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Developing Silent Unmanned Aerial Vehicles

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Introduction

The optimization of a drone propeller's acoustic signature can play an important role in the Department of Defense, observation of nature, commercial operations, and marine propulsion.

The aim of this research is to optimize the acoustic signature of propellers by isolating and modifying specific propeller characteristics. Propeller variations being researched in this project include:

- **Leading-edge serrations:** break up incoming fluid and evenly disperse it along airfoil
- **Trailing-edge serrations:** minimize vortex occurrences along the trailing edge of airfoil
- **Airfoil ribs:** force fluid through tangential channels along airfoil
- **Winglets:** disrupt turbulence and vortices at the tips of the propeller

Successful drone propeller designs are those that minimize their acoustic signatures while maintaining or improving thrust performance.

Table 1- Variations in acoustic signature and thrust performance based on propeller design

Characterization	Acoustic Level (dB(A))	% Impact	Thrust Level (kgf)	% Impact
Leading-Edge Serrations	65.64	1%	0.345	-5%
Trailing-Edge Serrations	77.3	-16.1%	0.320	-12.5%
Airfoil Ribs	66.78	-0.3%	0.329	-10%
Winglets	66.24	0.51%	.373	2.02%

Methods

Ten propellers are designed, 3D-printed, and compared using the following:

1. Shlieren Photography – Visualize air flow and sound wave propagation
2. Thrust testing – Load cell that computes and records: thrust, rpm, esc input, amperage, and efficiency

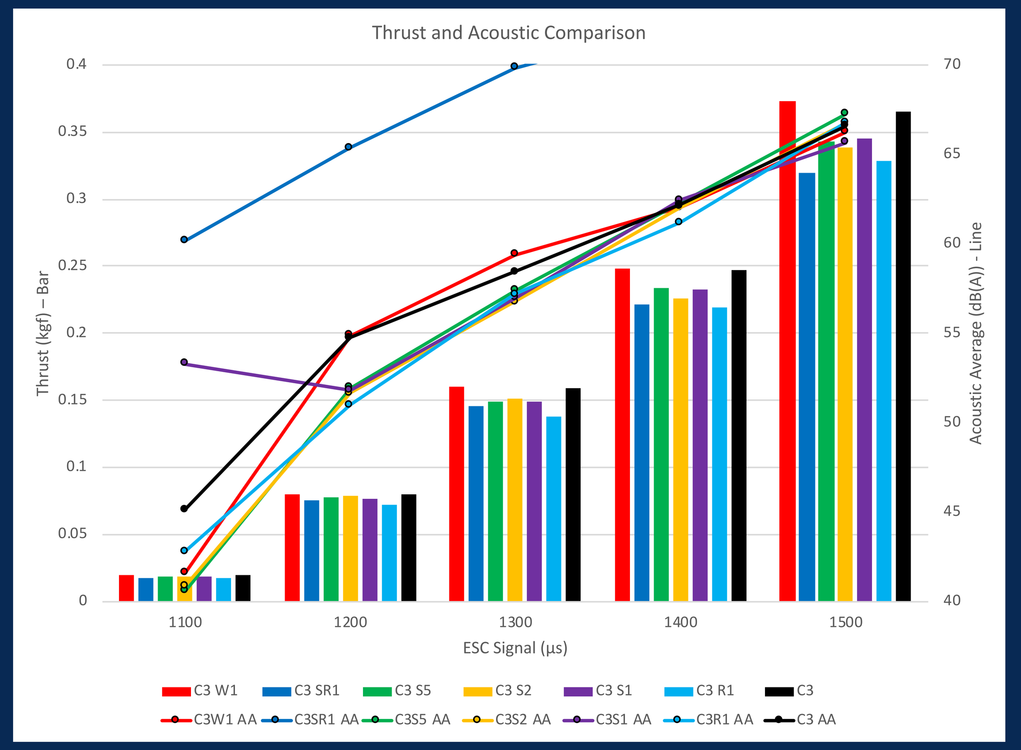
Results

Acoustic signatures and propeller integrity vary dramatically depending on how air flows across a propeller's airfoil. Table 1 shows how each characteristic changes a propeller's acoustic signature and thrust performance.

Figure 1 – Test processes and printed prototype

From left to right: Computer Fluid Dynamics analysis of 3d-modeled propeller; 3D-printed prototype; Load cell thrust testing with Schlieren mirror.

Figure 2 – Thrust/ acoustic comparison



Results start to diverge at higher operation speeds.

Conclusions

3D-printing is an effective way to produce high-quality, innovative, and custom propellers that match the performance of their injection-molded counterparts.

In comparing characterization groups, acoustic optimization occurred most often with symmetric propeller alterations.

Further research is anticipated with a focus on larger-scaled drones and high-speed Schlieren.

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