
# Validation Results - A Multi-Sensor Approach for Measuring Bird and Bat Collisions with Wind Turbines

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## Introduction

No studies to date have empirically measured bird or bat collision offshore over long periods of time. On land the timing of collision events within a 24-hour period remains unknown and constrains the design of effective management. The development of an automated collision monitoring system to measure collision would support offshore and land-based wind monitoring. The technology would:

- Enable estimation of the number of bird and bat collisions at turbines where physical searches are not possible, offshore or on land.
- Identify the time of collision and collision location on the blade. This precise information is needed to support minimization strategies.

This presentation documents a U.S. Department of Energy funded research and development project, to improve and validate a multi-sensor collision detection system, WT-Bird®

## Objectives

Refine the sensitivity of the multi-sensor collision detection system and validate its function:

### Increase WT-Bird® in-blade sensor sensitivity

- Detect the collision of a range of birds and bats.
- Small (8 g), medium (25 g) and large (250 g).

### Evaluate which camera sensors can independently determine collision events and identify object size using computer vision.

- Visible spectrum cameras with infrared illuminators, and/or
- Thermal imaging cameras.

## Methods

Collision launcher development and collision testing were conducted at NREL during 2021.

### Safer, air-propelled launch system to mimic wildlife collisions with turbine blades (Figure 1).

- Repeatable launch velocities and biodegradable projectiles.

### WT-Bird® system installed for testing in 2021.

- Compared two sensor and three sensor installations in blades at 6- &12 m from hub *or* at 6- 12- & 18 m (mid-span).
- Collision detection interpretation algorithms improved.
- Full color cameras continuously capture images of rotor sweep.

### NREL conducted collision tests with their launcher on a generating turbine.

- 8 g, 25 g, 40 g, and 250 g objects.
- Using NREL and TNO datasets, WEST independently reconciled collision tests and evaluated results.

Figure 1. The NREL air propelled launcher for evaluating collision at wind turbines. Photos by Werner Slocum/NREL

### Computer Vision

- WEST collected direct observation and color and thermal imagery of birds and bats at two Minnesota locations and in offshore Maine.
- Objects in images delineated.
- Model developed using convolutional neural networks with 80% of data and validation with 20%.
- Models used an Intersection over Union (IoU) = 0.25.

## Results

### Collision Testing

- Collisions: 91 of 146 detected; no false negatives.
- Each collision detected on two or more sensors in a blade, and detection rate increased substantially when blades had three sensors (Figure 2).
- Detection rates increased as projectiles size increased. Although not intentional, the distribution of projectile collisions on the blade by sensor varied by projectile mass.
- Indirect/glancing collisions were detected, despite their likely reduced force of impact.

### Computer Vision

Over 300,000 color images were evaluated identifying 1,637 birds and bats. Overall, detection models had an average precision (0.83; Table 1), with limited confusion or cross classification (Table 2).

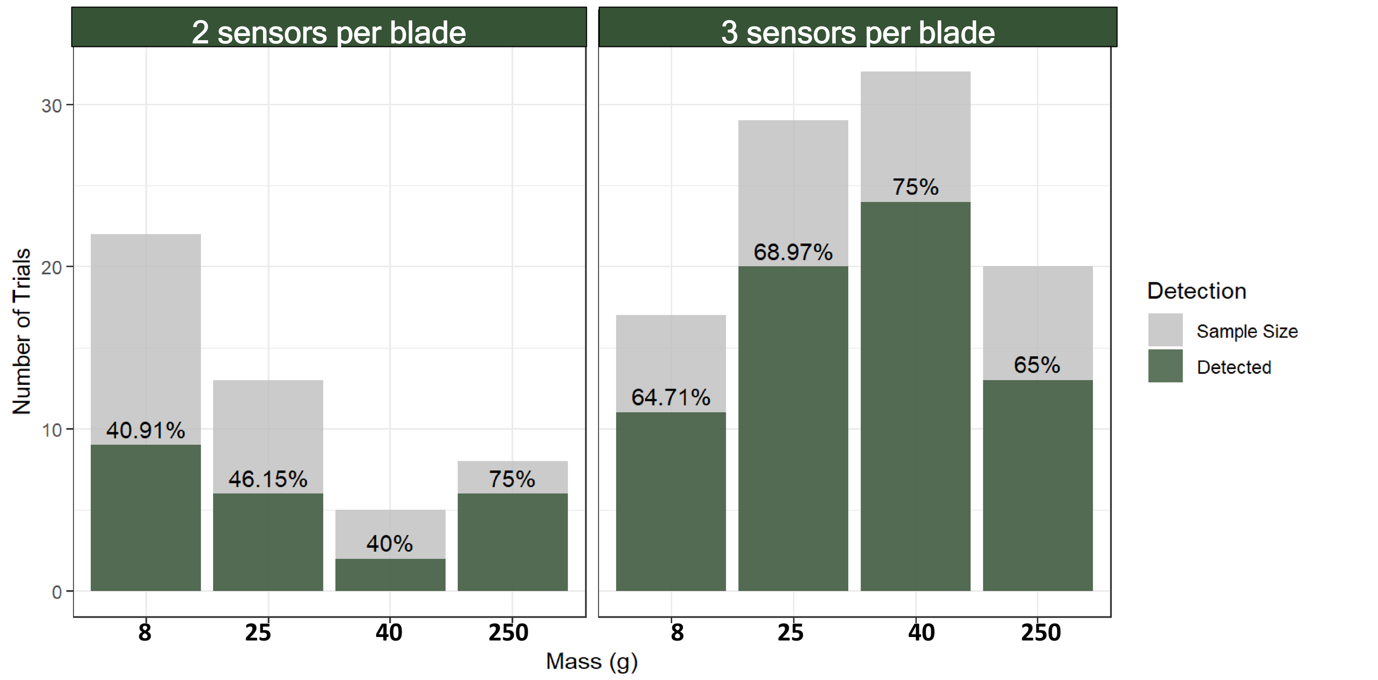


Figure 2. The number and percentage of collision detections by projectile mass (g) for turbines blades with two and three sensors.

## Discussion

The collision trials at NREL provided validation that the WT-Bird® collision sensors detect better than what is expected during a conventional ground-based carcass search. Based on the results, sensors should be installed to maximize detection toward the blade tip.

**Table 1.** Sample sizes (N) and average precision estimates for birds and bat categories used for training and validation of the model. Average Precision indicates the area under the precision-recall curve for each category.

| Category | N (training, 80%) | N (validation, 20%) | Average Precision |
|---|---|---|---|
| large bird | 527 | 136 | 0.91 |
| medium bird | 331 | 74 | 0.81 |
| small bird | 333 | 84 | 0.88 |
| bat | 122 | 30 | 0.71 |
| *mean Average Precision (mAP)* | 328 | 81 | **0.83** |

**Table 2.** Confusion matrix comparing predicted object categories and ground truth annotations. Values along the diagonal (shaded green) represent true positive detections with an IoU > 0.25. Values in the ground-truth "none" row indicate instances where no ground truth annotation overlapped the predicted bounding box with an IoU > 0.25.

| | Model Predicts | | | | |
|---|---|---|---|---|---|
| Ground Truth | large bird | medium bird | small bird | bat | none |
| large bird | 124 | 0 | 0 | 0 | 13 |
| medium bird | 0 | 78 | 0 | 0 | 0 |
| small bird | 1 | 0 | 77 | 5 | 1 |
| bat | 2 | 1 | 0 | 23 | 4 |
| none | 4 | 2 | 5 | 20 | 0 |

Computer vision algorithms demonstrate promise, for identifying objects in order to minimize the volume of imagery that must be retained for further review.

### Continued Testing in 2022 - 2023

- Ongoing validation testing of the WT-Bird System compared to traditional ground-based mortality estimation at the University of Minnesota,
- Computer vision model refinement, and
- Offshore installation and testing of the WT-Bird® System in Denmark early 2023.

## Conclusions

Collision detection technologies for turbines are in reach, and may be suitable when:

- Physical searches are logistically impossible, or
- fine-scale time resolution of collisions is needed.

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