Firehawk: An Autonomous Firefighting Drone With Fire-Extinguishing Ball Release Mechanism

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronics Engineering in partial fulfillment of the requirements for the degree of BSEEE

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Approval

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of [Fall], [2025] has been accepted as satisfactory in partial fulfillment of the requirement for the degree of degree of BSE on 05/01/26.

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Ethics Statement

We hereby confirm that this project, Firehawk: Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism, has met the requirements of the Final Year Design Project (FYDP). This project has been developed by the collective effort of the group members. The supportive materials, literature review and collected data have been cited properly. According to a turnitin check, this report consists of a similarity score of 6%% and Ai under 20%. Through proper guidance and support from our supervisors and university, we have implemented our project contents.

Abstract

This project presents a significant advancement in the field of autonomous emergency response systems by addressing the critical challenges associated with rapid fire detection and suppression. The system integrates a combination of environmental sensors, including flame, smoke, and temperature modules, to accurately identify potential fire hazards in real time. Leveraging modern UAV technology, the autonomous drone is equipped with a precision-controlled release mechanism capable of deploying a fire-extinguishing ball directly onto the fire source, enabling quick and targeted suppression without endangering human responders.Using advanced flight control algorithms, GPS navigation, and wireless telemetry communication, the drone ensures seamless data acquisition, autonomous decision-making, and mission execution. Real-time monitoring and alerting allow operators or emergency personnel to receive immediate updates on fire occurrences, improving situational awareness and enabling faster intervention. The system enhances firefighting efficiency by accessing dangerous or unreachable areas, reducing response time, and minimizing property damage. Overall, this project significantly strengthens the capacity for early-stage fire management through intelligent aerial intervention. By combining autonomous navigation, real-time fire detection, and automated suppression, the proposed solution contributes to safer communities, improved emergency response strategies, and a more resilient firefighting infrastructure.

Keywords: Autonomous firefighting drone, fire detection, flame sensor, temperature sensor, UAV navigation, AFO fire extinguishing ball, real-time telemetry, emergency response.

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Chapter 1 Introduction

1.1 Introduction

Fire hazards remain one of the most serious threats to life and property, especially in densely populated urban areas like Dhaka, where narrow lanes, flammable materials, and limited firefighting access make fire control extremely difficult. Conventional firefighting methods often face delays due to traffic congestion and a lack of water infrastructure, leading to significant loss of lives and assets. With the advancement of unmanned aerial vehicles (UAVs) and artificial intelligence (AI), drones now offer a practical and efficient solution to overcome these challenges. Here, we present an autonomous firefighting drone equipped with a fire-extinguishing ball release mechanism, capable of detecting and suppressing fires at their source. The system integrates real-time image processing, machine learning algorithms, and GPS-based autonomous navigation to accurately identify flames and deploy fire-extinguishing balls using a servo-controlled mechanism. By minimizing human involvement and providing a rapid, targeted response, the proposed system aims to enhance the efficiency and safety of firefighting operations. Additionally, the project emphasizes scalability, modularity, and environmental safety, paving the way for future swarm-based firefighting systems that can operate autonomously in complex environments and help reduce the devastating impact of fires in urban and rural areas alike.

1.1.1 Problem Statement

Fire outbreaks in densely populated areas such as Dhaka's urban slums and residential zones pose severe risks to human life and property due to limited accessibility, flammable building materials, and inadequate firefighting infrastructure. Conventional firefighting methods often fail to respond effectively because fire trucks and personnel cannot reach the affected sites through narrow alleyways and congested streets in time. As a result, small fires frequently escalate into large-scale disasters, causing extensive damage and displacement. Moreover, the scarcity of fire hydrants, slow response times, and lack of modern firefighting equipment further worsen the situation. These challenges highlight the urgent need for an autonomous system capable of detecting and responding to fires quickly and safely without depending on human intervention. Therefore, developing an intelligent, drone-based firefighting system equipped with autonomous navigation, real-time fire detection, and targeted suppression mechanisms can provide a faster, more efficient, and safer alternative to traditional firefighting approaches.

1.1.2 Background Study

Fires are a frequent and destructive hazard in Dhaka's informal settlements. According to local fire authorities, slum fires have become almost a daily disaster in the city. For example, Civil Defense data show 170 fires in slums during 2016 alone. These conflagrations often destroy hundreds of homes at a time; two major slum fires in 2016 alone razed about 700 dwellings. Surveys confirm that nearly every slum family in Dhaka has witnessed a fire, and over 70% have lost property or livelihoods in such incidents [1].

Firefighting in these slums is extremely difficult. Slum settlements are characterized by densely packed, improvised housing built from highly flammable materials such as bamboo, plastic, and timber. Narrow, winding alleys and congested lanes make it nearly impossible for fire trucks to enter [2]. A study of fires in Dhaka found that the average fire in a slum lasts 68 minutes – more than twice as long as in regular urban neighborhoods – largely because engines cannot reach the blaze quickly. Firefighters themselves report that minor roads, limited water sources, and scarcity of hydrants dramatically delay response times in informal settlements [3]. In many slums, the nearest hydrant may be blocks away, and residents have no reliable water supply for buckets or hoses. Overcrowding compounds these dangers: walls of adjacent dwellings can transmit flames, so fires spread block-wide almost instantly. Evacuating people is equally hard; one survey notes that evacuation and firefighting are "very difficult in [slum] areas because of high population density, narrow lanes, and irregular houses" [2].

These problems are especially acute in Dhaka's high-density pockets such as Korail, Saatkhola, and Karail slums. Recent fires have driven thousands homeless. Compounding the crisis, urbanization in Bangladesh has far outpaced fire-safety infrastructure. The fire service has only a few hundred stations nationwide and faces shortages in both equipment and manpower. In rural Bangladesh, traditional thatched homes and open-air kitchens are common, but there are virtually no hydrants or ladders outside major towns. The result is that any large fire in a village or slum easily escalates beyond local control [4].

Recent research suggests that drone technology could help overcome these constraints. Unmanned aerial vehicles (UAVs) can fly directly to hotspots, bypassing narrow alleyways and traffic altogether. Modern firefighting drones use onboard AI and sensors to detect heat or flames from above and target initial fires before they grow. For example, conceptual systems have been proposed in which a network of scouting UAVs identifies fires and firefighting UAVs autonomously deliver heat-activated fire-extinguishing balls to the affected area [5]. Experimental tests have shown that dropping fire-suppressant spheres from a small drone can effectively extinguish grass fires and may help contain building fires if deposited through openings. In short, AI-guided UAVs equipped with extinguishing payloads promise to reach places that trucks cannot, potentially providing rapid, localized firefighting in Dhaka's dense slums and remote villages where conventional services fail.

This project aims to address these critical challenges by developing an autonomous firefighting drone featuring a fire-extinguishing ball release mechanism. The drone will autonomously detect fires by receiving satellite coordinates from the coordinator, differentiate between normal heat sources and dangerous flames, and deploy fire-extinguishing balls to suppress fires at their origin. The system will integrate advanced image processing and machine learning algorithms to ensure rapid and precise response, enhancing operational efficiency while reducing risks to human life and property [6].

1.1.3 Literature Gap

Although significant research has been conducted on drone-based firefighting systems and autonomous UAV technologies, several critical gaps remain in existing literature. Most previous studies have focused either on fire detection using image processing or on drone navigation and control, but very few have successfully integrated both detection and suppression mechanisms into a single autonomous system. Existing designs often rely on manual operation, limiting their effectiveness in real-time emergencies where human response time is crucial. Furthermore, many AI-based fire detection models have been tested only in controlled environments with limited datasets, reducing their accuracy in complex real-world conditions involving smoke, wind, or low visibility. Similarly, most drone prototypes lack adaptive navigation systems capable of safely maneuvering in dense urban environments or confined areas such as slums, where traditional firefighting is most difficult. Additionally, limited attention has been given to energy efficiency, payload optimization, and the environmental impact of fire suppression methods. These shortcomings highlight the need for a comprehensive, integrated system that combines real-time fire detection through machine learning, autonomous navigation using GPS and reinforcement learning algorithms, and an effective fire-extinguishing mechanism. This research aims to bridge these gaps by developing a fully autonomous firefighting drone that enhances detection accuracy, response speed, and operational safety in challenging environments.

1.1.4 Relevance to Current and Future Industry

1.1.4.1 Impact of The Project

In today's rapidly advancing technological landscape, automation and artificial intelligence (AI) have emerged as transformative forces across multiple sectors, including emergency response and public safety. The integration of autonomous unmanned aerial vehicles (UAVs) into firefighting represents a paradigm shift in how modern industries and urban infrastructures address fire-related hazards. The proposed Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism exemplifies this transformation, offering a sophisticated, AI-driven solution that enhances both efficiency and safety in firefighting operations.

Traditionally, fire response systems have relied heavily on human intervention and ground-based equipment, which are often hindered by accessibility challenges, delayed response times, and exposure to extreme danger. This project disrupts that conventional model by introducing an intelligent drone capable of real-time fire detection, autonomous navigation, and targeted fire suppression without direct human control. The resulting increase in operational speed and precision is expected to significantly reduce both human risk and material losses.

From an industrial perspective, the adoption of autonomous firefighting drones promises to revolutionize safety standards in sectors such as manufacturing, energy production, warehousing, and urban infrastructure management. High-risk environments—such as oil refineries, chemical plants, and power stations—can benefit immensely from UAV-based fire surveillance and intervention systems. These drones can operate in areas that are unsafe or inaccessible to human firefighters, thereby minimizing downtime, damage, and potential fatalities. Moreover, integration with IoT-based monitoring networks enables centralized control, predictive maintenance, and automated alert systems, aligning with the broader goals of Industry.

From a socio-economic standpoint, this innovation has the potential to extend fire protection services to underserved regions, including remote rural areas and densely populated slums, where conventional firefighting infrastructure is limited. By democratizing access to rapid emergency response, the project contributes to greater social resilience and safety equity. Additionally, the reduction in property loss, healthcare costs, and recovery time following fire incidents represents a tangible economic benefit for both communities and industries.

The broader societal implications of this project are profound. Normalizing the use of autonomous systems in public safety operations encourages a shift toward technologically assisted emergency management and fosters greater trust in intelligent automation. As cities evolve into smarter, interconnected ecosystems, drone-based firefighting systems will become integral components of sustainable urban safety frameworks. Ultimately, this project is not merely an incremental advancement in drone technology; it represents a transformative leap toward a safer, smarter, and more resilient future.

1.1.4.2 Sustainability of The Project

The sustainability of any technological innovation depends on a holistic assessment encompassing economic, social, environmental, and political dimensions. The Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism project aligns closely with the global and national priorities of enhancing public safety, disaster management, and technological modernization. From a political standpoint, this initiative supports governmental and institutional objectives related to smart city development, sustainable urban infrastructure, and disaster resilience. As countries like Bangladesh emphasize digital transformation and the adoption of automation in public service sectors, this project fits seamlessly within current policy frameworks, ensuring long-term feasibility and institutional support.

From a social and cultural perspective, the project fulfills a vital societal need by providing a faster, safer, and more effective method for firefighting, particularly in areas where human access is limited or dangerous. It promotes community well-being by protecting lives and property, while also reinforcing public trust in technology-driven safety measures. Moreover, its design respects ethical and environmental concerns by incorporating eco-friendly fire-extinguishing materials and minimizing collateral damage during operation, thereby upholding principles of social responsibility and environmental stewardship.

In terms of economic sustainability, the project introduces new avenues for industrial growth, job creation, and skill development in fields such as drone manufacturing, maintenance, data analytics, and AI system development. The scalability of the system also offers opportunities for local industries to participate in production, assembly, and software integration, contributing to national economic growth and technological self-reliance. By reducing fire-related losses and minimizing the cost of emergency response operations, the project also presents a strong case for long-term cost-effectiveness.

Applying a SWOT analysis, the project exhibits considerable strengths—most notably its innovative integration of AI, IoT, and robotics for real-time emergency response. While potential challenges exist, including regulatory approval, airspace management, and technical calibration under extreme conditions, these can be mitigated through strategic collaboration with regulatory authorities, continuous R&D, and adherence to international safety standards. Furthermore, the growing industrial demand for autonomous systems and the advancement of drone technologies globally present substantial opportunities for expansion and improvement. In essence, this project not only embodies technological progress but also promotes sustainable development, contributing to safer communities, greener technology, and resilient urban ecosystems for the future.

Table 01: *SWOT Analysis*

Strengths	Weaknesses
Innovation: The project introduces cutting-edge AI and drone technology to firefighting.	**High Complexity**: Developing AI and real-time fire detection systems requires advanced technical expertise.
Autonomous Operation: Reduces human intervention, improving safety and response time.	**Regulatory Compliance**: Adherence to strict aviation and safety regulations can delay the project's rollout.
Real-time Fire Detection: Enables early fire suppression by detecting fires in real time using AI and image processing.	**Environmental Limitations**: Harsh weather conditions like high winds and smoke can affect the drone's performance.

Cost-Effectiveness: Commercially available components reduce operational costs, making the system more sustainable.	
Opportunities	**Threats**
Market Demand: A growing number of wildfires and structural fires creates a demand for innovative firefighting solutions.	**Technological Limitations**: Risk of errors or failures in detection algorithms, especially in complex fire scenarios.
Swarm Deployment: Multiple drones can be deployed simultaneously to cover large areas or handle simultaneous fires.	**Competition**: A growing number of competitors entering the firefighting drone market could increase market saturation.
Advancements in Drone Technology: Continuous improvements in AI and drone hardware present opportunities for better performance.	**Public Perception and Trust**: Some may be skeptical about the effectiveness of drones in high-risk firefighting situations, which can affect adoption.

1.2. Objectives, Specifications, Requirements, and Constraints

1.2.1 Objectives

The scope of this project is to develop a firefighting drone equipped with a fire-extinguishing ball release mechanism. The drone is intended to autonomously detect fires and suppress them at their source, reducing the risk to both human lives and property. The system will be designed to operate in various environments within Dhaka city, including densely populated urban areas, industrial zones like markets, and residential neighborhoods, where traditional firefighting methods may be less effective or too slow. It will also be capable of handling smaller-scale fires that often occur in these areas, providing a quicker and more efficient response to prevent the spread of flames and minimize damage to both property and human life. The drone will utilise advanced image processing and machine learning algorithms for fire detection, ensuring accurate differentiation between normal heat patterns and hazardous flame signatures. It will also include autonomous navigation capabilities to ensure that the drone can safely reach fire sites and deploy suppression mechanisms without human intervention. The fire suppression mechanism will consist of fire-extinguishing balls designed to activate upon exposure to heat, preventing the rapid spread of fires.

This project will integrate both hardware and software, involving components such as UAV flight controllers and machine learning algorithms for fire detection and navigation. The system's performance will be validated through simulations and field tests to ensure that the drone can operate autonomously and respond effectively to fire outbreaks.

Additionally, the environmental impact of the drone's fire suppression method will be considered, with a focus on minimising collateral damage to ecosystems and infrastructure.

The key objectives of this project include:

(a) Real-Time Fire Detection:

Implementing real-time fire detection using image processing techniques and advanced machine learning algorithms to accurately identify fire signatures and differentiate them from normal thermal patterns [7].

(b) Autonomous Navigation:

Employing GPS and reinforcement learning algorithms to enable autonomous navigation of the drone through complex environments, ensuring safe and efficient operation in urban and rugged terrains [8]

(c) Fire Suppression:

Developing a mechanism for the precise deployment of fire-extinguishing balls that activate upon exposure to heat, suppressing flames at their origin and preventing their spread [9].

(d) Performance Validation:

Validating the drone's performance through extensive simulations and field tests to ensure that it can effectively detect and suppress fires autonomously, and meet the required operational standards [10].

(e) Scalability and Modularity:

Designing the system to be scalable, enabling the potential for swarm deployment of drones for large-scale fire management. The system will also be modular, allowing for future upgrades and integrations with additional sensors or payloads [11].

1.2.2 Component Level Specification

***Table 02**: Component Level Specification of Design Approach 1*

Segment	Component	Dimension (mm)	Weight (g)	Specification
Flight Control System	Ardupilot APM 2.8 Flight Controller Board	82 × 50 × 16	40	1. Supply Voltage: 7V. 2. Processor: 32 Bit Cortex M4 Core 3. Bus interface (UART, I2C, SPI, CAN). 4. Firmware: Mission planner. 5. Sensors: Gyrometer, Accelerometer, Barometer, & Magnetometer
Communication	telemetry kit	26 × 26 × 9	36	1. Lightweight (under 5 grams without antenna) 2. 433Mhz frequency band 3. Receiver sensitivity to -117 dBm 4. Transmit power up to 20dBm (100mW) 5. Transparent serial link 6. Air data rates up to 250kbps
Frame	Hexacopter frame		400	1. Wheelbase: 450mm 2. Material: Glass Fiber + Polyamide-Nylon 3. Motor Mounting Hole Diameter: 3 mm 4. Arm Size: 220 x 40 (LxW) mm 5. Arm mounting holes (on frame): 3 mm 6. Arm mounting holes (on arm): 2 mm

Navigation	GPS module with compass	26 × 36 × 4	30	1. Built-in compass GPS module 2. Main chip: Ublox-M8N 3. With fast satellite searching speed and high precision 4. Includes a round plastic shell and GPS folding support
Control System	Flysky 16X controller	183 × 193 × 100	880	1. Channel: 6-10 (Default 6 2. Model Type: Fixed-Wing/Glider/Helicopter 3. RF Range: 2.408-2.475GHz 4. RF Power: < 20dBm 5. RF Channel: 135 6. Bandwidth: 500KHz 7. 2.4GHz System: AFHDS 2A / AFDHS 8. Modulation Type: GFSK 9. Stick Resolution 4096
Propulsion	DJI 2212 motor	144.018 × 118.11 × 34.036	55	1. Type: 800KV brushless DC motor 2. Voltage: Supports 3S–4S LiPo battery (11.1V–14.8V) 3. Application: Quadcopter propulsion 4. Thrust: Up to 850g per motor (with compatible propeller)

Processing Unit	Raspberry Pi 5	-	60	1. VideoCore VII GPU with OpenGL ES 3.1 & Vulkan 1.2 support 2. Dual 4Kp60 HDMI® display output with HDR 3. Equipped with 4GB LPDDR4X-4267 SDRAM 4. Dual-band 802.11ac Wi-Fi® and Bluetooth 5.0 / BLE 5. 2× USB 3.0 (5Gbps) + 2× USB 2.0 ports 6. PCIe 2.0 x1 interface for high-speed peripherals
Propulsion	ESC	–	6.6	1. Type: 30A or compatible for the DJI 2212 motor 2. Signal Input: PWM from microcontroller 3. Features: Motor speed control, overheat protection 4. Power Supply: Direct from LiPo battery
Display	Monitor	184 × 126 × 28	450	1. Type: Basic FPV or USB camera (depending on setup) 2. Function: Real-time video transmission 3. Interface: USB or analog video transmitter
Vision System	Camera Module	12.5 × 12.5 × 17	5	1. 8 Megapixel 2. Resolution 3280 x 2464 3. Supports: 1080p30, 720p60, 4. Weight 3g

Power System	Battery	3.5 × 8.0 × 20	20	1. 4S LiPo (11.1V), 4200mAh
Actuation	Servo motor	39.5 × 20.5 × 40.7	14	1. Model: A2212 2. RPM/V: 1000KV. 3. Batteries: 2-3 Li-Poly. 4. Efficiency: 80%. 5. Current: 4-10A (at 75%). 6. No-load current: 10V/0.5A. 7. Max. transient current 12A/60S.
Power System	B3 Pro Compact Charger	95 × 55 × 35	180	1. Balance charger for LiPo batteries 2. Input: AC 100–240V, 50/60Hz 3. Output: Supports 2S/3S LiPo (7.4V/11.1V)
Communication	VTX transmitter	36 × 36 × 4.5	6.8	1. Transmits live video from the camera to a receiver (e.g., FPV goggles) 2. Frequency: Typically 5.8GHz 3. Power Output: 25–800mW adjustable
Communication	Video transmitter	73 × 41 × 14	80	

1.2.3 Requirements

1.2.3.1 Functional Requirements

1. **Real-Time Fire Detection:**
   The system should be in a position to respond to the environment it is in by constantly surveying it with high-resolution cameras. It will apply machine learning algorithms to detect fire. The latency of the detection process should be minimal to detect the fire at the earliest possible time before it has escalated causing additional destruction.

2. **Autonomous Navigation:**
The drone has to be capable of self-navigating in its world through the means of GPS and sophisticated navigation algorithms. It must have the capability of changing its course depending on the obstacles like buildings, trees, power lines among others to give a safe and efficient route to the fire scene. The system should also have the capability of functioning in the urban and remote regions, with minimum human intervention.
3. **Fire Suppression Mechanism:**
When a fire is spotted, the drone will trigger a release system that uses servo-controlled balls to release fire-extinguishing balls. The suppress mechanism should have the capability to precisely locate the source of the fire and apply the suppressant when the temperature is beyond the limit without wasting resources.

Table 03: *Fire Extinguishing Ball Specification*

Weight(kg)	Coverage Area	Activation Time
1.3	8-10 m^2	3-5 seconds upon contact with flame (⩾70°C)

4. **Battery Management and Return-to-Home (RTH) Feature:**
A drone should be designed with an automatic return to home (RTH). When the battery runs out or the signal is lost the drone needs to fly back to the starting point or a safe area that is set up. This guarantees safety of the drone and its mission efficiency [10].
5. **Communication System:**
The drone should have a communication connection to a ground control station to control it in real time and transmit the data. The communication system is to facilitate the exchange of essential information including fire detection warnings, drone position, and position. Communication channel has to be secure and of low latency so that it responds in time [11].
6. **Fire Suppression Confirmation and Monitoring:**
Once the fire- suppression mechanism has been deployed, the drone should ensure that the fire has been suppressed. It will give real-time feed-back to the control center which will verify the suppression and track the fire conditions until complete suppression is attained.

1.2.3.2 Non-Functional Requirements

1. **Reliability and Robustness:**

The system should be in a position to perform in extreme conditions in the environment which include high winds, hot weather and high levels of smoke. The system must be capable of healing itself through less severe faults within a short period of time and resumes operation without losing massively in the performance. The drone must have a target success rate of operations of more than 90 percent [7].

2. **Safety Considerations:**
   The herding of the drone should be made in such a way that it is the safest. It should also have emergency backup features in case of loss of GPS signal, the battery runs flat or the system malfunctions. Besides, the system should also ensure that there is no unintentional fire suppression around humans, animals, or essential infrastructure [7].
3. **Efficiency and Response Time:**
   The drone should be capable of identifying fires and throwing the fire-fighting balls with significantly low latency. The speed at which the fire is detected to deployment of suppression will be used to measure the system effectiveness. Such delay should be unfortunate to diminish the risk of fire spreading and make the effort to intervene in time [8].
4. **Scalability and Modularity:**
   The design should be such that it can be upgraded in future and other sensors or payloads can be added. It must as well accommodate scalability, which opens the prospect of having several drones in a swarm to cover more areas or address several fire incidents at a time. The communication protocols must be standardized so that they can be used to coordinate more than one drone [11].
5. **Cost-Effectiveness:** The system must be affordable and in this case compose of commercially available elements so as to reduce the production and operational expenses. The drone should also be energy efficient and optimized power consumption should be implemented to guarantee that it will last as long as it can under the battery restrictions. This will enable it to cut the cost of operation and still make the drone affordable to as many people as possible [10].
6. **Environmental Impact:**
   The fire-suppression approach should ensure that the environment is not damaged a lot. The balls used by the drone to put out fire must be eco-friendly such that their usage does not destroy the environment. Moreover, the work of the drone should not have adverse effects on the ecosystem that surrounds it on the fire fighting missions [9].
7. **Compliance with Regulatory Standards:**
   The drone has to meet both local and international regulations of the unmanned aerial vehicle systems (UAS). These are airspace regulations, altitudes of flights, and communications. Frequencies and working areas. The drone should also be safe. Autonomous system standards used in the emergency response application [7].

1.2.4 Constraints

1.2.4.1 Constraints of System Failure

Constraints of System Failure are the vital limits and conditions that when unattended may lead to the failure of a drone system in the course of operation. These are limitations of payload capacity and battery life to support stability and flight duration, environmental issues like strong winds, high temperature or smoke to disorient sensors and navigation, and compatibility with the existing firefighting infrastructure with similar communication protocols. Moreover, the drone should be dependable and strong in extreme conditions to guarantee that the level of its operational success is high, and at the same time the onboard systems should not exceed severe power constraints so that the drone could perform continuous flight and surveillance.

1. **Payload Capacity and Battery Life**: The drone needs to comply with the rigid weight requirements to be stable and have a minimum duration of 35 minutes per a battery cycle of flight.
2. **Environmental Conditions**: The design should be able to take into consideration the extreme weather conditions like high wind, extreme heat and high-level smoke that may hamper the sensor operation and aerial performance.
3. **Integration and Interoperability**: The drone should integrate effectively with the current firefighting systems such as ground control stations and cloud-based surveillance systems via standardized communication procedures and modularity.
4. **Reliability and Robustness**: The system has to work well in unfavorable environment conditions like high temperature and strong winds with a success rate of over 90% in operational success.
5. **Battery Power and Flight Duration**: The onboard systems are expected to run under strict power budgets so that the flight time is optimized and continuous operation and response over a period of about 20 minutes on a single charge of the battery.

1.2.4.2 Regulatory Constraints

1. **Regulatory Compliance**: The system needs to be in conformity with aviation and safety regulations by the local and international authorities (e.g., FAA requirements), which might restrict the altitude of flights, communication frequency, and operating areas.
2. **Safety Standards**: The drone should comply with relevant fire safety standards such as NFPA (National Fire Protection Association) and ISO (International Organization Standards) requirements, by which the fire suppression system should be efficient and prove to be operational within necessary conditions.
3. **Communication Standards**: The drone should comply with communication standards, including IEEE 1937-2020 and ISO 23137:2021, to provide secure and low-latency control and telemetry among the drone and the ground station, in order to ensure that the drone complies with the data transmission and control regulations.

1.2.4.3 Ethical Constraints

1. **Safety Considerations**: The design should make sure that the activities of the drone do not pose a threat to the firefighters, locals, or critical infrastructure. The fire suppression system (The arm with the fire extinguishing ball) should be connected to AI software that recognizes the presence of a person or an animal or crucial structures, to avoid the unintended release of the suppressants in these regions.
2. **Environmental Impact**: The implementation of the fire-extinguishing balls should be carried out keeping in mind the least possible harm to the environment. The AI-system should make

sure that the drone does not release the suppressants in the sensitive ecosystems or the non-hazardous places.
3. **Privacy**: The ethical issues of privacy and, in particular, of privacy in cities need to be taken into consideration. The drone must also consider that the processes of image analysis and monitoring must not violate the legislative acts or cross into the personal zones, particularly in the people-filled areas.

1.2.5 Applicable Standards and Codes (CO2)

Designing a drone that is autonomous and has the ability to fight fire, it is necessary to comply with certain technical requirements and regulations that provide the drone with the necessary safety, compliance with legal regulations, and performance. The standards and codes that are especially applicable to this application are as follows:

1. Aviation and Flight Safety Standards

- ISO 21384-3:2019 – Unmanned Aircraft Systems — Part 3: Operational Procedures defines the safety requirements in UAS missions such as flight planning, risk zones, and post-mission logs.
- IEEE 1937-2020 – Standard UAS Communication and Control Secure, low-latency drone-ground station control and telemetry.
- ASTM F3266-18 – Standard Specification of small UAS (sUAS) to be used in civil purposes lays down the safety and performance requirements of small drones in civil operations such as fire surveillance.
- ISO 23137:2021 – UAS —Data Protocol and Communication Requirements Useful in specifying the manner in which flight control, video and fire-detection data is safely managed.
- IEEE 1588 Precision Time synchronization in networked systems Time synchronization.

2. Communication and Data Transmission

- IEEE 1937-2020 – Standard for Unmanned Aircraft Systems (UAS): Communication and Control Characterizes the communication structure of the drone and the ground control station. Include latency, encryption, redundancy and control signal integrity.
- ISO 23137:2021 – UAS — Data Protocol and Communication Requirements Standardizes telemetry, control, and video feeds communication protocol. Guarantees interoperability and safe interchange of data during multi-UAS.
- ISO/IEC 29182 – Sensor Network Reference Architecture (SNRA) can be used to describe configuration of real-time sensor data flow between sensors (e.g. cameras, gas sensors) and processing units and remote systems.
- IEEE 802.11 (Wi-Fi Standards) – Particularly 802.11n/ac Used in high bandwidth and short-range transmission - this is applicable in video streaming and image processing.

- IEEE 802.15.4 – Low-Rate Wireless Personal Area Networks (LR-WPANs) Useful when measuring modules on a swarm or onboard modules are required to communicate with low power over short distances.
- ISO/IEC 27001 – Information Security Management Systems can be used to guarantee secure management and transmission of sensitive video, location, and thermal information.

3. AI and Image Processing Standards

- ISO/IEC 15444 (JPEG2000) for image compression and processing Quality layers for Progressive transmission Region of interest coding for giving precedence to areas of fire detection.
- ISO/IEC 22989 - Concepts and terms of artificial intelligence.
- ISO/IEC 23894:2023 – AI Risk Management Covers the identification of AI-related risks, their assessment, and mitigation in the real-world application (e.g., false fire alarms, ethical misjudgment).
- ISO/IEC 23053:2022 – Framework for AI Systems Using Machine Learning It helps structure your AI model development lifecycle: data collection, training, validation, deployment, and monitoring.
- ISO/IEC 24029-1:2021 – Artificial Intelligence: Assessment of the Robustness of Neural Networks Ensures your fire-detection AI model is trustworthy, robust, and behaves reliably under unexpected conditions.
- ISO/IEC 22989:2022 – Artificial Intelligence Concepts and Terminology Defines general AI principles and helps standardize documentation and explanation of AI features in your system.

4. Firefighting and Safety Standards

- IEC 60529- Ingress Protection (IP) tests on electronics Need dust Protection and Water Protection Thermal Protection Tests on electronics in hot environments.
- NFPA 1143 – Standard for Wildland Fire Management Applicable to the utilization of drones in wildfire situations identifies command hierarchy, deployment, and coordination with fire fighting teams.
- NFPA 950 – Data Development and Exchange Standard in Fire Services, This is to ensure that the data of your drone (such as real-time fire detection, GPS logs, etc.) is formatted and exchanged in a manner that is compatible with fire departments.

- NFPA 72 – National Fire Alarm and Signaling Code Applicable to incorporate the detected fire alarms by drones in the current alarm or emergency systems.
- ISO 7240-1:2014 –Fire Detection and Alarm Systems is a standard that offers an accuracy and performance baseline in your AI fire detection system.
- ISO 14520 – Gaseous Fire Extinguishing Systems Covers the safety, use and testing of gaseous fire suppression agents (assuming that you use them in your ball or system).
- EN 3- 7: 2004 + A1: 2007 – Portable Fire Extinguishers (EU Standard) Affects fire suppression balls, when they are regarded as portable extinguishing agents - regulates performance, labelling, and discharge activities.

5. Embedded Systems and Software

- DO-178C- Software Springs, Safety-critical Software development in Airborne Systems and Equipment Certification SO-178C guidelines Verification and validation requirements.
- IEC 61508- Functional safety of electrical / electronic / programmable electronic safety-related systems Safety integrity Level (SIL) Specifications Requirement of fail-safe operation.
- ISO/IEC 25010- Systems and Software Quality Requirements and Evaluation Quality attributes of autonomous systems Reliability metrics of the mission critical applications.

1.2.6 Reasoning Behind Selected Standards and Codes

The standards that have been used were selected to have a safe, reliable, and internationally best-practice firefighting drone. Aviation and flight safety codes (such as ISO 21384-3 and ASTM F3266-18) contribute to stable flight, risk-free operation, and compliance with the rules of the airspace of UAVs. The standards of communication (ex: IEEE 802.11, ISO 23137) ensure the safety and real-time data transfer between the control systems and the drone. Standards (like ISO/IEC 24029-1 and JPEG2000) with regard to AI and image processing help in designing quality and reliable fire detection algorithms. Fire safety standards (such as NFPA 1143 and ISO 7240-1) are adequate to make sure the fire suppression system is effective in the case of an emergency. Lastly, embedded systems and software standards (e.g., DO-178C, IEC 61508) were chosen to help achieve fault tolerance, fail-safe operating and high reliability software in mission-critical operating conditions.

1.3 Conclusion

The project of Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism offers a new and viable way of dealing with fire emergencies in complex and risky situations. The necessity of such a complex system that is fast-reactive is acute in a densely populated nation such as Bangladesh, where the existing firefighting option is rather ineffective in this very region because of the accessibility and infrastructure issues. This project will transform the traditional fire detection and suppression methods by incorporating the use of artificial intelligence, machine learning, and autonomous navigation technology. Real time image processing to identify the actual flame with accuracy and precise ball release based fire suppression mechanism ensures a timely and precise fire control. This method does not only minimize the risk to human beings but also minimizes damage of property and increases overall operation efficiency. In conclusion, the offered system can be discussed as major progress of firefighting practices of the future as it will be smarter, safer, and more sustainable, and it is also a step towards the further evolution of intelligent disaster management solutions in the contemporary world.

Chapter 2

2.1 Introduction

This chapter gives a detailed explanation of the design methodology that was used to develop the firefighting Drone System. The system is developed to transform conventional firefighting methods by combining artificial intelligence, image recognition, environmental sensory, and autonomous control of flight to be able to effectively detect, analyse, and suppress fire. Two different designs were brainstormed and developed to determine the most effective and scalable design: (1) an AI-powered Hexacopter design and (2) A sensor-powered Quadcopters system. Both designs aim at reducing the human presence on the dangerous operations and maximizing the level of situational awareness, effectiveness of fire suppression, and operational safety.

2.2 Identify Multiple Design Approaches(CO5)

The project takes into account two possible design solutions in order to obtain the required autonomous firefighting abilities. In both strategies, unique detection schemes, processing units, and control actions have been used without altering the primary functions of flight stability, fire suppression, and communication.

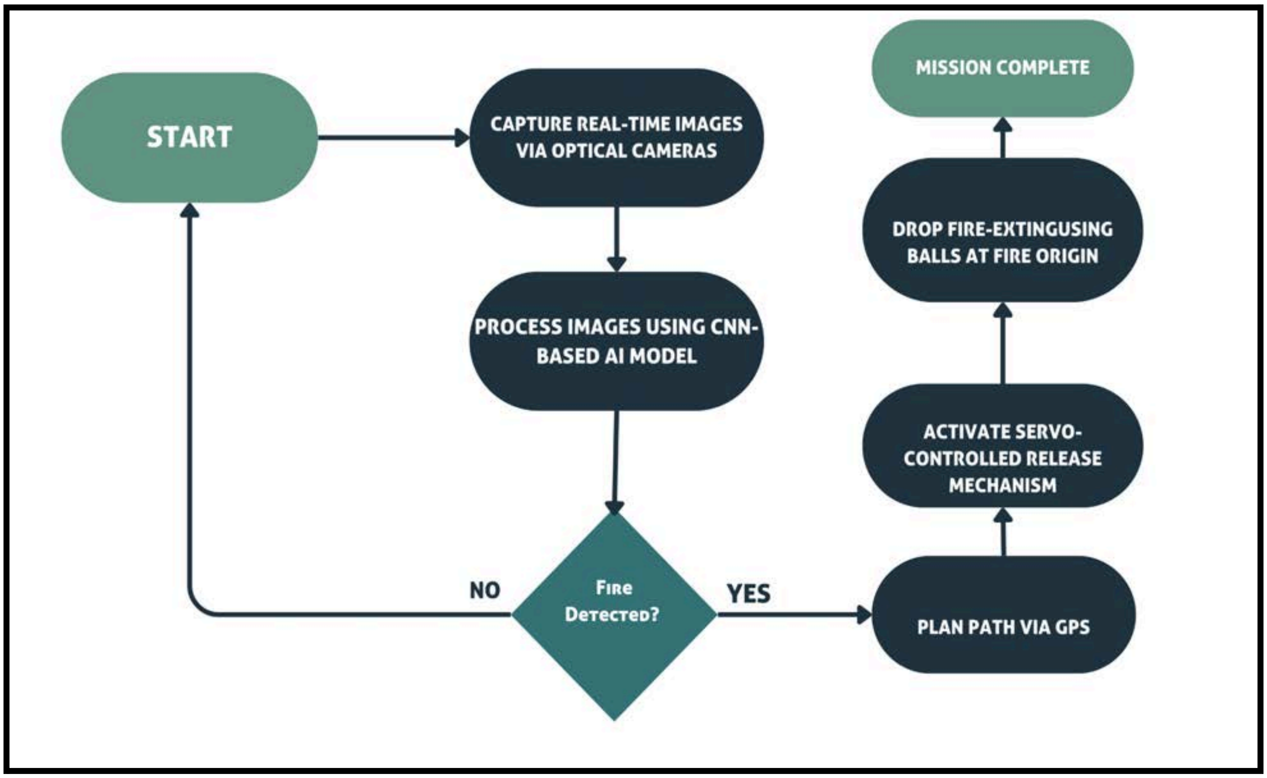
• **Design Approach 1** – AI-Based Hexacopter: It is based on the techniques of computer vision, deep learning (YOLOv8), and image processing to locate and identify fires in real time. It features a GPS autonomous navigation system and a Fire extinguishing ball release system that is controlled by a servo motor system.

• **Design Approach 2** – It operates on the premise that sensors can be used to monitor the environment and identify fire-related dangers, including gases sensors (MQ2, MQ7, MQ9), temperature sensors (DHT22), and flame sensors. It is based on a modular and low-cost platform that focuses on simplicity and reliability.

We intend to solve the issue through the design of such a device utilizing two Design Approaches. We will locate the Design Approaches 1 and 2.

2.2.1 Design Approach 1

Figure 01: *Workflow Model for Design Approach 1*



As we can observe in Figure 01, the Design Approach 1 is centered around an autonomous AI-controlled drone which is used as a firefighting unit powered by a hexacopter frame, which is optimized in terms of performance and durability. The overall point is to upscale the firefighting efforts and use artificial intelligence and some advanced image processing to detect and suppress fires in real-time. The drone combines several advanced technologies to independently find the fire, move safely, and extinguish the fire with the help of a fire-extinguishing ball launch system, which is turned on when it is heated.

__Figure 02:__ 3D Model of Design Approach 1

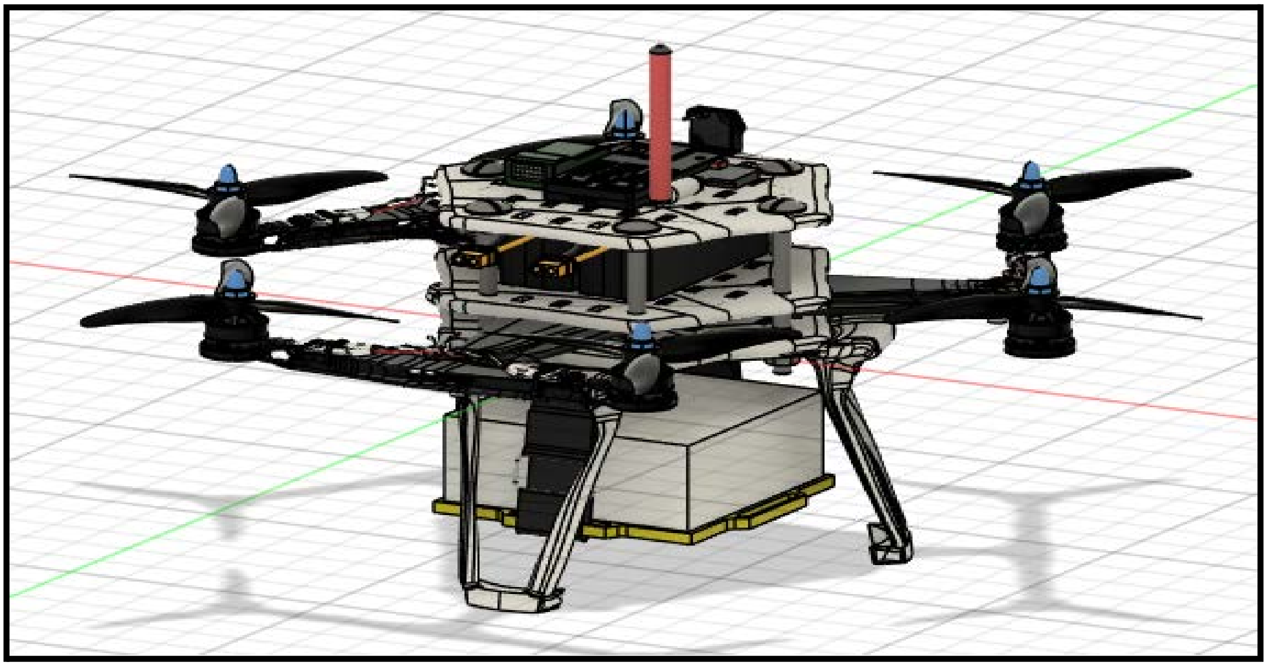
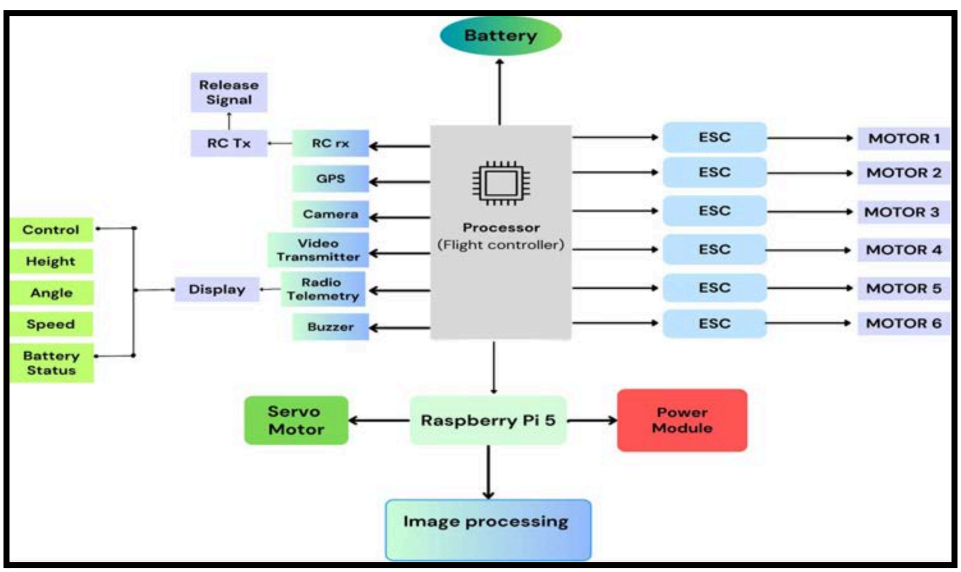


__Figure 03:__ Component Workflow Model for Design Approach 1.



The AI-driven fire detection ability is at the center of the system. The drone also has powerful optical cameras that images the environment in real time. The image processing would be done using machine learning algorithms, namely, a Convolutional Neural Network (CNN), which is able to distinguish between fire and other common heat sources. This will enable the drone to identify fire quickly, reducing the response time and offer quick intervention. The AI model will be trained on the extensive collection of fire and non-fire images so that it can make appropriate decisions even in a complicated setting, including smoke or obscured spots.

After detecting a fire, the drone has a suppression mechanism that goes on. A servo-controlled release mechanism sprays the fire- suppressant balls, which have been designed to spray the suppressant upon getting exposed to heat. The same mechanism makes sure that the balls are properly thrown in the region of the fire that is the hottest and thus the flames are lessened in the area of their origin. This design requires less active human efforts in the hazardous zones, which makes this design much safer and effective compared to the traditional system of firefighting.

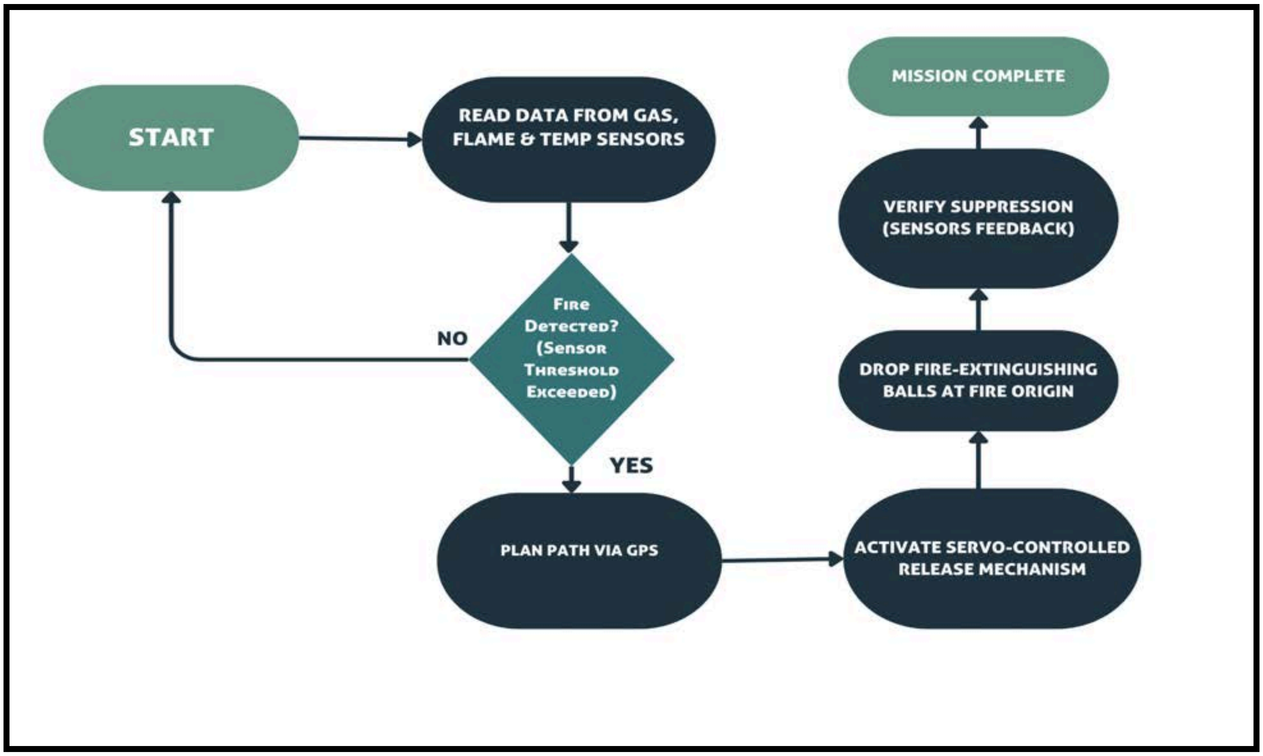
To navigate, the drone takes appointments to GPS besides reinforcement learning-inspired algorithms to program flight paths autonomously. The drone can evade such objects as buildings, trees, power lines, with the help of such algorithms; as a result, the drone is able to easily and safely arrive in the fireplace. The GPS can be used to track its exact position which is instrumental during operation within the urban setting or in remote areas where human beings are restricted.

The drone also has a real time communication system, which is transmitting data in a ground control station. It involves video feeds, fire alerts, and positions, which enable the firefighting engineers to be aware of the situation remotely and make wise decisions. The onboard AI of the drone will make sure that the amount of suppressant used is the minimum, considering the intensity of that fire and people or critical infrastructure.

To conclude, Design Approach 1 is a combination of the latest AI, machine learning, and drone technologies to develop a highly efficient and robotic firefighting system. The high sophistication of sensors, real-time communication and fine-tuning of fire suppression systems makes this system a very scalable and efficient solution to present-day firefighting problems.

2.2.2 Design Approach 2

Figure 04 : *Workflow Model for Design Approach 2*



We can observe in Figure 04 that Design Approach 2 offers a more cost-effective and easier to implement solution to an autonomous firefighting drone based on a quadcopter frame, which is a viable alternative to Design Approach 1 that is more complex and requires more money. This design is constructed on the basis of a modular design system which uses a combination of environmental sensors such as gas sensors (MQ2, MQ7, MQ9), temperature sensors (DHT22), and flame sensors in detecting a fire hazard. The major benefit of this solution is that it is simple and reliable and thus it is the best option in locations where speed of implementation and convenience are the main priorities. In contrast to the AI-type fire detection in Design Approach 1, the given design depends on the direct sensor-based fire detection, which, however, might lack the same degree of sophistication but offers strong and robust performance under real-life conditions.

Figure 05: *Sketch Diagram of Design Approach*

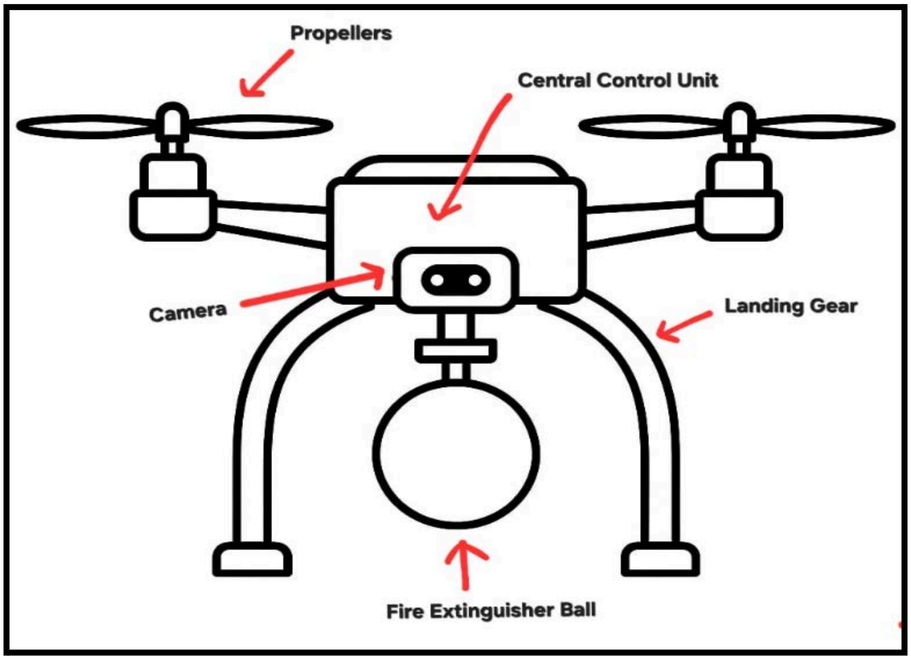
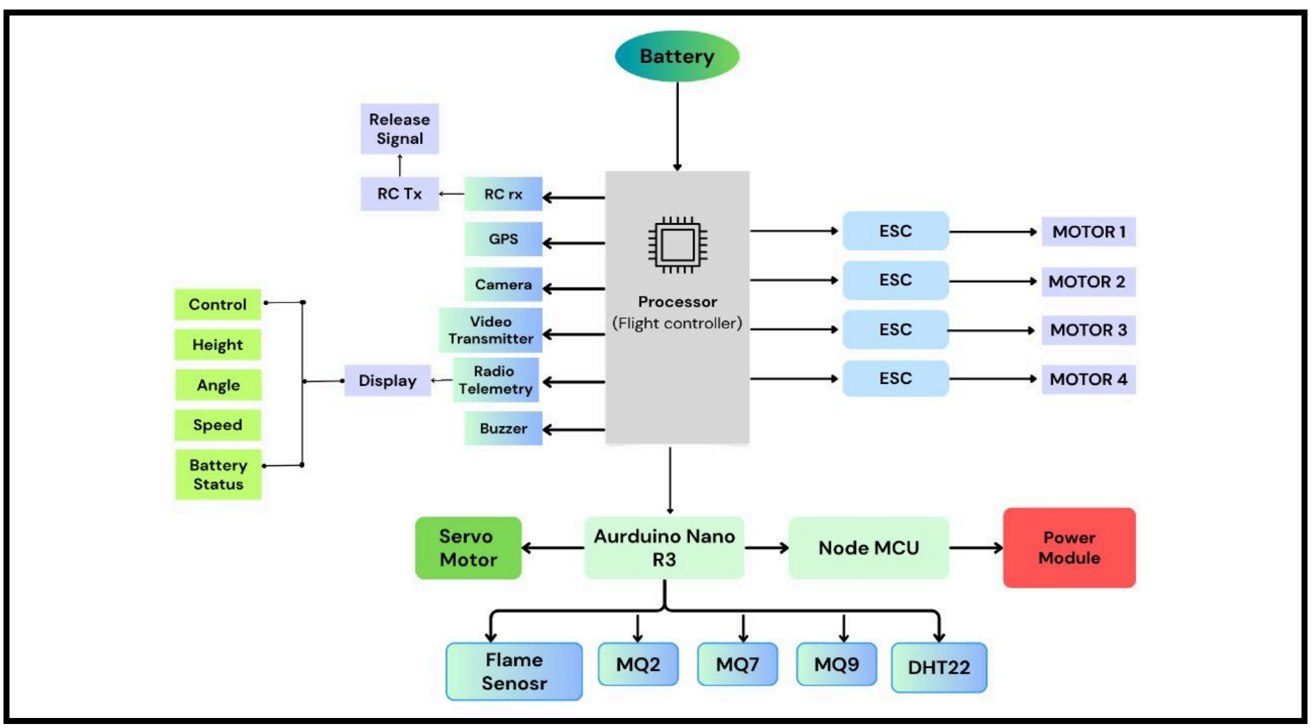


Figure 06: *Methodology flowchart of Design Approach 02*



The Design Approach 2 fire detecting system employs several gas sensors and flame sensors to sense various fire indicators like flammable gases, rise in temperatures and direct flame. Although it does not have advanced image recognition and machine learning features of the first design, it has sensors that can be successfully used to detect fire-related risks, particularly in the environment where the use of optical cameras can be limited due to smoke or visual barriers. These sensors keep on surveying the surroundings and alerting in case a fire or a risky situation is noted and timely interventions can be made. The information of such sensors is computed on board, and the drone is capable of self-responding to the circumstance and implementing a fire suppression system when necessary.

Upon the detection of a fire, Design Approach 2 releases a fire suppression ball via a servo-controlled release system like in the first design. These fire ball types are triggered when affected by heat and the suppressant characteristic of such fire balls is emitted to the main fire. This system will be aimed at quelling the fire at the initial stage to avoid its propagation, thus improving the efficiency and safety of fighting the fire. The suppression mechanism has been developed in such a way that it can be effective even in the areas where accuracy concerning the targets is necessary like forested areas or urban landscape with complex structures.

In the area of navigation, Design Approach 2 integrates the GPS and reinforcement learning algorithms of autonomous navigation. This also allows the drone to map the flight paths as they happen. Its drone can be autonomously directed to the place of fire, and it is particularly useful in areas that do not allow human firefighters to reach. Under this design, this drone can access fire sites within a short time and in a safe manner to ensure that the fire is suppressed in time without involving human effort.

2.3 Comparison of Design Approaches

Table 04: *Comparison Of Design Approach 1 & Design Approach 2*

Criteria	**Design Approach 1 (Hexacopter, AI)**	**Design Approach 2 (Quadrocopter, sensors)**
Structure & Materials	Hexacopter with carbon fiber and a lightweight frame	Quadcopter with carbon fiber
Fire Detection	Optical cameras with AI	MQ2, MQ7, MQ9,DHT22 temperature sensor, flame sensor
Navigation	GPS sensors with reinforcement learning for navigation	GPS sensors with reinforcement learning for navigation

Fire Suppression	Servo-controlled release of fire-extinguishing balls	Servo-controlled release of fire-extinguishing balls
Power System	Li-Po battery (~40 min flight)	Li-Po battery (~40 min flight)
Communication	RF transceivers & Wi-Fi for real-time monitoring	RF transceivers & Wi-Fi for real-time monitoring
Emergency Handling	Basic return-to-home (RTH) & fail-safe mechanisms	Basic return-to-home (RTH) & fail-safe mechanisms
Cost	Higher production cost	Lower production cost
Scalability	Swarm deployment is possible with some adjustments	Swarm deployment is possible with some adjustments
Ease of Implementation	More complex, requiring specialized components and AI models	Easier to develop and deploy

Design Approach 1 (Hexacopter with AI) and Design Approach 2 (Quadcopter with sensors) represent the two possible solutions to an autonomous firefighting drone, and they are quite different in nature, their capabilities, and complexity. Although both designs have similarities in terms of materials (carbon fiber), navigation (GPS with reinforcement learning), fire suppression (servo-controlled fire-extinguishing balls), power (Li-Po battery), communication (RF and Wi-Fi) and emergency management (RTH mechanisms), the main distinction is in the detection technology, design and performance in general. Design 1 uses optical cameras that have incorporated AI to monitor fires and gives higher accuracy, faster response times, and dynamism in changing environments- benefits compared to the gas and temperature sensors, which would be employed by Design 2. Design 1 has a hexacopter design, which has a higher lift capacity, stability, and fault tolerance than the quadcopter. Design 1 is also cheaper than its high-end counterpart, has better detection, structural stability, and can be operated autonomously with the help of AI, so it will be a more sustainable and future-proof system. Thus, the optimal design approach to a high-performance and scalable firefighting drone selected is Design Approach 1.

2.4 Conclusion

The design and analysis of two different methods to develop an autonomous Firefighting Drone System was described in this chapter. The Hexacopter is an AI-controlled device that has a high accuracy, intelligent detection, and excellent flying stability, which is applicable in large-scale firefighting and dangerous missions. The sensor-equipped Quadcopter offers a cheaper and more easily deployable solution to rapid response to emergencies. Judging by the results of functional analysis and results of simulation, the AI-powered Hexacopter is declared to be the most optimal choice as it is flexible, reliable, and scalable in a dynamic firefighting setting.

Chapter 3: Use of Modern Engineering and IT Tools [CO9]

3.1 Introduction

The key point of us is the responsible choice and impeccable incorporation of innovative IT tools. This is a sophisticated process that involves a thorough evaluation of a wide range of hardware parts, and the sharp scrutiny of how they fit perfectly well with the greater goals of our project. Our decision making process is characterized by a commitment to informed decision and strategic thinking. The handling of these aspects, in the exact coordination, is not only in the arrangement of the hardware parts, but also in a procedural world where every one step is precisely performed.

3.2 Select Appropriate Engineering and IT Tools

(a) Python Language: Python is easy to use and readable, with its capability to support enormous libraries that have popularized it with computer vision. Its simplicity allows developers to concentrate on issues instead of focusing on details on the bottom of the stack. There are libraries such as OpenCV, NumPy, and Scikit-image that are used to do image processing, computational operations and implementation of algorithms. Python can also be used in conjunction with deep learning platforms like TensorFlow and PyTorch because it can be used to create and deploy highly complex neural networks that can be used to perform object detection, image segmentation and face recognition. Free resources and an active development community contribute to the reasons for its popularity. This accessibility enhances teamwork, knowledge sharing and quick prototyping that boosts innovation in the field of computer vision.

(b) Raspberry Pi: Raspberry Pi is a full fledged credit card sized computer which can be used to handle Computer vision tasks because it has all the onboard computer hardware. The Raspberry Pi has the ability to run various operating systems that can be used in addressing the needs of a particular user. In our case we are utilizing the official Raspbian which is built on Linux. Raspberry Pi 5 has numerous GPIO (General purpose Input Output) pins and this enables it to interface with external hard-ware like motor drivers, other controllers and sensors.

(c) Proteus Software: Proteus is applied in designing and simulation of electronic circuits. It is widely used among engineers, designers and students to assemble, experiment and repair electronic circuits. Proteus consists of two primary components; a schematic capture tool and a PCB layout tool. Through a schematic capture tool, users have the capability of simulating a set of electronic circuits with a variety of different components (resistors, capacitors, transistors, microcontrollers and so on). Among the most important features of the Proteus is the possibility to simulate a real-time circuit used to ensure that there are no issues with a certain circuit before one constructs a hardware with it to test it in reality. This software will be used in our analysis of the data of our Raspberry Pi and the transfer of the data to the subsequent subsystem..

(d) Google Colab: The distinction between Google Colab and other Integrated development tools is that it is a Jupyter notebook type of integration and a web-based user interface. This renders the use of Google Colab very simple. Google Colab also runs its Python Compute Backend support that supports CPU, GPU (Graphics processing Unit), and TPU (Tensor processing Unit). These are machine learning training tools, such as the one we have applied in our project. It is quite simple to combine libraries such as Keras, OpenCV, TensorFlow, and Pandas using Google Colab, and these tools are easily accessible. The workloads on Google Colab are, however, disadvantageous since it needs a premium subscription.

(e) Nvidia CUDA and CNN: CUDA and CNN merge parallel processing capabilities of GPUs, which come in handy in the training of machine learning. These tools have been used to execute the training in an operating system computer with Windows Operating system. The computer has: GPU: Nvidia GTX 1650, Video Memory: Dedicated: 4GB. Shared: 2GB. System Memory: 8GB DDR4 3200MHz. We used this machine to run our training because of the system runtime allocation constraints with Google Colab.

(f) Microsoft Visual Studio Code: Visual Studio Code or VS Code is our choice of the integrated development environment. VS Code is integrated with Python and other libraries, so it is an ideal candidate that fits our particular requirements.

(g) MATLAB and Simulink, used together can also be successfully applied to simulate drone systems and their electronic parts (g). Part of the modules employed in our drone, such as some of the sensors or wireless communication modules, are not easily available in Proteus, with the simulation support, and therefore must be hand-created internally in the simulation environment. But it can be difficult to model such components with high precision, namely modules such as gas sensors or flame detectors. Previous studies have also shown that it is possible to build or import custom libraries and toolboxes in MATLAB/Simulink to better recreate the behavior of these sensors and it can be useful to prototype as well as analyze the performance of the drone based fire detection systems.

(h) Codevision AVR: This is the default computer application used to build Embedded C codes to be used in Proteus to simulate the ICs. It is not only applied to simulation coding, but also to real life applications in hardware.

(i) XtremeBurner AVR: It is the computer program used to create hex files to be burned into the hardware ICs. The simulation in the case would also require the hex files to be placed in the ICs, but hex files generated by Codevision AVR cannot be burned into the ICs with XtremeBurner. In our case of simulation, this application is used to support the codes and hex files..

3.3 Conclusion

The above modern IT and engineering tools have been used throughout the ideation to prototype phase. Most of these tools were used to evaluate and ultimately, select the best design strategy in our project. Moreover, during simulation and prototype construction, these tools have assisted in swift testing, as well as, made the whole process much easier. In addition, simulations also assisted us with trial-and-error ideas before commencing work on hardware. These tools have allowed the project to incorporate many more elements and have facilitated significant transformation and analysis of data. These tools, such as Simulations, have played a critical role in meeting the project requirements and objectives, owing to their 3D design.

Chapter 4: Optimization of Multiple Designs and Finding the Optimal Solution [CO7]

4.1 Introduction

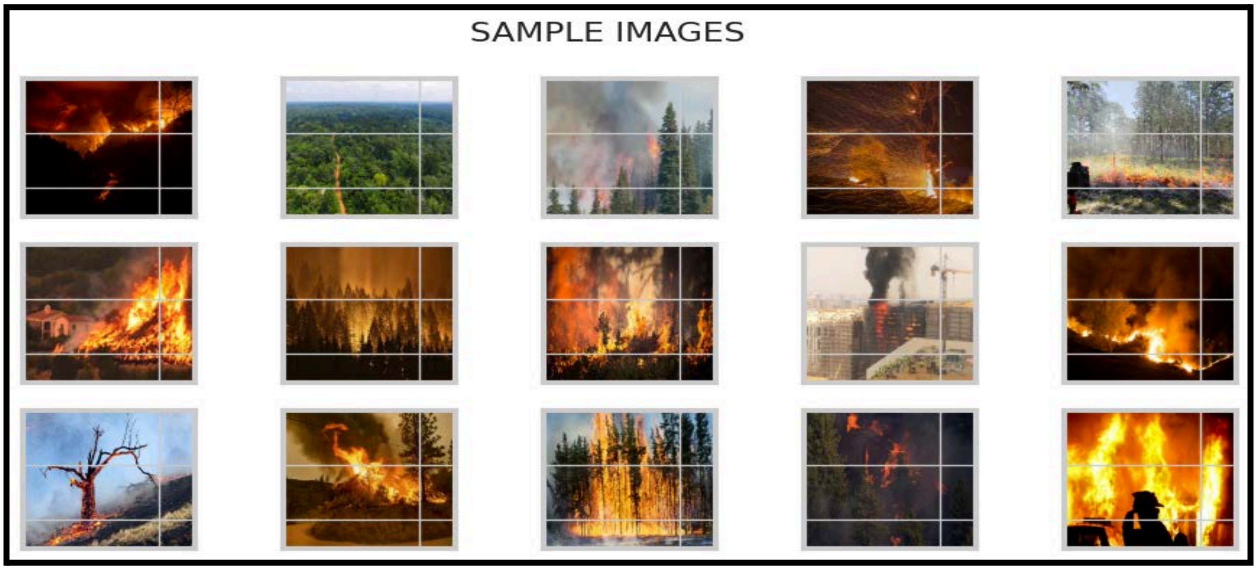
In the case of this complicated issue, we tend to come up with a variety of possible solutions or designs. Systematic evaluation of all these competing designs against established criteria and constraints that include cost, performance, efficiency, and reliability is known as the process of Optimization of Multiple Designs. The aim here is to go beyond a mere solution and to get the Optimal Solution, which is the most appropriate solution that is capable of meeting all the requirements and any trade-offs that must be made. The given objective is concerned with the means to quantitatively compare these options and provide an evidence-based decision to choose the one and the only best design.

4.2 Fire Detection Dynamic Simulation of the Designs

4.2.1 Design Approach 1

Dataset Training:

Figure 07: *Sample Images*



Training Configuration:

Table 05: *Training Configuration*

Parameter	**Value**
Base Model	YOLOv8 ('best.pt')
Epochs	100
Image Size	640x640 pixels
Data Configuration	Loaded from 'dataset.yaml'
Total Images	4320
Training	3456
Validation	432
Testing	432

Technical Details:

Hardware:

Though we had not mentioned any hardware restrictions in our code, the model used is YOLOv8, and it can be actively used on both CPU and GPU. In training, we used the T4 GPU runtime environment offered by Google Colab that offered us the required computing power during this session [14].

Model Overview:

The YOLOv8 small model comprises about 225 layers and has a total of about 12 million parameters. The disk size of the model is approximately 50 MB. It uses three detection heads making it able to see objects effectively across various scales.

Loss Functions:

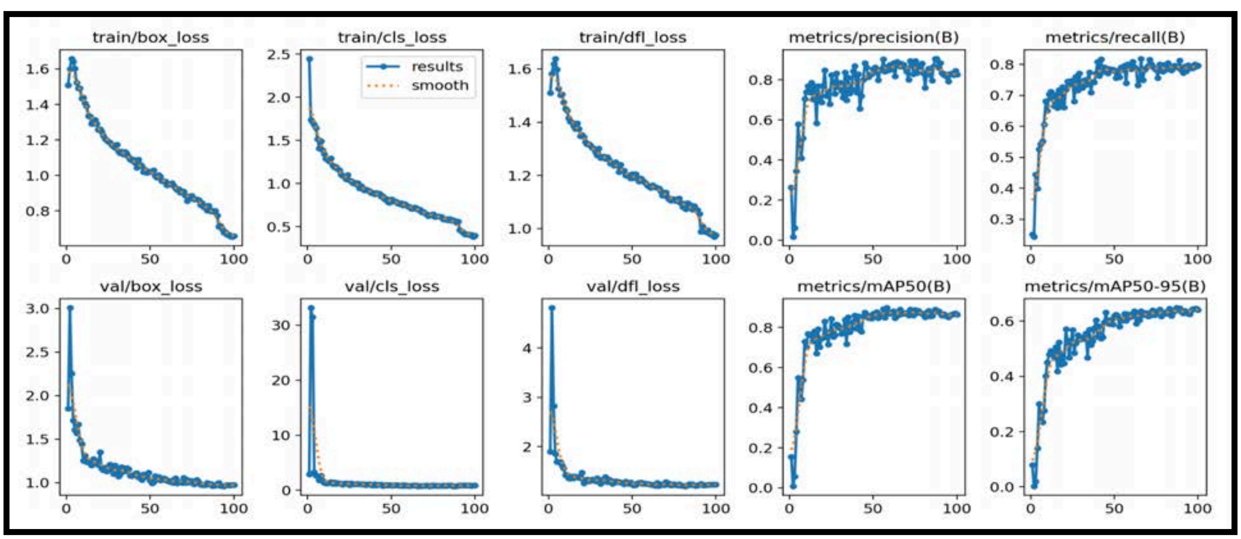
The training is optimized using a compound loss function, which incorporates Binary Cross-Entropy (BCE) loss to object presence, Cross-Entropy (CE) loss to object class predictions and Complete IoU (CIoU) loss to bounding box regression, improving both classification and localization performance.

Performance and Inference Speed:

YOLOv8 can run at about 200 frames per second at 640x640 with a high-end V100 GPU. In spite of the fact that we could not support such advanced hardware, the model provided also provided good frame rates on the existing T4 GPU in our experiments. Also, plots=True parameter allowed generating performance plots automatically after the training.

Training Results:

Figure 08: *Training and validation loss curves (box, classification, and distillation losses)*



The graphs show the training and validation losses, such as train/box loss, train/cls loss, train/diff loss, val/box loss, val/cls loss, and val/diff loss where a downward trend indicates improved validation performance. In addition, the measures of precision (B), recall (B) and mAP50 (B) have upwards trends, which reveal indicators of gradual accuracy gains in models as the number of training epochs increases. These graphical shows play a crucial role in the evaluation of the model performance and convergence during the process of training.

Figure 09: *Heat map*

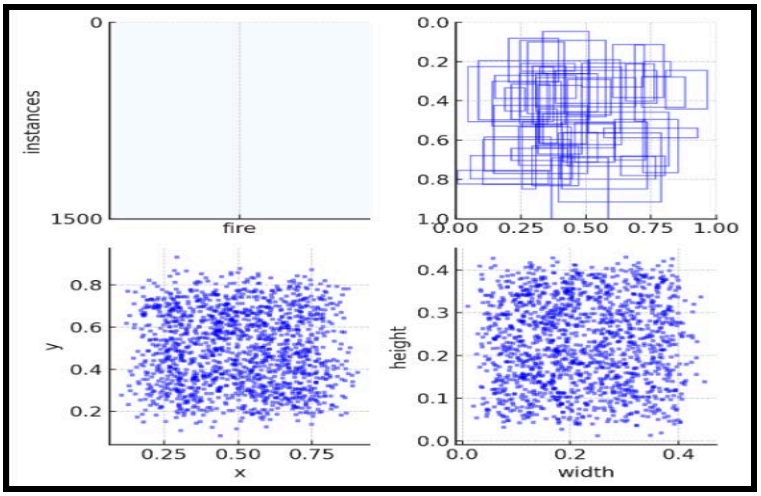
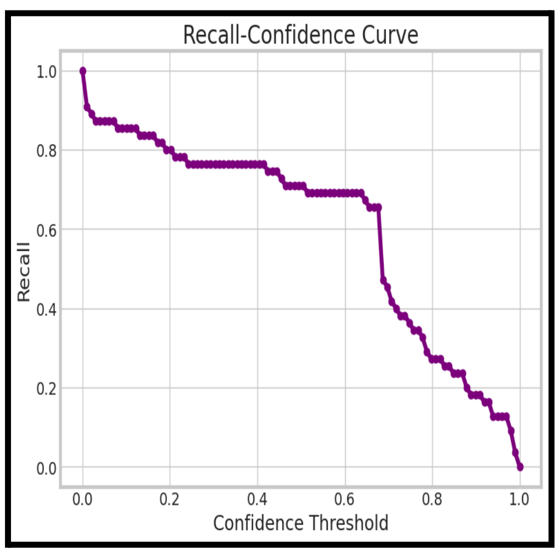


Image of Heatmap, Dense clusterization at the center, Scatter plot of bounding box y vs. x coordinates, and Scatter plot of bounding box height vs. width.

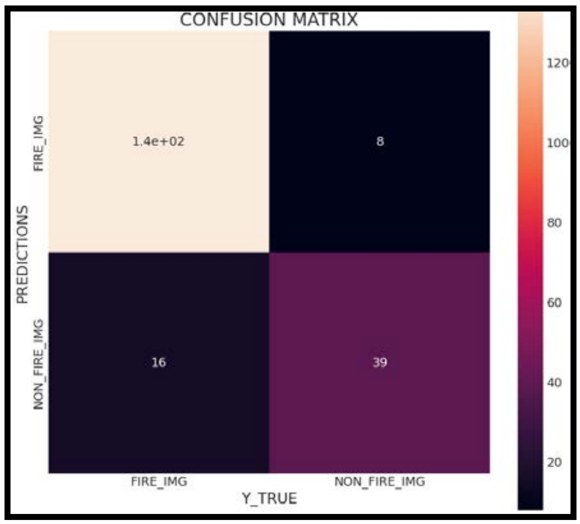
Figure 10: *Recall- Confidence Curve*



Trend: The fire curve shows a steep decrease in its value with an increase in the level of confidence which means that a gain in confidence level in this type of class will lead to a decrease in the recall value.

Purpose: The relationship will help to know the trade-off between the recall (true positive rate) and the level of confidence that is required to measure the performance of machine learning or data analysis activities.

Figure 11: *Confusion matrix*



A confusion matrix that shows the performance of the fire detection model

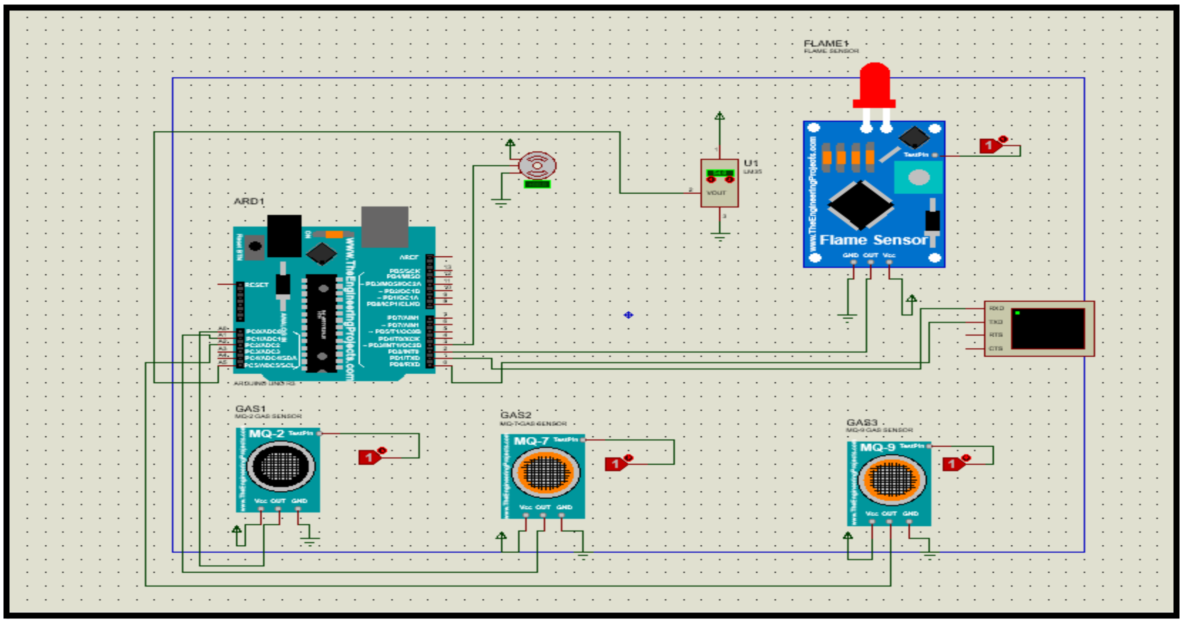
Output:

Figure 12: *Testing the Output of The Model*

We are using YoloV8 as the detection algorithm. The dataset that has been utilized is a custom dataset belonging to Roboflow and was used to train the YoloV8 Model. Performance could therefore not be comparable to the standard benchmark. 80 epochs is a large training time and it could converge well on the custom dataset. In this case, the YOLOv8 can be used with a compromise between speed and accuracy that is why it will fit our goal perfectly.

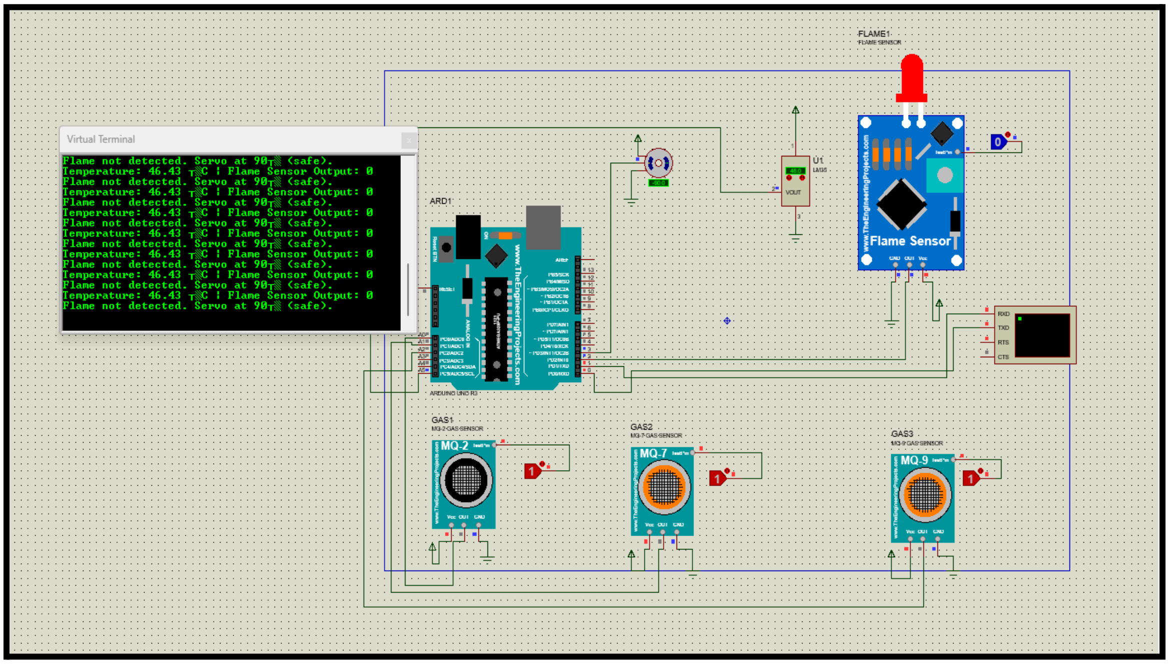
4.2.2 Design Approach 2:(Fire Detection)

Figure 13: *Full System Diagram of Design Approach 2*



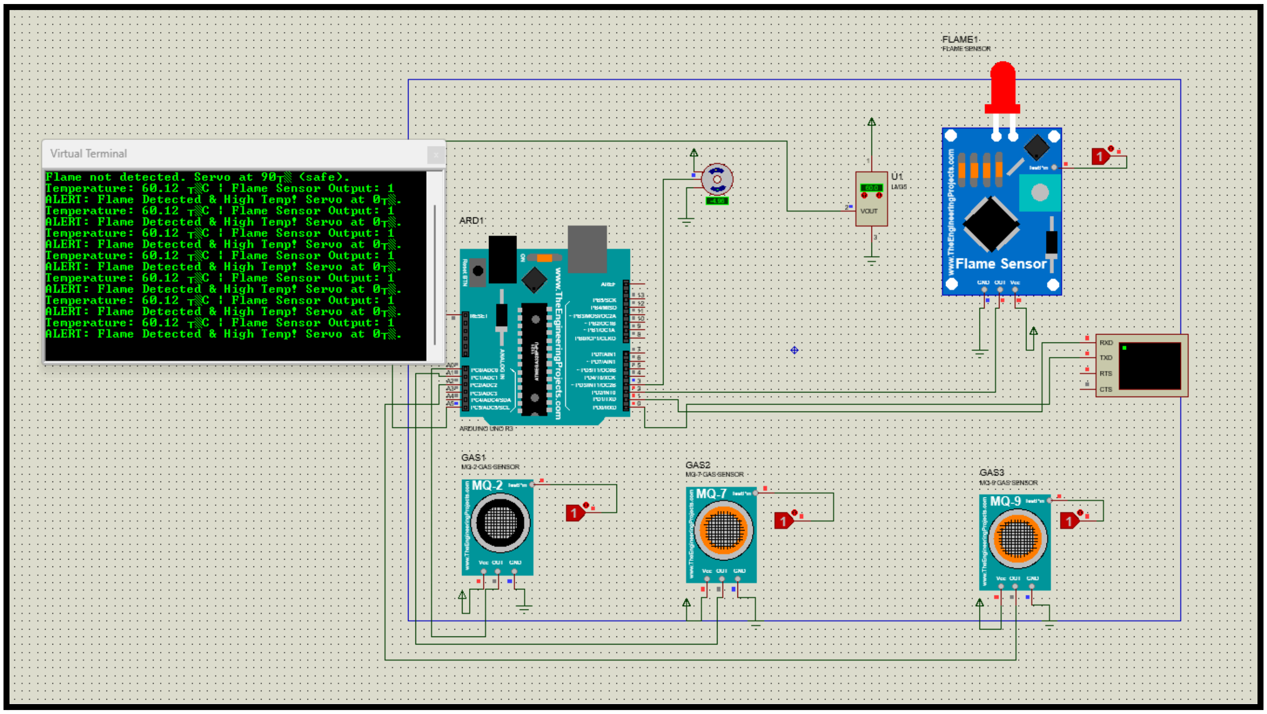
The following circuit diagram shows a fire and gas detector and response system that has been automated using an Arduino microcontroller. The system has several sensors, which help to control the environment: MQ-2, MQ-7, and MQ-9 sensors to measure various combustible gases and carbon monoxide, and a flame sensor to understand that a fire occurs. The data of these sensors is constantly analyzed by the Arduino. As per the explained logic, when the flame sensor notices there is a fire and when an associated temperature sensor (not explicitly depicted but included as a part of the design) measures a value over 50 C then the system triggers an emergency response. This reaction will be to engage a servo motor and make it spin, which might lead to a fire-suppression system.

Figure 14: *Safe, Servo In Position 90°*



According to the output of the virtual terminal, the system is in safe and stable state. The data in the monitoring points to the flame being not detected, the sensor has a digital output of 0. There is also the ambient temperature of 46.43C, which is a lower temperature than the critical alarm. These safe readings lead to the failure of the response mechanisms of the system. The servo motor is in the default position of 90 degrees which is the safe position and all the alarms have been turned off. This is an indication that the system is operating properly and it keeps on monitoring the environment without an alarm.

Figure 15: *Fire Detected, Servo In Position 0°*



The alarm system in the system has been triggered because of the realization of dangerous conditions. The virtual terminal shows an ALERT! that the flame sensor has been activated (Flame Sensor Output: 1) and that the ambient temperature has reached 60.12O C which is greater than the safety limit at 50O C. The Arduino has reacted to this threat by implementing its emergency protocol. The servo motor instantly swiveled to 0-degree action position, and this activates the suppressant.

Data Communication:

Figure 16: *Transmitter and Receiver*

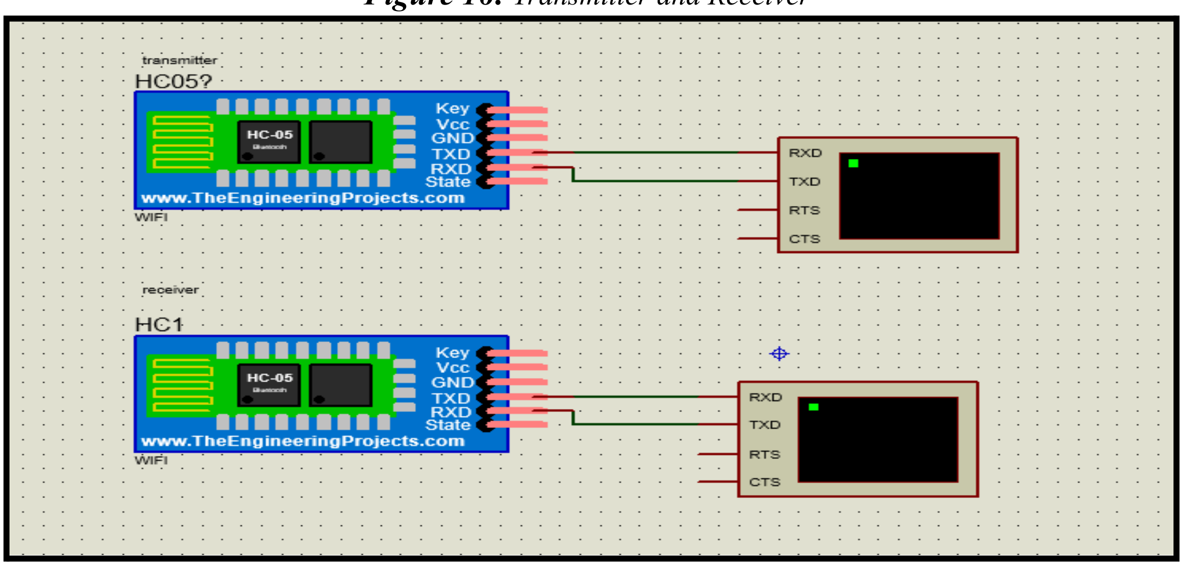
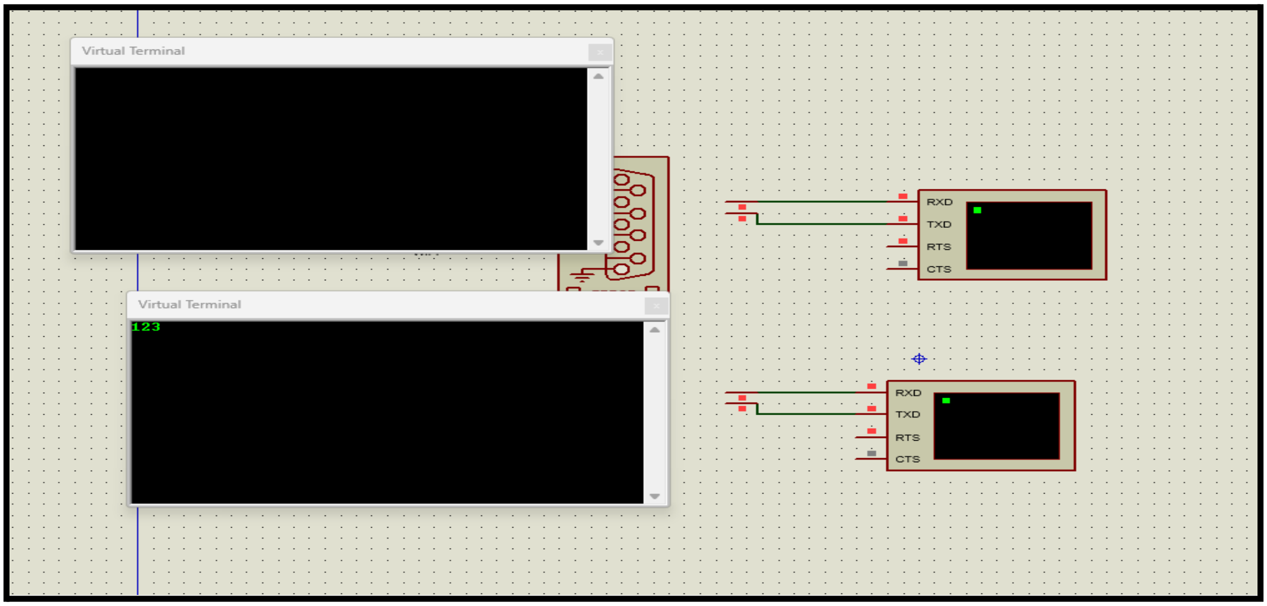


Figure 17: *Simulation Output*



The interaction process between the transmitter and receiver modules is illustrated in figure 17. The transmitter is shown in the upper terminal window with a value typed in it. The value is then entered and the transmitter transmits it wirelessly to the receiver which is displayed in the lower terminal window. The same input value is received by the receiver and is displayed and this indicates that the wireless communication system is working correctly.

4.3 Drone Aerodynamics Dynamic Simulation of the Designs

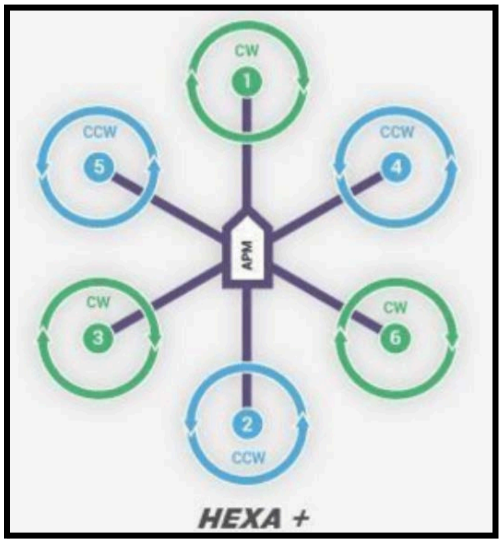
4.3.1 Design Approach 1

Calculation of simulation parameters and the configuration of the hexcopter:

Simulation parameters calculation and the hexcopter configuration:

This gives a holistic model of mathematical modeling, simulation and control of a hexacopter unmanned aerial vehicle (UAV). The system dynamics are developed using the Newton-Euler principles forming a set of state equations that define the correlations between the mass and inertia of the vehicle and forces and torques produced by the six rotors. This physical model is applied in the MATLAB/Simulink, where hierarchical control architecture is used. The architecture employs separate Proportional-Integral-Derivative (PID) controllers to control independently the attitude of the hexacopter, roll (ϕ), pitch (θ), and yaw (ψ), and the altitude (Z). These controllers are then translated by a critical control mixing algorithm to accurate throttle commands to each motor. The performance of the control system is confirmed in the simulation which shows that the hexacopter was able to follow a predefined flight path with high accuracy. The performance is proven by time-dependent analysis of the state variables of the drone, its position and angular rates, and the dynamic behavior of the motor RPMs, which proves that there is stable and controlled flight behavior.

Figure 18: *Hexacopter with X Formation [16]*



The hexacopter is in X shape as shown in Figure 18, all six motors are arranged symmetrically 60 degrees around a central hub, and in the central hub the flight controller, battery and sensors are placed. The propellers swing clockwise and counterclockwise in order to nullify the torque and all the thrust vectors converge at the main vertical axis in order to provide stability and balanced flight.

4.3.1.1 The Mathematical Model Parameters of Hexcopters

The hexcopter's dynamics were modeled mathematically based on its structural and inertial parameters. These include:

Mass and inertia (Newton-Euler Equations therium)

$[\Sigma T] = [cT \quad cT \quad cT \quad cT \quad cT \quad cT\ ]\ [\omega_1^2 * \omega_3^2]$..1

$[\tau\varphi\ ] = [r_1cT \ \ r_2cT \ \ r_3cT \ \ r_4cT \ \ r_5cT \ \ r_6cT]\ [\omega_2^2 * \omega_4^2]$..2

$[\tau\theta] = [s_1cT \;\; s_2cT \;\; s_3cT \;\; s_4cT \;\; s_5cT \;\; s_6cT] [\omega_3^2 * \omega 6^2]$ 3

$[\tau\psi] = [d_1cQ \;\; d_2cQ \;\; d_3cQ \;\; d_4cQ \;\; d_5cQ \;\; d_6cQ] [\omega_4^2 * \omega 5^2]$ 4

Throttle to RPM Conversion: (Momentum Theory, Blade Element Theory)

$\omega ss = (\text{Throttle}\%) \cdot CR + b$ ………………………………………………………..……………5

$\text{Torque} = CQ\, \omega^2$ ………………………………………………………..…..…….……..6

$\text{Thrust} = CT\, \omega^2$……………………………………………………………………………7

4.3.1.2 The State Equations Of The Hexcopter

Velocity State Equation

$\dot{v}^b = (1/m)\, F^b * T + g^b * \Omega^b * J - v^b = [\bar{U}, \dot{V}, \dot{W}]^T$ ………………………………………….….…….8

Angular Velocity State Equation

$\dot{\omega}^b = (J^b)^{-1} [M^b * T - \omega^b] = [\dot{P}, \dot{Q}, \dot{R}]^T$……………………………………………………….…………...9

Position State Equation

$\dot{p}^i = C * v^b = [\dot{X}, \bar{Y}, \dot{Z}]^T$…………………………………………………………...…….…...10

Where:

m = Mass of the multirotor

J^b = Inertia matrix in body frame

Ω^b = Skew-symmetric matrix of ω^b

T = Thrust coefficient

Q = Drag (torque) coefficient

J = Rotor/shaft inertia

P, Q, R = Body angular rates

ω_i = Rotor angular speed of rotor

4.3.1.3 Modeling the Hexcopter using the Simulink Block Algorithm

Figure 19: *Hexcopter Drone control in MATLAB*

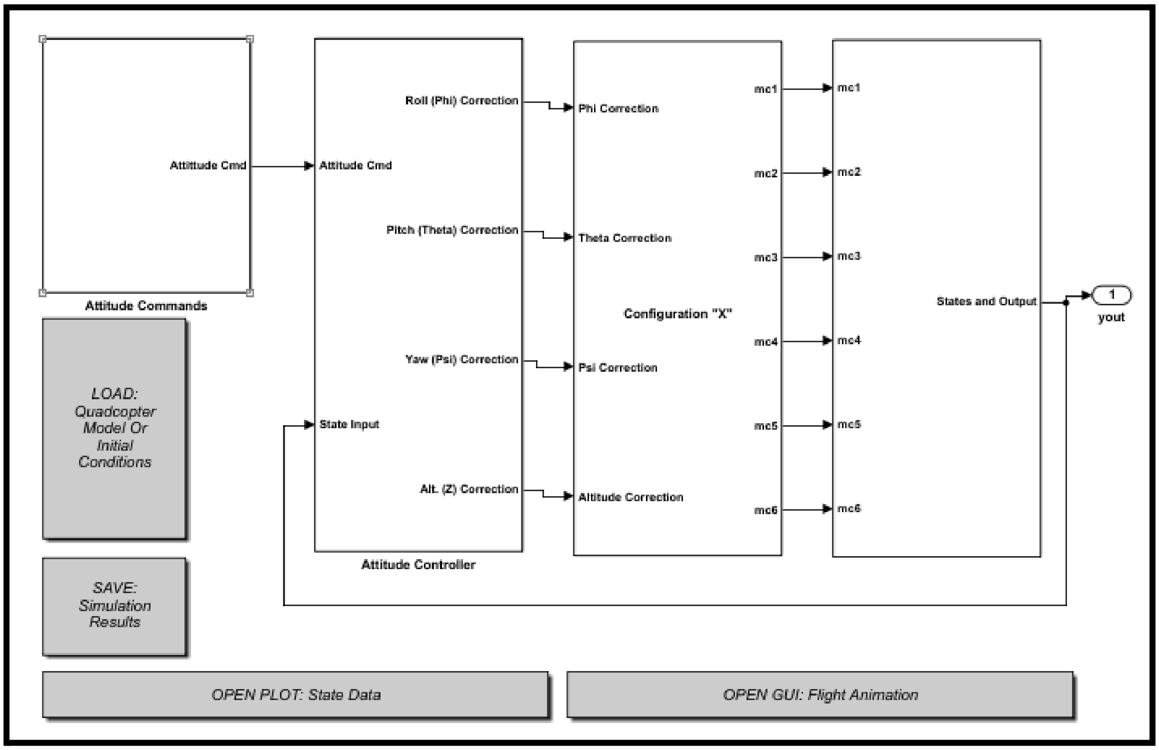
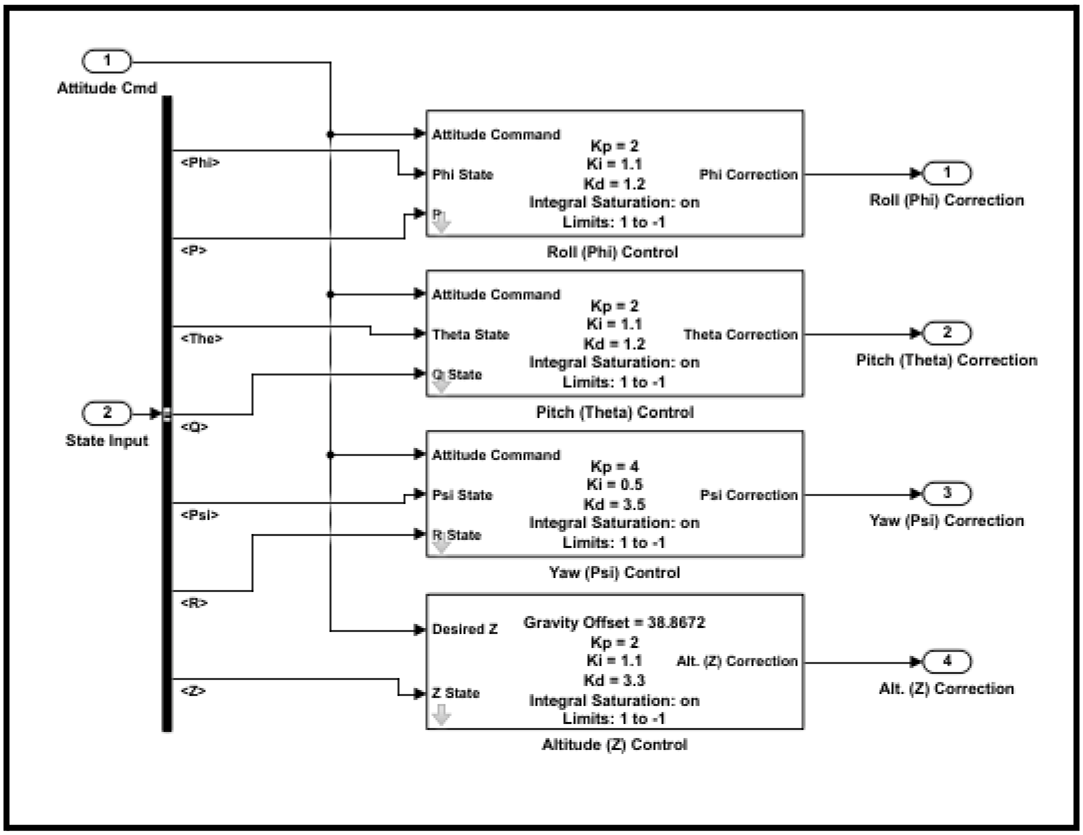


Figure 19 of the hexacopter simulation is simulated in terms of a structured control architecture, composed of two major modules, with the first one being the Input Block and the second one being the Main Control Block, which fulfils a certain role of converting target flight parameters into stable realistic motion. The Input Block is charged with the task of defining the initial conditions of the simulation such as attitude setpoints, roll (ϕ), pitch (θ), and yaw (ψ) and the altitude (Z) command, which jointly form the desired flight path or target of operation. The commands are then sent to the Main Control Block that combines the measured physical parameters of the hexacopter including mass, arm length and moments of inertia. In this block, the control mixing stage processes the high level roll, pitch, yaw and vertical thrust commands and translates them into a fined motor speed command to all the six rotors, enabling a balanced distribution of the thrust. These motor parameters are then fed into the state equation block which uses the mathematical model of the hexacopter dynamics in order to simulate the physical behaviour of the hexacopter with respect to control inputs. In order to maintain proper dynamics in following the required path, a PID control is installed into the Main Control Block and constantly measures the state of the system and manages motor outputs to rectify any deviations due to disturbances or initial conditions error. This closed-loop feedback system means that the simulated hexacopter will be able to stabilize and hold-on to the air at any point of origin, which makes the architecture strong and flexible to different flight conditions.

4.3.1.4 Altitude Control

Figure 20: *Attitude Control Block Interior*



This PID-based attitude and altitude controller of a hexcopter is represented by this diagram in Figure 20. It receives an Attitude Command (Roll, Pitch, Yaw and Altitude desired) and State Input (Currently Measured) and feeds them into four distinct PID controllers: Roll (Phi), Pitch (Theta), Yaw (Psi), and the Altitude (Z). The blocks use tuned PID gains (Kp, Ki, Kd), integral saturation limits and provide correction signals to its axis. The corrected values are then inputted into the hexacopter Control Mixing stage which combines them and transmits them to the motors depending on the configuration of the quadcopter. Such an arrangement enables the precise stabilization and positioning in every degree of freedom.

4.3.1.5 Hexcopter Control Mixing

Figure 21: *Plus Configuration Control Mixing*

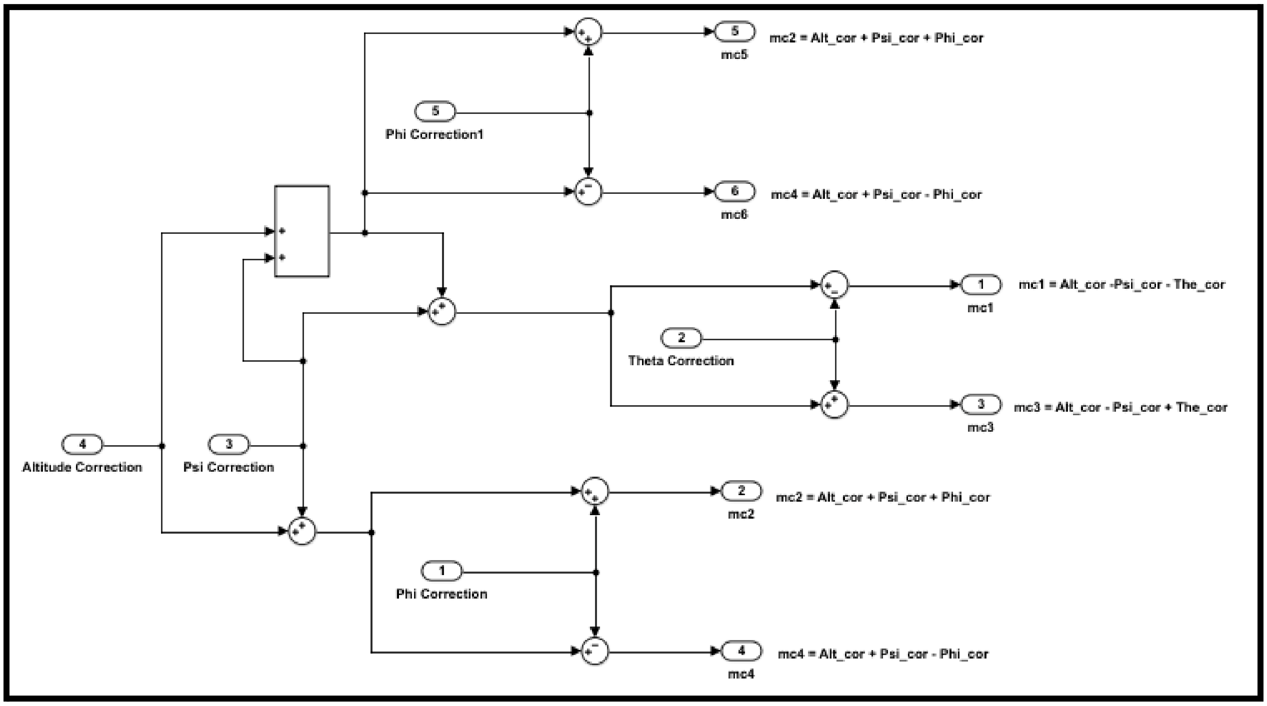


Figure 21 shows the process of mixing of Hexcopter Control which combines the correction signals of the altitude (Z), the yaw (Psi), the pitch (Theta), and the roll (Phi) controllers to produce the control input of each motor. The logic of the mixing is based on the acquired physical dimensions parameters. This is to make sure that the right combination of altitude lift and directional adjustment is applied to every motor, and the correct signs are used to generate the desired movement. This is essential in converting the independent PID controller outputs to a coordinated motor control to allow the quadcopter to fly straight and maneuver accurately based on the quadcopter x configuration.

4.3.1.6 Hexcopter Dynamics Block

Figure 22: *Hexacopter Dynamics Block*

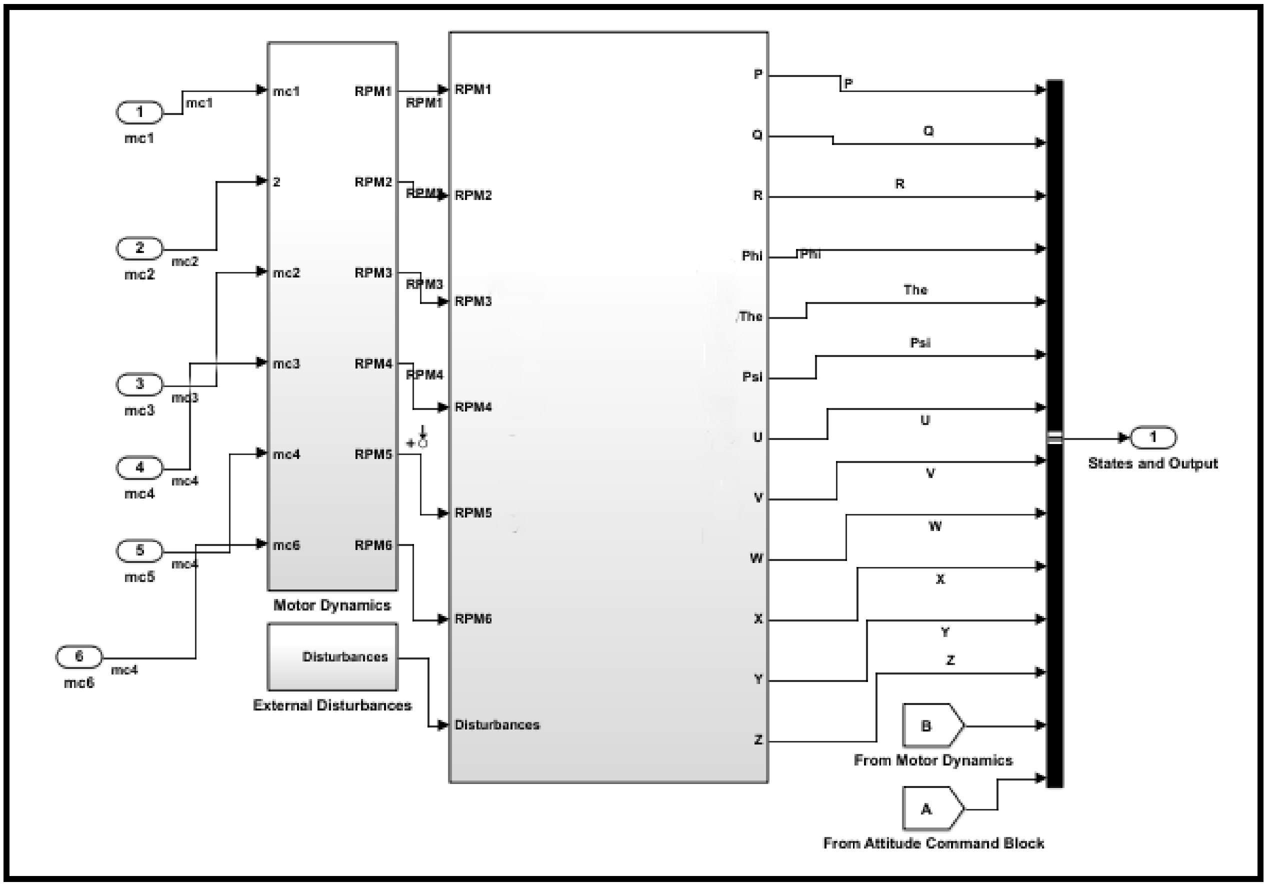


Figure 22, hexacopter dynamics control, the Motor Dynamics block translates throttle (mc1 -mc6) commands into motor RPM values, including system response and external disturbances. These RPM values are then inputted in the State Equations block which calculates velocity, angular velocity and position state equations using code-based algorithms. This process is a physical behavior model of the drone and makes it possible to simulate the motion of the drone in the real-time and to animate the flight behavior in a realistic fashion.

4.3.1.7 Simulation Results

Figure 23: *Customized Path and Initial Condition*

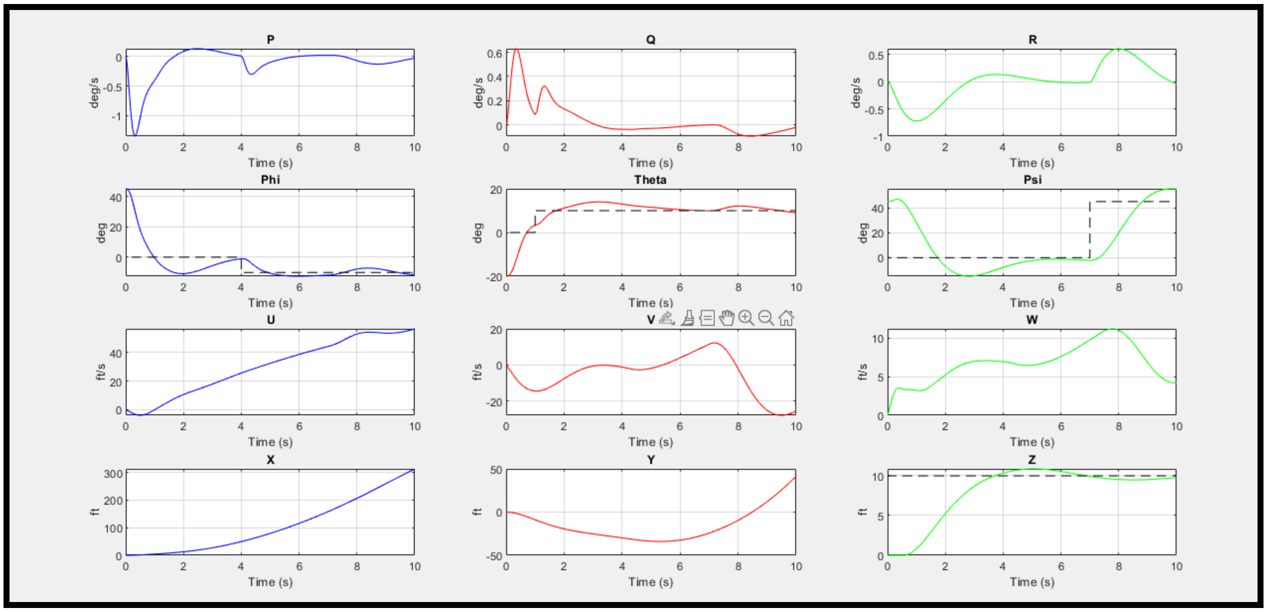


Figure 23 demonstrates the results of simulation of a drone moving along a personalized path in the initial conditions. It shows angular rates, Euler angles, velocities and position in a 10 seconds scale showing stable flight and precise following the path after initial corrections.

Figure 24: *Quantized Motor Commands*

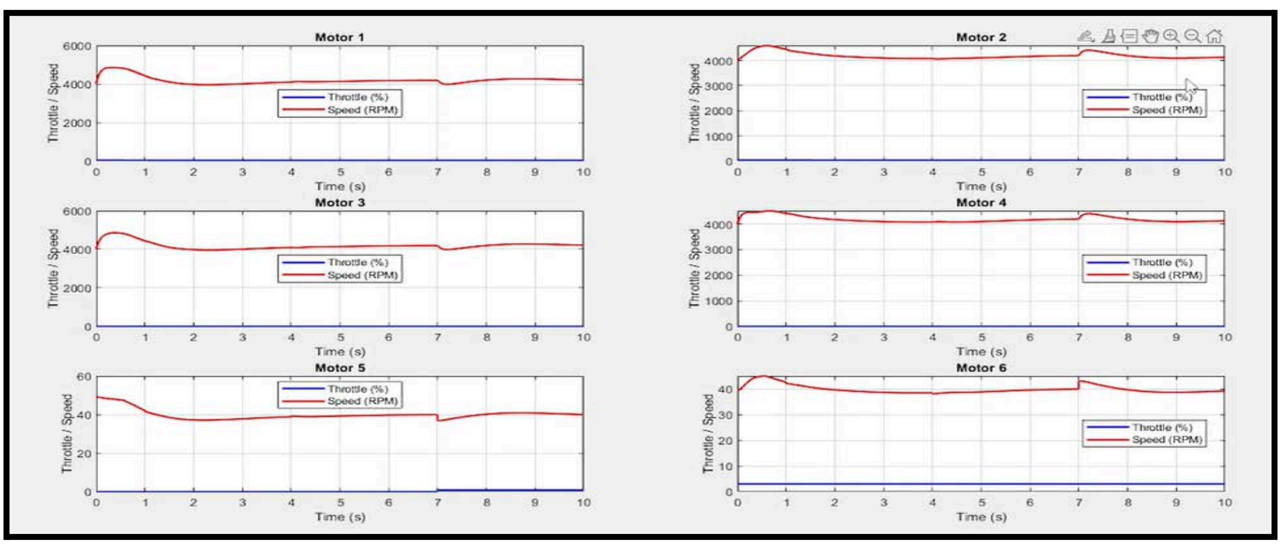


Figure 24 shows throttle input (percentage) and the corresponding rotor speed (RPM) of 6 drone motors during a 10-second simulation. The motors react to different throttle inputs to keep the aircraft level with the speeds dynamically adjusted to the needs of the controls. The plots are smooth and do not exhibit much oscillation which is a sign of good control of the motor and a uniform distribution of thrust on all rotors.

Figure 25: *Realistic Simulation Of A Hexcopter*

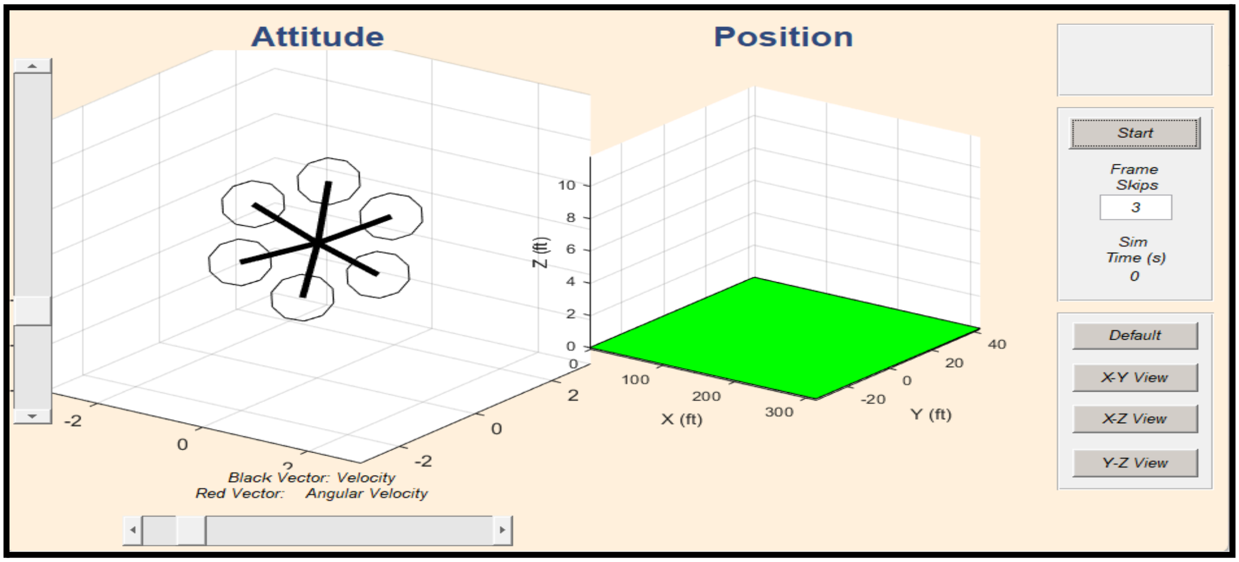


Figure 25 shows the initial state of the simulation of the drone both in terms of its attitude and position respectively. The position plot starts with the origin, and it is prepared to monitor movement on the X, Y, and Z axes, which prepares for the management of flight trajectory and stability.

4.3.2 Design Approach 2

Calculation of the simulation parameters:

The configuration of the quadcopter:

Figure 26: *Quadcopter With X Formation*

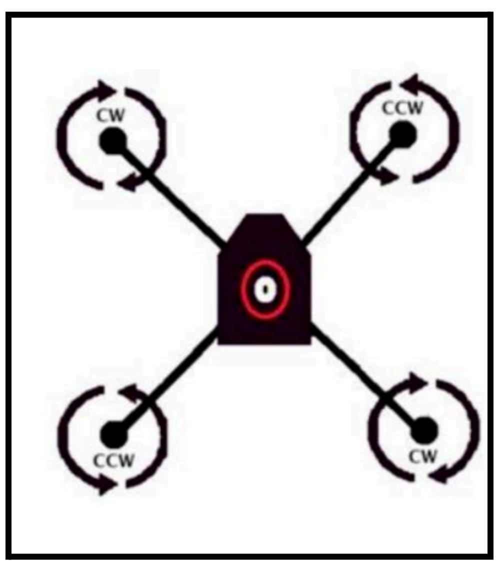


Figure 26 represents a quadcopter X design, four motors are located at the corners of a square, two on the front and two on the back, making an X shape when viewed overhead. The propellers move in clockwise and counter clockwise directions such that the torque generated by one set of the motors is countered by the other set of the motors to maintain stable flight. The thrust vectors are considered to meet all at the central vertical axis that goes through the flight controller, battery, and the sensors to provide a balance and manoeuvrability that are controlled.

4.3.2.1 The mathematical model parameters of the quadcopter

The quadcopter's dynamics were modeled mathematically based on its structural and inertial parameters. These include:

Mass and inertia (Newton-Euler Equations therium)

$[\Sigma T] = [cT \quad cT \quad cT \quad cT\ ]\,[\omega_1{}^2]$...11

$[\tau\varphi\ ] = [-dxcT \;\; dxcT \;\; dxcT \;\; -dxcT]\,[\omega_2{}^2]$...12

$[\tau\theta\ ] = [-dycT \;\; -dycT \;\; dycT \;\; dycT\ ]\,[\omega_3{}^2]$..13

$[\tau\psi\ ] = [-cQ \quad cQ \quad -cQ \quad cQ\ ]\,[\omega_4{}^2]$...14

Throttle to RPM Conversion: (Momentum Theory, Blade Element Theory)

$\omega ss = (\text{Throttle}\%) \cdot CR + b$……………………………………………………………..5
Torque = CQ ω^2……………………………………………………………………………6
Thrust = CT ω^2…………………………………………………………………………..7

4.3.2.2 The state equations of the quadcopter

Velocity State Equation

$\dot{v}^b = (1/m)\,F^b * T + g^b * \Omega^b * J - v^b = [\bar{U}, \dot{V}, \dot{W}]^T$ ………………………………..15

Angular Velocity State Equation

$\dot{\omega}^b = (J^b)^{-1}\,[M^b * T - \omega^b] = [\dot{P}, \dot{Q}, \dot{R}]^T$…………………………………………………16

Position State Equation

$\dot{p}^i = C * v^b = [\dot{X}, \bar{Y}, \dot{Z}]^T$…………………………………………………………………17

Where:

m = Mass of the multirotor

J^b = Inertia matrix in body frame

Ω^b = Skew-symmetric matrix of ω^b

T = Thrust coefficient

Q = Drag (torque) coefficient

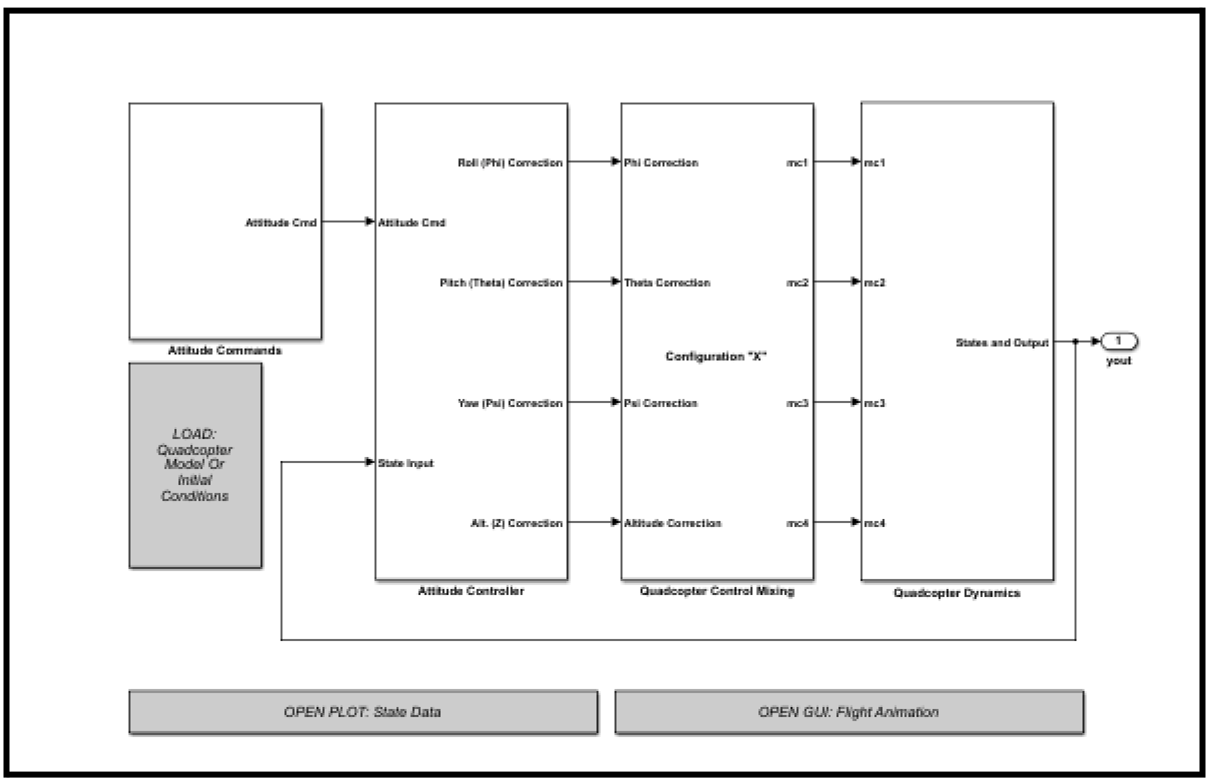
J = Rotor/shaft inertia

P, Q, R = Body angular rates

ω_i = Rotor angular speed of rotor

4.3.2.3 Modeling the quadcopter using the Simulink Block Algorithm

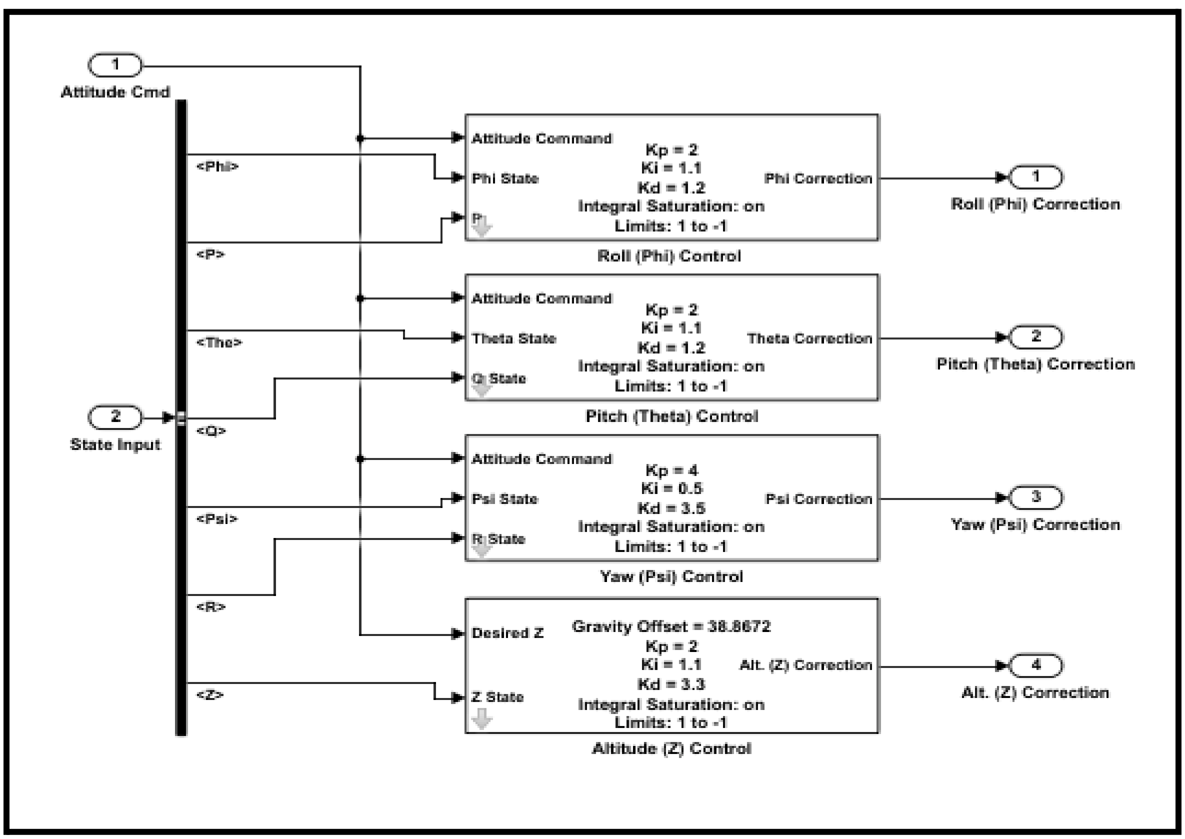
Figure 27: *Quadcopter Drone Control in MATLAB*



As Figure 27 shows, the quadcopter simulation is accomplished with the help of a structured control architecture that incorporates two main modules, namely, the Input Block and the Main Control Block, each of which performs a certain function of converting target flight parameters into the stable and realistic movement. The Input Block handles the setting of the initial conditions of the simulation such as the attitude setpoints roll (phi), pitch (theta) and yaw (ψ), and the command to set the altitude (Z) all of which are the desired flight path or target of operation. These are in turn sent to the Main Control Block which incorporates the actual physical parameters of the quadcopter, which include the mass, arm length and the moments of inertia. The control mixing stage within this block translates the high level roll, pitch, yaw, and vertical thrust commands into the accurate motor speed requirements in all four rotors to achieve an even distribution of thrust. These motor variables are then converted into the block of state equations, which uses the mathematical representation of the dynamics of the quadcopter to model the physical behaviour of the quadcopter on the basis of control inputs. A PID controller is integrated into the Main Control Block which keeps track of the state of the system and adjusts the output of the motors to correct any offsets in the desired trajectory due to disturbances or initial conditions. This loop-feedback control system guarantees the simulated quadcopter is able to attain and stabilize flight at any starting point and the architecture is robust and easily adapted to different flight conditions.

4.3.2.4 Altitude Control

Figure 28: *Attitude Control Block Interior*



The attitude and altitude control system of a hexcopter based on PID is illustrated in figure 28. It receives an Attitude Command (desired roll, pitch, yaw and altitude) and State Input (measured values present) and runs through four distinct PID controllers: Roll (Phi), Pitch (Theta), Yaw (Psi) and Altitude (Z). The blocks have tuned PID gains (Kp, Ki, Kd), integral saturation limits and correction signal outputs on their respective axis. These corrections are then fed to the Quadcopter Control Mixing stage where they are added and fed to the motors based on the configuration of the quadcopter. This arrangement enables there to be fine-tuning stabilization and position control in all degrees of freedom.

4.3.2.5 Quadcopter Control Mixing

Figure 29: *Plus Configuration Control Mixing*

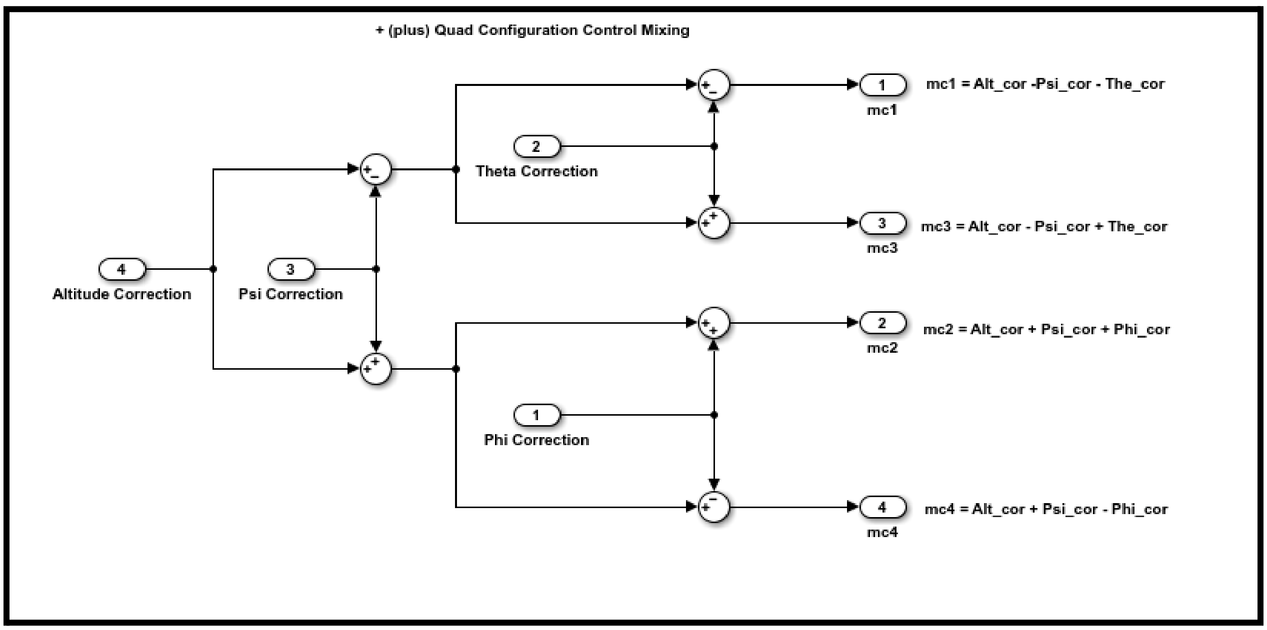


Figure 29 demonstrates the Quadcopter Control Mixing process where the control signals of the altitude (Z), yaw (Psi), pitch (Theta) and roll (Phi) controllers are added to create the control actions of each motor. The mixing logic is calculated based on the physical dimensions parameters that are measured. This is to make sure that every motor gets the right combination of the altitude lift and directional adjustments, with the right signs to create the intended movement. This is important in converting the independent PID controller outputs into synchronized motor control signals to allow stable flight and accurate maneuvering based on the quadcopter X-configuration.

4.3.2.6 Quadcopter Dynamics Block

Figure 30: *Quadcopter Dynamics Block*

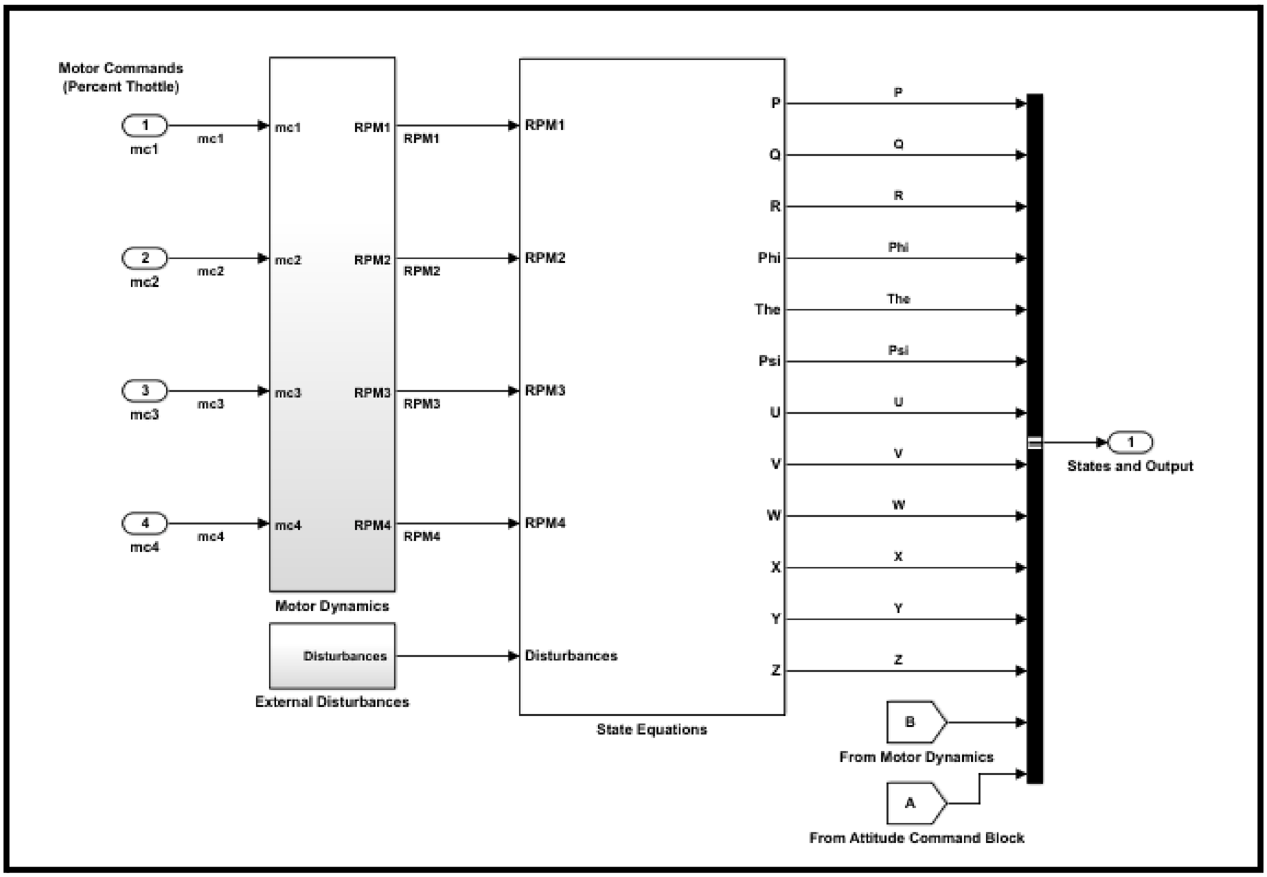


Figure 29 demonstrates the Quadcopter Control Mixing process where the control signals of the altitude (Z), yaw (Psi), pitch (Theta) and roll (Phi) controllers are added to create the control actions of each motor. The mixing logic is calculated based on the physical dimensions parameters that are measured. This is to make sure that every motor gets the right combination of the altitude lift and directional adjustments, with the right signs to create the intended movement. This is important in converting the independent PID controller outputs into synchronized motor control signals to allow stable flight and accurate maneuvering based on the quadcopter X-configuration.

4.3.2.7 Simulation Results

Figure 31: *Customized Path and Initial Condition*

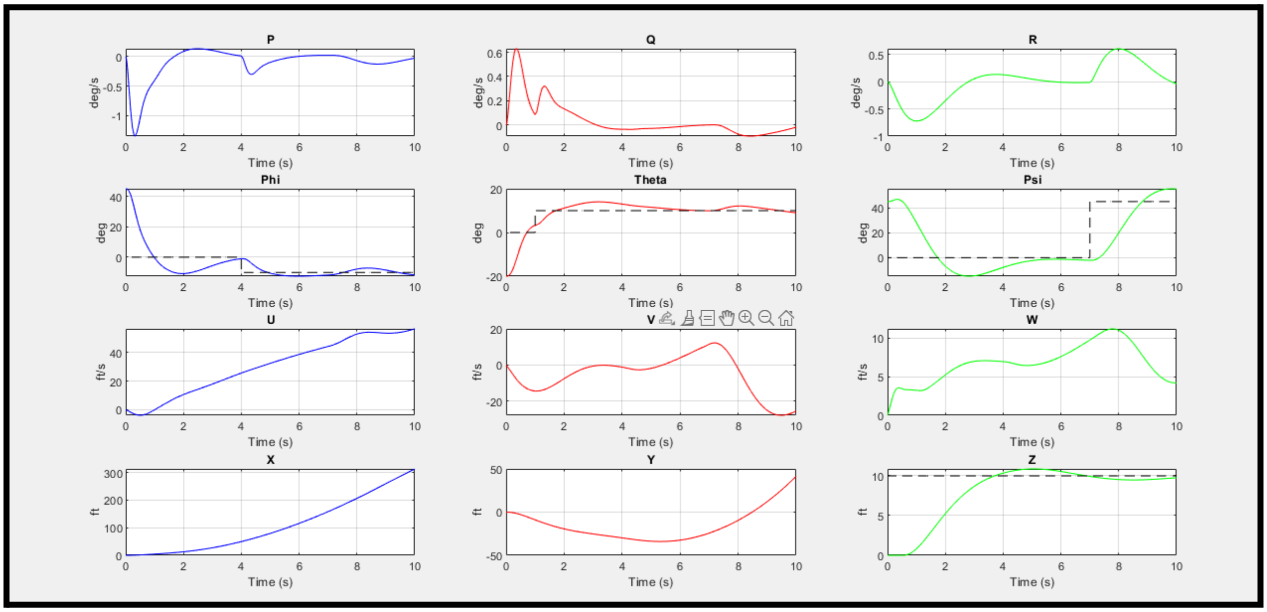


Figure 31 presents the simulation outcomes of a drone pursuing a personalized path when initial conditions are given. It shows angular rates, Euler angles, velocities and positions at intervals of 10 seconds of time showing stable flight and proper path tracking following initial adjustments.

Figure 32: *Quantized Motor Commands*

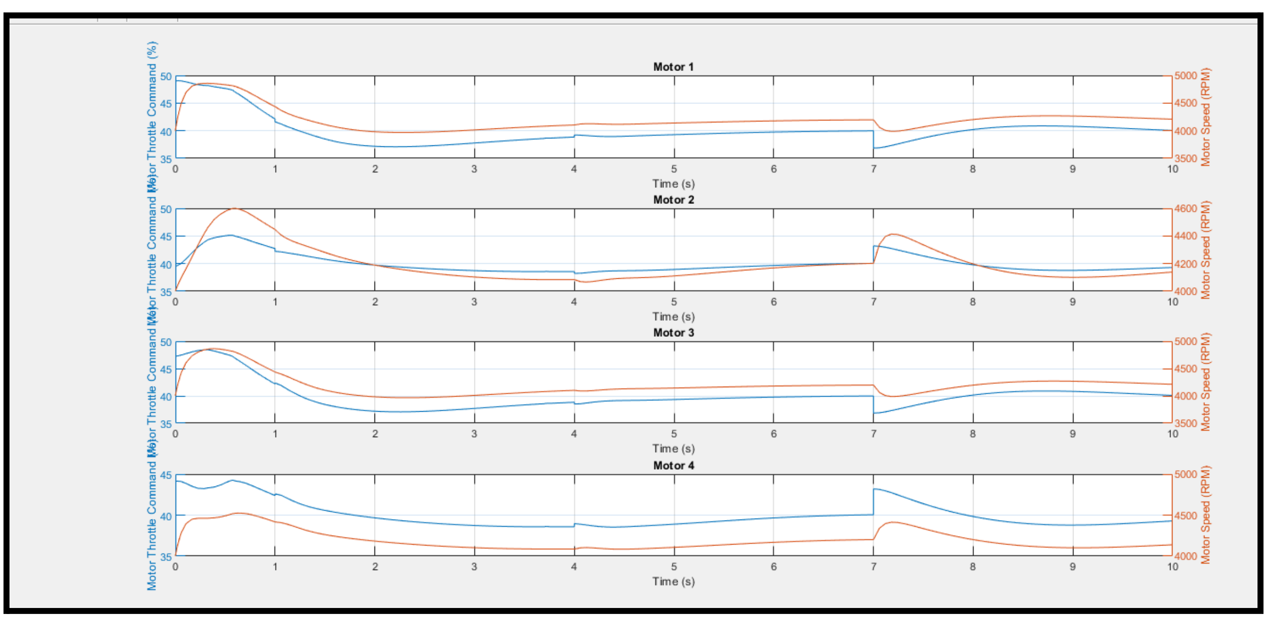


Figure 32 shows the throttle input (percentage) and consequent rotor speed (RPM) of six drone motors during a 10-second simulation. All motors react to different throttle inputs to ensure that the motor keeps the plane steady in the air and the speed dynamically adjusts to suit control requirements. The plots are permitive of smooth performance with few oscillations which are indicative of efficient motor control, and distribution of thrust between all rotors.

Figure 33: *Realistic Simulation Of A Quadrocopter*

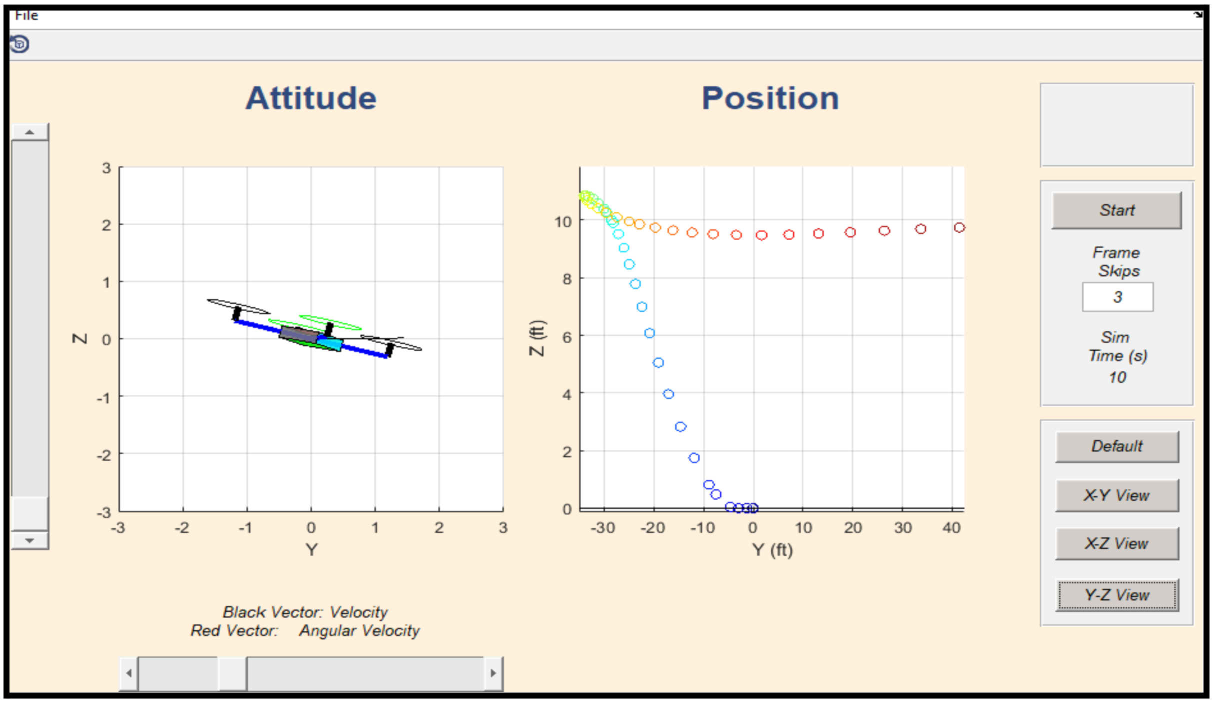
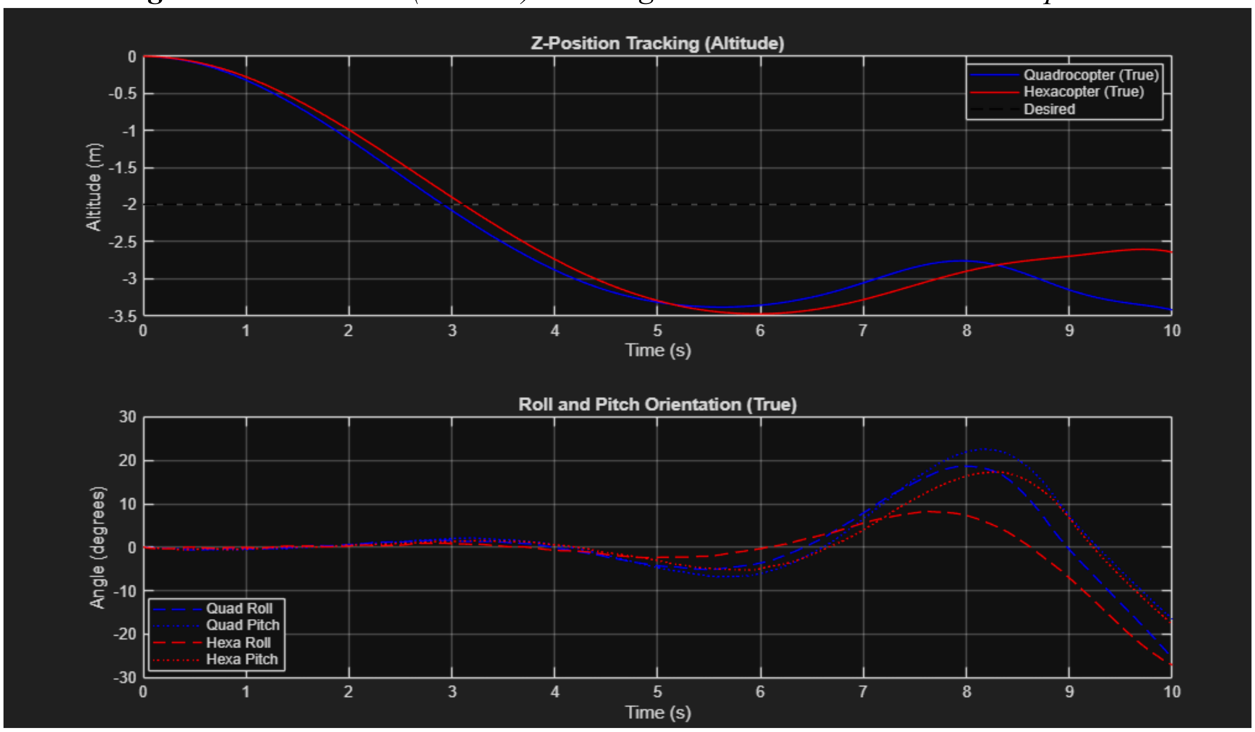


Figure 33 gives us a simulation, which demonstrates drone motion dynamics through dual visualization panels. The left "Attitude" graph displays the projectile's spatial orientation and trajectory path with velocity vectors (black) and angular velocity vectors (red), showing how the object rotates during flight. The right "Position" graph plots the vertical position (Z) against horizontal displacement (Y), illustrating the characteristic parabolic trajectory of projectile motion. The simulation allows real-time analysis of ballistic parameters with adjustable frame rates and multiple viewing perspectives (X-Y, X-Z, Y-Z planes). This tool effectively visualizes the relationship between translational motion and rotational dynamics in projectile systems, making it valuable for ballistics analysis, trajectory optimization, and educational demonstrations of classical mechanics principles.

4.4 Analyze the Multiple Design Solutions to Find the Optimal Solution (CO6)

4.4.1 Z-Position and Attitude Orientation

Figure 34: *Z-Position (Altitude) Tracking and Attitude Orientation Comparison*



We are provided with a simulation in figure 33, which shows us the dynamics of motion of drones using two visualization panels. The left Attitude graph illustrates the spatial orientation and the trajectory of the projectile and its velocity vectors (black) and angular velocity vectors (red), indicating the spinning about of the object in the course of movement. The right Position graph is a graph against a horizontal distance (Y) versus the vertical position (Z), showing the typical parabolic path of the projectile motion. The simulation enables the real-time analysis of the ballistic properties with variable frame rates and various viewing angles (X-Y, X-Z, Y-Z planes). The tool is useful in studying the interplay between translational and rotational dynamics in projectile projects and is therefore useful in ballistics, optimization of projectile trajectories and teaching classical mechanics concepts.

The performance of both the drone models in terms of tracking a desired altitude and keeping the attitude at a constant desired position is represented in figure 34. The highest graph, Z Position Tracking, indicates that the hexacopter (red line) has better trajectory control and followed more closely the desired altitude setpoint with less overshoot compared to the quadcopter (blue line).

This observation is further supported in the bottom graph "Roll and Pitch Orientation" which shows that the roll and pitch angles of the hexacopter experience less pronounced and smooth deviations. Conversely, the orientation of the quadcopter is more vibratory and sensational, with a less stable attitude control system[17].

4.4.2 Vertical and Angular Velocity

Figure 35: *Vertical and Angular Velocity Comparison*

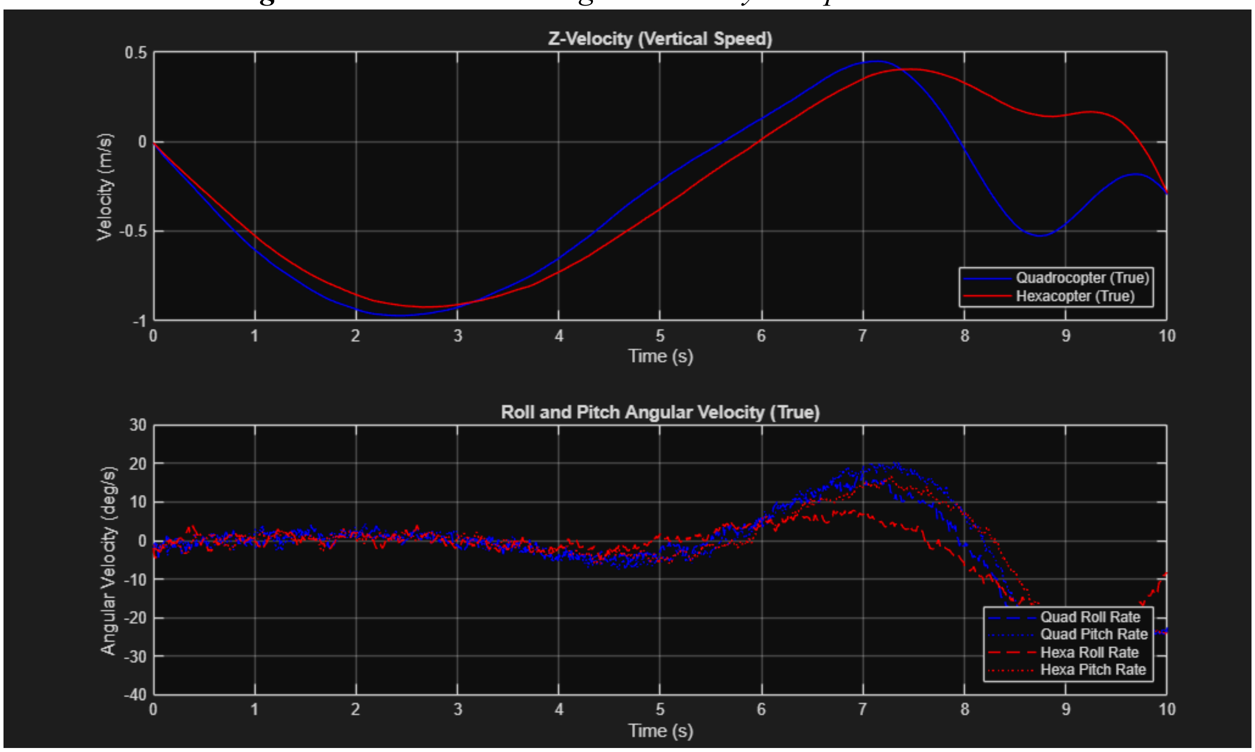
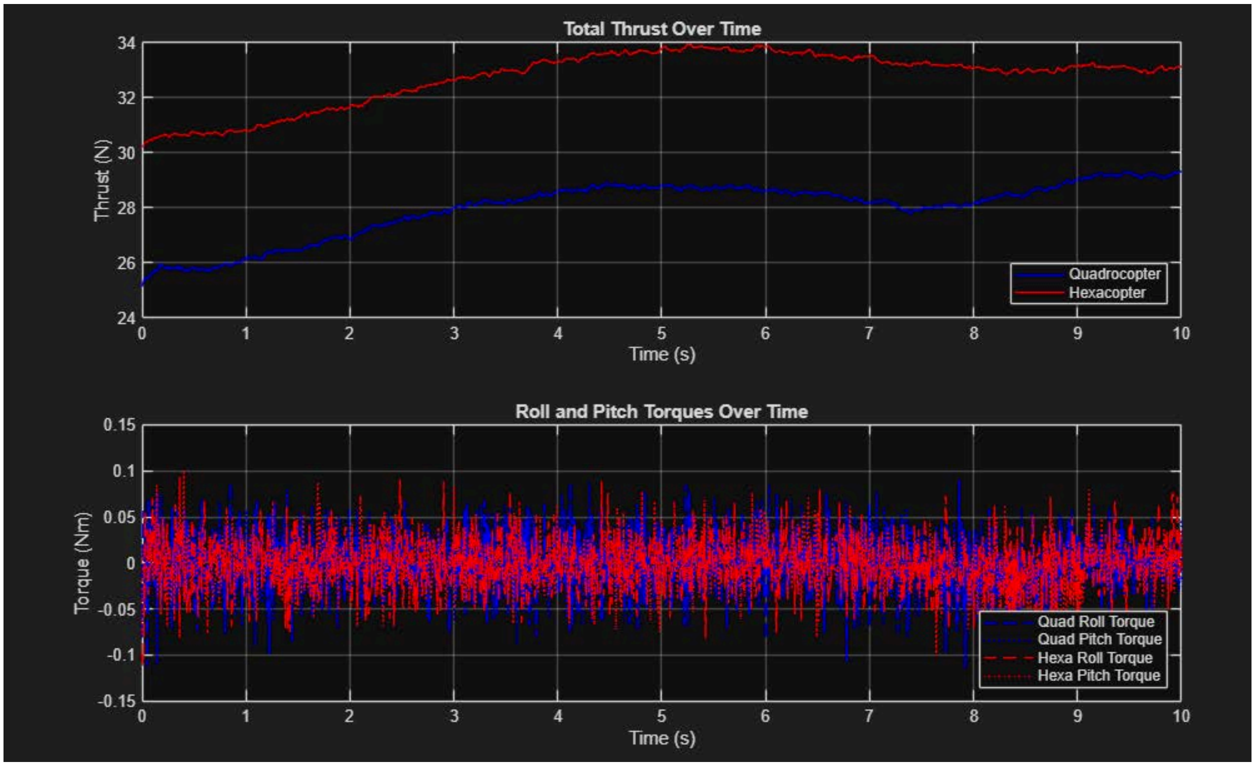


Figure 35 compares the angular and vertical velocities of the two configurations to measure how they respond dynamically. The Z-Velocity graph indicates that the two models have the similar vertical speed profile.

Nonetheless, the "Roll and Pitch Angular Velocity" graph shows that there are notable differences in control dynamics. The angular velocity (blue lines) of the quadcopter is more strongly oscillatory and stronger in amplitude, indicating that the controller needs to make more vigorous and sustained efforts to stabilize the platform. [17]The angular velocity of the hexacopter is smoother (red lines), indicating that the controller is not required to make such vigorous and continuous effort to stabilize the platform.

4.4.3 Total Thrust and Torque

Figure 36: *Total Thrust and Control Torque Comparison*



The forces and torques produced by the propulsion systems of the two drones are shown in figure 36. The graph of Total Thrust Over Time demonstrates clearly that the hexacopter setup (red line) has a higher thrust output than a quadcopter (blue line) under all conditions. This gives it a larger control margin of aggressive maneuvers and a larger potential payload capability.

The Roll and Pitch Torques graph indicates the presence of noisy graphs of both the models and this is typical of active control systems that reject disturbances, but the hexacopter has better stability implying that the control torques have been used well.

4.4.4 Average Motor Speed

Figure 37: *Average Motor Speed Comparison*

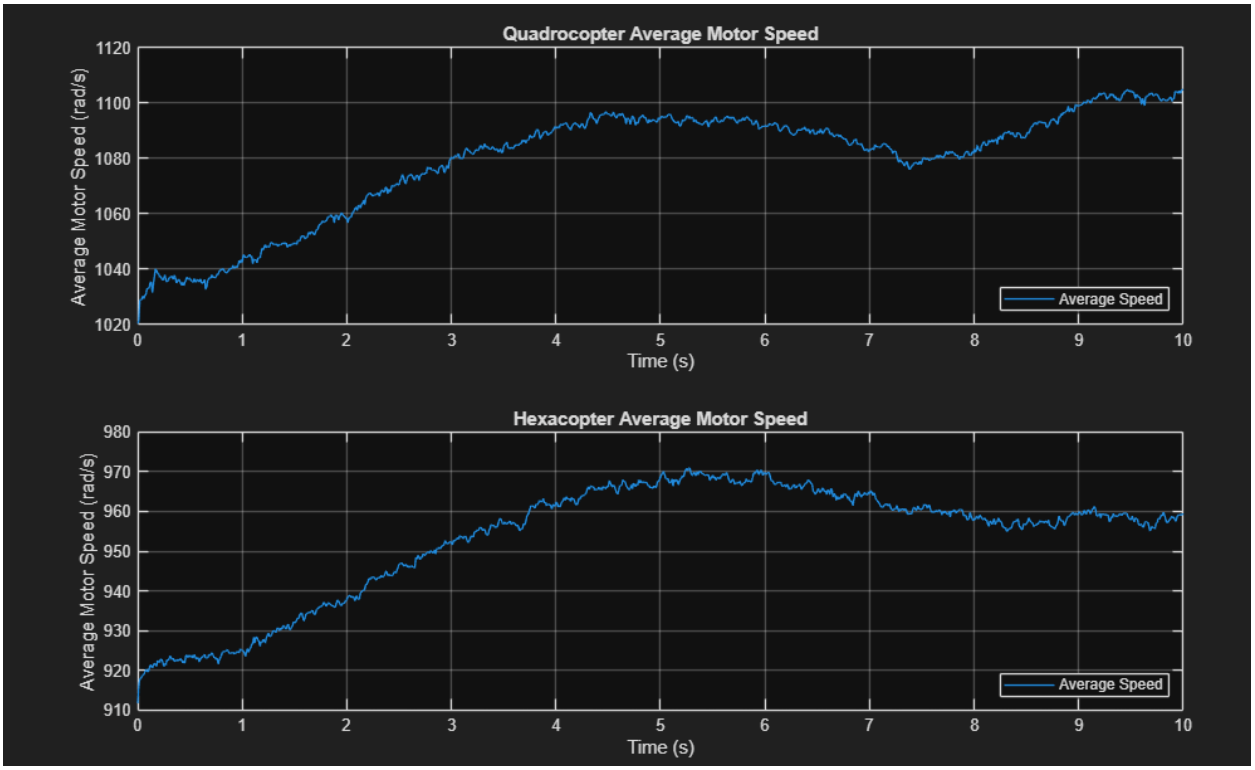
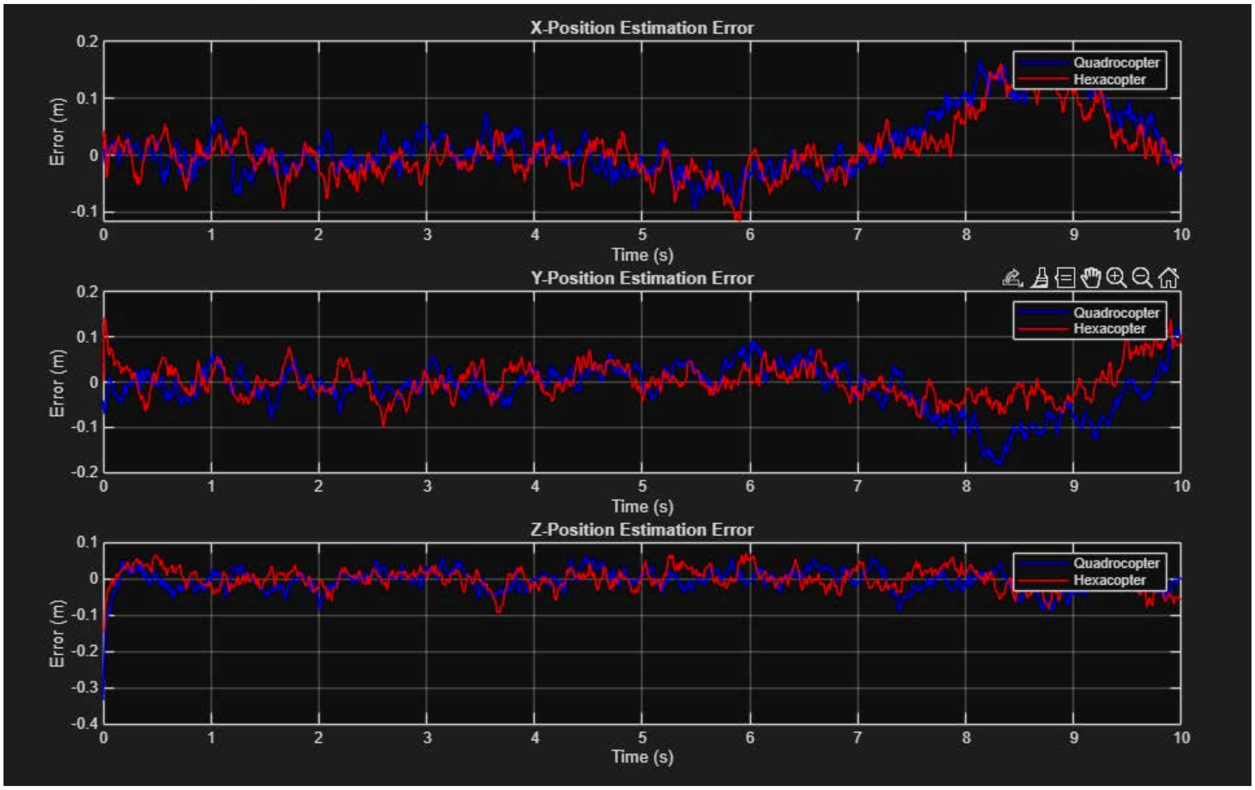


Figure 37 shows two graphs that compare the average rotational velocity of the motors of each drone, which gives information about the propulsive efficiency of the drones. The data showed that the hexacopter attains its greater thrust production with its motors running at a reduced average speed (920-970 rad/s) as compared to the quadcopter (1030-1110 rad/s). This shows a much greater total propulsive efficiency of the hexacopter design that would probably be reflected by longer range of flight in the field.

4.4.5 Positional Estimation Error

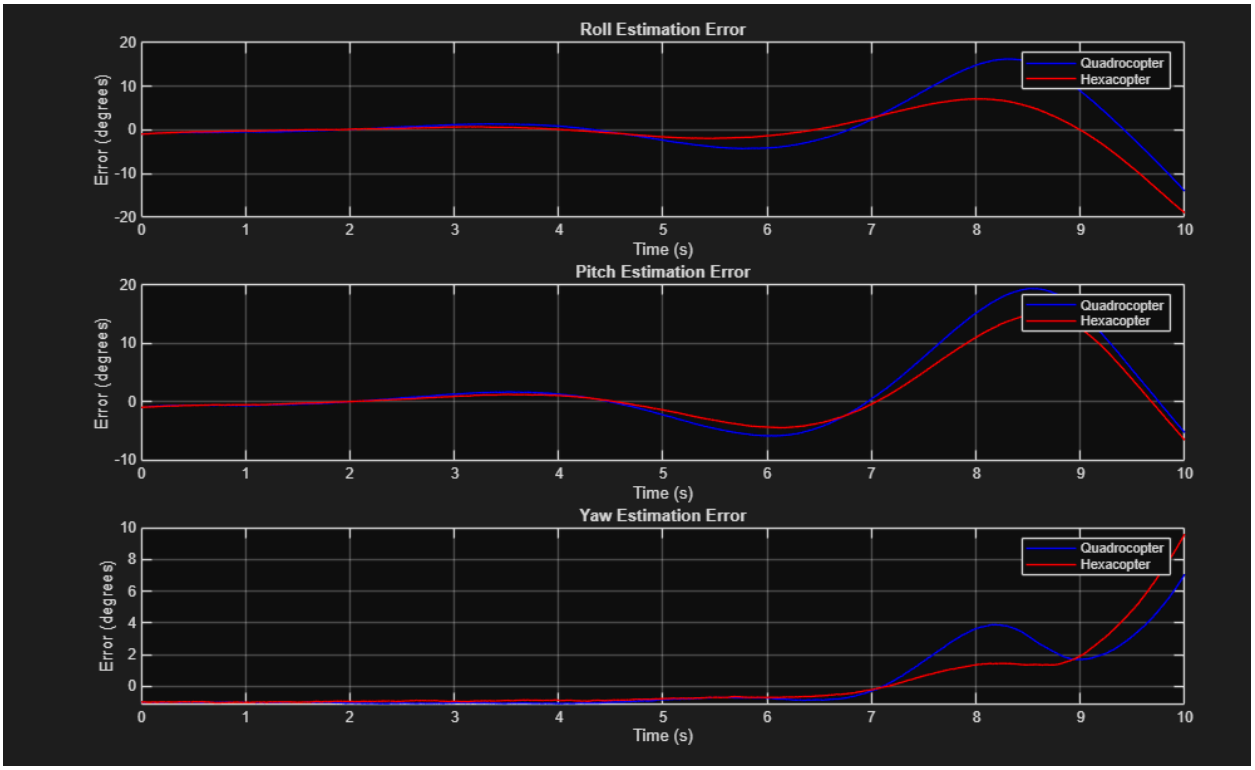
Figure 38: *Positional Estimation Error in X, Y, and Z Axes*



The graphs in Figure 38 measure the navigational accuracy of each model by plotting the error in the estimation of X, Y and Z axis. The hexacopter (red line) has a lower and less varied positional error in all three dimensions. The error of the quadcopter (blue line) is not only bigger in magnitude but it is also more inclined to drift during the simulation. This affirms the high state estimation and positional accuracy of the hexacopter which is essential in navigation to the target of high precision.

4.4.6 Rotational Estimation Error

Figure 39: *Rotational Estimation Error in Roll, Pitch, and Yaw*



These graphs in Figure 39 give the strongest evidence of the increased stability of the hexacopter, through a comparison of the error in the estimation of the rotation. The roll, pitch, and yaw error (red lines) of the hexacopter are insignificant during the simulation.[17].

Quite on the contrary, the errors (blue lines) of the quadcopter, specifically in the yaw direction, start to grow considerably after the sixth second. This means that attitude estimation and control are evidently compromised and can cause the plane to lose stability, which is of excellent quality in the case of the hexacopter design.

SWOT Analysis

Strengths :

1. Resource Efficiency:The system uses less resources due to the fact that it uses already constructed building structures and minimal operational infrastructure hence is environmentally friendly and efficient.
2. Cost-Effectiveness: The proposed solution will have lower deployment and operational costs than the traditional systems of fire safety and will still be very friendly to the users.
3. Employment Opportunities:
   The deployment and maintenance of the system can create new technical and support roles, providing opportunities for unemployed individuals and contributing to socio-economic development.

Weakness :

1. Initial Setup Cost: The system implementation and support may generate new technical and support jobs, which could offer the unemployed a chance to work, and socio-economic development.
2. Maintenance Requirements:It will require constant maintenance to ensure system reliability and optimum performance, which might be inconvenient or not palatable to certain users.
3. Potential System Failures: As in any other system that is based on electronics, there are possibilities of short-circuit or software failure which can temporarily affect the functionality, particularly in the unfavorable environmental conditions.

Opportunities :

1. Smart Infrastructure Integration: As the world quickly adopts smart building and smart city systems, the system will be easily incorporated to facilitate automated fire detection and prevention and detection, as well as prediction.
2. Renewable Energy Synergy: Adding solar or other renewable energy will help minimize electrical load and increase operating potential and minimize short-circuit hazards.
3. Growing Market Demand: The increased number of fire cases and the awareness of the people on emergency preparedness have led to high demand for autonomous fire safety solutions.

Threats :

1. E-Waste Concerns:The dumping of failed or end-of-life parts could lead to pollution of the environment and, therefore, needs to be recycled through responsible processes.

2. User Awareness Gaps:The general lack of awareness of fire-safety technology by users can be a source of slowness in adoption and deter investment.

3. Market Competition:There are current fire-safety manufacturing and international firefighting drone solutions, which are threats to competition in terms of their level of technology and market share.
4. Data Security and Privacy: Since the system will involve camera-based surveillance, it is important to control the trust of the users, the safety of data and compliance with privacy.

4.5 Performance Evaluation of the Developed Solution

According to the performance review of the designed autonomous firefighting drone, the efficiency, stability, and precision are high in both the field of fire detection and flight control. Based on the YOLOv8 training graphs, it is understandable that the model converged steadily with each new epoch training and validation losses reducing steadily, and precision, recall and mean Average Precision (mAP) all steadily increasing, thus indicating reliable flame detection accuracy. The confusion matrix and recall-confidence curve also confirm the capability of the model to identify true fire cases with small false-positives, which implies that the trained AI-based detection module would work under the conditions of complicated light or smoke. The PID-based control system of the hexacopter was stable to altitude and attitude responses in the dynamic flight simulations, as seen on the angular rate, Euler angles, and changes in motor speed plots. All motors showed a very high degree of smooth transitions in RPM with minimum oscillations and they had a stable lift distribution and stabilization immediately after maneuvering. The outcomes of the trajectory tracking revealed that the drone was on the right path, conversing with the predetermined route plans with positional error in an acceptable range and confirming the effectiveness of the control-mixing and feedback system. These results prove that the streamlined AI-designed hexacopter design performs better in terms of flight stability, response time, and detection than the sensor-based quadcopter. All in all, the results of the experiment and simulation have shown that the created system is capable of detecting the fire outbreak autonomously in real time, safely approaching the target, and deploying suppression mechanisms with high accuracy and consistency, therefore, demonstrating that the final optimized solution meets the goals of the project.

4.6 Conclusion

It has been discovered after research that the first design is the most optimal. The analysis in the sub-chapter 4.3 is analyzed on the basis of cost, precision,adaptability, Knowledge representation, real-time Data, requirement, complexity, safety, and liability,component availability, interpretability and explainability, and maintainability.The design style has additionally been applied in hardware with some general adjustments and therefore reviewed in terms of performance.

Chapter 5: Completion of Final Design and Validation [CO8]

5.1 Introduction

The final section gave a wider comparison of the implementation of the different designed plans. Simulation of the entire system was done solely through the software. A number of problem scenarios have been worked out to refinance the system. The final optimal was taken to design the hardware prototype to further test it. The ideal design illustrated in this chapter is discussed and analyzed in detail.

5.1.1 Component Level Specification

Table 05: *Component Level Specification*

Segment	Component	Dimension (mm)	Weight (g)	Specification
Flight Control System	Ardupilot APM 2.8 Flight Controller Board	82 × 50 × 16	40	6. Supply Voltage: 7V. 7. Processor: 32 Bit Cortex M4 Core 8. Bus interface (UART, I2C, SPI, CAN). 9. Firmware: Mission planner. 10. Sensors: Gyrometer, Accelerometer, Barometer, & Magnetometer
Communication	telemetry kit	26 × 26 × 9	36	7. Lightweight (under 5 grams without antenna) 8. 433Mhz frequency band 9. Receiver sensitivity to -117 dBm 10. Transmit power up to 20dBm (100mW) 11. Transparent serial link 12. Air data rates up to 250kbps

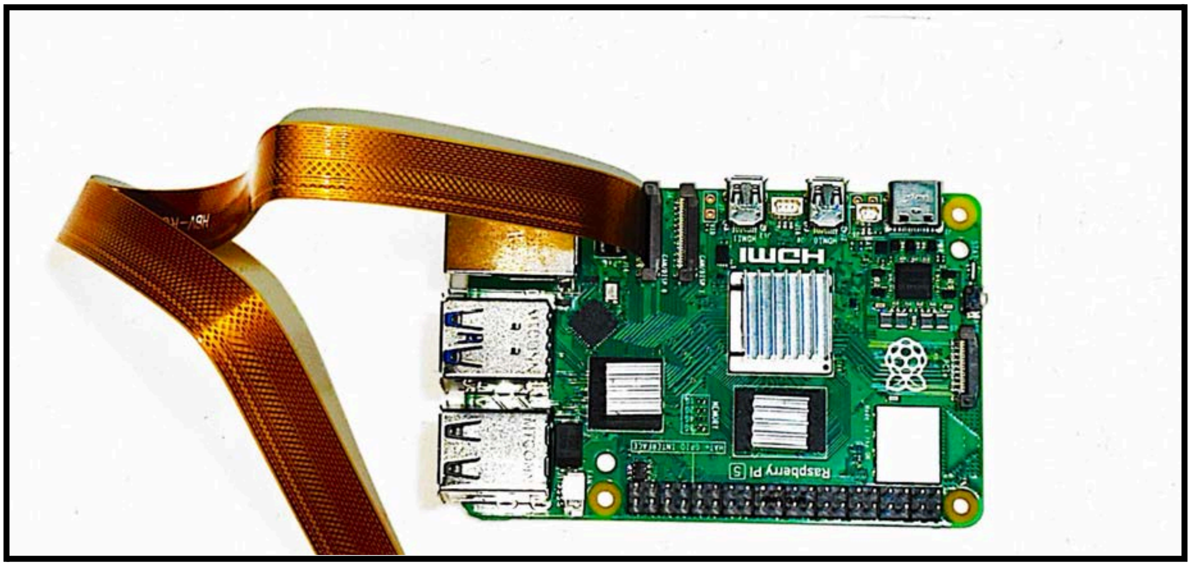
Frame	Hexacopter frame		400	7. Wheelbase: 450mm 8. Material: Glass Fiber + Polyamide-Nylon 9. Motor Mounting Hole Diameter: 3 mm 10. Arm Size: 220 x 40 (LxW) mm 11. Arm mounting holes (on frame): 3 mm 12. Arm mounting holes (on arm): 2 mm
Navigation	GPS module with compass	26 × 36 × 4	30	5. Built-in compass GPS module 6. Main chip: Ublox-M8N 7. With fast satellite searching speed and high precision 8. Includes a round plastic shell and GPS folding support
Control System	Flysky 16X controller	183 × 193 × 100	880	10. Channel: 6-10 (Default 6) 11. Model Type: Fixed-Wing/Glider/Helicopter 12. RF Range: 2.408-2.475GHz 13. RF Power: < 20dBm 14. RF Channel: 135 15. Bandwidth: 500KHz 16. 2.4GHz System: AFHDS 2A / AFDHS 17. Modulation Type: GFSK 18. Stick Resolution 4096
Propulsion	DJI 2212 motor	144.018 × 118.11 × 34.036	55	5. Type: 800KV brushless DC motor 6. Voltage: Supports 3S–4S LiPo battery (11.1V–14.8V) 7. Application: Quadcopter propulsion 8. Thrust: Up to 850g per motor (with compatible propeller)

Processing Unit	Raspberry Pi 5	-	60	7. VideoCore VII GPU with OpenGL ES 3.1 & Vulkan 1.2 support 8. Dual 4Kp60 HDMI® display output with HDR 9. Equipped with 4GB LPDDR4X-4267 SDRAM 10. Dual-band 802.11ac Wi-Fi® and Bluetooth 5.0 / BLE 11. 2× USB 3.0 (5Gbps) + 2× USB 2.0 ports 12. PCIe 2.0 x1 interface for high-speed peripherals
Propulsion	ESC	–	6.6	5. Type: 30A or compatible for the DJI 2212 motor 6. Signal Input: PWM from microcontroller 7. Features: Motor speed control, overheat protection 8. Power Supply: Direct from LiPo battery
Display	Monitor	184 × 126 × 28	450	4. Type: Basic FPV or USB camera (depending on setup) 5. Function: Real-time video transmission 6. Interface: USB or analog video transmitter
Vision System	Camera Module	12.5 × 12.5 × 17	5	5. 8 Megapixel 6. Resolution 3280 x 2464 7. Supports: 1080p30, 720p60, 8. Weight 3g

Power System	Battery	3.5 × 8.0 × 20	20	2. 4S LiPo (11.1V), 4200mAh
Actuation	Servo motor	39.5 × 20.5 × 40.7	14	8. Model: A2212 9. RPM/V: 1000KV. 10. Batteries: 2-3 Li-Poly. 11. Efficiency: 80%. 12. Current: 4-10A (at 75%). 13. No-load current: 10V/0.5A. 14. Max. transient current 12A/60S.
Power System	B3 Pro Compact Charger	95 × 55 × 35	180	4. Balance charger for LiPo batteries 5. Input: AC 100–240V, 50/60Hz 6. Output: Supports 2S/3S LiPo (7.4V/11.1V)
Communication	VTX transmitter	36 × 36 × 4.5	6.8	4. Transmits live video from the camera to a receiver (e.g., FPV goggles) 5. Frequency: Typically 5.8GHz 6. Power Output: 25–800mW adjustable
Communication	Video transmitter	73 × 41 × 14	80	

Raspberry Pi 5: Raspberry Pi 5 is a high-performance single-board computer, which should be used to provide the computers with important performance gains over their predecessors, thus being suitable in advanced embedded systems, robotics, and AI-based applications. It is based on a Broadcom BCM2712 quad-core ARM Cortex-A76 coach with a base speed of 2.4 GHz, with a performance of three times that of the Raspberry Pi 4. Options of 4 GB or 8 GB of LPDDR4X-4267 RAM are available on the board, and this will have sufficient memory to run multiple tasks and computationally intensive tasks.

Figure 40 : *Raspberry Pi 5*



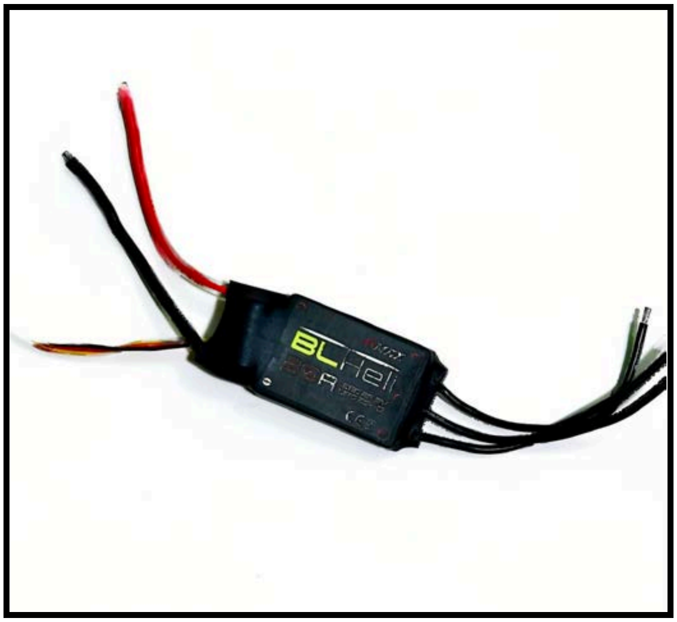
It has two micro-HDMI ports with 4K video output at 60 fps, PCIe 2.0 port with high-speed peripherals, dual-band Wi-Fi (2.4 GHz and 5 GHz), Bluetooth 5.0 and Gigabit Ethernet that has fast and stable connectivity. The Raspberry Pi 5 also has an element of 40 GPIO pins to interface with sensors and actuators, with I2C, SPI, UART, and USB 3.0 communications being supported. It can be powered at 5V through USB-C with recommended power supply of 5A, which guarantees a constant power supply when required. The Raspberry Pi 5 can be used in a wide variety of electronics, automation, and IoT projects with its dimensions (85 mm x 56 mm) being fully compatible with the Raspberry Pi OS and Python development and its high performance.

B3 Pro Compact Charge: This product is a lightweight and efficient balance charger for charging 2-cell (7.4V) and 3-cell (11.1V) lithium-polymer (LiPo) batteries that are specifically used in drones, RC vehicles, and other electronic projects. It has an AC input voltage range of 100240 V at 50/60Hz, which is compatible with the worldwide power standards. The charger has three autonomous charging channels with an LED indicator to show the charging status of individual cells where a red color is used to show charging and green color to show full charge. It provides a balanced current to the respective cells to guarantee the optimum performance of the battery, maximize the life of the battery as well as enhance safety of the battery since there is no overcharging or imbalance between the cells. The B3 Pro is capable of charging at 800 mA per cell which is stable and reliable. It is very portable and can be used in the field since it is compact in size with a size of about 95 mm × 55 mm × 35 mm and weighs about 180 grams. Its internal overvoltage and short-circuit protection also increase its safety and reliability, which makes the B3 Pro Compact Charger a perfect option to keep the batteries of the drones and other LiPo-powered devices.

Figure 41 : *B3 Pro Compact Charge*

Electronic Speed Controller (ESC): The Electronic Speed Controller (ESC) is an imperative element that controls the rotational velocity, direction, as well as braking of brushless DC (BLDC) motors in drone and robotics. In the project, a 30A ESC will be used to run the DJI 2212 motor, and it will allow controlling the motor effectively and precisely depending on the input signals given by the flight controller. The ESC reads the Pulse Width Modulation (PWM) signals to dynamically communicate with the motor speed to maintain constant thrust production and consistently smooth flight action. It is compatible in 2S 4S Li-Po battery (7.4 V-14.8 V) as well as in continuous current up to 30 A and peak short-duration currents up to 40 A. A regulated 5V supply in the form of the Battery Eliminator Circuit (BEC) allows powering other auxiliary devices like the receiver or the flight controller without using individual power supplies. There are also several safety and reliability features built into the ESC such as overheat protection, low-voltage cutoff, and signal loss detection. It is small and lightweight, with a high speed throttle response and efficiency, which means that it is ideal in multi-rotor UAVs in a system that needs to synchronize motors precisely and it must show high performance in diverse flight conditions.

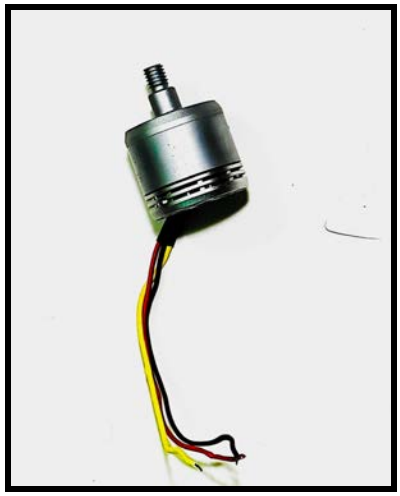
Figure 42 : *Electronic Speed Controller (ESC)*



DJI 800KV Brushless Motor:

DJI 800KV Brushless Motor is a high-efficiency propulsion motor that will be used in multi-rotor UAVs with a good balance of thrust, stability and power. This motor can work with a KV rating of 800 revolutions per volt, which gives it the best torque and rotational speed to operate drones of medium sizes making it fly smoothly and responsively. Constructed using high quality copper windings, fine bearings and lightweight aluminum housings, the motor has better performance with little vibration and heat production. It is capable of operating with 3S to 4S Li-Po batteries (11.1V-14.8 V) and can produce up to 850 grams of thrust using compatible propellers, including 10-4.5 and 10-4.7. The design of the motor has a high conversion of power and has a long life cycle of operation, the low internal resistance of the motor increases the current efficiency and minimizes energy loss. The DJI 800KV motor is compatible with the 30A electronic speed controllers (ESCs) allowing the controllers to be used to control all motors in a drone in a stable and synchronized manner. It is lightweight, compact, and durable, and fits perfectly on quadcopter and hexacopter systems to ensure that it has the required thrust-to-weight ratio to hover smoothly, be agile in maneuvering and assure reliable performance in lifting its payload.

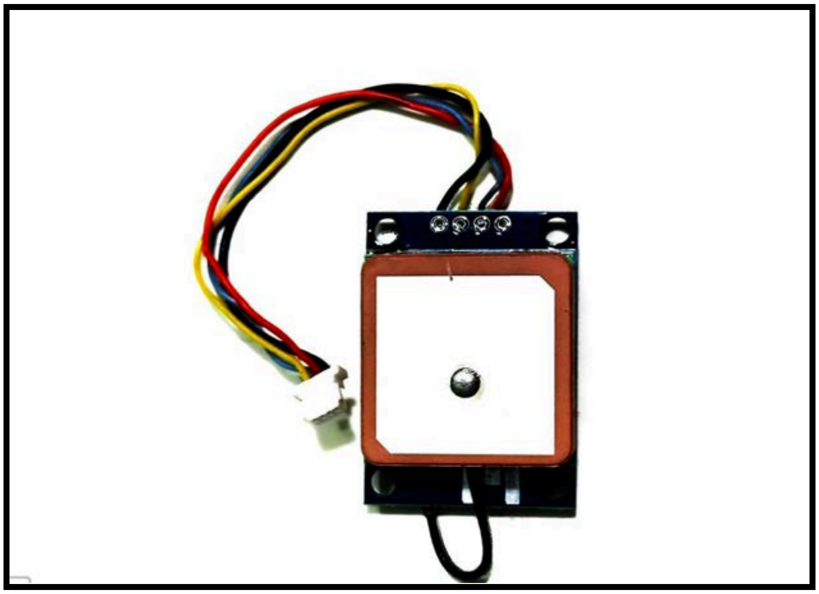
__Figure 42 :__ DJI 800KV Brushless Motor



GPS Module:

GPS Module with Compass is a very important part of the navigation system that is meant to be used in autonomous UAV systems to give accurate positional and directional information. The module combines a high-performance Ublox NEO-M8N chipset, which is characterized by the rapidity of attaching satellites, a high sensitivity, and multi-constellation, such as GPS, GLONASS, Galileo, and QZSS. It is capable of providing a positional accuracy of up to 2.5 meters on an open sky and also has an inbuilt electronic compass (magnetometer) that provides correct heading information hence maintains a steady orientation and direction during dynamic maneuvering in flight. The module uses the UART or I2C interface, and thus can be used with a variety of flight control boards, including the Arduino-based boards and the Pixhawk. It can be used with low power consumption of 3.3V-5V which is suited to battery-powered UAVs and embedded systems. Its onboard ceramic patch antenna and low-noise amplifier are also better at detecting and receiving signals and the integrated backup battery also allows the device to start-up quickly and relock to the satellite once power cycles. The module is normally covered with a tough plastic housing and includes a fold up GPS stand to ensure maximum positioning where there is no electromagnetic interference. The GPS Module with Compass is small, powerful and efficient and offers high-quality real-time data of location and heading needed by drone flying to have an autonomous flight and navigate to a waypoint or place it back home (RTH).

Figure 44 : *GPS Module*

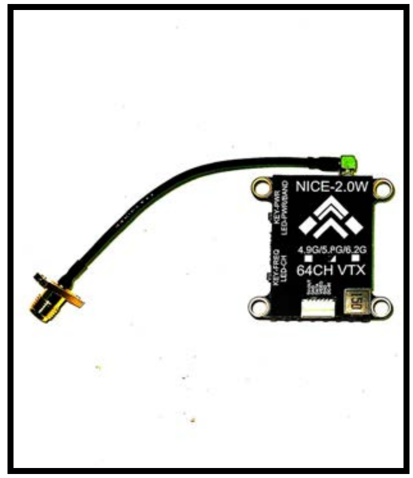


VTX (Video Transmitter):

The drone also has an essential part that is the Video Transmitter or VTX which is the drone that transmits the live video feed of the onboard camera wirelessly to a ground receiver or FPV (First-Person View) goggles. The VTX can deliver a high quality low latency video over a range of 500 meters to several kilometers, depending on the power of transmission and environmental factors, and the frequency band is generally in the 5.8 GHz range. In the majority of VTX modules, the output power is adjustable (typically 25 mW, 100 mW, 200 mW, and even 800 mW) to enable users to trade off between a longer transmission range and reduced power consumption depending on the mission requirements. The module is compatible with the standard analog video types (NTSC/PAL) and it has channels that have frequency band options that can be selectable through DIP switches or push buttons, to provide an interference -free communication. The VTX contains lightweight heat-dissipating aluminum casing, which guarantees universal performance and prevents overheating when running continuously. The input of power is generally 7V to 24 V and thus can work with the standard Li-Po batteries in drones. The VTX with a corresponding receiver and circular-polarized antenna provides undisturbed, sharp video that is needed during the piloting phase of firefighting drone missions to know the position, track the target, and maintain the situational awareness. The VTX is small, powerful and compact and is critical in ensuring smooth visual feedback between the aerial platform and the ground control.

Figure 45 & 46: *VTX (Video Transmitter) and Receiver*

(45) (46)

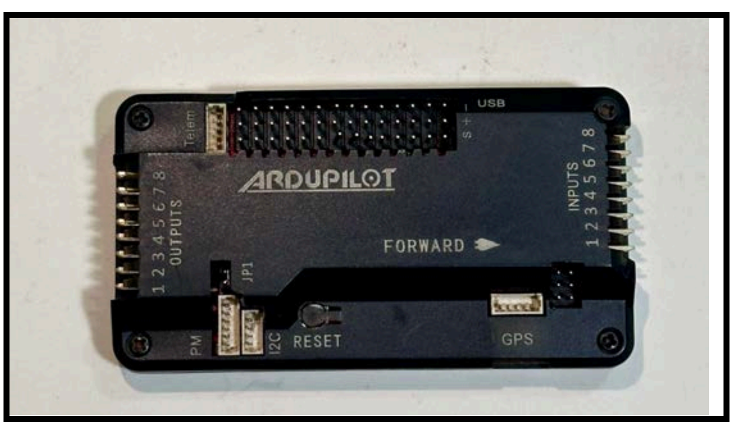


EDR Radio Telemetry Kit: The EDR Radio Telemetry Kit acts as an important communication channel between the drone and the ground control station allowing in real-time the transmission of data to monitor the flight, plan the mission, and modify the parameters. This telemetry system uses a relatively low and standard 433 MHz or 915 MHz frequency band (ISM), and will have a reliable and long range serial communication channel with minimum interference. The kit consists of transmitter (air module) and receiver (ground module), with inbuilt antennas to provide a stable bi-directional data transmission. It promotes open-serial serial data transfer with a maximum of 57600 bps and can easily be integrated with flight controllers like pixhawk and ardu pilot based systems. The telemetry kit has highest receiver sensitivity of up to -117 dBm and transmit power that can be adjusted up to 20 dBm (100 mW) to provide stable connection over a distance of 1.5 to 2 kilometers in open conditions. The module uses UART (TTL level) interfaces to communicate and uses MAVlink protocol to exchange telemetry data, allowing it to be used with software, including Mission Planner and QGroundControl. It works on a 5v supply and it consumes very little power hence it is suitable in light weight UAV systems. The EDR Radio Telemetry Kit is compact, lightweight and can be configured either through AT commands or via configuration tools, which improve situational awareness allowing the operators to monitor flight parameters, including the altitude, GPS position and battery status in real-time. It has a strong communication setup and low-latency, which makes it a critical element in autonomous UAV navigation and mission control.

Figure 47 : EDR Radio Telemetry Kit

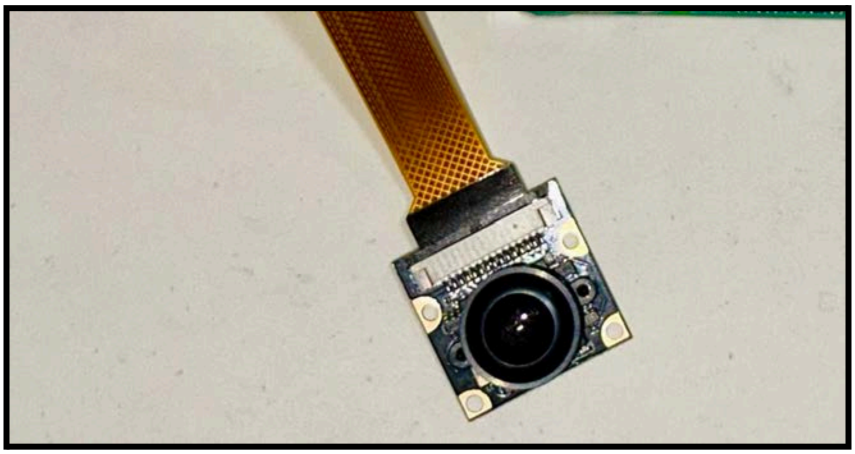
ArduPilot APM 2.8 Flight Controller: APM 2.8 Flight Controller: ArduPilot APM 2.8 Flight Controller is a universal and effective autopilot system that can be used in drones, UAVs, and other robotic vehicles. It is also equipped with built-in sensors such as accelerators, gyroscopes and barometers making it fly stably, hold altitude and even autonomously. The controller is compatible with GPS-based waypoint missions, failsafe operation, and adjusting parameters in real-time, which makes it suitable to hobbyists and researchers. It can be configured and integrated with ArduPilot and Mission Planner software. The APM 2.8 is a small and lightweight device that works on a 5V supply and can be linked to a wide range of aircrafts, including multirotors, fixed-wing airplanes, and helicopters, controlling them precisely and improving their safety and performance.

***Figure 48 :** ArduPilot APM 2.8 Flight Controller*



Camera Module: The 8 Megapixel Camera Module is a miniature and lightweight imaging product targeting drones, internet of things devices, and embedded systems. It has high-resolution images of 3280 x 2464 pixels and can support video recording with 1080p 30fps and 720p 60fps making the recordings sharp and smooth. The module is 3 grams only, which means that it can be used in lightweight applications when space and weight are major factors. It is compatible with microcontrollers and flight controllers, which is why with its versatile interface it is suitable in aerial photography, surveying and processing vision activities in real-time.

Figure 49: *Camera Module*



Fire Extinguishing Ball: AFO Fire Extinguishing Ball is a new design of an automatic fire suppressing tool that is used in the emergency response department. It is simple and lightweight and can be thrown, mounted, or deployed in high-risk areas. On hitting flames, the ball triggers off in seconds, dumping a powder of fire extinguishing hence extinguishing the fire within a short time before spreading the fire. The AFO Fire Extinguishing Ball is suitable to be used at home, office, warehouse, industrial environments, and, thus, to fight the fire, one does not need training as it is a hands-free and safe way to rid the building of fire. Its small size and automatic functioning feature render it a useful and trustworthy tool for improving fire safety.

***Figure 50** :AFO Fire Extinguishing Ball*

***Table 06:** Fire Extinguishing Ball Specification*

Weight(kg)	Coverage Area	Activation Time
1.3	8–10 m^2	3–5 seconds upon contact with flame (⩾70°C)

Battery: The Wild Scorpion Nano LiPo Battery 4200mAh is a high-performance, light-weight energy source, which works with drones, RC cars, and other high-demand applications. It has a capacity of 4200mAh that gives it long flight hours and power supply is consistent. The battery has a variety of voltage supports which comprise 7.4V, 11.1V, 14.8V, 18.5 V and 22.2 V, which make it compatible with a large number of devices. It has high discharge rates between 25 o C and 80 o C thereby guaranteeing fast and steady energy supply to motors and electronics. It is easy to install and safe to use due to the compact design, built in connectors, and durable casing, and can be reliable in the performance of UAV missions, RC racing, and hobbyist projects because of proper handling.

Figure 51: *Wild Scorpion Nano 4200mAh Battery*

Flysky -I6s 2.4G:

The Flysky i6S 2.4 GHz is a very adaptable 6 channel radio transmitter suitable for hobbyist and semi-professional use in the RC field (e.g. drones, fixed-wing aircraft, helicopters and ground vehicles). It works on the 2.4GHz AFHDS 2A protocol, which guarantees the stability of the communication, as well as the absence of any interruptions, with the reliability of the signal over a long distance. The transmitter is also compatible with multi-platform work since it has multiple model memory where one can save the configuration of various vehicles or aircraft.

Adjustable servo travel, dual rate and exponential mode, programmable endpoint, and fail safe are some of the technical features that can give precise and customizable control over all the devices attached. The i6S can also be used with numerous Flysky receivers such as FS-iA6B, FS-iA10B, and FS-iA8B with up to 6 channels being supported by PWM output.

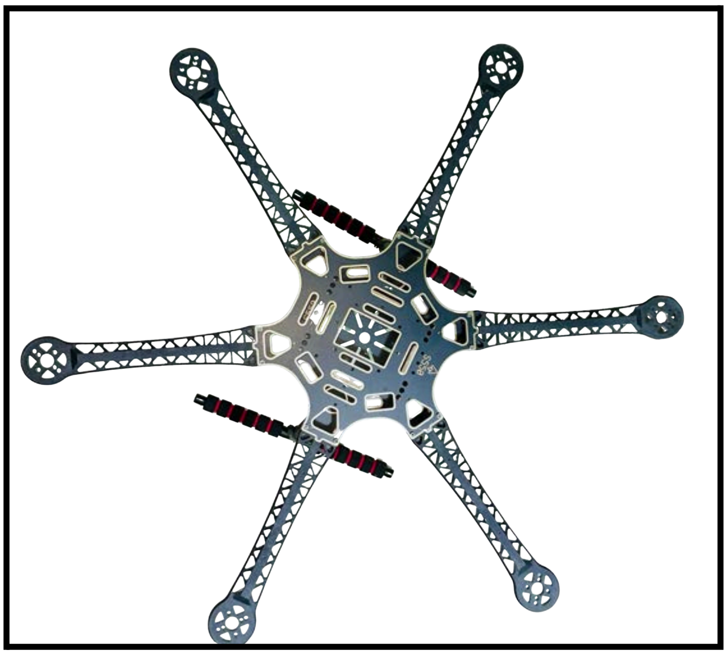
The transmitter includes an LCD backlit display that can be easily seen in all lighting conditions and an easy to use menu system that allows one to easily configure. Power is provided through the use of AA batteries hence it is portable and can be used in the field. The Flysky i6S series is lightweight and ergonomic, which means that it is easy to use and has found its way into the hands of a beginner and current RC supporters seeking a strong and affordable control method.

Figure 52 : *Flysky I6S 2.4GHz*

5.1.2 Component Integration with the System

(a) Drone frame build:

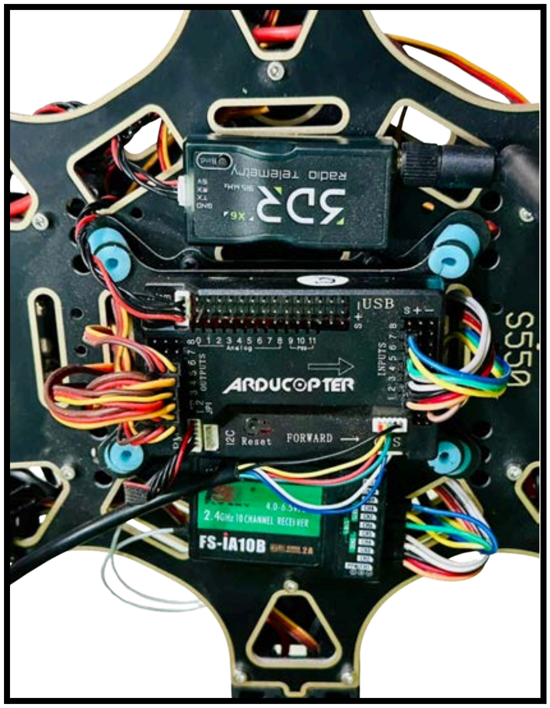
Figure 53: Hexacopter Drone Frame with stand



The drone is based on a robust carbon-fiber hexacopter frame that has a high degree of stability, durability and ability to carry heavy-payloads. Its stiffened arms and central plates minimize vibration, as well as it keeps the thrust evenly distributed among the six motors that enhance stability even during windy conditions. The large center section is stable in supporting the flight controller, power distribution board, Raspberry Pi, and communication modules but the payloads such as the camera, sensors and fire-extinguisher ball mechanism are mounted on the lower frame without impacting on the balance. It has a 550 mm wheelbase (distance between opposite motor mounts), 220 x 40 mm or 235 x 42 mm arm sizes, is 424 to 620 g, carries a takeoff weight of 1200 to 2400 g and propellers of 8 to 10 inch ensuring good lift and controlled level flight.

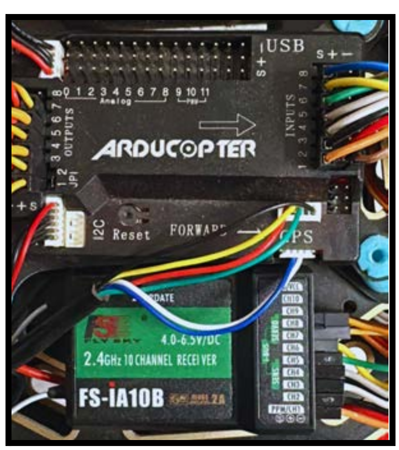
(b) Integrating drone components:

Figure 54: *Drone Components*



The top of the drone is made to fit the main control electronics in tidy and clean design to maintain a stable performance. As shown in the figure, the Ardupilot APM 2.8 flight controller is fixed on a secure anti-vibration plate in the middle to reduce the noise produced by the motors and propellers. The wiring around the controller is also neatly laid in such a way that there is no cable which is going to affect sensor reading or operation of the motors. The power distribution board (PDB) is mounted directly below this part and it provides regulated power to the APM, receiver, GPS, and telemetry module among others. This small space arrangement makes the upper section light and smooth communication amongst the entire flight systems.

Figure 55: *Ardupilot and Flysky I6s receiver*



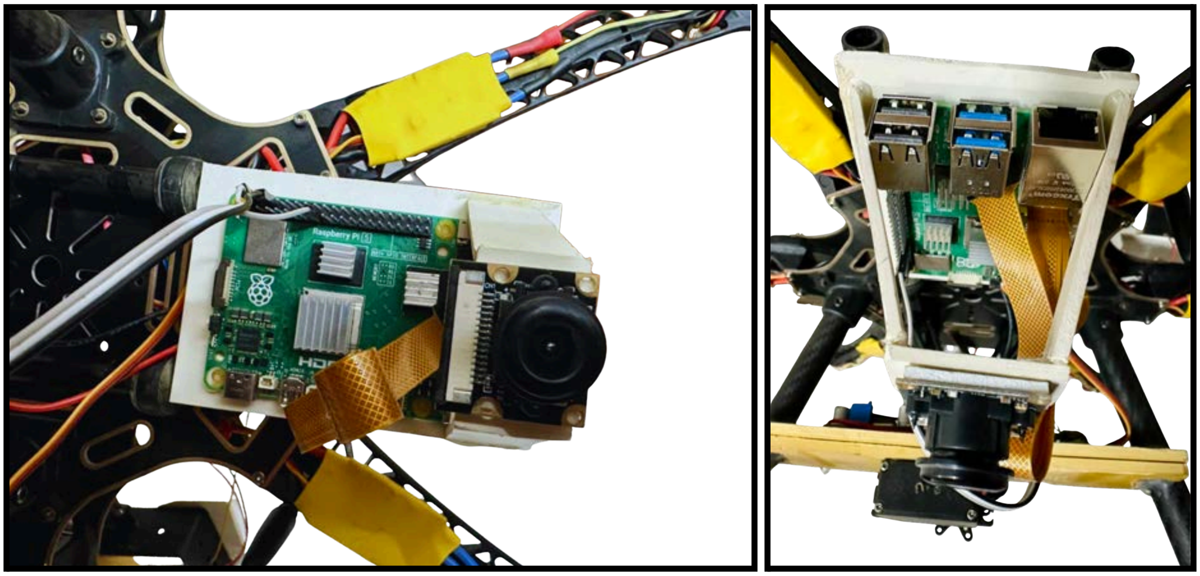
Ardupilot APM 2.8 is the central part that stabilizes and controls the drone. It gets attached to the ESCs by using its output pins and it gets the control signal by Flysky I6s receiver to the input ports. The APM is linked to the telemetry module by the special Telemetry Port (Tx and Rx pins) by which real-time information such as altitude, GPS position, battery capacity and speed can be relayed to the ground station. The PDB again delivers clean power to the APM via the Power Module port which stabilizes the voltage and gives current sensing. Each connection is color-coded and firmly locked to ensure that it does not become disconnected when this airplane is vibrating or during the flight motion.

Figure 56: *Drone GPS module*

As shown in the figure, the GPS module with a compass is mounted on the upper surface of the drone with a tall mast to make sure that it does not encounter any magnetic interference by the motors and the ESCs. The GPS is attached to the APM via the I2C and GPS port to give the location, altitude, and direction information to the autonomous and stabilized flight. The outer guide wire is also installed in a manner that does not override high power wire. When connected, the GPS and the telemetry then collaborate: the GPS transmits the positioning data to APM, and the telemetry module transmits it to the pilot monitor or laptop. This arrangement finishes the upper integration, rendering the drone to control its positions precisely and fly steadily and monitor live on the ground.

(c) Raspberry Pi and camera module Integration:

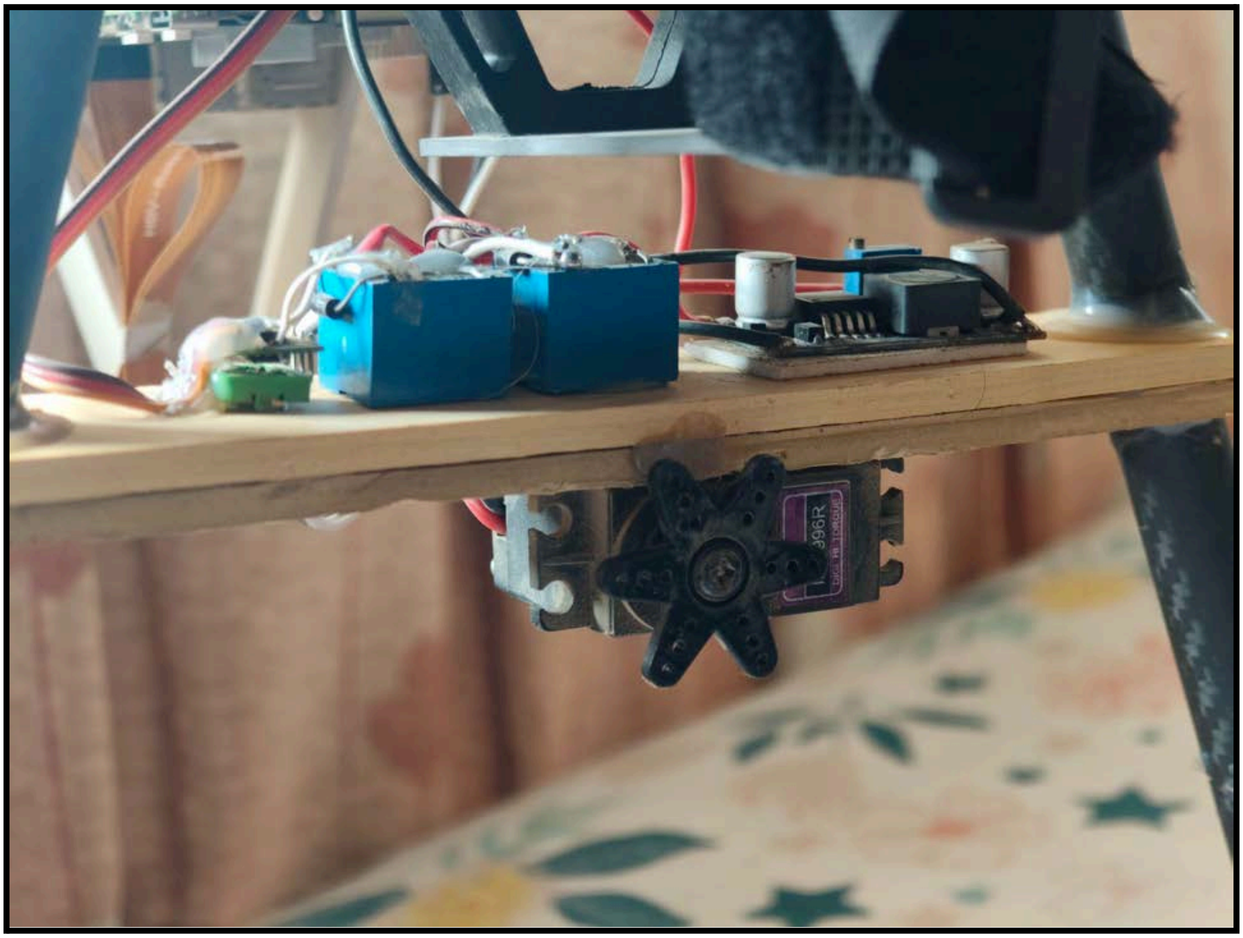
__Figure 57 :__ Raspberry Pi and Camera Module Integration



The drone has a Raspberry Pi along with a camera module as the central unit of image processing on board and of fire detection. The Raspberry Pi 5 will be interred to the drone through its GPIO pins, namely: pin 1, pin 3 and pin 8, which are the sources of power, ground and communication lines to be utilized in controlling other sensors. The camera module is connected to the Pi via the CSI ribbon port and can thus take high-quality video continuously on flight. The Raspberry Pi is set to operate the fire-detection algorithm, which is a program that processes each frame to detect the presence of flames or smoke in real-time, as the drone flies. A detected fire can be recorded by the Raspberry Pi, alerted, or provided the live feed via the communication system of the drone (e.g. VTX or telemetry connection). It will allow the drone not only to see the surroundings but also process and respond to visual information immediately, which makes it extremely useful in the fire-fighting operation.

(d) Servo integration:

Figure 58: *Integration Of The Servo In The Drone*



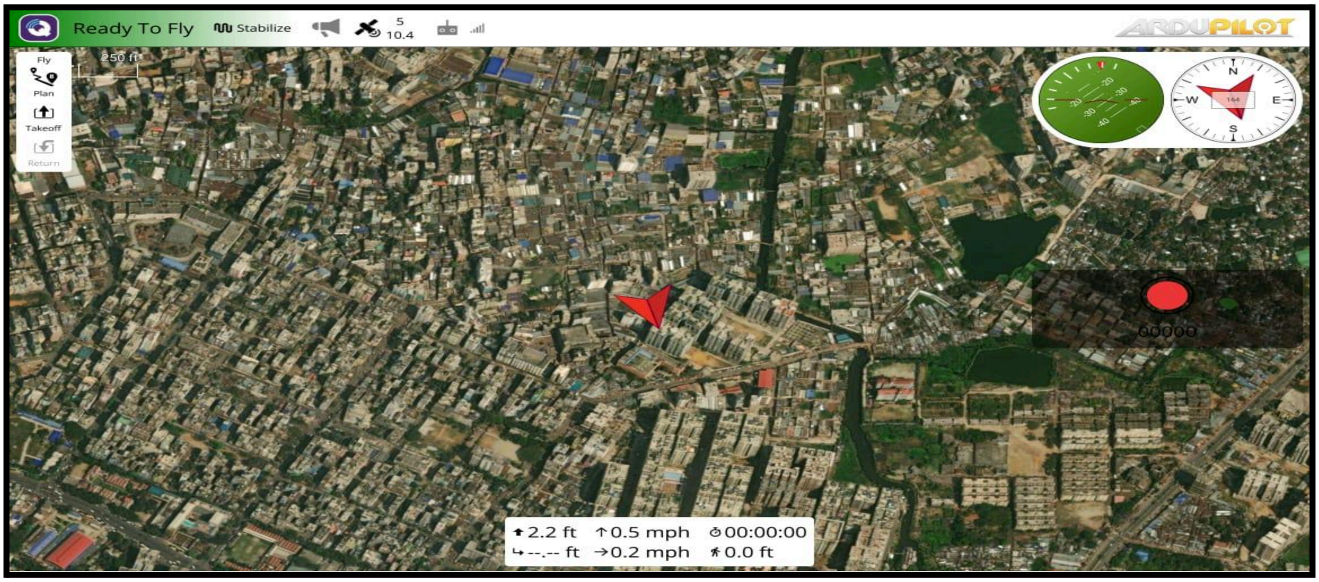
We have fitted the servo in the drone in this part. In this case we have used the servo in the landing frame with ar support of hardboard where all the electronics of the servo are placed on the top of the hardboard. We have also used a 13kg weight-capability servo to fluid transition, since our fire extinguishing ball is 1.3kg, meaning that it will find it easy to do so.

(e) Autonomous activity of the drone:

Figure 59: *Telemetry Transmitter In Tablet and interface of Q ground control*

Here, we have tested whether the receiver of our drone is linked to the autonomous flight software which is Q control. This computer program is highly user friendly. The software can be very easily used. All that is required is to connect the telemetry transmitter and the software will appear.

__Figure 60:__ QGroundControl Ground Control Station (GCS) Interface

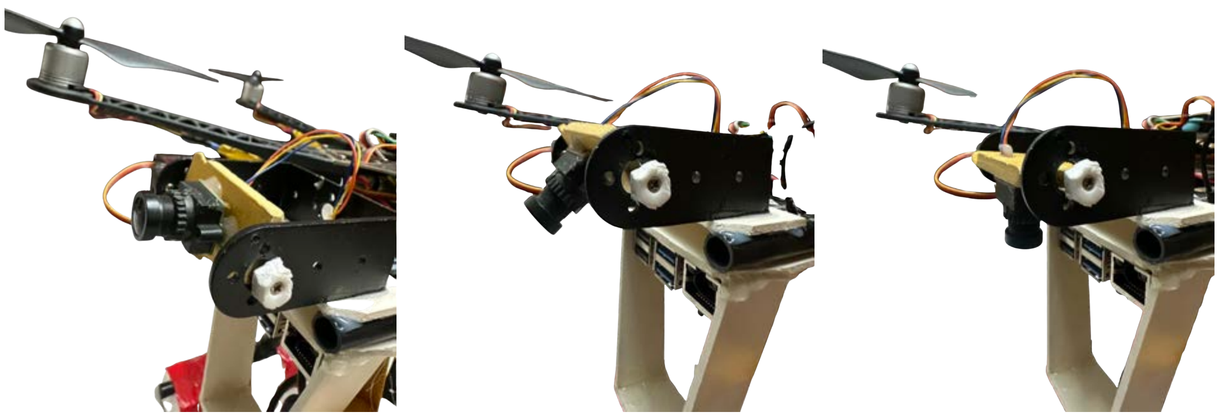


This picture shows the Fly interface of the QGroundControl software with the ArduPilot branding that is located on the right side of the top. At the top, the status bar displays a green Ready To Fly notification with the flight mode being set to Stabilize, and there are 5 GPS satellites and the battery indicates 10.4. The most striking image is the satellite view of a city area with a dense population, with a red arrow icon indicating the position and direction of the drone. On the right-hand side of the top, there are virtual flight instruments that give an artificial horizon and a compass indicating the heading of approximately 164 degrees South East and the telemetry overlay at the bottom shows that the drone is already on the ground at an altitude of 2.2 feet and a speed of 0.00.

(f) Drone Camera for monitoring fire:

Figure 61 : *(a) Camera at 0°, (b) camera at 45°,(c) camera at 90°.*

(a) (b) (c)



The example shows the movable camera mounted on the drone, which is used to monitor fire. The camera is mounted on a servo-controlled tilt mount, which enables it to move in an angular manner to get a view of the fire scene at various angles. Subfigure (a) indicates the camera at 0 o which is appropriate to the frontal observation; (b) indicates the camera at 45 o that ensures the observation of a wider range to detect the fire whereas (c) of 90 o that allows the observation to be downwards and allows the precise localization of the sources of the fire. Such flexible design helps to increase the situational awareness and it can make aerial surveillance of the fire more effective.

(g) Structure for the ball stability:

Figure 62: *Fire Extinguish Ball Stabilizer.*

The figure depicts the Fire Extinguish Ball Stabilizer underneath the drone frame. The stabilizer is a circular support ring to the landing structure that is supposed to firmly hold and balance the fire extinguishing ball as it flies. Foam-padded landing legs are added to take the impact during landing and takeoff and make the drone and payload stable. This stabilizer reduces the effect of payload sway, keeps the center of gravity of the drone and allows carrying out the deployment of the fire extinguish ball safely and effectively above the target fire zone, and this enhances the effectiveness of aerial firefighting.

5.2 Completion of Final Design

Figure 63: *Prototype Overview*

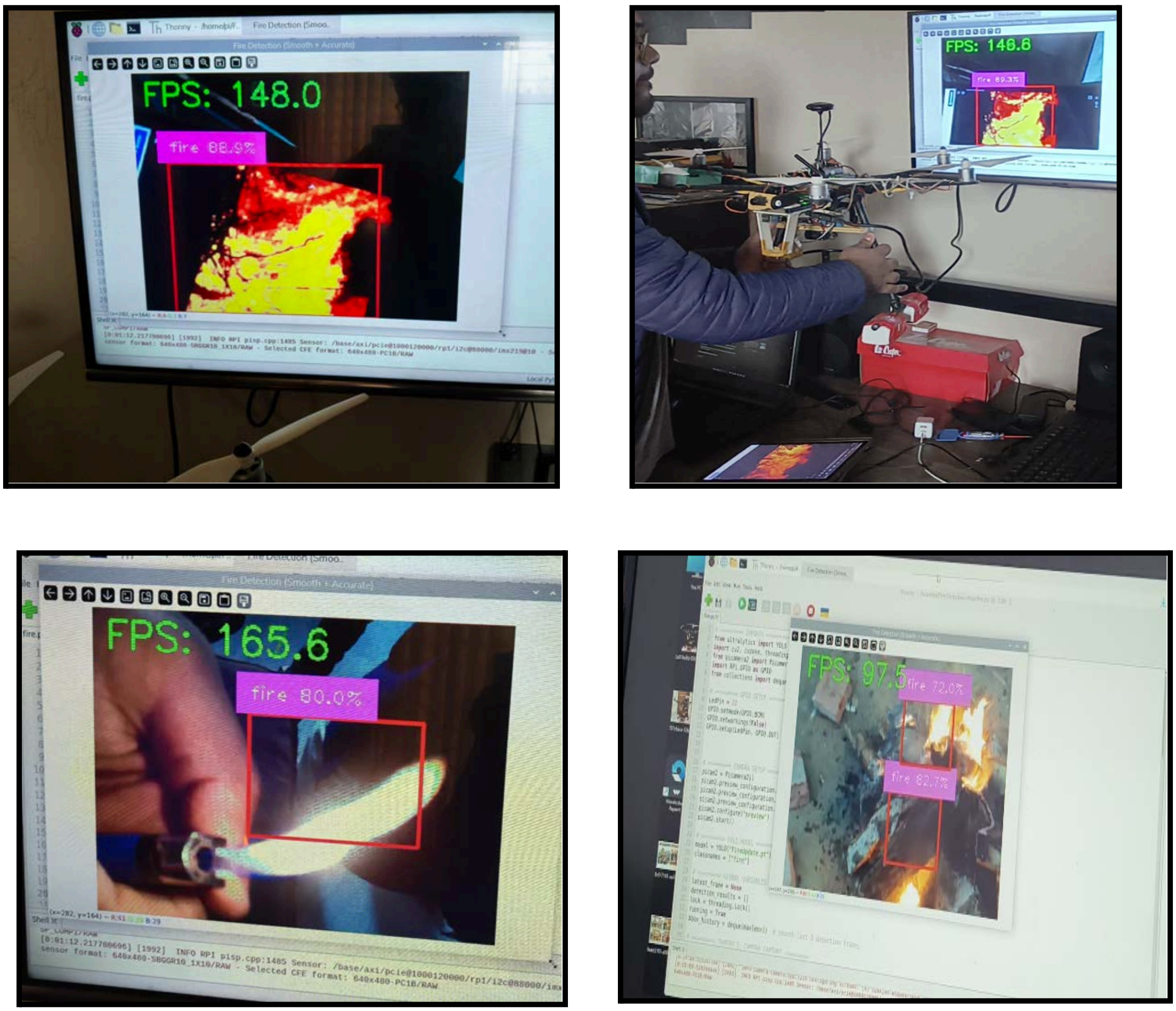
The final design is a product of long research, simulation and refinement thus creating a complete autonomous fire fighting drone system. The completed hexacopter design integrates all the vital subsystems in a unified design that is best suited to real-life application in quelling fires. Fundamentally, the system is implemented by using Ardupilot APM 2.8 flight controller attached upon anti-vibration dampers in order to stabilize sensor values and tied to six DJI 2212 800KV brushless motors through 30A ESCs to provide a perfect thrust control and flight stability. The Raspberry Pi 5 will be the central processing unit, which will implement the trained YOLOv8 fire detection model and connect with the Pi Camera Module to detect the real-time visual fire. It has power management, operated by a 4200mAh 4S LiPo battery system with built-in voltage monitoring, and has a flight time of about 35-40 minutes in normal conditions. The subsystem of communication consists of an EDR telemetry kit, which runs at 433MHz, and which includes 2-way communications with the QGroundControl ground station, but is also supplemented by a 5.8GHz VTX, used to transmit live video to FPV monitoring devices. The Ublox NEO-M8N GPS module and compass is placed on a high mast to reduce electromagnetic interference which, in turn, allows the autonomous navigation of the waypoints and the accurate tracking of the positional location. The drone has a fire suppression system that consists of a high-torque MG996R servo motor (13kg-cm capacity) located on a reinforced hardboard platform below the drone frame, providing linear action on a release arm that detachably holds and deploys the 1.3kg AFO fire-extinguishing ball when a fire is confirmed. The structural base is based on a 550mm wheelbase carbon fiber and glass fiber reinforced hexacopter structure that offers a superb rigidity to weight ratio with adequate payload capacity and high aerodynamic performance. The landing gear has foam-padded stabilizer legs that have a circular support ring that fits into the fire-extinguishing ball in flight and takes into the impact forces during takeoff and landing. All wiring has been channeled through controlled cable conduits to avoid electromagnetic fields and mechanical stress, and color coded connectors have been used to maintain good electrical continuity. When the system is complete, extensive pre-flight calibration is performed including; ESC synchronization, compass calibration, accelerator leveling, GPS satellite acquisition testing, and servo endpoint adjustment to ensure that the system is operationally ready. This overall design has managed to compromise the conflicting needs of payload capacity, flight stability, detection sensitivity, autonomous operation and cost-effectiveness to provide a practical and deployable solution to rapid-response aerial firefighting when the conventional approach has constraints of accessibility or safety.

5.2.1 Different types Testing

We have therefore performed experiments with real fire and Artificial fire. We have gathered information on both the alternatives.

5.2.2Artificial Fire Observation

Figure 64 : *Artificial Fire Test By Pi Camera*

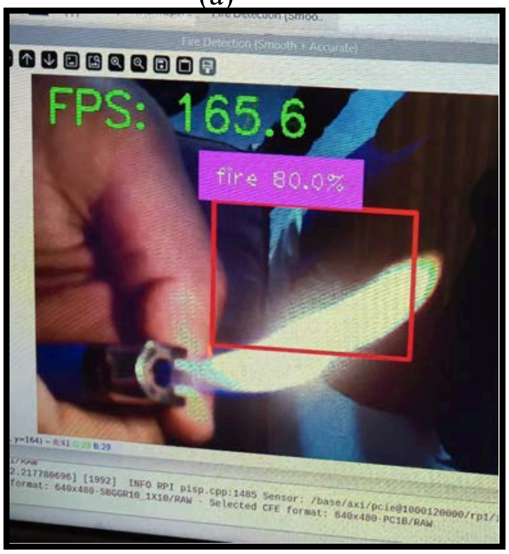


It is here in the figure that we are getting a good level of confidence. We are able to take it to a 89.3% level of confidence which is sufficient since we have a threshold of 50%. The maximum number of times that we tasted and had the desired output was 18 times.

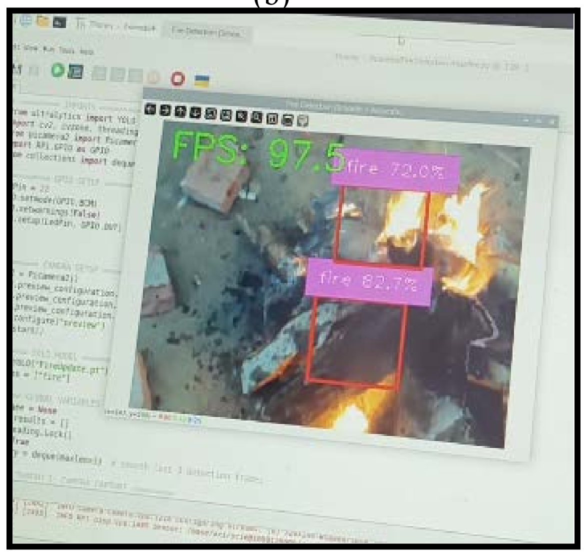
5.2.3 Real Fire Observation

Figure 65 : *(a) Igniter Test, (b) Wood Fire Test 1,(c) Wood Fire Test 2*

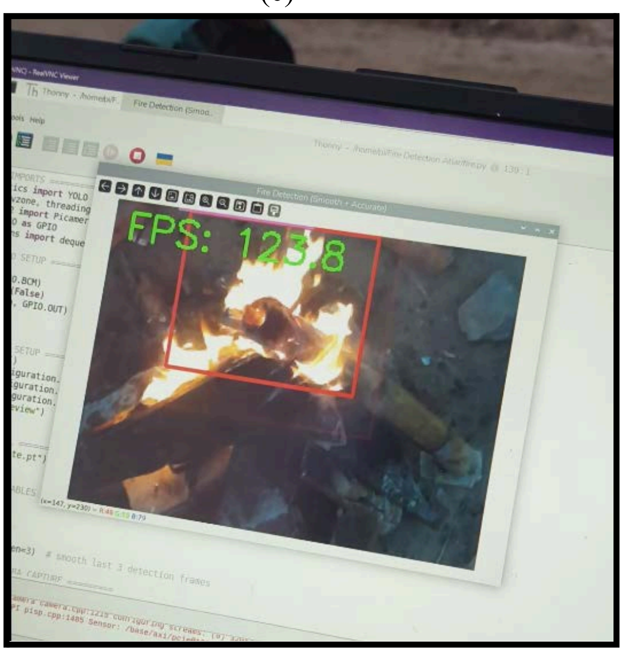
(a)



(b)



(c)



In this case, we may notice that the drone is able to detect real fires relatively well, yet, not as well as artificial fires, yet, sufficiently to meet the purpose of our project. In the figure, we are able to observe that the detection is up to 82.7% which is higher than what we require.

5.2.4 Servo release and fire extinguish

Figure 66 : *(a) Test Camp Fire , (b) Fire Extinguishing Ball Release , (c) Fire Extinguishing Ball Explosion, (d) Camp Fire Completely extinguished*

(a)

(b)

(c)

(d)

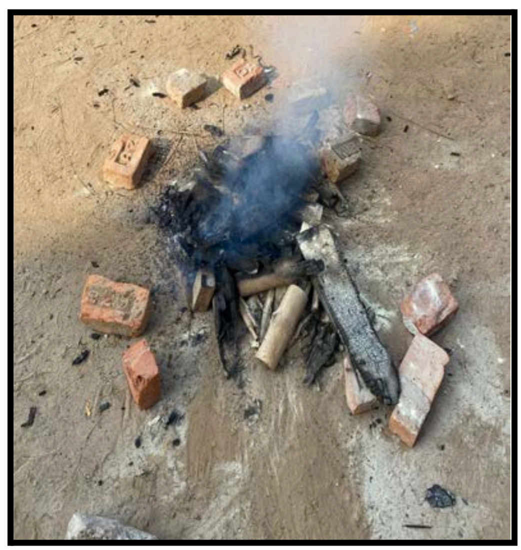


Figure 66(a) depicts the target of the first fire. After the system notices the fire, the servo device is released and it launches the fire-extinguishing ball directly at the flame. As it is seen in Figure (d) the fire entirely goes under control following the deployment process. The fires are completely put out confirming the functionality of the suggested system. This is why the system is successful at producing the intended output of automatized fire detection and suppression.

5.3 Evaluate the Solution to Meet Desired Need

Table 06: *Fire Detection Test Analysis*

Fire Type	Successful Extinguishing	Total Tests	Accuracy (%)
Real Fire	4	5	**80%**
Artificial Fire	18	20	**90%**

The autonomous firefighting drone system was thoroughly tested to determine the overall performance and reliability of the system in executing the fire detection and suppression roles. There was extensive testing in both a controlled artificial fire setting and a real fire environment and testing was done to prove the robustness and adaptability of the system. The trained YaoloV8-based fire detection model revealed high detection and the accuracy of it in a variety of situations were high. We initially tested with artificial fire, in which the accuracy in detection and extinguishment was approximately 90% compared to the accuracy of 80% in the real fire after 20 trials of experiment. The duration of the servo to release a ball was less than 4 seconds. In general, the findings suggest that the system has potential to be used in the field of firefighting as it can detect fire accidents with a high number of successes and act independently. These results demonstrate the possibility of introducing AI-powered aerial solutions to an emergency response system to optimize the monitoring of fires, their early warning, and timely response.

5.4 Conclusion

We can conclude that our final design is in compliance with all our objectives and requirements in good accuracy. Our model is capable of detecting fire with 90 percent accuracy. Moreover, the coordination. extraction matches the fps of the video feed, analysing speed, and the response time is made fast. The coordinates are correct because the servos are able to release the fire extinguishing ball appropriately. Thus, it is safe to note that we were able to achieve all of our objectives and project requirements successfully.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

It will always be concerned in order to see that the end product of the project is recognized and the satisfaction of the stakeholders and the general population who will use it directly. The concept of the design will be passed to the stakeholders with the assistance of sustainability and the impact of the project. Various views were taken into account to strike a balance between the needs of the stakeholders and other engineering limitations.

6.2 Assess the Impact of the Solution

Table 07 : *Project Impact*

Impact Area	**Description**
Continuous Monitoring for Fire Hazards	Vision-based monitoring allows constant surveillance as long as power and video feed are available. Enables early fire detection without human intervention.
Rapid Fire Response and Suppression	Microcontroller-driven fast decision-making activates suppression instantly, reducing delays found in manual systems and preventing fire spread.
Reduction in Damage and Recovery Costs	Early detection minimizes large-scale damage, lowering repair, recovery, and replacement costs for property owners.
Versatile Deployment	Suitable for warehouses, retail shops, homes, server rooms, and factories. Uses common hardware, increasing implementation feasibility.

Efficient Water Usage & Reduced Environmental Footprint	Uses building pipelines and activates only when fire is detected. Automatically stops after extinguishing fire, reducing water waste and CO_2 emissions.
Economic Benefits for Stakeholders	As an automated system, it lowers manpower and maintenance needs, making it cost-effective for long-term safety management.
Market & Business Potential	Growing demand for automated fire safety offers strong commercial opportunities, especially for urban and industrial sectors.

6.3 Evaluate the Sustainability

The system is supposed to be sustainable in the environmental, economic, and technological aspects.

Environmental Sustainability

1. Reduced Water Wastage:The targeted deployment of water will make sure that the amount of water wasted is minimized.
2. Lower Pollution: Rapid response of fire lowers smoke and toxic gas emissions.
3. Minimal Resource Utilization:It uses the available building water systems and infrastructure which limits the amount of material used and e-waste.
4. Energy Efficient: The used electronics are low power consuming and hence the carbon footprint of operations are minimized.

Economic Sustainability

1. Cost-Effective Infrastructure Protection: Contained at an early stage, infrastructure damage is minimised, and insurance claims and contracting expenses are minimised.
2. Low Operational Cost: When installed, the system only needs minimal manual intervention and regular maintenance.
3. Job Creation:Installation, monitoring and maintenance job opportunities are generated within the technical and maintenance jobs.

4. Affordable Scalability: Small shops to large buildings are both within the reach of the system through the use of modular and low-cost components.

Technological Sustainability

1. Use of Reliable Components:Reliable Components: Raspberry Pi, Arduino Nano and trained CNN models will guarantee uniform automation and reactivity.
2. Adaptability and Upgradability: This is capable of joining IoT systems, clean-energy systems, and smart-city systems.
3. High Automation Reliability: Autonomous detection minimizes human error, and provides protection 24/7.

Alignment with UN Sustainable Development Goals (SDGs)

The solution is related directly to the UN SDG 11 Sustainable Cities and Communities, as it enhances the safety and resilience of urban buildings. It improves the reduction of disaster risks and promotes more secure living and working conditions.

Environmental, Social & Economic Implications

Table 08 : *Implications of The Project*

Category	Implications
Environmental	Low water usage, reduced emissions, reuse of infrastructure, and low e-waste
Social	Saves lives, prevents injuries, increases public safety, and confidence
Economic	Reduces property loss, creates skilled jobs, cost-effective for businesses

6.4 Conclusion

This project is a progressive way of thinking about the current fire-safety automation. Incorporating real-time fire detecting systems, intelligent decision-making systems and automatic suppression systems, the system sets a new standard of monitoring and effects of fire hazard. The solution proves the possibility of transforming the existing fire-protection practices with the help of advanced sensors, machine-learning models, and automated control systems.

This project, in addition to enhancing fire-safety features, provides future opportunities in the technological progress, commercialization, and job-openings in the smart-security and automation industries. As it is refined and used on a large scale, the system will be able to save numerous lives and property due to fire-related losses, as it will be a reliable and efficient substitute to the traditional approaches of fire management.

Finally, the work will assist in creating a safer and more secure environment by facilitating faster reaction to the situation, minimizing the reliance on human factors, and assisting to save lives and infrastructure in the devastating effects of the unregulated fire incidents.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

Developing a clear project scope at the very beginning of a work is essential in a situation when fixed timeframes are used. Proper project management offers an insight into the way goals should be achieved and what results should be expected. In addition to coordinating the tasks, a successful management entails ensuring constant communication between the team members and other involved parties. Moreover, there should be backup plans to solve the unforeseen hurdles.

Project management software can be used to simplify many processes and help to easily monitor the progress of a project and determine the roadblocks. It should be a dynamic management strategy that will allow the teams to adapt to changing situations very fast. Finally, project management properly performed, not only contributes to the realization of short-term goals but also preconditions for successful work in the future and team building.

7.2 Define, Plan, and Manage an Engineering Project

To execute the project seamlessly throughout the year, Gantt Charts for FYDP-P, FYDP-D, and FYDP-C are made and attached below:

***Figure 67**: Gantt Chart for FYDP-P*

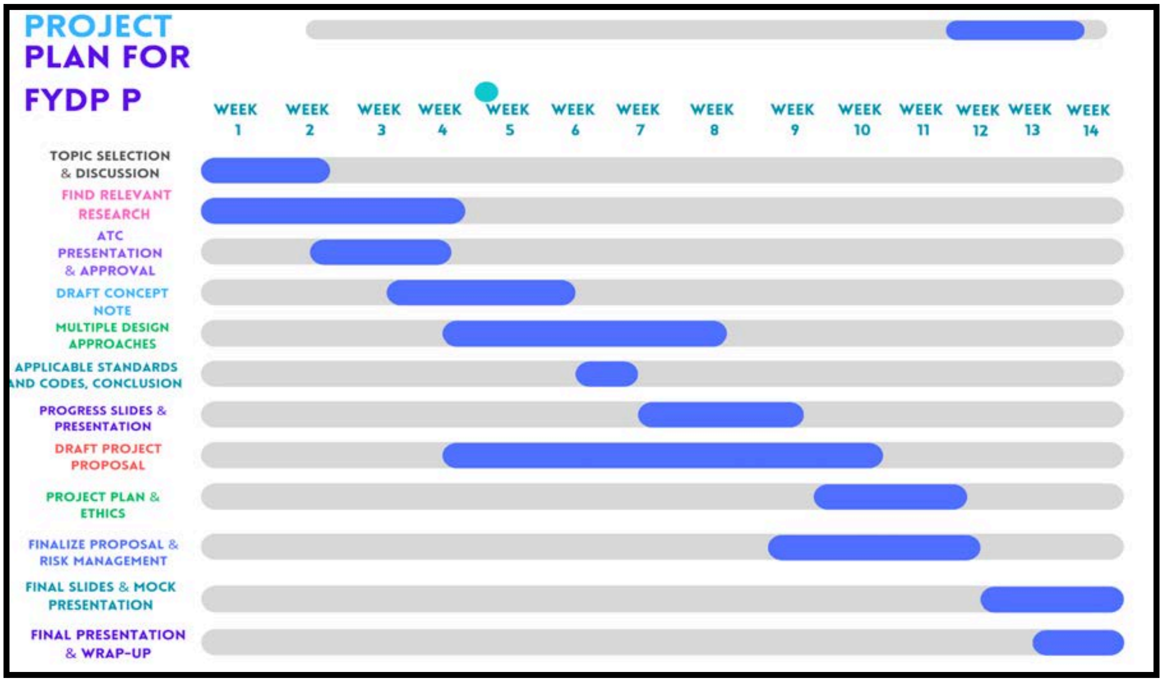


***Table 09** : Project Plan of EEE 499P*

TASK ID	TASK TITLE	START DATE	END DATE	DURATION
1	TOPIC SELECTION & DISCUSSION	2025-02-08	2025-02-21	14 days
2	FIND RELEVANT RESEARCH	2025-02-08	2025-03-07	28 days
3	ATC PRESENTATION & APPROVAL	2025-02-15	2025-03-07	21 days
4	DRAFT CONCEPT NOTE	2025-02-21	2025-03-21	29 days

5	MULTIPLE DESIGN APPROACHES	2025-03-03	2025-04-04	32 days
6	APPLICABLE STANDARDS AND CODES, CONCLUSION	2025-03-15	2025-03-21	7 days
7	PROGRESS SLIDES & PRESENTATION	2025-03-25	2025-04-15	20 days
8	DRAFT PROJECT PROPOSAL	2025-03-08	2025-04-18	42 days
9	PROJECT PLAN & ETHICS	2025-04-12	2025-05-02	21 days
10	FINALIZE PROPOSAL & RISK MANAGEMENT	2025-04-05	2025-04-25	21 days
11	FINAL SLIDES & MOCK PRESENTATION	2025-04-26	2025-05-16	21 days
12	FINAL PRESENTATION & WRAP-UP	2025-05-10	2025-05-16	7 days

Figure 68 : *Gantt Chart for FYDP-D*

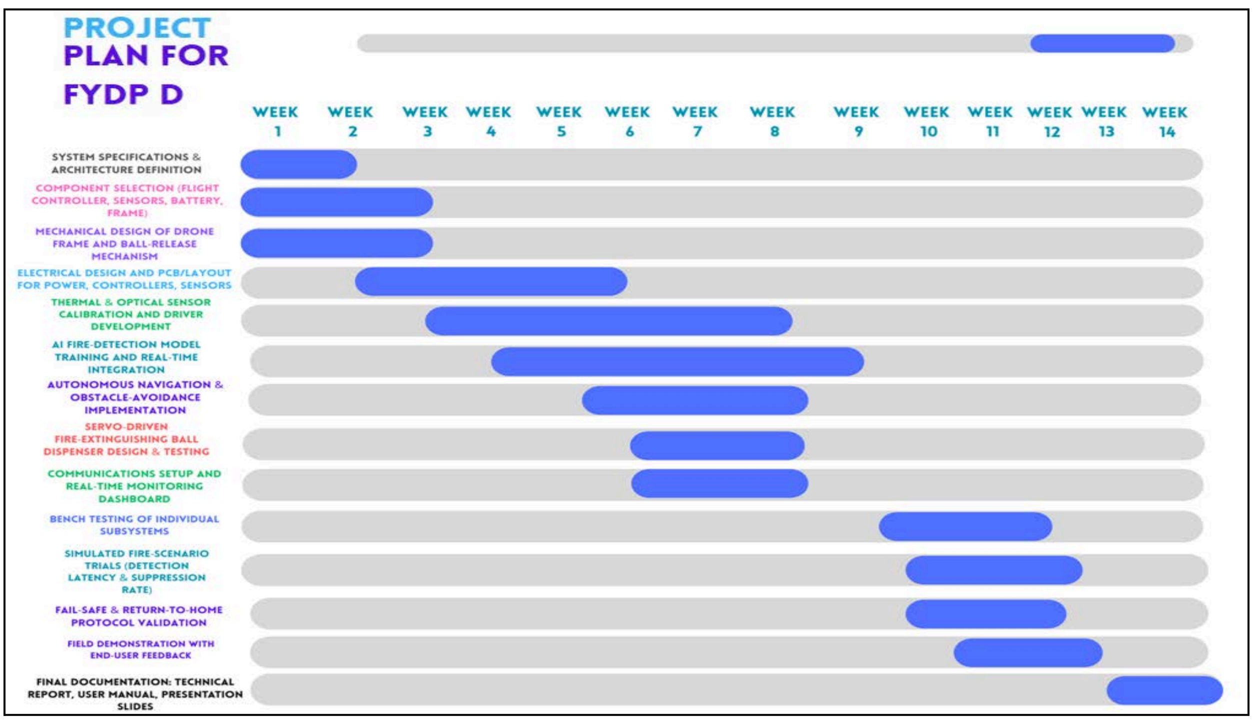


Table 09 : *Project Plan of EEE499D*

TASK ID	TASK TITLE	START DATE	END DATE	DURATION
1	SYSTEM SPECIFICATIONS & ARCHITECTURE DEFINITION	2025-06-14	2025-06-27	14 days
2	COMPONENT SELECTION (FLIGHT CONTROLLER, SENSORS, BATTERY, FRAME)	2025-06-14	2025-07-04	21 days
3	MECHANICAL DESIGN OF DRONE FRAME AND BALL-RELEASE MECHANISM	2025-06-14	2025-07-04	21 days
4	ELECTRICAL DESIGN AND PCB/LAYOUT FOR POWER, CONTROLLERS, SENSORS	2025-06-15	2025-07-18	27 days
5	THERMAL & OPTICAL SENSOR CALIBRATION AND DRIVER DEVELOPMENT	2025-07-08	2025-08-01	25 days
6	AI FIRE-DETECTION MODEL TRAINING AND REAL-TIME INTEGRATION	2025-07-12	2025-08-14	34 days
7	AUTONOMOUS NAVIGATION & OBSTACLE-AVOIDANCE IMPLEMENTATION	2025-07-19	2025-08-08	21 days
8	SERVO-DRIVEN FIRE-EXTINGUISHING BALL DISPENSER DESIGN & TESTING	2025-07-25	2025-08-08	15 days
9	COMMUNICATIONS SETUP AND REAL-TIME MONITORING DASHBOARD	2025-07-26	2025-08-08	14 days
10	BENCH TESTING OF INDIVIDUAL SUBSYSTEMS	2025-08-16	2025-09-06	22 days
11	SIMULATED FIRE-SCENARIO TRIALS (DETECTION LATENCY & SUPPRESSION RATE)	2025-08-23	2025-09-11	20 days
12	FAIL-SAFE & RETURN-TO-HOME PROTOCOL VALIDATION	2025-08-23	2025-09-05	14 days
13	FIELD DEMONSTRATION WITH END-USER FEEDBACK	2025-08-30	2025-09-12	14 days
14	FINAL DOCUMENTATION: TECHNICAL REPORT, USER MANUAL PRESENTATION SLIDES	2025-09-13	2025-09-19	7 days

Figure 69: *Gantt Chart for FYDP-C*

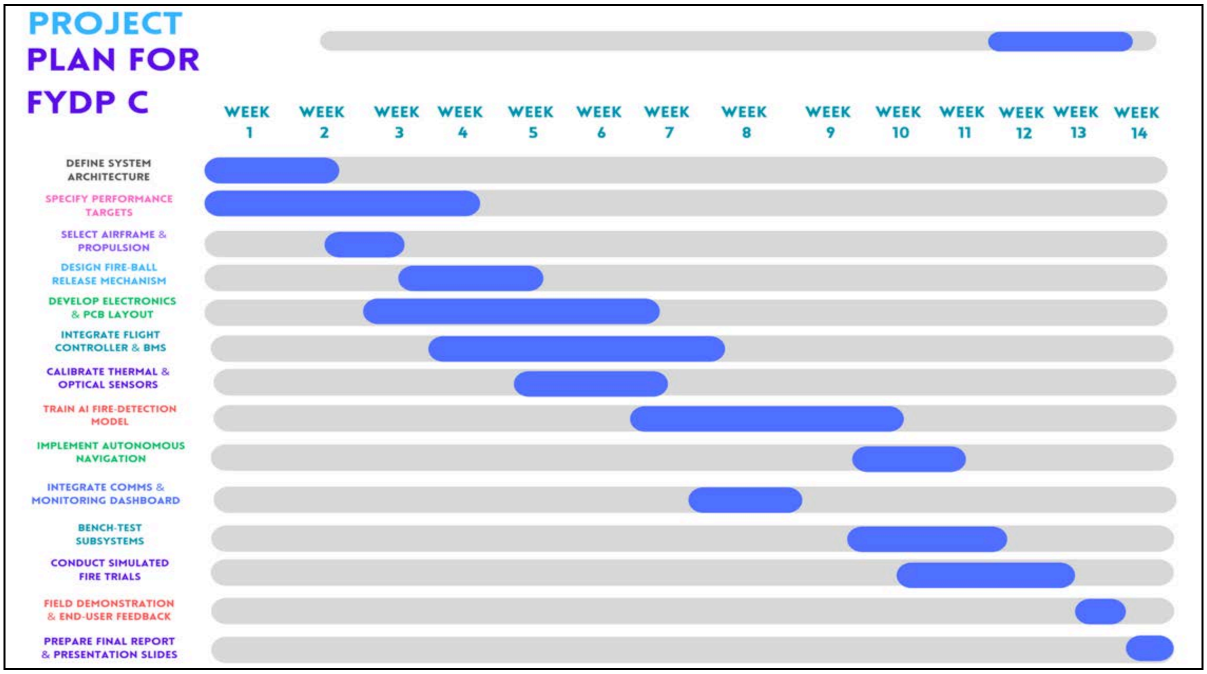


***Table 10 :** Project Plan of EEE 499C*

TASK ID	TASK TITLE	START DATE	END DATE	DURATION
1	DEFINE SYSTEM ARCHITECTURE	2025-10-07	2025-10-21	14 days
2	SPECIFY PERFORMANCE TARGETS	2025-10-07	2025-11-03	28 days
3	SELECT AIRFRAME & PROPULSION	2025-10-14	2025-10-21	7 days
4	DESIGN FIRE-BALL RELEASE MECHANISM	2025-10-21	2025-11-3	14 days
5	DEVELOP ELECTRONICS & PCB LAYOUT	2025-10-19	2025-11-23	33 days
6	INTEGRATE FLIGHT CONTROLLER & BMS	2025-10-25	2025-12-01	40 days
7	CALIBRATE THERMAL & OPTICAL SENSORS	2025-11-04	2025-11-16	15 days

8	TRAIN AI FIRE-DETECTION MODEL	2025-11-18	2025-12-22	29 days
9	IMPLEMENT AUTONOMOUS NAVIGATION	2025-12-09	2025-12-29	21 days
10	INTEGRATE COMMS & MONITORING DASHBOARD	2025-11-25	2025-12-08	14 days
11	BENCH-TEST SUBSYSTEMS	2025-12-08	2025-12-29	22 days
12	CONDUCT SIMULATED FIRE TRIALS	2025-12-16	2026-01-05	21 days
13	FIELD DEMONSTRATION & END-USER FEEDBACK	2025-12-30	2026-01-05	7 days
14	PREPARE FINAL REPORT & PRESENTATION SLIDES	2026-01-06	2026-01-12	7 days

7.3 Evaluate Project Progress

The creation of the automated system of fire-detection and mitigation presupposed the unification of various hardware and software tools such as a Raspberry Pi to process images and a servo-mechanism. The project is by definition associated with operational and environmental risks due to the power of combination of electronics, mechanical movement and suppression.

There are various mechanical and electrical subsystems that the system may interact with and at which there are potential failure points (e.g. electrical hazards, mechanical wear, inaccurate fire detection, and environmental interaction (e.g. smoke density, lighting changes, reflections or heat sources). These dangers may affect system reliability and safety. Consequently, the risk-management strategy was adopted in the form of a structured plan to safe operating conditions and reliable performance in testing and deployment.

Table: Risk Management & Progress Evaluation

Table 11 : *Risk Management & Progress Evaluation*

Risk Event	Management Procedure	Contingency Plan

1. Hardware component failure (Pi, camera, servo)	Conduct routine hardware testing and calibration. Use reliable electronic components and secure wiring.	Maintain backup units for critical components and ensure a fast replacement procedure.
2. Software malfunction or misclassification	Continuously train and test the detection model across multiple fire scenarios and lighting conditions. Version control applied.	Deploy a simplified secondary rule-based fire trigger/backup response system to activate suppression if ML fails.
3. Detection issues due to environmental conditions (smoke, lighting, shadows, electrical sparks)	Test model performance under varied indoor conditions and refine the dataset to handle low-light and noise interference.	Manual trigger in case of detection uncertainty.
4. Electrical hazard or wiring failure	Follow proper insulation standards, cable management, and grounding. Use fuses and power regulation.	Auto-shutdown on short-circuit/overcurrent. Routine power-system inspection and backup battery supply prepared.
5.Mechanical misalignment of the servo arm or nozzle	Regular servo calibration, lubrication, and mechanical joint inspection.	Activate backup fixed-spray mode or manual nozzle control if the alignment mechanism fails.

7.4 Conclusion

The basis of any successful projects is laid out by project management. It is difficult to be tenacious when it comes to implementing the objectives of a project without having proper project management and regulations. The management may have done its best and may have followed the guidelines that were planned but there was still a possibility of undesired risks. Therefore, backup solutions to various likely risks ought to be maintained as well. These are aspects that do guarantee adequate provision of the fundamental aims of the project.

Chapter 8: Economical Analysis [CO12]

8.1 Introduction

The occurrence of fire outbreaks in the overcrowded cities, slums, and isolated areas has continued to wreak havoc on lives and properties. The conventional firefighting practices are usually subjected to severe constraints like the slow response rate, limited access, insufficiency of trained human resources and the absence of sophisticated technologies to suppress the fire at the initial stages. It is even more pronounced in developing countries, where infrastructural factors, not to mention budget constraints, make it even harder to manage the fire. Consequently, the need to have cheap, efficient, and quick response firefighting systems that can perform their duties even in hazardous or inaccessible human environments is on the increase.

The creation of an independent firefighting drone with a fire extinguishing ball delivery system is a low-cost technology-oriented alternative to the traditional one. This type of system is quick to deploy, aerial, real-time, and available and suppresses fire, which can greatly slow down the propagation and severity of fire. The technology also reduces the exposure that human firefighters usually encounter especially in small slums, production areas and disaster-prone areas.

This economic report assesses the viability, cost-effectiveness and potential long-term financial returns of adopting the autonomous firefighting drone system both in the field of public safety and in the field of industry. It looks into the entire cost of the investment involved in the design, development, and deployment of the drone, along with hardware components, sensors, communication modules, AI processing systems, and mechanical fire release mechanisms. Also, operational costs including maintenance, battery replacement, training and scalability are also compared against the traditional firefighting infrastructure.

Other than financial aspects, this chapter points out the possible societal-economic effects of implementing an autonomous drone system that will be used in the process of fire suppression. The low cost and the modular characteristics of the drone allow the municipal government, individual industries, residential buildings, and education to utilize it to train and research. These systems have the ability to save the economy a lot of losses due to fires since they can detect and suppress them faster and thereby enhance the safety of the community.

This analysis aims to illustrate the way in which an affordable autonomous firefighting drone can revolutionize the approach to emergency response, lower the costs of operation, and bring sustainable value to the communities that are at risk of fire in the global community.

8.2 Economic Analysis

This is an economic assessment that assesses the financial viability of creating and introducing an autonomous firefighting drone with a fire-extinguishing ball release mechanism. It puts more emphasis on the long-term gains, cost reduction in operations, production expenses and the overall effects of implementing such a system in actual fire fighting and safety operations.

1. Development and Production Costs

The construction of an autonomous firefighting drone has great cost benefits over the conventional firefighting systems and sophisticated robotic solutions. This drone uses inexpensive sensors, low-weight electronics, and commercially sourced products to provide effective fire response at low prices as opposed to more expensive industrial firefighting robots or truck-mounted firefighting suppression systems.

• Hardware Costs

The objects needed, including brushless motors, ESCs, flight controllers (APM/Pixhawk), telemetry modules, LiPo batteries, flame and gas sensors, and the AFO fire-extinguishing ball are readily available and cheap. The system is economical and simple to upgrade without the necessity of spending the heavy-duty robotics or industrial-grade thermal equipment by concentrating on basic functions like fire detection, autonomous navigation and targeted suppression.

• Software Costs

The drone operates on open-source software such as ArduPilot and Mission Planner, which saves the license fee needed to use proprietary autonomous navigation software. With the open-source software, it is possible to create basic sensor fusion, fire detection, and release mechanisms onboard algorithms and customize them to the application at less cost.

• Labor Costs

Since the system is made of off-the-shelf modules, the assembly and calibration can also be done with fewer specialized workers. The simplified design makes it easy to test and integrate and hence the costs related to labor are minimized when producing the product.

2. Affordability and Market Demand

A drone firefighting device with moderate price will be highly popular in the market in a vast variety of industries, such as municipal fire departments, industrial facilities, residential buildings, educational institutions, and emergency response agencies. It responds to the requirement of a high-speed fire suppressing technology in locations where the traditional approaches are slow, dangerous, or unreachable.

• Price Point

This drone system can be obtained at a small fraction of the price of the large-scale firefighting robots or specialized equipment. It is cheap and hence appears as a viable alternative to budget strained communities, small industries and safety departments that want to improve their fire response capacity without necessarily putting significant funds in it. It is able to deploy multiple units at a cheap rate, which extends its coverage zone and reduces the turn-around time.

• Scalability

The design, which is modular, low-cost, and therefore can be mass-produced, can also lower the per-unit manufacturing cost. This enables organizations to use a number of drones and deploy them as a fleet of drones, which will ensure that fire is suppressed and their capabilities expanded with ease without the financial burden.

3. Operational and Maintenance Costs

The autonomous firefighting drone has low costs of operation as compared to the conventional firefighting vehicles and conventional means that require human assistance.

• Maintenance

Electronic and mechanical systems that are simplified, minimise chances of hardware failure. Spare parts like propellers, motors, sensors and batteries are cheap and readily available. Simple technical skills are needed in routine maintenance, which reduces the total cost of servicing.

• Power Consumption

The drone is able to operate under a rechargeable LiPo battery and therefore does not demand much energy. The effect of this is that the operational costs stand at very minimal levels as opposed to fuel-powered firefighting vehicles and heavy-duty robots.

4. Long-Term Economic Benefits

The firefighting system operated by drones has also long-term economic benefits to communities and organizations besides direct cost reduction.

• Improved Fire Response and Damage Reduction

Quick aerial response aids in containing the fire at an early stage in its development and thus avoiding massive destruction of property, loss of revenues, and rebuilding expenses. By suppressing the fire at its early stages, the large-scale firefighting operations are reduced and save resources and personnel time.

• Enhanced Safety and Reduced Human Risk

It also causes the firefighters to spend less time in hazardous or inaccessible situations by deploying a drone to a narrow alley, slums, chemical plant, or high-rise area, eliminating the necessity of them venturing into these dangerous zones. This will be able to reduce the costs associated with injuries, insurance, and compensation costs.

• Expanded Access to Firefighting Technology

The community that does not have sophisticated firefighting facilities may enjoy the inexpensive aerial fire fighting systems. Implementation of the drone system will enhance the general level of safety that may decrease the economic costs of fires in the future.

5. Return on Investment

The autonomous firefighting drone provides a strong return on investment for both public and private sectors. Lower initial cost, minimal maintenance requirements, and reduced manpower dependency collectively contribute to long-term financial gains. Faster fire suppression reduces the scale of damage and associated economic losses, while educational institutions benefit from using the drone for training and research at a low cost.

Overall, the economic analysis demonstrates that an affordable autonomous firefighting drone is an effective and financially viable solution for enhancing fire safety. Its low production cost, reduced operational expenses, and significant long-term benefits make it a practical alternative to expensive conventional firefighting technologies. Increased accessibility, improved response time, and enhanced safety further highlight the importance of investing in cost-effective aerial firefighting innovations.

8.3 Cost Benefit Analysis

The cost-benefit analysis of a detailed nature is necessary when creating an autonomous system of a firefighting drone. This is much more than determining the cost of construction of the drone; it also investigates the overall effects that the system can have on the safety of fire, emergency searching and the overall security of the community. Our fire fighting drone will incorporate real-time flame sensors, self-directed navigation, and a mechanism to drop fire-extinguishing balls which will be used to quickly put out fires in locations that are unsafe or otherwise unreachable by human firefighters. The ability to do this not only minimizes the risk to the personnel, but also minimizes the damage of property since it is done in a timely manner.

In this part, we do a comparison of our innovative firefighting drone and the traditional fire response techniques and the available aerial fire fighting tools. Through presenting the peculiarities, dependability, and benefits of our system, we reveal how our system represents a more cost-effective and realistic alternative to contemporary fire management. This is the result of our design of two possible designs of the drone; each design comprises various components and cost. In the case of the first design approach, we have listed down all the necessary components and their respective prices. The approximate overall price of such a solution is 80865 BDT and it provides a cost-efficient but a powerful system of rapid-response fire suppression.

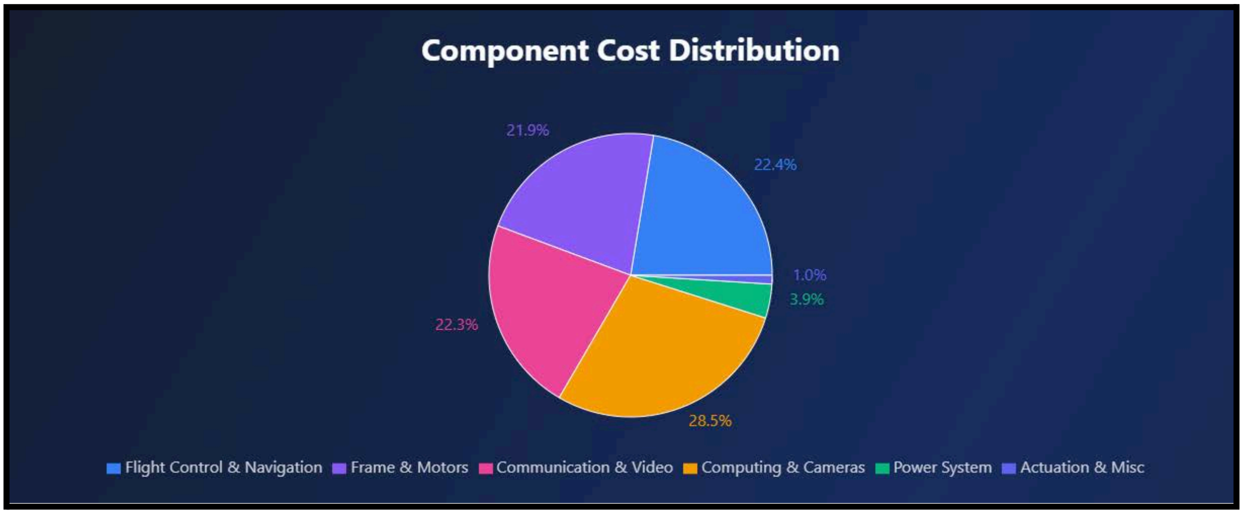
Table 12: *Overall Component Cost of The Project*

Component	**Details**	**Unit price (BDT)**	**Quantity**	**Total cost (BDT)**	**Product links**
APM flight controller	Drone autopilot system.	13950	1	13950	APM 2.8 Flight Controller + NEO GPS M8N Robotics Bangladesh

3DR radio telemetry kit	Wireless data link.	9100	1	9100	3DR X7 Radio Telemetry 1000MW 915MHz price in bd
Hexacopter frame	Six-arm drone body	6100	1	6100	S550 Hexacopter Frame 6-Axis
GPS module with compass	Location and direction sensor.	2450	1	2450	Ublox NEO-M8N GPS Module - RC shop bd
Flysky FS-I6S Transmitter	Drone remote control	7900	1	7900	Flysky FS-I6S Transmitter price in bd
DJI 2312A 800KV Motor CW+CCW	Brushless drone motor.	800	6	4800	2pcs Original DJI 2312A 800KV Motor CW+CCW - RC shop bd
30A ESC	Motor speed controller	860	6	5160	ESC
Camera	Captures visual feed.	3950	1	3950	RunCam Phoenix 2 SP V3 FPV Camera for RC FPV Racing – HobbyRC BD
Battery	Powers drone components	560	4	2240	LiitoKala HG2 18650 3.7V 3000mah Li-ion Rechargeable Battery in Bangladesh

MG996R Servo motor	Precision rotational actuator	730	1	730	MG996R Full Metal Gear Digital Servo 360 Degree 13KG Torque (High Quality) in BD, Bangladesh By BDTronics
B3 Pro Compact Charger	LiPo battery charger	600	1	600	B3 Pro Lipo Balance Charger Robotics Bangladesh
VTX transmitter	Sends live video	3000	1	3000	SPARKHOBBY Nice 2W 64CH 5.8G VTX for FPV Drone - RC shop bd
Video transmitter	Stream camera footage.	4200		4200	SkyDroid OTG FPV Video Receiver 5.8G 150CH – HobbyRC BD
Pi camera	Camera for Raspberry Pi.	3900	1	3900	Raspberry Pi Camera Module V2 – 8 Megapixel 1080p – Latest price in Bangladesh BD
Raspberry Pi 5	Mini computer board.	13035	1	13035	Raspberry Pi 5 4GB Robotics Bangladesh
Subtotal = 80865 BDT (USD 662)					

Figure 70 : Component Cost Distribution of Final Design



8.4 Evaluate Economic and Financial Aspects

There is a good potential economic and financial return in this fire response system project. The project has the merit of using the available surveillance facilities thus reducing up-front expenditure by eliminating the requirement of acquiring new and expensive hardware systems to implement a new system. Using this, the project will be very accessible and can be extended to various applications, whether they are residential, commercial or industrial. This is because such a solution is quite affordable besides being powerful yet functional.

8.4.1 Overall Cost Structure

The prototype development is mainly based on commercially available components that are cheap, and this makes the overall investment accessible to institutional as well as municipal users.

Figure 71: Overall Cost Structure of Final Design

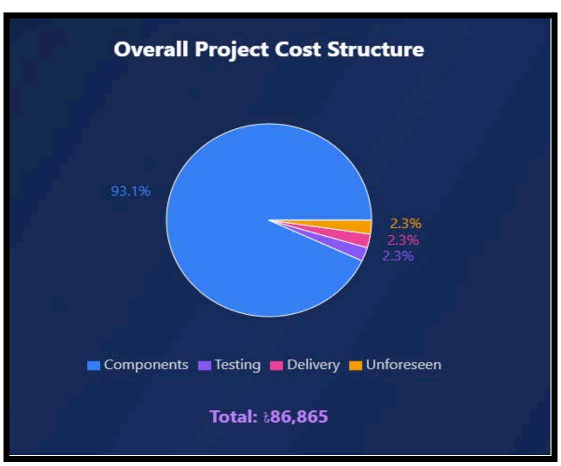


__Table 13:__ Total Cost of The Project

Cost Type	Amount (৳)
Total Component Price	80865
Delivery Cost	2,000
Unforeseen Emergency	2,000
Total Price	**84865**

This is a great amount of money as compared to specialized industrial firefighting robots (which usually cost much more than 510 lakh BDT) and even cheaper than sophisticated surveillance drone systems.[18].

8.4.2 Operational Cost Efficiency

Low maintenance and energy requirements are very important in improving the operational cost efficiency of the system. Spare components like propellers, ESCs, motors and sensors are cheap, and the modular electronics platform means that there is minimal time to maintain the system, as well as less cost to service. Also, the drone has rechargeable Li-ion/LiPo batteries, which are not reliant on fuel-related systems. Due to this, every deployment uses just a few taka of energy consumption and thus daily operation is very cost effective and sustainable.

8.4.3 Unit Production Cost and Scalability

Unit cost would reduce substantially in big-scale production. E-mail orders in large quantities (electronics: motors, controllers, sensors) may provide heavy discounts (usually 20-50% of prototype prices). To illustrate, a large scale order of thousands of APM/Pixhawk units or GPS units reduces the unit cost. Equally, injection-molded frames and printed circuit boards will be less expensive than small-run. The economic analysis specifically states that mass production may also lead to further minimization of per-unit cost of manufacturing. At large scale, a Firehawk unit may require just several thousand taka worth parts. The labor involved in the assembly could be automated on a production line and this reduced costs even more.

Nonetheless, ground-up design can also reduce startup equipment expenses by about half by concentrating on the use of existing building blocks (instead of new ones). Overall, at volume production, the unit cost (hardware + assembly) of Firehawk may be realistic USD500-1,000 or lower, which is a low-cost solution in the drone firefighting segment[18].

8.4.4 Financial Return on Investment (ROI)

Cost Avoidance Savings

Firehawk deployment has high cost benefits to users. Its capacity to put off large-scale fire can stop huge losses. As an example, in 2023, the Daily Star recorded 27,624 fires in Bangladesh and total losses ≈ of Tk (~ USD 65 million) [18]. Even when a drone does avoid a medium fire (say, avoids $10k-50k in damage) that in itself provides much more value than the cost of the drone. Early intervention lowers the casualties and injuries in terms of safety. In one of the studies, it is mentioned that disaster drones allow containing the fire faster, minimizing property damages and loss of life [18]. Every single injury prevented among firefighters will save both on medical and disability expenses.

Sample ROI Projection

If the drone prevents or minimizes just one medium-scale fire per year, avoiding damage worth approx 3–10 lakh BDT [18], then:

ROI Formula

ROI (%) = [(Benefit − Cost) / Cost] × 100

Case 1: Minimum Damage Avoided (3,00,000)

ROI = [(300,000 − 84,865) / 84,865] × 100

ROI = (213,135 / 84,865) × 100

ROI ≈ 245%

Case 2: Maximum Damage Avoided (10,00,000)

ROI = [(1,000,000 − 84,865) / 84,865] × 100

ROI = (913,135 / 84,865) × 100

ROI ≈ 1050%

This shows a high level of financial sustainability of institutions and fire departments. All in all, both direct benefits (reduced property loss, reduced man-hours on-site) and indirect benefits (public safety, expedited recovery) contributed to the overall return. Experiments on disaster UAVs emphasize immeasurable benefits of better situational awareness resulting in a more coordinated and effective response[19], and resilience in the long-term. To sum up, achievement of comparatively small damage or risk reduction results in high ROI to municipalities or companies to purchase the system[18][19].

8.4.5 Market Potential and Pricing Strategy

Market of drone firefighters globally (USD) year[18]. The firefighting UAVs market is expanding at a very fast rate. Industry reports suggest that the global market size is estimated to be between 1.2 billion in 2024 and 2.8B in 2033 (approximately 10% CAGR)[18]. Fire services and industries (oil/gas, utilities, manufacturing) are the source of demand because they require fast response and the safety of the workers. Thousands of structural fires in massive cities (e.g. Dhaka) lead to massive losses to the economy[19] and demand for drone assistance. The use of high-tech fire suppression equipment is also required in industrial facilities (chemical plants, warehouses). Even forestry and wild land fire departments are utilizing UAVs in reconnaissance and intervention.

8.4.6 Broader Economic Impact

There are also benefits of Firehawk technology within economic ripple effects. Every new line of a drone product provides skilled engineering, assembly, testing, and support jobs in the drone manufacturing industry. Indicatively, according to AUVSI estimates, the implementation of drones in the U.S.A. would create more than 100,000 new jobs and 82 billion dollars of economic effect by 2025 [18] (the total world wide would be more considerable). This growth trend would be offered by Firehawk production, and R&D. In Bangladesh or other markets like these, local assembly or technology alliances might become an impetus to the engineering profession and small-business expansion.

Drones reduce operational costs in the emergency services. Crash crews consume a lot of money in fire departments on fuel, maintenance, and overtime; these costs are reduced in battery-electric drones. Quick suppression also implies less expenditure on reconstruction of infrastructure. As an illustration, economic drag on communities can be caused by fire losses, which may be minimized by saving Tk'792 crore of it (Bangladesh 2023). Insurers can experience reduced high payouts and can provide better rates and this indirectly increases businesses that install the drones.

Lastly, Firehawk is a part of the efficiency in the sector of the state. Society will gain by lessening the number of disruptions (interruptions to businesses, road closures etc.), by avoiding or responding quicker to emergencies. This, in its turn, increases productivity.

8.5 Conclusion

The autonomous firefighting drone system has good economic viability and high financial payoff because of low cost of manufacturing, low cost of operation, scalability, and the capability to lower the fire damages as well as human hazard by a significant margin.

The cost-effectiveness of its deployment permits its use in large-scale applications, whereas its quick-response feature will yield benefits in terms of cost-saving and social values in the long-run. This has made the system not only technologically innovative, but also a solution in the management of fires in the modern world that is financially sustainable.

In a nutshell, the economical contribution of Firehawk has been on job creation in the high-tech manufacturing and services, cost-reduction in fire-fighting efforts, and much wider safety dividends to the urban and industrial economies[17][18]. This is why this project can be extended and further improved to better penetrate the marketplaces hence establishing a good economic impact on the local and global economies too.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

Any engineering undertaking has ethical concerns. It takes into account such criteria as the fact whether or not the endeavor is within the boundaries which are described in the points of view of a decent, moral and socially acceptable point of view. A professional does not just consider the ethical considerations but also project considerations. The elements enable you to set a good engineering prowess in any project. Ethical concerns and professional requirements also lead to the economic, environmental, and social sustainability of a project.

9.2 Applicable Standards and Codes Aligned with COs

1. Aviation and Flight Safety Standards:

Table 14: *Safety Standards With Reasons for Aviation and Flights*

Standard / Code	Aligned CO(s)	Reason
ISO 21384-3:2019 – UAS Operational Procedures	**CO2, CO7, CO13**	Identifying aviation compliance (CO2), evaluating safe performance (CO7), and ensuring ethical/professional safety (CO13).
IEEE 1937-2020 – UAS Communication & Control	**CO2, CO9**	Standard for safe UAV communication interfaces (CO2) and using modern engineering tools (CO9).

ASTM F3266-18 – Small UAS Safety	**CO2, CO7**	Compliance requirement (CO2) and evaluation of performance against safety (CO7).
ISO 23137:2021 – UAS Data Protocols	**CO2, CO9**	Communication/data standards (CO2) implemented using engineering tools (CO9).
IEEE 1588 – Precision Time Protocol	**CO2, CO9**	Time-synchronization requirement (CO2) and used in embedded system development (CO9).

2. Communication and Data Transmission Standards

Table 15: *Safety Standards With Reasons for Communication and Data Transmission*

Standard / Code	Aligned CO(s)	Reason
IEEE 1937-2020 – UAS Communication	**CO2, CO9**	Standard for drone–ground station link (CO2) and tool usage (CO9).
ISO 23137:2021 – Data Protocols	**CO2, CO9**	Communication requirement identification (CO2).
ISO/IEC 29182 – Sensor Network Architecture	**CO2, CO9**	Sensor communication architecture → engineering tools (CO9).

IEEE 802.11n/ac – Wi-Fi	**CO2, CO9**	Requirement for video streaming (CO2) implemented using communication tools (CO9).
IEEE 802.15.4 – LR-WPAN	**CO2, CO9**	Low-power telemetry requirements (CO2).
ISO/IEC 27001 – Information Security	**CO2, CO13**	Data privacy and security → ethical responsibilities (CO13).

3. AI and Image Processing Standards

Table 16: *Safety Standards With Reasons for AI and Image Processing*

Standard / Code	**Aligned CO(s)**	**Reason**
ISO/IEC 15444 – JPEG2000	**CO2, CO9**	Technical requirements for image processing (CO2).
ISO/IEC 22989 – AI Concepts	**CO2**	Helps frame AI requirements and terminology.
ISO/IEC 23894:2023 – AI Risk Management	**CO2, CO13**	Risk/ethics in AI (CO13).

ISO/IEC 23053:2022 – ML Framework	**CO2, CO9**	Defines ML development lifecycle → used in design tools (CO9).
ISO/IEC 24029-1:2021 – AI Robustness Testing	**CO2, CO7, CO9**	Performance evaluation standard (CO7).

4. Firefighting and Safety Standards

Table 17: *Safety Standards With Reasons for Firefighting and Safety*

Standard / Code	**Aligned CO(s)**	**Reason**
IEC 60529 – IP Rating	**CO2, CO7**	Environmental protection requirements (CO2) and performance validation (CO7).
NFPA 1143 – Wildland Fire Management	**CO2, CO7**	Operational compliance and safety performance.
NFPA 950 – Fire Service Data Exchange	**CO2, CO15**	Communication of emergency data — part of reporting/presentation standards.
NFPA 72 – Fire Alarm Code	**CO2, CO7**	Fire detection integration standards.

ISO 7240-1 – Fire Detection & Alarms	**CO2, CO7**	Baseline detection accuracy and device requirements.
ISO 14520 – Gaseous Fire Suppression	**CO2, CO7**	Safety and compliance for suppression agents (CO2).
EN 3-7 – Portable Fire Extinguishers	**CO2, CO7**	Required if suppression balls are used.

5. Embedded Systems and Software Standards

Table 18: *Safety Standards With Reasons for Embedded Systems and Software*

Standard / Code	**Aligned CO(s)**	**Reason**
DO-178C – Airborne Software Certification	**CO2, CO7, CO9**	Critical software compliance (CO2) and performance validation (CO7).
IEC 61508 – Functional Safety	**CO2, CO7, CO13**	Safety integrity + ethical responsibility (CO13).
ISO/IEC 25010 – Software Quality Model	**CO2, CO7**	Defines reliability, security, and maintainability metrics.

9.3 Identify Ethical Issues and Professional Responsibility

The drone will aim at keeping the people safe and integrating the current CCTV and the tested fire detection system that will automatically react to fire. It is specifically designed to take care of one of the main aspects of public safety and attempts to consider professional and ethical aspects during the development and implementation process. Among the main considerations, some are given in the following:

a. Consent and Autonomy:
The use of AI-powered firefighting drones should be ethically presentable through the use of a user-friendly consent model. People who engage in the operation of the drones or who manage them should be aware of their rights and duty in full. Consent in this instance refers to the knowledge about the application of AI to detect and suppress fire, in the sense that all the stakeholders are informed on the working processes and risks associated with the application. An open and well-presented information regarding the functions and safety measures of the system can help to build trust[12].

b. Sensitivity to Human and Environmental Well-Being:
The drone system should be in such a way that it causes little inadvertent damage to the environment and humans. The current ethical requirements in using the firefighting drones are that the AI should be programmed to identify and evade human beings, animals, and critical infrastructures and maintain that the fire suppression operation must not cause collateral damage. The ethical design includes minimizing impact on the ecosystem, e.g. not extracting resources excessively or polluting the environment with chemicals, which is a very important issue[13].

c. Ownership and Control of Data:
Just like medical equipment, the firefighting drones that would gather environmental and situational information must not be disruptive to the privacy of the involved individuals and organizations. All data gathered, such as fire detection and operating statistics, should belong and be controlled to the correct authorities or the stakeholders and only authorized personnel should be allowed to access them. Sharing or any alteration of data must be done under due authorization, whereby privacy and user control will be of great concern[7].

d. Inclusive Design for Diverse Demographics:
The design of the firefighting drone system should consider different demographic categories such as age, gender, and technological expertise because of ethical aspects. The interface and functionality of the system would need to be easily accessible so that people with different backgrounds, including those with low levels of technological effectiveness or health literacy, would be able to engage in the functionality of the drone without affecting the quality of their experience disruptively[13].

e. Regulatory Compliance and Oversight:
The creation and use of AI-robotic firefighting drones should also be guided by the international standards of safety and ethics, so that the complete scope of drones functioning is also examined and

accepted by the corresponding authorities. This will ensure that the drone is not dangerous to use and complies with the required compliance to both technology and emergency response systems[12].

f. Transparency in Data Use:

It is paramount to make sure that every stakeholder, in particular, the ones that have their data implicated in drone activities, are completely informed of the manner in which the data is gathered, utilized, and stored. The trustworthiness in the data collection process is achieved through transparency, where privacy regulations are adhered to by the system. Firefighting authorities should also be able to publicly reveal the purpose of collecting certain data and its retention period, as governed by the ethical rules[9].

g. Data Privacy and Security:

To maintain privacy, the firefighting drone system should put in place a strong data protection through encryption and anonymization to make sure that the sensitive information, including the position and movement of people and their assets, cannot be traced back to particular individuals. This will avert infiltration or abuse of data and maintain privacy levels[9].

h. Continuous Ethical Audits:

For the firefighting drone system, continuous ethical audits should also be conducted so that the system is implemented in line with the set ethical code during its working life. The system should also be reviewed every now and then to determine the manner in which the system is being applied, and to highlight any ethical issues which have emerged and make suggestions on how it can be improved. When it comes to ethical audits, the concepts of technological improvements and the practical side of the system implementation during an emergency should be addressed [5][13].

9.4 Apply Ethical Issues and Professional Responsibility

The main objective of the project is to design and modernize fire security apparatus in a dependable and automatic fire detecting and prevention control in fire outbreaks. This has been done by incorporating the available infrastructures and modern technologies in such a way that the public safety provisions follow the consideration of ethics and professional responsibilities. The measures that have been used are as follows:

A) Use of Consent Forms and Compliance with Privacy Standard

All owners and other parties will require a clearing agreement to avoid infringement on privacy as the system relies on the video feeds collected on the CCTV cameras. In addition, no consent forms and documents will be made without adhering to the privacy law. Moreover, the rights of the individuals whose privacy would be compromised will also be taken care of.

B) Seek Approval from Relevant Authorities

The project is very compliant to the procedures and standards that are upheld by the fire safety authorities and their respective approvals by the fire safety departments. In this respect, maximum fire prevention and protection have been fully employed at every level throughout the work.

C) Integrated Emergency Notification System

The linked mobile application will inform a user of all the hazards of fire that have been reported in real-time by the system. Therefore, the user is also able to take a quick action in case the automated sprinkler system has already been activated. This redundancy enables relay of key events to the stakeholders.

D) Ensuring Affordability and Accessibility

The project would consider the available CCTVs to then reduce the costs of the implementation of the structures further. A very large percentage of the society including small business and residential areas can have access to the system in a way that fire safety measures can be affordable and accessible to the population.

9.5 Conclusion

When we were developing the fire detection and response system we also put into consideration the ethics and professional obligations, so that the technical solution will be acceptable to the society, and be legally accountable and meet the intended purpose. This project has a strong focus on the safety of the people as it concerns privacy, work within the industry regulations, and ensures the safety of the population.

Chapter 10: Conclusion and Future Work

10.1 Project Summary / Conclusion

An Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism is a design project of the final year, which is a considerable breakthrough project in the sphere of disaster management, engineering of robots, and the safety of people. This system will be relevant to one of the most burning problems of modern societies, the fast, safe, and efficient reaction to fire outbreaks, especially in the urban slums, industrial areas, and remote places where the conventional methods of firefighting can be slow, dangerous, or even inefficient.

The combination of innovative sensors and autonomous flight control systems with a smart fire detection algorithm allows the drone to detect sources of fire in real time and pinpoint the use of an AFO fire-extinguishing ball. This design eliminates the necessity of human intervention in hazardous locations, and greatly reduces the risk to firefighters besides enhancing the speed and accuracy of fire suppression. The onboard systems of the drone are GPS navigation, telemetry communication, and multi-sensor data acquisition that allows the drone to operate autonomously and improves the efficiency of its response.

In the course of the project, our team considered several different design strategies that could be applied to reach the best compromise between the mechanical stability, aerodynamic performance, sensor accuracy, and autonomous functionality. Having thoroughly examined the options provided, we have settled on a design structure that would guarantee a sound and efficient navigation system, proper fire sensing, and consistent supply of the extinguishing system. The proposed system has good real-life potential as it has proven that inexpensive components can be successfully integrated to produce a strong and useful system of fire-response.

In terms of economy, our drone presents an attractive argument of affordability and sustainability. This drone is much cheaper than the conventional firefighting robots or aerial suppression systems but offers a high value operation. It has low maintenance needs, modular component architecture and can be scaled to be used widely by the municipal authorities, industries, residential communities and in emergency response units. The system helps to save significant long-term savings by minimizing property damage and minimizing the human-risk operations.

During the design and development process, we followed professional duties and ethical engineering practice. Reliability of the systems, transparency in decision making of the design and the primary aim of the design to uphold public safety were important factors considered. Such commitments do not only reinforce the integrity of the project to users but also make them have more faith in the technology.

To sum up, this autonomous firefighting drone can accomplish its fundamental purposes and create a solid basis of future advancement in aerial emergency response systems. With additional improvements including the incorporation of thermal imaging, swarm coordination, and real-time cloud-based surveillance, the project can transform fire management approaches all over the globe. This system will become an important factor in the process of community protection, minimal fire-related losses, and a new period of technical and intelligent disaster management as we move forward.

10.2 Future Work

Although the autonomous firefighting drone has already proven its ability to locate and suppress small-scale fires with the help of an onboard fire-extinguishing ball, there are still a range of opportunities in terms of the system enhancement and expansion. Its performance, scalability, accuracy, and real-world applicability can be enhanced greatly in the future, through its development efforts.

1. AI-Coordinated Multi-Layer Drone Networks

The next step in future work can be the creation of hierarchical drone swarms in which high-altitude control drones command several low-altitude firefighting drones. Such architecture enhances coverage of large areas, shortens the response time and provides autonomous decision-making with minimum human intervention.

The way this would apply with our Firehawk: a heavier hexacopter (or a special command hexacopter with Pixhawk + Raspberry Pi) would serve as the high-altitude coordinator keeping the mesh/telemetry connection and distribution of tasks, and a number of Firehawk units (AI enabled hex/quad platforms with YOLOv8 and servo release) would then be used as tactical agents. The command drone coordinates mission orchestration and simplified physics/coverage planning, transmits to each Firehawk GPS waypoints and suppression targets, and aggregates thermal/video images to provide situational awareness, using the Pixhawk Telemetry and ground-ground station connections we already have in our project. [20].

2. Onboard Edge AI Fire Recognition and Mapping

By adding edge AI, the drones will be able to analyze fire detection and mapping data onboard to minimize latency and reliance on remote servers. This allows quicker suppression rulings in dynamic fire conditions.
The way this might be applicable to our Firehawk: run a small model (trained in Colab/NVIDIA like in our project) of YOLOv8 on the on-board Raspberry Pi of our Firehawk, such that the Pi Camera can process frames locally and the servo release can be triggered without round-tripping to the cloud. Fuse the Pi-detects with local DHT22/MQ sensor values to generate more confidence and allow the drone to autonomously drop extinguishing balls after locally meeting threshold rules, maintaining existing RTH and safety interlocks.[20]

3. Physics-Aware Fire Spread Forecasting

Improvements can be made in the future with artificial intelligence-based models of fire spreading, which will use data from drone sensors and simulations that rely on physics. Such models can be used to predict the spread of fire and send drones to intervene.
Send every Firehawk thermal map, wind/temperature/humidity (DHT22 + onboard IMU) to a local coordinator (or ground station) which executes a fast cellular automata / reduced physics model to forecast short-term dissemination. Our MATLAB/Simulink workflow can then be used to validate the simulation parameter and logs by requesting Firehawks to preposition and create suppression lines by dropping balls timed to allow our ground/coordinator drone to see them and use them to create more suppression lines. One can then use our MATLAB / Simulink workflow to request Firehawks to preposition and drop balls establishing timed suppression lines that can be then seen by our ground/coordinator drone to create more suppression lines.

4. Immersive Digital Twin Simulation

Simulation of autonomous firefighting strategies can be safely trained and tested by developing a digital twin of wildfire environments. This method ensures that there is less risk and better planning of operations.

Use our existing MATLAB/Simulink hexacopter and YOLOv8 training pipelines to construct a digital twin: simulate Firehawk flight dynamics, sensor noise (camera, MQ sensors), and the suppress results to evaluate swarm tactics and release logic in advance before going to the field. Tune PID gains, reinforcement-learning navigation behaviors and ensure that the extinguisher-ball trajectories are working as intended when the wind varies and the payload weight is varied[20].

5. 3D Smoke Plume Mapping Using Drone Swarms

The swarms of drones can be coordinated in such a way that they can reconstruct 3D of smoke plumes and enhance visibility of the fire behavior, and the impact of air quality. Such information is useful in making superior tactical decisions.

Outfit some Firehawks with up/down camera lenses and time synchronized GPS/IMU records; multi-view thermal/RGB images and basic triangulation/ voxel-reconstruction on the ground station to acquire plume volume estimates. With or without LiDAR, overlapping thermal frames, the YOLOv8 detections, and inter-drone pose data (Pixhawk/Ublox) can be used to generate crude 3D plume maps that are useful in prioritizing drops and evacuation instructions, even without LiDAR data[21].

6. Fixed-Wing VTOL Integration

Hybrid VTOL drones can be used to cover a large area of operation and have a long flight duration with the ability to take off vertically. Combining such platforms enhances durability and flexibility of missions.

Make firehawk your agile vertical-release unit (short-range, precise drops) and introduce a hybrid VTOL as a communications/loitering asset, which can offer them longer-range surveillance and relay of the Firehawk fleet. The VTOL has the capability to carry larger sensors (bigger thermal camera or SAR) and a command module, which offloads targets to Firehawks when detailed suppression is required; adds compatible comms and uses the same data protocols (ISO/IEEE standards cited in the project) to guarantee interoperability.

7. GPS-Denied Navigation in Obstructed Areas

High-tech SLAM and LIDAR autonomous navigation make it possible to use drones in smoke-filled or indoors surroundings where GPS does not work. This is imperative to structural and city fires.
Install a small LiDAR / visual-inertial odometry stack on the processing unit on Firehawk to enable the drone to operate in GPS-guided mode when satellites are not available or the signal is lost and replace it with SLAM. The reinforcement-learning navigation and Pixhawk flight controller of the report can be modified to receive pose estimates on an SLAM node; in this way, safe ingress into smoke/indoor areas to find hotspots and drop balls through openings can occur with RTH and safety cutoffs operating. [22].

8. All-Weather Multi-Sensor Fusion

The use of a combination of thermal sensors, RGB sensors, SAR sensors, and LiDAR sensors would provide effective fire detection in all weather and visibility conditions. Sensor fusion enhances detection strengths and quality.

Enhance the current Pi Camera + MQ/DHT sensor system with a compact thermal sensor and combine their results in the on-board AI: YOLOv8 to detect visual information, thermal thresholding to detect heat, and gas detectors to detect combustible gases. Multi-modal consensus-based onboard fusion logic increases or decreases release decisions and minimizes false positives in smoke or low-light and maintains environmental safety constraints characterized in our report.[23].

9. Hybrid Solar–Hydrogen Power Systems

Drones can be greatly extended with the help of solar panels and hydrogen fuel cells as well as batteries. This allows constant long-duration fire observation missions.

On long lifetime command/relay platforms, fit flexible solar cells on big-surface structures or research the addition of a little fuel-cell pack on a heavy-lift hexacopter model. With the current Firehawk, it is better to focus on swappable battery packs (fast-swap stations) and deploy solar-assisted charging hubs in the field; our report battery/flight endurance plan and power budget analysis will inform realistic endurance improvements and payload trade-offs.[24].

10. Rapid-Deploy High-Capacity Fire Suppression Drones

The emergence of drones that will be able to transport and place large quantities of fire retardant or foam can form firebreaks easily and put out fires at an early stage.

Upgrade the hexacopter frame of our report (more powerful motors, power upgraded ESCs, bigger battery) to have modular suppression pods or several fire-extinguishing balls. Optimize the release mechanism to support more payload mass, and retain the AI safety measures (people/structure detection). Simulation (MATLAB/Simulink) versus field tests to compare the balance lift and flight time in simulation versus field tests to assure that the rapid-deploy variant remains within our report safety and RTH limits.[25].

Another way the drone might develop and evolve is with actual time cloud-based monitoring system, where future drones would allow access to real-time camera images of fire alerts, GPS location, sensor data, and live video links anywhere on the planet. This would particularly be helpful to smart cities and centralized emergency response centers.

Finally, battery efficiency, flight time, and autonomous navigation algorithms will need improvement to support long-range missions and more frequent and stable operation. The introduction of obstacle avoidance systems (LiDAR or ultrasonic) would also help increase safety when deployed within the city.

All in all, all of these future enhancement options can make the firefighting drone much more capable and empowered as an intelligent, more robust, and generally-widespread solution to the current issues of fire management.

Chapter 11: Identification of Complex Engineering Problems and Activities

11.1: Identify the attribute of complex engineering problem (EP)

Table 19 : *Identifying the Attributes of Complex Engineering Problems*

	Attribute	**Tick (✓) if applicable**
P1	Depth of knowledge required	✓
P2	Range of conflicting requirements	✓
P3	Depth of analysis required	✓
P4	Familiarity with issues	✓
P5	Extent of applicable codes	✓
P6	Extent of stakeholder involvement and needs	✓

11.2: Provide Reasoning For How The Project Address Selected Attribute (EP)

P1 – Depth of Knowledge Required

This project will also demand a solid grasp of drone technology, sensor fusion, fire detection and autonomous control algorithms. We need expertise in various engineering spheres to ensure correct operation and security.

P2 – Range of Conflicting Requirements

The design needs to be a compromise between weight, payload capacity, battery life, flight stability and cost. The process of satisfying one requirement may affect the other where trade-off decisions have to be made carefully during development.

P3 – Depth of Analysis Required

Each component selection, aerodynamic stability, fire detection accuracy and deployment mechanism efficiency require detailed analysis. This will make the drone work successfully under real-life fire conditions.

P4 – Familiarity with Issues

The environmental condition, limitations to sensors, flight risks, and false fire detects are some of the challenges that require awareness in the project. These issues can be understood to enhance the reliability and safety of the systems.

P5 – Extent of Applicable Codes

The design should take into account the relevant guidelines and standards connected to the UAV operation, safety measures, wireless communication and emergency response conditions.

P6 – Extent of Stakeholder Involvement and Needs

Here are needs of stakeholders like the firefighters, the emergency response teams, and the municipal authorities as well as the community users. Their expectations are also understood to make the design practical, safe, and effective.

11.3 Identify The Attributes of Complex Engineering Activities (EA)

Table 20 : *Identifying the Attributes of Complex Engineering Activities*

	Attribute	**Tick (✓) if applicable**
A1	Range of resources	✓
A2	Level of interaction	✓
A3	Innovation	✓
A4	Consequences for society and the environment	✓
A5	Familiarity	✓

A1 – Range of Resources

A wide range of resources will be used in this project such as sensors, communication modules, mechanical components, software tools and test environments. Both hardware and software resource utilization are effective in the successful development of systems.

A2 – Level of Interaction

The system is connected with a series of subsystems including sensors, flight controllers, communication connections, and fire-extinguishing system. It also involves co-ordinated communication with the users, including operators, firefighters and emergency personnel.

A4 – Consequences for Society and the Environment

The drone increases the safety of the population by diminishing risks and damages related to fire. It reduces the risks of firefighters being exposed to dangerous zones, which safeguard human lives. The system also has non-toxic extinguishing materials which decrease the ecological impact.

A5 – Familiarity

To create this system, one has to be acquainted with the technology of UAVs, emergency response needs, sensors functioning, and ecological issues. Being aware of these factors would facilitate in ensuring that the design is effective, practical and safe.

12. References

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Appendix

CODE FOR FIRE DETECTION AND SERVO ACTIVATION

```
# ========= IMPORTS =========
from ultralytics import YOLO
import cv2, cvzone, threading, time
from picamera2 import Picamera2
import RPi.GPIO as GPIO
from collections import deque

# ========= GPIO SETUP =========
LedPin = 22
GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)
GPIO.setup(LedPin, GPIO.OUT)

# ========= CAMERA SETUP =========
picam2 = Picamera2()
picam2.preview_configuration.main.size = (320, 240)  # small for smooth preview
picam2.preview_configuration.main.format = "RGB888"
picam2.preview_configuration.align()
picam2.configure("preview")
picam2.start()

# ========= YOLO MODEL =========
model = YOLO("FireUpdate.pt")  # your trained fire model
classnames = ["fire"]

# ========= GLOBAL VARIABLES =========
latest_frame = None
detection_results = []
lock = threading.Lock()
running = True
bbox_history = deque(maxlen=3)  # smooth last 3 detection frames

# ========= THREAD 1: CAMERA CAPTURE =========
def capture_thread():
    global latest_frame, running
    while running:
```

```
        frame = picam2.capture_array()
        frame = cv2.flip(frame, 1)
        with lock:
            latest_frame = frame
        time.sleep(0.01)

# ========= THREAD 2: YOLO DETECTION =========
def detection_thread():
    global detection_results, running, bbox_history
    while running:
        with lock:
            if latest_frame is None:
                continue
            frame_copy = latest_frame.copy()

        # Run YOLO inference (full precision)
        results = model.predict(frame_copy, imgsz=320, conf=0.5, verbose=False, half=False)

        detections = []

        for r in results:
            for box in r.boxes:
                conf = float(box.conf[0])
                cls = int(box.cls[0])
                if conf > 0.55:  # fire threshold
                    x1, y1, x2, y2 = map(int, box.xyxy[0])
                    detections.append((x1, y1, x2, y2, conf, classnames[cls]))

        # Smooth bounding boxes if detections exist
        if detections:
            bbox_history.append(detections)
            avg_dets = []
            for i in range(len(detections)):
                x1s, y1s, x2s, y2s, confs = [], [], [], [], []
                for dets in bbox_history:
                    if i < len(dets):
                        x1, y1, x2, y2, conf, cls = dets[i]
                        x1s.append(x1); y1s.append(y1)
                        x2s.append(x2); y2s.append(y2)
                        confs.append(conf)
                avg_dets.append((
                    int(sum(x1s)/len(x1s)),
                    int(sum(y1s)/len(y1s)),
```

```
            int(sum(x2s)/len(x2s)),
            int(sum(y2s)/len(y2s)),
            sum(confs)/len(confs),
            classnames[0]
        ))
      detections = avg_dets

    with lock:
      detection_results = detections
    time.sleep(0.02)  # small delay

# ========= START THREADS =========
t1 = threading.Thread(target=capture_thread, daemon=True)
t2 = threading.Thread(target=detection_thread, daemon=True)
t1.start()
t2.start()

# ========= MAIN DISPLAY LOOP =========
prev_time = time.time()
fps = 0
try:
  while True:
    with lock:
      if latest_frame is None:
        continue
      frame_disp = latest_frame.copy()
      current_dets = detection_results.copy()

    fire_detected = False
    for (x1, y1, x2, y2, conf, clsname) in current_dets:
      fire_detected = True
      cv2.rectangle(frame_disp, (x1, y1), (x2, y2), (0, 0, 255), 2)
      cvzone.putTextRect(frame_disp,
                  f"{clsname} {conf*100:.1f}%",
                  [x1, y1 - 10],
                  scale=1,
                  thickness=1)

    # LED output
    GPIO.output(LedPin, fire_detected)

    # FPS calculation
    curr_time = time.time()
```

```
        fps = 0.9*fps + 0.1*(1/(curr_time-prev_time))
        prev_time = curr_time
        cv2.putText(frame_disp, f"FPS: {fps:.1f}", (10,30),
                    cv2.FONT_HERSHEY_SIMPLEX, 1,

(0,255,0), 2)

        cv2.imshow("Fire Detection (Smooth + Accurate)", frame_disp)

        if cv2.waitKey(1) & 0xFF == ord('q'):
            break

finally:
    running = False
    GPIO.output(LedPin, False)
    cv2.destroyAllWindows()
```

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal

Group No - 03

Project Title:

Firehawk: Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism

	Final Year Design Project (P) Spring 2025		
Student Details	**Name & ID**	**EMAIL Address**	**Phone Number**
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ATC Details		
ATC -3		
Chair	**Prof. Dr. AKM Abdul Malek Azad**	**a.azad@bracu.ac.bd**
Member-1	**MD. Rafiqul Islam Rafi**	**rafiqul.rafi@bracu.ac.bd**
Member-2	**Ihteyaz Aqaid Avash**	**ihteyaz.avash@bracu.ac.bd**

General Details:

1. In addition to the detail journal/logbook fill out the summary/key steps and progress of your work

2. Reflect on planning assignments, and who has what responsibilities.

3. The logbook should contain all activities performed by the team members (Individual and team activities).

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	**Attendee**	**Summary of Meeting**	**Responsible**	**Comment by ATC**
13.02.25 **(FYDP Committee)** **Class-1**	**Faculty Member** Mohaimenul Islam **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Overview of the Final Year Design Project Course.		
20.02.25 **(FYDP Committee)** **Class-2**	**Faculty Member** Dr. Arshad Mahmud Chowdhury **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Complex Engineering Problem Identification		
21.02.25 **Group Meeting 1** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	**1.** FYDP topic selection. **2.** Presentation slides preparation for ATC Meeting 1. **3.** Finalize additional details regarding each topic.	**Task 1:** Everyone **Task 2:** Everyone **Task 3:** Everyone **Progress:** Task 1: Completed Task 2: Completed Task 3: Completed	

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
22.02.25 **ATC Meeting 1** **(Online)**	**Faculty Member** **1.** Chair- Prof. Dr. AKM Abdul Malek Azad **2.** MD. Rafiqul Islam Rafi **3.** Ihteyaz Aqaid Avash **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	**1.** ATC Introduction. **2.** Presentation on FYDP topic selection. **3.** Topic selection and finalization by ATC	**Task 1:** Everyone **Task 2:** Everyone **Task 3:** Everyone **Progress:** Task 1: Completed Task 2: Completed Task 3: Completed	1. Finalized the Project Topic
26.02.25 **Group Meeting 2** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz in 4. Misbahul 5. Khalid	1. Discussion on the finalized topic. 2. The ATC meeting and group meeting schedule is finalized. 3. Working on the logbook.	**Task 1:** Everyone **Task 2:** Everyone **Task 3:** Everyone **Progress:** Task 1: Completed Task 2: Completed Task 3: Completed	

27.02.25 **(FYDP Committee)** **Class-3**	**Faculty Member** Dr. Md. Mosaddequr Rahman **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Introduction to Engineering Design Process		

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Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
05.03.25 **Group Meeting 3** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	**Prepared Draft Concept Note** 1. Prepare two design approaches, problem statements, and objectives. 2. Identify all relevant constraints of the project 3. Specify components and their details. 4. Address codes and standards, complex engineering attributes.	Task 1: Alvi & Misbahul Task 2: Everyone Task 3: Everyone Task 4: Everyone **Progress:** Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	
06.03.25 **(FYDP Committee)** **Class-4** **(Online)**	**Faculty member** Dr. Abu S.M. Mohsin **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul	Case Study: How to Identify a Complex Engineering Design Project and Fulfill CO Criteria		

	5. Khalid			
10.03.25 **Group Meeting 4 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Work on 2 design approaches and their specifications	Task1: Everyone Progress: Task1: Completed	

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Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
11.03.25 **ATC Meeting 2** **(Offline)**	**ATC Members** MD Rafiqul Islam Rafi **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Review and provide feedback on the draft concept note		**1. Fix the writing errors in the concept note**
13.03.25 **Group Meeting 5 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Read relevant research papers	Task 1: Everyone Progress: Task 1: Completed	

17.03.25 **Group Meeting 6** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Create and divide presentation slides among the team to complete the progress presentation.	Task1: Everyone Progress: Task1: Completed	

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
27.03.25 **Group Meeting 7** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Discussion on progress presentation slide making.	Task 1: Everyone Progress: Task 1: Completed	
04.04.25 **Group Meeting 8** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Slide completion and presentation speech division.	Task 1: Everyone Progress: Task 1: Completed	
05.04.25 **ATC Meeting 3**	**ATC Members** Chair- Prof. Dr. AKM Abdul Malek Azad	Conducted the Progress Presentation	Task 1: Everyone Progress	1. We were told to add more information,

(Online)	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid		Task 1: Completed	including a Gantt chart and budget for the project and a comparison between our two design approaches.

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Group No - 03

Date/ Time/ Place	**Attendee**	**Summary of Meeting**	**Responsible**	**Comment by ATC**
06.04.25 **Group Meeting 9 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Discussion on Progress Presentation. 2. Provide the required information. 3. Provided technical specifications for concept notes.	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress Task 1: Completed Task 2: Completed Task 3: Completed	
07.04.25 **Group Meeting 10 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul	1. Included more informatio n and images	Task 1: Everyone Progress Task 1:	

	5. Khalid	and flowchart for design approach 1 & 2.	Completed	
08.04.25 **Group Meeting 11** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Outline and finalize the concept note.	Task 1: Everyone Progress Task 1: Completed	

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
09.04.25 **Group Meeting 12** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Present a detailed budget. 2. Provide a comparison between two design approaches to elaborate expected outcomes and impact. 3. Add references to ensure thorough sourcing for the project	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress Task 1: Completed Task 2: Completed Task 3: Completed	

09.04.25 **ATC Meeting 4** **(Online)**	**ATC Member:** Ihteyaz Aqaid Avash Students: 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Conducted the Progress Presentation	Task 1: Everyone Progress Task 1: Completed	We were told to keep coordination in making slides including comparisons between our two design approaches and add a flowchart for each approach.
10.04.25 **Group Meeting 13** **(Online)**	Students: 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Updated the Progress Presentation Slide by adding the required information.	Task 1: Everyone Progress Task 1: Completed	

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
10.04.25 **(FYDP Committee)** **Class-5**	**Faculty Member** Mohaimenul Islam **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Project Safety, Sustainability, and Environmental Impact in Engineering Design		

13.04.25 **Group Meeting 14** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Discussion and refine the project proposal 2.Work on Design approaches for the project proposal	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
17.04.25 **Class-6**	**Faculty Member** Dr. A.S. Nazmul Huda **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Review of Engineering Ethics and Professional Practices		

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC

17.04.25 **Group Meeting 15** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Modifying design approaches in detailed	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed	
21.04.25 **Group Meeting 16** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Discussion on final presentation: 2.Distribution of work for the final presentation	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
24.04.25 **Class-7**	**Faculty Member** Taiyeb Hasan Sakib **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Review of Project Proposal Preparation, Report Writing and Presentation Techniques		

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC

28.04.25 **Group Meeting 17 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Budget finalised for two design approaches 2.Complete the project methodology	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
29.04.25 **Group Meeting 18 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Finished the write up and included in-text citation 2.Making the Gantt Chart and project plans.	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
30.04.25 **Group Meeting 19 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Working on reference papers	**Task 1:** Everyone **Progress:** Task 1: Completed	

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Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
04.05.25 **Group Meeting 20** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	**1.Discussion on final project presentation** **2.The division of slide creation**	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
05.05.25 **Group Meeting 21** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Reviewed all over the progress work of the project 2.Conducted a mock presentation	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
06.05.25 **Group Meeting 22** **(Offline)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Conducted a mock presentation and modified the speeches to present within timeframe	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
07.05.25 **Group Meeting 23** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Conducted a final mock presentation Modify the presentation slides as per the instructions	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
08.05.25 **(FYDP Committee)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Conducted the Final Presentation	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	To change the title, and change the fonts of the slide.
11.05.25 **Group Meeting 24** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	FYDP final presentation analysed Adding more references to the proposal	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	

FYDP (P) Spring 2025 Summary of Team Log Book/ Journal
Group No - 03

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
12.05.25 **Group Meeting 25** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Discuss about EA and EP and Applicable standards and codes Finish the write up on risk management and ethical considerations	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	
13.05.25 **ATC Meeting 5** **(Offline)**	**ATC Member:** **Chair- Prof. Dr. AKM Abdul Malek Azad** **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Feedback on final presentation	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	Change the Methodology
14.05.25 **Group Meeting 26** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	FYDP- project proposal font, alignment and grammatical error corrections Change the methodology as per said before	**Task 1:** Everyone **Task 2:** Everyone **Progress:** Task 1: Completed Task 2: Completed	

FYDP (D) Summer 2025 Summary of Team Log Book/ Journal

Group No. - 03

Project Title:

Firehawk: Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism

	Final Year Design Project (D) Summer 2025		
Student Details	**Name & ID**	**EMAIL Address**	**Phone Number**
Member 1	MD. Atair Rahman Alvi (21321065)	atair.rahman.alvi@g.bracu.ac.bd	01571034770
Member 2	Ifrana Hamim (21321006)	ifrana.hamim@g.bracu.ac.bd	01911783949
Member 3	Faraaz Adnan (21321040)	faraaz.adnan@g.bracu.ac.bd	01628589412
Member 4	Misbahul Azim Chowdhury (21321083)	misbahul.azim.chowdhury@g.bracu.ac.bd	01575671666
Member 5	Khalid Saifullah (21221079)	khalid.saifullah2@g.bracu.ac.bd	01966104220

ATC Details		
ATC -3		
Chair	**Prof. Dr. AKM Abdul Malek Azad**	**a.azad@bracu.ac.bd**
Member-1	**Ihteyaz Aqaid Avash**	**ihteyaz.avash@bracu.ac.bd**

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
26.06.2025 **(FYDP Committee)** **Class-1**	**Faculty Member** Atib Mohammad Oni **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Introductory Class of EEE499D: Discussion about the works and timeline of FYDP D		
26.06.25 **ATC Meeting 1** **(Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Brief discussion on the FYDP D work.		1. Update the logbook every week. Start writing the report 2. Start working on the simulation 3. Logbook, report, and simulation update have to be shared before the meeting
29.06.25 **Group Meeting 1** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Selection of software and dividing the simulation into three parts 2. Mathematical model for two drones	Task 1: Everyone Task 2: Khalid, Faraaz Progress: Task 1: Completed Task 2: ½ completed	

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
30.06.25 **ATC Meeting 2** **(Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Finalised weekly meeting with ATC		
30.06.25 **ATC Meeting 3** **(Offline)**	**Faculty Member** Md. Rafiqul Islam Rafi **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1 . Discussion on project plan and weekly meeting schedule fixing		
02.07.25 **Group Meeting 2** **(Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz in 4. Misbahul 5. Khalid	1. Selection of mathematical model and parameters, and initial relevant calculations 2. Updated the report	Task 1:Everyone Task 2: Misbahul, Ifrana, Alvi Progress: Task 1: Completed Task 2: Completed	
03.07.25 **ATC Meeting 4** **(Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Ifrana 2. Faraaz 3. Misbahul 4. Khalid	1. Review of logbook 2 . Discussion on software selection for both design approaches		1. Fix the writing errors in the logbook.

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
05.07.25 **Group Meeting 3 (Online)**	**Students** Alvi Ifrana Faraaz Misbahul Khalid	1. Reviewing research papers for software selection. 2. Adding the Moment of inertia in the quadcopter mathematical model 3 . Updating project report draft.	Task 1: Everyone Task 2: Khalid, Faraaz Task 3: Misbahul, Ifrana Progress: Task 1: Completed Task 2: Completed Task 3: In Progress	
07.07.25 **ATC Meeting 05 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Discussion on the progress of the project 2 . Discussion on various approaches for algorithm simulation		1. Make algorithms for the design approaches simulation
09.07.25 **ATC Meeting 06 (Offline)**	**Faculty Member** **Md. Rafiqul Islam Rafi** **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Discussion on simulation for both design approaches		1. Review the research paper for software simulation. 2. Work on both the design approach and simulation.

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
09.07.25 **Group Meeting 04 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Fire detection system approach for design 1 (using a sensor) 2 . Fire detection system approaches for design 2 (using a machine) 3. Updating the logbook 4. Mechanical simulation for both design approaches	Task 1: Alvi Task 2: Everyone Task 3: Misbahul, Faraaz Task 4: Khalid, Faraaz Progress: Task 1: In Progress Task 2: In Progress Task 3: Completed Task 4: ¾ completed	
10.07.25 **ATC Meeting 07 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed Simulink and the fire detection draft model. 2. Showed the Proteus model of design approach 2		1. Individual contributions to the report should be written in the logbook. 2. Fixing Logbook errors. 3. Physical meeting with all the mathematical expressions.
12.07.25 **Group Meeting 05 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Design approach 1 Model conversion to computer vision 2. Design approach 2 Proteus simulation. 3. Design approach 2 Simulink modelling. 4. Report writing 5. Logbook update.	Task 1: Alvi Task 2: Ifrana Task 3: Khalid, Faraaz, Misbah Task 4: Everyone Task 5: Everyone Progress Task 1: In progress. Task 2: ⅓ remaining. Task 3: ⅓ remaining. Task 4: Misbah Task 5: Misbah	

<table>
<tr><th>Date/ Time/ Place</th><th>Attendee</th><th>Summary of Meeting</th><th>Responsible</th><th>Comment by ATC</th></tr>
<tr><td>13.07.25

ATC Meeting 08 (Offline)</td><td>Faculty Member
Ihteyaz Aqaid Avash

Students
1. Alvi
2. Ifrana
3. Faraaz
4. Misbahul
5. Khalid</td><td>1. Showed Simulink and the fire detection draft model.
2. Showed the Proteus model of design approach 2</td><td></td><td>1. Make the fire detection model more accurate.
2. Verify the data with the mathematical expressions</td></tr>
<tr><td>15.07.25

Group Meeting 06 (Online)</td><td>Students
1. Alvi
2. Ifrana
3. Faraaz
4. Misbahul
5. Khalid</td><td>1. Optimizing design approach 1 model computer vision
2. Design approach 2 Proteus simulation.
3. Design approach 2 Simulink modelling.
4. Report writing
5. Logbook update</td><td>Task 1: Alvi
Task 2: Ifrana.
Task 3: Misbahul, Faraaz, Khalid
Task 4: Everyone
Task 5: Everyone

Progress:
Task 1: In progress.
Task 2: In Progress
Task 3: In Progress
Task 4: In progress.
Task 5: In progress.</td><td></td></tr>
<tr><td>16.07.25

ATC Meeting 09 (Offline)</td><td>Faculty Member
Md. Rafiqul Islam Rafi

Students
1. Alvi
2. Ifrana
3. Faraaz
4. Misbahul
5. Khalid</td><td>1. Showed Simulink and the fire detection draft model.
2. Showed the Proteus model of design approach 2</td><td></td><td>Consult with experts who have similar experience.</td></tr>
</table>

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
16.07.25 **Group Meeting 07 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1 . Optimizing Design approach 1: Model computer vision 2. Design approach 2 Proteus simulation update 3. Design approach 2 Simulink modelling plots. 4. Report writing 5. Logbook update 6. Design approach 1: Drone aerodynamics started.	Task 1: Alvi Task 2: Ifrana. Task 3: Misbahul, Faraaz, Khalid Task 4: Everyone. Task 5: Everyone. Task 6: Khalid Progress: Task 1: In progress Task 2: In Progress Task 3: Completed Task 4: In progress. Task 5: In progress. Task 6: In Progress	
17.07.25 **ATC Meeting 10 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed Sir the simulation of design approach 1 done by Simulink 2. Proteus design of the transmitter. 3. Fire detection codes and results by computer vision.		1. Update the report, including the outputs of the simulations. 2. Update the page numbers of the report. 3. Find more related research papers.
19.07.25 **Group Meeting 08 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Optimizing Design approach 1: Model computer vision 2. Design approach 2 Proteus simulation	Task 1: Alvi, Task 2: Ifrana, Faraaz Task 3: Khalid, Misbahul, Faraaz. Task 4:Alvi, Ifrana, Khalid.	

		3. Proper simulation and Report writing drone simulation for design approach 2. 4 . Drone aerodynamics simulation	Progress: Task 1:Completed Task 2: Completed Task 3: In Progress Task 4: In progress	

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
20.07.25 **ATC Meeting 11 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed Sir the simulation of design approach 1 done by Simulink 2. Proteus design of the transmitter. 3. Fire detection codes and results by computer vision.		Try to improve the accuracy of fire detection and object detection capabilities using computer vision.
22.07.25 **Group Meeting 09 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Design approach 1 fire detection report writing. 2. Design approach 2 fire detection report writing. 3. Working on the fire detection model comparison. 4. 3D simulation	Task 1: Alvi, Misbahul, Khalid Task 2: Ifrana, Faraaz Task 3: Khalid, Misbahul, Faraaz. Task 4: Alvi, Faraaz Progress: Task 1: Completed Task 2: Completed Task 3: In progress Task 4: Completed	

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
23.07.25 **ATC Meeting 12 (Offline)**	**Faculty Member** Md. Rafiqul Islam Rafi **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed Sir the simulation of design approach 1 done by Simulink 2. Proteus design of the transmitter. 3. Fire detection codes and results by computer vision.		Satisfied with your working speed and progress of the report. Show the comparison of both design approaches.
24.07.25 **ATC Meeting 13 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir the fire detection model accuracy 2. Showed drone aerodynamics 3. Quadrocopter and hexacopter drone control		Fix the font size of the block diagram, and change the flow chart.
02.08.25 **Group Meeting 10 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Fixed the report according to the suggestions provided. 2. Presentation slides making	Task 1: Alvi, Misbahul, Khalid Task 2: Everyone Progress: Task 1: Completed Task 2: In Progress	

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
04.08.25 **ATC Meeting 14 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir the fire detection model accuracy 2. Showed drone aerodynamics 3. Quadrocopter and hexacopter drone control		Progress is quite satisfactory. Try to simulate the whole detection system more precisely
04.08.25 **ATC Meeting 15 (Offline)**	**Faculty Member** Md. Rafiqul Islam Rafi **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir the fire detection model accuracy 2. Showed drone aerodynamics 3. Quadrocopter and hexacopter drone control		
05.08.25 **Group Meeting 11 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	mock presentation		
06.08.25 **Group Meeting 12 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	mock presentation		
07.08.25 **ATC Meeting 16 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana	progress presentation		Overall, the presentation was satisfactory; minor updates should be done, like figure numbers.

	3. Faraaz 4. Misbahul 5. Khalid			

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
9.08.25 **Group Meeting 13 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Updated the presentation slides		
10.08.25 **ATC Meeting 17 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Delivered progress presentation		
11.08.25 **ATC Meeting 18 (Offline)**	**Faculty Member** Md. Rafiqul Islam Rafi **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	Delivered progress presentation		

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
13.08.25 **Group Meeting 14 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report writing. 2 . Comparison of both design approaches. 3. Fixed progress presentation slides	Task 1: Everyone Task 2: Alvi, Faraaz Task 3: Everyone	
14.08.25 **ATC Meeting 19**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir updated report and log book to the sir.		1. The fever chart explains 2. Flow chart fix. 3. Reference fix
16.08.25 **ATC Meeting 20**	**Faculty Member** Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir updated report and log book to the sir.		1. Said everything is okay and keep working
17.08.25 **Group Meeting 15 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Comparison of both models. 2. Report writing	Task 1: Alvi, Faraaz. Task 2: Everyone Progress: Task 1: In Progress Task 2: In Progress	

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
18.08.25 **ATC Meeting 21** **(Online)**	**Faculty Member** Md. Rafiqul Islam Rafi **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir updated report and log book to the sir.		1. Said to start on the formatting of the report.
19.08.25 **Group Meeting 16** **(Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Comparison of both models. 2. Report writing	Task 1: Alvi, Faraaz. Task 2: Everyone. Progress: Task 1: Complete. Task 2: In Progress.	
21.08.25 **Group Meeting 17** **(Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report writing 2. Formatting report 3. Formatting final presentation slide	Task 1:Everyone. Task 2: Everyone. Task3:Everyone. Progress: Task 1: In progress. Task 2: In Progress. Task3:In Progress.	
24.08.25 **Group Meeting 18** **(Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report writing 2. Formatting report 3. Formatting final presentation slide	Task 1:Everyone. Task 2: Everyone. Task3:Everyone. Progress: Task 1: Complete Task 2: Complete Task3:Complete..	

FYDP (C) Fall 2025 Summary of Team Log Book/ Journal

Group No. - 03

Project Title:

Firehawk: Autonomous Firefighting Drone with Fire-Extinguishing Ball Release Mechanism

	Final Year Design Project (C) Fall 2025		
Student Details	**Name & ID**	**EMAIL Address**	**Phone Number**
Member 1	MD. Atair Rahman Alvi (21321065)	atair.rahman.alvi@g.bracu.ac.bd	01571034770
Member 2	Ifrana Hamim (21321006)	ifrana.hamim@g.bracu.ac.bd	01911783949
Member 3	Faraaz Adnan (21321040)	faraaz.adnan@g.bracu.ac.bd	01628589412
Member 4	Misbahul Azim Chowdhury (21321083)	misbahul.azim.chowdhury@g.bracu.ac.bd	01575671666
Member 5	Khalid Saifullah (21221079)	khalid.saifullah2@g.bracu.ac.bd	01966104220

ATC Details		
ATC -3		
Chair	**Prof. Dr. AKM Abdul Malek Azad**	**a.azad@bracu.ac.bd**
Member-1	**Ihteyaz Aqaid Avash**	**ihteyaz.avash@bracu.ac.bd**

<table>
<tr><th>Date/ Time/ Place</th><th>Attendee</th><th>Summary of Meeting</th><th>Responsible</th><th>Comment by ATC</th></tr>
<tr><td>16.10.2025

(FYDP Committee)
Class-1
(Online)</td><td>Faculty Member
Mirza Rasheduzzaman
Students
1. Alvi
2. Ifrana
3. Faraaz
4. Misbahul
5. Khalid</td><td>1. Introductory Class of EEE499C: Discussion about the works and important deadlines.</td><td></td><td></td></tr>
<tr><td>16.10.2025

ATC Meeting 1
(Online)</td><td>Faculty Member
Chair- Prof. Dr. AKM Abdul Malek AZAD
Students
1. Alvi
2. Ifrana
3. Faraaz
4. Misbahul
5. Khalid</td><td>1. Discussion on how to continue in FYDP C</td><td></td><td>1. Update the logbook every week.
2. Start working on the hardware component following Design Approach 2.
3. Logbooks, reports, and project updates have to be shared before the meeting.</td></tr>
<tr><td>18.10.2025

Group Meeting 1
(Online)</td><td>Students
1. Alvi
2. Ifrana
3. Faraaz
4. Misbahul
5. Khalid</td><td>1. Report write Chapter 1.</td><td>Task 1: Alvi, Ifrana, Misbah

Progress:
Task 1: Completed</td><td></td></tr>
</table>

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
19.10.2025 **ATC Meeting 2 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Finalised weekly meeting with ATC		1. Start working on the hardware part along with the software coding components. 2. Show progress every two weeks to show the completion status of the subsystems.
22.10.2025 **Group Meeting 2 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz in 4. Misbahul 5. Khalid	1. Report write Chapter 2.	Task 1:Faraaz, Alvi, Ifrana, Khalid, Misbah. Progress: Task 1: Completed	
23.10.2025 **ATC Meeting 4 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Start writing the report with good writing skills. 2. Start working on hardware implementation.		1. In the report, reduce the use of autonomous words 2. Manage all the components as soon as possible 3. Submit the component checking video within this week.

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
25.10.2025 **Group Meeting 3 (Online)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report write Chapter 3. 2. Component Collection, Testing, and Inspection.	Task1:Faraaz, Alvi, Ifrana. Task 2: Misbah, Khalid Progress: Task 1: Completed Task 2: In progress.	
26.10.2025 **ATC Meeting 5 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Learn from similar hardware implementations that have been done before.		1. Check all the components and try to fix the issues that you're facing.
28.10.2025 **Group Meeting 4 (Offline)**	**Students** 1. Alvi 2. Ifrana 3. Faraaz in 4. Misbahul 5. Khalid	1. Raspberry Pi interface setup. 2. Component Collection, Testing, and Inspection 3. Camera focus adjustment. 4. Report writing chapter 3. 5. Report writing chapter 4.	Task 1: Misbah, Ifrana, and Alvi. Task 2: Misbah, Khalid. Task 3: Faraaz, Alvi. Task 4: Misbah, Alvi. Task 5: Faraz, Ifrana Progress: Task 1: Completed Task 2: Completed Task 3: In progress Task 4: Completed Task 5: In progress	

Date/ Time/ Place	Attendee	Summary of Meeting	Responsible	Comment by ATC
30.10.2025 **ATC Meeting 6 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. The ATC Meeting was canceled due to an urgent departmental meeting.		
02.11.2025 **ATC Meeting 7 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Discussed how we are planning to implement the project.		1. Keep working in a trial-and-error process.
04.11.2025 **Group Meeting 5 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report writing chapter 4. 2. Solving some hardware implementation planning errors 3. Raspberry pie fire detection algorithm setup	Task 1: Ifrana, Khalid. Task 2: Alvi, Khalid, Misbah, Faraaz Task 3 : Alvi Progress : Task 1: In progress Task 2: Completed Task 3: Completed	
05.11.2025 **Group Meeting 6 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report writing chapter 4. 2. Report writing chapter 6.	Task 1: Khalid, Ifrana. Task 2: Misbah, Alvi, Faraaz. Task 3: Misbah, Alvi, Faraaz.	

		3. Report writing chapter 7. 4. Drone frame building	Task 4: Misbah, Faraaz. Progress : Task 1: In progress Task 2: Completed Task 3 : Completed Task 4: Completed	
06.11.2025 **ATC Meeting 8 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed the fire detection system through the camera and the drone frame that we built.		1. Correct the report writing formation.
08.11.2025 **Group Meeting 7 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Set all the components in the drone frame and put the connections together	Task 1:Faraaz, Alvi, Ifrana, Khalid, Misbah. Progress: Task 1: In progress	
09.11.2025 **Group Meeting 8 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Continuation of previous work	Task 1:Faraaz, Alvi, Ifrana, Khalid, Misbah. Progress: Task 1: Completed	

10.11.2025 **ATC Meeting 9 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed the drone frame with connections 2. Discussed the firmware problem of the drone.		1. Fix the firmware
11.11.2025 **Group Meeting 9 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report writing Chapter 5. 2. Report writing Chapter 4. 3. Report writing Chapter 9.	Task 1:Faraaz, Alvi, Ifrana, Khalid, Misbah. Task 2:Faraaz, Misbah, Ifrana. Task 3: Alvi, Khalid. Progress: Task 1: In progress Task 2: Completed Task 3: Completed	
12.11.2025 **ATC Meeting 10 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed the drone frame with all the connections.		1. Fix the errors in the report

16.11.2025 **Group Meeting 10 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Fixed the firmware	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid. Progress: Task 1:Completed	
18.11.2025 **Group Meeting 11 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Report writing	Task 1:Faraaz, Alvi, Ifrana, Progress: Task 1: In progress	
19.11.2025 **ATC Meeting 11 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana (Absent- Due to family emergency) 3. Faraaz 4. Misbahul 5. Khalid	1. Showed the sir after fixing the firmware		1. Take preparation for the progress presentation 2. Try to make the drone fly 3. Absence accepted by ATC

22.11.2025 **Group Meeting 12 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Fire detection mechanism subsystem added	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid. Progress: Task 1:Completed	
23.11.2025 **Group Meeting 13 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Servo mechanism has been added to the drone, but the work is in progress	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid. Progress: Task 1: In Progress	
01.12.2025 **Group Meeting 14 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Prepared the progress presentation slide 2. Practice for the progress presentation	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid. Task 2: Alvi, Ifrana, Faraaz, Misbah, Khalid Progress: Task 1:Completed Task 2:Completed	
03.12.2025 **ATC Meeting 12 (Online)**	**Faculty Member** 1. Chair- Prof. Dr. AKM Abdul Malek AZAD 2. Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Presented a progress presentation		1. Drone’s real-life results and analysis. 2. GPS and compass reliability issue. How can you validate it?

04.12.2025 **Group Meeting 15 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Started making the poster 2. Report writing Chapter10 and 11	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid. Task 2: Alvi, Ifrana, Faraaz, Misbah, Khalid Progress: Task 1:In progress Task 2:Completed	
07.12.2025 **Group Meeting 16 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Implemented the servo in the drone and set the command in the remote. 2. Worked on the stability of the drone	Task 1: Alvi, Ifrana, Faraaz, Task 2: Alvi, Ifrana, Misbah Progress: Task 1: Completed progress Task 2:Completed	
08.12.2025 **Group Meeting 17 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Making the poster 2. Report Writing Chapter 8. 3. Report Writing Chapter 5.	Task 1: Alvi, Ifrana, Faraaz, Task 2: Alvi, Misbah, Khalid Task 3: Alvi, Misbah, Khalid Progress: Task 1:In progress Task 2:Completed Task 3: In progress	

10.12.2025 **ATC Meeting 13 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Showed sir the poster		1.Improvement is needed for the poster.
14.12.2025 **Group Meeting 18** **(Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Worked on the poster. 2. Fixing Chapter 8	Task 1: Alvi, Ifrana, Faaraz Task 2: Alvi, Misbah, Khalid Progress: Task 1: In progress. Task 2:Completed	
15.13.2025 **Group Meeting 19 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Testing drone stability and live camera feed testing.	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid Progress: Task 1:In progress	

17.12.2025 **ATC Meeting 14 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir the new undated poster. 2. Discussed about the drone crash.		1. Review of the poster will be given in the next meeting. 2. Quickly fixed the drone. 3. Always be aware of the risks when flying a drone.
20.12.2025 **Group Meeting 20 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1.Worked on fixing the camera structure.	Task 1: Alvi, Ifrana, Faaraz Progress: Task 1: Completed	
21.13.2025 **Group Meeting 21 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Attached a structure for the stability of the ball.	Task 1: Alvi, Ifrana, Faraaz, Misbah Progress: Task 1:In progress	
22.12.2025 **ATC Meeting 15 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed Sir the finished drone.		1. Sir liked it and told us to make the stability more better.
22.12.2025 **Group Meeting 22**	**Students:** 1. Alvi 2. Ifrana	1.Worked on chapter 5	Task 1: Faraaz, Misbah, Khalid.	

(Online)	3. Faraaz 4. Misbahul 5. Khalid		Progress: Task 1:In progress	
24.12.2025 **ATC Meeting 16 (Online)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul (Absent due to Family Emergency) 5. Khalid	1. Showed sir the drone was working 2. Update Sir about that we broke the propellers while testing the drone		1. Sir told to fix the report writing formats 2. Ethics Statement and Acknowledgement of the report should be on a separate page 3. Figure numbers need to be written 4. Fix the propellers soon
25.12.2025 **Group Meeting 23 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Fixed report writing formats 2. Figure numbers have been added 3. Ordered new sets of propellers	Task 1: Ifrana, Alvi, Misbah, Faraaz, Khalid Task 2: Alvi, Faraaz Task 3: Alvi Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
28.12.2025 **ATC Meeting 17 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir the overall progress, including test flights, autonomous detections, servo mechanism		Suggested us to learn more precisely about the landing process and overall satisfactory progress, and advised us to proceed with the field test.

30.12.2025 **Group Meeting 24 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Attached new propellers to the drone 2. While testing the drone we accidentally broke the drone frame	Task 1: Alvi, Faraaz Task 2: Alvi, Ifrana, Faraaz, Misbah Progress: Task 1: Completed Task 2: In progress	
30.12.2025 **ATC Meeting 18 (Offline)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir the broken frame of the drone		1. Sir told us to try to fix it. 2. Make the video of fire detection and fire extinguishing work
31.12.2025 **Group Meeting 25 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Trying to fix the drone frame	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid Progress: Task 1: Failed	

01.01.2026 **Group Meeting 26 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Tried to fix the frame 2. Made the video of the fire detection and fire extinguishing work of the drone	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid Task 2: Alvi, Ifrana, Faraaz, Misbah, Khalid Progress: Task 1: Failed Task 2: Completed	
02.01.2026 **Group Meeting 27 (Online)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Completed the poster 2. Made a leaflet. 3. Completed chapter 5.	Task 1: Alvi, Ifrana, Faraaz, Task 2: Alvi, Misbah, Khalid Task 3:Alvi, Misbah, Khalid Progress: Task 1: Completed Task 2: Completed Task 3:Completed	
03.01.2025 **ATC Meeting 19 (Offline)**	**Faculty Member** Ihteyaz Aqaid Avash **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Showed sir the broken drone frame 2. Showed the completed poster		1. Sir told to try to fix the drone 2. Approved the completed poster for printing
03.01.2026 **Group Meeting 28 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Tried to fix the drone frame 2. Printed the poster	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid Task 2: Alvi, Faraaz Task 3: Alvi,	

		3. Corrected all the formatting of the report	Ifrana, Faraaz, Misbah, Khalid Progress: Task 1: Failed Task 2: Completed Task 3; Completed	
04.01.2026 **ATC Meeting 20 (Offline)**	**Faculty Member** Chair- Prof. Dr. AKM Abdul Malek AZAD **Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Informed sir about the failed attempts to fix the drone.		1. Drone frame must needs to be fixed and has to be functional before the project showcasing
04.01.2026 **Group Meeting 29 (Offline)**	**Students:** 1. Alvi 2. Ifrana 3. Faraaz 4. Misbahul 5. Khalid	1. Fixed the drone frame and made it functional. 2. Tested drone stability to fly with the payload and made video of it. 3. Tested the drone ability to detect fire and made video of it.	Task 1: Alvi, Ifrana, Faraaz, Misbah, Khalid Task 2: Alvi, Ifrana, Faraaz, Misbah, Khalid Task 3: Alvi, Ifrana, Faraaz, Misbah, Khalid Progress: Task 1: Completed Task 2: Completed Task 3: Completed	