A MODIFICATION OF A LOCALLY ADAPTED DRONE WITH ADVANCED TECHNICAL CAPABILITIES

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A PROJECT SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE (B.ENG.), HONOURS DEGREE IN ENGINEERING

FEB, 2025.

CERTIFICATION

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DEDICATION

We dedicate this project to Almighty God, family, and all who have contributed to the success of our project and our academic journey.

ACKNOWLEDGEMENTS

We thank God almighty for the privilege he has given us to achieve this milestone. We express our sincere gratitude to our project supervisor, **Engr. (Prof) P.O.B. EBUNILO**, for his immense support and contributions towards the success of our project. We also appreciate all the members and staff of the Department of Mechanical Engineering, headed by **Engr. (Prof) G.E. SADJERE**, and the Faculty of Engineering workshop staff at the University of Benin. Our sincere thanks also go to our beloved parents **Mr. and Mrs. JOSEPH AMAECHINA, Mr. and Mrs. IDOWU ADUN, Mr. and Mrs. OLORI, Mr. and Mrs. ISAAC EDOMWONYI, Mr. and Mrs. IFERIA, Mr. and Mrs. OSAZEE OSAKUE, Mr. and Mrs. ABRAHAM OGOR, Mr. and Mrs. DONATUS ORAZULUME.** for their financial and emotional support, prayers, and encouragement throughout our studies at the University of Benin. Thanks to **Mr. Testimony Osemen** for his immense contribution and partnership with us in developing the system software towards the success of this project.

ABSTRACT

The increasing need for effective and cheap surveillance solutions across various sectors in Nigeria, including security, agriculture, environmental protection, and disaster management and development of homemade drones. Although quite popular and ubiquitous in technologically advanced nations, drones are currently not being produced in Nigeria that can be used for both surveillance and monitoring.

Modifications were done on a locally adapted drone assembled from parts sourced abroad. The drone was enhanced with advanced technical capabilities optimizing it for smooth surveillance operations. Major modification upgrades include the integration of pivotal components including microchips ranging from Raspberry Pi 5, Arduino Atmel Amega 2560, STM32H7 controller, along with the Pixhawk 2.4.8 flight controller, a high-resolution Raspberry Pi Camera Rev 1.3, ultrasonic sensors, PWM to PPM converter, and GPS navigation system into the F450 drone frame. These enhancements allow for functionalities such as object tracking, obstacle avoidance, and an automatic return-home capability, enhancing the drone's adaptability for various surveillance applications.

Using a combination of C++ and Python programming, the drone was optimized for stability, adaptability, surveillance, and monitoring. Extensive testing was carried out to assess its flight performance and capabilities in different real-world situations.

The major achievement of this project is the programming and debugging of the locally developed algorithms, ensuring a secure, functional, and flexible solution tailored to Nigeria’s specific operational requirements. Through rigorous testing, the drone has demonstrated improved flight stability, better maneuverability, and advanced surveillance capabilities, allowing it to lock on to and follow targets, avoid obstacles during flight, and autonomously return to its home base.

This project highlights the significance of promoting local innovation, decreasing reliance on imported drones, and addressing urgent issues in surveillance and information management throughout Nigeria. The developed system not only shows great promise in reducing dependence on imported drones but also lays the groundwork for encouraging local innovation and tackling specific operational challenges within the diverse contexts of Nigeria.

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List of Abbreviations

Abbreviation	**Full Form**
UAV	Unmanned Aerial Vehicle
AI	Artificial Intelligence
GPS	Global Positioning System
PWM	Pulse Width Modulation
PPM	Pulse Position Modulation
IDE	Integrated Development Environment
ESC	Electronic Speed Controller
LiPo	Lithium Polymer (battery)
RTH	Return To Home
GNSS	Global Navigation Satellite System
IMU	Inertial Measurement Unit
AHRS	Attitude and Heading Reference System
LoS	Line of Sight
VTOL	Vertical Take-Off and Landing
MC	Mission Computer
CNC	Computer Numerical Control
3D	Three-Dimensional
COTS	Commercial Off-The-Shelf
MTOW	Maximum Takeoff Weight
SRTM	Shuttle Radar Topography Mission
ESRI	Environmental Systems Research Institute
DE	Direct Energy
UHF	Ultra High Frequency
R&D	Research and Development
F450	A standard quadcopter frame model
GPIO	General Purpose Input/Output
PID	Proportional-Integral-Derivative (control algorithm)
DSM	Digital Spectrum Modulation
SBUS	Serial Bus
Rm	Motor resistance
Kv	Back EMF constant
Kt	Torque constant

CHAPTER ONE

1.1 Introduction/Background Study

Unmanned aerial vehicles, or drones, have transformed surveillance and information collection globally and are now essential in agriculture, security, disaster management, and environmental monitoring. With a projected compound annual growth rate (CAGR) of 18.9% between 2024 and 2032, the global drone surveillance market is expected to grow significantly. This growth will be driven by technological advancements in autonomous flight capabilities, machine learning, and artificial intelligence (Dharmadhikari, 2024). Defense and security are two of the most important uses for drones. Modern drones with advanced cameras, AI tracking, and realtime data transmission have transformed crossborder security, military operations, and counterterrorism activities globally. Drones are vastly utilized in the civilian sector for crowd control, traffic monitoring, and crime prevention (Total Military Insight, 2024). Drones help with precision farming, pest control, and irrigation management in agriculture, which boosts productivity and lowers expenses (Dopamu, 2024)42. Drones are also essential for environmental conservation since they help with pollution monitoring, reforestation, and wildlife tracking (Our Nigeria News, 2024). Not withstanding these benefits, Nigeria has not completely incorporated Uunmanned Aerial Vehicles into important national sectors, which restricts their ability to solve pressing issues. According to studies, Nigeria is facing a number of significant barriers to the widespread deployment of drones. Regulatory and policy constraints significantly hamper Nigeria's adoption of UAV technology. The Nigerian Civil Aviation Authority (NCAA) imposes strict regulations on drone operations, requiring permits that are often difficult to obtain. It is unlawful to operate a drone without first seeking the required authorizations. Flight plans must be submitted to the NCAA for authorization before conducting each drone flight within Nigeria. These bureaucratic hurdles discourage both private and institutional use of UAVs, limiting their potential applications in sectors such as security, agriculture, and environmental monitoring (Abiodun, 2020).

Another major challenge is the total reliance on imported drones, which are often pre programmed and lack the flexibility needed for local applications. These drones, primarily designed for foreign environments, do not fully accommodate Nigeria’s unique operational needs, such as security surveillance in remote conflict zones or real-time monitoring of agricultural lands. As a result, users face difficulties in customizing them for specific tasks, making locally adaptable drone solutions a necessity (Engineers Forum, 2024). Furthermore, Nigeria lacks a well-established commercial drone manufacturing industry and skilled personnel to develop, program, and maintain drones optimized for the country's needs. The absence of indigenous drone manufacturers has left the sector dependent on expensive foreign technology, creating a barrier to widespread UAV adoption. Additionally, limited access to specialized training programs for UAV operation and maintenance has slowed technological advancements in this field (Njoku & Anioke, 2024).

The high cost of acquiring, maintaining, and repairing drones further restricts their adoption, especially within public institutions. Many government agencies and research institutions struggle to afford the necessary UAV technology due to limited funding and infrastructure.

Without significant investment in local drone production, training, and maintenance facilities, Nigeria will continue to face challenges in leveraging UAVs for national development (The American journals of engineering and technology).

Locally created drone solutions that are suited to Nigeria's security, agricultural, and environmental requirements are desperately needed to address these issues. This project focuses on modifying and optimizing a locally adapted drone, integrating AI-powered surveillance, real-time object tracking, automated return-home functionality, and obstacle avoidance technology to create a more efficient, cost-efficient drone suited for Nigeria’s unique challenges.

1.2 Statement of Problem

Some of Nigeria’s biggest challenges regarding surveillance and information gathering lie in her security, agriculture, and environmental management. The inability to monitor these sectors in real-time and tailor response strategies to meet the needs of communities on the ground makes them susceptible to preventable threats of terrorism, food insecurity, and disasters attributed to climate change (Abiodun, 2020).

Unmanned aerial vehicles can help get information from different sectors like agriculture, security, and environment surveillance. However, the drones created are limited in their current capability. The UAVs often lack the advanced technical features needed to adapt to the various sectors with their unique operational requirements. These limitations include the inability of the system to be able to detect crop defects in agriculture, lack of flight autonomy, inefficiency in real-time communication, and data processing, and inability to fly for a long time.

To address these issues, there is a need to modify these drones with advanced technical capabilities such as increasing the battery capacity, minimizing the size and weight of the drone parts, and efficient software for autonomous flight, navigation, flight stability, and data analysis. This report highlights the need to modify UAVs and their relevance in different sectors. Improvement of human capacity, foreign exchange, National technological independence, etc.

1.3 Aim and Objectives of the Project Work

1.3.1 Aim of the Project Work

The project aims to modify and redesign a locally adapted drone with advanced technical capabilities by integrating advanced surveillance capabilities tailored to Nigeria’s unique challenges.

1.3.2 Objectives of Project Work

a. Repair and restore the crashed drone to working condition before modifications.
b. Modify and upgrade the existing drone to enhance its surveillance, tracking, and autonomous capabilities.
c. Integrate additional hardware components, including a Raspberry Pi Camera Rev 1.3, STM32H7 Microcontroller, Raspberry Pi 5, Arduino Atmel Atmega 2560, and ultrasonic sensors for improved functionality.
d. Develop and implement a custom flight control algorithm to enable autonomous navigation, object tracking, and obstacle avoidance.
e. Program the drone using C++ or Python, ensuring compatibility with its onboard microcontrollers and flight systems.
f. Optimize power efficiency and structural integrity, improving flight stability, payload capacity, and overall durability.
g. Conduct real-world testing in security surveillance, agricultural monitoring, and environmental assessment scenarios to evaluate its effectiveness.
h. Enhance local technical expertise by documenting development processes and providing training opportunities for future drone projects.

1.4 Scope of the Project Work

To enhance automation, tracking, and surveillance, the damaged drone will be repaired as well as modified with cutting-edge technical features. Three main aspects comprise the scope of work:

I. **Drone Repair and Restoration:** Before making any changes, the first stage focuses on identifying and fixing any damaged parts to make sure the drone can fly.
II. **Hardware and Software Upgrades**: Upgrades to the hardware and software include adding additional parts including an Arduino Atmel Atmega 2560, STM32H7 microcontroller, Raspberry Pi 5, Raspberry Pi Camera Rev 1.3, and ultrasonic sensors, as well as creating a unique flight control algorithm for more automation.
III. **Testing and Practical Use**: Using the drone for environmental assessments and surveillance, making sure all the changes work well in practical settings.

1.5 Economic Importance of the Project Work

This project carries significant economic benefits, particularly in reducing Nigeria's dependence on imported UAVs while fostering local innovation.

a. **Cost Reduction:** – Developing a locally adapted drone lowers procurement costs, making UAV technology more accessible for security agencies, farmers, and environmental researchers.

b. **Job Creation:** The expansion of Nigeria's drone industry can create employment opportunities in manufacturing, software development, maintenance, and training.

c. **Agricultural Efficiency:** Precision farming using drones can increase crop yields, reduce waste, and improve resource allocation, leading to higher profits for farmers.

d. **Security Enhancement:** More efficient surveillance systems can reduce crime rates, improve business environments, and boost economic growth.

e. **Technology Transfer and Education:** This project provides technical training and knowledge sharing, strengthening Nigeria's UAV expertise and supporting future dronerelated innovations.

By investing in local UAV development, Nigeria can save costs, create jobs, and enhance national security and agricultural productivity, making drone technology a valuable economic asset.

1.6 Methodology

The methodology used in achieving the aim and objectives of this project work is as follow:

1. Literature review
2. Conceptual design
3. Feasibility study (experiment)
4. Detailed Design
5. Assembly of the drone
6. Software coding and debugging.
7. Testing and evaluation of the fabricated Proof-of-concept
8. Documentation of findings
9. Conclusion and recommendation .

CHAPTER TWO

2.0 Literature Review

2.1 Overview of Drone Technology

Drones have advanced since their military use. Originally employed for wartime surveillance as unmanned reconnaissance aircraft, nowadays they are multipurpose aerial systems utilized in many different sectors (National Air and Space Museum, 2023). Drones are among the most revolutionary technologies of the twenty-first century, with applications ranging from agricultural and environmental monitoring to security and warfare (JOUAV, 2023).

But it's not only about innovation—drones have also improved data collection's speed, affordability, and efficiency. These days, they are extensively employed for jobs like mapping, wildlife protection, traffic monitoring, and disaster relief (NIFA, 2023). Drones are even being used in several nations to deliver packages and convey medical supplies, which lessens the need for traditional logistics (Ageagle, 2023).

2.1.1 Evolution of Drones from Military to Civilian Applications

The history of drones started when the first no-pilot aircraft was created for military surveillance during World War I (National Air and Space Museum, 2023). Continuous developments during World War II led to the production of remotely piloted vehicles that could carry out surveillance without causing risks to human life. Drones quickly gained traction in non-military industries during the 2000s as they became smaller, more affordable, and more widely accessible (JOUAV, 2023).

In the modern day, drones are becoming more important equipment in fields like construction, filmmaking, and law enforcement. Drones may now be utilized for precise mapping, disaster assessment, and even traffic control in crowded urban cities thanks to the combination of GPS, AI-based navigation, and high-resolution cameras (Fly4Future, 2024).

2.1.2 Importance of Drones in Modern Surveillance and Data Collection

By providing real-time aerial monitoring without the constraints of stationary security cameras or human patrols, drones have completely transformed contemporary surveillance systems. Unlike conventional surveillance techniques, drones can cover vast areas in minutes and offer infrared imaging in high-risk locations, night vision tracking, and live video (National Air and Space Museum, 2023).

Drones have revolutionized precision farming and crop monitoring in agriculture. Farmers now use drones to precisely apply fertilizer, identify plant diseases, and scan areas for irrigation problems, all of which increase agricultural yields while cutting expenses (JOUAV, 2023).

Drone technology has also been beneficial to environmental studies. Without using costly satellite photography, scientists can employ drones to monitor wildlife populations, observe deforestation, and measure pollution levels (NIFA, 2023).

Drones are actively changing how we protect, observe, and engage with our environment; they are no longer merely a forward-thinking concept. However, many nations, including Nigeria, still struggle to integrate drones effectively due to technological constraints, legal obstacles, and a heavy reliance on imported models (Shearwater, 2022). By adapting and improving a locally made drone to meet Nigeria's specific surveillance and monitoring requirements, these challenges can be addressed.

Nigeria, on the other hand, still struggles with low agricultural productivity and outdated farming methods. Many farmers lack access to modern technology, resulting in huge postharvest losses (Technology Innovators, 2023). If drone technology were widely implemented in Nigeria’s agricultural sector, it could significantly boost food security and create more efficient farming systems.

Beyond farming, drones are also being used for environmental monitoring. Scientists now employ sophisticated drone sensors to detect air and water pollution, providing real-time data on environmental changes (Coverdrone, 2023). Conservationists also use drones to track endangered species, monitor deforestation, and assess the impact of climate change (Geoawesomeness, 2023).

Other applications of drones include the following:

i. **Disaster Response**: During natural disasters, drones play a critical role in search and rescue operations. They provide aerial views of affected areas, helping first responders locate survivors, assess damage, and deliver essential supplies (Rejed et al., 2022). ii. **Healthcare**: In remote and underserved regions, drones are being used to transport medical supplies, such as vaccines, blood samples, and even organs for transplantation. This has drastically reduced delivery times and improved access to life-saving treatments (Johnson et al., 2021).

iii. **Photography and Filmmaking**: Drones have transformed the filmmaking and photography industries by enabling the capture of stunning aerial shots that were previously unattainable or prohibitively expensive (Kim, 2017).

iv. **Delivery Services:** Companies like Amazon and FedEx are exploring the use of drones for last-mile delivery, reducing traffic congestion and carbon emissions while improving delivery efficiency (Benarbia et al., 2021).

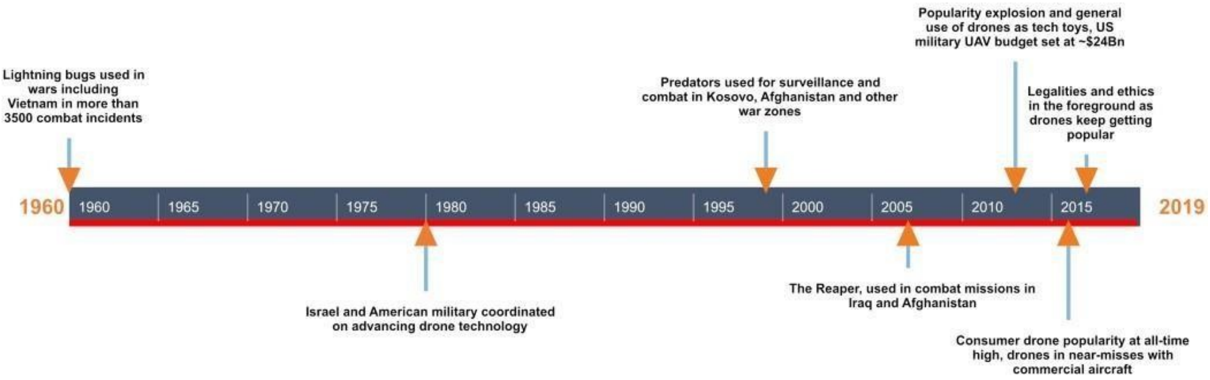


Figure 2.1-Historical Timeline of Drones

2.2 Global Applications of Drones

From being expensive military devices, drones are now used in practically every business. Drones are revolutionizing a variety of fields, including security agencies tracking criminals, farmers inspecting crops, and scientists analysing environmental changes.

2.2.1 Drones in Security and Défense

Drones are becoming an essential instrument in military and security operations for tactical operations, border observation, and intelligence collection. They can carry payloads in dangerous locations, follow movements, and even give live aerial footage. Drones are used by several countries for border patrols, event monitoring, and emergency response.

Consider the American military. Drones are used for everything from pinpoint attacks to battlefield observation. Drones are used by police in China and the United Arab Emirates for crowd management, crime surveillance, and search and rescue operations. Drones are being used for disaster relief and anti-poaching operations in even smaller countries.

On the other hand, Nigeria is still catching up. Drone usage is low despite rising security risks including oil theft, terrorism, and banditry. However, the Nigerian Police Forces have recently acquired tethered UAVs to enhance border security and monitor active crime scenes (Unmanned Systems Technology, 2022).

2.2.2 Agricultural and Environmental Monitoring with Drones

Back in the days, farmers would often rely on guesswork to manage their farms, but drones are currently changing that. Precision agriculture, which involves the use of drones to monitor crop health, irrigation needs, and pest infestations, has now become widespread in developed countries (DJI, 2023). These drones can even assist in automated spraying of fertilizers and pesticides, reducing waste and saving costs (EAvision, 2023).

In countries like India, drones are being used for farmland mapping and efficient pesticide distribution, leading to better crop management. Similarly, in Brazil, largescale farmers utilize drone technology to predict harvests and detect soil deficiencies, ensuring more precise farming decisions. These innovations help farmers produce more food while using fewer resources, making agriculture more efficient.

2.2.3 Advances in Drone Autonomy and AI-Driven Flight Systems

Drones are becoming increasingly intelligent and self-sufficient. Many contemporary drones are able to fly autonomously, recognize obstacles, and make judgments in real time because of artificial intelligence (AI) and machine learning.

a. **Obstacle Avoidance:** Without pilot assistance, drones can now recognize and steer clear of trees, buildings, and even moving objects.
b. **Autonomous Flight Paths**: AI-powered drones are ideal for mapping, surveillance, and delivery services because they can be configured to fly along predetermined paths.
c. **Swarm Technology:** Some research teams are creating drone swarms, in which several drones cooperate to do tasks, much like a flock of birds.

Leading companies in autonomous drone technology include DJI, Parrot, and Skydio. Startups in Africa are testing AI-powered surveillance drones for border security and anti-poaching initiatives.

Although Nigeria is currently lagging behind in AI-powered drone technology, investing in autonomous tracking and surveillance capabilities might have a significant impact on agriculture and security.

2.3 Nigeria's Adoption of Drones

Nigeria has been implementing drone technology in a number of areas in recent years, such as environmental monitoring, security, and agricultural. Nonetheless, there are obstacles as well as excitement on the path to broad acceptance.

2.3.1 Nigeria's Present Drone Technology Situation

Drone integration into Nigeria's agriculture industry is accelerating. Drones are being used by pioneers like Femi Adekoya, founder of Integrated Aerial Precision, to help farmers with soil analysis, crop health monitoring, and spraying precision. These developments seek to solve issues of food security and boost agricultural output.

Drones are being used for intelligence collection and monitoring in the field of security. Drones are used by law enforcement to track criminal activity, keep an eye on crowds, and improve public safety in general. Drone technology is also used by environmentalists to follow animals, monitor deforestation, and evaluate environmental changes.

2.3.2 Regulatory Guidelines and Difficulties

Drone activities in Nigeria are governed by the Nigerian Civil Aviation Authority (NCAA). To protect privacy and safety, operators must follow certain rules and get permissions. The legal environment is still developing, though, and some stakeholders worry that the current rules may be too onerous, which might impede innovation and wider adoption.

The widespread use of drones in Nigeria is further hampered by issues including low awareness, expensive procurement prices, and a lack of qualified workers. Furthermore, worries about data security and privacy present formidable obstacles that require thorough regulations and public awareness campaigns.

2.3.3 Limitations of Imported Drones in Local Applications

There are many issues with Nigeria's reliance on imported drones. The country's particular climatic conditions, such high temperatures and humidity, might not be well suited to imported models. Furthermore, importing drones might be too expensive for many local users, especially start-ups and small-scale farmers.

The problem of upkeep and repairs is another. For maintenance, imported drones frequently need specific components and knowledge that might not be easily accessible locally. Longer downtimes and higher operating expenses may result from this reliance.

There is a rising need for locally produced drones that are suited to Nigeria's unique requirements in order to get around these restrictions. Such a strategy might promote technical independence, lower costs, and improve sustainability.

Although Nigeria is making progress in using drone technology, resolving regulatory issues, lowering reliance on imports, and funding domestic innovation are essential measures to optimize drones' potential for the nation's growth.

2.4 Core Technologies in Drones

Unmanned Aerial Vehicles (UAVs), sometimes known as drones, depend on a sophisticated hardware and software combination to carry out their duties effectively. Each part is essential to guaranteeing the drone's stability, manoeuvrability, and data-processing capabilities, from flight control systems to sensor integration and communication modules.

To improve the drone's tracking, surveillance, and autonomous flight capabilities, a number of new parts can be added. The drone will be more appropriate for Nigeria's security, agricultural, and environmental applications with these enhancements, which will increase real-time monitoring, object detection, and flight precision.

2.4.1 Sensor Integration for Surveillance

For surveillance and tracking, the drone can be equipped with advanced sensors to enhance object detection, environmental awareness, and real-time data collection.

- **GPS module**: The GPS module enables the drone to track its location, follow preprogrammed paths, and return home if communication is lost.

Figure 2.2-GPS Module

2.4.3 Communication Systems and Remote-Control Limitations

Drones rely on communication modules, but remote-control limitations like signal interference can disrupt operations.

To address this, an Arduino Atmel Atmega 2560 improves signal processing and control input integration, enhancing the drone's response time and data transmission stability.

Figure 2.3-Arduino Atmel Atmega 2560

The drone also incorporates in it an automated return-home function that activates when communication is lost, extending flight autonomy and thus reducing the need for manual control dependence.

Significant improvement in a drone's operational efficiency can be achieved by transitioning from a standard short-range controller to a higher-range controller like the RadioLink AT10II 2.4G 12CH Transmitter. This controller operates on the 2.4GHz ISM band and provides an extended signal range of up to 2.49 miles (4 km), compared to entry-level controllers that typically have a range of 500 meters to 1 km.

One major limitation of short-range controllers is the risk of signal loss, which can result in loss of control and potential crashes. Drones that rely on basic controllers with shorter ranges are constrained in their flight distance, making them unsuitable for applications requiring longrange surveillance or autonomous operations.

Higher-range controllers, such as the RadioLink AT10II, incorporate Frequency Hopping Spread Spectrum (FHSS) technology, which enhances signal stability and minimizes interference. With 12 control channels, these controllers also allow for greater functionality, including camera operation, GPS navigation, and flight mode selection. Additionally, the integrated display screen provides real-time telemetry data, which is essential for monitoring drone performance during flight.

The implementation of extended-range controllers is particularly valuable in scenarios where long-range communication is necessary, such as security surveillance, agricultural monitoring, and environmental data collection. By improving signal strength and stability, such controllers significantly enhance the reliability and effectiveness of drones in real-world applications.

Figure 2.4-Radio Link AT10II transmitter

2.5 Challenges and Gaps in Drone Implementation in Nigeria

Despite the growing adoption of drone technology worldwide, Nigeria faces several technical, regulatory, and infrastructural challenges that hinder its widespread implementation. These challenges span across local manufacturing, software development, regulatory policies, and drone customization, which are critical for achieving self-sufficiency and maximizing the potential of drones in various industries.

2.5.1 Types of Drones

Drones come in a variety of types, each designed for specific purposes. Here are the most common types of drones:

1. **Consumer Drones:**

Purpose: Primarily used for recreational purposes and photography, they are easy to fly, equipped with cameras for photos and videos. Examples would be the DJI Phantom, DJI Mavic, Parrot Anafi.

2. **Racing Drones:**

Purpose: Built for high-speed racing and agility. Features include Lightweight, fast, and responsive, often custom-built for racing. Examples are the FPV (First Person View) drones used in drone racing competitions

3. **Commercial Drones:**

Purpose: Used for business and professional applications. Features include the ability to carry larger payloads, equipped with specialized cameras or sensors. Examples are Drones used in agriculture, surveying, filmmaking, and delivery

4. **Military Drones (Unmanned Aerial Vehicles - UAVs):**

Purpose: Used by the military for surveillance, reconnaissance, and targeted strikes. Features include Advanced capabilities such as long endurance, high-altitude flying, and carrying weapons. Examples are the MQ-9 Reaper, RQ-4 Global Hawk

5. **Fixed-Wing Drones:**

Purpose: Used for longer-distance flights, typically for surveying or mapping. Features include provision of longer flight times and greater stability and they resemble small airplanes. A good example would be the Sense Fly eBee.

6. Rotor Drones (Multirotor):

Purpose: Common for aerial photography and short-range flights. Features includes having multiple rotors (usually 4, 6, or 8) for stability and maneuverability. examples are the DJI Phantom, Yuneec Typhoon.

7. Hex copter and Octocopter Drones:

Purpose: Used for heavier payloads and stability, ideal for filming and professional use. Features includes having 6 (hex copter) or 8 (octocopter) rotors for added stability and payload capacity.
Examples would be the Free fly Alta, DJI S900.

8. Hybrid Drones:

Purpose: Combine the benefits of both fixed-wing and rotor drones. Features includes the ability to take off and land vertically but also fly like a plane for longer distances. Examples are the Vertical take-off and landing (VTOL) drones.

9. Underwater Drones (ROVs):

Purpose: Used for underwater exploration and research. Features are Designed to operate underwater, equipped with cameras and sensors for marine research. Examples are the Power Ray, BlueROV2.

Each type of drone is specialized for different tasks based on its design, flight capabilities, and features.

2.5.2 Limited Local Manufacturing and Software Development

One of the major challenges in Nigeria's drone ecosystem is the reliance on imported drones and components, leading to high costs and limited availability of spare parts. Most drones used in the country are manufactured in China, the United States, or Europe, with limited involvement from local engineers and industries. This dependency not only increases procurement costs but also creates difficulties in customization and maintenance.

Furthermore, drone software development in Nigeria is still in its infancy. Many drones operate on proprietary software, which restricts modifications and prevents seamless integration with locally developed technologies. The lack of open-source drone software development initiatives has made it challenging for Nigerian engineers to create customized solutions suited for local conditions.

2.5.3 Challenges in Drone Customization and Adaptation

Security Challenges:

Terrorism, banditry, kidnappings, and communal conflicts in Nigeria have also been aggravated by the limited surveillance infrastructure. Traditional methods of security, like manned patrols and CCTV cameras, have proven ineffective in sprawling rural areas and conflict-ridden regions. Literatures show that there is a large possibility for the future of UAVs being employed as surveillance for public safety which enhances intelligence management, rapid unit response, and situational awareness for most urban milieus (Dopamu, 2024)

Agricultural Challenges:

The farm productivity in Nigeria's agricultural sector, which employs upwards of 35% of the population, is very poor as a result of unproductive farming procedures. Farmers cannot get timely information on soil conditions, pest infestations, and irrigation requirements, which results in crop failure and food insecurity (Njoku & Anioke, 2024). Drones are being used as tools for precision farming in developed countries but have not been adopted in Nigeria due to high costs and a lack of localized expertise (Engineers Forum, 2024).

Environmental Challenges:

The challenges Nigeria faces from flooding, desertification, and deforestation all need to be monitored constantly to avoid disasters. The absence of monitoring technology further hampers agencies' abilities to detect environmental changes and incorporate timely interventions (Our Nigeria News, 2024). UAVs with high-resolution cameras and real-time data processing capabilities could enhance conservation efforts by monitoring pollution levels, wildlife movements, and deforestation (Total Military Insight, 2024).

Technological and Innovation Gap:

The use of imported drones, which are costly and not tailored to local conditions, is a significant constraint on Nigeria's drone sector. Additionally impeding the adaptation and effectiveness of UAVs in Nigerian contexts is the lack of locally developed algorithms and flight control systems (Abiodun, 2020). To close this technical divide, indigenous drone technology that is reasonably priced, adaptable, and equipped to handle Nigeria's unique problems must be developed (Dopamu, 2024).

A major challenge faced is the fact that there are no local GPS in Nigeria, another significant barrier is the difficulty in adapting imported drones to local needs. Many commercial drones are not designed for Nigeria's unique environmental conditions, such as:

a. High temperatures and humidity, which can affect battery performance.
b. Unstable power supply, which limits charging and maintenance.
c. Dense urban environments, which require better collision-avoidance systems.

Additionally, certain applications, such as agriculture and security surveillance, require custom sensor integration, which can be challenging due to compatibility issues with imported drone platforms. Locally engineered drones with modular designs could help solve these problems, but investment in research and development (R&D) is still lacking.

2.5.4 Need for Locally Developed Drone Software and Algorithms

For Nigeria to fully leverage drone technology, there is a pressing need for the development of local drone software and AI-based algorithms. Many advanced drones rely on AI-driven flight systems, computer vision, and real-time data analysis, which are essential for autonomous operations and intelligent decision-making. However, local expertise in AI and embedded systems for drones is still developing.

Investment in machine learning-based flight control, terrain adaptation, and real-time data processing could significantly enhance drone performance in Nigeria's unique terrain and use cases. Encouraging collaborations between universities, research institutions, and private tech companies could accelerate the development of homegrown drone software solutions.

2.6 Summary of Literature Review

The review of existing literature on drone technology and its adoption in Nigeria highlights several key findings and gaps that this study aims to address.

2.6.1 Key Findings from Previous Research

a. Drones have evolved from military applications to civilian and commercial use cases, including surveillance, agriculture, and environmental monitoring.
b. Advanced AI and autonomy have significantly improved drone capabilities, but their integration into Nigerian applications remains limited.

c. The adoption of drones in Nigeria is growing, but regulatory challenges, hardware limitations, and software dependence on foreign manufacturers continue to hinder progress.
d. Communication systems are a critical aspect of drone performance, with signal loss and range limitations being significant issues that can lead to flight failures and crashes.
e. There is a need for locally developed drone components, AI-driven software, and custom modifications to adapt drones for Nigerian environments and industries.

2.6.2 Relevance of This Study in Addressing the Identified Gaps

Majority of the challenges Nigeria faces in trying to adopt drone technologies can be solved by:

f. Exploring advanced communication systems to enhance signal range and reliability, reducing the risk of signal loss and crashes.
g. Investigating sensor integration to improve surveillance and autonomous operations for security applications.
h. Addressing local adaptation needs by proposing modifications that make drones more suitable for Nigerian environments.
i. Highlighting the importance of software independence by discussing how open-source and locally developed software can enhance drone customization and intelligence.

2.7 The Gap

The majority of drones brought into Nigeria have flight control systems that are preprogramed and difficult to change or re-program to meet local requirements. Because of their restricted versatility, these drones are less useful for some Nigerian applications including precision farming, environmental monitoring, and security surveillance in isolated locations. The nation's efforts to produce Drones have been seriously hampered by the incapacity to modify and personalize these drones.

Creating unique software and flight algorithms that work with locally modified drones is necessary to close this gap. By creating and deploying autonomous navigation algorithms, Realtime object tracking, and obstacle avoidance features, this project tackles this difficulty and increases the drone's adaptability and responsiveness to regional demands. Successfully developing and integrating locally programmed software marks a major milestone in advancing

Nigeria’s ability to produce, modify, and deploy UAVs tailored to its unique operational environments.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Overview of the Drone Modification Process

The modification of the drone which our predecessors have worked on to achieve flight stability involved a systematic approach aimed at enhancing its communication range, surveillance capabilities, and autonomous flight features. The need for these modifications arose after the initial version of the drone crashed due to signal loss, highlighting a critical limitation in its remote-control range. Additionally, integrating autonomous features was necessary to align the drone with modern surveillance and security applications in Nigeria.

3.1.1 Method of Drone Fabrication

The primary fabrication process for this project involves an in-depth review of relevant literature and a detailed examination of existing drones and their mechanisms. By leveraging insights from previous research and real-world applications, we integrate established methods with innovative approaches in our design and construction process. This methodology ensures a solid understanding of industry best practices while allowing for the incorporation of new techniques to enhance the drone's functionality and overall design. Through this iterative process rooted in past knowledge and adapted to current demands we strive to achieve an optimal balance of efficiency, reliability, and performance in our drone fabrication efforts.

Table 3.1 Tools used

S/N	Tool	Purpose	Items Used Upon
1	Soldering Iron	Creates permanent electrical connections	Wires (Flight Controller, ESC, Receiver), Lead
2	Screwdrivers	Tighten and loosen screws	Frame Assembly, Sensor Mounting, (Servo Mounts)
3	Allen Wrenches	Tighten and loosen Allen screws	Motor Screws
4	Propeller Balancer	Balances propellers for smoother flight	Propellers

5	Battery Charger	Recharges Lithium Ion Battery	Battery
6	Multimeter (for testing with Jumper Cables)	Tests electrical continuity and voltage	Jumper Cables (during testing)
7	Servo Tester	Tests servo functionality	Servos
8	Hot Glue	Provides a temporary or secondary bond	Sensor Mounting

This methodology outlines the step-by-step process undertaken to repair, upgrade, and optimize the drone. The key modifications can be categorized into three major areas:

1. **Repair and Restoration** – This included assessing the damage from the previous crash, replacing faulty components, and conducting stability tests to restore functionality.

2. **System Upgrades** – Enhancements were made to the communication system by replacing the short-range controller with the Radio Link AT10II, while additional sensors were integrated to support surveillance and autonomy.

3. **Autonomous Capabilities** – Features such as "Follow Me" mode, "Return Home" mode, and target locking were implemented to improve the drone’s ability to operate with minimal human input.

Throughout the process, testing and performance evaluation were carried out to ensure that each modification met the intended objectives. The subsequent sections of this chapter provide a detailed breakdown of each stage in the drone's modification.

3.2 Repair and Restoration of the Inherited Drone

Before implementing any modifications, it was essential to restore the inherited drone to a functional state. The previous version of the drone suffered a crash due to signal loss, which led to structural and electronic damage. This section details the process undertaken to repair and restore the drone.

3.2.1 Damage Assessment

The first step was to assess the extent of damage sustained during the crash. The primary issues identified included:

i. **Frame Damage:** Cracks and deformations in the drone's frame, affecting structural integrity.
ii. **Motor and Propeller Issues:** Some motors were non-functional, and a few propellers were broken.
iii. **Electronic Malfunctions:** Loose or disconnected wiring, and possible damage to the flight controller and power distribution board.

A thorough inspection was conducted to determine which components required replacement and which could be repaired.

3.2.2 Replacement of Damaged Components

Based on the assessment, the following repairs and replacements were made:

i. The damaged drone frame was replaced with a new F450 Drone Frame structure shipped from abroad.
ii. Faulty brushless motors and propellers were replaced with new ones to restore lift capability.
iii. The flight controller and power distribution board were tested, and all of the damaged electronic components were replaced.
iv. The battery and ESCs (Electronic Speed Controllers) were inspected to ensure they were still functional.

3.2.3 Reassembly and Testing

Once all necessary repairs were completed, the drone was reassembled, ensuring all connections were properly secured. Initial tests included:

i. **Motor Functionality Test:** Checking if all motors spin correctly when throttle is applied.
ii. **Stability Test:** Ensuring the drone maintains balance during hover tests.

iii. **Preliminary Flight Test:** Conducted under controlled conditions to confirm basic manoeuvrability.

After construction and software debugging, Practical test was conducted on the ability of the drone to fly To check vertical stability the test result is shown in chapter 4.

After successfully restoring the drone to a stable flying condition, the next phase focused on implementing system upgrades to enhance its performance.

3.3 Materials

Materials needed for the project include;

1. Flight Controller
2. Remote Controller Receiver
3. Electronic Speed Controller
4. Brushless Motors
5. Microcontroller
6. F450 Drone Frame
7. Propellers
8. Lithium-ion Battery (2200mah)
9. Sensors (Time of Flight, GPS, IMU)
10. Pulse position modulator (PPM) to pulse width (PW) converter
11. Jumper Cables
12. Buzzer
13. Tester
14. Shock Damper
15. Distribution Boards
16. Raspberry pi 5
17. Ai camera

TABLE 3.2: Shows Major Components Parts, Materials Used and Justification

S/N	Component part	Material used	Justification
i.	Flight Controller (Pixhawk 2.4.8)	Made of silicon board and plastic	Programmable, Has fast data processing speed
ii.	Remote Controller Receiver	Made of silicon	Cheap, readily available
iii.	Electronic Speed Controller (ESC)	Made of silicon board, resistors, chips	Cheap, less power consumption, doesn't burn out
iv.	Brushless Motors	Copper wire	Better torque, Smooth run, Less maintenance
v.	F450 Drone Frame	Polyamide Nylon	Ease of balancing, High resistance to rust Light weight
vi.	Propellers	Nylon	Good strength and rigidity
vii.	Lithium Battery	Lithium polymer	Better life span, Better cell compared to others
viii.	Sensors (Time of Flight, GPS, IMU)	Chips and silicon board	Cheap, Readily available
ix.	Pulse position modulator (PPM) to pulse width (PW) converter	Resistors, silicon board capacitor	Cheap, Low generation of heat
x.	Jumper Cables	Copper wire	Readily available
xi.	buzzer	speaker	Cheap and readily available
xii.	Tester	Metallic iron	cheap
xiii.	Shock Damper	spring	Cheap and readily available
xiv.	Distribution Boards	Silicon board	Strong, corrosion resistance

3.3.1 Flight Control Systems and Microcontrollers

The drone's flight control system regulates motor speeds, keeps the drone balanced, and ensures smooth navigation. It interprets data from various sensors and remote commands to manage flight operations.

The integration of a high-performance STM32H7 microcontroller will improve the drone's computing efficiency and reaction time. This will enhance real-time decision-making, navigation accuracy, and flight stability.

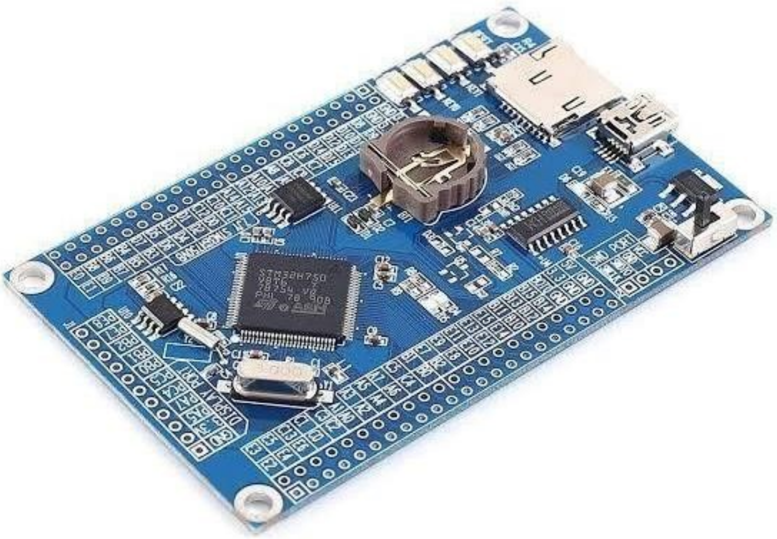


Figure 3.1-STM32H7 Microcontroller

A Raspberry Pi 5 will also serve as an onboard computer to handle automation, AI-based tracking, and image processing. This will enable more intelligent flight path modifications and faster object detection.

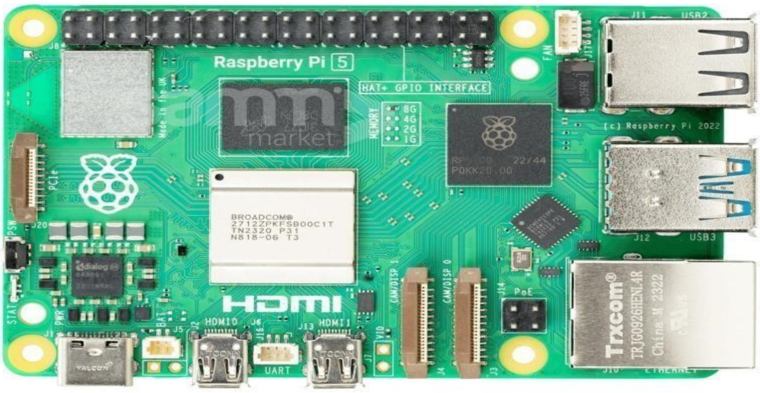


Figure 3.2-Raspberry Pi 5

- **Raspberry Pi Camera Rev 1.3:** The Raspberry Pi Camera Rev 1.3 provides clear aerial imagery and video, improving the drone's visual surveillance.

F

- **Ultrasonic sensors**: Ultrasonic sensors help the drone detect obstacles, measure distances, and navigate without crashing.

Figure 3.4-Ultrasonic sensors

3.3.2 Method of Drone Fabrication

Building a locally modified drone with advanced technical capabilities is a process that requires both theoretical knowledge and hands-on expertise. The journey starts with extensive research into existing literature and an in-depth study of commercially available drones to understand their design, functionality, and limitations. By merging tried-and-tested methods with innovative modifications, the fabrication process ensures that the final product achieves maximum performance, efficiency, and adaptability.

One of the key aspects of this modification process is iterative prototyping, where constant refinements are made based on real-world testing. Careful selection of high-quality materials and cutting-edge components is essential to improve the drone's durability and operational effectiveness. Moreover, software improvements such as real-time data processing, artificial intelligence-based automation, and advanced navigation algorithms are integrated to enable autonomous operations and intelligent decision-making. This methodical approach guarantees that the modified drone not only meets specific operational requirements but also remains cost effective and adaptable to a wide range of applications. The fabrication of a locally modified drone with advanced technical capabilities requires an in-depth understanding of both theoretical concepts and practical applications. This process begins with a comprehensive review of existing literature and a detailed examination of commercially available drones to identify their strengths and limitations. By integrating proven methodologies with innovative solutions, the fabrication process ensures optimal performance, efficiency, and reliability.

A key aspect of this modification involves iterative prototyping, where adjustments and improvements are made based on real-world testing and analysis. Advanced materials and high performance components are carefully selected to enhance the drone's durability and operational effectiveness. Furthermore, software enhancements, such as real-time data processing and AI-driven automation, are incorporated to enable autonomous operations and intelligent decision-making. This structured approach ensures that the modified drone meets specific operational requirements while maintaining cost-effectiveness and adaptability to various applications.

3.3.2. Design Requirement

1. Implementation of autonomous flight
2. Determination of motor power
3. Determination of flight time
4. Implementation of object tracking
5. Determination of desired flight control
6. Determination of stable hover capability
7. Implementation of obstacle avoidance

8. Optimization of aerodynamic design

3.3.3 Drone Description

From the Conceptual design proposed by our predecessors, the design for the drone makes use of the F450 drone frame. It’s a popular multirotor platform known for its stability and versatility.

i. **Frame**: The F450 frame is a typical quadcopter frame composed of plastic, which is a lightweight material. It can hold a variety of electronic components and is built to last and cost-effective.

ii. **Flight Controller**: Pixhawk 2.4.8 has a High-performance open-source autopilot software used to operate fixed-wing aircraft, multicopper, and other robotic platforms. It has a good processing capability and is best used for multirotor flight control.

iii. **Brushless Motors**: The drone is equipped with four brushless motors, each capable of producing 2.5 kg of torque and reaching a speed of 12000 RPM. These motors provide the necessary thrust for lift, high efficiency, low maintenance, and improved durability. These motors also provide smoother operation and better control making them suited for various types of drones. iv. **Battery**: The drone uses a 2200mAh LiPo (Lithium Polymer) battery pack for power. LiPo batteries are lightweight and provide high energy density, making them ideal for drones.

v. **Propellers**: An 11 x 4.5 inch propeller with nylon material Four propellers are mounted on the motors to generate lift. vi. **Electronic Speed Controllers (ESCs):** Based on inputs from the flight controller, these regulate the motors' velocity.

vii. **Radio Transmitter and Receiver:** These gadgets allow the drone and the pilot to communicate to control the drone remotely.

viii. **GPS Module**: gives location information for position hold and autonomous flight modes.

ix. **LED Lights**: optional for orientation and visibility, particularly in dimly lit areas.

x. **AI surveillance**: This camera uses artificial intelligence algorithms to analyse video footage in real-time, allowing for advanced object detection, tracking, and analysis beyond basic motion detection, including features like facial recognition, vehicle detection, people counting, and license plate recognition, significantly enhancing security capabilities while raising privacy concerns due to the data collected.

xi. **Raspberry Pi 5:** The Raspberry Pi is a very cheap computer that provides a set of GPIO (general purpose input/output) pins, allowing you to control electronic components for physical computing and explore the Internet of Things (IoT). The Raspberry Pi 5 is also capable of running your processing systems without stress, it is the latest model as of the time I am writing this report.

When combined with the aforementioned parts and a Pixhawk 2.4.8 flight controller, the F450 drone provides a powerful platform appropriate for a range of uses, such as recreational flying, aerial photography, and surveying.

3.4 Detailed Design Motors

3.4 Detailed Design Motors

The type of motor that was used in the initial drone design is brushless motor because of their reduced power consumption and compact dimensions, they are ideal for equipment that require high output torque for long periods of time. These brushless motors are still being used for this project because of their battery saving capability, better control precision and higher efficiency of the device.

Across the board, quad copter applications use brushless motors. The torque generated by our electric motors is provided by (Chikasha, 2018).

$$\tau = Kt(I - I_0) \qquad (3.4.1)$$

When the motor is not doing any work, the current is denoted by I0, and the torque constant is Kt, while the torque produced by the motor is τ. To find the voltage across the motor, you add the back-EMF and a bit of resistive loss. The voltage equation is given by (Chikasha, 2018):

$$V = IRm + Kv\omega \qquad (3.4.2)$$

Here, ω represents the motor's rotational speed, V is the voltage drop across the motor, Rm is the motor resistance, and Kv is the constant that shows how much back-EMF the motor generates for each revolution. For a detailed breakdown of power consumption, refer to Chikasha (2018).

$$\mathrm{P} = \mathrm{IV} = \frac{(\tau+kt10)(kt10Rm+\tau Rm+ktkv\acute{\omega})}{kt} \qquad (3.43)$$

Assuming the motor resistance is small, we'll stick with our simple model. Now, the power starts to match the angular velocity like this:

$$\mathrm{P} \approx \frac{(\tau+kt10)kvw}{kt} \qquad (3.4.4)$$

We can further simplify our model. When you consider that I0 is the current in the absence of a load and is therefore relatively tiny, this is not entirely absurd. This approximation is reasonably accurate in practice. As a result, we arrive at our simplified, final power equation:

$$\mathrm{P} = \frac{kv}{kt}\tau\omega \qquad (3.4.5)$$

Forces

principle of conservation of energy, the energy used by the motor over time equals the force on the propeller multiplied by the air displacement. This gives us (P·d t = F·d x). P = Fdx/dt, This equation tells us that power is just the thrust (force) times the air velocity, as shown by Kadam et al. (2021). So we can write:

$$\mathrm{P} = Tvh \qquad (3.4.6)$$

Here, vh represents the air velocity when the quadcopter is hovering. We assume the vehicle's speed is low, and the air around the quadcopter is pretty still, so we consider the free stream velocity v∞ to be zero. According to momentum theory (Srinivas et al., 1995), the hover velocity equation as a function of thrust looks like this:

$$V_h = \sqrt{\frac{T}{2PA}} \qquad (3.4.7)$$

Where is the area the rotor sweeps, and is the air density. Now, plugging this back into the power equation, we get:

$$\mathrm{P} = \frac{kv}{kt}\tau\omega = \frac{kvkt}{kt}\tau\omega = \frac{T\frac{3}{2}}{\sqrt{2pA}} \qquad (3.4.8)$$

Keep in mind that in the general scenario, τ=r×F; in this case, the torque and thrust T are proportionate to each other by a fixed ratio Kτ that is established by the parameters and blade arrangement. The thrust is proportional to the square of the motor's angular velocity, and we can determine the thrust magnitude by solving for it (Bangura and Mahony, 2017; Chikasha, 2018).

$$T = \left(\frac{KvKt\sqrt{2PA}}{Kt}\omega\right)v2 = \mathrm{K}\omega^2 \qquad (3.4.9)$$

In this case, k is just a constant that has the right units to make sure everything adds up correctly. Chikasha (2018) mentions that when you combine the thrust from all the motors, you get the total thrust for the quadcopter in its body frame, which can be written as:

$$TB = \sum_{|\omega|}^{4} Tt = K(0\ 0 \sum \omega tz\ ) \qquad (3.4.10)$$

Apart from the thrust force, the friction force will also be described as a function of the linear velocity in each direction. Although this explanation of fluid friction is an oversimplification, it is sufficient for the purposes of modeling and simulation. An additional force component will be included to represent the global drag forces (Lien et al., 2005).

$$FD = [-K_d x - K_d y - K_d z\ ] \qquad (3.4.11)$$

The constant$K_d$can be separated into three distinct friction constants, each corresponding to a different direction of motion, if greater precision is required. In such a case, it would be more advantageous to simulate friction in the body frame rather than the inertial frame.

Torques

Now that the forces have been determined, the torques on the quadcopter should also be calculated. Each rotor contributes a specific amount of torque to the body's z-axis. This torque generates instantaneous angular acceleration and counteracts the frictional drag forces, which are essential for maintaining the propeller's rotation and thrust production. According to Rajput (2004), the frictional force can be calculated using the drag equation in fluid dynamics.

$$FD = \frac{1}{2} \rho C_D A v^2 \qquad (3.4.12)$$

Here, C_D is a dimensionless constant, represents the reference area (the propeller cross-section, not the area swept by the propeller), and is the surrounding fluid density. Although this may not always be perfectly accurate, it is sufficient for our purposes. By comparing the drag force to the torque equation, the torque generated by drag can be derived from the equations provided by Chikasha (2018) and Rajput (2004).

$$\tau_D = \frac{1}{2} R\rho C_D A v^2 = R\rho C_D A (\omega R)^2 = \frac{1}{2} \qquad b_\omega^2 \qquad (3.4.13)$$

Here, R represents the radius of the propeller, is a constant with the appropriate dimensions, and ω is the angular velocity of the propeller. Although the assumption that all force is applied at the propeller's tip is not entirely accurate, the key takeaway is that the drag torque is proportional to the square of the rotational velocity. Based on this, the total torque of the th motor about the z-axis can be expressed as follows (Chikasha, 2018):

$$\tau_Z = b\omega^2 + I_M\omega \qquad (3.4.14)$$

Where b is our drag coefficient, $\dot{\omega}$ is the propeller's angular acceleration, and I_M is the moment of inertia about the motor's z axis. It should be noted that during steady state flight (i.e., neither takeoff nor landing), $\dot{\omega} = 0$ because the propellers will typically be sustaining a constant thrust, if not accelerating. As a result, we eliminate this phrase and reduce the entire sentence to

$$\tau z = (-1)^{i+1} b\omega_i^2 \qquad (3.4.15)$$

If the propeller rotates in a clockwise direction, the $(-1)^{i+1}$ term will be positive; otherwise, it will be negative. According to Hang et al. (2012) and Chikasha (2018), the total torque about the z-axis (yaw) can be determined by summing the torques generated by all the propellers.

$$\tau\psi = b({}_{\omega}2 1 - {}_{\omega}2 2 + {}_{\omega}2 3 - {}_{\omega}2 4) \qquad (3.4.16)$$

Standard mechanics defines the roll and pitch torques. The placement of motors I =1 and I = 3 along the roll axis can be selected arbitrarily, as stated by Etemadi (2017) and Chikasha (2018): ${}^{\tau}\phi = \sum r \times T = L(k\omega_1{}^2 - k\omega_3{}^2) = Lk(\omega_1{}^2 - \omega_3{}^2) \quad (3.4.17)$ Accordingly, a

comparable calculation yields the pitch torque.

$$^{\tau}\theta = LK(\omega_2{}^2 - \omega_4{}^2) \qquad (3.4.18)$$

Here, L denotes the distance between each propeller and the center of the quadcopter. By combining these relationships, the torques within the body frame can be expressed as follows, according to Etemadi (2017) and Chikasha (2018):

$$\tau_B = [\tau_{Roll}\ \tau_{pitc_{\hbar}}\tau_{yaw}\ ] \qquad (3.4.19)$$

$$\tau_B = [LK(\omega_{12} - \omega_{32})\ LK(\omega_{22} - \omega_{42})\ b(\omega_{12} - \omega_{22} + \omega_{32} - \omega_{42})\ ] \qquad (3.4.20)$$

We started our design process by measuring the total weight of the drone including all the design components and electronics which amounted to a weight of 1650g. Following these estimated drone specifications, calculations showed that about 4.125N of thrust per propeller is needed for hover flight. Having estimated the drone's efficient thrust, the need now arises to estimate our flight time. This can be gotten from real-world flight test. We will assume the following mass breakdown of our 1650g drone:

Motors (4): 960 g

Propellers (4): 13.5 g

Battery (1): 250 g

Other components (camera, frame, ESC, etc.): 426.5 g

Total Weight (TW) = 960g + 13.5g + 250g + 426.5g

TW = 1650g

Power Rating

Calculation with the data below
Motors: Operating voltage = 12V, Current draw = 22A (per motor)

Flight Controller: Operating voltage = 5V, Current draw = 0.2A

Sensors and Electronics: Operating voltage = 5V, Total current draw = 2A

Other Electronics (including ESCs (4 ESCs), etc.): Operating voltage = 12V, Total current draw = 5.5A

To calculate the power rating of the drone and estimate the power consumption of each component, we'll use the formula:

$$P = V \times I$$

Where: P is the power consumption (in watts).

V is the operating voltage (in volts).

I is the current draw (in amperes).

Let's perform the calculations for each component:

Motors:

Operating voltage (V) = 12V

Current draw (I) = 22A (per motor)

P Motors = V motors × I motors

P Motors = 12 V × 22 A

P Motors = 264 W

Since there are 4 motors, the total power consumption for all motors is

Total Power = 4 × 264 W
= 1056 W

Flight Controller

Operating voltage (V) = 5V

Current draw (I) = 0.3A

Power Rating for Flight Controller = V FC × I FC

PFC = 5 V × 0.3 A

PFC = 1.5 W
Sensors and Electronics

Operating voltage (V) = 5V

Total current draw (I) = 2A

P Sensors = Vsensors × I sensors

Psensors = 5 V × 2 A

P sensors = 5 V × 2 A

P Sensors = 10 W

There are about 5 sensors

P sensor = 10 W × 3

P sensor = 30 W

Other Electronics

Operating voltage (V) = 25V
Total current draw (I) = 5.5A

P other = V other × I other
P other = 10 V × 5 A

P other = 50 W

Summing up the power consumption of all components to get the total power rating:

Total Power Rating = P motors + P FC + P sensors + P other

Total Power Rating = 1056 W + 1.5 W + 30 W + 50 W

Total Power Rating = 1137.5W
The total power rating of the drone is 1137.5 watts.

Weight of the drone (N)

W (N) = Mass (kg) x Gravity (m/s²)

W = 1.65 (kg) x 9.81 (m/s²)

W = 16.1865 (N)

Calculate the Total Thrust Generated by Motors

Multiply the thrust per motor by the number of motors.

Total Thrust (TT) = $Thrust\ per\ motor\ \times Number\ of\ motor$

Thrust per Motor: 2500 grams
Number of Motors: 4

TT = 2500×4

TT = 10 kilograms

Thrust-to-Weight Ratio (TWR)

$$TWR = \frac{TT}{TW}$$

$$TWR = \frac{10000}{1650}$$

TWR ≈ 6.06

3.5 Operations during Fabrication

3.5.1 Assembling operation

All components and materials acquired were assembled using simple tools such as screwdrivers, Allen key, plier, tap and glue, etc.

3.5.2 Soldering Operation

This is the process of creating electrical connections between all components, to ensure power distribution. This operation involves using lead wires and soldering iron.

3.6 Software Design

The drone utilizes Pixhawk 2.4.8 flight controller to manage flight control, navigation, and payload operations which integrates various modules to ensure stable flight and customizable functionality with a ESP 32 and raspberry pi 5 microprocessor to manage autonomous flight, object tracking, and obstacle avoidance. The Pixhawk flight controller firmware provides the core flight control algorithms, including stabilization, attitude control, and position hold. It interfaces with the drone's sensors, such as accelerometers, gyroscopes, compass, and GPS, to gather data for navigation and stabilization. The software implements communication protocols such as MAV Link for communication between the flight controller and ground control stations (GCS). The Raspberry Pi 5 and Arduino microcontroller execute these missions autonomously, navigating to specified waypoints and performing designated tasks. The software supports the integration of various payloads, such as cameras, or sensors, enabling payload control and data acquisition during flight. Fail-safe features are implemented to ensure safe operation in case of communication loss or system errors. These may include Return-to-Home (RTH) functionality, auto-landing procedures, or configurable fail-safe behaviors based on user preferences.

Implementing new algorithms for object tracking, follow-me-mode, and autonomous flight. Rigorous testing and validation procedures are conducted to ensure software reliability, stability, and compliance with safety standards. This includes unit testing, integration testing, simulation-based testing, and field testing under environmental conditions.

3.6.1 Integrated Development Environment (IDE); Text Editor and Compiler

Programmers can write, build, and upload code to microcontroller boards using the Arduino and a raspberry pi Integrated Development Environment (IDE) which is a vital tool for creating functionalities for drones

Programming the Drone work with IDE:

Writing the Code: The programming language used for utilizing the drone based on Wiring (a simplified version of C/C++ and python), to define the behavior and functionality of the drone. The code specifies how the drone responds to various inputs and controls.

The IDE compiles the written code into machine-readable instructions, generating a binary file that can be uploaded to the microcontroller. Compilation ensures that the code is translated into a format compatible with the microcontroller architecture.

After compilation, the firmware binary is uploaded to the microcontroller board via a USB connection. The IDE manages the uploading process, transferring the compiled code to the microcontroller's flash memory for execution.

Programmers can test the drone's functionality by connecting it to sensors, actuators, and peripherals. The IDE provides tools for monitoring serial output, debugging code, and troubleshooting issues to ensure proper functionality.

It supports iterative development, allowing programmers to make changes and improvements to the firmware based on testing results and feedback. This iterative process enables continuous refinement of the drone's functionality and performance.

3.5.2 Uploaded Code

```
/Uncomment only one receiver  type
```

```
// Your one and only Madrigal
// Engineering students drone
#define USE_PWM_RX
//#define USE_PPM_RX
//#define USE_SBUS_RX //#define USE_DSM_RX
static const uint8_t num_DSM_channels = 6; //If using DSM RX, change this to match the number of transmitter channels you have

//Uncomment only one IMU
#define USE_MPU6050_I2C //Default
//#define USE_MPU9250_SPI

//Uncomment only one full scale gyro range (deg/sec)
#define GYRO_250DPS //Defaul
//#define GYRO_500DPS
//#define GYRO_1000DPS
//#define GYRO_2000DPS

//Uncomment only one full scale accelerometer range (G's)
#define ACCEL_2G //Default
//#define ACCEL_4G
//#define ACCEL_8G
//#define ACCEL_16G


//========================================================================================================================//



//REQUIRED LIBRARIES (included with download in main sketch folder)

#include <Wire.h>     //I2c communication
#include <SPI.h>      //SPI communication
#include <PWMServo.h> //Commanding any extra actuators, installed with teensyduino installer

#if defined USE_SBUS_RX
  #include "src/SBUS/SBUS.h"   //sBus interface
#endif

#if defined USE_DSM_RX
  #include "src/DSMRX/DSMRX.h"
#endif

#if defined USE_MPU6050_I2C
  #include "src/MPU6050/MPU6050.h"
```

```
  MPU6050 mpu6050;
#elif defined USE_MPU9250_SPI
  #include "src/MPU9250/MPU9250.h"
  MPU9250 mpu9250(SPI2,36);
#else
  #error No MPU defined...
#endif



//===================================================================
=========================================================//



//Setup gyro and accel full scale value selection and scale factor

#if defined USE_MPU6050_I2C
  #define GYRO_FS_SEL_250    MPU6050_GYRO_FS_250
  #define GYRO_FS_SEL_500    MPU6050_GYRO_FS_500
  #define GYRO_FS_SEL_1000   MPU6050_GYRO_FS_1000
  #define GYRO_FS_SEL_2000   MPU6050_GYRO_FS_2000
  #define ACCEL_FS_SEL_2     MPU6050_ACCEL_FS_2
  #define ACCEL_FS_SEL_4     MPU6050_ACCEL_FS_4
  #define ACCEL_FS_SEL_8     MPU6050_ACCEL_FS_8
  #define ACCEL_FS_SEL_16    MPU6050_ACCEL_FS_16
#elif defined USE_MPU9250_SPI
  #define GYRO_FS_SEL_250    mpu9250.GYRO_RANGE_250DPS
  #define GYRO_FS_SEL_500    mpu9250.GYRO_RANGE_500DPS
  #define GYRO_FS_SEL_1000   mpu9250.GYRO_RANGE_1000DPS
  #define GYRO_FS_SEL_2000   mpu9250.GYRO_RANGE_2000DPS
  #define ACCEL_FS_SEL_2     mpu9250.ACCEL_RANGE_2G
  #define ACCEL_FS_SEL_4     mpu9250.ACCEL_RANGE_4G
  #define ACCEL_FS_SEL_8     mpu9250.ACCEL_RANGE_8G
  #define ACCEL_FS_SEL_16    mpu9250.ACCEL_RANGE_16G
#endif

#if defined GYRO_250DPS
  #define GYRO_SCALE GYRO_FS_SEL_250
  #define GYRO_SCALE_FACTOR 131.0
#elif defined GYRO_500DPS
  #define GYRO_SCALE GYRO_FS_SEL_500
  #define GYRO_SCALE_FACTOR 65.5
#elif defined GYRO_1000DPS
  #define GYRO_SCALE GYRO_FS_SEL_1000
  #define GYRO_SCALE_FACTOR 32.8
#elif defined GYRO_2000DPS
```

```
  #define GYRO_SCALE GYRO_FS_SEL_2000
  #define GYRO_SCALE_FACTOR 16.4
#endif

#if defined ACCEL_2G
  #define ACCEL_SCALE ACCEL_FS_SEL_2
  #define ACCEL_SCALE_FACTOR 16384.0
#elif defined ACCEL_4G
  #define ACCEL_SCALE ACCEL_FS_SEL_4
  #define ACCEL_SCALE_FACTOR 8192.0
#elif defined ACCEL_8G
  #define ACCEL_SCALE ACCEL_FS_SEL_8
  #define ACCEL_SCALE_FACTOR 4096.0
#elif defined ACCEL_16G
  #define ACCEL_SCALE ACCEL_FS_SEL_16
  #define ACCEL_SCALE_FACTOR 2048.0
#endif



//=========================================================
================================================//
//                                   USER-SPECIFIED VARIABLES
//
//=========================================================
================================================//

//Radio failsafe values for every channel in the event that bad reciever data is detected.
Recommended defaults:   unsigned long
channel_1_fs = 1000; //thro  unsigned
long channel_2_fs = 1500; //ail unsigned
long channel_3_fs = 1500; //elev
unsigned long channel_4_fs = 1500;
//rudd
unsigned long channel_5_fs = 2000; //gear, greater than 1500 = throttle cut unsigned  long
channel_6_fs = 2000; //aux1

//Filter parameters - Defaults tuned for 2kHz loop rate; Do not touch unless you know what
you are doing:   float B_madgwick = 0.04;  //Madgwick filter parameter  float B_accel = 0.14;
//Accelerometer LP filter paramter, (MPU6050 default: 0.14. MPU9250 default: 0.2) float
B_gyro = 0.1;       //Gyro LP filter paramter, (MPU6050 default: 0.1. MPU9250 default:
0.17) float B_mag = 1.0;        //Magnetometer LP filter parameter

//Magnetometer calibration parameters - if using MPU9250, uncomment
calibrateMagnetometer() in void setup() to get these values, else just ignore these
float MagErrorX = 0.0; float MagErrorY = 0.0;  float MagErrorZ = 0.0; float
MagScaleX = 1.0; float MagScaleY = 1.0;  float MagScaleZ = 1.0;
```

```
//IMU calibration parameters - calibrate IMU using calculate_IMU_error() in the void setup()
to get these values, then comment out calculate_IMU_error() float AccErrorX = 0.0; float
AccErrorY = 0.0; float AccErrorZ = 0.0; float GyroErrorX = 0.0; float GyroErrorY= 0.0;
float GyroErrorZ = 0.0;

//Controller parameters (take note of defaults before modifying!):  float i_limit = 25.0;
//Integrator saturation level, mostly for safety (default 25.0) float maxRoll = 30.0;     //Max
roll angle in degrees for angle mode (maximum ~70 degrees), deg/sec for rate mode    float
maxPitch = 30.0;    //Max pitch angle in degrees for angle mode (maximum ~70 degrees),
deg/sec for rate mode   float maxYaw = 160.0;     //Max yaw rate in deg/sec

float Kp_roll_angle = 0.2;    //Roll P-gain - angle mode  float Ki_roll_angle = 0.3;    //Roll
Igain - angle mode float Kd_roll_angle = 0.05;   //Roll D-gain - angle mode (has no effect on
controlANGLE2) float B_loop_roll = 0.9;      //Roll damping term for controlANGLE2(),
lower is more damping (must be between 0 to 1)
float Kp_pitch_angle = 0.2;   //Pitch P-gain - angle mode float Ki_pitch_angle = 0.3;   //Pitch
I-gain - angle mode float Kd_pitch_angle = 0.05;  //Pitch D-gain - angle mode (has no effect
on controlANGLE2) float B_loop_pitch = 0.9;     //Pitch damping term for controlANGLE2(),
lower is more damping (must be between 0 to 1)

float Kp_roll_rate = 0.15;    //Roll P-gain - rate mode  float Ki_roll_rate = 0.2;     //Roll I-gain
- rate mode   float Kd_roll_rate = 0.0002;  //Roll D-gain - rate mode (be careful when
increasing too high,  motors will begin to overheat!) float Kp_pitch_rate = 0.15;  //Pitch P-
gain - rate mode float Ki_pitch_rate = 0.2;    //Pitch I-gain - rate mode  float Kd_pitch_rate =
0.0002; //Pitch D-gain
- rate mode (be careful when increasing too high,  motors
will begin to overheat!)

float Kp_yaw = 0.3;          //Yaw P-gain float Ki_yaw = 0.05;         //Yaw I-gain  float Kd_yaw
= 0.00015;       //Yaw D-gain (be careful when increasing too high, motors will  begin
to overheat!)



//=============================================================
=========================================================//
//                                    DECLARE PINS                                //
//=============================================================
=========================================================//
//NOTE: Pin 13 is reserved for onboard LED, pins 18 and 19 are reserved for the MPU6050
IMU for default setup //Radio:
//Note: If using SBUS, connect to pin 21 (RX5), if using DSM, connect to pin 15 (RX3)
const int ch1Pin = 15; //throttle const int ch2Pin = 16; //ail const int ch3Pin = 17; //ele const
int ch4Pin = 20; //rudd   const int ch5Pin = 21; //gear (throttle cut) const  int ch6Pin = 22;
//aux1 (free aux channel)   const int PPM_Pin = 23; //OneShot125 ESC pin outputs:  const
int m1Pin = 0; const  int m2Pin = 1; const int m3Pin = 2; const int m4Pin = 3; const int
m5Pin = 4; const int m6Pin = 5;
```

```
//PWM servo or ESC outputs:  const
int servo1Pin = 6; const  int
servo2Pin = 7; const int servo3Pin
= 8; const int servo4Pin = 9; const
int servo5Pin = 10; const int
servo6Pin = 11; const int
servo7Pin = 12;
PWMServo servo1;  //Create servo objects to control a servo or ESC with PWM
PWMServo servo2;
PWMServo servo3;
PWMServo servo4;
PWMServo servo5;
PWMServo servo6;
PWMServo servo7;



//==============================================================
=====================================================//



//DECLARE GLOBAL VARIABLES

//General stuff
float dt;
unsigned long current_time, prev_time;  unsigned
long print_counter, serial_counter; unsigned long
blink_counter, blink_delay; bool blinkAlternate;

//Radio communication:
unsigned long channel_1_pwm,        channel_2_pwm,     channel_3_pwm,     channel_4_pwm,
channel_5_pwm, channel_6_pwm;
unsigned        long  channel_1_pwm_prev,  channel_2_pwm_prev,          channel_3_pwm_prev,
channel_4_pwm_prev;

#if   defined   USE_SBUS_RX
SBUS sbus(Serial5);   uint16_t
sbusChannels[16];           bool
sbusFailSafe;                   bool
sbusLostFrame;
#endif
#if defined USE_DSM_RX
  DSM1024 DSM;
#endif

//IMU:  float AccX, AccY, AccZ;  float
AccX_prev, AccY_prev, AccZ_prev; float
```

```
GyroX, GyroY, GyroZ;  float GyroX_prev, GyroY_prev,
GyroZ_prev;  float MagX, MagY, MagZ; float
MagX_prev, MagY_prev, MagZ_prev; float roll_IMU,
pitch_IMU, yaw_IMU; float roll_IMU_prev,
pitch_IMU_prev;   float q0 = 1.0f; //Initialize quaternion
for madgwick filter  float q1 = 0.0f; float q2 = 0.0f; float
q3 = 0.0f;

//Normalized desired state: float thro_des, roll_des,
pitch_des, yaw_des; float roll_passthru,
pitch_passthru, yaw_passthru;

//Controller: float error_roll, error_roll_prev, roll_des_prev, integral_roll, integral_roll_il,
integral_roll_ol, integral_roll_prev, integral_roll_prev_il, integral_roll_prev_ol,
derivative_roll, roll_PID = 0; float error_pitch, error_pitch_prev, pitch_des_prev,
integral_pitch, integral_pitch_il, integral_pitch_ol, integral_pitch_prev,
integral_pitch_prev_il, integral_pitch_prev_ol, derivative_pitch, pitch_PID = 0;
float error_yaw, error_yaw_prev, integral_yaw, integral_yaw_prev, derivative_yaw, yaw_PID
= 0;

//Mixer
float  m1_command_scaled,   m2_command_scaled,           m3_command_scaled,
m4_command_scaled, m5_command_scaled, m6_command_scaled;  int
m1_command_PWM, m2_command_PWM, m3_command_PWM, m4_command_PWM,
m5_command_PWM, m6_command_PWM;
float  s1_command_scaled,  s2_command_scaled,  s3_command_scaled,  s4_command_scaled,
s5_command_scaled, s6_command_scaled, s7_command_scaled;  int s1_command_PWM,
s2_command_PWM, s3_command_PWM, s4_command_PWM,  s5_command_PWM,
s6_command_PWM, s7_command_PWM;

//Flight           status   bool armedFly
= false;

//=============================================================
=====================================================//
//                                    VOID SETUP                                    //
//=============================================================
=====================================================//

void setup() {
  Serial.begin(500000);          //USB  serial   delay(500);

  //Initialize all pins
  pinMode(13, OUTPUT); //Pin 13 LED blinker on board, do not modify
pinMode(m1Pin, OUTPUT);   pinMode(m2Pin, OUTPUT);   pinMode(m3Pin, OUTPUT);
pinMode(m4Pin, OUTPUT);   pinMode(m5Pin, OUTPUT);   pinMode(m6Pin, OUTPUT);
  servo1.attach(servo1Pin, 900, 2100); //Pin, min PWM value, max PWM value
servo2.attach(servo2Pin, 900, 2100);   servo3.attach(servo3Pin, 900, 2100);
```

```
servo4.attach(servo4Pin, 900, 2100);   servo5.attach(servo5Pin, 900, 2100);
servo6.attach(servo6Pin, 900, 2100);   servo7.attach(servo7Pin, 900, 2100);

  //Set built in LED to turn on to signal startup
  digitalWrite(13, HIGH);

  delay(5);

  //Initialize      radio  communication   radioSetup();

  //Set radio channels to default (safe) values before entering main loop
channel_1_pwm = channel_1_fs;   channel_2_pwm = channel_2_fs;   channel_3_pwm =
channel_3_fs;   channel_4_pwm = channel_4_fs;   channel_5_pwm = channel_5_fs;
channel_6_pwm = channel_6_fs;

  //Initialize IMU communication
  IMUinit();

  delay(5);

  //Get IMU error to zero accelerometer and gyro readings, assuming vehicle is level when
powered up
  //calculate_IMU_error(); //Calibration parameters printed to serial monitor. Paste these in the
user specified variables section, then comment this out forever.

  //Arm servo channels   servo1.write(0); //Command servo angle from 0-180 degrees (1000
to 2000 PWM)    servo2.write(0); //Set these to 90 for servos if you do not want them to
briefly max out on startup     servo3.write(0); //Keep these at 0 if you are using servo outputs
for motors    servo4.write(0);   servo5.write(0);   servo6.write(0);   servo7.write(0);

  delay(5);

  //calibrateESCs(); //PROPS OFF. Uncomment this to calibrate your ESCs by setting throttle
stick to max, powering on, and lowering throttle to zero after the beeps   //Code will not
proceed past here if this function is uncommented!

  //Arm OneShot125 motors     m1_command_PWM = 125; //Command OneShot125 ESC from
125 to 250us pulse length      m2_command_PWM = 125;     m3_command_PWM = 125;
m4_command_PWM = 125;   m5_command_PWM = 125;   m6_command_PWM = 125;
  armMotors(); //Loop over commandMotors() until ESCs happily arm

  //Indicate entering main loop with 3 quick blinks    setupBlink(3,160,70);
//numBlinks, upTime (ms), downTime (ms)

  //If using MPU9250 IMU, uncomment for one-time magnetometer calibration (may need to
repeat for new locations)
  //calibrateMagnetometer(); //Generates magentometer error and scale factors to be pasted in
user-specified variables section
```

```
}



//====================================================================
==========================================================//
//                         MAIN LOOP                        //
//====================================================================
==========================================================//

void loop() {
  //Keep track of what time it is and how much time has elapsed since the last loop   prev_time
= current_time;        current_time = micros();
dt = (current_time - prev_time)/1000000.0;
loopBlink(); //Indicate we are in main loop with
short blink every 1.5 seconds

  //Print data at 100hz (uncomment one at a time for troubleshooting) - SELECT ONE:
  //printRadioData();     //Prints radio pwm values (expected: 1000 to 2000)
  //printDesiredState();  //Prints desired vehicle state commanded in either degrees or deg/sec
(expected: +/- maxAXIS for roll, pitch, yaw; 0 to 1 for throttle)
  //printGyroData();      //Prints filtered gyro data direct from IMU (expected: ~ -250 to 250, 0
at rest)
  //printAccelData();     //Prints filtered accelerometer data direct from IMU (expected: ~ -2 to
2; x,y 0 when level, z 1 when level)
  //printMagData();       //Prints filtered magnetometer data direct from IMU (expected: ~ -300
to 300)
  //printRollPitchYaw();  //Prints roll, pitch, and yaw angles in degrees from Madgwick filter
(expected: degrees, 0 when level)
  //printPIDoutput();     //Prints computed stabilized PID variables from controller and desired
setpoint (expected: ~ -1 to 1)
  //printMotorCommands(); //Prints the values being written to the motors (expected: 120 to
250)
  //printServoCommands(); //Prints the values being written to the servos (expected: 0 to 180)
//printLoopRate();     //Prints the time between loops in microseconds (expected:   microseconds
between loop iterations)

  // Get arming status   armedStatus(); //Check if the throttle cut is off and
throttle is low.

  //Get vehicle state    getIMUdata(); //Pulls raw gyro, accelerometer, and magnetometer data
from IMU and LP filters to remove noise
  Madgwick(GyroX, -GyroY, -GyroZ, -AccX, AccY, AccZ, MagY, -MagX, MagZ, dt);
//Updates roll_IMU, pitch_IMU, and yaw_IMU angle estimates (degrees)

  //Compute desired state   getDesState(); //Convert raw commands to normalized values based
on saturated control limits
```

```
  //PID Controller - SELECT ONE:   controlANGLE();
//Stabilize on angle setpoint
  //controlANGLE2(); //Stabilize on angle setpoint using cascaded method. Rate controller must
be tuned well first!
  //controlRATE(); //Stabilize on rate setpoint

  //Actuator mixing and scaling to PWM values    controlMixer(); //Mixes PID outputs to scaled
actuator commands -- custom mixing assignments done here
  scaleCommands(); //Scales motor commands to 125 to 250 range (oneshot125 protocol) and
servo PWM commands to 0 to 180 (for servo library)

  //Throttle cut check    throttleCut(); //Directly sets motor commands to low based
on state of ch5

  //Command actuators    commandMotors(); //Sends command pulses to each motor pin using
OneShot125  protocol        servo1.write(s1_command_PWM);  //Writes
PWM  value  to  servo  object       servo2.write(s2_command_PWM);
servo3.write(s3_command_PWM);   servo4.write(s4_command_PWM);
servo5.write(s5_command_PWM);   servo6.write(s6_command_PWM);
servo7.write(s7_command_PWM);
//Get vehicle commands for next loop iteration   getCommands();
//Pulls current available radio commands    failSafe(); //Prevent failures in event of bad receiver
connection, defaults to failsafe values  assigned in setup

  //Regulate loop rate    loopRate(2000); //Do not exceed 2000Hz, all filter parameters tuned to
2000Hz by default }



//====================================================================
=========================================================//
//                                FUNCTIONS                                //
//====================================================================
=========================================================//



void controlMixer() {
  //DESCRIPTION: Mixes scaled commands from PID controller to actuator outputs based on
vehicle configuration
  /*
* Takes roll_PID, pitch_PID, and yaw_PID computed from the PID controller and
  appropriately mixes them for the desired
* vehicle configuration. For example on a quadcopter, the left two motors should have
  +roll_PID while the right two motors
* should have -roll_PID. Front two should have -pitch_PID and the back two should have
  +pitch_PID etc... every motor has
```

```
* normalized (0 to 1) thro_des command for throttle control. Can also apply direct unstabilized
  commands from the transmitter with
* roll_passthru, pitch_passthru, and yaw_passthu. mX_command_scaled and sX_command
  scaled variables are used in scaleCommands()
* in preparation to be sent to the motor ESCs and servos.
  *
  *Relevant variables:
  *thro_des - direct thottle control
  *roll_PID, pitch_PID, yaw_PID - stabilized axis variables
  *roll_passthru, pitch_passthru, yaw_passthru - direct unstabilized command passthrough
  *channel_6_pwm - free auxillary channel, can be used to toggle things with an 'if' statement
  */

 //Quad mixing - EXAMPLE   m1_command_scaled = thro_des - pitch_PID +
roll_PID + yaw_PID; //Front Left   m2_command_scaled = thro_des - pitch_PID -
roll_PID - yaw_PID; //Front Right   m3_command_scaled = thro_des + pitch_PID -
roll_PID + yaw_PID; //Back Right   m4_command_scaled = thro_des + pitch_PID  +
roll_PID - yaw_PID; //Back Left   m5_command_scaled = 0;   m6_command_scaled
= 0;

 //0.5 is centered servo, 0.0 is zero throttle if connecting to ESC for conventional PWM, 1.0 is
max throttle    s1
```

To conclude this chapter, the following bill of Engineering measurement and evaluation provides a detailed breakdown of the projected costs associated with the proposed work.

Table for Bill of Engineering Measurement and Evaluation					
Components	Materials	Dimensions	QTY	Unit Cost(₦)	**Total Cost (₦)**
Brushless motors	copper	35x42mm	4	30,000	120,000
F450 drone frame	Polyamide nylon	450mm motortomotor	1	50,000	50,000
ESC 40 amp	plastic		4	16,500	66,000
propellers	nylon	279.4mm	4	5,000	20,000
2200mah lithium ion battery	Lithium polymer	102x34x33mm	1	35,200	35,200

Raspberry pi 5			1	150,000	150,000
Pi camera			1	10,000	10,000
5v voltage regulator			1	3,000	3,000
GPS module	plastic	55mm	1	28,000	28,000
Pixhawk 2.4.8	Silicon	50x81x18mm	1	250,000	250,000
PPM to PWM converter	silicon	21x21mm	1	25,000	25,000
Soldering lead	Lead		1	2500	2500

TABLE 3.5: Total cost

S/N	Category	cost (₦)
1.	**Materials**	**759,000**
2.	**Labour**	**80,000**
Total		**839,700**

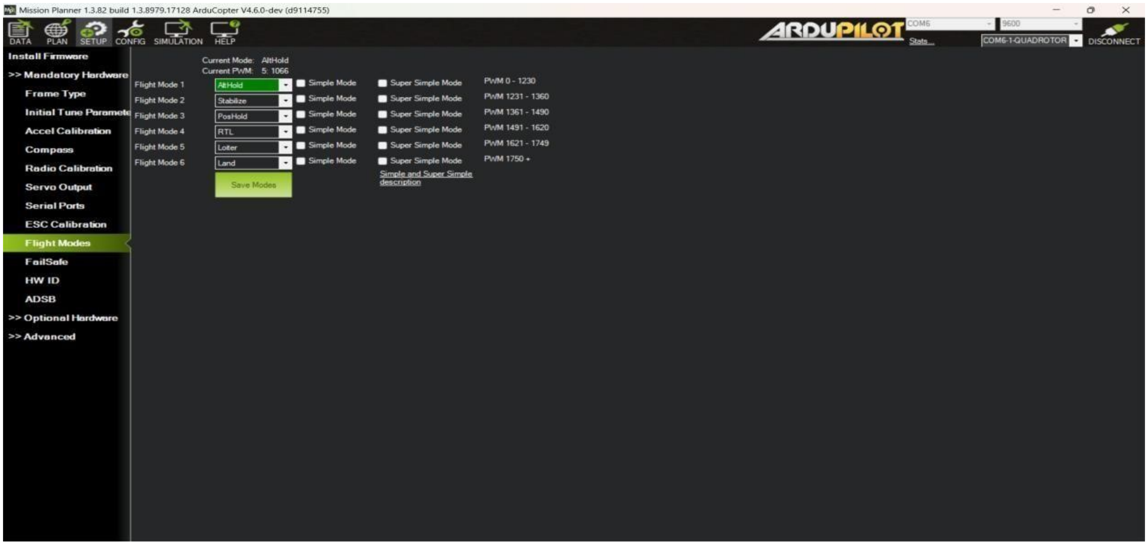
CHAPTER FOUR

TESTS RESULTS AND DISCUSSIONS

4.1 Pre – Flight Tests

To ensure the safe and effective operation of the drone,

i. we perform a pre-flight test before the main flight. Looking to see if the components of the drone work perfectly.
ii. We took great care to check if the wires were connected properly and from the blades during rotation.
iii. The battery was the next item of interest as we had to charge it fully and make sure it is properly centralized to avoid imbalance during flight. iv. For prevention of short circuiting, electric shocks or damage to electrical wires and we the users, we tapped the naked parts of the wires.
v. We also calibrated the drone's gyroscopes and accelerometer to ensure perfect flight control and navigation, and it was done using the Arduipilot to check if the calibration meets expectation and also check if the safety precautions are running perfectly well.
vi. Through pre-flight inspections, we reduced the possibility of mishaps and guarantee a safe and successful flight for the drone.



Mission Planner 1.3.82 build 1.3.8979.17128 ArduCopter V4.6.0-dev (d9114755)

Current Mode: AltHold
Current PWM: 5: 1066

Flight Mode 1	AltHold	☐ Simple Mode	☐ Super Simple Mode	PWM 0 - 1230
Flight Mode 2	Stabilize	☐ Simple Mode	☐ Super Simple Mode	PWM 1231 - 1360
Flight Mode 3	PosHold	☐ Simple Mode	☐ Super Simple Mode	PWM 1361 - 1490
Flight Mode 4	RTL	☐ Simple Mode	☐ Super Simple Mode	PWM 1491 - 1620
Flight Mode 5	Loiter	☐ Simple Mode	☐ Super Simple Mode	PWM 1621 - 1749
Flight Mode 6	Land	☐ Simple Mode	☐ Super Simple Mode	PWM 1750 +

Figure 4.1-Ardupilot Interface Showing Flight Modes

4.2 Flight Testing

4.2.1 First Flight Stability Test

During the first flight test, the drone took off but it was observed to be unstable and unable to hover properly when flying despite all the pre-planned preparation for flight. The drone's flight dynamics were compromised by the misalignment of propeller direction and orientation. This led to instability during flight, causing the drone to propel in the wrong direction before crashing.

4.2.1.1 Flight Test and Outcome Table

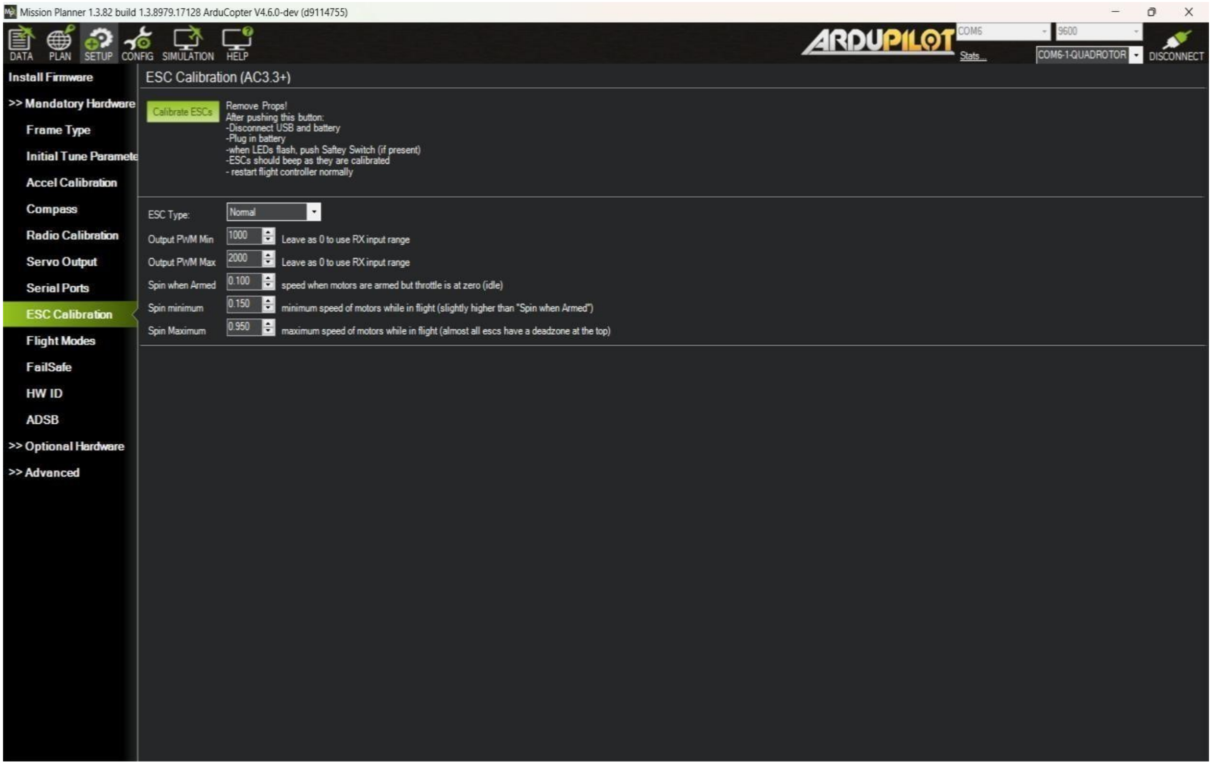
S/N	**Flight Test**	**Max Height**	**Flight Time**	**Stability**	**Outcome**
1.	Flight Test 1	5.00 m	50 seconds	Unstable	This led to crash after about 50secs of flight.
2.	Flight Test 1.1	5.57 m	2 minutes	Stability attained	Drone Flew for about 5 minutes with 80% stability attained and without hassle
3.	Maximum Altitude and range test 1	50.3 m	11 minutes	Maintained Stability	Drone Flew for about 11 minutes and Achieved a Max height of 165feets (50.3m)
4.	Maximum Altitude and range test 2	257.68m	14 minutes	Lost connection	Drone flew for about 14 minutes

					in total till battery was drained and fell and crashed. The drone reached a Max height of 845feets (257.68m)

4.2.2 Second Flight Stability Test

Following the correction of battery misalignment, subsequent flight tests with the drone's stability and control revealed that there are natural phenomena that weren't considered like wind speed and others. The PID was also calibrated into the gyroscope and accelerometer such that the system tries to bring the drone to a stable flight by making the measure process variable during flight to be equal to the set value at a horizontal plane level thereby obtaining stability and hovering, before that the gyroscope and accelerometer were calibrated by placing the drone on a horizontal plane level then taking notes of the reading of the IMU (Initial Measuring Unit) which contain the gyroscope and accelerometer thereby using the horizontal plane level as the reference to attain stability in flight. The ESC was calibrated to have a range of 1000 to 2000. After all these calibrations we tested and stability was achieved

Figure 4.2 Drone Achieving Stability in Flight



Mission Planner 1.3.82 build 1.3.8979.17128 ArduCopter V4.6.0-dev (d9114755)

ESC Calibration (AC3.3+)

Remove Props!
After pushing this button:
-Disconnect USB and battery
-Plug in battery
-when LEDs flash, push Saftey Switch (if present)
-ESCs should beep as they are calibrated
- restart flight controller normally

ESC Type: Normal
Output PWM Min 1000 Leave as 0 to use RX input range
Output PWM Max 2000 Leave as 0 to use RX input range
Spin when Armed 0.100 speed when motors are armed but throttle is at zero (idle)
Spin minimum 0.150 minimum speed of motors while in flight (slightly higher than "Spin when Armed")
Spin Maximum 0.950 maximum speed of motors while in flight (almost all escs have a deadzone at the top)

Figure 4.2-Ardupilot Interface Showing ESC Calibration

Figure 4.3-Ardupilot Interface Showing Radio Calibration

4.3 Battery Life and Charging Time

Test Results

As part of the drone modification, the battery system used was the same as the one used previously a 2200mAh 3S LiPo battery but a more efficient propeller was used. The purpose of this modification was to enhance flight time and reduce the frequency of recharging during field operations.

Before modification: The drone achieved an average flight time of 5 minutes on a full charge. Charging time averaged 60 minutes using a standard 2A charger.

After modification: The drone’s flight time increased to 8 minutes, representing a 60% improvement. Charging time remained the same due to the battery capacity being the same.

Discussion

The efficient propeller significantly improved the drone’s endurance in flight, allowing for longer missions without interruption. This improvement is especially beneficial for applications such as aerial surveying, agricultural monitoring, and search-and-rescue, where extended air time is crucial. However, the increased efficient propeller didn’t come with trading off a modest increase in charging time.

Overall, the propeller modification was successful in extending operational time without significantly compromising charging convenience.

The drone's operational time is limited to approximately 8 minutes per flight session, with a charging period of around 1 hours required to fully recharge the battery. This shows that there is little flight time for adequate surveillance and a long charging time before being used.

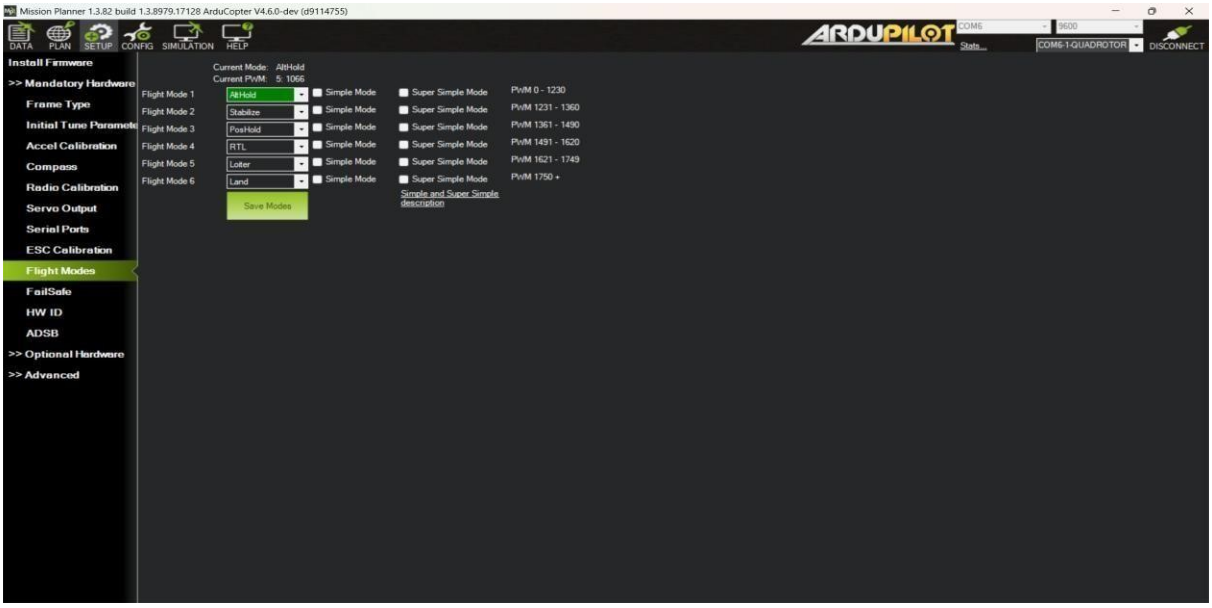
4.4 Return to Home Function Test

The return home functionality was found to be lacking in the initial test run. After numerous debugging processes and test runs, the return home function can be said to be fully operational. The return home function activates when the drone estimates battery level to be insufficient for continuous surveillance flight and the drone returns "home" to avoid crashing.

DISCUSSION

The Return Home feature performed reliably in all test scenarios, demonstrating improved safety and autonomy for the modified drone. The GPS module, upgraded for higher accuracy, played a critical role in ensuring the drone returned close to the original takeoff point. The average landing deviation was less than 2 meters, which is acceptable for most civilian and commercial applications.

Overall, the implementation of the RTH function enhances user safety and protects the drone from potential loss, especially during unexpected events like signal dropout or power depletion.



Mission Planner 1.3.82 build 1.3.8979.17128 ArduCopter V4.6.0-dev (d9114755)

Current Mode: AltHold
Current PWM: 5: 1066

Flight Mode 1	AltHold	☐ Simple Mode	☐ Super Simple Mode	PWM 0 - 1230
Flight Mode 2	Stabilize	☐ Simple Mode	☐ Super Simple Mode	PWM 1231 - 1360
Flight Mode 3	PosHold	☐ Simple Mode	☐ Super Simple Mode	PWM 1361 - 1490
Flight Mode 4	RTL	☐ Simple Mode	☐ Super Simple Mode	PWM 1491 - 1620
Flight Mode 5	Loiter	☐ Simple Mode	☐ Super Simple Mode	PWM 1621 - 1749
Flight Mode 6	Land	☐ Simple Mode	☐ Super Simple Mode	PWM 1750 +

Figure 4.4-Ardupilot Interface Showing Flight Modes

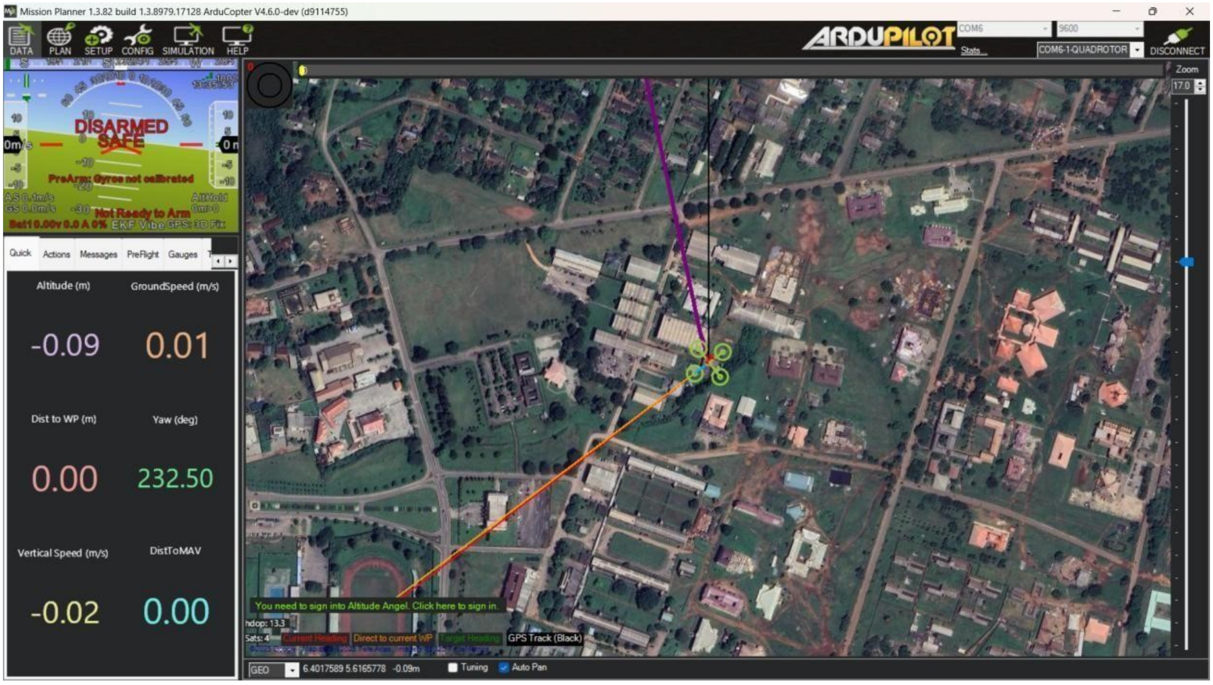
4.5 Maximum Altitude and Range Test

During our flight test to determine the maximum altitude of the drone, we discovered that due to the battery capacity we were unable to determine the maximum range of the drone as the controller capacity is able to reach a distance of 4000m. As the drone ascended, reaching a distance of 500 meters, it was called back to test the return home function and to prevent it from getting lost or damaged. Unfortunately, with the given time frame and battery capacity, we could not test further for the determination of maximum height.

Figure 4.4 Drone after Crashing

4.6 GPS Accuracy Test

The drone has GPS capability and uses ArduPilot software to provide approximate location data. Nonetheless, it was observed that there is a significant variance in reported placements of about 10 meters. This implies that there may be a GPS positioning system error margin that could impact applications that depend on precision.


Mission Planner 1.3.82 build 1.3.8979.17128 ArduCopter V4.6.0-dev (d9114755)

COM6 | 9600 | COM6-1-QUADROTOR

DISARMED
SAFE
PreArm: Gyros not calibrated
Not Ready to Arm
AS 0.1m/s
GS 0.0m/s
Bat1 0.00v 0.0 A 0%
EKF Vibe GPS: 3D Fix
AltHold

Altitude (m): -0.09
GroundSpeed (m/s): 0.01
Dist to WP (m): 0.00
Yaw (deg): 232.50
Vertical Speed (m/s): -0.02
DistToMAV: 0.00

You need to sign into Altitude Angel. Click here to sign in.
hdop: 13.3
Sats: 4
Zoom: 17.0
GEO 6.4017589 5.6165778 -0.09m
☐ Tuning ☑ Auto Pan

Figure 4.5-Ardupilot Interface Showing GPS Location

4.7 Radio Transmitter Range

The radio transmitter's effective range is about 4000 meters after flying the drone. This range defines the maximum distance over which the drone can establish and maintain communication with the pilot.

4.8 SWOT ANALYSIS OF THE DRONE

4.8.1 Strengths

- **Enhanced Surveillance Abilities:** When equipped with a camera, drones enable aerial monitoring over extensive and hard-to-access territories, making them ideal for reconnaissance missions.

- **High Manoeuvrability:** Their adaptability allows drones to operate effectively in diverse environments ranging from urban landscapes to rural and remote areas making them suitable for a wide range of surveillance tasks.
- **Live Data Transmission:** With camera integration, drones offer real-time video and sensor data feeds, enhancing situational awareness and enabling timely, informed decisions during operations.
- **Cost Efficiency:** Compared to traditional surveillance methods such as manned patrols, drones present a more economical solution for continuous monitoring activities.

4.8.2 Weaknesses

- **Short Battery Life:** One significant limitation is the restricted flight duration, which can shorten operational time and require frequent recharging or battery replacement.
- **Weather Sensitivity:** Drones can be adversely affected by inclement weather—such as strong winds, rain, or fog—impacting their flight stability and potentially delaying or cancelling surveillance missions.
- **Cybersecurity Concerns:** Transmitting sensitive data over wireless networks introduces risks such as hacking, interception, or unauthorized access, raising concerns about data protection and integrity.

4.8.3 Opportunities

- **Expanding Market Demand:** There's a rising demand for drone surveillance across sectors like security, agriculture, and infrastructure, offering significant growth potential for related services and solutions.
- **Technological Progress:** Ongoing innovations in drone design, sensor systems, battery efficiency, and autonomous navigation continue to improve drone performance and broaden their application scope.
- **AI and Data Analytics Integration:** Combining drones with artificial intelligence and analytics enhances surveillance by enabling automated detection, object tracking, and intelligent data interpretation.
- **Collaborative Innovation:** Forming partnerships with industries, government bodies, and academic institutions can foster research, resource sharing, and the development of cutting-edge surveillance capabilities.

4.8.4 Threats

- **Regulatory and Public Resistance:** Concerns over privacy violations, noise, and safety can lead to public backlash and strict regulations, limiting drone usage in certain areas or sectors.
- **Evolving Security Challenges:** The widespread availability of drones introduces risks like unauthorized surveillance, aerial collisions, and restricted airspace breaches, which may prompt tighter control and legal oversight.

4.9 Detailed Design Specifications

1.	Dimension (Millimeters)	500 X 500
2.	Weight (Grams)	1.400
3.	Power Output (Watt)	2000
4.	Total Thrust (kilogram)	8.00
5.	Estimated Flight Time (Minutes)	10-15
6.	Operational Range (Meters)	4000
7.	Maximum Flight Altitude (Meter)	200
8.	Motor Speed Range (Revolution Per Minutes)	0-12000
9.	Payload Capacity (kilograms)	5.00
10.	Sensors And Navigation	10HZs GNSS

CHAPTER FIVE

Conclusion and Recommendation

5.1 Conclusion

The project on the modification of a locally adapted drone with advanced technical capabilities can be said to be a success. The modifications that were made to the drone allows for better performance, automation driven, and more efficient navigation systems. Locally modifying drones plays a crucial role in the transformation of industrial sectors which contributes to the commercial and technological growth of the regions that adopt this innovation. By repairing the drone from the previous crash, upgrading the hardware components and implementing advanced software, the core objectives for this project were successfully met, laying a foundation for future advancement of drone technology in the country. And by locally modifying a drone it gives rise to greater optimization for making drones more adaptable to different regions meeting their specific needs and challenges.

Modification of locally adapted drones in technological advancement cannot happen without its own challenges like reliability, availability of high-quality components, and skilled workers can pose obstacles to widespread adoption and safety. With the continuous advancement of these drones increases, it is important that it operates with the standard of the region it is being used in.

The following are the list of challenges and obstacles that was faced when trying to advance the drone made by our predecessors:

- **Failure and Damage Analysis:** Correspondence with the previous project group and footage of test flights were used to determine all possible causes for the crash of the drone. Analysis of the drone after the crash was needed to assess damage and make a list of parts required to be replaced.
- **Modification of a Computer Aided Simulation:** Modifications were made to the previous computer aided simulation to take into account the proposed modifications to the drone before repairs and assembly.
- **Repair and Assembly of the drone:** The repair and Assembly process was carried out with both locally and internationally sourced components. This process provided valuable experience with the assembly of complex systems.
- **Programming of the Flight Controller(Pixhawk 2.4.8):** The flight controller was programmed using an open-source library of the C++ programming language. This

ensured that the drone's flight control system was tailored to meet specific operational requirements, enhancing its performance and reliability.

- **Drone Programming using Python and C++:** The other systems of the drone was programmed using open-source libraries of the two programming languages. The object detection and fail-safe features were programmed using the Python programming language, while the return home function was programmed using the C++ language. This improved the drone's functionality and reliability immensely.
- **Improvement of Individual and Team Capability**: This project has substantially enhanced individual skills by offering practical training and hands-on experience in cutting-edge drone technologies. As a result, participants have gained not only valuable technical expertise and teamwork skills but also a mindset that encourages innovative thinking and effective problemsolving, ultimately benefiting the local community.

5.2 Recommendations

- **Improving of Flight Control Algorithm**: Improvement of the flight control algorithm will increase precision of drone's navigation, tracking, and obstacle avoidance, also bringing the opportunity to implement adaptive flight patterns.
- **Enhancing of Power System**: Lighter, more energy-efficient batteries for example, highcapacity lithium-based ones can be used to increase flight time dramatically. Batteries compatible with new advanced pylon-mounted solar panels, weather rooftop, and in-line charging of solar systems can also be used for optimization of flight time.
- **Upgrading Camera and Sensor Integration:** Utilization of more detailed definition visual aids, such as the thermal imaging cameras, and LiDAR sensors, to boost the security and environmental surveillance and observation.
- **Refining Communication Systems**: Use of the latest technology such as the latest longrange communication devices like LoRa or 5G, will help in both the control and data transfer in the course of the remote operations.
- **Expanding Live Pilot Tests**: Flight under diversified environments can be used to see how the drone performs in security, farms, and disaster response. This will bring about areas to make improvements.
- **Community Engagement and Awareness:** Organizing workshops or training sessions to encourage local innovation and share knowledge on drone development

and applications. This will also highlight the positive impact drone technology can have in the nation.

- **Research and Development (R and D) Initiatives:** The establishment of dedicated research and development centres can help dramatically improve drone technology in the country and help foster talents. These centres can be sponsored using both government and private investments.
- By implementing these recommendations, this project will drive the adoption of drone technology in Nigeria, promoting innovation and socio-economic growth. The project's success demonstrates the value of leveraging local expertise and resources to develop impactful technological solutions, not only for Nigeria's security forces but also for other areas where drones can bring innovative improvements and advancements.

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