Design of a semi-automatic fire extinguishing drone

By

Prithwiraj Chakraborty 2020-1-80-050

Sakib Hassan Mitul 2020-1-80-092

Fahim Munshi 2020-1-80-095

Nayem Ahmed 2019-3-80-030

Submitted to the Department of Electrical and Electronic Engineering, East West University as requirements of the Final Year Design Project (EEE400)

Spring, 2024 (write semester of EEE400(i))

Approved by

Thesis Advisor	Department Chairperson
Dr. Mohammad Mojammel Al Hakim	Dr. Mohammad Ryyan Khan

Dedication

(Optional)

ACKNOWLEDGMENTS

AUTHORIZATION

We hereby declare that we are the sole authors of this report. We authorize East West University to lend this report to other institutions for the purpose of scholarly activities. We further authorize East West University to reproduce this report by photocopy or other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly activities once the embargo set by the supervisor is lifted.

Prithwiraj Chakraborty	Sakib Hassan Mitul
Fahim Munshi	Nayem Ahmed

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

EXECUTIVE SUMMARY

The project's topic is "Design of a semi-automatic fire extinguishing drone". Here we discuss the whole process and other related things with that project. First we are talking about the motivations and reasons behind the project. We also discuss 6 papers based on our topic. We take ideas from these reports. Here, we discuss the project managements and all gantt charts and CPM. Stakeholders requirements and their demands are also included in the report. In Part 1, we also discuss the health and safety issues on environmental issues related to the drone.

PART-I

This part contains the concept, proposal and the functional design as prepared on EEE400-I.

Chapter 1 Project Concept and Functional Design

1.1 Project Introduction

The topic of "Design of a semi-automatic fire extinguishing drone" is our capstone project. The primary goal of the project is to create a semi-automated firefighting drone that can be operated automatically. Here, we quickly go over the goal, inspiration, and uses of our project.

The target of the project: Our project aims to protect society from fire hazards, which are particularly challenging in our densely populated country. We have developed an efficient tool for fire extinguishing: a semi-automatic drone that supports firefighters, reduces fire damage, and saves lives. This drone is intended for use in open spaces such as Banga Bazar Market, New Market, and Karwan Bazar. Primarily used by the defense sector, the drone serves as a first response tool, helping control fires before emergency teams arrive, thus making fire management more effective for authorities and firefighters.

The Motivation behind the project: Between 1996 and 2018, Bangladesh experienced 253,048 fire incidents, resulting in property losses totaling Tk 64.23 billion. In 1996, the property loss was approximately Tk 633.9 million, but by 2022, it had risen sharply to Tk 3.42 billion. According to data from the Bangladesh Fire Service and Civil Defense (FSCD) headquarters, 27,624 fire incidents occurred nationwide in 2023 alone, leading to the deaths of 102 people and causing burn injuries to 281 others. One incident in particular profoundly affected us, occurring just before the 2024 election, when a train coming from India to Bangladesh with a majority of Bangladeshi and some Indians,caught fire. The tragic event resulted in significant loss of life and disturbing images and videos that left a lasting impact on us. We initiated the project to address the extensive damage and loss of life and property caused by fire hazards every year. Our semi-automatic fire extinguishing drone is designed to be an effective and valuable tool for firefighters, aiming to reduce the impact of such disasters. While it may not be able to prevent all losses or ensure complete accuracy, it is a significant step towards minimizing the devastation caused by fires, which is urgently needed in our country.

Applications: Our drone offers several practical applications to help protect against fire hazards:

i. Open Spaces: The drone is highly effective in open areas such as markets and convention halls. It is particularly useful in places like Banga Bazar and Karwan Bazar, where many open markets are located. The drone can be a valuable asset in these settings.

ii. Remote Operation: The drone can be controlled remotely, allowing it to fly and extinguish fires from a safe distance. This remote capability enhances the safety and efficiency of firefighting efforts.

iii. Thermal Imaging: Equipped with a thermal imaging system, the drone uses microcontrollers to detect smoke and hot spots. This technology helps identify the source of the fire and enables the drone to navigate safely during a fire incident.

iv. Fireball Deployment: The drone can deploy fireballs containing chemical agents to extinguish fires effectively. This method helps to control and suppress fires quickly.

v. Durable Construction: Made with a carbon fiber body and other protective materials, the drone is designed to withstand high temperatures and remain operational during fire emergencies.

These are the primary applications of our fire extinguishing drone. Additional applications and features are discussed in other parts of the report.

1.2 Literature review

Innovative firefighting technologies are essential for improving safety and efficiency, especially in hard-to-reach areas. Drones equipped with fire extinguishing mechanisms provide rapid response and access to difficult locations. Before detailing our design, we review the existing literature to understand current advancements and areas for improvement.

The report “Design and Implementation of Fire Extinguishing Ball Thrower Quadcopter” introduces a quadcopter that deploys fire-extinguishing balls to tackle fires in hard-to-reach places like skyscrapers. It details the development of a quadrotor framework for precise navigation and a specialized ball thrower mechanism. The system uses efficient brushless DC motors and propellers for stability and thrust, with fire-extinguishing balls designed to release agents upon impact. Control systems ensure stability and accurate navigation, with integrated mechanisms for precise ball deployment. Testing evaluates stability, accuracy, response, ball speed, and impact force under various conditions. Simulated fire scenarios assess effectiveness, with data on fire suppression, response times, and reliability. The paper reports successful controlled tests but notes limitations such as extreme weather challenges and the need for more field testing. Future enhancements include integrating AI for better navigation and researching more effective, eco-friendly extinguishing agents.[1].

The paper “Development of an IoT-Based Firefighting Drone for Enhanced Safety and Efficiency in Fire Suppression” by Jahan et al. enhances firefighting technology with a sensor-equipped, IoT-enabled drone. Building on studies like Abro et al. (2021), it incorporates gas sensors for comprehensive environmental monitoring. Key components include three microcontrollers: Pixhawk PX4 for central control, Arduino Nano R3 for sensor interfacing, and NodeMCU ESP8266 for data processing and communication. The drone features flame detectors, MQ series gas sensors (MQ3, MQ4, MQ9, MQ135), GPS modules, brushless motors, and an FPV camera for real-time monitoring. Software tools like Mission Planner and Arduino IDE are used for configuration and calibration. The control system employs a fuzzy-based backstepping control (FBSC) technique for stability and precision. The system detects fires through NodeMCU processing, uses a mission planner for real-time monitoring, and deploys fire-extinguishing balls via servo motor-controlled dispensers. Despite successes in real-time data processing and sensor integration, it faces limitations in communication stability and scalability. This study presents a comprehensive, IoT-based solution that enhances firefighting efficiency and safety.[2].

The paper "Cloud Enabled Smart Firefighting Drone Using Internet of Things" by N. Jayapandian presents an innovative approach to tackling high-rise fires using UAVs integrated with IoT technology. The methodology involves installing IoT-enabled sensors throughout skyscrapers to detect fires and send alerts to a central command unit via the cloud. The Fire Control Unit (FCU) monitors real-time data, including video and fire scans, and uses GPS to pinpoint the fire's location, coordinating with security agencies to deploy pre-loaded UAVs. These quadcopters, equipped with fire suppressants, cameras, thermal sensors, and collision detection systems, autonomously navigate to the fire site using a path planning algorithm. They release fire extinguishing balls containing non-toxic Mono Ammonium Phosphate upon reaching the fire, then return for reloading if necessary. The system enhances firefighting quality of service by ensuring rapid, accurate responses, reducing risks to human firefighters, and minimizing property damage. Advanced features like collision avoidance, real-time data processing, and compliance with safety protocols further improve operational efficiency and safety, making this a promising solution for modern firefighting challenges.[3]

The paper "Prototype of a Functioning Urban Firefighting Drone" by Adib Ahnaf and Faisal Hossain details the creation and evaluation of an octocopter designed to combat fires in high-rise buildings and urban environments. This UAV features eight brushless DC motors and lightweight custom aluminum frames, stabilized by a 6-axis gyro, barometer, and accelerometer. It's equipped with temperature, gas, humidity, infrared, UV, and barometric pressure sensors for real-time data collection, as well as a thermal camera for video capture. Powered by a LiPo battery for up to 55 minutes of flight, it employs a tethering method to extend flight time. The GPS-guided autonomous flight reduces manual control needs, and the ground station, using a 12V lead-acid battery, houses a radio transmitter, analog video receiver, and telemetry system, ensuring robust monitoring and control. The drone's firefighting mechanisms include a water hose for large fires and a ball-throwing system for lightweight fire extinguishing balls, both controlled via a servo motor. Obstacle avoidance is managed by six ultrasonic sensors linked to an Arduino microcontroller, enabling safe navigation around urban obstructions. This prototype offers a cost-effective and efficient solution for firefighting in congested urban areas, addressing the challenges where traditional methods fall short.[4].

The paper titled "Fire-fighting UAV with Shooting Mechanism of Fire Extinguishing Balls" details the development and testing of a specialized drone designed for firefighting. The methodology involves several critical components: First, the conceptual framework outlines the input-process-output system, where the UAVs flight is controlled and monitored via a user interface using a radio frequency transmitter. The UAV is designed as an octocopter, featuring eight rotating arms, with propellers rotating in opposite directions to ensure stability. A unique servo mechanism integrated into the arm rotor controls the UAVs movement, allowing precise directional control. The drone is equipped with a gyroscope and a GPS module to stabilize flight and provide accurate navigation, even compensating for potential GPS glitches. Additionally, the UAV can carry a payload of up to five kilograms, including fire extinguisher balls, and has a flight range of up to one kilometer. The gyroscope ensures aerial stability by measuring rotations around the x, y, and z axes, while the barometric pressure sensor provides altitude data. Real-time video streaming to the controller's LCD allows for monitoring, and the system can automatically stabilize the drone if the remote-control signal is lost. This comprehensive approach integrates multiple technologies to create an effective firefighting tool capable of operating autonomously or under direct control, providing a versatile solution for high-rise fire incidents.[5].

The paper titled “Design and Implementation of an IOT based fire and survivor detection drone” by three undergraduate students from AIUB outlines a project focused on using IoT technology in a drone system to provide firefighters with crucial information via cameras and sensors. This information helps them assess situations like checking for trapped individuals or identifying combustible materials near a fire, as well as detecting harmful gasses. The project includes a block diagram and working principle covering aspects such as control systems, power systems, HMI, safety engineering, tools and software used, and environmental engineering. The hardware components include an Arduino Uno microcontroller, flame sensor, smoke sensor (MQ2), temperature sensor, GPS sensor, ESP32-CAM, and GSM Arduino shield. Proteus 8.13 software is utilized for designing and simulating electronic circuits. The drone's construction involves lightweight plastic and metal materials and includes various components like the Arduino Uno microcontroller, GSM module, servo motors for drone control, and ESP32 camera. Communication with the user occurs wirelessly via the internet through an app, enabling remote access and control. Sensors send data to the Arduino for monitoring the environment and detecting fire presence. The GSM module sends fire alerts through messaging and the Blynk app and server.

For IoT implementation, esp8266 ES-01 is used instead of the GSM module due to its performance and ease of implementation. Two separate Arduinos are utilized—one as a flight controller and another for sensor data capture, IoT implementation, and live streaming. Live streaming is achieved using the ESP32-CAM, controlled and powered by Arduino. Drone control is facilitated through the FlySky iA6 transmitter.[6].

1.3 Standards and codes of practices

There are such standards and codes of practices in our country to fly a drone. There are no such rules in our country to fly or use fire extinguishing drones. Because there was no such project functioning in our country. That is why there are no specific codes and standards for "Fire Extinguishing Drone."

Here we describe the standards and codes of the normal drones:

a. Fire-resistant construction: The Code mandates that all buildings must be constructed with fire-resistant materials that can withstand the spread of fire.
b. Fire detection and alarm systems: The Code requires that buildings be equipped with fire detection and alarm systems that can detect smoke, heat, and fire and alert occupants in case of a fire.
c. Means of escape: The Code requires buildings to have multiple means of escape, such as staircases, corridors, and exits, to enable occupants to evacuate quickly in case of a fire.
d. Smoke management systems: The Code requires buildings to have smoke management systems such as smoke vents, exhaust fans, and pressurization systems to control the spread of smoke in case of a fire and

e. Fire drills and training: The Code mandates that building owners and occupants must conduct regular fire drills and training sessions to ensure that everyone is prepared to evacuate safely in case of a fire.

Standard and Codes for Fire extinguishing process in Bangladesh:

a. In Bangladesh, firefighting operations are guided by various standards and codes to ensure safety for both firefighters and the public.

b. The Bangladesh National Building Code (BNBC) outlines fire safety measures for building construction, including materials, escape routes, and firefighting equipment.

c. The Fire Service Act defines the responsibilities of the Bangladesh Fire Service and Civil Defence (FSCD), covering firefighting, rescue operations, fire prevention, and firefighter training.

d. While not mandatory, the National Fire Protection Association (NFPA) codes, such as NFPA 10, NFPA 13, and NFPA 101, are widely used for fire safety practices in Bangladesh.

e. Occupational Safety and Health Administration (OSHA) standards are also relevant, particularly concerning workplace safety, training, and personal protective equipment (PPE) for firefighters.

f. Although not officially adopted, the International Fire Code (IFC) influences firefighting practices, especially in buildings with international connections.

g. Additionally, there are government regulations on hazardous materials, industrial sites, and public safety that impact firefighting operations in Bangladesh.

h. Comprehensive training and adherence to these standards and codes are essential for Bangladeshi firefighters to effectively respond to fires, safeguard lives, and minimize property damage.

1.4 Stakeholders' expectations/requirements

Anyone with a personal stake in the outcome of an organization's decisions or actions is considered a stakeholder. Three categories of interested parties have been defined.

1. Bangladesh fire service and civil defense.
2. Residential building owner
3. Defense force.

We took a total of 27 responses. 11 responses are from our stakeholders and others are common people. Our stakeholders give their responses and suggestions about the fire extinguishing drone. They suggest what to add and not to add. They also give their suggestions about their requirements and wants from that project.

Fires can result in various disasters and consequences, depending on factors like their size, location, and the presence of flammable or hazardous materials. We found that fires cause injuries such as burns, smoke inhalation, physical harm from building collapses, and injuries during escape attempts. Exposure to smoke, toxic gasses, and harmful substances emitted during fires can also lead to long-term health issues. Additionally, fires have significant environmental impacts, particularly in habitats like forests, grasslands, and wetlands. There are several ways to combat fires, and after talking to firefighters, we discovered that many struggle with handling large fires and would appreciate a device to assist in extinguishing them.

Requirements:

Stakeholders involved in using fire extinguisher drones have diverse requirements influenced by their roles and goals. Here are common criteria stakeholders want in fire extinguisher drones:

Safety and Reliability:

Stakeholders expect fire extinguisher drones to be reliable and include safety features to function effectively in different environments and fire scenarios. They should have robust construction, multiple safety measures, and fail-safe systems to minimize accidents or malfunctions.

Battery Backup:

Stakeholders require a decent battery backup for the device. The majority of stakeholders want at least 45-50 minutes of battery backup.

Versatility and Adaptability:

Fire extinguisher drones should be versatile and adaptable, allowing them to combat various types of fires, navigate different terrains, and respond to diverse emergency situations.

Proper Range:

Firefighting agencies and responders need drones with ample range, endurance, and flying capabilities to access remote or challenging locations, monitor fire progression, and efficiently dispense extinguishing chemicals.

Payload Capacity:

Stakeholders expect fire extinguisher drones to have sufficient payload capacity to transport necessary extinguishing chemicals with accuracy and precision.

Cost-effectiveness:

Government agencies, firefighting organizations, and private firms seek cost-effective fire extinguisher drones that provide solutions for fire suppression and emergency response. Drones should offer a positive return on investment by reducing property damage, mitigating risks to workers, and improving operational efficiency.

Manufacturers, developers, and operators of fire extinguisher drones can meet these needs and contribute to effective firefighting and emergency response efforts by addressing these requirements and collaborating closely with stakeholders.

1.5 Project requirements and functional design

1.5.1 Project requirements

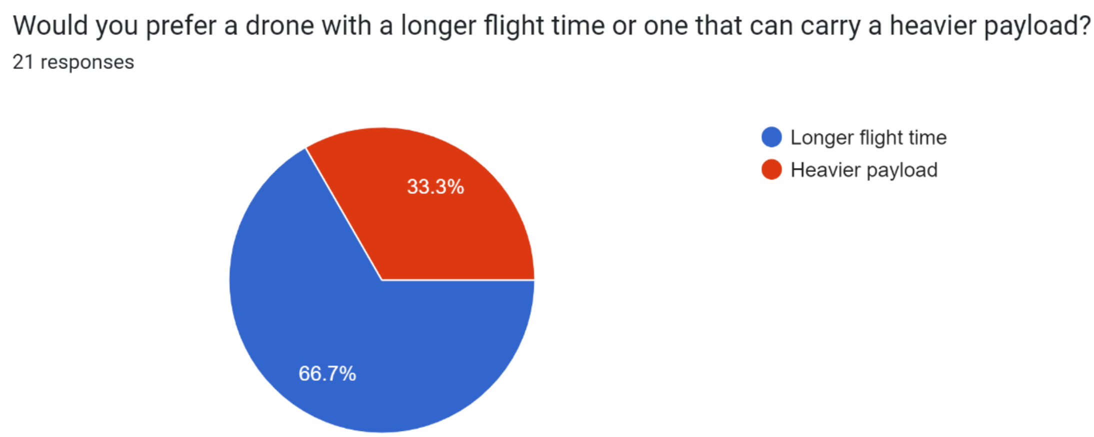
The semi-automatic fire extinguishing drone' is a wide range project where we take our three stakeholders' suggestions. We do a survey on our stakeholders. We have three stakeholders.

1. Bangladesh fire service and civil defense.
2. Residential building owner
3. Defense force.

Basically, we take suggestions and their requirements in the project. We make a functional design. We also design our project requirements including technical requirements.

1. Initial Takeoff: The drone has a radio receiver, and it is a semi-automated drone. So, stakeholders' main requirement is its Initial takeoff. It is also the most important thing. We make our drone so fluent that its initial takeoff will be so easy and fast.

2. Fly time: It's also a very important requirement. The drone's operation is to extinguish fire, but the main concern is its flying time capacity. We take surveys to answer. 66.7% of our stakeholders want a long-time flying capability in our drone.

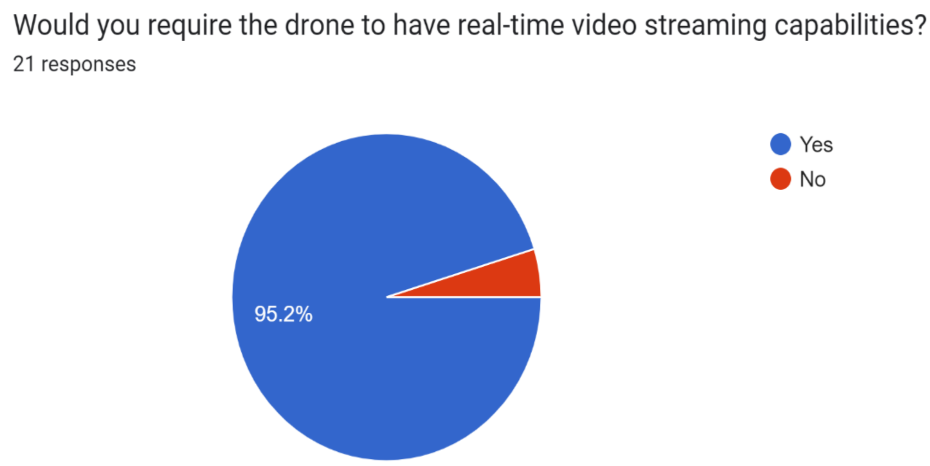


In literature review, we discuss the whole flying system. Here we use the Microcontroller ATmega2560 in the flying module.

3. Same distance from fire: The drone is a high price product. So, stakeholder's another concern about its safety from fire. It is used in fire accidents, so it has a chance of being destroyed by fire. In the frame, we use aluminum tube and carbon tube. It saves the drone from fire. We also use thermal sensors. It is also a semi-automatic drone. So, all these qualities keep the drone a safe distance from the drone.

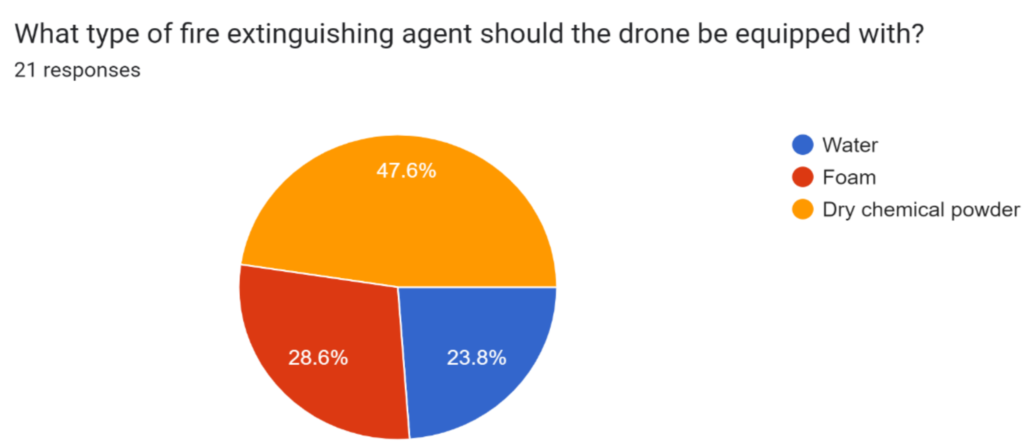
4. Capable of throwing extinguishing agent: Stakeholder's other question is, is the drone capable of throwing extinguishing agent from a good distance? Previously, we discussed its flying module and frame. So, we say that, yes, our drone is 100% capable of throwing fireballs in fire from a good distance.

5. Fire detection: Our drone has a thermal sensor, which can detect fire. Also our 95.2% stakeholders demand a real time video streaming capability.



All these functions to detect fire are when the drone is takeoff and near the fire location. When the drone is off and so far from the fire accident location, it cannot detect fire, automatically.

6. Fire extinguishing agent: Our main plan in the project is to set a fire ball to extinguish fire. We use dry chemical elements in our fireballs. Our major Stakeholders also want dry chemical elements to extinguish fire.



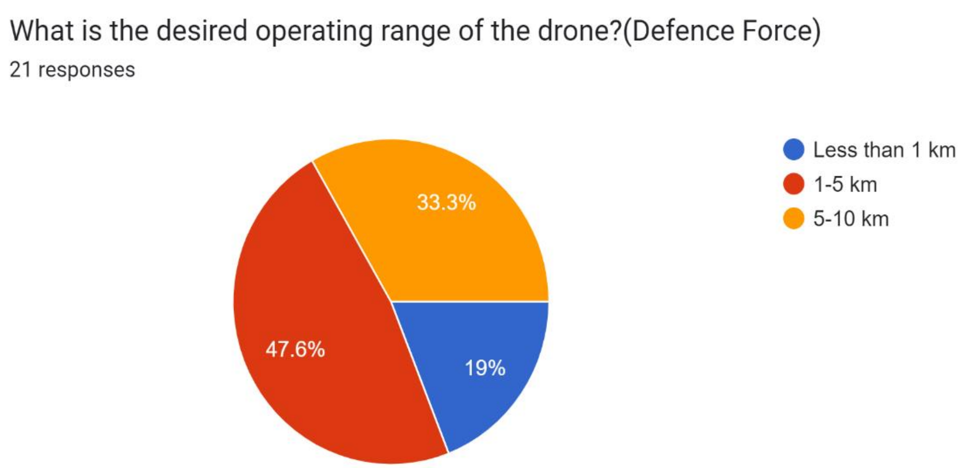
7. Return to user: We use great technology for our drone's take off and landing system. It's a valuable property. So, it is obvious that stakeholders feel concern about its landing system and return to its user. We use a remote control system in our drone. We also make our drone capable of a good range to control. We took a survey about the range of the drone to fly and control.

What will be the range?(Feet)

7 responses

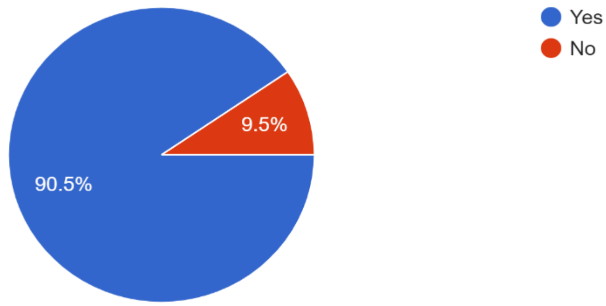
- 10
- 20-30 Feet
- 400 feet
- 800+ feet
- 1000feet
- 100 feet
- 200

Our stakeholders demand different kinds of range for the drone. Because it's a fire extinguishing drone, we need a good range for our drone. 100 or 200 feet will be the best range to make the drone capable.



8. Able to operate in extreme weather: Another requirement of stakeholders is to make the drone capable of control in extreme weather. Majority of the stakeholders want the drone to be capable of controlling extreme weather. So, our project or drone is to save lives and property and to use in hazardous times, so their requirement is clearly justified.

Is there a requirement for the drone to be able to operate in extreme weather conditions, such as high winds or heavy precipitation?
21 responses



1.5.2 Functional design

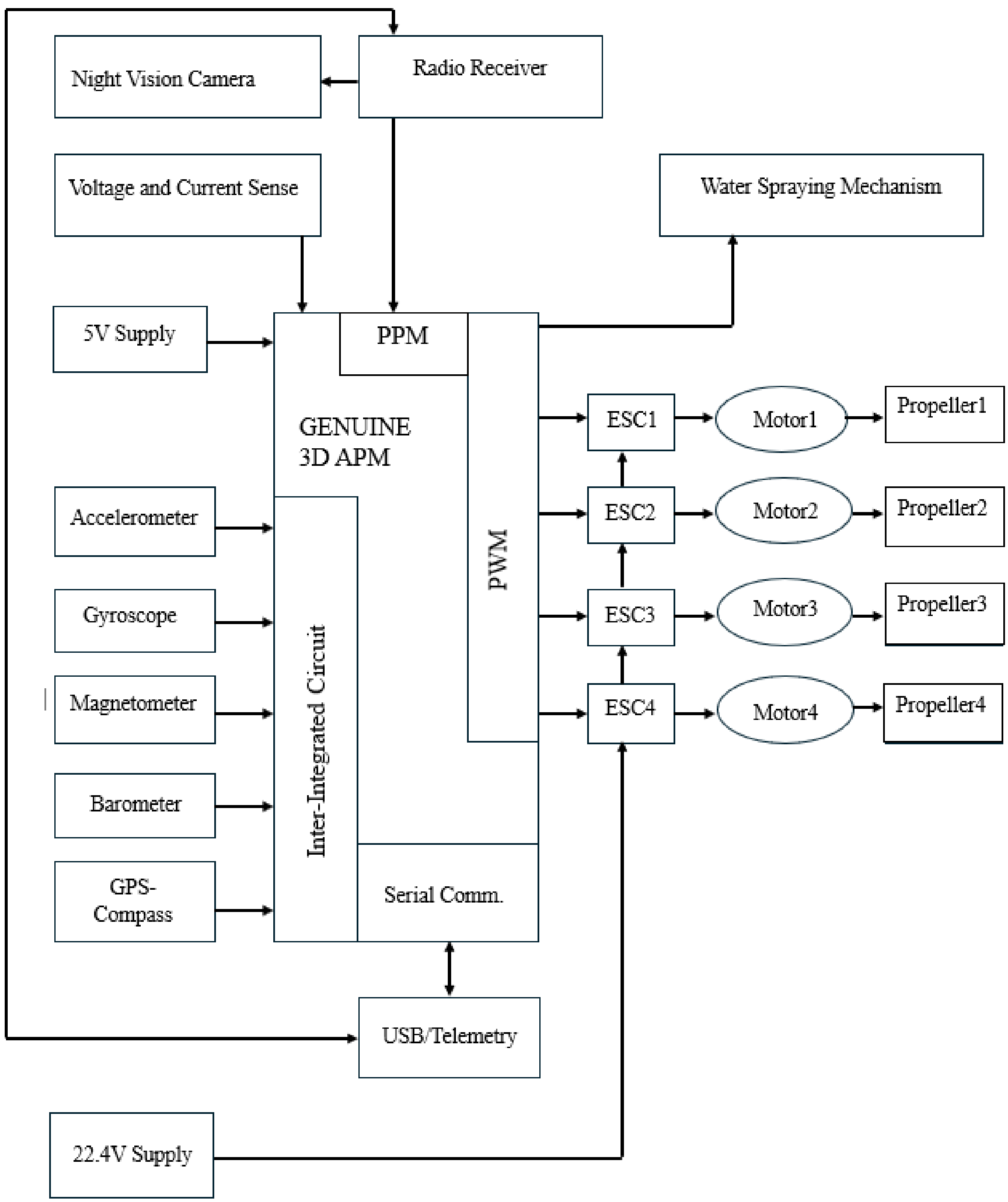


Fig1.5.2.1 Block diagram of the Functional design

This block diagram shows how our drone operates. We used an APM flight controller powered by a 5V supply. Various sensors are connected to ensure the drone flies as smoothly and stably as possible. The accelerometer and gyroscope help keep the drone level, while the magnetometer maintains a steady direction. To hold altitude, we use a barometer since barometric pressure changes with height. The GPS tracks the drone's position, providing latitude, longitude, and altitude data.

Being a quadcopter, the drone has four motors, each controlled by an electronic speed controller (ESC) that receives pulse-width modulation (PWM) signals from the flight controller. A radio receiver operates on 2.4GHz to receive signals from the ground station and transmits PPM signals to the flight controller. The drone is also equipped with a night vision camera and a water-spraying mechanism, allowing the user to control it manually from the ground.

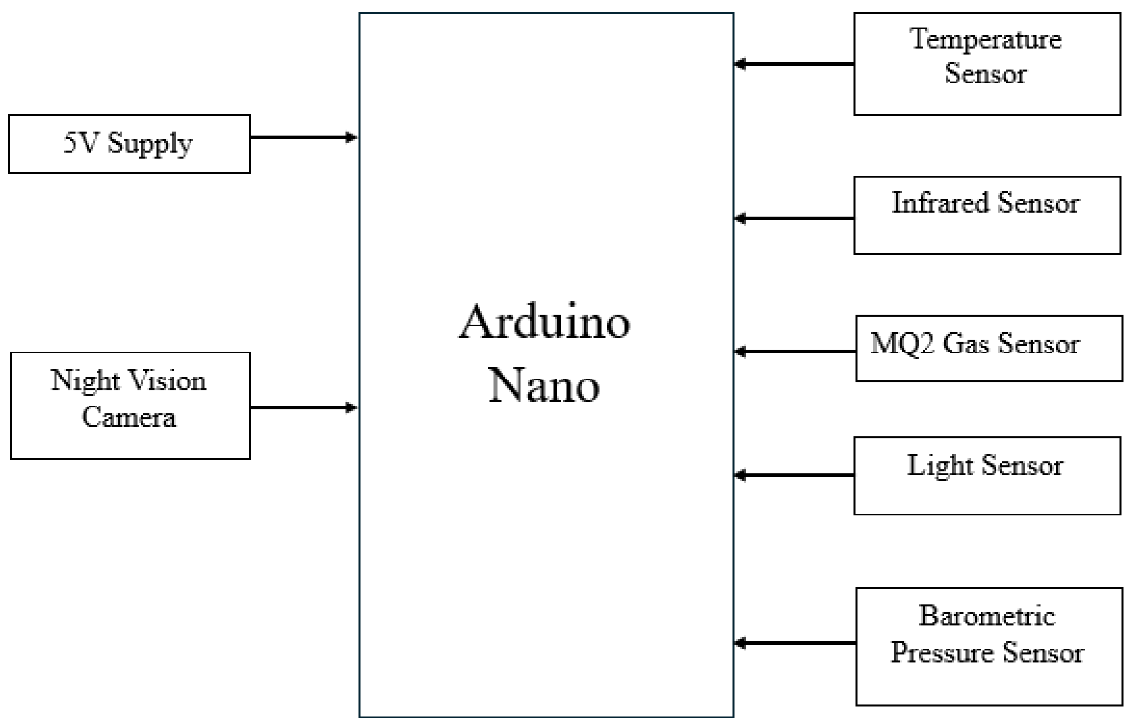


Fig1.5.2.2 Block diagram of the environment sensing circuit

This block uses an Arduino Nano with various sensors connected to it to monitor the environment. A night vision camera is also included for basic image processing. All the collected data is sent to the ground station.

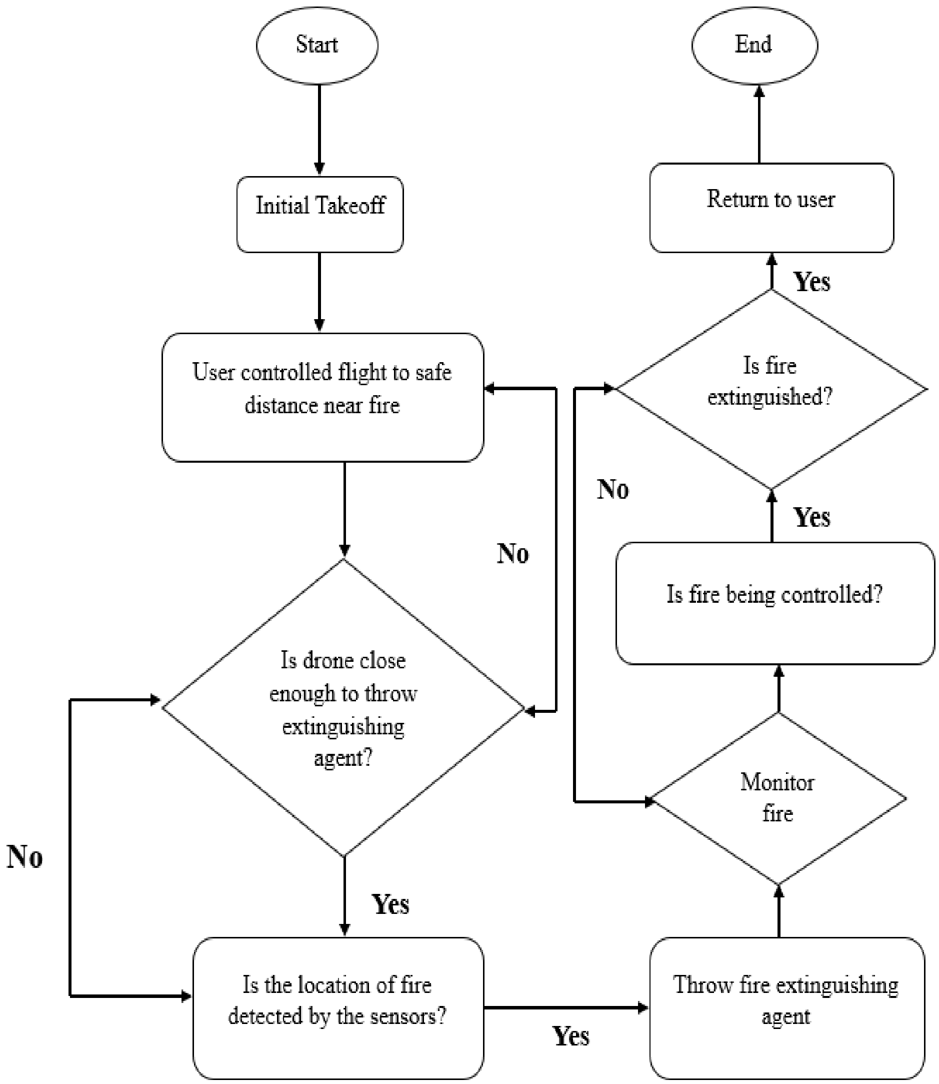


Fig 1.5.2.3: Flow chart of the functional design

1.6 Project Management

1.6.1 Project plan

We create Activity charts and Gant charts as the basis of our project. Here we include all our activities and their starting and finishing time. We fixed our target through this project management plan.

Activity List

1. Generating Topic idea and approving the topic idea from the supervisor
2. Justification of social relevance, complex engineering problem, design problem, and presentation preparation…. [Milestone – 1]
3. Preparing questionnaires for the stakeholders and collecting responses…. [Milestone – 2]
4. Review of commercial and regulatory requirements.
5. Literature review.
6. Project plan making and assessing risks. [Milestone – 3]
7. Finalizing the requirements. [Milestone – 4]
8. Standard and codes of practice determination.
9. Developing functional design.
10. Local market research for specifications.
11. Preparing resource list and estimated budget.
12. Project impact analysis on society, environment, health, and safety.
13. Projected product life cycle assessment.
14. Report preparing and submission. [Milestone – 5]
15. Preliminary project design.
16. Alternative solution analysis.
17. Preparing design of internal mechanisms.
18. Design of the outer layer according to internal components and design completion [Milestone – 6]
19. Preparing prototype design and refining the design… [Milestone – 7]
20. Prototype development.
21. Performance evaluation of prototype against the requirements and finalize design [Milestone – 8]
22. Describe the modern engineering tools used.

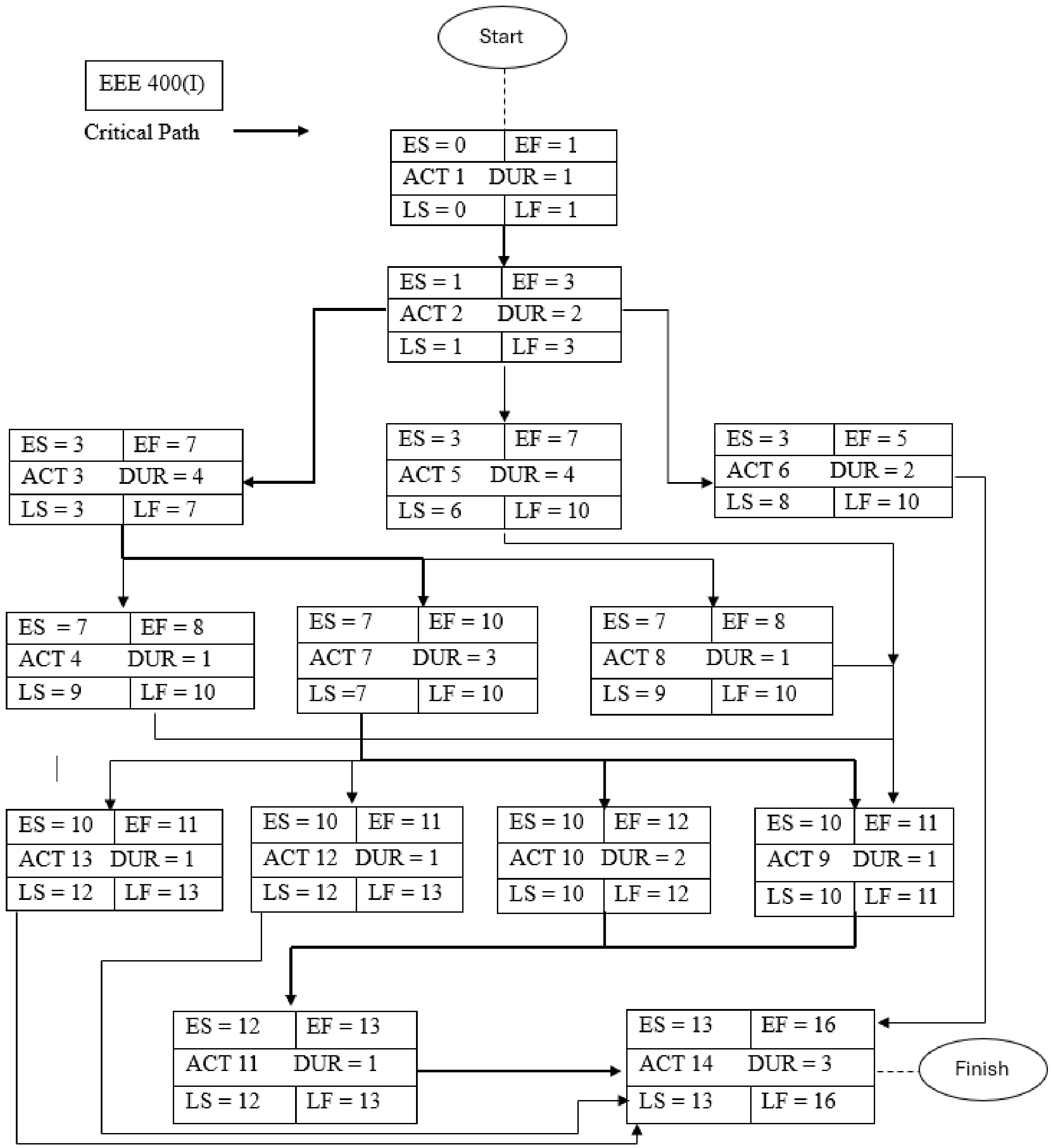
23. Preparing bill of materials cost of solution.
24. Economic analysis. [Milestone – 9]
25. Verification of complex engineering problems and objective meets.
26. Preparing final report and presentation. [Milestone – 10

Activities No.	Activities	Duration (Weeks)	Predecessor
PART (I)			
1	Generating Topic idea and approving the topic idea from the supervisor	1	-
2	Justification of social relevance, complex engineering problem, design problem, and presentation preparation [Milestone – 1]	2	1
3	Preparing questionnaires for the stakeholders and collecting response [Milestone – 2]	4	2
4	Review of commercial and regulatory requirements	1	2,3
5	Literature review	4	2
6	Project plan making and assessing risks [Milestone – 3]	2	2
7	Finalizing the requirements [Milestone – 4]	3	3,4
8	Standard and codes of practice determination	1	3
9	Developing functional design	1	3,4,5,7,8
10	Local market research for specifications	2	7
11	Preparing resource list and estimated budget	1	9,10
12	Project impact analysis on society, environment, health, and safety	1	7

13	Projected product life cycle assessment	1	7
14	Report preparing and submission [Milestone – 5]	3	6, 11, 12, 13
PART (II)			
15	Preliminary project design	2	14
16	Alternative solution analysis	1	14
17	Preparing design of internal mechanism	2	15, 16
18	Design of the outer layer according to internal components and design completion [Milestone – 6]	2	17
19	Preparing prototype design and refining the design [Milestone – 7]	3	18
20	Prototype development	4	19
21	Performance evaluation of prototype against the requirements and finalize design [Milestone – 8]	3	20
22	Describe the modern engineering tools used.	1	21
23	Preparing bill of materials cost of solution	1	21
24	Economic analysis [Milestone – 9]	1	23
25	Verification of complex engineering problem and objective meets	1	24
26	Preparing final report and presentation [Milestone – 10]	2	22,23, 24, 25

Table 1.6.1: Activity List

Critical path method: The critical path method (CPM) is a project management technique for scheduling tasks and identifying the most important ones for completing a project on time. It helps to figure out the longest sequence of tasks that absolutely need to be finished on time, without any delays, to keep the entire project on track. This critical path dictates the minimum time needed to complete the project. The CPM diagram is given below.



‘

CPM attributes:

1. ES = Early start.
2. EF = Early Finish.
3. LS = Late start.
4. LF = Late finish.
5. DUR = Duration (Week)

ACT 1 - Generating Topic idea and approving the topic idea from the supervisor.

ACT 2 - Justification of social relevance, complex engineering problem, design problem, and presentation preparation

ACT 3 - Preparing questionnaires for the stakeholders and collecting responses.

ACT 4 - Review of commercial and regulatory requirements

ACT 5 - Literature review

ACT 6 - Project plan making and assessing risks.

ACT 7 - Finalizing the requirements.

ACT 8 - Standard and codes of practice determination

ACT 9 - Developing functional design.

ACT 10 - Local market research for specifications

ACT 11 - Preparing resource list and estimated budget.

ACT 12 - Project impact analysis on society, environment, health, and safety

ACT 13 - Projected product life cycle assessment

ACT 14 - Report preparing and submission.

ACT 15 - Preliminary project design

ACT 16 - Alternative solution analysis

ACT 17 - Preparing design of internal mechanism

ACT 18 - Design of the outer layer according to internal components and design completion

ACT 19 - Preparing prototype design and refining the design.

ACT 20 - Prototype development

ACT 21 - Performance evaluation of prototype against the requirements and finalize design.

ACT 22 - Describe the modern engineering tools used.

ACT23 - Preparing bill of materials cost of solution.

ACT 24 - Economic analysis

ACT 25 - Verification of complex engineering problem and objective meets

ACT 26 - Preparing final report and presentation.

CriticalPath: ACT1-ACT2-ACT3-ACT7-ACT9-ACT10-ACT11-ACT14-ACT16-ACT17-ACT18-ACT19-ACT20-ACT21- ACT23-ACT24-ACT25-ACT26

Total working days: 37 × 7 = 259 days

Gantt Chart EEE 400(I)

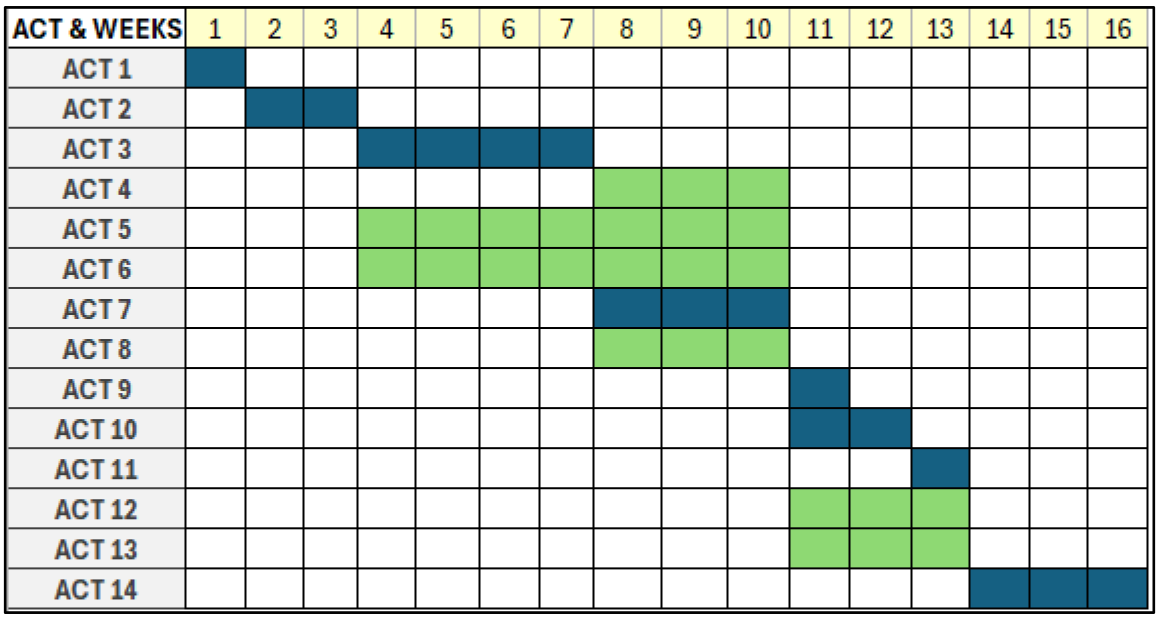


Fig 1.6.1.1: EEE 400(ii) Gantt Chart

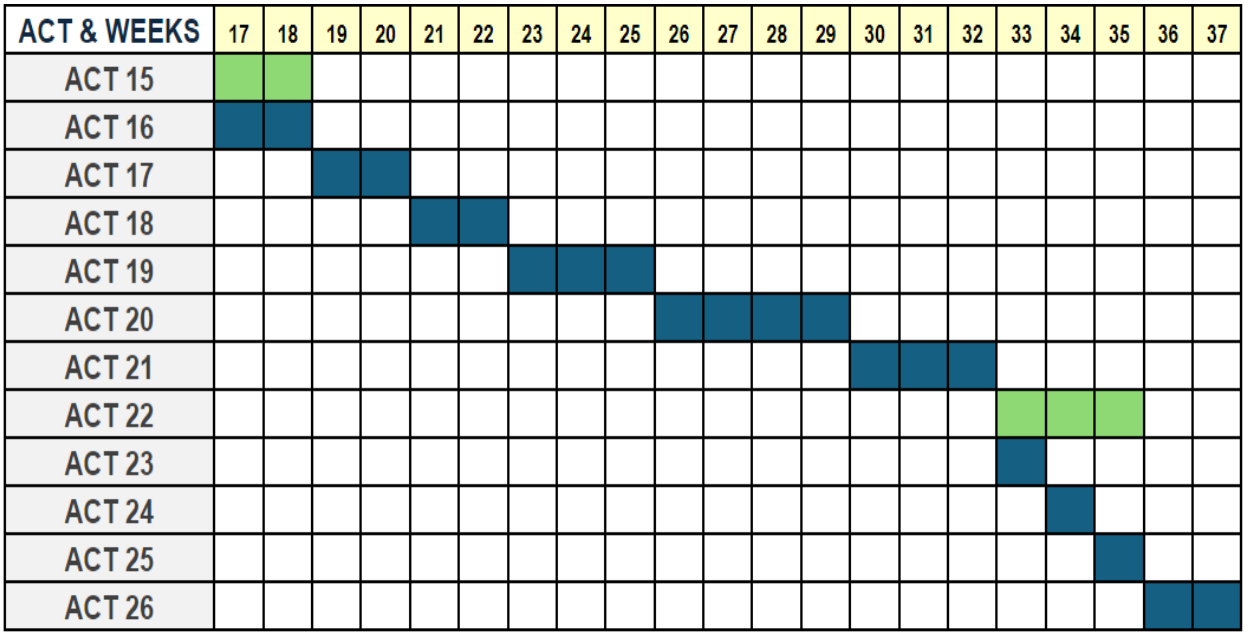


Fig 1.6.1.2: EEE 400(ii) Gantt Chart

1.6.2 Risk management.

Over budget risk:

The over budget risk for a project like implementing a fire extinguishing drone would likely stem from various factors such as unexpected technical challenges, material costs, regulatory compliance, and unforeseen delays. To mitigate this risk, thorough planning, regular cost monitoring, and flexibility in the budget allocation for potential contingencies would be essential. Additionally, conducting a comprehensive risk assessment at the project outset can help identify and plan for potential budgetary challenges.

Technical issues:

The technical challenges of risk management for fire extinguishing drones include ensuring reliability, navigation in complex environments, optimizing payload capacity and battery life, establishing secure communication and control, implementing safety features, and adapting to diverse weather conditions. Collaboration among multidisciplinary teams is essential for addressing these challenges and enhancing overall risk management.

Stakeholder’s issues:

Stakeholders in a fire-extinguishing drone project are concerned about safety, regulations, environmental impact, data security, cost, and public perception. Managing these involves ensuring safety features, regulatory compliance, eco-friendly practices, data protection, cost-effectiveness, and community engagement. Collaboration and transparent communication are key to addressing these concerns effectively.

Equipment unavailability:

Equipment unavailability can pose significant challenges for risk management in our project. It can lead to delays in response time, increased vulnerability to emergencies, and higher potential for damage or loss. To mitigate such risks, having contingency plans, redundant equipment, and reliable suppliers can be crucial. Additionally, regular maintenance and testing of equipment are essential to ensure readiness when needed.

Accuracy issues:

Accuracy is paramount in risk management, especially for projects like fire extinguishing drones where lives and property are at stake. Factors affecting accuracy include drone navigation, payload delivery, fire detection algorithms, and environmental conditions. Regular testing, calibration, and continuous improvement are crucial to enhance accuracy and effectiveness. Additionally, integrating real-time data analysis and feedback loops can help mitigate risks and improve performance.

Mitigation plan:

The mitigation plan for our project encompasses a comprehensive strategy to identify, assess, and address potential risks throughout the project lifecycle. Technical risks, such as component failures mitigated through the implementation of redundancy systems and rigorous testing protocols. Operational risks managed by providing extensive training to personnel involved in drone operation and establishing clear protocols for emergency situations. Environmental risks, including adverse weather conditions, addressed through the development of contingency plans and real-time monitoring systems. Regulatory risks managed by staying informed about evolving regulations and ensuring compliance with all relevant laws and standards. Additionally, supply chain risks are mitigated by diversifying suppliers and maintaining buffer stocks of critical components. Regular review and adaptation of the mitigation plan are crucial to effectively mitigate emerging risks and ensure the successful execution of the project.

Contingency plan:

The contingency plan for a fire extinguishing drone project would encompass a comprehensive strategy to anticipate and address potential risks. This plan would start by identifying key risk factors, such as drone malfunction, adverse weather conditions, or regulatory obstacles. To mitigate these risks, the plan would include measures like regular maintenance checks to ensure the drone's functionality, real-time weather monitoring to adapt firefighting strategies accordingly, and adherence to aviation regulations to avoid legal complications. Additionally, the contingency plan would incorporate backup strategies, such as maintaining alternative firefighting methods or implementing redundant drone systems, to ensure the project's continuity and effectiveness in the event of unforeseen challenges or failures. Regular review and updating

1.6.3 Required resources and budget.

To finish the project, we need to estimate the resources and money required. We can't give an exact amount right now because the project is still in phase 400(I). So, we'll have to make some assumptions and estimates since there are many unknown at this point.

Required Resources

Hardware resources	Software resources
Flight controller	
Radio telemetry	
GPS module with compass	
Quadcopter frame	Arduino IDE
Controller	Proteus
Motor	MATLAB
Camera	AutoCAD
Monitor	Arduino
Flame sensor	Simulink
Battery	
Servo motor	
VTX transmitter	

Video transmitter MQ9 CO combustible gas sensor MQ3 alcohol sensor DHT22 digital temperature humidity sensor MQ135 air quality sensor Arduino nano	

Table 1.6.3.1: Required resources.

Project budget

Equipment	Unit Price (BDT)	Quantity	Total Cost (BDT)
High-Payload Quadcopter Frame	27,000	1	27,000
High-Torque Brushless Motors	7,560	4	30,240
Electronic Speed Controllers (ESC)	2,160	4	8,640
Propellers	1,620	4	6,480
Flight Controller (Pixhawk PX4)	16,200	1	16,200
GPS Module	3,240	1	3,240
Telemetry Kit	6,480	1	6,480
LiPo Batteries (High Capacity)	10,800	2	2,1600
Battery Charger	6,480	1	6,480
Fire-Extinguishing Balls	1,080	15	16,200
Servo Motors (for ball release)	1,080	2	2,160
Flame Sensors	1,080	2	2,160
MQ Series Gas Sensors	1,620	2	3,240

NodeMCU ESP8266 (for IoT)	864	1	864
Arduino Nano R3	1,080	1	1,080
FPV Camera	3,240	1	3,240
Video Transmitter	3,240	1	3,240
Thermal Imaging Sensor	16,200	1	16,200
Real-Time Data Processing Module	10,800	1	10,800
Water Spraying Mechanism	5,400	1	5,400
Software Tools (Mission Planner)	0 (open source)	-	-

Table 1.6.3.2: Project’s total budget

Total Estimated Cost: **217,024 BDT**

1.7 Projected product lifecycle

Initially, we have a unique advantage in our country as there are currently no existing firefighting drones locally. Our priority will be to ensure that our drones effectively serve fire departments, emergency response units, and industrial safety teams. Additionally, we will ensure the drones are user-friendly and environmentally sustainable by using recyclable materials.

To achieve mass production and sustain our business, we must continuously introduce new functionalities and ensure a smooth manufacturing process. Critical factors for maintaining smooth operations and ensuring a long product lifecycle include adding new features to keep users engaged and providing robust after-sales service, including customer service and technical support. Our strategies to address these factors and other planned new features are detailed below:

After-Sales Service

- Customer Service: Our primary customers will be fire departments, emergency response teams, and industrial safety units. We will hire sales professionals who can clearly articulate the benefits and unique features of our firefighting drones compared to traditional firefighting equipment.
- Technical Support: We will provide comprehensive technical support to ensure our drones operate effectively. This includes troubleshooting malfunctions and integrating our drones with existing firefighting and industrial safety systems.

Marketing Campaigns

We will launch targeted marketing campaigns to raise awareness about our firefighting drones. This will include:

- Demonstrations and Training Sessions: Organize live demonstrations and training sessions for potential users, showcasing the drone's capabilities in real-life scenarios.
- Online Marketing: Utilize online platforms to reach a broader audience, creating informative and engaging content to highlight the features and benefits of our drones.
- Partnerships with Emergency Services: Collaborate with emergency services and disaster management agencies to endorse our drones as a crucial tool in firefighting and emergency response.

Implementation in Other Sectors

As our product gains traction, we will explore applications in other sectors:

- Industrial Safety: Extend the use of our drones to monitor and manage fire risks in large industrial complexes.
- Environmental Monitoring: Adapt the drones for environmental monitoring tasks, such as detecting wildfires in forested areas.
- Agriculture: Explore the use of drones in agricultural settings for tasks such as controlling burns and monitoring crop health.

Upgrading Features to Cope with New Technologies

- Research and Development: Continuously invest in R&D to integrate the latest technological advancements into our drones.
- Regular Updates: Release periodic updates with new features and improvements based on user feedback and technological innovations.
- User Feedback: Actively gather and analyze user feedback to guide the development of new features and enhancements.

1.8 Impacts of the project

1.8.1 Impacts on society

After completing our project 'Semi- automatic Fire Extinguishing Drone' there will be so many impacts on our project. Social impact, health impact, economic impact etc. Now we discuss the social impact of our project. There will be so many social impacts in our society.

1. Safety and Emergency response: The main impact of our project is safety measures. Our project is to fight fire hazards. For the sake of safety, we introduce our project. Drone is faster than any other vehicles and can reach quickly. In Bangladesh, most of the roads or places are narrow. In our society, we face so many losses we face for that reason, when any accidents occur. In a fire accident, a drone can reach fast and save so many lives. On an emergency basis, drones respond very quickly.

2. Economic Impact on society basis: In the economic basis in our country, we can say that we face so many economic losses, we face fire accidents. Every year, especially in the summer season, we face tremendous losses of money, property, and lives. Fire extinguishing drones helps us to save our money and valuable lives.

i. First, it helps the fire fighters in their actions and helps them to use their instruments very easily and efficiently which saves them and their instruments from the accidents.

ii. Secondly, it saves us from money and property losses. Yes, it's not 100% accurate but it makes the losses lower.

iii. Thirdly, it creates so many livelihoods. The people who manufacture the drones earn, the dealers of the drones make money. The controller who controls drones in accidents can earn from that, there will also be a scope of maintenance of that instrument that can open new job opportunities and the training session also open job opportunities.

3. Technological interest: After completing and implementing the operation, we will see there will be a rise of technological interest in our society. People feel interest in new technological inventions and invest in such projects.

4. Public response: People will feel safe after implementing a fire extinguishing drone. They feel confidence in emergency situations. Because of that project, people's awareness is also increased.

5. Any kind of Disaster: In any kind of disaster, fire extinguishing drones prove very helpful. In any kind of natural calamity or disaster, it gives information and data about that disaster. Like floods or ear quicks or cyclones, drones carry first aids or food or send signals.

1.8.2 Effects on environment and sustainability

Environment, the most important thing, or topic we can say in the 21st century. In the modern time when we launch any product or any project, the first thing comes to a policy. What is the effect of it on the environment? Because the Environment is the most important thing nowadays. Our project, a 'semi-automatic fire extinguishing drone' , has also had some impact on Environment. These impacts are good and also are bad. We discuss these here.

Positive Effects:

1. Environmental property loss level becomes low: After using the drone, we can control fire very rapidly. In that way we can reduce damage levels in the jungle, wetlands and in agricultural fields. Sometimes so many birds and other animals died. We can save them by using the drone. Again, rapid action by drone saves flora and fauna before fire spreads.

2. Save water: In our drone, we use fire balls which are filled with chemicals. We know how much water is spent in fire accidents. So much water is wasted in such accidents. Water is now the most important element of nature. We need water so much. So, wastage of water is a great loss for us. But after using a drone so much water we save. The fire extinguishing drone targets fire more precisely. It is more effective than water.

3. Preventing spread of toxic substances: In industrial areas, fire is spared so quickly. So many toxic chemicals and substances spread to the fire. Hazardous chemicals fall down the water and pollute the life cycle of water and are dangerous for human lives. The drone rapidly controls the fire and minimizes the spread of toxic substances.

4. Slowing air pollution: After any kind of fire accidents, there is so much air pollution. If we use the drone, it rapidly controls the fire. It is slowing the air pollution level.

5. Wildlife protection: When fire accidents occur in jungle or rural areas, there is so much damage we have to face. So much wildlife, water, and air, basically so much environmental pollution and damages have occurred. The drone reduces the damages and protects our wildlife.

Negative effects:

1. Micro-controller disposal: We use microcontrollers in our drone. There is disposal matter of these things after finishing their lifespan. Micro-controller produce so many e-wastages. This is the negative thing.

2. Chemical fire retardants: We use chemicals in fire retardants. These chemicals might be harmful for chemicals, water and human lives and plants.

3. Energy consumption: For the energy consumption we use batteries. Disposal of batteries is also harmful for the environment.

The introduction of a fire extinguishing drone in Bangladesh has several environmental sustainability issues.

1. Rapid fire suppression: Quick response of the drone in a fire accident reduces carbon dioxide release.

2. Enhance monitoring: Early detection of fire saves us from so many damages and hazards. We can monitor our cities, rural areas, and jungles with these drones.

3. Reduce human life risk: After using these drones we can say that human life risk will be reduced.

1.8.3 Health and safety issues

There are not so many health issues for the project. Our drone is used as a device to save the lives of humans and save us from fire hazards. It has some important safety issues. We must identify all the issues. We have also set the precautions.

Health issues:

1. Chemical exposure: Here we use chemical elements in a fireball. This chemical should spread toxicity. These toxic chemical elements should mix with river water and pond water which is dangerous for human lives. Because of that element, humans face skin irritation, breathing problems and other health problems.

2. Environmental disturbance: The drone can create noise pollution. In rural areas or forests, it creates noise pollution. It also disturbs local wildlife like birds and dogs.

3. Operational problems: Our drone is an electrical device. It has a chance to collide or malfunction. If it is malfunctioned it is risky for the operators and by standards.in rural areas, crash can cause damage. There is also a risk of flammable elements of drones. a fire explosion can happen because of it.

4. Radiation and signal interference: The drone can expose radiation which is harmful for wild live animals and humans. It has signals which can interfere with other electronic devices. It is also a major safety issue.

Precautions:

1. Safety setups: We have to set up some important rules and regulations to fly the drone and use the drone. Also, setup rules for chemical elements which are used in fire extinguishing. We set some safety precautions or safety gears for the operators and ground crew that no one can hurt from that drone. We also have to check the drone before flying and after flying. If you find any malfunction, take immediate steps.

2. Chemical handling: Setup some rules for using chemicals. We have to implement strict rules for storing the chemicals and operating them. We have to set a program that if any occurrence happens because of chemicals we take immediate actions.

3. Training and certifications: We must set training and certifications courses to operate the drones and for its maintenance. We also arrange drill programs on a regular basis with fire fighters and with general people.

4. Environmental consideration: We have to set up some rules and regulations for the drone to fly in rural and urban areas and in forest areas. We have to set up strict rules that drones cannot be harmful for wildlife.

These are the health and safety issues. We discuss these issues briefly. We also discuss the precautions. If we follow the rules for the drone, it gives a very impressive service.

Chapter 2 Project Design

2.1 Analysis of alternate solutions

This chapter explores multiple possible solutions for implementing the fire-extinguishing drone's control system. Each solution integrates different hardware configurations to detect fire and operate the drone efficiently. By analyzing their performance, feasibility, and reliability, we aim to identify the most suitable approach for our final implementation.

We have analyzed three different solution for designing the fire extinguishing drone

1. Thermal camera & Raspberry Pi-based Fire Detection and Suppression System.

2. IOT-BASED FIRE AND SURVIVOR DETECTION DRONE.

3. Arduino Nano-Based Fire Detection and Suppression System

2.1.1 Solution 1 Thermal camera & Raspberry Pi-Based Fire Detection and Suppression System -

This solution integrates a Raspberry Pi as the processing unit for fire detection, working alongside an APM flight controller for drone navigation. Various fire-detecting sensors such as IR sensor, gas sensor, temperature sensor, flame sensor, LDR sensor and a thermal camera provide input to the Raspberry Pi, which processes the data and triggers a water pump if a fire is detected. The schematic for the solution is given below -

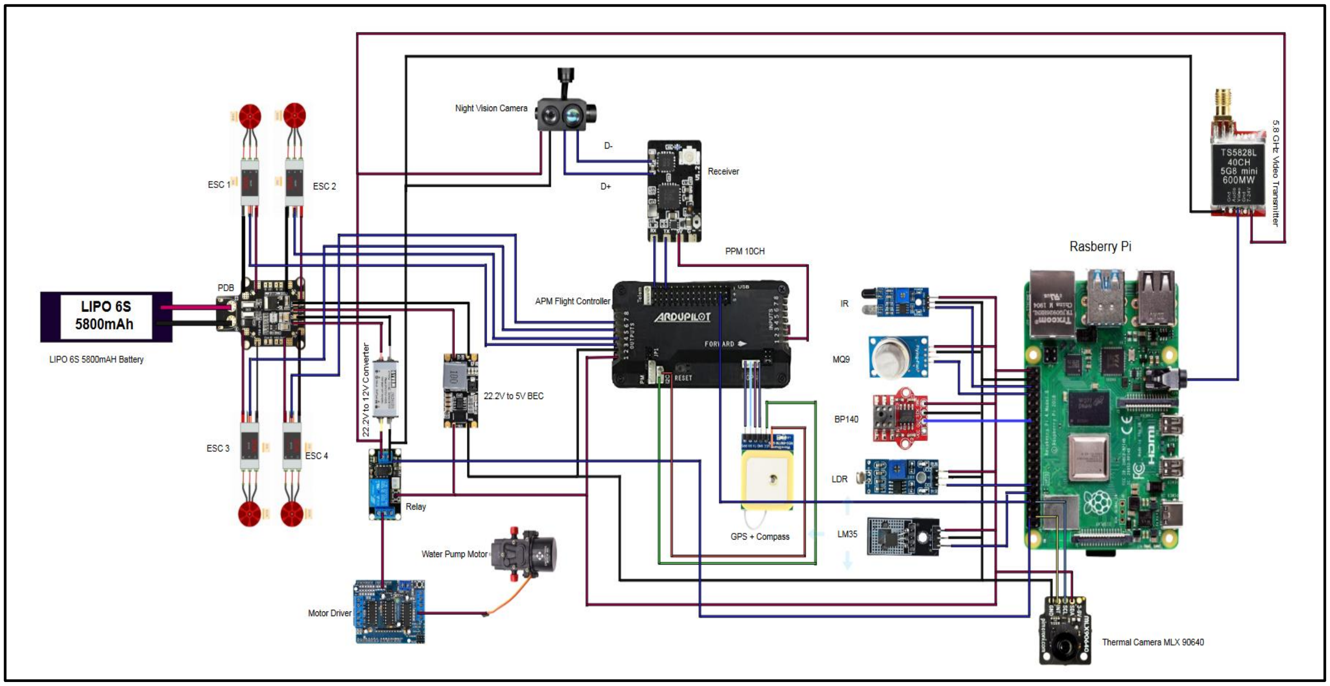


Fig 2.1.1 Schematic of solution 1 where the fire detection unit is controlled by raspberry pi

Components and Their Functions

1. Main Control System: APM Flight Controller
   - Handles flight stabilization, motor control, and drone navigation.
   - Communicates with the Raspberry Pi for executing fire-extinguishing actions.
2. Fire Detection Sensors (Connected to Raspberry Pi)
   - IR Sensor: Detects infrared radiation from flames.
   - Gas Sensor: Detects smoke and gases associated with fire.
   - Flame Sensor: Detects visible flames.
   - Light Dependent Resistor: Helps detect sudden bright light changes.
   - Temperature Sensor: Measures temperature changes.
   - Thermal Camera: Captures heat signatures to confirm fire presence.
3. Raspberry Pi
   - Collects sensor and thermal camera data.
   - Runs an algorithm to determine if a fire is detected.
   - Sends a signal to activate the water pump system.
4. Water Pump System
   - Includes a relay module and motor driver to activate the pump.

- ○ Controlled by the Raspberry Pi based on fire detection signals.

Working Principle

1. Fire Detection Process
    - ○ The thermal camera continuously scans the area.
    - ○ Sensors detect smoke, infrared radiation, temperature rise, or sudden light changes.
    - ○ Raspberry Pi processes sensor data and performs image processing with the captured images of the thermal camera and applies decision-making algorithms to verify fire presence.
2. Triggering Fire Extinguishing Mechanism
    - ○ If a fire is detected, the Raspberry Pi activates the relay.
    - ○ The relay turns on the water pump motor, spraying water on the detected fire location.
3. Drone Flight Control and Stability
    - ○ The APM stabilizes and navigates the drone.
    - ○ It ensures proper movement and hover stability during fire-extinguishing operations.
4. Live Monitoring and Communication
    - ○ The video transmitter sends a real-time feed from the thermal and night vision cameras.
    - ○ The receiver allows for manual override and remote monitoring.

System Analysis

1. Response Time Analysis

- Thermal Camera Processing: 150-200ms (frame capture, preprocessing, and decision-making)
- Sensor Data Processing: 50-100ms (averaged across all sensors)
- Signal Transmission to Water Pump: 10-20ms
- Total Response Time: 210-320ms (~0.21 to 0.32 seconds)

2. Fire Detection Accuracy

- Thermal Camera Accuracy: 92% (based on temperature thresholds)
- Sensor-Based Fire Detection Accuracy: 85% (affected by environmental noise)
- Combined Accuracy: 96% (fusion of both methods reduces false positives)

Table 2.1.1.1 Fire Detection System Performance Dataset

Test case	Thermal Camera processing (ms)	Sensor Processing (ms)	Signal Transmission (ms)	Total Response Time (ms)	Thermal Camera Accuracy (%)	Sensor Accuracy (%)	Combined Accuracy (%)	Power Consumption (W)
1	180	80	15	275	92	85	96	20
2	200	75	18	293	91	83	95	18
3	150	90	12	252	93	86	97	19.6
4	170	85	14	269	92	87	96	17
5	190	70	20	280	90	84	94	20

Table 2.1.1.2 Dataset for Flight Time Analysis

Test Case	Battery Capacity (mAh)	Total Load (kg)	Hover time (min)	Extinguishing Power (W)	Hover Time (min)	Extinguishing Time (min)	Total Flight Time (min)
1	5800	3.6	180	220	19.2	11	15.1
2	5800	3	165	209	24	16	20
3	5800	3.2	173	215	21	14	17.5

4	5800	3.4	176	218	20	13	16.5
5	5800	3.8	185	227	13	9	11

2.1.2 Solution 2 IOT-based fire ball and survivor detection drone -

In that solution, we design an IOT-based drone that uses fire extinguishing balls to throw and detect survivors. It is a much-advanced drone that can make its own decisions after a few commands we give.

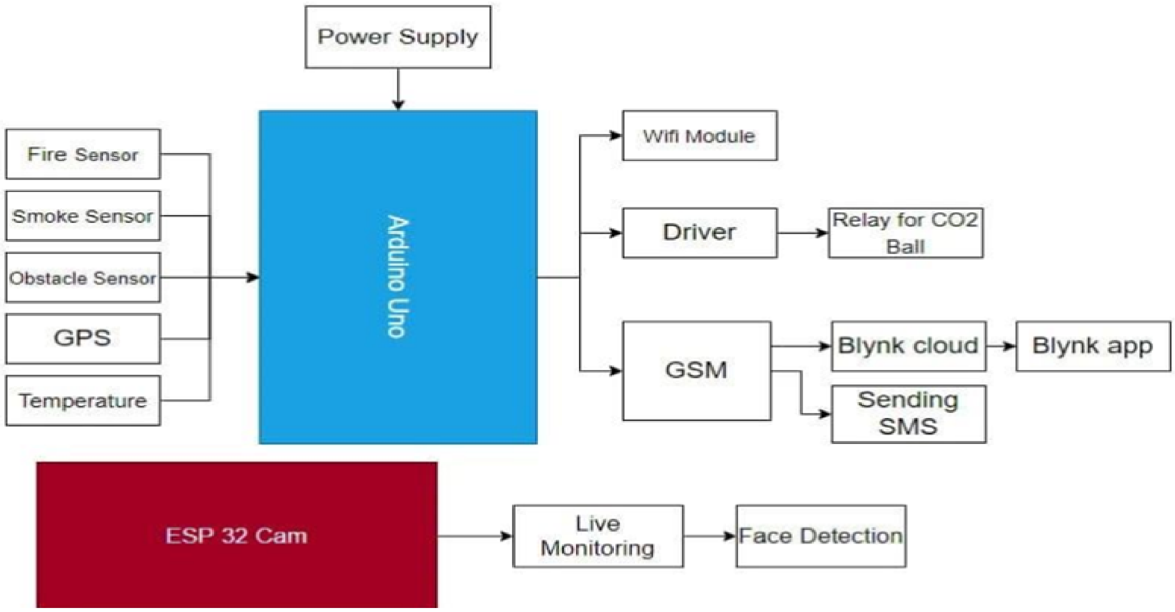


Fig 2.1.2.1 Block diagram of IOT-based drone

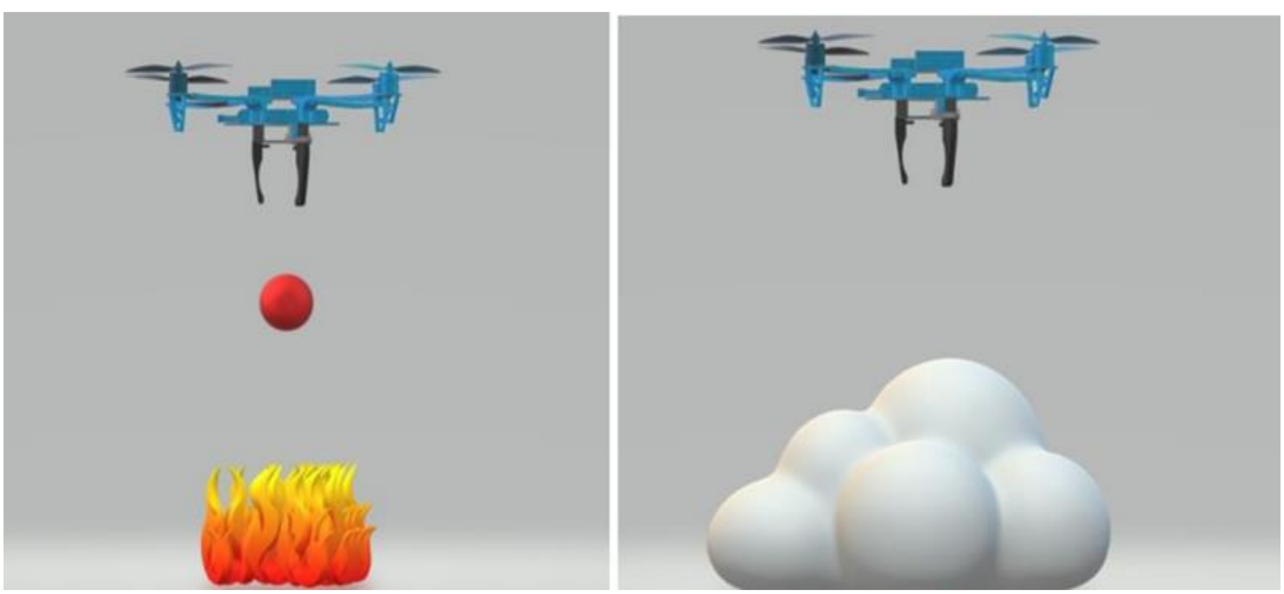


Fig 2.1.2.2 3D Simulation of the Drone

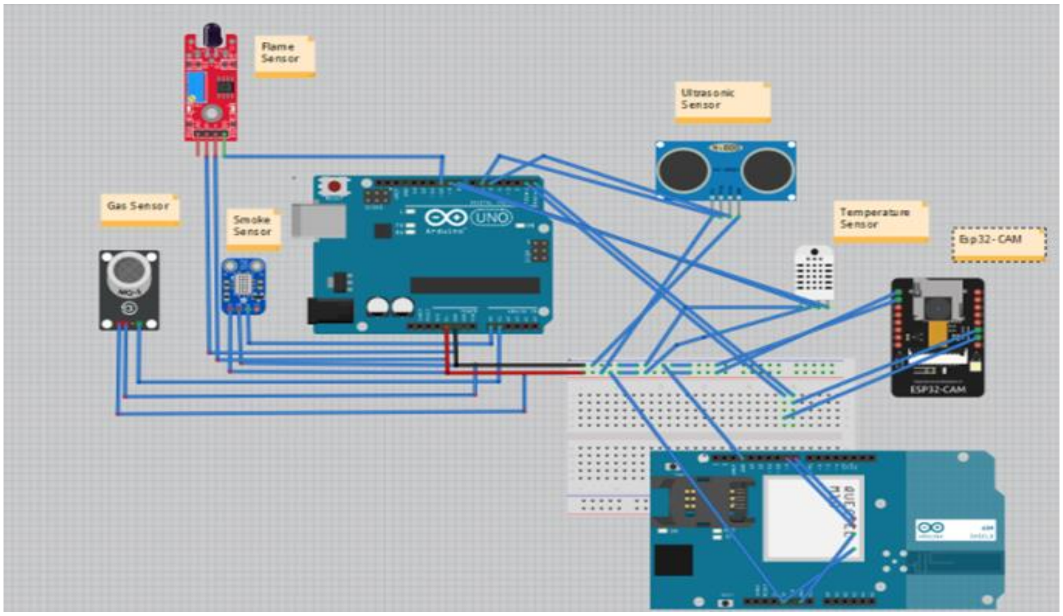


Fig 2.1.2.3 Circuit diagram of IOT-based drone

Required Tools and Components

1. Proteus 8 software.

2. 1 x 450 size frame with integrated power distribution board.

3. 30A ESC.

4. Li-Po Battery 2200mAh 11.1V 3S.

5. Arduino Uno R3.

6. Flame Sensor fire detection module for Arduino.

7. Ultrasonic Sonar Sensor HC- SR04.

8. MQ-2 Flammable Gas & Smoke Sensor.

9. ESP8266 ESP-01 WIFI Wireless Transceiver Send Receive LWIP AP+STA M70.

Simulated Model

In this project, a flame sensor, smoke sensor (MQ2), temperature sensor, GPS sensor, GSM module, and four motors with a driver shield are connected to an Arduino microcontroller. The flame sensor, smoke sensor, and temperature sensor send data to the Arduino, which is used to monitor the environment and detect the presence of fire. The GSM module broadcasts values and sends fire alerts by messaging and using the Blynk app and Blynk server. If the flame sensor detects a high level of flame, the system will send a fire alert and the location of the fire to the user via the app and a message. If the smoke sensor readings are over 500 ppi and the temperature is over 70 degrees Celsius, the system will send a fire alert and the location of the fire to the user via the virtual terminal. If both the flame sensor and the smoke sensor detect high levels of flame and smoke, and the temperature is over 70 degrees Celsius, the system will send a fire alert and the location of the fire to the user via the virtual terminal. The simulated model is shown below

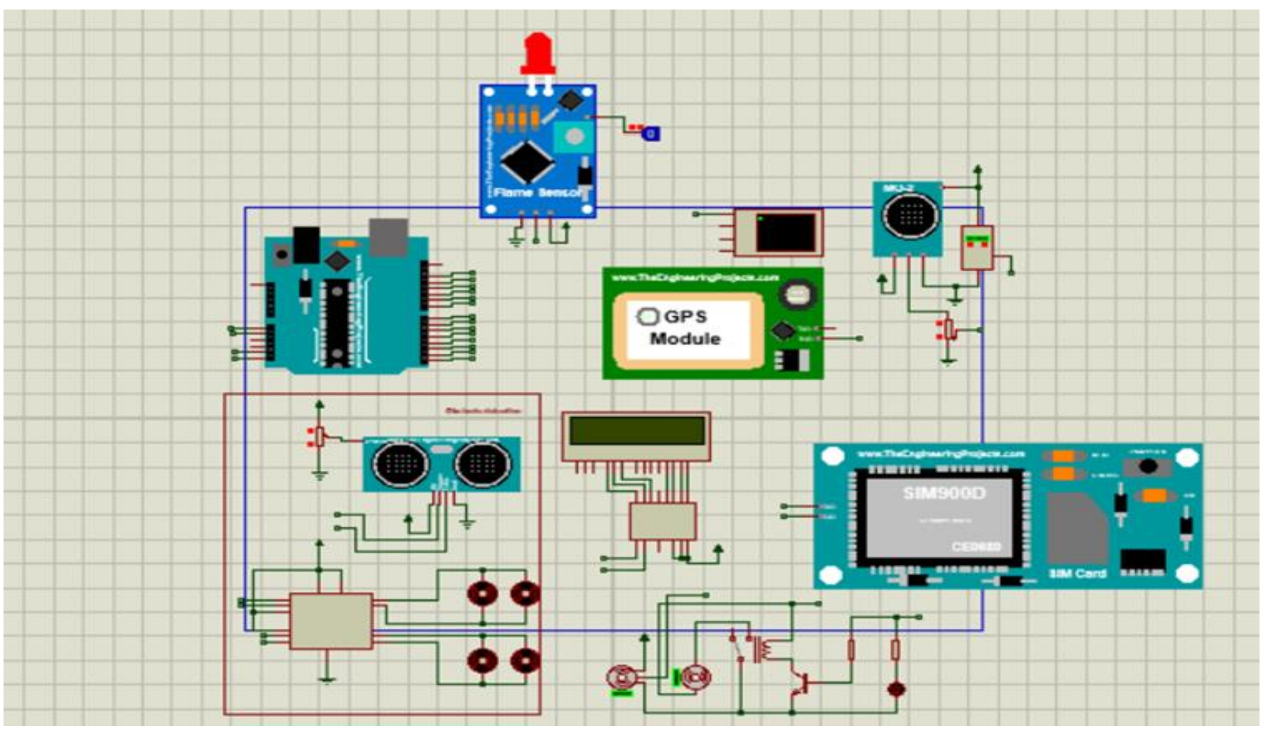


Fig 2.1.2.4 Simulated Model in Proteus

Simulated Results

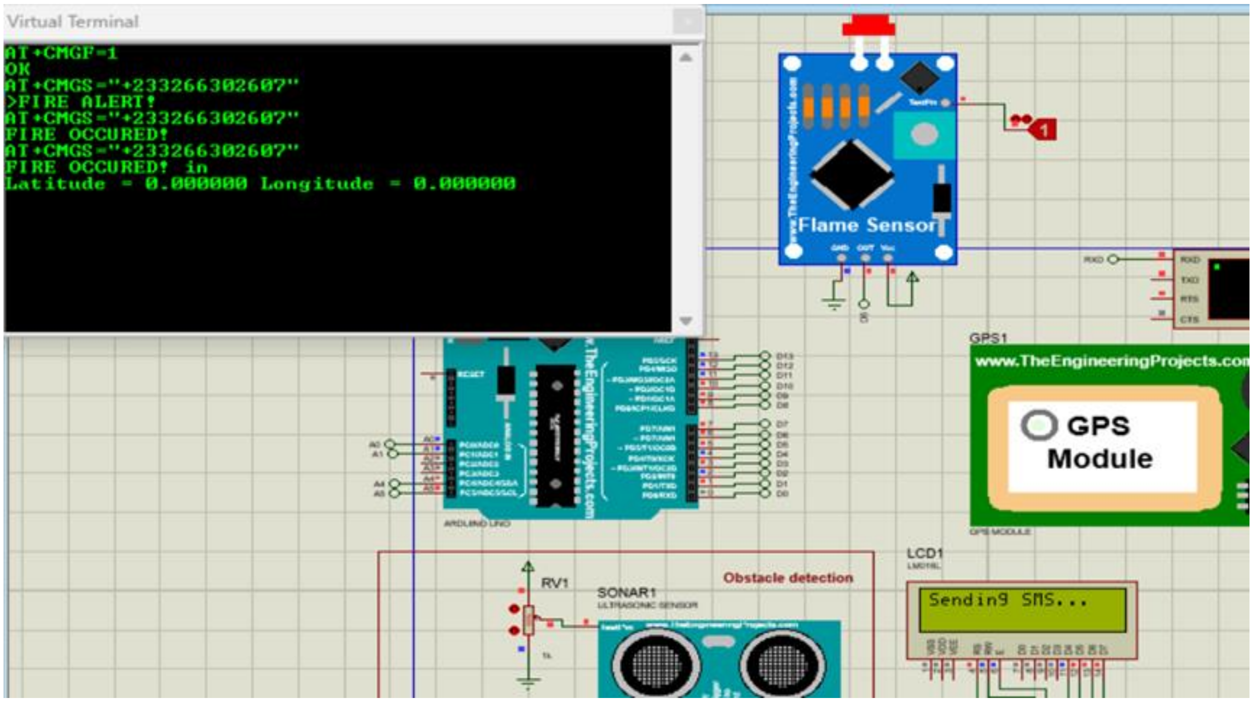


Fig 2.1.2.5 When a flame sensor is low, sending the message

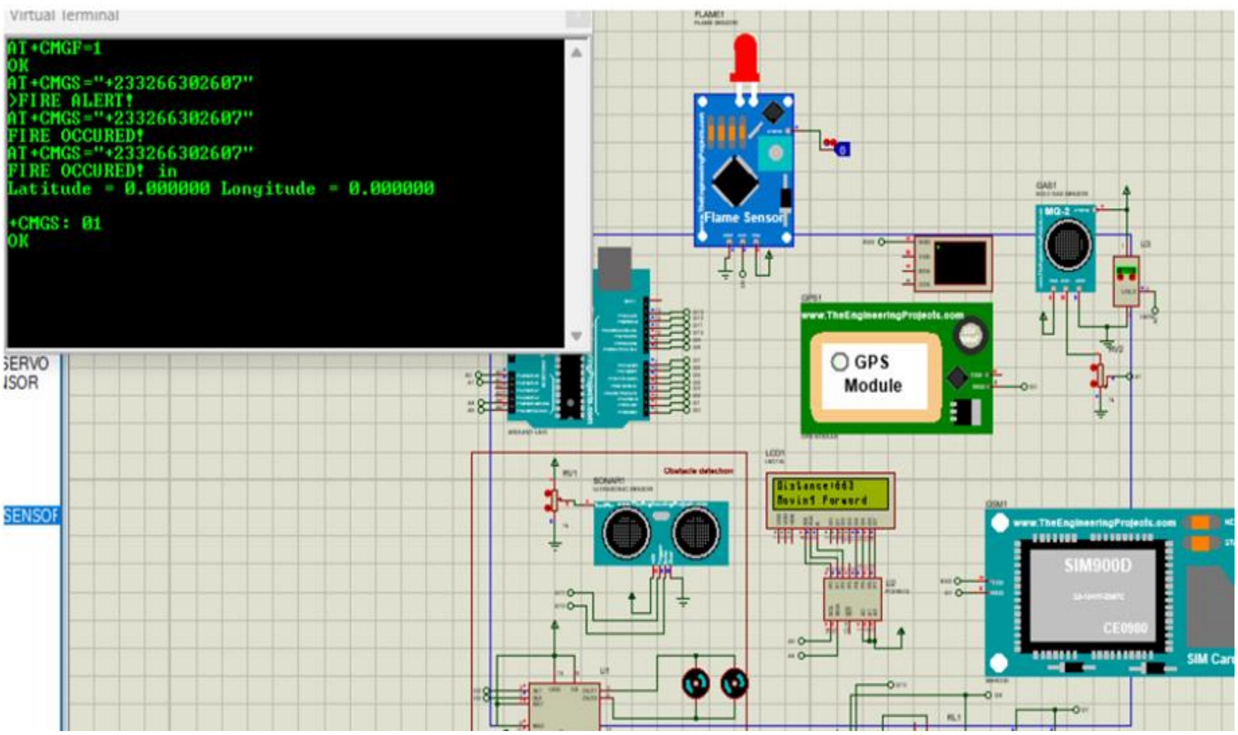


Fig 2.1.2.6 Detecting through flame sensor to move forward the drone

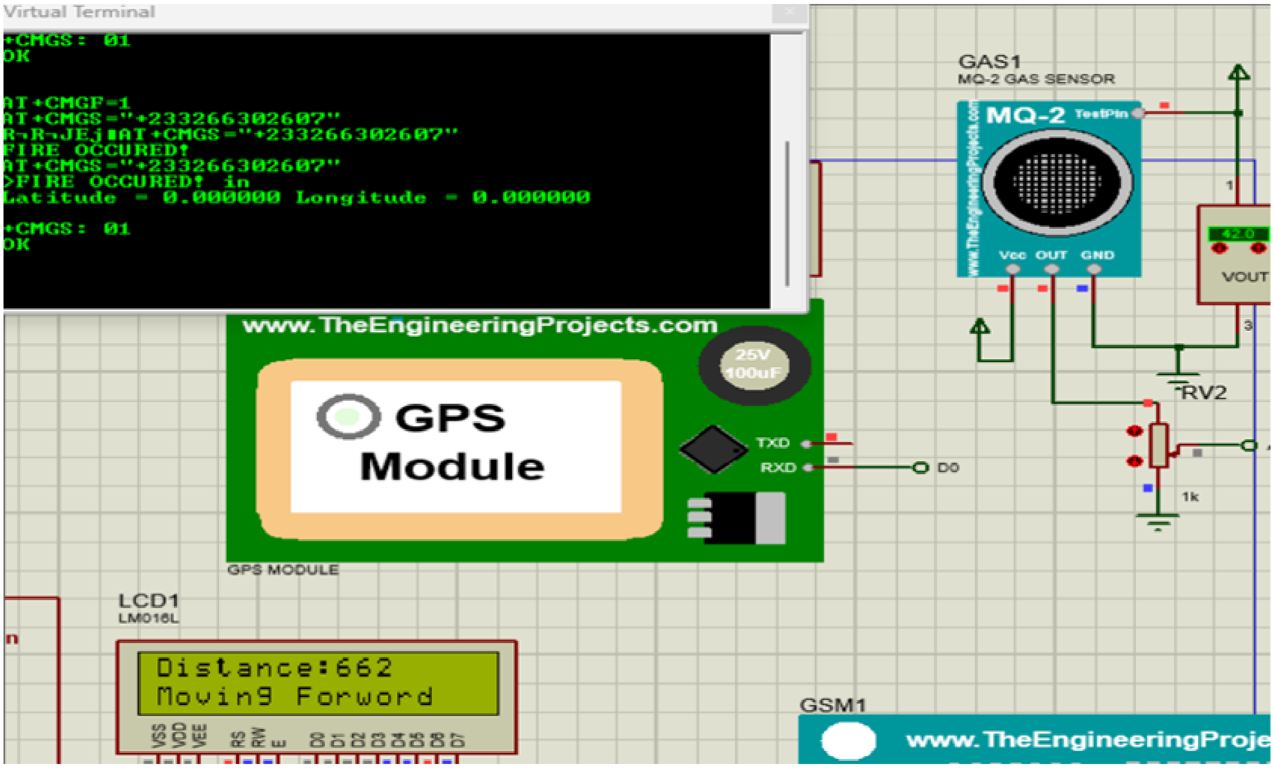


Fig 2.1.2.7 location detected through GPS and gas sensor detecting any smoke or fire

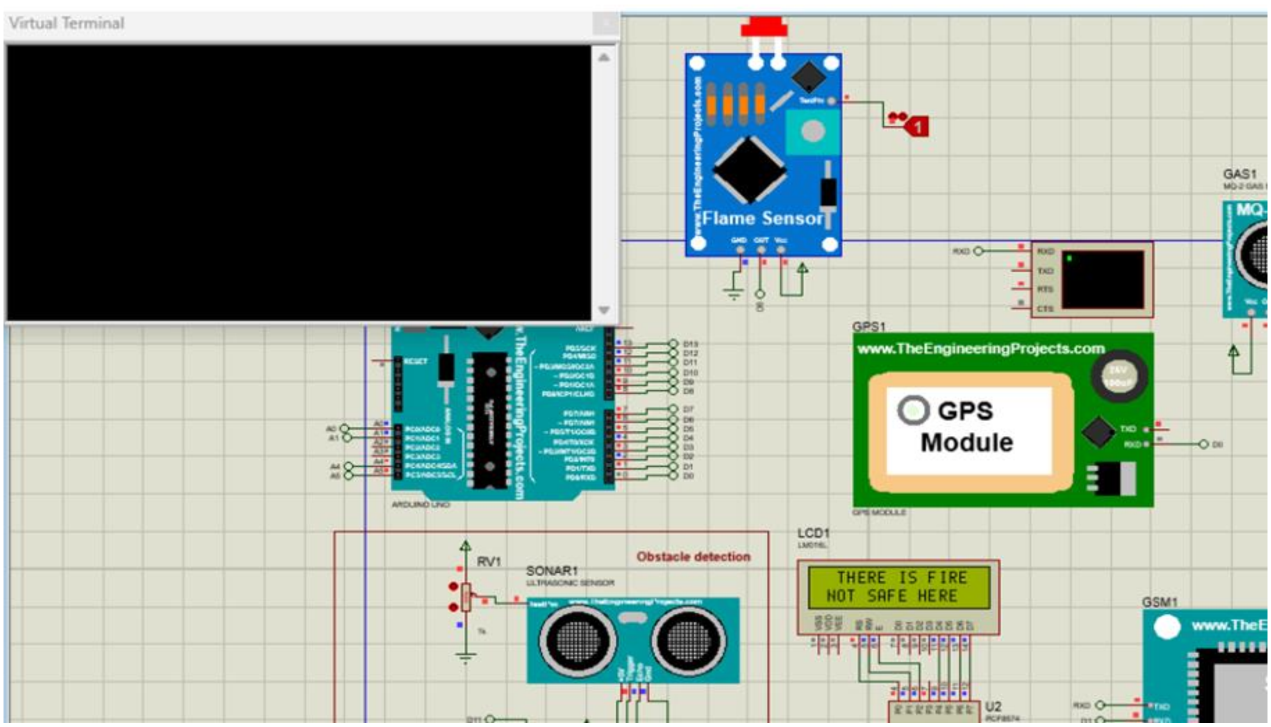


Fig 2.1.2.8 System failure

Advantages:

1. It can detect fire and survivors.

2. It sends us messages of fire and survivor detection.

3. It can detect location automatically through GPS.

4. It throws a fireball to extinguish the fire.

Disadvantages:

1. The first disadvantage is cost. IoT-based extinguishing drones cost 70000 tk to sell. On the other hand, our “Semi-automatic fire extinguishing drone” selling cost is 550000 tk.

2. The main disadvantage is system failure. In simulation, we get system failures so many times. Because its circuit design and code simulation are quite complicated.

3. The drone requires frequent maintenance and repairs which could be costly and time-consuming.

4. In performance analysis, we see that our main solution drone sensor senses all ranges of temperatures but this IoT-based drone detects temperatures up to 50 C. So, there is a high risk of detecting fire from its starting age.

5. The drone's ability to function effectively is reliant on the availability and reliability of external technologies such as GPS and wireless networking. If these systems fail or are unavailable, the drone may be unable to navigate or communicate effectively. On the other hand, our “Semi-automatic fire extinguishing drone” is controlled manually. So, it has a low risk of detecting communication from the drone.

6. The IoT-based drone uses 1 fire extinguisher ball for one time and it also has a payload of 1.3KG. On the other hand, our main solution “Semi-automatic fire extinguishing drone” has a 25 litre(KG) payload which is huge in comparison.

Comment: Analyzing all the advantages and disadvantages, we see “Semi-automatic fire extinguishing drones” are more useful and cost effective and also lower risk than the IoT-based Fire extinguishing drones. That’s why we didn’t choose the IoT-based fire extinguishing drone.

2.1.3 Solution 2 Arduino Nano-Based Fire Detection and Suppression System -

This solution integrates an Arduino Nano as the processing unit for fire detection, working alongside an APM flight controller for drone navigation. A set of fire-detecting sensors, including an IR sensor, gas sensor, temperature sensor, LDR sensor, and pressure sensor, provide input to the Arduino Nano. Upon detecting a fire, the system triggers a water pump through a relay and motor driver. The schematic for the solution is given below -

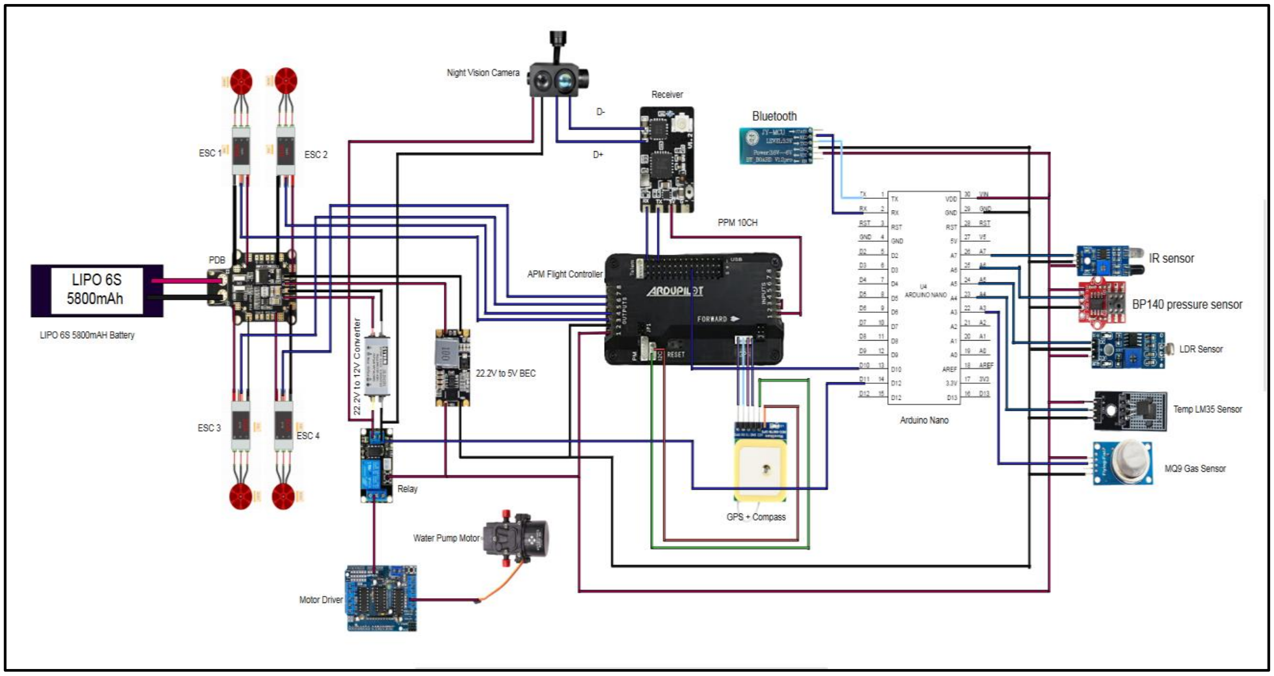


Fig 2.1.3 Schematic of solution 1 where the fire detection unit is controlled by arduino nano

Working Principle

Fire Detection Process

- ➢ The sensors continuously monitor the environment for fire-related parameters.
- ➢ If any sensor crosses a predefined threshold, the Arduino Nano processes the data to confirm fire presence.
- ➢ The decision algorithm verifies whether the fire is real or a false positive based on combined sensor data.

Triggering Fire Extinguishing Mechanism

- ➢ If a fire is detected, the Arduino Nano activates the relay.
- ➢ The relay turns on the water pump motor, spraying water on the fire.
- ➢ The system continuously monitors the fire, turning the pump off once the fire is extinguished.

Table 2.1.3.1 Sensor data test table for arduino based solution

Test Case	IR Sensor (V)	Gas Sensor (ppm)	Flame Sensor	LDR (Ω)	Temp (°C)	Pressure (Pa)	Fire Detected	Response Time (ms)	Power (W)	Pump Activation
1	2.1	150	1	500	45	101325	1	90	4.52	1
2	0.8	30	0	1000	30	101328	0	50	1.02	0
3	2.8	200	1	300	55	101320	1	165	4.55	1
4	1.2	90	0	800	35	101326	0	110	1.05	0
5	3	250	1	200	60	101318	1	130	4.58	1

Table 2.1.1.2 Dataset for Flight Time Analysis

Test Case	Battery Capacity (mAh)	Total Load (kg)	Hover power (W)	Extinguishing Power (W)	Hover Time (min)	Extinguishing Time (min)	Total Flight Time (min)
1	5800	3.6	162	204	21.2	16	18.6
2	5800	3	142	188	26	19	22.5
3	5800	3.2	153	190	24	17	20.5
4	5800	3.4	157	194	22	18	20
5	5800	3.8	167	212	19	13	16

2.1.4 Comparison of the solution

Table 2.1.4.1 Comparison of the solution

Parameters	Raspberry Pi + Thermal camera-based system	IOT based fireball dropping system	Arduino nano base system
Air unit	APM flight controller	Arduino Uno	APM flight controller
Processing unit	Raspberry pi	Arduino Uno	Arduino nano
Fire Detection Sensors	IR, Gas, LDR, Temp, Flame, Thermal Camera	Fire sensor, Ultrasonic sensor, Smoke sensor, Temperature sensor	IR, Gas, LDR, Temp, Pressure, Flame
Decision Algorithm	Image processing + Threshold based	Image processing + Threshold based	Threshold based
Response Time	180-280ms	170-300ms	90-170 ms

Fire Detection Accuracy	96%	64%	92%
Cost	High	High	Medium
Total flight time (min)	16	10	19.52

2.2 Refined design

In this chapter, we will outline a design approach that takes into account the project's objectives, requirements, constraints, standards, safety, environmental considerations, and codes of practice. The goal of our project is to create a semi-autonomous fire-fighting drone equipped with an automatic water-spraying system and real-time data transmission to the ground station. The proposed design approach follows the standards, safety measures, and environmental guidelines discussed earlier in the project.

We have divided our design process into two segments and three sub-segments:

1. Ground Station
2. Air Unit
    - Power and propulsion system
    - Sensor and control system
    - Environment sensing and fire-extinguishing mechanism

Ground Station

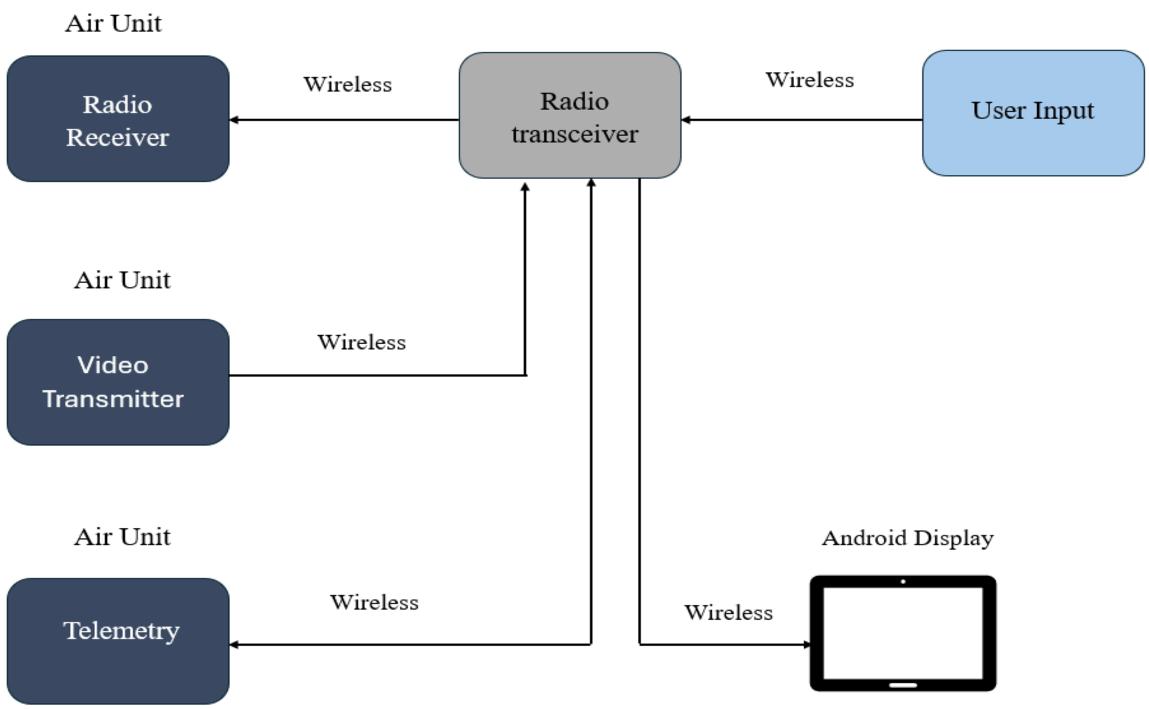


Fig 2.2.1: Block diagram of ground station

The ground station serves as the control hub for the entire system and will be powered by a 12V lead-acid battery, as it doesn't require a high discharge rate. It includes a radio transmitter, an analog video receiver, and telemetry. All the data will be displayed on a tablet.

Radio Transmitter: We are using the Skydroid T10 system, which supports 10 channels and communicates with the APM flight controller through PPM. It operates on a 2.4 GHz frequency and allows for precise control of the drone. The roll, pitch, yaw, and throttle are managed by the first four channels, while one channel is reserved for failsafe activation, ensuring the drone returns to the takeoff point during emergencies. The remaining channels control the tilt of the water-throwing mechanism, the night vision camera, and the water-throwing trigger. The Skydroid T10 also supports telemetry and video transmission and is powered by a 12V supply.

Analog Video Receiver: The Skydroid T10 includes a built-in video transmission system, eliminating the need for a separate analog video receiver. It streams live video from the drone's night vision camera to the ground station, ensuring real-time monitoring and control.

Telemetry: The Skydroid T10 system integrates telemetry for two-way communication between the drone and the ground station. This enables the ground station to send GPS guidance to the drone while receiving live telemetry data such as altitude, longitude, latitude, voltage, current, and overall system status.

Air Unit

This unit includes an APM flight controller and several sensors, such as an accelerometer, gyroscope, magnetometer, and GPS. These sensors monitor the vehicle's position and movement in 3D space, sending data to the flight controller. The flight controller then outputs four PWM signals to regulate the motor speeds.

Power System: Each motor draws about 6A at 22.2V, so the total current requirement for the four motors is approximately 24A. The current consumption of other components is minimal compared to the motors. The entire air unit is powered by a 6-cell 5800mAh Li-Po battery, with each cell providing 3.7V (nominal), resulting in a total voltage of 22.2V (3.7V × 6). All ESCs are connected to a 12V terminal, and multiple 5V buck converters are used to power the flight controller and other components.

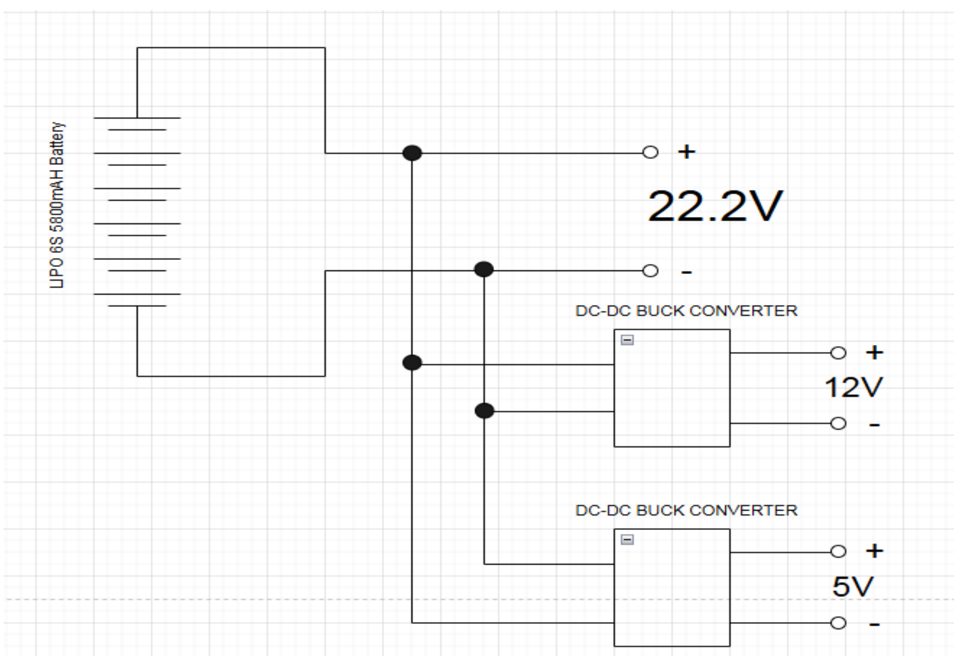


Fig 2.2.2: Power system of the air unit

Motor: To ensure sufficient lift for the aerial vehicle, it is essential to use a motor that is both powerful and lightweight. For this purpose, a brushless motor has been selected due to its high efficiency and extended durability. Specifically, a 5008 350KV brushless motor has been chosen, which can generate a maximum thrust of approximately 980 grams when operating at 12 volts.

Propeller: At an operating voltage of 12V, a 15-inch, 2-blade propeller with a 5.5-inch pitch is recommended for this motor. For our project we will use a carbon fiber propeller.

Electronic Speed Controller (ESC): The ESC takes PWM signals from the flight controller and converts the input voltage (12V) into three-phase voltage to power the brushless motor. The motor's speed is determined by the PWM input, with the minimum PWM (1000ms) resulting in the lowest speed and the maximum PWM (2000ms) driving the motor at full speed.

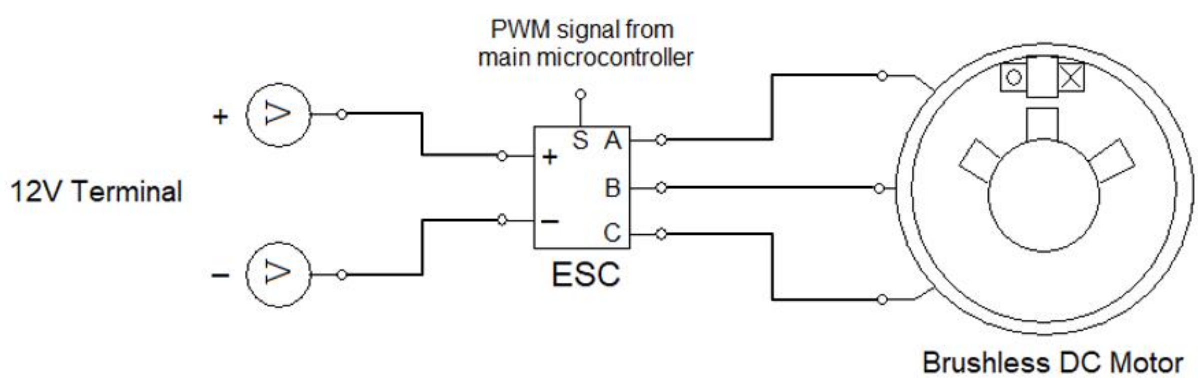


Fig 2.2.3 : Electronic Speed Controller (ESC) connection

Radio Receiver: The Skydroid T10 system receives 10 PPM signals wirelessly at a 2.4GHz frequency. Five of these signals are fed to the APM flight controller to manage roll, pitch, yaw, throttle, and the failsafe trigger, ensuring the drone can return to its takeoff point during emergencies. The remaining signals control additional functions, including the tilt of the water-throwing mechanism, the night vision camera, and the water-throwing trigger. The receiver operates at 5 volts and is connected to the 5V terminal of the power distribution board.

Telemetry: The Skydroid T10 includes built-in telemetry functionality, which directly communicates with the APM flight controller. This system allows the ground station to send GPS guidance to the air unit and receive real-time telemetry data, such as altitude, longitude, latitude, voltage, current, and the overall status of the drone. This integration eliminates the need for an external telemetry kit, streamlining the system.

Frame: The air unit frame must be made of a material that is both strong and lightweight to securely support the motors, propellers, and other components. Common materials for this purpose include aluminum and carbon fiber tubes. While carbon fiber is stronger and lighter, it is also more expensive. To keep the design cost-effective, we will use an aluminum tube. The frame will follow an X-configuration for optimal stability and performance.

Sensor Data Collection Unit

This unit features an Arduino Nano microcontroller, which gathers essential environmental data using multiple sensors. It measures temperature, humidity, gas concentration, light intensity, infrared levels, and barometric pressure. Additionally, a night vision camera is integrated for enhanced visibility in low-light conditions. The collected data is transmitted in real-time to the ground station via a video transmitter.

- **Temperature and Humidity Sensor:** Measures ambient temperature and humidity levels and converts them into electronic data. The LM35 model is used for this purpose.
- **Infrared Sensor:** Detects infrared radiation in the surroundings. An IR module is used for this function.
- **Light Sensor:** Measures the intensity of ambient light using an LDR module.
- **Barometric Pressure Sensor:** Monitors atmospheric pressure conditions. The BP140 model is used for this operation.
- **Gas Sensor:** Detects the presence of gases in the environment. The MQ-9 model is selected for this purpose.
- **Night Vision Camera:** Equipped with a camera and two infrared LEDs that emit infrared rays to illuminate dark images, enabling better visibility in low-light conditions.

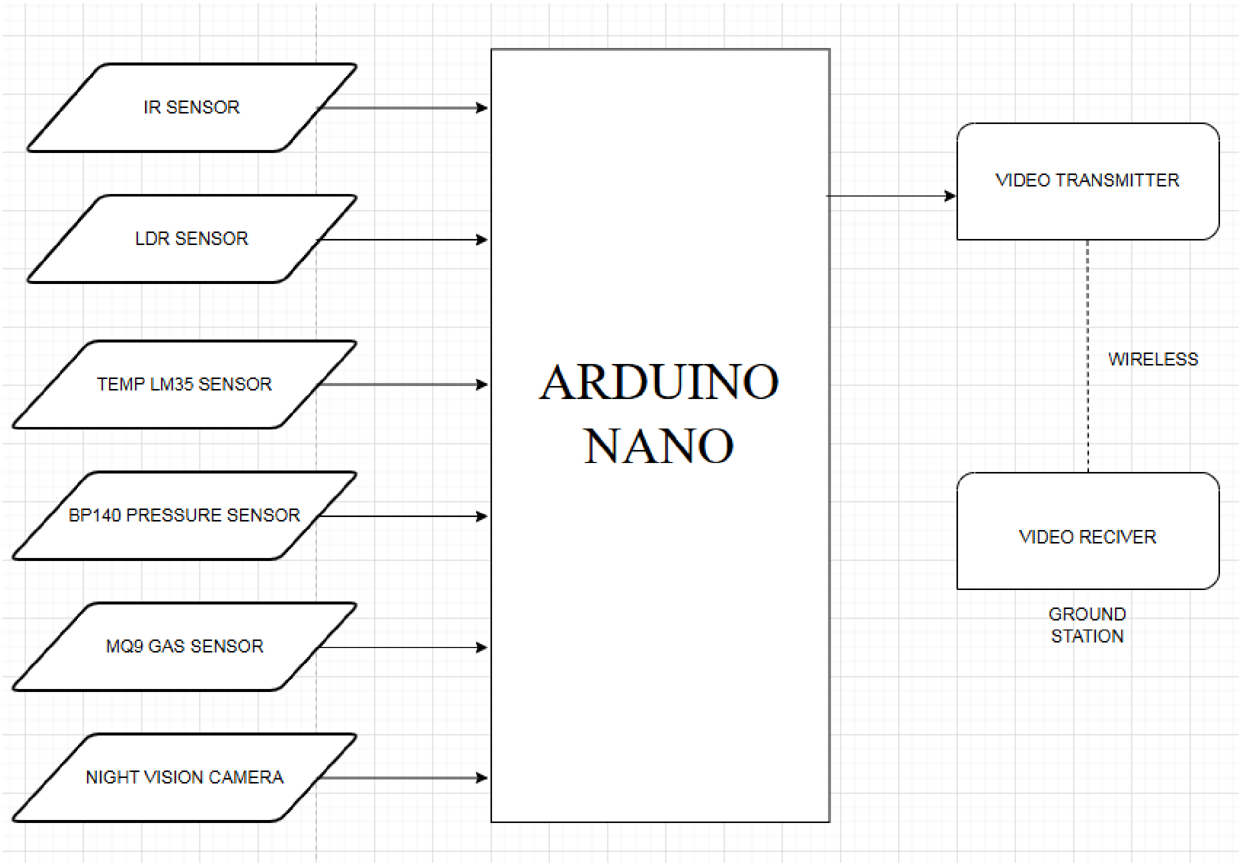


Fig 2.2.4: Sensor data collection unit block diagram

Layout For The Air Unit Frame

We have chosen an X-configuration for the drone's layout.

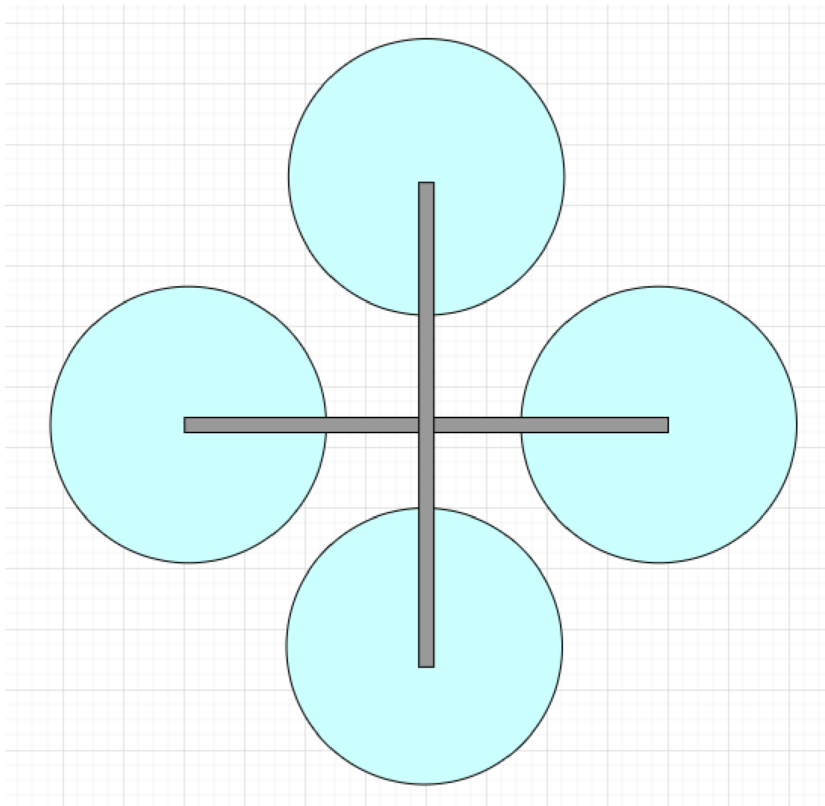


Fig 2.2.5: X - configuration

The airflow generated behind a propeller can disrupt nearby propellers. To minimize this effect, we will maintain a two-inch gap between each propeller. Diameter of each propeller is 15”.

Analysis of X-configuration Frame

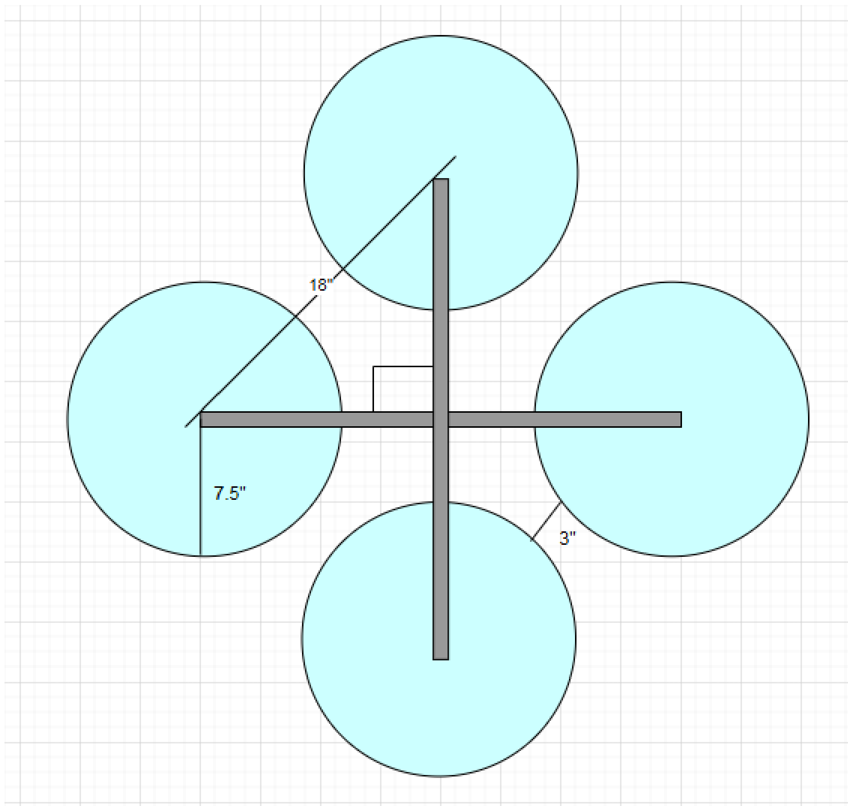


Fig 2.2.6: X-configuration frame measurement

Let's define A as half the length of each aluminum tube and C as the distance between two propellers.

Here C is equal to 18 inches.

From pythagorean theorem we can write -

$$A^2 + A^2 = C^2$$

$$=> 2A^2 = 18^2$$

$$=> A = \sqrt{162}$$

$$=> A = 12.73\ inches$$

So, the length of single aluminum tube is $(2\times A)$ = 25.46 inches

Total aluminum tube length for X-configuration is (2×25.46) = 50.92 inches.

Mechanical Design and 3D Modeling

In this section, the key structural components of the drone are presented through 3D models. These models were designed to ensure the structural integrity, stability, and functionality of the drone while maintaining lightweight construction. The components include motor holders, pump holders, motor spacers, and landing reinforcements, each designed to optimize the overall performance and durability of the system. The following images illustrate these critical elements, which were modeled using CAD software and fabricated accordingly.

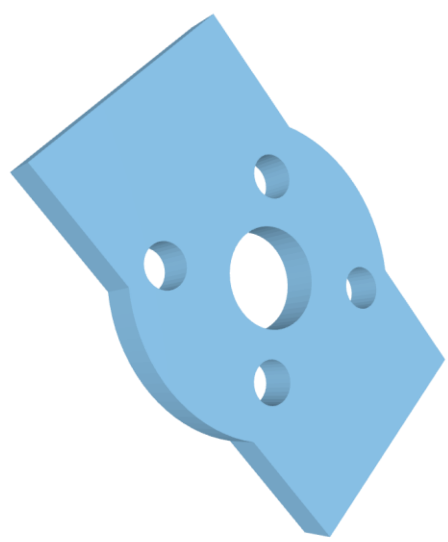


Fig 2.2.7: Motor mount 3D structure

Fig 2.2.8: Pump holder 3D structure

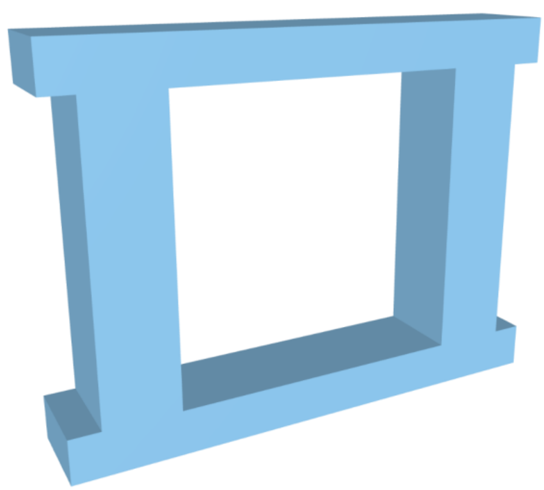


Fig 2.2.9: Tube motor mount holder 3D structure

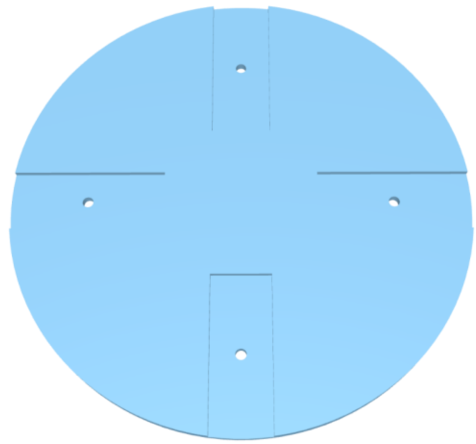


Fig 2.2.10: Middle shell 3D structure

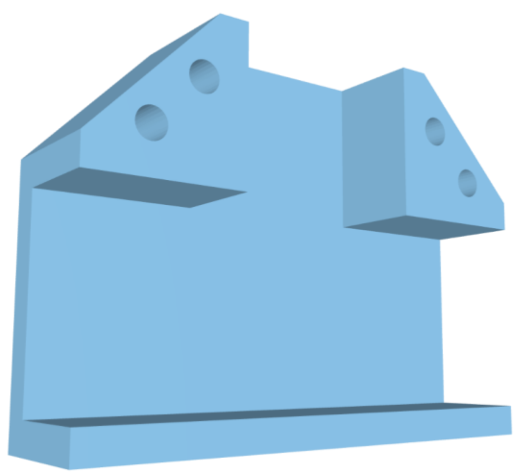


Fig 2.2.11: Tube joint 3D structure

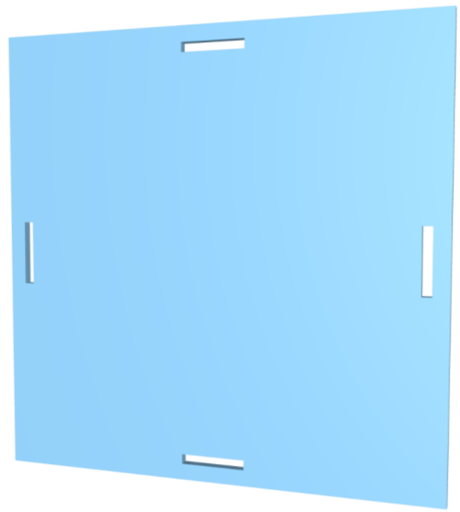


Fig 2.2.12: Top mount 3D structure

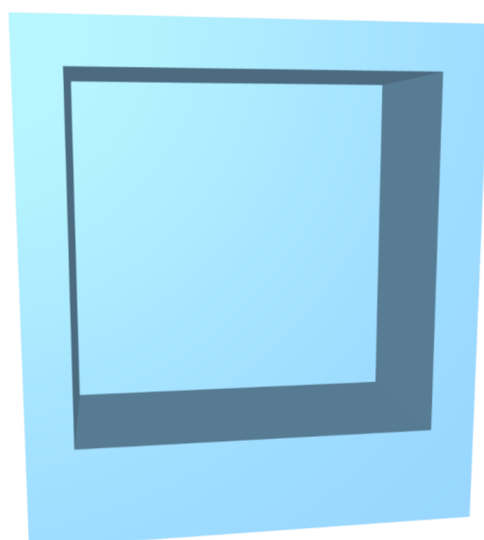


Fig 2.2.13: End Cover 3D structure

An experimental setup was designed to collect various motor performance data, including current (amperes), power, thrust, efficiency, and operating temperature at different throttle levels. The ambient room temperature during the tests was 29°C.

Motor Data (4 Motors) 5008 350KV Brushless Motor						
Throttle (%)	Voltage (V)	Current (A)	Power (W)	Thrust (g)	Efficiency (g/W)	Temp (℃)
25	22.2	8.317178	184.641	2188	11.85	21
40	22.2	15.35094	340.791	3275	9.61	26
50	22.2	18.08793	401.552	3622	9.02	28
60	22.2	20.98569	465.882	3960	8.5	28
75	22.2	24.68423	547.99	4362	7.96	30
90	22.2	35.62416	790.856	5449	6.89	30
100	22.2	45.85894	1018.069	5449	6.42	34

Table 2.2.1 Motor data for different level of throttle

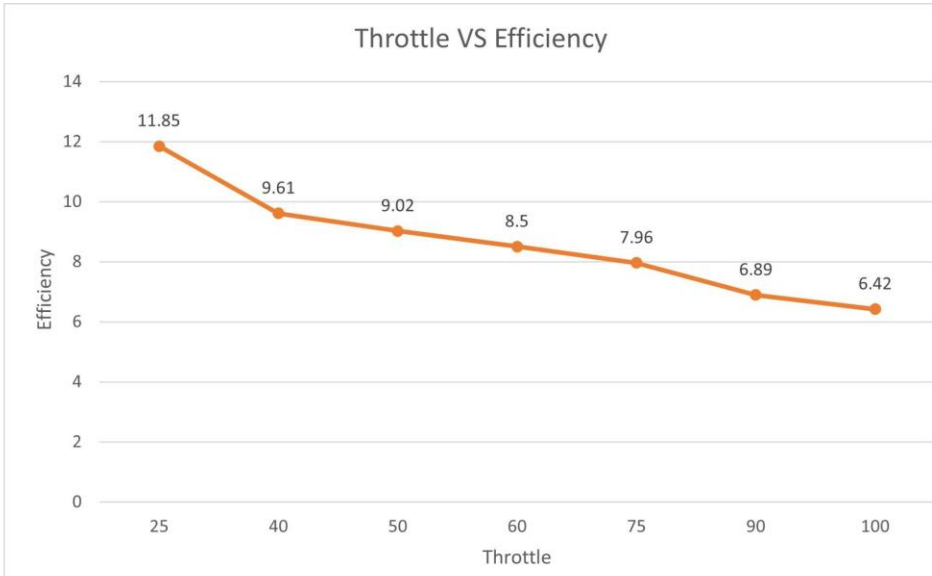


Fig 2.2.14 : Plot of motor throttle vs efficiency

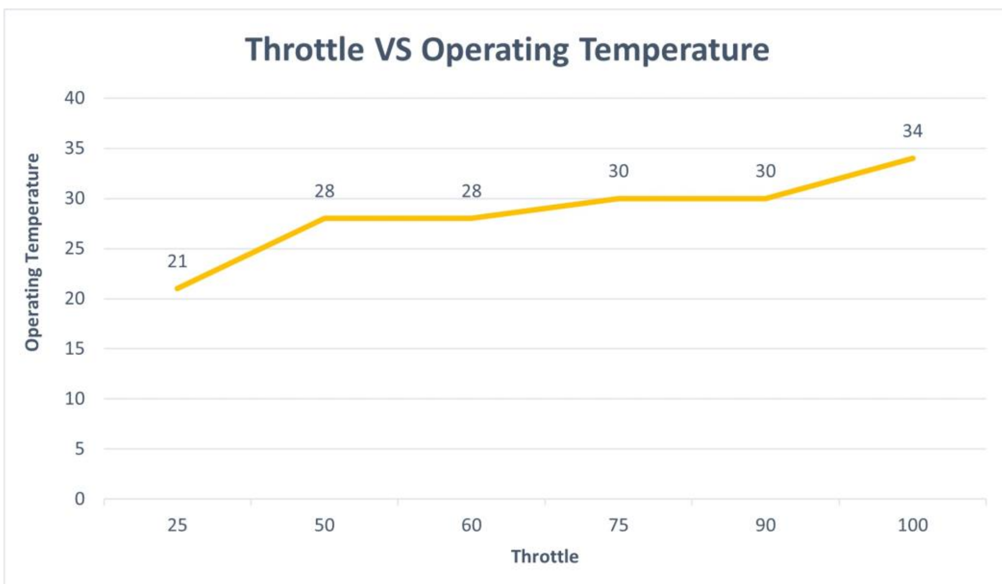


Fig 2.2.15: Plot of motor throttle vs operating temperature

From the data, it can be observed that efficiency is highest at 25% throttle, where the 5008 350KV motor with a 15-inch propeller draws 8.32A at 22.2V, generating 2188 grams of total thrust for four motors. However, at 50% throttle, each motor consumes 18.09A at 22.2V, producing 3622 grams of total thrust, which closely matches the required 3.6 kg (3600 g) for stable flight.

For optimal efficiency and maximum flight time, the total weight of the drone should ideally remain around 3.6 kg to ensure balanced performance without excessive power consumption.

Flight time calculation

Weight of the total drone with 1kg payload is 3.6kg. For generating 3.6 kg of thrust, the drone requires a total current draw of 18.08A at 22.2V.

Since additional onboard electronics consume a small amount of power, we estimate an extra 2A at 22.2V. Thus, the total current consumption of the air unit is: 18.08A + 2A = 20.08A.

Since the drone has four motors, the current drawn by each motor is - $\frac{20.08A}{4} = 5.02A$

In our design, we are using a 22.2V, 5800mAh (5.8Ah) Li-Po battery.

Discharge rate of the battery = $\frac{Current\ capacity\ of\ the\ Battery \times 60}{Total\ Current\ Draw}$

$$= \frac{5.8 \times 60}{20.08} = 17.33\ minutes.$$

So, the air unit will operate for a maximum of **17.3 minutes** on a single battery charge under ideal conditions.

To refine our final design, we conducted multiple tests based on our design requirements. In the previous section, we also explored alternative solutions. After developing the prototype, we will conduct further analyses, including coverage range, practical flight time, and maximum weight capacity. Additionally, we will develop the necessary code and fine-tune the UAVs PID controller through trial-and-error during the initial flight tests.

Schematic of the prototype -

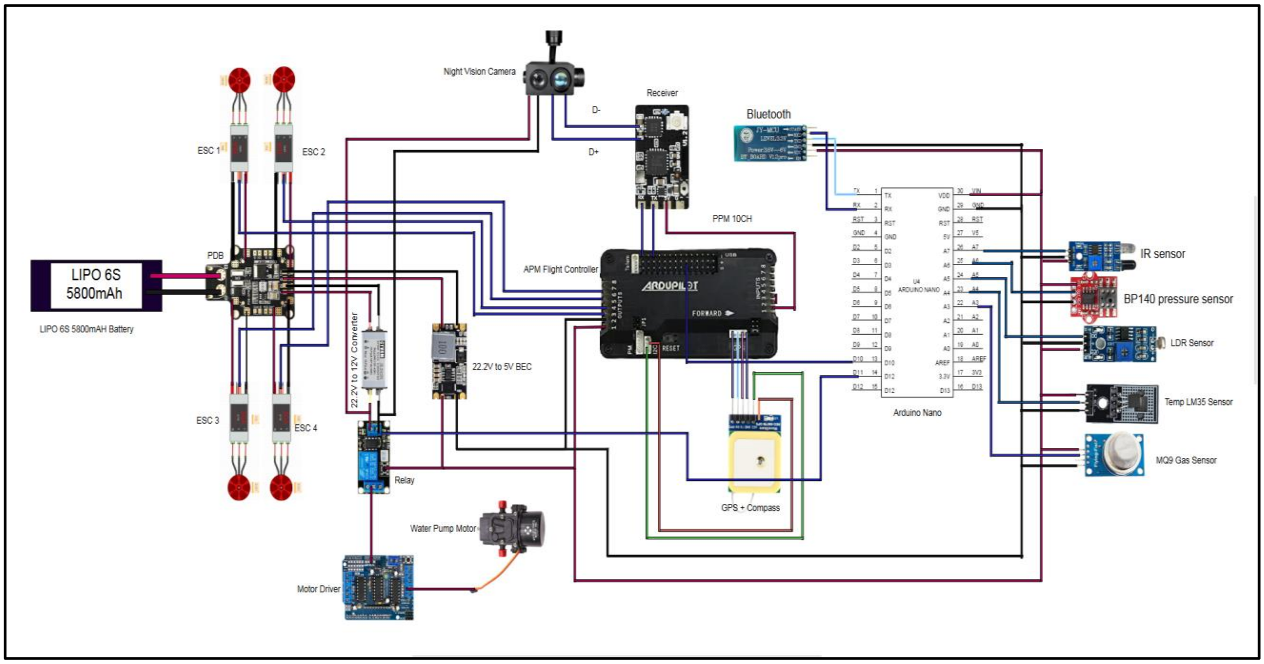


Fig 2.2.16 Schematic of the prototype that can carry 1.5 liter of water

2.3 Main solution - Firefighting drone that is capable of carrying 25 liter of water

This drone system is designed in an H-configuration and is capable of carrying 25 liters of water for fire extinguishing applications. It features eight high-thrust brushless motors, each generating 4555g of thrust at 10.19A and 48V, paired with 30×10" propellers for optimal lift. The system integrates an APM flight controller and an Arduino Nano for sensor management, enabling autonomous and remote-controlled operation. Various onboard sensors, including IR, pressure, LDR, temperature, and gas sensors, provide real-time environmental data. The drone is equipped with a night vision camera for enhanced visibility, an M8N GPS module for precise navigation, and a Bluetooth module for wireless communication. Additionally, a dedicated water pump system, controlled via a relay and motor driver, ensures efficient fire suppression.

Frame Layout

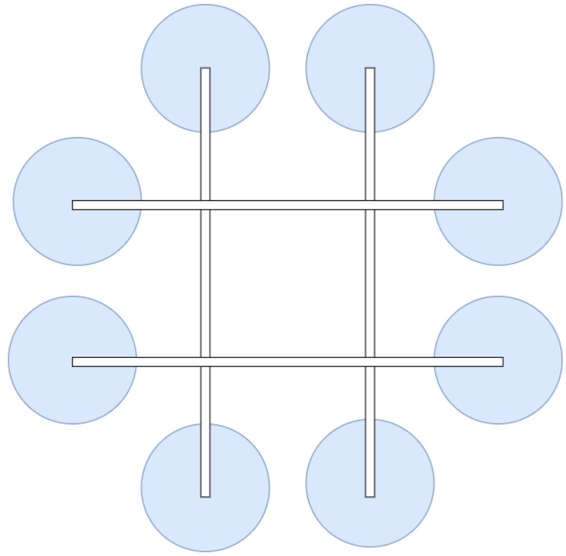


Fig 2.3.1 H-configuration

Analysis of H-configuration frame

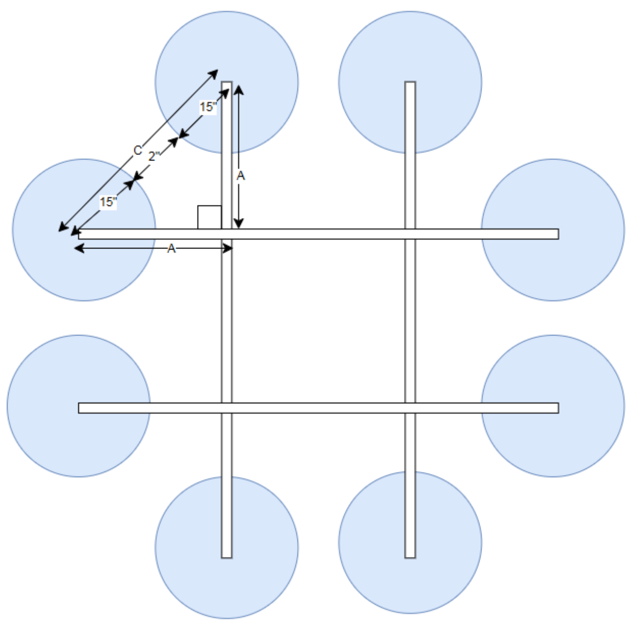


Fig 2.3.2 H-configuration frame measurement

Let’s define A as one third the length of each aluminum tube and C as the distance between two propellers.

Here C is equal to (15+2+15) = 32 inches.

From pythagorean theorem we can write -

$$A^2 + A^2 = C^2$$

$$=> 2A^2 = 32^2$$

$$=> A = \sqrt{1024}$$

$$=> A = 32 \text{ inches}$$

So, the length of single aluminum tube is ($3\times A$) = 96 inches

Total aluminum tube length for X-configuration is (4×96) = 384 inches.

The schematic of the main system is given bellow -

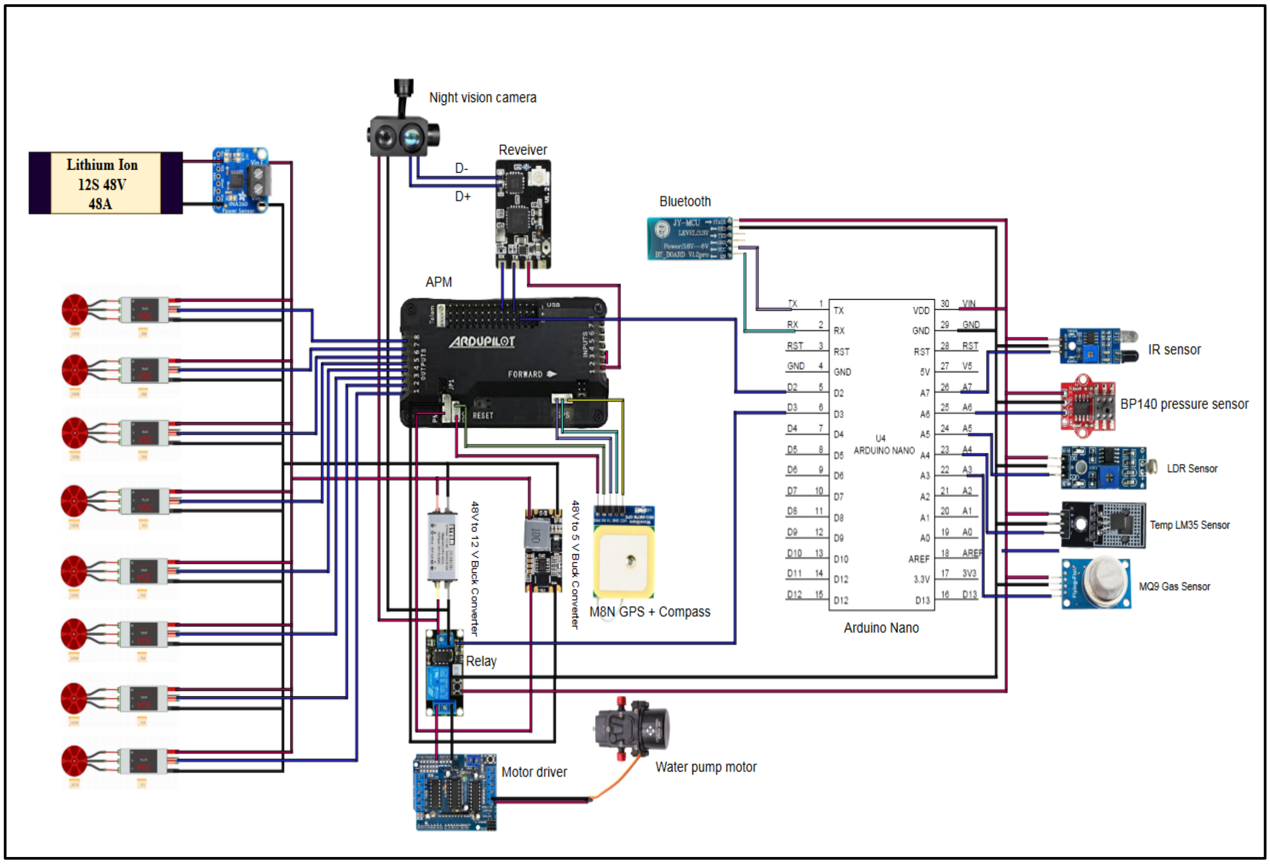


Fig 2.3.3 H configuration 25 liter firefighting drone

Drone simulation in eCalc software

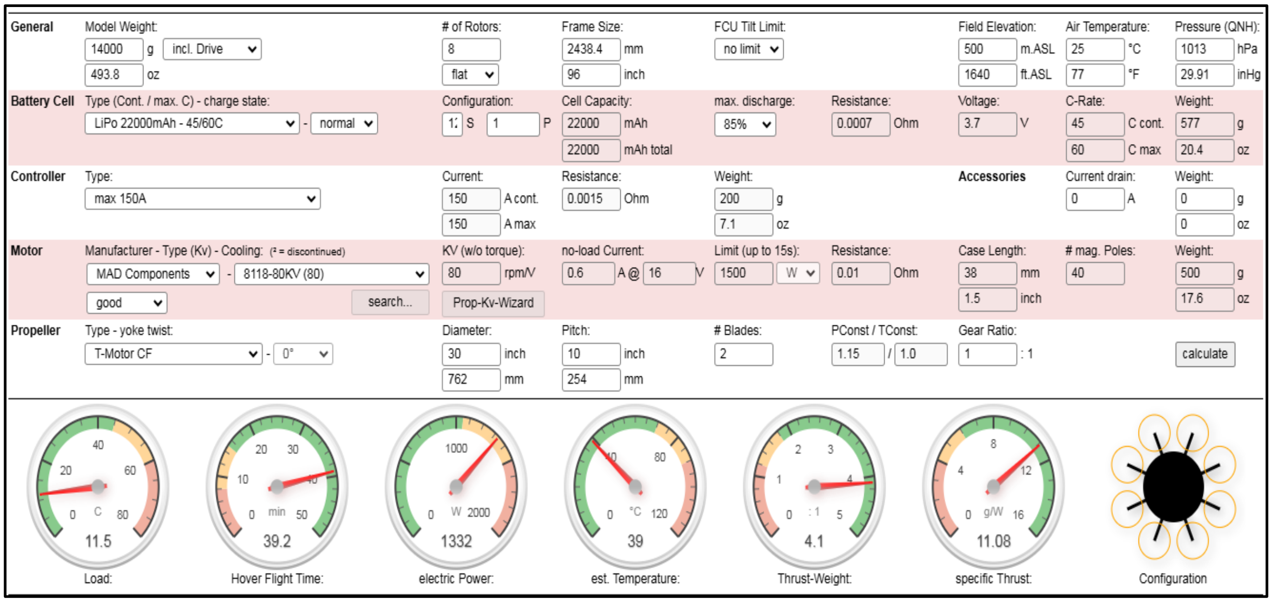
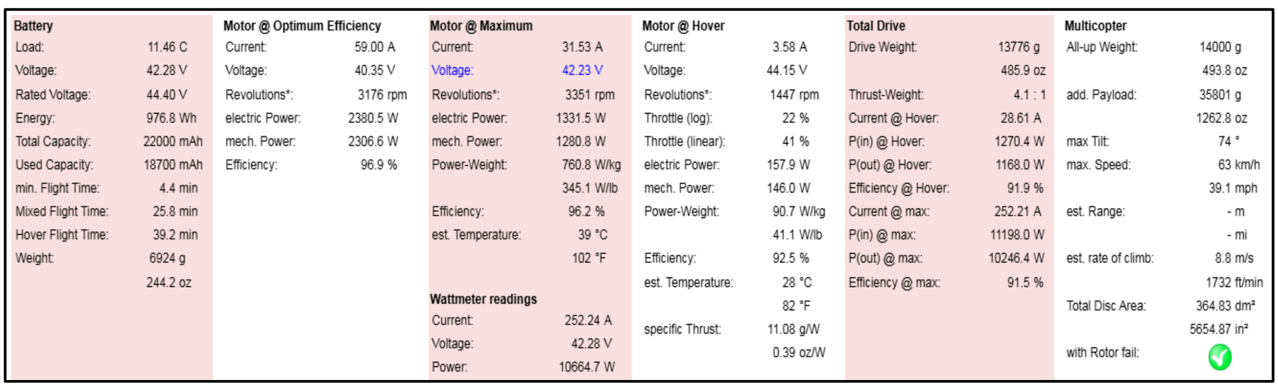


Fig 2.3.4 Model configuration with specific component model in eCalc



Battery	
Load:	11.46 C
Voltage:	42.28 V
Rated Voltage:	44.40 V
Energy:	976.8 Wh
Total Capacity:	22000 mAh
Used Capacity:	18700 mAh
min. Flight Time:	4.4 min
Mixed Flight Time:	25.8 min
Hover Flight Time:	39.2 min
Weight:	6924 g
	244.2 oz

Motor @ Optimum Efficiency	
Current:	59.00 A
Voltage:	40.35 V
Revolutions*:	3176 rpm
electric Power:	2380.5 W
mech. Power:	2306.6 W
Efficiency:	96.9 %

Motor @ Maximum	
Current:	31.53 A
Voltage:	42.23 V
Revolutions*:	3351 rpm
electric Power:	1331.5 W
mech. Power:	1280.8 W
Power-Weight:	760.8 W/kg
	345.1 W/lb
Efficiency:	96.2 %
est. Temperature:	39 °C
	102 °F
Wattmeter readings	
Current:	252.24 A
Voltage:	42.28 V
Power:	10664.7 W

Motor @ Hover	
Current:	3.58 A
Voltage:	44.15 V
Revolutions*:	1447 rpm
Throttle (log):	22 %
Throttle (linear):	41 %
electric Power:	157.9 W
mech. Power:	146.0 W
Power-Weight:	90.7 W/kg
	41.1 W/lb
Efficiency:	92.5 %
est. Temperature:	28 °C
	82 °F
specific Thrust:	11.08 g/W
	0.39 oz/W

Total Drive	
Drive Weight:	13776 g
	485.9 oz
Thrust-Weight:	4.1 : 1
Current @ Hover:	28.61 A
P(in) @ Hover:	1270.4 W
P(out) @ Hover:	1168.0 W
Efficiency @ Hover:	91.9 %
Current @ max:	252.21 A
P(in) @ max:	11198.0 W
P(out) @ max:	10246.4 W
Efficiency @ max:	91.5 %

Multicopter	
All-up Weight:	14000 g
	493.8 oz
add. Payload:	35801 g
	1262.8 oz
max Tilt:	74 °
max. Speed:	63 km/h
	39.1 mph
est. Range:	- m
	- mi
est. rate of climb:	8.8 m/s
	1732 ft/min
Total Disc Area:	364.83 dm²
	5654.87 in²
with Rotor fail:	✓

Fig 2.3.5 Model simulation and flight time calculation

The total flight time is found to be 39.2 minute

Mixed flight time is 25.8 min

Hover Power: 157.9W/Motor

Motor efficiency is Above 92% in all modes

Thrust-to-Weight Ratio: 4.1:1

Max Power Draw: 11,198 W (⚠️ Heavy Energy Demand at Max Load)

Additional Payload: Up to 35 kg (Heavy-Duty)

Max Speed: 63 km/h (~39.1 mph) (Fast Response)

Climb Rate: 8.8 m/s (1732 ft/min (Rapid Deployment)

Max Tilt Angle: 74° (Extreme Maneuverability)

Emergency Rotor-Fail Mode Supported

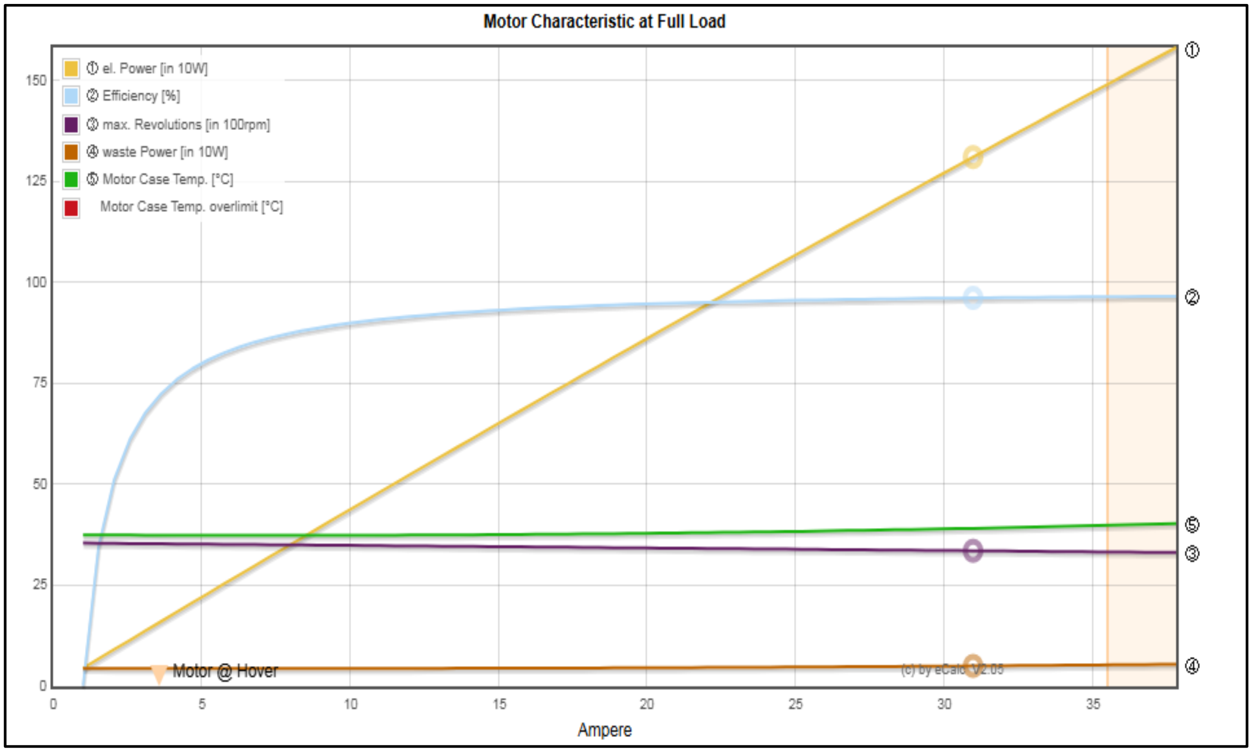


Fig 2.3.6 Motor characteristics at full load

The graph illustrates the motor's performance under full load conditions as current increases. Electrical power consumption rises linearly, while efficiency improves initially before stabilizing. The motor maintains relatively constant revolutions per minute (RPM), ensuring steady performance. Waste power, representing energy losses, increases gradually, and the motor case temperature rises accordingly, indicating heat buildup over time. The hover point shows the current level at which the motor operates efficiently without excessive power draw. The over temperature limit marks the critical threshold beyond which the motor risks overheating. From this analysis, it can be concluded that the motor operates efficiently within a safe current range, but exceeding 35A may lead to overheating and performance degradation. Proper cooling and current management are essential for maintaining long-term reliability.

Chapter 3 Demonstration of Implemented Solution and Finalization of Design

3.1 Development of the prototype

The development of our fire extinguisher drone has reached its final stage, where we demonstrate the implemented solution and finalize the design for practical deployment. This phase ensures that all components—aerial stability, fire suppression mechanism, control system, and structural integrity—function as intended under real-world conditions. The demonstration process involves testing the drone's flight performance, payload capacity, and fire extinguishing effectiveness in controlled environments. Key aspects such as motor efficiency, propeller thrust, landing stability, and fire suppression system accuracy are evaluated to verify the design's reliability. Any observed limitations or inefficiencies are addressed through design modifications and optimizations to ensure peak performance.

Finalizing the design includes reinforcing structural components, optimizing weight distribution, improving energy efficiency, and enhancing control precision. This ensures the drone is ready for real-world firefighting applications, capable of rapid response in hazardous situations where human access is limited.

Figure 3.1.1: Central Mounting Platform and Structural Frame

The central mounting platform is connected to a four-arm structural frame in the provided image. This combination forms the foundation of the fire extinguisher drone, ensuring stability and proper weight distribution. Here we can see the Central Mounting Platform with a Quad-Frame Structure.

A 3D-printed, double-layer circular platform is secured at the center of the frame. The top layer serves as the mounting area for electronics, such as the flight controller, GPS module, and power distribution board. The bottom layer can house additional structural reinforcements or the fire extinguishing system. The platform is bolted onto the frame, ensuring a firm and vibration-resistant connection. The drone features four sturdy arms extending from the center, arranged in an X-configuration. These arms are made of lightweight metal or carbon fiber to provide strength without adding excessive weight. The four arms act as motor mounts, where the propulsion system (motors and propellers) will be installed.

Figure 3.1.2: Three-phase brushless DC motors

To power the drone, four three-phase brushless DC motors were securely mounted on the quad-frame structure, one on each arm. These motors were chosen for their high efficiency, lightweight design, and precise speed control. The mounting was done using custom 3D-printed brackets, which were firmly attached to the aluminum arms with adhesive and bolts to ensure stability during flight. The motors are connected to Electronic Speed Controllers (ESCs), which regulate power distribution from the battery. The three-phase wiring was carefully routed along the arms to minimize interference and ensure smooth operation. This motor setup provides the necessary thrust and maneuverability for stable flight and controlled fire suppression.

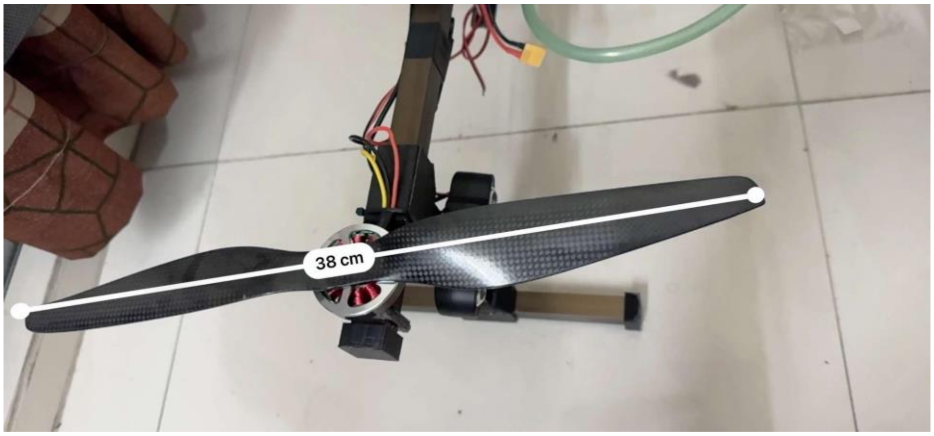


Figure 3.1.3: 38 cm carbon fiber propellers

To generate the required thrust for lifting the drone, 38 cm carbon fiber propellers were installed on each of the four motors. These high-strength, lightweight propellers were chosen for their efficiency and durability, ensuring optimal performance while reducing power consumption. The propellers are securely fastened to the motor shafts, ensuring stability during high-speed rotation. Their large diameter (38 cm) allows for greater airflow, generating sufficient lift to carry the fire extinguisher payload. Additionally, the propeller size was carefully matched with the motor’s KV rating and power output, ensuring balanced thrust and smooth flight control.

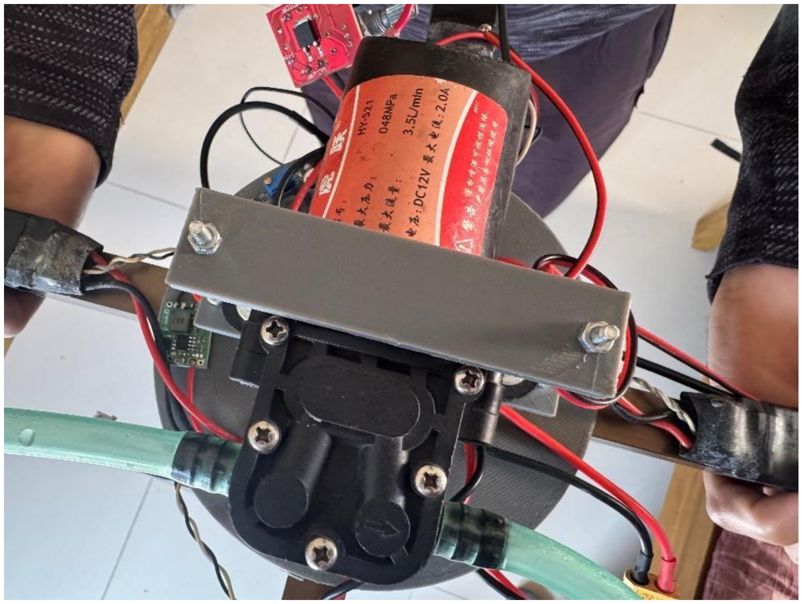


Figure 3.1.4: Water pump

Here the integration of a water pump into the fire extinguisher drone's system reveals a critical component for delivering the extinguishing agent. A black water pump, clearly labeled with specifications such as voltage (DC 12V), maximum current (2.0A), maximum pressure (0.48MPa), and maximum flow rate (3.5L/min), is securely mounted atop a gray platform, likely 3D-printed or custom-fabricated for this purpose. This platform is then affixed to the drone's central chassis, ensuring the pump is rigidly attached. Red and black wires directly connected to the pump provide power, while clear tubing is visible connecting to both the intake and output ports of the pump. This tubing suggests a system where water is drawn from a reservoir (not pictured) and expelled through the output tube towards the fire. The presence of a small red circuit board near the top of the image hints at an electronic control mechanism for the pump, potentially allowing for remote activation or adjustments in flow rate as needed. This setup confirms the drone's liquid-based fire suppression approach, utilizing a pump to propel water toward the target.

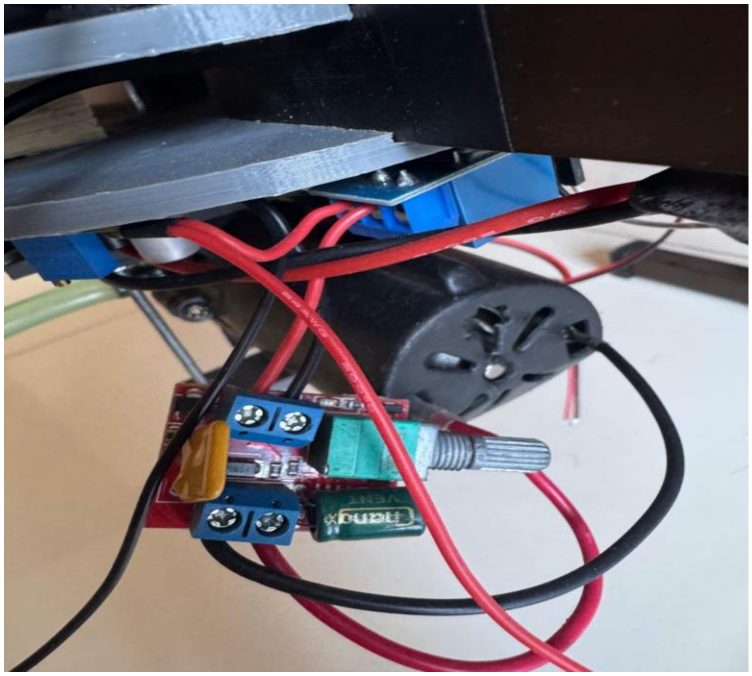


Figure 3.1.5: Speed control mechanism for water pump

Here is the speed control mechanism for the fire extinguisher drone's water pump, centered around a Pulse Width Modulation (PWM) regulator. A DC motor, connected via red and black wires, powers the pump, while the red rectangular PWM regulator board manages the motor's speed. A prominent green potentiometer, labeled "VENT," allows for manual adjustment of the motor speed by varying the resistance and thus the duty cycle of the PWM signal sent to the motor. Blue capacitors on the board likely contribute to voltage filtering. This setup enables manual control of the water flow rate, useful for testing and potentially for variable fire suppression, though automated control might be implemented later.

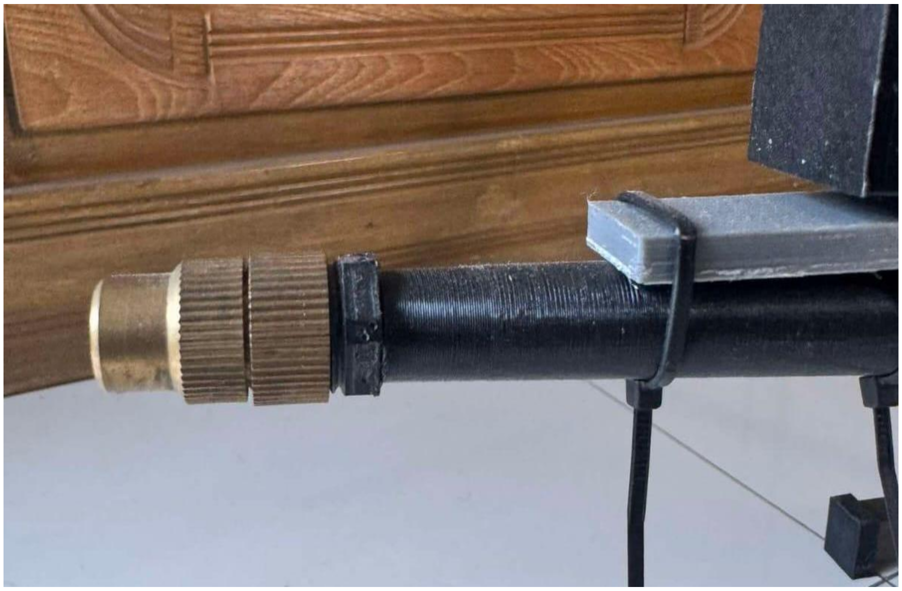


Figure 3.1.6: Water spray nozzle

The water delivery nozzle of your fire extinguisher drone is a crucial component for directing the extinguishing agent towards the fire. The nozzle appears to be constructed from a black plastic or composite material, likely chosen for its lightweight and durable properties. It's attached to a black tube, which presumably connects to the water pump (as seen in previous images). The nozzle's design suggests a focus on creating a focused stream of water, rather than a wide spray. The tip of the nozzle, made of a gold-colored metal, likely brass, suggests durability and resistance to corrosion. The presence of threads on the metal tip may indicate that it's detachable or adjustable, potentially allowing for different nozzle tips to be used for varying spray patterns. The overall design appears simple and functional, prioritizing directed water delivery for effective fire suppression.

Figure 3.1.7: Camera for fire

This camera unit is a crucial component for your fire extinguisher drone, providing a combination of visual and communication capabilities. The prominent circular lens at the front captures video, offering a wide field of view for navigation and situational awareness. This real-time video feed is essential for the pilot to guide the drone, especially when maneuvering in complex environments or close to potential fire hazards. The unit's compact design integrates the camera with other functionalities, potentially including video transmission and control signals, simplifying the drone's overall system architecture.

Its robust housing suggests it's designed to withstand the rigors of flight and potentially challenging environmental conditions. Beyond navigation, the camera's imagery could be used for fire detection (either manually by the pilot or through automated image processing) and precise targeting of the extinguishing agent.

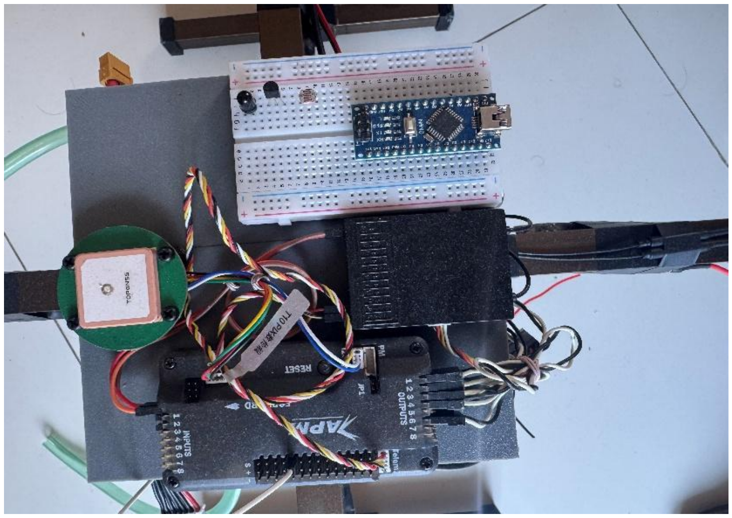


Figure 3.1.8: Component of upper part

Here we have the core electronics and control systems of the fire extinguisher drone.

1. **APM (ArduPilot Mega) Flight Controller:** The prominent blackboard labeled "APM" is the heart of the drone. This sophisticated flight controller houses a powerful microprocessor, gyroscopes, accelerometers, barometers, and other sensors to stabilize the drone, interpret commands, and manage flight operations. It's pre-programmed with flight control software, enabling autonomous navigation, altitude hold, and other advanced features.
2. **GPS Module (Green Circle):** The green circular module with a clear top is a GPS receiver. It acquires signals from GPS satellites to determine the drone's precise location, altitude, and speed. This is crucial for enabling autonomous flight modes like return-to-home, waypoint navigation, and loitering.
3. **Telemetry Module (Black Rectangle with Pins):** The black rectangular module with pins is likely a telemetry radio. It transmits data wirelessly between the drone and a ground control station (typically a laptop or tablet). This data includes flight parameters (altitude, speed, battery level), GPS location, and sensor readings. It also allows for real-time control of the drone and adjustments to its settings from the ground.
4. **Receiver (Smaller Black Rectangle):** The smaller black rectangle is likely a radio receiver. It receives control signals from the remote control transmitter operated by the pilot. These

signals translate the pilot's stick movements into commands for the flight controller, directing the drone's movements.

5. **Arduino Nano (Blue Board on Breadboard):** The blue board mounted on a white breadboard is an Arduino Nano microcontroller. This likely serves as a custom control unit for specific functions, possibly including the fire extinguishing mechanism. It might receive commands from the APM or the ground control station to activate the water pump or release the extinguishing agent. The breadboard facilitates easy prototyping and connection of the Arduino to other components.

6. **Sensors:** Here a fire extinguisher drone is equipped with multiple sensors for fire detection and environmental monitoring. The LDR detects changes in light intensity, helping to identify flames, while the LM35 measures temperature to sense heat variations. An IR sensor detects infrared radiation from a fire, aiding in navigation and flame detection. The BP140 pressure sensor monitors air or gas pressure, which can be useful for drone stability or detecting pressure changes in hazardous environments. Lastly, the MQ-9 gas sensor detects combustible gases like carbon monoxide and methane, ensuring early warning of dangerous fumes. Together, these sensors enhance the drone's effectiveness in firefighting and safety operations.

Figure 3.1.9: Developed prototype

3.2 Performance evaluation of implemented solution against design requirements

We checked almost all of the component and sensor's performance analysis by undergoing some experiment.

1) Drone Stability

We have hovered the drone for 15 minutes while it was locked by 13 to 14 satellites. From the GPS position data we have recorded 0.7 meter horizontal drift and 1 meter vertical drift. From the data we can say that the drone was quite stable.

2) Wind resistance

We used a 1500 watt blower to test the wind resistivity of the drone. We tested with an anemometer and saw that, up to 44 km/h speed the drone was quite stable on its position. So the drone is level 6 wind resistant.

3) Motor heat analysis

We have flown the drone for continuous 34 minutes and logged the motor temperature using an infrared thermometer.

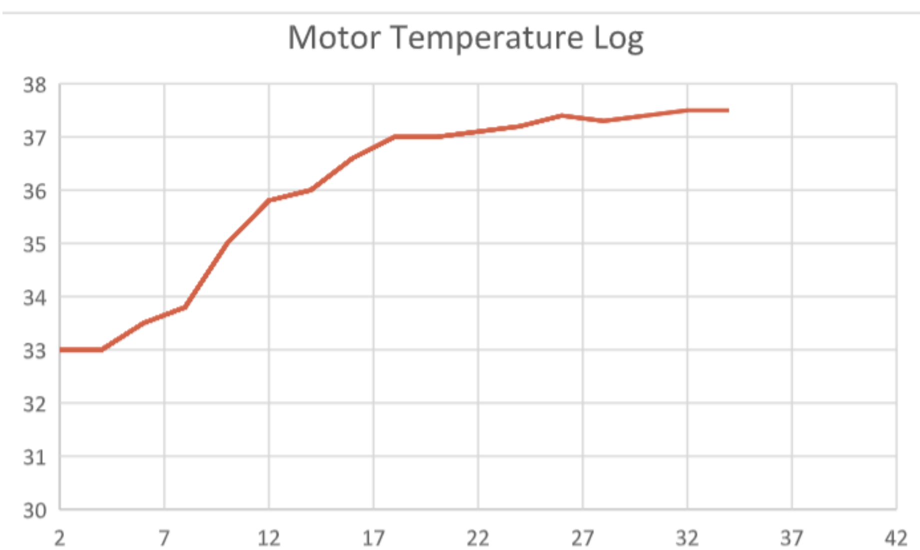


Fig: 3.2.1 Motor Temperature Log

-IR thermometer

4) Weather station data Arduino serial monitor

We have tested our weather station in various conditions and we saw that it is working perfectly.

We use Arduino IDE software to check IR sensor value.

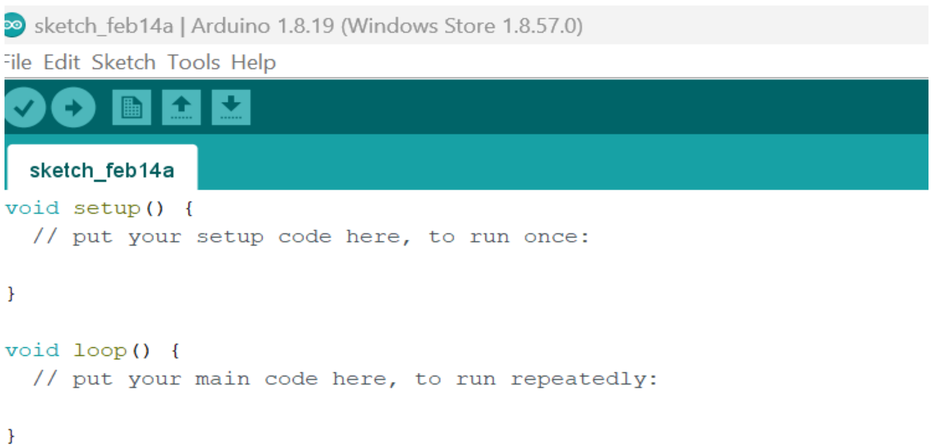


Fig: 3.2.2 Arduino IDE software

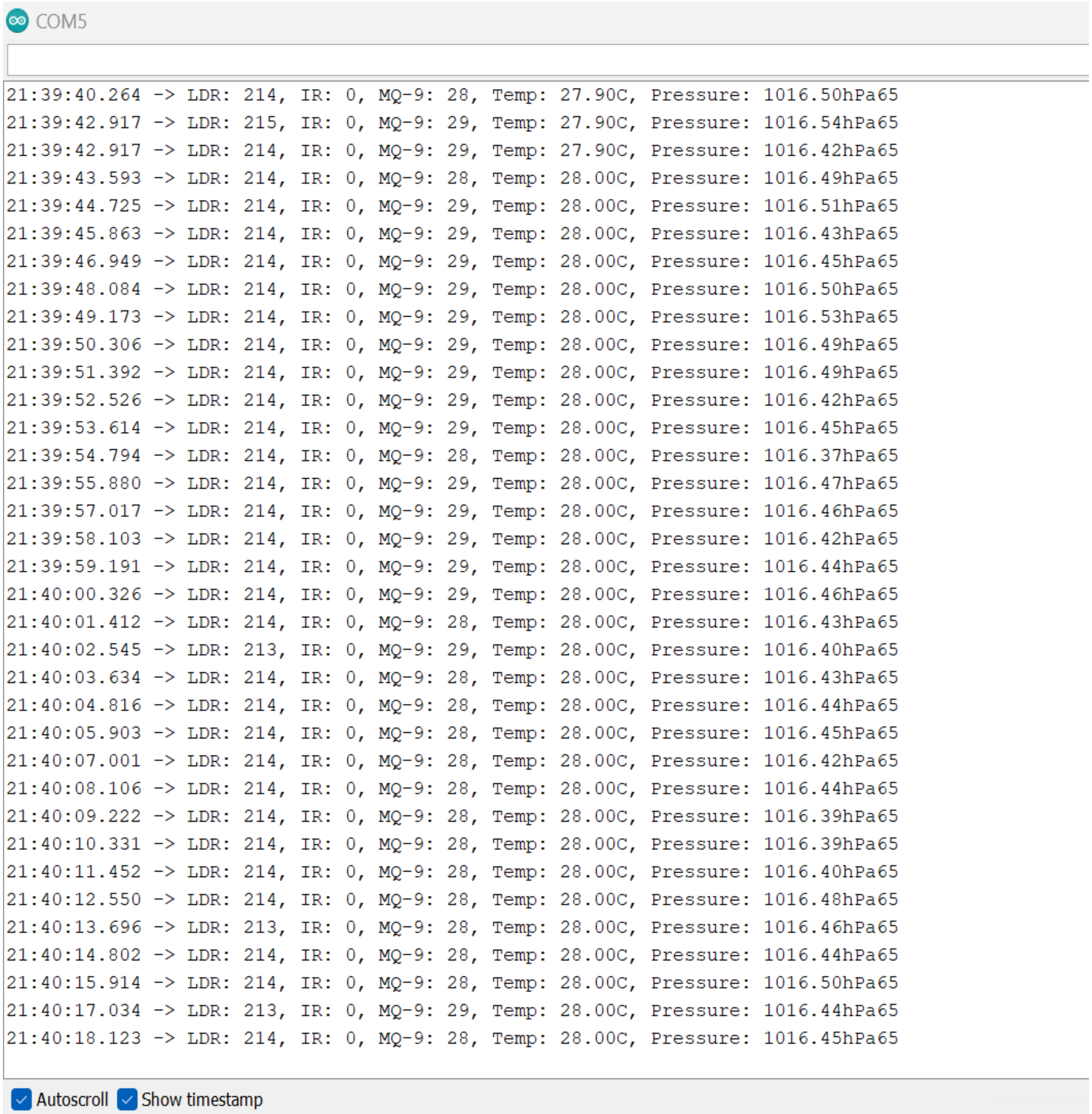


Fig: 3.2.3 All sensor data through software. (LDR / IR / MQ-9 / Temperature sensor / Pressure Sensor)

```
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
IR: 0,
```

Fig: 3.2.4 IR sensor

Comment: Before fire hazard or any kind of fire, we see there is 0 value in the IR sensor.

5) MQ Gas sensor

Sensitivity: Detects CO, methane, and LPG effectively, useful for early fire detection.

Response Time: 10–30s, good for gas detection but slower than thermal cameras.

Power Efficiency: Low (~150mW), but requires continuous heating.

Environmental Impact: Works in -10°C to 50°C, affected by humidity and airflow.

Integration: Easy with microcontrollers, but needs calibration.

```
, MQ-9: 40,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 40,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 39,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 38,
, MQ-9: 37,
, MQ-9: 38,
, MQ-9: 37,
, MQ-9: 37,
, MQ-9: 37,
, MQ-9: 37,
, MQ-9: 37,
, MQ-9: 37,
, MQ-9: 37,
, MQ-9: 36,
, MQ-9: 36,
```

Fig: 3.2.5 There is no change in MQ-9 gas sensor before fire.

```
MQ-9: 56,
MQ-9: 56,
MQ-9: 56,
MQ-9: 55,
MQ-9: 56,
MQ-9: 56,
MQ-9: 58,
MQ-9: 61,
MQ-9: 64,
MQ-9: 69,
MQ-9: 67,
MQ-9: 66,
MQ-9: 64,
MQ-9: 118,
MQ-9: 304,
MQ-9: 346,
MQ-9: 320,
MQ-9: 307,
MQ-9: 270,
MQ-9: 233,
MQ-9: 198,
MQ-9: 172,
MQ-9: 165,
MQ-9: 165,
MQ-9: 228,
MQ-9: 197,
MQ-9: 247,
MQ-9: 344,
MQ-9: 341,
MQ-9: 274,
MQ-9: 229,
MQ-9: 188,
MQ-9: 156,
MQ-9: 132,
MQ-9: 114,
```

Fig: 3.2.6 After sensing fire MQ-9 change

6) Temperature sensor:

Any kind of temperature our sensor detects. here are the simulation result:

```
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.40C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.40C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
Temp: 30.50C,
```

Fig: 3.2.7 Temperature sensor works effectively before any kind of fire.

```
Temp:  30.40C,
Temp:  30.40C,
Temp:  50.40C,
Temp:  50.40C,
Temp:  60.40C,
Temp:  60.40C,
Temp:  70.40C,
Temp:  70.40C,
Temp:  80.40C,
Temp:  80.40C,
Temp:  90.40C,
Temp:  90.40C,
Temp:  100.40C,
Temp:  100.40C,
Temp:  130.40C,
Temp:  130.40C,
Temp:  130.40C,
Temp:  150.40C,
Temp:  150.40C,
Temp:  170.40C,
Temp:  200.40C,
Temp:  200.40C,
Temp:  200.40C,
Temp:  200.40C,
Temp:  200.40C,
Temp:  200.40C,
Temp:  230.40C,
Temp:  230.40C,
Temp:  230.40C,
Temp:  200.40C,
Temp:  150.40C,
Temp:  130.40C,
Temp:  100.40C,
Temp:  50.40C,
Temp:  30.40C,
Temp:  31.40C,
Temp:  30.40C.
```

Fig: 3.2.8 Temperature changes after sensing fire

7) GPS:

We use GPS for location detection. Through GPS we detect the speed of our drone and it’s all position and live location. We use MIssion Planner software for GPS.

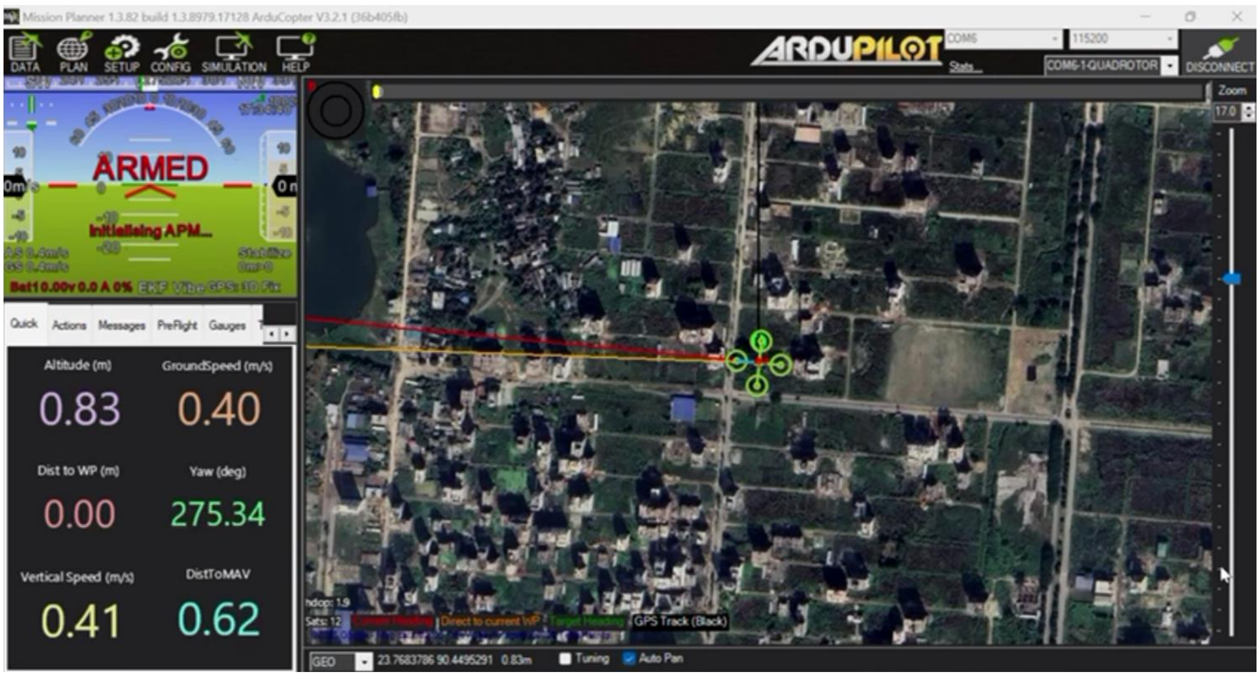


Fig: 3.2.9 GPS location (Drone speed)

Sensor performance Comparison:

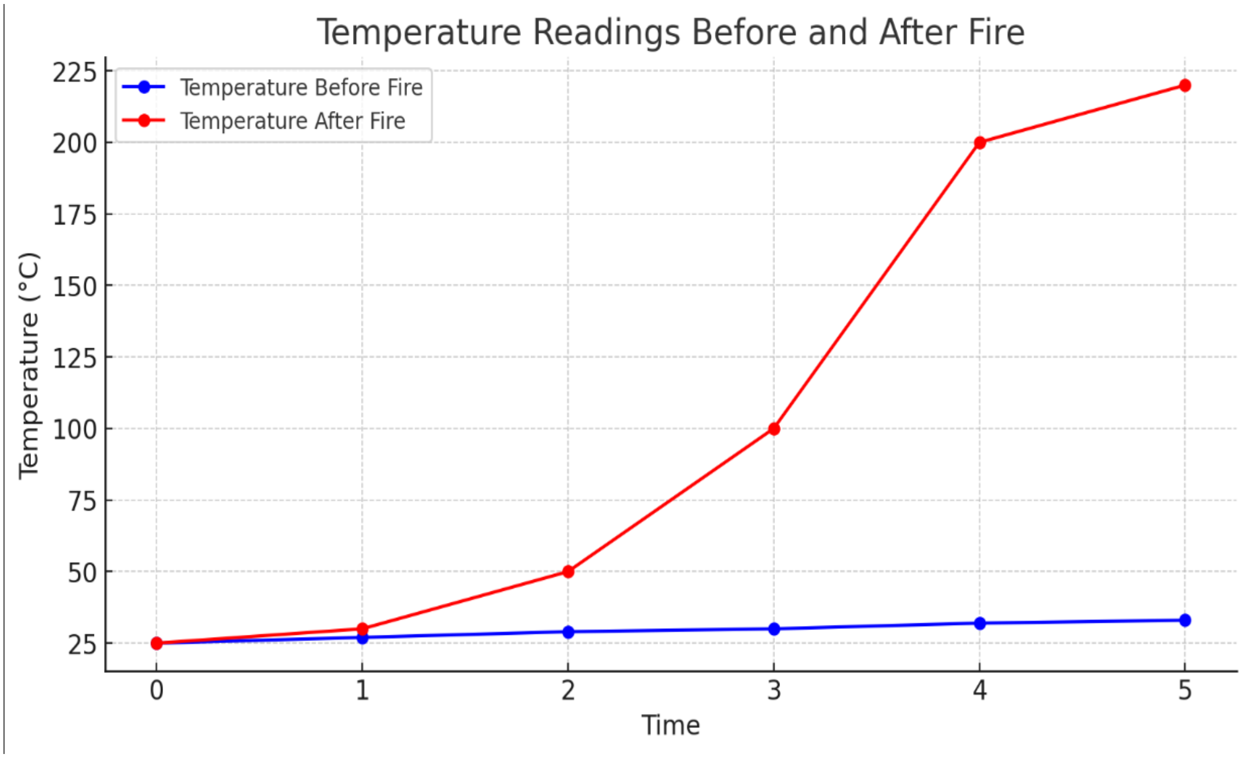


Fig: 3.2.10 Temperature sensor performance

The first graph compares temperature readings before and after the fire. The blue line represents the temperature before the fire, showing a relatively stable trend with only slight increases over time. In contrast, the red line, which represents temperature after the fire, shows a sharp increase. This indicates a significant rise in temperature due to the fire, with values reaching over 200°C, compared to the pre-fire condition where temperature remained close to 25°C.

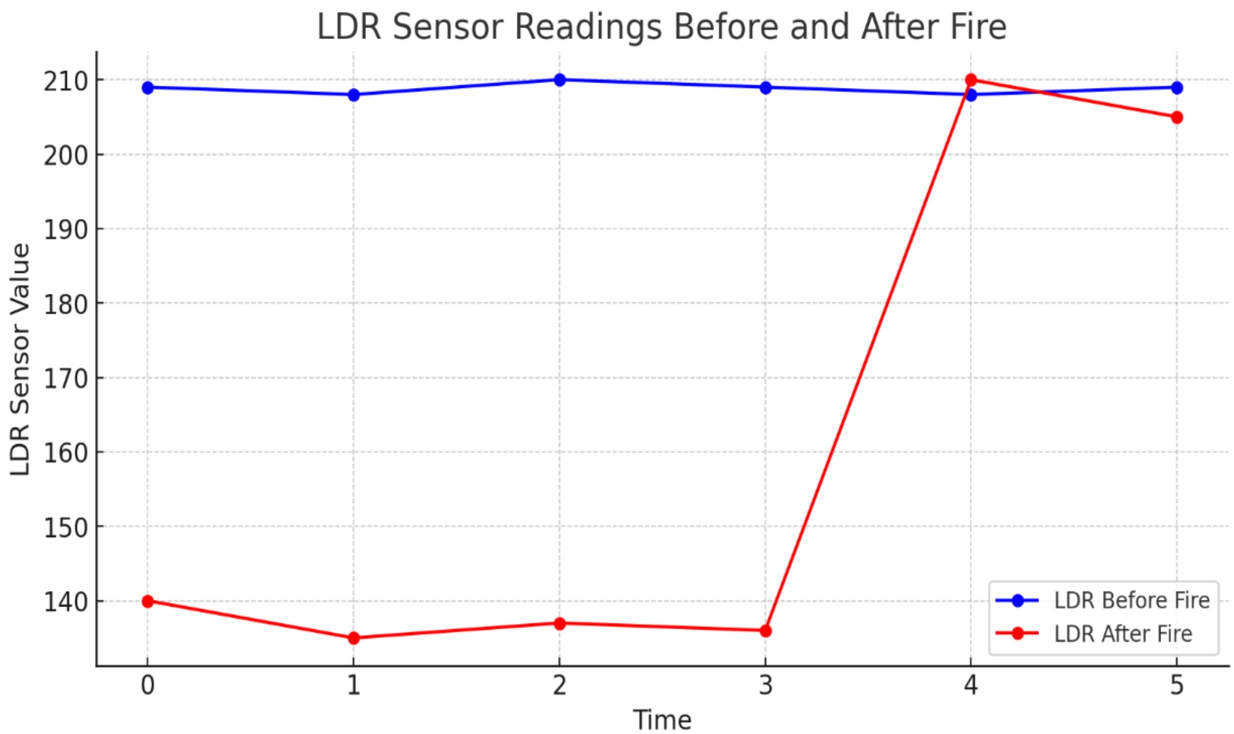


Fig: 3.2.11 LDR sensor performance

The second graph represents the readings from the LDR (Light Dependent Resistor) sensor before and after the fire. The blue line shows that the sensor readings before the fire were stable, maintaining values around 210. However, the red line, representing readings after the fire, initially shows a drop in LDR values, followed by a sharp increase at the later stages. This suggests that the fire caused a temporary decrease in light detection, possibly due to smoke, before the sensor detected increased light intensity, likely due to flames.

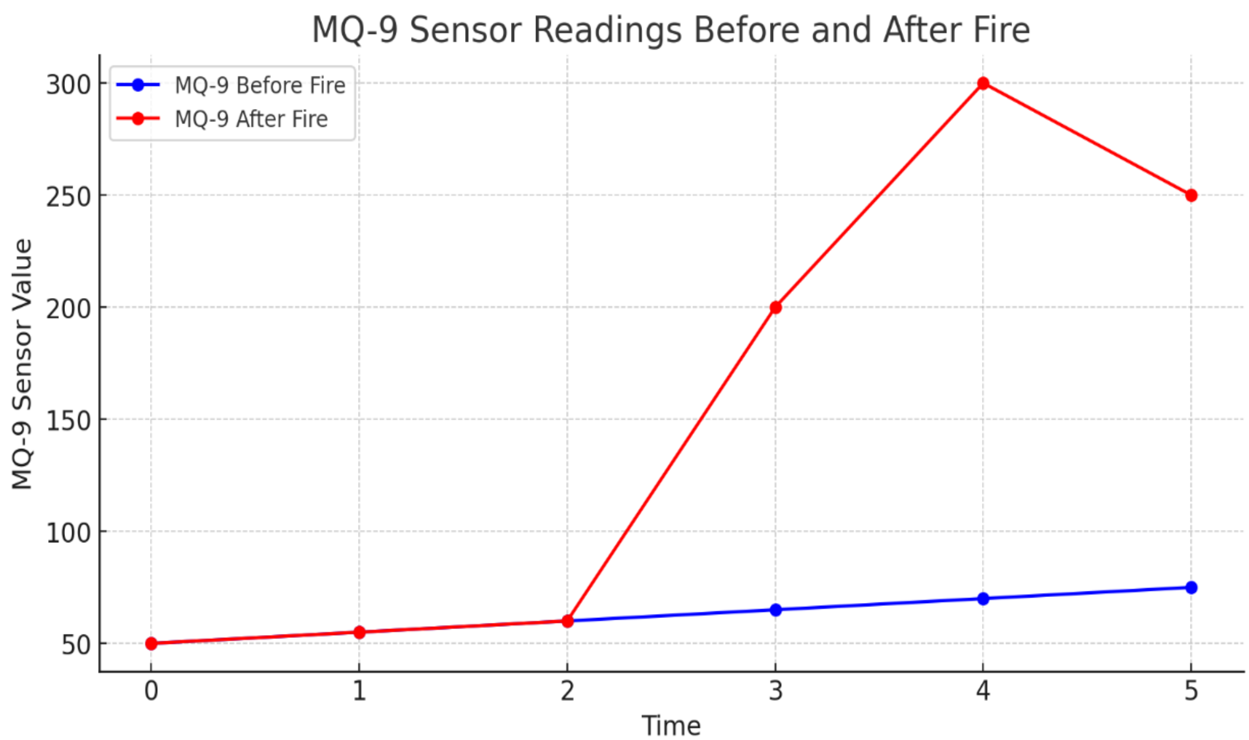


Fig: 3.2.12 MQ-9 gas sensor performance

The third graph compares the MQ-9 gas sensor readings before and after the fire. The blue line indicates a steady, low level of gas concentration before the fire. However, the red line shows a sharp increase in gas levels after the fire, peaking at over 300 before slightly decreasing. This suggests that the fire led to a significant release of gases, which were detected by the sensor, indicating the presence of combustion byproducts.

Table 3.2.1: Performance Evaluation

Evaluation Criteria	Test Parameters	Results (Example)	Efficiency (%)
IR Sensor Accuracy	Detection range, response time	Detects fire up to 7 meters	90%
BP140 Pressure Sensor Accuracy	Pressure measurement precision	± 5 Pa error	92%
LDR Sensor Accuracy	Sensitivity to fire brightness	Detects light above 500 lumens	88%
LM35 Temperature Sensor Accuracy	Temperature detection range & response time	± 2˚C error	85%
MQ9 Gas Sensor Accuracy	Smoke and gas detection range	Detects CO at 200 ppm	87%

Combined Sensor Accuracy	Cross-verification of fire detection data	False alarm rate:5%	90%
Pump Motor Efficiency	Water flow rate, power consumption	2L/min 50watts	89%
Water Throw Distance	Maximum reach of water spray	3 meters	85%
GPS+ Compass Accuracy	Position holding, navigation precision	Error ± 1 Meter	95%
Fire Extinguishing Test	Area extinguished with 1.5L water over time	Covers 2 meter in 5 seconds	88%
Drone Stability While Spraying	Effect of water spray on drone balance	Minimal drift, stable hover	90%
Response Time	Time from detection to suppression	8 seconds	86%
Wind Resistance	Performance under different wind speeds	Effective up to 5m/s	80%
Battery Consumption	Power usage per fire extinguishing operation	12% battery used per cycle	87%

3.3 Finalization of design

The finalization of the fire-extinguishing drone's design was based on performance evaluation and real-world testing. Several refinements were made to enhance system efficiency and compliance with design requirements.

1. Design Improvements Based on Performance Evaluation

- Structural Reinforcement: The central mounting platform and four-arm structural frame were optimized for better weight distribution and stability.
- Battery Efficiency: The drone operates for 17.3 minutes per charge, which is sufficient for short-term fire suppression but could be improved by integrating higher-capacity batteries or optimizing power consumption.
- Control System Optimization: The PID controller was fine-tuned through trial-and-error flight testing, ensuring improved stability and navigation accuracy.

2. Demonstrated Improvements Through Testing

- Flight Stability: GPS tests showed minimal horizontal (0.7m) and vertical (1m) drift, proving adequate stability.
- Wind Resistance: The drone remained stable against wind speeds up to 44 km/h (Level 6 wind resistance), confirming its reliability in outdoor conditions.
- Motor and Heat Analysis: Continuous 34-minute flight tests monitored motor temperatures to ensure safe operation.

3. Potential Areas for Further Improvement

- Extended Battery Life: Exploring lighter battery options or alternative energy sources could extend flight duration.
- Payload Optimization: Reducing unnecessary weight and enhancing fire suppression efficiency could improve overall performance.
- AI-Based Navigation: Future iterations could incorporate machine learning for fire detection and autonomous response.

3.4 Use of modern engineering tools

1) Arduino IDE

The Arduino IDE (Integrated Development Environment) is a Software which contains a text editor for writing code, a serial monitor and some other useful functions. It helps to upload the code to the Arduino microcontroller.

2) Fusion 360

Fusion 360 is an excellent tool for the precise modeling of 2D and 3D objects. We designed our 3D printed part with the help of this software.

3) Tinkercad

Tinkercad is a powerful and easy-to-use tool for building 3D designs.

4) 3D printing machine.

3D printing machines are specialize in making custom 3d design parts with good accuracy. 3D printer’s works by adding material, layer-by-layer, to form a 3D object from a 3d design file.

5) IR thermometer

Infrared thermometers are very useful for measuring temperatures that need to be tested from a specific distance. It can give accurate temperature data without getting too close to a specific object.

Chapter 4 Review of Milestone Achievements and Revision of Schedule

Activity No.	Activities	Duration [Week]	Predecessor	On-Time/ Delay
1	Topic selection	2	-	On-Time
2	Approving the topic idea from the supervisor	2	1	On-Time
3	Prove social relevance, complex engineering and design problems (Milestone - 1)	3	2	On-Time
4	Literature Review, Identify the stakeholders and prepare questionnaires for the stakeholders.	4	2&3	On-Time

5	Proceeding with the stakeholder survey and finalizing the requirements (Milestone - 2)	3	4	On-Time
6	Identification of the impact of the project on society, Identification of the effect of the project on the environment, sustainability, health, and safety issues & Reviewing standards and codes of practice	1	4	On-Time
7	Project plan and Risk management	1	6	On-Time
8	Identifying required resources and budget and Analysis of project product lifecycle (Milestone - 3)	1	5&6	On-Time
9	Preliminary design of the system	3	8	On-Time
10	Analysis of alternate solution and verify the preliminary design (Milestone - 4)	4	9	On-Time

11	Cost Optimization	1	10	On-Time
12	Preparing Project concept and Proposal report (Milestone - 5) 400(I)	2	11	On-Time
13	Find out equipment availability	2	12	On-Time
14	Preparation of draft design	2	13	On-Time
15	Purchase equipment	4	14	Delay
16	Implementation	3	15&16	Delay
17	Performance evaluation of the system	2	16	Delay
18	Finalization of design based on performance evaluation (Milestone - 6)	1	17	On-Time
19	Demonstration of the working product And Bill of materials cost of the solution and Economic analysis	1	18	On-Time
20	Preparing final report of 400(II) (Milestone - 7**)**	**2**	**19**	**On-Time**

Table 4.1 Activity chart and revision of schedule

Purchase equipment delay: The project faced several delays, primarily due to challenges in acquiring the necessary components for the fire-extinguishing drone. Supplier issues, extended delivery times, and the unavailability of certain parts were significant obstacles. Additionally, sourcing some components from abroad added further complexity and impacted the timeline. These procurement challenges disrupted progress, as work could not proceed without all the essential materials. Alongside these issues, delays also stemmed from unclear requirements, insufficient resources, and unforeseen technical challenges. These delays hindered overall progress, as work could not resume until all the necessary materials were obtained.

Implementation delay: The implementation phase of our capstone project, a fire extinguisher drone, was delayed due to several technical challenges. Hardware integration issues arose as we worked to ensure seamless functionality between components such as motors, sensors, and the fire-extinguishing mechanism. Additionally, weight and balance problems caused by the payload and other equipment impacted the drone's stability and required adjustments to its design. Flight stability and control proved challenging, especially under varying environmental conditions, necessitating further tuning and testing. Navigation difficulties, including maintaining accuracy in potentially obstructed or complex environments, also contributed to the delays, requiring additional development time to address these issues effectively.

Performance evaluation delay: The delay in the implementation phase of our capstone project, a fire extinguisher drone, caused a subsequent delay in the performance evaluation phase. Since the hardware integration, weight and balance issues, flight stability, and navigation challenges required additional time to address, the testing and optimization processes could not proceed as scheduled. Moreover, procurement delays for essential components, along with iterative adjustments and troubleshooting, further pushed back the timeline. These setbacks prevented us from evaluating the drone's performance under real-world conditions, as critical implementation milestones had to be completed first. Consequently, the overall progress of the project was significantly impacted.

Chapter 5 Cost of Solution and Economic Analysis

We conducted hardware implementation and software simulation to develop an elevator control system. While software simulations did not incur any direct costs, we had to allocate funds for the hardware implementation.

5.1 Bill of materials cost of solution

Table 5.1.1 Cost of the developed solution

SL	ITEM	QTY	RATE	PRICE
1	Custom Made Aluminum Frame (X)	1	BDT 2,000	BDT 2,000
2	Filament for 3D Print	1	BDT 1,800	BDT 1,800
3	5008 350KV Brushless Motor	4	BDT 2,900	BDT 11,600
4	15 inch Carbon Fiber Propeller	4	BDT 800	BDT 3,200
5	Hobbywing X-Rotor 30A 6S ESC	4	BDT 1,600	BDT 6,400
6	Genuine 3DR APM	1	BDT 8,500	BDT 8,500
7	Neo-7M GPS+Compass	1	BDT 1,100	BDT 1,100

8	Skydroid T10 (10ch, Telemetry, Night Vision Camera, Video Transmission)	1	BDT 22,500	BDT 22,500
9	5V BEC (6S Supported)	1	BDT 250	BDT 250
10	Power Distribution Board	1	BDT 120	BDT 120
11	Lipo Battery 6S 5800mAh	1	BDT 6,800	BDT 6,800
12	B3 Lipo Battery Charger	2	BDT 450	BDT 900
13	Pump Motor	1	BDT 500	BDT 500
14	Voltage Regulator	1	BDT 150	BDT 150
15	Motor Driver	1	BDT 800	BDT 800
16	Carbon Pipe	1	BDT 150	BDT 150
17	Nozzle	1	BDT 150	BDT 150
18	Servo 9G Metal Gear	1	BDT 180	BDT 180
19	Arduino Nano	1	BDT 350	BDT 350
20	LM35,BP140,LDR,MQ9,IR (Sensors)	1	BDT 800	BDT 800

21	Bluetooth Module	1	BDT 490	BDT 490
22	Others + Transportation cOST	1	BDT 2,000	BDT 2,000
TOTAL				BDT 70,740

Cost of the final product capable of carrying 25 kg of water

Table 5.1.2 Cost of the proposed solution

SL	ITEM	QTY	RATE	PRICE
1	Custom Made Carbon Fiber Frame (Octacopter)	1	BDT 12,000	BDT 12,000
2	Filament for 3D Print	1	BDT 6,000	BDT 6,000
3	8118 100KV Brushless Motor	8	BDT 18,000	BDT 144,000
4	30x10" Carbon Fiber Propeller	8	BDT 16,400	BDT 131,200
5	Flycolor 150A ESC FlyDragon 5-12S HV ESC	8	BDT 1,600	BDT 12,800

6	Genuine 3DR APM	1	BDT 8,500	BDT 8,500
7	M8N GPS+Compass	1	BDT 2,500	BDT 2,500
8	Skydroid T10 (10ch, Telemetry, Night Vision Camera, Video Transmission)	1	BDT 22,500	BDT 22,500
9	5V 5A BEC (12S Supported)	1	BDT 1,300	BDT 1,300
10	Power Distribution Board	1	BDT 250	BDT 250
11	Lithium Ion 12S 48A Battery	1	BDT 122,000	BDT 122,000
12	X12 1100W 30A 12S Balance Battery Charger	1	BDT 25,250	BDT 25,250
13	Wa3510 48VDiaphragm Water Pump	2	BDT 6,650	BDT 13,300
16	Rubber Pipe	1	BDT 100	BDT 100
17	Nozzle	2	BDT 150	BDT 300
18	Servo 9G Metal Gear	2	BDT 180	BDT 360
19	Arduino Nano	1	BDT 350	BDT 350

20	Temp, Light, UV sensor	1	BDT 650	BDT 650
21	Wifi Module	1	BDT 490	BDT 490
22	Others + Transportation cost	1	BDT 2,000	BDT 2,000
TOTAL				BDT 505,850

Per Motor thrust 4555g at 10.19A 48V

The cost of the proposed solution is 505,850 BDT.

5.2 Economic analysis

Below is an estimate of the monthly operating and maintenance expenses for our system.

Table 5.2.1 Operational Cost

Designation	No. Of Employee	Salary Month (BDT)	Salary Per Year (BDT)
Manager	1	32000	384000
Marketing Executive	3	75000	2700000

Engineer	4	65000	3120000
Technician (Assemble)	8	45000	4320000
Accountant	1	17000	204000
Cleaner	2	15000	360000
Total			11088000

The business plan includes setting up an office, two service centers, and a manufacturing facility in Dhaka, employing a total of 19 people. Both the office and the manufacturing center will be situated in Tongi, with the office occupying 1,200 square feet and the manufacturing facility covering 2,400 square feet. The first service center will be established in Banani, while the second will be in Mirpur, each spanning approximately 620 square feet.

For marketing, we will primarily focus on Facebook advertisements. The estimated cost per click (CPC) for targeting users in Bangladesh ranges from 5 to 30 BDT, while the cost per action (CPA) falls between 50 and 500 BDT. Additionally, the cost per thousand impressions (CPM) is expected to be between 50 and 300 BDT. To further enhance our reach, we will also invest in television advertising.

Table 5.2.2: Utility Cost

Description	Unit	Expenditure per month (BDT)	Expenditure per year (BDT)
Office Rent	1	22000	264000

Manufacturing Centre	1	60000	720000
Service Centers	2	18000	432000
Utility Bills	-	10000	120000
Marketing Cost	-	8000	96000
Refreshments	20	3000	36000
Others	-	2000	24000
Total			1668000

Considering our initial plan is to manufacture 1200 units annually.

Total annual expenditure = Production cost of 1200 pieces + O&M Cost

= (380680 × 1200) + 11088000 + 1668000

= 469572000 BDT

We surveyed almost 1 year ago. Since then, the price of electronic components and others have increased drastically. Considering that we have set our unit selling price.

Unit Selling Price = 550000 BDT

Annual sale = 1200 units × 550000 BDT = 660000000 BDT

Discount Rate, d = 8.52%

Interest Rate, i = 11%

Considering all the basic elements, we calculated the average lifetime of the device and determined it to be years.

n = 11 Years

Present Value Function, PVF (d, n) = $\frac{(1+d)^n-1}{d(1+d)^n} = \frac{(1+0.0852)^{11}-1}{0.0852\times(1+0.0852)^{11}} = 6.96$

Capital Recovery factor, CRF(i, n) = $\frac{i(1+i)^n}{(1+i)^n-1} = \frac{0.11\times(1+0.11)^{11}}{(1+0.11)^{11}-1} = 0.1611$

Annual expenditures, P = 498372000 BDT

Annual loan Payment, A = P × CRF(i, n)

= 469572000 BDT × 0.1611

= 75648049 BDT

Annual Savings Without Tax,
ΔA' = Annual sale - Annual Loan Payment - Total annual expenditure

= 660000000 – 75648049 – 469572000 = 114779951 BDT

In Bangladesh, the rate of tax imposed on corporations is 30%.

Annual savings after paying tax,
ΔA = ΔA' x 0.7

= 114779951 × 0.7

= 80345865 BDT

Initial first cost, ΔP = 469572000 BDT

Net Present Value, NPV = ΔA × PVF (d, n) – ΔP

= (80345865× 6.96) – 469572000

= 89820712 BDT

Simple payback period = $\frac{\Delta P}{\Delta A}$ = $\frac{469572000}{89820712}$ = 5.23 Years= 5 Years 2 Months 3 Days

Cash Flows at year 0 = -Initial Investment = -469572000 BDT

Annual Cash Inflows (Years 1-11) = 80345865 BDT

IRR by equating NPV = 0

0 = $-469572000 + 80345865 \times [\frac{1-(1+r)^{-11}}{r}]$

Solving for r using iterative methods we get r = 12.37%

At r = 12.37%

the present value of annual inflows equals the initial investment confirming NPV = 0

The IRR for the project is 12.37%

The simple payback period for the project is 5.23 years, which is in line with the expected return on investment. Based on the financial analysis, the Net Present Value (NPV) is positive, indicating that the project's future cash inflows will surpass the initial investment and generate a profit. Additionally, the Internal Rate of Return (IRR) is approximately 1.12 times higher than the discount rate of 8.52%, suggesting that the project will provide an attractive return on investment. These results highlight the financial viability of the project, making it a promising investment opportunity

Chapter 6 Conclusion

6.1 Verification of complex engineering problem

The verification of the fire-extinguishing drone as a **complex engineering problem** was conducted based on standard engineering attributes. The analysis confirmed that the project meets the criteria for complexity due to the following key aspects:

1. **Depth of Knowledge Required (P1)**
   - The project required an in-depth understanding of multiple engineering disciplines, including aerodynamics, electronics, fluid dynamics, and control systems.
   - A fundamentals-based analytical approach was necessary to design, test, and validate the drone's functionality.
2. **Conflicting Requirements (P2)**
   - The design had to balance weight constraints, payload capacity, flight stability, and fire-extinguishing efficiency.
   - Ensuring thermal insulation for electronics while maintaining lightweight materials posed a significant challenge.
3. **Depth of Analysis Required (P3)**
   - No obvious solution existed; hence, abstract thinking and originality in modeling drone behavior under fire conditions were essential.
   - Simulation tools were used to predict system performance under different firefighting scenarios.
4. **Familiarity of Issues (P4)**
   - Fire-extinguishing drones are an emerging technology, and their application in autonomous firefighting is relatively unexplored.

- The need to adapt drones for various fire environments (e.g., industrial, forest, building fires) added complexity.

5. **Extent of Applicable Codes (P5)**

   - The project went beyond standard engineering codes, requiring modifications to existing aerospace, safety, and fire suppression standards.
   - Compliance with aviation regulations for drone operations in emergency scenarios was considered.

6. **Stakeholder Considerations (P6)**

   - The design had to account for the needs of firefighters, environmental regulators, emergency responders, and drone operators.
   - Integration with existing firefighting protocols was crucial to ensure practical deployment.

7. **Interdependence of Components (P7)**

   - The drone design involved a high level of system integration, requiring seamless communication between:
     - Sensors (gas, thermal, infrared)
     - Flight control system (stability, navigation, obstacle avoidance)
     - Fire-extinguishing mechanisms (pump, nozzle, fireball thrower, etc.)

6.2 Meeting the project objectives

The project successfully met its primary objectives by designing a semi-automatic fire-extinguishing drone with key features like autonomous control, GPS tracking, and a water-spraying system. Stakeholder requirements, such as long operational range and fire suppression efficiency, were addressed, and the functional design and prototype development were completed effectively. Despite minor delays in equipment procurement and implementation, risk mitigation strategies ensured progress. The project also proved to be economically viable, with a positive NPV and IRR, and had a significant social and environmental impact by improving emergency response and minimizing fire-related losses.

Overall, the project objectives were successfully achieved with only minor challenges.

APPENDIX A. ACTIVITY CHART

Part-I

Date	Participants	Activity Description	Approx. hrs. spent

Part-II

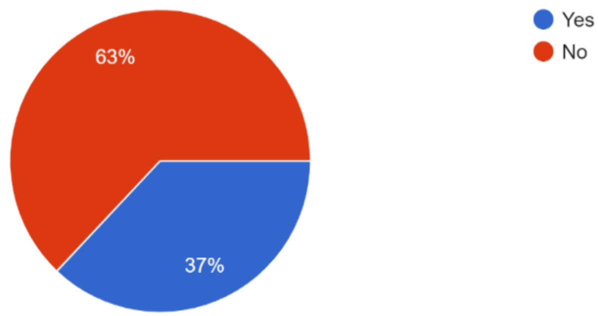
Date	Participants	Activity Description	Approx. hrs. spent

APPENDIX B. OTHER TECHNICAL DETAILS.

1.

Have you previously used drones for firefighting or emergency response operations?

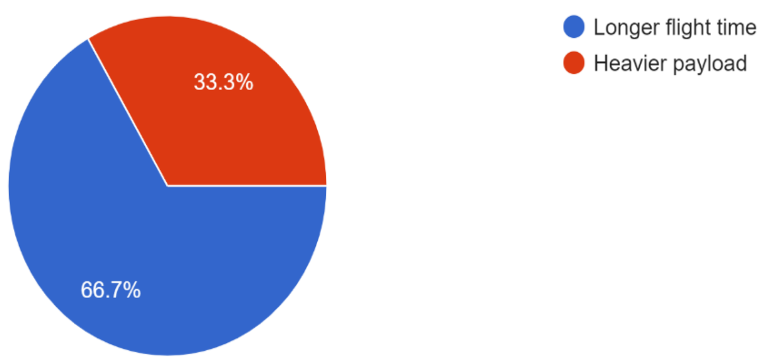
27 responses



2.

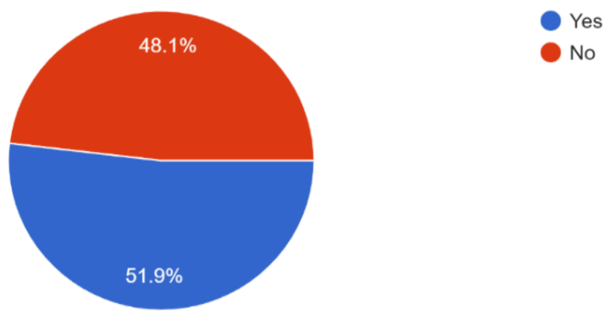
Would you prefer a drone with a longer flight time or one that can carry a heavier payload?

27 responses



3.

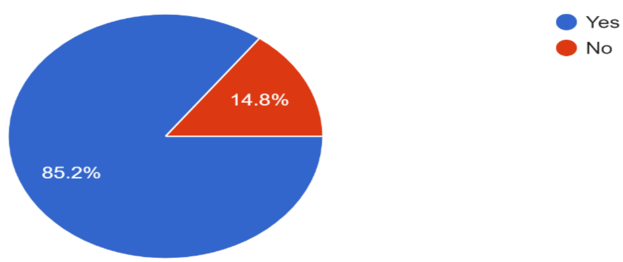
Do you have any specific size or weight constraints for the drone?
27 responses



.

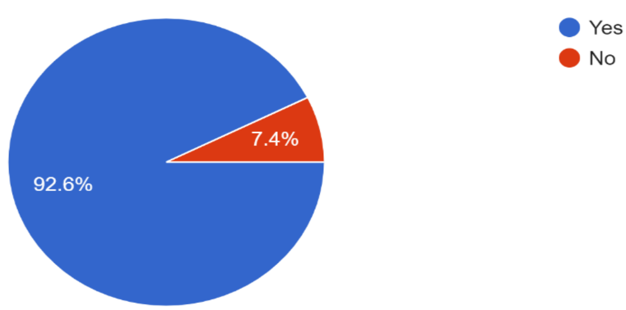
4.

Would you require the drone to be able to operate in smoky or low-visibility conditions?
27 responses



5.

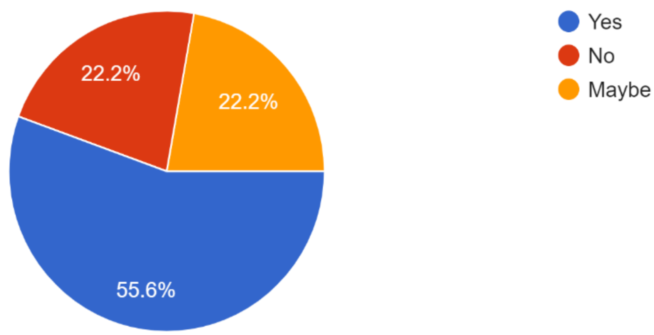
Would you require the drone to have real-time video streaming capabilities?
27 responses



6.

Do you have any specific requirements for the drone's control range or communication system?

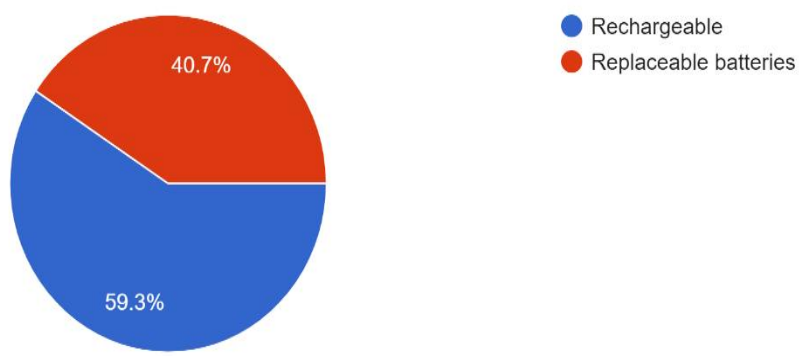
27 responses



7.

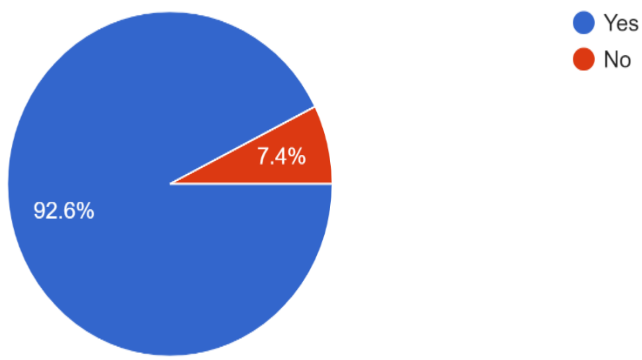
Would you prefer a drone that can be recharged or one with replaceable batteries?

27 responses



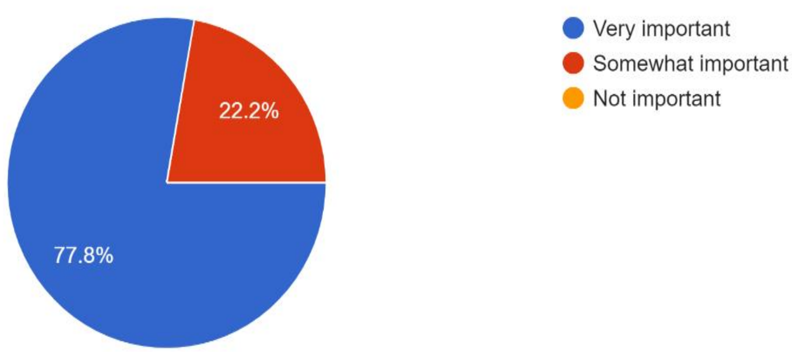
8.

Is it important for the drone to have obstacle avoidance capabilities?
27 responses

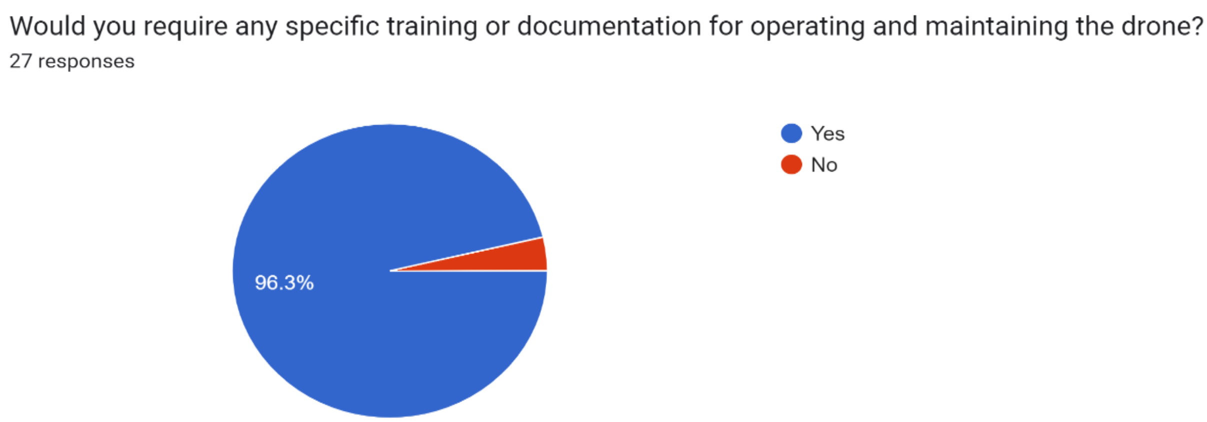


9.

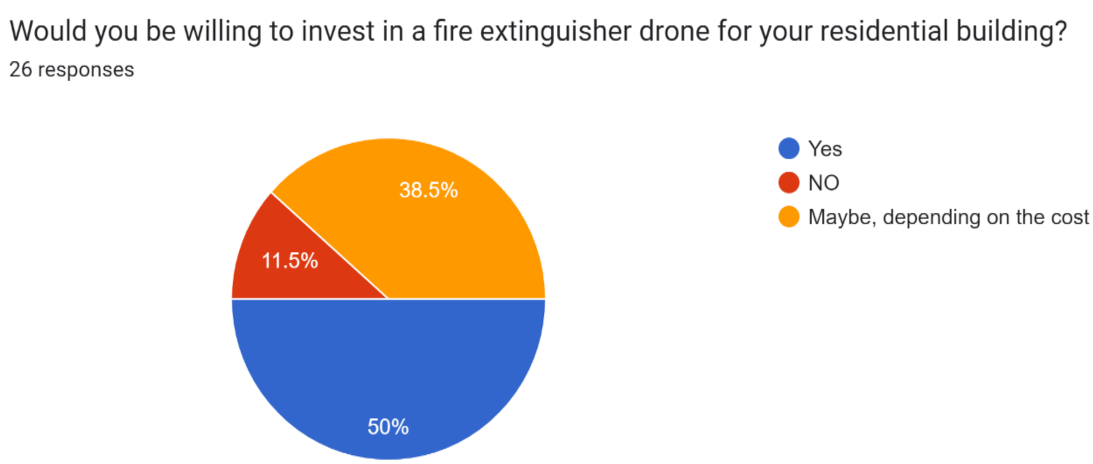
How important is it for the drone to be cost-effective?
27 responses



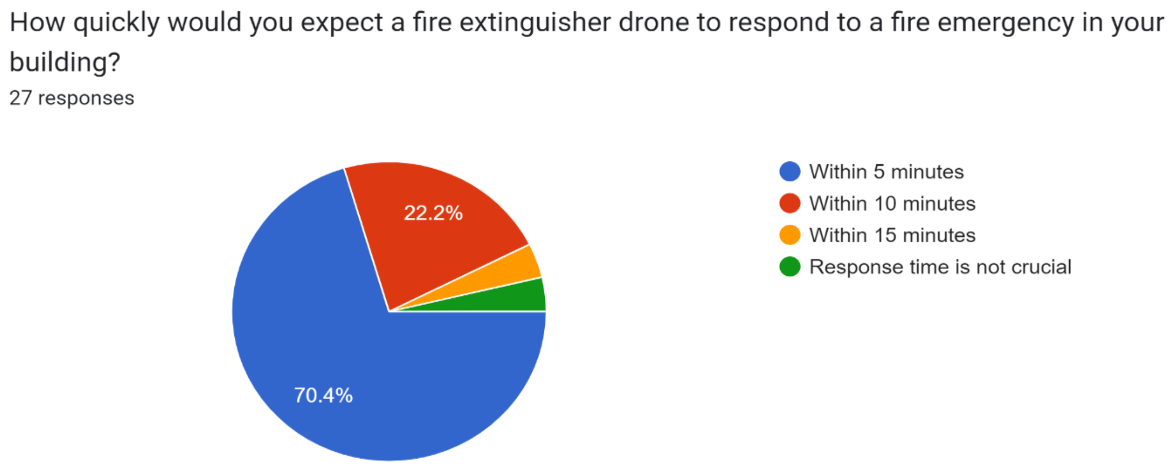
10.


Would you require any specific training or documentation for operating and maintaining the drone?
27 responses
96.3%
Yes
No

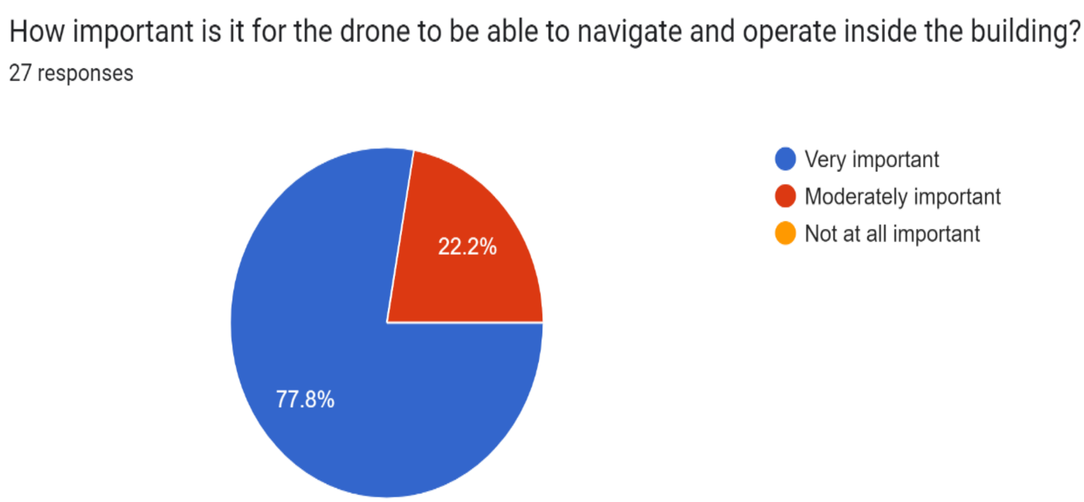
11.


Would you be willing to invest in a fire extinguisher drone for your residential building?
26 responses
38.5%
11.5%
50%
Yes
NO
Maybe, depending on the cost

12.


How quickly would you expect a fire extinguisher drone to respond to a fire emergency in your building?
27 responses
22.2%
70.4%
Within 5 minutes
Within 10 minutes
Within 15 minutes
Response time is not crucial

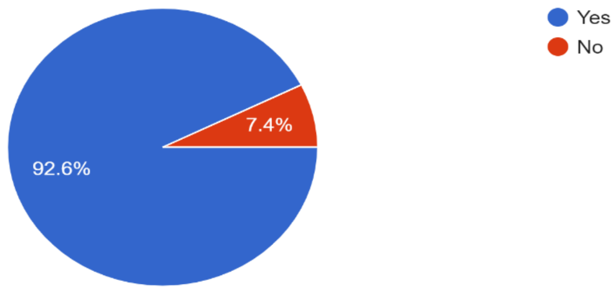
13.


How important is it for the drone to be able to navigate and operate inside the building?
27 responses
22.2%
77.8%
Very important
Moderately important
Not at all important

14.

Would you be willing to pay a monthly/annual fee for the maintenance and operation of a fire extinguisher drone in your building?

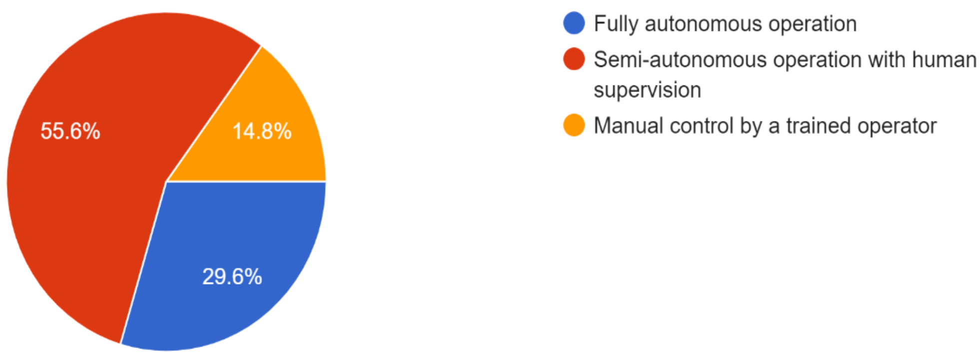
27 responses



15.

What level of autonomy would you prefer for the fire extinguisher drone?

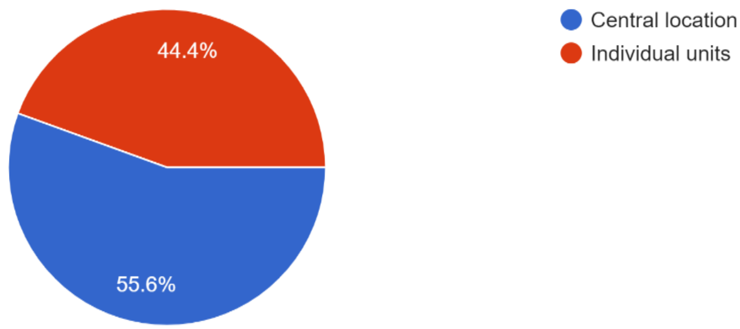
27 responses



16.

Would you prefer the fire extinguisher drone to be stored and deployed from a central location, or have individual units stationed in each residential unit?

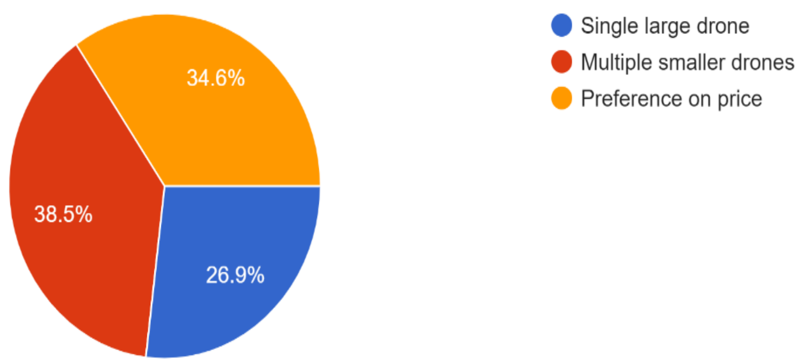
27 responses



17.

Would you prefer a single large drone or multiple smaller drones for fire extinguishing in your building?

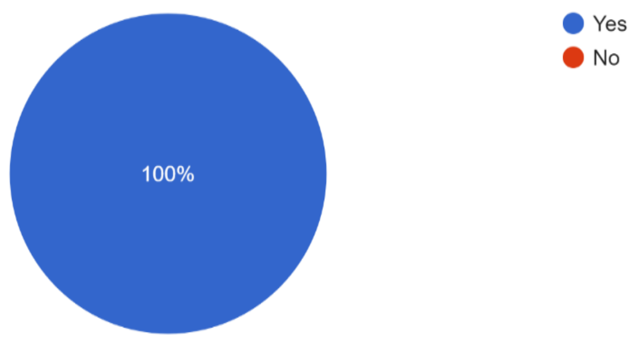
26 responses



18.

Would you require any special training or instructions for residents regarding the use of a fire extinguisher drone in your building?

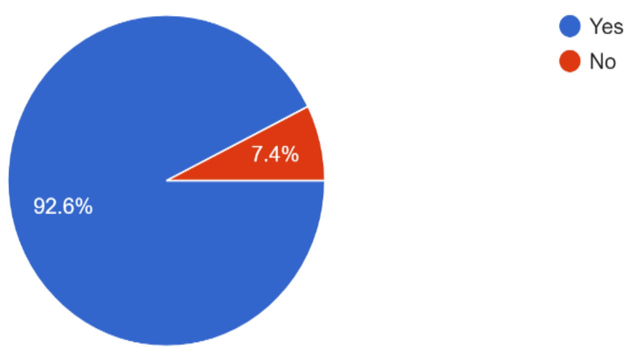
27 responses



19.

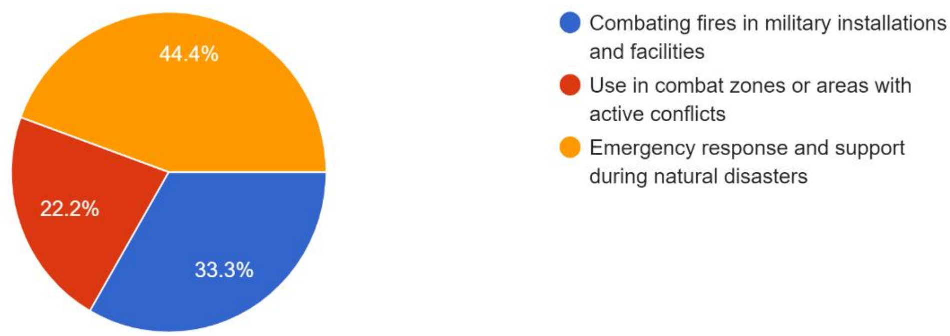
Do you think having a fire extinguisher drone in your building would increase the property value or appeal to potential buyers/tenants?

27 responses



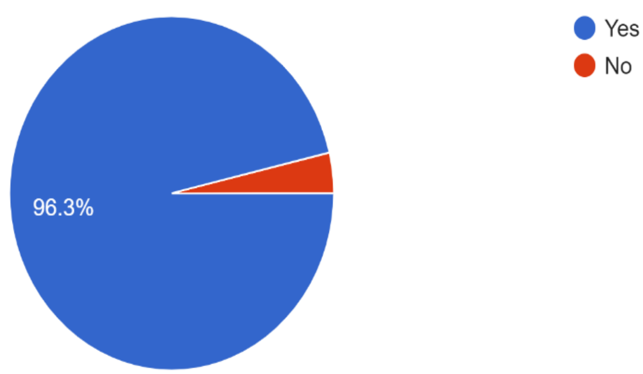
20.

What is the primary intended use of the fire extinguisher drone?
27 responses



21.

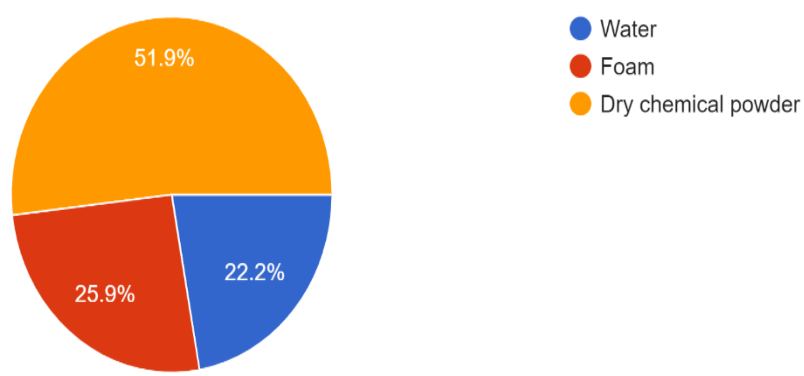
Should the drone be equipped with night vision or thermal imaging capabilities?
27 responses



22.

What type of fire extinguishing agent should the drone be equipped with?

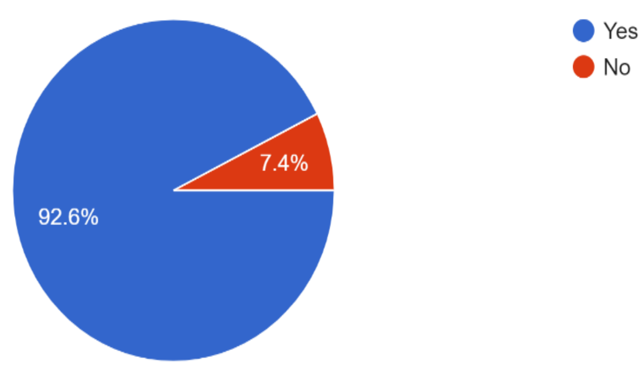
27 responses



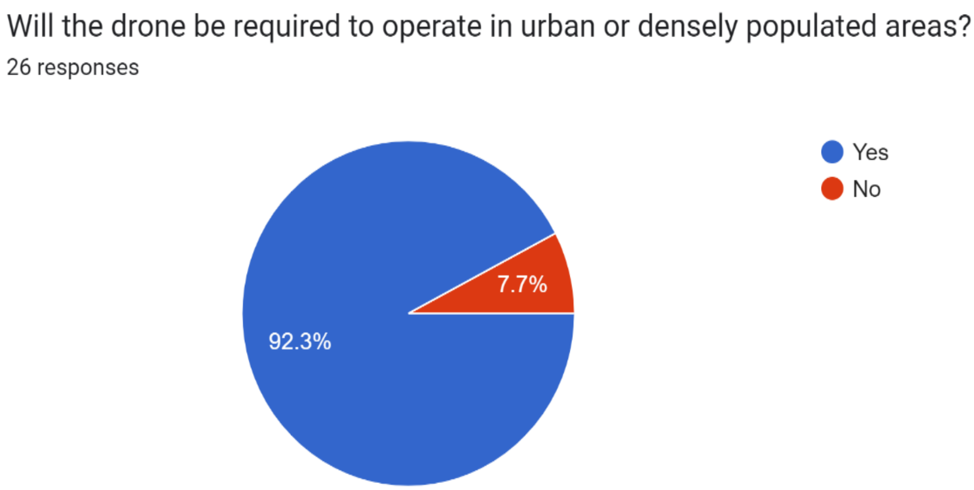
23.

Is there a requirement for the drone to be able to operate in extreme weather conditions, such as high winds or heavy precipitation?

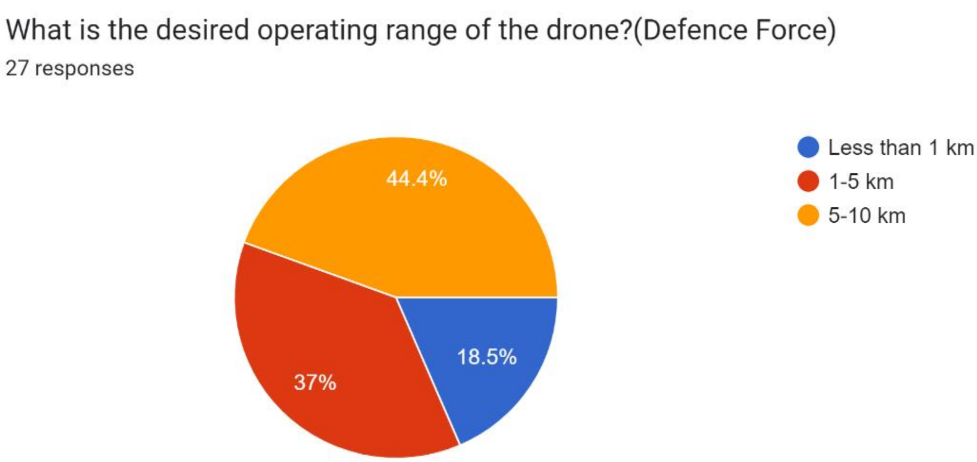
27 responses



24.

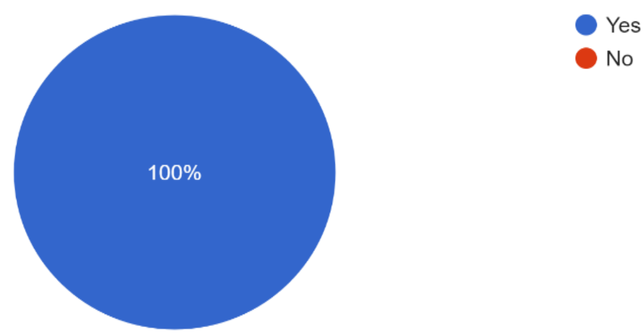

Will the drone be required to operate in urban or densely populated areas?
26 responses
Yes
No
7.7%
92.3%

25.


What is the desired operating range of the drone?(Defence Force)
27 responses
Less than 1 km
1-5 km
5-10 km
44.4%
37%
18.5%

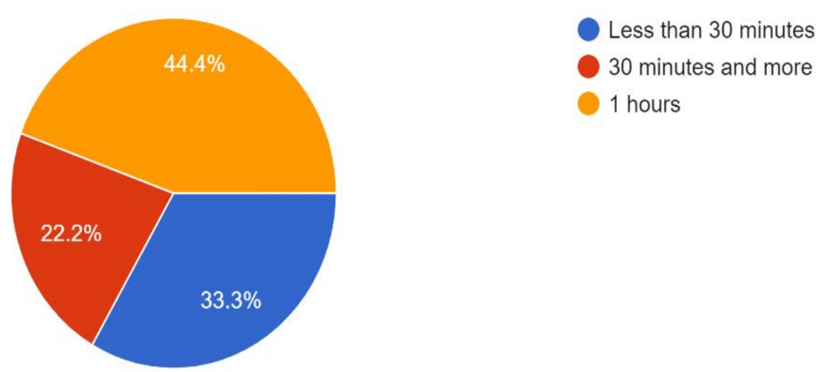
26.

Should the drone be designed for easy maintenance and repair in the field?
27 responses



27.

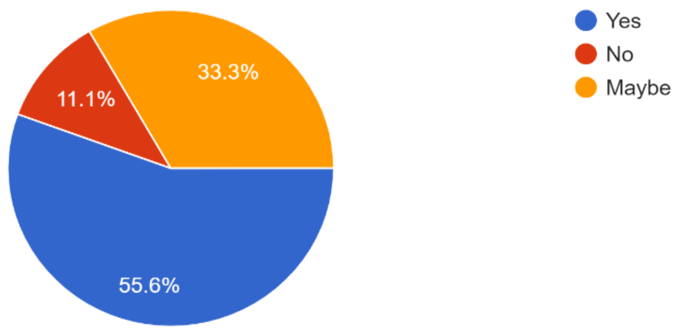
What is the desired flight time or endurance of the drone?
27 responses



28.

Is there a need for the drone to have a silent or low-noise operation mode?

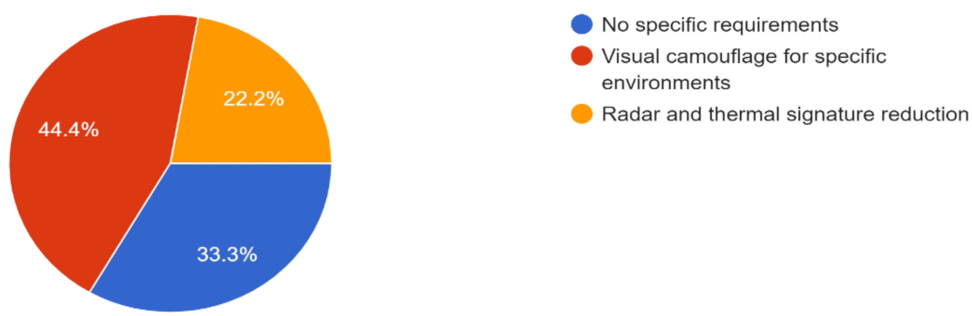
27 responses



29.

Are there any specific requirements for stealth or camouflage features?

27 responses



30.

What will be the weight or size for the drone?

14 responses

150nm

150 nm

40lbs

2260mm

7kg

1-20 kg

Don’t know

31.

What will be the range?(Feet)

12 responses

100 feet

20 feet

10

20-30 Feet

400 feet

800+ feet

1000feet

32.

Do you have any other specific requirements or concerns regarding the implementation of a fire extinguisher drone in your residential building?

5 responses

No
Taking minimal time
Easy to operating
conern about it's accuracy.

APPENDIX C. JUSTIFICATION OF COMPLEX ENGINEERING PROBLEM

This table prepared in EEE400(i) justifies the proposed project as a complex engineering problem.

Attribute	**Complex Engineering Problems** have characteristic P1 and some or all of P2 to P7:	**Covered in the project? (Y/N)**	**Explain/justify**
Depth of knowledge required	P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach		
Range of conflicting requirements	P2: Involves wide-ranging or conflicting technical, engineering and other issues		
Depth of analysis required	P3: There is no obvious solution, and abstract thinking and originality in analysis are required to formulate suitable models		
Familiarity of issues	P4: Involves infrequently encountered issues		
Extent of applicable codes	P5: Are outside problems encompassed by standards and codes of practice for professional engineering		
Extent of stakeholder involvement and conflicting requirements	P6: Involves diverse groups of stakeholders with widely varying needs		
Interdependence	P7: High level problems including many component parts or sub-problems		

APPENDIX D. JUSTIFICATION OF COMPLEX ENGINEERING ACTIVITIES

This table prepared in EEE400(ii) describes the complex engineering activities in the project

Attribute	**Complex activities mean (engineering) activities or projects that have some or all of the following characteristics:**	**Covered in the project? (Y/N)**	**Explain**
Range or resources	A1: Involves the use of diverse resources (for this purpose, resources include people, money, equipment, materials, information and technologies)		
Level of interaction	A2: Requires resolution of significant problems arising from interactions among wide-ranging or conflicting technical, engineering, or other issues		
Innovation	A3: Involves creative use of engineering principles and research-based knowledge in novel ways		
Consequences for society and the environment	A4: Has significant consequences in a range of contexts; characterized by difficulty of prediction and mitigation		
Familiarity	A5: Can extend beyond previous experiences by applying principles-based approaches		

APPENDIX E. RUBRICS

Rubrics for EEE400

Table 1: Rubrics for assessment of PO9 (Individual work and teamwork)

Performance indicators	Outstanding (8 – 10)	Good (6 – 7)	Satisfactory (4 – 5)	Unsatisfactory (0 – 3)
Individual skills	Actively participates in group discussions and decision making, contributes useful ideas, completes assigned responsibilities thoroughly on time	Participates in group discussions and decision making, contributes ideas, completes assigned responsibilities mostly on time	Somewhat participates in group discussions and decision making, sometimes contributes ideas, completes some of the assigned responsibilities on time	Does not participate in group discussions and decision making, does not contribute relevant ideas, does not complete assigned responsibilities on time
Team skills	Always collaborates with others, always promotes constructive team atmosphere, always identifies and responds to conflicts promptly and positively	Usually collaborates with others, usually promotes constructive team atmosphere, usually identifies and responds to conflicts positively	Sometimes collaborates with others, sometimes promotes constructive team atmosphere, sometimes identifies and responds to conflicts positively	Does not collaborate with others, does not promote constructive team atmosphere, does not identify and respond to conflicts
Leadership skills	Always provides direction to achieve goals, always respects and listens to other members, always plans for improvement, always motivates others	Usually provides direction to achieve goals, usually respects and listens to other members, usually plans for improvement, usually motivates others	Sometimes provides direction to achieve goals, sometimes respects and listens to other members, sometimes plans for improvement, sometimes motivates others	Does not provide direction to achieve goals, does not respect and listen to other members, does not plan for improvement, does not motivate others
Multidisciplinary activities	Fully understands and appreciates the multidisciplinary nature of the project activities, shows interests and	Mostly understands and appreciates the multidisciplinary nature of the project activities, participates in activities in	Somewhat understands and appreciates the multidisciplinary nature of the project activities, participates	Does not understand or appreciate the multidisciplinary nature of the project activities, does not participate in activities

	participates in activities in disciplines outside of own	disciplines outside of own	in some activities in disciplines outside of own	in disciplines outside of own

Table 2: Rubrics for assessment of PO8 (Ethics)

Performance indicators	Outstanding (8 – 10)	Good (6 – 7)	Satisfactory (4 – 5)	Unsatisfactory (0 – 3)
Equity	Always approaches situations with consideration of equity, always behaves inclusively	Mostly approaches situations with consideration of equity, mostly behaves inclusively	Sometimes approaches situations with consideration of equity, Sometimes behaves inclusively	Does not approach situations with consideration of equity, does not behave inclusively
Accountability	Always understands about accountability and personal responsibility, always assumes responsibility of own actions	Mostly understands about accountability and personal responsibility, mostly assumes responsibility of own actions	Sometimes understands about accountability and personal responsibility, sometimes assumes responsibility of own actions	Does not understand about accountability and personal responsibility, does not assume responsibility of own actions
Proper use of others' works	Always recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and acts accordingly	Mostly recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and mostly acts accordingly	Sometimes recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and sometimes acts accordingly	Does not recognize the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and does not act accordingly
Professionalism	Fully understands the role of the engineer in protecting public interests, fully understands and is aware of relevant codes of ethics	Mostly understands the role of the engineer in protecting public interests, mostly understands and is mostly aware of relevant codes of ethics	Somewhat understands the role of the engineer in protecting public interests, somewhat understands and is somewhat aware of relevant codes of ethics	Does not understand the role of the engineer in protecting public interests, does not understand or is not aware of relevant codes of ethics

Rubrics for EEE400(i)

Table EEE400(i): Rubrics for assessment of the project concept and functional design

Performance indicators	Outstanding (8 – 10)	Good (6 – 7)	Satisfactory (4 – 5)	Unsatisfactory (0 – 3)
PCFD_PI1: Able to identify a suitable complex engineering design problem (1a) [sec-1.1, Appendix C] **(CO1/PO12, P1)**	Demonstrates an ability to explore a topic thoroughly, and to identify a suitable complex engineering problem	Demonstrates an ability to explore a topic, and to identify a reasonably suitable complex engineering problem	Demonstrates an ability to somewhat explore a topic, and to identify a somewhat suitable complex engineering problem	Demonstrates minimal or no ability to explore a topic, or to identify a suitable complex engineering problem
PCFD_PI2: Engages to stay up to date on the relevant topic (2b) [sec-1.2] **(CO1/PO12, P1)**	Demonstrates thorough engagement to stay up to date on the relevant topic	Demonstrates engagement to stay up to date on the relevant topic	Demonstrates some engagement to stay up to date on the relevant topic	Demonstrates minimal or no engagement to stay up to date on the relevant topic
PCFD_PI3: Identifies the regulatory requirements, standards, and codes of practice (2a) [sec-1.3] **(CO2/PO3, P5)**	Identifies all the relevant regulatory requirements, standards, and codes of practice	Identifies most of the relevant regulatory requirements, standards, and codes of practice	Identifies some of the relevant regulatory requirements, standards, and codes of practice	Does not identify any of the relevant regulatory requirements, standards, and codes of practice
PCFD_PI4: Explains the objectives, project requirements and constraints of the solution considering the expectations of the stakeholders (2c) [sec-1.4, 1.5.1] **(CO2/PO3, P2, P6)**	Clearly explains the objectives, project requirements and constraints taking into account all the expectations of the stakeholders	Explains the objectives, project requirements and constraints taking into account most of the expectations of the stakeholders	Somewhat explains the objectives, project requirements and constraints fully taking into account some the expectations of the stakeholders	Does not explain the objectives, project requirements and constraints and/or does not take into account any expectation of the stakeholders
PCFD_PI5: Develops a functional design considering applicable standards, codes of practice, health, safety, and environmental considerations. (2d) [sec-1.5.2] **(CO3/PO3, P2, P7)**	Appropriately partitions the problem into sub-problems, considers all relevant engineering standards and codes where applicable, involves all health, safety, and environmental issues in design	Partitions the problem into sub-problems, considers most relevant engineering standards and codes where applicable, involves major health, safety, and	Partitions the problem into subproblems to some extent, considers some relevant engineering standards and codes where applicable, involves some health, safety, and	Does not usefully partition the problem into sub-problems, does not consider relevant engineering standards and codes, health, safety, and environmental issues not involved in design

			environmental issues in design	
PCFD_PI6: Prepares project management plan, setting up milestones and considering risks and contingencies (2e) [sec-1.6.1, 1.6.2] **(CO4/PO11)**	Prepares a comprehensive project management plan, clearly sets up milestones, thoroughly considers risks and contingencies	Prepares a project management plan, sets up milestones, considers risks and contingencies	Prepares a project management plan, sets up a few milestones, attempts to considers risks and contingencies	Prepares a unclear/incomplete project management plan, does not set up milestones, does not consider risks and contingencies
PCFD_PI7: Identifies required resources and prepares a realistic budget (2f, 2g) [sec-1.6.3] **(CO4/PO11)**	Identifies all resources and prepares budget that covers all applicable areas of the project including room for contingency	Identifies most resources and prepares budget that covers most applicable areas of the project including room for contingency	Identifies some resources and prepares budget that covers some applicable areas of the project	Cannot identify resources and cannot prepare a budget addressing major applicable areas of the project
PCFD_PI8: Explains how to sustain and maintain the product/service in business if the solution is successfully commercialized. (2g) [sec-1.7]	Clearly explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Somewhat explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Does not explain how to sustain and maintain the product/service in business if the solution is successfully commercialized.
PCFD_PI9: Considers the impact of the solution on society including health, safety, cultural, and legal issues (2h) [sec-1.8.1, 1.8.3] **(CO5/PO6)**	Considers all the impacts on society including health, safety, cultural and legal issues	Considers most of the impacts on society including health, safety, cultural and legal issues	Considers some of the impacts on society including health, safety, cultural and legal issues	Does not consider any impact on society including health, safety, cultural and legal issues
PCFD_PI10: Considers the impact of the solution on environment and sustainability over the entire product life cycle. Proposes	Consider all the impacts on environment and sustainability. If necessary, proposes solutions to mitigate negative impact	Consider most of the impacts on environment and sustainability. If necessary, identifies impacts which need mitigation	Considers some of the impacts on environment and sustainability	Minimal or no consideration of impacts on environment and sustainability

mitigating solutions if needed. (2i) [sec-1.8.2] **(CO6/PO7)**				

P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach.

P2: Involves wide-ranging or conflicting technical, engineering and other issues.

P4: Involves infrequently encountered issues.

P5: Are outside problems encompassed by standards and codes of practice for professional engineering.

P6: Involves diverse groups of stakeholders with widely varying needs.

P7: High level problems including many component parts or sub-problems

Rubrics for EEE400(ii)

Table 1: Rubrics for assessment of the Final Report

Performance indicators	Outstanding (8 – 10)	Good (6 – 7)	Satisfactory (4 − 5)	Unsatisfactory (0 – 3)
FR_PI1: Formulates and evaluates alternate solutions (1a) [sec-2.1] **(CO1/PO2, P1, P3)**	Effectively formulates multiple solutions that functionally meet most requirements, compares and evaluates alternate solutions, extracts valid conclusions	Formulates multiple solutions that functionally meet most requirements, partially compares and evaluates alternate solutions, conclusions in line with analysis	Formulates multiple solutions that functionally meet some requirements, attempts to compare and evaluate alternative solutions, conclusions somewhat in line with analysis	Does not formulate multiple solutions, no attempt to compare and evaluate alternative solutions, conclusions not based on analysis
FR_PI2: Prepares and refines design with analysis and/or simulation of the system for implementation (1b, 1c) [sec-2.2] **(CO2/PO3, P1)**	Performs all design calculations, produces detailed design, analyzes and/or simulates to verify that the design satisfies all requirements. Design is skillfully refined to facilitate implementation.	Performs most design calculations, produces design with some details, analyzes/simulates to verify that the design satisfies most requirements. Design is refined to facilitate implementation.	Performs some design calculations, produces design with a few details, attempts to analyze/simulate the design to verify satisfaction of requirements. Design is somewhat refined to facilitate implementation.	Does not perform design calculations, detailed design not produced, analysis/simulation not done to verify satisfaction of requirements. Design is not refined to facilitate implementation.
FR_PI3: Discusses how the prototype of the solution is developed. (2a) [sec 3.1]	Comprehensively discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Somewhat discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Poorly discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams
FR_PI4: Evaluates performance of the developed system as per requirements. Finalizes design based on performance evaluation (2b and 2c) [sec 3.2, 3.3]	System meets all requirements, or the students can identify and explain clearly when deviation from requirements occurs. Revises design with appropriate technical analysis if necessary	System meets major requirements. Students can identify and explain most deviations from requirements. Revises design with technical analysis if necessary to achieve compliance	System meets some requirements. Students can identify and explain some deviations from requirements. Revises design with some technical analysis if necessary to achieve	System does not meet most requirements. Students cannot identify and explain most deviations from requirements. Design not revised to achieve compliance.

(CO3/PO4, CO4/PO3)	to achieve compliance with all specification and requirements	with most specification and requirements	compliance with some specification and requirements	
FR_PI5: Selects and uses appropriate modern engineering tools for modeling, simulation and/or performance evaluation throughout the project (EEE400-I, and II) (2d) [sec 3.4] **(CO5/PO5)**	Carefully selects and skillfully uses modern engineering tools knowing all the relevant limitations of the tools	Selects and uses modern engineering tools with some degree of care and skill knowing major relevant limitations of the tools	Selects and uses modern engineering tools knowing some relevant limitations of the tools	Selected and used modern engineering tools are mostly not appropriate. No knowledge of relevant limitations of the tools
FR_PI6: Achieve the milestones set in the project proposal or revises the schedule appropriately to complete the project within the deadline (EEE400-I, and II) (3a) [Chapter 4] **(CO6/PO11)**	All milestones are reached on time or corrective measures are appropriately taken to revise the schedule to complete the project within deadline	Most milestones are reached on time or corrective measures are taken to revise the schedule to complete the project within deadline	Milestones are somewhat reached on time or some corrective measures are taken to revise the schedule to complete the project within deadline	Milestones are mostly not reached on time. Corrective measures are not taken to revise the schedule to complete the project within deadline
FR_PI7: Estimates the cost of the system and prepares the bill of materials (3b) [sec 5.1] **(CO7/PO11)**	Prepares bill of materials considering all the project components and/or parts and the cost is accurately estimated	Prepares bill of materials considering most the project components and/or parts and the cost is estimated	Prepares bill of materials considering major project components and/or parts and the cost is reasonably estimated	Prepares bill of materials ignoring important project components and/or parts and the cost is not reasonable
FR_PI8: Performs economic analysis to calculate suitable economic parameter(s) to evaluate the economic prospect of the proposed project (3c) [sec 5.2] **(CO7/PO11)**	Evaluates the financial prospect of the project through detailed and thorough analysis. Interpretation is clear	Evaluates the financial prospect of the project through analysis. Provides interpretation	Evaluates the financial prospect of the project through analysis.	Does not evaluate the financial prospect of the project through analysis

P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach.

P2: Involves wide-ranging or conflicting technical, engineering and other issues.

P3: There is no obvious solution, and abstract thinking and originality in analysis are required to formulate suitable models.

P7: High level problems including many component parts or sub-problems.

Table 2: Overall rubrics on report writing

Performance indicators	Outstanding (8 – 10)	Good (6 – 7)	Satisfactory (4 – 5)	Unsatisfactory (0 – 3)
Communicates the main ideas in written form [Overall] **(CO8/PO10)**	Communicates the main ideas clearly and to the point	Communicates the main ideas	Communicates the main ideas to some extent	Does not communicate the main ideas
Uses illustrations (graphs, tables, diagrams) to support ideas, analysis and interpretation [Overall] **(CO8/PO10)**	Skillfully uses illustrations to support ideas. Illustrations enhance comprehension of analysis and interpretation	Uses illustrations to support ideas. Illustrations somewhat enhance comprehension of analysis and interpretation	Uses illustrations which are related to analysis and interpretation	Either does not use illustrations or illustrations used are not relevant to ideas, analysis and interpretation
Uses citations and references [Overall] **(CO8/PO10)**	Citations and references are effectively used to duly acknowledge prior art and other people's works	Citations and references are used to acknowledge prior art and other people's works	Citations and references are used to somewhat acknowledge prior art and other people's works	Citations and references are not used or prior art and other people's works are not acknowledged
Uses a language which is mechanically (punctuation, spelling and grammar) correct [Overall] **(CO8/PO10)**	The report is free from mechanical errors	The report contains a few mechanical errors	The report contains some mechanical errors	The report contains several mechanical errors

Table 3: Rubrics for oral presentation

Performance indicators	Outstanding (9 – 10)	Good (7 – 8)	Satisfactory (6)	Unsatisfactory (0 – 5)
Communicates appropriately targeting the society at large **(CO8/PO10)**	Communication is skillfully tailored to appropriately suit the level of target audience	Communication is tailored to suit the level of target audience	Communication is somewhat tailored to suit the level of target audience	Communication is not tailored to suit the level of target audience
Focusses on the creative aspects of the solution with clarity **(CO8/PO10)**	Creative aspects are clearly articulated and emphasized. Presentation is logically and skillfully structured	Creative aspects are articulated and emphasized. Presentation structure is logical	Creative aspects are somewhat articulated and emphasized. Presentation structure is somewhat logical	Creative aspects are not articulated or emphasized. Presentation structure is not logical
Above two PIs will assess the sales pitch part of the presentation. Following PIs are for the technical part				
Designs and integrates visual aids (illustrations, demonstrations, props, etc) to support and focus presentation **(CO8/PO10)**	Visual aids are creatively designed, skillfully used and seamlessly integrated to enhance and focus presentation	Visual aids are designed, used and integrated to enhance and focus presentation	Visual aids are designed, used and integrated to enhance and focus presentation to some extent	Visual aids are not designed, used or integrated to enhance and focus presentation
Completes presentation within the allotted time **(CO8/PO10)**	Finishes the presentation as prepared within time without rushing or skipping content	Finishes the presentation as prepared within time with rushing or skipping content occasionally	Finishes the presentation as prepared within time with rushing or skipping content a few times	Does not finish the as prepared presentation within time or skips major contents to finish within time
Listens to the questions and answers appropriately **(CO8/PO10)**	Carefully listens to the questions, answers concisely transitioning skillfully between presentation and Q/A	Listens to the questions, answers to the point transitioning well between presentation and Q/A	Listens to the questions, answers somewhat to the point transitioning between presentation and Q/A in an acceptable manner	Does not listen to the questions, answers not to the point transitioning between presentation and Q/A not in an acceptable manner

REFERENCES

[1] S. Barua, M. S. Shafkat Tanjim, A. N. Oishi, S. C. Das, M. A. Basar and S. A. Rafi, "Design and Implementation of Fire Extinguishing Ball Thrower Quadcopter," *2020 IEEE Region 10 Symposium (TENSYMP)*, Dhaka, Bangladesh, 2020, pp. 1404-1407, doi: 10.1109/TENSYMP50017.2020.9230808.

[2] N. Jahan et al., "Development of an IOT-based firefighting drone for enhanced safety and efficiency in fire suppression," Measurement and Control, Apr. 2024. doi:10.1177/00202940241238674

[3] N. Jayapandian, "Cloud Enabled Smart Firefighting Drone Using Internet of Things," *2019 International Conference on Smart Systems and Inventive Technology (ICSSIT)*, Tirunelveli, India, 2019, pp. 1079-1083, doi: 10.1109/ICSSIT46314.2019.8987873

[4] Adib Ahnaf; Faisal Hossain. "Prototype of a Functioning Urban Firefighting Drone." Volume. Volume. 7 Issue. 10, October - 2022 , International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165, PP :- 816-837. https://doi.org/10.5281/zenodo.7295664

[5] Zadeh, Nastaran & Abdulwakil, Ameralden & Amar, Mike & Durante, Bernadette & Santos, Christian. (2021). Fire-fighting UAV with shooting mechanism of fire extinguishing ball for smart city. Indonesian Journal of Electrical Engineering and Computer Science. 22. 1320. 10.11591/ijeecs.v22.i3.pp1320-1326

[6] A. Undergraduate, C. Project, Hossain, and M. Islam, "DESIGN AND IMPLEMENTATION OF AN IOT BASED FIRE AND SURVIVOR DETECTION DRONE Under the Supervision of."Available:https://dspace.aiub.edu/jspui/bitstream/123456789/874/1/Capstone%20Project%20Book_2022.2.27.pdf