AE463

Aeromodel Design and Fabrication

Department of Aerospace Engineering

Design, Fabrication, and Flight Testing of a Twin-Fuselage Drone

Group 5

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All members of Group 5 contributed to the overall design, fabrication, and testing process. Specific responsibilities for documentation and analysis are detailed below.

1. Introduction (1.1, 1.2)
Authored by: Abhijeet Kumar, Paarth Jindal, & Rangan Pal

2. Design Analysis (OpenVSP)
Authored by: Adarsh Anurag, Arush Raju Chinchkhede, Pratham Singhal, & Sankalp Pande

3.1 Fabrication (Wings, Fuselage, etc.)
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3.2 Electronics Integration
Authored by: Adarsh Anurag & Paarth Jindal

3.3 Landing Gear Design
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4. Flight Testing
Authored by: Abhijeet Kumar, Adarsh Anurag, Rangan Pal, & Sankalp Pande

5. Conclusion & Future Work
Authored by: Arush Raju Chinchkhede, Paarth Jindal, & Pratham Singhal

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1 Introduction

1.1 Introduction to Model

Our project is a scratch-built, radio-controlled (RC) scale model inspired by the **PLA WZ-9 "Soaring Dragon"** (Xianglong). The real WZ-9 is a High-Altitude Long Endurance (HALE) reconnaissance UAV developed by China, notable for its unique "joined-wing" or "tandem-wing" configuration.

Our model adapts this advanced concept into a more practical, propeller-driven, twin-fuselage drone. The design uses lightweight thermocol (Styrofoam/EPS) for the airframe. The goal is to create a functional prototype that demonstrates stable flight while exploring the unique aerodynamic and fabrication challenges of a non-conventional, twin-boom airframe.

(a) Inspiration: The real WZ-9 Soaring Dragon.

(b) Our twin-fuselage RC model.

Figure 1: Comparison of the original aircraft and our scale model adaptation.

1.2 Motivation

The primary motivation was to apply aerodynamic principles to a complex, non-conventional airframe. The WZ-9 "Soaring Dragon" was chosen as an inspiration for several challenging reasons:

- **Unique Aerodynamics:** The twin-boom (twin-fuselage) layout, combined with a central wing, presents unique stability and control challenges, particularly in yaw.
- **Fabrication Challenge:** Fabricating two identical fuselages and ensuring perfect alignment of the wings and tail (H-tail) is a significant construction challenge.
- **Propulsion Adaptation:** We chose to adapt the design to a twin, central "pusher" propeller. Introducing its own challenges with torque and control surface blanking.

Our objective was to successfully fabricate this complex design from thermocol and demonstrate stable, controlled flight.

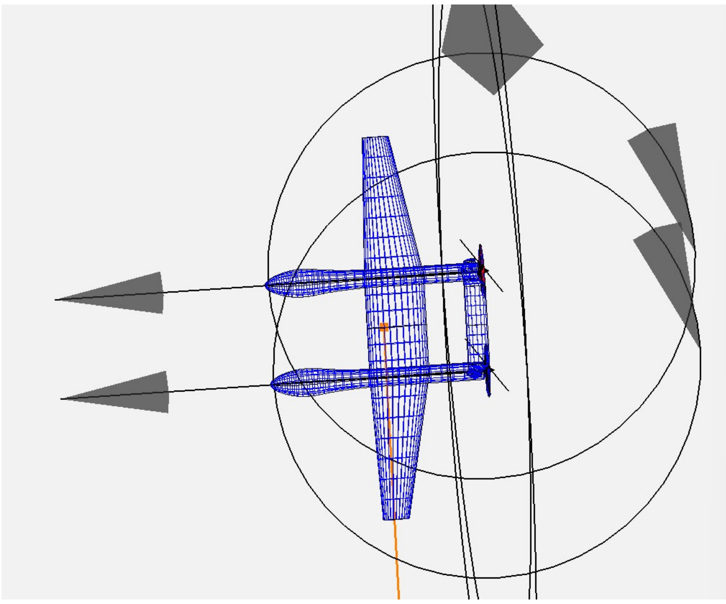
2 Design Analysis

The entire aircraft was first designed and modeled virtually to analyze its aerodynamic properties and ensure stability before fabrication began.

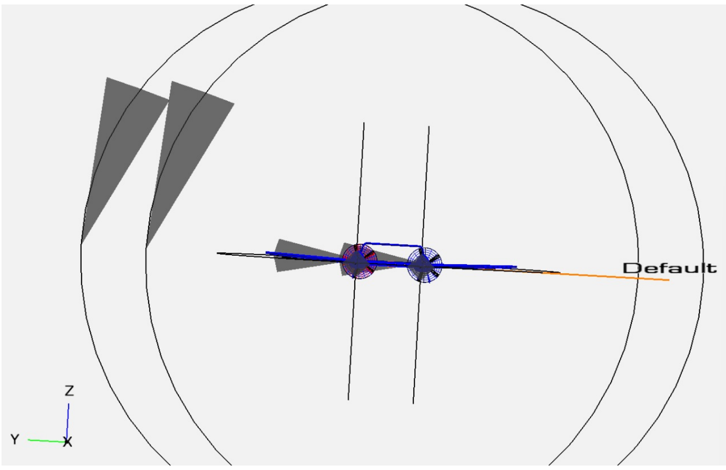
We used a combination of **OpenVSP (Open Vehicle Sketch Pad)** for 3D modeling and aerodynamic analysis.

The analysis was set up using the 3D model. This data was then used in a 3D stability analysis. We obtained the following key results:

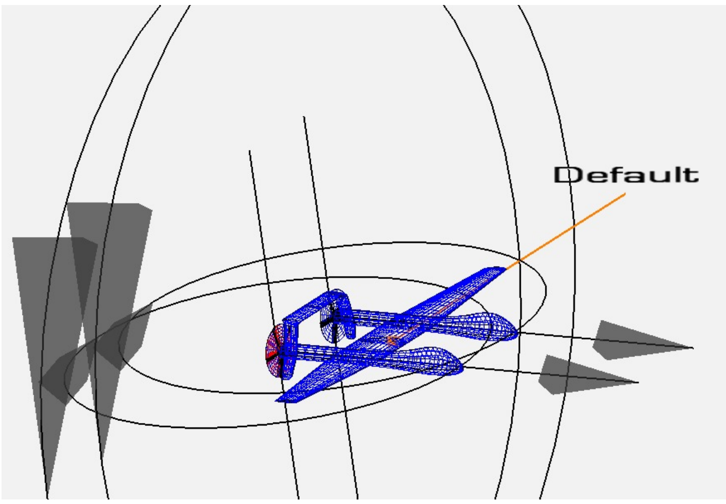
- **Lift Curve Slope ($C_{L\alpha}$):** Determined to be [e.g., 0.09 per degree].
- **Static Margin:** Calculated to be [e.g., 10%] with the Center of Gravity (CG) placed at [e.g., 6 cm] from the wing's leading edge. This indicated good longitudinal stability.



(a) Top View



(b) Front View



(c) Side View

Figure 2: 3D model of the WZ-9-inspired scale model rendered in OpenVSP.

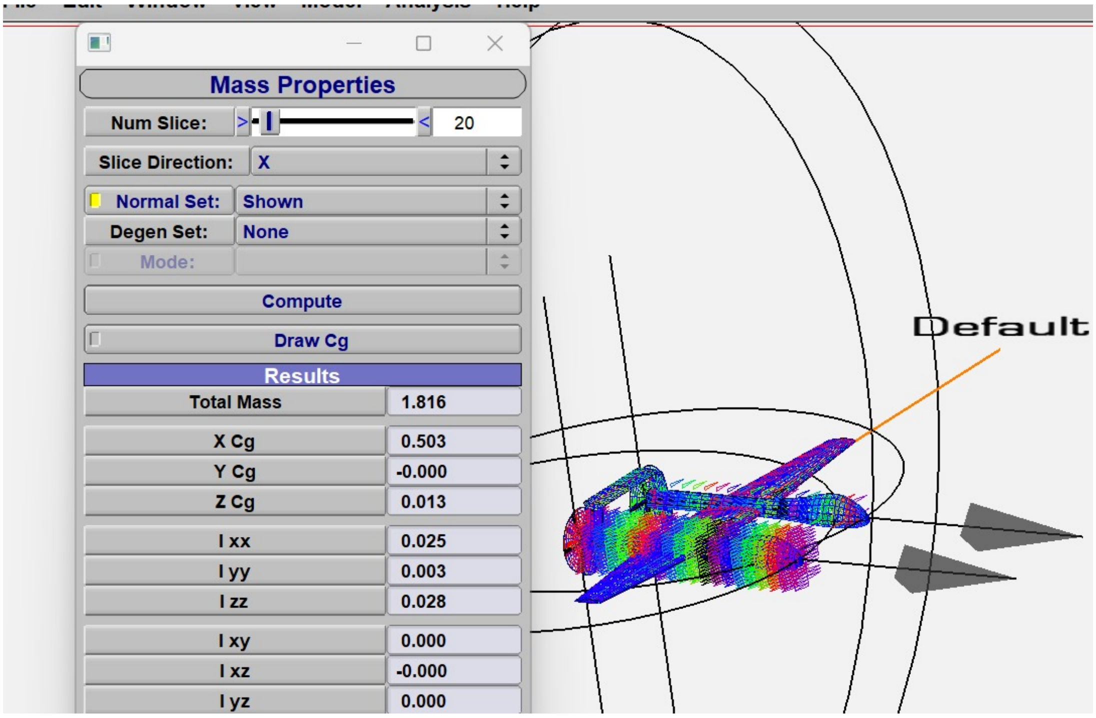


Figure 3: Mass properties and Center of Gravity (CG) analysis from OpenVSP.

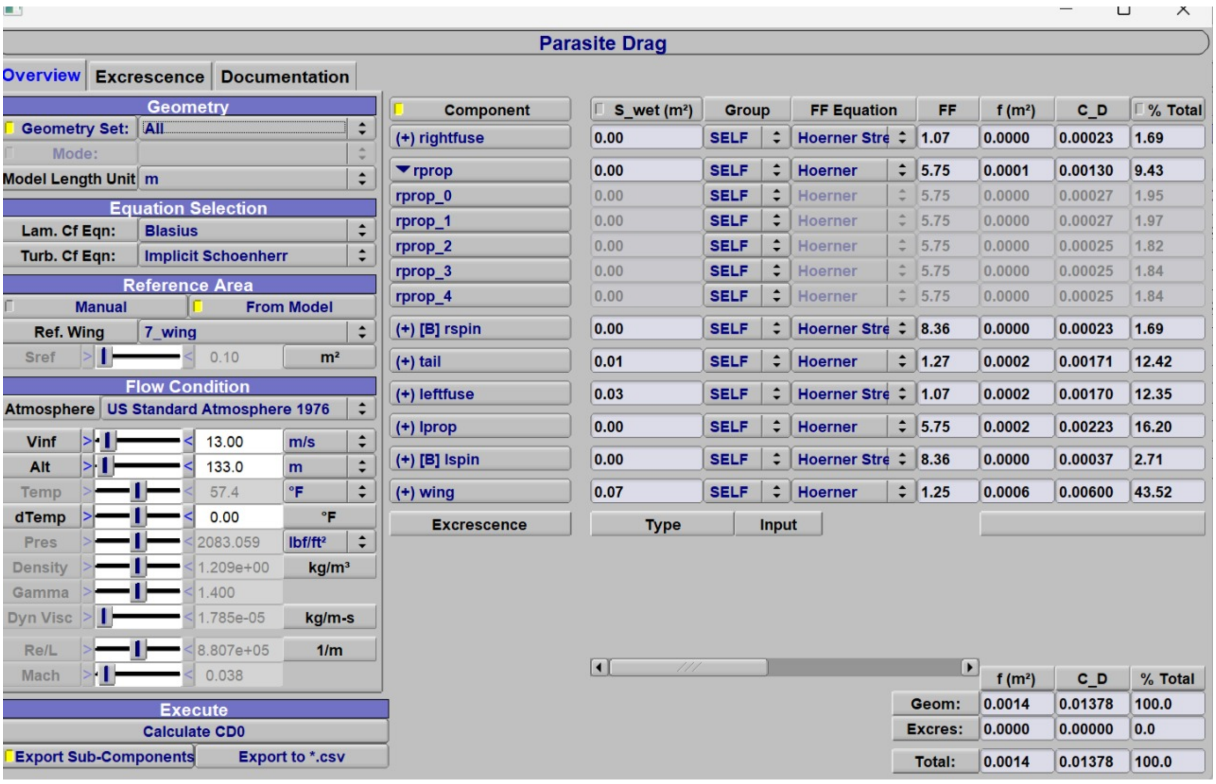


Figure 4: Parasite drag analysis calculated in OpenVSP, showing component contributions.

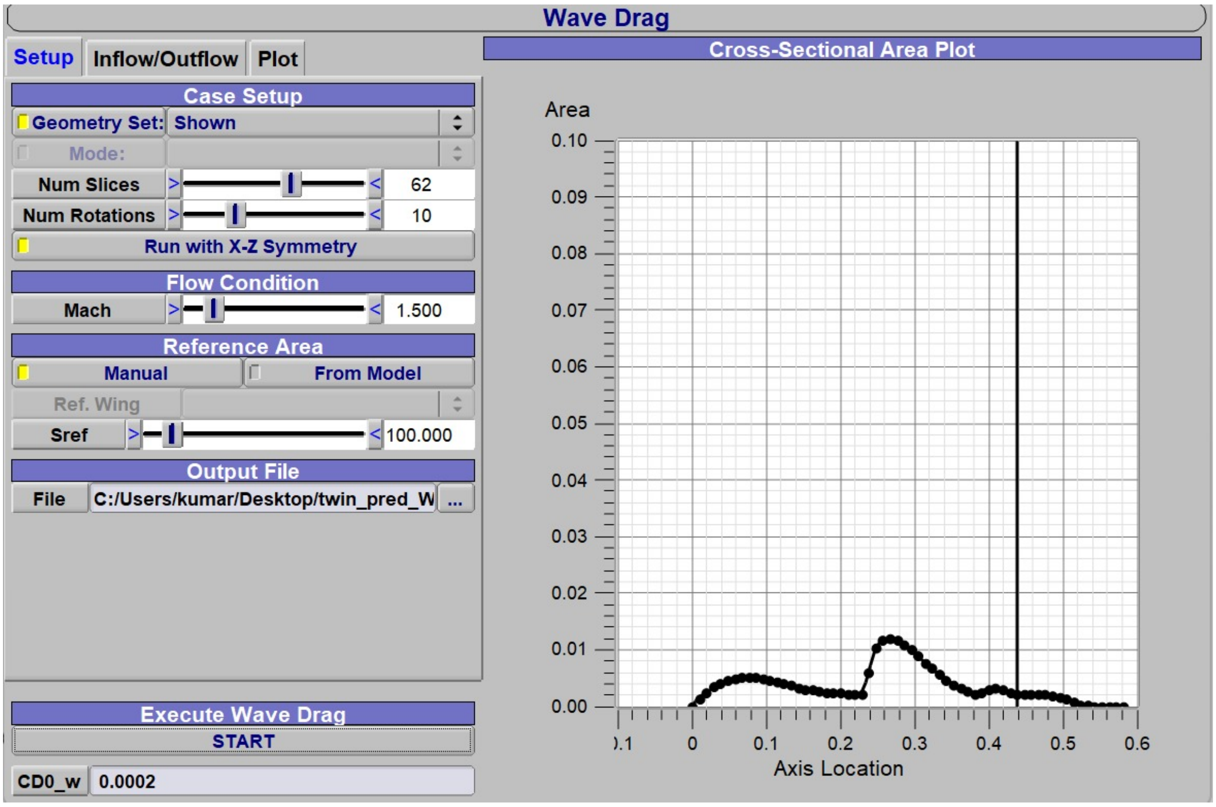


Figure 5: Wave drag estimates and cross-sectional area plot from OpenVSP.

- **Yaw Stability ($C_{n\beta}$):** This was a key focus. The twin booms and large H-tail provided a very high yaw stability moment, which is excellent for a reconnaissance-style platform.

A primary challenge was modeling the propeller wash from the central pusher motor and its effect on the H-tail. We ensured the horizontal stabilizer was placed [e.g., above the propeller disk] to maintain elevator authority.

3 Fabrication

3.1 Materials and Inventory

The airframe was constructed from a variety of materials as detailed in the project inventory (Table 1). The primary structure utilized thermocol (Styrofoam/EPS) sheets and balsawood.

Table 1: Project inventory and materials list.

Material/Item Name	Quantity	Component(s)
Wing		
T alimunium Rods	As needed	Main wing structure
Styrofoam (2" and 4")	As needed	Main wing core
Gi Rod (1m x 5mm x 2mm)	1+	Wing spars for reinforcement
Fuselage / Booms		
Balsawood (various sizes)	As needed	Fuselage structure
Styrofoam (2" and 4")	As needed	Fuselage shaping/core
Balsaply (760x380x3mm or 6mm)	As needed	Motor mounts
		Continued on next page

Table 1: Project inventory and materials list (continued)

Material/Item Name	Quantity	Component(s)
Tail Assembly		
Balsawood (various sizes)	As needed	Tail sections (horizontal & vertical stabilizers)
Styrofoam (2" and 4")	As needed	Tail sections (horizontal & vertical stabilizers)
Control Surfaces		
Nylon & Pinned Hinges, Horns, Clevis	1 bag (10 pcs)	Ailerons, elevator, and rudders
Propulsion		
Brushless Motors (Cobra 2204 or TURNIGY 2204)	2	Propulsion
Gemfan HQ 6045 Propellers (CW/CCW Set)	1 Set	Propulsion
Electronic Speed Controllers (ESCs)	2	Motor control
LiPo Battery 3000mAh	2	Power source for entire system
LiPo Battery Charger	1	Charging the LiPo battery
3.5mm Bullet Connectors	As needed	Connecting motors to ESCs
XT60 Connectors	As needed	Connecting battery to PDB/ESCs
Electronics & Control System		
Servos (Turnigy XGD11HMB)	4 to 6	Ailerons, elevator, rudders
Transmitter & Receiver (e.g., Futaba/skylink 6 ch)	1 Set	Aircraft control
Flight Controller (e.g., Flysky)	1	Flight stabilization and control
GPS Module	1	Autonomous flight functions
Power Distribution Board (PDB) or 5V BEC	1	Flight stabilization and control
Landing Gear & Mount		
Landing Wheels	4	Based on CAD design (required)
Assembly Tools & Adhesives		
Adhesives (Bondtite, Vetra Bond Quick)	As needed	General assembly
Surgical Knife, Paper Cutter, Hack-saw Blade	1 each	Cutting and shaping materials
Various Tapes	As needed	General assembly and reinforcement

3.2 Wings, Fuselage, and Control Surfaces

The airframe was constructed almost entirely from thermocol (Styrofoam/EPS) sheets.

Step 1. Airfoil Plotting and Cutting: The [e.g., NACA 2412] airfoil profile was printed to scale on paper to create templates.

Step 2. Hot-Wire Cutting: A hot-wire cutter was used to cut the main wing panels.

Step 3. Spars and Reinforcement: A [e.g., 6mm Alimunium fiber tube] spar was embedded in the main wing.

Step 4. Fuselage Construction: The twin fuselages (booms) were built using a "box-and-former" method. Identical thermocol formers were cut, and flat thermocol sheets were wrapped around them. A plywood "wing box" joined the two booms and provided a rigid mounting point for the wing.

Step 5. Control Surfaces: Ailerons were cut from the main wing. The H-tail was built as a single unit, with a central elevator and twin rudders. They were attached using rods and bondtide.

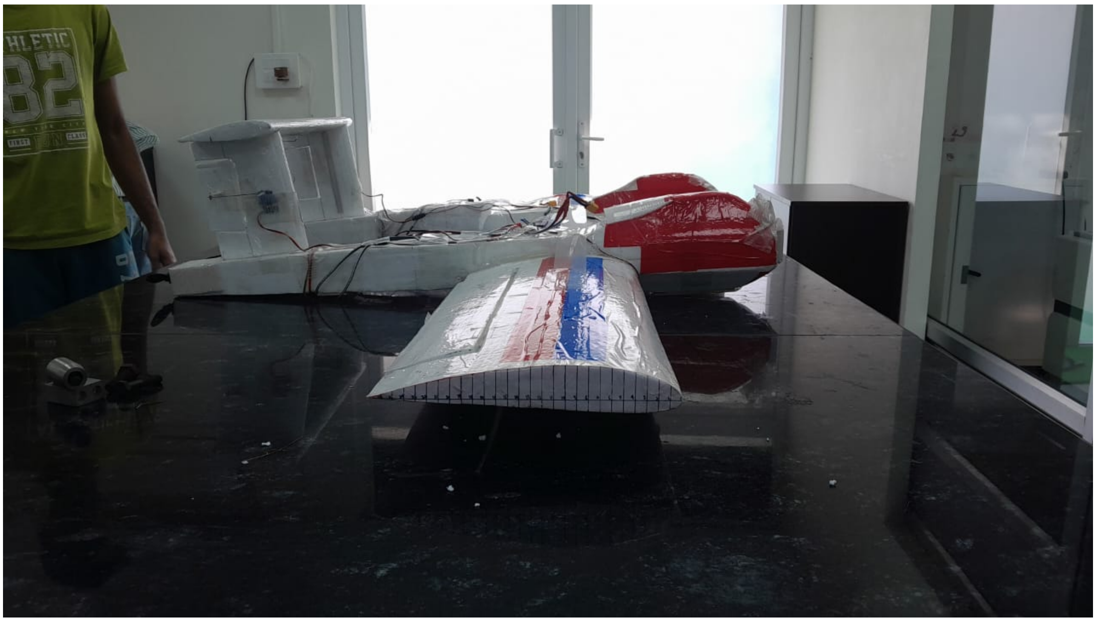


Figure 6: Airfoil cut with hot wire using equidistant markings on paper

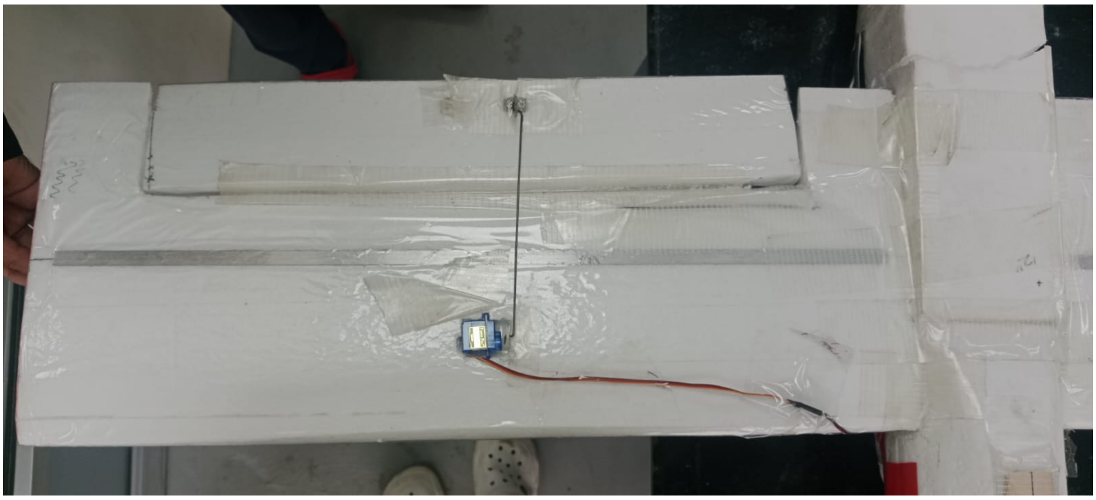


Figure 7: Spar used in the wing for strengthening.

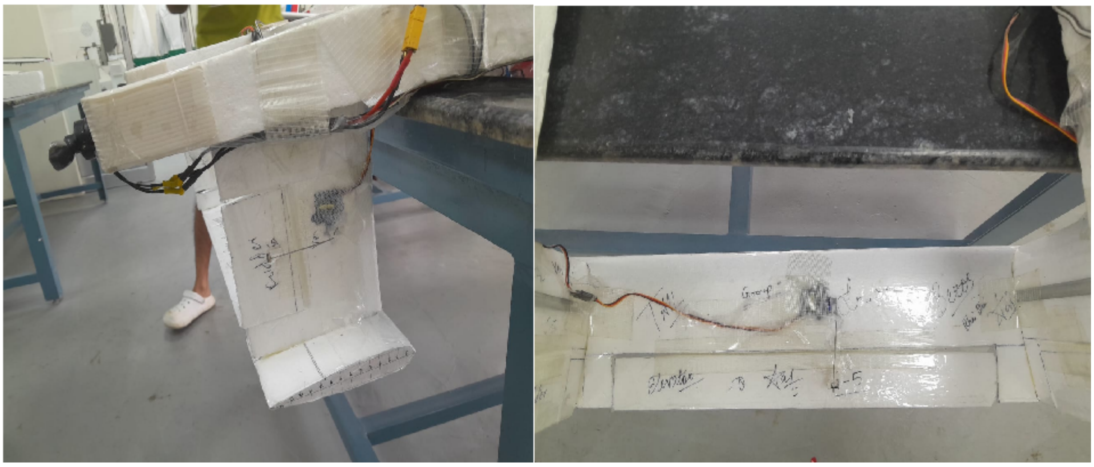


Figure 8: H-tail and V-tail configuration with control surfaces

Figure 9: Fabrication of the airframe and fuselage.

3.3 Electronics

The electronics were selected for a twin-propeller configuration. A detailed list of all electronic components, including motors, ESCs, servos, and the control system, is provided in the project inventory (see Table 1).

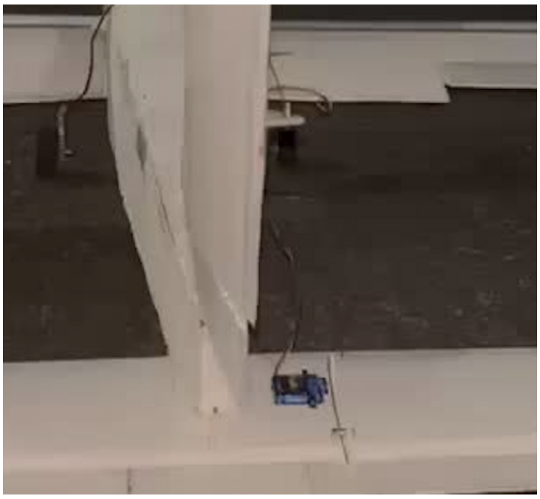
Integration Steps:

1. Plywood motor mounts were epoxied to the *front* of each fuselage boom.
2. Servos were hot-glued into pockets. Aileron servos were placed in the wings; elevator and rudder servos were placed in the tail.
3. The ESCs were placed in each fuselage with good airflow for cooling.
4. The receiver and battery were placed in the [e.g., central pod or one fuselage] to achieve the correct CG.

Calibration: Calibration was performed using the transmitter. This involved:

- **ESC Calibration:** Setting the throttle endpoints for the ESCs.
- **Control Surface Trimming:** Adjusting sub-trims so all control surfaces were neutral.
- **CG Balancing:** Shifting the LiPo battery forward or backward to achieve the design CG (see Figure 3).

(a) Rudder servo installation.



(b) Elevator servo installation.

Figure 10: Servo installation on the aircraft model

3.3.1 Propulsion System

The propulsion relies on two brushless DC motors mounted in a pusher configuration. As detailed in the inventory, these motors are mounted on 3mm plywood firewalls attached to the rear of each fuselage boom. This plywood reinforcement is critical to dampen vibrations and handle the thrust loads.

As shown in Figure 11, the motors are fitted with propellers (utilizing a CW/CCW pair) to neutralize torque effects, ensuring straighter tracking during throttle changes.

Figure 11: Close-up of the installed brushless motor and propeller setup.

3.3.2 Wiring and Connectivity

The connection between the Transmitter's receiver unit and the Flight Controller (or direct servo channels) was established using standard jumper wires. As illustrated in Figure 12, specific attention was paid to the channel mapping to ensure the transmitter stick inputs corresponded correctly to the aircraft's control surfaces.

To mitigate the risk of in-flight disconnection due to vibration or G-forces, the wiring harnesses were routed flat against the airframe and secured with tape. This also served to reduce drag and prevent loose wires from interfering with the pusher propellers.

Figure 12: Electronics integration details showing jumper wire connections between the receiver and control components.

3.4 Landing Gear

A fixed quad-cycle landing gear system was designed and fabricated, as seen on the final model (Figure 10b).

- **System:** Fixed configuration with two main gear and two nose gear.
- **Main Gear:** Attached to the twin fuselages for a wide, stable base.
- **Manufacturing:** The status of landing gear components is listed in the project inventory (Table 1).

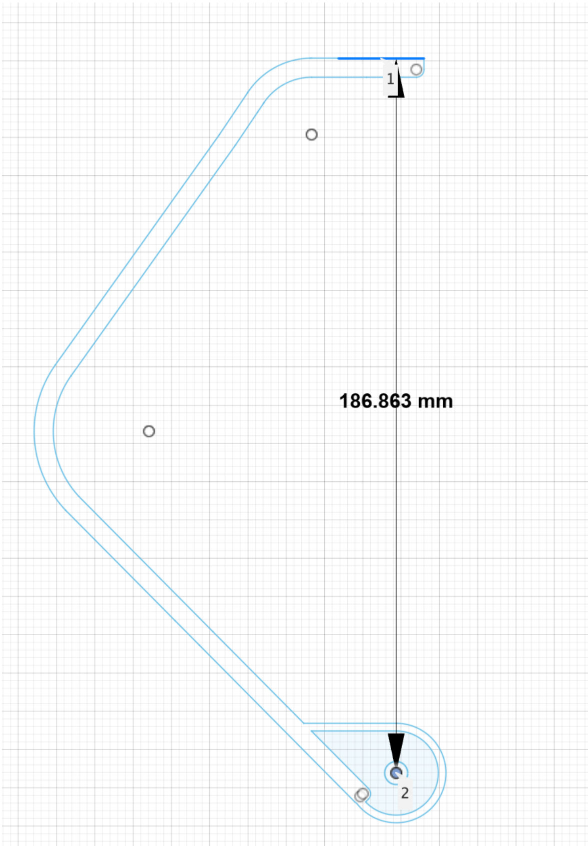


Figure 13: Installed Landing gear design.

4 Flight Testing

Flight testing was conducted at Airstrip. The flight (maiden) revealed several challenges.

- **Take-off:** The initial take-off roll was very unstable due to the wide landing gear.
- **Drive case:** The installed thrust should be 2.5 times higher than we installed since the takeoff required the wheels' frictional effects to be taken care of.
- **Wheels balance:** The wheels were need to be aligned to make a succesful takeoff possible after a sufficient takeoff distance.

Challenges and suggested Fixes:

1. **Tail-Heavy:** We needed to move the 3500 mAh LiPo battery forward to shift the CG and moments, which corrected the pitching-up tendency.

2. **Rudder Authority:** The rudders were [e.g., less effective than expected]. We [e.g., increased the control throws (deflection) on the transmitter].

3. **Landing Speed:** We learned to fly the approach with a lower throttle setting to "drag" the plane in and bleed off speed.

5 Conclusion

The twin-fuselage drone project was a partially successful. We demonstrated that a complex, non-conventional airframe inspired by the WZ-9 Soaring Dragon can be effectively fabricated using materials stated.

The design and analysis phase in OpenVSP (Figures 2 - 5) proved crucial, as our initial stability calculations for the twin-boom layout were accurate. The main challenges were mechanical (fabrication, aligning the booms and tail) and aerodynamic (calculating CG for a complex layout). The final aircraft flight was unsuccessful due to complexity and required precise fabrication strategy.

Future work could involve:

- Creating 3D printed components (motor mount, landing gear struts) for better durability.
- Adding flaps to reduce landing speed for takeoff.
- Integrating an FPV (First Person View) system, for which this stable platform is ideal.
- Integrating a larger propeller with larger thrusting capabilities for its takeoff.

A Appendix: Hand-Thrown Glider (HTG)

Prior to the main project, a simple hand-thrown glider was also designed and fabricated. The motivation was to test basic airfoil and stability principles with a simpler model.

- **Material:** styrofoam or thermocol
- **Airfoil:** A symmetric airfoil profile was taken
- **Design:** Conventional tail and wing model, with a 1 m wingspan.
- **Balance:** A small amount of [modeling clay and weights] was added to the nose to achieve the correct CG.

Testing involved simple hand tosses. We adjusted the CG and added a small amount of "up-elevator" angle of attack while testing. This project served as an excellent hands-on validation of stability principles.

Figure 14: flight of a hand glider.