U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

E15 - Passive Ultrasonic Deterrents to Reduce Bat Mortality in Wind Farms

Mitigate Market Barriers – Environmental Research

Anupam Sharma

Iowa State University

Aug 4, 2021

FY21 Peer Review - Project Overview

Project Summary:

- ***Challenge***: bat mortality at wind farms; *operational mitigation* (curtailment) is effective but reduces energy capture
- Transducer-based ultrasonic "jamming" devices proven in lab tests but suffer from short range (nacelle-mounted devices do not protect outboard blade regions)
- ***Our concept***: *aerodynamic whistle* -- blade-mounted, passive ultrasound generation using flow instability & resonance
  - Provide full blade rotor swept area coverage
  - multiple resonators for broad spectral coverage
- Optimize prototype with computational fluid dynamics & lab testing
- ISU developing this alone; some discussions with GE

Project Objective(s) 2019-2020:

- Design & test in the ISU anechoic chamber with pressurized air: demonstrate ultrasound generation in 20-50 kHz frequency range
- Develop preliminary concepts of a 'nozzle' to enable passive operation when mounted on rotor blades

Overall Project Objectives (life of project):

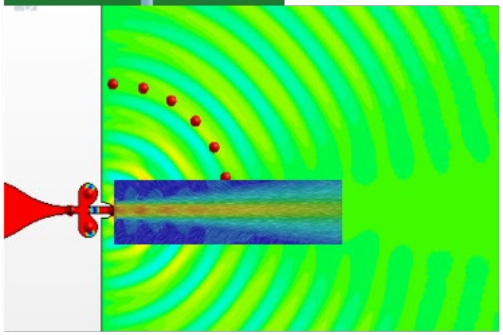
- Develop a passive, blade-mounted ultrasonic bat deterrent
- Characterize performance in anechoic chamber & wind tunnel

Project Start: Sep 2019
Expected Completion: Aug 2021
Period of Performance: 2 years

DOE Share: $160,000
Cost Share: $40,142
Total Project Budget: $200,142

Key Project Personnel: Anupam Sharma (PI), Zhangming Zeng (PhD student)

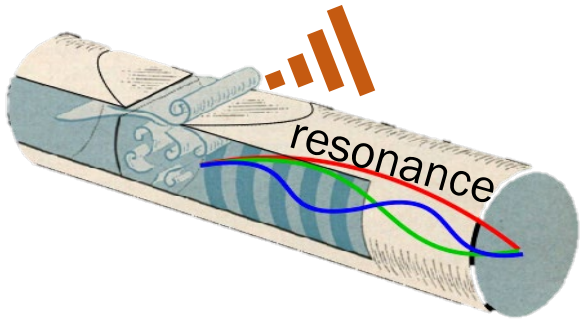
Key DOE Personnel: Jocelyn Brown-Saracino, Michael Carella, Raphael Tisch



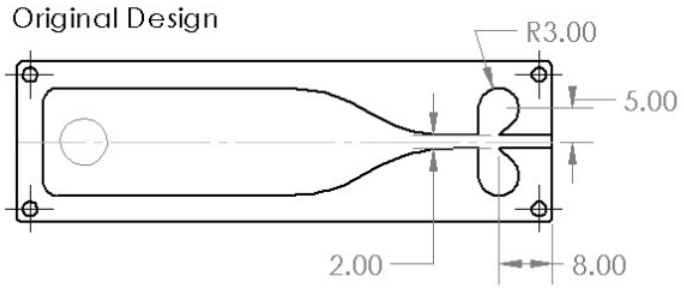
Project Impact

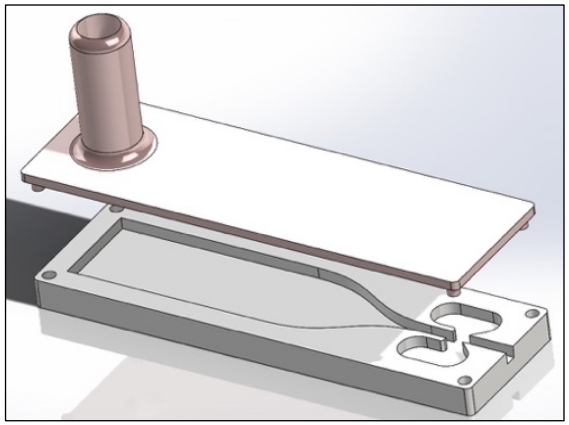
- Mitigate bat fatality → **wildlife preservation**

- ***Proposed technology***: passive, blade-mounted ultrasonic deterrent
  Core idea: aerodynamic whistle (resonance)



- **Advantages** over current state-of-the-art:
  - *Passive operation*:
    - Minimal change to turbine design … potential to install on existing fleet
    - Minimal reduction in energy capture:
      - no curtailment required
      - small profile → aero loss negligible
  - *Blade-mounted*:
    - Technology scales with rotor size … nacelle-mounted devices offer limited spatial coverage
    - Ultrasound localized around each blade – minimize ultrasound "pollution" / undesirable impact on wildlife





- Evaluate ultrasound generation capability & aero impact

Program Performance – Scope, Schedule, Execution

Scope/schedule

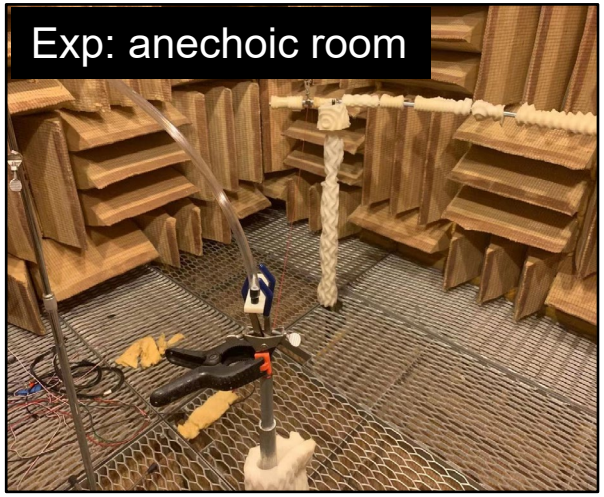
- ✔ Demonstrate capability to generate ultrasound using the whistle concept
- ✔ Optimize design for high-intensity ultrasound generation
- ✔ Verify passive operation numerically
- – Verify passive operation experimentally (ongoing)
- – Quantify adverse aero performance impact using section model tests (not started)
- – Requesting 1-year no-cost extension

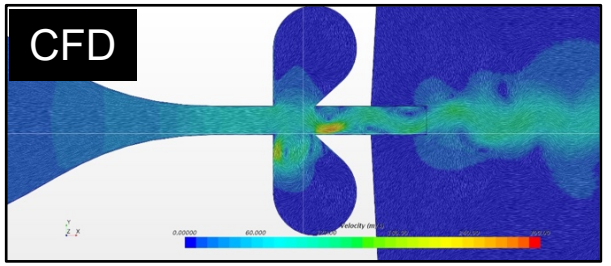
Execution: approach

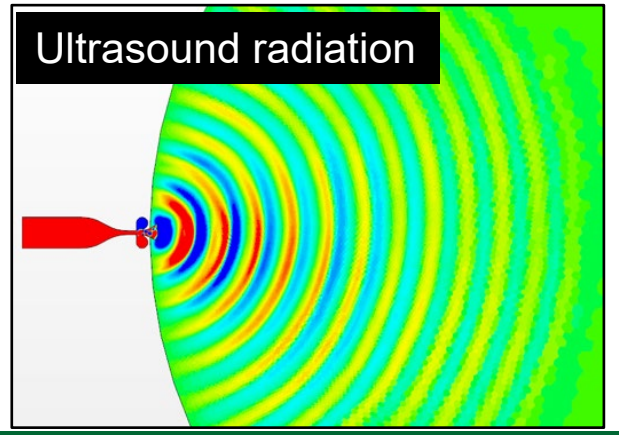
- – Adapt Galton's (dog) whistle
- – Working principle: fluid flow instability + resonance → high-intensity (ultra)sound
- – Mount on rotor blades with an inlet/diffuser assembly that guides flow into the whistle → passive operation

Execution: methods

- – *Experiments:* using pressurized air in anechoic chamber
- – *CFD simulations*: 2-D for design & optimization, 3D for analysis



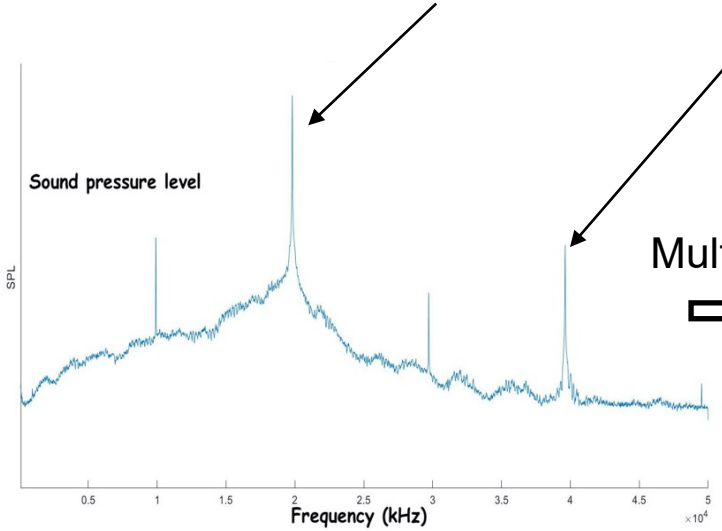




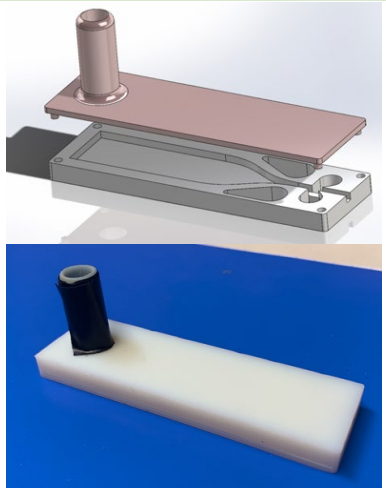
Program Performance – Accomplishments & Progress

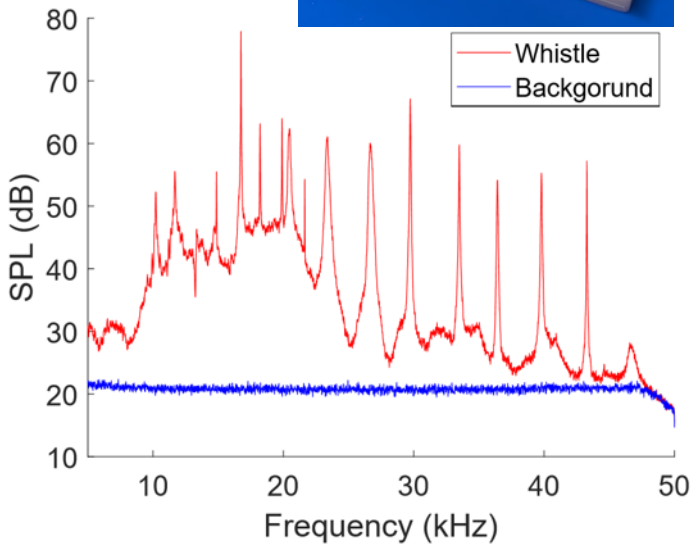
✓Demonstrated ultrasound generation

- Whistle designed, prototyped and tested
- 2-D CFD simulations:
  - enhance understanding of sound generation mechanism
  - optimize for high-intensity sound generation
- Testing in anechoic room with pressurized air
- One resonator: fundamental tone + harmonics



Multiple resonators



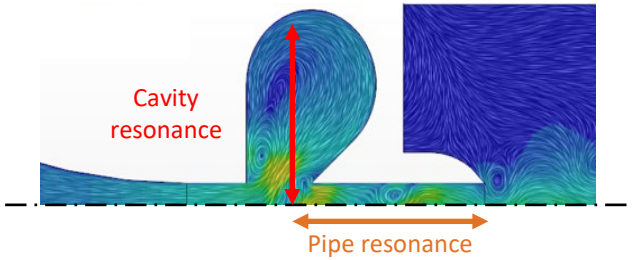


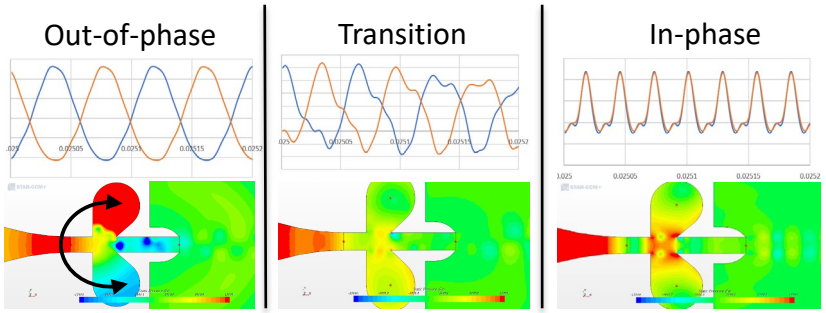
- Multiple resonators to cover 20-50 kHz range

Program Performance – Accomplishments & Progress

✓Identified sound generation mechanisms → optimization

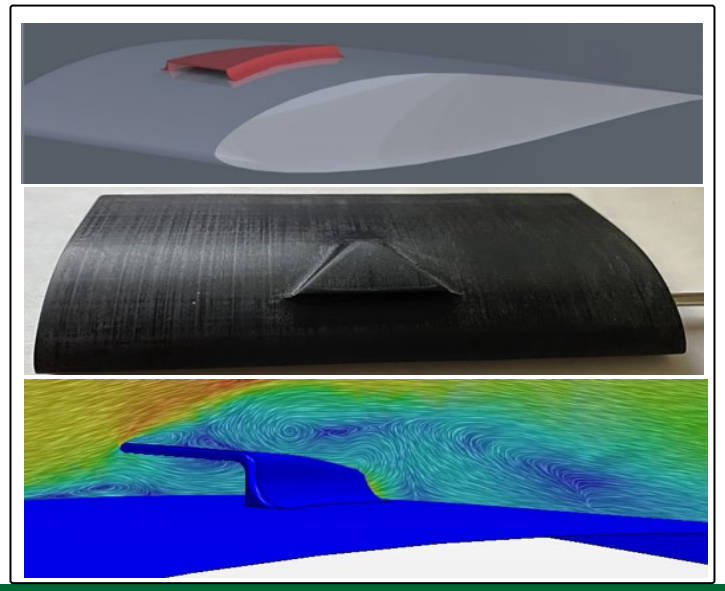
- Cavity resonance enhanced by pipe resonance
- Whistle operates in 3 modes:
  - out-of-phase (low pressure)
  - Transition (med pressure)
  - In-phase (high pressure)
- Enables design of cavity & pipe dimensions





✓Passive operation

- Initial designs of inlet/diffuser assembly
- Designed & prototyped
- Preliminary analysis and experiments
  - Negligible adverse impact on aerodynamic performance is expected (wind tunnel tests)
  - Computational fluid dynamics simulations consistent with experiments



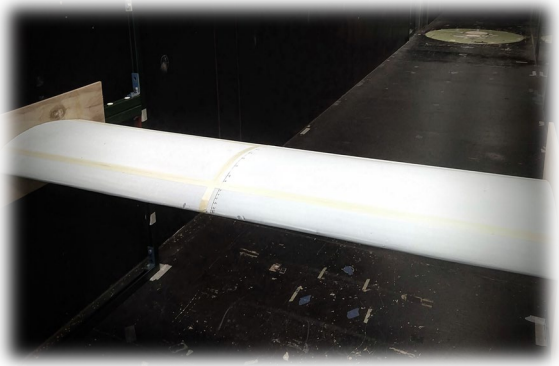
Project Performance - Upcoming Activities

1. Passive operation in lab

- Verify whistle performance mounted on a blade section in a wind tunnel
  - Test aerodynamics and acoustics
- Investigate multiple inflow conditions

2. Assess aero performance impact

- Wind tunnel tests with inlet assembly & whistle mounted
- Multiple flow conditions



3. **Publications** (in progress)

1. Z. Zeng and A. Sharma, “Experimental and numerical aeroacoustic analysis of an ultrasound whistle,” AIAA Aviation Meeting, August 2021
2. Z. Zeng and A. Sharma, “Blade-mounted ultrasound whistle to reduce bat mortality at windfarms,” AIAA Aviation Meeting, January 2022 (abstract submitted)

Stakeholder Engagement & Information Sharing

General Electric Company

- Had initial discussions with GE
- Our whistle can potentially be used in combination with the GE nozzles installed on towers

MidAmerican

- Has shown interest in the technology
- No plans yet of field-scale tests with MidAmerican yet

ENEL Green Power

- Discussions about potential collaboration for field testing

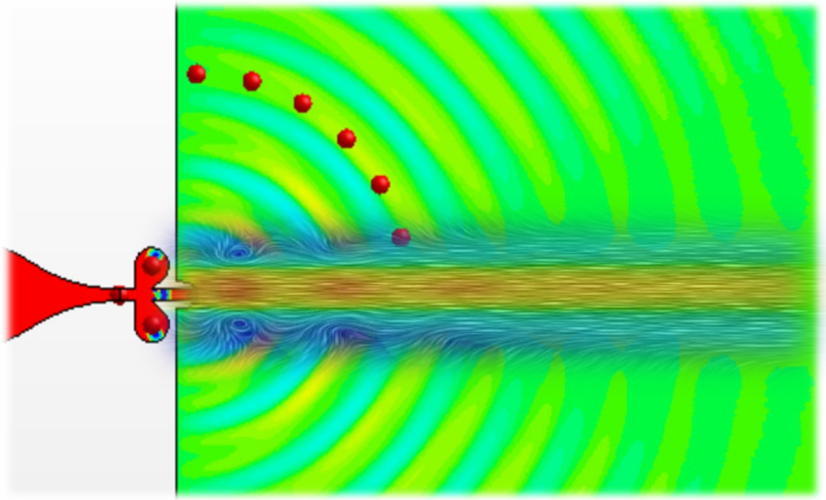
Conference Presentations

1. Z. Zeng and A. Sharma, “Experimental and numerical aeroacoustic analysis of an ultrasound whistle,” AIAA Aviation Meeting, August 2021
2. Z. Zeng and A. Sharma, “Blade-mounted ultrasound whistle to reduce bat mortality at windfarms,” AIAA Aviation Meeting, January 2022 (abstract submitted)

Key Takeaways and Closing Remarks

Project Impact:

- **Blade-mounted ultrasound whistle technology can reduce bat mortality**
- **Little-to-no aero penalty**



Project Performance:

- **Demonstrated ultrasound generation capability**
- **Identified sound generation mechanisms**
- **Passive operation nearly demonstrated**

Stakeholder Engagement:

- **Talks with GE & MidAmerican**
- **Conference papers / presentations**