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Advanced Collision Detection and Site Monitoring for Avian and Bat Species for Offshore Wind Energy

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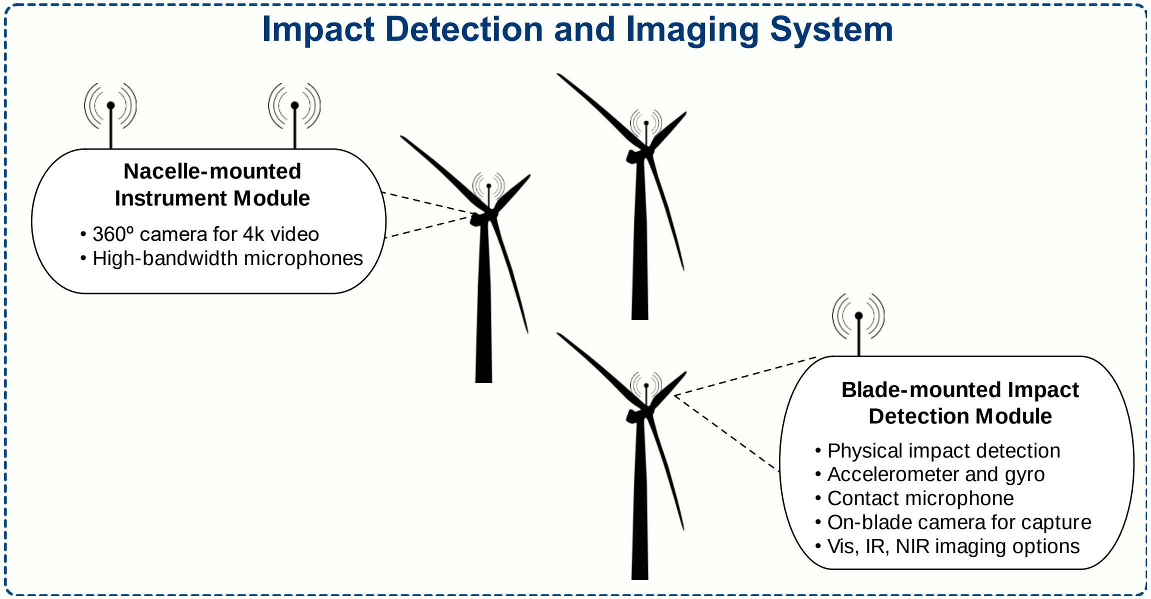
Integrated Collision Detection System Overview

- Three primary objectives in the development of a blade collision detection system for offshore wind energy, focused on bird and bat species:
  - **Collision detection**, using on-blade multi-sensor impact detection modules with continuous, low-power monitoring
  - **Object identification,** using blade-mounted and turbine-mounted visual and audio systems for automated image capture of colliding objects and offline classification
  - **Field-based system validation** in phases, including testing on a ground-based blade and two planned up-turbine field tests
- Enabled by advances low-power sensors, machine learning, and sensor fusion
- Testing to be performed on-site at National Wind Technology Center, Boulder, CO

An effective impact/collision detection and identification system will reduce negative impacts of wind turbine installations to support continued growth of wind energy through improved siting and monitoring for offshore wind energy.

Technology Overview: Collision Detection and Image Capture



- On-blade module monitors continuously for impacts, automatically captures images of colliding object(s) using down-blade cameras
- Sensor network enhances sensitivity for small mass (10g-50g) objects
- Vis and IR cameras for daylight and nighttime operation
- On-nacelle 360º imaging and high-bandwidth acoustic recording

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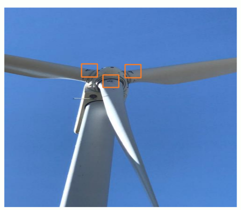
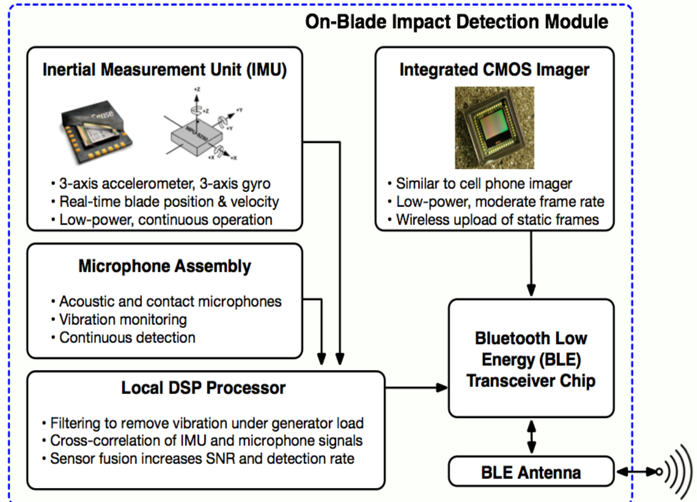
Prior Work in On-Blade Collision Detection

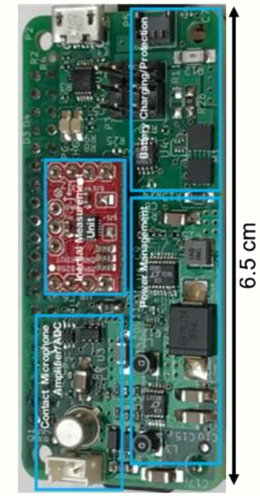
On-blade Impact Detection:

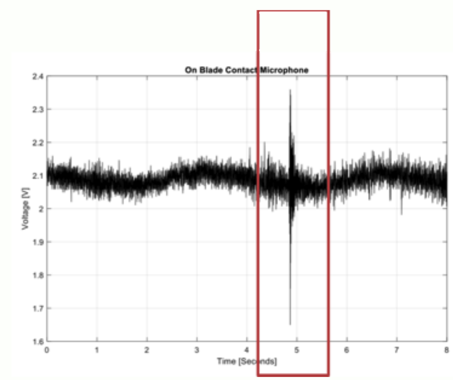
- Automated impact detection and image capture
- Enables (offline) identification of impacting objects

- On-blade low-power sensor module
- Multiple sensors:
  - Vibration detection
  - 3-axis accelerometer
  - 3-axis gyrometer
  - Down-blade camera for video







On-blade impact detection

January 22, 2020

Supported previously by EERE/WETO EE0007885.

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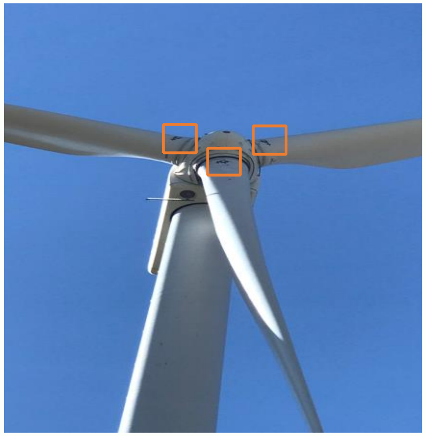
Prior Work Tested at NREL-NWTC

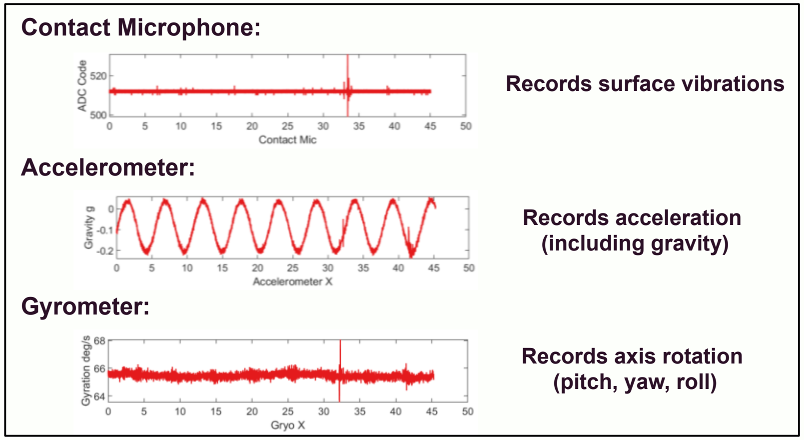
Test setup:

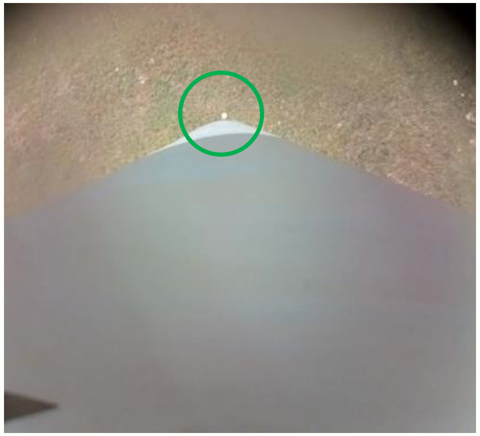
- Tested on 1.5MW GE turbine
- Collision detection modules installed on each blade root
- Wired power from hub, weather-proof enclosures, wireless data

Sensors:

- Accelerometer, gyrometer, contact microphone on blade surface
- Looping video imager angled down-blade to capture collision
- Automated impact detection to trigger image capture







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Goals: Offshore Bird/Bat Collision Detection

Improved sensitivity

Enhanced vision

Augmentation of On-Blade Impact Detection System

Impact Detection of Small Objects

Detection of low-energy impacts:
i) Multi-sensor "patch" approach for improved sensitivity and impact localization
ii) Machine-learning approach using sensor fusion to improve detection SNR

Enhanced Vision

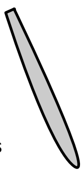
- On-blade IR/NIR cameras
- Nighttime impact images
- Vis-NIR stereovision

Long-term deployment

- Kinetic energy harvesting
- Wire-free sensor patch install

Multi-vehicle Deployment Plan

On-Blade Impact & Image



- Distributed vibration sensing
- Remote access of impact alerts

On-Nacelle Vision & Data

- 360º camera footage & IR reference
- Broadband microphone integration
- Wireless contact point
- Local sensor signal machine learning

- Targeted impact detection of small mass objects
- Multi-camera on-blade imaging for offshore applications
  - Dual visible light imagers at near/far focal lengths for improved imaging of small objects
  - Investigation of on-blade lo-res and hi-res NIR and IR imagers for nighttime image capture
- Automated impact detection, image capture

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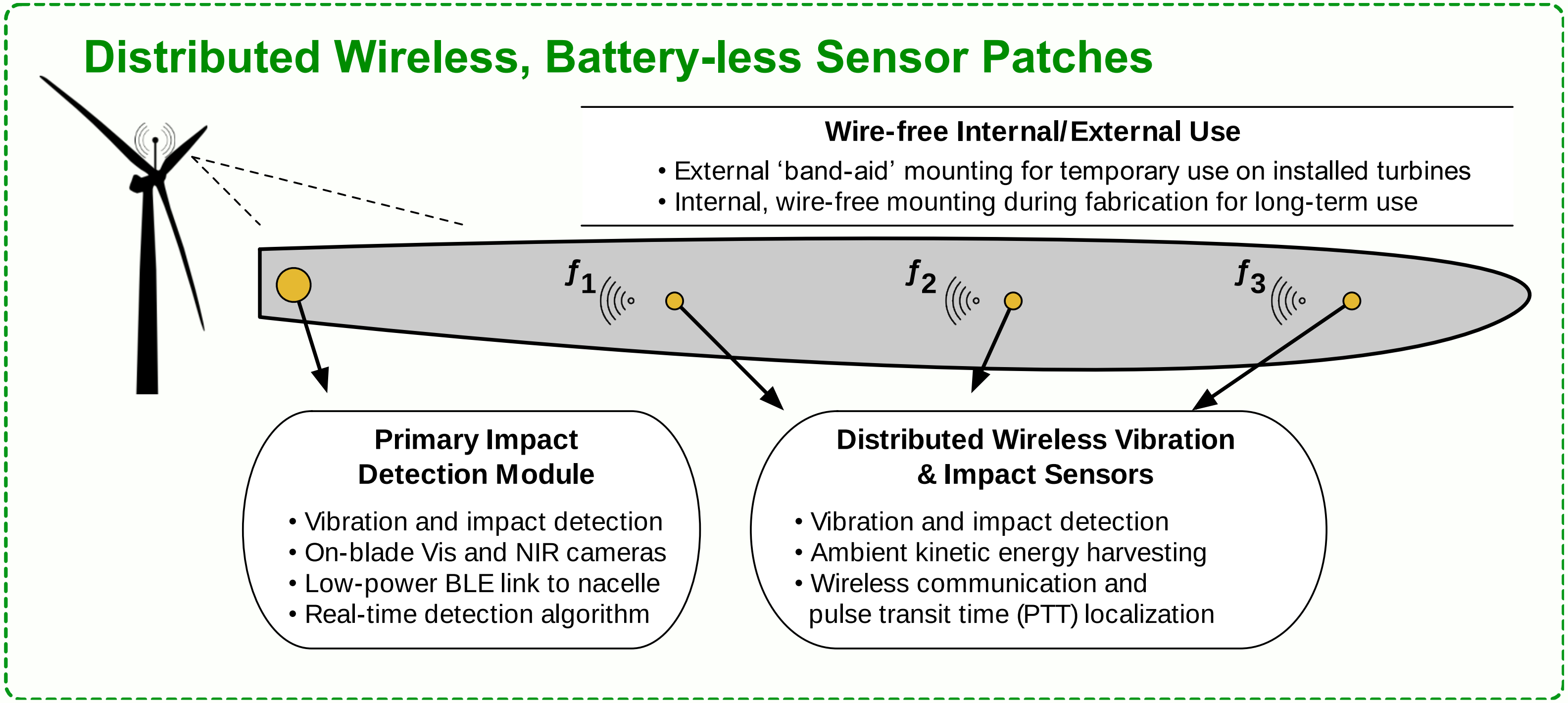
Goals: Offshore Bird/Bat Collision Detection



- Distributed vibration/impact detection using networked sensor nodes
- Targeted detection sensitivity of 10g-50g objects (bats & small birds) >90%
- Investigation of power and communication schemes for minimum size/volume

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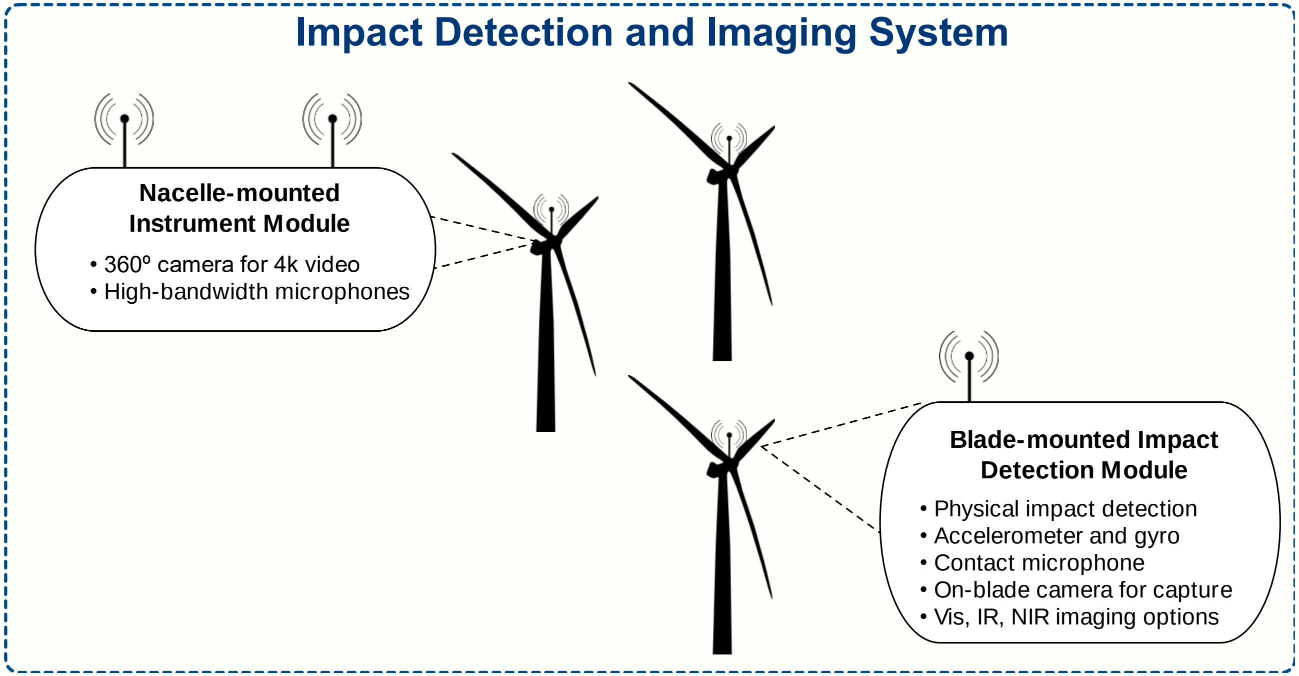
Technology Target Outcomes



- Development of multi-sensor impact detection using on-blade training data
- Validation of sensitive (~10g) collision detection using on-blade sensor network
- Determination of imaging parameters (FPS, pixel density, #) for full-blade coverage
- Integration of on-nacelle and on-blade sensor modules for deployed testing
- Demonstration of TRL 7 prototype up-turbine in Spring/Summer 2021

Development and Testing Timeline

- **Multi-camera root module** in development now, alongside Vis-NIR and IR imager characterization (e.g. pixel density, FPS); bench-top validation planned for Summer 2020.
- **Distributed impact sensor patch** in development now; bench-top validation planned for Summer 2020.
- **Field validation** using a ground-based turbine blade planned for Fall/Winter 2020 to demonstrate target sensitivity / specificity.
- **Future on-turbine testing** with NWTC for newly developed hardware and software planned for Spring/Summer 2021.
- **Future work** toward minimization of system size/cost/complexity for commercial feasibility and long-term validation in the field.

Acknowledgments

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- **Learn more: https://www.energy.gov/eere/wind/wind-energy-technologies-office**