Environment and Natural Resources Trust Fund

M.L. 2024 Approved Work Plan

General Information

ID Number: 2024-237

Staff Lead: Lisa Bigaouette

Date this document submitted to LCCMR: June 13, 2024

Project Title: LiDAR Technology to Help Prevent Wildlife Fatalities from Wind Turbines

Project Budget: $525,000

Project Manager Information

Name: Sayan Biswas

Organization: U of MN - College of Science and Engineering

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Project Reporting

Date Work Plan Approved by LCCMR: June 20, 2024

Reporting Schedule: June 1 / December 1 of each year.

Project Completion: June 30, 2026

Final Report Due Date: August 14, 2026

Legal Information

Legal Citation: M.L. 2024, Chp. 83, Sec. 2, Subd. 08m

Appropriation Language: $525,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to create a low-cost and advanced LiDAR system to detect bats and birds approaching wind turbines that may be used in concert with deterrence or impact avoidance methods to prevent collisions. This appropriation is subject to Minnesota Statutes, section 116P.10.

Appropriation End Date: June 30, 2027

Narrative

Project Summary: Create a low-cost and advanced LiDAR package to detect wildlife and prevent wildlife collisions with wind turbines, safeguarding bats and birds from fatal accidents.

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Wind energy is a cost-competitive and clean energy source, but it has an undesirable environmental impact on wildlife, particularly birds and bats. Nearly 1.7 million birds and bats (including endangered species) are killed from collisions with wind turbines in North America each year, which is a significant fatality rate considering that wind energy accounts for only 10.2% of electricity generation in the US. This problem will only get worse if more states commit to wind energy in the future. LiDAR (Light Detection and Ranging) technology can help prevent bird and bat fatalities with wind turbines by providing real-time data on the flight patterns of these wildlife near the turbines. By installing LiDAR sensors on wind turbines, wind turbine operators can track the movement of birds and bats in the vicinity of the turbines, enabling operators to adjust the turbines' operation and lower the collision risk. Unlike regular camera imaging that works only in daylight or thermal cameras that have limited detection range, a long-range LiDAR system combined with bioacoustics sensors can precisely estimate the 3D flight paths of wildlife near wind turbines. The project aims to develop a low-cost LiDAR package to prevent wildlife fatalities with wind turbines.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

LiDAR works by emitting a laser beam that bounces off objects and returns to the sensor, creating a 3D map of the surrounding environment. A cost-effective long-range LiDAR detection technology that can detect bats and birds from 0.3-0.5 miles away will be developed to precisely estimate the location, attitude, and 3D flight paths of bats and birds. In conjunction with LiDAR, bioacoustic detectors will be used to identify different bird and bat species. A computationally inexpensive machine learning algorithm will be developed to plot the direction of travel of these bats and birds. Our LiDAR-based sensor package will be deployed and tested at the University of Minnesota's 2.5 MW wind energy research station in Rosemount, Minnesota. This test site is just 2 miles from the western bank of the Mississippi River and attracts a large number of Minnesota birds (eagles, hawks, songbirds, waterfowl, and grouse) and bats (hoary, big brown, eastern red, silver-haired, and little brown bats). We will collaborate with the UMN Office of Technology Commercialization to bring this technology to market. The technology will be commercialized in the future to help save birds and bats while promoting clean wind energy.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

Minnesota is home to 400 bird species, including eagles, hawks, falcons, songbirds, waterfowl, and 8 bat species, with four bats listed as Special Concern by the Minnesota DNR, including the northern long-eared bat which is also protected by the Federal Endangered Species Act. Growing demands for clean wind energy may threaten bird and bat populations, and make some critically endangered. These bird and bat species appear to be most vulnerable during migration when they can come into contact with wind turbines while flying at low altitudes. Our LiDAR technology will help design reliable wildlife deterrence or impact avoidance technologies.

Project Location

What is the best scale for describing where your work will take place?

County(s): Dakota, Hennepin,

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

Activity 1: Development, instrumentation, and integration of LiDAR-based sensor systems

Activity Budget: $195,000

Activity Description:

In this activity, the LiDAR, camera imaging, bioacoustics, and data acquisition sensors will be calibrated, tested, and prepared for field testing. Presently, there is no off-the-shelf LiDAR system available for seamless integration into this project. Calibration, testing, and customization are essential to tailor the LiDAR system for our specific requirements, particularly for long-range detection of airborne wildlife. Minimizing false detections and rigorously testing the system in challenging environments on the ground are imperative before deploying it on a wind turbine. This phase is of utmost importance to ensure the system's effectiveness and reliability.

In addition to PI Biswas's two Luminar LiDAR systems, three additional long-range LiDAR systems will be acquired for this project with a 0.3-0.5 miles range and spatial accuracy of less than 2 cm. PI Biswas possesses high-speed and infrared thermal cameras that will be synchronized with LiDAR systems as a reference measuring system. Different LiDAR systems will cover upstream and downstream air space of the wind turbine, blades, and meteorological (met) tower. Co-PI Feist's noise logger, weather station, and a wind speed LiDAR system will be used to monitor the weather conditions and wind speed/directions. WEST, Inc. will acquire/provide 14+ ultrasonic microphones.

Activity Milestones:

Description	Approximate Completion Date
Set up and synchronize LiDAR, cameras, and bioacoustic sensors	December 31, 2024
Complete testing of the sensor system in a laboratory setting	February 28, 2025
LiDAR systems capable of detecting bats and birds from 500+ meter distance	April 30, 2025
Activity 1 summary report	May 31, 2025

Activity 2: Comprehensive field testing of bird and bat interactions with wind turbine using LiDAR

Activity Budget: $160,000

Activity Description:

A full season, June to October (5 months), when wildlife birds and bats are most active in central Minnesota, will be dedicated to field testing at the University of Minnesota's state-of-the-art 2.5 MW wind energy research station in Rosemount, Minnesota. Some of the major bird species that are threatened by wind turbines in Minnesota include bald eagles, golden eagles, hawks, falcons, songbirds, and waterfowl. The common bats encountered in central Minnesota are hoary bat, big brown bat, eastern red bat, and silver-haired bat. Every day during the season, the LiDAR and imaging data will be recorded all day and night, from sunset to sunrise. LiDAR and cameras will be remotely monitored and will be checked in person on a weekly basis. PI Biswas is currently working on a machine-learning algorithm to develop an automated triggering system to start recording LiDAR and camera data once a bird or bat is detected. This would significantly reduce the man hours needed to review the data to find bat activities in the LiDAR videos. The aim of this task is to determine the appropriate operating parameters for the LiDAR technology and to calibrate and incorporate the LiDAR sensor with the bioacoustic sensor.

Activity Milestones:

Description	Approximate Completion Date
Deploy LiDAR sensing systems for field testing	June 30, 2025
Complete the first field testing campaign	October 31, 2025
Calibrate and optimize the LiDAR system	November 30, 2025

Complete analysis of LiDAR data of bats and birds interacting with wind turbine	December 31, 2025
Activity 2 summary report	December 31, 2025

Activity 3: LiDAR package development, calibration, data analysis and hypotheses testing

Activity Budget: $80,000

Activity Description:
In this activity, we will perform sensor integration, combining LiDAR with bioacoustic sensors (this will be called "package development"). The integrated system aims to detect wildlife (LiDAR) and identify their species (bioacoustics). However, field tests are crucial to optimize the efficiency of this sensor integration.
The success of this integration will be assessed by testing hypotheses that aim to understand the theories behind the attraction of birds and bats to wind turbines. We intend to vary the speed of turbine blades extensively to analyze the impact of operational parameters on bird and bat interactions with turbines. The following hypotheses will address the reasons behind bird and bat collisions with wind turbines.
H1) Bird flight in relation to turbine heading (wind direction) is the same.
H2) Migratory bird flights are predicted by weather fronts.
H3) Bats are attracted to operating turbines. Blade movement (visual stimulus) or sounds may attract bats.
H4) Bats use turbines as roosts. Bats see turbines as tree-like structures and are attracted to both operating and non-operating turbines.
Success will be determined if the package can detect and identify airborne wildlife as per the hypothesis.

Activity Milestones:

Description	Approximate Completion Date
Complete LiDAR video processing and data analysis	March 31, 2026
LiDAR + bioacoustics sensor integration and sensor package development	April 30, 2026
Detailed testing of LiDAR sensor package in the field, calibrate and optimize the LiDAR sensor	May 31, 2026
Activity 3 summary report	May 31, 2026
Wind turbine and wildlife collision hypothesis testing	May 31, 2026

Activity 4: Additional field testing to fine-tune LiDAR package, if necessary (optional)

Activity Budget: $20,000

Activity Description:
If our team realizes that we need additional field test data towards a specific situation with a specific sensor arrangement, in case a) we did not obtain conclusive results in the first field testing or b) we found interesting bird and bat behavior that requires additional field testing. The same UMore park wind turbine facility will be used to gather a few more weeks' worth of field data in the following season Y2025, between March to May, which covers the spring bird and bat migration time period. If, for some reason, we do not find enough wildlife activities at the Rosemount wind facility, our backup option is Xcel Energy's Blazing Star wind farm with a 200 MW capacity located in southwest Minnesota's Lincoln County. Xcel Energy is extremely supportive and enthusiastic about our project (please see their support letter), and they will partner with us if we are successful in receiving funding.

Activity Milestones:

Description	Approximate Completion Date
Complete additional field testing to recalibrate and fine-tune the LiDAR system, if necessary	May 31, 2026

Activity 5: Reporting, IP and patent filing, results dissemination, and journal paper writing

Activity Budget: $70,000

Activity Description:

This phase of the project will focus on the final data analysis and report writing. In addition to meeting the deliverable requirements of the LCCMR Fund, the project team will prepare manuscripts for submission to peer-reviewed journals and will communicate the results of the project to the wind industry as well as companies that produce bat detection and deterrent systems.

The reports primarily serve the interests of stakeholders, including entities like Xcel Energy, the Department of Commerce, and the scientific community, as well as LCCMR. Our ultimate objective is to implement LiDAR technology to reduce wildlife fatalities near wind turbines, requiring partnerships with entities such as Xcel Energy. The dissemination of knowledge through these reports is part of our strategy. It is important to note that PI Biswas has an extensive history of intellectual property (IP) and patenting. Therefore, we intend to file patents before making any public disclosures.

Activity Milestones:

Description	Approximate Completion Date
File IP and patents before any public disclose of research results	September 30, 2025
Finished writing the first draft of the journal/conference article	March 31, 2026
Final project report	June 30, 2026

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Christopher Feist	St. Anthony Falls Laboratory, University of Minnesota	Christopher Feist has been involved in SAFL and wind energy research on projects ranging from novel wind turbine drivetrains to health monitoring of wind turbine foundations to mapping the hearing abilities of bald and golden eagles. Chris will be in charge of the Rosemount wind turbine operation and sensor development.	Yes
Christopher Milliren	St. Anthony Falls Laboratory, University of Minnesota	Chris Milliren will provide technical support and develop the sensor systems used in examining wildlife-bat behavior near wind turbines.	Yes
Richard Christopher	St. Anthony Falls Laboratory, University of Minnesota	Richard Christopher will provide technical support for the development of the sensor system. Richard is also the safety officer of the research site and will develop safety plans for sensor installation at the wind energy research site.	Yes
Jennifer Stucker	Senior Research Biologist, Western EcoSystems Technology, Inc.	Dr. Jennifer Stucker is an expert in evaluating bat behavior and habitat selection in an ecological context. She has extensive experience using innovative measurement approaches to evaluate natural resources questions. She will help develop the sensor system and evaluate hypotheses. She has prior experience working at the Rosemount wind turbine.	Yes
Kevin Heist	Consulting Biologist, Western EcoSystems Technology, Inc.	Dr. Kevin Heist has a decade of experience in bat acoustic analysis, radar deployment, and analysis of imaging sensors to support bat and migration and ecology questions. He will help deploy the sensor system in the field and provide feedback on our hypotheses.	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
We intend to adhere to the ENRTF Acknowledgement Requirements and Guidelines for disseminating, presenting, documenting, and sharing our project's data, results, samples, physical collections, and other products. Our approach involves several key steps:

Our major deliverable: In addition to producing reports, data, and standard project results, our primary output will develop a detailed blueprint of LiDAR-powered sensing technology aimed at averting collisions between wind turbines and wildlife. This design/blueprint will be filed for a patent and will serve as a foundation for creating an inexpensive, compact commercial LiDAR package.

1) Data Management and Documentation: We will meticulously document all project data, results, and relevant information, ensuring clarity and traceability. This documentation will adhere to ENRTF guidelines, including proper metadata tagging and version control. Note that LiDAR will generate a significant amount of data. We will be strategic about saving such a large amount of data.
2) Open Access Repository: We will establish an open-access digital repository to host our project's data, results, and related materials. This repository will follow ENRTF standards to ensure accessibility, proper organization, and ease of navigation for stakeholders.

3) Publication and Presentations: We plan to publish our findings in peer-reviewed journals and present our results at relevant conferences and workshops. In these publications and presentations, we will acknowledge ENRTF's support and follow the guidelines for proper attribution.
4) Sample and Collection Sharing: If applicable, we will share physical samples or collections generated during the project (e.g., bat/bird carcasses). These samples will be made available to the scientific community and relevant stakeholders in alignment with ENRTF guidelines.
5) Online Platforms: Our project will maintain an online presence, such as a dedicated project website or platform, where we will provide updates, summaries, and access to project-related materials while adhering to ENRTF's acknowledgment requirements.
6) Training and Outreach: We will conduct outreach activities, such as webinars, workshops, and training sessions, to share our project's methodologies, findings, and best practices with interested parties. These activities will emphasize ENRTF's support and guidelines.
7) Collaboration and Partnerships: We will actively engage with collaborators, stakeholders, and partners (e.g., DNR, Dept of Commerce, Xcel Energy, etc.) to promote the dissemination of our project's outcomes from LiDAR-based bat/bird measurements. This includes fostering discussions, sharing resources, and jointly organizing events while recognizing ENRTF's contribution.

By following these steps, we are committed to ensuring that our project's data, results, samples, physical collections, and other products are effectively disseminated, presented, documented, and shared in alignment with ENRTF Acknowledgement Requirements and Guidelines.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
Our project aims to develop an advanced yet affordable LiDAR and bioacoustic sensor package that can effectively detect birds and bats from long distances. By doing so, we intend to enhance deterrent technologies to minimize wildlife fatalities caused by wind turbines and gain insights into the behavioral patterns of birds and bats around wind facilities. We will share the outcomes of our project with the wind industry and companies that manufacture wildlife detection and deterrent systems. We will also collaborate with the UMN office of technology commercialization to license and patent our integrated sensor technology and bring it to market.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Behavioral Response of Bald Eagles to Acoustic Stimuli	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 07d	$261,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Sayan Biswas		Principal Investigator			26.9%	0.16		$23,960
Richard Christopher		Co-Principal Investigator			26.9%	0.12		$12,514
Chris Feist		Co-Principal Investigator			26.9%	0.32		$30,606
Chris Milliren		Co-Principal Investigator			26.9%	0.12		$11,684
Research Scientist		The research scientist would oversee the design and implement experimental protocols for collecting LiDAR data in various environments. They would support the postdoc to analyze the collected data to identify and quantify bat activity patterns, contribute to the development of algorithms for automated bat detection and classification, and collaborate with interdisciplinary teams to interpret findings and advance understanding of bat ecology and behavior in relation to LiDAR technology.			27%	0.18		$17,766
Post Doctoral Associate		The postdoctoral researcher will be the primary on-ground scientist fully dedicated to this project. This individual will be responsible for designing and developing the LiDAR system, collaborating closely with Principal Investigator Dr. Biswas. In addition to the technical development, the postdoc will analyze the collected data, compile detailed reports, and create comprehensive presentations. This role is critical to the success of the project, ensuring that all aspects of the LiDAR system are meticulously managed and that the findings are effectively communicated.			27%	2		$153,103
							Sub Total	**$249,633**
Contracts and Services								
Western EcoSystems Technoloy, Inc.	Professional or Technical Service Contract	WEST Inc. contributes vital expertise in environmental consulting for wildlife behavior to the project, complementing PI Biswas's LiDAR and sensor development skills and the Saint Anthony Falls Lab's wind turbine expertise. Their insights are				2		$170,000

		crucial for understanding and optimizing LiDAR system coverage and interpreting wildlife behavior observed through detection.						
Vertical Limit	Professional or Technical Service Contract	Vertical Limit is a local Minnesota company who will help install the LiDAR and other sensors at the wind turbine and met tower. They are experts in mounting specialized sensors on tall structures.				2		$10,000
							Sub Total	**$180,000**
Equipment, Tools, and Supplies								
	Equipment	14 bioacoustics sensors will be purchased and each sensor costs around $1,000.	Bioacoustics will provide us with information about bat species. Bioacoustic signature along with LiDAR sensing will provide the bat's activity near wind turbines.					$12,000
	Equipment	thermal imaging camera, sensor mounting	Thermal imaging of wildlife-bats near wind turbines at night					$2,000
	Tools and Supplies	Sensor mounting, lenses, weatherproof box for LiDAR, wiring supplies, plumbing parts, LiDAR maintenance and mechanical parts and fasteners	Tools and supplies (e.g., fasteners, sensor mounting boards, etc.) to add sensors to the turbine and surrounding area					$9,367
							Sub Total	**$23,367**
Capital Expenditures								
		3 LiDAR systems will be procured, with a useful lifespan of 5-7 years for each LiDAR.	LiDAR sensing system to measure the 3D flight path of bats and birds near wind turbines	X				$65,000
							Sub Total	**$65,000**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Travelling to the wind energy test site, weekly 1-3 times for 6 months	Testing campaign, acquire LiDAR data					$3,000

	Miles/ Meals/ Lodging	One trip per year for one PI to a relevant conference	Knowledge dissemination, sharing/presenting research results with the relevant community and other experts in this field	X				$2,000
							Sub Total	**$5,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication cost in open source journals	Open source journal let everyone access the research results at free of cost					$2,000
							Sub Total	**$2,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$525,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		3 LiDAR systems will be procured, with a useful lifespan of 5-7 years for each LiDAR.	To the author's knowledge, LiDAR sensing has never been used for bat sensing in the field. PI Biswas has been working in this area, wildlife detection using LiDAR for the last two years, and possesses two LiDAR sensing systems. However, for this project, 3 additional systems will be needed. A total of 5 LiDAR systems will be monitoring the wind turbine space simultaneously. This will help us understand and design the bat deterrent systems, which have not been understood and done before. The project's success is entirely reliant on simultaneous measurement of the entire air space using LiDAR. **Additional Explanation :** 3 LiDAR systems will be procured, with a useful lifespan of 5-7 years for each LiDAR. While the manufacturer's warranty covers 2 years, PI Biswas's experience indicates that with proper care, a LiDAR system can effectively operate for up to 5 years. PI Biswas will purchase 3 more ($20-30k each) to cover the entire airspace near the turbines. The sensor system will be mounted on the wind turbine and met tower for monitoring. This capital equipment will be essential for our project that will pay off in two years. After two years, the PI can use these LiDAR and bioacoustic sensors for remediation of bat fatalities purposes. Bats can be detected using LiDAR and bioacoustic sensing, and different deterrent strategies will be used. These sensing systems can also be permanently installed in one of the Minnesota wind firms (e.g., Rosemount, Blazing Star, etc.) after the project life is over.
Travel In Minnesota	Miles/Meals/Lodging	One trip per year for one PI to a relevant conference	Participating in a conference can significantly benefit by showcasing our technology to the wind energy and wildlife community, creating awareness and facilitating its deployment.

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	unrecovered F&A calculated at 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$246,398
			Non State Sub Total	**$246,398**
			Funds Total	**$246,398**

Attachments

Required Attachments

Visual Component

File: 728e3d89-cb3.pdf

Alternate Text for Visual Component

The visual illustrates the crisis wildlife birds and bats are facing due to growing wind energy demand in North America and Minnesota. Our proposed LiDAR-based detection technology package and its novelty/uniqueness, research team, planned experimental arrangement of LiDAR, and bioacoustic sensors in the Rosemount wind energy site are described...

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
WEST, Inc. Support Letter	f3dc88fc-5dd.pdf
DOC-EERA Support Letter	56eded2d-aea.pdf
Xcel Energy Support Letter	fb867543-9ed.pdf
UMN Sponsored Projects Agency Letter	fc67593d-c6b.pdf
Ambient Particle Effects on LiDAR	b86efafe-f64.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

There are no significant alterations to our proposal and work plan, except for accommodating a budget reduction of $25k. Initially, we had requested $550k and were approved for $525k, which has been entirely allocated to the decreased number of LiDARs (originally plans 4-8 LiDARs, not planning 2-6 LiDARs) outlined in this proposal. This reduction in equipment also impacts our capacity to effectively monitor the wind space. Consequently, we have made adjustments to two of our original hypotheses:

H1) Birds flying in flocks are less inclined to approach turbines.
H2) Birds flying during daylight hours are less likely to come close to turbines compared to birds flying at night.

It's important to emphasize that our project's objective remains centered on developing and showcasing a precise LiDAR system that can adeptly identify bats and birds. We will achieve this by refining LiDAR settings through field testing at the Rosemount wind turbine facility. Notably, the overall scope of our proposal and work plan remains unchanged.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

Yes

Do you agree travel expenses must follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I agree to the UMN Policy.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No