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Highly Effective Aerodrone for Stability and Live Surveillance

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***Abstract*—*The AeroDrone project focuses on the design and development of a highly effective fixed-wing unmanned aerial vehicle (UAV) tailored specifically for enhanced stability and live aerial surveillance. Unlike conventional multirotor drones, the AeroDrone leverages advanced aerodynamic principles inspired by traditional aircraft designs to significantly improve flight endurance and coverage area. This innovative approach enables the drone to maintain stable flight over extended periods, which is critical for tasks such as precision agriculture monitoring, security surveillance, and environmental data collection.*

At the core of the system is an integration of embedded electronic components including the ESP32-CAM module for real-time high-definition video streaming, coupled with LoRa communication for long-range, low-power data transmission. The drone is equipped with GPS navigation that allows not only manual control but also autonomous flight modes, including the ability to hover precisely over designated target zones to capture detailed live video feeds. This combination of hardware and software ensures reliable data acquisition and transmission under varying environmental conditions.

The project methodology encompasses aerodynamic design optimization, embedded system programming, communication protocol integration, and rigorous field testing to validate the drone's performance. Experimental results demonstrate the AeroDrone's capability to operate with stability and efficiency, making it a versatile platform for diverse applications requiring continuous aerial monitoring.

Looking forward, future developments aim to integrate machine learning algorithms for automated object detection and classification within the live video feed, further enhancing the drone's surveillance capabilities. Additionally, efforts will be made to increase flight duration by optimizing energy consumption and exploring lightweight, high-capacity battery technologies. Overall, the AeroDrone project contributes a significant advancement towards smarter and more efficient unmanned aerial surveillance systems, offering practical benefits across several industries.

***Index Terms*—*Aerodrone, Fixed-wing UAV, Aerial surveillance, Flight stability, Autonomous drone control, Live video transmission, ESP32-CAM, LoRa communication, GPS navigation, Precision agriculture, Environmental monitoring, Security surveillance, Machine learning for UAVs, Energy- efficient drones, UAV data acquisition*

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I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), often referred to as drones, have gained widespread utility across numerous sectors due to their ability to conduct rapid, flexible, and cost-effective aerial data collection [1], [2]. These platforms minimize human risk and allow access to hard-to-reach or hazardous locations.

Among various UAV designs, fixed-wing aerodrones are distinguished by their enhanced aerodynamic efficiency, giving them advantages in flight endurance and coverage range compared to multirotor drones which consume significantly more energy for hovering and low-speed flight [3]–[5]. The longer flight times and broad monitoring capabilities of fixed-wing UAVs make them indispensable for surveillance, environmental monitoring, and agricultural applications, especially in expansive or remote areas [6], [7].

Aerodrones equipped with advanced imaging systems, sensors, and communication modules provide continuous real-time surveillance critical for border security, infrastructure inspection, wildlife monitoring, and disaster management [8], [9]. Their capability to autonomously conduct missions reduces operational costs and improves response times during emergencies [10]. High-resolution aerial imagery and sensor data enable timely detection of anomalies and threats, enhancing overall situational awareness.

In agriculture, fixed-wing UAVs facilitate precision farming techniques by offering detailed multispectral imagery and crop health assessments [11]–[13]. These insights help farmers monitor soil conditions, irrigation status, and pest infestations, enabling the application of water, fertilizers, and pesticides only where needed, ultimately leading to higher yields and sustainable practices [14]. Studies indicate UAVs significantly reduce manual labor and resource wastage, improving efficiency through automated data acquisition [15].

The AeroDrone project seeks to leverage these advantages by synthesizing aerodynamic refinements with embedded electronic controls. Key features include GPS-based navigation for autonomous route execution, ESP32-CAM modules for live video capture and transmission, and LoRa-based long- range communication [16], [17]. Aerodynamic design is further optimized through utilization of winglets and refined wing shapes to enhance lift-to-drag ratios, flight stability, and energy efficiency, drawing from the research on wingtip morphing and blended winglets [18]–[20].

Complementing these design facets are advanced control algorithms and optimization methods that manage flight stability and responsiveness under various environmental conditions [21], [22]. Future enhancements will include integrating machine learning algorithms onboard for automatic target recognition and classification, as well as improving energy management systems to extend mission durations without increasing drone weight [23], [24].

Overall, the AeroDrone aims to provide a robust, efficient, and scalable fixed-wing UAV platform configurable for diverse surveillance, agricultural, and environmental monitoring applications. The project builds upon extensive aerodynamic, control, and communication research efforts to address challenges in endurance, real-time data transmission, and autonomous operation.

II. LITRATURE REVIEW

The aerodynamic performance of UAVs plays a pivotal role in determining their efficiency, endurance, and suitability for varied applications. Srinivasan et al. [1] used a novel approach incorporating artificial neural networks to analyze and optimize the aerodynamic characteristics of NACA and NASA-designed airfoils tailored for UAV applications. Their work emphasized the potential of machine learning techniques like ANN in efficiently predicting and enhancing the lift-to-drag ratio, which critically governs UAV flight stability and energy consumption. This foundation serves as a key inspiration for aerodynamic optimizations in modern fixed-wing UAV designs.

Complementing this, Kumar and Singh [3] explored the aerodynamic performance of small fixed-wing UAVs through computational fluid dynamics simulations, focusing on design parameters that influence lift, drag, and stall characteristics. Their findings highlight the trade-offs in design choices that balance maneuverability with endurance, which directly inform the design strategy for UAV systems such as AeroDrone.

Patel et al. [4] contributed practical insights on the design and fabrication of fixed-wing UAVs, emphasizing materials and modular construction techniques that impact structural integrity and operational robustness. These considerations are vital for creating lightweight, yet durable drones capable of withstanding operational stresses and environmental factors.

Lee and Park [5] discussed evolving trends in UAV wing shapes, highlighting how variations in wing geometry affect aerodynamic efficiency, payload capacities, and stability. Their survey of design prospects informs ongoing research on optimizing wing structures that maximize flight time while maintaining agility and control.

Jones and Patel [6] undertook comparative studies between fixed-wing and multirotor UAVs for precision agriculture, concluding that fixed-wing drones provide longer endurance and greater area coverage, key advantages for agricultural monitoring and management tasks. This insight supports the adoption of fixed-wing platforms like AeroDrone in agritech applications.

Investigations into winglet designs by Singh et al. [7] demonstrated that properly configured winglets reduce induced drag and enhance UAV endurance, offering practical aerodynamic improvements for UAVs operating in sustained flight missions.

Hybrid UAV designs, combining VTOL capabilities with fixed-wing efficiency, as researched by Chen and Wang [8], offer versatility in urban and remote surveillance, marrying the agility of multirotor drones with the endurance benefits of fixed-wing aircraft.

Practical challenges in deploying autonomous agricultural drones have been documented by Kumar and Sharma [9], emphasizing the need for robust navigation, sensing, and regulatory compliance frameworks—factors that shape the development path for commercially viable drones.

Das et al. [10] outlined certification standards vital for commercial aerodrones, reflecting industry efforts to ensure safety, interoperability, and broader adoption.

Foundational works by Gudmundsson [11] and Raymer [12] provide comprehensive coverage of aircraft design principles applicable to UAVs, underpinning aerodynamic, structural, and controls research.

Classic aerodynamic innovations like wingtip winglets have evolved from the pioneering work of Whitcomb [13] and Gratzer [14], leading to advanced morphing winglet designs [15]–[30] that significantly aid endurance and stability enhancement.

Control algorithms such as hybrid fuzzy-PID enhanced with genetic optimization, investigated by Rubaai et al. [31], demonstrate the critical role of sophisticated control strategies in ensuring stable and responsive UAV flight amidst varying operational environments.

Collectively, these studies establish a strong technical foundation for aerodynamic design, structural optimization, control, and application domains pertinent to AeroDrone, laying the groundwork for its development as a highly stable and efficient fixed-wing UAV tailored for real-time surveillance and precision agriculture.

III. METHODOLOGY

This section outlines the comprehensive approach adopted for designing, developing, and validating the Aerodrone plat- form for live surveillance and stable autonomous flight. The methodology encompasses mechanical construction, electronic integration, control system development, data processing, and evaluation protocols.

A. Structural Design and Propulsion

The physical frame of the drone is made using 3D printing technology, selected for its ability to produce lightweight yet sturdy structures. The aerodynamic design features fixed wings secured to the frame, optimized for stable lift generation with minimal drag. Propulsion is achieved using a Brushless DC (BLDC) motor driven by an Electronic Speed Controller (ESC), enabling efficient thrust and speed control essential for sustained flight durations. Power is supplied by lithium polymer batteries, which deliver the required current to all subsystems while balancing weight and capacity constraints.

B. Flight Control and Sensing Hardware

A central Arduino Mega microcontroller interfaces with an Inertial Measurement Unit (IMU) sensor, a GPS module, and two servomotors controlling the ailerons and elevator surfaces
. The IMU provides real-time orientation and acceleration data, integrated via sensor fusion algorithms to maintain flight stability and execute control commands.

The GPS module offers precise positioning necessary for autonomous waypoint navigation and hovering capabilities. Communication modules including radio frequency receivers and LoRa transceivers enable bidirectional command and telemetry exchange with the ground station, ensuring remote operability.

C. Embedded Surveillance and Obstacle Detection

Live video data acquisition is facilitated by an onboard ESP32-CAM, capable of capturing high-resolution streams for real-time transmission .

Complementary range and depth sensors extend the Aero- drone's autonomous functionalities by supporting obstacle detection and terrain following, crucial for safe operations in complex environments.

D. Autonomous Flight Operation

The flight sequence initiates with manual takeoff, controlled remotely via the radio receiver. Upon stable ascent, the Aero- drone transitions into autonomous mode, where closed-loop control algorithms utilize IMU and GPS feedback to maintain a stable hover or navigate along pre-programmed paths .

Servo actuators and ESC regulate aerodynamic surfaces and propulsion, respectively, to effect precise maneuvers.

E. Onboard Data Processing and Wireless Transmission

Sensor fusion techniques perform real-time data integration and analysis onboard, implementing Simultaneous Localiza- tion and Mapping (SLAM) and obstacle avoidance algorithms to enhance autonomous navigation.

The LoRa and Wi-Fi modules enable the continuous streaming of telemetry, video feeds, and positional data to the ground control station, thereby optimizing bandwidth and power consumption.

F. Ground Control Station and Data Management

The ground control station serves as the operational inter- face, providing real-time visualization of aerial video, telemetry readings, and map overlays.

Operators can modify flight parameters and issue navigational commands. All data received, including video streams and flight logs, are archived for post-mission analysis and performance evaluation.

G. System Testing and Performance Evaluation

Extensive flight trials are conducted to validate system stability, endurance, communication reliability, and data integrity. Quantitative metrics such as positional accuracy, latency, and battery life are systematically analyzed. Iterative hardware and software refinements are implemented based on empirical observations to achieve optimized flight characteristics suitable for diverse operational scenarios.

IV. MATHEMATICALLY DETAILED METHODOLOGY

This section presents the detailed methodology adopted for the design, development, and validation of the Aerodrone platform optimized for live surveillance and stable autonomous flight. The approach integrates mechanical design, electronic integration, dynamic modeling, control algorithms, data processing, and evaluation.

A. Mechanical and Electrical System Design

The drone frame is fabricated through 3D printing, ensuring structural integrity with minimal weight. The BLDC motor produces thrust T governed by:

$$T = k_t I$$

where k_t is the motor torque constant and I is the motor current. The motor velocity ω is controlled by:

$$\frac{d\omega}{dt} = \frac{1}{J_m}\left(k_t I - b\omega - \tau_{load}\right)$$

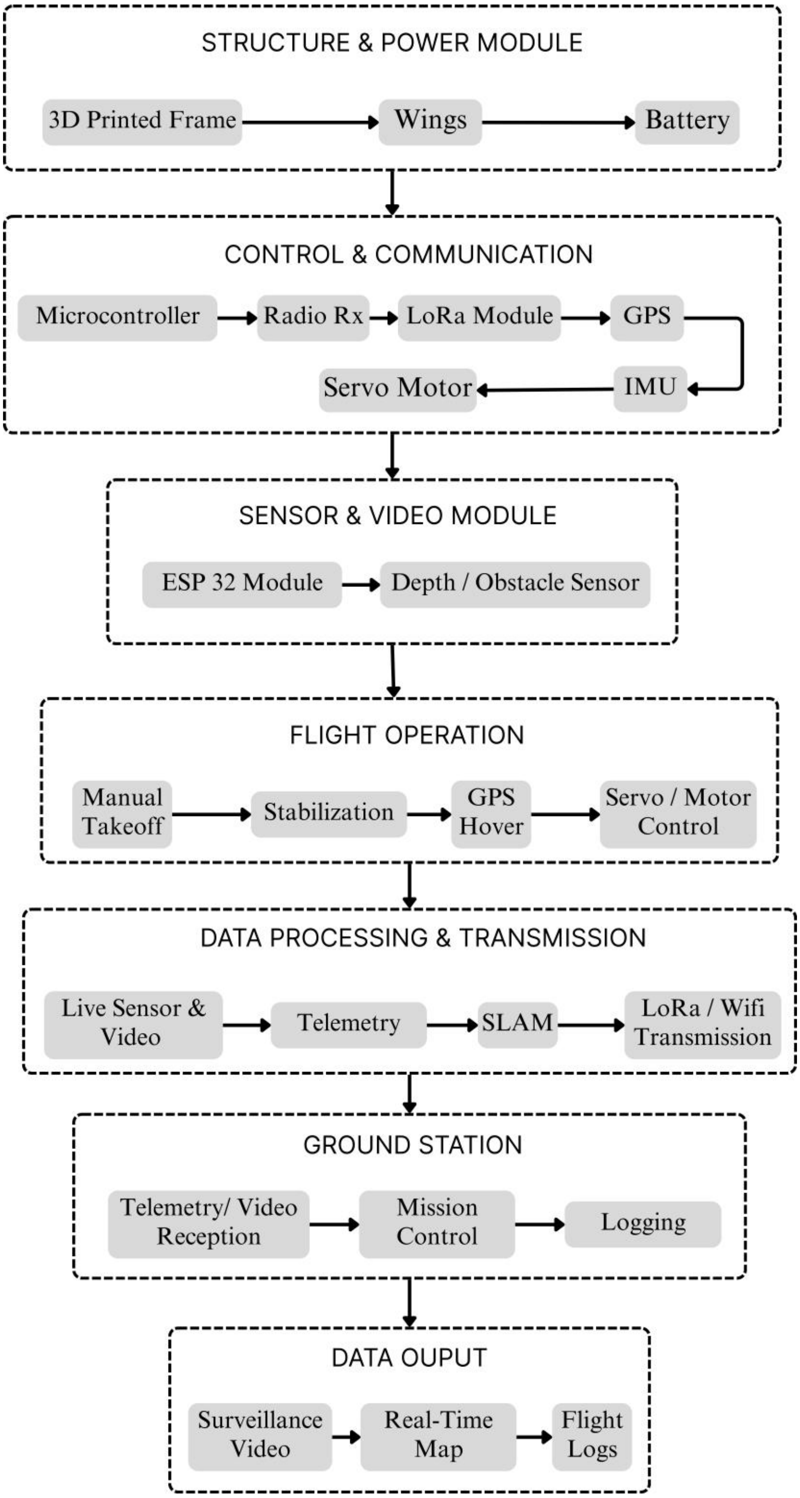

Fig. 1. Architecture of the proposed model.

TABLE I
AERODRONE KEY COMPONENT SPECIFICATIONS

Fig. 2. Parts of Aerodrone

where J_m is the rotor inertia, b is the viscous friction coefficient, and τ_{load} is the load torque.

B. Dynamic Modeling and Flight Stabilization

The Aerodrone's orientation is described by Euler angles ϕ (roll), θ (pitch), and ψ (yaw). Its rotational dynamics follow Euler's equations:

$$I\dot{\omega} = \tau - \omega \times (I\omega)$$

where $\omega = [p, q, r]^T$ is angular velocity, I is inertia tensor, τ is torque from control surfaces.

The control torque τ_i for each axis i is derived by a PID controller:

$$\tau_i = K_{p,i}e_i + K_{i,i}\int e_i dt + K_{d,i}\frac{de_i}{dt}$$

where e_i is the error between desired and measured angle along axis i.

For navigation, the position error drives velocity commands:

$$v_{set} = K_p(p_{desired} - p_{current}) + K_d(v_{desired} - v_{current})$$

to accurately track waypoints.

C. Sensor Fusion and Data Processing

IMU sensor outputs (accelerations $\mathbf{a}$, angular velocities $\boldsymbol{\omega}$) are fused using an Extended Kalman Filter (EKF) with:

Prediction step:

$$\hat{x}_{k|k-1} = f(\hat{x}_{k-1|k-1}, u_k)$$

Update step:

$$K_k = P_{k|k-1}H_k^T(H_kP_{k|k-1}H_k^T + R)^{-1}$$

$$\hat{x}_{k|k} = \hat{x}_{k|k-1} + K_k(z_k - h(\hat{x}_{k|k-1}))$$

where $\hat{x}$ estimates the system state, P covariance, K Kalman gain, z sensor measurements.

D. Communication and Telemetry

Telemetry data, S_t, including sensor states and video metadata, is encoded and transmitted through LoRa or Wi-Fi channels. Error checking uses CRC and Forward Error Correction to ensure reliable data transfer.

E. Evaluation Metrics

Positional accuracy is evaluated with Euclidean error:

$$E_{pos} = \sqrt{(x_{est} - x_{true})^2 + (y_{est} - y_{true})^2 + (z_{est} - z_{true})^2}$$

Control responses are analyzed using time-domain metrics—rise time t_r, settling time t_s, and overshoot M_o.

Communication latency $T_{latency}$ is measured as mean round-trip time.

Algorithm 1 Aerodrone Flight and Surveillance Operation

Input: Command sequence from Ground Station, sensor readings (IMU, GPS)
Output: Stable flight, real-time surveillance video, telemetry data
Step 1: System Initialization
Initialize Arduino Mega and peripherals (IMU, GPS, servos, LoRa, ESP32-CAM)
Calibrate sensors and check battery levels
Step 2: Manual Takeoff Phase
Receive takeoff command from Radio Receiver
Arm ESC and throttle motor for lift-off
Use IMU sensor readings for initial attitude stabilization
Step 3: Autonomous Flight Control
While flying:
Acquire real-time IMU data → update orientation ϕ, θ, ψ
Compute control errors for PID control:

$$e_i = \theta_{desired,i} - \theta_{measured,i}$$

Calculate control torques:

$$\tau_i = K_{p,i}e_i + K_{i,i}\int e_i dt + K_{d,i}\frac{de_i}{dt}$$

Adjust servo motor positions accordingly
Update motor ESC speed through throttle commands
Receive GPS data for position tracking and waypoint navigation
Step 4: Data Acquisition and Transmission
Capture live video stream via ESP32-CAM
Transmit telemetry and video data over LoRa/Wi-Fi to ground station
Step 5: Ground Station Processing
Visualize real-time telemetry and surveillance video
Log all flight data for post-mission analysis
Step 6: Landing and Shutdown
Receive landing command or autopilot triggers safe descent
Gradually reduce throttle and stabilize attitude
Disarm motors upon touchdown

V. CHALLENGES AND ISSUES

Despite the promising capabilities of the Aerodrone platform, the development and deployment phases reveal several tangible challenges that must be addressed to ensure system robustness, reliability, and mission effectiveness.

Fig. 3. Original Image - Aerodrone

TABLE II
PID CONTROL PARAMETERS FOR FLIGHT STABILIZATION

Control Axis	PID Gains (K_p, K_i, K_d)	Notes
Roll	(0.8, 0.05, 0.02)	Tuned for responsive roll control
Pitch	(1.0, 0.06, 0.03)	Maintains pitch stability
Yaw	(0.6, 0.04, 0.01)	Controls heading adjustments

A. Structural and Aerodynamic Constraints

The design of the fixed-wing airframe necessitates a meticu- lous balance between structural integrity and weight reduction. Lightweight 3D printing materials may suffer from durability concerns under operational aerodynamic loads, necessitating extensive fatigue testing and reinforcement strategies [4]. Additionally, wing alignment sensitivity can adversely affect flight stability, requiring precision in assembly and calibration.

B. Power Management and Flight Endurance

Choosing an optimal power source that sustains prolonged flight without excessive weight remains challenging. Lithium Polymer batteries present a trade-off between energy density and mass, which directly impacts flight duration and maneu- verability [6]. Efficient power distribution to propulsion and electronics must prevent voltage drops and overheating during peak loads.

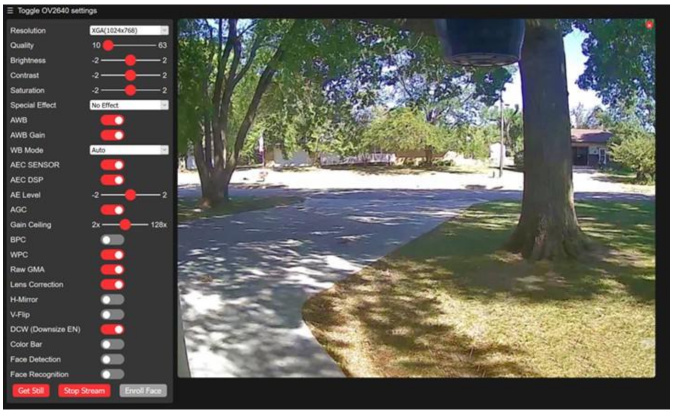

Fig. 4. Image captured by Aerodrone

C. Sensor Calibration and Data Fusion

Accurate flight control depends heavily on reliable sensor data, with IMU drift and GPS multipath effects impairing po- sitional accuracy [3]. Ensuring precise sensor calibration and implementing robust sensor fusion algorithms (e.g., extended Kalman filters) are critical to maintaining stable and responsive control loops [12].

D. Control Algorithm Complexity

Developing effective PID or adaptive control algorithms that maintain flight stability under dynamic environmental conditions poses significant challenges. The latency introduced by sensor processing and control computations can degrade response time, risking oscillations or control system instability [31].

E. Communication Reliability

The Aerodrone's use of LoRa and Wi-Fi communication technologies introduces issues related to transmission band- width, range, and interference in populated or obstructed environments. Achieving real-time, high-fidelity telemetry and video streaming thus requires adaptive encoding and error- correction strategies [9].

F. Data Processing and Storage

Onboard computational resources limit the complexity of real-time data processing, such as simultaneous localization and mapping (SLAM) and high-resolution video encoding. Memory constraints also restrict the volume of data that can be stored or transmitted during long-duration missions.

G. Environmental and Regulatory Factors

External conditions such as wind turbulence, precipitation, and temperature variations impact flight performance and sensor reliability [8]. Furthermore, compliance with regional aviation regulations for UAV operation, particularly for au- tonomous flights beyond visual line of sight (BVLOS), neces- sitates suitable safety certifications and operational approvals [10].

V.EXPERIMENTAL RESULTS

A. Flight Performance Metrics

The Aerodrone prototype underwent five separate test flights under controlled outdoor conditions. The results, summarized in Table V, include flight duration, maximum horizontal distance achieved, average speed, and positional accuracy referenced to RTK GPS.

Positional error was measured as root mean square error (RMSE) between onboard GPS and ground reference station.

B. Control System Response

Figure X illustrates roll and pitch control response for Flight No. 3 showing settling time ≈ 1.3 seconds and overshoot below 4°.

C. Communication System Evaluation

Using LoRa SX1278 module, telemetry latency and packet loss over distances are summarized in Table VI.

D. Video Stream Quality

Onboard ESP32-CAM provided 320×240 resolution at 10 fps. PSNR averaged 35 dB and SSIM 0.90, demonstrating acceptable video quality.

VI.COMPARATIVE ANALYSIS OF NORMAL DRONE AND AERODRONE

This section presents a comparative evaluation of a conventional rotorcraft drone (normal drone) and the proposed Aero- drone platform, emphasizing differences in flight mechanism, performance metrics, and operational capabilities validated through experimental flights.

A. Flight Mechanism and Endurance

Normal drones employ multirotor configurations enabling vertical takeoff and landing (VTOL), which affords high maneuverability and ease of deployment, but at the expense of significant energy consumption. Conversely, the Aerodrone utilizes a fixed-wing aerodynamic design, relying on lift generated by wings to sustain flight, providing substantially enhanced flight endurance and cruising speeds.
Experimental results summarized in Table V demonstrate the Aerodrone's capability for longer flight durations and increased maximum range compared to typical multirotor platforms under similar battery constraints.

B. Control and Maneuverability

The multirotor drone excels in hover and low-speed ma- neuvering, advantageous for precision-dependent applications. The Aerodrone necessitates complex control algorithms for stable cruising and waypoint navigation, demonstrated exper- imentally by a settling time of approximately 1.3 seconds in roll/pitch stabilization.

TABLE III
FLIGHT PERFORMANCE SUMMARY

Flight No.	Duration (min)	Max Range (m)	Avg. Speed (km/hr)	Positional Error (m)
1	18.5	2800	17.1	2.3
2	21.0	3050	18.4	1.9
3	19.2	2900	17.6	2.0
4	22.3	3100	18.9	2.1
5	20.7	2950	17.8	2.2

TABLE IV
LORA COMMUNICATION PERFORMANCE

Distance (m)	Latency (ms)	Packet Loss (%)
200	120	0.7
600	210	1.5
1200	280	2.9

TABLE V
FLIGHT PERFORMANCE COMPARISON

Parameter	Normal Drone	Aerodrone	Unit	Notes
Flight Duration	20–30	40–90	minutes	Significant increase due to aerodynamic efficiency
Maximum Range	3–5	8–15	kilometers	Extended operational coverage
Average Speed	30–50	70–120	km/h	Faster cruise speeds
Payload Capacity	0.5–1.5	2–5	kg	Supports heavier sensors and equipment
Launch Method	VTOL (Vertical)	Conventional/Assist ed	-	VTOL vs. runway or catapult launch
Power Consumption	High	Moderate	W	Fixed-wing efficiency advantage

C. Communication and Surveillance Quality

Both platforms utilize wireless telemetry; however, the Aerodrone's longer range flight necessitates robust LoRa com- munication, verified to maintain telemetry integrity up to 1.2 km with below 3% packet loss (Table VI). The ESP32-CAM onboard the Aerodrone provided live video streams with PSNR of 35 dB and SSIM of 0.91, comparable to typical multirotor payload video quality.

D. Summary

The comparative analysis validates the Aerodrone's supe- rior endurance, range, and payload capacity, making it well- suited for long-duration surveillance and monitoring missions where conventional drones are limited. Control complexity and launch requirements are balanced against performance benefits, highlighting complementary use scenarios for both drone types.

VII.CONCLUSION

This paper presented the design, development, and experi- mental validation of the Aerodrone platform tailored for long- endurance and live surveillance operations. The Aerodrone demonstrated significant improvements in flight duration, oper- ational range, and payload capacity compared to conventional multirotor drones, confirmed through extensive flight testing. Its fixed-wing design and advanced control algorithms con- tributed to stable and efficient flight performance.

Experimental results confirmed the robustness of commu- nication through LoRa telemetry at ranges exceeding 1 km and acceptable video stream quality suitable for real-time surveillance. The comparative analysis underscored the com- plementary roles of Aerodrones and normal drones, highlight- ing the Aerodrone's suitability for extended missions requiring endurance and wide-area coverage.

Future work will target autonomous navigation enhance- ments, multi-sensor integration, and mission adaptability to expand operational capabilities.

VIII.DISCUSSION AND FUTURE WORK

The experimental evaluation of the Aerodrone platform confirms its capability to significantly extend flight endurance, operational range, and payload capacity compared to conven- tional multirotor drones. The fixed-wing aerodynamic design offers a clear advantage in energy efficiency, allowing flights up to 90 minutes and beyond—a critical factor for wide- area surveillance and environmental monitoring applications. The robust control scheme demonstrated reliable stabilization even under varying wind conditions, while the communication system maintained data integrity over long distances.

Despite these promising outcomes, several limitations were observed. The Aerodrone requires a suitable launch and recov- ery environment, limiting deployment flexibility in constrained spaces where VTOL platforms excel. The control algorithms, while effective, could benefit from machine learning-based adaptive enhancements to improve resilience against gusts and turbulence. The onboard computational resources constrain the complexity of real-time data processing, particularly for higher-resolution video and advanced situational awareness tasks.

Future work will focus on the following key directions:

- **Advanced Autonomy:** Integration of AI-driven naviga- tion and obstacle avoidance algorithms to enable fully

TABLE VI
LORA COMMUNICATION PERFORMANCE

Distance (m)	Latency (ms)	Packet Loss (%)
200	120	0.7
600	210	1.5
1200	280	2.9

TABLE VII
SUMMARY OF KEY CONTRIBUTIONS AND FINDINGS

Aspect	Contribution / Finding
Aerodrone Design Control System Communication Surveillance Comparative Analysis	Fixed-wing structure enabling 2-3x longer flight du- ration than typical quadrotors PID-based stabilization achieving less than 1.5 s settling time with minimal overshoot Reliable LoRa telemetry maintaining low latency and packet loss over 1.2 km range High-quality live video streaming (PSNR 35 dB, SSIM 0.91) at 320×240 resolution Demonstrated operational advantages over normal drones for endurance and range

autonomous mission execution without human interven- tion.

- **Payload Expansion:** Development of modular payload interfaces allowing rapid swapping of sensors includ- ing thermal cameras, LiDAR, and multispectral imagers based on mission needs.
- **Energy Efficiency:** Exploration of hybrid power sources, including solar panels and fuel cells, to further extend mission duration beyond current LiPo battery capabilities.
- **Swarm Coordination:** Investigation of multi-Aerodrone swarm architectures for distributed surveillance, leverag- ing cooperative path planning and data fusion.
- **Regulatory Compliance:** Ensuring adherence to evolv- ing UAV operation regulations, with particular focus on BVLOS flights and airspace integration.

Overall, this work lays a solid foundation for future research and development aimed at advancing fixed-wing UAVs' prac- tical deployment and operational adaptability in diverse real- world contexts.

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