

Design and Development of a Radio-Controlled Aircraft and Concept of Electric Vertical Takeoff and Landing (eVTOL)

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Abstract: This study presents the design, development, and preliminary testing of a radio-controlled (RC) aircraft and conceptual work on its electric vertical take-off and landing (eVTOL) capabilities. The primary objective is to explore the feasibility of incorporating VTOL functionality into a lightweight RC platform using accessible, low cost materials and components. The aircraft is constructed using foam board for its favorable weight to strength ratio and employs a straightforward elevon-based control mechanism for pitch and roll modulation. A brushless DC motor, electronic speed controller (ESC), and Li-Po battery constitute the propulsion system, while an Arduino Nano and IMU (MPU6050) support the eVTOL's stability and control. The system is manually operated via a Flysky FS-i6 transmitter and receiver. The prototype demonstrated stable flight in fixed wing mode and basic lift-off and hover capabilities in VTOL mode; however, it encountered instability during mode transitions due to limitations in PID control tuning and power demands. The outcomes suggest that hybrid flight systems are achievable on a small scale, albeit with significant challenges in stability control and energy efficiency. This work lays a foundation for future investigations into hybrid UAV platforms and low-cost autonomous aerial mobility solutions.

Index Terms: RC aircraft, eVTOL, PID control, brushless DC motor, elevon, UAV, Arduino, foam board, flight stability.

I. Introduction

Advancements in electric propulsion and the increasing demand for urban air mobility have catalyzed the emergence of electric vertical take-off and landing (eVTOL) aircraft. These vehicles combine the vertical lift capability of helicopters with the aerodynamic efficiency of fixed wing aircraft, offering transformative potential for transportation, emergency response, and surveillance in urban environments. eVTOL technology is integral to evolving concepts such as NASA's Urban Air Mobility (UAM) initiative, which envisions integrated air transport solutions in dense urban centers.

Parallel to this trend, the proliferation of unmanned aerial vehicles (UAVs) and hobby grade radio-controlled (RC) aircraft has opened avenues for educational and experimental research. These platforms provide cost effective and manageable environments to test complex flight concepts like VTOL on a smaller scale. This project takes advantage of these opportunities by designing a lightweight RC aircraft with integrated eVTOL capabilities, emphasizing simplicity, modularity, and low-cost construction.

Problem Statement

Traditional fixed-wing RC aircraft require runways or launch mechanisms for takeoff and landing, limiting their deployment in constrained environments. In contrast, multirotor VTOL systems, while maneuverable, often necessitate complex control algorithms and exhibit high power consumption. This project seeks to bridge the gap by developing a hybrid design that retains the operational simplicity of fixed wing aircraft and enabling vertical take off and landing through integrated VTOL functionality.

Project Overview

The project encompasses the conceptualization, CAD design, construction, and testing of a RC aircraft and its eVTOL functionality. It features foam board construction for reduced weight, an elevon based control mechanism for maneuverability, and a propulsion system centered around a brushless DC motor and electronic speed controller. The eVTOL functionality is enabled through an Arduino Nano based control system incorporating an inertial measurement unit (IMU). The aircraft is operated manually using a Flysky FS-i6 transmitter, supporting both horizontal and vertical flight testing.

Significance of the Study

This study holds educational and experimental significance by providing practical insights into UAV design, control systems, propulsion technology, and flight dynamics. It demonstrates how hybrid aircraft models can be constructed using accessible tools and components, making the research relevant for academic institutions, UAV hobbyists, and early-stage prototyping in aerospace engineering. Furthermore, the integration of CAD modeling and electronic control fosters a multidisciplinary approach essential for next-generation aerial mobility solutions.

Objectives

This project aims to design, construct and evaluate a hybrid radio-controlled (RC) aircraft and conceptual work on its electric vertical take off and landing (eVTOL) capabilities. It emphasizes a low cost, modular approach using accessible materials and

digital design techniques. The research focuses on achieving aerodynamic efficiency, functional control systems, and structural integrity suitable for experimental and educational purposes.

General Objective

To develop a functional prototype of a hybrid RC aircraft and conceptual work on its eVTOL features, leveraging computer aided design (CAD) tools for precision modeling, and applying electronic control systems to achieve both horizontal and vertical flight operations.

Specific Objectives

- **Structural Design:** To model the RC aircraft and eVTOL configuration using CAD software to ensure dimensional accuracy, component alignment, and weight distribution optimization.
- **Component Selection:** To identify and integrate suitable propulsion and control components, including motors, electronic speed controllers (ESCs), servos, batteries, and microcontrollers, based on thrust to weight ratios and system compatibility.
- **Airframe Construction:** To fabricate a light weight, aerodynamically stable airframe using foam board and supporting materials such as hot glue, 3D-printed parts, and control links.
- **Control Mechanism Implementation:** To configure an elevon-based control system that combines pitch and roll control via two SG90 servos, simplifying the mechanical design.
- **Manual Control Integration:** To implement remote manual control using a Flysky FS-i6 transmitter and receiver system, ensuring real-time response in both RC and VTOL modes.
- **Propulsion System Configuration:** To assemble a propulsion system comprising a 2200KV brushless DC motor, a 30A ESC, and an 11.1V 1500mAh 40C Li-Po battery to achieve sufficient lift and endurance.
- **Testing and Evaluation:** To perform preliminary flight tests in controlled environments, assessing lift, maneuverability, and stability during both vertical and horizontal flight phases.
- **Performance Assessment:** To analyze flight performance data and propose iterative improvements for enhanced stability, control, and energy efficiency.

II. Literature Review

This section reviews existing research and technological developments relevant to the design of electric vertical take-off and landing (eVTOL) systems and radio-controlled (RC) aircraft. It examines key elements including flight configurations, control mechanisms, material choices, and electronic components. The review highlights both academic studies and practical implementations that have informed this project.

Evolution of eVTOL Technology

eVTOL aircraft are at the forefront of urban air mobility (UAM) initiatives aimed at addressing transportation inefficiencies in congested urban areas. They merge vertical lift capabilities with fixed-wing efficiency, thereby eliminating the dependency on runways. NASA's UAM initiative emphasizes the transformative potential of eVTOLs in urban transportation systems [1]. The integration of electric propulsion, autonomous control systems, and advanced materials is enabling rapid evolution in this field.

Fixed-Wing and Hybrid VTOL Systems

Hybrid VTOL aircraft combine characteristics of fixed-wing aircraft and multi rotors, facilitating efficient cruising and vertical operations. Configurations such as tilt-rotor, tilt-wing, and tail-sitter are explored extensively in academia. Anderson et al. [2] at Stanford University demonstrated the advantages of hybrid VTOL designs in achieving better range and efficiency compared to pure multi rotor systems. However, these designs often require advanced control systems including GPS, IMU, and real-time orientation feedback to handle flight transitions.

RC Aircraft Design Principles

RC aircraft serve as valuable tools for research and hobby applications due to their simplicity and adaptability. Stability in flight is governed by key parameters such as thrust-to-weight ratio, center of gravity (CG), wing loading, and airfoil design. The research by Rehan et al. [3] underscores the importance of balancing CG and minimizing wing loading for low-speed flight stability. Foam board is a popular material for RC aircraft due to its low cost, ease of manipulation, and lightweight properties.

Elevon Control Mechanism

Elevons are a hybrid control surface that combines the functions of elevators and ailerons, commonly used in delta wing and flying wing configurations. They provide pitch and roll control using only two servos, which reduces weight and mechanical complexity. Beard and McLain [4] demonstrated the efficiency of elevons in minimalist UAV platforms, particularly when paired with programmable transmitters that support mixing functions, such as the Flysky FS-i6 used in this study.

Precise Component Selection

The performance of RC and eVTOL systems is significantly influenced by component compatibility. High KV brushless motors offer high rotational speeds ideal for lightweight platforms. ESCs should exceed expected current loads by at least 20 – 30%, and Li-Po batteries must have high discharge rates to support peak loads during take-off. The SG90 micro servo is frequently employed in educational UAVs for its cost effectiveness and adequate torque for foam-based applications. The MPU6050 IMU and Arduino Nano are commonly used for basic flight stabilization in small UAVs [5].

Role of CAD in UAV Development

Computer-aided design (CAD) tools such as SolidWorks and Fusion 360 are instrumental in UAV prototyping. They allow precise modeling of geometries, simulate weight distribution, and ensure structural symmetry. CAD also supports the generation of cutting templates and layout planning, which are vital for error-free assembly. As evidenced in student UAV competitions, CAD contributes to improved build accuracy and facilitates early stage validation of design concepts.

III. Methodology

This section outlines the experimental and design methodology employed in developing the RC aircraft and conceptual work on its eVTOL functionality. The approach encompasses iterative design, component selection, CAD modeling, prototyping, and performance testing.

Design Approach

A prototyping methodology was adopted, combining theoretical design with practical fabrication and iterative testing. Initial design concepts were sketched, followed by precise modeling using CAD tools. The system design aimed to simplify mechanical complexity while integrating both RC and eVTOL flight modes.

Materials Used

Two primary construction phases were implemented:

- **Prototype phase:** Built using cardboard for concept validation.
- **Final build:** Constructed with foam board for structural strength and minimal weight.

Additional materials included:

- Hot glue for assembly
- 1.1 mm push rods for control linkages
- Velcro straps for battery mounting
- 3D printed parts: motor mounts, tilt mechanisms, control horns
- Spray paint for protective coating and visual differentiation

Electronic Components

Table I Electronic Components Used

Component	Specification
Motor	2200KV Brushless DC motor
ESC	30A Electronic Speed Controller
Battery	11.1V 3S 1500mAh 40C Li-Po
Transmitter/Receiver	Flysky FS-i6 with FS-iA6B receiver
Servos	SG90 micro servos
Propeller	5149N tri-blade
Microcontroller	Arduino Nano
IMU	MPU6050

CAD Modeling

SolidWorks was used for structural design, including:

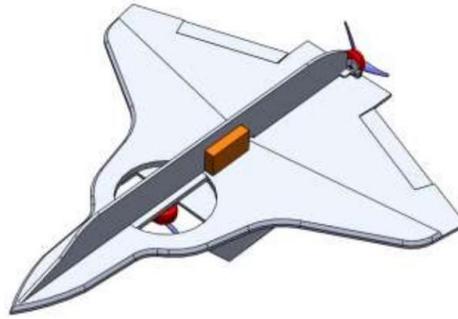


Fig. 1. Cad Model

- Symmetric airframe modeling
- Component layout (motor, battery, control surfaces)
- Generating 2D templates for material cutting
- Weight distribution and CG alignment estimation

Control System Configuration

For RC Plane:

- Elevons controlled by two SG90 servos via Flysky FS-i6 transmitter
- ESC powered by Li-Po battery with integrated BEC for servo supply

For eVTOL:

- Arduino Nano interfaced with MPU6050 IMU for angle detection
- Flysky receiver interfaced via iBus to read throttle, pitch, roll, and mode input
- ESCs controlled via PWM signals from Arduino for dual- motor thrust
- Elevon and tilt servos adjusted via PID-controlled feed- back from IMU

Software Implementation

Arduino IDE was used to implement a custom control program with the following features:

- Sensor initialization and calibration
- PID control for pitch and roll stabilization
- iBus signal reading from FS-i6 for user commands
- Smooth transition between hover (90° tilt) and forward flight (0° tilt)
- Real-time computation loop for servo and motor control every 10 ms

Testing Procedure

Two modes of testing were conducted:

- **Fixed-wing RC testing:** Evaluated in open ground with direct user input.
- **eVTOL testing:** Conducted in a controlled indoor space for hover and lift validation.

Key metrics assessed:

- Stability (during hover and cruise)
- Lift-off capability and thrust adequacy
- Response to control inputs
- Transition reliability from vertical to horizontal mode
- Battery consumption and flight duration

IV. Results and Discussion

This section presents and interprets the experimental findings from the RC aircraft and eVTOL prototype tests. It compares

observed performance metrics with theoretical expectations and evaluates the limitations and successes of each flight mode.

Observations

RC Plane Performance

- **Stability:** The aircraft maintained consistent forward flight stability with responsive pitch and roll control via elevons. The airframe showed minimal oscillations at lower speeds.
- **Speed and Efficiency:** The plane achieved a ground-tested cruising speed of 5–8 m/s, with a theoretical capability up to 10 m/s. Low aerodynamic drag contributed to efficient propulsion.
- **Flight Duration:** The RC plane sustained a flight time of approximately 10–15 minutes per full battery charge, consistent with comparable lightweight UAVs.
- **Control Response:** Elevon-controlled maneuvering was adequate. However, at higher speeds, minor roll instability was detected, likely due to servo limitations or aerodynamic disturbances.

eVTOL Performance

- **Lift-Off and Hover:** The vertical thrust was sufficient for lift-off, allowing for stable hovering at low altitudes for brief periods (5–8 minutes).
- **Transition to Forward Flight:** Attempts to transition from vertical to forward flight were unsuccessful due to instability and control divergence during tilt-servo actuation.
- **Landing:** The VTOL system allowed controlled vertical descent and landing with moderate stability.
- **Control Issues:** The PID system exhibited tuning limitations, resulting in oscillatory behavior during hover and transition attempts.
- **Power Consumption:** Hover mode required both motors at high throttle, causing rapid battery depletion, thus limiting flight time to 5–8 minutes.

Discussion

RC Plane Analysis

The RC configuration met expectations for forward flight stability and efficiency. The use of foam board and proper CG positioning contributed to aerodynamic balance. SG90 servos provided effective elevon actuation, though some responsiveness degradation occurred at higher airspeeds. These findings are in alignment with other lightweight RC aircraft studies, validating the design choices made.

eVTOL Analysis

The eVTOL mode revealed the inherent complexity of stable vertical flight and transition control. While hovering was achieved, the system lacked the control precision required for smooth mode switching. Key limitations included:

- Inadequate PID tuning for dynamic adjustments during flight transitions.
- Sensor noise and delayed actuator response.
- Software constraints related to the iBus library and low processing speed of the Arduino Nano.

Power consumption during VTOL operations further constrained the aircraft's usability, demonstrating the need for high-efficiency propulsion and larger-capacity energy systems in future iterations.

Comparison with Literature

These results reflect common challenges in small-scale hybrid UAV development as reported by Rehm [6] and Brooking [7], including PID tuning, flight mode transitions, and battery limitations. The project confirms that while hybrid RC-eVTOL systems are achievable at low cost, achieving full performance parity with commercial UAVs requires enhancements in control algorithms, power systems, and structural integration.

V. Conclusion

Summary

This study demonstrated the feasibility of building a low cost hybrid RC-eVTOL aircraft. The RC plane showed reliable performance, while the eVTOL system revealed limitations in transition stability and power management.

Recommendations

- Replace Arduino Nano with faster microcontrollers (e.g., ESP32).

- Apply advanced control algorithms and filters (e.g., Kalman).
- Optimize aerodynamics and weight distribution.
- Use higher capacity and energy-efficient batteries.

Limitations

Control instability during transitions, software constraints, and single prototype testing limited generalization.

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