EEET2610 – ENGINEERING DESIGN 3

Project Proposal

Design And Control of a Quadcopter

Lecturer: Dr. Dinh-Son Vu

Group G_ Tutorial 2: Thursday 14:30 – 16:00

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What's next...

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1. Abstract

This project focuses on developing a wireless control quadcopter from scratch, a cost-effective option compared to popular expensive drones. The primary reason behind this project is to make the quadcopter affordable to a more extensive range of users, including students, unprofessional researchers, hobbyists, or whoever has budget limitations. The project's scope includes developing and constructing a quadcopter that operates on a lithium polymer (LiPo) battery. The battery is selected because of its lightweight characteristics and high energy density, extending the quadcopter's flight duration and improving efficiency. In addition, four brushless motors, which are reliable and have a high power-to-weight ratio, perform quadcopter propulsion. Besides, the combination of the ESP32 microcontroller and the Motion Processing Unit (MPU) is the brain of the quadcopter. These two components facilitate the Proportional Integral Derivative (PID) control mechanism to maintain the balance and stability of the drone during the flight. In addition, the ESP32 is responsible for receiving wireless signals from the controller to process the drone's movement. To reduce the production cost, we selected recycled wood as the main material for the airframe of this drone. The outcome of this project is a fully functional quadcopter and a comprehensive assembly instruction document. Furthermore, with its competitive price, this quadcopter has potential applications across many fields, such as education, surveillance, entertainment, etc. The project discusses other relevant research, improvements, and collaborations as we progress. Hence, the final goal is to make drone technology better and more accessible to more people.

2. Introduction

A type of drone or Unmanned Aerial Vehicle (UAV) known as a quadcopter is equipped with four propellers and belongs to the multi-rotor category. This design enables it to easily facilitate six degrees-of-freedom (DOF) movement, making it stand out from other types like tricopters and hexacopters [3]. Its stabilization mechanism requires less effort and boasts a balanced ratio of producing cost to payload. Increasing the propellors can boost the drone's payload, but the lead trade reduces the flight duration because it requires a battery with a higher discharge rate. On the other hand, decreasing the number of propellers could bring more challenges to handling stability and maneuverability, making it less suited for application in small environments where precise control and balance are essential. Therefore, the quadcopter is the most optimized form of the drone, and its ability is sufficient for many purposes. There are some exciting examples of quadcopter applications, including taking remarkable photography shots [4], fast-delivering service [5], and detecting plant diseases in an agricultural field [6].

Figure 1. Types of multi-rotors drones [1].

Currently, the market includes more than 25 quadcopter manufacturers, among which the five most popular brands are DJI, Yuneec International, AeroVironment, PowerVision, and Parrot. Their products are of high quality and have a stunning appearance; however, the average price of a mid-range drone ranges from $1,000 to $2,000, a barrier preventing low-income individuals from accessing these products. According to Statista, the demand for using quadcopters in daily life is increasing rapidly, with the market valued at up to 4 billion US dollars in 2023 and expected to grow by 3.20% annually. Therefore, a comprehensive instruction manual for assembling a quadcopter using affordable and easily accessible materials and components would meet the market's demand and make drone technology more accessible to a broader range of people. [7] [8] [9]

In this project, our objectives include researching and providing comprehensive documentation for building a DIY quadcopter at around $200, which is significantly more affordable than commercial drones, being nearly ten times cheaper. We believe that by doing so, we can bridge the gap between the high cost of commercial drones and the growing need for quadcopter technology. Furthermore, the documentation of this project will clarify the complexities of drone construction, offering our audience a deep understanding of drone maneuvering techniques.

2.1. Literature Review

A comprehensive understanding of the essential components of a quadcopter and its functionalities is crucial, as it directly guides this project towards its final goal, ensuring efficient use of time and resources. This literature review aims to analyze the role of each component and how they integrate to form a functional quadcopter, providing an overview of the tradeoffs between methods and options in different academic studies.

The structure of a quadcopter commonly consists of four brushless motors positioned at the corners where the main body intersects. Regarding materials, Singh et al. concluded that the deformation and stress of the frame are directly proportional to the motor's thrust [10]. Consequently, they recommend using hard and durable materials such as carbon, which not only withstand these stresses but also offer compatibility with various types of brushless motors. Additionally, Ahmad et al employed ANSYS software to identify the most vibration-prone parts of the drone during motor rotation, which were found to be the heads of the beams located beneath the motors [11]. Their study notes that the Young's Modulus and Bulk Modulus of Carbon Fiber Reinforced Polymer (CFRP) are exceptionally high, reaching up to 70,000 MPa and 58,333 MPa, respectively. This makes CFRP about ten times more durable compared to softwood [12]. Therefore, if using less durable material like softwood, reinforcing the beams with a motor mount is necessary to reduce the vibration force from the motor.

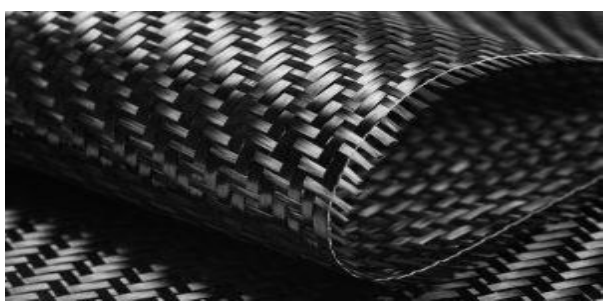


Figure 2. Carbon Fiber Reinforced Polymer material [2].

The brushless DC motor (BLDC) is well-known for its high performance, lightweight design, low noise, and reliability. Zhang et al. describe the BLDC as comprising the motor body, a position sensor, a power inverter, and a controller [13]. The motor body converts electrical energy into mechanical energy, while the power inverter supplies this energy to the motor. The controller acts as the central unit, receiving speed and position signals to control motor operation. Additionally, the study proposes a software method, Back Electromotive Force (BEMF) Zero-Crossing Detection, for detecting the position of the BLDC's rotor without a sensor. This method increases efficiency, simplifies the structure of the brushless motor, and reduces costs. On the other hand, Manohar et al. pointed out that a disadvantage of the BLDC motor is some vibration, which can contribute to a significant resonance phenomenon [14]. However, this vibration can be reduced by correctly wiring the negative wire to the negative terminal and the positive wire to the positive terminal. Nevertheless, the wiring and operating instructions for the BLDC motor are not always clear, requiring users to figure out which wire is negative, which is positive, and which is the signal wire.

The study of Ahmad et al focuses on the structural comparison between two-blade and four-blade quadcopter propellers, utilizing the Finite Element Method (FEM) for analysis [15]. The study reveals that four-blade propellers demonstrate lower stress and deformation, making them suitable for heavier loads, albeit at a higher cost. Conversely, with their higher frequency range, two-blade propellers are more apt for limited load applications due to cost-effectiveness. This research is instrumental in guiding the selection of propeller types based on specific operational needs, marking a significant step in optimizing quadcopter performance. In addition, Kuantama et al. delves into the aerodynamic analysis of 16 × 5 inches quadcopter propellers using Solidworks software [16]. It shows that the 16 x 5 inches propeller has a maximum thrust capacity of 4144 g-forces at various rotational speeds. Hence, both studies demonstrate the critical role of propeller design in quadcopter performance.

The Inertial Measurement Unit (IMU) sensors have the capability to measure angular velocity and acceleration; all this data generated by the IMU is used to maintain the drone's balance. Azfar et al. introduce a method for integrating IMU sensor fusion into a PID controller to stabilize quadrotor flight [17]. The combination of accelerometer and gyroscope data from the IMU is used as input for the Kalman Filter algorithm to achieve accurate flight control. As a result, Azfar et al. demonstrate that this approach significantly improves the quadcopter's stability during flight. Additionally, Ho et al. provide another method to maintain the stabilization of the quadcopter by estimating its mass during flight [18]. The method, known as Instrumental Variable, is proven to be more reliable compared to two other methods, namely the Least

Squares Estimation and the Extended Kalman Filter. Both studies emphasize that statistical methods effectively handle the drone’s stabilization by processing data from the IMU.

Furthermore, to enhance the drone’s stabilization during its movement and to achieve precise attitude tracking, it's essential to implement the function of a Global Positioning System (GPS) sensor. According to Afrisal et al., the application of a GPS sensor, when used in conjunction with an IMU, significantly enhances the drone's positioning and navigation capabilities [19]. In this study, the researchers focus on how GPS data, integrated with IMU readings, contributes to improved bearing navigation and attitude estimation. This integration allows the drone to calculate its position more accurately by comparing its current GPS coordinates with a predetermined destination. This method ensures more precise navigation, which is vital in scenarios where the drone must follow a specific path or reach a particular location.

Lastly, a reliable wireless communication protocol is essential to control a drone wirelessly. Abdul et al. introduce the ESP-NOW protocol, a peer-to-peer communication method utilizing the ESP32 microcontroller, enabling direct device communication without needing a router [20]. This protocol is especially beneficial in indoor environments, where signal obstruction can be problematic. The ESP-NOW protocol effectively transmits data even at low transmission power, highlighting its potential in scenarios where maintaining continuous and reliable communication is crucial, such as drone operations. The research demonstrates that ESP-NOW can ensure effective communication between a drone and its remote controller, facilitating data transmission in challenging indoor settings. This study is significant for its contribution to the development of robust and efficient communication methods for IoT devices, particularly in drone technology, where consistent communication is key to operational success and safety.

2.2. Problem Statement

Designing a quadcopter that meets the requirements of efficiency, versatility, and reliability is challenging. The primary challenges that this project seeks to address are:

- **Design and Model:** The quadcopter drone design requires CAD modeling that can hold the parts and systems required for stable flight. A precise balance between weight, durability, and aerodynamics is required for this design.

- **Stability:** The inverted pendulum concept is the basis of our project. With additional propellers—four in our case—balancing becomes more difficult. The sole method of achieving balance with fixed-pitch propellers is to modify the speed of each propeller separately. It is essential to comprehend the idea of an inverted pendulum while designing a system to improve the stability of our drones.
- **Efficiency:** To guarantee an effective power supply and communication between all the quadcopter drone's components, system wiring, and PCB design are essential. The design manages the demands of flight while effectively using the battery.
- **Maneuverability:** Due to the absence of a magnetometer, the MPU6050 is renowned for its inaccurate yaw angle estimation. Achieving steady and responsive flying requires fine-tuning the quadcopter's control system, especially the PID (Proportional-Integral-Derivative) tuning for roll and pitch.
- **Safety:** There is risk involved while operating a quadcopter. Before being assembled, every part of the quadcopter must pass the unit test and validation. For crew safety, emergency stop implementation must work. Recognizing the possible danger is essential to maintaining everyone's safety and extending the lifespan of each component.

2.3. Contribution

Making a drone involves multiple components and contributions from various fields, including mechanical engineering, electronics, software engineering, and aerodynamics. These are the fundamental steps and skills involved:

a. Design and Mechanics

Designing and constructing the drone's frame and body are critical steps. These carry all electronic components and must consider factors like weight and material choice to ensure stability, durability, and prevent overload.

b. Propulsion System

This system includes motors and propellers. The type of motors and size of propellers are chosen to provide sufficient power and carry the expected weight. These configurations impact the drone’s performance and flight capabilities.

c. Electronics and Power Supply

The drone's electronics and component placement, including flight controllers, GPS systems, batteries, and sensors, must be designed and soldered properly onto the Printed Circuit Board to ensure functionality.

d. Control System and Software Programming

Software developers create control algorithms and design programs that enable the drone to stabilize itself, navigate, and respond to user commands. PID controllers and algorithm coding are commonly used for controlling the drone's orientation and position.

e. Communication System

Drones often require wireless communication systems between the remote and drone microcontrollers. Developers write code for wireless communication to enable signal and data transmission.

f. Sensors

Various sensors such as accelerometers, barometers, or cameras provide real-time data for the drone's flight. These sensors help maintain stability, status, and navigation in different environments.

g. Testing and Calibration

Engineers conduct extensive testing and calibration to ensure the drone functions correctly, verifying that all systems and components work together seamlessly.

h. Compliance and Regulations:

Compliance with aviation regulations is essential. This includes obtaining necessary allowances and ensuring the drone meets safety and operational standards.

i. Mechanical Assembly

All components and materials are assembled according to CAD design specifications. This involves soldering, mounting, and connecting various parts into a single drone.

j. Quality Assurance

Quality checks ensure the drone operates safely and reliably, without defects or issues that might affect its performance over long-term use.

k. Continuous Improvement

Engineers and software developers continually work on improving the drone’s components, adding new features, replacing advanced components, or addressing problems that may require redesigning and retesting.

2.4. Proposal Structure

This group proposal is primarily designed to outline the entire group's schedule and delivery processes for drone-making over three months. Initially, the project introduction states all the requirements and tasks that need completion, while the task description details specific activities and responsibilities, emphasizing dependencies. Resource Management identifies resource allocation, followed by gathering materials and components needed to build the drone; bills of materials and documents are provided for reference. The Organization and Partner Presentation introduces project stakeholders and their roles and external stakeholders involved. Risk Analysis assesses potential risks encountered during the making of a complete drone. The Team Contract and Teammates Introduction provides more detail on individual qualifications and collaboration guidelines. Lastly, the Conclusion summarizes key points intending to secure approval and support for the successful execution of this drone project.

3. Project Task Description

This project split it into three sections representing three work packages.

3.1. Work package 1: Design of the drone

3.1.1. Objectives

The first work package is to design a quadcopter. Given the fundamental design from the project description, four motors are attached to four wooden beams and fastened to two plywood plates. The deliverables consist of:

1. CAD modeling.

2. Wiring diagram and PCB design.
3. Step-by-step assembly guide.

3.1.2. Deliverables and milestones

According to the deliverables given above, the project divides each of the deliverables into four sub-milestones, and the developer should follow the deadlines for each milestone. The milestones for work package one are given in the table below:

No.	Activities	Deliverable	PIC	Priority
	Milestone 1.1 – CAD Modelling			
1.1.1.	Measure and create bill of material	Measure the components dimension and make a BOM	All team	HIGH
1.1.2.	Understand and improve initial design	Read and understand the project description. Then, make the decision for final design	All team	HIGH
1.1.3.	Design CAD model for all components	Use SolidWorks to design the drone frame model and motor mounts	Thu Tran, Khoi Duong, Tuan Nguyen	HIGH
1.1.4.	Fabrication and testing	3D print motor mounts and test parts fitness	Thu Tran, Duong Khoi, Tuan Nguyen	MEDIUM
	Milestone 1.2 – Wiring diagram and PCB design			
1.2.1.	Read component datasheets	Find the datasheets for all electronics components	All team member	HIGH
1.2.2.	Decide the correct footprints	Find the matching footprints to the provided electronics components	All team	HIGH
1.2.3.	Design PCB layout and	Use easyEDA to design PCB	Thu Tran,	HIGH

	routing	layout and the appropriate routing	Khoi D, Tuan N	
1.2.4.	Fabrication and testing	Fabricate the PCB and test mount the components to the board	Dinh Minh, Cuong Nguyen, Minh Phan	MEDIUM
	Milestone 1.3 – Step by step assembly guide			
1.3.1.	Gathering all components in BOM	Testing the whole system back end of the drone about the sensors, ESC	All team member	LOW
1.3.2.	Soldering board components on to the PCB	Make all the components look cleaner and good UI	All team member	MEDIUM
1.3.3.	Assembly according to CAD	Used to demonstrate how the drone designed	Thu Tran, Khoi Duong, Tuan Nguyen	LOW

Table 1. Deliverables and milestones of the work package 1.

3.2. Work package 2: Unit testing

3.2.1. Objectives

The objective of the WP2 can be defined as follows:

1. Design of the remote control.
2. Calibration and functioning of the driving unit.
3. Testing and validation of the sensors.

Each component will be tested individually before integrating them together.

3.2.2. Deliverables and milestones

The estimated milestones and subtasks that must be accomplished to meet the above-described goals are listed below.

No.	Activities	Deliverable	PIC	Priority
	Milestone 2.1 - Design of the remote control			
2.1.1.	Skim through the project description of the WP2.	Understand the requirement of the WP2.	All members	MED
2.1.2.	Create and draw the BOM of the WP2.	A list of all components required of the WP2.	All members	MED
2.1.3.	Gather all the components of the WP2.	All the components must be ready before starting the WP2.	Minh Dinh Minh Phan Thu Tran	MED
2.1.4.	Research the voltmeter.	Understand how to use a voltmeter and understand the data output from a voltmeter.	Minh Phan Thu Tran	HIGH
2.1.5.	Design the electrical circuit of the remote controller.	A detail electrical circuit display the connection between each component.	Thu Tran Minh Nguyen	HIGH
2.1.6.	Assemble the remote controller.	Step by step assemble the remote controller.	Thu Tran Khoi Duong	MED
2.1.7.	Design the coding part for each component of the remote controller.	Implement the coding for testing the remote controller components.	Minh Dinh Cuong Nguyen Minh Phan	MED
2.1.8.	Testing and validating the remote controller.	Follow the step 1.1 to 1.7 in the Test Plan section.	Minh Phan Cuong Nguyen	HIGH
	Milestone 2.2 - Calibration and functioning of the driving unit.			
2.2.1.	Gather all the component of the driving unit.	All the components of the driving unit must be ready.	Thu Tran Minh Dinh	MED

2.2.2.	Design the electrical circuit of the driving unit.	A detail electrical circuit display the connection between each component.	Thu Tran Khoi Duong	HIGH
2.2.3.	Assemble the driving unit.	Step by step connect the driving unit (motor, ESC, battery, motor).	Minh Phan	MED
2.2.4.	Testing and validating the driving unit.	Following the step 2.1 to 2.4 in the Test Plan section.	Minh Phan Minh Dinh Cuong Nguyen	HIGH
	Milestone 2.3 - Testing and validation of the sensors.			
2.3.1.	Research the inertial measurement unit (IMU) document based on the MPU6050.	Understand the IMU document and the data output.	All members	HIGH
2.3.2.	Research the GPS document.	Understand the GPS document and the data output.	All members	HIGH
2.3.3.	Assemble required parts.	Step by step connect the GPS and the IMU into the drone system.	Thu Tran Tuan Nguyen Khoi Duong	MED
2.3.4.	Implement the coding for reading output from the sensors.	Getting the output data from the GPS and the IMU for validating.	Minh Phan Minh Dinh Cuong Nguyen	HIGH
2.3.5.	Collect data and validate the sensors.	Following the step 3.1 and 3.2 in the Test Plan section.	All members	HIGH

Table 2. Deliverables and milestones of the work package 2.

3.2.3. Test Plan

The table below estimates the unit test plan for the WP2:

No.	Test Name	Test Description	Test Expected Result
1.1	Test and validate the drone pitch control.	Moving the joystick forward and backward to control the drone rotating around the pitch axis.	Moving the joystick forward and backward results in the drone tilting forward and backward around the pitch axis.
1.2	Test and validate the drone roll control.	Moving the joystick left and right to control the drone rotating around the roll axis.	Moving the joystick left and right results in the drone rolling left and right around the roll axis.
1.3	Test and validate two push buttons of the drone yaw rate control.	The first button controls the positive velocity of the yaw rate of the drone and the second button controls the negative velocity of the yaw rate of the drone.	Press the first button makes the drone rotate to the right (clockwise when viewed from above) and press the second button makes the drone rotate to the left (counterclockwise when viewed from above).
1.4	Test and validate the potentiometer.	Turning the potentiometer controls the drone thrust.	Turning the potentiometer increases and the motor's speed.
1.5	Test and validate the emergency stop button on the controller.	Pressing the button immediately stops all motor rotation.	Pressing the emergency stop button forces all the motors to stop rotating.
1.6	Test and validate the switch button on the drone.	Turn on the switch and measure power from the battery into the drone PDB using the voltmeter.	The result from the voltmeter displays the voltage of the drone’s battery.
1.7	Test and validate the switch button	Turn on the switch and measure power from the battery into the controller’s	The result from the voltmeter displays the voltage of the remote controller’s battery.

	on the controller.	circuit using the voltmeter.	
2.1	Test and validate the connection of the ESC, the battery, the microcontroller, and one motor.	Use the voltmeter to check the connection of the ESC, the battery, the microcontroller, and one motor.	The result from the voltmeter must show the connection of all components is not short circuit.
2.2	Test and validate the ESC calibration of a single motor.	Check and validate if the ESC is calibrated.	Upon connecting the power source, the motor releases a series of beeps indicating that the ESC is calibrating.
2.3	Test and validate the connection of the ESC, the battery, the microcontroller, and four motors.	Use the voltmeter to check the connection of the ESC, the battery, the microcontroller, and the four motors.	The result from the voltmeter must show the connection of all components is not short circuit.
2.4	Test and validate the ESC calibration of four motors.	Check and validate if the four ESCs are calibrated.	Follow the unit test 2.2 result for 4 motors.
3.1	Test and validate the inertial measurement	Manually rotate the drone and validate the angle (pitch, roll, yaw) coming out of the IMU.	Actual angle data should roughly match the findings obtained from the IMU. A maximum of 5% inaccuracy is allowed.

	unit (IMU) output.		
3.2	Test and validate the GPS.	Perform and validate the live data response from the GPS, including latitude, longitude, and altitude.	The acquired latitude, longitude, and altitude should approximately correspond with the GPU's results. An error of up to 5% is permitted.

Table 3. Test plan of the work package 2.

3.3. Work package 3: Control and validation of the drone

3.3.1. Objectives

Benefiting from the WP2 unit testing, the focus of the WP3 is the integration of each unit to build the final drone.

The objective of the WP3 can be defined as follows:

1. PID tuning of the drone for the pitch and the roll.
2. Safety implementation for the drone emergency stop.
3. Establish a reliable remote control of the drone.

3.3.2. Deliverables and milestones

No.	Activities	Deliverable	PIC	Priority
	Milestone 3.1 - PID tuning of the drone for the pitch and the roll.			
3.1.1.	Skim through the project description of the WP3.	Understand the requirement of the WP3.	All members	MED
3.1.2.	Research the PID controller document.	Understand the PID controller. Initial PID controller configuration with basic parameters.	All members	MED
3.1.3.	Tuning the PID controller.	Tuning PID settings experimentally, with a primary focus on the roll	Cuong Nguyen Minh Phan	HIGH

		and pitch axes.		
3.1.4.	Finalize the PID controller setting.	Complete PID settings and drone system integration.	Khoi Duong Thu Tran	HIGH
	Milestone 3.2 - Safety implementation for the drone emergency stop.			
3.2.1.	Test and validate the stop button.	Redo the WP2 Unit Test Section 1.5.	All members	HIGH
3.2.2.	Research for drone safety methods	Understand the drone safety requirements and options.	All members	HIGH
3.2.3.	Design the propeller guard.	A detailed design of the propeller guards.	Thu Tran	MED
3.2.4.	Test and validate the propeller guard.	Check if the propeller guard passed the safety check.	All members	HIGH
3.2.5.	Test and validate the power switch buttons on the drone and the remote controller.	Redo the WP2 Unit Test Section 1.6 and 1.7.	All members	HIGH
	Milestone 3.3 - Establish a reliable remote control of the drone			
3.3.1.	Test and validate the pitch and roll movement of the drone.	Check and validate the drone movement when moving the joystick.	Tuan Nguyen Minh Dinh	MED
3.3.2.	Test and validate the yaw rate movement of the drone.	Check and validate the drone movement when pressing two buttons controlling the yaw rate.	Thu Tran Khoi Duong	HIGH
3.3.3.	Test and validate the thrust control of the drone.	Check and validate the drone elevation when turning the potentiometer.	Cuong Nguyen Minh Phan	HIGH

Table 4. Deliverables and milestones of the work package 3.

3.3.3. Test Plan

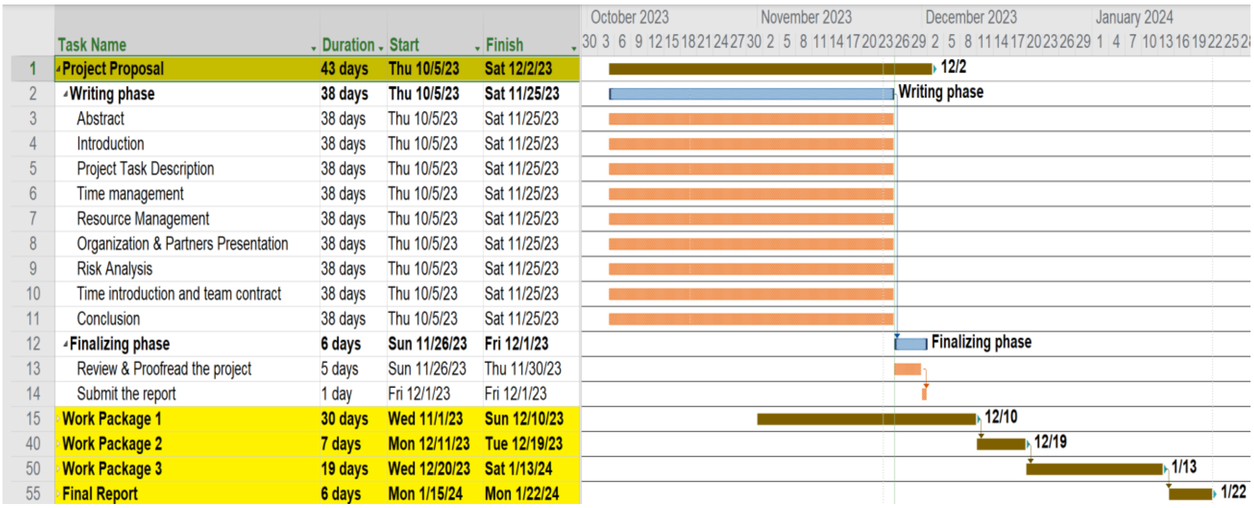
The table below presents the test plan of the WP3.

No.	Test Name	Test Description	Test Expected Result
1.	Test and validate the propeller guards.	Ensure the propeller guards are securely connected and can protect the propellers during a collision.	The propeller guards should remain stable and provide effective protection against damage during collisions.
2.	Test and validate the pitch and roll movement of the drone.	Move the joystick to control the drone's tilt around the pitch and the roll axis.	When moving the joystick, the drone should tilt correspondingly around the pitch and the roll axis.
3.	Test and validate the yaw rate movement of the drone.	Press the first button to regulate the positive velocity of the drone's yaw rate and press the second button to control the negative velocity of the drone's yaw rate.	Pressing the first button should make the drone rotate to the right (clockwise from above) and pressing the second button should make the drone rotate to the left (counterclockwise from above).
4.	Test and validate the thrust control of the drone.	Rotate the knob of the potentiometer to adjust the drone motors' speed.	Rotating the knob should result in the motors' speed either increasing or decreasing, demonstrating effective thrust control.

Table 5. Test plan of the work package 3.

4. Time Management

4.1. The Project Proposal Stage



	Task Name	Duration	Start	Finish
1	Project Proposal	43 days	Thu 10/5/23	Sat 12/2/23
2	Writing phase	38 days	Thu 10/5/23	Sat 11/25/23
3	Abstract	38 days	Thu 10/5/23	Sat 11/25/23
4	Introduction	38 days	Thu 10/5/23	Sat 11/25/23
5	Project Task Description	38 days	Thu 10/5/23	Sat 11/25/23
6	Time management	38 days	Thu 10/5/23	Sat 11/25/23
7	Resource Management	38 days	Thu 10/5/23	Sat 11/25/23
8	Organization & Partners Presentation	38 days	Thu 10/5/23	Sat 11/25/23
9	Risk Analysis	38 days	Thu 10/5/23	Sat 11/25/23
10	Time introduction and team contract	38 days	Thu 10/5/23	Sat 11/25/23
11	Conclusion	38 days	Thu 10/5/23	Sat 11/25/23
12	Finalizing phase	6 days	Sun 11/26/23	Fri 12/1/23
13	Review & Proofread the project	5 days	Sun 11/26/23	Thu 11/30/23
14	Submit the report	1 day	Fri 12/1/23	Fri 12/1/23
15	Work Package 1	30 days	Wed 11/1/23	Sun 12/10/23
40	Work Package 2	7 days	Mon 12/11/23	Tue 12/19/23
50	Work Package 3	19 days	Wed 12/20/23	Sat 1/13/24
55	Final Report	6 days	Mon 1/15/24	Mon 1/22/24

Figure 3. Gantt chart of the project proposal stage.

The process of the Project Proposal begins at the start of the project on October 5th and is scheduled to last until December 2nd. However, our team aims to complete the writing phase by November 25th. Following the release of the project description, we immediately assigned all tasks related to the Proposal and all team members are expected to contribute to this process. The Project Proposal is divided into 9 distinct tasks, as illustrated in the Gantt chart above, and these tasks have been evenly distributed among the 6 group members.

The most significant parts of the Project Proposal are the Project Task Descriptions and Time Management. The project includes 3 Work Packages (WPs), with each pair of team members responsible for one. The Task Description's importance lies in its role in guiding our research and defining requirements clearly, which helps us gain a comprehensive understanding of the project. This understanding is crucial for effectively working on the 3 WPs after completing the Proposal. Time Management is another critical component, providing a timeline of tasks that helps readers and team members understand the workflow and adhere to deadlines.

Finally, we will enter the Finalizing phase, which spans 6 days from November 26th to December 1st. During this stage, we will hold an online meeting on November 30th to review and proofread the entire Project Proposal thoroughly before its submission on the following day.

4.2. The WP1 Stage

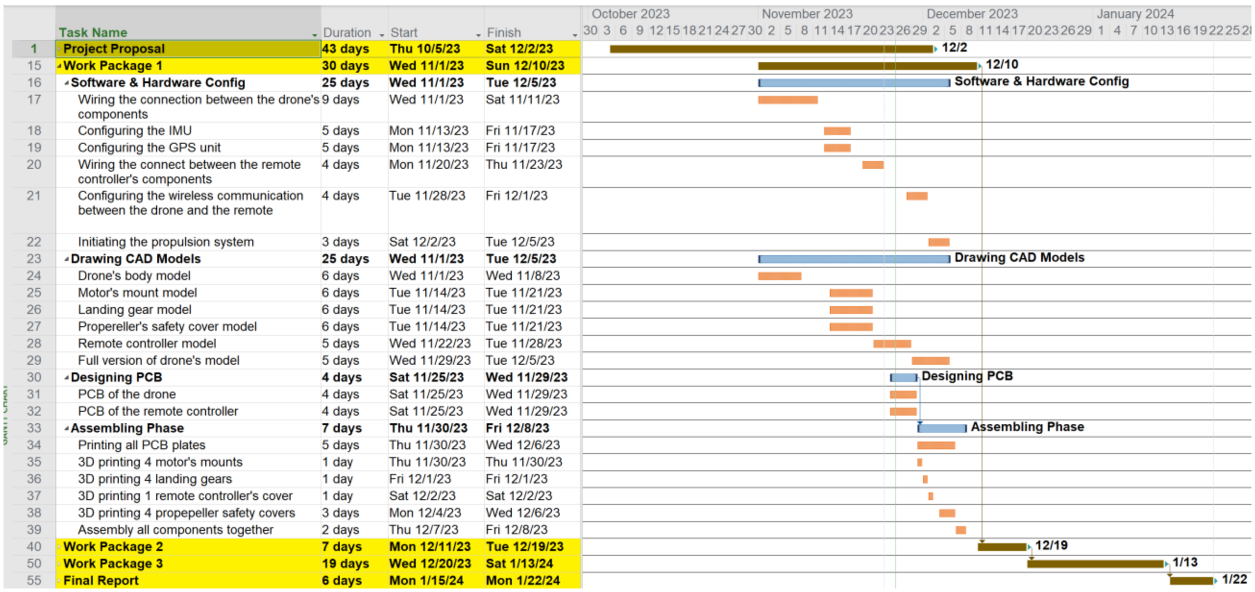


Figure 4. Gantt chart of the work package 1.

Work package one starts during the proposal stage, which is divided into four sub-tasks: Software and Hardware Configuration, Drawing CAD, Designing PCB, and Assembling phase. All the subtasks above must be finished by the 10th of December. In the first work package, we mainly focus on the hardware and software aspects are divided to work with the microcontroller, sensors, and modules as given in the list below:

- Configuring IMU.
- Configuring the GPS unit.
- Configuring the wireless communication between drone and remote.

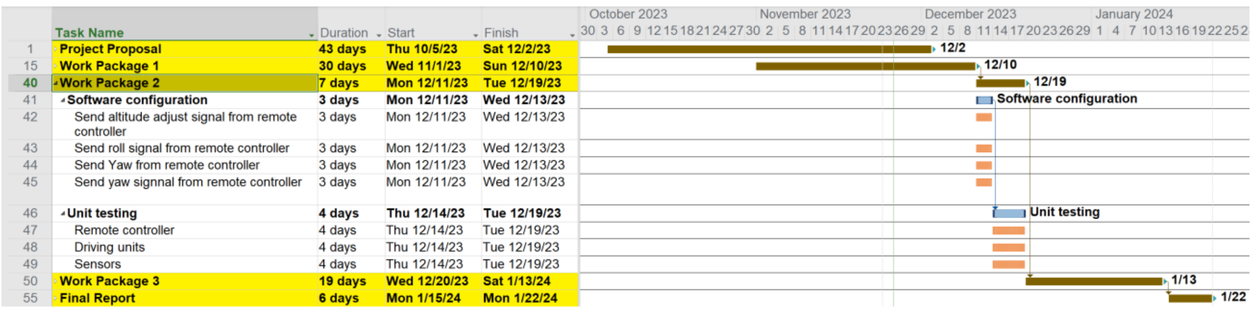
The task for hardware concentrates in the included aspects:

- Wiring all of the components.

- Designing and drawing CAD models, including drone’s body, motor mount, landing gear, remote, and the full frame of the drone.
- Designing PCB for drone and controller.
- Doing the 3D printing for the given components above.
- Assembly of all of the components.

The mentioned tasks above in both the hardware and software side are divided for the members who had experience in doing those specific tasks before or for members who can do the research for those tasks. In case some of the tasks are out of scope, the rest of the team members who finished their task before must be ready to solve the problem altogether.

4.3. The WP2 Stage



	Task Name	Duration	Start	Finish
1	**Project Proposal**	**43 days**	**Thu 10/5/23**	**Sat 12/2/23**
15	**Work Package 1**	**30 days**	**Wed 11/1/23**	**Sun 12/10/23**
40	**Work Package 2**	**7 days**	**Mon 12/11/23**	**Tue 12/19/23**
41	**Software configuration**	**3 days**	**Mon 12/11/23**	**Wed 12/13/23**
42	Send altitude adjust signal from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
43	Send roll signal from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
44	Send Yaw from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
45	Send yaw signnal from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
46	**Unit testing**	**4 days**	**Thu 12/14/23**	**Tue 12/19/23**
47	Remote controller	4 days	Thu 12/14/23	Tue 12/19/23
48	Driving units	4 days	Thu 12/14/23	Tue 12/19/23
49	Sensors	4 days	Thu 12/14/23	Tue 12/19/23
50	**Work Package 3**	**19 days**	**Wed 12/20/23**	**Sat 1/13/24**
55	**Final Report**	**6 days**	**Mon 1/15/24**	**Mon 1/22/24**

Figure 5. Gantt chart of the work package 2.

Our project's Work Package 2 (WP2) stage is scheduled to start after completing the final task in Work Package 1. The WP2 begins on December 11, 2023, and finishes on December 19, 2023. The stage is divided into three milestones: the remote control's design, the driving unit's calibration and functioning, and the sensors' testing and validation. Completing each milestone before moving to the next one is a must. The task is divided into software and hardware aspects during this stage.

On the software aspect, we focus on the coding implementation of the remote control and reading the data output from the sensors. There are four main focuses of the software implementation:

- Send the attitude to adjust the signal from the remote control.
- Send the roll angle signal from the remote control.

- Send the yaw angle signal from the remote control.
- Send the pitch angle signal from the remote control.

Following the hardware setup, unit testing for each component before assembly is necessary. We will do three milestones for unit testing:

- Test and validate the remote control.
- Test and validate the driving unit.
- Test and validate the sensors.

Certain minor tasks will be assigned to specific members based on their unique expertise and the specific requirements of the tasks. The detailed task description is outlined in the Task Description section. This approach leverages our team's diverse backgrounds and skills, ensuring that the most capable individuals handle each aspect of WP2.

4.4. The WP3 Stage

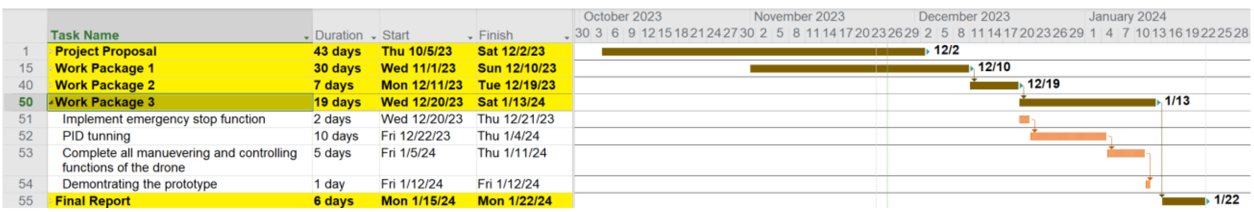


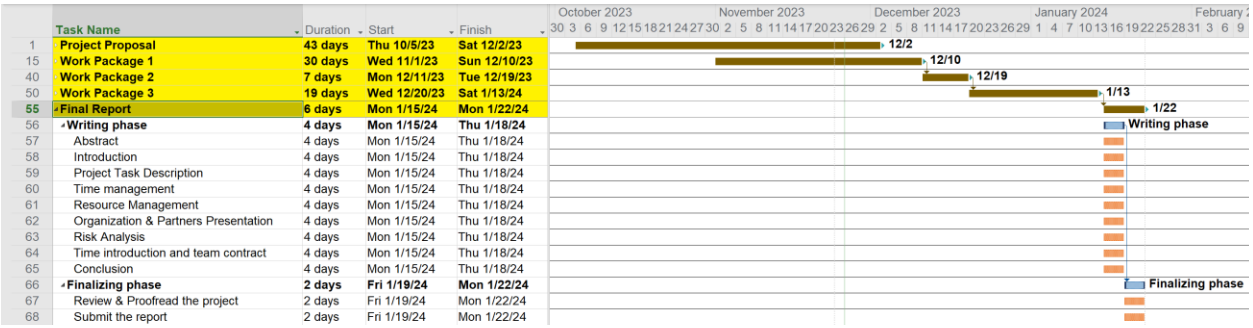
Figure 6. Gantt chart of the work package 3.

In this project stage, we will be working on WP3, which is scheduled to start immediately on December 20 after the completion of WP2. The deadline for WP3 is set for January 13th, providing a total time duration of more than two weeks (19 days). This stage is divided into four key phases:

- Implementing the emergency stop function.
- Tuning the PID (Proportional-Integral-Derivative) controller.
- Completing all maneuvering and controlling functions of the drone.
- Demonstrating the prototype.

Work Package 3 is an important stage in this project, focusing primarily on drone control and validation. The primary goal is to successfully integrate individual components into the final drone design, addressing challenges such as PID tuning, wiring errors, and assembly adaptations. Among the key deliverables are a finely tuned PID controller, safety measures for emergency stops, and the capability to control the drone across various degrees of freedom for testing purposes.

4.5. The Final Report



	Task Name	Duration	Start	Finish
1	**Project Proposal**	**43 days**	**Thu 10/5/23**	**Sat 12/2/23**
15	**Work Package 1**	**30 days**	**Wed 11/1/23**	**Sun 12/10/23**
40	**Work Package 2**	**7 days**	**Mon 12/11/23**	**Tue 12/19/23**
50	**Work Package 3**	**19 days**	**Wed 12/20/23**	**Sat 1/13/24**
55	**Final Report**	**6 days**	**Mon 1/15/24**	**Mon 1/22/24**
56	**Writing phase**	**4 days**	**Mon 1/15/24**	**Thu 1/18/24**
57	Abstract	4 days	Mon 1/15/24	Thu 1/18/24
58	Introduction	4 days	Mon 1/15/24	Thu 1/18/24
59	Project Task Description	4 days	Mon 1/15/24	Thu 1/18/24
60	Time management	4 days	Mon 1/15/24	Thu 1/18/24
61	Resource Management	4 days	Mon 1/15/24	Thu 1/18/24
62	Organization & Partners Presentation	4 days	Mon 1/15/24	Thu 1/18/24
63	Risk Analysis	4 days	Mon 1/15/24	Thu 1/18/24
64	Time introduction and team contract	4 days	Mon 1/15/24	Thu 1/18/24
65	Conclusion	4 days	Mon 1/15/24	Thu 1/18/24
66	**Finalizing phase**	**2 days**	**Fri 1/19/24**	**Mon 1/22/24**
67	Review & Proofread the project	2 days	Fri 1/19/24	Mon 1/22/24
68	Submit the report	2 days	Fri 1/19/24	Mon 1/22/24

Figure 7. Gantt chart of the final report stage.

This is the final stage of the project, and while it resembles the first stage (writing the proposal), it requires more specific details and system parameters. This stage should begin on January 15th, with a deadline set for six days later, on January 21st. There are two milestones: the Writing and Finalizing phases, with four and two days, respectively. In the Writing phase, the tasks are similar to those in the proposal, including sections such as the Abstract, Introduction, Project Task Description, Time Management, Resource Management, Organization & Partners Presentation, Risk Analysis, and Conclusion.

The goal is to compile and summarize all project data in the report. This stage emphasizes effective time management, individually and as a team, and fosters the ability to collaboratively design and develop a functional product prototype. Participants are encouraged to reflect on their technical and non-technical learning experiences by applying fundamental engineering knowledge. The report is then presented to peers, academics, and industry professionals, showcasing the comprehensive skills acquired throughout the project.

5. Resources Management:

Resource management in drone-making involves a multifaceted approach, focusing on various aspects such as the choice of materials and components and design and fabrication. To incorporate these specific requirements into drone-making, a thorough and detailed approach is necessary for each component of the BOM (Bill of Materials) across the three work packages. It is essential to ensure that the drone can operate safely and efficiently while carrying a 4kg payload and effectively utilize the ESP32, GPS, and IMU sensors for communication and control. Each factor should be carefully planned and organized to ensure the final output meets the desired specifications and performance.

5.1. The WP1 Bill of Materials

Item Name	Description	Quantity	Total Price (VND)
ESP32-wroom	A microcontroller module for this project, which supports Wi-Fi protocol and able to connect and communicate over Wi-Fi networks. It is one of the low-cost modules and widely used in various Internet-Of-Things applications. We will use two ESP32 to utilize on PCB of drone and controller.	2	158,000
Breadboard	Small breadboard to form the circuit.	1	20,000
Wood beams and plates	Wood beams and plates.	6	30,000
Lipo_Battery for Drone	Power supply for drone.	1	473,000
Lipo_Battery for controller	Power supply for remote control.	1	23,000
ESC	An electronic Speed Controller (ESC) is an important component empowered electrical RC model such as drone, car and boats. It serves as an intersection between power source and motor	4	289,640

	to control speed and direction of the motor based on remote control system from user.		
PDB	A Power Distribution Board is an essential component in many electronic systems. In this drone making project, it plays a role to distribute electrical power from high voltage battery to supply into 4 different ESC components.	1	67,623
Lipo Battery charger	Charger for drone and controller battery.	1	359,000

Table 6. Bill of materials of the work package 1.

5.2. The WP2 Bill of Materials

Item Name	Description	Quantity	Total Price (VND)
PCB printing	PCB production refers to a process of making Printed Circuit Boards, which are used mechanically support and electrically connect components after finished the schematic design from EasyEDA online open platform.	2	TBA
Red button	Two buttons for controlling yaw rate angle.	2	16,000
Joystick	Joystick controls roll and pitch rate of the drone.	1	17,000
Switch button	Power the remote control and the drone.	2	8,000
PLA material for 3d printing	It is known as Polylactic Acid, widely used for 3d printing. It is an environmentally friendly material and offers high quality 3d printing in the market.	1	310,000
USB_C cable	Transmission wire between the ESP and laptop.	2	134,000
Brushless Motors	A brushless motor to utilize onto the frame of drone.	4	360,000
Potentiometer	Control the thrust level of the drone.	1	2,500

Propellers	The drone's propeller	4	38,000

Table 7. Bill of materials of the work package 2.

5.3. The WP3 Bill of Materials

Item Name	Description	Quantity	Total Price (VND)
MPU6050	Low-cost inertial measurement unit (IMU) used in various applications in electronic and robotic. It provides 3-axis from both accelerometer and gyroscope that help to track 3d environments and motion process on object.	1	27,500
Red button	A red button to stop the drone.	1	8,000
GPS NEO8M with ceramic antenna	Sensor sends the latitude, longitude and altitude of the drone.	1	242,000

Table 8. Bill of materials of the work package 3.

5.4. The Total Bill of Materials

No. Of Work Package	Items	Total cost
Work Package 1	8 items	1,420,263
Work Package 2	9 items	885,500
Work Package 3	3 items	277,500
Total Bill	**20 items**	**2,583,263**

Table 9. Total cost of the project.

6. Organization And Partners Presentation

Given the scope of the quadcopter, we identify the potential stakeholders and companies that could be interested in our project.

6.1. Military

Drone use in military operations has increased massively because of its versatility, cost, and ability to do tasks that might endanger human life. Among the many military applications are border and coastal surveillance, training and simulation, target acquisition, surveillance and reconnaissance, and more. We aim to partner with defense contractors. Aero Sentinel, an Aerosol company, could be a potential stakeholder in our project. Aero Sentinel is a leading manufacturer in the tactical UAS (Unmanned Aerial Systems) industry that could enhance our quadcopter project success [21].

6.2. Education

Drones nowadays have greatly impacted education for many of their good reasons. Here are some examples illustrating how drones influence education:

- **Encouraging the interest in learning STEM for students:** It is stated that drones are commonly used as learning topics in school, which is evaluated as remarkably interesting ideas to teach students [22]. For example, students can use drones to demonstrate how the projectile works or learn about the wiring connection inside the drone. So, using drones in education is a superior way to intrigue students.
- **Drone are used in demonstration purpose:** Mostly in every STEM class now, the professors use drones as an illustrating tool to collect data and monitor the environment for learning purpose. For example, in Science class, drones are used to keep track of air qualification by sensors or study the attitude of animals in the wild [23].
- **Make the lectures fun and attractive:** Drones are identified as a new technology now, and drones may be developed further in the future [24]. As a result, students are intrigued by the unique and interest of the drone.
- **Drones are used in computer science teaching:** Students can learn the backend logic or reverse engineering based on the drone's source code. The logical programming concept inside the drone is necessary for application to real-world programming, especially in the IoT field. The National University of Tainan is a real example of applying drones in education. Students are instructed to understand every piece of code from a drone, and then, at the final stage, they can build a flying one [25].

6.3. Entertainment

Quadcopters are those agile flying machines that elevate technology to a new level while providing entertainment. Imagine a group of quadcopters dancing elegantly in the sky, enthralling onlookers below with their coordinated motions. Quadcopters are a source of entertainment value due to their ability to fly and the numerous creative and dazzling opportunities they present. Moreover, Quadcopters enable filmmakers to capture stunning aerial shots that were previously difficult, if not impossible, to achieve. This includes panoramic landscape shots, dynamic tracking shots, and unique perspectives that add a new dimension to storytelling. Quadcopters' agility and maneuverability allow filmmakers to navigate tight spaces and capture shots from various angles, providing versatility previously reserved for high-budget productions using helicopters or cranes. This ability has become a defining feature of many films, enhancing visual storytelling and immersing audiences in breathtaking landscapes. Two very famous brand films are Warner Bros. Discovery and Marvel Studio; they always use drones to capture or record scenes from the sky [26].

6.4. Services

The development of the Internet had a positive impact on the transportation industry. Anyone can shop online and get their cart delivered right to their house. More demands mean that we need a more effective way to transport goods or packages, and the solution is drone delivery services. Since drones can move freely in 3D planes, they can take shortcuts, not be affected by traffic congestion, and emit less carbon footprint. From an economic aspect, using drones is cheaper because they use less labor cost and are more energy-effective than typical diesel trucks [27].

Amazon and Walmart are potential stakeholders interested in using drones as delivery services. Both companies have invested big funding to expand the US drone delivery network in recent years. Walmart is currently leading in this field. They have finished over 10000 deliveries after initiating their program in 2021[28]. The partnership with these two big retailers could bring valuable assets and funding to help the project be more profitable.

In addition, drones can be used in agriculture for multiple applications [29]. The first application is scouting and monitoring using a camera on the drone. Farmers can collect data on the field, such as crop growth, density, and coloration. After collecting the data from drone imaging, farmers can adjust their watering or fertilize accordingly. The second application is using drones to apply pesticides, which helps farmers avoid hazardous chemicals and maximize efficiency on cost and time. Lastly, they used automated drone seeders to follow a programmed path and distribute plant seeds from above. This technique is more efficient and resolves the problem of the shortage of field workers.

The potential partner in using drone technology for farming operations is Agribotix, located in the US. They provide operational-specific drones with high-resolution cameras for precision agriculture [30]. The company was acquired by AgEagle, a provider of drones for the precision agriculture market, on August 28, 2018 [31]. This acquisition will improve Agribotix distributions and expand their service offerings. Collaborating with Agribotix's agriculture and drone technology expertise could elevate our project scope and design.

7. Risk Analysis

	Likelihood				
	1	2	3	4	5
Risk probability	Rare	Unlikely	Possible	Likely	Certain
Risk impact	Insignificant	Minor	Moderate	Major	Catastrophic

Table 10. Risk assessment likelihood.

Overall Risk Scale		
Below 5	From 5 – 8	Over 8
Minor	Moderate	Require attention and risk mitigation

Table 11. Risk assessment scale.

7.1. Internal Risks

Risk Description	Risk Probability	Risk Impact	Overall Score	Mitigation
Teammates are unable to work due to external factors.	3	4	12	Frequently communicate and check on the progress of each member to plan beforehand the resolution.
Poor planning led to tasks taking longer to complete.	4	4	16	Use project management software to streamline project tasks for example (Loop, Trello).
Computer or equipment damaged.	4	5	20	Transport the computer or equipment in a cushioned bag. Avoid liquid near the electrical components.
Software glitches or accidentally deleted files.	3	5	15	Make sure to save the project regularly in the secure folder or create backups.
Component delivery delay.	2	4	8	Keep track with the component status and prepare backup plant.
Low individual performance.	3	4	12	Document performance history and provide feedback. Encourage member to ask for help.
Disagreement and conflict.	4	3	12	Address disagreement and come to a mutual understanding.

Table 12. Internal risks.

7.2. External Risk

Risk Description	Risk probability	Risk impact	Overall score	Mitigation
Legal Concerns and Regulatory Compliance.	3	3	9	Flight Restrictions, Data Protection, and Insurance Requirements must be included.
Environment factors.	3	4	12	Wind conditions, Altitude, Obstacles, and Terrain may significantly impact the drone testing process.
Public Perception and Acceptance.	3	3	9	Negative public opinion or hostility to drone testing might affect public policy, limit usage, or damage outside people or buildings.

Table 13. External risks.

7.3. Safety Risk

Risk description	Risk probability	Risk impact	Overall score	Mitigation
Electric shock	3	2	6	Check the wire connection carefully to find if a wire is being opened. Always wear insulating gloves to avoid being electrocuted.
Injuries when working with propeller.	3	3	9	Carefully remove the batteries and ensure the motor is off before starting the assembly.
Short circuit.	3	2	6	Use multimeter to find short circuit then immediately fix it.

Table 14. Safety risks

8. Team Introduction and Team Contract

8.1. Team Introduction

8.1.1. Dinh Ngoc Minh

Name: Dinh Ngoc Minh

Student ID: s3925113

Personal Email: s3925113@rmit.edu.vn

Career Path: Embedded Software Developer

Personal Summary: I am a Software Engineer student who is passionate about programming Embedded development. My career path is to become a embedded Software Engineer. Even though I lack experience in this field, I am willing to learn and contribute my best efforts to my work.

8.1.2. Nguyen Nam Cuong

Name: Nguyen Nam Cuong

Student ID: s3891758

Personal Email: s3891758@rmit.edu.vn

Career Path: Software Engineering

Personal Summary: I am a software engineering student passionate about web development and embedded systems. Coding is my lifestyle, where I continuously learn and grow. When I'm not lost in the world of code, I love being outdoors, especially hiking. It is my escape and a source of fresh inspiration. I also hit the gym regularly, which keeps me energized and focused. In short, I balance myself with outdoor activities, fitness, and gaming, keeping life exciting and fulfilling.

8.1.3. Phan Nhat Minh

Name: Phan Nhat Minh

Student ID: s3904422

Personal Email: minh40490@gmail.com / s3904422@rmit.edu.vn

Career Path: Software Engineering

Personal Summary: I enjoy taking on new tasks and solving problems. My goal is to contribute to the Software Engineering community. In addition to balancing myself, I enjoy going hiking and playing badminton.

8.1.4. Tran Thinh Thu

Name: Tran Thinh Thu

Student ID: s3894296

Personal Email: huang.harry1314@gmail.com

Career Path: Mechatronic Engineering

Personal Summary: Patience with learning and enthusiasm while helping others.

8.1.5. Nguyen Bao Tuan

Name: Nguyen Bao Tuan

Student ID: s3713061

Personal Email: s3713061@rmit.edu.vn

Career Path: Mechatronic Engineering

Personal Summary: Enjoy mathematics subjects and stay updated on latest technology news.

8.1.6. Duong Hoang Dang Khoi

Name: Duong Hoang Dang Khoi

Student ID: s3879524

Personal Email: s3879524@rmit.edu.vn

Career Path: Mechatronic Engineering

Personal Summary: I am good at Mathematics, but I usually have troubles with communication with others.

8.2. Team Contract

8.2.1. Group Contract

1. Dinh Ngoc Minh is the Leader. Leader also in charge of communication between members and professor.
2. Online meeting on Team every Saturday from 7 PM to 8 PM.
3. In case the team deadline conflicts with personal deadlines, the member must announce the team 3 days in advance.
4. Not doing work or missing a deadline will be tagged with 1 flag each time. More than 3 flags result in deducting that person's contribution. An announcement about the incident will be sent to the professor.
5. Be respectful and contribute to the team idea.
6. Every member must publish their problems to the group.

8.2.2. Signatures

Name	Student ID	Signature	Date
Dinh Ngoc Minh	s3925113	Dinh Ngoc Minh	12/02/2023
Nguyen Nam Cuong	s3891758	Nguyen Nam Cuong	12/02/2023
Phan Nhat Minh	s3904422	Phan Nhat Minh	12/02/2023
Tran Thinh Thu	s3894296	Tran Thinh Thu	12/02/2023
Nguyen Bao Tuan	s3713061	Nguyen Bao Tuan	12/02/2023
Duong Hoang Dang Khoi	s3879524	Duong Hoang Dang Khoi	12/02/2023

Table 15. Signatures of team's contract.

9. Conclusion

In conclusion, this project has significantly advanced the field of drone technology, focusing on making it more accessible and cost-effective. Despite the challenges of limited research skills and budget constraints, we prioritized simplicity and affordability, opening up new possibilities for innovation in areas like education and entertainment. The core of our project involved designing and constructing a battery-operated drone. This drone was not just a simple machine; it was equipped with advanced features like brushless motors and was controlled by an ESP32 microcontroller. We also integrated an MPU and a GPS module to ensure a precise and stable flight, combining all these elements into a single, custom-designed Printed Circuit Board (PCB).

One of the key aspects of our project was the strategic choice of materials. We opted for wood for the drone's frame, considering its lightness, durability, and cost. Similarly, selecting specific bolts and nuts for assembly was done thoughtfully to ensure the drone's robustness. Our project was methodically divided into three work packages (WPs), each focusing on a different aspect of the drone's development. WP1 dealt with the initial design and material selection, including wood, bolts, nuts, and basic electronic components. WP2 focused on the propulsion and control systems, encompassing brushless motors, the microcontroller, sensors, and the necessary components for the PCB. WP3 was all about assembling, testing, and making final adjustments, involving additional materials like fasteners and adhesives and any replacement parts needed after testing.

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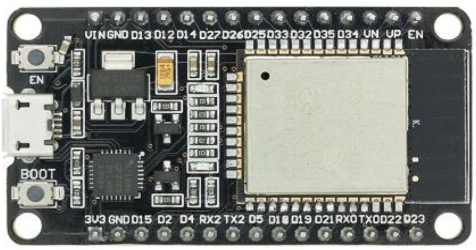
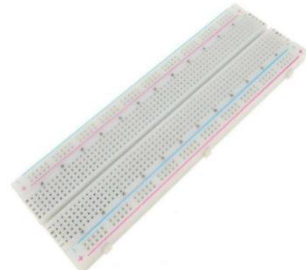
11. Appendix



Appendix 1. ESP32. Link

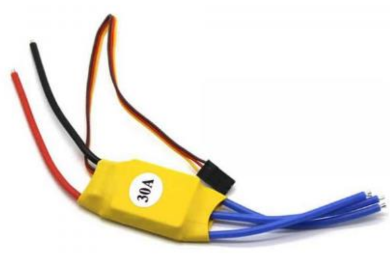


Appendix 2. Breadboard. Link

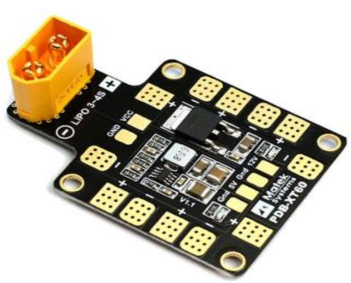
Appendix 3. Wood beams and plates. Link

Appendix 4. Lipo battery for controller. Link

Appendix 5. Lipo battery for drone. Link



Appendix 6. ESC. *Link*



Appendix 7. PDB. *Link*

Appendix 8. Lipo Battery Charger. Link

Appendix 9. Red button. Link

Appendix 10. Joystick. Link

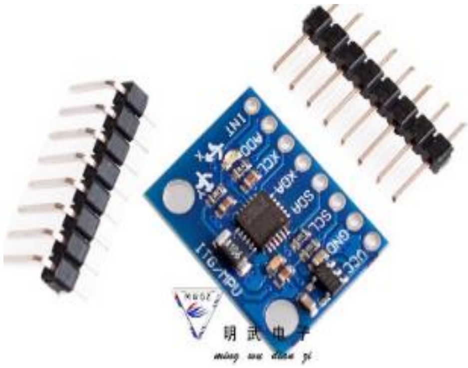
Appendix 11. Power switch button. Link

Appendix 12. USB_C cable. Link

Appendix 13. Motors. Link

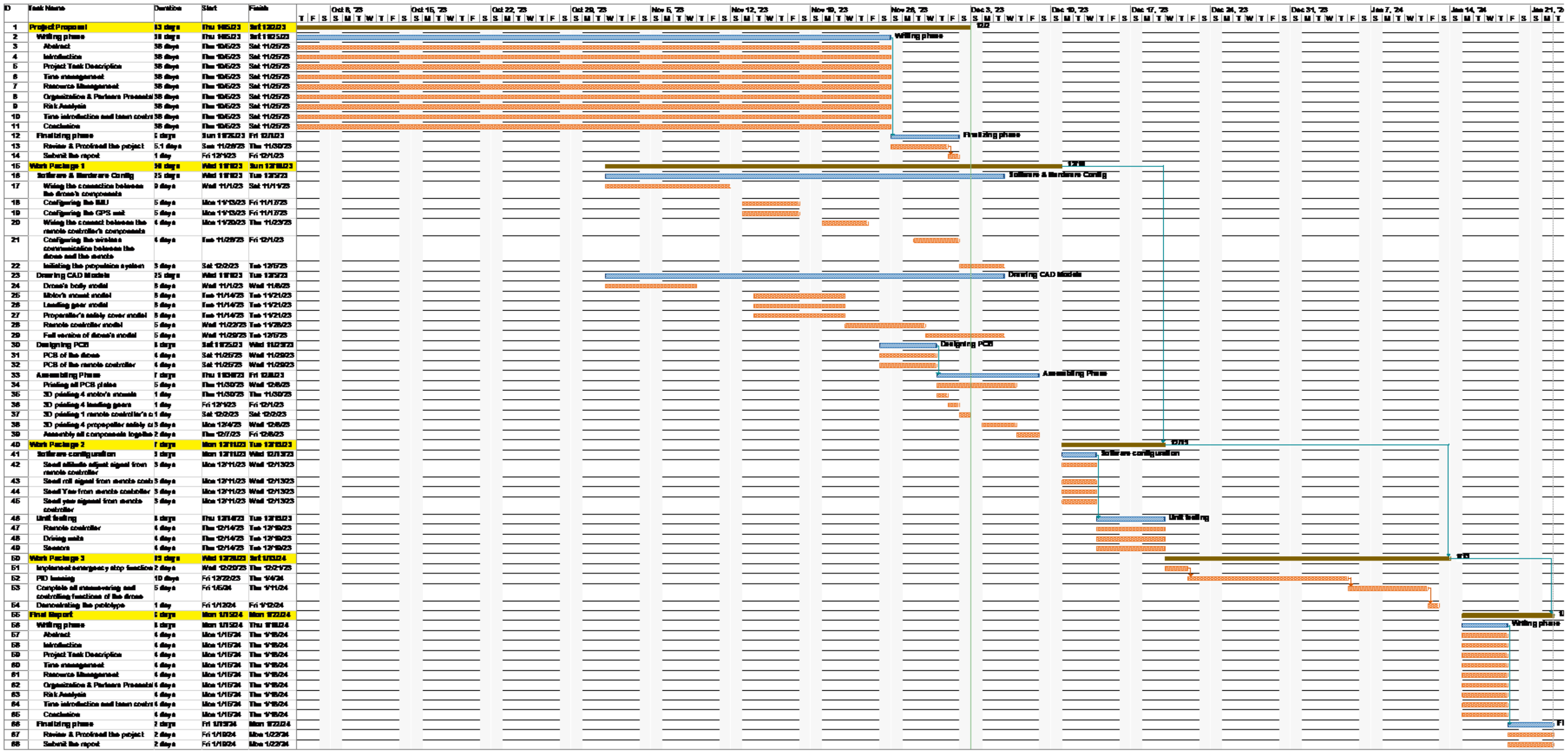
Appendix 14. Potentiometer. Link

Appendix 15. Propellers. Link



Appendix 16. MPU6050. Link

Appendix 17. GPS NEO8M. [Link]



Appendix 18. Full version of the project's Gantt chart.