Electric Vertical Takeoff and Landing Drone with Outboard Horizontal Stabilizers

THE Applied CFD & Aero-Design Research Group

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Abstract

- This project aims to develop a prototype that demonstrates the design of an OHS configuration aircraft with eVTOL capabilities
- Prototyped OHS configuration increases the lift to drag ratio by approximately 30%, compared to that of a conventional aircraft. Research of eVTOL capabilities was promising to serve a more efficient takeoff and landing system
- A refined understanding of the OHS and eVTOL, and a successful prototype was developed. Investigations will serve to aid the ACAD laboratory and future research efforts

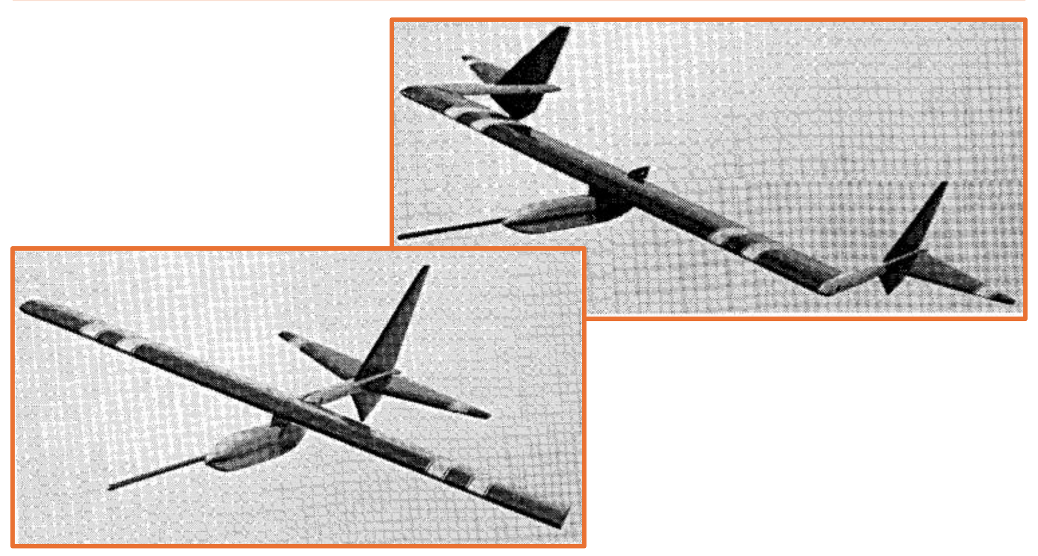

Figure 1. Conventional Aircraft vs. OHS Configuration [1]

Introduction

- OHS configuration places the horizontal and vertical stabilizers back from the wing tips to catch the upwash velocity
- The CoG changes the static margin which ultimately affects the stability of the plane
- The CoG for the OHS configuration is further back than most conventional aircraft, but the positive static margin needed for stability is greatly reduced
- This introduces the need for eVTOL, with the addition of ease of takeoff
- Additionally, the CoG combined with the characteristics of the OHS configuration allows for an increase in maximum L/D ratio by up to 30%
- An increase in lift results in improved endurance and battery or fuel economy

Objectives

1. Establish detailed designs and CAD models, and a final prototype
2. Manufacture with LWPLA
3. Final weight less than 750 grams
4. Maintain quadcopter flight for at least 2 minutes
5. Maintain forward flight for at least 8 minutes
6. Transition flight within 10 seconds

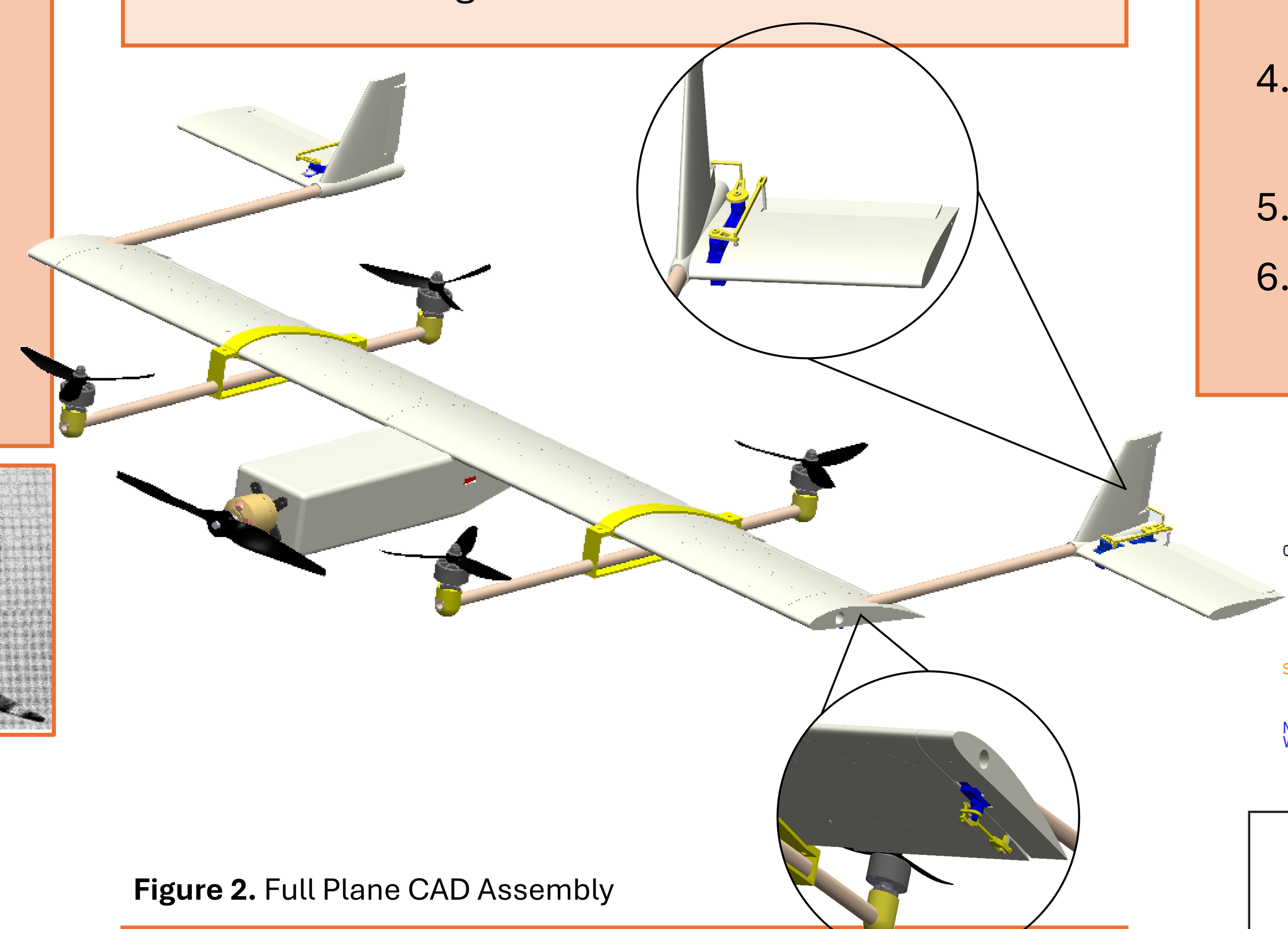

Figure 2. Full Plane CAD Assembly

Design Process

The chosen design is shown above in Figure 2. This was derived from over 50 initial candidates, with the top 6 compared against one another in a decision rubric. The final design includes 4 upright motors for eVTOL connected by brackets, a front motor for forward flight, booms connecting OHS to wing tips, and a cambered fuselage that matches the profile of the wings.

Iterative Prototyping

1. Calculate, size, and design initial plane specifications and avionics following objectives
2. Develop CAD assembly to reflect design and ease of manufacturability
3. Finalize 3D print settings and manufacture parts
4. Modify design based on iterative testing
   - (maintain CoG, verify static margin, validate approximate weight and assembly fit)

Research and Development Methods

1. Decision rubric to isolate working design
2. Select avionics and flight controller; MPU 6050 IMU controller, Teensy 4.0 development board; Arduino dRehmFlight flight controller. Full electronic schematic researched and developed from scratch
3. Literature review for wing and OHS stabilizer constants [1]
4. ACADLLT software to determine static stability and moment coefficient [2]
5. OpenVSP to design the wing and verify lift
6. Manufacturing, purchasing, and assembly of drone

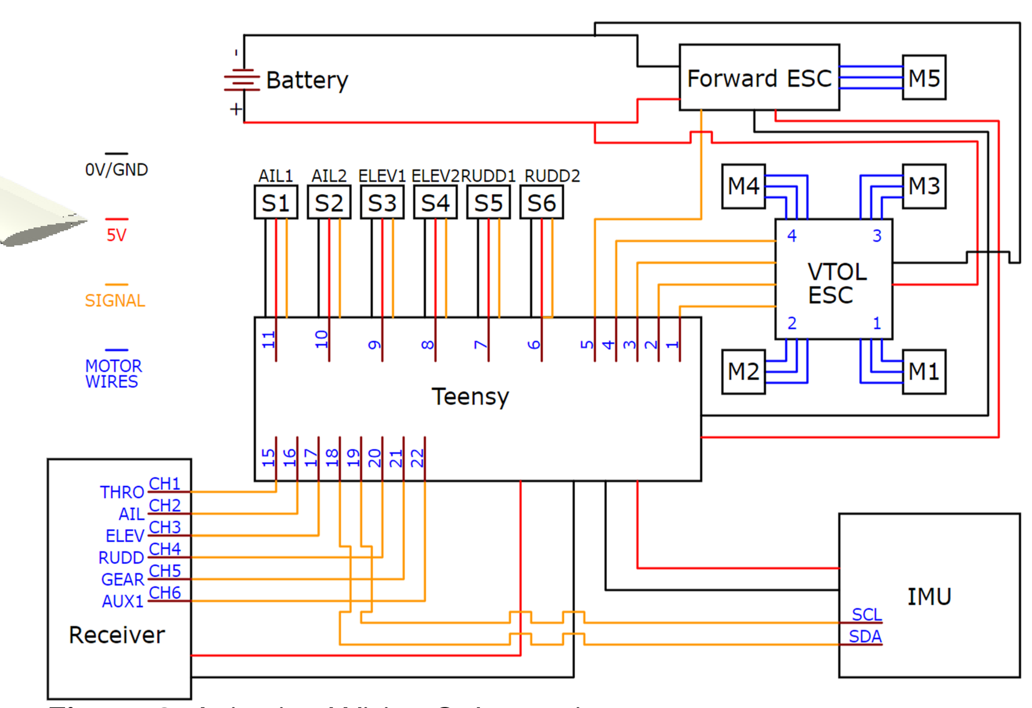

Figure 3. Avionics Wiring Schematic

Materials and Manufacturing

1. Hybrid of regular and lightweight PLA for drone body and control surfaces
   - LWPLA: requires zero supports; minimal retraction; ideal foaming at 240C and flow from 65-100%; selective infill based on part size and structure
   - Regular PLA: when supports or nozzle retraction are required
2. Carbon fiber and balsa wood for spars
   - Structure within while also joining parts
3. Nylon bolts and nuts for assembly
   - Avoids magnetic field interference from steel bolts/nuts
4. Velcro strips to adjust CoG as required

Aerodynamic Results

Top Speed: 27.5 m/s; **Stall Speed:** 10.46 m/s;
CoG: 1 cm behind C/4; **NP:** 6.7 cm behind C/4;
Static Margin: 0.4; **Max L/D Ratio:** 13.11;
Wing Incident Angle: 8 degrees;
SST Coefficient of Lift: 0.70;

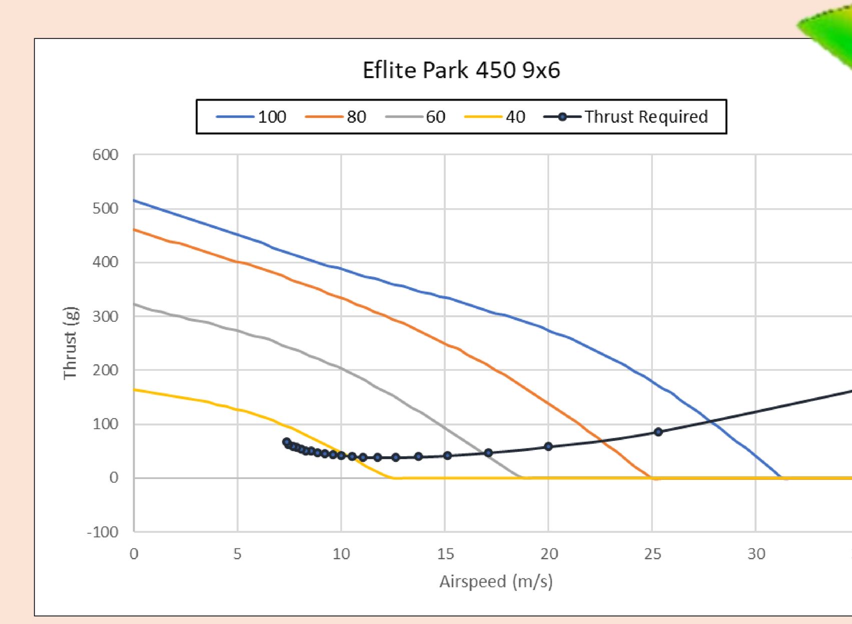

Figure 4. Thrust Required vs. Airspeed

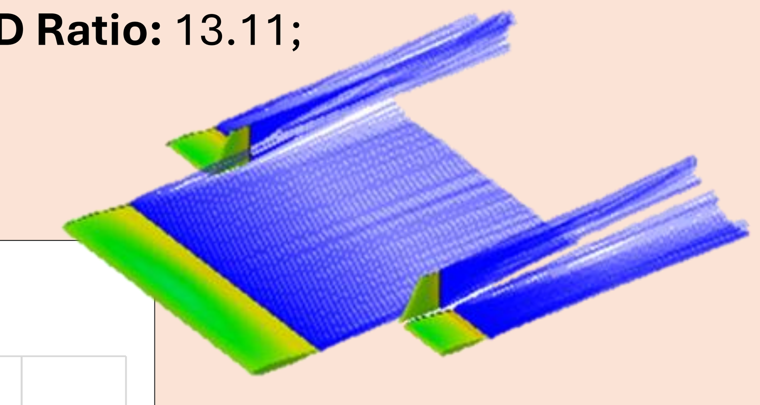

Figure 5. OpenVSP Streamlines

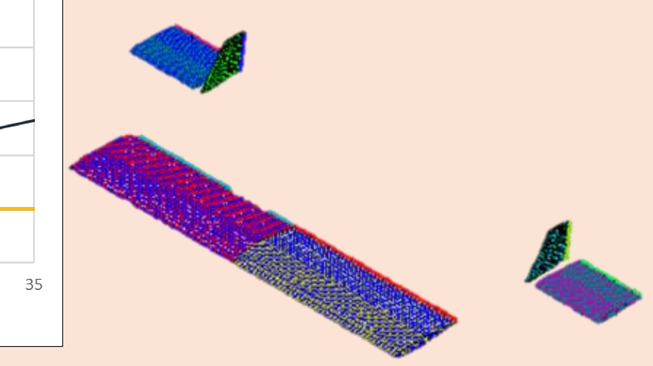

Figure 6. OpenVSP Mesh

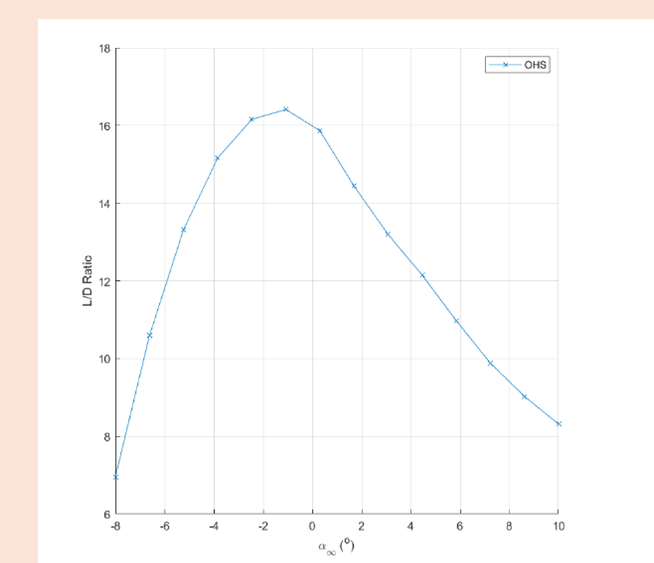

Figure 7. Lift to Drag Ratio vs. Angle of Attack

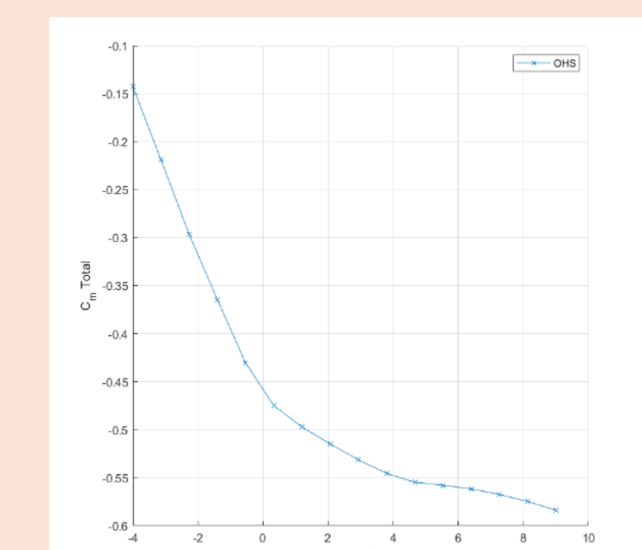

Figure 8. Moment Coefficient vs. Angle of Attack

Conclusions

Within this project, a successful prototype for an eVTOL version of the ACAD OHS drone was developed through engineering skills including aerodynamic concepts, CAD modeling, electronics, and manufacturing with LWPLA. The final weight exceeded 750 grams and flight was attempted. Future research efforts from the ACAD lab will work to meet the weight and flight time objectives.

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Nomenclature

eVTOL – Electric Vertical Takeoff-and-Landing
OHS – Outboard Horizontal Stabilizer
ACAD – Applied CFD and Aero-Design
LLT – Lifting Line Theory
CoG – Center of Gravity
NP – Neutral Point
L/D – Lift-to-Drag
SST – steady state
ESC – Electronic Stability Control
PLA – Polylactic Acid
LWPLA – Lightweight Polylactic Acid

References

[1] J.A.C. Kentfield, *Case of Aircraft with Outboard Horizontal Stabilizers,* AIAA. Journal of Aircraft. vol. 32, no. 2, pp. 398-403, March-April 1995

[2] De Alwis, A., Ward, R., Hinman S., (2024). Updated Aerodynamic Analysis of Outboard Horizontal Stabilizers. In *AIAA SCITECH 2024 ORUM* (p. 2336).

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