Islamic University *of* Technology

Department of Mechanical and Production Engineering

DESIGN AND FABRICATION OF A FIRE FIGHTING DRONE

A Thesis by

Chowdhury Hassan bin Mizan
&
Md. Anwarul Islam

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Bachelor of Science in Mechanical Engineering

May (2022)

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CERTIFICATE OF RESEARCH

This thesis titled ***"DESIGN AND FABRICATION OF A FIRE FIGHTING DRONE"*** *submitted by* ***CHOWDHURY HASSAN BIN MIZAN (170011018)*** *and* ***MD. ANWARUL ISLAM (170011067)*** *has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Mechanical Engineering.*

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DECLARATION

I hereby declare that this thesis entitled "DESIGN AND FABRICATION OF A FIRE FIGHTING DRONE" is an authentic report of our study carried out as requirement for the award of degree B.Sc. (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of Prof. Dr. Shamsuddin Ahmed, Professor, MPE, IUT in the year 2022.

The matter embodied in this thesis has not been submitted in part or full to any other institute for award of any degree.

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Acknowledgments

"Bismillahir Rahmanir Rahim"

All praise to Almighty Allah , We want to say that Allah the almighty has given us the energy, knowledge, and patience to work on our goal to design our drone. Our supervisor Dr Shamsuddin Ahmed sir has always supported us and showed the path of research and helped us to improve our project day by day. We both teammates has always been supportive to each other and worked hard together to achieve our goal and do the research. We hope that our research will be very useful to the future workers who will be working on our project and establish a better future.

ABSTRACT

Fire is a disaster that can occur from different natural causes and from manmade causes. Generally, natural fires are the wildfires that occur due to global warming caused by human beings. Generally, the manmade causes are focused on as the fire at homes and industries cause a lot of damage which may be beyond repair sometimes. So to minimize the loss caused by the fires every nation has a firefighting unit that puts emphasis on extinguishing fires and saving our lives and property. Firefighting is done by humans and fire extinguishers which have been operated manually throughout these years. This manual system puts many firefighters in danger and takes a lot of time to extinguish the fire, as a result, the amount of damage increase with time and practically It is not easy for a human to enter the hazardous place and find the victims so Fire Fighting Drone is the best solution to find out the victims and also to control the fire. Fighting drones can approach though airways and can save a lot of time as well as loss of health and wealth. Recently we came to cross the globe to know that 1449 firefighters were injured trying to fight fires and trying to save people. So to reduce this loss of health and precious human life our project will put much more emphasis to extinguish the fire in a short period of time and replacing our valuable human lives by becoming operators of the drones in remote areas.

In 2019, the number of reported fire incidents was 24,078, and estimated damages were 330.04 million (in BDT), which caused 184 deaths and 560 injuries in Bangladesh. We designed the drone keeping some of the key factors in minds such as cost of production, technology availability, nonhazardous, performance, durability, and appearance. We design the layout of the drone using SolidWorks and design the basic flow diagrams and circuit diagrams using Microsoft PowerPoint and words. We analyzed the flight of the drone using two types of propellers basically 8” and 10” and calculated the payload and analyzed the data of errors found on the transmitter while different experimental flights were done.

KEYWORDS: Design, Drone, Quadcopter, Transmitter-receiver, SolidWorks

Table of Contents

List of Figures

LIST OF TABLES

Nomenclature

TX – Transmission/ Transmitter

RX – Receiver

CW – Clockwise

CCW – Counterclockwise

BLDC – Brushless Direct Current Motor

ESC – Electronic Speed Controller

RPM - Rotation per minute

6 DOF – Six Degree of Freedom

3D - Three Dimensional

A – Ampere

V – Voltage

Li-Po – Lithium-polymer Battery

RC – Remote Control

FC – Flight Controller

F- Force / thrust

W – Weight / payload

PDB – Power Distribution Board

VTOL – Vertical take-off and landing

UAV – Unmanned Aerial Vehicle

D - diameter of the propeller

ρ - the density of the air

v - the velocity of the air

Vp - the velocity of air due to the propeller

F_c - Centrifugal Force

L - perpendicular distance from drone to the road surface

Yaw Motion (ψ) - The rotation of the quadcopter around the vertical axis is called Yaw.

Roll Motion (Φ) - The rotation of the quadcopter around the front-to-back axis is called Roll.

Pitch Motion (θ) - The Rotation of the quadcopter around the side to side axis is called Pitch.

2. INTRODUCTION

1.1 Quadcopters and types

A quadcopter is a type of unmanned aerial vehicle. UAV can generally be defined as a device used or intended to be used for flight in the air that has no onboard pilot.[1] These devices are sometimes referred to as drones, which are programmed for autonomous flight, and remotely piloted vehicles (RPVs), which are flown remotely by a ground control operator. [2]. A quadcopter is a simple flying mechanism also known as a quadrotor that has four arms, and each one of them has a motor that is attached to a propeller. In the quadcopter, two of the rotors turn counter-clockwise (CCW) while the two others turn clockwise (CW). [3] Some applications implement an autonomous flight mode, however, the autonomy here is intended as a simple path planning through several given points.[1] In another sense, A quadcopter is an aircraft heavier than air, capable of vertical take-off and landing (VTOL), which is propelled by four rotors, positioned in the same plane, parallel to the ground.[4]

Figure 1: A quadcopter

Dimensions of quadcopters can vary from the size of an insect to a size of a professional aerial vehicle. Dimensions differ according to the type of application in which this UAV are going to be implemented and the equipment they are taking. [1] For the firefighting purpose we will need to make a drone enough to carry water tank or extinguishing materials or stuffs like fire extinguishing balls and also can carry the medical supplies important for the injured persons during the rescue or extinguishing the fires.

Quadcopters are basically drones or UAVs having four arms and the arms contains a BLDC each. Depending on the combination of the BLDC motors on the drone we can divide the types of quadcopter into 4 different categories. They are.

1. Quad X
2. Quad H
3. Quad +
4. Quad V

In Quad X the opposite BLDC motors rotate in the same direction. We will now show how a Quad X works.

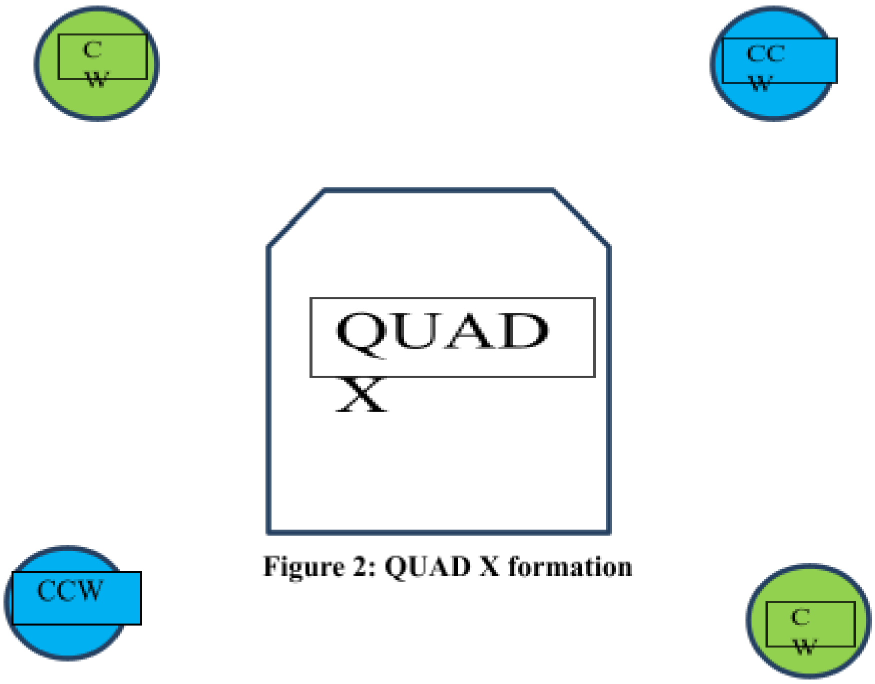
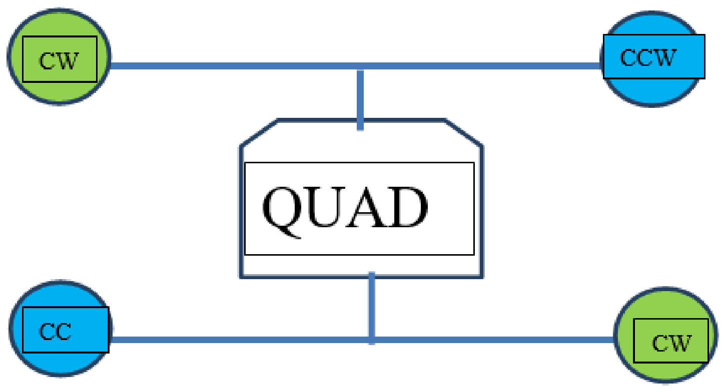


Figure 2: QUAD X formation

In case of the Quad H the motor are in the H formation and the CW and CCW motors are in the alternatively form in the arms of the H formation. Generally, the forward part of the drone has 1 CW and 1 CCW and the rear part of the drone has 1 CW and 1 CCW motor. We will now see the formation of the motors of the quad H.



3: QUAD H formation

Now in case of quad + formation the opposite motors formation are same. So 2 CW motors are placed on opposite to each other and 2 CCW motors are placed opposite to each other. The Formation

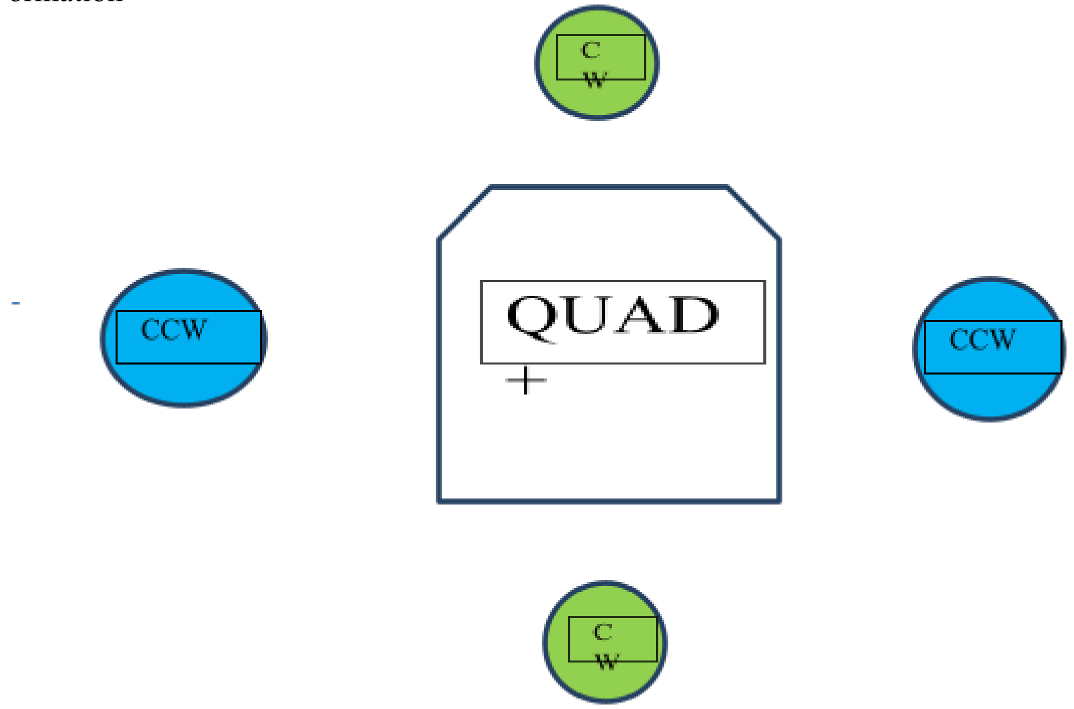


Figure 4: QUAD + formation

Quad V is almost similar to quad X but the frontal part is extended by an angle and the rear part is contracted a bit by angle. So the rear motors are closed and the frontal motors are extended a bit.

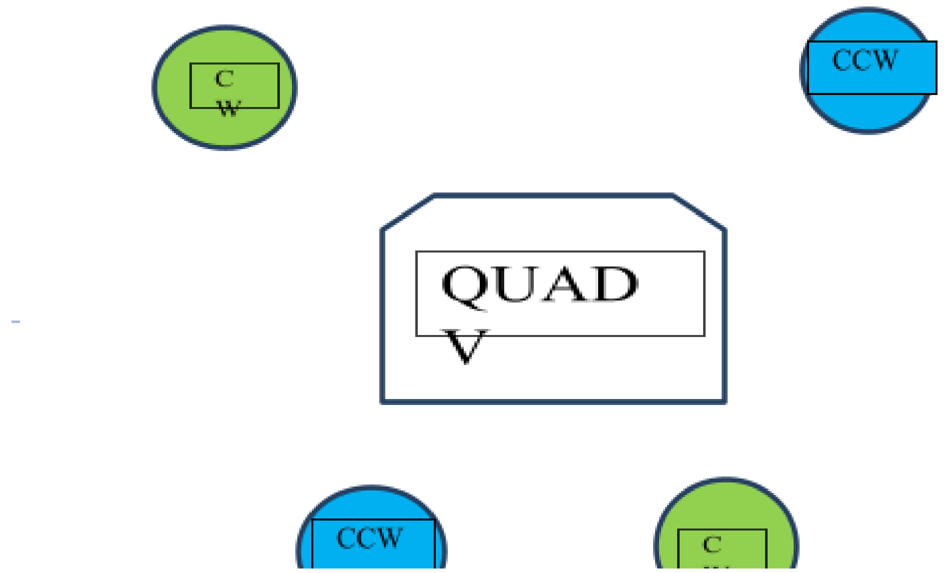


Figure 5: QUAD V formation

1.2 Background of Drone:

The earliest unmanned aircraft war probably hot air balloons. However, these balloons are generally not considered drones, mainly because their flights could be controlled.[5] During World War I, radio control techniques were used to build unmanned aircraft. The first flight of the Hewitt-Sperry Automatic Airplane was in 1917.[5] In 1918 was the first flight of the Kettering Bug, an unmanned aerial torpedo capable of striking ground targets in a range of 120 km, while flying at 80 km/world War I ended before the Kettering Bug could be deployed. After World War I, airplanes were converted into drones. Examples are the Larynx (1927), the Fairy Queen (1931), and the Queen Bee. The name Queen Bee is said to have led to the use of the term 'drone' for pilotless aircraft [5] During World War II, the Radio controlled plane Company manufactured nearly 15,000 drones for the Radio-controlled plane OQ-2 for the US Army.[6] After World War II, drones were also used for purposes other than dropping bombs. The first drone for aerial reconnaissance was the MQM-57 Falconer [5]. During the Vietnam War, the US used Ryan Firebee drones which were developed in 1951.[7]. More than 7000 Firebees were built and, although production ended in 1982, some of them are still in service [5] Firebees were used to lay chaff corridors (radar distraction with thin pieces of aluminum, metalized glassfibre or plastic) during the 2003 invasion of Iraq.[7]

Figure 6 : Radio-controlled plane OQ-2

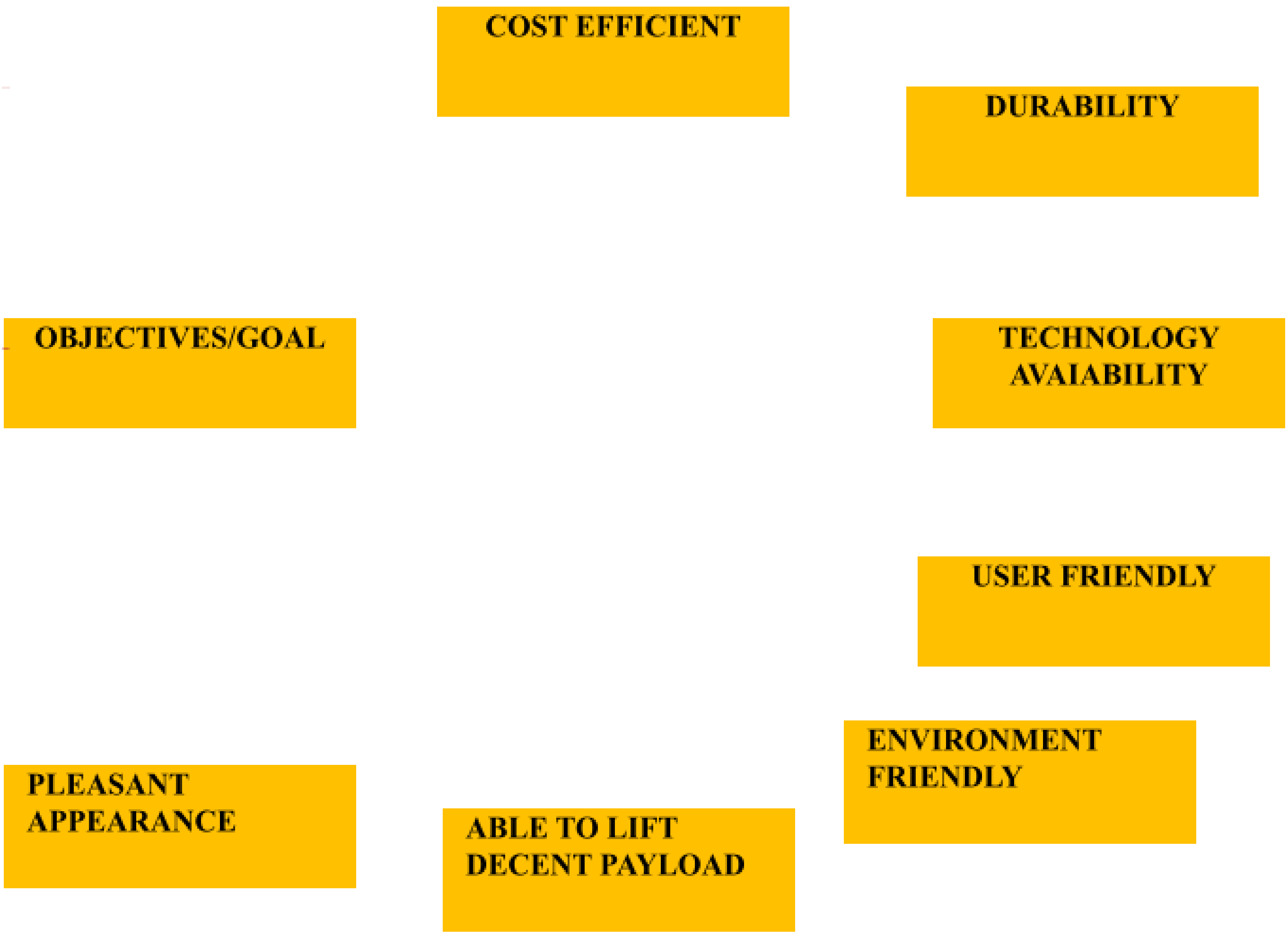
After World war 2, the development of drones started in the US air force as well as the Russian Air force. In the Vietnam war, drones were used but the actual development started in the 80s and 90s. We came to know that the autonomous flight of the drones was initiated by the GPS installation in the drones. The GPS created a connection between the drone with the satellite and travels places following different points.

Figure 7: Modern Drone with GPS

Drones are now being used in different sectors of daily life including the agricultural sector, transportation sector, firefighting sector, surveillance sector along with military sector. There is a vast future for drones in every possible sector. It can replace people and do aerial operations being controlled by the pilot at a distance from hazardous and dangerous places. Different future plans and developments are being planned by different nations and they are developing the drones gradually. We will learn about the future plans and works of the drones in the later part of the book. There is a growing need to use drones with diverse capabilities and various civilian and military applications including search and rescue missions, environmental protection, mailing and delivery, active weapon engagement, space, and marine drones, etc. . This project specifically emphasizes the use of drones in firefighting applications. The time to suppress a high-raised building fire is critical with regard to the fire burden consisting of economic, environmental, and social losses. To decrease the fire burden, currently, drones are used by several fire departments worldwide for search and rescue operations, and for situational awareness assessed by monitoring, detection, diagnosis, and prognosis thanks to the remote-sensing capabilities via incorporated sensors and processing units. Our approach in this research project is similar to throwing fire extinguishing balls into the fire, rather than the latter approach of starting controlled fires. Specifically, the purpose of our study is to use merging technologies concurrently; drones, remote sensing, and so-called fire extinguishing balls to combat wildfires. The proposed system consists of scouting UAS to detect spot fires and monitor the risk of wildfire approaching a building, fences or firefighting crew via remote sensing, communication drones to establish and extend the communication channel between scouting UAS and fire-fighting UAS, and a fire-fighting drone remotely traveling to the waypoints to drop fire extinguishing balls (environmentally friendly, heat-activated suppressants). As forementioned, the development of this proposed system is an ongoing multi-institutional, transdisciplinary research project. This paper illustrates the initial part of the research; controlled experiments to examine the effectiveness and efficiency of fire extinguishing balls.

1.3 Objective or goal of the firefighting drone:

1. The firefighting drone which we will be designing needs to be cost-efficient and it should have to be affordable by the industries and companies.
2. Our main objective is to design, build and do the possible experiments and find the errors which can be developed in the future.
3. Our drone needs to withstand any sort of weather so experiments can be done during windy rainy and dry weather respectively.
4. The technology which we will be using for our drone should be easily available and affordable and import time is quite quick.
5. For the performance objective we want to make sure our drone can lift up enough payload, can move in all directions, and drop the extinguishing ball at an angle avoiding direct airflow to the fire.
6. The appearance of the drone should be pleasant to watch.
7. The controlling of the drone should be easy and the flight controller should be easy to program.
8. We will make the drone environment friendly and it will be less possible to get crushed due to battery loss.
9. Our drone should not be hazardous to residential areas and may not harm birds.



3. Literature Review

Charaf Bennani Karim on April 2020 designed and build a drone by showing the effect of different materials used as the framework like ABS, plastic and wood, and showed different simulations of the drone using different software[8] . Burchan et al. showed us the use of drones assisting to put out wildfire using fire extinguishing balls as a helping part and developing of the traditional firefighting methods.[9] The proposed system was a drone having six arms with a payload weighing around 15 kg and balls of weight 0.5kg each. In the year 2020 Rupali S. Patil designed ahexa copter which was made using pixhawk flight controller and they proposed an approach to use thermal detection of the fire and to use it to guide the drone towards the fire and extinguish the fire by throwing fire extinguishing ball at the fire. . Manuj et al. in 2019 proposed the use of semiautonomous drones for firefighting operations rather than putting the life of firefighter at risk. Dr. Ronald T. et al. in 2018 discussed the concept and issues related to the unmanned aerial systems in the fire service[10]. Emphasis is placed on airworthiness of the

drone, command, and control of the drones and crash avoidance[10]. Unmanned Aerial Vehicles (UAVs) called drones, have gotten a lot of attention in academic research and commercial applications due to their simple structure, ease of operations and low-cost hardware components[11]. Abhishek Ukey in 2016 designed a quadcopter with 10 DOF Arduino having IMU or Inertia measurement unit and they used an accelerometer, and barometer for altitude hold which was classified and they also showed the flight dynamics of the drone in every direction[12]. Osama Jamal Al- zogphy designed a quadcopter and showed the weight distribution and the general equations needed to design and manufacture a quadcopter he also showed the different types of forces that are acting on the drone[13].
Maryna Zharikova in 2018 showed a forest firefighting monitoring system with help of UAVs or drones which will be having a payload of 20kg and can move at a speed of 20 Km/h[14]. We gained the knowledge about the framing work and the components of the drones from the designing and manufacturing of the heavy drones by Charaf bennani Karim. We have studied the other research papers to understand flight dynamics, kinematics and other components of the quadcopter. The components can be divided into two different divisions. One is the mechanical part and the other one is the electrical part. The mechanical part of the components includes the framing, propeller design, shock absorbers and landing gear of the drone. The electrical components are the motors, ESCs , flight controllers, batteries and TX-Rx components. We learned about these components from the research papers. Though some of them didn't think of the cost efficiency and affordability which we cared about at utmost importance.

MH Zakaria in 2020 made a way of producing or designing a drone that will be power efficient by using simulation software varying the battery capacity, pitch of the propeller, and other variable electrical voltages, and current supplied through the motors of the drone[15]. Serhii leinkov on August 2020 showed the designing of a hexacopter using a ATmega2560 and showed the connection of ESC with the BLDC and motors and programming done to fly the drone using ATmega2560.[16] Martin Skriver on 2018 showed a survey on the weighting and different dimensions of the components which are used for making the drone[11]. Omakar Tatale in 2018 designed and tested a quadcopter concluding the formulas and gyroscopic analysis of movements of the drone[4]. Irteja Hasan on 2018 described the problems of firefighting in Bangladesh and the amount of damages that is endured in the last few years due to different fire accidents in the different industrial areas of Bangladesh[17]. Rene Rossi discussed the firefighting processes and effect of direct firefighting by the firefighters causing different types of diseases and the problems faced by the firefighters while they are on direct action against any fire accident[18].

Karthik Balajee gave a review on the SWOT analysis of the quadcopters being used in the modern days in different sectors of our daily life[19][10].

4. SWOT Analysis of the quadcopter

We know the SWOT analysis of any project means to differentiate the strength, weaknesses, opportunities and threats of the project which are estimated or found from the previous research done on the project or the base of the project. So at first we need to talk about the strength of our quadcopter then we will talk about its weaknesses of it then the opportunities and at last we need to talk about the threats of the project.

The strengths are the positive sides of the projects. It is basically the advantages which we will be getting from the quadcopter that we are going to make. The weaknesses show what are the disadvantages or the limitations we may face after the project is being produced. The weaknesses are required to be withdrawn and new advantages are to be implemented in the place of the weaknesses. The opportunity part discusses what are the aspects which can be adopted to do future development of the project. Generally the opportunity of the project discusses the future of the project which can be evolved to some extend by the future researchers. And at last we need to consider the threats which may be occurred by the project. The threats are the hazards which may take part if the project malfunctions or any sort of problem occurs in the systematic operation of the project. The threats are also the negative side of a project which may be rectified or try to be solved by the future researchers for the betterment of the project.

3.1 Strength

The quadcopter can fly over traffic jams which helps the drones to be time-efficient and punctuality is maintained. In case of a fire accident due to traffic jams, the fire trucks are late to arrive at the accident or fire source as a result of this life casualties increase and the damages cannot be minimized. Another strength of the project is that the drones are fuel-efficient and they don’t actually burn any fossil fuel rather they run on a simple Li-po battery. Drones can fly at a low altitude so they can avoid cloud contamination. Drones can be operated in difficult terrains from remote areas where ground or physical forces may not be able to enter.

3.2 Weakness:

Controlling a drone is quite difficult for untrained staff. A simple fluctuation in the controlling panel can cause huge damage to the drone and even to the environment where it is operating and may cause huge financial and physical losses. Legality issue is another problem for operating a drone because in our country Bangladesh we need permission from CIVIL AVIATION AUTHORITY. Without proper license and legal permission, no operations can be operated. Drones have a limited amount of payload a quadcopter with 1000 KV BLDC motors at 100% current can carry only a 2.8 kg payload. So this weight carrying capacity of the drones being very small is a vital limitation of the drones.

3.3 Opportunity

Detection of fire source can be done by the use of thermal sensors and FPV camera which may be fitted to the drones and immediate actions can be taken to extinguish the fire. The drone can be used to carry some of the medical supplements like bandages, injectable saline and medicines, and basic first aid stuff which can help to give a primary aid to the injured people at the spot of the accident. Sometimes oxygen cylinder may be required for people who will be having breathing problems so we can plan to add an oxygen cylinder but again we have the limitation of the weight management and payload of the drone. Drones may be designed to carry both water and extinguishing balls for firefighting purposes. Surveillance in difficult terrains can be done with drones where firefighters may find it difficult to go[10].

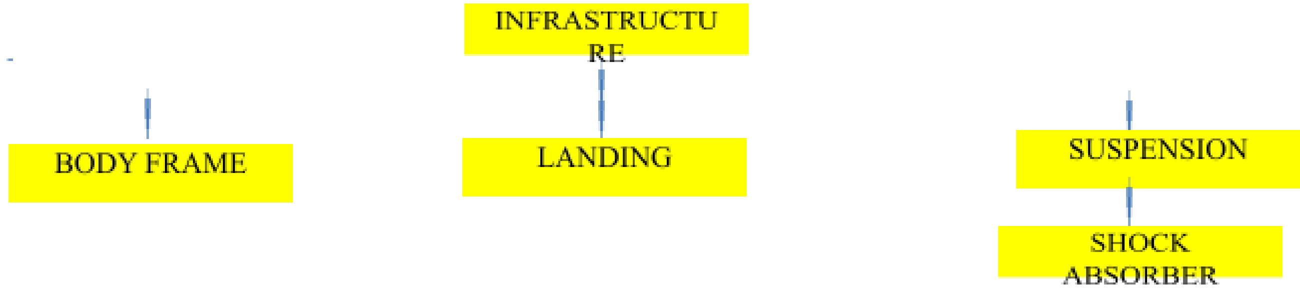
3.4 Threats

The GPS of the drones may get hacked by GPS jammers used by the hackers so due to the loss of GPS the drone may go anywhere and hackers may even capture the drone and take away valuable parts of the drone or even the payload it was carrying. Due to technical faults and an inexperienced pilot, the drone may crash in a residential area which may cause a hazardous situation for the residents of that area. Sometimes birds get hit by the propellers and get injured severely and die. Though drones fly below 400 feet altitude they may cause air congestion and interfere with the airport radar causing signal problems between the radar and the airplanes connected with it. Such interference may cause signal imbalance and planes may crash. That’s why it is forbidden to run any drone near any airport as it interferes with the signals between the radar and the airplanes.

5. Design Methodology

4.1 Infrastructure design

For every project it is the first and foremost job for the initiator to establish a basement or infrastructure of the project. Our project also required a certain step to form the infrastructure of the quadcopter. The infrastructure is the basic formation of the project which includes the body framing , landing gears and the suspension system used to absorb the sudden shock during the landing or any sort of crash to minimize the damage on the quadcopter. So we have divided the infrastructure of our quadcopter into three divisions. The figure below shows the infographic of the infrastructure of out quadcopter.



a. Body Frame

The body frame of the quadcopter need to be light in weight and the melting point of the frame has to be high. So we can have a number of options like mixture of glass fiber and polyamide nylon , carbon fiber and ABS(Acrylonitrile Butadiene Styrene). But we need to see the cost efficiency of the materials as well. The following table will show some comparison of some properties which will be essential to discuss to set the material which will be used for making purpose of the body frame of our quadcopter. After several judgement we will be able to understand which material we should choose.

TABLE-1 Comparison of Body frame materials

MATERIALS PROPERTIES	Glass Fiber + Polyamide nylon	Carbon Fiber	ABS	UNIT
MELTING POINT	300	3652	200	°C

YOUNGS MODULUS	2.26	183	1.79	GPa
THERMAL CONDUCTIVITY	**0.05**	1000	0.14	W/mK
DENSITY	2440	1750	940	kg/m3
TENSILE STRENGTH	0.0799	3.5	0.028	GPa
COST (FRAME)	1800	3900	900	Taka

We can see from the table that we should select the carbon fiber since its melting point is quite high than the other materials. Though the thermal conductivity of the material is quite high compared to the other materials. The cost of the carbon fiber is quite high and it won't be feasible to do prototyping with the material. The ABS material has the lowest melting point so it is not suitable for the framing work. So we will be selecting the composite material of Glass fiber with polyamide nylon. But we can't afford a high percentage of glass fiber so we can see some graph stating percentages of polyamide with glass fiber affecting different properties of the materials.

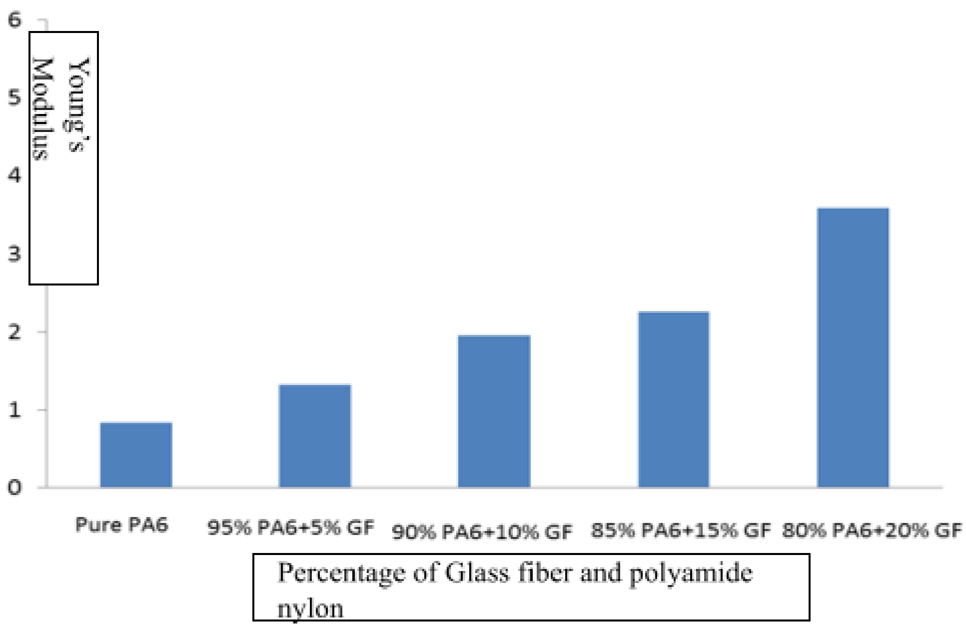


Figure 8 : Comparison of Young's Modulus of different compositions of glass fiber and Nylon[20]

It is observed that 85 % PA6 + 15 % GF composite shows an increased elastic modulus 2.26 GPa which is about 169 % higher than that of pure nylon[20]. So we think we can use the 85%

polyamide nylon and 15% of the glass fiber for a better Young's Modulus compared to that of the ABS. We know Young's Modulus = Stress/ Strain. Now we move forward and see the graph for different combination of polyamide and glass fiber for the tensile strength.

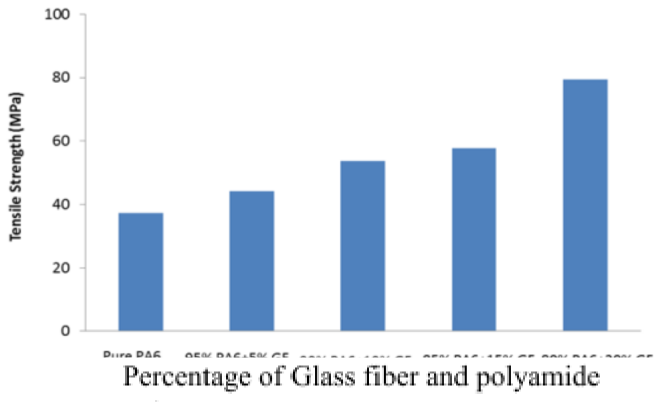


Figure 9: Comparison of Young's Modulus of different compositions of glass fiber and Nylon

It is observed that 80% PA6 + 20% GF composite shows a significantly increased tensile strength 79.5 MPa which is about 113% higher than that of pure nylon[20]. So we can see that by comparing different factors we can select the combination of the glass fiber and the polyamide nylon possibly 80% Polyamide and 20% Glass fiber. So we came up with a ready-made product named DJI F450 quadcopter frame which contains a composite of high-quality glass fiber and polyamide.

Figure 10: DJI F450 quadcopter frame

We also drew the frame in solid Works so that we can understand the dimensions and the placements of our electrical and electronic substances. We will be showing the drawing and the sheet diagram of the frame with the necessary dimensions. The dimensions may vary a bit due to the corrections done by the solid works but more or else it will be almost the same. Figure 11 shows the isometric view of the frame with glossy red material and figure 12 shows the sheet diagram with necessary views like the top, front , right and isometric views and dimensions.

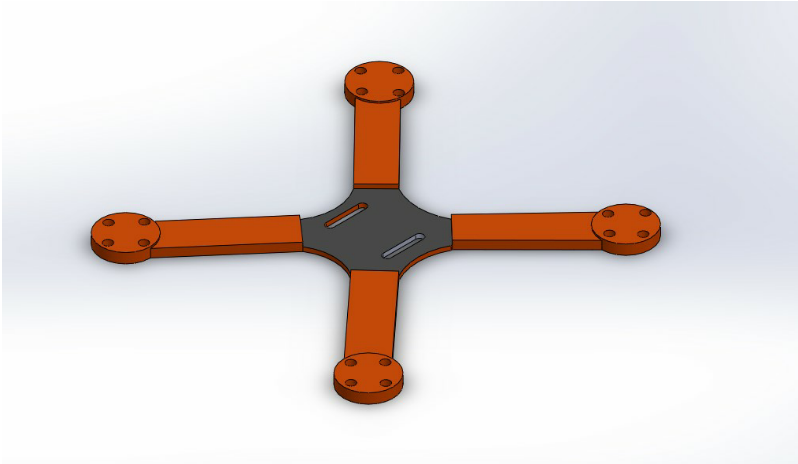


Figure 11: Isometric view of the frame in solid works

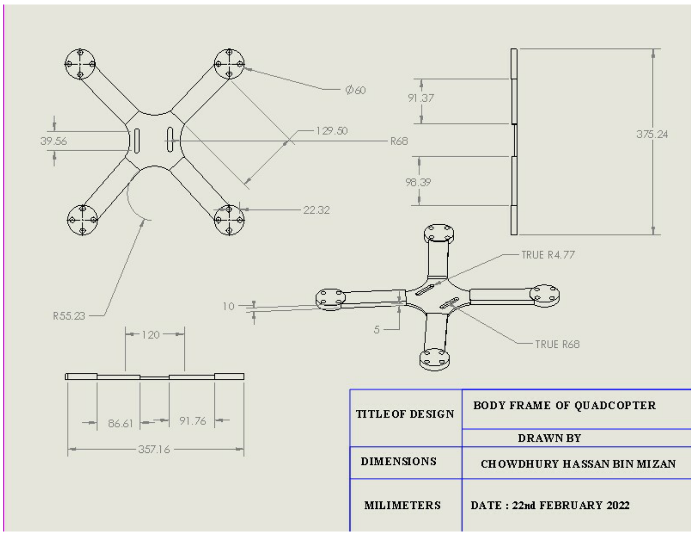


Figure 12: Sheet Diagram of the frame with necessary views and dimensions

b. Landing Gear:

Generally, the DJI F450 has its own landing part of about 6 cm but that won't be enough for the quadcopter we are making because we will have to add a dropping mechanism with the quadcopter which will eventually require a good amount of space at the bottom part of the quadcopter. So we decided to find out the compatible landing gears with the frame that we are going to buy which is the DJI F450. Figure 13 shows the four arms which is compatible with the DJI F450 quadcopter frame. It has a pack of 4 landing gears curved and it is made of the same material as used for the framing work which is the glass fiber and the polyamide mixture.

Figure 13: Landing gear compatible with DJI F450 frame

For connecting the 4 landing gears we were given 8 M2.5 screws which are basically hexagonal screws and a special L-shaped screwdriver is used for tightening up the screws. Figure 14 will show the screws which we used to connect the landing gear with the frame. We will also show the special type screw driver for tightening up the screws.

Figure 14: M2.5 screw and L hexagonal screw driver

c. Suspension System (Shock absorber)

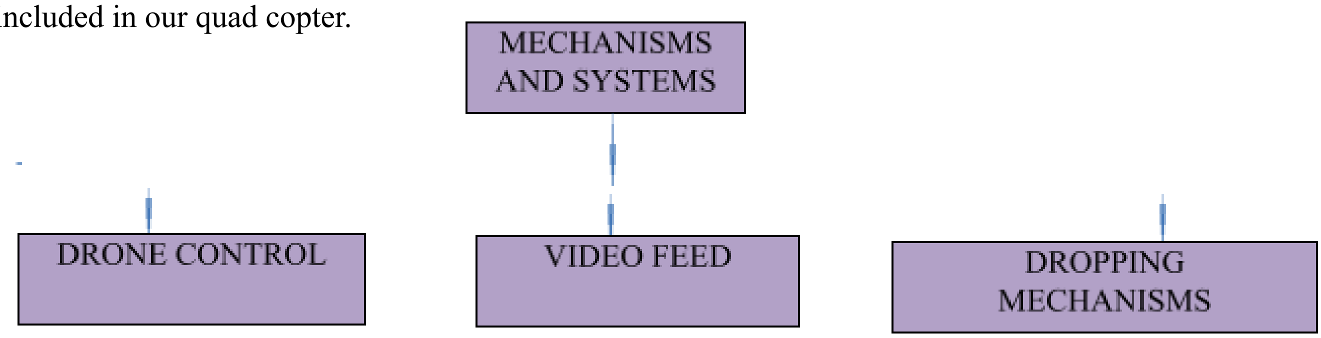
Generally, we have a strong landing gear at the bottom of the quadcopter but for the flight controller we need a shock absorber to absorb the reaction force when the quadcopter lands on the ground. Direct force on the flight controller may seriously damage the flight controller and may cause malfunctions. We will be showing the shock absorber which can be used for any type of flight controller to safe guard it from sudden force. Figure 15 shows the shock absorber we used for our suspension system.

Figure 15: Shock Absorber for flight controller

The shock absorber also saves the flight controller from vibration due to the motors and the material of the shock absorber is high-quality glass fiber which gives good temperature control and don't get heat up easily.

4.2 Mechanism and Control System Block Diagrams

After putting a basement of the quadcopter we can move forward to make the mechanisms that will be included in the quadcopter. Generally, we have three systems that we want to include in our drone we have created an infographic for the divisions of the mechanisms which are being included in our quad copter.



a. Drone control system:

The main mechanism or system which we need to focus on is drone controlling. The drone controlling section includes the throttle, landing, right and left turn, and nose turning of the drone. We have created a block diagram of how the drone is being controlled and the full setup of controlling the drone starting from the pilot to the drone. The pilot will be carrying the transmitter or TX and the receiver part or RX is connected to the quadcopter which is further connected to the flight controller of the quadcopter. We have drawn an infographic for the control system of the quadcopter. We also showed a control system we researched from different research papers.

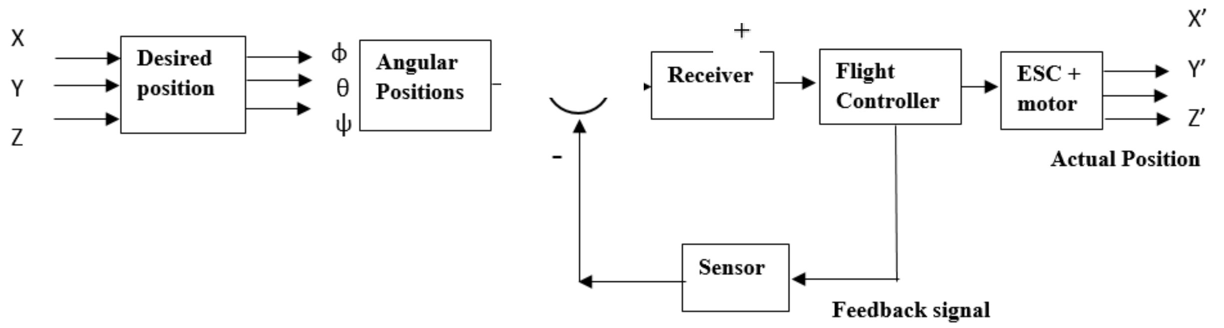


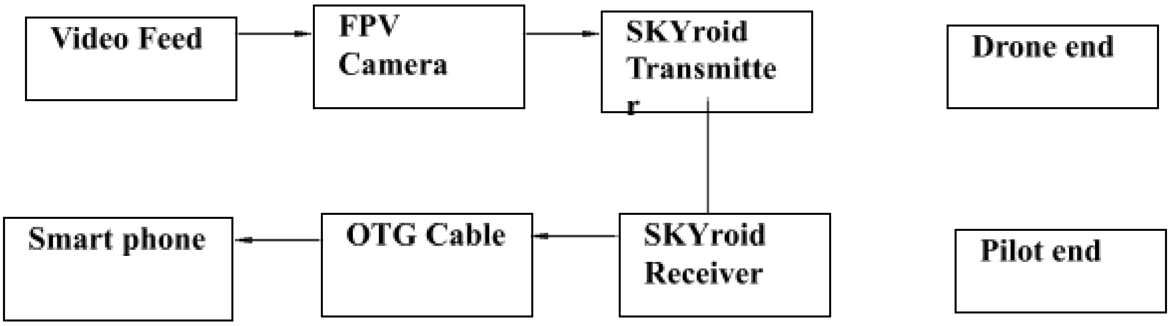
Figure 16 : Control System

Here the X,Y,Z are the translational positions which are our desired positions for pitch, roll and yaw of the quadcopter. The translational positions are converted into angular positions then signals are sent from the transmitter to the receiver placed in the quadcopter then the flight controller takes the signal and use the sensors to send signal to the signal accumulator to get repetitive signal and the feedback signal is sent to the sensors of the flight controller. Then from the output we get the actual translational position X',Y' and Z'. We will learn more from the Newton-Eulers Kinematics model to know about the angular positions of the quadcopter. Comparing with a simple control system we can see that the reference signal is being sent from the transmitter as translational position later on as angular positions. The receiver acts as the actuator of the control system and sensors are in the flight controller placed in the quadcopter and sends feedback to the receiver to see if the desired signal is close enough to the actual signal or position that has been acquired. All DOFs are covered by the linear and angular orientation vectors of the quadcopter, thus it can be seen that the quadcopter has four inputs from the rotor propellers and six state outputs of the dynamic and complex system[21].Later on this chapter we will be knowing about the video transfer process and the dropping mechanism of the quadcopter. We will be seeing the flow diagram of how the video feed is being captured and how the dropping mechanism is working at a certain distance.

b. **Video feeding system**

An important part of the quadcopter is the video feeding of the camera. The camera is the eye of the pilot with which he can search for fire source and drop fire extinguishing balls on the fire to extinguish it. We have drawn a simple flow diagram of the signal passage from the transmitter part that is the pilot end and the drone part where the camera will be placed.

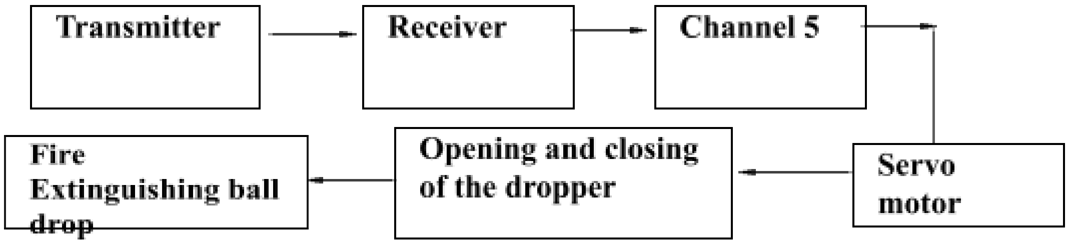
Figure 17: Skyroid FPV Camera with transmitter and receiver



So it's a very simple system and we don't need to get into any specific network under any Wi-Fi range to get video feed from the drone. The receiver end is now in the pilot end in case of the video feed system but the transmitter of the video feed is in the drone but in case of the controlling system the whole system was different and actually it was opposite. The transmitter was in the hand of the pilot and the receiver part was in the drone so the signal from the transmitter is sent to the receiver in the drone and uses the signal to fly around . the last subsection of the system is the dropping system we will now discuss about it.

c. Dropping system

Another most important part of the drone is the dropping system. The main purpose of the firefighting drone is the dropping of the dire extinguishing balls which will be thrown in to the fire. We will be using one of the channels of the receiver to rotate a servo motor. The servo motor will act as an actuator for our dropping mechanism. The dropping part will be slanted so that the fire extinguishing ball falls at an angle and looks similar of the throwing mechanism. We are using angle to get a thrust over the fire extinguishing ball. So we are taking Channel number 5 of the receiver for the servo motor. We are showing a simple flow diagram of signals which is over simplified to understand the working process of the dropping system.



We will learn more about the designing process of the dropping mechanism in the later chapter of our book. We will show some illustrations of how the dropping mechanism works and also we made some solid work files of the dropping mechanism with dimensions that must not exceed the space made by our landing gear. We hope the simple flow diagram shown above gives a clear knowledge about the dropping mechanism and the working procedure which is being followed by the pilot and the drone to execute any dropping operation using the quadcopter.

5. Flight Dynamics

5.1 Six degree of freedom (6 DOF)

We can divide the six degree of freedoms of the quadcopter into two major divisions. One of the division shows the translational movements which are basically the movement of the quadcopter in X-axis , Y- Axis and Z-axis. And the second division of the six degree of freedom of the quadcopter contains the rotation of the quadcopter along the X , Y and Z axis. They are known as the roll , pitch and Yaw movement of the quadcopter. Figure 18 will show us the roll, pitch and yaw movement of the quadcopter.

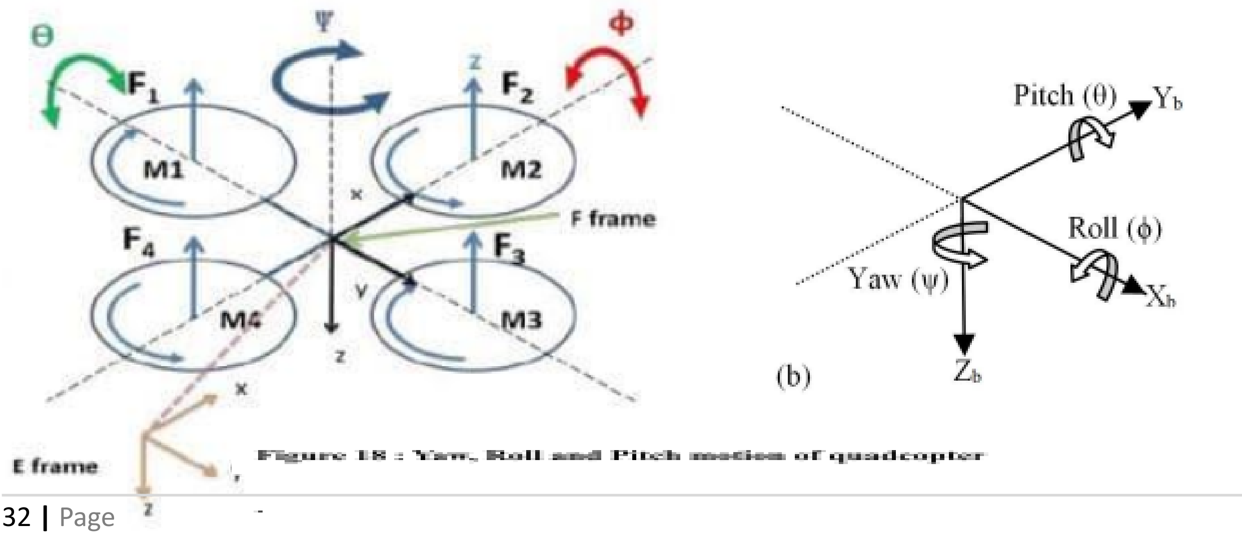


Figure 18 : Yaw, Roll and Pitch motion of quadcopter

[13][4]

Yaw Motion (ψ): The rotation of the quadcopter around the vertical axis is called Yaw.
Roll Motion (Φ): The rotation of the quadcopter around the front-to-back axis is called Roll.

Pitch Motion (ɵ): The Rotation of the quadcopter around the side to side axis is called Pitch.

Z-axis movement is generally the take-off and the landing of the quadcopter.

Y-axis movements are the left and right movements assuming translational movement.

X-axis movement is the forward and backward translational movement.

5.2 Take-off and landing movement

The take-off and landing of the quadcopter is controlled by increasing or decreasing speed of four rotors simultaneously which means changing the vertical motion[4]. So when all the four motors are rotating at a high speed then the quadcopter moves upward in the Z direction and when the speed of the motors are reduced the quadcopter comes down and lands on the ground automatically. The figure 19 will demonstrate the taking-off and landing of the drone.

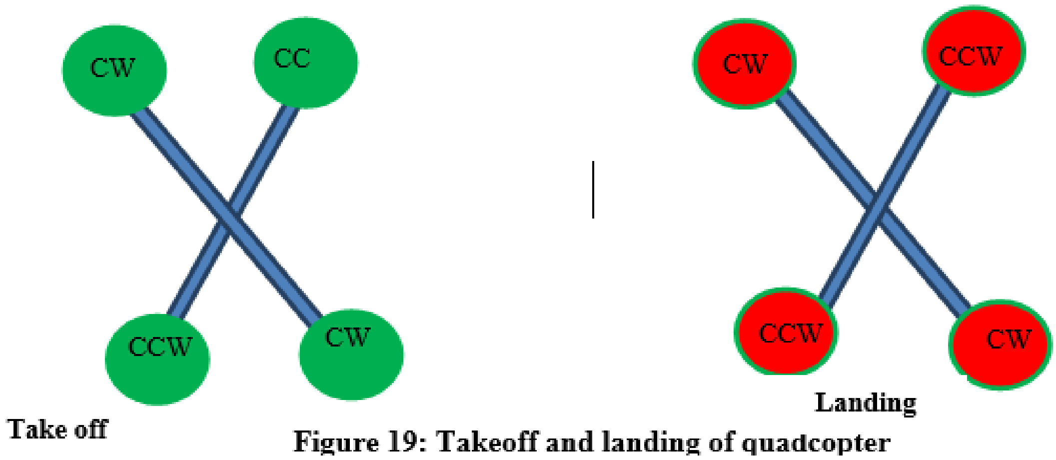


Figure 19: Takeoff and landing of quadcopter

We assume as increasing speed and as decreasing speed. So here we are making a Quad X so the diagonal motors will be same and here w[illegible] to increasing of the speed the drone takes off and when we decrease the speed the drone lands on the ground.

5.3 Forward and Backward Motion (Pitch control)

Forward and backward motion is controlled by increasing or decreasing the speed of the rear or front motor[4]. The pitch angle ɵ is being changed gradually by increasing and decreasing the speed of the rear side motors and front side motors. We will Demonstrate the forward and backward motion of the drone by figure 20.

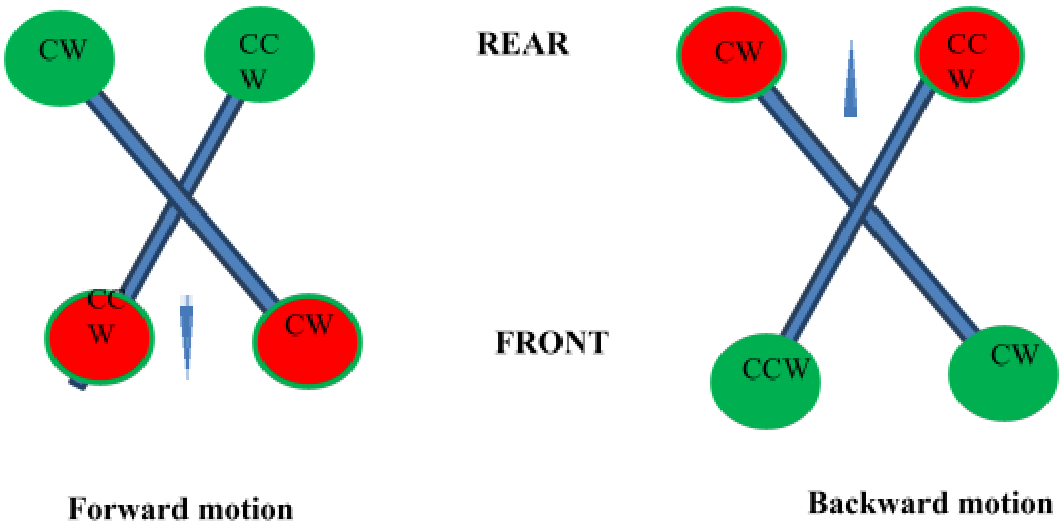


Figure 20 : Forward and backward motion of quadcopter

So in case of the forward motion the front motors will rotate faster than the motors of the rear end and there will be an angle of rotation along the axis which will cause the front side to go down and the rear side to go up and eventually the drone will be moving forward. Uite similar case for the backward direction in this case the rear motors will rotate with more speed then the frontal motors and the drone leans towards the backward direction and the pitch angle again creates the rotation along the axis.

5.4 Left and right motion (roll control)

When the quadcopter wants to bend in left or right direction of quadcopter then it is controlled by changing the roll angle Φ[4]. In case of the left turning of the quadcopter the right side motors will be having increasing speed then the left side motors of the quadcopter. And when we want to have a right side turn then the left side motors will be having more speed than the right side motors. The roll angle is the angle of rotation along the X axis. So the more rolling angle is got due to imbalance of speed from the both side. We will show the demonstration of the left turn and right turn of the drone in the figure 21.

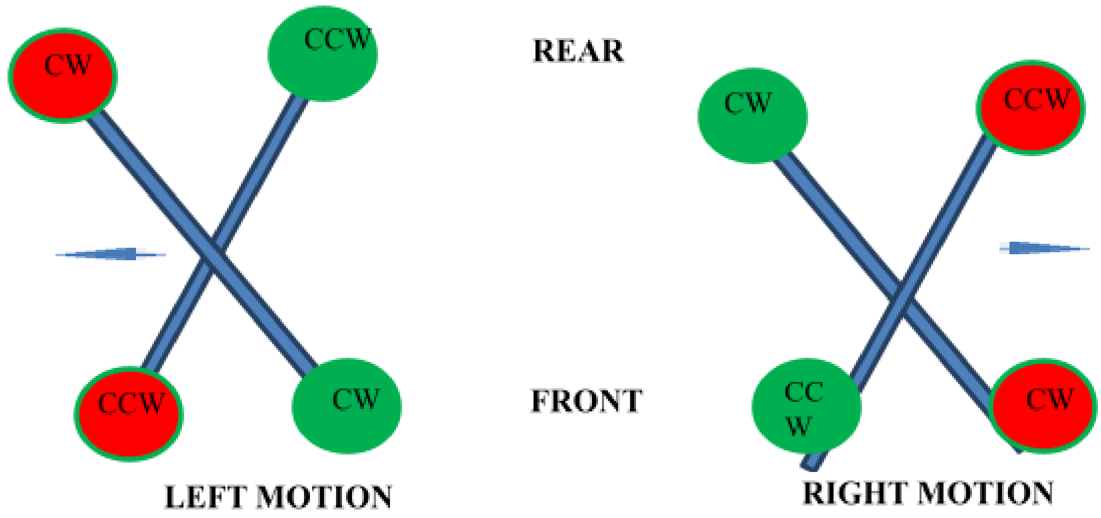


Figure 21: Left turn and Right Motion of quadcopter

5.5 Rotation on left and right (yaw control)

In this motion, we take about the rotation of the quadcopter along the vertical axis or the Z-axis. The diagonal propellers rotate in the same direction and changing the speed of the diagonal motors can cause the rotation along the vertical axis. We will try to demonstrate the Rotation on the left side as well as the rotation towards the right side in figure-22. So if the clockwise rotating motors run slowly compared to the counterclockwise rotating motors then we will see that the drone is rotating in the left direction. So the Yaw angle rotates towards the left side and causes the drone to rotate towards the left side. Again when the clockwise rotating motors are rotating faster than that of the counterclockwise rotating motors we can say that the drone will rotate right along the Z Z-axisThe yaw angle is rotating along the z-axis and it rotates in the right direction and as a result of this, the drone will be rotating in the right direction. Yaw angle is controlled by increasing /decreasing counterclockwise or decreasing /increasing clockwise rotor speed[4].

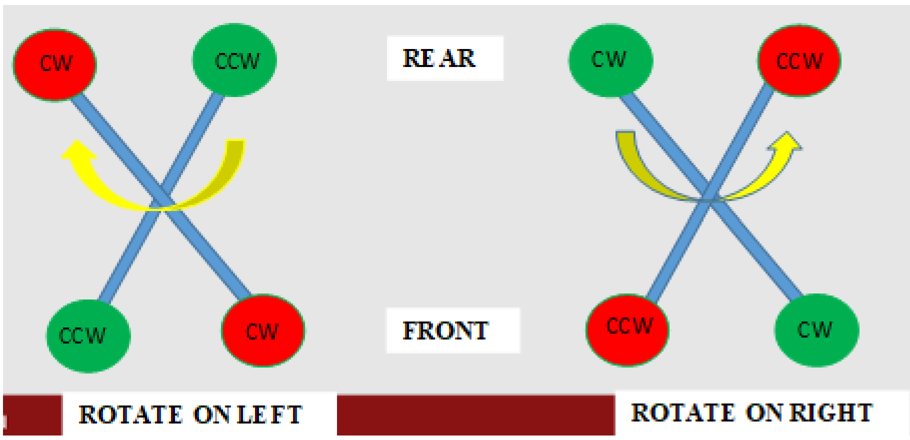
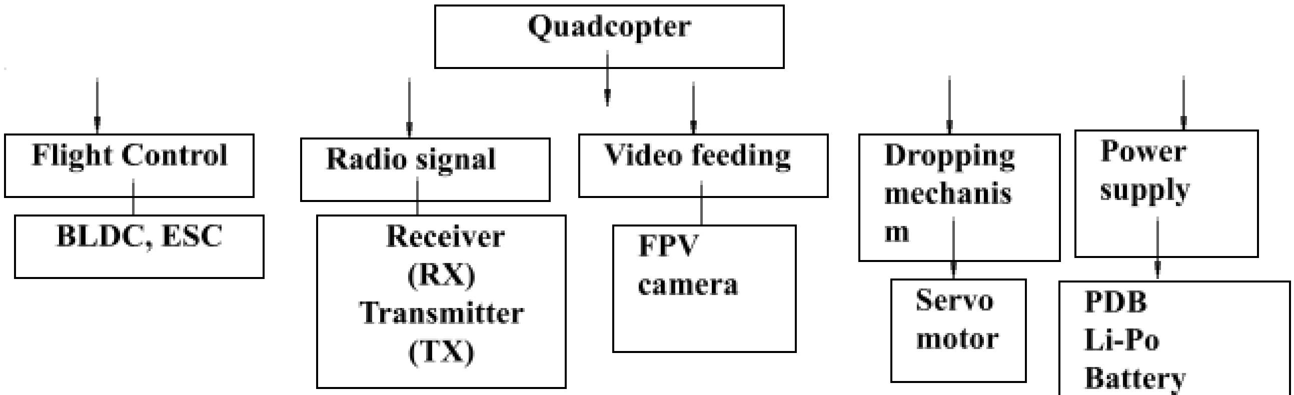


Figure 22: Left and Right rotation of quadcopter

6. Electronic Components and connections

After the mechanical designing of the frame, landing gear and dropping mechanism we came to learn about the electrical part of the drone. The electrical and electronic components give the drone a life. We can divide the electrical components of the quadcopter into some parts. The division of the electrical and electronic components are done based on the functions. Basically the functions are quite simple. There are functions like flight, radio control, video feeding and the dropping mechanism. So we can divide the quadcopter in a hierarchical infographic form. The following infographic will show us the division of the electrical and electronic components based on their functions.



6.1 BLDC motors and ESCs

BLDC motors are the Brushless Direct Current motors which gives a high speed and can give a good amount of thrusts. They are generally marked as KV in the local markets. The KV rating indicates how fast the motor will spin (RPM) when 1V voltage is applied[13]. Lower the KV gives more thrusts. Drones generally use brushless DC motors, as they provide thrust-to-weight ratios superior to DC motors[13]. For cost efficiency we bought 1000 KV BLDC motors which could give up to 745 gm thrust when connected to 3S batteries of 11.1 V with 1045 propellers. The motor comes with 3 wires one is for the positive end another one for the negative end and we also have a wire for the signal to be passed through the BLDC so that it can get the signal to rotate clockwise or counterclockwise. We also have shaft which can be tighten with the rotating one and a pyramidal shaped or cone shaped bolt which can be used to tighten the propeller with the BLDC. We are choosing the A2212/13T 1000KV BLDC Motor. Lets see its specifications.

Table-2 : Specifications of BLDC Motors

Dimension	27.5*28 mm
Shaft Diameter	3.17mm

Efficiency	80%
Current range	4-10A
Thrust with 1045 propeller	745 gm

Figure 23: A2212/13T 1000 KV BLDC motor with mounting

Now lets talk about ESCs which are the most important part of the connections of the BLDC motors with the flight controller. ESC or an electronic speed controller is a device installed in a drone or Rc car to control the speed and direction of a brushless motor[8]. The ESC has two input for power and 3 input from the flight controller and three outputs for the BLDC motor. Generally the ESCs are marked or denoted by A we are choosing a 30A ESC which is from Simonk brand a typical Chinese brand which supplies this electronic part. ESCs must be chosen to ensure that they can provide enough current for the motors. We know that our motors can take 10A of current but we want to ensure that our motor is getting enough current that's why we will be using 30A ESCs. Figure 24 shows the 30A Simonk ESC which we will need 4 of them though we can also run the 4 BLDCs with only 2 ESCs. But for better performance and preventing burnout of the ESCs we are using 4 ESCs for 4 BLDC motors.

Figure 24: 30A Simonk ESC

Though we are talking about the electrical and electronic part we need to talk about the propeller which will be tighten to our BLDC shaft. So we researched a bit and discussing different factors like cost and thrust we come to an end of selecting a 1045 propeller. The 10 in 1045 means the length is 10 inch and the 45 means the pitch is the 4.5 inch. So for the 1000KV BLDC 1045 propeller creates a thrust of 745 gm and 0845 propellers can give a thrust of 475 gm at a power of 11.1V of 3S battery. The Shaft hole is 6mm and we are provided with washers to tighten the propeller shaft with the shaft of the BLDC. The material is plastic though its for a prototyping we also have the carbon fiber propeller in mind which gives more thrust but its costlier than the 1045 propeller. Figure 25 will show the image of the 1045 propeller.

Figure 25: 1045 Propeller set of CW and CCW

6.2 Transmitter and Receiver:

The most important part of controlling a drone is having a good pair of transmitter and receiver. The transmitter is the control panel which remains in the hand of a pilot and the transmitter has 2 set of joystick. Generally, the left joystick is used for the engaging of the transmitter and maintaining the throttle of the motors during take off and landing of the drone. The joystick at the right side works for controlling the movement of the drone in forward, backward , right and left directions. There are also some switches at the top of the transmitter , we can switch the mode of flight by it. And the switches on the left side are for the servo controls on channel 5 and 6 respectively. And the receiver is the most important part of receiving the signal from the transmitter and send the necessary signal or data to the flight controller so that the flight controller can send necessary signal to the ESCs and advise the motors to run accordingly. We are using a six Channel transmitter receiver set. It has some specifications we need to look for and its ideal for quadcopters or planes or remote controlled helicopters. The nest table will show us the specifications of the FlySky FS – i6 6 channel RF transmitter and receiver set. The receiver part is denoted by FS-iA6B.

Table-3 : Specifications of the Flysky FS i6 and FS-iA6B

Channels	6
RF range	2.40-2.48 GHz
Bandwidth	500 KHz
Transmitter Weight	392 gm
Transmitter dimension	174x89x190mm
Control range	500 m
Receiver Dimensions	47x26.2x15mm
Receiver weight	14.9 gm
Antenna length	26mm x 2
Power to run transmitter	6V
Receiver Sensitivity	-105 dbm

We have known about the specification about FlySky i6 now we can see the set in figure 26.

Figure: FlySky i6 RF transmitter and receiver

6.3 Flight Controller

Flight controller is the brain of the drone. Generally the flight controller contains a microprocessor unit which processes the signals which are got from the receiver end and after proper calculation gives a processed data which is understandable by the ESCs. Then the ESCs send the signals to the BLDC motors to run accordingly. The flight controller helps in the maneuvering operations of the drone and also it provides auto altitude hold mode. The accelerometer and gyroscope sensors in the Flight controller process the signals from the receiver and givehe output to the ESC[3]. We wanted the altitude hold mode for our drone so we need to select a flight controller which has a barometer in it. The barometer can calculate the height or altitude of the drone where it is staying and can maintain a fixed height depending on the throttle increase or decrease. We have studied about two of the most common flight controllers which are being used in making of drones. One is the APM 2.8 ArduPilot and KK2.1.5 flight controller. We will briefly discuss about the specifications and a comparison between them.

a. APM 2.8 Flight Controller

APM 2.8 is one of the most advanced flight controller. Generally there are two types of APM 2.8. One is the sidepin flight controller and other one is the straight pin flight controller. The Side pin flight controller is known as the Ardupilot and the straight pin flight controller is the Ardu copter type flight controller. The features of the APM 2.8 Ardupilot are given below-:

I. 6 DOF Accelerometer
II. A high performance barometer
III. 4 Mb data flash chip for data logging
IV. Optional off-board GPS
V. ATMEGA2560 chip

Due to having Barometer it can judge the height or altitude and can give the drone an altitude hold mode which is very essential for the fire fighting drone. Figure 27 shows the APM 2.8 Ardu pilot Flight controller.

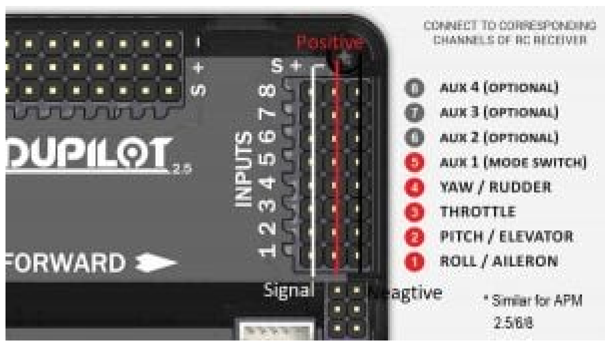


Figure 27: APM 2.8 Ardupilot Flight controller with connection pins

The Forward arrow shows the forward part of the drone basically that's the frontal part of the drone. We have an offboard GPS system but after 2016 the GPS doesn't work that much good but the overall performance of Ardupilot is good. For calibration we need to download a software named mission planner and download a firmware and just put then on the board and we are good to go.

b. KK2.1.5 Flight Controller

The KK2.1.5 is the flight controller which is used for multirotor aircrafts. It has a 6050 MPU which micro processing Unit which is a vital point of it. The flight controller takes input of the roll, pitch and yaw of the drone as given through the receiver which is the desired one. The MPU passes the signal to ATMEGA 644PA IC chip which processes the signal according to the conditions set for the type of the aircraft. The features and specifications which are required to know about the KK2.1.5 are given below.

Size: 50x50x12 mm

Weight : 21 grams

Input Voltage: 6V

Signal from Receiver : 4 Channels

Display : LCD display

IC : ATMEGA644 PA

Figure 28 shows the KK2.1.5 flight controller.

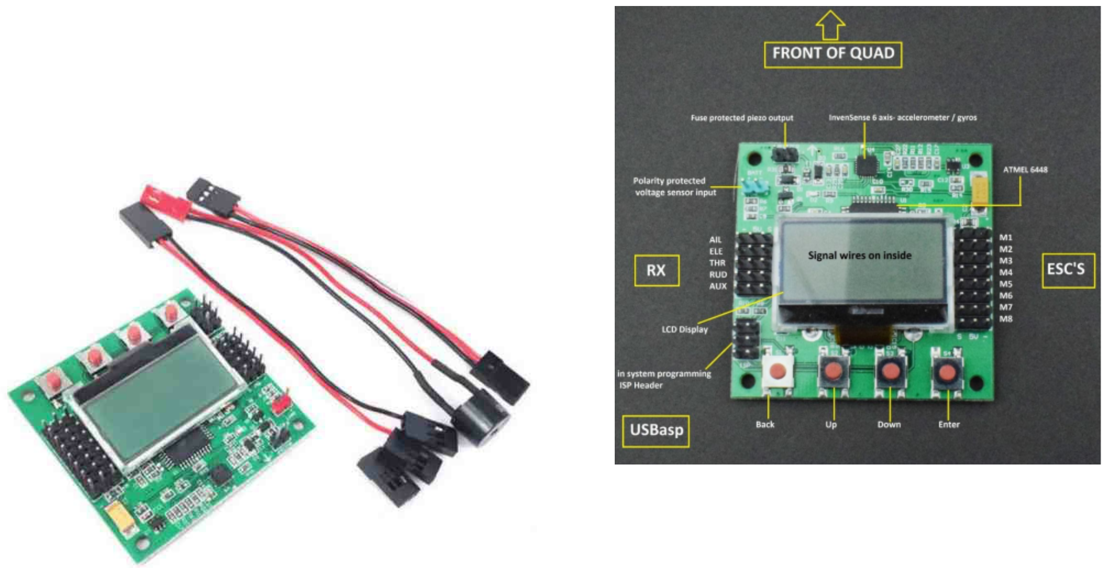


Figure 28: KK2.1.5 Flight controller with connection pins[22]

The kk2.1.5 can be calibrated by using the buttons given on the flight controller using the LCD display. The display shows most of the options which we need and after selection we can use it for flying our drone and its quite simple.

Table-4 :Comparison between APM 2.8 and KK2.1.5 flight controller.

Features	APM2.8 Ardupilot	KK2.1.5
GPS	Yes	No
Telemetry	Yes	No
On board firmware	No	Yes
Barometer	Yes	No
Channels Required	5	4
IC used	ATMEGA2560	ATMEGA644 PA
Altitude Hold	Yes	No
Cost	3900 taka	1850 taka

So comparing the features of the two flight controllers we can say that the APM 2.8 ArduPilot is much better than the KK2.1.5 flight controller. Though the price of KK2.1.5 is much less but for better performance we suggest to use the APM 2.8 Ardupilot which has side pins.

6.4 Li-Po batteries and charger

Li-Po batteries are the most common type of batteries used for making of RC products. They are generally 3S batteries which means 3 batteries are connected in series. So each of the cell is 3.7V and when they are connected in series the total voltage of the battery becomes 3.7x3 =11.1V. We are using two 1100 mAh battery they are connected in parallel so that we get a good ampere here. The lipo battery is charged by B3 charger which can give output up to 800x3 = 2400 mAh.
Some specifications about the Li-po battery we are usin :
Battery capacity : 1100 mAh Discharge rate : 25C Charging rate : 5C Voltage : 11.1V Plug : T port

Figure 29: 3S Li-Po Batter and B3 Li-Po charger

6.5 Power Distribution Board and FPV camera

The PDB or the power distribution board comes with the DJI F450 frame which has 4 ports for 4 ESCs and the main power input can be taken from one part of the board. We can also take the power required for the camera from the board. Figure 30 shows the PDB which comes with the frame.

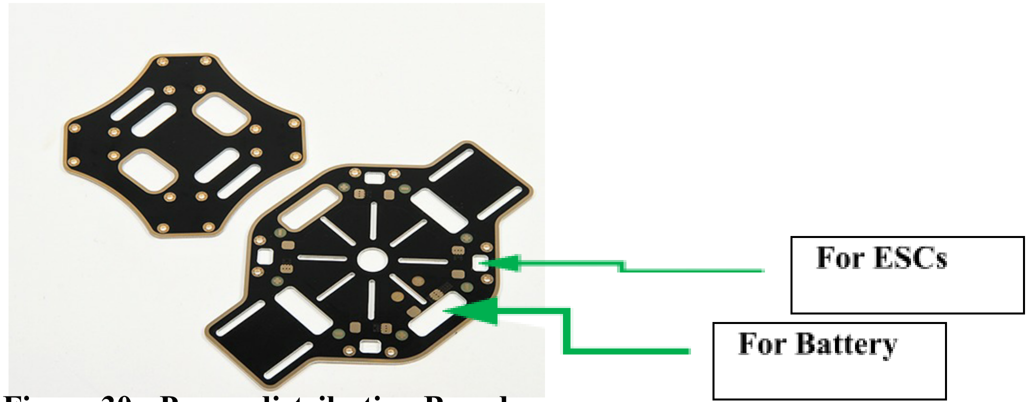


Figure 30 : Power distribution Board

For surveillance purpose we have the Skyroid wireless transmitter and receiver FPV camera. The Transmitter part of the camera remains in the frame of the drone and power is taken from the PDB. For the receiver end we can connect the receiver with our smartphone or laptop using an OTG cable and see the video. We have showed the set of the FPV camera in the figure 17 where we can see the transmitter and the receiver part of the FPV camera set.

After all these components we also need some tools which are essential for making the drone. This includes soldering iron, soldering wire, screw driver set , pliers , hot glue gun. Hot glue stick and sharp cutter.

6.6 Circuit Diagram of the quadcopter

In figure 31 we can see the circuit diagram of the quadcopter which we need to follow to make the drone.

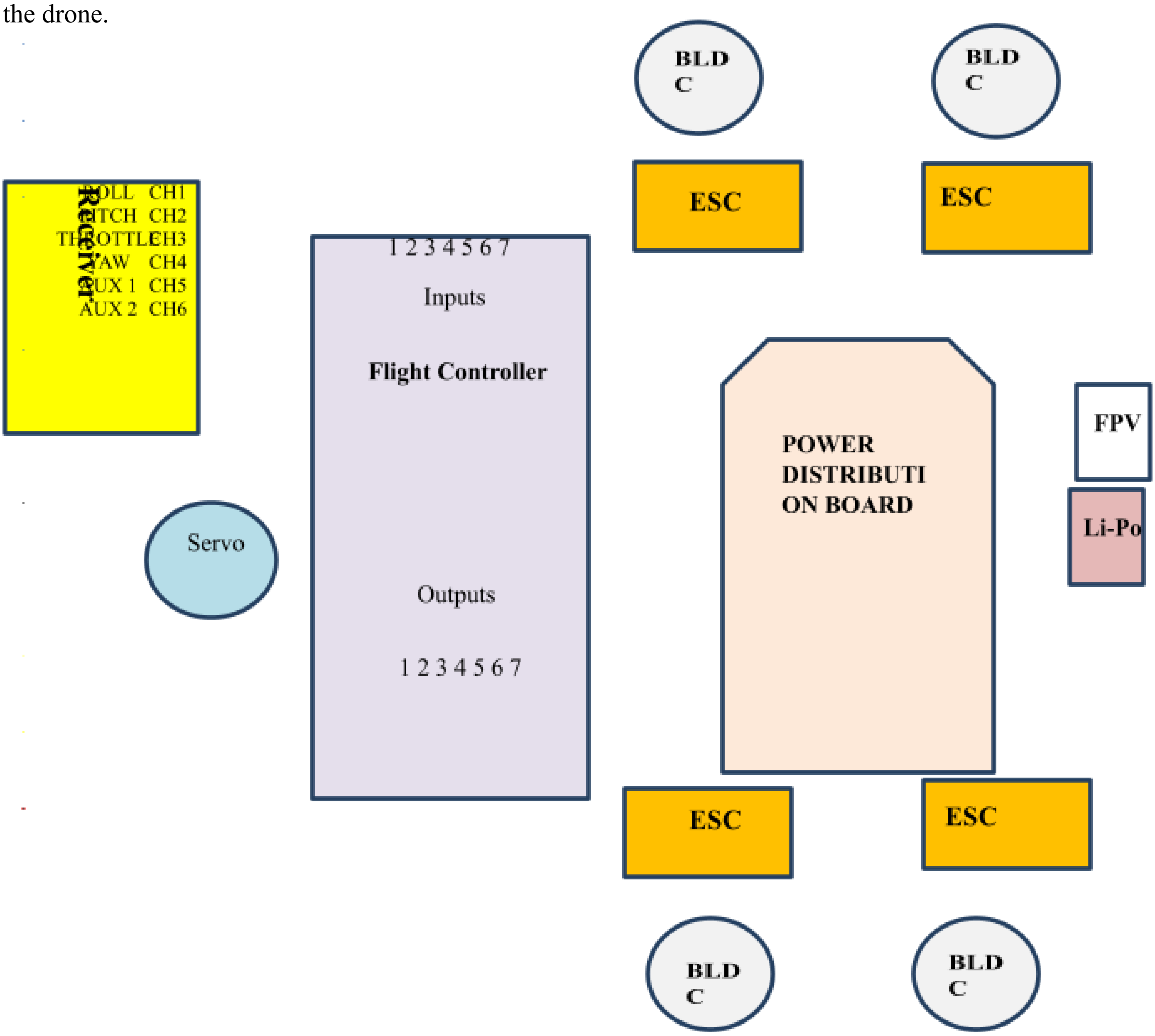


Figure 31: Circuit Diagram of quadcopter

7. Calibration of flight controllers

Calibration of flight controllers means the installation of required firmware and selectin of type of quadcopter type so that the drone can adjust its coordinates during flight. The calibration of the flight controller is the most important part since it helps the MCU of the flight controller to process the signal which is used to convert signals for the ESCs and later on adjusting the rotational direction and the speed of the rotors. We learned about 2 different types of flight controller from the previous chapter. In this chapter we will learn to calibrate the flight controller with our requirements.

7.1 Calibration of APM 2.8 ArduPilot

APM 2.8 Ardupilot requires a firmware to be installed from PC or laptop using an open source software name Mission Planner which is easily available on the internet. We need to connect the Arm 2.8 with our PC or laptop with microSD USB port. After connecting the Laptop will show the board as Arduino Mega. We need to select the port COMP 34 for installing the firmware in the flight controller. We download the Mission Planner and install it on our PCs. Then while initiating a command prompt may arrive like figure 32

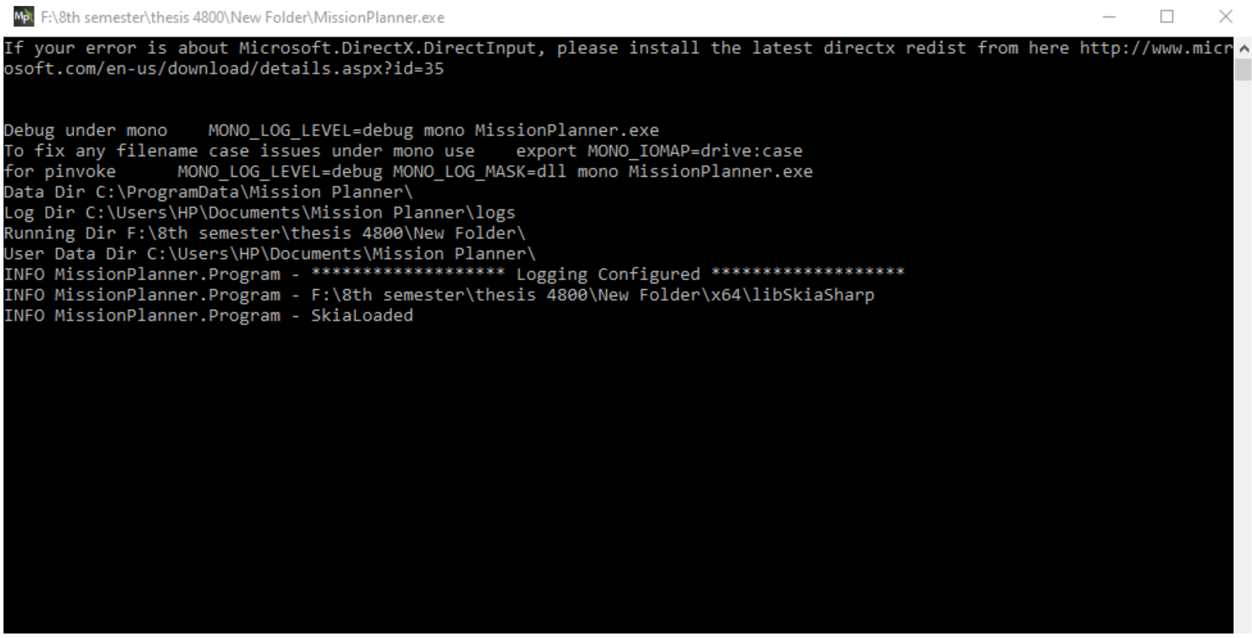


Figure 32: Initializing Mission Planner

After that we will see a software interface which will have different options for planning, simulation and other configuration. Figure 33 shows the interface of the mission Planner.

Figure 33: Mission Planner software

After opening we go to the setup option of the software and install the firmware on our flight controller board. For installing the firmware we need to select the type of multirotor we will be using. We will select the quad X format which is the version V4.1.5 official. Figure 34 will show the demonstration of the installation.

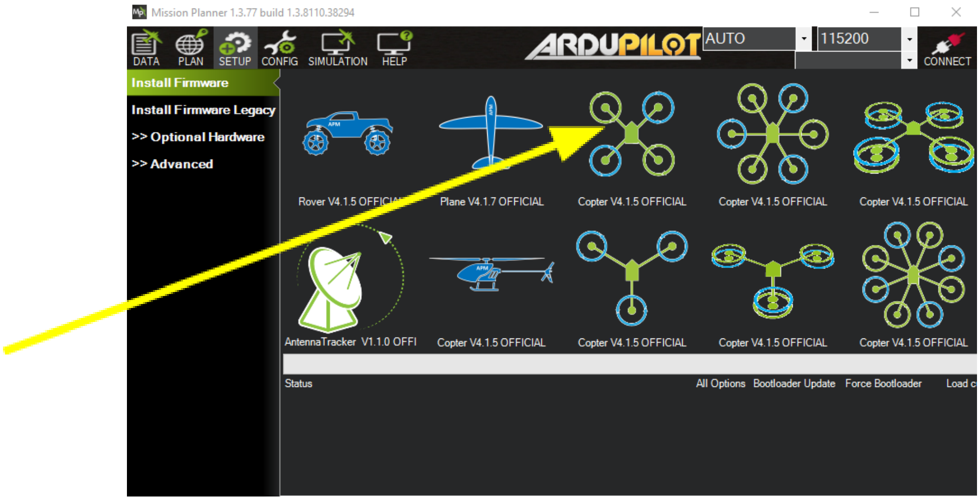


Figure 34: Firmware installation for quad X

After the installation, we calibrate the roll, pitch, yaw considering the type of environment of the flight and try to calibrate as much centered as we can. Figure 35 will show how we calibrate the angles.

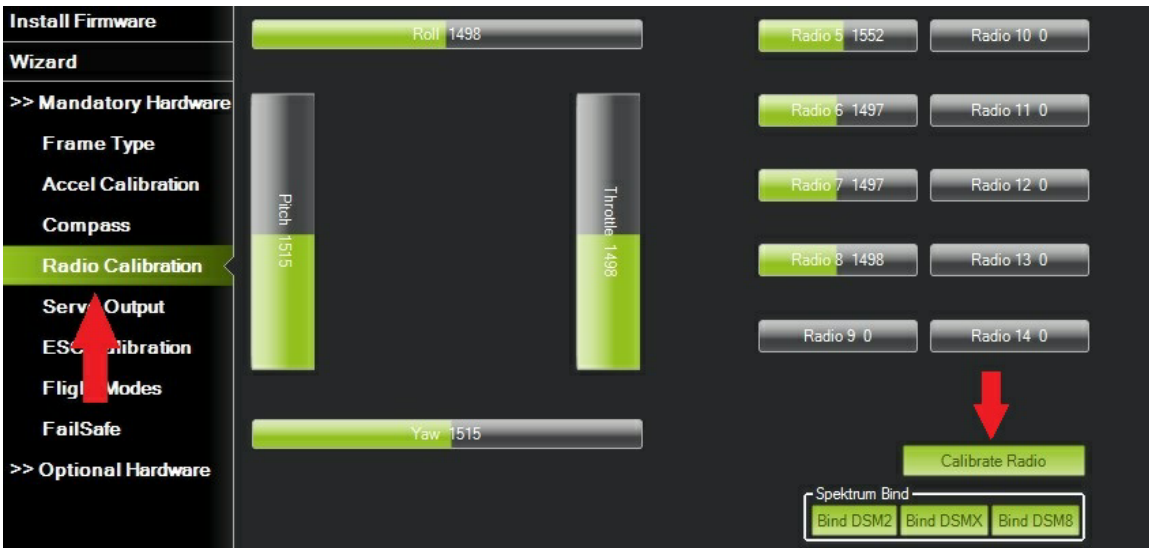


Figure 35: Radio Calibration of the quadcopter

It is better to have the yaw and pitch count closer to each other and it gives better adjustment while flying the drone. The throttle and roll should have the same value for better adjustment. After calibration we can bind the receiver with the transmitter and we are good to fly.

7.2 Calibration of KK2.1.5 Flight controller

Another flight controller we learned about is the KK 2.1.5 which doesn't require any other device to get calibrated. We can calibrate the flight controller onboard. So we start by deleting all previous files by going to the factory reset by using S4 button on the flight controller. After resetting the flight controller, we can go to the menu again and select the receiver test and turn on AUX after that we will see the flight controller is getting calibrated automatically and it will show the motor formations showing M1 M2 M3, and M4. After that we adjust the roll, pitch, yaw and throttle by going to the Mode setting and we prefer closer values of X and Y on the flight controller. The whole step by step process is shown in the figure 36 and figure 37.

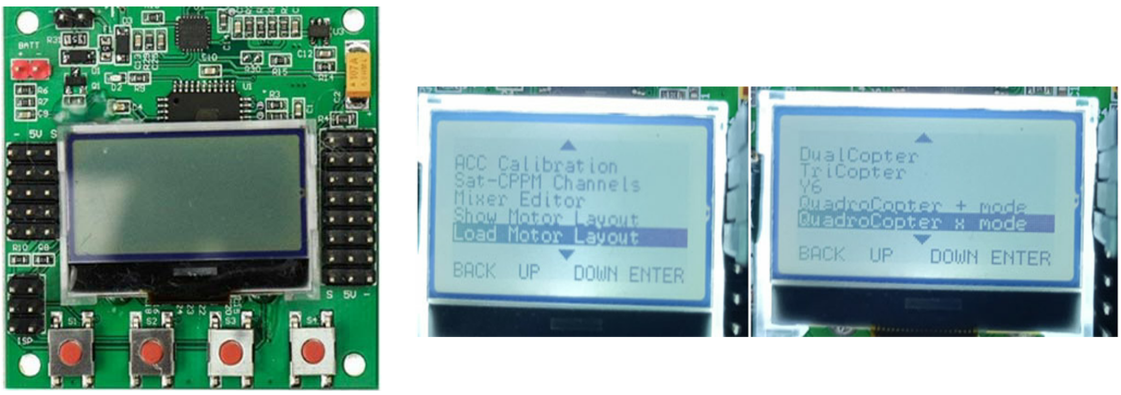


Figure 36: ACC calibration of the Flight controller

The ACC calibration is the accelerometer calibration of the flight controller. After that we do the PI editing and calibrate the roll, pitch, yaw and throttle of the drone. Then we select the mode setting and Self Level should be turned on for the balancing.

Figure 37(a) : PI setting of the drone

Figure 37(b): Mode Setting of the drone

After calibrating the flight controller will show safe on the display and when the left joystick is held right then it gets armed. After, that we can fly our drone. We need to keep in mind that during the calibration we need to keep the drone on a flat surface.

8. Dropping mechanism:

A vital mechanism part of the firefighting drone is the dropping mechanism because we will be dropping fire extinguishing balls at fire using this mechanism. The mechanism should be light enough but the mechanism has to be strong enough to hold the weight of the payload or the fire extinguishing balls which will be dropped on the fire to extinguish it. Let's talk about the components and working procedure of the dropping mechanism in this chapter. In The first section we will learn about the components and making process of the mechanism and in the second part we will learn about the working procedure of the dropping mechanism.

8.1 Components, designing and manufacturing of the dropping mechanism

We have selected the 5mm PVC board which will be reinforced with 3mm PVC board to withstand the weight of the fire extinguishing balls. We have taken the dimensions of the space at the bottom of the landing gear where we will put the dropping mechanism. The components of the dropping mechanism are the container part, the door part, a servo motor and a simple hinge for the opening and closing operation of the dropping mechanism. For hanging purpose, we used a wooden stick. We will make a slanted dropping mechanism. Due to maintaining an angle we can see that the drone won't require to go directly vertical to the fire. So we can save the direct interaction and air due to thrust is not being passed on the fire. As a result the air flow is restricted saving the increase of fire in the accident zone. We will be showing an illustration how the dropping mechanism will work and the whole situation in figure 38 and in the figure 39 we will learn about the solid works drawing of individual components of the dropping mechanism and the assembly of the components to make our mechanism. We are taking an angle of 30 degrees for the slanting purpose. The features of the dropping mechanism is showed below.

Table -5 Dropping mechanism features

Features	
Dimension	24x16x6 cm
Material	5+3mm PVC
Servo	9gm
Total weight	121 gm

Let's see the solid works drawing and the sheet diagram of the components and the assembly

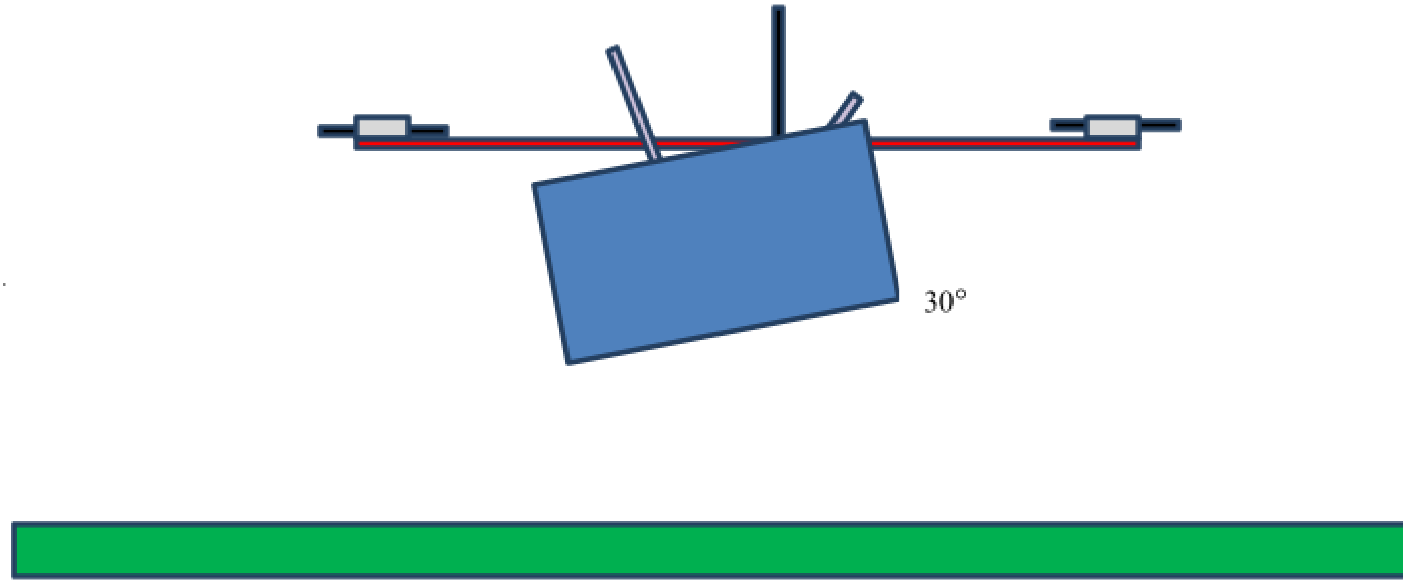


Figure 38: Illustration of dropping mechanism

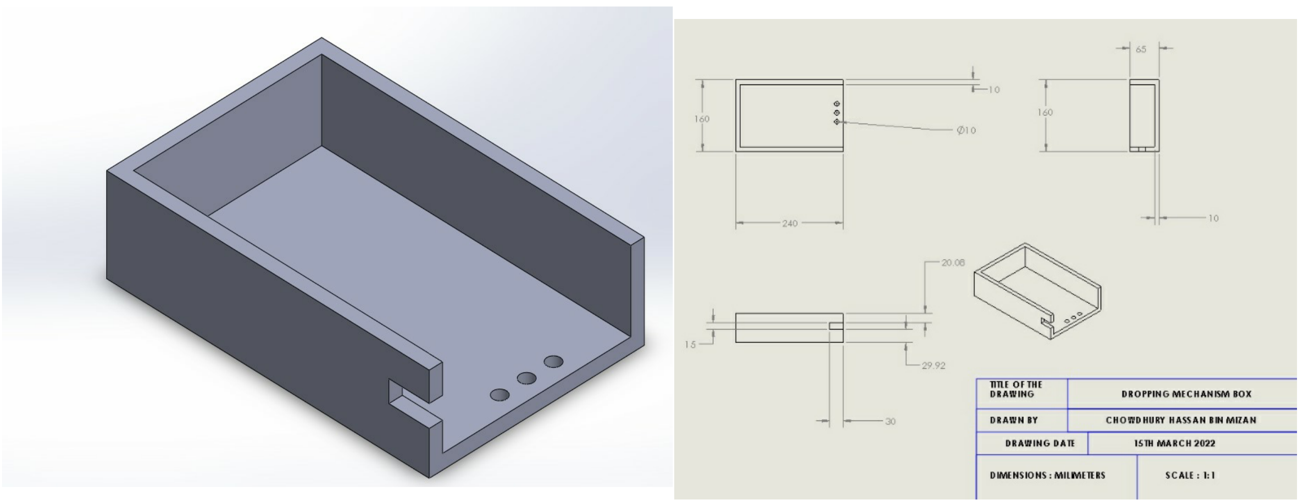


Figure 39a: Dropping mechanism container

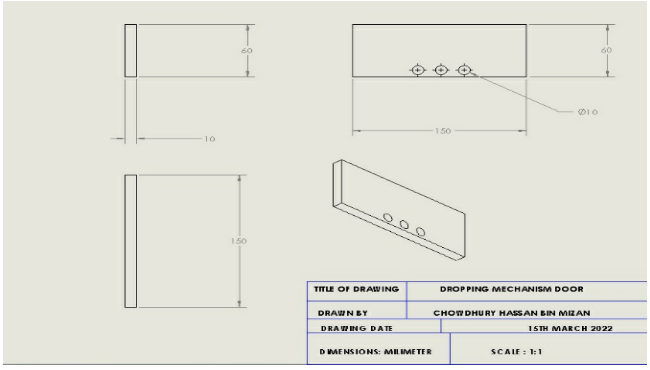


Figure 39b: Dropping mechanism Door

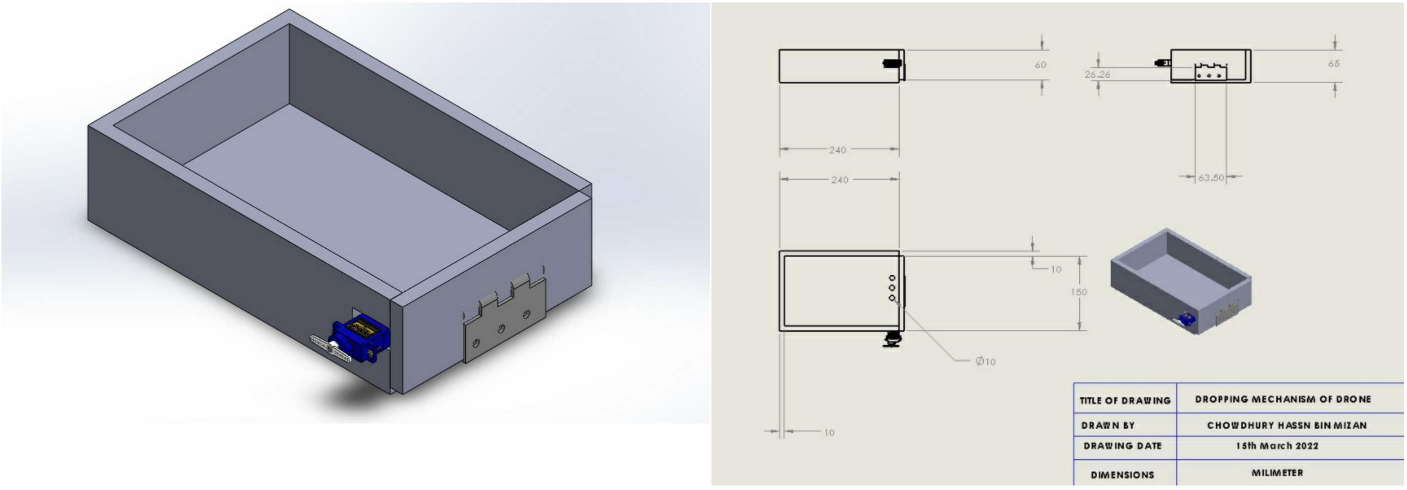


Figure 40: Assembly of the dropping Mechanism

8.2 Working procedure of dropping mechanism

The dropping mechanism works by the AUX of the receiver which is connected with the servo motor. We can use AUX1 or AUX2 of the receiver to connect with the servo. We can use the left switches which trigger the AUX 2 of the receiver. We can adjust the arm of the servo as required the connection of the receiver and the Servo. We will now see the switch of FS-i6 to be used to trigger the dropping mechanism and the connection is also shown in figure 41.

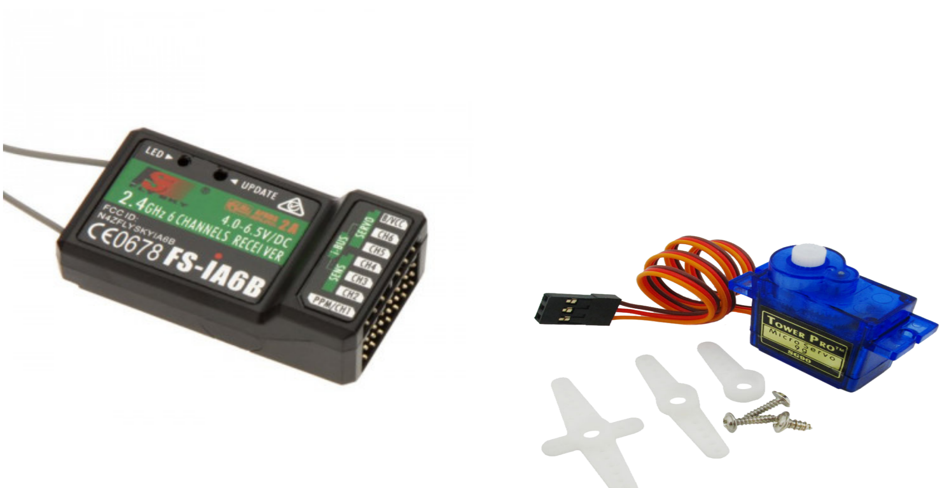


Figure 41a : Connection of receiver and the servo motor

Figure 41b: Flysky FS i6 transmitter switch to trigger Channel 6 (AUX 2)

9. Calculations, results and Errors

9.1 Thrust calculation and force analysis:

At first we want to do the thrust calculation of the BLDC motors**.** For the calculation we use a equation which gives the answer in Newton.

Thrust = $\frac{\pi \times D^4 \times \rho \times v \times V_p}{4}$ [4][23]

D is the diameter of the propeller for our case its 10 in that is 0.254 m
ρ is the density of the air which is 1.25 kg/m^3
v is the velocity of the air suppose its 150 m/s
Vp is the velocity of air due to propeller and is assumed it as 50 m/s.
So the thrust will be 6.12 N thrust is implemented by each of the motors.
Now we need to calculate the thrust of how much gram a motor can produce.
So converting the newton to gram we get 624 gm of thrust.

Now again by Thrust = $\frac{Propeller\ length \times propeller\ pitch \times battery\ voltage}{efficiency\ of\ motor}$

Propeller length – 10 inch
Propeller pitch – 4.5 inch
Battery voltage – 11.1 V
Efficiency -80% or 0.8

Thrust = 10x4.5x 11.1 / 0.8
= 624 gm
For 4 of the motors, we get a thrust of 624 x 4 = 2496 gm.

Now we calculate the centrifugal force.

At first we need to find the angular velocity at first. For calculating the angular velocity we need to know the rpm of the motor. At 80% efficiency we find the rpm is 7500. Now we find the angular velocity.

$\omega = \frac{2\pi N}{60}$

= 785.4 rad/s

Now we calculate the centrifugal force using the Equation

$F_c = mR\,\omega^2$

Here m= mass of the propeller in kg = 0.04kg

R= radius of propeller in m = 0.127 m

Now Centrifugal force = 3084 N

Now we calculate the moment of the quadcopter with respect to the road surface.

M = Fc x l

l= perpendicular distance from drone to the road surface.

M= 3084 x 0.5

= 1542 Nm

9.2 Power and lift calculation:

For power calculation we need an equation which is correlated with the propeller of the motors.

Power, $P = K_p\, D^4$ pitch x N^3 [4]

Here K_p is the propeller constant D is the diameter of the propeller in m and N is the rpm of the propeller. We assume N = 7500

Kp for 1045 propeller is 1.12

Now power = $1.12 \times (0.254)^4 \times 0.11 \times (7500)^3$

= 216 W

Now we can move on to the lift calculation of the drone.

$$\text{Lift} = \frac{W \times D^4 \times N^2 \times \frac{\rho \times 24}{Cl \times 29.9}}{2.2}$$

Here C_l is the lift coefficient we assume it as 1

W is the weight of the drone = 1236 gm = 1.236

D = 0.254 m

N = 7500

Now lift = 145.175 KN

Now the total mass lifted by our drone = thrust / 9.8

2496/ 9.8 = 254.69 gm

9.3Battery life analysis

Battery are the source of energy to our drone. We have used two 1100 mAh batteries in parallel and the total power output is 2200 mAh

Now at 100% rpm the current used by a motor is 10A

For 4 motors the current will be used = 10A x 4 = 40 A

At 80% rpm the current usage is 8 A for 4 motors = 32A

At 60% rpm the current usage is 6A for 4 motors = 24A

Battery life for 100% rpm = 2200 / 60 [4]

= 2.2 x60 / 40 = 3.3 minutes

Battery life for 80%

2.2 x 60 / 32 = 4.125 minutes

Battery life at 60% rpm

2.2x 60/ 24 = 5.5 minutes
Battery life at 50% rpm
= 2.2x 60 / 20 = 6.6 minutes

Now we will see the graph of battery life at different % of rpm of BLDC

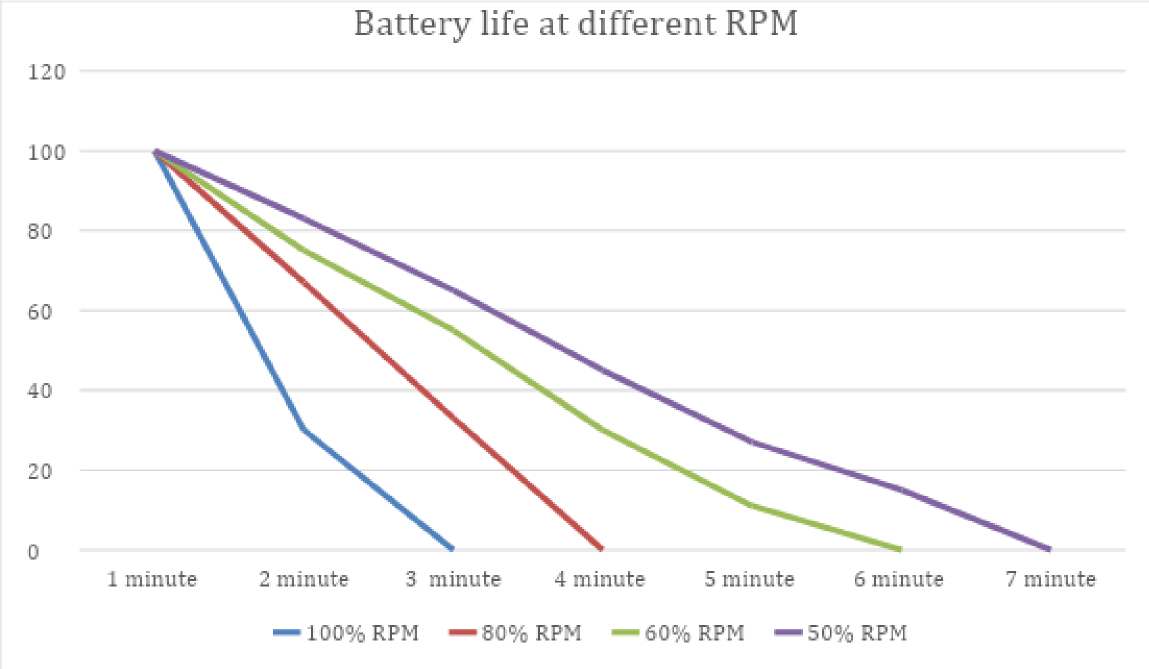


Figure 42: Battery life percentage vs Different Rpm %

We will be flying the drone at 80% rpm so we can fly 3.3 minute theoretically but on field we can fly for around 7 minutes at 70-80% rpm of the motors.

9.4 Weight Analysis

The following table shows the weight analysis of the quadcopter.
Table-6 Weight analysis

Components	No. of use	Weight
Bldc Motor	4	72x 4= 288 gm
Frame	1	340 gm
Battery	2	84x2 = 168 gm
Dropping mechanism	1	121 gm
ESC	4	23 x 4 = 92 gm
Receiver	1	14gm
Ball	1	200 gm
Propeller	4	4x40 = 160gm
Total weight		1223gm

Weight – thrust ratio = Drone weight / Thrust

= 1223:2496
= 1:2
For flight and maneuverability, the expected ratio of the weight- thrust ratio is 1-2[4], [8].

9.5 Transmitter – receiver error

When the transmitter is at a distant place from the receiver of the drone while the drone is flying there is error percentage shown on the display of the transmitter. The error may show whether the drone is flying upward or to any translational distance. We will now see the error percentage with respect to the distance. We were able to find a 93% error by moving around 60m away from the drone. The flowing graph shows the increase of error with respect to the distance. We also made a table with the values of the error percentage with respect to the distance.

Table -7 Error percentage vs Distance travelled

Error Percentage	Distance Travelled
1%	5m
13%	15m
28%	30m
47%	40m
68%	50m
93%	60m

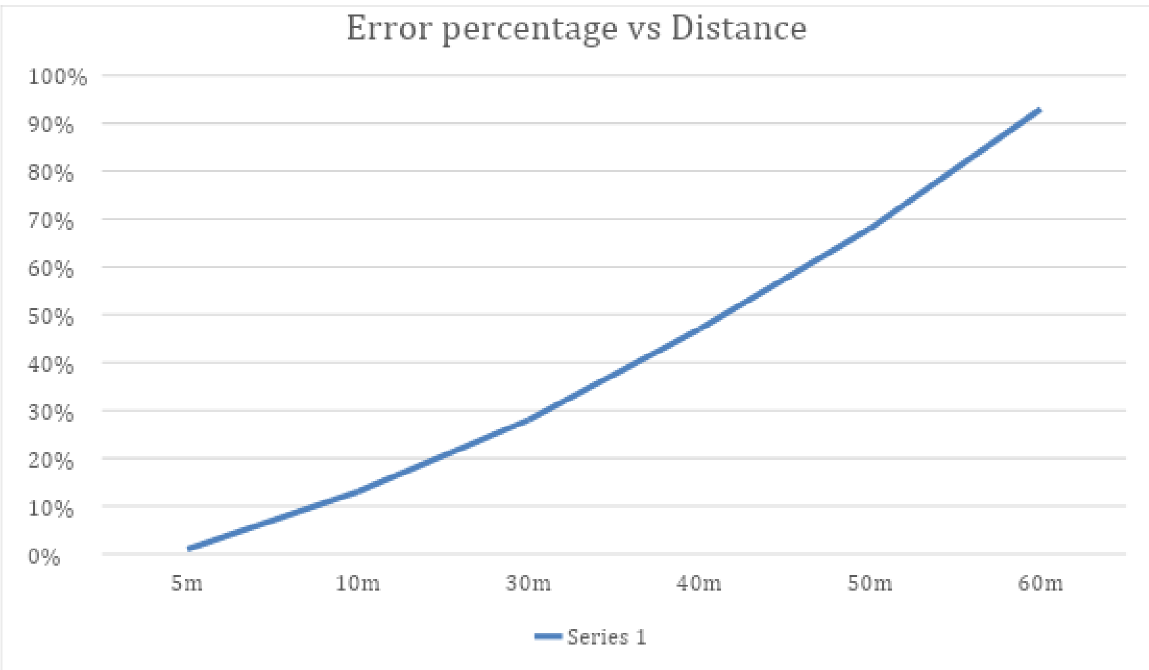


Figure 43: Error percentage vs Distance

Figure 44 shows our firefighting quadcopter prototype with dropping mechanism.

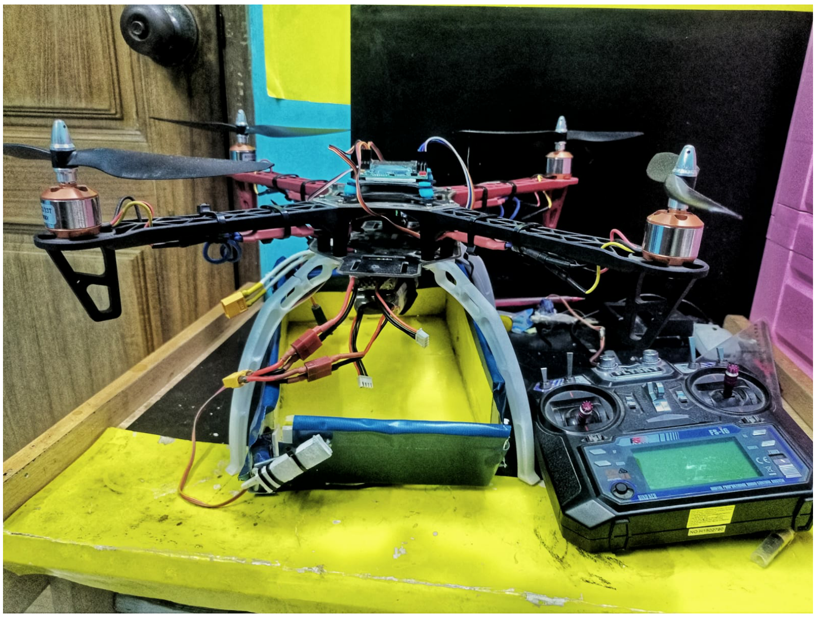


Figure 44: Firefighting quadcopter prototype with dropping mechanism

10. Cost Analysis

The following table shows the cost of the components and overall expenditure to build our quadcopter prototype.

Table-8 Cost Analysis

Components	Price per unit(Taka)	Units used	Total price(Taka)
BLDC Motor	480	4	1920
ESC 30A	430	4	1720
KK flight controller	1	1850	1850
APM 2.8 Flight controller	1	4100	4100
Battery	1500	2	3000
Servo	160	1	160
FlySky FS i6	6500	1	6500
Propeller pairs	130	4	520
connectors	50	1	50
PVC board	1000/ per board	1/2	500
Shock Absorber	350	1	350
Frame DJI F450	950	1	950
Hot glue stick	10	3	30

Soldering iron	50	2	100
Zip ties	70	1	70
Double-sided tape	40	1	40
Landing gear	350	1	350
Binding Tape	70	1	70
Total			22,280 Taka

So the cost estimation we have is 22,280 taka for making the prototype of the fire fighting drone.

11. Developments or improvements

- The first development which has been made is the avoidance of vertical dropping because during vertical drop the thrust air from the propeller will provide more oxygen to the fire accident spot. We are providing a slanted angle to the dropping system as a result of which the extinguishing ball falls at a distance of 1m ahead when we tested the prototype at a height of 8m.
- We don't need to do hours of programming for calibrating the flight controllers and we don't need any extra microprocessor unit for the job. As a result it has become more time-efficient and cost efficient as well
- The quadcopter doesn't require much maintenance so we can say that the cost of maintenance is less.
- The APM 2.8 has 3 modes of apllication

12. Future Works

12.1 Solar Charging:

In the future, we can plan to have solar charging in the drone. So that when the drone is in a flight it doesn't crash. So the solar panels can be fit on the body surface and there may be different type of DNI which may result in different production of electricity which can be used again for charging the batteries of the drones while they are in a flight. There will be some advantages that can be included in the drones which will be using the solar charging methods.
The advantages which can be found are given below:

1. Increased flight time of the drone
2. No manual charge needed
3. No sudden crash
4. Daytime charge in anywhere

Figure 45: Future drones with solar charging

12.2 Better GPS control

Though we are working with kk 2.1.5 and APM 2.0 flight controllers. The GPS of the APM 2.0 doesn't work properly now a day so there is a possibility that the drone may go far without connecting with the GPS. So the proper use of the GPS can be assured by the pixhawk flight controller. This will help in the increase of the extension of the range of the drone.

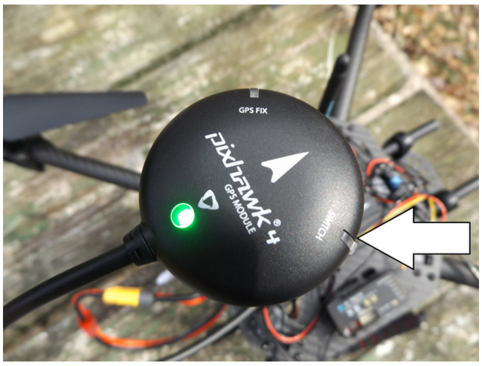


Figure 46: GPS of Pixhawk 4

12.3 Higher weight carrying capacity:

There is a huge scope of increasing the weight carrying capacity of the drone. This will help to increase the payload of the drone which may take the result of increasing thrust of the drone. It will help to carry more fire extinguishing balls and also more medical supplies of the drone. As a result of increased carrying capacity the drone will help much more in extinguishing the fires. The drone may also carry humans and also a water tank so that the drone can be used to throw water as well as the fire extinguishing balls.

13. Conclusion

The firefighting drone is the most advanced technology which can assure less loss of wealth and health by extinguishing the fire at a short period of time. It can fly over traffic jams and save a lot of time and its very effective against fire accidents at high raised buildings. This would be a very revolutionary change in the perspective of technological development of the firefighting equipment. We are living in a digital world so the manual systems are not that much of use now a days and most importantly analog systems have a lot of errors which can be solved using our digital and electronic technologies. So we can assure the safeguard of precious human life by replacing them with high tech drones by saving our time, life and wealth. Implementation of drone systems in the industry can boast new opportunities and new innovative business models. From the industrial point of view, implementation of this technology can be ideal in the technology and automation industry. The firefighting drone is the most advanced technology which can assure less loss of wealth and health by extinguishing the fire at a short period of time. It can fly over traffic jams and save a lot of time and its very effective against fire accidents at high raised buildings. This would be a very revolutionary change in the perspective of technological development of the firefighting equipment. We are living in a digital world so the manual systems are not that much of use now a days and most importantly analog systems have a lot of errors which can be solved using our digital and electronic technologies. So we can assure the safeguard of precious human life by replacing them with high tech drones by saving our time , life and wealth.

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