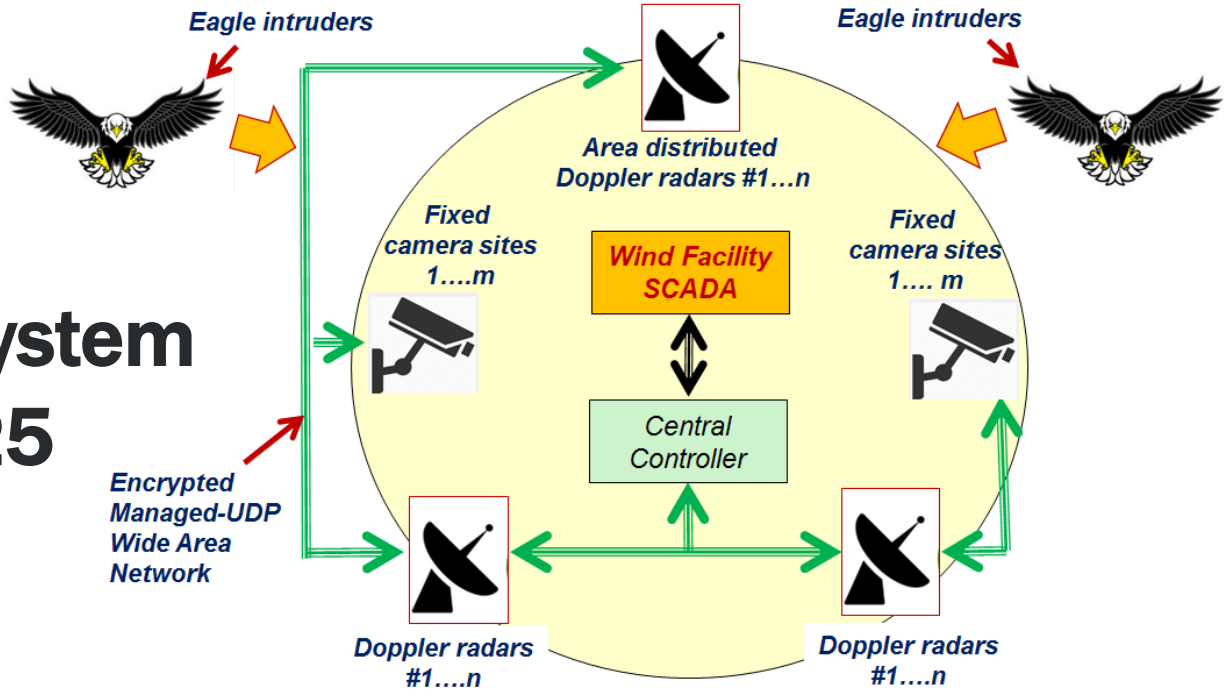
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Eagle Take Minimization System Project ID # M25

Raphael Tisch (on behalf of)

Laufer Wind Group, LLC



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

M25: Eagle Take Minimization System

Technology Summary:

Laufer Wind (LW) has developed a prototype Eagle Take Minimization System that shows capabilities for autonomously detecting, tracking, and visually identifying eagles and other protected birds out to approximately 1 km range with no human-in-the-loop. The SCADA-connected system would then trigger curtailment or activate a deterrent system.

Period of Performance:

June 2017 – Dec. 2018 (**project terminated by Awardee, effective March 8, 2018**)

Technology Impact:

This technology would advance the state of the art for detecting and responding to eagles at wind farms from human observers, to an automated, always-on, cost savings solution to to help wind developers, and owner/operators reduce risks to eagles, and support compliances with federal regulations protecting eagles.

Project Goals:

To develop a networked system comprised of a sensor-fused commercial-off-the-shelf (COTS) X-band radar (to detect far-field objects), a Pan-Tilt-Zoom (PZT) visible-spectrum camera (to identify the object), and a central controller computer to process the radar and visual data and interface with a wind facility Supervisory Control and Data Acquisition (SCADA), to inform turbine curtailment, or to trigger a deterrent if an eagle is within a high-risk proximity to an operating wind turbine.

Partners:

National Renewable Energy Laboratory

Technical Merit and Relevance

- The Bald and Golden Eagle Protection Act (BEGPA), and the Migratory Bird Treaty Act (MBTA) are regulatory mechanisms that protect golden and bald eagles in the United States.
- Current best practices for compliance involves humans-in-the-loop ("biomonitors") stationed at wind facilities for eagle identification and triggering curtailment, which comes at a substantial annual cost to the operator.

Photo: Duke Energy

Technical Merit and Relevance

- Based on proven commercial off the shelf components, and machine learning tools
- Potential to vastly reduce the cost of mitigation, in increase efficiency
- Real-time, automated, direct interface with the turbine SCADA to curtail operations based on eagle provides a significant innovation over state of the art

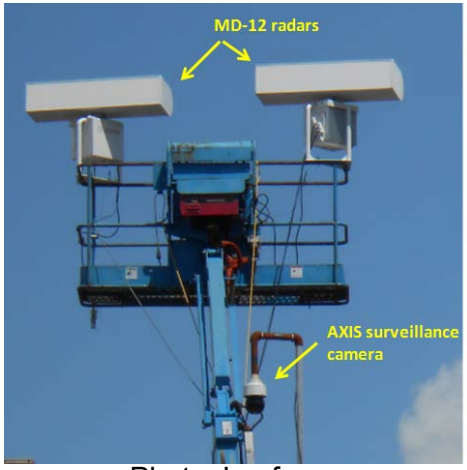


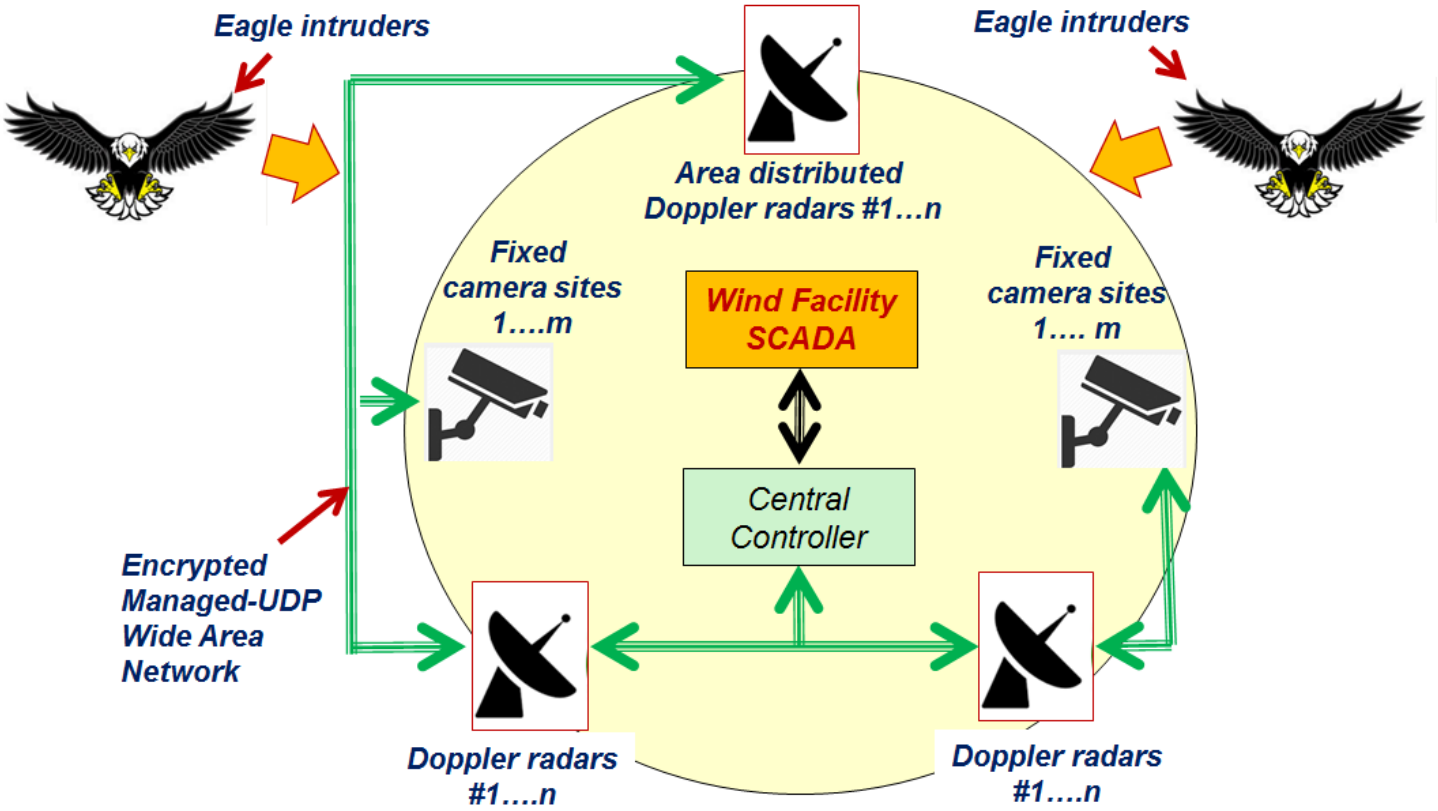
Photo: Laufer


Photo: Nathan Rolls/Audubon


Photo: Laufer

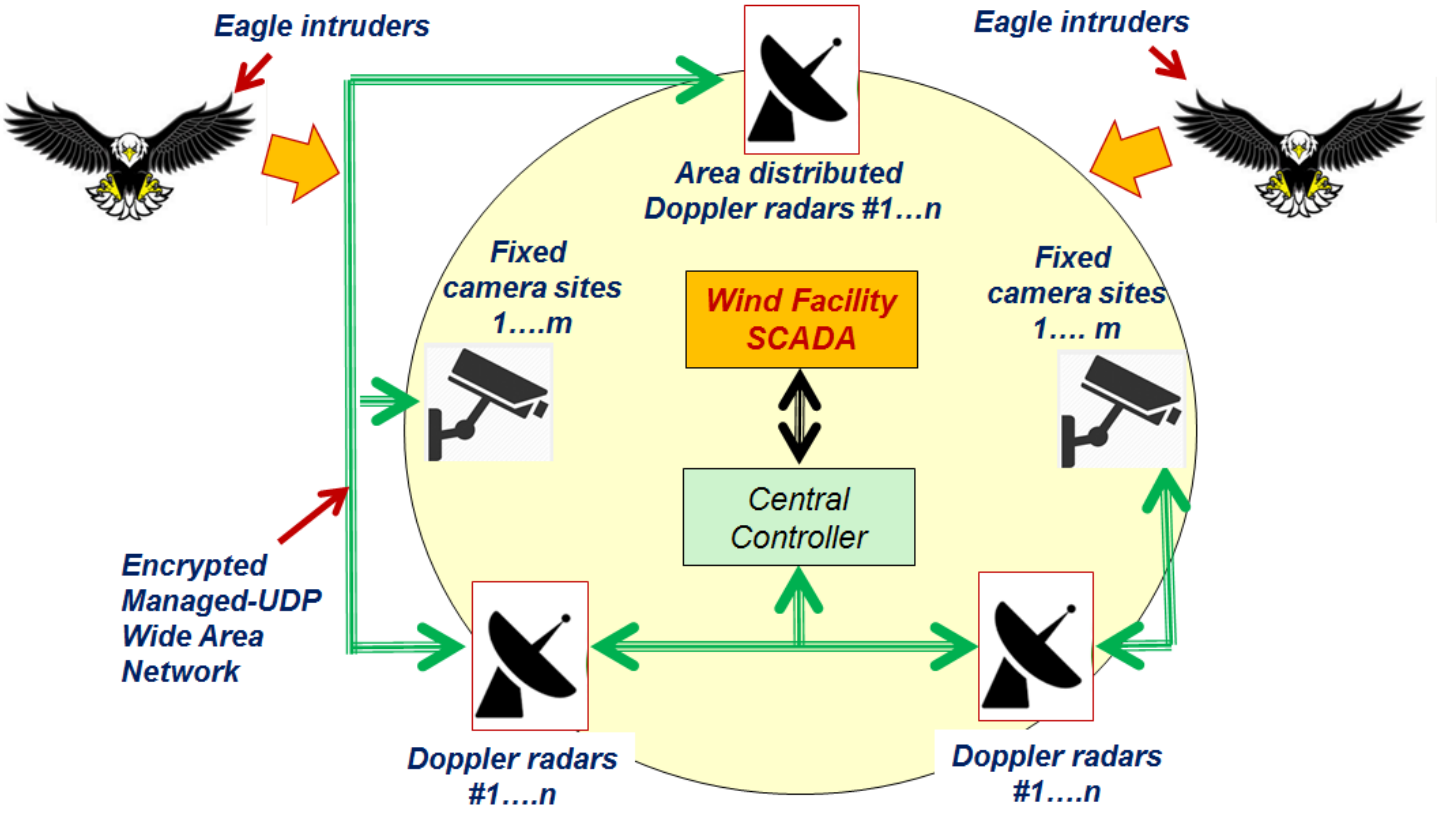
Approach and Methodology

- The system is comprised of two levels of sensor networks (radars and cameras), which are combined with a central controller computer that uses powerful machine learning algorithms to identify avian species, and wind farm SCADA interfacing.



Approach and Methodology

- Evaluate system needs -> Select compliant hardware components
- Construct and Train System -> Test system at NREL



Accomplishments and Progress

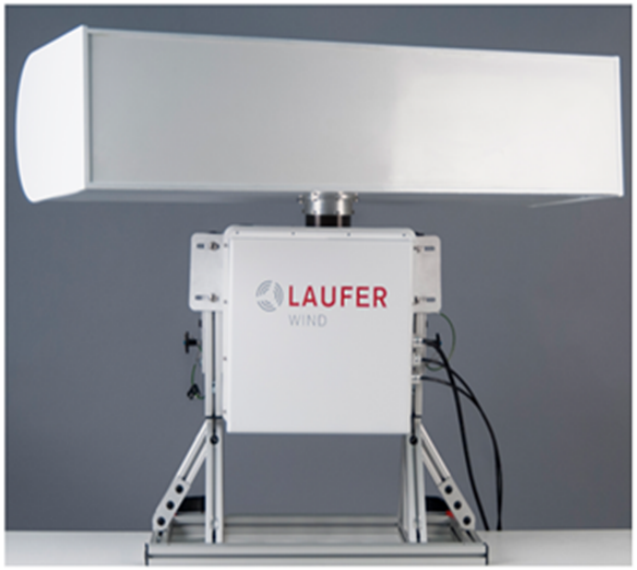


Photo: Laufer

- Detection range: > 12 km for 1 sq-m RCS (all weather)
- Tracking: > 30 simultaneous aircraft
- Frequency: X-band, 9.41 GHz
- Peak rf power: 12 kW
- Average rf power: 12 W
- Rotating antenna: 20 rpm
- Radar package size: ~ 15 in x15 in x20 in
- Antenna package: 12 in x 12 in x 48 in
- Beam pattern: 2 by 11 degrees
- Radar weight: 103 lbs with antenna
- Power: 115/230VAC, 50/60Hz, 200W
- Temp range: -40 degC to + 55 degC
- Environmental: IP56
- Safety: ETL and CE approved
- EMC: FCC approved
- Reliability: > 6.5 years (MTBR)

Photo: Laufer

Task 2 - Laufer wind purchased a commercial MD-12 pulsed Doppler X-band radar (previously tested at NREL in 2016), and the Axis Q6115-E 2

Accomplishments and Progress

Task 3 - Radar Tuning for Eagle Detection

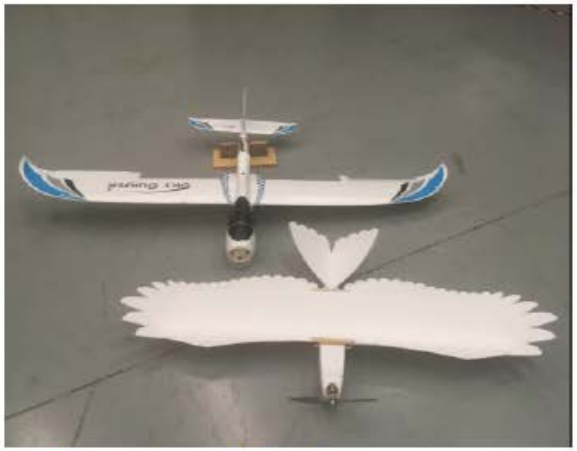
Targets in the image below are 500 meters down range. The radar filters for tracking birds include reducing minimum target velocity to 5 m/sec and reducing STC (sensitivity time control) to 50 meters.

Two examples of MD-12 radar tracking small birds near Bedford NH. Nominal range is 500 meters.

Accomplishments and Progress

Task 3 - Development and testing of UAV Target Surrogates & Radar Cross Section Measurement Tests

Critical to evaluate the radar and optical trackers



Operational Eagle surrogate drones at Bedford NH

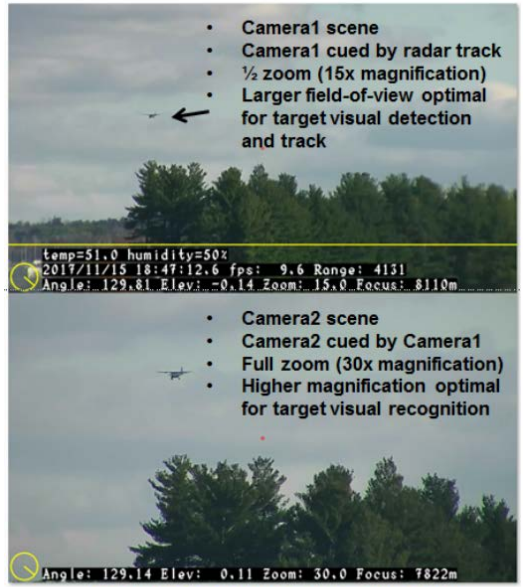
Automated Landing in Bedford ~ 7m Precision

Planned Eagle Paint Scheme

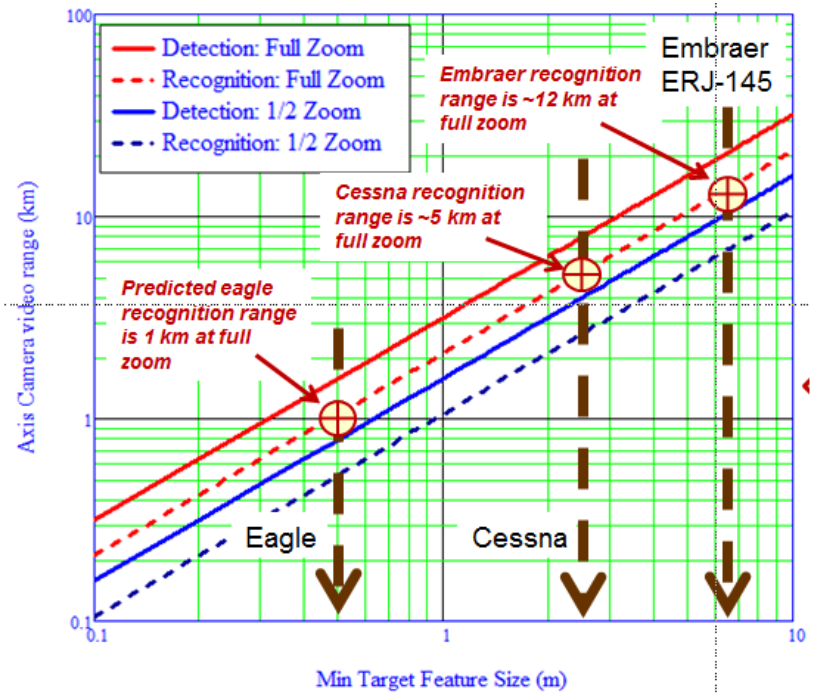
Photographs of surrogate-eagle drone targets being flown and tested at Bedford, NH.

Accomplishments and Progress

Curing Response too slow: added 2nd camera (15x zoom) for course tracking. 1st Camera (30x zoom) for target recognition and identification.



Example of autonomous, real-time radar and camera tracking scene



Task 4 - Fixed Cameral Optical Tracking Axis Camera video detection and resolution ranges (in km) versus minimum target feature size (in meters) for eagles (0.5 m min feature size), and Cessna (2.5 m min size) and Embraer ERJ-145 (6.5 m min size) aircraft for clear weather and Pd = 0.9 and Pfa = 1 e-5. The predicted eagle recognition range for the camera system is 1 km at full zoom.

Accomplishments and Progress

Task 5 - Eagle Image Recognition and Classification - Laufer Wind used open-source Caffe Recognition Software to recognize and identify targets.

Software integration of the Caffe model was successful, and LW uccessfully worked at retraining the classifier to recognize birds.

Accomplishments and Progress

- **Project Terminated by Awardee, Effective March 2018**
- Milestones 1 – 6 were completed or underway and on task at time of project termination.
- Laufer did not complete the following activities:
  - Eagle Take system (tracking and identification) lab testing at the National Renewable Energy Laboratory's (NREL) National Wind Technology Center (NWTC)
  - SCADA interface with NWTC turbine, and
  - Full demonstration at NWTC.

Cost Analysis:

175 MW wind farm, which would require 4 Radars, 4 Cameras, and 1 Central Controller - $850,000 - including hardware, software license, installation support (not including physical installation), regulatory support, commissioning, and training

Major Takeaways from Project Research

- A prototype shows capabilities for autonomously detecting, tracking, and visually identifying eagles and other protected birds out to approximately 1 km range without human intervention.
  - Drone Tracking Tests – Bedford, NH. Tracked UAV target 3km, successfully cued camera to target, and identified drone as an eagle

- The Central Controller was able to:
  - Fuse tracks from The MD-12 radar, and demonstrated ability to detect and track eagle-sized targets at ranges of greater than 3 km
  - Use tracks to cue Axis camera to targets, and classify and recognize eagle targets at 1 km range
  - Use OpenCV & BAIR Caffe to accurately identify eagle targets