tracking of birds and bats (trajectory, speed, altitude); classification by species group. Birdtrack software claims to track and classify targets.
- Validation Results: Has been deployed at various wind farms on and offshore; no published results were found
- TRL Range: Mid/High

DHI Bird Detection System w/ Scanter 5000 - *Terma/DHI*

- Components: Solid State Radar + DHI Bird Tracking Software
- Advertised Capabilities: Flexible frequency selection, enhanced capacity to suppress interference/clutter from slow moving/stationary objects.
- Validation Results: Skov *et. al* 2018 – Thanet Offshore Wind Farm (UK). Required pairing with a human-operated range-finder to verify targets.
- TRL Range: Mid/High (depending on application)

DHI Bird Detection System w/ LWAR 25 - *DHI*

- Components: Fan beam and magnetron-based radar
- Advertised Capabilities: Vertical and horizontal positioning. Coupled with bespoke software for signal processing (bird tracking)
- Validation Results: Skov *et. al* 2018 - Thanet Offshore Wind Farm (UK). Required pairing with a human-operated range-finder to verify targets.
- TRL Range: Mid/High (depending on application)