NOISE-CON 2025 Classic Paper
Competition Judging

Overview of I.J. Sharland's 1964 paper on

Sources of noise in axial flow fans

William Johnston

MADLab

Michigan Technological University
Mechanical and
Aerospace Engineering

About I.J. Sharland

Ian James Sharland

UNIVERSITY OF SOUTHAMPTON
B.S., Aeronautical Engineering (1960)

44 YEARS IN NOISE AND VIBRATION CONTROL
University research and private consultancy

OTHER WORKS
Hovercraft noise suppression (1965)
Intake noise from axial superchargers (1967)

UNIVERSITY OF Southampton
Institute of Sound and Vibration Research

Presentation Overview

Journal of Sound & Vibration

SOURCES OF NOISE IN AXIAL FLOW FANS

I. J. Sharland

Institute of Sound and Vibration Research,
University of Southampton, Hampshire, England

(*Received 5 December*, 1963)

The various possible mechanisms of noise generation in axial flow fans are described. Quantitative expressions have been derived for the sources of broad band noise by dimensional arguments, from which orders of magnitude estimates have been made. These have been found to give fair agreement with observed levels of broad band noise from an isolated plate under different flow conditions, and from a model fan. It is concluded that broad band noise in fans arises from vortex shedding at the blade trailing edges under normal conditions, but that any large-scale turbulence in the flow can increase the noise significantly.

Discrete noise from multi-stage fans has been found to arise from aerodynamic interaction between fixed and moving blades. The amplitude of this noise is strongly dependent on axial spacing between rows, and it appears that stator area may also be a significant parameter.

1. INTRODUCTION

Up to the time of the introduction of the turbo-jet engine on a commercial scale, the dominant source of aircraft noise, at least as far as external levels were concerned, was the propeller. This had been recognized for some time, and a considerable amount of theoretical and experimental work has been carried out on propeller noise with the result that quite accurate predictions can now be made of both the radiated noise and the near field pressures set up on adjacent structures by the propeller.

The jet engine introduced new noise problems and in the early stages the most important of these was the noise of the jet itself. It soon became apparent however that the noise of aircraft under approach conditions, when the levels of jet noise were known to be low, was causing as much annoyance as that under take-off conditions where the jet noise was dominant. A large part of this approach noise was subsequently identified with the engine compressor, which on modern aircraft is usually of a multi-stage axial flow type. If this noise is not to become an operational limitation there is need for a detailed knowledge of its origin to provide the understanding on which methods of suppression can be based.

1964

Key Topics

PAPER'S PURPOSE
Noise issues in 1964

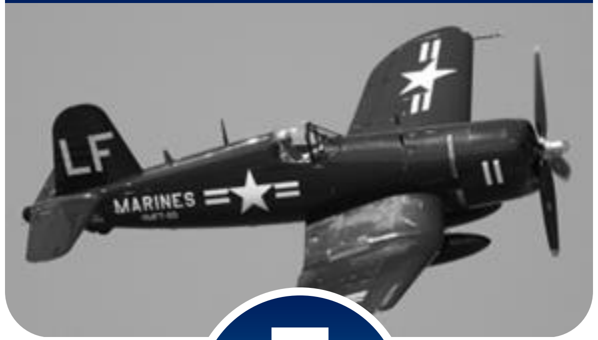
SUMMARY
Main thrust and findings

IMPACT
Influence on today's literature

MY WORK
Impact on "AeroFeathers"

Fan Noise: An Emerging Issue

World War II
Propeller Aircraft



Mid 20th Century
Turbojet Aircraft

Problem

Aircraft were still loud during landing despite quieter jet engines

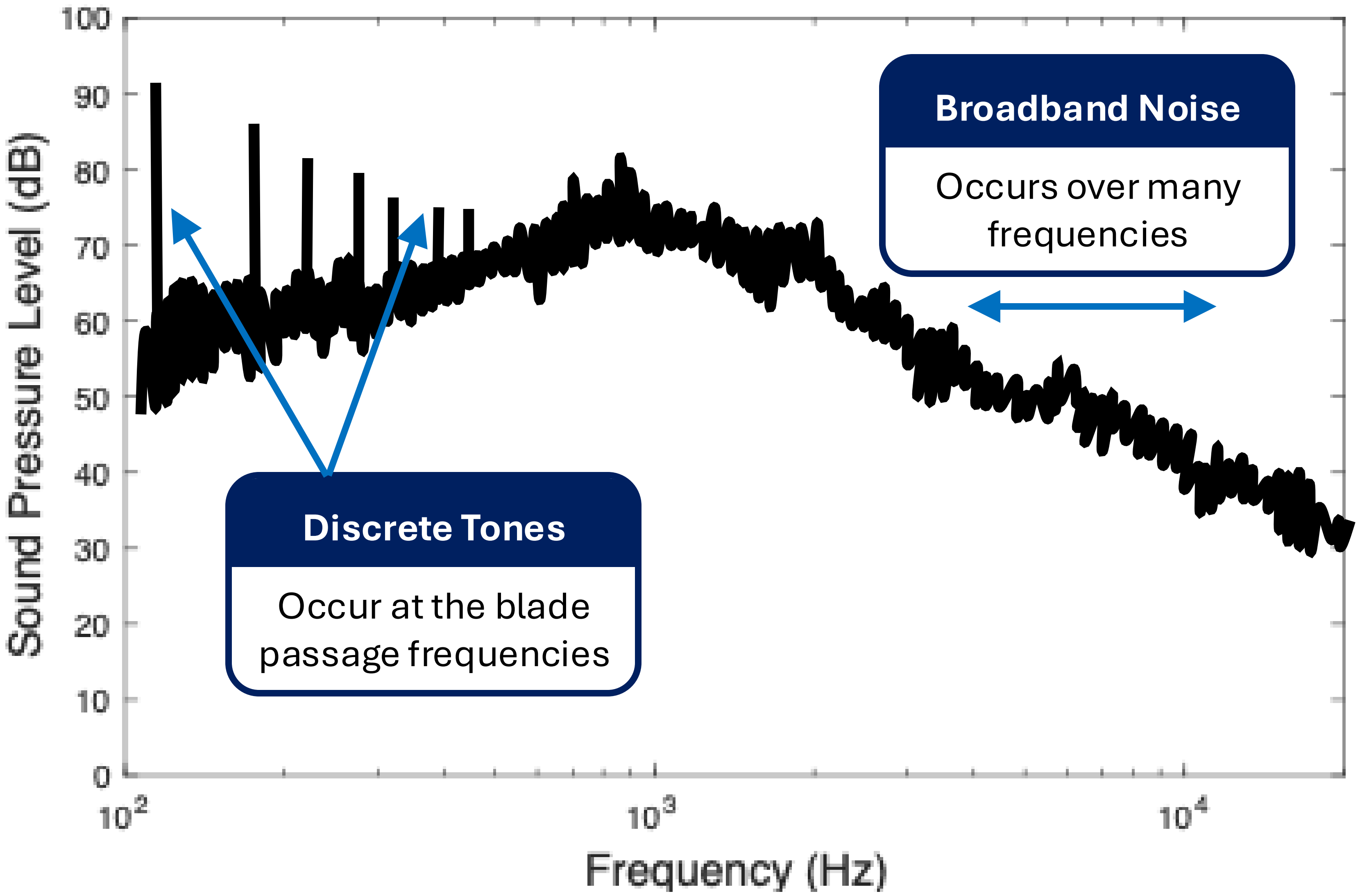
Realization

The **axial compressor** was a major noise source

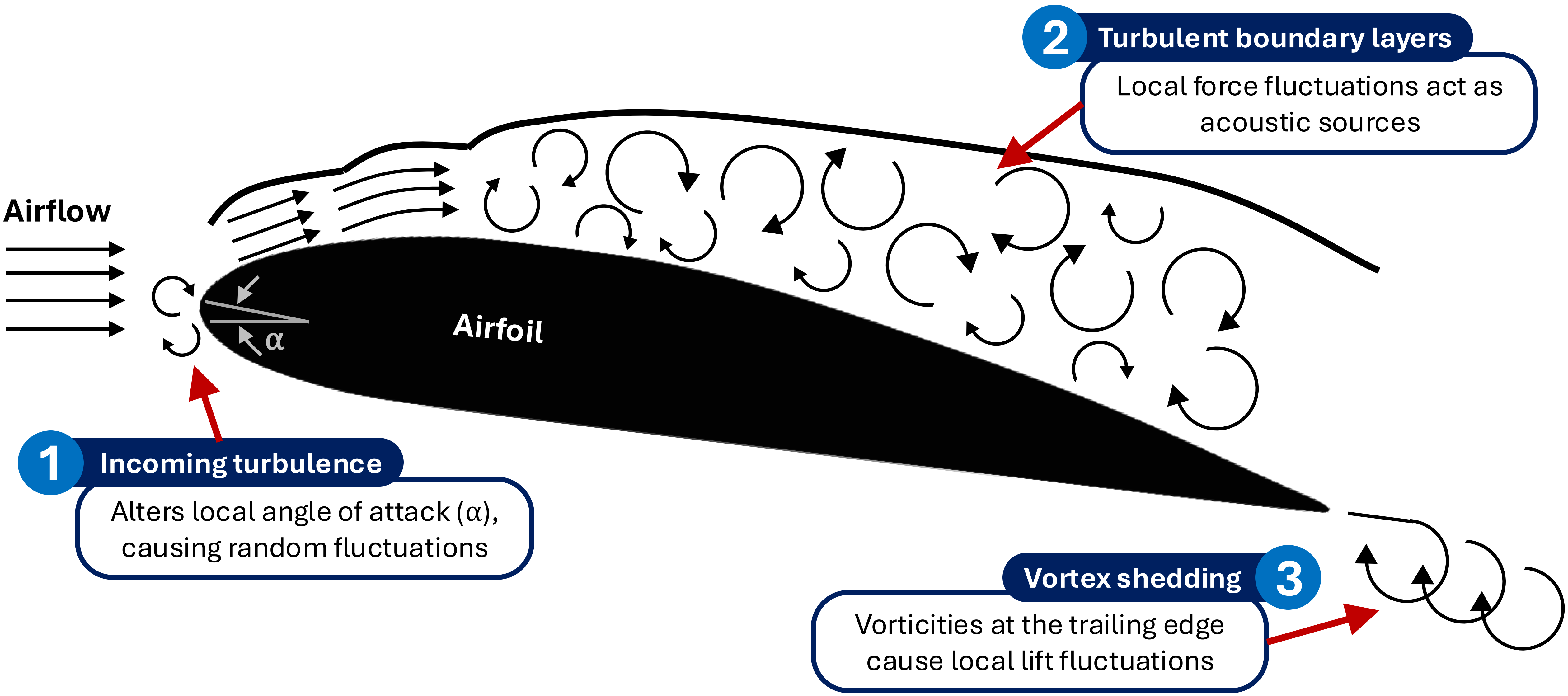
Sharland's Goal

Identify noise mechanisms and quantify their strengths

Two Types of Noise



Causes of Broadband Noise



Quantifying Broadband Noise

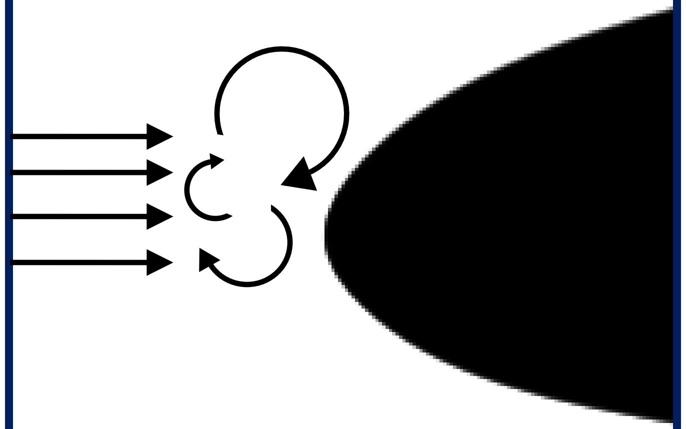
NOISE-CON 2025

Acoustic Power

$$W = \frac{\rho_0}{48\pi a_0^3}\int_{SPAN} \phi^2 C\,.\,U^2(x_2)\,.\,S_c\left(x_2, \frac{\partial w}{\partial t}\right)\left[\overline{\frac{\partial w}{\partial t}(x_2, t')}\right]^2 dx_2\,.$$

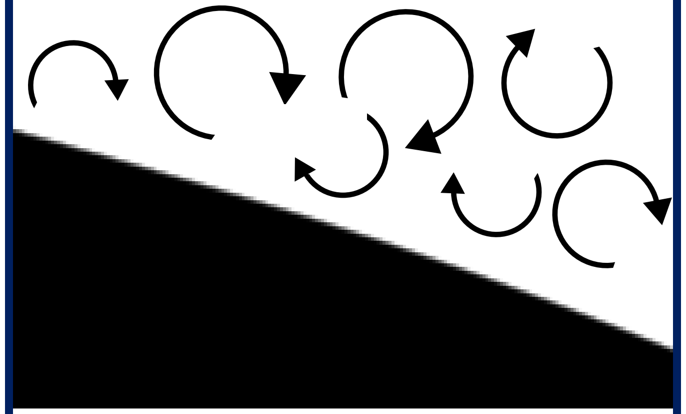
$$W = \frac{1}{12\pi\rho_0 a_0^3}\int_S \overline{[p(x_1, x_2, t')]^2}\,\omega^2\,.\,S_c(x_1, x_2, p)\,dx_1\,dx_2$$

1 Incoming turbulence



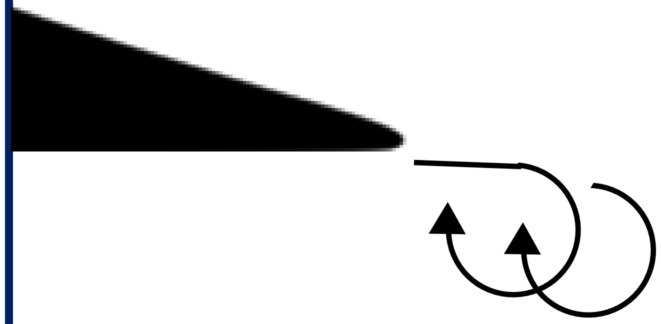
Noise ∝ Blade Speed ^{6}

2 Turbulent Boundary



A **very weak** source compared to others

3 TE Vortex Shedding



Noise scales with speed and Reynolds number

Key Sources of Noise

Higher air speeds

Larger blade surfaces

Stronger lift fluctuations

Sharland's Experiments

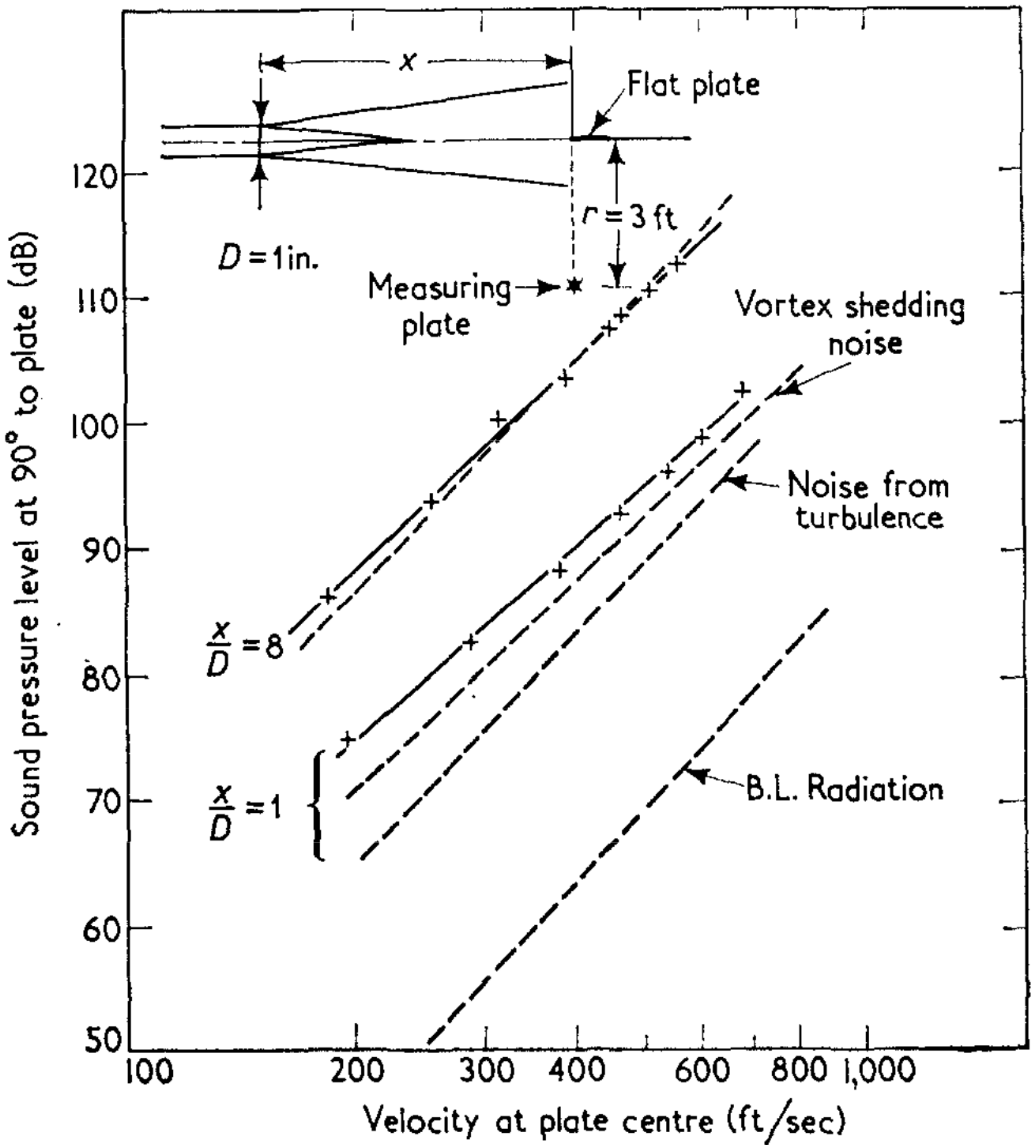
NOISE-CON 2025

Isolated Flat Plate

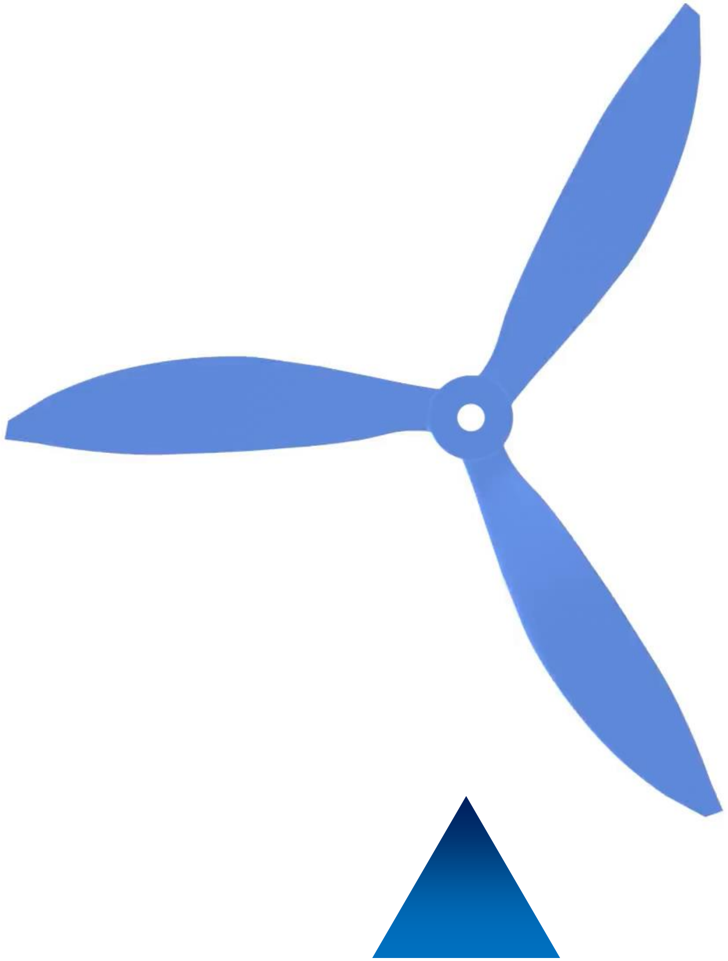
- Good agreement with formulas
- Turbulent flow & vortex shedding **~15 dB louder**

Fan Rotor

- Broadband noise centered around 1000 Hz
- Noise increases when blades are at a high angle of attack



Quantifying Tonal Noise



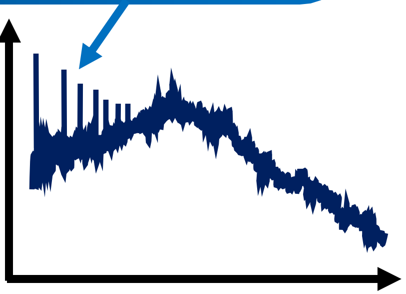
Fixed Point

Classic Propeller Theory

Blade Passing Frequency (BPF)

$$BPF = \frac{n \times RPM}{60}$$

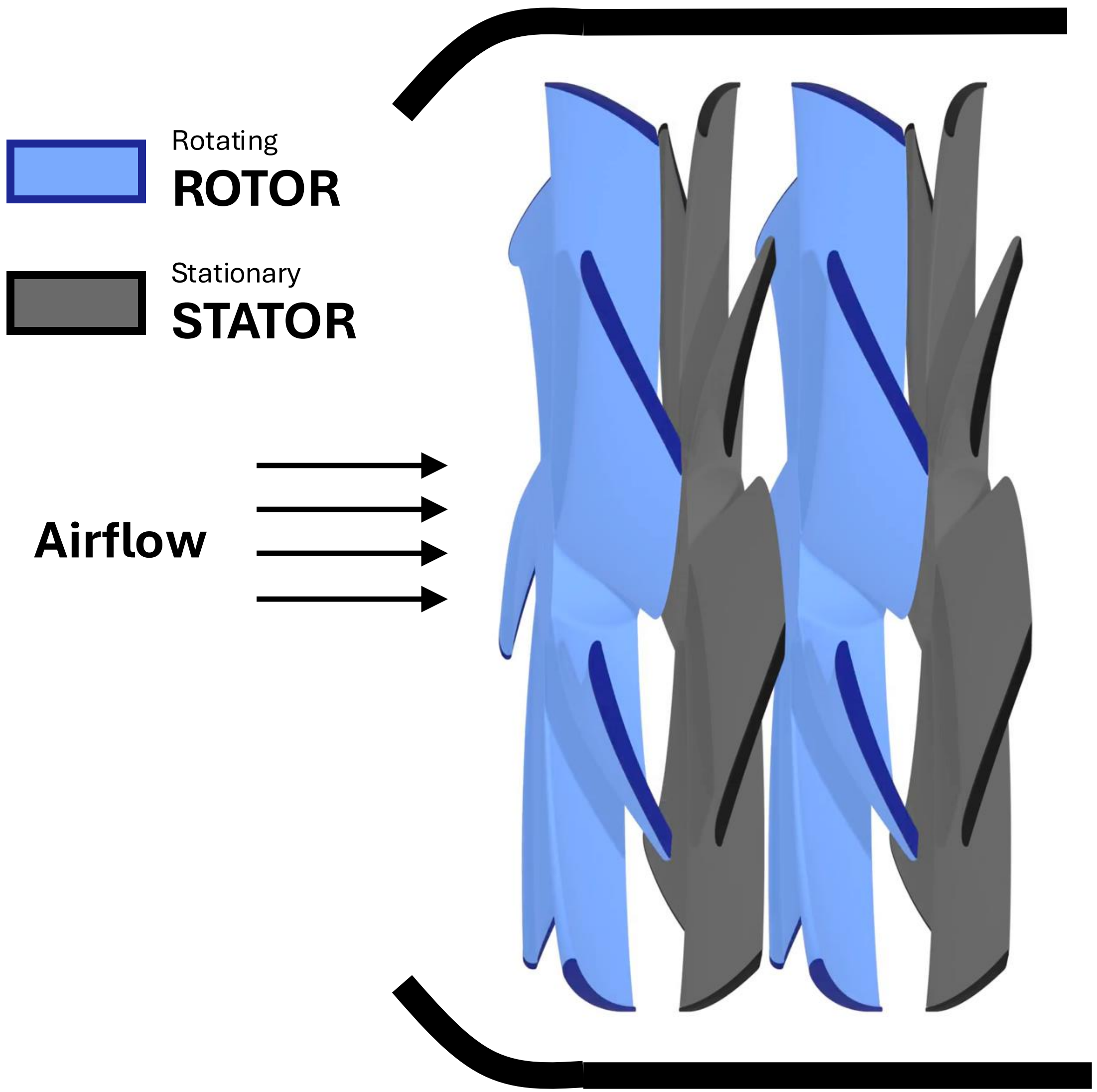
n: Number of blades
RPM: Blade speed



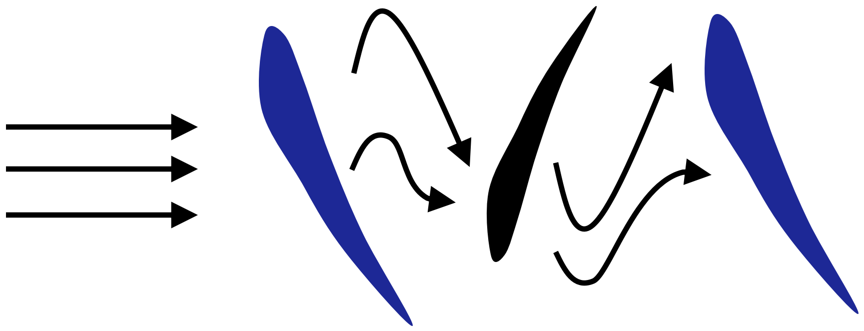
Sharland's Findings

- Did not explain **fan tones** well
- **Underpredicted** noise levels compared to experiments

Quantifying Tonal Noise



Rotor-Stator Interactions



Uneven airflow causes periodic lift fluctuations

RESULT:
Louder tones

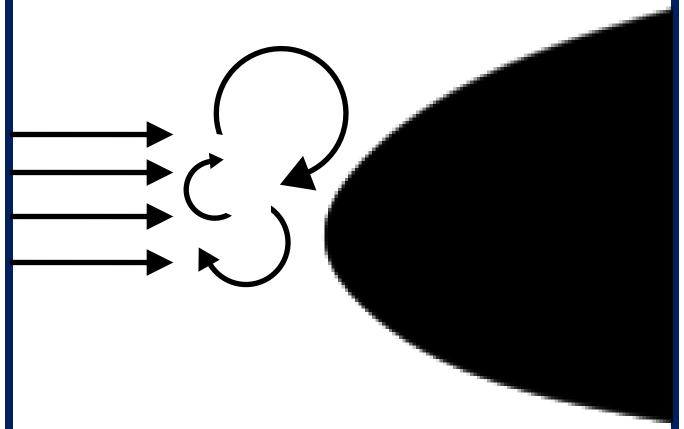
FACTORS

- Rotor-stator angle & spacing
- Stator shape & thickness

Sharland's Recommendations

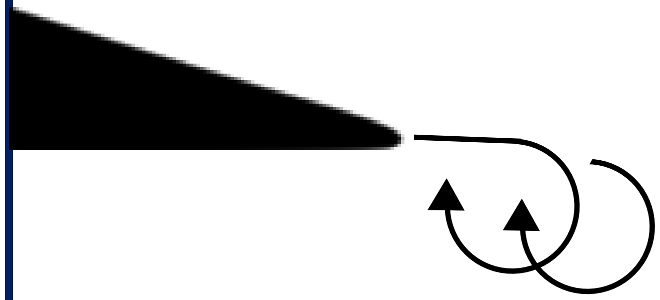
To Reduce Broadband Noise

Reduce Turbulence



Design smoother air paths ahead of the fan

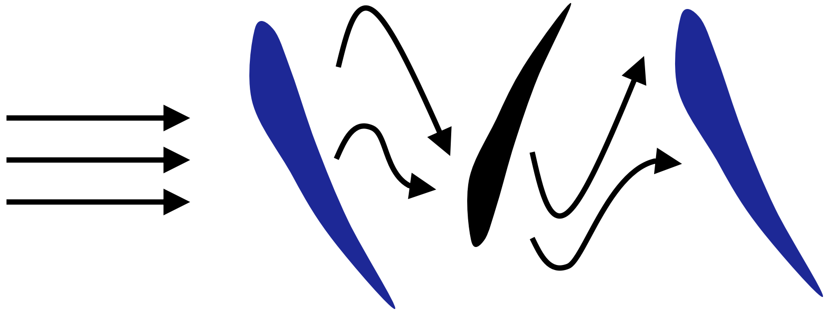
Reduce Vortex Shedding



Design sharper trailing edges

To Reduce Tonal Noise

Reduce Rotor-Stator Interactions



- Use thin stator blades
- Increase rotor-stator spacing
- Tilt the stator blades

Sharland’s Impact

Sharland's Impact

Influence

- Compressor design in aviation
- HVAC noise reduction
- Computational aeroacoustics

Legacy

Dimensional Reasoning

+

Real Experiments

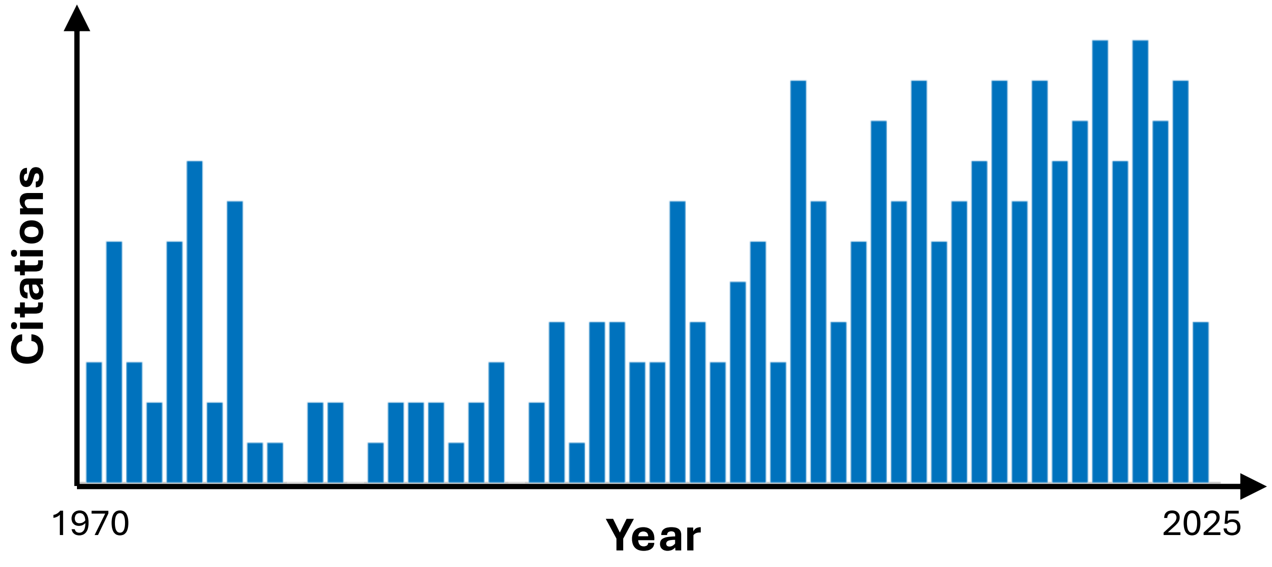
=

Practical Design Rules

Today's Impact

512

Citations on Google Scholar



Sharland's Impact: Case Study

NOISE-CON 2025

Devenport, Staubs, and Glegg

"Sound radiation from real airfoils in turbulence"

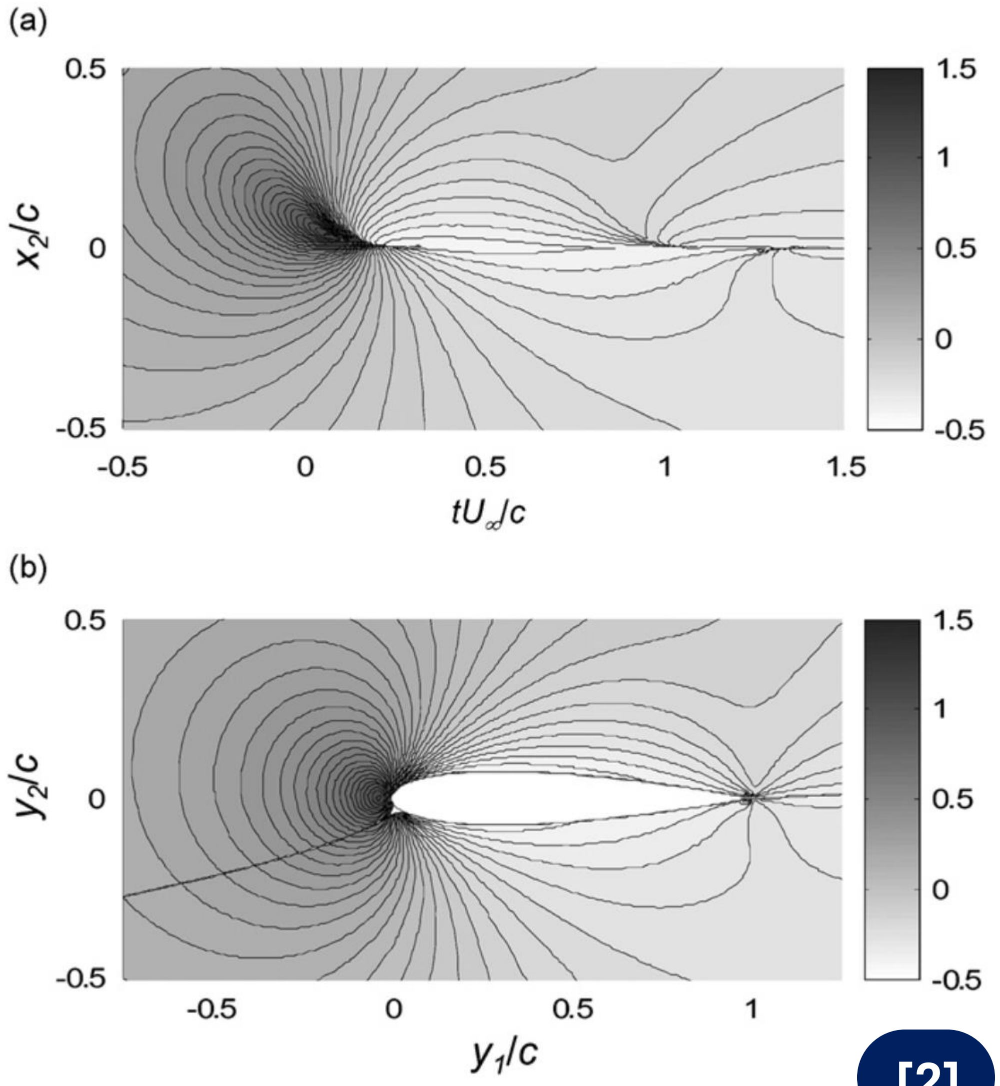
JSV (2010)

Key Purpose

- Investigated rotor-stator interaction noise using detailed flow measurements
- Studied effect of rotor tip clearance on tonal noise

Sharland's Impact

- Foundational in identifying rotor-stator interactions as dominant tone sources
- Expands Sharland's work by directly measuring wake distortions



[2]

Sharland's Impact: Case Study

NOISE-CON 2025

Amoiridis *et. al*

"Sound localization and quantification of an automotive engine cooling module"

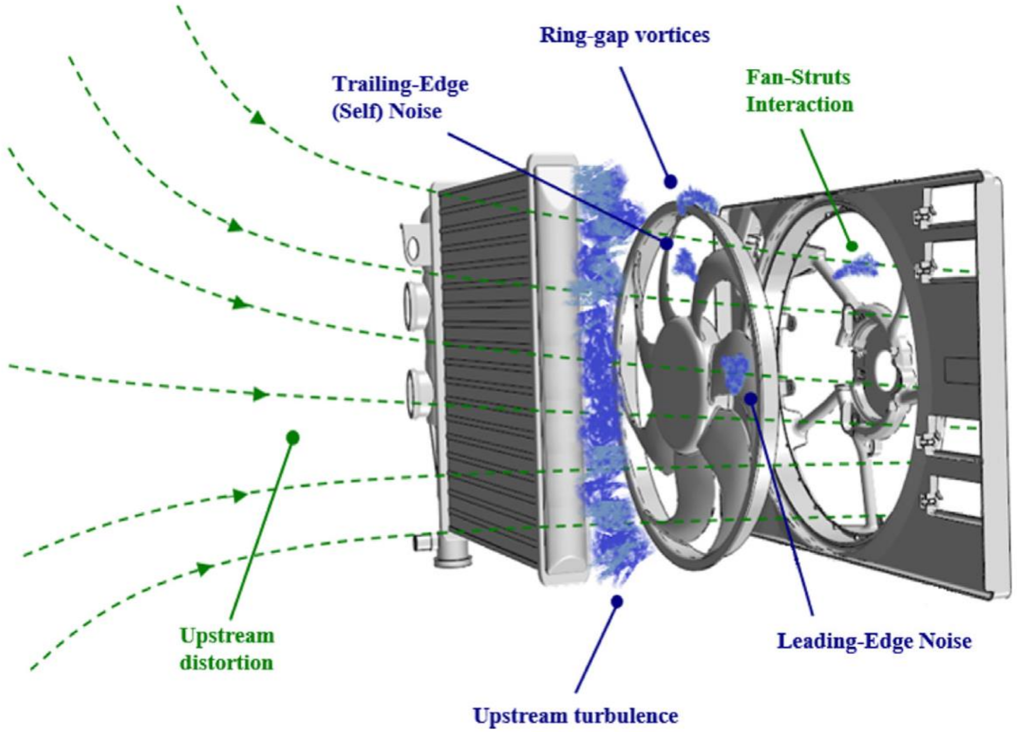
***JSV* (2022)**

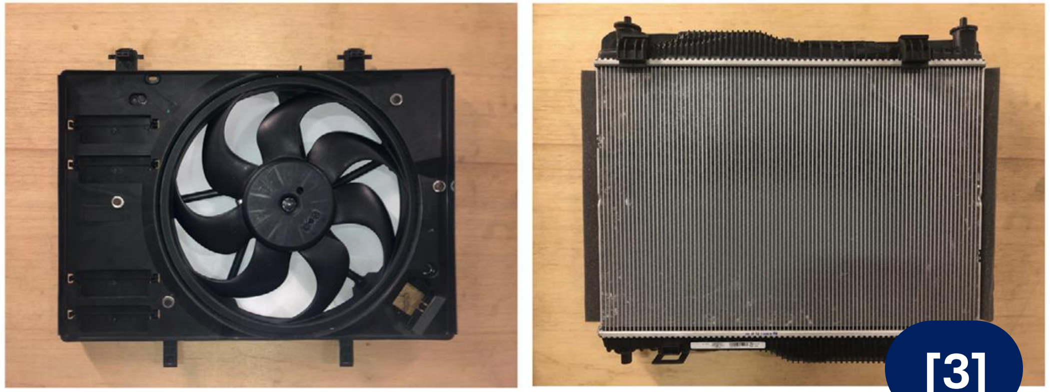
Key Purpose

- Developed a computational approach to predict tonal fan noise
- Validated the method against experimental data from a low-speed fan rig

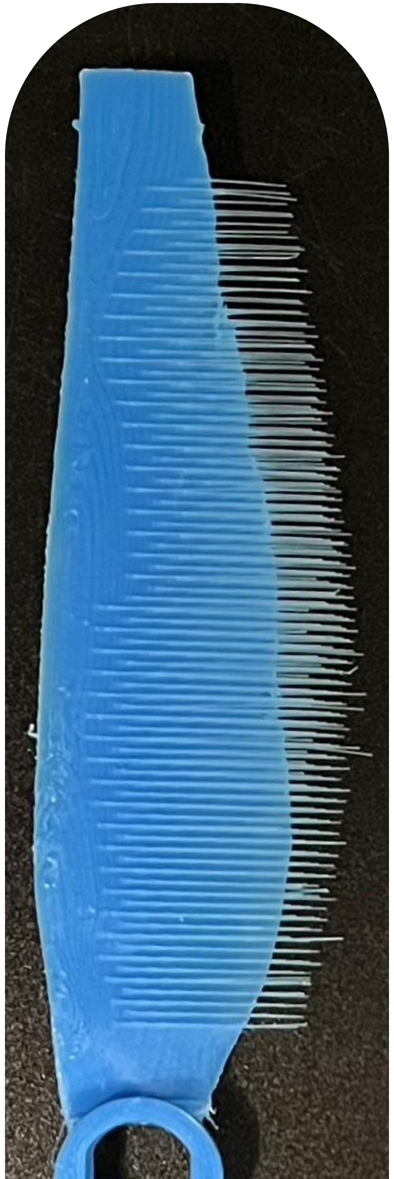
Sharland's Impact

- A key source identifying rotor–stator interaction
- Advances Sharland's empirical findings with modern CFD-based predictions





[3]



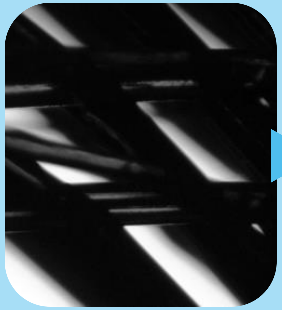
Case Study: AeroFeathers

An actual owl feather

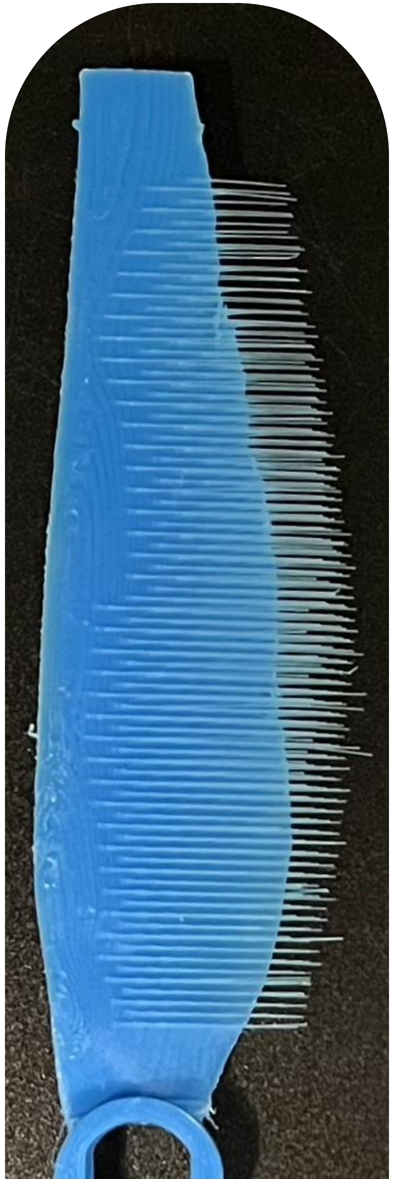
Upper Surface
Soft downy coat

Trailing Edge
Soft flexible fringes

Leading Edge
Comb-like serrations

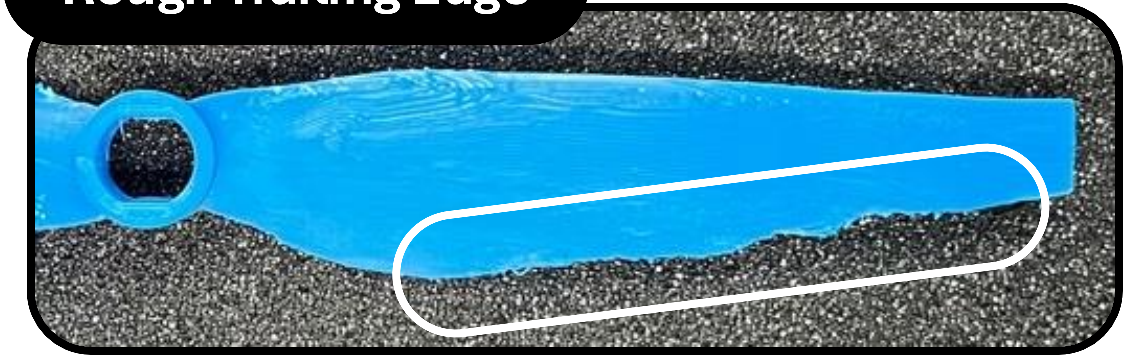


Replica 3D printed using our method

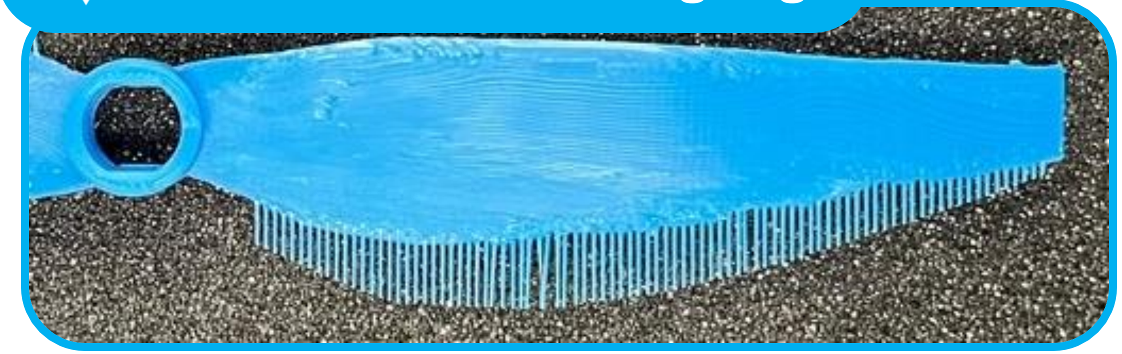


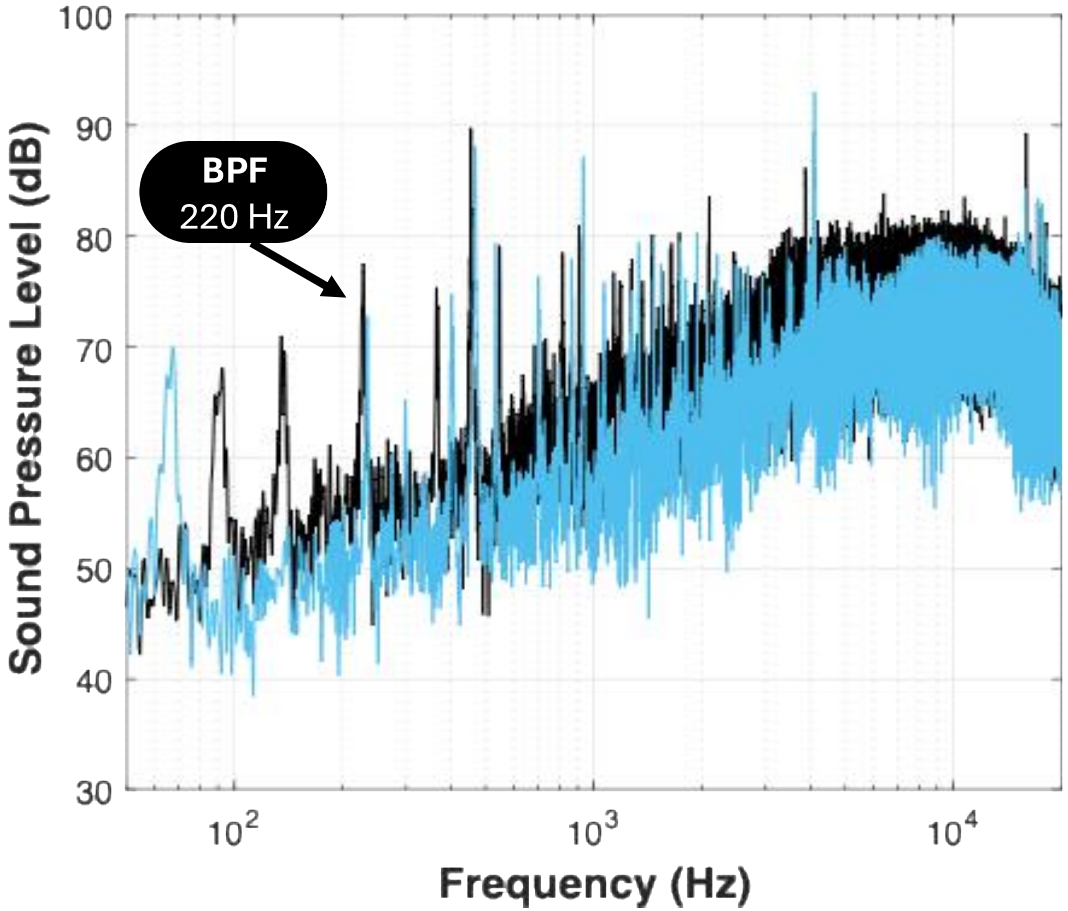
Case Study: AeroFeathers

Rough Trailing Edge



AeroFeathers Trailing Edge



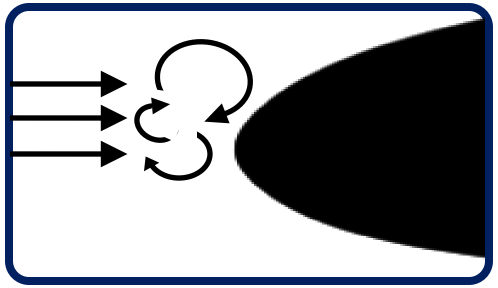


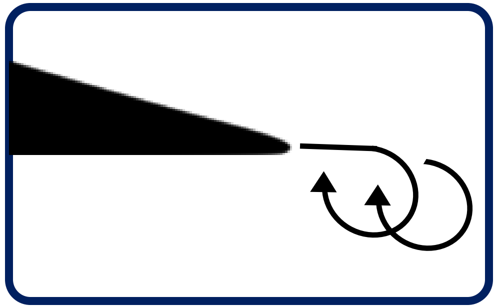
From Sharland:

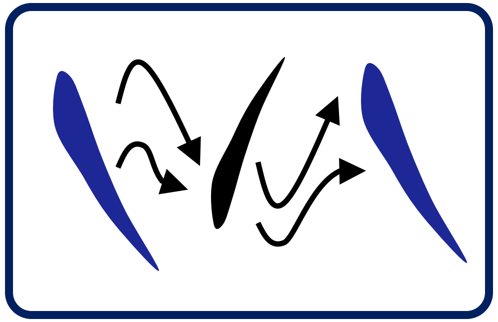
AeroFeathers **reduce broadband noise** by **reducing trailing edge vortex shedding**

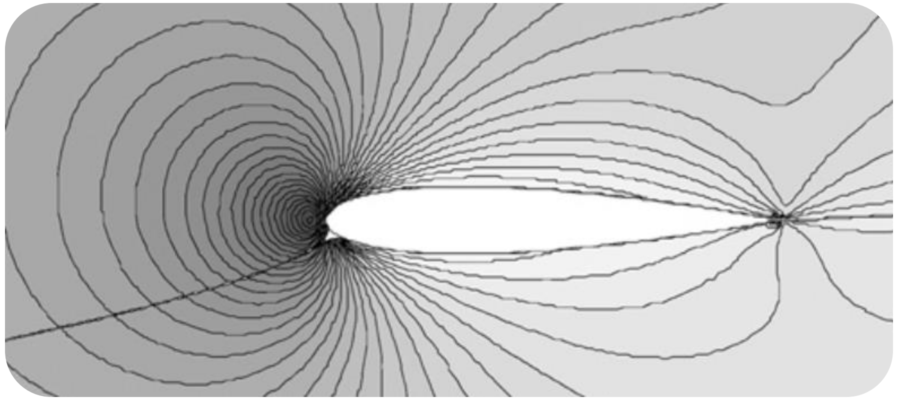
Summary & Conclusions

Sharland's Impact: A Noisy Mystery ➡ A Solvable Engineering Problem









1964 — 2025

Then & Now

Acknowledgements

AeroFeathers is based upon work supported by the NASA University Student Research Challenge under Grant No. 80NSSC24K0232. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NASA.

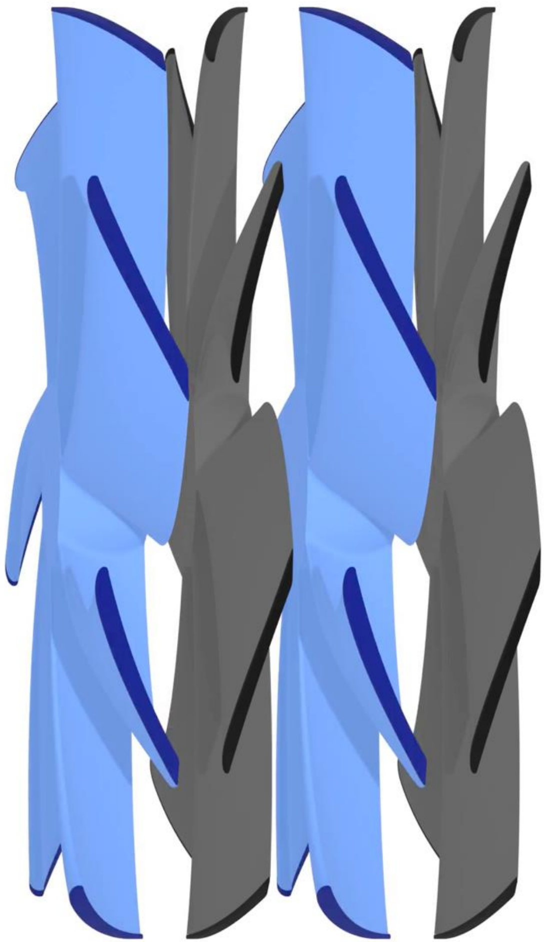
References

[1] Sharland, I. J. (1964). Sources of noise in axial flow fans. *Journal of Sound and Vibration*, 1(3), 302-322.

[2] Devenport, W. J., Staubs, J. K., & Glegg, S. A. (2010). Sound radiation from real airfoils in turbulence. *Journal of Sound and Vibration*, 329(17), 3470-3483.

[3] Amoiridis, O., Zarri, A., Zamponi, R., Pasco, Y., Yakhina, G., Christophe, J., ... & Schram, C. (2022). Sound localization and quantification analysis of an automotive engine cooling module. *Journal of Sound and Vibration*, 517, 116534.

Some Photos from: Institute of Sound and Vibration Research



NOISE-CON 2025 Classic Paper Competition Judging

THANK YOU!

William Johnston

wjohnsto@mtu.edu

Mechanics, Acoustics, and Dynamics Lab
Michigan Technological University

Michigan Technological University
Mechanical and Aerospace Engineering
1885

MADLab