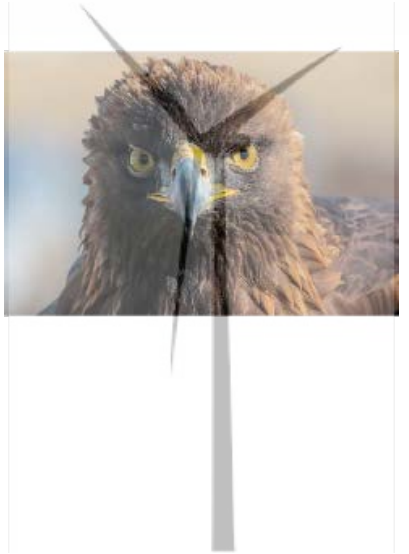
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

A Heterogeneous System for Eagle Detection, Deterrent, and Wildlife Collision Detection for Wind Turbines



Project ID # EE0007885

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Oregon State University

FY17-FY18 Wind Office Project Organization

"Enabling Wind Energy Options Nationwide"

Technology Development	Market Acceleration & Deployment
Atmosphere to Electrons	Stakeholder Engagement, Workforce Development, and Human Use Considerations
Offshore Wind	Environmental Research
Distributed Wind	Grid Integration
Testing Infrastructure	Regulatory and Siting
Standards Support and International Engagement	
Advanced Components, Reliability, and Manufacturing	

Analysis and Modeling (cross-cutting)

Project Overview

A Heterogeneous System for Eagle Detection, Deterrent, and Wildlife Collision Detection for Wind Turbines

Technology Summary: Automated system for visual detection of eagles, kinetic eagle deterrent, and wind turbine blade collision detection using a wireless network of intelligent sensors.

Period of Performance: April 2017 – July 2020

Technology Impact: Primary proposed project outcome is an intelligent and robust eagle impact minimization technology necessary for validation, certification, and site permitting of wind turbine installations.

Project Goals:

- Detection of eagles flying in proximity of wind turbines, including flight trajectory prediction
- Eagle deterrence using ground-based kinetic visual deterrents
- Automatic blade collision detection for continuous monitoring

Partners:

- Todd Katzner, US Geological Survey
- Manuela Huso, US Geological Survey
- Robert Suryan, Hatfield Marine Sciences Center, Oregon State University
- Northwest Wind Technology Center, National Renewable Energy Laboratory
- North American Wind Research and Training Center, Mesalands Community College

Technical Merit and Relevance

- **Project address three primary needs for impact minimization of wind energy on golden eagles and other bird/bat species:**
  - **Eagle Detection**, using turbine-mounted visual system and automated machine learning algorithm
  - **Eagle Deterrent,** using ground-based kinetic humanoid 'air dancers' with automatic triggering
  - **Collision Detection**, using on-blade multi-sensor module and integrated camera for object identification following turbine blade strikes
- **Enabled by advances in machine learning and low-power sensors**
- **Tested on-site at National Wind Technology Center, Boulder, CO**

An effective detect and deter system, coupled with an automatic monitoring and certification system, will reduce negative impacts of wind turbine installations to support continued growth of wind energy through improved siting and monitoring.

Approach and Methodology

Visual Recognition, Kinetic Deterrent, and Impact Detection.

On-Blade Impact Detection and Image Capture for Blade Strikes

Blade Vibration Node

Blade Optical Node
Wireless Micro Camera

Eagle Detection

Automated Visual Eagle Detection using Machine Learning and 360º Camera

Central Processing

Remote Transmission of "Event" Data

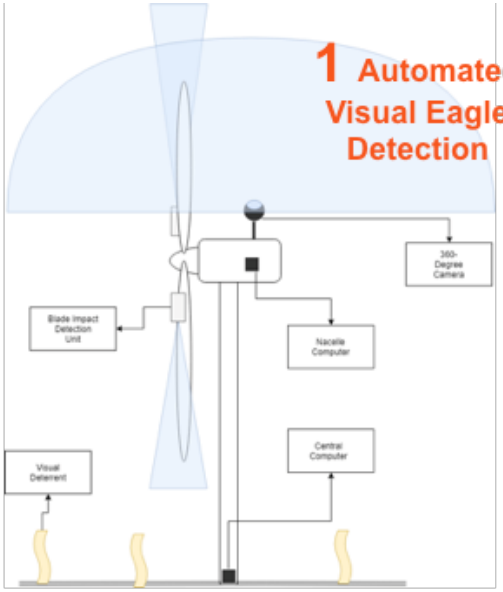
Eagle Deterrent

Eagle Deterrent using Automatically Triggered Kinetic Deterrent

1 Automated Visual Eagle Detection

3 On-Blade Event Detection and Image Capture

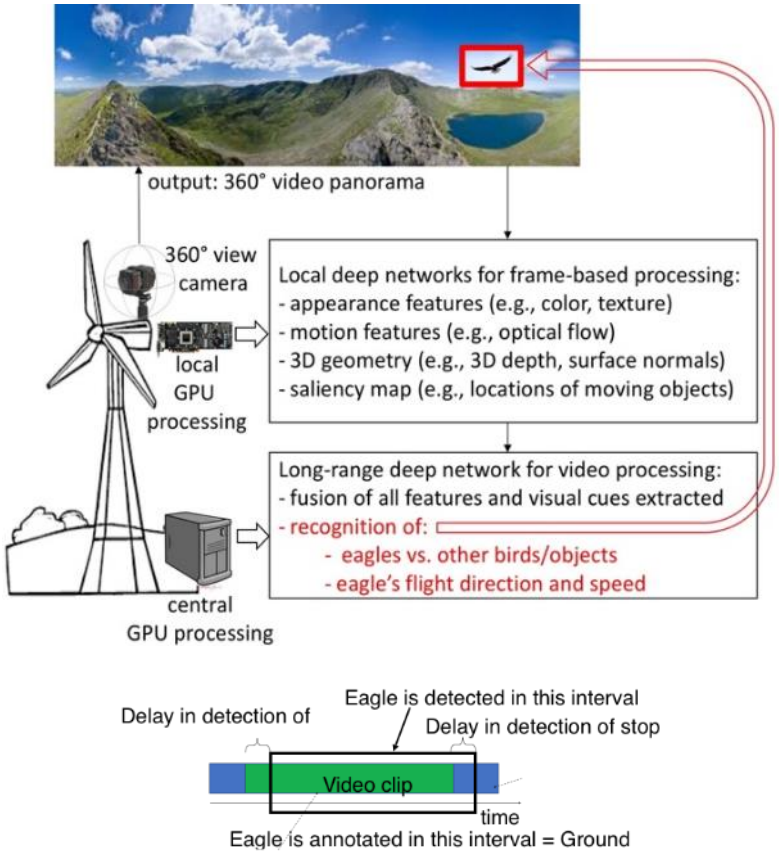
2 Eagle Deterrent using Anthropomorphic Kinetic Figure



Accomplishments and Progress

Visual Eagle Detection

System Overview:



Progress to date:

- 44 videos collected at the High Desert Museum (Bend, OR) of golden eagles and other raptors on trained flights (9/2017 and 6/2018)
- Videos used to train and test deep neural network machine learning algorithm for automated recognition of eagle vs. non-eagle

360° Image from Nacelle

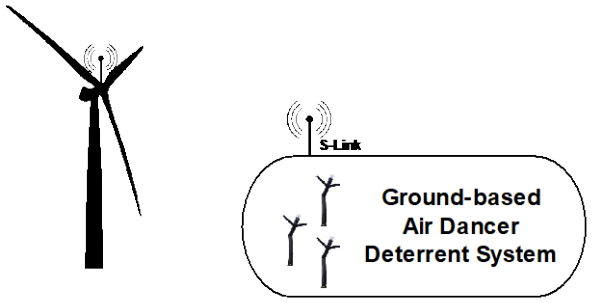
High Desert Museum, Bend, OR

Completed Milestones: 1.31, 1.36, 1.59, 1.69, 1.79, 1.89

Accomplishments and Progress

Kinetic Eagle Deterrent

System Overview:



- Moving 'scarecrow'
- Kinetic 'air dancer' device mimics large-scale humanoid movement
- Remotely triggered following automated visual detection
- Automated, infrequent usage my mitigate habituation

Progress to date:

- Testing kinetic deterrent under varying wind conditions and accelerated aging
- Adapted deterrent for remote wired and wireless triggering follow detection
- Deployed for field testing with wild eagles (1/2018) near Worden, Oregon.

Deterrent at base of 1.5MW turbine (Boulder, CO)

High-wind feasibility testing

Completed Milestones: 2.29, 2.79, 2.89

Accomplishments and Progress

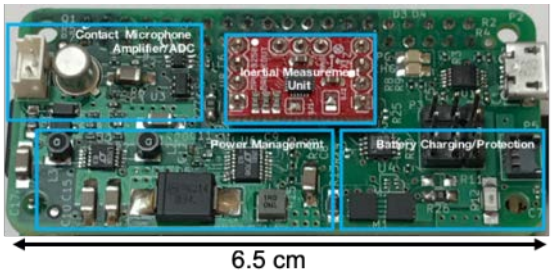
Turbine Blade Collision Detection

System Overview:

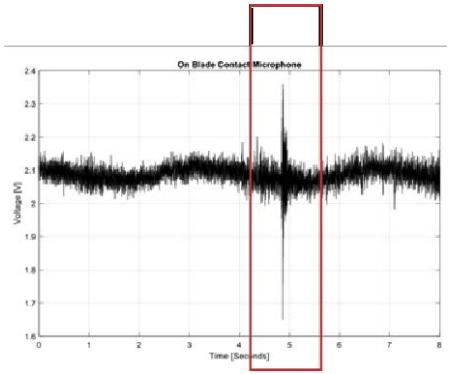
- On-blade low-power sensor module
- Vibration detection, accelerometer, and down-blade camera
- Automated impact detection and image capture
- Enables (offline) identification of impacting objects

Progress to date:

- Design and fabrication of multi-sensor module for on-blade impact detection and image capture (10/2017).
- Validation of sensors, impact detection, and wireless communication (1/2018).
- Deployed for integrated system (10/2018).



Custom sensor electronics module



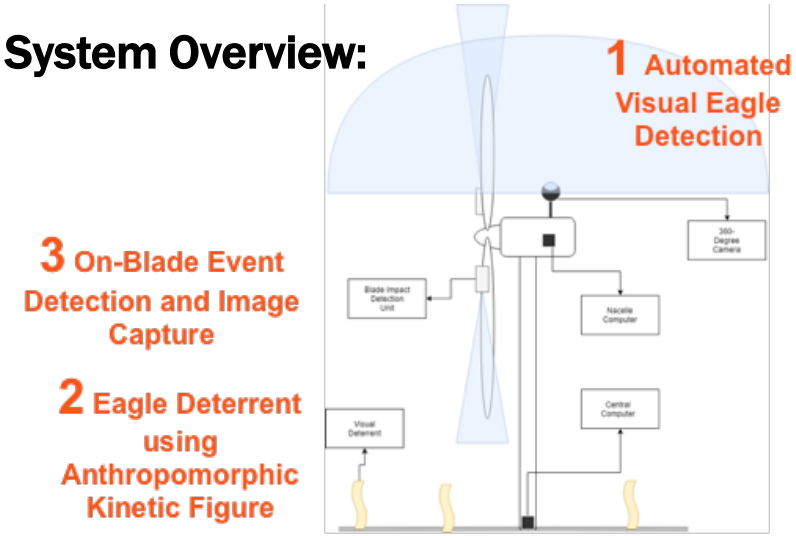
On-blade impact detection

Completed Milestones: 3.29, 3.59, 4.59

Accomplishments and Progress

Integrated System Testing

System Overview:

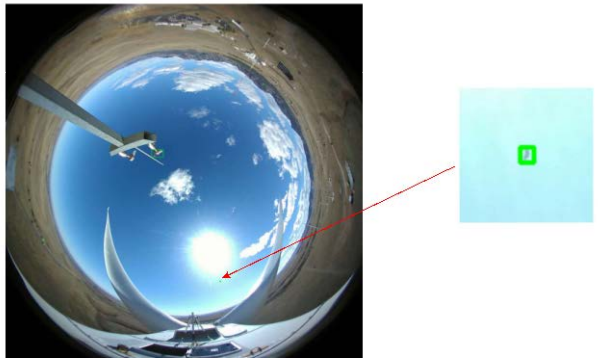


Progress to date:

- Full system validation and testing on 1.5MW GE wind turbine at NREL's National Wind Technology Center, Boulder, CO (10/2018)
- Validated wireless integration of sensors and systems, functional impact detection, and remote deterrent triggering
- Drone flights for testing of visual system; validated motion detection

Image capture of impacting object

Deterrent at base of turbine



Automated motion detection of drone

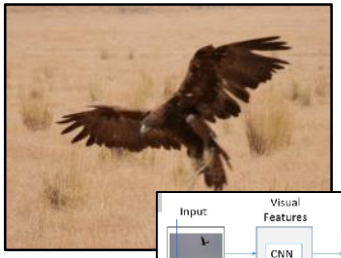
Completed Milestones: 4.19, 4.59, 4.79, 5.29

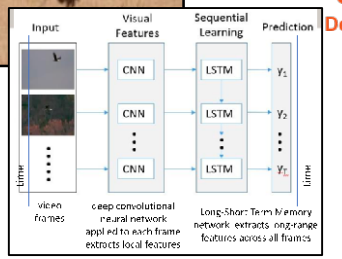
Accomplishments and Progress

Visual Timeline:

FY17 FY18

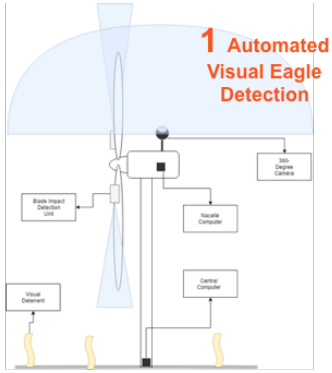
Q2 Q3 Q4 Q1 Q2 Q3 Q4

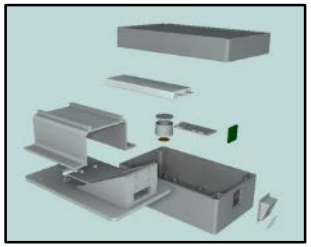


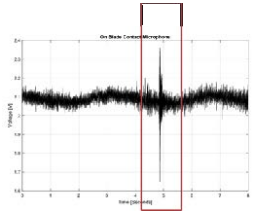


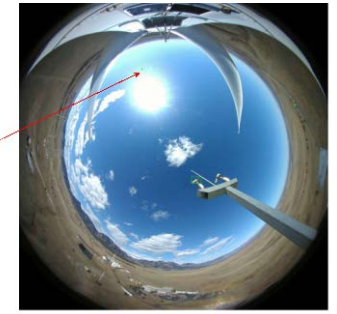
3 On-Blade Event Detection and Image Capture

2 Eagle Deterrent using Anthropomorphic Kinetic Figure



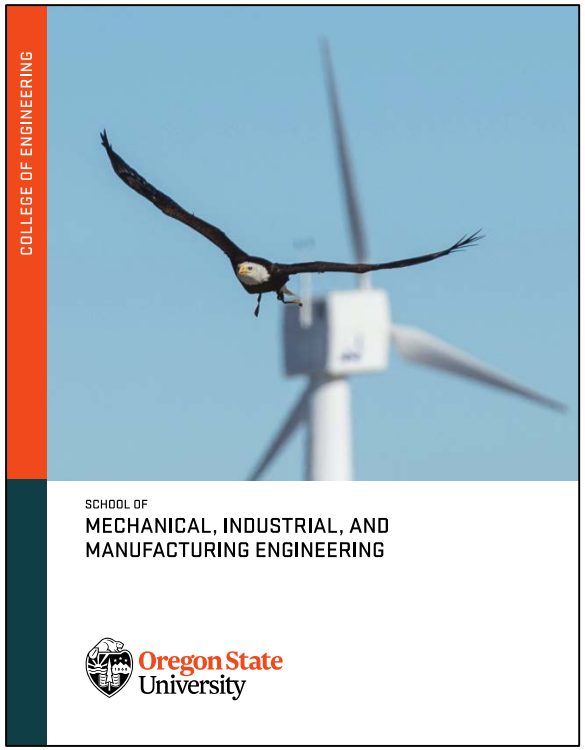






Communication, Coordination, and Commercialization

- Presentation at Wind Wildlife Research Meeting XII (November, 2018)
- OSU School of Mechanical, Industrial and Manufacturing brochure cover
- Two presentations at Audubon Society local chapters
- Patent application 62/792,319 "WIND TURBINE BLADE IMPACT DETECTION AND ANALYSIS"
- News coverage:
  - The Oregonian, OregonLive.com, AP
  - KGW8, KPTV



Upcoming Project Activities

- Additional full-system testing at North American Wind Research And Training Center (NAWRTC), Mesalands Community College, New Mexico in Spring 2019 (Milestone 5.30)
- Final full-system testing at NREL-NWTC, Boulder, CO in Summer 2019 (Milestone 5.49)