Designers Challenge

TECH GC 2025

Team Name: **BABY SHARKS**

Introduction

The pursuit of designing an RC plane suitable for industrial applications is both challenging and rewarding. Our design seeks to optimize performance, durability, and transportability while accommodating a meaningful payload capacity. This report presents the conceptualization, analysis, and detailed fabrication methodologies for our RC plane, developed by Team BABY SHARKS for TECH GC 2025. Our project integrates advanced aerodynamic theory, state-of-the-art material selection, and rigorous computational analyses to ensure the final design meets both performance and practical criteria.

Survey and Problem Statement

1. Challenges and Pain Points

Designing an RC plane for industrial purposes involves overcoming multiple interconnected challenges. One of the foremost challenges is **weight reduction**. To maximize payload capacity and improve flight dynamics, the structure must be lightweight; however, it also needs to maintain the necessary strength to endure aerodynamic loads, frequent takeoffs, and potential crashes. Our research indicates that materials such as balsa wood, PLA plastic, and carbon fiber offer a promising balance between low weight and high strength.

Aerodynamic efficiency is another critical challenge. The aircraft must achieve an optimal lift-to-drag ratio to ensure stable flight performance. Selecting the right airfoil shape (in our case, the **Selig S1223**) and optimizing wing geometry is essential for lift generation and minimizing drag during various phases of flight. Maintaining **structural integrity,** under variable load conditions is of paramount importance. This involves ensuring that key components like the wing spars and fuselage joints can withstand high stresses during takeoff, flight maneuvers, and landing impacts. Additionally, the design must include measures for crash resistance without incurring unnecessary weight.

The necessity for **modularity and transportability** further complicates the design process. Our plane must be disassembled and packed into a box with dimensions of 120 cm x 50 cm x 40 cm. This requirement drives design decisions related to detachable wings, tail assembly, and fuselage segmentation, ensuring that assembly and repair processes remain straightforward without compromising structural performance. Finally, **electronics integration is** crucial. Proper placement of electronic components (battery, ESC, receiver, and servos) is needed to maintain balance, functionality, and ease of access during maintenance. Ensuring compatibility among these components is essential for robust control and stability.

2. Key Factors in RC Plane Design

Our design approach is built on the following factors:
- **Aerodynamics**: Focusing on the Selig S1223 airfoil for high lift at low speeds and designing a trapezoidal wing planform with a slight taper.
- **Material Selection**: Employing lightweight yet durable materials. Balsa wood is chosen for the main structure, PLA plastic for aerodynamic coverings and components, and carbon fiber for reinforcing critical areas.
- **Payload Capacity**: The design is optimized to carry 11 golf balls (approximately 505 g) while maintaining stability of flight dynamics.
- **Modularity**: Key components are designed for rapid assembly/disassembly to meet transportability requirements without sacrificing performance.
- **Electronics Integration**: A deliberate layout is adopted to maintain proper weight distribution and facilitate reliable performance of electronic systems.

3. Research Methodology and Literature Review

Our approach began with an extensive literature review of RC aircraft design principles, exploring academic papers, industry reports, and case studies of previous designs. This research informed our selection of the Selig S1223 airfoil and guided our material choices. We then conducted iterative design studies, incorporating feedback from preliminary models and simulations. Our findings were further refined using advanced CFD simulations and FEA to validate aerodynamic and structural performance under anticipated operational conditions.

We also examined previous designs and industry standards, referencing sources such as:
- "Fundamentals of Aerodynamics" by John D. Anderson Jr.
- Various journal articles on CFD applications in low-speed aerodynamics.
- Industry whitepapers on material engineering for lightweight structures.

Design Specifications

1. Dimensional Analysis

The RC plane is designed with the following key dimensions:
- **Wingspan**: 1000 mm (1 m), providing a balance between lift generation and maneuverability.
- **Wing Chord**: An average chord length of 200 mm, ensuring adequate wing surface for lift.
- **Fuselage Length**: 700 mm, optimized to accommodate internal components while maintaining aerodynamic efficiency.
- **Payload Rack Roof Opening**: 100 mm x 290 mm located on the top of the fuselage, designed for easy payload insertion and secure mounting.

These dimensions have been selected to optimize the plane's aerodynamic profile and to fit within the specified disassembled storage dimensions.

2. Weight and Payload Considerations

Weight analysis is critical for both flight performance and structural integrity. The individual component weights are estimated as follows:
- Fuselage: Approximately 350 g

- Wings (with integrated spars): Approximately 400 g
- Tail Assembly: Approximately 100 g
- Electronics: Approximately 220 g
- Payload: Approximately 505 g

The overall estimated weight of the aircraft is around 1152 g. This balance of lightweight design and sufficient payload capacity ensures that the plane can maintain stable flight dynamics while carrying its designated payload.

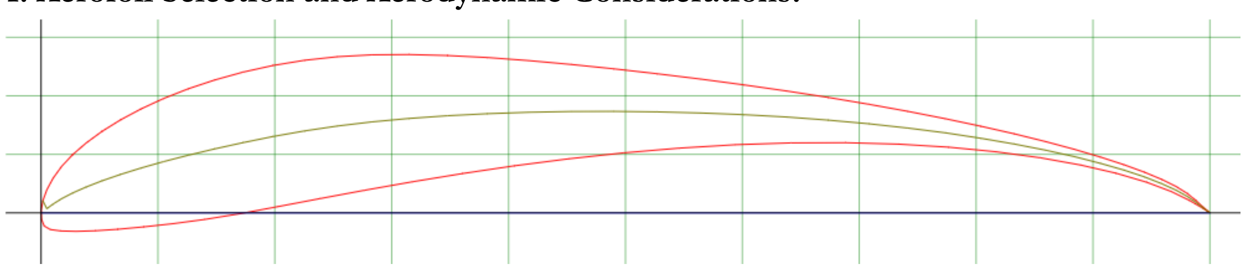
3. Structural Integrity Requirements

Structural integrity is maintained through a robust design of key load-bearing elements:
- **Wing Spars**: Constructed from balsa wood rods and further reinforced with PLA plastic coverings. Additional reinforcement using carbon fiber or extra balsa rods is provided in high-load regions.
- **Fuselage Joints**: Critical connection points are strengthened with carbon fiber rods, ensuring that joints can withstand stresses experienced during flight and impact events.

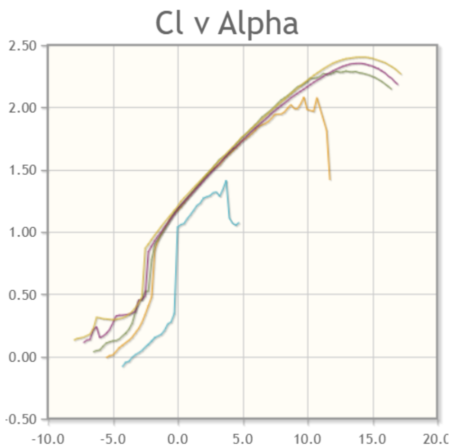
Our design is supported by FEA analyses, which confirm that maximum stress on the wing spars remains around 10 MPa, well within safe limits compared to the carbon fiber yield strength of approximately 400 MPa. Maximum deflections under load have been limited to about 3 mm, ensuring robust performance during operational conditions.

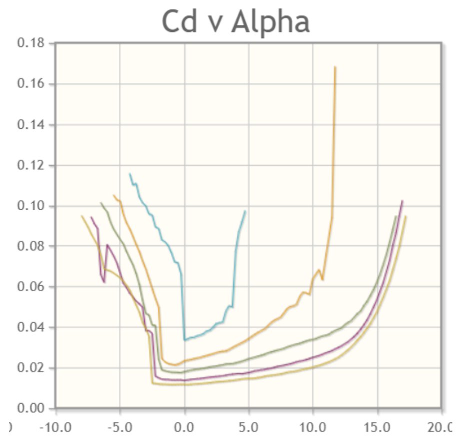
Design Analysis

1. Aerofoil Selection and Aerodynamic Considerations:



After evaluating various airfoil options, the Selig S1223 was chosen due to its high lift coefficient and gentle stall characteristics. At an angle of attack (AoA) of 14Â°, this airfoil achieves a lift coefficient (C_L) of approximately 2.2, while maintaining stable and predictable stall behavior. At cruise conditions (AoA of 4Â°), the airfoil offers an optimal lift-to-drag ratio of around 40, contributing significantly to battery efficiency and overall performance.





2. Computational Fluid Dynamics (CFD) Analysis

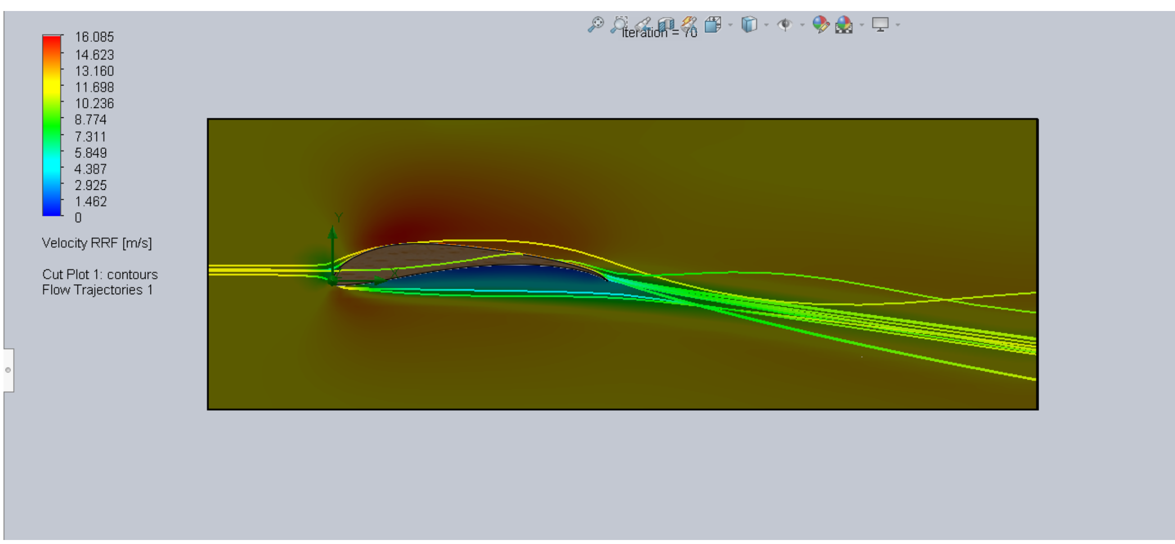
A detailed CFD simulation was performed on the Selig S1223 airfoil under cruise conditions. Key parameters in the simulation were:

- Airspeed: Approximately 12 m/s
- Angle of Attack: ~4Â°

The CFD results indicated:

- A lift coefficient (C_L) of approximately 1.2 at cruise,
- A drag coefficient (C_D) of roughly 0.03,
- A lift-to-drag ratio (L/D) of about 40.

These results confirm that our selected airfoil and wing geometry deliver efficient aerodynamic performance with minimal drag at cruising speeds. The simulation also identified that flow separation begins to occur at AoA values exceeding 14Â°, which aligns with our expectations for stall behavior and informs our operational envelope.

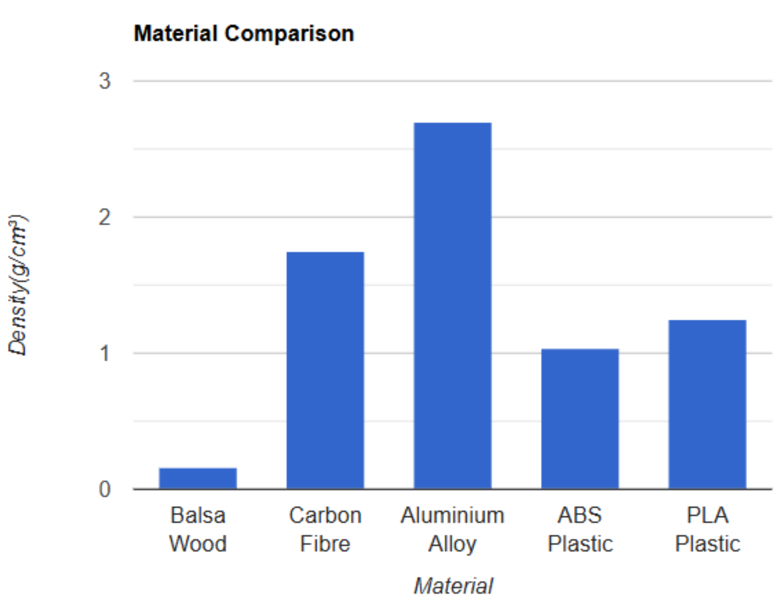


3. Finite Element Analysis (FEA) for Structural Stability

FEA was conducted on key structural components to ensure the design's resilience under maximum payload conditions. The analysis focused on:
- **Wing Spars**: Maximum stress levels were calculated to be approximately 10 MPa. This is significantly below the yield strength of the reinforcing carbon fiber (around 400 MPa), ensuring ample safety margin.
- **Deflection**: Maximum deflection under load was observed to be no more than 3 mm, confirming that the wing structure maintains sufficient rigidity during maneuvers and impacts.
These results validate our material selection and reinforcement strategy, ensuring that the design not only meets but exceeds the required safety and performance parameters.

4. Material Selection and Density Calculations

The final design incorporates a combination of balsa wood, PLA plastic, and carbon fiber. The rationale for material selection is as follows:
- **Balsa Wood**:
  - Usage: Main structure of the fuselage and wings.
  - Density: Approximately 0.16 g/cmÂ^{3}.
  - Rationale: Its low density makes it ideal for weight-sensitive applications while providing sufficient strength when properly reinforced.
- **PLA Plastic**:
  - Usage: Covering for the wings, skid plates, and certain internal components.
  - Density: Around 1.25 g/cmÂ^{3}.
  - Rationale: PLA is easy to work with (via laser cutting or 3D printing) and offers durability plus a smooth aerodynamic surface.
- **Carbon Fiber**:
  - Usage: Reinforcement in high-stress regions such as wing spars and fuselage joints.
  - Density: Approximately 1.75 g/cmÂ^{3}.
  - Rationale: Although denser than balsa, its exceptional strength-to-weight ratio is crucial for maintaining structural integrity during high-load scenarios.



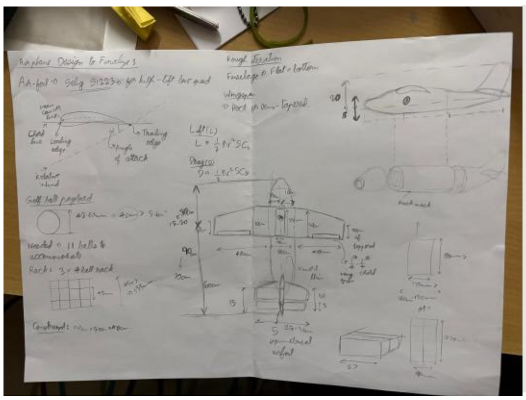
Sketches and CAD Model

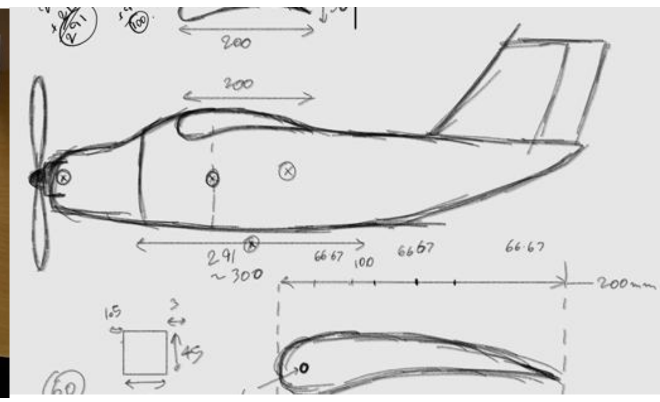
1. Conceptual Design and Hand Sketches

Our initial design phase involved detailed hand sketches that captured the overall configuration of the RC plane. These sketches highlighted:

- The fuselage design with internal channels for wiring and component placement.
- The wing structure, including the integration of spars and attachment points.
- The tail assembly and the payload rack roof opening, ensuring easy access for payload insertion.
- The modular connections allowing for quick assembly/disassembly without sacrificing joint integrity.

Each sketch was annotated with dimensions and material specifications to ensure a seamless transition to digital modeling.



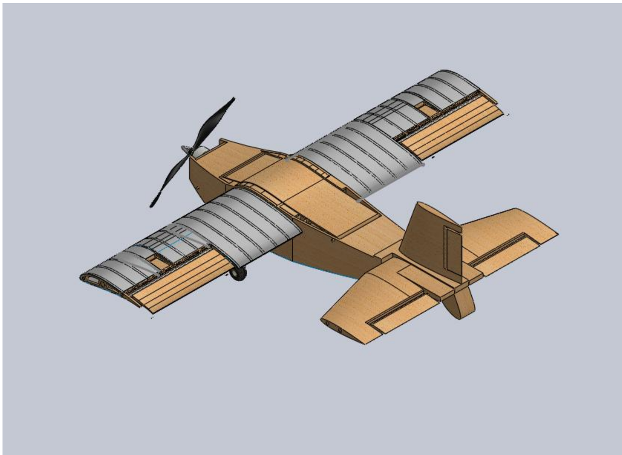


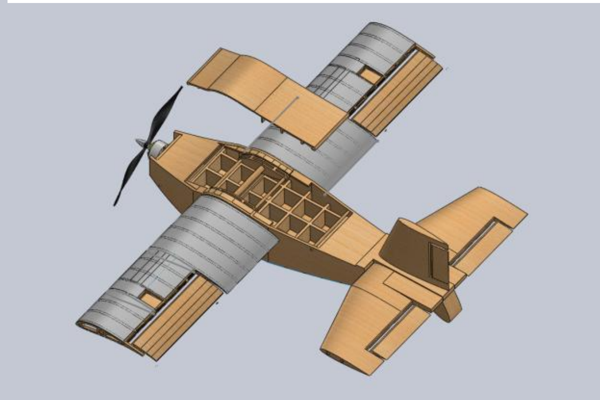
2. Detailed CAD Model and Assembly Files

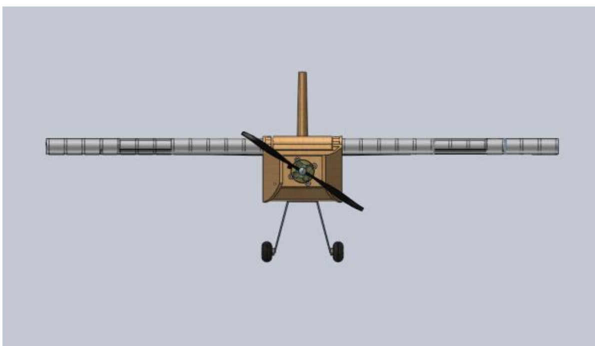
A comprehensive CAD model was developed using industry-standard software, where each component was designed as an individual part file. The assembly file integrates all components into a full-scale 3D representation of the aircraft. Key highlights of the CAD model include:

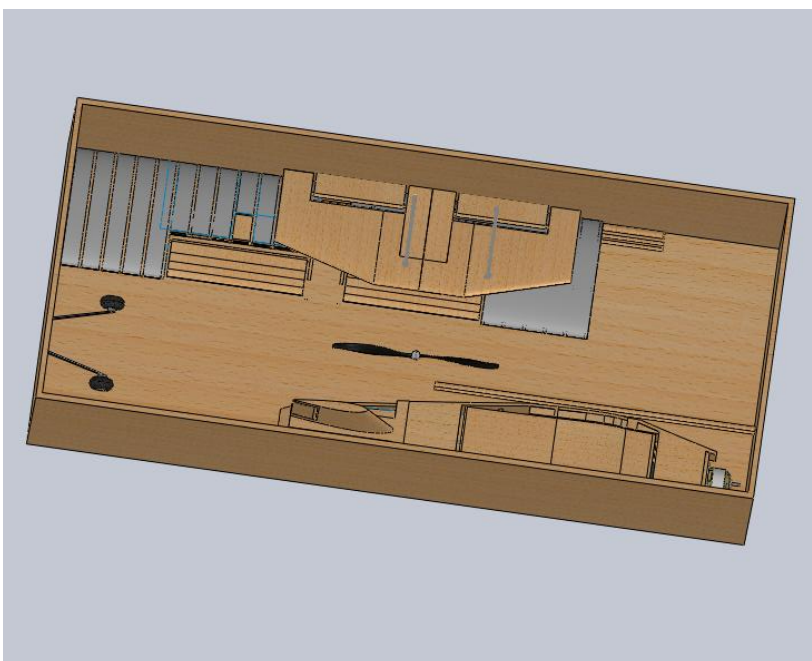
- **Parametric Design**: Allowing for quick adjustments to dimensions and tolerances.
- **Interference Checks**: Ensuring that all parts fit correctly within the disassembled box dimensions (120 cm x 50 cm x 40 cm).
- **Detailed Drawings**: Each component drawing includes precise dimensions, material specifications, and assembly instructions.

An example of the CAD model can be seen in Figure 4. Additionally, Figure 5 shows the mass properties derived from the CAD software, confirming the total weight (~1152 g) and center of mass coordinates.









Fabrication Methods

1. Manufacturing Processes

The manufacturing process for the RC plane involves a combination of modern fabrication techniques:
- **Laser Cutting**: Balsa wood sheets are laser-cut to precise dimensions, ensuring accurate and repeatable parts for the fuselage and wing surfaces.
- **3D Printing**: FDM-based PLA printing is employed to produce connectors, fasteners, and small-scale components. This method allows for rapid prototyping and customization.
- **Manual Assembly**: Certain reinforcements, such as the integration of carbon fiber rods, require manual assembly to ensure that the rods are correctly positioned in load-bearing regions.

2. Assembly and Disassembly Procedures

Ease of assembly and disassembly is critical for transportability. Our design incorporates:
- **Quick-Release Connectors**: The wings are attached to the fuselage using robust quick-release mechanisms that are reinforced with carbon fiber rods. This ensures that the wings can be detached and reattached within minutes.
- **Snap-Fit Joints and Screws**: The tail assembly and fuselage segments are connected via a combination of snap-fit joints and traditional screws, providing both ease of assembly and a secure connection.
- **Pre-Routed Wiring Channels**: The electronics compartment features pre-designed channels within the fuselage to neatly route wiring, reducing assembly time and minimizing potential damage during disassembly.

3. Tools and Techniques

Our fabrication approach leverages:
- Laser Cutting Machines: For rapid and precise cutting of balsa wood.
- FDM 3D Printers: For producing custom connectors and fasteners from PLA plastic.
- Manual Tools: Including precision screwdrivers, clamps, and measuring devices to ensure that all components are assembled to exacting tolerances.

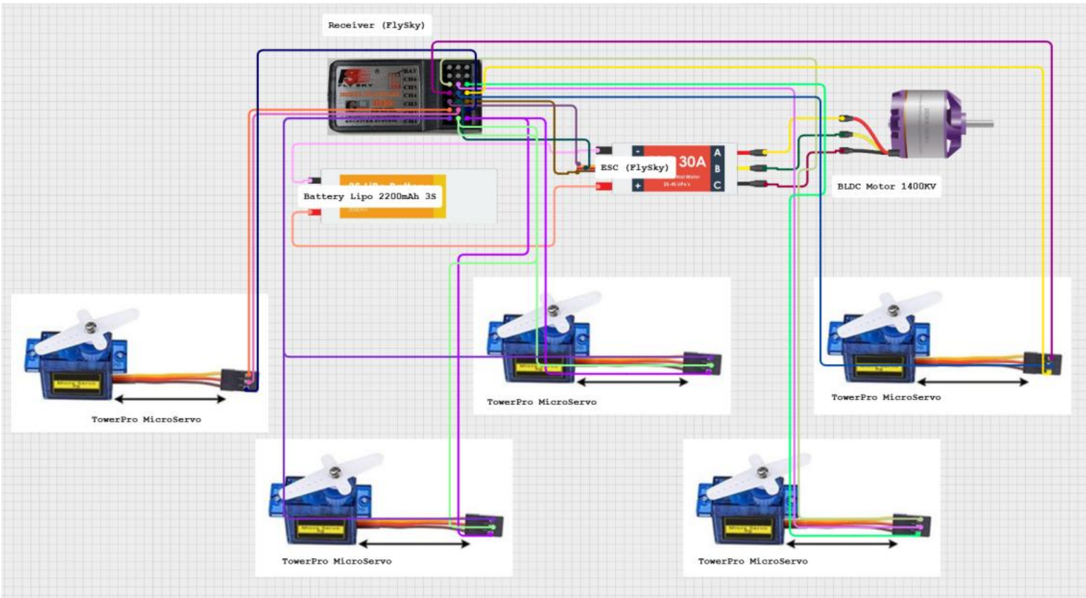
Electronics Design

1. Component Layout and Placement Rationale

The electronic system is carefully integrated to maintain the plane's center of gravity and ensure optimal performance:
- **Battery**: Positioned near the center of gravity (approximately 350 mm from the nose) to balance weight distribution.
- **Electronic Speed Controller (ESC)**: Located directly below the battery (around 300 mm from the nose), facilitating efficient cooling and minimal wiring complexity.
- **Receiver and Servos**: Strategically placed near the payload rack and control surfaces (receiver at approximately 400 mm from the nose) to ensure robust signal reception and precise control.

2. Block Diagram and Circuit Functionality

A detailed block diagram of the electronics layout is shown in Figure.



This diagram illustrates the power distribution network and control signal pathways, ensuring that each component functions in concert to deliver stable flight dynamics.

3. Weight and Balance Considerations

All electronic components have been selected not only for functionality but also for their minimal weight impact:

- The overall electronic assembly weighs approximately 220 g.
- Careful placement ensures that the aircraft maintains proper balance, which is critical for both stability in flight and ease of handling during ground operations.

Bill of Materials

1. Detailed Cost Breakdown

The following table provides an estimate of the total manufacturing cost:

Component	**Quantity**	**Total Cost (INR)**
Balsa Wood Sheets	5	Rs 2,000
PLA Filament (1 kg)	1	Rs 1,600
Carbon Fiber Rods	4	Rs 3,200
MicroServo	5	Rs 400
Battery	1	Rs 1,200
ESC	1	Rs 800
Receiver	1	Rs 640
Total Cost:		Rs 9,840

2. Justification and Analysis of Expenses

The overall cost is justified by the selection of high-quality, lightweight materials and precision fabrication techniques. While balsa wood and PLA plastic are chosen for their cost-effectiveness and ease of processing, the use of carbon fiber in critical areas ensures that the plane can withstand high-stress conditions without a significant weight penalty. The electronics have been sourced with a focus on balancing cost, performance, and reliability, ensuring that the overall design remains within budget while meeting performance expectations.

9. References

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