REWI

Renewable Energy Wildlife Institute

2025 REWI Technology Catalog Portfolio

WILDLIFE RISK MINIMIZATION TECHNOLOGIES
U.S. AND INTERNATIONAL

Renewable Energy Wildlife Institute
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Disclaimer

Inclusion of any technology in this Catalog does not constitute endorsement by REWI or its Partner & Friend organizations. REWI makes no guarantees as to the effectiveness of any technology and presents the content within for informational purposes only. All information in this Catalog has been provided by the technology vendors or manufacturers, and not all requested information may be completed for each technology. Some information in this document may be summarized or condensed for the sake of clarity. Updates to existing technologies and submissions of new technologies are accepted on a rolling basis.

Technology Readiness Level (TRL) is a metric used for describing technology maturity, used by many U.S. government agencies of evolving technologies prior to incorporating that technology into a system or subsystem. ***TRLs for all technologies featured are assigned by the vendor or manufacturer of the technology in the request for information form submitted to the Technology Catalog. The TRL and its justification do not constitute REWI's assessment of this technology.***

Note to Contributors

"Thank you for your continued participation in REWI's science-based and collaborative approach to addressing wildlife concerns at renewable energy facilities. We aim to create connections between technology firms, researchers, and utility-scale renewable energy owners so that technologies can be tested in the field and be applied with confidence. Please be sure to share any new publications or success stories for your technologies in the upcoming year so that we can keep the Technology Catalog up to date and possibly feature your work across REWI communications platforms. Also don't hesitate to let us know how the Technology Catalog is helpful to you and ways we can improve future editions."

— Ryan Butryn, REWI Senior Information Science Manager

About The REWI Technology Catalog

The REWI Technology Catalog was established in 2016 following the REWI Innovative Technologies Workshop, where participants from the renewable energy and wildlife science community identified the need for a catalog of wildlife deterrence and detection technologies. Since then, REWI has been uniquely positioned to catalog these technologies and has also received funding from the U.S. Department of Energy (DOE) to conduct several field-based technology effectiveness studies.

Currently, the REWI Technology Catalog has been designed to serve as a reference for parties interested in learning about, developing, testing, and using technologies intended to minimize impacts of operating wind and solar energy facilities on wildlife. The Technology Catalog is a resource for those looking to learn about or work with innovative technologies.

The REWI Technology Catalog serves three types of users:

Technology Contributors (Vendors)	Partners & Friends*	General Public*
✓ Submit New Technology Request for Information Form (RFI) ✓ Edit and Update Previous Technology Entries ✓ Search Technologies and View Technology Profiles** ✓Annual Access to a Portfolio with Full RFIs from Technology Contributors (January)	✓Search Technologies and View Technology Profiles** ✓ Early Access to a Portfolio with Full RFIs from Technology Contributors (October)	✓ Search Technologies and View Technology Profiles** ✓ Search Technologies and View Technology Profiles**

*Partners, Friends, or the General Public can become Technology Contributors or General Users, by making an Account on the Research Hub whereby they can access additional features and/or complete a Request for Information form for the Technology Catalog. If no account is created, users are limited to General Public view and features only.

**Technology Profiles are a one-page snapshot of a Technology and do not include information about testing, efficacy, or installation of a specific technology.

The application of the Technology Catalog is wide-ranging. Users, such as owners and operators, may find site-specific solutions, regulators may identify mitigation options, and researchers might select technologies to conduct validation studies. The Technology Catalog accepts submissions from both domestic and international sources that apply to land-based and offshore wind, solar, and transmission. These technologies include a wide range of capabilities including remote monitoring, artificial intelligence (AI), advanced imaging, radar, and photographic trackers.

The 2025 REWI Technology Catalog Portfolio includes 61 unique technologies from United States and International Vendors. Changes since the 2024 edition include 10 new technologies and updates to existing technologies.

For questions or more information on the REWI Technology Catalog, reach out to REWI Senior Information Science Manager Ryan Butryn (rbutryn@rewi.org) or Project Manager La' Portia Perkins (lperkins@rewi.org).

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MONITORING TECHNOLOGIES

ACCIPITER® AVIAN RADAR SYSTEM | TRL 9

Updated September 2024

Company	Accipiter Radar Corporation
Website	www.accipiterradar.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Birds Raptors Bats
Technology Components	Detection component, Deterrent component
Description & Application	The Accipiter system combines advanced radar tracking leading to intelligent automation of wide-ranging deterrent types that are triggered based on target movement behavior and bird-strike / threat trajectories. Advanced digital avian radar systems with state-of-the-art clutter suppression and tracking algorithms that can track hundreds of flying vertebrate targets in 3D in high clutter environments, 24/7/365 in real-time, with automated alerting and device activation and advanced real-time and historical data analytics. Water in an animal's tissue is the primary reflector of microwave energy, and thus the reflected energy is an indirect measure of the target's biomass. Accipiter® Avian Radar Systems typically employ a commercial X-band marine radar outfitted with a custom Agile parabolic dish antenna with a 4° beam that can incrementally slewed from 0°-90° in elevation angle while rotating through 360° of azimuth in our Total Coverage™ configuration. The returned analog waveform is digitized by a radar processor that implements adaptive clutter mapping algorithms to dynamically remove returns from ground clutter, volume clutter (e.g., light-moderate rain), multi-path (returns from large reflectors, like wind turbines), and side-lobes off the main radar beam. This, and the short (3 cm) wavelength of an X-band radar enables detection and tracking of targets ranging in size from small passerines & bats to large raptors. Accipiter employs the military gold standard MHT/IMM tracking algorithms to generate true 3D trajectories for all targets which are stored in real-time in

	an industry-standard, open-source relational database, and from here the data can be distributed across local or wide-area networks to multiple end-user displays, used to activate alerts based on target data associated by Boolean logic, or for historical analysis of spatial and temporal patterns. While radar cannot identify biological targets to species, processor analytics can classify them into guilds based on their size, speed, and flight behaviors. Radar is the best surveillance sensor on the market, and Accipiter's advanced analytics to turn that Surveillance-2-Intelligence™ (S2I) for both real-time and historical applications, using its patented M3 Target Information System from detections that appear above a selectable threshold level, updating each target's position, size, speed, and heading every ~2.5 seconds. Because the radar processor computes true 3D trajectories, it can "coast" targets that disappear behind an obstruction (e.g., turbine or ridge line) for several rotations of the radar and pick them up when they come out the other side - without generating a specious new track ID.
Mechanism(s) by which the Technology Operates	Radar
Monitoring or Minimizing	Both
Detect and/or Deter Non-Target Species	Radar cannot identify targets to species, but radar processors can classify them into "guilds" based on their size, speed, flight behavior, etc. Other sensors can be deployed to identify species such as cameras.
Avoidance of False Positives and False Negatives	The Accipiter® Digital Radar Processor can distinguish birds based on size, speed, heading, etc. It can make those determinations over far greater distances and under a greater range of environmental conditions than any other sensor on the market. Surveillance radars cannot distinguish a Bald Eagle from a Golden Eagle.
Effective Range	Detection range depends on the size of the target. Accipiter® Avian Radars can routinely detect sparrow-sized birds at a range of 1-1.5 nautical miles, and eagle-sized birds at a range of 5-6 nmi.
Timeline of Production	The first commercial avian radar system was delivered in 2007.
Product Manufacturing	Buffalo, New York, USA and Ontario, Canada
Tech Support	Fenwick, Ontario, Canada
TRL Justification	Accipiter® Avian Radar Systems have undergone extensive field validation studies by independent investigators and have been installed and operated in a variety of environments, including wind farms, civil and military airfields, and mining operations.
Efficacy Testing	Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Facility Outside of Wind (e.g., airport,

	agriculture, other energy resources, etc.), Field Testing at a Commercial Wind Facility, Other energy resources
Planned or Underway Testing	Yes, but this is proprietary information.
Safety or Public Nuisance Issues	Minimal. Radar emits microwave frequency radiation, which can have adverse health effects on humans in close proximity. These hazards are well-known, well-understood, and easily moderated. Moreover, the commercial radars Accipiter utilizes must comply with Federal safety standards and are typically marine radar sensors that are used on small boats to large ships, as well as on land. Operationally, maintaining a zone with a radius of >10m from a transmitting 25kW marine radar reduces the hazard to personnel to below the Federal exposure limits.
Testing with Direct or Indirect Regulatory Agency Engagement	The marine radars Accipiter uses have been type-certified by the US Federal Communications Commission (FCC) and individual radars must be licensed by the FCC to operate at a specific location.
Commercial Deployment	Due to confidentiality, we cannot disclose specifics, but this technology has been deployed many times.
Installation and Operation Components	Tower-mounted, Interface with SCADA System, Requires Internet for Data Upload/Back Up, Requires Power Source, Ongoing Operation and/or Data Management with Technology Vendor, Cell Service Access
Installation and Setup	An avian radar system includes a number of components, which can be mounted on a trailer (flatbed or enclosed) for siting evaluations, or if mobility is required, or can be affixed to a concrete pad for permanent installations. While the system can be powered by a diesel generator, access to a stable, 220VAC 60W circuit is recommended. Communications can be wired (fiber optic or coax) or wireless (directional Wi-Fi or 3G/4G cellular data). The location of the radar is based on a field evaluation of factors such as the size of the area to be covered, topography, access to shore power and communications, and clutter sources. Nothing needs to be affixed to the turbine, although Accipiter often mounts radars on towers for some applications (e.g., homeland security). For tracking birds & bats, it is generally better to have the radar on the ground looking up, rather than elevated and looking down.
Timeline for Installation and Operation	Typically, 90-120 days from date of order.
Coordination with Facility for Installation and Operation	The facility owner/operator typically installs the concrete pad (if necessary) on which the radar is mounted and provides power & communications to the radar.
Coordination with turbine manufacturers or OEMs for	None. Should automatically curtailing of the turbines be required, then a SCADA format/interface can be provided.

Installation and Operation	
Other Products Required for Installation	The radar is delivered with a Tracker workstation for the radar operator, and typically includes one or more user workstations, either mobile or desktop. Optional hardware and software for data storage, analysis, visualization, etc. are available.
Potential Interference with other Technologies	No. The radar transceivers Accipiter uses are certified by the FCC and Accipiter® Radar Systems have been thoroughly tested for interference with other electronic equipment by the FAA at their Oklahoma City Test Center and numerous military airfields. Any X-band radar operated on land must have an operating license issued by the FCC.
Operational Limitations	None Anticipated. Accipiter® radar systems have been operated in the harsh conditions of Alberta, Canada, and along the southern border of the United States. Radar performance is degraded by heavy precipitation, but birds typically are not flying under those conditions anyway.
Continued Costs Required (Contracts, Maintenance or Licensing Fees)	Confidential continued costs. Ongoing involvement is not required but recommended. Accipiter technicians can monitor the radars' performance remotely, often diagnosing, and correcting issues before the customer is even aware of them. The technicians can also perform radar tuning, preventive maintenance, and install software updates remotely.
Remotely Monitored or Near Real-Time Status & Operation	Yes
Utility Scale Units Sold or Installed	Contact Company for Specific Numbers
Expected Lifespan	Accipiter has avian radar systems that have been, except for brief periods, in continuous operation in the field for 17 years.
Warranty	Warranty coverage is customized to meet the customer's requirements and can be set from 1 year, 3 years, 5 years as required based on maintenance package included.
Extended Warranty	Yes, as required.
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://www.accipiterradar.com/resATOMources/collateral-material/
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ACOUSTIC AND THERMOGRAPHIC OFFSHORE MONITORING (ATOM) | TRL 9

Updated January 2025

Company	Normandeau Associates, Inc.
Website	https://www.normandeau.com/environmental-specialists-consultant-atom-technology
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors Bats
Additional Species	Passerines (Songbirds), Migratory Tree Roosting Bats, Cave-dwelling bats
Technology Components	Detection component, Collisions detected if observed in camera field of view
Description & Application	ATOM provides around-the-clock, all-weather monitoring of the rotor swept zone (RSZ) using a multi-sensor array to detect, track, identify, and behaviorally classify bats and birds interacting with the turbine. ATOM's ability to detect and document insects adds a layer of biologically relevant data that provides new knowledge and further understanding of drivers of bat and bird activity at onshore or offshore wind facilities. ATOM's acoustic detectors can identify bats and birds regardless of the time of day and weather. Visible-light HD imaging provides further identification capacity during light hours, and thermal imaging provides 24-hour and foggy conditions detection. Motus antennae detect tagged animals (birds and possibly bats). Advanced AI tools provide preliminary data analysis (target acquisition, tracking, and initial classification). Normandeau's wildlife experts perform high-resolution analysis (e.g., species ID, behavioral classification, blade interaction context, etc.) and produce detailed reports. ATOM is commercially deployed

	offshore and has weathered a hurricane unscathed proving its robustness. Its design and performance have been validated in peer-reviewed studies as have the results of its deployment. ATOM provides the developer with an accurate tool to monitor turbine-wildlife interactions to meet regulatory requirements, and provides the regulator with high-quality biological information, thus helping both achieve profitable wind energy production while reducing its environmental impact.
Mechanism(s) by which the Technology Operates	Video, Ultrasonic Acoustic Monitor, GPS/VHF Radio Transmitters, Infrared/Thermal Imaging Cameras, Acoustic Monitor (Audible Sound)
Monitoring or Minimizing	Monitoring
Detect and/or Deter Target Species	Not applicable. This system is capable of detecting all birds and bats depending on their position in the RSZ (not hidden behind infrastructure) and distance from the system.
Avoidance of False Positive and False Negatives	There is an image analysis algorithm that is designed to filter out blade detection from the video. There are also acoustic filters that remove turbine and ocean noise to the extent possible. Manual vetting avoids false positives; ATOM includes redundancies – both within sensor types (e.g., two bat recorders), and between sensor types (e.g., bats are recorded acoustically, via thermal imaging, and HD videography) – thus reducing the chances of false negatives due to equipment malfunctions or sensor limitations.
Effective Range	One turbine; however, detection ability declines as the targets are further from the system.
Timeline of Production	This product has been in production for 10 years.
Product Manufacturing	Florida
Tech Support	Florida
TRL Justification	The ATOM system completed a three-year commercial deployment at the Coastal Virginia Offshore Wind Pilot Project.
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility
Planned or Underway Testing	Normandeau is in the process of testing new configurations to improve detection capabilities and AI analysis tools. Normandeau is also planning a biological calibration test to compare collision detected by ATOM to carcasses found on the ground. Additional camera configurations are being considered to be installed on the nacelle to improve collision detection.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	Yes, the original research and testing of the system from 2011 and 2013 was funded and reviewed by BOEM.
Commercial Deployment	Yes, since March 2021.

Installation and Operation Components	Nacelle-mounted, Free-standing, Requires Internet, Requires Power Source, Ongoing Operation and/or Data Management with Technology Vendor, Commercially available Detectors, IP-65
Installation and Setup	ATOM system components are assembled and tested in Normandeau's workshop. The system is mounted on the turbine platform. Custom mounts are designed per turbine features and measurements, with coordination with the developer and the manufacturer to ensure secure and durable mounting. In most cases installation will involve facility personnel. System assembly generally takes two weeks, and installation is about one day per turbine.
Timeline for Installation and Operation	Approximately 6 months. Ready platform availability and understanding how the system will be transported to the platform will speed up the process.
Coordination with Facility for Installation and Operation	Installation generally requires facility staff active involvement (one technician). If the facility is an offshore facility an appropriate vessel is necessary as well. Day-to-day operation does not require any facility owner or operator coordination. If high speed fiber internet is available, data can be transmitted via the internet and minimal interaction with the systems is required. If high-speed internet is not available, manual data retrieval trips are required every 4-6 months require coordination, and in offshore facilities – a vessel.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Minimal coordination with manufacturers: detailed measurements and plans of the nacelle to design custom-made mounts, and information regarding safe locations on the nacelle to mount the system. This can be coordinated with operator instead of OEM.
Other Products Required for Installation	The ATOM field equipment is custom-built and supplied when the service is purchased. It is a custom system but self-contained and designed to work independently.
Potential Interference with other Technologies	No
Operational Limitations	ATOM is designed to operate 24/7. Since the ATOM system is typically installed near the wind turbines where it can be very windy, the wind loading of the main box and solar panels (if power is not provided by the associated turbine) does require that ATOM be securely attached to the platform.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Varies by installation details, number of ATOM systems, and contract duration. We monitor the systems on a 24/7 basis and receive alerts if the system is not operating properly. ATOM is a service rather than a product. Normandeau provides both maintenance for the physical system, and results analysis and reporting. Results are uploaded to Normandeau's secure

	ReMOTe data portal and analysis tool. Access can be public or restricted, as per client requirements.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	Typically, we decommission and service the units after the field season before putting them out for a subsequent field season. This ensures optimal reliability and operation. Based on three years of offshore deployment, we assess component lifespan as follows: Motherboard and other internal electronics: ~10 years. Thermal and HD sensors: ~10 years. Acoustic recorders: 3-6 years. Microphones: 1-3 years.
Warranty	This is dependent on the ATOM services contract, which extends for the life of the installation.
Peer-Reviewed Literature	Yes, we have peer-reviewed research available. https://doi.org/10.1007/s13280-015-0707-z https://doi.org/10.1088/1742-6596/2507/1/012006
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AERIAL DIGITAL SURVEYS (ADS) | TRL 9

Updated January 2025

Company	Normandeau Associates, Inc.
Website	http://www.normandeau.com
Target Renewable Energy	Solar, Land-Based Wind, Offshore, Transmission
Target Species	Other marine/aquatic animals Eagles Birds Raptors Marine Mammals
Additional Species	Fish Schools, Large Bony Fish, Rays, Sharks, Turtles
Technology Components	Detection component
Description & Application	Aerial digital imagery to photograph animals visible from the air over the ocean. Imagery provides identification, flight height, flight speed, and accurate effort and detection values.
Mechanism(s) by which the Technology Operates	Photographs
Monitoring or Minimizing	Monitoring
Avoidance of False Positive & False Negatives	Human reviewers manually QA/QC identifications
Effective Range	Entire facility, if desired.
Timeline of Production	This product has been in production for approximately 10 years.
Product Manufacturing	It is a service not a product. Normandeau has two teams available.
Tech Support	Gainesville, Florida
TRL Justification	It has been used commercially in multiple applications.
Commercial Deployment	Yes, it is used regularly in the US and Europe as a way to survey wildlife.
Submission Contact	Julia Robinson Willmott | Phone: (352)-327-3262 | Email: jwillmott@normandeau.com | Address: 4581 NW 6th Street, Suite H | Gainesville, FL 32609

AUTONOMOUS AVIAN GEOFENCE ALERT SYSTEM | TRL 9

Updated September 2024

Company	Cellular Tracking Technologies San Diego Zoo Global/Institute for Conservation Research
Website	https://institute.sandiegozoo.org/
Target Renewable Energy	Land-Based Wind
Target Species	Eagles Birds Raptors
Additional Species	Customizable for specific bird species, Whooping crane, Condors
Technology Components	Detection component, Collision detection component
Description & Application	This is an autonomous alert system that successfully miniaturizes and integrates virtual geofence capability into solar-powered biotelemetry devices used to track species of large birds currently impacted by wind farms, such as cranes and raptors. These units combine a GPS receiver with a GSM communications system that transmits acquired high-resolution location data via cellular networks in near real-time. Custom-sized geofences can be placed around wind farms. When a telemetered bird ingresses one of these virtual boundaries the GPS location fix rate decreases from 15-min to 30-sec and an SMS alert is automatically transmitted to a user group within 2-min. When the bird egresses the geofence zone, a second alert is sent, and the fixed rate returns to 15 minutes to conserve transmitter energy and data acquisition costs. Combining GPS level accuracy, a high fixed sampling rate, location data received in near real-time, and automated SMS alerts into an integrated, flexible, and cost-effective geofence biotelemetry system will provide conservation managers and wind farm operators with sufficient warning and time to implement mitigative actions to curtail avian collision fatalities. A series of concentric virtual geofence boundaries is installed around a wind farm by the operator. These

	boundaries exist only on a remote server. If a bird that has been telemetered with a geofence GSM/GPS tag ingresses the geofence zone, an SMS alert will be automatically sent to a predetermined secure user group. The geofence zones should be spaced around the wind farm at sufficient distances to provide time for the wind farm operators to take appropriate action to minimize collision risk (i.e., shut down the turbines). The GPS fix rate collected by the tag will increase from 15 minutes to 30 seconds so that the bird can be monitored in near real-time. When the bird egresses the geofence zone, a second SMS alert will be sent, and the GPS fix rate returns to 15 minutes to conserve energy and data. The dimensions of the geofence can be altered after the units have been deployed, and additional new geofences can also be installed. A video demonstrating this system can be viewed here: http://youtu.be/2oWodZpmbHo
Mechanism(s) by which the Technology Operates	GPS/VHF Radio Transmitters
Detect and/or Deter Target Species	The system will only work on birds that have been captured and telemetered with the GSM/GPS tags.
Avoidance of False Positives and False Negatives	Each geofence tag is fitted to a specific bird and can be identified via its factory ID number.
Effective Range	The system will operate anyway on earth that has cellular network coverage.
Timeline of Production	This product has been in production for 5 years.
Product Manufacturing	All geofence tags are manufactured by Cellular Tracking Technologies, LLC: http://celltracktech.com
TRL Justification	Our exhaustive in situ field trials have repeatedly demonstrated the efficacy of the system and it is currently installed around at least 2 wind farms.
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility
Planned or Underway Testing	No
Safety or Public Nuisance Issues	No
Testing and Direct or Indirect Regulatory Agency Engagement	The system in integrated into the biotelemetry tags currently used to track condors and eagles that have been approved by USFWS.
Commercial Deployment	We have deployed 20 geofence transmitters on free-ranging California condors in northern Baja, Mexico. A version of the system has been integrated into the Tehachapi Wind Resource Area by Alta Environmental Services.

Installation and Operation Components	Ongoing Operation and/or Data Management with Technology Vendor
Installation and Setup	The user provides the geofence boundaries as GIS layers to CTT, who then program them in to their operating system. The boundaries are 100% virtual - there is no physical infrastructure involved beyond the GPS tags attached to the birds.
Timeline for Installation and Operation	This can take 2-3 months for delivery of the tags.
Coordination with Facility for Installation and Operation	The owner/operator must have a contact number added to the user list that receives the SMS alerts so that they can take collision avoidance actions in sufficient time if a telemetered bird flies in proximity of the wind farm.
Other Products Required for Installation	Only the geofence tags and a data plan need to be purchased from CTT.
Potential Interference with other Technologies	No
Operational Limitations	The GSM/GPS tags need sufficient cellular coverage to transmit location data and because the tags are solar-powered they operate only during the day (with a few hours overlap with night).
Continued Costs Required (Contracts, Maintenance or Licensing Fees)	A $300 data plan per tag per annum and regular maintenance of the client data access program.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Expected Lifespan	Solar-power means the geofence tags can be deployed for >5 years before replacement.
Warranty	Standard customer warranty covering defective parts.
Extended Warranty	No
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BATmode | TRL 9

Updated Fall 2023

Company	BioAcoustic Technology
Website	http://www.bioacoustictechnology.de/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Additional Species	Customizable for specific bat species, Migratory Tree Roosting Bats, Cave-dwelling bats
Technology Components	Detection component, Curtailment component
Description & Application	The BATmode System allows a calibrated long-term acoustic monitoring of bat activity on wind turbines. The system is specially designed for an easy and standardized installation in wind turbines and provides various ways of remote access and data download (GSM, LTE, WIFI, Remote Desktop Connection, etc.). Curtailment algorithms can be calculated with the free PROBAT tool which is required by law in Germany. The specialized BATmode-System allows a cost-efficient precise acoustic monitoring of bat activity at wind turbines. The system provides the possibility for an accurate calibration and therefore has a definite and large detection volume. This feature (among other features) makes this system highly suitable for collecting acoustic activity data, which is later used to calculate site-specific bat-friendly shutdown times, according to methods, which are already mandatory in some German federal states. PC-based bat detector specifically designed for an application at the nacelles of wind turbines.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, Weather/Environment Sensors (wind, precipitation, etc.)
Monitoring or Minimizing	Both
Detect and/or Deter Non-Target Species	No
Avoidance of False Positives and False Negatives	The BATmode includes an efficient real-time bat call filter, which allows us to separate between acoustic noise and bat calls based on frequency range, call curvature, etc. Furthermore, a real-time AI bat call detector is applied as the second filter stage to increase accuracy and allow species identification.
Effective Range	Approximately 20 - 75m, depending on bat species.

Timeline of Production	This technology has been in production since 2015.
Product Manufacturing	Germany
Tech Support	Germany
TRL Justification	Over 500 devices are currently used to determine bat activity and calculate curtailment algorithms in the whole of Europe.
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	Several pilot studies to assess the potential with respect to real-time curtailment.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	The BATmode system is currently used in over 200 onshore wind turbines mainly in Germany and France. The systems are used by biological experts to calculate bat-friendly curtailment algorithms.
Installation and Operation Components	Nacelle-mounted, Tower-mounted, Requires Internet for Data Upload/Back Up, Requires Power Source, Cell Service Access, Commercially available Detectors
Installation and Setup	For bat monitoring at nacelle height, the microphone is installed in a 100mm hole in the floor of the nacelle facing towards the ground. Moreover, microphones can also be mounted on tower walls with magnetic brackets or in 21mm holes. The detector itself is mounted in a small optional available steel-made cabinet, the so-called BATbox. So, the system can be installed in every type of wind turbine. A 230V AC power supply has to be provided by the turbine. For remote access, GSM/LTE or network access is required at the installation site.
Timeline for Installation and Operation	The system has to be installed over a time period of two years in times when bat activity is high (e.g., 01.03. - 31.10). After this curtailment algorithms can be calculated and implemented in the turbine control. This needs no further bat activity monitoring.
Coordination with Facility for Installation and Operation	The facility owner has to provide a service team for installation and deinstallation of the BATmode system. Furthermore, the subsequent implementation of the curtailment algorithm has to be done by the operator of the turbine.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Due to wireless remote access and data transmission, unique access to the nacelle of the wind turbine has to be granted to install the BATmode. Since the System is quite small it can be integrated into all types of wind power plants.
Other Products Required for Installation	A PC, Tablet, or Smartphone is needed for parameterization and remote control of BATmode.

Potential Interference with Other Technologies	No
Operational Limitations	No. Since the microphone is equipped with a small heating unit constant acquisition conditions can be ensured, and environmental influences are minimized.
Continued Costs Required (Contracts, Maintenance or Licensing Fees)	Besides costs for telecommunication (the system sends daily short messages about its status) there are no continued costs since full remote parameterization and wireless data transfer ensure minimal on-site maintenance. Annual recalibration of the microphones should be considered.
Remotely Monitored or Near Real-Time Status & Operation	Yes
Number of Utility Scale Units Sold or Installed	100-1000
Warranty	The standard warranty is one year excluding microphones.
Extended Warranty	No
Submission Contact	bat bioacoustictechnology GmbH | Address: Brunngasse 1,90610 Winkelhaid, Germany | Phone: 0049 (0) 9187 956519 | Email: info@bioacoustictechnology.de
Technical Contact	Thomas Scharrer | Phone: 0049 (0) 9187 956519 | Email: thomas.scharrer@bioacoustictechnology.de

B-FINDER | TRL 9

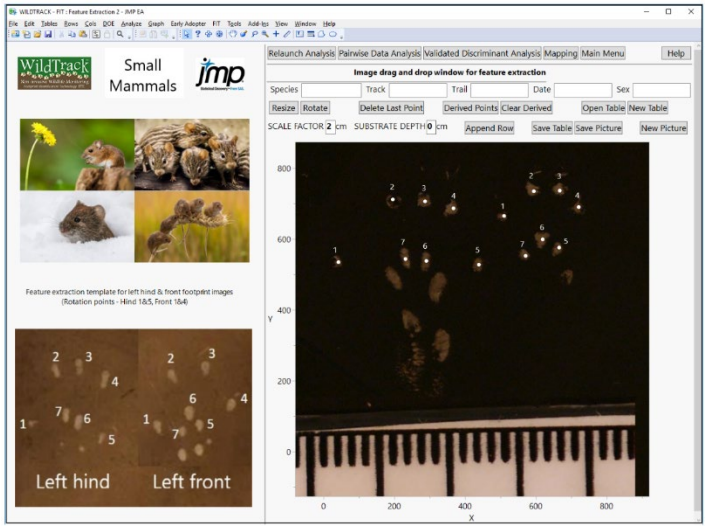
B-FINDER

Updated September 2024

Company	Empeka S.A.
Website	https://b-finder.eu
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors Bats
Additional Species	Customizable for specific bat species. Customizable for specific bird species, Migratory Tree Roosting Bats, Whooping crane, Condors, Passerines (Songbirds)
Technology Components	Detection component, Collision detection component, Location of the Carcass
Description & Application	B-Finder offers increased precision and resolution through automatic monitoring of both bat and bird mortality at wind farms to better tailor minimization and mitigation strategies.
Mechanism for Operation	Video, Infrared/Thermal Imaging Cameras
Monitoring or Minimizing	Monitoring
Detect and/or Deter Non-Target Species	B-finder system detects collisions of all bats and all birds species.
Avoidance of False Positives and False Negatives	Algorithms and human analytics are possible for every event.
Effective Range	Up to 50 m from the wind tower for bats and small birds and up to +100m for big birds. The range and efficiency can change depending on weather conditions.
Timeline of Production	This technology has been in production since Fall 2023.
Product Manufacturing	Poland and U.S. manufacturing in progress
Tech Support	Poland and U.S. manufacturing in progress
TRL Justification	B-finder system is commercially ready after 3 years-long test of the prototype in real conditions.
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility

Planned or Underway Testing	Publication of results https://b-finder.eu/rd-report-for-b-finder-t-series/
Testing with Direct or Indirect Regulatory Agency Engagement	Regulatory agency can test B-finder system directly. More details about the test procedure: https://b-finder.eu/test-drive/
Commercial Deployment	The product has been commercially ready since September 2019, after 3 years-long prototype test in real conditions.
Installation and Operation Components	Tower-mounted, Requires Internet, Requires Power Source, Ongoing Operation, and/or Data Management with Technology Vendor
Installation and Setup	External sensors are mounted on the wind tower using magnets. Internal or external computer box needs power and internet access.
Timeline for Installation and Operation	Installation - ca. 3 working days. Calibration - few hours.
Coordination with Facility for Installation and Operation	Installation: access to a wind turbine, external lift, free place for computer box inside the tower or outside the tower with power supply. Operation: access to power, access to computer box for service, access to wind tower for sensors service if needed. Service access schedule according to contract.
Other Products Required for Installation	B-finder is a complete system.
Potential Interference with Other Technologies	No. We are using passive sensors.
Operational Limitations	Some weather conditions (for example: very intensive rain, snow, fog, or extremely high air temperature) can affect the detection range.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	It depends on the model, number of contracted units, and duration of the contract.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Expected Lifespan	Up to 10-years if serviced.
Warranty	Yes. Contact the company for more information.
Extended Warranty	Yes. Contact the company for more information.
Submission Contact	EMPEKO S.A. B-finder Team | Phone: +48730739737 | Email: info@b-finder.eu | Address: ul.Mleczowa 3A,61-680 Poznań, Poland

FOOTPRINT IDENTIFICATION TECHNOLOGY (FIT) | TRL 9



Updated January 2024

Company	WildTrack Inc.
Website	http://www.wildtrack.org/
Target Renewable Energy	Solar, Land-Based Wind, Transmission
Target Species	Turtles Tortoises Reptiles and Amphibians Mammals Other Wildlife Species Big Game
Additional Species	Any species that leaves a footprint that can be collected on land
Technology Components	Detection component, Other, Survey for Remote Construction Monitoring, Integrates with deterrent system, Deterrent component
Description & Application	The Footprint Identification Technology is a tool to identify wildlife species from their footprints either in natural substrate or from footprints left on track plates. The technology can identify the species, individuals, sex, and age-class of the animals that left the footprints. It uses both morphometrics and Artificial Intelligence. Using this data, it is possible to identify the numbers and distribution of species that might be impacted by energy installations, both before, during and after installation. Data collection is streamlined with an app (free on iOS or Android) and requires only basic training making it accessible for citizen scientists as well as professionals in the energy or biodiversity fields.
Mechanism(s) by which the Technology Operates	Photographs, Software
Monitoring or Minimizing	Monitoring: FIT can monitor the numbers and distribution of species of interest at the site of interest using footprint

	identification. Because data are easy and cheap to collect it can inform frequently on the success of techniques designed to minimize interaction for those species.
Detect and/or Deter Non-Target Species	Footprints collected at the site can inform the number and distribution of both target and non-target species.
Avoidance of False Positives and False Negatives	The technology has high accuracy in identifying both species and individuals. We use statistical holdback trials to identify the risk of false positives and false negatives.
Effective Range	The range is limited only by the ground area that can be surveyed by operatives with smartphones and the app
Timeline of Production	This technology has been in production for 10 years.
Product Manufacturing	North Carolina, USA
Tech Support	Global
TRL Justification	We have field projects on 5 continents using this technology for wildlife conservation and have published it widely in peer-reviewed journals but have not tested it in the EWRI community yet.
Efficacy Testing	Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.)
Planned or Underway Testing	We are constantly developing FIT. In 2024 we will be building stronger user interfaces for our web platform and mobile app, refining our AI platform, and rolling out the technology to many new projects. The technology can also be used as a rapid cost-effective metric for biodiversity monitoring in the Environmental Impact industry.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	Not yet WildTrack Inc. is a non-profit, but we are open to commercial development of this technology through an emerging for-profit entity.
Installation and Operation Components	Other (Please specify)
Installation and Setup	Data collection requires only a smartphone with the app, and metric scale to collect footprints from natural substrate at the site. Alternatively track-plates can be used to collect footprints where the substrate is not suitable. The app can record data online or offline and then upload back at base. Data processing is a service that can be offered by WildTrack.
Timeline for Installation and Operation	As every site and request is different, we operate to customize each request for assistance. Please contact zoe@wildtrack.org

Coordination with Facility for Installation and Operation	We provide training to use the product and assistance with data processing at whatever level is required.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	No installation is needed.
Other Products Required for Installation	None
Potential Interference with Other Technologies	Unlikely
Operational Limitations	The technology will only work where footprints can be collected, but in our experience this includes the majority of field sites.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	No
Remotely Monitored or Near Real-Time Status and Operation	Variable
Utility Scale Units Sold or Installed	Unrelated
Expected Lifespan	Unrelated
Warranty	Not yet
Extended Warranty	Not yet
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://www.wildtrack.org/our-work/publications
Submission Contact	Zoe Jewell, CEO | Phone: 919-345-3690 | Email: zoe@wildtrack.org | Address: PO Box 90328 Duke University Durham, NC 27708

MAX® FULL 3D BIRD MONITORING RADAR | TRL 9

Updated September 2024

Company	Robin Radar
Website	www.robinradar.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors Bats
Additional Species	All birds including Migratory Tree Roosting Bats, Whooping crane, Condors, Passerines (Songbirds), Cave-dwelling bats
Technology Components	Detection component, Deterrent component, Curtailment component, Integrates with deterrent system, Integrates with turbine controls for curtailment
Description & Application	MAX® is Robin's flagship bird radar. It took four years, millions of Euros, and thousands of coffees to develop. The result is mind-blowing. We quite simply had no other choice but to call it MAX®. MAX® has 360-degree coverage with 60rpm, resulting in track updates every second. This allows uniquely detailed 3D visualization of bird flight paths in real time. MAX® is a single-sensor system, providing full 3D information of all birds in range of the radar. Height information is provided for all bird tracks, and there is practically no cone of silence above the radar. Our flagship bird radar offers true and full 3D coverage, meaning you get height data for ALL bird tracks, all around the radar, all of the time. MAX® has been built to monitor birds from the start. That is its entire purpose. The antennas are designed explicitly with avian targets in mind. It finally brings phased array radar technology into the hands of bird control units and ornithologists. Users of MAX® include civil airports, air force bases, and windfarms, as well as environmental consultants and researchers. Simply put, if you need to detect, track, and monitor birds over wide areas, you are going to love MAX®.

	Bird movements are displayed in real-time on a computer or mobile device (including both iOS and Android). And MAX® comes with both computer-based software and our new web application, Bird Viewer, to control the radar and view the output. The MAX® radar transmits energy that reflects on objects around it. These reflections are received as echoes and filtered to distinguish birds from clutter. Highly sophisticated tracking algorithms combine echoes from the same birds and display them as tracks. The result is a real-time image of individual birds moving including their speed, exact location, height, and flight path in full 3D. Color coding is used to distinguish small, medium, and large birds & flocks. All data is logged in a geospatial (GIS) database including timestamp and weather information. Tools and training are provided to analyze these data and generate professional representations. MAX® is based on phased array technology and is able to cover an area of 300 km^2.
Mechanism(s) by which the Technology Operates	Radar, precipitation, Infrared/Thermal Imaging Cameras, Weather/Environmental Sensors (wind
Monitoring or Minimizing	Monitoring
Detect and/or Deter Non-Target Species	No. But we can also track drones with the MAX® radar.
Avoidance of False Positives and False Negatives	The essence of the system is in its unique filter and tracking algorithms. It filters out any object that is not a bird or bat to prevent false positives. False negatives do happen when a bird is flying behind an object, for example. The system software provided also allows for optimizing the setup per customer / project.
Effective Range	MAX® is a one sensor only Phased Array radar it has full 3D capability up to 10 km range easily covering an area of > 300 km^2.
Timeline of Production	Development of the technology started in the 1980s when Dutch Research institute TNO and the European Space Agency (ESA) first developed algorithms to use existing air defense radars to detect birds. In 2010 the technology was made commercially available by pursuing market leadership as an independent company. The first systems were installed in 2011. The MAX® has been officially launched in 2017.
Product Manufacturing	In The Hague, The Netherlands
Tech Support	In The Hague, The Netherlands
TRL Justification	TRL9. Over 30 MAX® systems have been sold, and half of these are operational at airports and wind farms (onshore and offshore)
Efficacy Testing	Lab Testing, Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Facility

	Outside of Wind (e.g. airport, agriculture, other energy resources, etc.) , Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate, Other energy resources
Planned or Underway Testing	Yes, but not public. Part of Robin's continuous improvement efforts.
Safety or Public Nuisance Issues	There are two recommended precautions that must be recorded in protocols: 1) When working near the antenna's (less than 2,5 meters) the radars should be completely shut, especially because of the mechanical danger of rotating parts. 2) When working for a longer period of time (>4 hours) within 0 to 15 meters to the radar (see figure) the emergency/maintenance switch should be used to completely shut down the radar system. The effect of radar radiation on humans is analyzed in detail by ICNIRP (International Commission of Non-Ionizing Radiation Protection). The radiation is measured by the amount of heating which a radar system eventually causes in water at a certain distance from the radar. The unit used here is W/m2. In this statement, the ICNIRP guidelines are applied (max 50W/m2 measured over 20cm2 and max 1000W/m2 measured over 1cm2). The radar supplier guidelines show values equal and below the ICNIRP guidelines. Values above the 10W/m2 are regarded as undesirable at prolonged exposure. As an example, the radiation within a short distance of a household microwave is 50W/m2. Although the 10W/m2 point is only 7.40 m, Robin Radar Systems BV recommends a minimal safe distance of at least 15 meters. Because of the low output power of the FMCW radar, there is no given distance for the 10W/m2 radiation level. The potential risk of being struck by a rotating antenna restricts the presence of people and equipment to a minimal safe distance of at least 2 meters.
Testing with Direct or Indirect Regulatory Agency Engagement	Yes. Our systems are CE/EMI/EMC certified.
Commercial Deployment	MAX® has been deployed on multiple locations all over the world such as: at Copenhagen Airport, the largest Dutch environmental consultancy Waardenburg Ecology, Royal Netherlands Airforce (three systems), and other wind farms and ecological consultancy agencies like Wind Park Friesland, Ostwind, Luminus, NiNA, Bluebear, Vleemo. The MAX® is also deployed offshore (with end-clients like Ørsted and Equinor).
Installation and Operation Components	Tower-mounted, Free-standing, Interface with SCADA System, Requires Internet, Requires Power Source, IP-65

Installation and Setup	• Power: The nominal electrical power requirement of the entire system is less than 1500W (230V AC) dependent on wind conditions and computer capacity. The peak power (start-up) is 2750W. • Internet: To interconnect the different computers, a switched gigabit local area network is incorporated. For remote operation and visualization, an internet connection of at least 2Mbit symmetrical capacity is required. • To mount the radar antenna unit, support mounts can be provided. Robin has constructed support mounts for field use; these can also be used for stationary setups. • The computer rack must be placed in a climate-controlled environment. The connection between the rack and the radar uses a fiber connection. During operation, the temperature must be kept stable within 2 degrees °C. The tolerable temperature range during operation is 15-25°C. The tolerable temperature range for an idle system is 5-65 °C. The tolerable relative humidity is 30% - 90% non-condensing. The standard industrial 19” inch computer rack, will need at least 30cm space at the rear for the cables and air flow.
Timeline for Installation and Operation	Expected delivery period: T0 + 6 months (average time provided, as it depends on capacity) - T0 being the acceptance of purchase order.
Coordination with Facility for Installation and Operation	Installation: Site preparation like power and internet connection, installation location selection, mechanical interface if customer specific (like a pedestal), frequency license to allow operation of the system (so required before the customer wants to start using the system). Operation / maintenance: Providing access to the system if required.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Alignment / integration with the SCADA is SoD is required.
Other Products Required for Installation	None: All hardware needed is included in the system sales.
Potential Interference with Other Technologies	That could be the case, but Robin has the tools to mitigate this risk. The system could be purchased in different operating frequencies. A small margin is available to set up the system in such way that it will not interfere with other systems (frequency separation).
Operational Limitations	Major benefits of radar are that it can 'see' bird movements equally well 24/7 at night as during day and in all weather conditions. As the European market leader, we feel responsible for addressing limitations as well as capabilities of bird radars.

	We call this our “be real” approach. Like any other technology, a bird radar is an enabler. Radar is a tool that provides unique data that requires experts to convert into information, reports, conclusions, or policies. That is why Robin works together with ornithologists and ecologists who specialize in this field of work. Radar is a monitoring tool; it does not deter birds. Deterrence requires other means like acoustic devices, green laser, or gas canons. Radar does not see everything: it cannot see through or behind physical objects like buildings. Coverage depends on terrain; detection range depends on the size of the birds and capabilities degrade in extreme weather conditions like heavy rain or snow. Also be aware that Radar distinguishes birds into categories, not (yet) species.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes: The continued costs are between 22,000 and 52,000 euros per year for a minimum of 3 years. This includes software license and product & maintenance support (customer could select the type of Service and Support coverage / package: Basic / Standard / Full). Systems are sold including support contracts. This is for continuous product and maintenance support including: software updates, preventive maintenance, repairs, remote monitoring, and a helpdesk.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	The expected lifespan is 10 years, based on the individual lifespan of proven and mostly commercial of the shelf hardware.
Warranty	Yes, a one (1) year warranty is included for all issues under normal usage.
Extended Warranty	This could be arranged via the different Service and Support packages.
Peer-Reviewed Research	We are currently conducting peer-reviewed research and will update the technology once received.
Submission Contact	Okke van Elsen, Head of Bid and Quote Management | Phone: +31 6 28 07 93 49 | Email: okke.vanelsen@robinradar.com | Address: Laan van Waalhaven 355, 2497 GM The Hague, The Netherlands
Technical Contact	Meije Kenston, Head of Technical Sales | Phone: +21 88 700 8700 | Email: meije.kenston@robinradar.com | Address: Laan van Waalhaven 355, 2497 GM The Hague, The Netherlands
Sales Contact	Sibylle Giraud, Business Development Manager | Phone: + 31 6 18 52 48 63 | Email: sibylle.giraud@robinradar.com | Address: Laan van Waalhaven 355, 2497 GM The Hague, The Netherlands

MERLIN AIRCRAFT BIRDSTRIKE AVOIDANCE RADAR (ABAR) SYSTEM | TRL 9

Updated July 2025

Company	DeTect, Inc.
Website	www.detect-inc.com
Target Renewable Energy	Land-Based Wind
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors Bats
Additional Species	Any biological target, Whooping crane, Condors, Passerines (Songbirds)
Technology Components	Detection component
Description & Application	DeTect's MERLIN Aircraft Birdstrike Avoidance Radar (ABAR) System, introduced in 2003, is the first production model bird strike radar system and is the most advanced and widely used technology available for aircraft-bird strike risk management providing for real-time detection, tracking and alerting of hazardous bird and drone activity at commercial airports, military airfields, and military training and bombing ranges. Real-time avian awareness with up-to-the-minute information ensures the safest flights by focusing on when and where large flocks are moving, which is the greatest risk to commercial airports. With over 1,000 systems installed worldwide for aviation safety and environmental applications, MERLIN has a documented record in reducing bird strikes, increasing safety, and reducing aircraft damage at both military and commercial airfields. MERLIN is the only bird radar system to have been evaluated and certified for real-time, tactical flight safety use by the U.S. Government (NASA, US Air Force) and is the only bird radar approved for and in use at a commercial airport control tower under national flight safety standards.
Mechanism(s) by which the Technology Operates	Radar
Monitoring or Minimizing	Both, While the system uses Tue3D radar monitoring to provide reliable avian detection and tracking in almost any weather

	condition (i.e., fog, rain, snow), and real-time target filtering by size and mass for hazardous bird and drone activity, DeTect's system engineers, project managers and on-staff biologists work with Customers to identify bird activity, migration events, and nesting habits to not only ensure proper placement of technology sensors, but also to evaluate operational procedures that will minimize interactions.
Detect and/or Deter Non-Target Species	The operating software was developed specifically for detection and tracking of bird (all species) and drone activity.
Avoidance of False Positives and False Negatives	The MERLIN bird detection and tracking software operates in real-time applying advanced, military-grade target identification, classification, and tracking algorithms and clutter suppression and interference rejection routines to the radar data stream to provide superior, highly accurate identification and tracking of bird targets over aircraft/ship software or image processing-based systems. MERLIN additionally incorporates advanced dynamic, real-time ground clutter suppression, and Doppler processing to more reliably detect and track birds in high clutter environments - a functionality that is unique to MERLIN and that is critical to the delivery of an effective system for most complex industrial environments. The MERLIN system classifies targets into size classes generally corresponding to small, medium, large, and flock-size birds which generally correspond to these bird size classes but cannot definitively distinguish species as installed. As such, DeTect recommends that periodic field ground truthing of the radar system data be conducted by qualified biologists as part of any survey with the system for data validation and to develop data subsets on species predominant at the survey site or of species of interest using the MERLIN ground truth recording feature.
Effective Range	Individual small songbirds and bats are detected at a range of 1-2 NM (nautical miles), larger avian targets and flocks detected up to 4 NM and further from the radar. For larger sites, coverage is arranged by using multiple sensors with overlapping ranges for required coverage distances to maximize the probability of detection. Radar placement can also be at the leading edges of the wind farm or in critical areas to act as warnings for high-risk movements and function as triggers or thresholds for the entire location.
Timeline of Production	DeTect began production of MERLIN Avian Radar Systems in 2003.
Product Manufacturing	Originally designed, developed, and supported out of our global headquarters in Panama City, Florida, DeTect now has research, engineering and manufacturing facilities in Calgary, Alberta

	Canada; Goleniow, Poland; South Korea, and Taiwan (2026) with offices throughout the US, Canada, Europe & Asia.
Tech Support	Originally designed, developed, and supported out of our global headquarters in Panama City, Florida, DeTect now has research, engineering and manufacturing facilities in Calgary, Alberta Canada; Goleniow, Poland; South Korea, and Taiwan (2026) with offices throughout the US, Canada, Europe & Asia.
TRL Justification	TRL 9: The MERLIN radar system is commercially available with over 1,100 systems sold over the last 20+ years. Operational systems are deployed at airports, wind farms, mining operations, and research programs all over the world. Within the wind energy industry, MERLIN has been used extensively in pre-construction studies, risk assessment, and operational mitigation.
Efficacy Testing	Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	The system is continually tested to improve performance, and improvements are implemented to keep pace with technological advancements in available radar sensors and systems.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	MERLIN Avian Radar System has been approved for use in risk mitigation by permitting agencies regulating wind farms. Radar surveys have long been accepted and in some cases are required by state and federal agencies for pre-construction data on wildlife movements. In terms of the safety of operations, DeTect equipment has been certified by occupational health and safety groups and has all the frequency and technical licenses required to operate a radar system.
Commercial Deployment	Over 1,100 MERLIN units have been sold and delivered worldwide in addition to surveys carried out with DeTect-owned radars. See attached documents for representative projects.
Installation and Operation Components	Tower-mounted, Free-standing, Interface with SCADA System, Requires Power Source
Installation and Setup	These are small, mobile, trailer-mounted systems or can be skid-mounted for permanent installation on a site. They are ground-based installations with no direct attachment to wind farm structures.
Timeline for Installation and Operation	90-120 days depending on production schedule for delivery and installation. DeTect-owned equipment is often available for lease to cover interim periods while production is completed.
Coordination with Facility for Installation and Operation	DeTect handles the installation and deployment of the avian radar systems and includes one full year of data support, remote monitoring, and project management with the purchase of equipment. The infrastructure required for the installation of the

	system includes a concrete pad and commercial power supply for operational sites. Trailer and generator units are available for preconstruction surveys with the operator responsible for fuel and generator maintenance. For operational mitigation systems connection to the on-site network communications is recommended for monitoring and communication of risk in real time.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	No, coordination with turbine structure is needed during installation but an operational mitigation system generally requires the ability to communicate and exchange information with the wind farm SCADA system.
Other Products Required for Installation	All required components can be purchased with the system, and it can be operated as a stand-alone system.
Potential Interference with Other Technologies	No
Operational Limitations	The MERLIN radar system collects data continuously during operations and the workstations and other sensitive equipment are installed in environmentally controlled trailers or cabinets to protect from environmental extremes. The MERLIN technology was originally developed and is currently used by the US Air Force and NASA for aircraft-bird strike risk management and includes advanced, military-grade signal processing software, however, radar is susceptible to interference from weather, structures, vegetation, high sea state, and other radars that may limit detection in certain areas and/or environments. These factors are all taken into consideration when selecting a radar location. The system will require installation in a representative location with a relatively clear line-of-sight of the area(s) of interest. Precipitation may affect the data collected by the system.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	For the operation of the system, there are costs of generator fuel or commercial power, dependent on the system and location. If generators are in use the system requires basic maintenance every 250 hours, with commercial power the generators are a backup power source and require minimal service to maintain reliability. The maintenance schedule for the radar sensors is dependent on the sensor type with solid-state radars having no 'wear' components and a 50,000 hr MTBF manufacturer rating. Some clients operate the radar completely independent of DeTect involvement including certain consulting companies that own DeTect equipment and some federal agencies such as USFWS. Other clients contract with DeTect for additional data analysis after the initial studies or for complete management of the radar program.

Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1000+
Expected Lifespan	The oldest MERLIN system at an operating windfarm is at the Near Shore Wind Park off of the Dutch coast and the system has operated unattended nearly continuously since 2003. O&M schedules and costs have been worked out for a 20-year operating period but with proper maintenance, radar systems can operate beyond that time frame.
Warranty	DeTect provides a one-year full parts and labor warranty that includes repair or replacement of any defective parts for the term of the warranty, exclusive of worn parts. Wear parts are parts that degrade under normal use and include, but are not limited to, radar magnetrons, motor brushes, generators, tires, and other such components, or parts that fail due to deterioration from adverse environments or chemical exposure. Options for service contracts and extended warranties are available beyond that.
Extended Warranty	Extended warranties are available. The systems are customized for each location and costs are dependent on the equipment purchased and complexity and extent of the installation.
Submission Contact	Helen Lewis | Phone: (850)-763-7200 | Email: helen.lewis@detect-inc.com | Address: 2817 Hwy 77, Panama City, Florida 32405
Technical Contact	Jesse Lewis | Phone: (850)-763-7200 | Email: jesse.lewis@detect-inc.com
Sales Contact	Gary Andrews | Phone: (850)-763-7200 | Email: contact@detect-inc.com

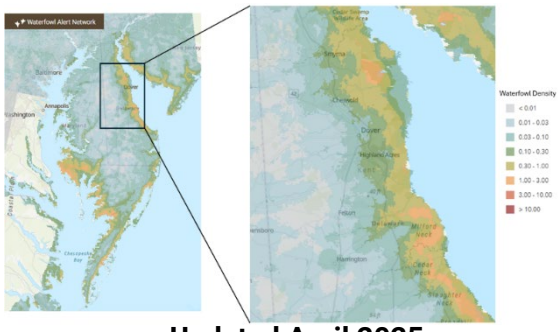
NTQB TRANSMITTERS | TRL 9

Updated October 2023

Company	Lotek Wireless
Website	www.lotek.com
Target Renewable Energy	Land-Based Wind
Target Species	Other marine/aquatic animals Wading, Sea birds, or Waterfowl Eagles Birds Raptors Marine Mammals Bats
Additional Species	Customizable for specific bat species. Customizable for specific bird species, Migratory Tree Roosting Bats, Whooping crane, Condors, Cave dwelling-bats, Passerines (Songbirds)
Technology Components	Detection component
Description & Application	Tags emit IDs that can be detected by strategically placed loggers. Therefore, it is possible to know when an individual was using an area (e.g., one proposed for turbines), or the fate of an individual because it is possible to track the tag and find it. Using proprietary software, our coded nanotags emit a VHF signal that uniquely identifies each transmitter. Tens of thousands of unique ID & burst rate combinations are possible.
Mechanism(s) by which the Technology Operates	GPS/VHF Radio Transmitters
Monitoring or Minimizing	Monitoring
Detect and/or Deter Non-Target Species	Loggers only detect tagged individuals, so non-target species are not a problem.
Avoidance of False Positives and False Negatives	False positives are logged as a unique code by the receiver, which can be easily identified and removed from the final dataset.
Effective Range	This is model- and environment-dependent, and ranges from several hundred meters to > 10 km.
Timeline of Production	Over 15 years for birds and bats, over 30 years for fish.
Product Manufacturing	Newmarket, Ontario, Canada
Tech Support	Ontario-Canada, England, New Zealand
TRL Justification	TRL 9. Our coded nanotags have been used successfully in field applications for over 8 years (including assessing bats at wind farms) and are currently in use with the Motus antenna array with stations around the world.

Planned or Underway Testing	Already proven.
Safety or Public Nuisance Issues	No. The transmitters operate in the VHF range of 130 -174 MHz and cannot be detected without the appropriate receivers and antennae.
Testing with Direct or Indirect Regulatory Agency Engagement	Yes
Commercial Deployment	Customer confidentiality means we cannot disclose this, but as before, it has been used successfully in numerous projects over the last 15 years.
Installation and Setup	The transmitters are attached to the animals by mounting to the back using glue or a harness system. The transmitters can also be attached to a bird's tail using glue or string.
Timeline for Installation and Operation	These devices are typically dispatched 6-8 weeks after the order is confirmed. Installation of the logging equipment can take time to optimize, and some time should be allowed for that.
Coordination with Facility for Installation and Operation	None
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Choosing an operating frequency.
Other Products Required for Installation	Tags, Receivers, antennas, power supply if remote, connecting cables. Computers need to download and analyze data
Potential Interference with Other Technologies	No
Operational Limitations	Operational temperature from 0 to 35 degrees Celsius
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Tag life is variable (on weight), so they need renewing. Receiving equipment when installed should last for many years. Mobile Yagi antennas may need replacing depending on use. Only for technical assistance.
Remotely Monitored or Near Real-Time Status and Operation	Variable
Utility Scale Units Sold or Installed	10,000+
Expected Lifespan	This is model dependent, and ranges from `10 days to over 1 year
Warranty	Warranty is 80% of the expected life of the transmitter.
Extended Warranty	No
Submission Contact	Mike van den Tillaart | Phone: (905)-836-2912 | Email: mtillaart@lotek.com | Address: 115 Pony Drive, Newmarket, Ontario, Canada L3Y 7B5

NEW WATERFOWL ALERT NETWORK | TRL 9



Updated April 2025

Company	AgriNerds
Website	https://www.agrinerds.com/
Target Renewable Energy	Land-Based Wind, Offshore, Multiple Industries
Target Species	Agricultural Species Wading, Sea birds, or Waterfowl Birds
Additional Species	Ducks, Geese, and Swans
Technology Components	Detection component, Deterrent component, Other, Integrates with deterrent system, Integrates with turbine controls for curtailment
Description & Application	The Waterfowl Alert Network is a tool that creates daily waterfowl abundance and/or occupancy maps using a combination of Next Generation Weather Radar (NEXRAD) modeling and telemetry modeling.
Mechanism(s) by which the Technology Operates	Radar, GPS/VHF Radio Transmitters, Weather/Environment Sensors (wind, precipitation, etc.), Software, precipitation, GPS/VHF radio Transmitters
Monitoring or Minimizing	Both. Models track presence/absence of waterfowl & density at daily and seasonal levels. High resolution (up to 250m granularity). Historical analysis back to 1995 Real-time Alerts. It can be integrated into an automated curtailment or alert system.
Detect and/or Deter Non-Target Species	Detect, yes, deter no. Waterfowl are detected on the broad scale (250m resolution) with the use of NEXRAD radar or even finer scale if predicted using GPS data.
Avoidance of False Positives and False Negatives	Radar modelling is trained to sample the airspace at the time of day when the airspace is at least 95% dominated by waterfowl activity. Other species detected by the radar could include shorebirds such as gulls.
Effective Range	100km
Timeline of Production	This technology has been in production since 2019 as a software and since 1995 as the dual-pol NEXRAD.
Product Manufacturing	The software is an online SaaS based product.
Tech Support	Davis, California, USA
TRL Justification	We have a system which is already functional, globally scalable, and we already have clients in more than half the USA.

Efficacy Testing	Field Testing at a Commercial Facility Outside of Wind (e.g., airport, agriculture, other energy resources, etc.)
Planned or Underway Testing	Always being tested and improved.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No, but it can depend on whether it was a business-business model or business-government model.
Commercial Deployment	Yes
Installation and Operation Components	Requires Internet, Satellite Access
Installation and Setup	Clients will enroll into the system and will then have access through their own account.
Timeline for Installation and Operation	Client integration and onboarding within a few days depending on the project.
Coordination with Facility for Installation and Operation	Nothing on-site, everything is via online software.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Nothing, unless being integrated into a curtailment system. Nothing physically needs to be placed.
Other Products Required for Installation	Nothing
Potential Interference with Other Technologies	No
Operational Limitations	Predictive modelling-based technology, no model is perfect.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes. All of the above.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1000 +
Expected Lifespan	No lifespan.
Warranty	No, not applicable. Can be discussed further if required.
Extended Warranty	No, not applicable. Can be discussed further if required.
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://doi.org/10.1637/aviandiseases-d-20-00137; https://doi.org/10.1371/journal.pone.0041571
Submission Contact	Matthew Hardy | Email: mjhardy@agrinerds.com

BIRD AND BAT ACTIVITY ANALYSIS | TRL 8

Updated June 2025

POST-CONSTRUCTION MONITORING	FORMER NAME
Company	Spoor AI
Website	www.spoor.ai
Target Renewable Energy	Land-Based Wind, Offshore, Transmission
Target Species	Birds Bats
Additional Species	According to Client needs
Technology Components	Detection component
Description & Application	Spoor Bird and Bat Activity Analysis detects, identifies, and analyzes bird activity across land- and seascapes, with time resolution from seconds to years. The AI-based patent-pending software can read video from any commercially available high-resolution camera. The AI software is adapted to both steady and non-steady vantage points and can be deployed in easily accessible and remote locations like marine environments otherwise only accessible by large vessels or planes. Big Data processing and AI analysis, enriched with weather data, gives insight on parameters like species occurrence, behavior, flight heights, and distributions, and allows for comparison across hours, days, seasons, and years, and correlation with wind direction and speed. All detections and statistics are accessible through Spoor's online user interface. High quality combined with high quantity of data gives a trusted and objective data foundation that can be cross-examined, reviewed, and shared. This is invaluable in permitting processes, site prospecting, risk assessments, and environmental impact assessments. Utilizing the power of AI and machine learning, Spoor's algorithms are trained on a large and growing globally collected data set, ensuring constant improvements in both detections, identifications, range, and in handling variations in environmental, topographical, and weather-related conditions.
Mechanism(s) by which the Technology Operates	Video, Weather/Environment Sensors (wind, precipitation, etc.), Software

Monitoring or Minimizing	This product is to monitor, document and provide input to environmental assessments of onshore- and offshore infrastructure projects pre-construction and post-construction phases.
Detect and/or Deter Non-Target Species	Currently Spoor focuses on high precision and accuracy for avian and bat species. Future applications may include detection of other airborne or surface visible objects.
Avoidance of False Positives and False Negatives	Spoor assures ≥ 95 % accuracy for both false positives and false negatives. Spoor conducts routine verifications through Recall measurements; comparing Spoor AI results to an ornithologist's field observations. This is done at different sites to ensure the AI performance across varied conditions. In addition, Spoor prioritizes high-quality AI training data sets as the primary source of quality. These data sets are made in collaboration with Spoor's in-house ornithologist. Further, the AI assigns a confidence level to detections. If the confidence level drops below a certain threshold, the data is manually verified by trained members of staff. A random sample is also weekly sent for manual verification in order to monitor the general levels of false positives and false negatives. Last but not least, the self-learning nature of the AI ensures that the level of false positives and false negatives is reduced over time.
Effective Range	The effective range depends on a number of factors, most notably on the size of the species of interest and on the camera resolution and lens. For eagle size birds and an appropriate off-the-shelf 8K resolution camera, effective detection range is currently ~1.5 km and counting.
Timeline of Production	This technology has been in production since November 2020.
Product Manufacturing	Software development in Spoor's office in Oslo, Norway. Camera manufacturing location depends on camera choice.
Tech Support	Oslo, Norway
TRL Justification	Onshore birds (TRL 9): Deployed at several locations, producing bird activity statistics for over 1 year. Offshore birds (TRL 9):Deployed at several locations, producing bird activity statistics for over 1 year. Onshore bats (TRL 6): A prototype system has been deployed and has operated successfully since Q2 2025. Bat statistics are represented in the Spoor application.

	Offshore bats (TRL 5): Has not been deployed offshore for pre-construction, however the core software has been used for offshore thermal bird detection, and onshore thermal bat detection.
Efficacy Testing	Lab Testing, Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Wind Facility
Planned or Underway Testing	For onshore and offshore birds, the product accuracy is continually improved through refinements to AI model training, investments in AI model technology. Tests to improve the accuracy are undertaken at least twice per year, with field ornithologist studies to evaluate and compare product performance and to provide model training insights. Flight height and distance calibration tests are planned for H2 2025 using drones. Onshore bats: Throughout 2025, intensive testing is underway to evaluate and improve the performance of bat detection, including software techniques and new camera technologies. Offshore bats: No direct testing planned for offshore bats, though it is anticipated product performance for offshore bats will be improved with the planned onshore investments.
Safety or Public Nuisance Issues	Spoor's AI products are Software-as-a-Service that have no safety nor public nuisance issues that affect its deployment or use. However, if network requirements for data transfer cannot be met at a site, data storage equipment with accompanying manual data retrieval will be required. In these cases, safety precautions need to be considered for the person going on-site to retrieve data. Usually, the client needs to install camera equipment (although some customers have pre-existing camera systems installed, e.g., for surveillance purposes), and in these cases, the installer needs to consider health and safety according to regulations, Client policies and according to the site in question.
Testing with Direct or Indirect Regulatory Agency Engagement	Onshore: Depending on the site, there may be a requirement to receive a permit to install cameras and record. This is usually not the scope of Spoor's delivery. Offshore: The data collection itself does not require regulatory approvals, but the deployment of the platform (e.g., wave buoy) requires a permit. This is normally handled by the MetOcean campaign or buoy provider.

Commercial Deployment	Onshore birds: Yes, there are several active, multi-year deployments. Offshore birds: Yes, there are several active multi-year deployments. Onshore and offshore bats: No. Research deployments are in place at operational sites. Commercial deployments are expected to commence early 2026.
Installation and Operation Components	Tower-mounted, Requires Internet, Requires Internet via Satallite Modem, Requires Internet for Data Upload/Back Up, Requires Power Source, Commercially available Detectors
Installation and Setup	Onshore: Camera equipment is usually mounted on existing infrastructure or on bespoke platforms for the project. Sufficient power is required for cameras and ancillary equipment, and network connectivity is required for real-time data collection. In less hospitable environments, hard disk-based data collection may be used, resulting in time delayed availability of data insights. Offshore: Buoy/FLiDAR/MetOcean-platform mounted. The buoy provider ensures sufficient power, and data storage is agreed between Spoor and the buoy provider. Availability of Inertial Measurement Unit (IMU) data is required to enable sufficiently accurate range and height data.
Timeline for Installation and Operation	3-6 months
Coordination with Facility for Installation and Operation	This product is in principle platform agnostic, but there is a need for detailed coordination with the platform provider for installation, power supply, connectivity, and actual installation of the hardware. Once deployed, the operation of the cameras is passive, and functionality will be regularly observed remotely by Spoor.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None
Other Products Required for Installation	See "installation and setup". Potential need for power supply and connectivity upgrades.
Potential Interference with Other Technologies	Onshore: No. Offshore: Not if the communication and planning with the platform provider is good. If the cameras are placed without careful consideration of other sensors, e.g., the LiDARs, on the platform, these may be shielded; this is considered a very theoretical risk.

Operational Limitations	Onshore and offshore: Spoor performance may be diminished in extremely poor visibility conditions.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Spoor offers Software-as-a-Service, i.e., the contract is a subscription contract with monthly or yearly payments.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	Contact Company for Specific Numbers
Expected Lifespan	Spoor's Software-as-a-Service is continuously improved and updated and has no end-of-life expectancy. The camera warranty is typically 5 years, but this depends on the warranty of the manufacturer in question. Actual lifespan of the system can be shorter or longer depending on the conditions deployed in and the installation platform. As pre-construction campaigns typically are for 1-2 years, the system is considered robust for one or more full campaign deployments.
Warranty	Spoor AI software is provided with a Service Level Agreement that covers availability and data quality. Hardware is covered under the vendor warranty.
Extended Warranty	See "Expected lifespan of the technology"
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://www.bto.org/our-work/science/publications/reports/research-reports/00781-scientific-support-to-spoor-ai-trial
Submission Contact	uliana@spoor.ai, glen@spoor.ai, ralph@spoor.ai

NEW BIRD SENTINEL® | TRL 8

Updated May 2025

Company	Biodiv-Wind
Website	https://www.biodiv-wind.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Eagles Birds
Additional Species	Most bird species
Technology Components	Detection component, Survey for Remote Construction Monitoring
Description & Application	Bird Sentinel® is a fully autonomous bird detection and monitoring system designed to study diurnal aerial fauna. It uses the same advanced AI-based detection technology as our SafeWind® system, optimized for biodiversity monitoring during the development or repowering phases of wind farms. The system captures continuous visual data to assess flight paths, species presence, and behavioral patterns. It operates in real time, during the day. Its flexible deployment on masts, pylons, or rugged terrain makes it suitable for a wide range of environments, including offshore wind farm development zones.
Mechanism(s) by which the Technology Operates	Video
Monitoring or Minimizing	Bird Sentinel® is designed for monitoring, not for minimizing interactions. It provides high-resolution data on bird activity to better understand how species use the airspace in and around wind farm sites, especially during the development, permitting, or repowering phases. It helps identify potential risk zones and time windows.
Detect and/or Deter Non-Target Species	Bird Sentinel® is designed specifically for detecting diurnal birds and is not intended to deter any species.

Avoidance of False Positives and False Negatives	Bird Sentinel® minimizes false positives and false negatives through a combination of advanced AI algorithms, hardware optimization, and expert validation: AI Training and Continuous Improvement: The system uses the same AI-based detection technology as our SafeWind® product, trained on a large and growing dataset of real bird flights recorded in diverse conditions. This improves its ability to distinguish birds from non-target objects (e.g., insects, debris, shadows). Post-Processing with Expert Review: All detections are recorded and stored as short videos. These can be reviewed by ornithologists to validate species ID and filter out false positives or classify ambiguous cases, thereby refining datasets for ecological studies. High-Resolution Optics and Sensor Placement: Careful sensor orientation and optical quality reduce misidentification caused by image blur or distance.
Effective Range	up to 1000m depending of the species
Timeline of Production	This technology has been in production since 2015.
Product Manufacturing	Boujan sur Lirbon, Occitanie, France
Tech Support	Boujan sur Lirbon, Occitanie, France
TRL Justification	Bird Sentinel® has been fully developed, tested, and deployed in real field conditions, including operational wind farm environments and during wind project development phases. It has demonstrated reliable performance across multiple use cases and environmental contexts. The technology is commercially available and incorporates the same AI-based detection engine used in our TRL 9 SafeWind® system, with adaptations for observational and survey purposes.
Efficacy Testing	Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Wind Facility
Planned or Underway Testing	No
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	Bird Sentinel® has been commercially deployed in multiple onshore wind energy projects, particularly during development and repowering phases, to monitor avian activity and assess biodiversity. It has been installed on measuring masts,

	autonomous masts, and in open field locations, including remote and rugged environments.
Installation and Operation Components	Tower-mounted, Free-standing
Installation and Setup	Please briefly describe installation and setup. Bird Sentinel® is designed for flexible, low-impact installation. It can be mounted on a variety of existing or dedicated structures, such as measuring masts, autonomous masts, pylons or installed as a free-standing unit directly in open fields using a dedicated support Installation involves securely fixing the unit, aligning the camera and sensors to the target field of view, and connecting to power (typically solar or grid) and 4G network for remote supervision. Setup involves orienting the system to the desired field of view, configuring detection parameters, and establishing 4G connectivity for remote monitoring. Once installed, the system operates autonomously with minimal maintenance. The entire setup can typically be completed within a few hours by a small team.
Timeline for Installation and Operation	It usually takes 10 weeks.
Coordination with Facility for Installation and Operation	Installation and operation of Bird Sentinel® require minimal coordination with the facility owner or operator. However, the following considerations may apply: Site access and safety compliance: Coordination may be needed to access the site and adhere to relevant safety procedures. Power supply (if applicable): If not operating in fully autonomous mode, connection to a local power source may require operator support. Placement approval: Approval is required to ensure the system does not interfere with operational areas or other infrastructure. Landowner notification: When the unit is deployed in open fields (e.g., for baseline studies), coordination with the landowner, typically a farmer, is necessary to ensure awareness and prevent unintended disturbances. Bird Sentinel® is designed to be standalone, easy to deploy, and non-intrusive, making coordination straightforward.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Bird Sentinel® can be installed on a wind turbine structure similarly to SafeWind®, but it operates independently and is not connected to the SCADA system. It only requires access to a standard power outlet and an internet connection available inside

	the turbine. Therefore, coordination with OEMs is minimal and limited to confirming access to these basic utilities.
Potential Interference with Other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, Bird Sentinel® is offered as a service. Clients subscribe to the monitoring service, which includes access to detailed reports, and video footage.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	5 to 10 years depending of the components.
Warranty	Yes, this technology is proposed as a service.
Peer-Reviewed Research	No, we have not completed peer-reviewed research.
Submission Contact	Sébastien Masse, Communications Officer | Email: s.masse@biodiv-wind.com | Phone : +33 7 45 09 14 45 | 6 Mail Philippe Lamour, 34760 Boujan-sur-Libron France,
Technical Contact	Fabien Escudier, COO | Email: f.escudier@biodiv-wind.com | Phone: +33 (0)7 69 23 17 64,
Sales Contact	Fabrice Charrassier, Sales Manager | Email: f.charrassier@biodiv-wind.com | Phone: +33 (0)7 64 44 59 93,

BSTAR™ AVIAN SURVEILLANCE AND WARNING SYSTEM (ASWS) | TRL 8

Updated Winter 2017

Company	SRC, Inc.
Website	http://www.srcinc.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds
Description & Application	This is a pulsed-Doppler radar system operating in the L-Band. The system transmits radio frequency (RF) energy and detects the echoes from the bird or bat. Radar system that detects, tracks, and displays airborne wildlife activity. This information is then used to trigger some type of response (turning off turbine, activating a deterrent system, etc).
Detect and/or Deter Non-Target Species	The radar is designed as a moving target detector. The system will detect targets that are moving. Radar has classification capability to filter targets of non-interest.
Avoidance of False Positives and False Negatives	Tracking technology is utilized to ensure that targets are real with a high probability. A turbine filter is implemented to identify, classify and remove detections from turbines.
Effective Range	Expected range is greater than 9km
Timeline of Production	This technology has been in production since 2004.
Product Manufacturing	United States of America
TRL Justification	BSTAR is a TRL Level 9 product for airport applications. However, for wind farm applications BSTAR is a TRL Level 8.
Planned or Underway Testing	No tests are currently planned.
Safety or Public Nuisance Issues	Standoff distance to avoid issues related to RF radiation hazards.
Testing with Direct or Indirect Regulatory Agency Engagement	BSTAR has been undergoing testing by Center of Excellence for Airport Technology (CEAT) at the University of Illinois at Urbana-Champaign, which is funded by the FAA.
Commercial Deployment	Product has been deployed at US and foreign airports. Temporary wind farm deployments in the US have been completed, but the system is not currently deployed.
Installation and Setup	BSTAR can be deployed in different configurations, depending on placement and site requirements.

Timeline for Installation and Operation	Delivery is approximately 6-9 months ARO.
Coordination with Facility for Installation and Operation	Access to site for site survey, site preparation (power/network), in addition to discussions supporting system parameters (number of radars, areas to be covered, etc).
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	No coordination needed with turbine manufacturers.
Other Products Required for Installation	Access to site for site survey, site preparation (power/network), in addition to discussions supporting system parameters (number of radars, areas to be covered, etc).
Potential Interference with Other Technologies	No concerns raised. BSTAR has been tested for electromagnetic compatibility to MIL-STD-461
Operational Limitations	No known limitations.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Costs are low. No ongoing involvement is required.
Remotely Monitored or Near Real-Time Status & Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Technology Lifespan	Original systems delivered in 2004 are still in operation.
Warranty	12-month warranty is provided.
Extended Warranty	Warranty is available. Contact company for more information.
Submission Contact	Kevin Chambers | Phone: (315)-452-8373 | Email: kchambers@srcinc.com | Address: 6225 Runing Ridge Road, North Syracuse, New York 13212
Technical Contact	Stacy Ryan | Phone: (315)-883-4331 | Email: sryan@srcince.com
Sales Contact	Craig Marcinkowski | Phone: (315)-452-8866 | Email: cmarcinkowski@srcinc.com

SR HAWK | TRL 8

Updated January 2017

Company	SRC, Inc.
Website	http://www.srcinc.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds
Technology Components	Detection component
Description & Application	This is a pulsed-Doppler radar system operating in the Ku-Band. The system transmits radio frequency (RF) energy and detects the echoes from the bird or bat. Mobile configuration allows radar to be deployed in less than 10 minutes. This would be advantageous to a biologist going into the field to evaluate bird activity. Permanent installation mounts radar on a tower or structure where it is remotely operated. Targets and data feeds can be sent over a network to any location.
Detect and/or Deter Non-Target Species	The radar is designed as a moving target detector. The system will detect targets that are moving. Radar has classification capability to filter targets of non-interest.
Avoidance of False Positives and False Negatives	Tracking technology is utilized to ensure that targets are real with a high probability. A turbine filter is implemented to identify, classify and remove detections from turbines.
Effective Range	Crow sized targets can be detected > 3km.
Timeline of Production	This technology has been in production since August 2008.
Product Manufacturing	USA
TRL Justification	SR Hawk is a TRL Level 9 product. However, application to detect birds and bats is TRL Level 8.
Planned or Underway Testing	Continued testing in a wind farm environment will continue to be ongoing. However, there are no current deployments scheduled at this time.
Safety or Public Nuisance Issues	SR Hawk outputs less than 1.5w average power, and as such there is no threat to the personnel.
Testing with Direct or Indirect Regulatory Agency Engagement	SR Hawk has been tested and accepted by the US Navy, US Marine Corps, US Army, and the US Department of State. The system is also UL certified and FCC part 15 certified.
Commercial Deployment	SR Hawk has sold a couple hundred systems to customers all over the world, including the US, Middle East, Africa, Asia, Europe, and the Pacific.
Installation and Setup	SR Hawk has been deployed in many configurations. Known deployments consist of tripod, tower, vehicle, and building mounting.

Timeline for Installation and Operation	Delivery is 30 days ARO, as of October 2014.
Coordination with Facility for Installation and Operation	Access to site for site survey, site preparation (power/network), in addition to discussions supporting system parameters (number of radars, areas to be covered, etc).
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	No coordination is necessary with turbine manufacturers.
Other Products Required for Installation	All components are sold in a complete system package.
Potential Interference with Other Technologies	No concerns raised. SR Hawk has been tested for electromagnetic compatibility to MIL-STD-461.
Operational Limitations	Performance will be limited in rain/snow.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	SR Hawk has minor preventative maintenance requirements. Total cost is not known but is expected to be low. Radar has MTBF of 15,000 hours. No ongoing involvement of SRC is required.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	We determine product lifespan based on contractual requirements. We currently have requirements to maintain the product for over 10 years.
Warranty	SR Hawk comes with a twelve-month warranty.
Extended Warranty	An extended twelve-month warranty is available at $11,040.
Submission Contact	Kevin Chambers | Phone: (315)-452-8373 | Email: kchambers@srcinc.com | Address: 6225 Runing Ridge Road, North Syracuse, New York 13212
Technical Contact	Stacy Ryan | Phone: (315)-883-4331 | Email: sryan@srcince.com
Sales Contact	Craig Marcinkowski | Phone: (315)-452-8866 | Email: cmarcinkowski@srcinc.com

WILDLIFE ACTIVITY DETECTION SYSTEM | TRL 8

Updated February 2024

Company	Wildlife Imaging Systems
Website	https://www.wildlifeimagingsystems.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Birds Bats
Technology Components	Detection component
Description & Application	The wildlife activity detection system pinpoints the exact time, duration, and flight pattern seen from birds and bats around wind turbines. These data, as well as corresponding weather, environmental and mortality data, can then be used to determine a risk model for each project comparing bird and bat activity to the risk of mortality.
Mechanism(s) by which the Technology Operates	Video, Infrared/Thermal Imaging Cameras
Monitoring or Minimizing	The technology is used for monitoring activity around the wind turbine. The data this technology creates can be used to try and predict future activity and minimize interactions.
Detect and/or Deter Non-Target Species	The system can also detect insects, which may be a proxy for bat mortality risk around turbines.
Avoidance of False Positives and False Negatives	The technology uses an advanced machine learning model to classify all detections.
Effective Range	One turbine
Timeline of Production	The product has been commercially available since 2022.
Product Manufacturing	Hardware is available commercial off-the-shelf.
Tech Support	USA
TRL Justification	A commercial product is currently being sold and has monitored hundreds of turbines for over hundreds of thousands of hours.
Efficacy Testing	Field Testing at a Commercial Wind Facility
Planned or Underway Testing	No
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No

Commercial Deployment	Yes
Installation and Operation Components	Free-standing, Ongoing Operation and/or Data Management with Technology Vendor
Installation and Setup	A single camera can be deployed at each turbine you wish to monitor. They are remotely power from a solar powered battery system and free-standing. They can be put in your right of way on the edge of the road or pad and do not require them to be pointed in a particular direction. The video is recorded to an SD card and can be easily swapped every two weeks throughout the monitoring season.
Timeline for Installation and Operation	Once the hardware is acquired, deployment of cameras can be as quick as 1-2 days. Data is currently gathered at two-week intervals and processed throughout the monitoring season.
Coordination with Facility for Installation and Operation	The current model requires a bi-weekly data swap of internally stored SD cards.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None
Other Products Required for Installation	A solar powered battery system for an onshore deployment and PoE switches/NVRs for an offshore deployment.
Potential Interference with Other Technologies	No
Operational Limitations	No. The technology works 24 hours a day and in all weather conditions.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, there are data processing costs and labor hours associated with each project.
Remotely Monitored or Near Real-Time Status and Operation	No
Utility Scale Units Sold or Installed	Contact Company for Specific Numbers
Expected Lifespan	This depends on the camera warranty provided by the commercial off-the-shelf seller.
Warranty	Generally, yes, by the commercial off-the-shelf seller.
Submission Contact	Brogan Morton | Phone: (802)-343-9889 | Email: brogan@wildlifeimaginingsystems.com | Address: 328 Mechanicsville Road, Hinesburg, Vermont 05461

BIRD AND BAT COLLISION DETECTION | TRL 7

Updated June 2025

	PRE-CONSTRUCTION MONITORING | FORMER NAME
Company	Spoor AI
Website	www.spoor.ai
Target Renewable Energy	Land-Based Wind, Offshore, Transmission
Target Species	Birds Bats
Additional Species	According to Client Needs
Technology Components	Detection component, Collision detection component, Collisions detected if observed in camera field of view
Description & Application	Bird and Bat Collision Detection processes ultra-high-resolution (4K/8K stereoscopic) video through Spoor's AI-powered platform to detect, quantify and analyze avian and chiropteran (bat) collision events. Collision detection is typically deployed in conjunction with Activity Analysis for customers who need to understand the collision risk profile of an operation wind turbine installation more deeply. The software reads video from any commercially available high-resolution camera and can be deployed from steady or non-steady vantage points—including offshore buoys or turbine platforms. It assesses avoidance behavior, collision incidents and the efficacy of mitigation measures. Big Data processing and AI analysis, enriched with weather data, delivers collision counts, impact locations, flight-path deviations, and near-miss statistics through Spoor's online interface. High-quality, high-volume data supports risk assessments, permitting processes and refinements to future environmental impact assessments.
Mechanism(s) by which the Technology Operates	Video, Software
Monitoring or Minimizing	This product is to monitor, measure and document collision and avoidance behaviors.
Detect and/or Deter Non-Target Species	No. This product focuses on high-precision detection of avian and bat collision events. Other taxa are outside the current offering.
Avoidance of False Positives and False Negatives	Spoor assures ≥ 95 % accuracy for both false positives and false negatives for bird and bat detections. Determination for flyers in the collision risk zone is based on stereoscopic cameras and

	software algorithms calculating the 3D position of the bird in relation to the turbine. Routine verification compares AI collision detections with professional ornithologist observations across varied sites. Curated, high-quality training data underpin model performance. Each detection is assigned a confidence score; low-confidence events undergo manual review, and a weekly random sample is also verified to monitor error rates. The self-learning nature of the AI further reduces both false positives and false negatives over time.
Effective Range	The effective range depends on a number of factors, most notably on the size of the species of interest and on the camera resolution and lens. For eagle size birds and a cost-effective off-the-shelf camera, effective detection range is currently ~1.5 km and counting.
Timeline of Production	This technology has been in production since March 2025.
Product Manufacturing	Software development in Spoor's head office in Oslo, Norway. Camera manufacturing location depends on camera choice.
Tech Support	Oslo, Norway
TRL Justification	Lab validation and basic field pilots are complete. Live, operational prototypes are deployed in two commercial operating environments. Final software challenges are being resolved within those operational sites, and features are not yet complete.
Efficacy Testing	Lab Testing, Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Wind Facility
Planned or Underway Testing	Q3–Q4 2025: Validation of multi-camera reconciliation algorithms across all four stereoscopic installations Ongoing: Biannual ornithologist-led reviews of collision detections to tune model thresholds
Safety or Public Nuisance Issues	No inherent safety or nuisance issues. Standard site health and safety procedures apply during camera installation and data retrieval.
Testing with Direct or Indirect Regulatory Agency Engagement	Camera installation permits may occasionally be required (handled by the client). No direct regulatory approvals are needed for data collection; offshore platform permits (e.g., buoys) are managed by third-party providers.
Commercial Deployment	Yes. Four stereoscopic installations are live: two under research and two for paying customers receiving collision statistics.
Installation and Operation Components	Tower-mounted, Requires Internet, Requires Internet via Satellite Modem, Requires Internet for Data Upload/Back Up, Requires Power Source, Commercially available Detectors
Installation and Setup	Offshore & Onshore (turbine-based): Two high-resolution cameras are mounted on adjacent turbines (or tall structures) at

	a predefined crossover angle. This stereoscopic configuration enables precise triangulation of collision events on the target turbine. Power is drawn from turbine infrastructure and data is uplinked via the site's existing communications network. Onshore (mast option): Where turbine placement is impractical, Spoor supports camera mounting on a separate (3rd party provided) meteorological-style mast adjacent to the target turbine to support the stereoscopic camera pair. Power and connectivity requirements mirror those of turbine-based mounts.
Timeline for Installation and Operation	3-6 months
Coordination with Facility for Installation and Operation	This product is in principle platform agnostic, but there is a need for detailed coordination with the platform provider for installation, power supply, connectivity, and actual installation of the hardware. Once deployed, the operation of the camera is passive, and functionality will be regularly observed and controlled remotely by Spoor.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None
Other Products Required for Installation	See "installation and setup". Potential need for power supply and connectivity upgrades.
Potential Interference with Other Technologies	No
Operational Limitations	Performance may be diminished in extreme weather or extremely poor visibility.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Spoor offers Software-as-a-Service, i.e., the contract is a subscription contract with monthly or yearly payments.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	Contact Company for Specific Numbers
Expected Lifespan	Spoor's Software-as-a-Service is continuously improved and updated and has no end-of-life expectancy. The camera warranty is typically 5 years, but this depends on the warranty of the manufacturer in question. Actual lifespan of the

	system can be shorter or longer depending on the conditions deployed in and the installation platform.
Warranty	See "Expected lifespan of the technology"
Extended Warranty	See "Expected lifespan of the technology"
Peer-Reviewed Research	We are currently conducting peer-reviewed research and will update the technology once received.
Submission Contact	uliana@spoor.ai, glen@spoor.ai, ralph@spoor.ai

GS1000 ADVANCED X-BAND AVIAN RADAR | TRL 7

Updated January 2017

Company	SRC, Inc.
Website	http://www.srcinc.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds
Technology Components	Detection component
Description & Application	This is a pulsed-Doppler radar system operating in the L-Band. The system transmits radio frequency (RF) energy and detects the echoes from the bird or bat. Radar system that detects, tracks, and displays airborne wildlife activity. This information is then used to trigger some type of response (turning off turbine, activating a deterrent system, etc).
Detect and/or Deter Non-Target Species	The radar is designed as a moving target detector. The system will detect targets that are moving. Radar has classification capability to filter targets of non-interest.
Avoidance of False Positives and False Negatives	Tracking technology is utilized to ensure that targets are real with a high probability. A turbine filter will be implemented to identify, classify, and remove detections from turbines.
Effective Range	Expected performance is 10km range for crow sized bird.
Timeline of Production	This technology is still in development.
Product Manufacturing	Syracuse, New York
Planned or Underway Testing	Yes, but not publicly available.
Safety or Public Nuisance Issues	Standoff distance to avoid issues related to RF radiation hazards.
Testing with Direct or Indirect Regulatory Agency Engagement	SRC plans to have the product tested/certified by independent regulatory organizations
Commercial Deployment	Not yet
Installation and Setup	Radar is deployed on own tripod from location of optimal visibility of area of interest. Internet connection is required to the control center.
Timeline for Installation and Operation	Typically, 6 months after receipt of order.
Coordination with Facility for Installation and Operation	Access to site for site survey, site preparation (power/network), in addition to discussions supporting system parameters (number of radars, areas to be covered, etc).

Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Coordination with turbine manufacturer will not be needed.
Other Products Required for Installation	System is expected to be sold with all necessary components. Initial system spares are included in system pricing.
Potential Interference with Other Technologies	No
Operational Limitations	Performance will decrease in heavy rain/snow.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Our radars typically have very long MTBFs (>10,000 hrs) and require little maintenance. None expected once product is fielded.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	None
Expected Lifespan	Up to 10 years based on design and deployment data of previous radars.
Warranty	We typically offer a Contractor Logistics Support service that provides for the repair or replacement for failures that occur
Extended Warranty	Yes
Submission Contact	Kevin Chambers | Phone: (315)-452-8373 | Email: kchambers@srcinc.com | Address: 6225 Runing Ridge Road, North Syracuse, New York 13212
Technical Contact	Stacy Ryan | Phone: (315)-883-4331 | Email: sryan@srcince.com
Sales Contact	Craig Marcinkowski | Phone: (315)-452-8866 | Email: cmarcinkowski@srcinc.com

SPECIFIC OPTICAL AVIAN RECOGNITION (SOAR) | TRL 7

Updated January 2017

Company	Ornicept
Website	www.ornicept.com
Target Renewable Energy	Land-Based Wind
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors Bats
Technology Components	Detection component
Description & Application	This system applies computer vision technology to wildlife. Using continual monitoring of birds and bats using remote sensing technology and proprietary software to uniformly collect big data to develop predictive risk models. Remote sensing of birds/bats and using machine learning software to collect, analyze, and predict risk.
Detect and/or Deter Non-Target Species	Detect, but not deter.
Avoidance of False Positives and False Negatives	The system is based on many machine learning and artificial intelligence technologies that continue to get smarter in time.
Effective Range	Currently in data processing.
TRL Justification	7-Ornicept has deployed an integrated pilot system in the Tehachapi Mountains, CA on a large-scale operational wind farm
Planned or Underway Testing	Yes, June 2015
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	We are taking steps to collaborate with USFWS.
Commercial Deployment	Yes, project funded by DOE in collaboration with NREL at a large, operational wind farm in the Tehachapi Mountains.
Installation and Setup	The detection system is free standing and will not touch any wind generation equipment. Internet connection and power are necessary.

Timeline for Installation and Operation	2H 2015
Coordination with Facility for Installation and Operation	None, products sold, installed, and operated by Ornicept.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None
Other Products Required for Installation	Included in system
Potential Interference with Other Technologies	No, this is a passive collection system.
Operational Limitations	Yes, species detection is only available on medium and large diurnal species. Object detection and tracking possible in all conditions.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Quoted, depending on size and nature of deployment. Maintenance minimal and provided by vendor. Ornicept provides ongoing operational and maintenance support.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Expected Lifespan	Currently undergoing operational testing in a challenging real-world environment with conditions ranging from desert to snow.
Warranty	Yes, products only sold with extended service
Extended Warranty	Yes, it depends on scale and nature of project.
Submission Contact	Russell B. Conard | Phone: (855)-656-4237 x201 | Email: russell@ornicept.com | Address: 330 E. Liberty, LL, Ann Arbor, Michigan 48104

WILDLIFE MORTALITY DETECTION SYSTEM | TRL 7

Updated February 2024

Company	Wildlife Imaging Systems
Website	https://www.wildlifeimagingsystems.com/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors Bats
Additional Species	Migratory Tree Roosting Bats, Whooping crane, Condors, Passerines (Songbirds), Migratory Tree Roosting Bats, Cave-dwelling bats
Technology Components	Detection component, Collision detection component
Description & Application	The wildlife mortality detection system pinpoints both the precise location and time of wildlife mortality around utility-scale wind turbines. The system uses thermal cameras which can capture up to a 360° field of view around the turbine, coupled with advanced computer vision and machine learning algorithms to detect bat and bird mortality around each turbine.
Mechanism(s) by which the Technology Operates	Video, Infrared/Thermal Imaging Cameras, Software
Monitoring or Minimizing	Monitoring
Detect and/or Deter Non-Target Species	The system can also detect insects, which may be a proxy for bat mortality risk around turbines.
Avoidance of False Positives and False Negatives	The system first classifies all detections as bird, bat, insect, or a noise class. From the biological classes, these are then further classified as an activity track or mortality track.
Effective Range	The exact range is a function target size and camera focal length, 115m for small wildlife (~10cm), 285m for medium size wildlife (~25cm) for a 19mm focal length, and greater for larger wildlife.
Product Manufacturing	We use all commercial off-the-shelf products.
Tech Support	USA
TRL Justification	We have successfully performed proof-of-concept testing over two years in the field. Tens of thousands of hours of video have been recorded and analyzed for mortality.
Efficacy Testing	Field Testing at a Commercial Wind Facility

Planned or Underway Testing	No
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	Not deployed
Installation and Operation Components	Free-standing
Installation and Setup	For an onshore deployment, the cameras are free-standing and remotely powered using solar panels and battery. The cameras record to an internally installed SD card which can be swapped throughout the season in order to process the data as the season occurs. For an offshore deployment, the cameras are mounted to a bracket attached to the platform. They are powered from an ethernet connection and transmit data from the turbine to an onshore server.
Coordination with Facility for Installation and Operation	For onshore, the facility owner needs to allow the cameras to be set up in plots around the turbines, possibly working with landowners to make this happen. For offshore, the facility owner needs to approve the drawings of where the cameras are mounted, how power and data is routed to the camera and how data is transmitted onshore.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None
Other Products Required for Installation	A solar powered battery system for an onshore deployment and PoE switches/NVRs for an offshore deployment.
Potential Interference with Other Technologies	No
Operational Limitations	No. The technology works 24 hours a day and in all weather conditions.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, there are data processing costs and labor hours associated with each project.
Remotely Monitored or Near Real-Time Status and Operation	No

Utility Scale Units Sold or Installed	Contact Company for Specific Numbers
Expected Lifespan	This depends on the camera warranty provided by the commercial off-the-shelf seller.
Warranty	Generally, yes, by the commercial off-the-shelf seller.
Peer-Reviewed Research	We are currently conducting peer-reviewed research and will update the technology once received.
Submission Contact	Brogan Morton | Phone: (802)-343-9889 | Email: brogan@wildlifeimaginingsystems.com | Address: 328 Mechanicsville Road, Hinesburg, Vermont 05461

THERMAL TRACKER 3D | TRL 6

Updated February 2025

Company	Sightir
Website	https://sightir.com/
Target Renewable Energy	Solar, Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Mammals Raptors Prairie Grouse Other Wildlife Species Big Game Bats
Additional Species	Seabirds, Condors, Hoary Bats,
Technology Components	Detection component, Curtailment component, Collision detection component, Other, Survey for Remote Construction Monitoring, Integrates with deterrent system, Integrates with turbine controls for curtailment
Description & Application	Sightir has licensed PNNL's Thermal Tracker-3D. The Thermal Tracker 3D records the flight tracks of birds and bats in three dimensions. The flight track data can be used to analyze bird and bat behavior relative to the actual or theoretical rotor-swept zone of a wind turbine, or solar energy installation. The technology can be used to collect baseline passage rates and flight behavior prior to construction and to monitor behavior post-construction. The system can also be used to enable various collision mitigation deterrents. The system uses a stereo pair of thermal cameras plus a light-sensitive color camera. The system generates flight track data in real time and logs it for monitoring and analysis. More info at https://www.sciencedirect.com/science/article/pii/S1574954120300194

Mechanism(s) by which the Technology Operates	Video, Infrared/Thermal Imaging Cameras, Accelerometers, GPS/VHF Radio Transmitters, Photographs
Monitoring or Minimizing	The system monitors via thermal imaging and visible cameras and can be used to enable actions to minimize interactions. We also have the ability to synchronize audio data thermal and visible data.
Detect and/or Deter Non-Target Species	Yes, any species of animal that enters the camera's field of view would be detected. Thes would be classified as other or undetermined.
Avoidance of False Positives and False Negatives	False positives and negatives are avoided by filtering detection based on size, persistence, and motion.
Effective Range	This is determined by the cameras that are used. current systems use a 640x512 pixels, 25 deg field of view angle, small birds can be detected at 200m, medium at 300m and large at 400+m.
Timeline of Production	Each system has been customized for specific applications to date.
Product Manufacturing	Santa Barbara California USA
Tech Support	Santa Barbara California USA
TRL Justification	Sightir is commercializing PNNL's 3D Thermal tracker and the TRL described above is from the work that has been completed at PNNL in support of offshore wind farm Avian 3D Tracking.
Efficacy Testing	Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.)
Planned or Underway Testing	The system has been tested on land and sea buoy, additional testing and improvements are planned by PNNL and Sightir in support of the California's Energy Commission, GFO-22-401 - Advancing Environmental Monitoring Technologies for Floating Offshore Wind Program.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	The technology has been presented to BOEM and will be discussed with California regulators and NOAA officials as related to the proposed Chumash Marine Sanctuary for the California Central Coast.
Commercial Deployment	Not yet.
Installation and Operation Components	Tower-mounted, Free-standing, Requires Internet, Requires Power Source, Commercially available Detectors, Other (Please specify)
Installation and Setup	A camera assembly (approx. 44 in x 9 in x 9 in, 35 lbs.) must be affixed to a structure such as tower, railing or support; an electronics enclosure (approx. 20 in x 20 x 12 in) must be located within 10 meters of the

	camera assembly with access to 24V power and a communication link; 4 cables must be routed between the camera assembly and the electronics enclosure.
Timeline for Installation and Operation	6 months, depending on the customizations required to identify specific species of interest.
Coordination with Facility for Installation and Operation	Power hook up, Service access. Field test setup for pre-construction surveys on land is self-powered.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Power hook up, Service access, mounting bracket design and integration with turbines when applicable.
Other Products Required for Installation	A cellular Modem, WIFI adapter, or satellite modem and a data plan
Potential Interference with Other Technologies	Not that we are aware of, the system utilizes passive sensing so there should be little risk of interference.
Operational Limitations	Inclement weather such as heavy fog, rain, snow, or ice can reduce the efficacy of the system. Field of few blockages from salt build up or ice may require service.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Clean camera lenses occasionally (frequency depends on location, conditions), replace cables as needed (should last 2-3 years), replace hard disk in computer (should last 1-3 years). Service agreements can be discussed.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	None
Expected Lifespan	Indefinite with regular maintenance and parts replacement
Warranty	Yes, (to be negotiated).
Extended Warranty	Yes, (to be negotiated).
Peer-Reviewed Research	We are currently conducting peer-reviewed research and will update the technology once received. https://onepetro.org/OTCONF/proceedings-abstract/24OTC/1-24OTC/D011S003R001/544894
Submission Contact	Marcus Chevitarese, President | Phone: (808) 403 1825 | Email: marcus@sightir.com | Address: 315 Meigs Road STE 501A, Santa Barbara CA 93109

WT-BIRD | TRL 6

Updated May 2017

Company	Energy Research Centre of the Netherlands (ECN)
Website	www.ecn.nl
Target Renewable Energy	Land-Based Wind
Target Species	Birds Bats
Technology Components	Deterrent component
Description & Application	The WT-Bird, a system for detecting and registering bird collisions at wind turbines, was developed at the Energy research Centre of the Netherlands (ECN) during the early 2000s. This system uses a combination of accelerometers and microphones to detect collision incidents, and infrared (active infrared) video cameras to record video footage of the event. To measure collision rates, the WT-Bird detection system from ECN will be installed in the selected wind turbines. This system combines acoustic detection of collisions in the rotor blades of the turbines, with visual species-recognition. Acoustic detection allows continuous registration of collisions, both during day and night, under all weather conditions. Species determination with cameras is possible under daylight conditions as well as in the dark, using infrared cameras. The system has been validated in various turbine types and has already been deployed in an offshore wind farm. The system was recommended in the SOSS-review on methods to measure collisions offshore (Collier et al. 2011). The sensors for the WT-Bird system will be installed in the three blades of different wind turbines at different positions in the blade. For the installation of the sensors no modifications to the blades will be required. The sensors will be glued, and the sensor data will be transferred to the measurement system. Schematic view of noises within a turbine blade. In addition to the sensors in the turbine-blades, cameras will be installed either at the wind turbine platform or on the mast of the wind turbines.
Detect and/or Deter Non-Target Species	Yes, since the system is based on weight. Species from 50 grams/7 centimeters will be detected.
Avoidance of False Positives and False Negatives	Since the system registers both sound and images it is easy to check if false hit occurs. Furthermore, SCADA data will be used to check if and which wind turbine's own sounds appeared.
Effective Range	Unknown
Timeline of Production	This technology has been in production since 2008.
Product Manufacturing	The Netherlands

TRL Justification	TRL 6 (for onshore wind turbines) and TRL5 (for offshore wind turbines)
Planned or Underway Testing	As mentioned, testing far offshore has not been performed yet. This is scheduled for this year (2017).
Commercial Deployment	The different versions of the system have been deployed at least four times! Deployment has been done on different type of wind turbines (Vestas, Lagerwey, Nordex etc.) in The Netherlands on both onshore as well as offshore wind turbines. Clients where E-Connection en NoordzeeWind.
Installation and Setup	The sensors for the WT-Bird system will be installed in the three blades of different wind turbines at different positions in the blade. For the installation of the sensors no modifications to the blades will be required. The sensors will be glued, and the sensor data will be transferred to the measurement system.
Timeline for Installation and Operation	A normal installation itself can be done within 1-2 months after the order has been placed. This will be part of the negotiation phase! There are thinkable locations which would need a different time frame.
Coordination with Facility for Installation and Operation	The facility owner needs to facilitate ECN access to the wind turbine and allow sensors to be placed in the blades (ECN has a long history in installing and operating sensors in blades) and cameras on the mast.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	The wind turbine manufacturer is needed to install sensors in blade, use mast for camera operation and provide SCADA data to determine what turbine's own sounds occur.
Other Products Required for Installation	System will come as a complete system, so no further products need to be purchased.
Potential Interference with Other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	The impact algorithm is always improving and reduction of costs for the system is part of further research.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	The expected lifespan of the product will be minimal 10 years. This is based on the existing system which operates already mor then 6 years in an offshore wind turbine. Important for the correct functioning of the system is that preventive maintenance will be applied else the lifespan could be affected.

Warranty	At the present stage, a standard warranty is issued. That means that we will keep the system working for a period of two years and costs of replacement of sensors will be covered under this contract. Our staff can work on height in the wind turbine.
Extended Warranty	Unknown. At the present stage no extended warranty is part of running projects.
Peer-Reviewed Research	https://rewi.knack.com/rewi-research-hub#browse-documents/document-details/67fe880dcec08102c61ba397/
Submission Contact	Hans Verhoef | Phone: (+31) 224 56 4086 | Email: verhoef@ecn.nl | Address: Westerduinweg 3,1755 LE Petten, The Netherlands
Sales Contact	Glen Donnelly | Phone: (+31) 224 56 4548 | Email: donnelly@ecn.nl

STEREO-OPTIC HIGH-DEFINITION IMAGING | TRL 4

Updated September 2017

Company	Biodiversity Research Institute HiDef Aerial Surveying Ltd.
Website	www.hidefsurveying.co.uk
Target Renewable Energy	Land-Based Wind
Target Species	Eagles Birds Bats
Technology Components	Detection Component
Description & Application	The intended target species are birds and bats. The camera system uses a pair of 29-megapixel digital video cameras equipped with fisheye lenses. The fisheye lenses give a wide field of view enabling a single pair of cameras to cover the space up to and including the turbine blades and down to the water with a horizontal field of view of approximately 150 degrees. The control computer's tasks are to pre-process the data to enable transmission back to a base station (the raw video streams have far too large a data rate to be transmitted in their entirety), to manage the data until it is successfully transmitted, and to operate the camera cleaning system. The algorithms rectify the fisheye image to create a synthetic flat image, which enables the stereo algorithm to work. The field control computer records just those parts of the image that appear to be moving; the land-based stereo algorithm then pairs up moving objects and uses calibration data to calculate the three-dimensional (3D) location of the object. Development of this technology is currently being supported by the Department of Energy. More information is available at: http://www.briloon.org/our-science-services/research-centers/center-for-ecology-and-conservation-research-2/center-for-ecology-overview-page/wildlife-and-renewable-energy-program/wildlife-and-renewable-energy-research-projects/stereo-optic-high-definition-imaging
Detect and/or Deter Non-Target Species	The camera system would be able to detect any moving object in the field of view.
Avoidance of False Positives and False Negatives	The system is designed to detect moving objects. The DOE-funded project is working to reduce the data that needs to be manually reviewed. False positives would be non-wildlife images

	such as moving trees, airplanes, and clouds. Methods are currently being developed to mask those from the data.
Effective Range	1-3 turbines depending on the spacing and the size of the target species
Timeline of Production	At this time only prototypes have been developed.
Product Manufacturing	The systems are currently developed in the UK, but the individual components can be sources to allow manufacturing in the US. BRI will produce the units in the USA when the technology is made commercially available
TRL Justification	The technology is currently TRL 4 and the goal of the current DOE-funded project is to move to TRL 5.
Planned or Underway Testing	The DOE-funded project will be complete in September 2016 and test results will be available in a report at that time.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	DOE is funding the testing of the camera by BRI.
Commercial Deployment	An earlier system was tested in the UK at an offshore wind farm and a coastal location. As a part of the DOE-funded project, BRI is conducting ongoing testing at coastal, and inland sites with bird and bat concentrations. The system is currently deployed at an active terrestrial wind farm.
Installation and Setup	Currently, the system is mounted on the ground adjacent to a wind turbine. In the UK the system was mounted on the access platform of the offshore wind turbine. Depending upon the application, the system could potentially be mounted on the support structure of the turbine or the nacelle.
Timeline for Installation and Operation	Currently, the system is being developed for commercial application. However, an estimate to build a new system is approximately four months.
Coordination with Facility for Installation and Operation	While the role would depend upon the application, there would be limited tasks required of the wind farm operator. One potential task would be data transfer which can occur remotely via an internet connection, via an RF link, or by swapping external hard drives. The method of data transfer will depend upon logistics at specific sites.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None, unless there was a need to mount the system onto a turbine. If the system was mounted to a turbine, then there would need to be a bracket to support the camera, and there would need to be access to the camera for maintenance.
Other Products Required for Installation	In the field the system is stand alone. If the data is being transferred over the internet then there needs to be a server to receive the data. At the video lab there will need to be computers

	optimized for managing video imagery, and appropriate storage and back-up systems.
Potential Interference with Other Technologies	No
Operational Limitations	Not that we are aware of at this time. Extreme heat and cold could damage system components but these limits are not currently known. The system can operate during the day and night. At night visibility is limited by the amount of near infra-red illumination.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	There are no continued costs known at this time, but over time components of the system such as wiper motors, and computers will likely need to be replaced or upgraded. While dependent on the duration of the deployment, there will be a continued cost of storing and backing up data collected from the system. Yes, once the system is deployed in the field, BRI staff will need to retrieve the data, review the data, and identify wildlife detected by the system. The DOE-funded project is supporting software development to make detecting and identifying birds and bats more efficient.
Remotely Monitored or Near Real-Time Status and Operation	Variable
Warranty	The system would be used as a service and BRI would be responsible for ensuring that the system was operational.
Submission Contact	Wing Goodale | Phone: 207-839-7600, ext. 219 | Email: wing_gooddale@briloon.org | Address: 276 Canco Road, Portland, Maine 04103

EAGLE TAG | TRL 3

Updated May 2017

Company	Renewable Energy Systems Americas Inc. (RES)
Website	www.res-group.com
Target Renewable Energy	Land-Based Wind
Target Species	Eagles Birds Raptors
Additional Species	Condors
Technology Components	Detection component
Description & Application	The device consists of a miniature electronic tag carried as, e.g., a leg ring by the bird. The tag comprises an incredibly low power consumption radio transmitter which is always on. The combination of very low power electronics, a power optimized beaconing scheme and very long-life, low self-discharge battery cell gives a tag weighing < 30g a lifetime of almost 30 years on a single battery i.e., a tag that is compatible with the safe carrying capability and lifetime of golden and bald eagles. The presence of the tag is detected by a network of ground-based receivers carrying out direction of arrival measurements and mounted within the wind farm on turbines or masts. The tag can be detected out to a range of 3km from the receiver network and through triangulation can be located in space to within 50m. When integrated with the turbine or wind farm control systems, a turbine or turbines posing a danger to an approaching, tagged eagle or eagles can be safely shut down. Furthermore, each tag is uniquely identifiable by its radio signature and the communications are secure, minimizing the risk of tracking for illegal purposes or spoofing of tags to maliciously shut down turbines.
Detect and/or Deter Non-Target Species	No, only birds or other creatures fitted with the tag can be detected.
Avoidance of False Positives and False Negatives	Only eagles fitted with the tag are detected. Each tag has a unique ID and anti-spoofing protocols have been incorporated in the design to minimize the possibility of malicious replication of the tag transmission.
Effective Range	3km radius from the perimeter of the network of ground stations mounted on turbines or masts around the wind farm. Approximately one ground station per 3 turbines is required for typical wind farm spacing.
Timeline of Production	Not yet in production

TRL Justification	TRL 3. Over the past 2-3 years we have engaged a major international R&D consultancy with world leading expertise in radio communications and innovation to de-risk the technological aspects of the concept. Research has focused on the radio circuit, transmission protocol and battery. A battery supplier has been involved in simulating the battery lifetime performance under the duty cycle and ambient conditions to which it could be exposed. Ground based trials of the radio transmitter/receivers have taken place within an operational wind farm to ensure that the signals are duly affected by interference from wind turbines. Full scale, non-functional models of the tag have been created to assist discussion with ornithological experts.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	No
Installation and Setup	The eagle needs to be trapped, and a tag attached to its leg. This is the most challenging aspect. A radio antenna array is fixed around the circumference of approximately 1 in 3 turbines at a height below the lower rotor tip or alternatively on dedicated masts around the wind farm.
Timeline for Installation and Operation	Several years of prototype development and demonstration are required before the device can be deployed as a product.
Coordination with Facility for Installation and Operation	The facility developer or owner needs to have a permit to tag the eagle(s). The wind turbines or wind farm require auxiliary power to power the radio receiver network and control unit.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Provision of auxiliary power at the turbine where the antenna network is attached (magnetically) to the tower. SCADA integration of control signal to shut down turbines.
Other Products Required for Installation	Dedicated control system/server.
Potential Interference with Other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	The tag is fit once and forget so has no additional cost after installation. The system is autonomous, so besides routine server maintenance, there are unlikely to be additional costs except system licensing costs. As the system has the capability to provide a lifetime of eagle activity data in the vicinity of the tracking system, it is envisaged that these data may be centrally managed to a) protect the data on eagle location and activity and b) to provide a database for ornithological research purposes.

Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	None
Expected Lifespan	The tag has a minimum life of 27 years and a typical life of 32 years based on the lifetime of the battery, the duty cycle, and a range of typical environmental profiles. A battery lifetime of 30 years was the main design parameter for the system and hence was the focus of the research effort.
Submission Contact	Alan Derrick | Phone: +44 141 4045515 | Email: alan.derrick@res-ltd.com | Address: Renewable Energy Systems Limited 3rd Floor STV Pacific Quay Gvlasgow G51PQ United Kingdom

LOW COST SINGLE TURBINE RADAR | TRL 1

Updated January 2017

Company	SRC, Inc.
Website	http://www.srcinc.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds Bats
Technology Components	Detection component
Detect and/or Deter Non-Target Species	Radar will detect moving objects that will need to be filtered to determine if a target of interest is present.
Avoidance of False Positives and False Negatives	Tracking technology is utilized to ensure that targets are real with a high probability. A turbine filter is implemented to identify, classify and remove detections from turbines.
Effective Range	Expected range is greater than 9km.
Timeline of Production	This technology has been in production since 2003.
Product Manufacturing	USA
Safety or Public Nuisance Issues	Standoff distance to avoid issues related to RF radiation hazards.
Commercial Deployment	No
Coordination with Facility for Installation and Operation	Access to site for site survey, site preparation (power/network), in addition to discussions supporting system parameters (number of radars, areas to be covered, etc).
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Radar would need to be mounted on the base of turbine.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	No
Remotely Monitored or Near Real-Time Status and Operation	Yes
Expected Lifespan	Original systems delivered in 2004 are still in operation.
Warranty	12-month warranty is provided.
Extended Warranty	Warranty is available.
Submission Contact	Kevin Chambers | Phone: (315)-452-8373 | Email: kchambers@srcinc.com | Address: 6225 Runing Ridge Road, North Syracuse, New York 13212
Technical Contact	Stacy Ryan | Phone: (315)-883-4331 | Email: sryan@srcince.com

Sales Contact	Craig Marcinkowski | Phone: (315)-452-8866 | Email: cmarcinkowski@srcinc.com

BUOY MONITORING | TRL N/A

Updated January 2025

Company	Normandeau Associates, Inc.
Website	http://www.normandeau.com
Target Renewable Energy	Land-Based Wind
Target Species	Other marine/aquatic animals Wading, Sea birds, or Waterfowl Birds Marine Mammals Bats
Additional Species	Passerine (Songbirds)
Technology Components	Detection component
Description & Application	Both avian and bat acoustics and VHF tag receivers positioned above water, and marine mammal acoustics and VEMCO tag receivers mounted below water, provide species composition data for calling or tagged animals.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, precipitation, etc.), Acoustic Monitor (Audible Sound), GPS/VHF radio Transmitters, Weather/Environmental Sensors (wind)
Monitoring or Minimizing	Monitoring
Detect and/or Deter Non-Target Species	No
Avoidance of False Positives and False Negatives	Software categorizes calls into animal groups which are then verified and specified to species-level or most precise level possible via manual identification.
Timeline of Production	This technology has been in production for 2 years.
Product Manufacturing	It is assembled in Massachusetts.
Tech Support	Massachusetts and Florida
Installation and Operation Components	Free-standing, Ongoing Operation and/or Data Management with Technology Vendor
Submission Contact	Julia Robinson Willmott | Phone: (352)-327-3262 | Email: jwillmott@normandeau.com | Address: 13100 Tech City Circle, Suite 500 Alachua, FL 32615

EAGLE RISK MODELS | TRL N/A

Updated November 2018

Company	Conservation Science Global, Inc. U.S. Geological Survey (USGS)
Target Renewable Energy	Land-Based Wind
Target Species	Birds
Additional Species	Bald Eagles, Golden Eagles
Description & Application	Models based on eagle telemetry data predict which sites will have risky turbines and predictions of sites with similar wind values but lower risk to eagles.
Monitoring or Minimizing	Minimizing
Peer-Reviewed Research	https://doi.org/10.1111/2041-210X.14019 ; https://doi.org/10.1002/ece3.8395
Submission Contact	Todd Katzner | Phone: (208)-426-5232 | Email: tkatzner@usgs.gov | Address: 970 Lusk St., Boise, Idaho, 83706

AI-BASED BIRD MONITORING | TRL N/A

Updated June 2025

Company	Spoor AI
Target Renewable Energy	Land-Based Wind
Submission Contact	uliana@spoor.ai

Full RFI not completed.

MINIMIZING TECHNOLOGIES

ALGORITHM BASED INFORMED CURTAILMENT

ARTIFICIAL VISION | TRL 9

Updated April 2025

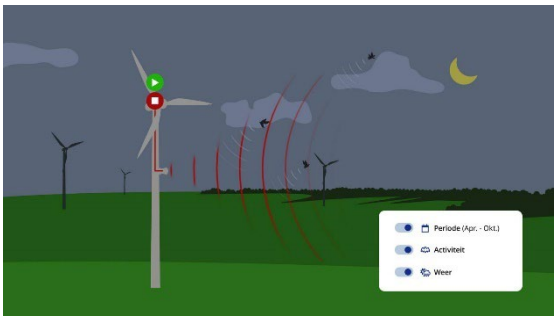
Company	Artificial Vision
Website	www.artificialvision.es
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Eagles Birds Bats
Additional Species	Birds of Prey
Technology Components	Deterrent component, Curtailment component, Integrates with turbine controls for curtailment
Description & Application	Artificial Vision delivers automatic protection for birds and bats in a given range. The system avoids the collision of bats and birds with the WTG using active or passive methods. There is a huge problem in the wind farms due to the high number of wildlife colliding with the wind turbines, which is an important environmental problem. Here is where our system comes into play, given that this is one of the main Artificial Vision Air Detection applications. Our automatic detect/dissuade/stop system can help enormously to alleviate this problem. The system can be installed in either Onshore or Offshore wind parks. The system integrates the latest existing technologies including artificial intelligence in real time in high-resolution images (4K), 3D stereoscopic vision, species recognition, image, and video recording. All results are presented in a web app accessible via

	VPN. The level of false positives is negligible, representing less than 1% of the total commanded stop.
Mechanism(s) by which the Technology Operates	Video, Software, Photographs
Monitoring or Minimizing	The Artificial Vision system is designed to minimize interactions between birds, bats, and wind turbine generators (WTGs) by actively or passively preventing collisions. Using high-resolution cameras as sensors, the system leverages artificial intelligence to automatically detect and protect against various species of birds and bats in real time. Unlike systems with complex moving parts like radars, this plug-and-play solution requires no calibration, making installation straightforward. The system can record image sequences and provide clear, intuitive reports of all events, ensuring comprehensive monitoring while minimizing risks to wildlife. Additionally, it can integrate with Deterrence Modules or Wind Turbine Brake Modules for enhanced collision avoidance.
Detect and/or Deter Non-Target Species	The Artificial Vision system is designed to detect and deter all potential threats to wind turbine generators (WTGs), including both target and non-target species. By utilizing high-resolution cameras and advanced artificial intelligence algorithms, the system identifies and tracks any bird or bat species within its range, regardless of type. This comprehensive approach ensures that the system protects WTGs from all aerial wildlife interactions. Furthermore, its integration capabilities with Deterrence Modules and Wind Turbine Brake Modules enable it to actively prevent collisions, offering robust protection against any species that may pose a risk.
Avoidance of False Positives and False Negatives	After years of development, the Artificial Vision system achieves exceptional accuracy in detection. The percentage of false positives is consistently below 1%, ensuring reliable identification of potential threats. Additionally, the system virtually eliminates false negatives when a bird or bat is near the wind turbine, guaranteeing comprehensive protection in critical proximity zones. This high level of precision is made possible by advanced artificial intelligence algorithms optimized for real-time detection and response.
Effective Range	1 km
Timeline of Production	This product has been in production for 10 years
Product Manufacturing	Spain
Tech Support	Spain
TRL Justification	The Artificial Vision system has reached Technology Readiness Level (TRL) 9, indicating that it is a fully mature technology. It has been proven in an operational environment, successfully deployed, and extensively validated under real-world conditions to ensure its

	reliability and effectiveness in protecting birds, bats, and wind turbine generators (WTGs).
Efficacy Testing	Field Testing at a Commercial Wind Facility
Planned or Underway Testing	Yes, tests are currently planned and underway in collaboration with both private companies and government entities, including the Ministry of Environment. These tests aim to further validate the system's performance and effectiveness in operational environments, ensuring compliance with environmental regulations and demonstrating its capability to protect wildlife while supporting sustainable energy production.
Safety or Public Nuisance Issues	No, there are no safety or public nuisance issues associated with the deployment or use of this technology. The Artificial Vision system operates using high-resolution cameras and advanced artificial intelligence, avoiding the use of complex moving parts, such as radars, or any elements that could pose risks to humans or wildlife. Its silent operation and non-intrusive design ensure that it does not disrupt the surrounding environment or nearby communities. Additionally, the plug-and-play nature of the system ensures easy installation and integration without causing any inconvenience or hazards.
Testing with Direct or Indirect Regulatory Agency Engagement	Yes, the testing efforts include direct engagement with the Ministry of Environment of Spain. This collaboration ensures that the system is evaluated under regulatory standards and aligns with environmental protection requirements. By working closely with the regulatory agency, the technology is validated for compliance and effectiveness in minimizing wildlife interactions with wind turbine generators (WTGs).
Commercial Deployment	Yes, the product has been commercially deployed in the field, and we are already working with some of the leading electric utility companies in Europe. This demonstrates the system's reliability, effectiveness, and readiness for large-scale implementation in operational environments.
Installation and Operation Components	Tower-mounted, Interface with SCADA System, Requires Internet, Requires Power Source, IP-65
Installation and Setup	The installation and setup of the system are very straightforward, requiring just one day per wind turbine generator (WTG). The process is non-invasive, as no holes or modifications are made to the WTG structure. The system is simply fixed to the designated installation point, making it quick and efficient to deploy.
Timeline for Installation and Operation	Once an order has been placed, the timeline for installation and operation of the product is swift, with installation taking approximately one day per wind turbine generator (WTG). After installation, the system operates throughout the entire lifespan of the WTG, with both preventive and corrective maintenance

	provided as needed. This ensures that the system remains fully functional and effective in protecting wildlife over the long term.
Coordination with Facility for Installation and Operation	The coordination required with the facility owner or operator for the installation and operation of the product is minimal. The system is designed to be plug-and-play, with installation taking just one day per wind turbine generator (WTG). The only coordination needed is to determine the appropriate installation point for the system, after which it operates autonomously with no further involvement from the facility owner or operator.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	The coordination required with turbine manufacturers or Original Equipment Manufacturers (OEMs) is minimal. The primary information needed is related to the SCADA system, ensuring that the technology can integrate seamlessly with the existing infrastructure. No significant modifications to the turbine itself are required, and the system is designed to operate independently once installed, without the need for ongoing coordination with turbine manufacturers or OEMs.
Other Products Required for Installation	None
Potential Interference with other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, the product has continued costs in the form of an annual maintenance fee. This ensures that the system remains fully operational, with both preventive and corrective maintenance provided as needed. The maintenance package covers ongoing support and any necessary updates, ensuring the technology continues to perform effectively throughout the lifespan of the wind turbine generator (WTG).
Remotely Monitored or Near Real-Time Status & Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	WTG lifespan
Warranty	2 years
Extended Warranty	Yes, contact me for more details.
Peer-Reviewed Research	No, we have not completed peer-reviewed research.
Submission Contact	Antón Hernández Albà | Phone: +34 608 99 11 52 | Email: info@artificialvision.es y ahernandez@artificialvision.es | Address: Avd Jaume Balmes 28, 08800 Vilanova i la Geltru. Barcelona, Spain

NEW BAT PROTECTION SYSTEM | TRL 9



Updated April 2025

Company	Topwind Consultancy BV
Website	https://bps.topwind.nl/en/
Target Renewable Energy	Land-Based Wind
Target Species	Bats
Technology Components	Detection component, Curtailment component, Integrates with turbine controls for curtailment
Description & Application	The Bat Protection System (BPS) has been developed for owners and operators of wind turbines who have to comply with ecological regulations regarding bat protection. This applies in particular to turbines for which the permit: Includes a monitoring obligation to record bat activity. Includes mandatory curtailing to minimize the number of bat victims.
Mechanism for Operation	Ultrasonic Acoustic Monitor, Acoustic Monitor (Audible Sound)
Monitoring or Minimizing	How does the Bat Protection System work? 1. Monitoring Once a bat exemption permit is issued, turbine owners are still obliged to conduct monitoring. This takes place by means of an ultrasound microphone in the nacelle and, for turbines higher than 120 meters, also at tip height. The collected data is stored immediately and can be accessed remotely. This eliminates the risk of data loss or delays and means that everything is accurately recorded from day one. 2. Protection The BPS system offers two methods for ensuring an optimal balance between protection and efficiency. Blanket Curtailment continuously monitors the weather activity and stops the turbine

	at pre-programmed values. Smart Curtailment stops turbines based on fixed conditions and bat activity, for minimum downtime and maximum protection.
Detect and/or Deter Non-Target Species	The BPS system offers two methods for ensuring an optimal balance between protection and efficiency. Blanket Curtailment continuously monitors the weather activity and stops the turbine at pre-programmed values. Smart Curtailment stops turbines based on fixed conditions and bat activity, for minimum downtime and maximum protection.
Avoidance of False Positives and False Negatives	Our Bat Protection System (BPS) monitors and detects bat activity with precision and controls turbines on the basis of dynamic time blocks. Through a combination of AI call detection and standstill models, only necessary standstills are implemented based on representative observations and current meteorological data. This not only offers higher levels of production and bat protection, but also clear, insightful reports for the competent authority.
Tech Support	Topwind Consultancy BV, Barneveld, The Netherlands
TRL Justification	For references click: https://bps.topwind.nl/en/#references
Safety or Public Nuisance Issues	No
Commercial Deployment	Yes, see https://bps.topwind.nl/en/#references for recent projects.
Installation and Operation Components	Tower-mounted, Requires Internet
Installation and Setup	Topwind's own installation team will ensure that the hardware is installed in a professional and sustainable way. The material is robust and designed to withstand impact, ensuring that the equipment continues to monitor the situation at all times. This guarantees reliability throughout the entire operational period, without you having to worry about anything.
Timeline for Installation and Operation	On request. Contact Company for Further Details.
Coordination with Facility for Installation and Operation	Topwind will provide full support and coordination with all relevant parties.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Topwind will provide full support and coordination with all relevant parties.
Other Products Required for Installation	Topwind will provide and install a complete system
Potential Interference with Other Technologies	No, the system is purely for detecting bats. Completely different systems exist for bird protection.

Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Please request for information about licensing fees or other yearly maintenance fees at Daniel Dubbelhuis, dd@topwind.nl .
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Warranty	Yes
Extended Warranty	Yes
Submission Contact	Daniel Dubbelhuis, Business Development Manager | Phone: +31645755855 | Email: dd@topwind.nl |

DTBAT®| TRL 9

Updated January 2025

Company	Liquen
Website	https://dtbat.dtbird.com/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Additional Species	Customizable for specific bat species, Migratory tree roosting bats, Cave-dwelling bats
Technology Components	Detection component, Curtailment component
Description & Application	DTBat® is an automatic system developed to reduce bat mortality in wind farms, which detects bat calls in real-time (Detection Module) through AI and takes automatic actions linked to bat activity detected, such as the Stop of a Wind Turbine (Stop Control Module). Bat calls, environmental data, wind turbine operation parameters, and DTBat® actions are recorded and uploaded daily to an Online Data Analysis Platform (NEST), available through the Internet. This also provides Automatic statistics, summarizing service profiles, bat calls, and system actions.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, Real-time ID of Bird/Bat Vocalizations, Weather/Environment Sensors (wind
Monitoring or Minimizing	Monitoring
Detect and/or Deter Non-Target Species	DTBat® Detection Module can detect all bat species. DTBat® Detection and Stop Control Module can be set to particular Species/Groups, but major efficiency will always be achieved when the protection is extended to all bat Species. To allow the collision

	of certain bat Species or not correct bat species identifications, can have legal consequences, and DTBat® declines any responsibility.
Avoidance of False Positives and False Negatives	There are software filters.
Effective Range	DTBat® System is effective in the Wind turbine where it is installed. Depending on the bat activity in the wind farm area and the goal of bat protection desire, the application of DTBat® stop triggers to other WTGs without DTBat® installed could be useful.
Timeline of Production	The technology had its first operation on a WTG in 2013.
Product Manufacturing	DTBat® System systems are assembled in Spain, and the origin of the components are mainly Europe.
Tech Support	Madrid, Spain
TRL Justification	Over 40 DTBat® units have been contracted in 6 existing/projected, onshore /offshore wind farms in 9 countries (Austria, Belgium, France, Germany, Italy, The Netherlands, Poland, Spain, and Switzerland). DTBat® has been operating at WTG since 2013.
Efficacy Testing	Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	Yes, however this is confidential
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	Yes. Public updated information is available on the DTBat website, www.dtbat.com.
Installation and Operation Components	Nacelle-mounted, Tower-mounted, Interface with SCADA System, Requires Internet, Requires Internet for Data Upload/Back Up, Requires Power Source
Installation and Setup	DTBat® Systems' design and needs are project specific.
Timeline for Installation and Operation	Installation is 2 months after the first payment and technical documentation exchange. Commissioning is less than 4 weeks months after installation.
Coordination with Facility for Installation and Operation	Project-specific characteristics.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Project-specific characteristics.
Other Products Required for Installation	Project-specific characteristics.

Potential Interference with Other Technologies	No
Operational Limitations	No, complete coverage of bat activity periods.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes. DTBat® service includes continuous checking of operation, software upgrades, Data Analysis Platform upgrades, bat calls & data storage, and change of settings according to daily checks, scientific public information, and DTBat knowledge gained worldwide.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	The general lifespan of the different DTBat elements is over 5 to 10 years (calculated by real data).
Warranty	2 years warranty worldwide.
Extended Warranty	No. Purchase of Spare Parts is available to the Client.
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://www.dtbird.com/index.php/dtbird-dtbat-document-downloads
Submission Contact	Agustin Rioperez | Phone: 0034 91 344 90 86 | Email: arioperez@dtbird.com | Address: Avenida de la Democracia, 7, N406. 28031 Madrid, Spain
Sales Contact	Déborah Olivier | Phone: 0034 648 268 966 | Email: dolivier@dtbird.com | Address: Avenida de la Democracia, 7, N406. 28031 Madrid, Spain

ECHOPITCH – ACTIVITY BASED SMART CURTAILMENT | TRL 9

Updated September 2024

Company	Stantec Consulting Services, Inc.
Website	www.stantec.com
Target Renewable Energy	Land-Based Wind
Target Species	Bats
Additional Species	Customizable for specific bat species, Migratory Tree Roosting Bats
Technology Components	Detection component, Curtailment component
Description & Application	Curtailment is an effective tool to reduce bat fatality rates because it reduces exposure of bat activity to turbine operation. Accordingly, the benefit of curtailing wind turbines to protect bats is proportional to the amount of bat activity occurring during a particular interval. We use passive acoustic monitors to characterize seasonal and temporal patterns in bat activity and relationships with weather variables. We then calculate acoustic exposure (the rate and/or proportion of bat passes detected when turbine rotor speed exceeds 1 rpm) and design smart curtailment programs that achieve a targeted reduction in acoustic exposure. The resulting strategies are tailored to site-specific bat activity patterns and can therefore achieve equivalent levels of exposure reduction as blanket curtailment with less energy loss. Our approach uses widely available technology and can be integrated with existing turbine control systems without the need for permanently altering turbines.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, precipitation, etc), Weather/Environmental Sensors(wind)
Monitoring or Minimizing	Minimizing and Monitoring
Detect and/or Deter Non-Target Species	This approach typically targets all bats that use echolocation (such as all North American bat species) but can be adapted to focus on priority species such as listed Myotis species, tricolored bat (Perimyotis subflavus) or long-distance migratory species such as hoary bats (Lasiurus cinereus).
Avoidance of False Positives and False Negatives	The approach uses acoustic data to characterize patterns in acoustic exposure and tailor curtailment strategies around these patterns; it does not use real-time acoustic detections to curtail turbines. Acoustic data are manually vetted to ensure that false

	positives are not included in the analysis used to characterize high risk conditions.
Effective Range	The approach can be adapted to wind projects of any size. The number of turbines to be monitored depends on project characteristics and management objectives. Curtailment decisions are based on turbine-specific meteorological data and can be configured for any groupings of turbines or project-wide.
Timeline of Production	Stantec began testing this system in 2012 and has worked with various wind developers to test and implement the system each year since then.
Product Manufacturing	USA and Australia
Tech Support	Topsham, Maine
TRL Justification	Our system uses technology and equipment that is already commercially available. Use of this equipment in design curtailment programs has been demonstrated at several commercial wind projects and is being tested in a rigorous manner in upcoming DOE-funded research.
Efficacy Testing	Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	Yes, DOE-funded research beginning in 2020-2024; private testing of approach at 20+ wind energy facilities in 2023 onward.
Safety or Public Nuisance Issues	No; passive acoustic monitoring does not generate any discernable audio or visual impact.
Testing with Direct or Indirect Regulatory Agency Engagement	Yes, field trials have been conducted in coordination with the US Fish and Wildlife Service and state wildlife agencies for the corresponding state(s).
Commercial Deployment	Yes, Stantec has implemented this approach successfully to manage risk to rare bats at over 25 wind energy facilities in more than 5 states.
Installation and Operation Components	Nacelle-mounted, Tower-mounted
Installation and Setup	Stantec deploys acoustic bat detectors in weatherproof enclosures that are temporarily attached to nacelle-mounted meteorological masts, turbine towers, or other appropriate structures. Detectors are typically powered using accessory power supplied in turbine nacelles or using solar-powered battery systems. Installation is typically done by site O&M staff and/or contractors with technical input and support from Stantec. Equipment is either purchased by sites or leased to sites by Stantec.
Timeline for Installation and Operation	Stantec can install acoustic monitors on turbines on short notice (e.g., 3 - 4 weeks) although the approach requires 1 full season (spring, summer, and fall) of acoustic monitoring to characterize

	relationships between bat activity and conditions. Monitoring is repeated during implementation to measure effectiveness of the system and inter-annual variation.
Coordination with Facility for Installation and Operation	Passive units must be installed by personnel that are qualified to climb turbines and typically require ~1-2 hours to install once up-to-to-the-tower.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None required, although integration with turbine power and communications improves system reliability and lower installation cost.
Other Products Required for Installation	Depending on turbine control mechanisms, wind project operators may need to update turbine control software to enable multiple parameters (e.g., temperature and wind speed) and adjust curtailment settings on a biweekly or monthly basis.
Potential Interference with Other Technologies	The approach may not work in conjunction with ultrasonic deterrents as these could interfere with the ability to monitor bat activity acoustically.
Operational Limitations	This approach relies on an assumption that the seasonal/temporal/spatial patterns in bat activity and relationships between bat activity and conditions will be consistent between years. Extensive monitoring conducted to date suggests that this assumption is valid.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	The primary costs are equipment used to monitor bat activity which depends on the number of turbines to be monitored and analysis of acoustic data. Stantec estimates that 1 year of monitoring will be required to set curtailment parameters and that an additional 1 - 2 years of acoustic monitoring may be required to demonstrate effectiveness of the curtailment program and/or adjust parameters. Each year of monitoring and associated analysis would likely cost approximately $45 - 75k. Costs associated with energy loss from curtailment will depend on management objectives (e.g., the desired reduction in risk to bats).
Remotely Monitored or Near Real-Time Status and Operation	No
Expected Lifespan	Implementation of the system relies on standard turbine control algorithms based on inputs such as wind speed, temperature, and time. As such, it does not depend on equipment or a product for continued implementation. Acoustic detectors used to design and validate effectiveness of the curtailment programs are prone to failure when installed on turbine nacelles but can typically operate autonomously for periods of 8 - 12 months, if configured properly.
Peer-Reviewed Research	Yes, we have peer-reviewed research available.

	https://doi.org/10.1002/wsb.1236
Submission Contact	Trevor Peterson | Phone: (207)-837-0979 | Email: trevor.peterson@stantec.com | Address: 30 Park Drive, Topsham, Maine 04086

FLEXIMAUS | TRL 9

Updated July 2024

Company	FlexiMaus GmbH
Website	https://www.fleximaus.de/en/
Target Renewable Energy	Land-Based Wind
Target Species	Birds Bats
Technology Components	Curtailment component, Integrates with turbine controls for curtailment
Description & Application	FlexiMaus provides a flexible solution for bat curtailment requirements. Through integration into the turbine controls, FlexiMaus can stop the turbines directly when necessary. The installed environmental sensors for rain, precipitation, etc. are combined with real time data from the turbines to guarantee correct and fast shutdowns. Blanket curtailments and smart curtailments are possible; their shutdown parameters are compared to environmental data and can be acted upon every minute. The FlexiMaus system is monitored automatically and continuously. Integration of blanket curtailments for bird protection, as well as shadow flicker curtailment and noise curtailment are possible. FlexiMaus can provide an interface between third party systems, such as bird detection modules, and the turbine and implement their shutdown commands.
Mechanism(s) by which the Technology Operates	Weather/Environment Sensors (wind, precipitation, etc.)
Monitoring or Minimizing	FlexiMaus minimizes interactions with bats and birds through smart curtailment based on environmental data.
Avoidance of False Positives and False Negatives	False positives and negatives are not an issue in this use case, because we work with environmental und turbine data only.
Effective Range	Entire wind farm
Timeline of Production	This technology has been in production since 2019.
Product Manufacturing	Germany
Tech Support	Germany
TRL Justification	In 2024 the FlexiMaus System has been installed and put into operation in over 500 turbines. The efficacy of the product is tested regularly by local authorities using ProBat Inspector.
Efficacy Testing	Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate

Commercial Deployment	Yes
Installation and Operation Components	Nacelle-mounted, Tower-mounted, Interface with SCADA System, Requires Internet, Requires Power Source, Other (Please specify)
Installation and Setup	Control Module is mounted inside turbine/substation and connected to Internet and Scada (directly, through operator router, DMZ or VLAN). The sensors are installed in a suitable location (substation if near or in park, tower, or nacelle)
Coordination with Facility for Installation and Operation	Access to Internet and SCADA, as well as access to Turbine and/or Substation.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Read and Write access needs to be granted to SCADA or other turbine control.
Potential Interference with Other Technologies	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	There are maintenance fees for the duration of the service contract.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	FlexiMaus can operate until the wind farm is taken off network or dismantled.
Peer-Reviewed Research	We are currently conducting peer-reviewed research and will update the technology once received.
Submission Contact	Jochen Rößler, CEO | Phone: +49(0)9868 3039-871 | Email: jochen.roessler@fleximaus.de | Address: Faulenberg 3, D-91583 Schillingsfürst

NEW OPTIMIZED SMART CURTAILMENT™ (OSC™) | TRL 9

Updated June 2025

Company	Western EcoSystems Technology, Inc.
Website	www.west-inc.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Additional Species	Algorithms can be developed for all bat species at a site, or tailored to a subset of the species at a site
Technology Components	Curtailment component, Integrates with turbine controls for curtailment
Description & Application	Optimized Smart Curtailment (OSC) produces turbine curtailment schedules (algorithms) that achieve risk reduction targets (percent fatality reduction) while minimizing energy production loss. The product requires site-specific bat activity data from thermal video or acoustic detectors along with weather data from the turbine SCADA system and the turbine power production curve as input data. OSC then uses a machine learning model to fit algorithms that are optimally tuned to meet conservation objectives while minimizing power loss. Following initial data collection and algorithm development, the algorithm can be left to curtail turbines indefinitely, without maintaining additional equipment.
Mechanism(s) by which the Technology Operates	Infrared/Thermal Imaging Cameras, Ultrasonic Acoustic Monitor, Weather/Environment Sensors (wind, precipitation, etc.)
Monitoring or Minimizing	OSC minimizes collision risk.
Detect and/or Deter Non-Target Species	No
Avoidance of False Positives and False Negatives	The machine learning model produces a classification algorithm by optimizing algorithm precision and recall. Overfitting is prevented using priors that constrain model complexity. Algorithms can be cross validated to ensure minimized false positives and false negatives if sufficient data are available. Finally, algorithms are reviewed by bat biologists to ensure ecological plausibility and compared to local post-construction fatality monitoring data to ensure adequate curtailment during periods of demonstrated higher risk.
Timeline of Production	This technology has been in production since 2019.
Tech Support	Wyoming

TRL Justification	OSC is implemented at a number of operating wind facilities in two Canadian provinces and nine US states. It has been approved for use by the USFWS in the Cardinal Point Habitat Conservation Plan (HCP) and is included in other draft HCPs.
Efficacy Testing	Field Testing at a Commercial Wind Facility
Planned or Underway Testing	A multi-year, multi-site study funded by REWI and industry partners is in progress.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	Yes. OSC is implemented at a number of operating wind facilities in two Canadian provinces and nine US states.
Installation and Operation Components	Other (Please specify).
Installation and Setup	Curtailment algorithms are implemented within the SCADA system so we work with operators to ensure that we understand SCADA capabilities and produce algorithms that can be implemented.
Timeline for Installation and Operation	We recommend at least one curtailment season of bat activity data to fit the algorithm and can deliver a product within two to three months after receipt of raw activity data.
Coordination with Facility for Installation and Operation	We work with operators to set minimization targets (percent risk reduction). The algorithm is delivered as a set of curtailment "rules" that the operator needs to enter into the SCADA system.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	We recommend operators coordinate with OEMs to ensure trouble-free deployment.
Other Products Required for Installation	None
Potential Interference with Other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	No
Remotely Monitored or Near Real-Time Status and Operation	Variable
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	Indefinite

Warranty	No
Extended Warranty	No
Peer-Reviewed Research	We are currently conducting peer-reviewed research and will update the technology once received.
Submission Contact	Jasmine Eatmon, Marketing Coordinator | Phone: 307-433-4781 | Email: jeatmon@west-inc.com | Address: 415 W. 17th Street, Suite 200 Cheyenne, WY, 82001,
Technical Contact	Paul Rabie, Principal Statistician
Sales Contact	Rhett Good, Principal Biologist

NEW ECHOSENSE ABIC | TRL 7-9

Updated June 2025

Company	Natural Power Consultants
Website	https://www.echosensellc.com/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Additional Species	Algorithms are typically designed based on all bat calls detected, but can be customized for certain species, species groups, or acoustic groups.
Technology Components	Curtailment component, Integrates with turbine controls for curtailment
Description & Application	EchoSense ABIC is a smart curtailment solution built on statistical and machine learning algorithms that uses data on bat occurrence, weather, and power production to design curtailment scenarios to minimize risk to bats while recovering lost energy associated with typical blanket curtailment. EchoSense ABIC can use any bat occurrence data, such as from acoustic detectors, thermal imaging video, or radar that records occurrences with date and time. EchoSense ABIC utilizes the EchoSense software to work with OEM's SCADA systemsLighting System to Enhance Turbine Detection and Avoidance by Raptors to enable flexible curtailment options that are tailored to a project's specific bat risk and energy production profile. It does this by using the wind speed and temperature data collected from each turbine's nacelle to apply the predicted EchoSense ABIC strategy for turbine operation. If projects need the advantage of real-time bat data, then they can seamlessly upgrade to the full EchoSense acoustic-activated system.
Mechanism(s) by which the Technology Operates	Weather/Environment Sensors (wind, precipitation, etc.), Software
Monitoring or Minimizing	Minimizing interactions. Curtailment commands are issued based on the predicted period when bats are known to occur and power production is maximized, which is derived from site-specific data. Blades are feathered to minimize the interaction between bats and turbine blades until the conditions (wind speed, temperature, and/or time) change in reference to the prescribed curtailment strategy.
Detect and/or Deter Non-Target Species	No

Avoidance of False Positives and False Negatives	Due to the predictive nature of this algorithm-based approach, false positives are minimized by predicting turbine operation for time periods when bats are likely to not be present, while false negatives are minimized by predicting turbine curtailment for time periods when bats are likely to be present.
Effective Range	Full facility
Timeline of Production	This technology has been in production for 1 year.
Product Manufacturing	Saratoga Springs, NY, USA
Tech Support	Saratoga Springs, NY, USA
TRL Justification	EchoSense ABIC has been developed and tested in a laboratory setting. It uses the EchoSense software to curtail/release turbines, which has gone through field and proof-of-concept testing in 2019 and in 2020-21 via support by the U.S. Department of Energy (DE-EE0008900) as well as the National Renewable Energy Laboratory (NREL), at the English Farms wind farm in Iowa. The EchoSense system has been used in commercial operations since 2020.
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility
Planned or Underway Testing	Further system refinements to improve bat conservation and energy return are underway.
Safety or Public Nuisance Issues	No
Commercial Deployment	The EchoSense ABIC results have not been deployed commercially, but the ability of the EchoSense software to control turbines based on real-time bat acoustic data and/or pre-determined rulesets has been deployed commercially.
Installation and Operation Components	Interface with SCADA System, Requires Power Source, Ongoing Operation, and/or Data Management with Technology Vendor
Installation and Setup	EchoSense ABIC can use any previously recorded bat occurrence data with corresponding date and time. But if this data needs to be obtained in order to design the curtailment scenarios, then to obtain acoustic activity, microphones would be mounted on the roof of the nacelle, and a bat detector is mounted in an enclosure inside the nacelle. As an option, network connections could be used to link each detector to a central server located in the ops building for the site in order to transmit data externally.
Timeline for Installation and Operation	1-3 months, depends on the need to acquire data to develop curtailment strategies.
Coordination with Facility for Installation and Operation	Coordination with site IT is required for the network and server setups. If needing to acquire bat data to develop EchoSense ABIC strategies, then on-site wind techs are recommended for detector installation.

Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Project and turbine manufacturer specific but may require coordination on SCADA integration; any necessary OEM coordination is normally managed by the project owner/operator.
Potential Interference with Other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, operated as a service once installed.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	Contact Company for Specific Numbers
Expected Lifespan	The system hardware has been designed and manufactured for long-term durability and minimal maintenance. Outdoor components are constructed from all-weather materials (aluminum, stainless steel, etc.) and acoustic detectors are installed inside NEMA-rated enclosures (optional if needing to collect this data).
Warranty	Specific details can be addressed at contracting.
Extended Warranty	Specific details can be addressed at contracting.
Submission Contact	Jared Quillen, Ecologist/Certified Wildlife Biologist® | Phone: 518-691-5284 | Email: jaredq@echosensellc.com | Address: 60 Railroad Place, Suite 205, Saratoga Springs, NY 12866
Technical Contact	Roger Rodriguez, Bat Biologist / Principal Consultant | Phone: +1 518 691 5303 | Email: rogerr@echosensellc.com
Sales Contact	Kevin Denman, Managing Director | Email: Hello@echosensellc.com

VESTAS BAT PROTECTION SYSTEM | TRL N/A

Updated March 2025

Company	Vestas
Target Renewable Energy	Land-Based Wind, Offshore
Submission Contact	joegg@vestas.com

Full RFI not completed.

REAL TIME ACTIVATED SMART CURTAILMENT

BIRD PROTECTION SYSTEM (BPS) – PREMIUM | TRL 9

Updated Fall 2023

Company	Bioseco
Website	www.bioseco.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors
Additional Species	The system classifies birds into two categories, Small and Large, based on wingspan. Birds with a wingspan of up to 1.2 meters are considered small, while all others are categorized as large.
Technology Components	Detection component, Deterrent component, Curtailment component, Integrates with deterrent system, Integrates with turbine controls for curtailment
Description & Application	The Bird Protection System (BPS) facilitates real-time monitoring of bird activity around the wind turbine, reducing collision risks by utilizing a smart deterrent system and/or turbine curtailment. The system is composed of independent detection and deterrence modules allowing it to cover specific observation areas. Based on stereovision the system is able to estimate the bird's distance, altitude, and flight trajectory. Furthermore, the system can classify birds' size* (small/large) and activate the deterrence or turbine stopping on selected parameters of distance, size, and altitude. False positives filtering is powered by artificial intelligence (AI).
Mechanism(s) by which the Technology Operates	Video, Photographs, Broadcast/Emission of Visible Light, Audible Acoustic Deterrent, Software
Monitoring and Minimizing	BPS detects and monitors birds in the vicinity of the turbine. It uses built-in light and audio deterrents to warn birds against potential danger. If a bird continues its path toward the turbine, BPS is feasible to curtail the turbine.
Detect and/or Deter Target Species	BPS is designed for all birds. It can be configured to, for example, activate deterrents for all birds but curtail turbine specifically for Large birds.

Avoidance of False Positives and False Negatives	Utilizing stereovision and advanced AI-based filtering.
Effective Range	1 turbine, a bird of Red kite size: high detection efficiency (minimum 80%) at 400m, with a maximum detection range of 500m
Timeline of Production	This technology has been in production since 2020.
Product Manufacturing	Gdansk, Pomeranian, Poland
Tech Support	Gdansk, Pomeranian, Poland
TRL Justification	The technology was installed in several counties across Europe and was verified by multiple clients through external companies. This verification included bird observations with Laser Range Finder measurements, and drone flights.
Efficacy Testing	Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Ongoing Testing	The effectiveness of BPS has been proven in several installations and tests. Nevertheless, each client has the ability to independently test BPS after installation.
Safety or Public Nuisance Issues	Depending on local regulations, light and audio deterrents may not be allowed. In some cases, the power of audio deterrents must be reduced.
Testing with Direct or Indirect Regulatory Agency Engagement	In some cases, test results are shared with local authorities so that they can permit BPS curtailment instead of permanent turbine stops, for example, during migration periods.
Commercial Deployment	Yes, over 350 BPS have been deployed since the market launch in 2020. The deployments are spread across multiple countries, indicating widespread commercial use. Here are the specific deployments by country: France: 146 BPS Spain: 95 BPS Poland: 84 BPS South Africa: 26 BPS Chile: 13 BPS Germany: 9 BPS Belgium: 2 BPS Luxembourg: 2 BPS This distribution confirms that the product is not only commercially available but has also been actively adopted in diverse geographical regions since 2020.
Installation and Operation Components	Tower-mounted, Interface with SCADA System, Requires Internet, Requires Internet for Data Upload/Back Up, Requires Power Source

Installation and Setup	The Bioseco BPS system is designed for fast, non-invasive installation directly onto the wind turbine tower, without the need for additional structures or ground infrastructure. Cameras are mounted on the tower at optimized angles, and the local computing unit (server) is installed inside the tower base. Setup includes a short calibration period—typically a few days—during which the system is adjusted to the specific site, considering environmental factors and potential dead zones (e.g., areas near masts or power lines). Once calibrated, the system operates autonomously and requires minimal ongoing maintenance.
Timeline for Installation and Operation	The implementation of the Bioseco Bird Protection System follows a structured sequence. It begins with the ordering and collection of all necessary components. Once the components are ready, the system is assembled and prepared for delivery. The equipment is then transported to the wind farm site, where installation takes place directly on the wind turbine tower. Following installation, the calibration phase begins, during which the system is configured and optimized based on local environmental conditions. The process concludes with the formal handover of the fully operational system. A preparatory site visit is also conducted in advance of the installation to finalize technical and logistical arrangements.
Coordination with Facility for Installation and Operation	Successful installation and operation of the Bioseco Bird Protection System requires close cooperation with the facility owner or operator. Access to the wind turbines—both inside and outside—is necessary for mounting the system hardware and running connection cables. The site must be prepared to ensure safe and unobstructed access, including ground conditions suitable for installation equipment. Regular communication and joint planning between Bioseco and the facility team help ensure smooth installation, reliable operation, and alignment with both environmental protection and energy production goals.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Coordination with turbine manufacturers or Original Equipment Manufacturers (OEMs) is important to ensure seamless integration and operation of the Bioseco Bird Protection System. This collaboration typically involves agreeing on technical interfaces to connect the BPS with the turbine's control systems, especially if automated turbine shutdowns or other safety actions are triggered by bird detections. OEMs may need to provide access to relevant communication protocols, SCADA systems, or control software to enable smooth data exchange and command execution.

	The system does not require any hardware modifications to the wind turbine structure. It is installed non-invasively, without the need for drilling holes. The system is attached using cable ties or magnets (depending on the type of tower). Existing ventilation holes or door openings are used to route the cables into the interior of the turbine.
Other Products Required for Installation	No major external products are typically required.
Potential Interference with Other Technologies	The Bioseco Bird Protection System is designed to operate seamlessly alongside existing wind farm technologies with minimal risk of interference.
Operational Limitations	Yes, like any advanced system, the Bioseco Bird Protection System has some operational limitations to consider. Its effectiveness depends on factors such as weather conditions—heavy fog, rain, or snow can reduce detection accuracy. The system also requires reliable power and internet connectivity to function optimally.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, the Bioseco Bird Protection System may involve some ongoing costs and continued involvement from our company. These typically include regular maintenance services to ensure the system operates at peak accuracy and reliability. We offer service contracts to provide ongoing support, maintenance, and upgrades, helping wind farm operators maximize the system's effectiveness and longevity while minimizing downtime.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	20~25 years
Warranty	Yes, 2 years.
Extended Warranty	Yes, with additional costs.
Peer-Reviewed Research	Yes, we have peer-reviewed research available.
Submission Contact	magda.bielawska@bioseco.com
Technical Contact	damian.dziak@bioseco.com
Sales Contact	magda.bielawska@bioseco.com

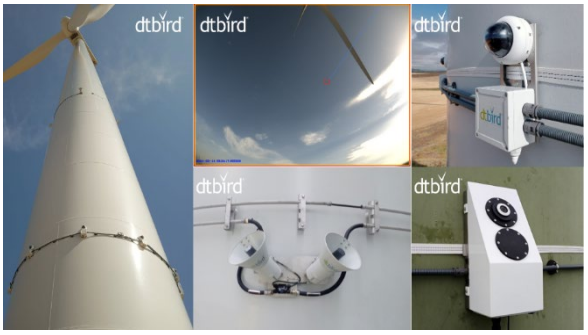
NEW

BIRDVISION® - ANTI COLLISION SYSTEM | TRL 9

Updated May 2025

Company	BirdVision
Website	https://birdvision.org/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Birds
Effective Range	A 360° view of the turbine and around 500 meters range, depending on the Bird size.
Product Manufacturing	Germany
Tech Support	Germany
Commercial Deployment	Yes, there are current running systems.
Installation and Operation Components	Tower-mounted, Requires Internet, Requires Internet for Data Upload/Back Up, Requires Power Source, Local Wind Operator Network Connection Access
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Peer-Reviewed Research	No, we have not completed peer-reviewed research.
Submission Contact	Benjamin Braun, Manager of the company | Email: Benjamin.Braun@birdvision.org | Phone: +497940 50 96 20 0 | Address: Braunsbergweg 5, 74676 Niedernhall, Deutschland

DTBIRD® | TRL 9



Updated January 2025

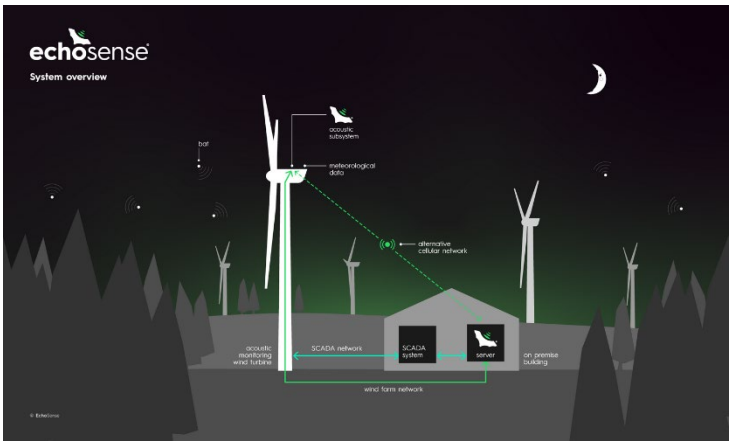
Company	Liquen
Website	www.dtbird.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors
Additional Species	Customizable for specific bird species, Whooping crane, Condors, Passerines (Songbirds)
Technology Components	Detection component, Deterrent component, Curtailment component, Collision detection component
Description & Application	DTBird® is an automatic Bird Monitoring and/or Mortality Mitigation system at On & Offshore Wind Turbines. Bird detection is based on AI with tracking and neural networks, through daylight or night (thermal) cameras. In standard operation, the DTBird® System surveys 360º around a Wind Turbine and detects birds in real-time.
Mechanism(s) by which the Technology Operates	Video, Photographs, Real-time ID of Bird/Bat Vocalizations, Audible Acoustic Deterrent, Infrared/Thermal Imaging Cameras
Monitoring or Minimizing	Monitoring
Detect and/or Deter Non-Target Species	DTBird® Detection Module can detect birds of many shapes and sizes, such as passerines, raptors, and seabirds. Via the DTBird Detection module model, species, size, and day/night activity determine the distance at which any target species may be detected. DTBird® Detection, Collision Avoidance, and Stop Control Module can be set to particular species or species groups. However, the collision risk will also be reduced for non-target species. The percentage of triggers attributable to non-targets versus targets will be determined by specific system configurations, similarity between the target and non-target species, and relative species activity around the wind turbine generators (WTGs). Allowing the collision of certain bird species or errors in species identifications can have legal consequences and DTBird® declines any responsibility.

Avoidance of False Positives and False Negatives	Artificial intelligence with software filters and neural networks.
Effective Range	Standard effective range is 1 single WTG. For WTG located at less than 100 m, when using the Stop Control module, this range could be higher, also it is project specific.
Timeline of Production	First Operation in a WTG: Detection in March 2009, Collision Avoidance in January 2010, Stop Control in March 2011.
Product Manufacturing	Spain
Tech Support	Madrid, Spain
TRL Justification	Over 500 DTBird® units have been installed in 110 existing/projected, onshore /offshore wind farms in 16 countries (Austria, Belgium, China, France, Germany, Greece, Italy, Norway, Poland, Spain, Sweden, Switzerland, Taiwan, The Netherlands, United Kingdom, and the United States). DTBird® has been operating at WTG since 2009.
Efficacy Testing	Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	YES. DTBird® is under continuous research and improvement and testing process with incomes from scientists, computer engineers, ornithologists, and veterinarians from many countries, including France (Projet MAPE: Réduction de la Mortalité Aviaire dans les Parcs Éoliens en exploitation), Greece (LIFE Project financed by the UE: "LIFE12 BIO/GR/000554- Demonstration of good practices to minimize impacts of wind farms on biodiversity in Greece"), Spain (DTBird project) and the USA (under the program “Wind Energy-Eagle Impact Minimization Technologies and Field Testing Opportunities”).
Safety or Public Nuisance Issues	DTBird® Detection, Collision Control, and Stop Control Modules do not produce any public nuisance issues. DTBird® Collision Avoidance Module includes 4 to 10 Speakers located around the wind turbine tower (project-specific configuration), triggering audible sounds only with the wind turbine in operation. DTBird® Collision Avoidance Module (Warning and Discouraging sounds) in standard operation does not reach 65 dBA at 500 m. DTBird® sounds are adjustable to local sound regulations or sound-sensible areas located at any distance from the Wind Turbine where the DTBird® System is installed. DTBird Collision Avoidance Module is not recommended at less than 500 m to sound sensible areas (inhabited areas, nests of endangered species, etc.). The use needs to be analyzed in the range of 700 m to 1 km. From 1 km onwards, it can be used without side effects.

Testing with Direct or Indirect Regulatory Agency Engagement	Yes. DTBird® System/Service is demanded by Environmental Agencies in Wind Farm Authorizations or Positive Environmental Decisions of Wind Farms in France, Greece, Poland, and Spain. DTBird system/service has also been accepted by each Regulatory Agencies of the countries where it is operating.
Commercial Deployment	Public updated information is available on the DTBird website, www.dtbird.com.
Installation and Operation Components	Nacelle-mounted, Tower-mounted, Interface with SCADA System, Requires Internet, Requires Power Source, Ongoing Operation, and/or Data Management with Technology Vendor
Installation and Setup	DTBird® Systems' design and needs are project specific. There are several DTBird models with customized locations of cameras and speakers.
Timeline for Installation and Operation	Installation is 2 months after the first payment and technical documentation exchange. Commissioning is less than 4 weeks after installation.
Coordination with Facility for Installation and Operation	Project specific characteristics.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Project specific characteristics.
Other Products Required for Installation	Project specific characteristics.
Potential Interference with Other Technologies	No
Operational Limitations	The maximum detection distance is conditioned by the visibility, camera model, and target species.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, DTBird service includes continuous checking of operations, software upgrades, Data Analysis Platform upgrades, videos & data storage, and change of settings according to daily checks, scientific public information, and DTBird knowledge gained worldwide.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	The general lifespan of the different DTBird elements is over 5 to 10 years (calculated by real data). Purchase of Spare Parts is available to the Client.
Warranty	Yes. 2-year worldwide warranty.
Extended Warranty	No. Purchase of Spare Parts is available to the Client.
Peer-Reviewed Research	Yes, we have peer-reviewed research available.

	https://www.dtbird.com/index.php/dtbird-dtbat-document-downloads
Submission Contact	Agustin Rioperez | Phone: 0034 91 344 90 86 | Email: arioperez@dtbird.com | Address: Avenida de la Democracia, 7, N406. 28031 Madrid, Spain
Sales Contact	Déborah Olivier | Phone: 0034 648 268 966 | Email: dolivier@dtbird.com | Address: Avenida de la Democracia, 7, N406. 28031 Madrid, Spain

ECHOSENSE® | TRL 9



Updated June 2025

Company	Natural Power Consultants
Website	https://www.echosensellc.com/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Additional Species	Rules sets are typically designed based on all bat calls detected, but can be customized for certain species, species groups, or acoustic groups.
Technology Components	Detection component, Curtailment component, Integrates with turbine controls for curtailment
Description & Application	The EchoSense technology is a smart curtailment system that uses detected bat acoustic data along with weather data to make real-time curtailment decisions to minimize risk to bats while recovering lost energy associated with typical blanket curtailment strategies. EchoSense can also be used to mitigate impacts to bats beyond those standard curtailment measures. The EchoSense system can be grouped into two subsystems – detection and decision. The detection subsystem consists of bat detectors deployed on the nacelles of turbines to monitor and record echolocation calls as bats are flying near the rotor swept zone. The system also collects wind speed and temperature data from the nacelle sensors. This information is sent through the wind farm network to the decision subsystem which consists of a server onsite, typically in an Operations and Maintenance building. This part of the system compares real-time acoustic detection information against a predefined set of rules (in accordance with the project-specific mitigation plan), and issues curtailment commands when these rules are met. Rules sets are typically designed based on all bat calls detected, but can be customized for certain species, species groups, or acoustic groups.

Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, Real-time ID of Bird/Bat Vocalizations, Weather/Environment Sensors (wind, precipitation, etc.), Software
Monitoring or Minimizing	Minimizing interactions. Bat echolocation calls are recorded and transmitted in real-time to initiate curtailment commands. Blades are feathered to minimize the interaction between bats and turbine blades until no further echolocation calls are recorded or wind speed increases.
Detect and/or Deter Non-Target Species	Yes. Birds and other audible wildlife can be detected by the acoustic units, but no action is taken based on their detection. Typically, these are low frequency sounds that are classified as noise.
Avoidance of False Positives and False Negatives	State-of-the-art ultrasonic detectors used have complex algorithms in place to limit the influence of false positives and minimize false negatives. Further signal processing is performed on the server to ensure that false positives and false negatives are kept to a minimum.
Effective Range	A full facility.
Timeline of Production	This technology has been in production for the past 5 years.
Product Manufacturing	Redmond, WA, USA
Tech Support	Various locations, USA
TRL Justification	Following a proof-of-concept deployment in 2019 and supported by the U.S. Department of Energy (DE-EE0008900) as well as the National Renewable Energy Laboratory (NREL), we worked with Alliant Energy to install and operate a full system from August to October 2020 at the English Farms wind farm in Iowa. In 2020-21 we tested EchoSense against minimal and blanket curtailment to prove it works. Curtailment with EchoSense resulted in bat fatality rates comparable to blanket curtailment and an average reduction in energy loss of 56%. Contact Natural Power for the results of this study. The EchoSense system has been used in commercial operations since 2020.
Efficacy Testing	Lab Testing, Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	Yes. Further system refinements to improve bat conservation and energy return are underway.
Commercial Deployment	Yes
Installation and Operation Components	Nacelle-mounted, Interface with SCADA System, Requires Power Source, Ongoing Operation and/or Data Management with Technology Vendor, Local Wind Operator Network Connection Access, Commercially available Detectors

Installation and Setup	Microphones are mounted on the roof of the nacelle, and a bat detector is mounted in an enclosure inside the nacelle. Network connections are needed to link each detector to a central server located in the O&M building for the site.
Timeline for Installation and Operation	2-3 months, systems are built and installed on-demand and customized per turbine type.
Coordination with Facility for Installation and Operation	On-site wind techs are recommended for installation. Coordination with site IT is required for the network and server setups.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Project and turbine manufacturer specific but may require coordination on SCADA integration; any necessary OEM coordination is normally managed by the project owner/operator.
Potential Interference with Other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, it is operated as a service once installed.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	The system hardware has been designed and manufactured for long-term durability and minimal maintenance. Outdoor components are constructed from all-weather materials (aluminum, stainless steel, etc.) and acoustic detectors are installed inside NEMA-rated enclosures.
Warranty	System components are covered under manufacturers' warranties; specific details can be addressed at contracting.
Extended Warranty	Specific details can be addressed at contracting.
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://doi.org/10.2172/2212448
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FLEXIBIRD | TRL 9

Updated July 2024

Company	FlexiMaus GmbH
Website	https://www.fleximaus.de/en/
Target Renewable Energy	Land-Based Wind
Target Species	Birds Raptors
Additional Species	Red Kite
Technology Components	Detection component, Other, Integrates with turbine controls for curtailment
Description & Application	FlexiBird is an autonomous cultivation detection system, designed to support the operator of the turbines in adhering to local regulations regarding bird curtailment after certain agricultural work has been done in a set radius around the turbine. Two of FlexiBird's 180° camera systems are mounted to the tower of the turbine. FlexiBird will send a notification including pictures of the detected cultivation to the operator who can then issue a shutdown command through the FlexiMaus interface. The FlexiBird AI is being trained to recognize the type of cultivation and to automatically issue a shutdown for the affected turbine. The FlexiBird system is monitored automatically and continuously. Reporting Data and Documentation of the Shutdowns is provided to the customer.
Mechanism(s) by which the Technology Operates	Photographs
Monitoring or Minimizing	Minimize interactions by curtailment during increased risk of collision after cultivation.
Effective Range	1 turbine - full wind farm
Product Manufacturing	Germany
Tech Support	Germany
TRL Justification	FlexiBird has been installed in multiple wind farms and has been operating for over a year.
Efficacy Testing	Field Testing at a Commercial Wind Facility
Commercial Deployment	Yes
Installation and Operation Components	Tower-mounted
Installation and Setup	The cameras are mounted with magnets at 80-120m above the ground on the tower. They are connected to a communication module via Ethernet (PoE), for which a hole has to be drilled into the tower.

Potential Interference with Other Technologies	No
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
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IDENTIFLIGHT® | TRL 9

Updated October 2024

Website	www.identiflight.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Eagles Birds Raptors Bats
Additional Species	The overwhelming advantage of IdentiFlight over other approaches is the ability to identify species in real time. New species are being trained regularly with more than 100+ species already trained. Learn more about IdentiFlight species at identiflight.com/species.
Technology Components	Detection component, Curtailment component, Survey for Remote Construction Monitoring, Collisions detected if observed in camera field of view, Integrates with turbine controls for curtailment
Description & Application	IdentiFlight® is an autonomous aerial monitoring, detection, and informed curtailment system meant to prevent eagles and other large, protected avian species from collisions with wind turbines. IdentiFlight can discriminate among species of similar size such as eagles and turkey vultures from colliding with rotating wind turbines. Atop an IdentiFlight tower, high-precision optical technology detects and identifies protected avian species that fly within a 1,500-meter hemisphere around each tower with 98% identification accuracy. Proprietary software and neural network technologies analyze images of detected birds to determine 3D position, size, velocity, and trajectory. In real-time, the species is identified as one of the protected species or as an unprotected species. By detecting a bird as far as 1,500 meters out and

	identifying it as a protected avian species in real-time, the IdentiFlight system provides wind farm operators with critical visual and quantitative data to reduce or eliminate collisions between protected avian species and wind turbines by over 85%. IdentiFlight monitors and in some cases initiate a shutdown of targeted turbines through the customer's SCADA network. Operators report less than 1% power generation loss.
Mechanism(s) by which the Technology Operates	Video, Photographs, Software, Weather/Environmental Sensors (wind, etc)
Monitoring or Minimizing	IdentiFlight can assist with bird observation data collection to support the permitting process and/or for further ecological assessment. Station(s) can also be installed during or after wind farm construction for informed curtailment (shutdown on demand), which helps minimize risk.
Detect and/or Deter Non-Target Species	IdentiFlight is designed to detect and curtail for specific species of interest that may pose a risk for collision. Species of interest are determined through agreements between the customer and regulatory stakeholders. Key considerations in determining a species of interest includes local or global population sensitivity (threatened, endangered, etc.), local protections, and cultural relevance.
Avoidance of False Positives and False Negatives	IdentiFlight uses convolutional neural network technology with supervised machine learning to examine size, shape, and color characteristics based on over 200 measurements 10x per second. This AI technology provides 1% species identification false negative rate and 5% species identification false positive rate.
Effective Range	An IdentiFlight imaging head is made up of high-precision optical technology detects and classifies protected avian species that fly within a 1,500-meter hemisphere around each station. The detection range varies on the size of the bird being tracked.
Timeline of Production	Boulder Imaging, founded in 1995, began development of the IdentiFlight product in 2012 in Louisville, Colorado. Commercial development launched in 2017 with commercial operation going live in 2018 at Deriva Energy's Top of the World wind farm. Since then, Boulder Imaging has installed more than 520 IdentiFlight stations globally. In 2024 alone the IdentiFlight fleet expanded by over 200 stations and continues with rapid expansion.
Product Manufacturing	Colorado
Tech Support	Colorado
TRL Justification	Technology has been tested by a DOE-sponsored project led by AWWI's Technology Innovation Program and direct sales ensued as a result of this verification/evaluation project. Independent testing has also been conducted by the TUV (Technical Inspection Association) in Germany.

Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	There is ongoing validation testing taking place at multiple IdentiFlight deployments in the US and Europe.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No, however, IdentiFlight has been recognized globally by multiple agencies as an effective in reducing bird fatalities. These agencies include the French Grand-East Region/DREAL, and the German Kompetenzzentrum Naturschutz und Energiewende. Additionally, IdentiFlight has been introduced to multiple regional offices of the U.S. Fish and Wildlife Service. The system has also been independently validated by the Peregrine Fund and TÜV Nord.
Commercial Deployment	No, however, IdentiFlight has been recognized globally by multiple agencies as an effective in reducing bird fatalities. These agencies include the French Grand-East Region/DREAL, and the German Kompetenzzentrum Naturschutz und Energiewende. Additionally, IdentiFlight has been introduced to multiple regional offices of the U.S. Fish and Wildlife Service. The system has also been independently validated by the Peregrine Fund and TÜV Nord.
Installation and Operation Components	Free-standing, Interface with SCADA System, Requires Internet, Requires Power Source, Ongoing Operation, and/or Data Management with Technology Vendor
Installation and Setup	The IdentiFlight imaging head is mounted on towers ranging from 7 to 40 meters. Foundation options include portable ballast-weighted feet, requiring no ground penetration, or caissons for permanent installation. Towers can withstand winds up to 120 mph and tilt down for easy servicing. Cattle fencing surrounds each tower to protect the electric subpanel, where power is routed from nearby turbines and stepped down to 240/230 volts. A control cabinet near the tower houses power systems, computer, network equipment, and weather station electronics. Data is transmitted to the Base Station via fiber or wireless.
Timeline for Installation and Operation	Production and installation of IdentiFlight varies greatly dependent on the scope and scale of the project. The installation timeline from contract signing is typically 6-8 months plus a 6-week commissioning period.
Coordination with Facility for Installation and Operation	Boulder Imaging will work with civil contractors and onsite operational staff to coordinate installation of the necessary infrastructure for the IdentiFlight system. Power, network, and

	internet access are required and will need to be fully commissioned and tested before IdentiFlight can be installed. Network (LAN) and power are typically routed underground from a nearby turbine through spare fiber-optic cores, eliminating additional networking complexities. Along with the SCADA network connection, the Base Station has an internet connection (WAN) to provide connectivity for remote monitoring for customers and IdentiFlight personnel.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Depending on a customer's SCADA implementation, coordination with the turbine manufacturer may be required. IdentiFlight has been integrated with, but is not limited to, the following wind turbine manufacturers: Vestas, GE, Siemens Gamesa, Goldwind, Envision, Enercon, Nordex, Suzlon.
Other Products Required for Installation	The customer is required to perform the civil work and site prep prior to system installation. The IdentiFlight system include the appropriate number of stations, one centralized Base Station, and a single use Dashboard license with more available under the Maintenance and Service agreement.
Potential Interference with Other Technologies	No
Operational Limitations	IdentiFlight has been designed and tested to operate in a variety of conditions, including: • Ambient temperatures from -10°C to 45°C • Wind gusts up to 54 m/s • Up to 100% humidity • Severe winter and desert climates • Coastal regions with salt spray Heavy snow fall or fog will cause occlusion and may reduce detection rates. Research and development are underway to introduce nighttime functionality for bats and nocturnal species of birds as well as offshore applications.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	IdentiFlight systems require annual and periodic maintenance. On-site maintenance includes inspecting and cleaning the camera viewports, checking the structural components, and servicing the pan-tilt unit, as necessary. The Boulder Imaging professional services team performs virtual maintenance, which includes manual calibration, clean-up of computer systems, data backups, software upgrades, and more. Maintenance and service costs are dependent upon site location, length of deployment, environment, and quantity of IdentiFlight stations deployed. Major hardware upgrades are required at pre-determined intervals over the lifetime of the system.

Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	IdentiFlight stations are designed for the lifetime of the wind farm, typically 25 years. This timespan assumes that wind farm operators adhere to a preventive maintenance program with component replacements at necessary intervals.
Warranty	Boulder Imaging offers a standard two-year hardware and software warranty, which begins at delivery on site. Details of the warranty are available in Boulder Imaging's standard Master Supply and Services Agreement (MSSA). A maintenance and service (M&S) plan is required for continued support of operations. Multiple plans are available to suit the site's specific needs.
Extended Warranty	Boulder Imaging offers extended warranties and service options upon request.
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://doi.org/10.1016/j.biocon.2018.04.041
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NEW MERLIN BIRD AND BAT MONITORING & MITIGATION SYSTEM (BMS/BMMS) | TRL 9

Updated July 2025

Company	DeTect, Inc.
Website	www.DeTect-inc.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Eagles Birds Raptors Bats
Description & Application	DeTect's MERLIN technology was originally developed for the U.S. Air Force and NASA as a precision bird detection radar system for critical flight safety. The BMS uses DeTect's advanced 2D and True3D radar to provide automated, unattended 24-7 collection of high-quality data on bird activity at ranges of 3-8 miles that can be used to develop detailed pre-construction mortality risk projections and for operational monitoring. With the MERLIN BMMS mortality risk mitigation upgrade, the system is integrated with advanced day/night tracking cameras, acoustic sensors, and AI technology to function as an "early warning" system, automatically engaging response mitigation actions up to and including idling of turbines until the risk passes.
Mechanism(s) by which the Technology Operates	Radar
Monitoring or Minimizing	Both. The system uses 2D and True3D radar monitoring to provide reliable avian detection and tracking in almost any weather condition (i.e., fog, rain, snow) and real-time target filtering by size and mass for hazardous bird and drone activity. New technology (precision tracking radar) is currently being tested that will allow monitoring of wing beats to assist with species identification.
Detect and/or Deter Non-Target Species	The operating software was developed specifically for detection and tracking of bird (all species) and drone activity.
Avoidance of False Positives and False Negatives	The MERLIN bird detection and tracking software operates in real-time applying advanced, military-grade target identification, classification, and tracking algorithms and clutter suppression and interference rejection routines to the radar data stream to

	provide superior, highly accurate identification and tracking of bird targets over aircraft/ship software or image processing-based systems. MERLIN additionally incorporates advanced dynamic, real-time ground clutter suppression, and Doppler processing to more reliably detect and track birds in high clutter environments - a functionality that is unique to MERLIN and that is critical to the delivery of an effective system for most complex industrial environments. The MERLIN system classifies targets into size classes generally corresponding to small, medium, large, and flock-size birds which generally correspond to these bird size classes but cannot definitively distinguish species as installed. As such, DeTect recommends that periodic field ground truthing of the radar system data be conducted by qualified biologists as part of any survey with the system for data validation and to develop data subsets on species predominant at the survey site or of species of interest using the MERLIN ground truth recording feature.
Effective Range	DeTect uses a combination of 2D, True3D and Precision Tracking Radar sensors, depending on the application, to detect and track avian targets out to 16 NM.
Timeline of Production	DeTect began production of MERLIN Avian Radar Systems in 2003.
Product Manufacturing	Originally designed, developed, and supported out of our global headquarters in Panama City, Florida, DeTect now has research, engineering and manufacturing facilities in Calgary, Alberta Canada; Goleniow, Poland; South Korea, and Taiwan (2026) with offices throughout the US, Canada, Europe & Asia.
Tech Support	Originally designed, developed, and supported out of our global headquarters in Panama City, Florida, DeTect now has research, engineering and manufacturing facilities in Calgary, Alberta Canada; Goleniow, Poland; South Korea, and Taiwan (2026) with offices throughout the US, Canada, Europe & Asia.
TRL Justification	TRL 9: The MERLIN radar system is commercially available with over 1,100 systems sold over the last 20+ years. Operational systems are deployed at airports, wind farms, mining operations, and research programs all over the world. Within the wind energy industry, MERLIN has been used extensively in pre-construction studies, risk assessment, and operational mitigation.
Efficacy Testing	Field Testing at a Commercial Wind Facility
Planned or Underway Testing	The system is continually tested to improve performance, and improvements are implemented to keep pace with technological advancements in available radar sensors and systems.
Safety or Public Nuisance Issues	No

Testing with Direct or Indirect Regulatory Agency Engagement	MERLIN Avian Radar System has been approved for use in risk mitigation by permitting agencies regulating wind farms. Radar surveys have long been accepted and in some cases are required by state and federal agencies for pre-construction data on wildlife movements. In terms of the safety of operations, DeTect equipment has been certified by occupational health and safety groups and has all the frequency and technical licenses required to operate a radar system.
Commercial Deployment	Over 1,100 MERLIN units have been sold and delivered worldwide in addition to surveys carried out with DeTect-owned radars. See attached documents for representative projects.
Installation and Operation Components	Tower-mounted, Free-standing, Interface with SCADA System, Requires Power Source
Installation and Setup	These are small, mobile, trailer-mounted systems or can be skid-mounted for permanent installation on a site. They are ground-based installations with no direct attachment to wind farm structures.
Timeline for Installation and Operation	Up to 9 months depending on specific radar sensor, configuration, and production schedule for delivery and installation. DeTect-owned equipment is often available for lease to provide interim coverage while production is completed.
Coordination with Facility for Installation and Operation	DeTect handles the installation and deployment of the avian radar systems and includes one full year of data support, remote monitoring, and project management with the purchase of equipment. The infrastructure required for the installation of the system includes a concrete pad and commercial power supply for operational sites. Trailer and generator units are available for preconstruction surveys with the operator responsible for fuel and generator maintenance. For operational mitigation systems connection to the on-site network communications is recommended for monitoring and communication of risk in real time.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	No, coordination with turbine structure is needed during installation but an operational mitigation system generally requires the ability to communicate and exchange information with the wind farm SCADA system.
Other Products Required for Installation	All required components can be purchased with the system, and it can be operated as a stand-alone system.
Potential Interference with Other Technologies	No
Operational Limitations	The MERLIN radar system collects data continuously during operations and the workstations and other sensitive equipment are installed in environmentally controlled trailers or cabinets to protect from environmental extremes. The MERLIN technology was originally developed and is currently used by the US Air Force

	and NASA for aircraft-bird strike risk management and includes advanced, military-grade signal processing software, however, radar is susceptible to interference from weather, structures, vegetation, high sea state, and other radars that may limit detection in certain areas and/or environments. These factors are all taken into consideration when selecting a radar location. The system will require installation in a representative location with a relatively clear line-of-sight of the area(s) of interest. Precipitation may affect the data collected by the system.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	For the operation of the system, there are costs of generator fuel or commercial power, dependent on the system and location. If generators are in use the system requires basic maintenance every 250 hours, with commercial power the generators are a backup power source and require minimal service to maintain reliability. The maintenance schedule for the radar sensors is dependent on the sensor type with solid-state radars having no 'wear' components and a 50,000 hr MTBF manufacturer rating. Some clients operate the radar completely independent of DeTect involvement including certain consulting companies that own DeTect equipment and some federal agencies such as USFWS. Other clients contract with DeTect for additional data analysis after the initial studies or for complete management of the radar program.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1000+
Expected Lifespan	O&M schedules and costs have been worked out for a 20-year operating period but with proper maintenance, radar systems can operate beyond that time frame.
Warranty	DeTect provides a one-year full parts and labor warranty that includes repair or replacement of any defective parts for the term of the warranty, exclusive of worn parts. Wear parts are parts that degrade under normal use and include, but are not limited to, radar magnetrons, motor brushes, generators, tires, and other such components, or parts that fail due to deterioration from adverse environments or chemical exposure. Options for service contracts and extended warranties are available beyond that.
Extended Warranty	Extended warranties are available. The systems are customized for each location and costs are dependent on the equipment purchased and complexity and extent of the installation.
Peer-Reviewed Research	We do not plan to produce peer-reviewed research.
Submission Contact	Helen Lewis | Phone: (850)-763-7200 | Email: helen.lewis@detect-inc.com | Address: 2817 Hwy 77, Panama City, Florida 32405

Technical Contact	Jesse Lewis | Phone: (850)-763-7200 | Email: jesse.lewis@detect-inc.com
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MERLIN™ BIRD CONTROL RADAR SYSTEM (BCRS) | TRL 9

Updated July 2025

Company	DeTect, Inc.
Website	www.detect-inc.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds
Technology Components	Detection component, Deterrent component
Description & Application	MERLIN BCRS is a radar-based detection and deterrence system. The detection technology is the same as listed under the Tech 1 MERLIN ARS tab with the addition of radar-based control of audio and visual deterrents. MERLIN detect and deter is highly customizable for each site and can be interfaced with a wide variety of bird deterrent devices to provide hazing responses specific to each user's operation, site characteristics, and environmental management needs. The BCRS system is designed to reliably detect and track birds at ranges out to 4-6 miles, monitor user-defined control zones, and automatically activate bird deterrent devices to effectively deter and harass birds from entering restricted areas.
Mechanism(s) by which the Technology Operates	Video, Radar, Moving Visual Deterrent, Audible Acoustic Deterrent
Monitoring or Minimizing	Minimizing
Detect and/or Deter Non-Target Species	The system is not designed to be species-specific as installed (see Tech 1 MERLIN ARS for details) although the array of deterrents and the catalog of sounds used can target certain species groups.
Avoidance of False Positives and False Negatives	The MERLIN bird detection and tracking software operates in real-time applying advanced, military-grade target identification, classification, and tracking algorithms and clutter suppression and interference rejection routines to the radar data stream to provide superior, highly accurate identification and tracking of bird targets over aircraft/ship software or image processing-based systems. MERLIN additionally incorporates advanced dynamic, real-time ground clutter suppression, and Doppler processing to more reliably detect and track birds in high clutter environments - a functionality that is unique to MERLIN and that is critical to the delivery of an effective system for most complex industrial environments. The MERLIN system classifies targets into size classes generally corresponding to small, medium, large,

	and flock-size birds which generally correspond to these bird size classes but cannot definitively distinguish species as installed. As such, DeTect recommends that periodic field ground-truthing of the radar system data be conducted by qualified biologists as part of any survey with the system for data validation and to develop data subsets on species predominant at the survey site or of species of interest using the MERLIN ground truth recording feature.
Effective Range	MERLIN BCRS is highly flexible and custom-programmable for each site. Each radar sensor can cover 3-4 NM and multiple detection sensors can be used at each facility to cover large areas of concern. The deterrents are trailer or skid-mounted to maintain flexibility in system design and coverage can be designed for any size property or area of concern. The system provides automatic activation of bird deterrents for unlimited control zones based on defined risk thresholds set for each site to humanely harass birds and prevent landing in or crossing over high-risk areas. The MERLIN BCRS technology supports an unlimited number of user definable control perimeters, areas/zones and deterrent devices within the MERLIN software and any bird targets detected approaching and/or entering the control area, trigger activation of the deterrent devices. The system is fully automated, scalable, and expandable & upgradable to meet changing facility needs.
Timeline of Production	This technology has been in production since 2007.
Product Manufacturing	Panama City, Florida
Tech Support	Panama City, Florida
TRL Justification	TRL 9: The MERLIN BCRS has been commercially available and in operation since 2007. Detection and deterrence systems are operational at oil and gas facilities, mining, and other industrial operations for mitigation of impacts on wildlife.
Planned or Underway Testing	The system is continually tested to improve performance, and improvements are implemented to keep pace with technological advancements in available radar sensors and systems.
Safety or Public Nuisance Issues	The deterrence system uses audio and in some cases visual deterrents. The system is designed to maximize the impact of deterrents within risk zones while minimizing the effects and sounds off-site through the use of directional audio technology and the implementation of radar-based detection and deterrence in zones. The deterrents are only activated when and where wildlife is at risk, this minimizes habituation for the wildlife and prevents excessive deployment of deterrents.
Testing with Direct or Indirect Regulatory Agency Engagement	MERLIN BCRS is an accepted technology for the mitigation of impacts on wildlife at oil and gas, mining, and industrial facilities.

Commercial Deployment	Refer to Tech 1 answer for MERLIN detection component of the detect and deter system. Full MERLIN BCRS systems have been in operation in the oil and gas and mining industry since 2007 for mitigation of environmental impacts on wildlife. See attached document DeTect MERLIN BCRS Catalog for list of representative locations and site descriptions.
Installation and Setup	These are small, mobile, trailer-mounted systems or can be skid-mounted for permanent installation on a site. They are ground-based installations with no direct attachment to wind farm structures.
Timeline for Installation and Operation	90-120 days depending on the production schedule for delivery and installation. DeTect-owned equipment is often available for lease to cover interim periods while production is completed.
Coordination with Facility for Installation and Operation	DeTect handles the installation and deployment of the avian radar systems and includes one full year of data support, remote monitoring, and project management with the purchase of equipment. The infrastructure required for the installation of the system includes a concrete pad and commercial power supply for operational sites. Trailer and generator units are available for preconstruction surveys with the operator responsible for fuel and generator maintenance. For operational mitigation systems connection to the on-site network communications is recommended for monitoring and communication of risk in real time.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	No, coordination with turbine structure is needed during installation but an operational mitigation system generally requires the ability to communicate and exchange information with the wind farm SCADA system.
Other Products Required for Installation	All required components can be purchased with the system, and it can be operated as a stand-alone system.
Potential Interference with Other Technologies	No
Operational Limitations	The MERLIN radar system collects data continuously during operations and the workstations and other sensitive equipment are installed in environmentally controlled trailers or cabinets to protect from environmental extremes. The MERLIN technology was originally developed and is currently used by the US Air Force and NASA for aircraft-bird strike risk management and includes advanced, military-grade signal processing software, however, radar is susceptible to interference from weather, structures, vegetation, high sea state, and other radars that may limit detection in certain areas and/or environments. These factors are all taken into consideration when selecting a radar location. The system will require installation in a representative location with a relatively clear line-of-sight of the area(s) of interest. Precipitation

	may affect the data collected by the system. Data from the magnetron X-band (3 cm wavelength) vertical scanning radar (VSR), if used, will not generally be available during periods of precipitation. The range and probability of detection for the S-band (10 cm) horizontal surveillance radar (HSR) will be somewhat attenuated by precipitation however some data collected will generally still provide useful information (the S-band functions in up to moderate precipitation).
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	For the operation of the system, there are costs of generator fuel or commercial power, dependent on the system and location. If generators are in use the system requires basic maintenance every 250 hours, with commercial power the generators are a backup power source and require minimal service to maintain reliability. The maintenance schedule for the radar sensors is dependent on the sensor type with solid-state radars having no 'wear' components and a 50,000 hr MTBF manufacturer rating. The older magnetron technology has a shorter MTBF and components that need to be replaced, in practice the time between magnetron replacements can be well over 5 years or even longer. It is entirely dependent on the client. Some clients operate the radar completely independent of DeTect involvement including certain consulting companies that own DeTect equipment and some federal agencies such as USFWS. Other clients contract with DeTect for additional data analysis after the initial studies or for complete management of the radar program.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Expected Lifespan	The oldest MERLIN system at an operating windfarm is at the Near Shore Wind Park off of the Dutch coast and the system has operated unattended nearly continuously since 2003. O&M schedules and costs have been worked out for a 20-year operating period but with proper maintenance radar systems can operate beyond that time frame.
Warranty	DeTect provides a one-year full parts and labor warranty that includes repair or replacement of any defective parts for the term of the warranty, exclusive of wear parts. Wear parts are parts which degrade under normal use and include, but are not limited to, radar magnetrons, motor brushes, generator, tires, and other such components, or parts that fail due to deterioration from adverse environments or chemical exposure. Options for service contracts and extended warranties are available beyond that.
Extended Warranty	Extended warranties are available. The systems are customized for each location and costs are dependent on the equipment purchased and complexity and extent of the installation.

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MULTI-SENSOR DETECTION SYSTEM (MUSE) | TRL 9

Updated July 2025

Company	DHI Group
Website	www.dhigroup.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors
Additional Species	Seabirds, Waterfowl, Raptors, Cranes
Technology Components	Detection component, Curtailment component, Collision detection component
Description & Application	MUSE is an automated multi-sensor monitoring system based on integrated radar and digital cameras. MUSE is designed to provide robust multi-scale data on flying birds at the species level (except for Passerines) in or near wind farms. One of the major challenges in mitigating bird collisions at wind farms is to collect accurate information 24-7 at the species level at multiple distances which provides the Controller sufficient time for an informed curtailment response. The MUSE system has been developed to circumvent these challenges by taking advantage of a fully integrated multi-sensor system which builds on the detection capacity specific for each sensor. MUSE is modular and is generally constructed as an interconnected system with multiple radars and cameras operating at different distances from the wind farm. The MUSE software controls the communication between the different radars and cameras and also facilitates communication between sensors and with SCADA and external user (Controller). The composition and type of radars and cameras are very flexible depending on the requirements. Typically, one high performance radar with long range and high resolution will detect approaching birds at distances of several kms from the wind farm. This is typically a solid-state radar with Doppler facility. This radar can communicate with other radars at closer range (e.g., 2 km) providing information on flight height of the bird and allowing for a forecast of bird trajectory relative to the turbines. The cameras which can be both state-of-the-art visual and thermal/infrared or a combination are installed in close proximity to the turbines to

	facilitate species identification within a range of 1 km and communicating either directly with a high-performance radar or with radars at 2-3 km distance. All detections are recorded and made available to the Controller in real time through the MUSE GUI, including watching the camera recording. The configuration allows both controlled curtailment in which the Controller issues a stop signal and automated curtailment in which the MUSE software sends a stop signal to the SCADA.
Mechanism(s) by which the Technology Operates	Video, Infrared/Thermal Imaging Cameras, Radar
Monitoring or Minimizing	Both
Detect and/or Deter Non-Target Species	Yes, detect.
Avoidance of False Positives and False Negatives	High-speed sampling and signal processing by radar, use of static and dynamic clutter filters and Doppler functionality, and classification of bird groups using cross-correlations with known bird pulses. Camera tracking and species recognition by AI-based algorithms.
Effective Range	Entire facility and up to 10 km distance by radar, 3-5 km by cameras
Timeline of Production	Beta version in July 2014, version at TRL 9 from December 2016
Product Manufacturing	Denmark
Tech Support	Copenhagen and Aarhus, Denmark
TRL Justification	Applied commercially in 21 projects since January 2017
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility
Safety or Public Nuisance Issues	No-radar in constant state
Testing with Direct or Indirect Regulatory Agency Engagement	Yes, the testing in the ORJIP project was part of a joint industry engagement including two regulators in the United Kingdom (Crown Estate, Marine Scotland)
Commercial Deployment	Yes, in 21 wind projects
Installation and Operation Components	Free-standing, Interface with SCADA System, Requires Internet, Requires Power Source, Ongoing Operation, and/or Data Management with Technology Vendor
Installation and Setup	Installation of both radar and camera (single or multiple) can be made on trailer or container on land, and on the turbine platform offshore. Connection to the wind farm network is required
Timeline for Installation and Operation	6-12 months
Coordination with Facility for Installation and Operation	In relation to installation the most important coordination is related to power and network connections as well as access and security issues related to SCADA. During operation coordination requirements depend on the degree of involvement from the owner in servicing the equipment. Full training in the servicing of the equipment can be provided if requested.

Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Coordination with SCADA designers
Other Products Required for Installation	Trailer or container, server, 4 workstations, air condition unit
Potential Interference with Other Technologies	Interference of the radar with another radar of the same type could cause interference. Effects of interference can be minimized due to high degree of flexibility in use of frequencies.
Operational Limitations	Daylight and thermal cameras have limitations in terms of reduced detection distance during periods of precipitation and fog
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	There is limited or no maintenance required. License fee is standard; service agreement is optional.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	The lifespan is approximately 15-20 years.
Warranty	We can provide a 15-year warranty with reservations for changes in SCADA and computer operating systems
Extended Warranty	Not beyond 15 years. Included in lease price.
Submission Contact	Henrik Skov | Phone: +45 30304236 | Email: hsk@dhigroup.com | Address: Agern Alle 5, DK-2970, Hoersholm, Denmark

RECON™| TRL 9

Updated January 2025

Company	Normandeau Associates, Inc.
Website	https://www.normandeau.com
Target Renewable Energy	Land-Based Wind
Target Species	Eagles Birds Bats
Additional Species	Customizable for specific bat species. Whooping crane, Condors
Technology Components	Detection component, Curtailment component
Description & Application	Normandeau designed ReCON as an early detection system that provides the energy facility operations center with real-time alerts of an approaching condor. The condor recovery program tags individual birds using unique VHF transmitter frequencies to identify which particular condor is being detected. ReCON creates a detection perimeter around the energy facility that provides enough time to confirm condor presence and initiate a response, if needed, to avoid injury or mortality. A detection event occurs when a VHF-tagged condor enters the monitoring area. Each tag emits a unique radio frequency that is picked up by the ReCON receiver. A standard ReCON scans all possible VHF-tag frequencies every 2 minutes, providing the opportunity for all tagged condors to be detected if they come within range of a facility. When ReCON detects a condor, the frequency is transmitted to a computer that sends out an alert with the tag number, date, time, antenna(e) that received the signal, and the signal strength for each antenna. Signal strength is a rough indicator of proximity (i.e., stronger signal = closer), which provides some guidance on the location of the detected condor. All of this occurs within a few seconds of the detection. The ReCON alert notifies the energy facility's operations center and any other designated parties. The response taken by the energy facility can vary, but options include deploying a field team to visually locate the condor and assess the level of risk or implementing a preset automated response to reduce the risk. As long as the condor is within the range, ReCON will reissue alerts every 2 minutes (configurable).
Mechanism(s) by which the Technology Operates	GPS/VHF Radio Transmitters
Monitoring or Minimizing	No, just monitoring presence of tagged individuals.

Detect and/or Deter Non-Target Species	No. Since the product depends on VHF radio tags installed on the bird or bat, other non-target species will not be detected. This system could be used to inform deterrents by identifying the presence of specific target individuals.
Avoidance of False Positives and False Negatives	The DSP receivers use a sophisticated algorithm to avoid false positives. If a pulse is detected, another pulse is anticipated a particular time distance away, as specified by the programmable ppm (pulses per minute) value. If one is not found, scanning continues with the next frequency. If one is found, 2 or 3 more pulses must then be received in the proper time positions for it to be considered a reception. Hence false positives are very rare.
Effective Range	ReCON has detected and tracked condors from 80km; however, the usual detection range of interest is about 8km or closer.
Timeline of Production	This technology has been in production for 9 years.
Product Manufacturing	Gainesville, Florida
Tech Support	Gainesville, Florida
TRL Justification	The ReCON systems in Kern County, California, have been in operation for 5 years in that location's very hostile environment (Mojave desert and mountains).
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	No
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	The project was reviewed by the Bureau of Land Management and was subsequently the basis for a Biological Opinion concerning ReCON (see above).
Commercial Deployment	Yes. To date 4 systems have been installed in Kern County, California and have been in operation for 5 years.
Installation and Operation Components	Tower-mounted, Free-standing, Requires Internet, Requires Power Source, Ongoing Operation, and/or Data Management with Technology Vendor
Installation and Setup	ReCON consists of a box containing the ReCON system (computer and receivers, etc.). ReCON requires 4 directional Yagi antennae typically mounted on a Meteorological Evaluation Tower (MET) or other tower at typically 50 feet, though, the higher the better. For power sources, either main power and direct LAN attachment have been used, as well as solar/battery power and satellite data communications. Cellular modems have been used at some locations but are found to not be dependable enough at other locations.
Timeline for Installation and Operation	Approximately 6 months. Ready tower availability for mounting the antennae does expedite the process.

Coordination with Facility for Installation and Operation	Coordination with the facility owner or operator is needed to gain access to the property where ReCON will be installed. Facility owner or operator also needs to arrange for the tower climbers who mount the antennae. If the SCADA interface is used, there needs to be discussion and planning for network integration. Also, for the SCADA integration, the operator needs to plan for an HMI interface to be developed, to display system status and allow manual control over determining either automatic or manual curtailment.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	None
Other Products Required for Installation	The ReCON field equipment is custom-built and supplied when the ReCON service is purchased. There is PC software that needs to run on either the customer's server, or Normandeau has also deployed it in the Amazon AWS Cloud for a client or in a VM on one of our own servers. The PC software communicates with the ReCON field unit and is what sends out the email and text alerts, as well as providing visible system status information.
Potential Interference with Other Technologies	No
Operational Limitations	Since the ReCON system field unit is typically installed near the wind turbines where it can be very windy, the wind loading of the solar panels does require that they be securely attached to the ground or concrete or other footing.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Varies by installation details and contract duration. Yes. Normandeau monitors the systems on a 24/7 basis and receives alerts if the system is not operating properly.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	The ReCON systems in Kern County, California have been in operation for 5 years. Normandeau anticipates field unit refurbishment to be required at some point.
Warranty	This is dependent on the ReCON services contract, which extends for the life of the installation.
Submission Contact	Julia Robinson Willmott | Phone: (352)-327-3262 | Email: jwillmott@normandeau.com | Address: 13100 Tech City Circle, Suite 500 Alachua, FL 32615

NEW SAFEWIND® | TRL 9

Updated May 2025

Company	Biodiv-Wind
Website	https://www.biodiv-wind.com/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Wading, Sea birds, or Waterfowl Eagles Birds Raptors Bats
Additional Species	Customizable for specific bird species, red kites, vultures, black stork, etc.
Technology Components	Detection component, Deterrent component, Curtailment component, Collision detection component, Collisions detected if observed in camera field of view, Integrates with deterrent system, Integrates with turbine controls for curtailment
Description & Application	SafeWind is a real-time video-based detection system that uses AI to monitor birds and bats near wind turbines and trigger curtailment and/or deterrence protocols when a collision risk is identified.
Mechanism(s) by which the Technology Operates	Video, Infrared/Thermal Imaging Cameras, Software
Monitoring or Minimizing	Minimizing interactions SafeWind continuously monitors the turbine's airspace using high-resolution cameras and AI-based species detection algorithms. When a collision risk is identified, it automatically slows or stops the turbine and activates acoustic deterrents to steer animals away. Once the airspace is clear, turbines can safely resume operation, minimizing both collision risk and downtime.
Detect and/or Deter Non-Target Species	Yes. The system includes filtering to limit curtailments triggered by non-threat species, and the AI can be further refined with site-specific data.
Avoidance of False Positives and False Negatives	SafeWind combines motion tracking and morphological analysis to reduce false positives. The AI has been trained on thousands of real-world images captured on turbines, and its detection

	models are continuously improved. Site-specific calibration and the use of multi-camera triangulation also contribute to improved reliability.
Effective Range	Up to 1,2km per turbines depending on visibility and species
Timeline of Production	This technology has been in production since 2015.
Product Manufacturing	Boujan sur Lirbon, Occitanie, France
Tech Support	Boujan sur Lirbon, Occitanie, France
TRL Justification	Over 700 SafeWind® units have been installed on onshore /offshore wind farms in 12 countries (Belgium, France, Germany, Austria, Finland, Iceland, Poland, Spain, Luxembourg, The Netherlands, South Africa, Brazil). SafeWind has been deployed in full-scale operational wind farms since 2015.
Efficacy Testing	Field Testing at a Commercial Wind Facility
Planned or Underway Testing	Yes. Ongoing deployments include long-term data collection for further performance validation, species-specific detection refinement, and integration with deterrent modules in some locations. New testing campaigns are also planned to assess the impact of SafeWind on reducing turbine curtailment duration while maintaining protection efficacy.
Safety or Public Nuisance Issues	SafeWind uses passive visual detection (cameras) but can emit sounds if the deterrence option is installed. It does not interfere with turbine operations beyond triggering controlled curtailment events through the SCADA. The system is compliant with standard safety protocols for turbine-mounted equipment.
Commercial Deployment	Yes
Installation and Operation Components	Tower-mounted, Interface with SCADA System, Requires Internet, Requires Internet for Data Upload/Back Up, Requires Power Source, Ongoing Operation and/or Data Management with Technology Vendor, Local Wind Operator Network Connection Access, IP-65
Installation and Setup	Installation involves mounting one or more high-resolution cameras on the nacelle or tower of the wind turbine. The cameras are connected to an onboard processing unit, usually installed in the tower or nearby cabinet. The system is calibrated on-site to define the monitored airspace and to interface with turbine control systems. Internet access is used for remote monitoring, data backup, and software updates, It is mandatory for local operation.
Timeline for Installation and Operation	Once an order is placed, installation and commissioning can typically be completed within 12-14 weeks, depending on site access, weather conditions, and number of turbines. The physical installation itself usually takes 1 day per turbine.

Coordination with Facility for Installation and Operation	Coordination is needed for access planning, installation scheduling, and SCADA integration (if curtailment is enabled). The wind farm operator also defines curtailment protocols and alert thresholds with Biodiv-Wind during setup.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Minimal coordination is required. SafeWind is a non-invasive add-on that does not modify turbine hardware or firmware. However, for full curtailment integration, the OEM must allow access to the turbine's SCADA system or external control interface. Biodiv-Wind has experience working with several major OEMs.
Other Products Required for Installation	A local power source is required.
Potential Interference with Other Technologies	No
Operational Limitations	Detection performance may be affected by dense fog, heavy rain, or very low-light conditions.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Yes, the system includes optional ongoing services such as remote monitoring, technical support, and maintenance. On site maintenance is optional. These are offered under annual service contracts, customized per client.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	The expected lifespan of the SafeWind system ranges from 5 to 10 years depending on the components. Typically, cameras last 5–7 years.
Warranty	Standard 2-year warranty covering parts and software.
Extended Warranty	Yes, extended warranty is available through our unlimited maintenance service per turbine. Availability and conditions depend on the site's location. This option is typically offered in France and select other regions. The service includes hardware replacement, software updates, and remote support throughout the contract duration.
Peer-Reviewed Research	No, we have not completed peer-reviewed research.
Submission Contact	Sébastien Masse, Communications Officer | Email: s.masse@biodiv-wind.com | Phone: +33 7 45 09 14 45 | 6 Mail Philippe Lamour, 34760 Boujan-sur-Libron France,
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Sales Contact	Fabrice Charrassier, Sales Manager | Email: f.charrassier@biodiv-wind.com | Phone: +33 (0)7 64 44 59 93

SONG METER WITH ANALYSIS AND REMOTE TRANSFER (SMART) SYSTEM | TRL 9

Update June 2025

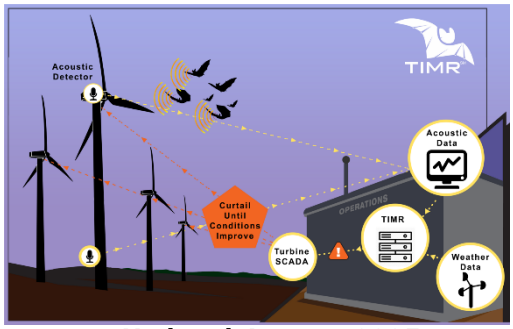
Company	Wildlife Acoustics
Website	https://www.wildlifeacoustics.com/smart-system
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Technology Components	Detection component, Curtailment component, Survey for Remote Construction Monitoring, Integrates with turbine controls for curtailment
Description & Application	Wildlife Acoustics' Song Meter with Analysis and Remote Transfer (SMART) System is an innovative solution for reducing bat fatalities and associated curtailment costs at wind farms through the use of Acoustically Triggered Curtailment (also known as Real-Time Acoustic-Activated Smart Curtailment). SMART can be integrated with SCADA or other control systems to minimize turbine downtime, eliminating the need for blanket curtailment and increasing annual energy production. The SMART System consists of one controller and up to three microphones that enable extensive monitoring and analyzing capabilities.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, Software
Monitoring or Minimizing	The SMART solution has been used for monitoring on met-masts for pre-construction surveys. The SMART System is ultimately suitable to minimize bat fatalities. From a high level, the SMART Controller is using Kaleidoscope Pro Technology to (1) analyze the data stream coming from the SMART Microphone to determine if the signal is a bat or something else (noise) (2) if it is a bat, then bat call characteristics are analyzed in real-time to assess if they meet the criteria of targeted bats and (3) Does the level of activity on a pass or pulse basis exceed a defined threshold. If all criteria are satisfied, then an alarm is raised. Up to 8 alarms that match bat call parameters at the pass and individual pulse levels can be configured. This information could be used to trigger alarms to pause turbine operation as needed and minimize turbine/bat collisions.

Detect and/or Deter Non-Target Species	No
Avoidance of False Positives and False Negatives	Prior to implementing smart curtailment, it is advised that customers install the SMART system and use logging features in the SMART Controller to model when alarms would occur and be released. Log data is compared to bat call files to determine whether the modeled alarm occurrence was justified. Filters can be created to prevent future false alarms from anthropogenic noise (for example, from turbine mechanics) and bat call parameter adjustments be made to optimize the system and reduce false positives.
Effective Range	This is an impossible question to answer. The factors that determine how far a sound travels include humidity, temperature, the source volume and directionality, characteristic frequency of the bat call and surrounding clutter.
Timeline of Production	This technology has been in production since April 2022.
Product Manufacturing	SMART Microphones are manufactured in Maynard, MA, USA. SMART Controllers are manufactured in Taiwan and assembled in the USA. Software development occurs in Maynard, MA USA
Tech Support	Maynard, MA
TRL Justification	SMART became commercially available in April 2022 at a TRL of 3 and over the last 2 years, its TRL has advanced to a 9. Currently, SMART is integrated with multiple wind farm systems to pause turbine operation in the presence of bats.
Efficacy Testing	Field Testing at a Commercial Wind Facility.
Planned or Underway Testing	There are currently multiple wind farm sites in Europe testing the SMART System for smart curtailment.
Safety or Public Nuisance Issues	No, not to our knowledge.
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	Yes
Installation and Operation Components	Nacelle-mounted, Free-standing, Interface with SCADA System, Requires Internet, Requires Power Source, Local Wind Operator Network Connection Access
Installation and Setup	The SMART System consists of a SMART Controller and 1-3 SMART Microphones (SMART MIC-1). The SMART Controller ships with SMART system software installed and default settings preconfigured. The SMART Controller requires 9-36V DC power. When the SMART Controller is deployed it should be properly grounded and mounted in a waterproof enclosure (optional enclosure available). The SMART Controller connects to the SMART Microphone(s) via Cat 5/6 cabling which should be UV protection rated if exposed to sun. The SMART MIC-1 features an

	IP67 weatherproof aluminum cylindrical housing. It is essential that the SMART MIC-1 has a connection to ground for the sake of electrical spike protection. The SMART MIC-1 has an external grounding strip for this purpose. A fully weatherproof stainless steel Mounting Bracket for the SMART MIC-1 is available from Wildlife Acoustics. The Mounting Bracket must subsequently be connected to ground. The SMART MIC-1 has directional pickup characteristics. Therefore, the sensors should be pointed in the direction of the most likely path of the bat. The surface or through-wall position to which the Mounting Bracket is connected can be at any angle or orientation. The Mounting Bracket provides six different positions of connection to facilitate directionality. Please Reference the SMART User Manual for further details.
Timeline for Installation and Operation	Timeline for installation and operation is dependent on the service schedule of the turbine. All SMART products are usually in stock and can ship within 1-2 weeks of order placement.
Coordination with Facility for Installation and Operation	Turbine will need to be paused. Personnel with authorized access will be needed for the installation.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Should the operator wish to mount the microphone on the tower, confirmation from the turbine manufacturer as to the allowable hole to be created within the tower is required. The operator will also require integration of alarms with turbine control.
Other Products Required for Installation	For installation of the SMART Microphones on the nacelle, a SMART microphone mounting bracket may be useful, but is not required. The SMART enclosure also products a waterproof housing for the SMART Controller.
Potential Interference with Other Technologies	No, not of which we are aware.
Operational Limitations	No, not that we are aware of beyond those already described above.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Wildlife Acoustics is the manufacturer and does not provide any maintenance contracts at this time. Third party environmental consultants typically are involved for long term maintenance and tuning of the system.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	100-1000
Expected Lifespan	With proper water protection, the SMART Controller has an expected lifespan of 8-10 years. The SMART Microphone has expected lifespan of 5+ years
Warranty	Yes, the SMART Controller has a 2-year manufacturer warranty, and the SMART Microphone has a 5-year manufacturer warranty

Extended Warranty	Not at the time, but negotiable
Submission Contact	Nicole Wright, Director of Marketing, Wildlife Acoustics | Phone: 978-369-5225 ext. 516 | Email: nicole@wildlifeacoustics.com | Address: 3 Mill & Main Pl. Suite 110, Maynard MA 01754,
Technical Contact	Mona Doss, VP Business Development | Phone: 978-369-5225 ext. 504 | Email: mona@wildlifeacoustics.com
Sales Contact	sales2025@wildlifeacoustics.com

TIMR (TURBINE INTEGRATED MORTALITY REDUCTION) | TRL 9



Updated January 2025

Company	Normandeau Associates, Inc.
Website	https://www.normandeau.com
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Additional Species	Migratory tree roosting bats, Cave-dwelling bats
Technology Components	Detection component, Curtailment component, Integrates with deterrent system, Integrates with turbine controls for curtailment
Description & Application	TIMR is a smart curtailment system that integrates real-time bat activity and wind speed data to mitigate operations only when bat mortality risk is highest. TIMR technology functions by receiving and integrating weather data collected on the nacelle and bat activity data collected using ultrasound acoustic sensors to calculate relative bat fatality risks. TIMR will calculate bat fatality risk using a rolling average wind speed, resulting in increased system reactivity and a significant reduction in the time bats are exposed to operating turbines. The TIMR system can communicate to the facility's existing supervisory control and data acquisition (SCADA) unit to curtail turbines when a bat is detected (within the designated wind speed thresholds; determined in conversation with client) until the risk value is once again low. The system relies on a network of acoustic sensors to inform TIMR on bat activity from dusk to dawn. Each sensor consists of two ultrasonic microphones—one at near ground level and one attached to the nacelle at hub height. While operational, the sensors continuously monitor the airspace for ultrasonic echolocation calls and remotely relay sound files identified as bat echolocation calls to the TIMR system to inform the real-time risk assessment mode. The specific combination of bat acoustic activity and wind speeds to be considered by the model as high risk will depend on the goals of stakeholders but can be adjusted to suit the specific needs of the wind project and adjusted over time to "dial in" performance.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, Real-time ID of Bird/Bat Vocalizations, precipitation, etc.), Weather/Environmental Sensors (wind)
Monitoring or Minimizing	Monitoring

Detect and/or Deter Non-Target Species	No
Avoidance of False Positives and False Negatives	TIMR uses well tested bat-not bat filters and bat call scrubbers to determine what a bat call is and what noise is. Redundancies (two detectors, two microphones each) reduce the chances of false negatives. False positives can be reduced in two ways: 1. adjusting recorder threshold settings to reduce identification of background noise as bats, and 2. Adjusting curtailment thresholds.
Effective Range	Effective detection range is different per species and can be as long as ~100 m for Hoary bats or as short as several meters for big eared bats. To increase TIMR's effective range, detection in one sensor can trigger curtailment in any chosen turbine or turbine groups, determined by Normandeau's biologists based on the facility's terrain and bats predicted movements within it (e.g., along linear landscape elements, vicinity to water, etc.).
Timeline of Production	TIMR is a service, not a product. It was successfully tested in 2015 and a peer-reviewed study was published in Ecological Applications describing the results of the test: https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/eap.1881
Product Manufacturing	United States
Tech Support	Gainesville, Florida and Worldwide
TRL Justification	The system was tested at a real-world working wind farm and was successful. A second test is currently underway to see if results are consistent among wind facilities. TIMR has not yet had a commercial application.
Efficacy Testing	Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	Yes, a second validation study is currently in its last stages at the Orient Wind Facility in Iowa. This study is meant to evaluate the ability of the TIMR system to be applied to multiple sites with different characteristics. The study was conducted during the summers of both 2021 and 2022, with published results expected in 2024.
Safety or Public Nuisance Issues	No
Testing with Direct or Indirect Regulatory Agency Engagement	No. However, Normandeau has met with and presented to multiple agencies, including all relevant staff in the Region 5 USFWS office in MA. All reception has been good and we are working towards USFWS accepting TIMR as best available science/technology.
Commercial Deployment	No commercial deployments yet.
Installation and Operation Components	Nacelle-mounted, Requires Internet, Ongoing Operation and/or Data Management with Technology Vendor, Cell Service Access, Local Wind Operator Network Connection Access
Installation and Setup	Normandeau will coordinate shipment of hardware to the wind facility and will deploy the equipment on turbine nacelles in collaboration with

	the wind facility operations staff and will coordinate with wind facility staff to determine the best way to mount acoustic sensors on the turbine nacelles. Normandeau will mount the sensors once a proper mounting approach is confirmed with the turbine operators. This process will require at least one person from the wind facility's operations staff to help a Normandeau employee climb each turbine to install sensors. The time commitment related to this will vary depending on the safety protocols of the facility but usually requires one day for each sensor deployed.
Timeline for Installation and Operation	Depending on number of units ordered and availability of wind facility personnel to establish cooperative work protocols, between 3-8 months.
Coordination with Facility for Installation and Operation	Coordination is needed for two aspects: 1. Physical installation of the units on the turbines. One person from the facility's operation staff should be available to work with Normandeau's personnel under the assumption of one turbine installed per day. 2. Cybersecurity personnel should be available for the process of connecting TIMR server to the facility's SCADA system and establish data security protocols. Typically, TIMR will only send operational status reports to Normandeau. Normandeau will have no way to communicate directly with TIMR for reasons of cybersecurity. For that reason, it is considered best practice to have one of the facility's IT personnel dedicated to TIMR troubleshooting, to be done in coordination with Normandeau personnel.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Since TIMR does not directly interface with the turbines, no coordination is needed with the turbine manufacturers or other OEMs.
Other Products Required for Installation	All peripherals for TIMR are purchased, owned, and maintained by Normandeau. No extra hardware or software is required to be purchased by the wind facility.
Potential Interference with Other Technologies	No
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	This depends greatly on the size of the wind facility. The larger the facility, the more ReBAT® detectors are needed to characterize the bat activity at the facility. Yes. TIMR is a service rather than a product. Though it operates autonomously Normandeau will continuously monitor the system health and uptime remotely, perform maintenance and repairs, provide reports and troubleshooting, and perform data analysis to assess functionality (e.g., false positives, false negatives, etc.).
Remotely Monitored or Near Real-Time Status and Operation	Yes

Utility Scale Units Sold or Installed	1-100
Expected Lifespan	This is a service not a product. The number of years the system is used for is contracted with Normandeau.
Warranty	Most normal maintenance and repairs are covered in the service contract. Abnormal repairs due to unforeseen circumstances (such as lighting strikes and vandalism) may be billed to the client.
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://doi.org/10.1002/eap.1881
Submission Contact	Julia Robinson Willmott | Phone: (352)-327-3262 | Email: jwillmott@normandeau.com | Address: 13100 Tech City Circle, Suite 500 Alachua, FL 32615
Technical Contact	Eran Amichai | Phone: (352)-327-3266 | Email: eamichai@normandeau.com

NEW AUDIOBAT® | TRL 8

Updated May 2025

Company	Biodiv-Wind
Website	https://www.biodiv-wind.com/
Target Renewable Energy	Land-Based Wind, Offshore
Target Species	Bats
Additional Species	Common pipistrelle (Pipistrellus pipistrellus), Nathusius' pipistrelle (Pipistrellus nathusii), Noctule (Nyctalus noctula), and other bat species commonly found around wind energy facilities.
Technology Components	Detection component, Curtailment component, Other
Description and Application	AudioBat is an ultrasonic acoustic monitoring system designed to detect bat activity in real time around wind turbines. It supports adaptive curtailment strategies and impact assessments to help minimize collision risks while maintaining energy production.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Monitor, Real-time ID of Bird/Bat Vocalizations, Software
Monitoring and Minimizing	AudioBat detects bat echolocation calls in real time and uses programmable thresholds to identify periods of high-risk activity. These data can trigger turbine curtailment protocols through SCADA. This allows mitigation of collision risks during peak bat activity periods (e.g., warm, low-wind nights), particularly during migration or mating seasons.
Detect and/or Deter Non-Target Species	No
Avoidance of False Positives and False Negatives	AudioBat uses calibrated microphones and advanced signal processing algorithms to filter out ambient noise and classify genuine bat calls. Species identification is supported by acoustic libraries. The system is regularly calibrated and can be configured to ignore turbine-generated sounds.
Timeline of Production	This product has been in production since 2022.
Product Manufacturing	Boujan sur Lirbon, Occitanie, France
Tech Support	Boujan sur Lirbon, Occitanie, France
TRL Justification	AudioBat has been developed, tested, and deployed at operational wind energy facilities in several European countries. It is currently used in commercial wind parks for both permanent monitoring and mitigation (curtailment).

Efficacy Testing	Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Wind Facility
Planned or Underway Testing	Yes. Ongoing deployments are being monitored in France to refine automated bat call classification and correlate detection data with meteorological conditions.
Safety or Public Nuisance Issues	No
Commercial Deployment	Yes
Installation and Operation Components	Nacelle-mounted, Tower-mounted, Interface with SCADA System, Requires Internet, Requires Power Source, IP-65
Installation and Setup	Installation of the AudioBat system typically involves placing the ultrasonic microphone inside the nacelle, using existing holes for acoustic exposure when available. In some cases, a small hole may need to be drilled to ensure proper sound capture. The microphone is connected to a local control unit installed inside the nacelle or at the turbine base. The system is powered by the turbine's internal supply and is configured for data transfer via internet or local storage. Installation is fast and non-intrusive, generally completed within a few hours per turbine.
Timeline for Installation and Operation	Typical delivery and installation timeline ranges from 10 to 12 weeks, depending on site location and number of turbines. Once onsite, setup and commissioning can be completed in 1 to 2 days per turbine.
Coordination with Facility for Installation and Operation	Basic coordination is needed for site access, technical contact, and power/network connection approval. The system can be integrated into the site's SCADA.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Minimal coordination is required. However, for full curtailment integration, the OEM must allow access to the turbine's SCADA system or external control interface. Biodiv-Wind has experience working with several major OEMs.
Potential Interference with other Technologies	No known interferences.
Operational Limitations	No
Continued Costs Required (Contracts, Maintenance or Licensing Fees)	Yes, the system includes optional ongoing services such as remote monitoring, technical support, and maintenance. These are offered under annual service contracts, customized per client.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	The expected lifespan of the AudioBat system ranges from 5 to 10 years depending on the components.
Warranty	SafeWind comes with a standard 2-year warranty

Extended Warranty	Yes, extended warranty is available through our unlimited maintenance service per turbine. Availability and conditions depend on the site's location—this option is typically offered in France and select other regions. The service includes hardware replacement, software updates, and remote support throughout the contract duration.
Peer-Reviewed Research	We are currently conducting peer-reviewed research and will update the technology once received.
Submission Contact	Sébastien Masse, Communications Officer | Email: s.masse@biodiv-wind.com | Phone: +33 7 45 09 14 45 | 6 Mail Philippe Lamour, 34760 Boujan-sur-Libron France,
Technical Contact	Fabien Escudier, COO | Email: f.escudier@biodiv-wind.com | Phone: +33 (0)7 69 23 17 64,
Sales Contact	Fabrice Charrassier, Sales Manager | Email: f.charrassier@biodiv-wind.com | Phone: +33 (0)7 64 44 59 93

VISUAL AND AUDIO DETERRENTS

BAT DETERRENT SYSTEM | TRL 9

Updated January 2025

Company	NRG Systems
Website	http://www.nrgsystems.com/
Target Renewable Energy	Land-Based Wind
Target Species	Bats
Additional Species	Myotis bats, Migratory Tree Roosting Bats, Cave-dwelling bats
Technology Components	Deterrent component
Description & Application	The NRG Systems Bat Deterrent System uses ultrasonic noise to 'jam' the echolocation capabilities that bats rely on for navigation and foraging. By generating a large ultrasonic noise field around the wind turbine nacelle and throughout the rotor-swept area, the system effectively discourages bats from entering the airspace near operating turbines. Traditionally, wind plant operators have used low-speed wind curtailment as a mitigation technique to reduce bat fatalities. However, this approach decreases energy production. NRG Systems recognizes the challenges of balancing wildlife protection with energy generation, which is why we developed the Bat Deterrent System. This solution significantly reduces bat fatalities while minimizing the need for curtailment, enabling operators to produce more renewable energy consistently while safeguarding bats. The Bat Deterrent System emits ultrasonic noise within the frequency range of bats' echolocation calls, disrupting their ability to receive and interpret these signals. This interference creates a disorienting environment, making the rotor-swept area difficult for bats to navigate. As a result, bat interactions with turbine blades are significantly reduced, offering a more effective and energy-efficient way to protect wildlife.
MECHANISM(S) BY WHICH THE TECHNOLOGY OPERATES	Ultrasonic Acoustic Deterrent
Monitoring or Minimizing	Minimizing
Detect and/or Deter Non-Target Species	No, it is doubtful that the ultrasonic frequencies will deter other animals. Bats' unique use of ultrasonic sonar is the biological

	basis for the deterrence and is not shared by other terrestrial animals.
Effective Range	The ultrasonic field will not be significant.
Timeline of Production	This technology has been in production since April 2019.
Product Manufacturing	Manufacturing is conducted at NRG's Systems headquarters in Hinesburg, Vermont, USA
Tech Support	Hinesburg, Vermont, USA.
TRL Justification	NRG Systems has manufactured over 1,000 bat deterrent units (ultrasonic speakers) and has made three major revisions to its BDS based on the testing done at large operating wind energy facilities. The BDS has been installed on over 200 turbines over the course of three years, including five different turbine types by four different manufacturers (Vestas, Gamesa, Siemens, and GE). The BDS integrates into wind plant SCADA systems.
Efficacy Testing	Lab Testing, Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Safety or Public Nuisance Issues	There are no safety or public nuisance issues associated with the System. All of the frequencies emitted are beyond the human hearing range and do not pose a safety risk. While the sound pressure level generated by the deterrent units is great at the source, they are mounted on the nacelle of the turbine so the sound pressure level measured at the ground will be negligible.
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	*30 BDS were deployed at Kawailoa Wind in Oahu, which is owned by D.E. Shaw Renewable Investments (DESRI). *DESRI also installed 15 BDS at their Red Horse 2 wind farm in Cochise County, Arizona. *Duke Energy Renewables has committed to installing BDS on 255 wind turbines at their Los Vientos wind project.
Installation and Operation Components	Nacelle-mounted, Tower-mounted, Requires Power Source
Installation and Setup	The devices are attached to the turbine's nacelle with custom mounts that meet the specifications for a specific turbine design.
Timeline for Installation and Operation	This heavily depends on the time of year the order is placed and what turbine platform the Systems will be used on. Please contact NRG Systems for more specific information.
Coordination with Facility for Installation and Operation	For retrofits of Bat Deterrent Systems, the installation process will take approximately half of a day per System. The installation is straightforward, and installation documentation is provided to support the installation teams. Much like other turbine retrofits, the operator is free to either use local technicians or contract out

	the installation. Once the Systems are installed and commissioned, no further support is anticipated. The long-term vision for the product is for OEMs to offer the Bat Deterrent System as a standard offer on new turbines. NRG Systems is working with several OEMs to ensure they are completely integrated, both physically and with the SCADA system, and meet all OEM requirements. In this case, there would be no additional work for the owner or operator.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	For retrofits, it will be critical to have standardized methods for integrating the Systems into different turbine platforms. Because the System must be mounted on the nacelle, several penetrations are required. If the turbines are under warranty, the OEM will need to sign off on all modifications made to the turbine. In the long term, the Bat Deterrent Systems will be completely integrated into new turbines, both physically and from a SCADA perspective. This requires direct engagement with the OEMs. NRG Systems is working with several OEMs to ensure clean integration.
Other Products Required for Installation	No other products need to be purchased to install and operate.
Potential Interference with other Technologies	NRG Systems has tested the deterrent units with several brands of ultrasonic wind sensors that are commonly mounted on the turbines. The deterrent units had no effect on the sensors. The use of the deterrents will likely prevent the use of ultrasonic acoustic detectors on top of the nacelle.
Operational Limitations	No
Continued Costs Required (Contracts. Maintenance or Licensing Fees)	No. The operation and maintenance of the Systems can be performed by the owner or operator without requiring involvement from NRG Systems. NRG Systems can perform additional monitoring or reporting, for a service fee. Contact NRG for more details.
Remotely Monitored or Near Real-Time Status and Operation	Yes
Expected Lifespan	Our goal is for a 10-year life with a refurbishment that would replace the ultrasonic speakers, which are the only moving components in the System. Based on the operating mode, the components used to generate the ultrasonic emission have a predicted life of 10 years, operating seasonally. This estimate has been done by analysis based on the manufacturer's data.

	This estimate includes component life derating based on the operating conditions and mode.
Warranty	The Bat Deterrent System comes with a 2-year warranty.
Extended Warranty	No extended warranty is available
Peer-Reviewed Research	Yes, we have peer-reviewed research available. https://doi.org/10.1002/jwmg.22244 ; https://doi.org/10.1016/j.gecco.2020.e01099
Submission Contact	Stuart Morigeau | Phone: (802)-482-2255 | Email: swm@nrgsystems.com | Address: 110 Riggs Road, Hinesburg, Vermont 05461
Sales Contact	Gus Gruner | Phone: (802)-482-2255 ext.177 | Email: awg@nrgsystems.com

BLADE MARK SYSTEM | TRL 9

Updated May 2017

Company	Swift Creek, Inc.
Target Renewable Energy	Land-Based Wind
Target Species	Birds Bats
Technology Components	Deterrent component
Description & Application	The decal system is attached to the outside and also inside of the turbine blades. Marking of all 3-turbine blade faces near the tip of the blades. Decals provide a visible barrier during diurnal and nocturnal hours for approaching birds and bats to turbine blades. The reflective and refractive decals are in the visible and ultra violet range of bird vision. The glow in the dark decal absorbs light below 400 nm in the ultra violet range for 10 -12 hours after sundown. The materials act as a visible circular barrier to approaching bats and birds.
Detect and/or Deter Non-Target Species	Bat species
Avoidance of False Positives and False Negatives	Product has no detection capabilities.
Effective Range	Product visible to approaching birds and bats up to 1/4 mile.
Timeline of Production	This technology has been in production for 11 years.
Product Manufacturing	Sweden and USA
TRL Justification	TRL 9. Firefly Diverter product has been fully tested and commercially available on the market since 2004, over 11 years ago. 500 k units have been installed on power lines worldwide since 2004. Efficacy from independent peer reviewed and published studies both in USA, Canada, and Europe. A US Patent was awarded in October of 2013 to the inventor.
Planned or Underway Testing	None
Safety or Public Nuisance Issues	None
Testing with Direct or Indirect Regulatory Agency Engagement	Western Area Power Administration (WAPA) in South Dakota, Central Valley of CA - PATH 15 transmission line,
Commercial Deployment	PacifiCorp, Northwestern Energy, WAPA, Florida Power & Light, Altalink Ltd. (Calgary, Canada), ATCO Electric Ltd. Canada, Scottish Power (Scotland) Spain, Estonia, Germany,

Installation and Setup	Product would be applied as a decal to the front and back side of the turbine blades, making it visible to approaching bats and birds.
Timeline for Installation and Operation	Product installation would depend on turbine maintenance.
Coordination with Facility for Installation and Operation	To deploy the product on to the turbine blades when in the static mode on site at the wind farm facility.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Company maintenance personnel would need to install the product with the manufacturer present.
Other Products Required for Installation	None
Potential Interference with Other Technologies	No
Operational Limitations	Decals should be applied during non-precipitation periods of summer and fall.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	No
Remotely Monitored or Near Real-Time Status and Operation	No
Utility Scale Units Sold or Installed	100,000+
Expected Lifespan	A 10-year material warranty from 3M testing.
Warranty	A 1-year material warranty on defects from normal wear.
Extended Warranty	Not defined yet
Submission Contact	Timothy M. Chervick | Phone: (801)-652-7212 | Email: timothychervick@msn.com | Address: 669 Easton Court Grantsville, Utah 84029

EAGLE EYE™ | TRL 9

Updated September 2017

Company	Bird Barrier America, Inc.
Website	www.birdbarrier.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds Bats
Additional Species	Ravens, Grackles, Starlings, Sea Gulls, Pigeon, Customizable for specific bird species
Technology Components	Deterrent component
Description & Application	The Eagle Eye™ bird control system is an eco-friendly system designed to deter specific bird species from unwanted areas. The units absorb the ultraviolet spectrum from natural sunlight, as well as certain artificial light sources, and reflect specific color spectra to the birds. These spectra (invisible to the human eye) are known as "danger spectra" and are associated to the presence of predator birds in the area. Studies found that birds see numerous color spectra that are invisible to the human eye. This is achieved by the large number of photoreceptors in their eyes. Up to 80% of these photoreceptors are made up of cones. The cones give them the ability to see a vast amount of different color spectra as well as ultraviolet spectra. Birds make use of this vivid color perception to find food as well as to avoid predator birds and other dangers. Most plants and food are covered by a thin layer of oil. These oils reflect a specific color spectrum to the birds. Birds use these spectra to find and navigate towards food sources. Predator birds also have certain oils on their feathers. These oils reflect a different color spectrum, and birds use these associations to avoid areas of danger. The Eagle Eye™ makes use of these instincts by reflecting the applicable "danger-spectra" from the ultraviolet range towards the birds. This association with danger makes the birds uncomfortable and they will leave the area.
Mechanism(s) by which the Technology Operates	UV Reflective Flags, Decals, Paint, or Other Surfaces
Detect and/or Deter Non-Target Species	Predator birds are not likely scared by the color spectrum, but it might irritate their eyesight and show them the rotors that they might otherwise not notice. Further testing would need to be done on these species.

Effective Range	One unit has an effective horizontal and vertical (mostly downwards) distance of 200ft (unobstructed).
Timeline of Production	This technology has been in production since 2005.
Product Manufacturing	Republic of South Africa
TRL Justification	TRL 9 The Eagle Eye™ system has been successfully implemented at numerous sites worldwide with a strong client reference base for the past 10 years.
Planned or Underway Testing	Yes. Several case studies involving actual bird counts pre- and post-installation are underway. Due to the intensive nature of these studies, we expect official results to be published by March 2016.
Safety or Public Nuisance Issues	The flashes emitted by the system may be an irritation to people staying in close proximity to the installation, but adequate placement of the units can avoid this issue.
Testing with Direct or Indirect Regulatory Agency Engagement	Yes - Accepted by Airports and State institutions
Commercial Deployment	Agriculture (More than 1,000 installations). Airports (2 Installations on the runways.) Open areas such as Salt pans (2 installations). Thousands of structures around the world.
Timeline for Installation and Operation	The products are in stock and can be shipped out usually within 24 hours.
Coordination with Facility for Installation and Operation	Installation and regular cleaning. Bird Barrier will need to train those who will be performing these tasks.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Clearance from the turbine manufacturer will be needed regarding allowed installation locations on the turbines itself.
Other Products Required for Installation	None
Potential Interference with Other Technologies	No
Operational Limitations	The Eagle Eye™ system is most effective during daytime and clear skies. Artificial light sources can be used for night-time, but a reduced effective range is to be expected.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	No, but the reflector heads need to be cleaned every 3-6 months.
Remotely Monitored or Near Real-Time Status and Operation	No
Expected Lifespan	Based on past experience, the Eagle Eye™ should have a lifespan of 8-10 years, given that it is serviced as prescribed. This has

	been determined based on ten years of selling this product in harsh climates all around the world.
Warranty	Yes. The Eagle Eye™ units have a 2-year warranty. This covers the motor, the reflector as well as the solar panel (if applicable). The system must be serviced once every 4-6 months for the warrantee to be active.
Extended Warranty	This is negotiable.
Submission Contact	Cameron Riddell | Phone: (310)-527-8002 | Email: cameron.riddell@birdbarrier.com | Address: 20925 Chico Street, Carson, California 90746

GE BAT DETERRENT SYSTEM (BDS) | TRL 9

Updated March 2021

Company	GE Renewables
Website	https://www.ge.com/renewableenergy/home
Target Renewable Energy	Land-Based Wind
Target Species	Bats
Technology Components	Deterrent component
Description & Application	The GE bat deterrent system is a cost-effective jet system to ensonify a wind turbine rotor with powerful, broadband ultrasonic noise that effectively reduces bat fatalities at wind turbines. The GE bat deterrent utilizes echolocation masking by ensonification of the wind turbine rotor with powerful broadband ultrasonic noise.
Mechanism(s) by which the Technology Operates	Ultrasonic Acoustic Deterrent
Detect and/or Deter Non-Target Species	No
Avoidance of False Positives and False Negatives	NA, this is a deterrent technology
Effective Range	One turbine
Timeline of Production	Prototypes installed in 2013. Commercial availability in North America since July 2018.
Product Manufacturing	USA
Tech Support	USA
TRL Justification	The GE bat deterrent system is fully integrated into select GE wind turbine platforms and is available as a commercial product on North American wind turbines. Test systems have been studied for bat fatality effectiveness at an Illinois wind farm.
Efficacy Testing	Lab Testing, Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate
Planned or Underway Testing	A 2022 US DOE funded study is planned for the bat deterrent system to compare bat deterrents to wind turbine curtailment. 40 or more wind turbines will be evaluated for effectiveness at the site using a four-way study of Control (no curtailment or deterrent), Deterred, Deterred plus curtailed, and Curtailed turbines. The results are planned to be published in a peer reviewed journal in 2023.

Safety or Public Nuisance Issues	The system produces ultrasonic noise outside the audible hearing range of humans. Audible noise is created by compressors inside the tower; this does contribute to overall wind turbine noise. The compressors can be configured to shut off at high wind speeds, when bats are not present and when the wind turbine generates peak noise, this prevents an increase in the peak noise produced by the wind turbine platform.
Testing with Direct or Indirect Regulatory Agency Engagement	The U.S. Fish and Wildlife Service, Illinois-Iowa Field Office, support the testing of the GE bat deterrent at the California Ridge Wind Energy Farm in Illinois, USA.
Installation and Operation Components	Tower-mounted
Installation and Setup	The GE bat deterrent equipment is installed inside the wind turbine tower. Long life industrial air compressors are installed on a tower platform and air flow is routed to ultrasonic acoustic jets that are pointed at the wind turbine rotor through small holes drilled in the tower wall. Controls are integrated with the turbine provide smart scheduling, wind speed, and ambient temperature operation.
Timeline for Installation and Operation	Approximately 6 months from order to commissioning of the bat deterrent on the wind turbine
Coordination with Facility for Installation and Operation	Coordination with bat deterrent facilities owner and operators will be needed to set desired control parameters for scheduling when the deterrent is operational. This includes deterrent operational wind speeds and ambient temperatures.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	GE coordinates the full integration into GE wind turbines as a feature and accessory.
Other Products Required for Installation	For modern wind turbines, no additional products are needed. For older generation wind turbines, some aspects of the wind turbine controls will need upgrading.
Potential Interference with Other Technologies	If a wind turbine operator desires to use acoustic bat monitors, the monitor may record the noise output of the bat deterrent ultrasonics depending on the distance between the sound measurement device and the deterrent system.
Operational Limitations	There are no operational limitations, the bat deterrent system is designed to run continuously, if desired.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	On an annual basis, the compressors will require a change of oil and drive belt replacement.
Remotely Monitored or Near Real-Time Status and Operation	Yes

Expected Lifespan	If maintained properly, the system lifespan is designed for 20 years, with operational periods during typical bat migration seasons.
Warranty	Yes, the bat deterrent system hardware has limited warranty.
Extended Warranty	Yes, it is optional, cost is negotiated.
Peer-Reviewed Research	Yes, we have completed research available.
Submission Contact	Jared Spense | Phone: (864) 254-2493| Email: jared.spense@ge.com | Address: 201 Brookfield Parkway, Brookfield Plaza Building Greenville, SC 29607, USA
Technical Contact	Myron Miller | Phone: (765) 476-1047 | Email: myron.miller@ge.com

PRO-PELLER™ | TRL 9

Updated September 2017

Company	Bird Barrier America, Inc.
Website	www.birdbarrier.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds Bats
Additional Species	Ravens, Grackles, Starlings, Sea Gulls, Pigeon, Customizable for specific bird species
Technology Components	Deterrent component
Description & Application	The Pro-Peller™ bird control unit is an eco-friendly system designed to deter specific bird species from unwanted areas. The units absorb the ultraviolet spectrum from natural sunlight, as well as certain artificial light sources, and reflect specific color spectra to the birds. These spectra (invisible to the human eye) are known as "danger spectra" and are associated with the presence of predator birds in the area.
Detect and/or Deter Non-Target Species	No
Effective Range	One unit has an effective radius of 100ft (unobstructed).
Timeline of Production	This technology has been in production since 2015.
Product Manufacturing	Republic of South Africa
TRL Justification	TRL 9 The Pro-Peller™ system has been successfully implemented at numerous sites worldwide with a strong client reference base for the past 2 years.
Planned or Underway Testing	Yes. Several case studies involving actual bird counts pre- and post-installation are underway. Due to the intensive nature of these studies, we expect official results to be published by March 2018.
Safety or Public Nuisance Issues	The flashes emitted by the system may be an irritation to people staying in close proximity to the installation, but adequate placement of the units can avoid this issue.
Testing with Direct or Indirect Regulatory Agency Engagement	Yes - Accepted by Airports and State institutions
Commercial Deployment	Agriculture (More than 1,000 installations) Airports (2 Installations) Open areas such as Salt pans (2 installations).
Installation and Setup	The Pro-Peller units will be installed at ground level around the perimeter of the farm as well as between the turbines.
Timeline for Installation and Operation	The products are in stock and can be shipped out usually within 24 hours.

Coordination with Facility for Installation and Operation	None. Installations and servicing are performed by trained and dedicated installers of the Eagle Eye™ system.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	Clearance from the turbine manufacturer will be needed regarding allowed installation locations around the turbines itself.
Other Products Required for Installation	None
Potential Interference with Other Technologies	No, in fact we recommend complimenting the Eagle Eye™ system with other bird control products to further enhance the effectiveness of the system.
Operational Limitations	The Pro-Peller™ system is most effective during daytime and clear skies.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	No, but the reflector heads need to be cleaned every 3-6 months.
Remotely Monitored or Near Real-Time Status and Operation	No
Expected Lifespan	Based on past experience, the Pro-Peller™ bracket and stainless-steel chain should have a lifespan of 5 years.
Warranty	Yes. The Pro-Peller™ units have a 2-year warranty.
Extended Warranty	This is negotiable.
Submission Contact	Cameron Riddell | Phone: (310)-527-8002 | Email: cameron.riddell@birdbarrier.com | Address: 20925 Chico Street, Carson, California 90746

DIM UV LIGHT DETERRENT | TRL 7

Updated November 2018

Company	University of Hawaii at Hilo Bat Research and Consulting U.S. Geological Survey (USGS)
Website	https://pubs.er.usgs.gov/publication/70159496
Target Renewable Energy	Land-Based Wind
Target Species	Bats
Technology Components	Manipulate the perception of approaching bats by dissuading them
Description & Application	Migrating tree-dependent bats compose the vast majority of fatalities at wind turbines. Evidence and logical arguments suggest that these bats visually mistake turbines for the silhouettes of trees in the dark and approach too closely. Our approach is to cover the wind turbine in flickering, visually moving light that only bats can see. In a manner similar to the lighting of monuments, we are testing whether bathing wind turbines in bat-visible, dim ultraviolet light persuades far-away bats that wind turbines are not trees and that it is not in their best interest to approach.
Mechanism(s) by which the Technology Operates	Broadcast/Emission of UV Light, Moving Visual Deterrent
Monitoring or Minimizing	Minimizing
Detect and/or Deter Non-Target Species	We do not anticipate non-target species being able to perceive the light cue we are using to communicate with approaching bats. The exception is likely certain night-flying insects, but to date our observations indicated they are not attracted to pure UV light. For more details see: Cryan, P. M., P. M. Gorresen, and D. C. Dalton. 2018. Selectively perceptible wind turbine system. United States Patent Grant US9995282B2. https://patents.google.com/patent/US20160169501
Effective Range	Visible to bats at distances > 1 km radius.
Timeline of Production	We are still in the testing phase and several years from production if it works.
TRL Justification	We are still testing the logistics of deploying the pilot system long-term and determining its effectiveness at keeping bats from approaching wind turbines.
Efficacy Testing	Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Wind Facility, Field Testing at a Commercial Wind Facility including Measurement of Reduction in Fatality Rate

Planned or Underway Testing	Results of current efficacy test will be made public in early winter of 2019/2020. If shown to be effective in the current test, additional testing at high-fatality commercial wind facilities is planned.
Safety or Public Nuisance Issues	No, the UV light we use is too dim to be perceived by humans from distance greater than a few meters from the illuminated turbines.
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	No
Installation and Operation Components	Tower-mounted, Requires Power Source
Installation and Setup	In current configuration, 12 small lights (the size of a deck of playing cards) are magnetically attached around the circumference of the tower 20 m above the ground. Thin wires running from each light are taped to the turbine tower with foil tape and run into the base of the tower where they connect to an automated timer (turns them on at sunset and off at sunrise) and 13VDC power supply run from a standard 120VDC outlet. Two people using a 30-m lift can install the system on a single turbine in approximately 4 hours.
Coordination with Facility for Installation and Operation	Occasional maintenance of light units, electrical lines, timer, and power supply, which most facility technicians are qualified to do.
Potential Interference with Other Technologies	No known interference issues with other systems.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	About 300 Watts of AC power and perhaps annual maintenance checks to verify LED light units are functioning and properly positioned.
Expected Lifespan	Unknown at this stage of development, but probably 5-10 years based on similar devices designed by the engineering team.
Submission Contact	Paul Cryan | Phone: (970)-226-9389 | Email: cryanp@usgs.gov | Address: USGS Fort Collins Science Center, 2150 Centre Ave., Bldg.C, Fort Collins, Colorado

NON-LETHAL WILDLIFE MITIGATION | TRL 2

Updated September 2023

Company	Lite Enterprises
Website	www.liteenterprises.com
Target Renewable Energy	Land-Based Wind
Target Species	Birds Raptors Bats
Technology Components	Deterrent component
Description & Application	The technology emits high, mono-colored LEDs which are capable of neurophysically disrupting the ocular sensory system of wildlife.
Detect and/or Deter Non-Target Species	Yes. Expect deterrence of a broad variety of avian/bat species; overall effectiveness dependent on model.
Effective Range	Effective range is specific to the tailored product design.
Product Manufacturing	New Hampshire, USA
TRL Justification	Models - NLD 100, NLD-160
Planned or Underway Testing	FAA ongoing Technical Research Contract
Safety or Public Nuisance Issues	ANSI IESNA RP 27 Compliant, ANSI/ISEA Z87.1-2010 standard “American National Standard for Occupational and Educational Personal Eye and Face Protection Devices”
Commercial Deployment	Saco Bay, Maine (mussel farm), NH State Fish Hatchery (Osprey), Cape May Banding Project, US Cellular
Installation and Operation Components	IP-65
Installation and Setup	Site specific-Customer responsible
Timeline for Installation and Operation	Around 90-120 days ARO, custom designs are subject to quote.
Expected Lifespan	10 years
Warranty	There is a 1-year warranty.
Submission Contact	Donald Ronning | Phone: (603)-821-0991 x 503 | Email: d.ronning@liteenterprises.com | Address: 4 Bud Way, Ste.15, Nashua, New Hampshire 03063

UV LIGHT FENCE | TRL 1

Updated September 2018

Company	Norwegian Institute for Nature Research (NINA)
Website	www.nina.no
Target Renewable Energy	Land-Based Wind
Target Species	Birds
Technology Components	Deterrent component
Description & Application	We envision utilizing UV lights that sweep upwards during night time encircling the rotor swept zone (i.e., light-fence). As this is an emerging technology, this task will be performed in the form of a feasibility study, where the technical, social, and economic issues will be explored. Existing UV-light systems will be explored to test if and how birds may react to such lights. If these tests are successful the project will take this method further to explore whether a “light-fence” can be construed surrounding the rotor swept zone, excluding birds from this risky area. Target species include gulls, terns, petrels, and gannets. Visual deterrence using UV lights will be most effective at low light levels and may therefore mainly help mitigate collisions of nocturnal birds. UV lights are invisible to the human eye but may deter nocturnal birds from entering the rotor swept zone without creating visual nuisance for humans. However, there are potential hazards connected with UV light, which can be harmful to people’s eyesight which will be considered.
Mechanism(s) by which the Technology Operates	Broadcast/Emission of UV Light, Ultrasonic Acoustic Monitor, Real-time ID of Bird/Bat Vocalizations, Weather/Environmental Sensors (wind, precipitation, etc.)
Timeline of Production	Not yet produced
Safety or Public Nuisance Issues	Yes, dependent on UV emission levels and manner of deployment this may harm the eyes of humans and/or birds.
Testing with Direct or Indirect Regulatory Agency Engagement	No
Submission Contact	Roel May | Phone: (479)-578-5995 | Email: roel.may@nina.no | P.O. Box 5685 Torgarden, 7485 Trondheim, Norway

UV LED DETERRENT | TRL 1-7

Updated October 2019

Company	Stantec Consulting Services, Inc.
Website	www.stantec.com
Target Renewable Energy	Land-Based Wind
Target Species	Eagles Birds Raptors Bats
Technology Components	Deterrent component
Description & Application	High intensity near-UV light bursts (currently) set at intermittent intervals that cause a startling effect and create avoidance behavior away from the rotor zone area. The physiology of bird and bat vision allows many species to see portions of the UV spectrum that are beyond normal human spectral sensitivity (400-700nm), suggesting that a deterrent based UV (or near UV) light system may be effective for birds and bats while not being a nuisance to people. Recent technical advancements in LED technology have also provided enhanced power capacity, capable of covering large areas and extended distances. Understanding the range of spectral (nm) values, as well as light intensity levels and duration, are key to developing an effective deterrent capable of causing an avoidance reaction for a range of individual target species, e.g., Myotis spp, raptors.
Detect and/or Deter Non-Target Species	Yes. Expect deterrence of a broad variety of avian/bat species; overall effectiveness dependent on individual unit parameters (i.e., nm, w, frequency).
Avoidance of False Positives and False Negatives	Not available with current prototype (i.e., not a detection-based system) but anticipated future system to include IR detectors for small targets (e.g., bat/passerine) and potential x-band radar for larger (raptor) targets at greater distance.
Effective Range	Current tests are focused on individual rotor zone area.
Timeline of Production	Prototypes only at this time
Product Manufacturing	Pelham, New Hampshire
TRL Justification	In 2012, Stantec and Lite Industries (LEI), with National Science Foundation support, conducted a field-based pilot study of the effectiveness of a prototype UV light-emitting diode (UVLED) system designed to deter bats and songbirds from entering a defined airspace (Stantec 2013; see separate attachment). The prototype utilized a 25-watt (emitted) UVLED system, designed and built by LEI, with a peak emission wavelength of 375-395

	nanometers (nm). The emitted light was conditioned through optical elements to produce an emission pattern focused to an angle of less than +/- 15 degrees beam divergence. An additional (longpass) filter was also incorporated into the system to minimize visible light while maximizing the UV emissions. The effectiveness of the UVLED system as a deterrent appeared to differ for birds versus bats, suggesting that the light did have an effect, as inter-night and inter-site variability among the control and test sites was presumably similar for birds and bats. However, the results of the 2012 pilot effort were negatively influenced by the relatively low (25-watt) power emission as well as by a late season initiation of the study relative to the fall bat migration. Since 2012, Stantec and LEI have continued to research the utility of UV deterrents against bird and bat species, investigating a line of increasingly more powerful (100W, including non-LED) light sources of varying spectral values. Relative to the AWWI RFI (DOE Table 1) Technology Readiness Levels, past and ongoing Stantec/LEI studies have ranged from TRL 1 to TRL 7 levels. Stantec and LEI - again in conjunction with NSF support - are presently continuing investigations re: the applicability of a near-UV light system for both daytime (raptor) and nighttime (bat) deterrence. Overall project concept and objectives, unit descriptions, and study methodologies are further described below for both current (Phase 1) and future (Phase 2) studies. Phase 1 studies are anticipated to be completed by 1Q 2015. Phase 2 Study information is presented under Tab 3 (UV-LED Phase 2 Studies).
Planned or Underway Testing	Results of the current (Phase1) investigations are anticipated in 1Q 2015.
Safety or Public Nuisance Issues	Potential night time reflectance concerns associated with 4 varying wavelength values and 2 power output levels are scheduled to occur at an operating wind farm this fall. As part of that effort, a variety of deployment and shuttering techniques will be evaluated to determine how best to address any identified concerns.
Testing with Direct or Indirect Regulatory Agency Engagement	To date, only National Science Foundation
Commercial Deployment	See Appendix A Stantec 2013 report. Fall 2014 studies are currently underway and include controlled field and turbine-related studies, as well as (uncontrolled) opportunistic events.
Installation and Setup	Unit placement for daytime applications is expected to be directly on nacelle and include both forward and rear-facing units. Nighttime applications for bat deterrence are dependent on further testing (in terms of reflectivity and shadow effect) but

	may potentially utilize shuttered, mid-point tower mounts to avoid detections from the ground.
Timeline for Installation and Operation	Limited (30-60 day) turnaround time anticipated at this time (also dependent on number of units)
Coordination with Facility for Installation and Operation	Provide local power source; install and maintain (timer-based) system.
Coordination with Turbine Manufacturers or OEMs for Installation and Operation	We appreciate any exterior device mounted on a tower or nacelle attracts potential turbine warranty concerns but expect mounting these devices on turbine structure will not cause significant concern.
Other Products Required for Installation	None anticipated at this time.
Potential Interference with Other Technologies	No
Operational Limitations	The visibility of night time operations (from the ground) of specific UV wavelengths is currently being assessed as part of the current studies and include methods for avoiding/limiting potential concerns via alternate unit positionings.
Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	Power supply costs only. We expect a potential need for an initial period of mortality monitoring to assess/confirm effectiveness once deployed.
Expected Lifespan	Anticipate 30,000 to 50,000 hours; to be confirmed.
Warranty	1 year warranty anticipated
Extended Warranty	TBD
Submission Contact	Steve Pelletier, CWB c/o Stantec | Phone: (207)-406-5495; (207)-798-1508 | Email: steve.pelletier@stantec.com | Address: 30 Park Drive, Topsham, Maine 04086
Technical Contact	Donald Ronning | Phone: (603)-233-1603 | Email: d.ronning@liteenterprises.com

LIGHTING SYSTEM TO ENHANCE TURBINE DETECTION AND AVOIDANCE BY RAPTORS | TRL 2-3

Updated January 2017

Company	Purdue University
Website	http://estebanfj.bio.purdue.edu/
Target Renewable Energy	Land-Based Wind3D
Target Species	Eagles Birds
Additional Species	Golden Eagles
Technology Components	Deterrent component
Description & Application	The technology is based on the physiological properties of the visual system of the specific raptor species. The technology tunes certain light characteristics (wavelength, angle of incidence, pulsing) to the eye of the raptor species. The equipment and expertise of Purdue and the USDA/APHIS/WS National Wildlife Research Center (NWRC) are unique worldwide to provide the physiological and behavioral information necessary to develop this lighting design. Lights will be attached to a wind turbine and, possibly, located in a perimeter configuration about the turbine. Specific locations will be determined through behavioral research.
Detect and/or Deter Non-Target Species	It likely deters other species, particularly if the combination of light characteristics falls within the visual range of other birds.
Avoidance of False Positives and False Negatives	This technology is not intended to enhance human detection of birds.
Effective Range	Because the product is tuned to the eye of a given species (Golden Eagles), the range will be given by the visual acuity of the species (to be determined, but very likely to be much higher than 1 sq km).
Timeline of Production	This technology has been in production for 5 years in the context of bird-aircraft applications (dependent on funding).
TRL Justification	Given ongoing research on bird collisions with aircraft, our work falls between TRL 2, Applied Research, and TRL 3, Proof of Concept Established as we have already conducted lab and

	controlled experiments in the field that validated the predictions of sensory models on avian vision.
Planned or Underway Testing	No, funding is pending.
Safety or Public Nuisance Issues	There is the potential issue of lights being visible to humans, but the proposed research to develop this product is expected to reduce these effects.
Testing with Direct or Indirect Regulatory Agency Engagement	No
Commercial Deployment	Yes
Potential Interference with Other Technologies	No
Operational Limitations	No
Submission Contact	Prof. Esteban Fernandez-Juricic | Phone: (765)-494-044 | Email: efernan@purdue.edu | Address: Department of Biological Sciences Lilly Hall G-325 916 W State St. West Lafayette, Indiana 47907

OTHER TECHNOLOGIES

NEW MYCONEST: BIODEGRADABLE HABITAT MODULE | TRL 5-6

Updated June 2025

Company	MycoNest
Website	https://www.instagram.com/myconester/
Target Renewable Energy	Solar, Land-Based Wind, Transmission, Multiple Industries
Target Species	Pollinators Microbes Agricultural Species Native Vegetation Insects Reptiles and Amphibians Birds Mammals Other Wildlife Species Bats
Additional Species	Solitary bees, Eurasian blue tit (*Cyanistes caeruleus*), common frog (*Rana temporaria)*, slow worm (*Anguis fragilis*), grass snake (*Natrix natrix*), and other temperate-region field and edge species.
Description & Application	MycoNest is a lightweight, modular wildlife habitat made from mycelium bound to locally sourced bio-waste such as straw, hemp, and wood chips, with added biochar to improve soil structure and fertility. Designed for use in solar parks and transmission corridors, it offers nesting and shelter opportunities for birds, insects, reptiles, amphibians, and small mammals. Its patented hook design allows quick, tool-free installation on fences, racks, or poles, with versions suitable for ground or aquatic placement. When left intact, MycoNest retains structural integrity for up to 24 months — sufficient to support a full insect life cycle, including overwintering phases. Once broken, it gradually biodegrades over

	a few months, releasing embedded native wildflower seeds and soil-enhancing biochar. These seeds foster pollinator-attracting vegetation, which in turn draws birds and other insectivores, strengthening ecological links. The biochar stabilizes moisture and nutrient levels, further reinforcing local plant resilience. This passive, circular intervention boosts biodiversity while coexisting seamlessly with renewable energy infrastructure and land management practices.
Monitoring or Minimizing	MycoNest minimizes negative wildlife-infrastructure interactions by creating microhabitats that attract and safely host species away from operational zones of solar and transmission infrastructure. By offering designated nesting, shelter, and overwintering spaces, it reduces the likelihood of wildlife interference with energy systems (e.g., nesting in hazardous electrical components or unintended perching). It also encourages natural behaviors like pollination and pest control in controlled zones, thus minimizing ecological disruptions caused by infrastructure.
Detect and/or Deter Non-Target Species	No, MycoNest does not detect or deter species.
Avoidance of False Positives and False Negatives	MycoNest is a passive biodiversity support structure and does not include any active detection or deterrence features. However, its size, surface texture, and entrance orientation may limit use by larger or invasive species by design (e.g., excluding predators or scavengers not adapted to small cavities).
Effective Range	The effective range is at the unit level, with potential to scale across full solar parks or linear transmission corridors. Each MycoNest unit provides benefit in a 1–10 m² microhabitat zone, and the technology is scalable across entire facilities or habitat networks through modular deployment.
Timeline of Production	Pilot program / Startup project (under active field testing for 6 months).
Product Manufacturing	Budapest, Hungary (Plans are underway to expand manufacturing and sales globally as part of scale-up strategy.)
Tech Support	MycoNest is a passive, non-electronic product requiring no technical support infrastructure.
TRL Justification	MycoNest has completed laboratory prototyping and has been field-tested in real-world environments, including solar parks and agricultural edge zones. Prototypes have demonstrated functionality under outdoor conditions with partial seasonal exposure (sunlight, precipitation, wind). Field trials confirmed physical durability, ease of installation, and initial species interactions. Additional testing is ongoing to validate fire resistance, waterproofing, and species uptake. Practical applications have been identified in biodiversity enhancement

	strategies for renewable infrastructure and early-stage discussions are underway with potential implementation partners.
Efficacy Testing	Lab Testing, Field Testing Outside of a Commercial Facility (pong, field, test facility, etc.), Field Testing at a Commercial Facility Outside of Wind (e.g., airport, agriculture, other energy resources, etc.), Other energy resources
Planned or Underway Testing	Ongoing pilot programs in Hungarian solar parks are measuring habitat use by target species (insects, birds, amphibians), physical durability under seasonal exposure, and decomposition dynamics over time. Upcoming testing phases include waterborne and ground-level variants, additional fire retardancy and waterproofing validation, and long-term monitoring of soil and vegetation regeneration at deployment sites. A reporting and data-tracking system is also in early development to quantify ecological outcomes.
Safety or Public Nuisance Issues	No significant issues have been identified. MycoNest is a passive, biodegradable habitat module weighing approximately 300 grams. It contains no synthetic materials, sharp edges, or electronics, and poses no known safety or nuisance risks under normal use. Its low weight reduces the risk of injury or damage even in the unlikely event of detachment or displacement. While laboratory testing is ongoing to confirm fire-retardant and waterproofing characteristics, its material composition (mycelium and plant-based biomass) is non-toxic and environmentally benign. Proper placement and lifecycle planning ensure that degradation does not interfere with energy operations or public access areas.
Testing with Direct or Indirect Regulatory Agency Engagement	MycoNest is a passive, biodegradable habitat module weighing approximately 300 grams. It contains no synthetic materials, sharp edges, or electronics, and poses no known safety or nuisance risks under normal use. Its low weight reduces the risk of injury or damage even in the unlikely event of detachment or displacement. While laboratory testing is ongoing to confirm fire-retardant and waterproofing characteristics, its material composition (mycelium and plant-based biomass) is non-toxic and environmentally benign. Proper placement and lifecycle planning ensure that degradation does not interfere with energy operations or public access areas. To further support safe monitoring and data collection, future versions of MycoNest may include a scannable QR code, allowing operators or citizen scientists to log occupancy without disturbing the habitat. A companion app is envisioned to

	incorporate AI-based visual recognition of used cavities or nest activity, enabling unobtrusive, scalable tracking of ecological value.
Commercial Deployment	Pilot deployments are underway, but full commercial rollout has not yet begun.
Installation and Operation Components	Free-standing, Other (Please specify)
Installation and Setup	MycoNest is designed for fast, tool-free installation by one person. The hook-shaped rear section allows each unit to be easily mounted onto horizontal or vertical bars, poles, or fences — common structures in solar and transmission environments. No power, data cables, or drilling are required. Ground-level deployment is achieved by lightly embedding the form in soil or stabilizing it with biodegradable stakes. Aquatic versions are currently being tested for floating stabilization. The compact 300 g form allows for manual transport and mass deployment without specialized equipment.
Timeline for Installation and Operation	Installation can begin within 2–4 weeks of placing an order, depending on production volume and site location. Once delivered, each MycoNest unit can be installed in less than 2 minutes without tools or special training. Operation begins immediately upon placement, with passive ecological benefits initiated from the start of the deployment season.
Coordination with Facility for Installation and Operation	Minimal coordination is required. The facility owner or operator simply needs to approve access to solar panel structures, fences, or designated land areas for placement. Since the product is lightweight, non-invasive, and tool-free to install, installation can be integrated into routine maintenance or biodiversity initiatives without disrupting energy operations.
Potential Interference with Other Technologies	No. MycoNest is a passive, non-electronic structure and does not emit signals, consume energy, or physically obstruct operational areas. It is specifically designed to coexist with renewable infrastructure and other wildlife monitoring or mitigation tools without interference.
Operational Limitations	Yes, minor limitations apply. MycoNest's ecological performance may vary based on climate, placement, and local species presence. In extremely wet or fire-prone environments, degradation speed or material stability may need adaptation (currently under testing). As a passive habitat, its impact depends on successful attraction and use by target species, which can be influenced by ecosystem context.

Continued Costs Required (Contracts, Maintenance, or Licensing Fees)	No ongoing fees are required. MycoNest is designed for annual replacement as part of its natural lifecycle, but it does not require maintenance, software updates, or licensing contracts. Follow-up support is available upon request, especially for large-scale deployment strategies or ecological performance tracking, but no formal ongoing involvement is required from the vendor.
Remotely Monitored or Near Real-Time Status and Operation	No
Utility Scale Units Sold or Installed	1-100
Expected Lifespan	
Warranty	No. Due to its fully biodegradable nature and ecological purpose, MycoNest is not covered by a conventional product warranty.
Extended Warranty	No. Extended warranties are not applicable. However, support for handling, storage, and ecological performance guidance is available for distributors and bulk purchasers.
Peer-Reviewed Research	No, we have not completed peer-reviewed research.
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