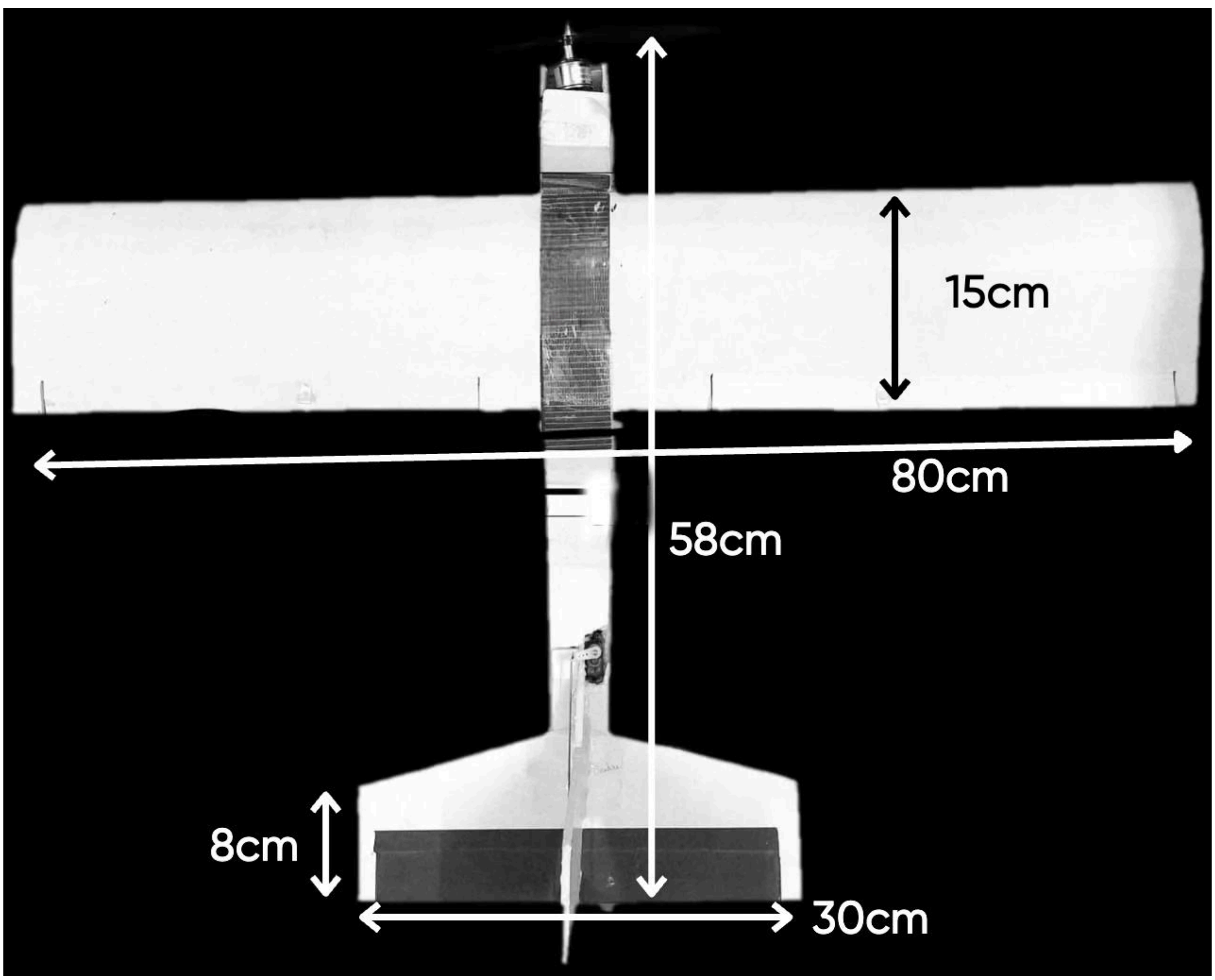
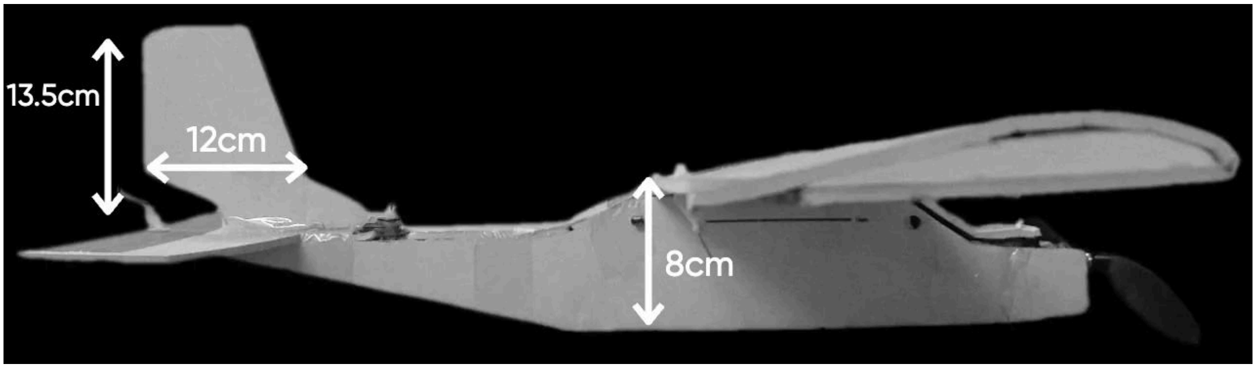
Wings Of Fire

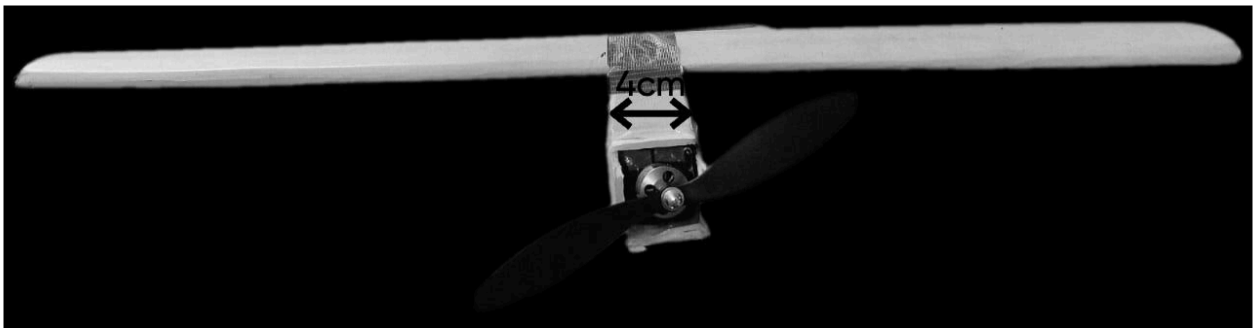
TECHNICAL REPORT

Design Overview and Configuration Selection

Airplane Drawings







Component selection

Airfoil Shape Selection: Semi-Symmetrical Clark Y

A Clark Y airfoil was selected for this RC aircraft design due to its balanced aerodynamic characteristics that suit both stable flight and moderate manoeuvrability. This airfoil type generates a good amount of lift while maintaining low drag at cruising speeds, which makes it well-suited for the required three laps around the field. Unlike a fully symmetrical airfoil, which prioritizes aerobatic performance, the semi-symmetrical profile provides increased lift at lower angles of attack, improving overall flight efficiency and stability during level flight.

Additionally, this airfoil shape enhances slow-speed handling, which is crucial during takeoff and landing within the 26-meter runway. The moderate camber of a semi-symmetrical design allows smoother airflow and better control at lower speeds, reducing the risk of stalling during approach and landing. This makes it an optimal compromise between performance and practicality, offering both reliable cruise efficiency and controlled slow manoeuvrability required for the mission profile.

Aileron - Differential aileron

Differential ailerons are a control surface configuration designed to minimize adverse yaw during roll maneuvers. In this setup, the upward-deflecting aileron moves through a greater angle than the downward-deflecting one. This difference in deflection reduces the increase in drag on the descending wing, which would otherwise cause the aircraft's nose to yaw opposite to the roll direction. By optimizing the up-to-down deflection ratio—typically between 1.5:1 and 2:1—differential ailerons enhance roll stability, improve coordinated turning, and reduce the need for rudder correction, leading to smoother and more efficient flight control.

Elevator - Conventional elevator

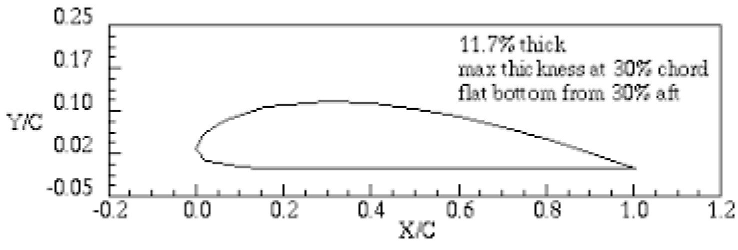
The selected elevator configuration is designed to provide stable and forgiving pitch control characteristics. This design choice ensures smooth and predictable aircraft response to control inputs, allowing for precise glide path adjustments during approach and landing. A stable elevator minimizes the likelihood of over-controlling, which is particularly beneficial during low-speed flight and flare maneuvers. Such characteristics are essential for maintaining consistent descent rates and achieving soft landings, which is especially important for the 26 m wingspan aircraft where smooth pitch transitions contribute significantly to overall flight stability and structural safety.

Propeller Selection

The 10-inch diameter provides adequate disk area to generate high static thrust, enabling rapid acceleration and climb performance. The 6-inch pitch offers a balance between top-end airspeed and low-speed controllability, allowing efficient cruise flight without excessive motor loading. The three-blade configuration improves thrust density and responsiveness compared to a two-blade alternative, while also increasing aerodynamic drag during throttle-off conditions, which assists in achieving a shorter landing rollout.

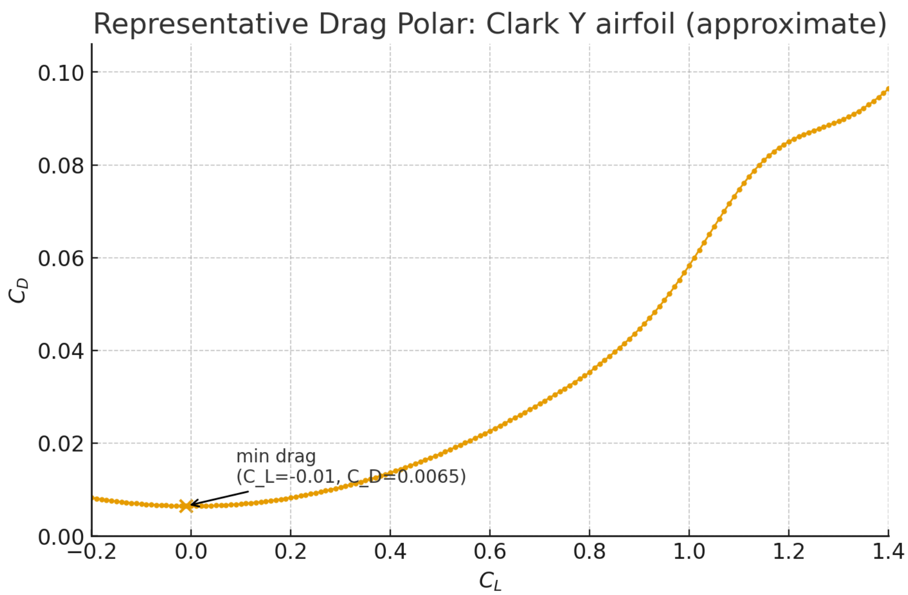
Overall, the APC 10×6E 3-blade propeller provides an optimal compromise between speed, thrust, and braking characteristics, fulfilling the design objectives of fast lap completion with controlled, short-distance landing.

Airfoil: Clark Y 1922

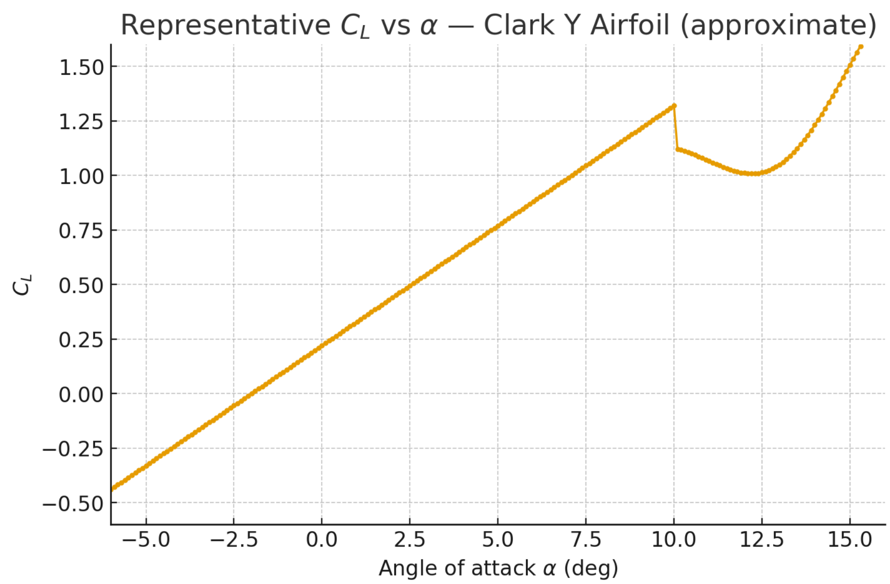


Clark Y airfoil

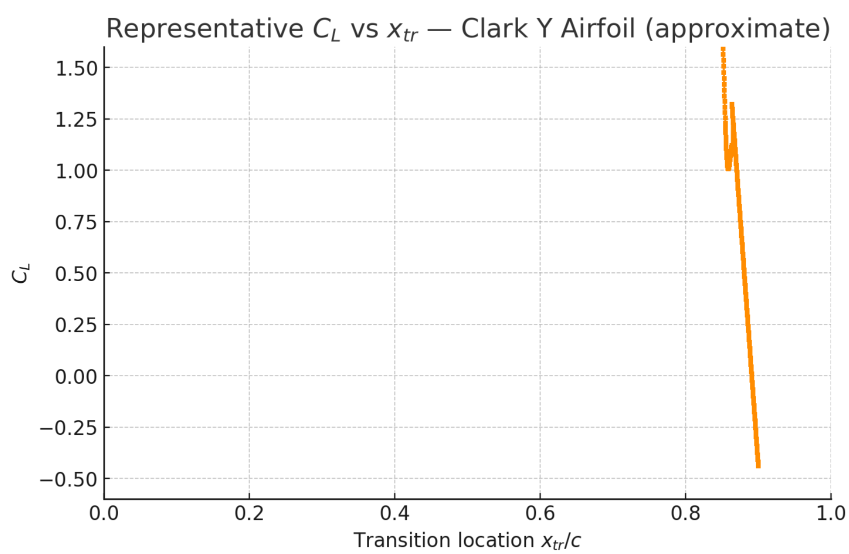
Aerodynamic Analysis and Performance Calculations



The C_D v/s C_L graph for the Clark Y airfoil is a smooth, upward-opening parabola showing that drag increases with lift. The Clark Y achieves a high maximum lift coefficient of approximately 1.8 to 1.9. The minimum drag coefficient is exceptionally low, typically around 0.008 to 0.010, which is achieved at a small positive lift coefficient. Beyond this region, near stall, flow separation causes a steep rise in drag, marking the boundary between efficient lift generation and high-drag, unstable flow. Overall, it's a well-balanced, efficient airfoil for general aviation and RC aircraft.



$C_L$vs α: The curve rises almost linearly with angle of attack, showing a steady lift increase as α grows. Lift is zero near 2°, matching the airfoil's zero-lift angle. Beyond about 10°–12°, C_L peaks and then drops sharply—indicating stall and flow separation.



This C_L vs xtr (top surface transition point) graph for the Clark Y (1922) airfoil illustrates how the laminar-to-turbulent transition shifts forward as lift increases. At low C_L, xtr remains close to 1.0, showing that most of the upper surface flow is laminar, resulting in low drag and smooth performance. As C_L increases, xtr decreases rapidly, indicating that the boundary layer transitions earlier due to higher surface pressure gradients and growing turbulence. Near stall, xtr approaches zero, meaning the flow over the upper surface becomes fully turbulent and begins to separate. This behavior reflects the Clark

Y's stable yet predictable boundary-layer transition characteristics across its operational lift range.

Design Rationale

Mission Objective and Design Priorities

The aircraft was designed as a **small-scale electric trainer and test platform** aimed at achieving *stable flight, low-speed controllability,* and *structural simplicity* while maintaining the ability to perform coordinated turns and basic aerobatic maneuvers.
Key design objectives included:

- Reliable control response with minimal pilot workload
- Safe take-off and landing within short runway distance
- Ease of repair and low fabrication cost
- Compatibility with common 3S Li-Po propulsion systems
- Balanced endurance (~10 min) and performance (~1.5:1 T/W ratio)

The design philosophy prioritized **efficiency and controllability** over extreme performance, targeting an ideal balance between lift, drag, and weight.

Performance predictions

Aircraft & Mass

Length: 640 mm

Wingspan: 800 mm

Flight weight (AUW): 495 g

Center of gravity (CG): 4.6 – 5.2 cm from wing leading edge

Aerodynamics & Speeds

Stall speed: 6.06 m/s

Cruise speed (nominal): 7.9 m/s

Typical contest cruise (laps): 9–12 m/s

Maximum speed (estimate): 55–60 km/h

Wing & Control Surfaces

Wing area: 0.12 m^2

Aspect ratio: 5.33

Aileron travel (cruise): ±12°

Aileron travel (demo/high): ±18°

Elevator travel: ±15°

Aileron differential: 60% up / 40% down

Thrust, Power & Endurance

Static thrust (approx.): 7.8 N (≈ 800 g)

Thrust-to-weight ratio: ~1.6

Cruise electrical current (typical): ≈ 7–9 A

Maximum electrical current (static/full throttle): ≈ 14–18 A

Cruise electrical power (typical): ~89 W

Peak electrical input (approx.): ~160–170 W

Battery energy (nominal): 24.42 Wh

Estimated flight time (typical): 14–16 minutes

Estimated flight time (range): 12–18 minutes

Performance

Typical climb rate: 3–6 m/s

Roll rate target: ~50–70°/s (tunable)

Endurance acceptance: flight time within ±15% of estimate

DIMENSIONS

Parameter	Value
Wingspan	80 cm
Wing width	15 cm
Aileron length	30 cm
Elevator Length	30 cm
Elevator width	8 cm
Rudder height	13 cm
Rudder Width	12 cm

Structural Design and Materials Selection

4.1 Overview

The RC model of the Pilatus PC-6 Turbo Porter is designed to be lightweight, strong, and easy to assemble, using coroplast sheets for the wings and sunboard for the wings .
The design maintains the same aerodynamic layout as the real aircraft — a high wing, conventional tail, and fixed landing gear — optimized for stable flight and short take-offs.

Design Goals:

- Keep the structure light for longer flight duration.
- Ensure enough strength to handle landings and minor impacts.
- Use easily available, low-cost materials.
- Maintain a proper center of gravity for stable flight.
- High wing design further increases the stability of the plane during the flight.

4.2 Wing Design

- Airfoil: NACA 2412
- Material: Depron
- Wingspan: 0.8 m
- Wing area: 0.12 m^2
- Type: High wing

Construction Details:

- The Depron sheet is made to form the airfoil shape, with the flutes aligned spanwise for strength.
- The leading edge is joined and sealed with hot glue; the trailing edge forms the ailerons.
- Differential ailerons are cut into the trailing edge and connected using small hinges or tape, controlled by 9 g servos.

Advantages:

- Lightweight, durable, and flexible — resists cracks from rough landings.
- Depron is waterproof and easy to repair by gluing.

4.3 Fuselage Design

- Material: Depron
- Shape: Rectangular box structure with tapering on the ends for simplicity and strength.
- Assembly: Panels are cut and glued using hot glue to form a hollow body.

Structural Reinforcements:

- The battery bay is placed near the center to help maintain correct balance (CG).

This fuselage design is light, and easy to modify for mounting electronics.

4.4 Tail Section

- Configuration: Conventional tail with separate elevator and rudder
- Material: Depron
- Elevator: Hinged using tape

This setup ensures good control response and flight stability.

4.5 Landing Gear and Wheels

- Type: Fixed undercarriage (non-retractable).
- Landing Gear Material: bent steel wire for strength and flexibility.
- Wheels: Rubber wheels

Component	Material Used	Reason for Selection
Wing	Depron	Lightweight, waterproof, flexible, easy to fold into airfoil
Fuselage	Depron	Light, strong enough for mounting internal parts and make airfoil
Tail	Depron	Low weight, easy to shape
Landing Gear	Aluminum / Steel wire	Strong and flexible, absorbs impact
Wheels	Rubber wheels	Durable and smooth-rolling on grass or hard ground
Control Rods	Steel wire	Precise control and good strength
Adhesive	Hot glue and scotch tape	Strong bonding for plastics and composites

4.7 Structural Strength and Balance

- Total weight:
- Center of Gravity (CG): 25–30% of the wing chord from the leading edge.

The chosen materials and structure provide a strong yet lightweight frame. The coroplast and sunboard combination keeps the model simple, inexpensive, and durable — perfect for reliable flight performance and easy repair.

4.8 Summary

The structural design of our RC model focuses on simplicity, durability, and flight stability.

- Depron gives strong and flexible wings.
- Rubber wheels and metal landing gear make it capable of safe landings.

This structure ensures a good balance between weight, strength, and performance — ideal for a practical and efficient RC aircraft.

Propulsion System Design

The propulsion system was designed to provide sufficient thrust-to-weight ratio and endurance for stable flight and controlled maneuvers while maintaining efficiency and reliability.
A brushless DC (BLDC) setup was selected due to its high power density, low maintenance, and precise throttle response suited for electric fixed-wing aircraft of this scale (~0.8 m wingspan).

MOTOR MODEL - A2212

Parameter	Specification
Motor Type	Brushless Outrunner Motor
KV Rating	1000 RPM/V
Number of Cells (Battery)	3 S Li-Po (Nominal Voltage = 11.1 V, Fully Charged = 12.6 V)
No-Load Speed	11,100 RPM (at 11.1 V) – 12,600 RPM (at 12.6 V)

No-Load Current (at 10 V)	0.7 A
Internal Resistance	65 mΩ
Maximum Efficiency Current	6 A – 12 A (> 75 %)
Maximum Efficiency	78 %
Maximum Power Output	180 W
Estimated Maximum Current	≈ 16 A (at 11.1 V)
Operating Voltage Range	9 V – 12.6 V (3 S Li-Po)
Typical Load Speed (under efficiency range)	Approximately 9,000 – 9,500 RPM
Motor Dimensions	27.5 mm (diameter) × 30 mm (length)
Shaft Diameter	3.17 mm
Motor Weight	47 g

ESC Details:

Model: FS-IA6B

Constant Current: 30A

BEC: 5V 2A.

Suitable Batteries: 3S LiPo

Battery (Pro Range LiPo):

Discharge rate = 3S
Charge = 2200 mAh
Voltage = 14.8 V
Approximate weight = 175 g

Thrust-to-Weight Ratio = $\frac{T}{W}$
T is the total thrust produced by the propeller and W is the total weight of the plane.
The estimated thrust in static air can be calculated using:
$T = C_T \rho n^2 D^4$
C_T - Thrust coefficient
ρ - Air density (approximately equal to 1.225 kg/m^3 at sea level)
n - Propeller rotation speed
D - Propeller diameter

Control System Architecture

Electrical components:

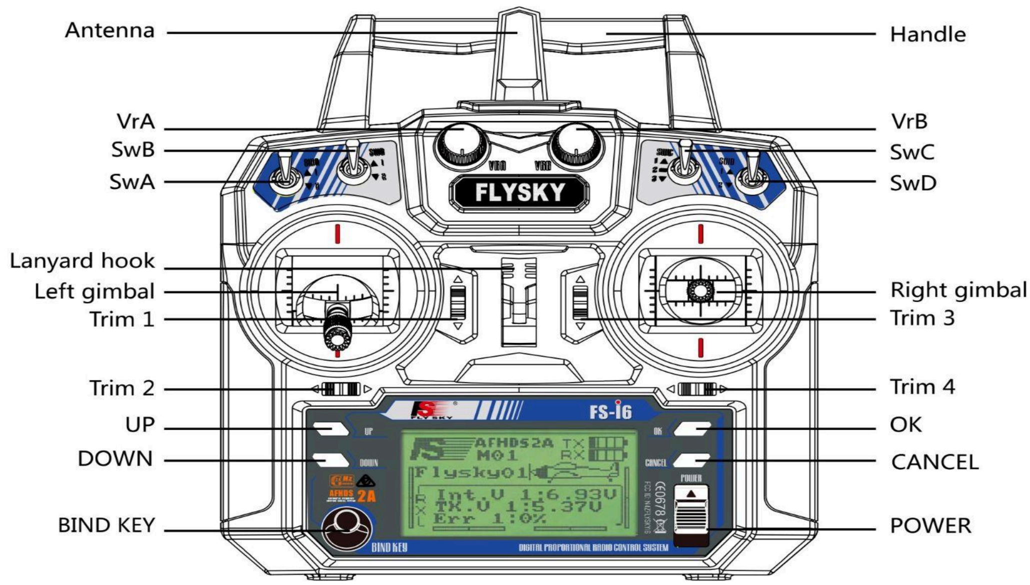
1. Electronic Speed Controller (ESC) with inbuilt Battery Eliminator Circuit (BEC) (FS-IA6B)
2. Brushless DC motor for the throttle (A2212/10T 1000kV)
3. 3 9g Mini Servo motors
4. Flysky FS-i6 remote control with receiver
5. 2200 mAh LiPo battery

Reason behind using the above components

- **2200 mAh 3S** increases usable flight time and gives more energy reserve for safe landings and longer demo flights — useful for competition demos and extra margin for heavier payloads.
- **1000 KV** is well matched to 3S for an 8×6 prop: good static thrust and controllable RPM without excessive current draw.
- **Dual aileron servos** Driving both from one channel preserves simplicity while keeping the benefits of two servos.

For the remote:
Channel 1 - Ailerons
Channel 2 - Elevons
Channel 3 - Throttle

Controller



Circuit