Title

Flapping-Wing Micro-Air-Vehicle Project (FMMAV)

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UCI FWMAV

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Introduction

In recent history, humanity has made remarkable strides in understanding and engineering flight. However, despite advancements in flying technology, the agility, mobility, and stability of flying creatures such as birds and insects still surpass those of our human-made aircraft. The purpose of the FWMAV Project is to delve into the intricacies of natural flight mechanisms, aiming to replicate and optimize the efficiency of flapping wings for practical aviation applications.

Figure 1: Hummingbirds are incredibly agile and precise in flight.

Figure 2: Quadcopters: constrained agility compared to nimble hummingbirds.

Goals & Objectives

Our project aims to enhance the performance of our existing Quadflappers, Alpha and Gamma, transforming them into a single, robust contender against conventional propeller drones. We also seek to explore novel conventions for flapping flight through our, X-Wing Quadflapper, Single Wing Flapper, and Payload Ornithopter. Furthermore, a goal of our research involves exploring various wing types, on a load cell, to figure out the most optimal wing material, size, etc. This year we have added a flight controller team to allow us to create flight controllers specific to the needs of each team, and have added a wind tunnel team to revamp our testing and post-processing steps.

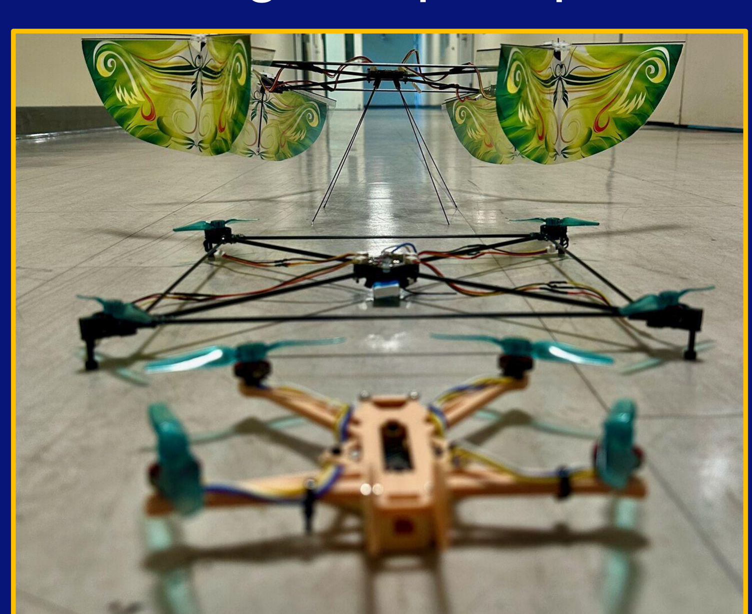


Figure 3: Alpha Quadflapper (Top), Alpha Quadcopter (Middle), and Prototype Quadcopter (Bottom).

Figure 4: The Russian Ornithopter Serenity pursues flapping powered flight.

Single Wing Flapper

Novel 2 Subteam Objectives

- Develop a single-wing flapper that utilizes the Quadflapper's mechanism for efficient glide flight.
- Design to prioritize versatility and adherence to FWMAV principles, enabling single-wing to mimic bird and sci-fi ornithopter behaviors.

Design Requirements

- Must use only one motor for propulsion.
- Mass less than 50 grams
- Pitch and roll control.

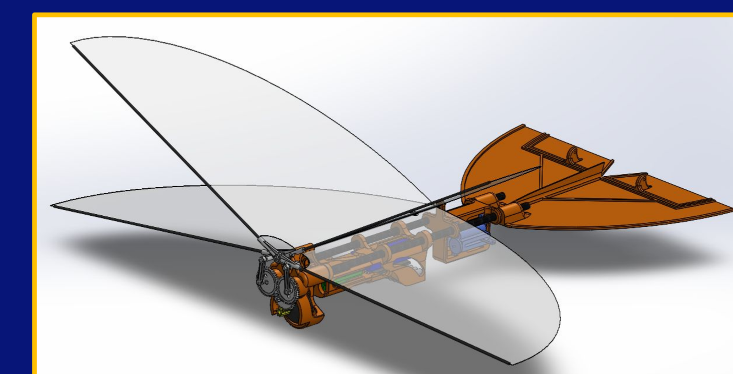
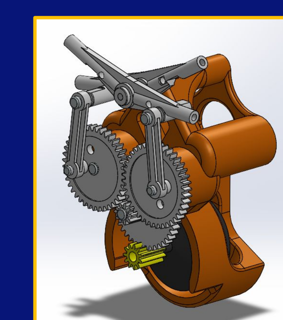


Figure 5: Single Wing CAD Assembly.

Single-Wing Subsystems

- Flapping Mechanism
  - Dual Carbon Fiber track for rigid mounting of all mechanisms
- Tail Wing Control Mechanism
  - Single layer 0.2 mm 3-D print which includes elevons, hinges, and stabilizer.
  - Bi-lateral linear servo mount allows for tail elevon motion creating pitch and roll control.
- Electronics Housing
  - Custom 3-D printed PLA parts.
- Hinged wing design
  - Carbon fiber rods provide stability against vibrations to wing axis.



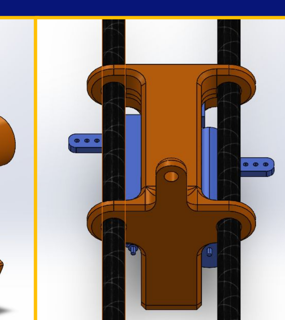


Figure 6 (Left): Flapping Mechanism.
Figure 7 (Right): Linear Servo Mount.

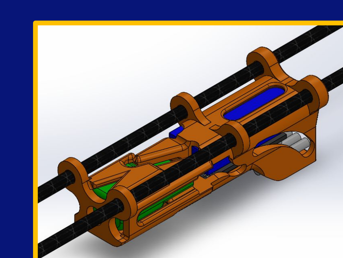


Figure 8 & 9: Main Electronics Housing

Figure 10: Single Wing Flapper Assembly.

Figure 11: Pitch and Roll control mechanism

Electronics

- 14000kV Brushless Motor
- 1s LiPo Battery
- 2x Micro Linear Servos
- 10A ESC, Micro Receiver
- FlySky i6X Transmitter

Team Members

Dante Masci, Eric Chen, Omar Lizarraga, and Vansh Mehta | Lead: Sophia Sweeney

Quadflapper

Quadflapper Subteam Objectives

- Utilize flapping power in quadcopter configuration
- Compare performance with propeller powered quadcopters
- Design for in-house manufacturing
- Research effect of clap angle on thrust performance

Quadflapper Cont.

Alpha Quadflapper

- Design and manufacture to improve robustness and perform flight maneuvers
- Design Iterations:
  - 45° Cross-link
  - M2 Heat insert connections
  - Individual landing gears

Figure 12: Alpha Quadflapper

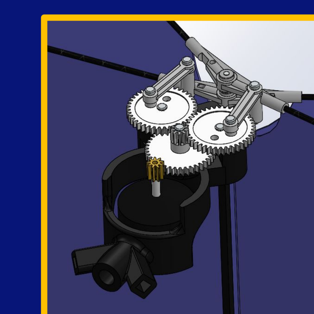


Figure 13: Chassis CAD

Figure 14: Wing Subassembly

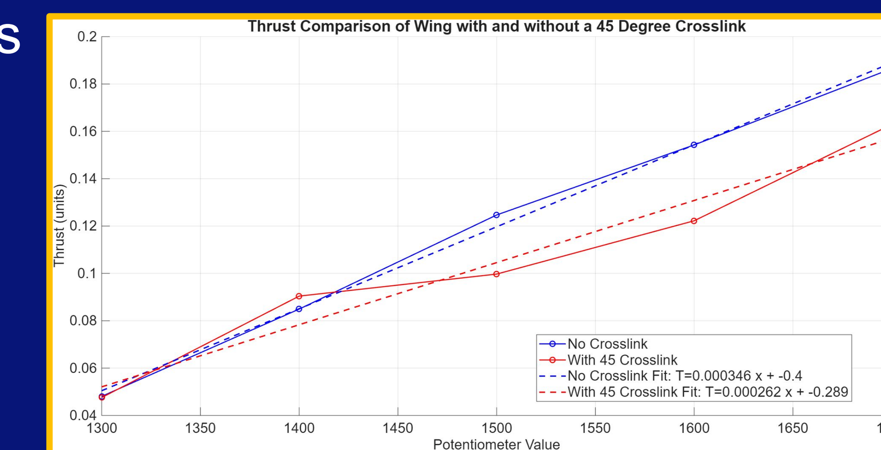


Figure 15: Thrust of Wing Subassembly vs Pot Value of Motor

Gamma Quadflapper

- Develop an in-house and robust version of a quadflapper
- Modular framework for ease of iterative design
- Research effect of clap angle on thrust performance
  - Develop MatLAB code to generate linkages for desired clap angle
  - Use experimental data to compare thrust and power performance

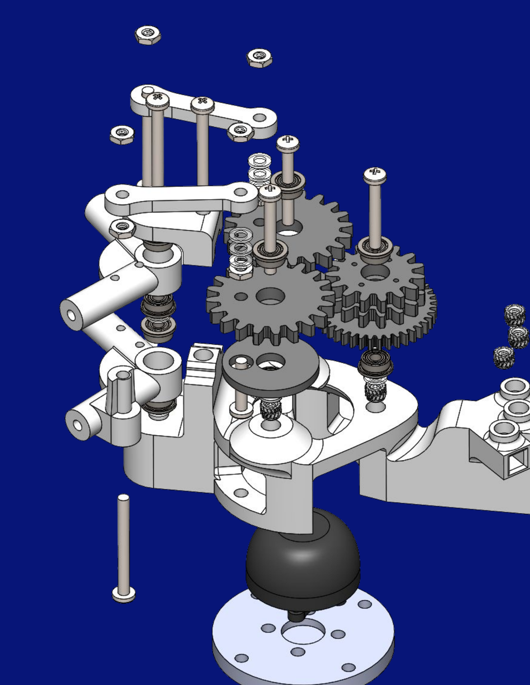


Figure 16: Gamma Subassembly

X-Wing Quadflapper

- Push limits of speed, efficiency and stability by developing and testing two variable drone frame mechanisms.

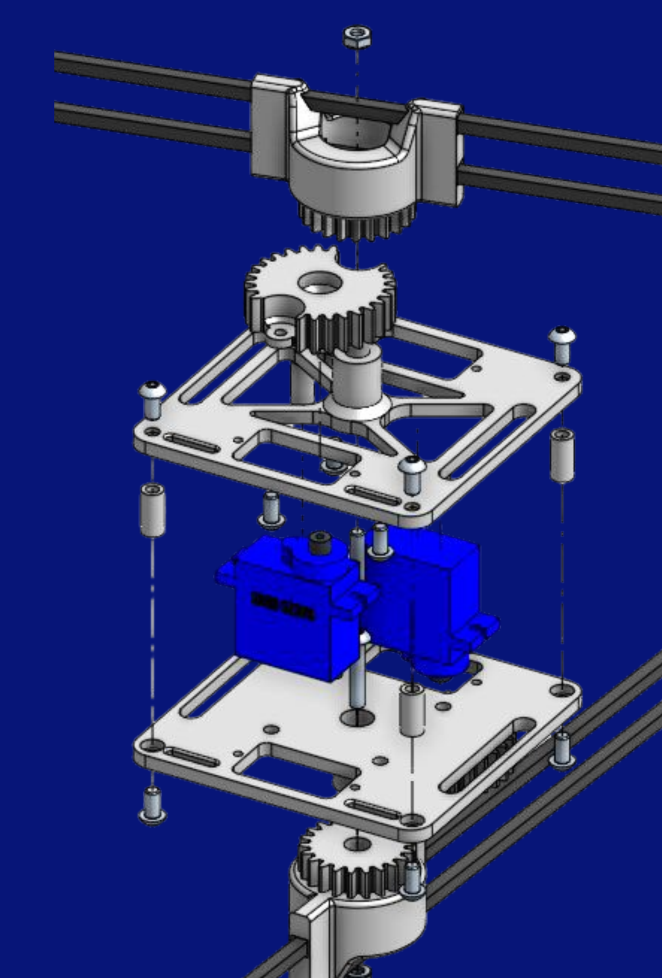


Figure 17: 2-Servo Gamma X-Frame

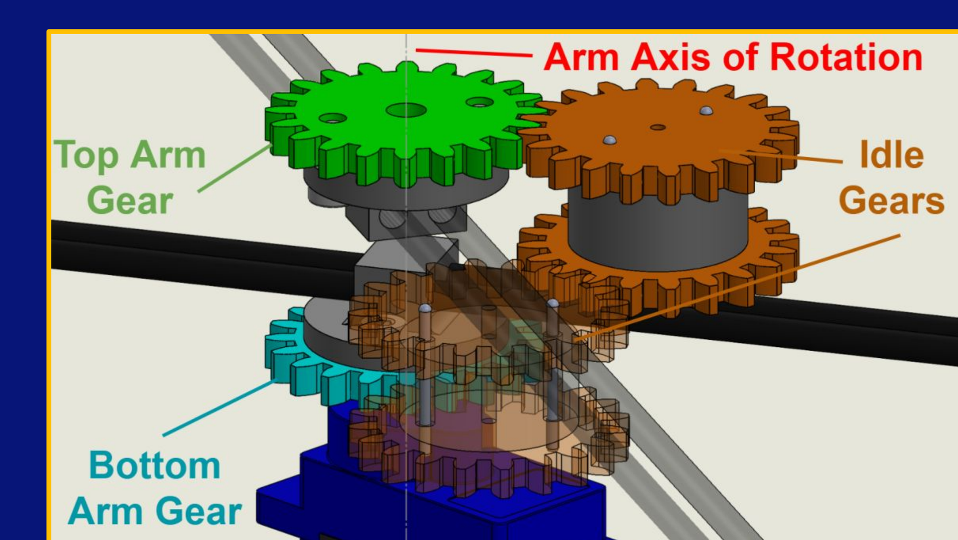


Figure 18: Single Servo Alpha X-Frame

Team Members

Alpha: Brian Truong, Daniel Grivennikov, Mylie Yu | Lead: Vanessa Salyer
Gamma: Nour Ammari, Ricky Yoshida, Vincent Nguyen | Lead: Hambik Margoosian
X-Wing: Matthew Kaiser and Thomas Ibrahim | Lead: Jenna Lee

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Payload Flapper

Novel 3 Subteam Objectives

- Design and fabricate a multi-wing ornithopter.
- Exploration of flapping mechanisms for carrying larger loads, testing the limits of a FWMAV's power to weight ratio.

Propulsion

- Chain & Sprocket: High torque transmission for flapping Dual Drive Gears: Allows for dual phase wing actuation
- Electronics Chassis: Motor is housed within the truss
- Variable-Length Wings: Maximize lift with each flap

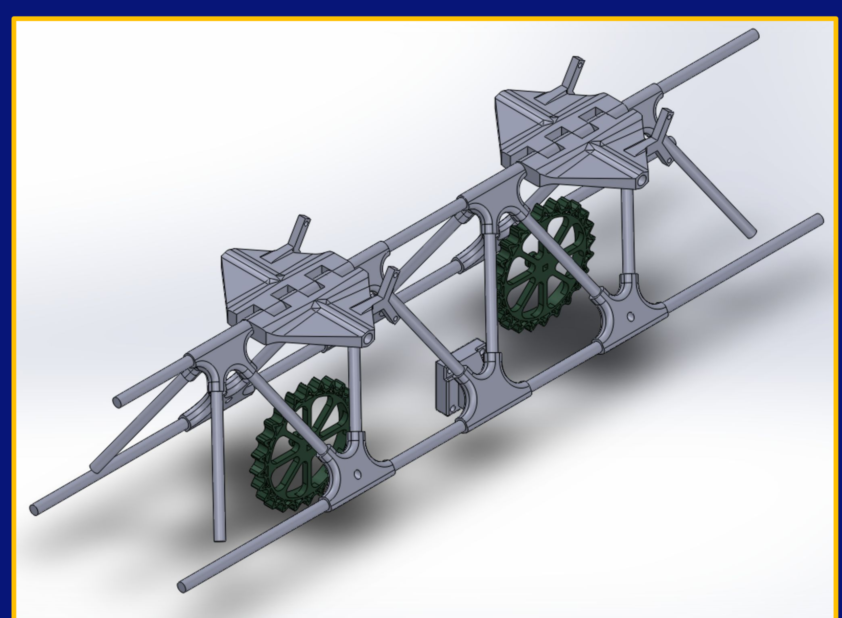

Figure 19: Truss design CAD without set of wings

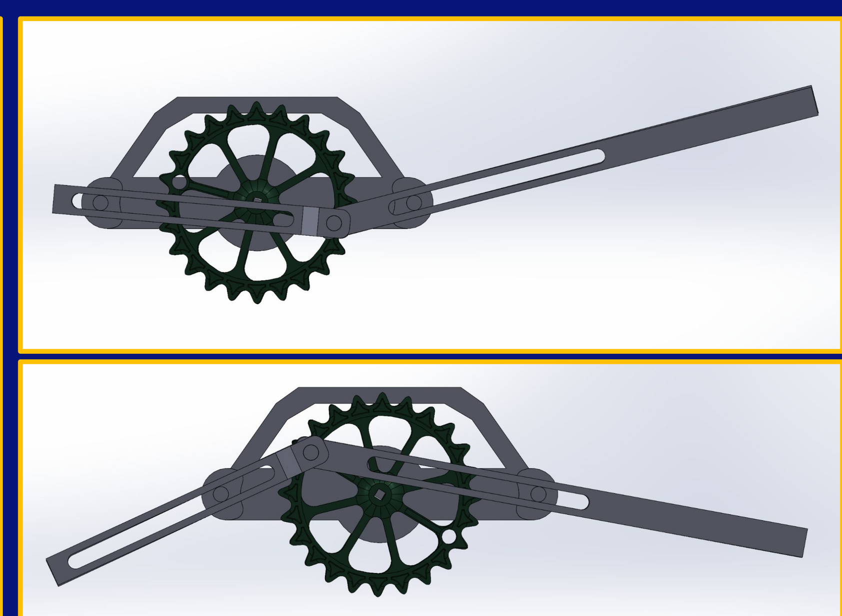

Figure 20: Alternative flapping mechanism CAD

Current Progress

- Currently, the ornithopter is in the design phase. We have completely shifted our focus towards saving weight.
- We chose a truss system for the subframe, consisting of 3D printed joints and carbon fiber rod truss members.
- The revised flapping mechanism uses variable length linkages to minimize downforce on upstroke, increasing lift.
- The ornithopter is mostly redesigned from previous prototypes, however the basic power transfer mechanism remains: a motor and a chain-driven sprocket system.

Next Steps

- Testing marks the immediate next step for the completion of the ornithopter project.
- First, we plan on conducting static load testing to ensure the structural integrity of the ornithopter is suitable for flight.
- Next, the flapping mechanism will be tested in order to optimize stroke frequency and ensuring that the powertrain can sustain flight under load.
- Finally, points of weaknesses will be identified during flight tests, and rectified in this phase.

Team Members

Andrew Le, Hayden Harrison, Omar Najjar, and Rene Urrea | Lead: Sophia Sweeney

Flight Controller

Flight Controller Subteam Objectives

- Design and create a custom flight controller tailored to the Alpha Quad Flapper
- Aim to be more reliable, efficient, and smaller flight controller compared to the off the shelf current Alpha Flight Controller
- Aim to finish manufacturing and testing by end of this school year

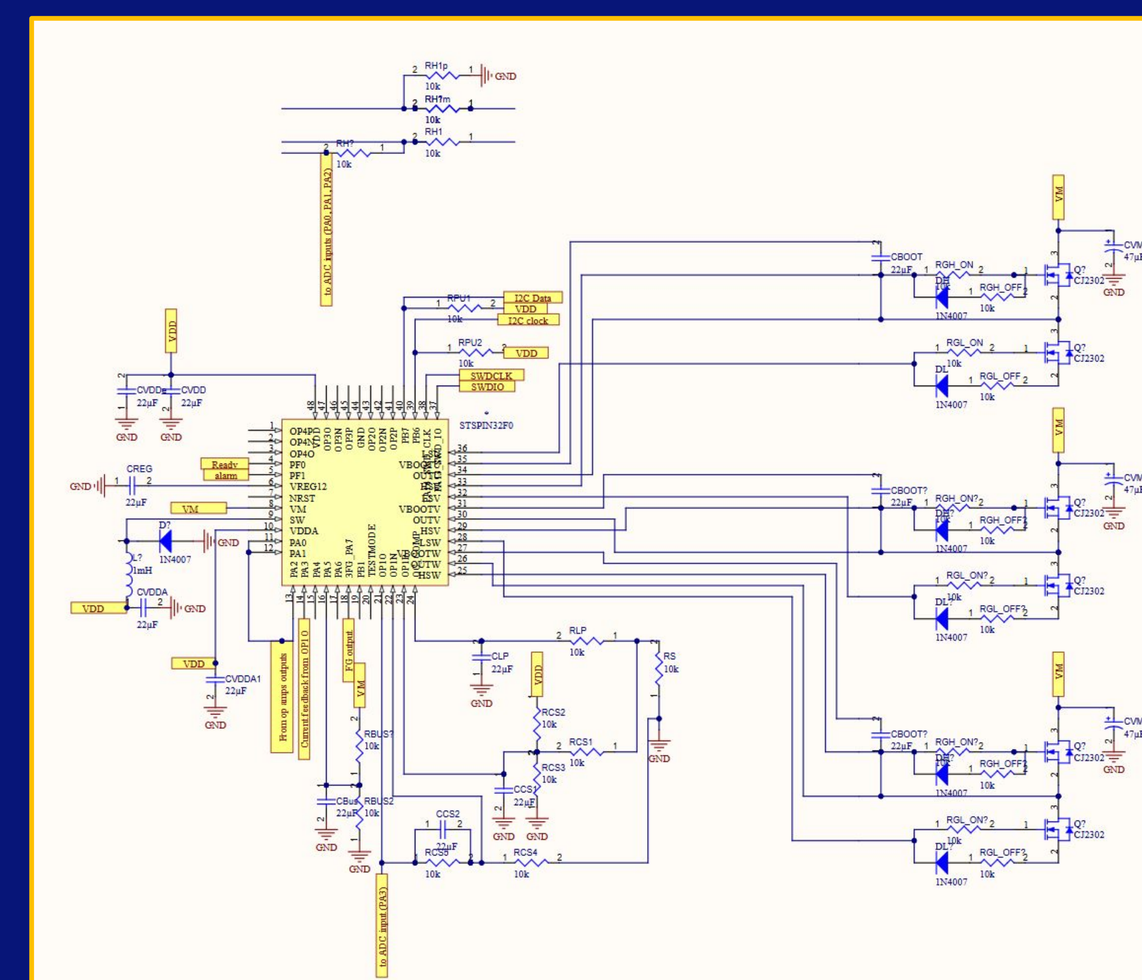

Figure 21: Current ESC Design for new Flight Controller

Team Members

Anderson Kwon, Richard Nguyen, and Yanilette Montano | Lead: Elizabeth Yang

Wind Tunnel

Figure 22: Flowline visualization

- Designing streamline smoke delivery to allow teams to perform flow visualization analysis'
- CNC Laser sheet module for highlighting streamlines in plane
- Computer vision enables non-invasive analysis of fluid flow by processing video data to measure, track, and predict velocity, pressure, and flow patterns

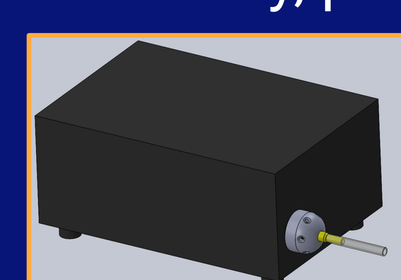

Figure 23: Fog Machine with nozzle

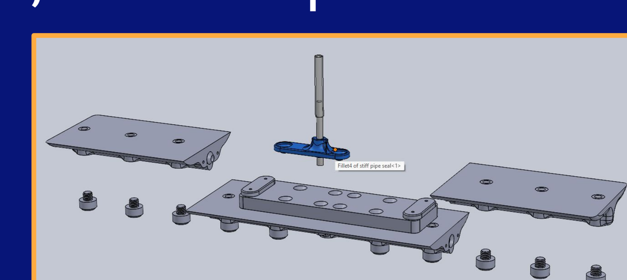

Figure 24: Streamline Plane Selection

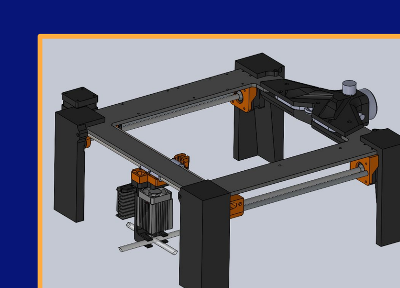

Figure 25: CNC Laser Sheet module

Team Members

Joshua Elvis Rodrigues and Dante Masci | Lead: Kshitij Anand

Wing Investigation

Wing Investigation Subteam Objectives

- Collect datasets while varying wing material and aspect ratio to refine wing designs for improved flapper efficiency

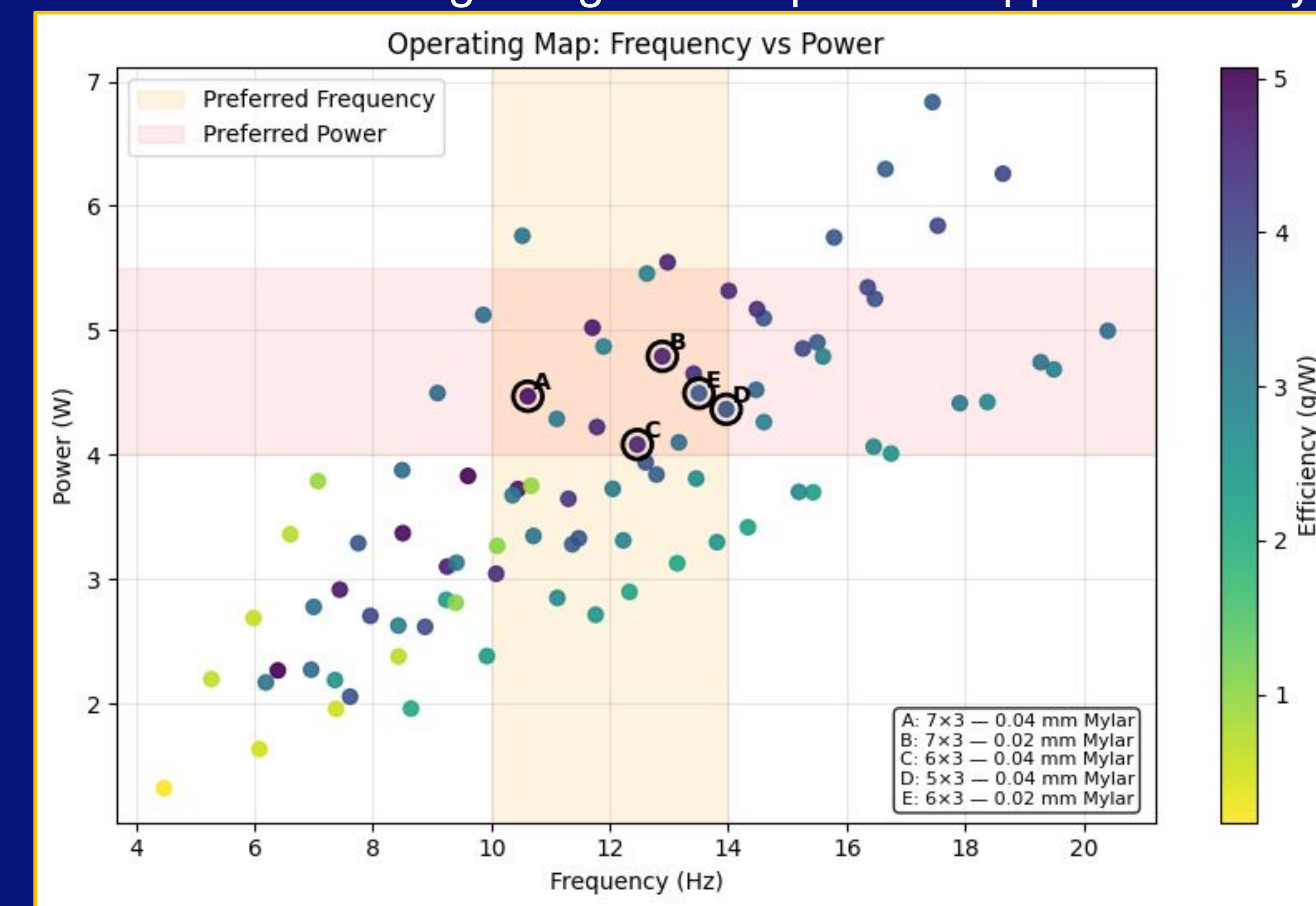

Figure 26: Top performers in the context of motor frequency and power

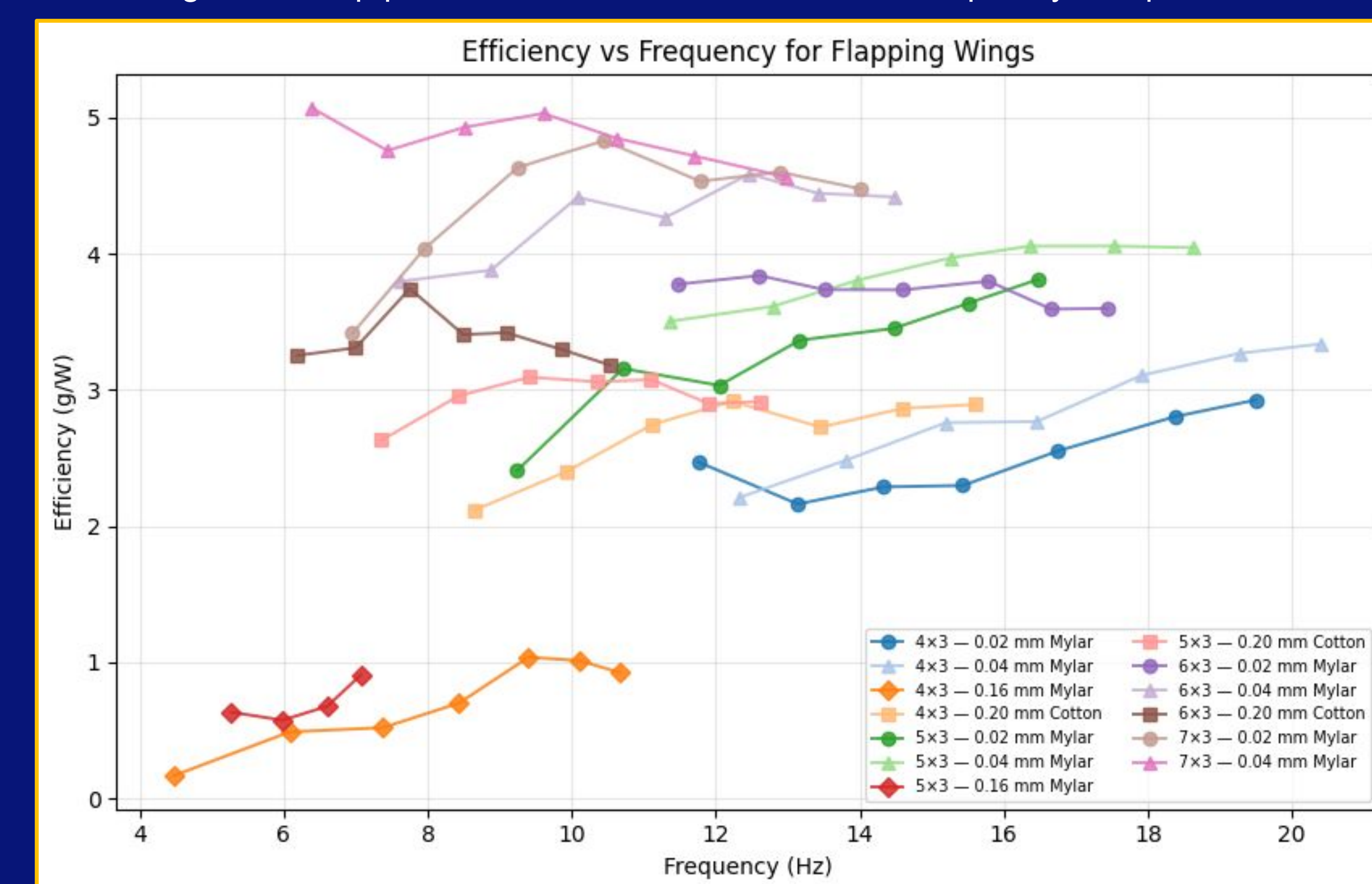

Figure 27: Efficiency trends vary by wing shape and material as frequency increases

Preliminary Conclusions

- Larger wings with both flexibility and structure are optimal

Future Directions

- Investigate how the elasticity of the material help capture air
- Visualize flapping air flowlines using a smoke machine

Team Members

Derek Zuo and Joshua Varela | Lead: Jenna Lee