

The background image shows several white wind turbines against a clear blue sky. The blades of the turbines are marked with red and white stripes. A large number of small, dark silhouettes of bats are scattered throughout the sky, appearing to fly around the turbines. The text is overlaid on this scene.

Whistling Like a Bat:

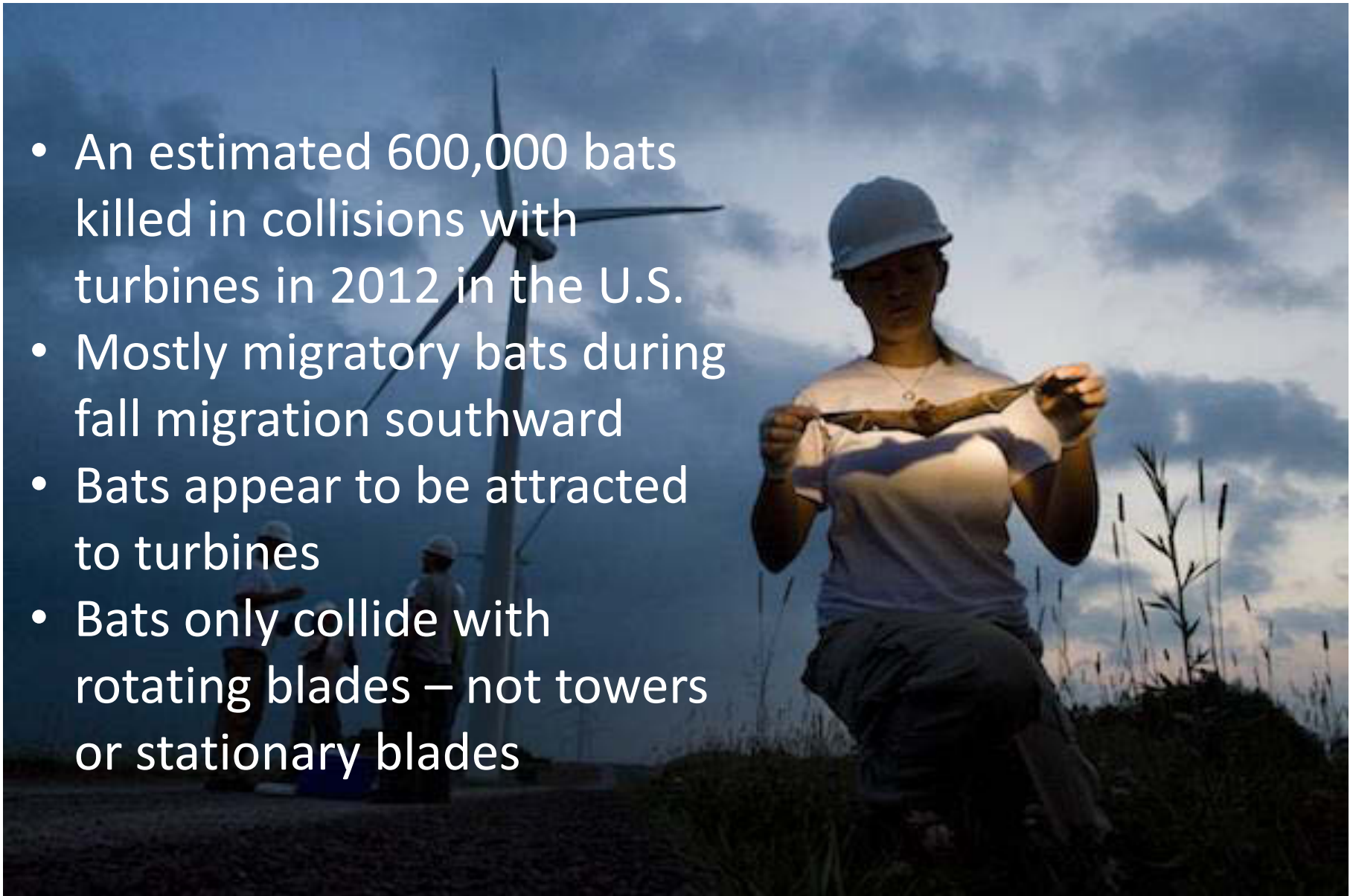
Development of an Ultrasonic Whistle to Deter Bats From Wind Turbines

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BAT MORTALITY AT WIND FACILITIES

- An estimated 600,000 bats killed in collisions with turbines in 2012 in the U.S.
- Mostly migratory bats during fall migration southward
- Bats appear to be attracted to turbines
- Bats only collide with rotating blades – not towers or stationary blades



Migratory Bats



Hoary Bat



Silver-haired Bat



Eastern Red Bat

ULTRASOUND AS DETERRENT



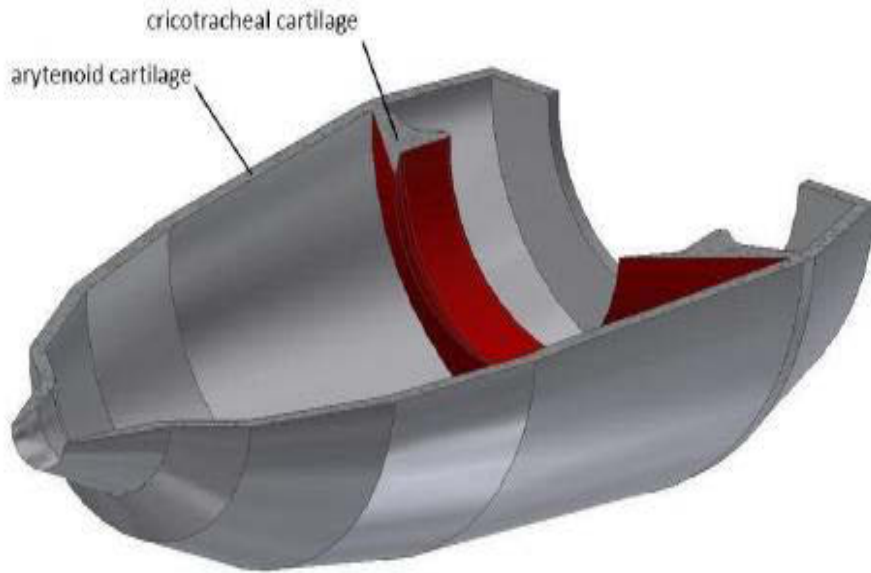
- Attenuates quickly in the atmosphere
- Birds and large mammals (including people!) can't hear it
- Bats avoid “noisy” environments when foraging
- Bats can learn to avoid toxic moths which emit ultrasonic warning clicks

CURRENT DETERRENT TECHNOLOGY



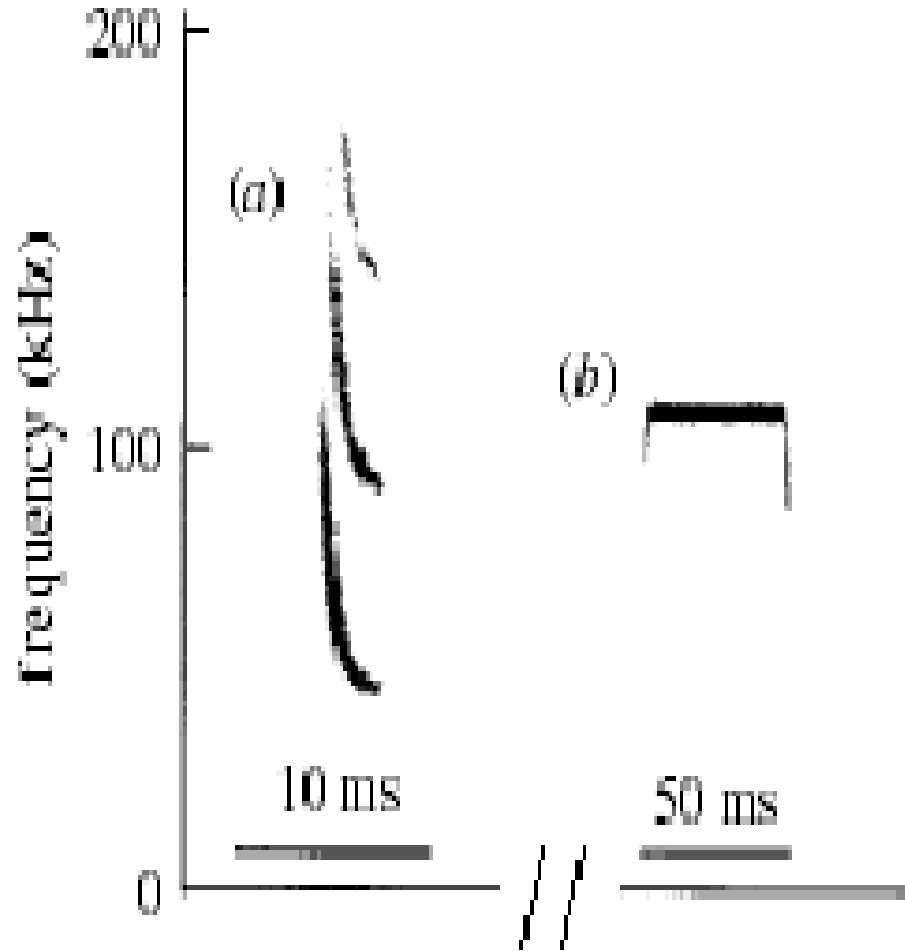
- Single tones do not appear to work (bats can alter call to avoid)
- Electrically-powered broadband ultrasonic noise generator
- 10-100 kHz range
- Success in lab trials and trials at foraging sites
- Not successful in reducing bat mortality when mounted on turbine nacelles

OUR PROPOSED SOLUTION



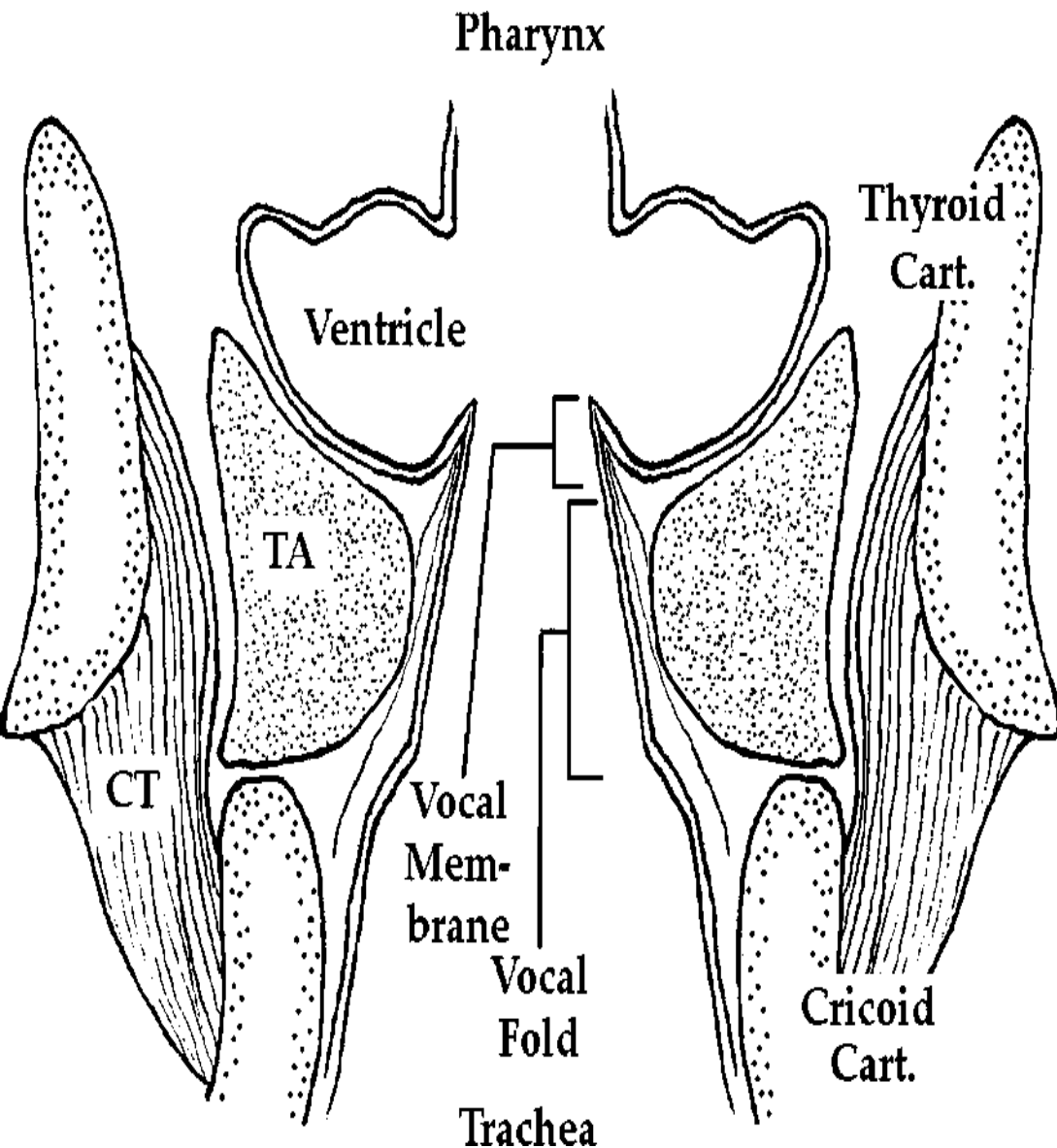
- Wind-blown whistles
- 25-55 kHz range
- Over wind speeds up to 6 m/s
- Blade speeds up to ~ 42 m/s
- Lower bound hard to predict
- Based on bat larynx, frequency-modulated

BAT ECHOLOCATION CALLS



- Frequency-modulated
- Constant frequency

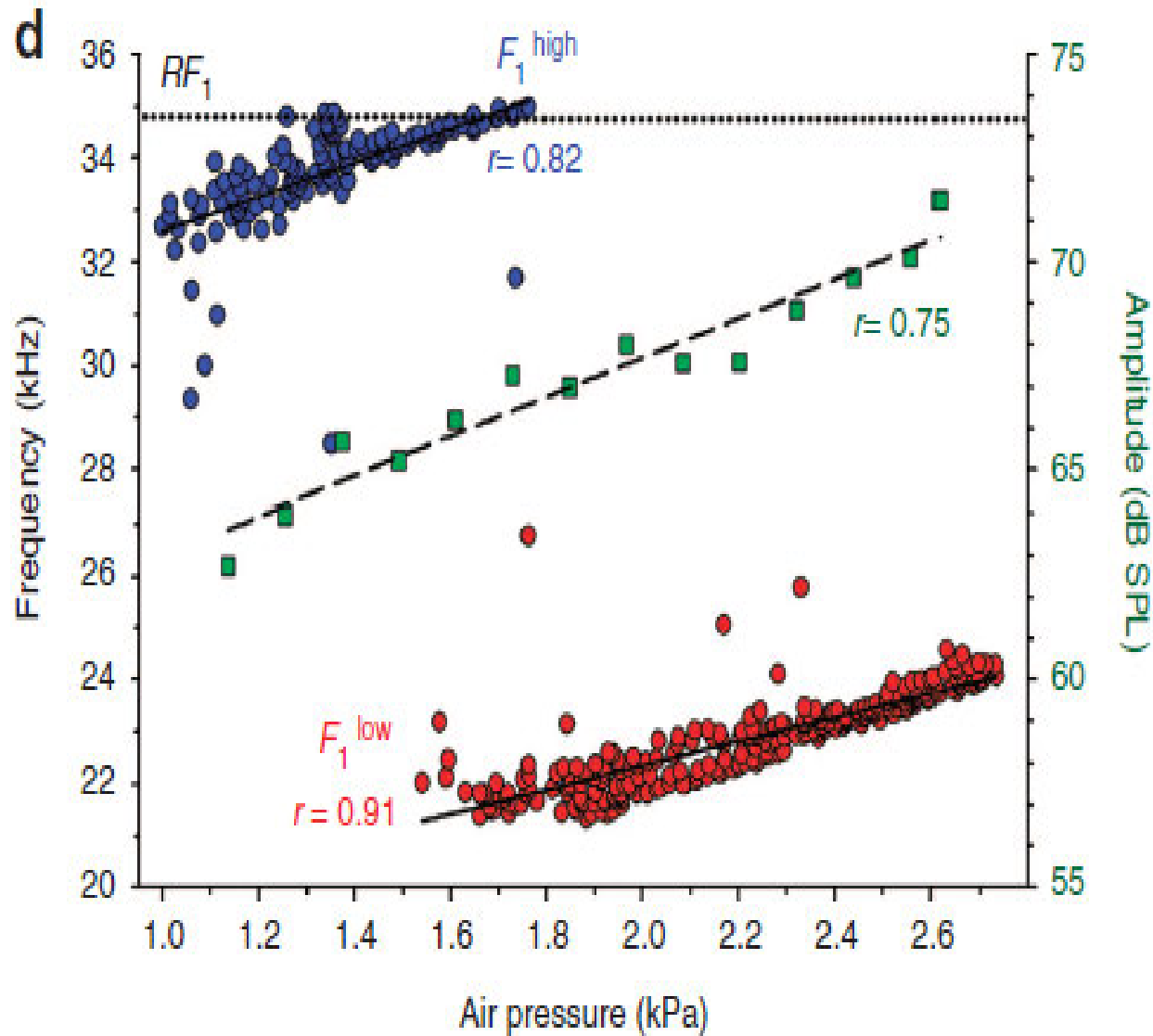
BAT LARYNX ANATOMY



Schematic coronal section through middle of larynx showing anatomy of the vocal membrane. The membrane projects upward (rostrally) from main body of vocal fold.

CT: Cricothyroid muscle.
TA: Thyroarytenoid (vocalis) muscle

EXCISED LARYNX VOCALIZATIONS





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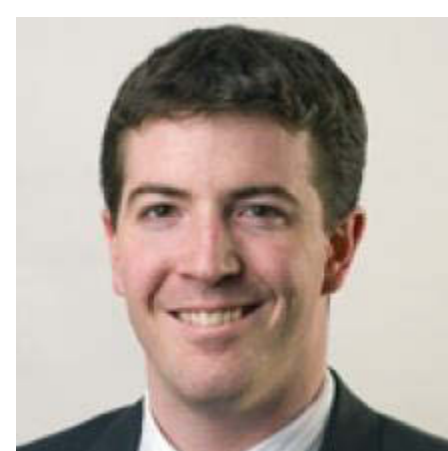
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Task 1: Characterize bat avoidance responses to ultrasound regimes

Task 2: Design initial biomimetic prototype

Task 3: Develop series of prototype whistles operating over range of frequencies

Task 4: Test prototype whistle series on bats in laboratory

Task 5: Test prototype whistles on wind turbine

Month	Task 1	Task 2	Task 3	Task 4	Task 5	
M1	Subtask 1.1	Subtask 2.1				
M2		Subtask 2.2				
M3		Subtask 2.3				
M4		Subtask 1.2				
M5						Subtask 2.4
M6						
M7	Subtask 1.3	Subtask 2.5				
M8						
M9	Subtask 1.4	Subtask 2.6				
M10						
M11						
M12						
M13			Subtask 3.1			
M14			Subtask 3.2			
M15			Subtask 3.3			
M16						
M17						
M18			Subtask 3.4			
M19						
M20			Task 4			
M21						
M22						
M23						
M24	Task 5					



Mexican Free-Tailed Bat

Task 1: Characterize bat avoidance responses to ultrasound regimes

- Capture wild bats
- Perform Y-maze selection trials
- Perform perch selection trials
- Evaluate free-flying bat trajectories



Tri-colored Bat



Little Brown Bat



Big Brown Bat



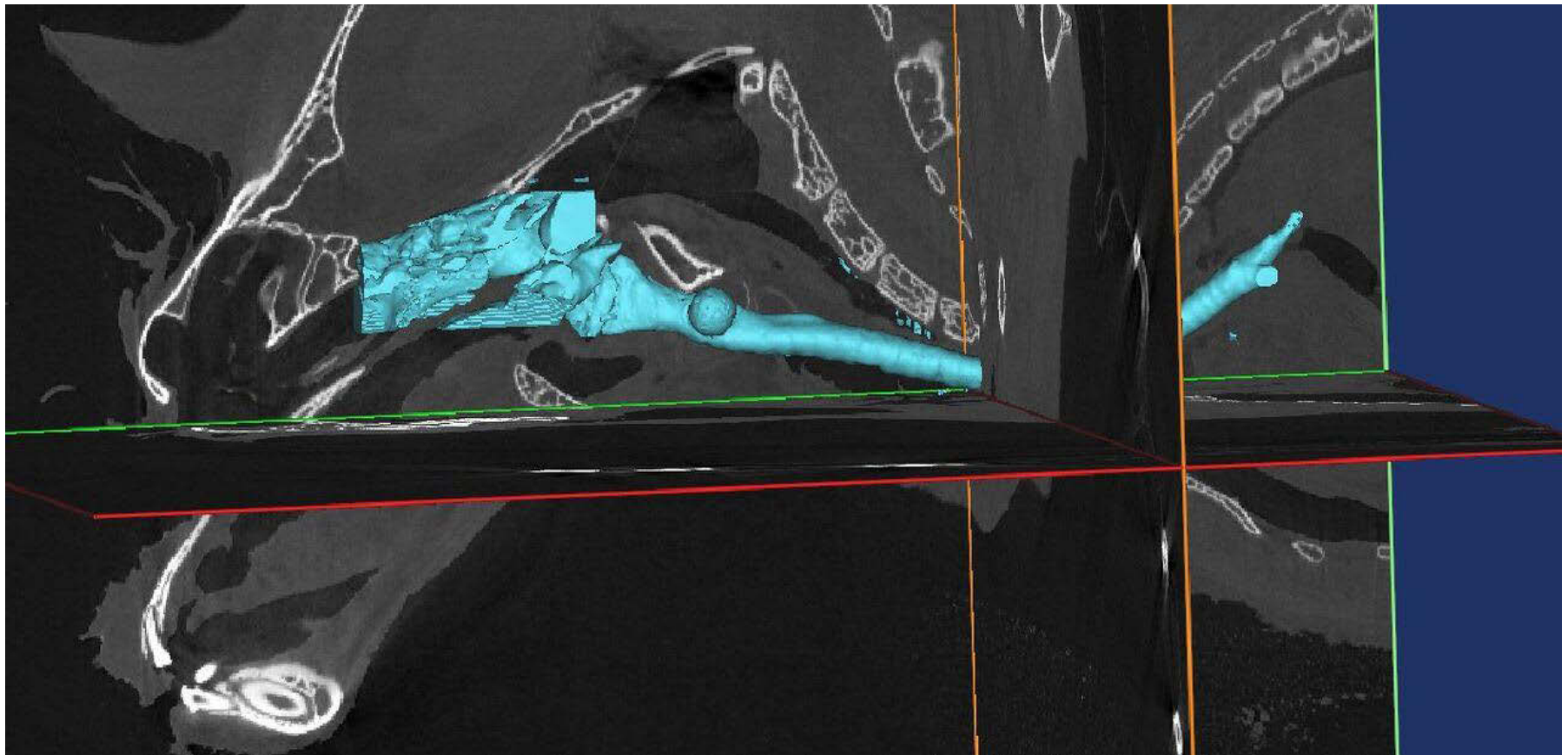
Task 2: Design initial biomimetic prototype

- Obtain candidate biological models
- Analyze candidate biological models
- Determine initial biological model through physical prototyping
- Increase sound power level of prototype
- Generate sound across range of wind speeds from prototype
- Generate frequency-modulated output from prototype



Task 3: Develop series of prototype whistles operating over range of frequencies

- Design a frequency-modulated whistle operating at $\sim 25\text{-}35$ kHz
- Design a frequency-modulated whistle operating at $\sim 35\text{-}45$ kHz
- Design a frequency-modulated whistle operating at $\sim 45\text{-}55$ kHz
- Recording of ultrasonic regimes produced by whistles operating in concert





Task 4: Test prototype whistle series on bats in laboratory



Tri-colored Bat

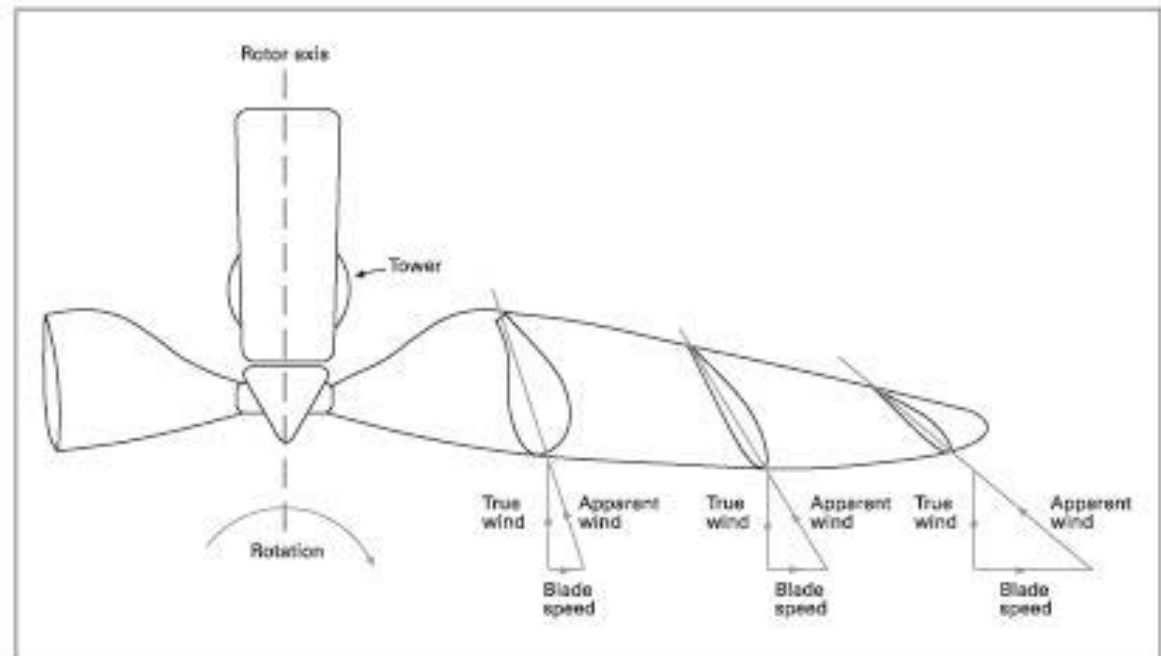


Little Brown Bat



Big Brown Bat

Task 5: Test prototype whistles on wind turbine



Blade twist

Future Directions: Test Effectiveness of Bat Whistles in the Field



Thank you!

