Cooper Union Vertical Flight

Capstone Senior Design
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Motivation

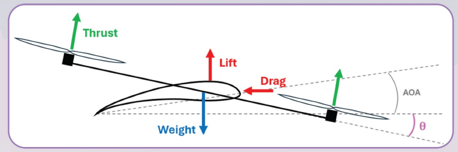
We competed in the Design Build Vertical Flight Competition hosted by Vertical Flight Society. The event pits student teams against each other to build an unmanned vehicle that transitions between vertical and horizontal flight. Vertical flight technology has applications including rapid urban transportation and delivery services, search and rescue missions, and military operations.

Mission

- Maximum weight of 20 lb.
- Minimum payload weight 2lb.
- Operate in manual and autonomous mode.
- Score combines # of laps in 10 minutes and payload weight.
- Each lap the aircraft takes off and lands vertically between horizontal sprints.

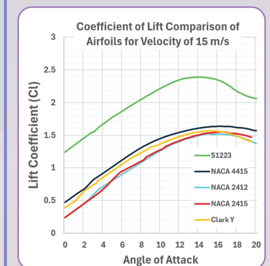
Design Concept

The vehicle uses a central wing to generate a portion of the lift in forward flight. This allows for a pitching motion to seamlessly transition between vertical and horizontal flight modes.



Airfoil and Wing

Airfoil and wing simulations were completed using Xflr5. The resulting angle of attack and coefficient of lift values were used to make design decisions and calculate deflections of the wing. We chose the S1223 Airfoil for its high lift despite higher drag and worse stall at lower speeds. The wing span of the vehicle is 1.5 meters and the chord length is 0.2 meters.



$$0.5 \cdot \underbrace{1.52}_{C_L} \cdot \underbrace{1.225kg/m^3}_{\rho} \cdot \underbrace{0.3m^2}_{A} \cdot (\underbrace{15m/s}_{V})^2 = \underbrace{62.8\,N}_{L}$$

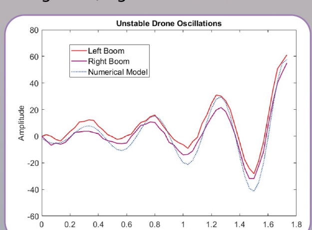
The lift gained from the wing reduces power usage in forward flight by **67%**

Manufacturing

- 3D printing allows for rapid iteration and modular designs that easily interface with off the shelf parts.
- Lightweight PLA is used for the wing sections to conserve weight. Structural components are printed in PETG for ductile strength.
- Carbon fiber spars are used as rigid framing members. The fuselage contains aluminum rods to stabilize the payload and electronics.
- Aluminum endcaps are epoxied into the end of the spars to interface with other components.

Stiffness & Vibration

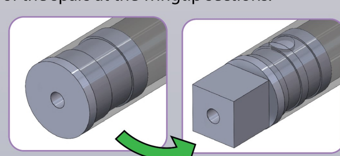
Testing the vehicle in the lab, we discovered the spars through the wing were not structurally rigid enough to prevent the propellor booms from twisting relative to eachother under load. Impact hammer testing revealed torsional natural frequencies at 3.8 and 9.2 Hz. The issue worsened at competition when we discovered that two spar endcaps broke loose, reducing the torsional stiffness further. During a test, a gust of wind excited instability in the system and caused the vehicle to crash. Reviewing the flight data, the oscillation frequency was identified to be 2.15 Hz.



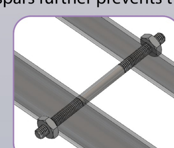
Design Iterations

There are two main changes being implemented to increase frame rigidity.

A square profile endcap will prevent rotation of the spars at the wingtip sections.



A threaded stud through both spars further prevents twist.



Competition

Communication System