ECE 445

Senior Design Laboratory

Design Document

FIXED-WING DRONE WITH AUTO-NAVIGATION

By

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22 March 2023

Project No. 7

Contents

1. Introduction

1.1 Problem and Solution

In recent years, the increase in natural disasters such as chemical leaks, wildfires, and volcanic eruptions has led to the need for prompt notification of affected areas and the collection of accurate environmental data to reduce casualties and prevent environmental damage. Traditional methods of communication and data collection may not be effective in hazardous or hard-to-reach areas, creating a need for a novel solution.

This project aims to build a fixed-wing drone using 3D printing technology, which offers several advantages over traditional manufacturing methods. 3D printing allows for greater design flexibility and faster production times, which is essential for rapidly responding to natural disasters. Additionally, the use of lightweight materials in 3D printing can enhance the drone's flight performance, making it more efficient and capable of flying longer distances.

The drone will be equipped with a loudspeaker, enabling it to broadcast information during flight to notify individuals in affected areas of imminent danger or provide evacuation instructions. The designed drone can automatically fly along a specified route based on computer instructions when it receives an alarm signal. This will improve the response speed to disasters and reduce the risks of flight operation. Additionally, the drone will carry an air quality sensor to collect air condition data including temperature, humidity, air pressure and so on, during flight and transmit it in real-time or store it in SD card for later analysis. This solution offers a more efficient and effective way to communicate and collect environmental data during natural disasters, reducing the risk of harm to individuals and the environment.

1.2 Visual Aid

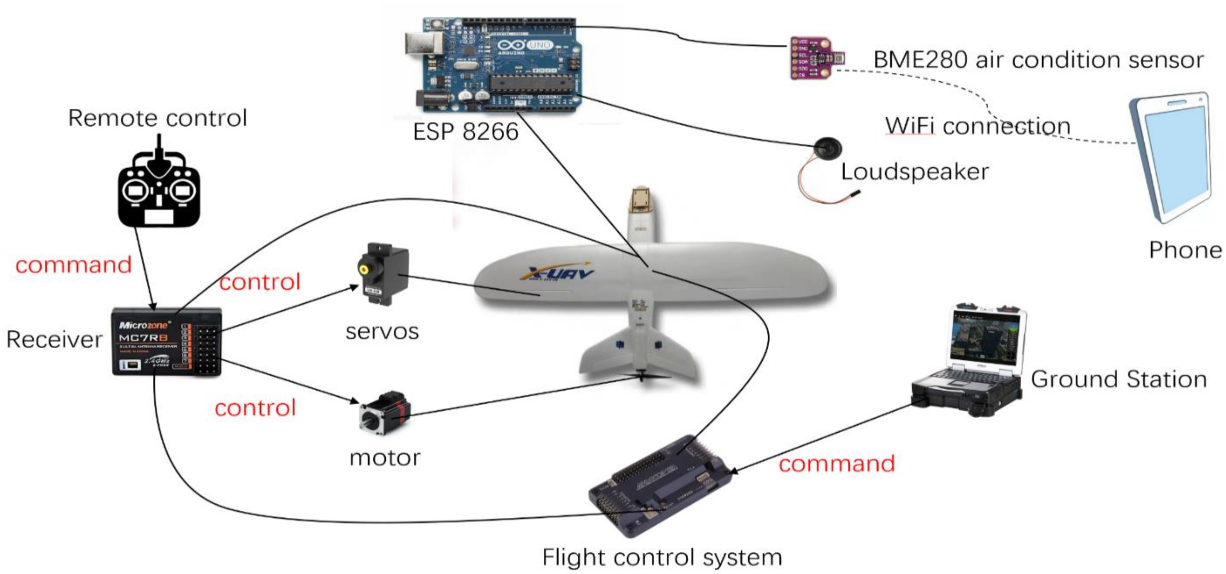

Fig 1. Visual aid

1.3 High-level Requirements List

i. The drone can be controlled manually so that we can control the drone to some places to collect data including the air quality.

ii. The drone can realize self-stabilization in the air, allowing the drone to work in extreme weather, especially the windy days.

iii. The drone\` can navigate autonomously so that the drone can collect data from different places autonomously when out of the remote controller's receiving range.

iv. The drone can be placed on the landing gear to take off instead of jettisoning, avoiding the risk of injury from the tail propeller.

2 Design

2.1 Block Diagram

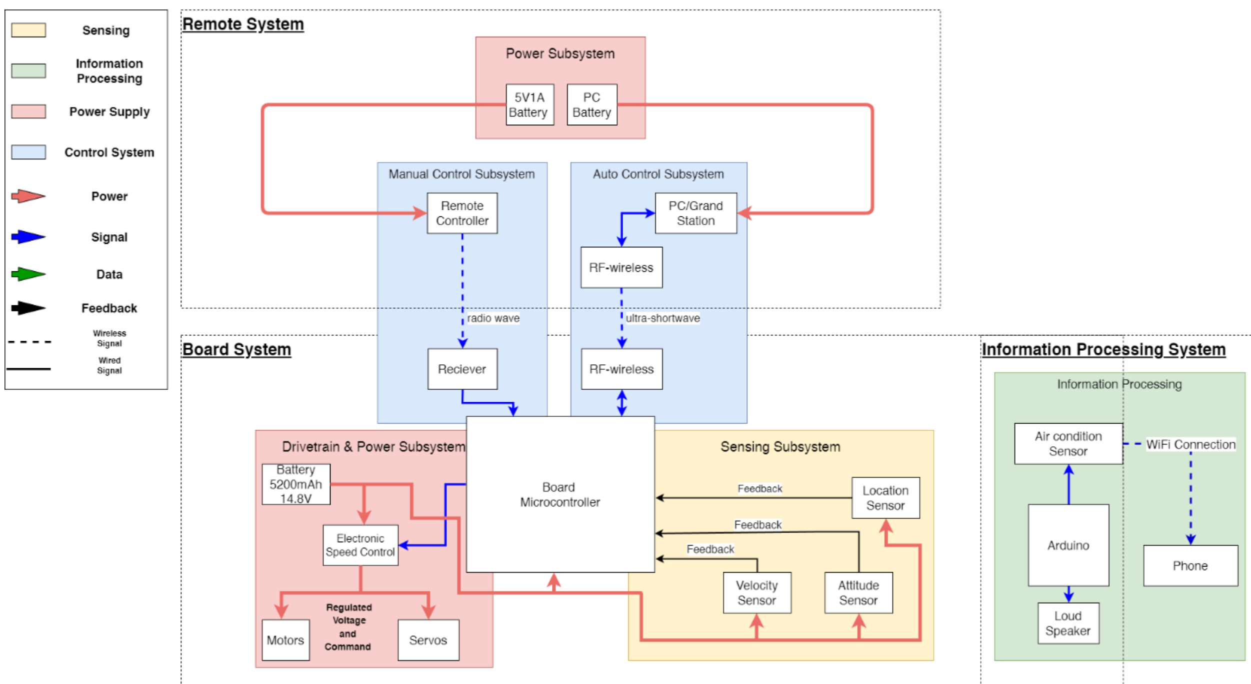

Fig 2. Block diagram

2.2 Manual Control Subsystem

This subsystem consists of the remote control and its receiver, which receives signals from the remote control and signals from the flight control system and sends signals to the drivetrain system. This subsystem is connected with the auto control subsystem through the receiver and with the power subsystem through the remote control.

2.2.1 Remote Controller & Receiver

The controller MICROZONE controller is used to control the drone to take off and turn. This controller is chosen for its affordability and the speed of the signal transmit 2.4GHz, which allows low interference degree and remote-control distance. The receiver, MC7RB matched with the remote control, is used to receive the signal from the remote control and the signal from computer through the flight control system.

Requirements	Verifications
1. The remote control can send and transmit the signal to the receiver with low interference degree and remote-control distance. 2. Receiver can receive the signal from the remote control. 3. Receiver can receive the signal from the flight control system.	1. A. Match the receiver with remote control. B. Connect the servos with the receiver through channel 1,2,4 and motor through channel 3. (The two servos installed on the ailerons connect to channel 2 through a y wire, servo installed on the left tail wing through channel 4 and servo installed on the right tail wing through channel 1.) C. Install the motor and servos on the model drone. E. Keep a distance between the receiver and remote control and set some obstacles between them. F. Operate the remote control. When pushing the left rocker of the remote control up and down, the motor can work to power the drone. Push the left rocker of the remote control to move left and right, the servo on the left can pull the tail wing to turn the drone. When pushing the right rocker of the remote control up and down, the two servos installed on the ailerons can work together pull the ailerons to make the drone go up and down. Push the right rocker of the remote control to move left and right, the servo on the right can pull the tail wing to turn the drone. 2. A. Match the receiver with remote control. B. Connect the servos with the receiver through 1-6 channels. C. Operate the remote control to see whether the servos can work under the command of the remote control. 3. A. Connect the servos with the receiver through 1-6 channels. B. Connect the flight control system with the receiver through the bus channel. C. Input the command in

	computer to see whether the servos can work under the command from the computer.

Table 1. Remote Controller & Receiver R&V table

2.3 Auto Control Subsystem

This subsystem consists of two main components: a ground station software Mission Planner installed on a laptop and a microcontroller PIXHAWK 2.4.8 installed on the aircraft, which are connected via a pair of RF-wireless module. The primary function of this subsystem is to enable the aircraft to achieve self-stabilization and perform automatic cruising, and acquire data from Sensing subsystems and send commands to the Drivetrain & Power Subsystem.

2.3.1 RF-wireless Module

The software Mission Planner and microcontroller are connected wirelessly through a pair of RF-wireless modules. One module is connected to the laptop, while the other is connected to the Microcontroller on board the aircraft, establishing a bidirectional wireless communication link between them.

Requirements	Verifications
1. The airborne RF-wireless module and the RF-wireless module connecting the ground station can be connected normally within an obstacle free range of 2 kilometers. 2. The RF-wireless modules can correctly transmit ground station instructions for flight control.	1. A. Pairing two RF wireless modules. B. Using the positioning function of mobile phone GPS, move two RF-wireless modules about 2km apart in an open area. C. Observe the indicator light on the RF-wireless modules. If it remains permanently green, it indicates that the connection is normal, which satisfies the requirement. 2. A. Set “Auto” mode on Mission Planner software. B. Test whether the drone can maintain horizontal flight. C. Set “Manual” mode on Mission Planner software. D. Test whether the drone can return to manual control.

Table 2. RF-wireless Module R&V table

Fig 3. Schematics of Microcontroller [1]

2.3.2 Microcontroller

The microcontroller receives commands from the ground station software and sensor data from the Sensing Subsystem, which it uses to control the aircraft through the Drivetrain & Power Subsystem. Additionally, the microcontroller will transmit data from various sensors described in the Sensing Subsystem back to the laptop via RF-wireless communication.

Requirements	Verifications
1. The microcontroller can automatically control the drone for stable horizontal flight. 2. The microprocessor can automatically control the drone to fly along a given path by performing functions such as climbing, descending, and turning during the flight. 3. The microprocessor will remain idle in manual mode and will not affect manual control operations.	1. A. Fly the drone smoothly in manual mode. B. Set the mode to "Auto". C. Observe whether the drone can maintain the previous stable flight. If it can, then the requirement is satisfied. 2. A. Set waypoints in Mission Planner. B. Set the mode to "Navigation". C. Observe whether the drone can fly along the waypoints and perform operations such as climbing, turning, and descending in the correct locations using GPS and visual observation. If it can, then the requirement is satisfied. 3. A. Switch back to "Manual" mode while in "Auto" or "Navigation" mode. B. Use the remote control for manual control. C. Observe whether the drone can adjust according to the remote controller commands. If it can, then the requirement is satisfied.

Table 3. Microcontroller R&V table

2.4 Sensing Subsystem

This subsystem consists of three types of sensors: position sensors, velocity sensors, and attitude sensors. The position sensors include a GPS M8N, which provides accurate location information for the drone. The velocity sensors consist of an MP6000 gyroscope, which measures the drone's rotational movements, and an L3GD20 gyroscope, which measures changes in angular velocity. Finally, the attitude sensors include an MS5611 barometer, which measures changes in air pressure, and an LSM303D magnetometer, which measures changes in magnetic fields. These components are powered by the 5200mAh battery in the Drivetrain & Power Subsystem of the drone. The sensors are responsible for collecting various types of data during flight, which are transmitted to the microcontroller.

2.4.1 Location Sensor

The GPS M8N is essential for accurate positioning and navigation of the drone. It uses satellite signals to provide the drone's location, altitude, and speed.

Requirements	Verifications
1. The GPS M8N can provide accurate location data within 5 meters. 2. The GPS M8N can provide accurate altitude data within 10 meters	I. A. Connect the GPS M8N to the microcontroller. B. Power on the GPS M8N and allow it to acquire a GPS fix. C. Read the location data output by the GPS M8N from software. D. Compare the location data to a known location within 5 meters of the GPS M8N. If the location data is within 5 meters of the known location, the requirement is satisfied. I. A. Connect the GPS M8N to the microcontroller. B. Power on the GPS M8N and allow it to acquire a GPS fix. C. Read the altitude data output by the GPS M8N from software. D. Compare the altitude data to a known altitude within 10 meters of GPS M8N. If the altitude data is within 10 meters of the known altitude, the requirement is satisfied.

Table 4. Location Sensor R&V table

2.4.2 Velocity Sensor

The MPU6000 gyroscope is responsible for measuring the drone's rotational movements and provides information on its pitch, roll, and yaw. The L3GD20 gyroscope measures changes in angular velocity and provides information on the drone's angular acceleration.

Requirements	Verifications
1. The Velocity Sensor can provide accurate angular velocity measurements	1. A. Connect the Velocity Sensors to the microcontroller. B. Power on the Velocity Sensors and allow them to initialize. C. Rotate the who board around its three axes, varying the rotation speed. D. Read the angular velocity measurements output by the Velocity Sensors. E. Compare the angular velocity measurements to known rotation speeds. If the angular velocity measurements match the known

	rotation speeds within an acceptable margin of error, the requirement is satisfied.

Table 5. Velocity Sensor R&V table

2.4.3 Altitude Sensor

The MS5611 barometer is used to measure changes in air pressure, which can be used to determine the drone's altitude. It is also useful for providing information on changes in weather conditions. Finally, the LSM303D magnetometer is used to measure changes in magnetic fields, which can be used to determine the drone's orientation and heading.

Requirements	Verifications
1. The Attitude Sensor can provide accurate orientation and heading measurements.	A. Connect the Attitude Sensor to the microcontroller. B. Power on the Attitude Sensor and allow it to initialize. C. Rotate the Attitude Sensor around its three axes, varying the rotation speed. D. Read the orientation and heading measurements output by the LSM303D magnetometer. E. Compare the orientation and heading measurements to known orientations and headings. If the orientation and heading measurements match the known orientations and headings within an acceptable margin of error, the requirement is satisfied.

Table 6. Altitude Sensor R&V table

2.5 Drivetrain & Power Subsystem

This subsystem consists of a 2200mAh battery that powers the remote's receiver by connecting to the electronic speed controller, one electronic speed controller, four steering engines and one motor. This subsystem provides power to various electronic components on the aircraft and adjusts the power to control the flight of the aircraft based on commands from the manual or automatic control subsystems. This subsystem is connected with the control subsystem through the ESC and the receiver of the remote control.

2.5.1 Battery

The battery has 2200mAh capacity which supplies the receiver through the electronic speed controller. And the battery supplies 11.1V voltage.

Requirements	Verifications
1. The battery can supply 11.1V +/-5% voltage 2. The battery can have 220mAh capacity.	1. A. Charge the battery in the way specified by the battery manufacturer B. Connect the multimeter to the battery C. Get the value of the voltage 2. A. Charge the battery in the way specified by the battery manufacturer. B. After fully shelving discharge at 1C rate to the cut-off voltage and record the released capacity. C. Test can be repeated 3 times to take the mean value to improve accuracy.

Table 7. Battery R&V table

2.5.2 Electronic Speed Controller

The SKYWALKER 50A electronic speed controller is connected with the battery and the receiver so that the battery can supply the receiver. And the electronic speed controller is also connected with the motor and can transmit the signal from the receiver to the motor, allowing that the remote control can control the motor.

Requirements	Verifications
1. Electronic speed controller can supply the receiver 2. The motor can be controlled by the remote control through the electronic speed controller.	1,2 A. Connect the electronic speed controller with the battery and motor and install the motor on the drone. B. Connect the electronic speed controller with the receiver C. Match the receiver with the remote-control D. Operate the remote control. When pushing the left rocker of the remote control up and down, the motor can work to power the drone.

Table 8. Electronic Speed Controller R&V table

2.5.3 Motor

We designed the motor, X2216 KV1250 motor installed on the tail of the drone. And the motor is connected to the propeller, which powers the drone.

Requirements	Verifications

1. Motor can be controlled by the remote control 2. Motor can work properly on the drone and power the drone with a speed of 10-30m/s.	1. A. Connect the motor with the receiver through the electronic speed controller B. Match the remote control with the receiver C. Control the remote control 2.A. Install the motor on the drone B. Connect the motor with the receiver C. Install the propeller on the motor D. Control the remote control. E. We chose to throw the model drone into the air, install the steering engines on the ailerons and tail wings, and conduct a test flight. F. When the drone flies in the sky, we can look through the data that the speed sensor to get the speed of the drone and ensure the speed in the range of 10-30m/s.

Table 9. Motor R&V table

2.5.4 Servos

We have four ES08MAII 8.5g steering engines. We design two of the steering engines installed on the ailerons and the others on the tail wings of the drone. The steering engines installed on the ailerons are connected through a y wire and then connected to the receiver and the others are connected to the receiver independently. Then we can control the steering engines through the remote control.

Requirements	Verifications
1. Servos can be controlled by the remote control 2. Servos can work properly on the drone and reverse the drone's tail wings and ailerons by between 30 and 40 degrees.	1. A. Connect the servos with the receiver B. Match the remote control with the receiver C. Control the remote control 2. A. Install the servos on drone B. Connect the servos with the receiver C. Adjust the position of the wings connected with the servos ensuring the balanced position without using the remote control. D. Control the remote control. Control the steering engines so that the tail wings and ailerons can reach the maximum angle that can be achieved and then measure the angle to ensure it is in the range of 30 to 40 degrees.

Table 10. Servos R&V table

2.6 Power Subsystem

This subsystem consists of four AA batteries that power the remote control and the power supply that powers the computer.

2.6.1 AA battery

The battery can supply 1.5V voltage which supplies the remote control.

Requirements	Verifications
1. The battery can supply 1.5V +/-5% voltage	A. Connect the multimeter to the battery B. Get the value of the voltage

Table 11. AA battery R&V table

2.6.2 PC battery

The battery has 4480mAh capacity and supply 13.05V voltage.

Requirements	Verifications
1. The battery can supply 13.05V +/-5% voltage 2. The battery can have 4480mAh capacity.	1. A. Charge the battery in the way specified by the battery manufacturer B. Connect the multimeter to the battery C. Get the value of the voltage 2. A. Charge the battery in the way specified by the battery manufacturer. B. After fully shelving discharge at 1C rate to the cut-off voltage and record the released capacity. C. Test can be repeated 3 times to take the mean value to improve accuracy.

Table 12. PC battery R&V table

2.7 Information Processing Subsystem

This is an independent subsystem. We plan to design the system to use Arduino to control the sensors and the speakers and put the system on the drone. While in the air, the drone can detect air quality through the sensor and transmit data to the ground. It can also emit a warning sound in the air.

2.7.1 ESP8266

For the type of the Arduino, we choose the ESP8266 because it can create its own wireless network, other devices can connect to that network and get data through that network. We plan to design the

Arduino to set the Wi-Fi and transmit the data through Wi-Fi and then we can use a computer or phone connected to this Wi-Fi to get the data.

Requirements	Verifications
1. The Arduino can create its own wireless network, and the phone or computer can connect to it.	A. Complete the code that create the Wi-Fi and set its IP address and password and then input the code some data to the Arduino. B. Connect the phone or computer to this Wi-Fi and test whether we can get the data.

Table 13. ESP8266 R&V table

2.7.2 BME280 air condition sensor

BME280 is an integrated temperature, humidity, air pressure, the trinity of environmental sensor.

Requirements	Verifications
1. The sensor can work properly (detect the air condition including temperature, humidity, air pressure).	A. Complete the code and input the code into the Arduino. B. According to the circuit below that we design, connect the sensor with Arduino. C. Record the data shown on the computer

Table 14. BME280 air condition sensor R&V table

Schematic

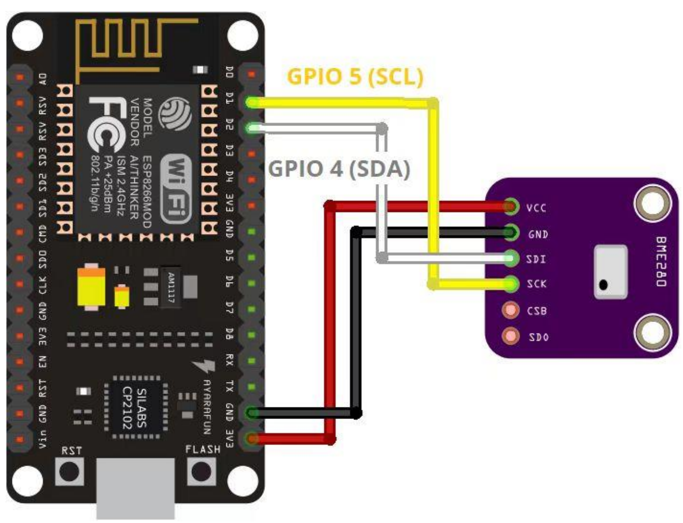

Fig 4. The sensor schematic

2.7.3 Loudspeaker

A simple speaker can be connected to the Arduino and used to play back sounds from the Arduino.

Requirements	Verifications
1. The speaker can work properly (emits sound normally).	A. Complete the code and input the code into the Arduino. B. Connect the speaker with Arduino. C. To see if the speaker can make the sound that we want the code to require.

Table 15. Loudspeaker R&V table

2.8 Tolerance Analysis

For the circuit of the Arduino

When we install it on the drone, we should have the power supply for the Arduino. For ESP8266, the input can be 3.3V and 5V. However, we just have a cell box that can contain 3 AA batteries which can supply 1.5V voltage. According to the pin rule, we cannot supply Arduino. Then after learning ESP8266, we find that the tolerance of voltage range of digital part is 1.8V ~ 3.3V and the operating voltage of the analog part is 3.0V ~ 3.6V, with the lowest 2.7V. We can use two AA batteries to supply Arduino.

Manufacturing of aircraft fuselage and control surfaces:

For the manufacturing of aircraft fuselage and control surfaces, we use numerically controlled (NC) machining equipment to ensure their precision and dimensional accuracy [2]. We measure the thickness of the fuselage and control surfaces with precise measurement tools to ensure thickness errors are within ±0.5 millimeters. We also pay attention to the symmetry of the fuselage, using precision measurement tools to detect any asymmetry and ensure it does not affect the stability of the aircraft [3].

To ensure the precision and dimensional accuracy of the fuselage and control surfaces, we need to pay attention to the following details during the manufacturing process:

1. The material selection needs to meet the design requirements [4].
2. Regular inspection of machining tools for wear and tear and timely replacement to avoid affecting machining precision [5].
3. Accurate calibration of the machine tools, including calibration of the coordinate axis and machine rigidity, to ensure machining precision [6].
4. For complex-shaped fuselage and control surfaces, multiple machining processes are required, such as milling, cutting, and stamping, to ensure their accuracy and dimensional accuracy [2].
5. In the manufacturing process, measures need to be taken to prevent deformation of the fuselage and control surfaces, such as fixing them with fixtures and making compensations during the machining process [2].

6. Regular inspection of the dimensions and thickness of the fuselage and control surfaces, as well as their symmetry, to ensure they meet the design requirements [3].

Numerical control equipment uses computer-aided manufacturing (CAM) technology to convert design drawings into machine language and control NC machine tools for processing. Common NC machine tools include CNC milling machines, CNC lathes, and CNC cutting machines, which can achieve the processing of complex curves and polyhedrons, as well as cutting and forming of different materials [2]. Precision measurement tools such as micrometers, vernier calipers, and height gauges are needed in the manufacturing process of the fuselage and control surfaces. In the manufacturing process, it is necessary to measure the dimensions and thickness of each component to ensure they meet the design requirements [5]. The thickness of the fuselage and control surfaces is an important parameter because their strength and weight are related to their thickness. We need to ensure that their thickness errors are within ±0.5 millimeters to ensure their performance and safety [3]. In addition, symmetry is also crucial for the fuselage. Asymmetry can cause unstable flight and affect the performance and safety of the aircraft. Therefore, we need to use precision measurement tools to detect any asymmetry of the fuselage and ensure it does not affect the stability of the aircraft [3].

Possible equations that may be used are:

Thickness formula for the fuselage and control surfaces:

$$t = \frac{m}{V}$$

where t represents thickness, m represents mass, and V represents volume [6].

Symmetry error formula:

$$e = \frac{(L1 - L2)}{L}$$

where e represents symmetry error, L1 represents the length of the left side of the fuselage, L2 represents the length of the right side of the fuselage, and L represents the total length of the fuselage [5].

Electric motors and electronic speed controllers (ESC):

For electric motors and electronic speed controllers (ESC), we use high-precision testing equipment to measure their rotational speed and current stability tolerance [7]. We have established strict tolerance standards, where the speed error of the motor should be within ±5%, and the current stability tolerance of the ESC should be within ±10%. During the manufacturing process, we use precision machining equipment and processes to control the tolerance of the motor and ESC, ensuring their performance meets design requirements.

To ensure the precision and performance of electric motors and ESCs, we need to pay attention to the following details during the manufacturing and testing processes:

1. Material selection: The motor and ESC should be made of high-quality materials that meet the design requirements, with high strength, good thermal conductivity, and low resistance [10].

2. Precision machining: The motor and ESC should be processed with high-precision equipment, such as CNC machines, to control their dimensions and tolerance [10].
3. Testing equipment: High-precision testing equipment, such as tachometers and ammeters, should be used to measure the rotational speed and current stability tolerance of the motor and ESC [8].
4. Tolerance control: Strict tolerance standards should be established for the motor and ESC, and the manufacturing and testing processes should be controlled accordingly [9].
5. Thermal management: Proper thermal management should be implemented to prevent overheating of the motor and ESC, which could lead to performance degradation or failure [7].

Possible equations that may be used are:

Motor speed formula:

$$\omega = 2\pi f$$

where ω represents the rotational speed of the motor, and f represents the frequency of the motor [6].

ESC current formula:

$$I = \frac{V}{R}$$

where I represents the current flowing through the ESC, V represents the voltage supplied to the ESC, and R represents the resistance of the ESC [7].

In summary, the use of high-precision testing equipment and strict tolerance standards, along with precision machining and thermal management, are crucial for ensuring the performance and reliability of electric motors and ESCs in aircraft systems.

3 Cost and Schedule

3.1 Cost Analysis

Our fixed development costs are estimated to be 30¥/hour, 20 hours/week, in total 10 weeks for four people.

$$4 \times \frac{30¥}{hour} \times \frac{10hours}{week} \times 10weeks \times 2.5 = 30000¥$$

Our parts and manufacturing prototype costs are estimated as flows:

Description	Quantity	Manufacturer	Vendor	Cost/unit (RNB)	Total cost (RMB)

Remote Controller	1	Wenzhou Yifeng Store	Taobao	138	138
Motors	1	Wenzhou Yifeng Store	Taobao	95	95
Electronics Speed Controller	1	Wenzhou Yifeng Store	Taobao	45	45
Propellers	1	Wenzhou Yifeng Store	Taobao	14	14
Servos	4	Wenzhou Yifeng Store	Taobao	25	100
Flight Controller	1	Wenzhou Yifeng Store	Taobao	75	75
Battery	1	Wenzhou Yifeng Store	Taobao	135	135
Charge	1	Wenzhou Yifeng Store	Taobao	108	108
Frame	1	Wenzhou Yifeng Store	Taobao	399	399
ESP8266	1	DFRobot Store	Taobao	89	89
BME280	1	DFRobot Store	Taobao	39	39
Total					1237

Table 16. Cost

The grand total is,

1237(parts)+30000(Labor)=31237¥ (Total)

However, when we design the sensor connected to the circuit, we should use the bread board and some wires, which are not estimated in our total cost. Also, For the parts that will be 3D printed, our drone, the cost not only includes the material cost, but also includes the electric cost for 3D printers because the process is time-consuming.

3.2 Schedule

03/20/23	Complete the design document	All

	Complete the assembling of the prototype and try to have a flight test.	Zhibo Teng
	Design the circuit to test whether the motor and servos can work properly.	Ziyang An
	Complete the connection of the data transmission module and test whether the data transmission signal can work properly.	Zhanhao He
	Complete the assembling of the prototype and try to have a flight test.	Yihui Li
03/27/23		All
	Start to design our own done model by CAD software.	Zhibo Teng
	Complete to test whether the motor and servos can work properly installed on the drone and design the circuit of the Arduino and BME280 sensor.	Ziyang An
	Set the automatic flight of the aircraft through the ground station software	Zhanhao He
	Start to design our own done model by CAD software.	Yihui Li
04/03/23		All
	Use Fusion 360 to simulate our own model and improve it	Zhibo Teng
	Help to complete the flight control system.	Ziyang An
	Adjust parameters, set aircraft autopilot, and conduct simulated flight tests	Zhanhao He
	Continue to complete the improve the CAD design.	Yihui Li
		All

04/10/23	Manufacture and assemble our designed drone prototype.	Zhibo Teng
	Complete the circuit of the Arduino and the BME280 sensor.	Ziyang An
	Complete the circuit design of the speaker based on Arduino	Zhanhao He
	Manufacture and assemble our designed drone prototype.	Yihui Li
04/17/23		All
	Based about our prototype, improve the CAD design and simulation.	Zhibo Teng
	Complete the code of the Arduino and input the code to the Arduino.	Ziyang An
	Complete the speaker code section	Zhanhao He
	Based on the situation of our prototype, improve the CAD design.	Yihui Li
04/24/23		All
	Improve the design and simulation.	Zhibo Teng
	Test whether the circuit can work properly (detect the air condition and transmit the data via Wi-Fi).	Ziyang An
	Integrate the entire drone and test	Zhanhao He
	Improve the design and debug.	Yihui Li
05/01/23	Flight test and start final report.	All

05/15/23	Final testing and debugging. Finish final report.	All
05/22/23	Functionality Demonstration.	All

Table 17. Schedule

4. Ethics and Safety

4.1 Ethics

4.1.1 Privacy

As we collect and process environmental data in remote areas, we must ensure that the data is collected and stored in a secure manner to protect the privacy of individuals and sensitive information. This ethical issue is particularly relevant to the ACM Code of Ethics [11], Section 3.7, To avoid ethical breaches related to data privacy, we will adhere to relevant data privacy regulations such as the General Data Protection Regulation (GDPR) [12]. We will also implement secure data storage practices such as encryption and access controls.

4.1.2 Autonomy and Responsibility

Autonomy and Responsibility: The use of autonomous drones raises questions about responsibility and accountability in the event of accidents or other incidents. The ACM Code of Ethics [11] emphasizes the importance of ensuring that autonomous systems are designed and used in ways that are consistent with ethical principles and that prioritize human welfare.

4.1.3 Environmental Impact

Environmental Impact: Our project involves the use of drone to collect environmental data. We must ensure that our project does not harm the environment and follows relevant environmental regulations such as the Clean Air Act [12] and the Clean Water Act [14]. This ethical issue is particularly relevant to the IEEE Code of Ethics, Section 7, [15] To avoid ethical breaches related to environmental impact, we will conduct our operations in compliance with relevant environmental regulations and implement best practices for environmental sustainability.

To avoid ethical breaches, it is important to follow best practices in the design and deployment of the drone, including conducting rigorous testing and ensuring that the system is transparent and accountable. It is also important to involve stakeholders, such as members of the public and regulatory agencies, in the design and deployment process to ensure that concerns are addressed proactively.

4.2 Safety

4.2.1 Electrical safety

Electrical safety is a major concern as the drone will be battery-powered and may carry sensitive electronic components. The use of high-voltage batteries and charging systems may pose a danger of electric shock or fire. It is important to use batteries that meet the voltage and current requirements of the drone. Batteries should be stored and charged in a fireproof container or area, away from flammable substances and liquids. To minimize the risk of electrocution, it is important to follow relevant safety standards and guidelines for battery selection, charging, and handling, such as those provided by the U.S National Committee (USNC) [16] of the International Electrotechnical Commission (IEC), National Electric Code (NEC) [17] , and the Occupational Safety and Health Administration (OSHA) [18] guidelines. It is also important to ensure that all lines and connections are properly insulated and grounded. A battery management system should be used to prevent overcharging or short circuits.

4.2.2 Mechanical safety

Mechanical safety is another important consideration, especially since the drone will be flying at high altitudes and may encounter adverse weather conditions. To minimize the risk of a crash or collision, we will need to implement safety features such as obstacle avoidance sensors and emergency landing systems. We will use durable materials and designs that can withstand harsh environmental conditions and resist damage caused by impacts or collisions. Refer to the MECHANICAL SYSTEMS QUALIFICATION STANDARD [19] by the U.S. Department of Energy for regular inspection and maintenance of all mechanical components and systems to ensure they are in good working condition. We also need to ensure that the drone is properly balanced and stable during flight. The Federal Aviation Administration (FAA) [20] and the Occupational Safety and Health Administration (OSHA) [18] have strict regulations governing the operation of drones, including requirements for registration, certification, and flight restrictions. It is important to ensure that the drone complies with all relevant FAA regulations [20].

4.2.3 Laboratory safety

Laboratory safety is another important consideration as the project will involve hazardous materials and equipment such as batteries, electrical components, chemicals, and tools. We need to follow relevant safety guidelines and protocols for handling these materials and equipment, including proper storage, labeling, and disposal of hazardous waste. We also need regular safety inspections and training to ensure that all team members are aware of potential hazards and equipped with the necessary safety equipment and knowledge to work safely in the laboratory. Our project may involve the use of chemicals for testing and research purposes, which could pose a risk of chemical exposure. To ensure chemical safety, our team should follow relevant safety standards such as the Occupational Safety and Health Administration (OSHA) [18].

Our project involves hazardous or volatile elements, and it is important to create a "Laboratory Safety Manual" to ensure that all team members are aware of potential risks and follow appropriate safety procedures. Here are some steps we can take to create a lab safety manual:

1. Identifying Hazards: First, we need to identify all potential hazards associated with our project. This may include toxic chemicals, flammable materials, or electrical hazards.

2. Assess the risks: Once we have identified the hazards, we need to assess the risks associated with each hazard. This includes assessing the likelihood and severity of potential incidents and identifying appropriate safety procedures to mitigate these risks.

3. Develop safety procedures: Based on our hazard and risk assessment, we need to develop detailed safety procedures for each hazard. These procedures should include step-by-step instructions for handling hazardous materials, operating equipment, and responding to emergencies.

4. Train team members: It is important to ensure that all team members are trained in the Laboratory Safety Manual and understand the procedures for handling hazardous materials and equipment. This may include providing hands-on training, conducting security walkthroughs, and incorporating security protocols into our regular project meetings.

5. Periodically review and update the Manual: Finally, we need to periodically review and update the Laboratory Safety Manual to ensure that it remains current and effective. This may include incorporating feedback from team members, conducting regular hazard assessments, and updating procedures as new hazards or risks are identified.

Creating a laboratory safety manual is an important step in ensuring that our project is conducted safely and responsibly. By taking the time to identify potential hazards, assess risks, and develop appropriate safety procedures, we can reduce risks and minimize the likelihood of accidents or injuries.

It is essential to consider our own and end-user safety. We must ensure that drones are safe for our team to operate and maintain and that they do not pose any risk to nearby people or property. To achieve this goal, we need to conduct thorough safety testing and implement fail-safe mechanisms to prevent accidents or failures. We should provide clear and concise instructions for the safe use and maintenance of drones, including appropriate warning signs and labels. We should also provide training and support to end users to ensure they are properly equipped to safely operate and maintain drones. If necessary, we will develop a safety plan outlining procedures for handling emergencies, such as collisions or equipment failures. The safety plan will also outline maintenance and inspection protocols to ensure that drones remain in good working order.

In summary, safety issues related to electrical, mechanical, and laboratory safety must be addressed during the development and testing of autonomous drones for environmental exploration. We must prioritize our own and end-user safety by taking appropriate safety measures, conducting thorough testing and inspections, and providing clear instructions, training, and support for the safe use and maintenance of drones.

To mitigate potential safety concerns, it is important to conduct thorough testing and risk assessments, and to implement appropriate safety features and procedures in the design and operation of the drone. It is also important to adhere to all relevant regulatory requirements and to seek guidance from regulatory agencies as needed.

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