Designing and Calibration of a Manual Afforestation Drone

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Abstract:- The alarming rate of deforestation in the present day world calls for a worldwide concern. One of the best ways to save the world from permanent damage, in order to restore its vitality is to increase the rates of afforestation programmes and schemes across the globe. As the name of the offered course suggests, indeed deforestation is a fast growing real world problem. Interestingly, it takes a few minutes to cut down a tree but it takes years and decades for the tree to grow. Hence the afforestation rate needs to be increased significantly in order to keep up with the rates of deforestation.

Keywords:- Drone, Afforestation.

I. INTRODUCTION

Although "seed bombing" is being seen as the finest approach for repairing deforested area, complete automation of regeneration remains a long way off.

During natural disasters, drones are frequently employed to fight wildfires and drop relief supplies. Thailand sees it as the most effective tool for combating deforestation. In an effort to reforest its deforested land,, Seed bombing or airborne reforestation, in which seeds are dropped from a flying drone or aeroplane, is being investigated. Thailand initiated a five-year trial project to use aerial replanting in July 2013. For forest regeneration, seeds from native plants such as phayungs, maka mongs, and kaboks were dropped. Over two million people participated in a recent exercise of this kind. In the first week of June, wild tree seeds were disseminated in Lopburi province.

A concept that first appeared in the early twentieth century.

The ancient Japanese tradition of tsuchi dango sparked the idea of airborne replanting (earth dumpling).

Masanobu Fukuoka, a proponent of natural farming, popularised it throughout the twentieth century. Since 1926, when aircraft were utilised for the first time to revive a burned tropical forest in Hawaii, aerial seeding for forest restoration has been performed.

However, it wasn't until 1999 that the concept of seed bombing on a large scale gained traction. Lockheed Martin Aerospace, a US aerospace company, chose to plant 900,000 young trees in one day. Scotland was chosen for the C-130 transport aircraft, which is commonly used to lay explosives throughout battle zones.

Benefits of aerial seeding

Drones can readily reach places that are difficult to reach by humans. One of the justifications used to persuade countries to use aerial seeding is this. Seed bombing by drones is rapidly being considered a viable alternative at a time when the world wants to assure efficient coverage of a big region in the shortest amount of time possible.

Aside from relieving people of the responsibility of forest restoration, sophisticated drones, Aerial planting increases agricultural yields. Furthermore, seed bombing is a non-disruptive procedure for crops.

When damp soil conditions and rolling terrain make other types of treatment ineffective, aerial reforestation is the best option.region Aerial application minimises soil runoff by not causing soil compaction. Tropical forests will benefit the most from this type of planting approach because they absorb carbon more faster than other forest types and support far higher biodiversity.

Optimising technology for forest restoration

Reforestation has always relied heavily on manual labour and rudimentary instruments such as spades and machetes. With the focus now shifting to creating automated forest restoration, people carrying 20-30 kg of saplings on their backs and walking steep hills to drill holes and plant trees may soon be a thing of the past.

Aerial seeding is being used in India.

The Andhra Pradesh government began an aerial seeding initiative in August 2015, utilising Indian Navy helicopters. Over a 3,320-hectare area, at least 15 spots have been found. Chief Minister Chandrababu Naidu declared in June 2016 that the government would begin aerial seeding on a large scale in partnership with the Civil Aviation Ministry.

A tree-planting drone was launched by Vikas Education Trust, an educational institute in the neighbouring state of Karnataka, to drop 1 lakh saplings, notably rare ones, in unoccupied forest land in the Western Ghats. How did it intend to use drones to deliver seeds? To begin, a 3D aerial assessment of forest areas will be carried out, with drones flying over possible planting zones and photographing the environment. Following the creation of a 3D map and the creation of a seeding plan, the data is analysed to determine the best planting pattern for that particular terrain.

Drones would deliver pressurised seed pods with germinated seeds immersed in a nutrient-rich gel in the penultimate step.The biodegradable seed pods are fired down to the ground by drones. The collision causes the pods to break open, allowing germinated seed to take root. The idea for aerial seeding comes from a start-up business in the United Kingdom called BioCarbon Engineering, which has been developing automated drones for large-scale automated reforestation. The goal of the company is to plant one billion trees per year..

Complete reforestation automation is still a long way off.

A lot of work needs to be done on the technology front before drones can effectively replace humans when it comes to planting seeds. Drones may lower costs, according to Simone Pedrini, a doctorate student at Curtin University in Perth, Australia, but seeds cannot be ruled out stumbling in the wrong direction "Even when seedlings reach the ground, various factors can stymie their emergence, including as soil composition, animal predation, and weed competition," Pedrini explained.

While drone-based forest restoration is technically feasible, there are still significant technological restrictions that prevent it from becoming a far more effective alternative to manual seeding. Before forest restoration to take off, the most pressing need is to improve drone sensing skills. This is critical, particularly if drones are employed to control weeds. They must use "smarter spraying" tactics, such as optical plant recognition systems, to ensure that the spray is directed at weeds rather than young trees.

India has set a goal of covering 33% of its land area with forest cover by 2025. In 2019, India's TFC is 21.67 percent of the country's total geographical area (TGA), compared to 21.54 percent in 2017.
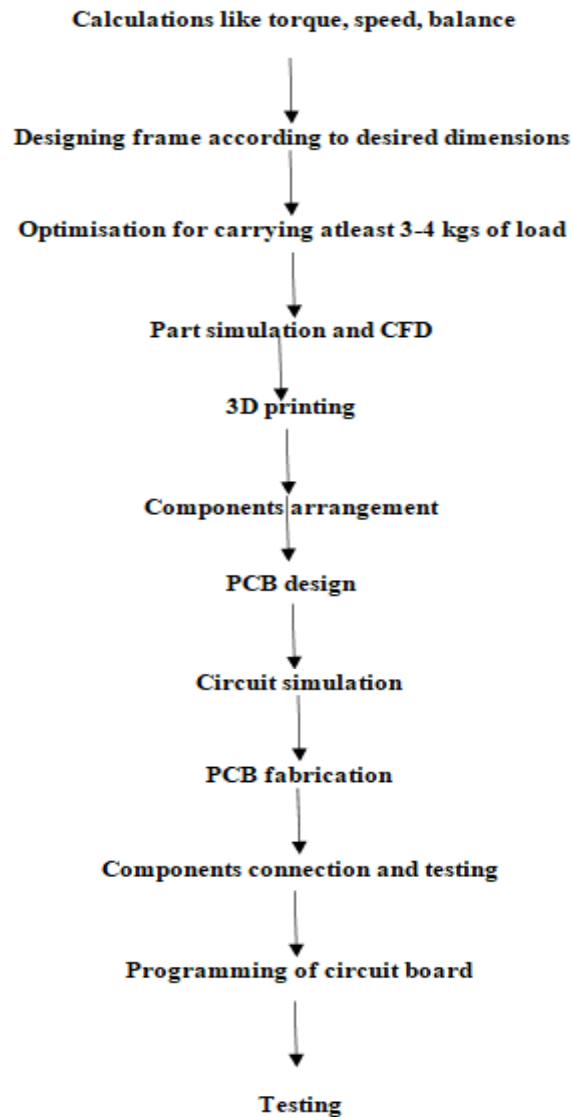*India's TFC was 6,92,027 sq km in 2011. As a result, despite the fact that the TFC has grown by 20,222 sq km, or 3%, since 2011, there remain some concerns about the expansion.Forest cover this decade (In sq km)*

Year	2019	2017	2015	2013	2011
Very dense forests (VDFs)	99,278	98,158	85,904	83,502	83,471
Moderately dense forests (MDFs)	308,472	308,318	315,374	318,745	320,736
Open forests (OFs)	304,499	301,797	300,395	295,651	287,820
Total	712,249	708,73	701,673	697,898	692,027

In terms of canopy density classifications, VDFs cover 99,278 sq km (3.02%), MDFs cover 3,08,472 sq km (9.39%), and OFs cover 3,04,499 sq km (9.26 per cent).

Looking at the forest cover over the last decade, there has been a steady growth in the area classified as OF, which includes commercial plantations. And it appears that this is happening at the expense of the MDF category, which is generally the most expensive.

According to the research, India has been losing MDFs since 2011, with only a little rise in 2012.

Between 2017 and 2019, there was a 0.04 percent increase. Between 2011 and 2013, the area in this category declined by 0.62 percent, and between 2013 and 2015, it declined by 1.05 percent. Then, between 2015 and 2017, it fell by 2.2 percent.

At the same time, India's open forests have grown in the last ten years. After increasing by 0.86 percent between 2011 and 2013, the area increased by 1.60 percent between 2013 and 2015. Between 2015 and 2017, the area classified as "OF" rose by 0.49 percent. According to the data, the forest cover in this category increased by 0.89 percent between 2017 and 2019.
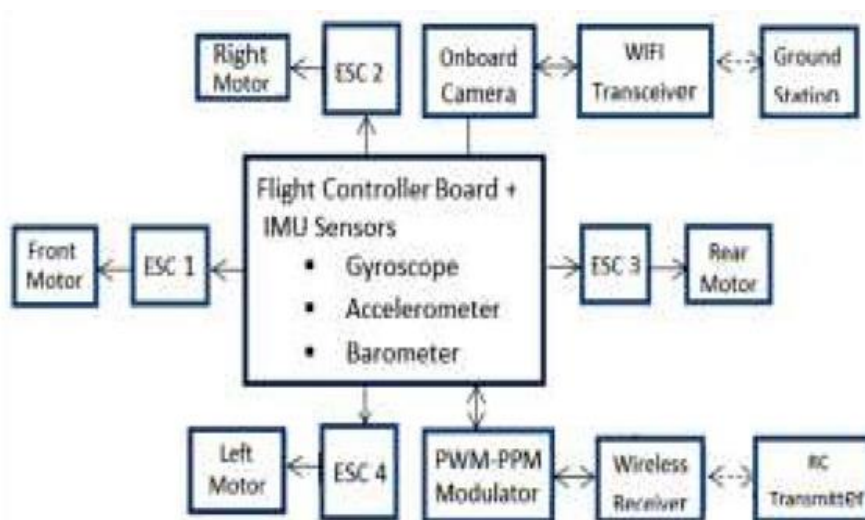
VDFs occupy only 3% of India's total land area. The category of a'very dense forest,' defined as a canopy cover of more than 70%, is an essential measure of a forest's quality. However, between 2017 and 2019, this only increased by 1.14 percent.

These forests absorb the most carbon dioxide from the atmosphere, and this slight increase in "VDFs" must be weighed against the improvement reported in the 2017 forest report, which showed that forests in this category had risen by roughly 14% between 2015 and 2017.
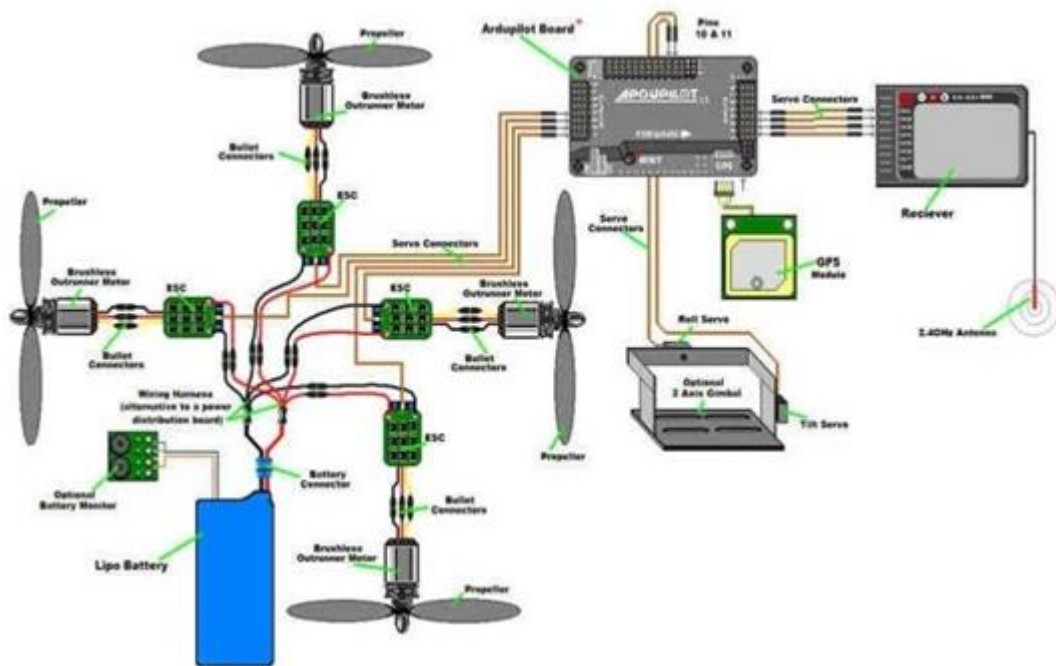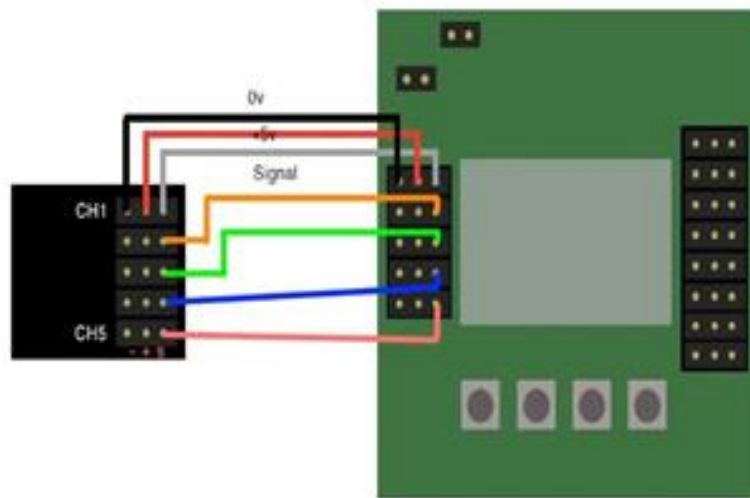
Work Flowchart:

Calculations like torque, speed, balance

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Designing frame according to desired dimensions

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Optimisation for carrying atleast 3-4 kgs of load

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Part simulation and CFD

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3D printing

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Components arrangement

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PCB design

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Circuit simulation

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PCB fabrication

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Components connection and testing

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Programming of circuit board

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Testing

BLOCK DIAGRAM :

Quadcopter Layout:

II. MAIN CONNECTIONS FOR RECEIVER TO BOARD

**Design procedure and CAD model preparation:**

Drone body or frame:

The arms and legs of the quadcopter are created in Solidworks. The symmetry ofthe arms was maintained for proper balance and flight of the drone. The legs of the drone were placed at proper points for the drone to take a stand while lying on the ground. Proper design procedures followed. First the drone was sketched to get a proper idea of its structure. The base and top act as PCBs with connectionsfor all electric components like the battery, ESC, receiver. The PCBs were designed in such a way that it can act as the base for carrying the battery and othercomponents as well as provide space to carry around the items.
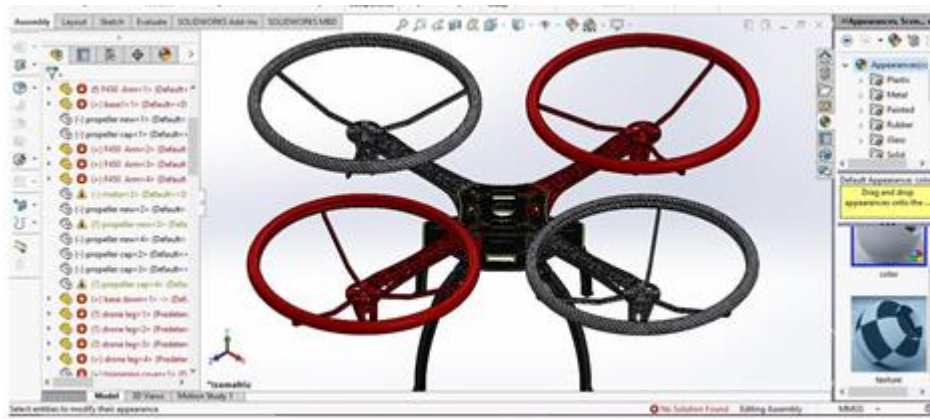
Fig: Frame:Isometric view

The arms were designed to provide the space for motor and propeller and also house the ESC. The arms were designed in such a way that maximum weight reduction has been achieved through patterned cuts about the arm. Also, a circularcovering for the propeller was designed. The purpose of this is that it provides a covering around the propeller while it is rotating at high speed and keep them safefrom peoples' contact which may cause damage or injury to the touched part as the propeller rotates at high speeds.
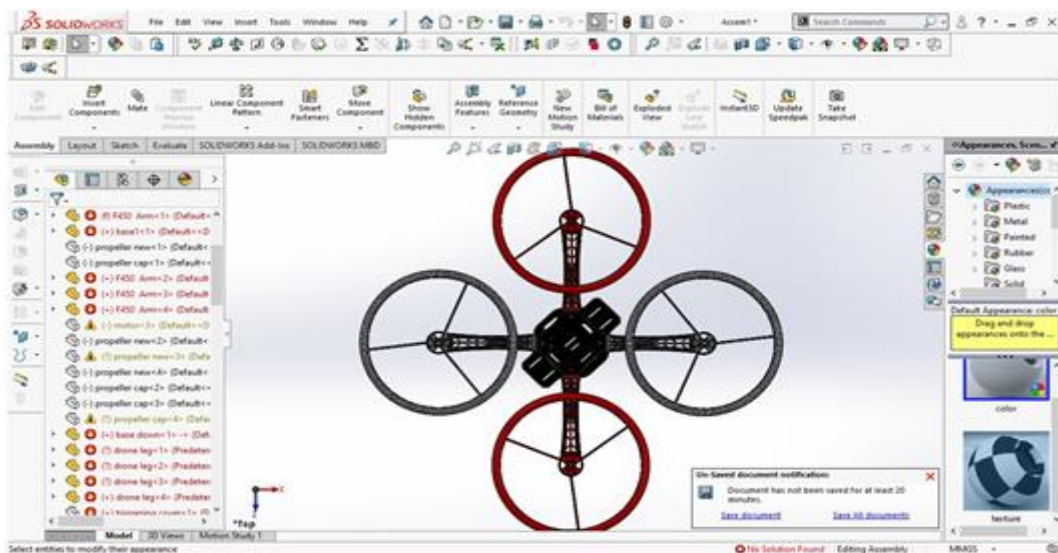
Fig: Frame: Top view
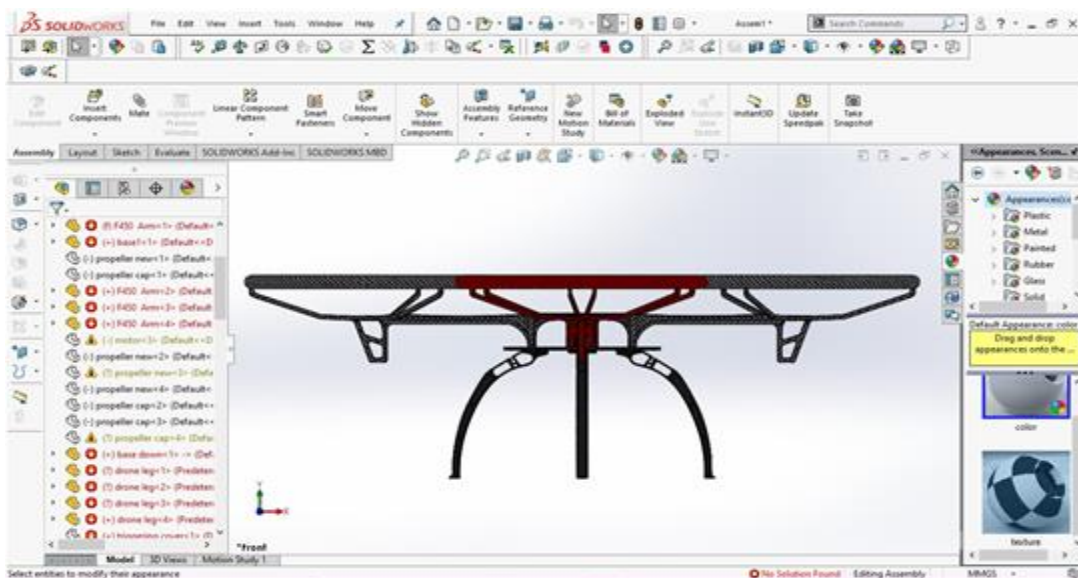
Fig: Frame: Front view

III. MATERIAL SELECTION FOR DRONE FRAME:

WOOD

When making the drone as cheaply as possible, a wooden frame is used. Wood isn't the most aesthetically pleasing material available, but it is one of the most cost-effective. The advantage of a wooden frame is that we can quickly and easily replace anything that breaks.

CARBON FIBER

Carbon fibre is a strong and lightweight material. This combination will allow our RC drone to fly more efficiently while using less energy. Because carbon fibre obstructs RF signals, it's crucial to bear this in mind while mounting crucial electronic components like an antenna.

PCB

This sort of material, also known as "Printed Circuit Board," has the same basic structure and qualities as fibreglass. Unlike fibreglass, PCD remains flat at all times. PCB is commonly used for the bottom and top plates of frames that are less than 600mm in length. In fact, a single printed circuit board may be used to construct miniature quadcopter frames..

PLASTIC

The majority of commercial RC drones sold today use plastic frames. Among DIY drone enthusiasts, 3D printed moulded plastic frames have become extremely popular. Using a 3D printer to manufacture a flawlessly moulded plastic frame is often reserved for smaller drones.

G10

Epoxy-LaminateG10 is a type of fibreglass that is frequently used as a low-cost substitute for carbon fibre. G10 and carbon fibre appear nearly identical from the outside, however their essential qualities differ slightly. G10 is available in sheet format. In terms of cost, it is less expensive than carbon fibre but still more expensive than wood, aluminium, or plastic.

ALUMINUM

When constructing your frame, you can alternatively utilise aluminium. It's light (though not quite as light as carbon fibre), flexible, and relatively simple to work with. You can make the entire frame out of aluminium, or only use it to supplement particular elements of the structure. Another advantage of aluminium frames is that they are both economical and easily available.

As far as our manual plantation drone is concerned, we have used Carbon fibreas a material because it is very tough and also light weight and consumes less energy than other types of frame materials. Carbon fibre drone components have dramatically improved flight capabilities. The drone must be light quick and strong. Carbon-fibre was used to achieve all these targets.
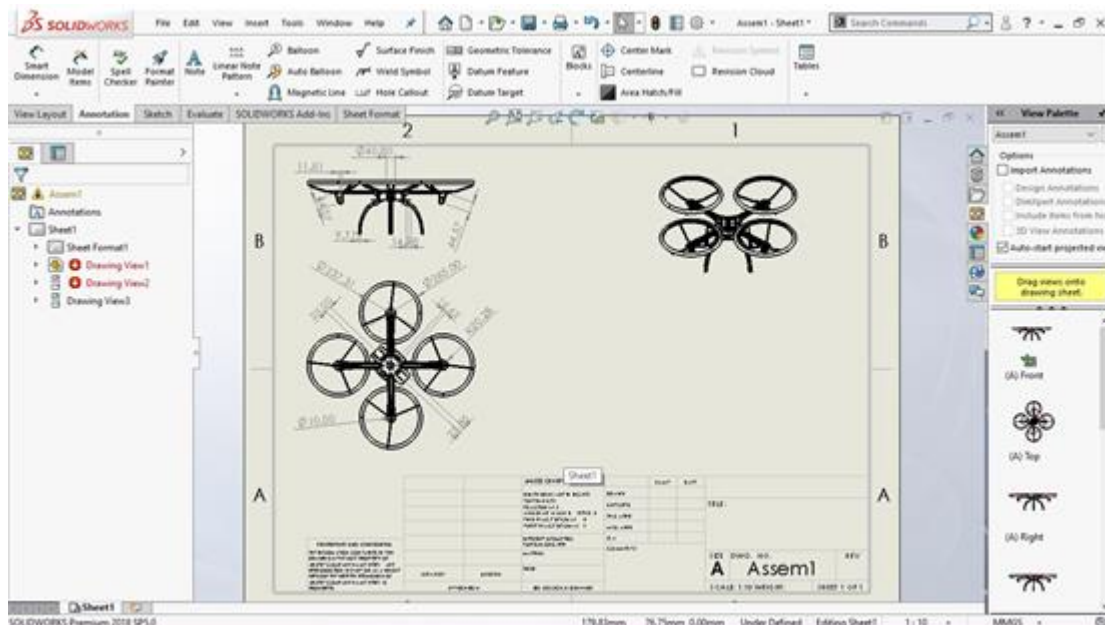

Fig: Frame 2-dAssembly of all electrical components:

After the drone frame was designed and assembled, the electrical components like the CT6B Radio Transmitter and Receiver, 30A Electronic SpeedController, A2212 1000/1400KV Brushless Motor, Pixhawk flight controller, 1045(2CW+2CCW) Black Propeller, Banana Gold Connectors, Lithium Polymer battery 11.1 V 2200mAh, GPS module, Camera for scanning and image processing,Servo motors were modelled and placed at respective positions on the frame.
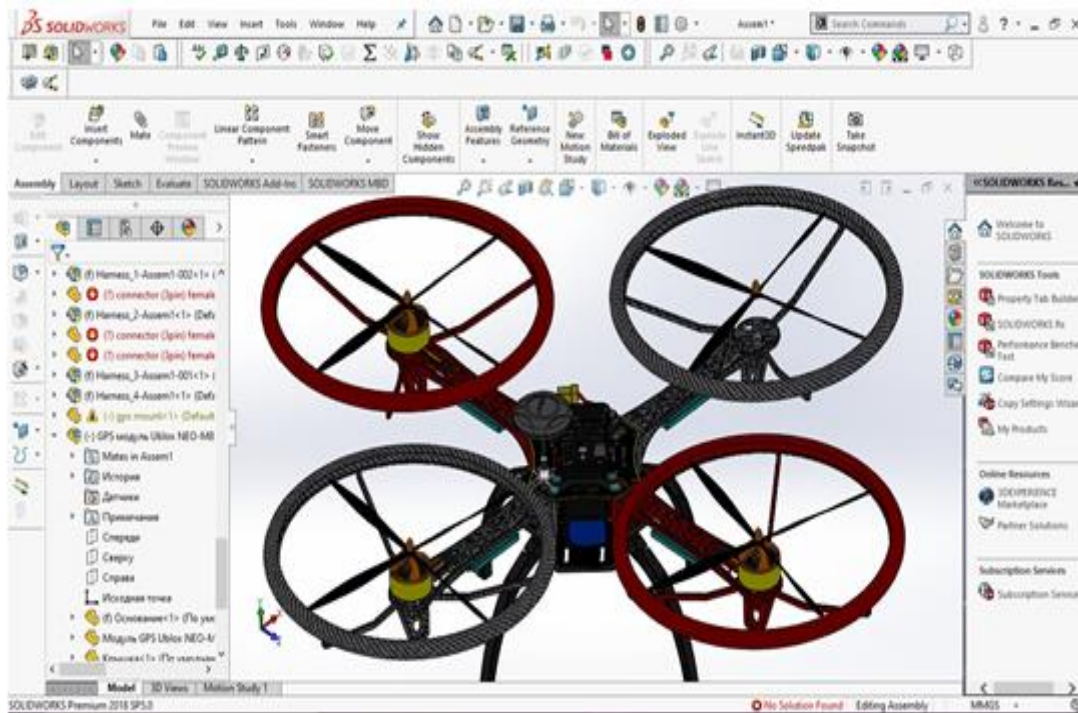
Fig: Drone assembly with electrical components
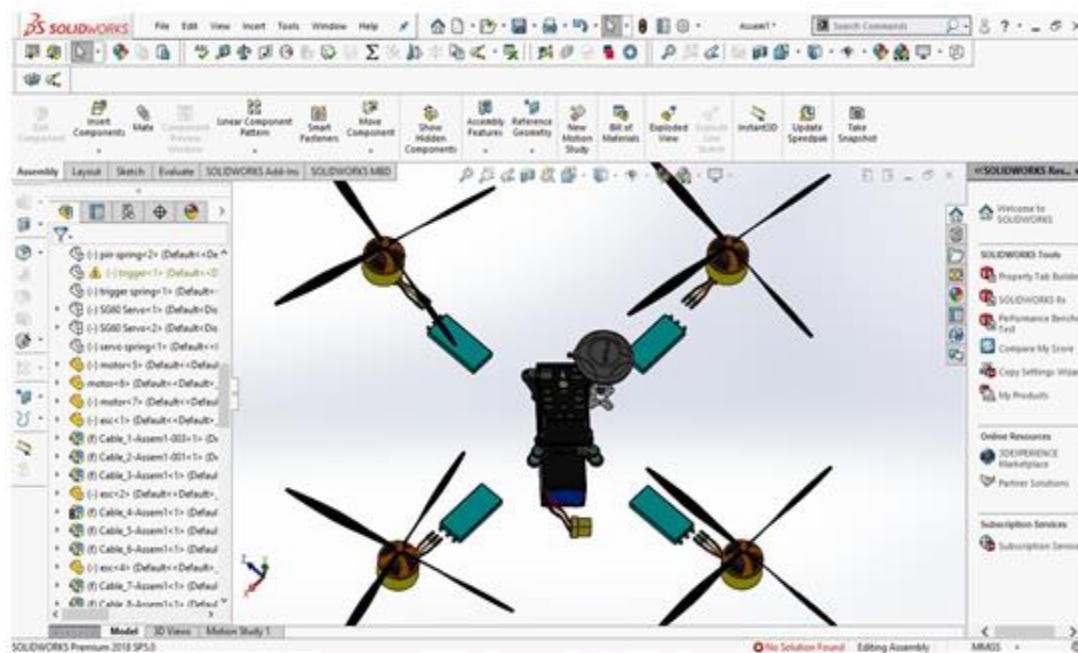

Fig: electrical components

Routing:

After the electrical components were assembled and mated with their location on the frame, electric routing was done, where the components were connected to their respective points through cables and harness. The routing points were added one by one and auto-route feature of Solidworks was used to find the path traced by the routing cables. Thus, electric connections were established in the design.
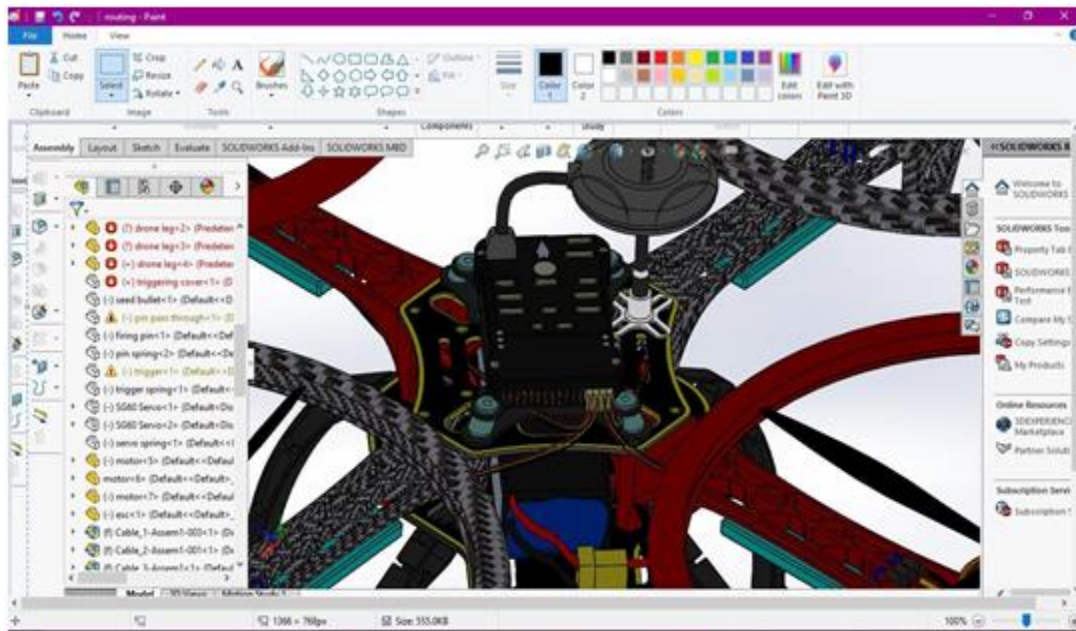
Fig: Routing of electrical components

The Electronic Speed Control, the Lithium polymer battery, receiver was connected to the base PDB or the Power Distribution Board and also to the flightcontroller Pixhawk. The GPS module was also routed with the flight controller.
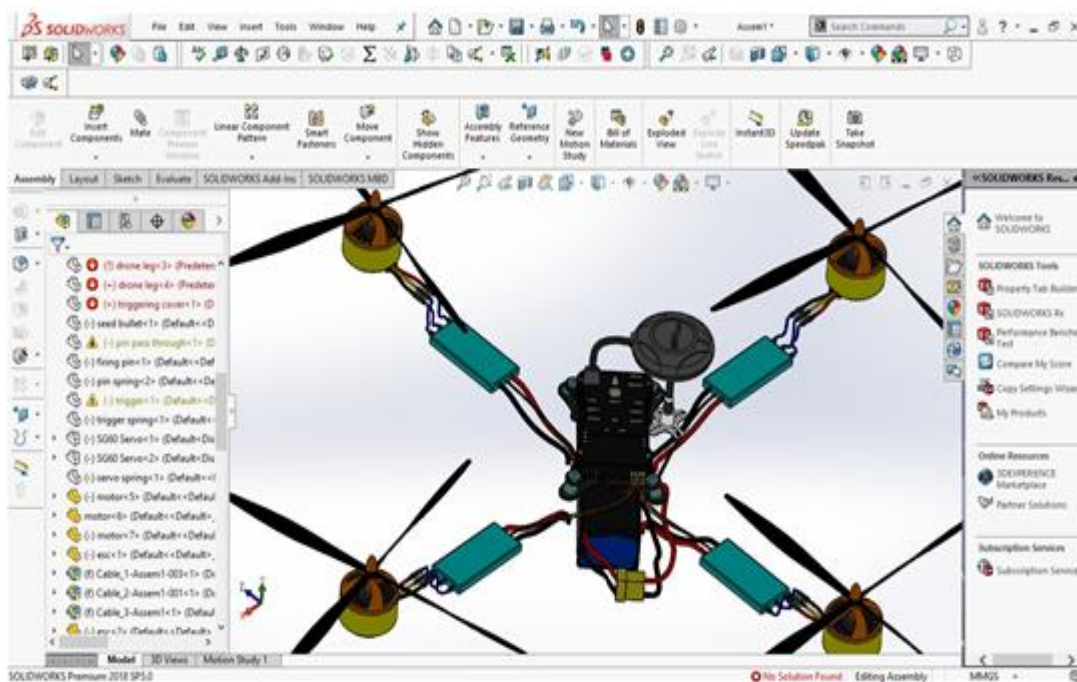
Fig: Routing shown separately

Design of seed ejector mechanism:

The seed ejector mechanism is basically the main part of the drone. It is the part where the seed bullets are stored in the compartment and one by one the seed is fired. The compartment is designed and servo motor is used which acts as a valveto drop the seeds for firing one by one. The seed bullet consists of propellent inside which contains powder, gunpowder is often used. The seed ejector mechanism is covered by a barrel for holding the parts
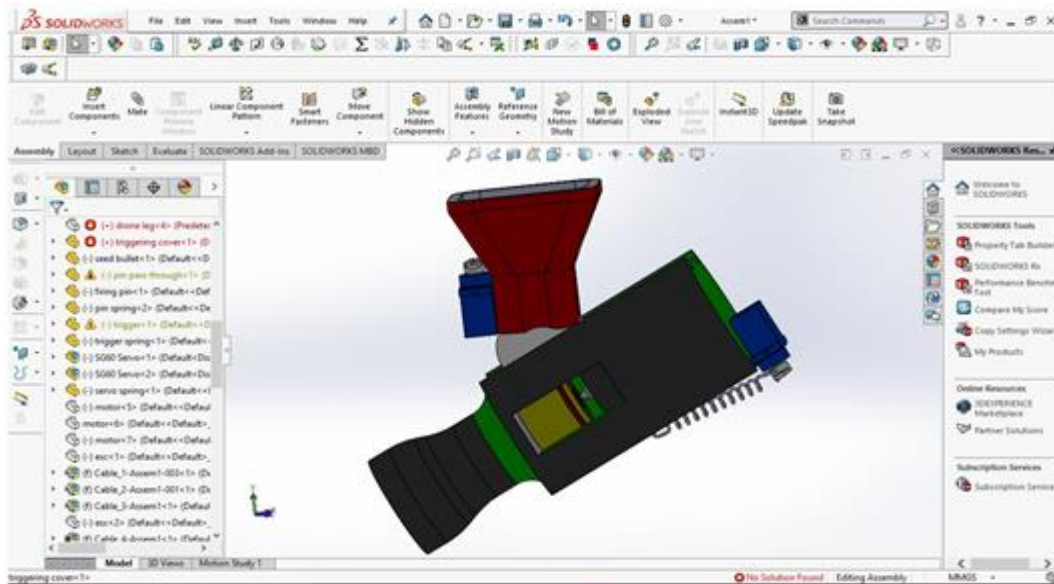
Fig: Seed ejector mechanism with cover and seed compartment
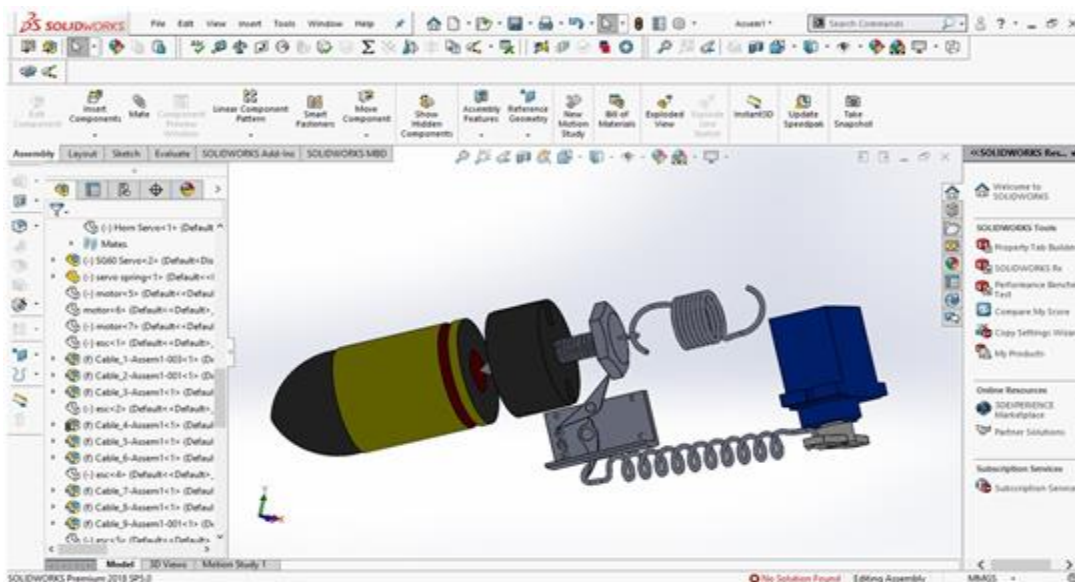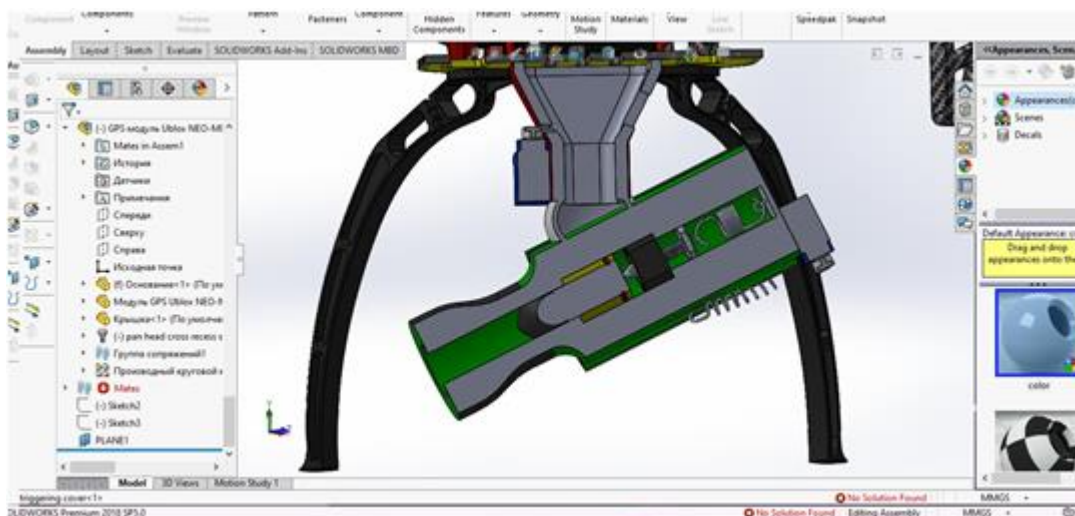

Fig: The seed ejector mechanism

Fig: Section view of the seed ejector mechanism
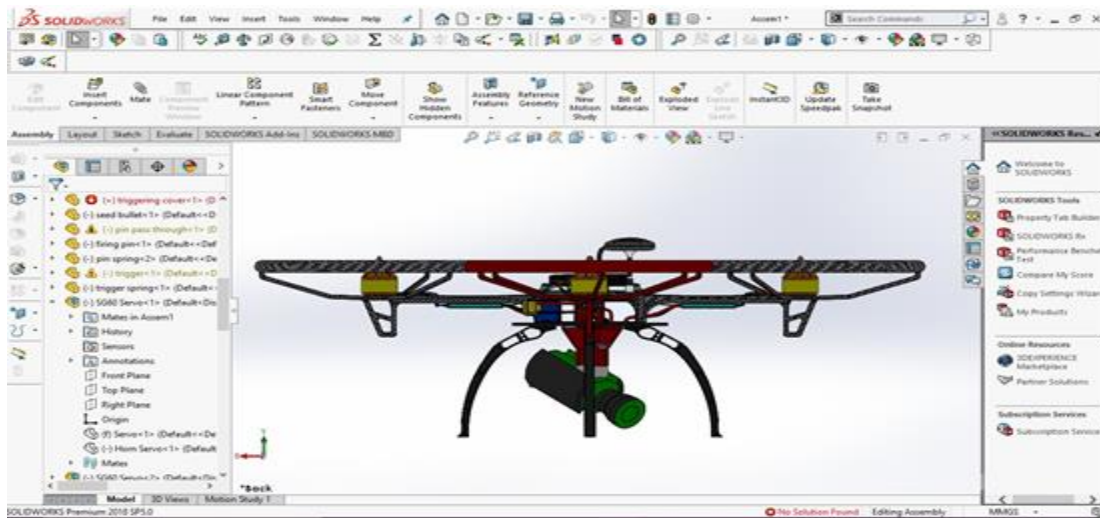
Complete assembly:
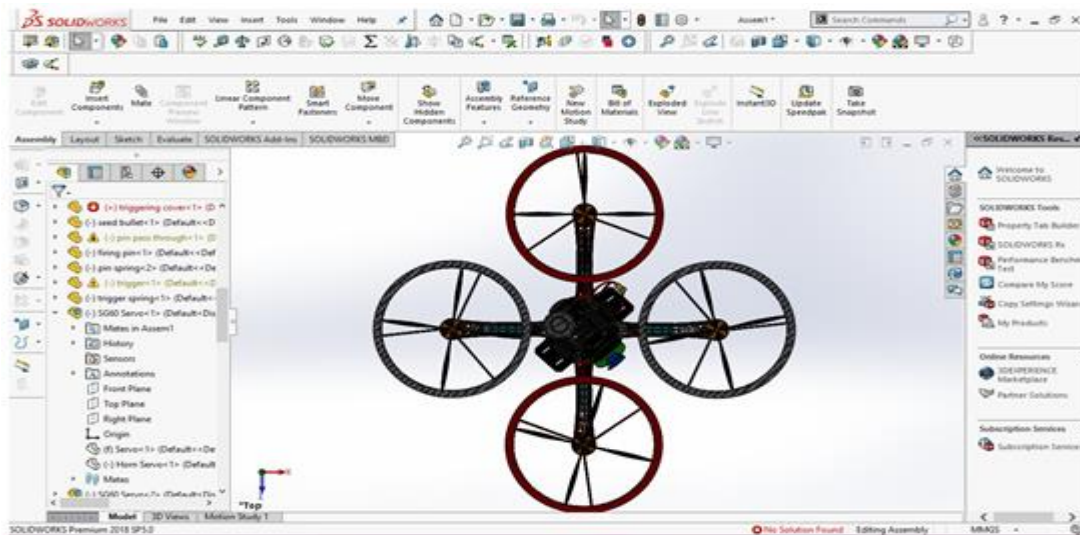

Fig: Final assembly: Front view

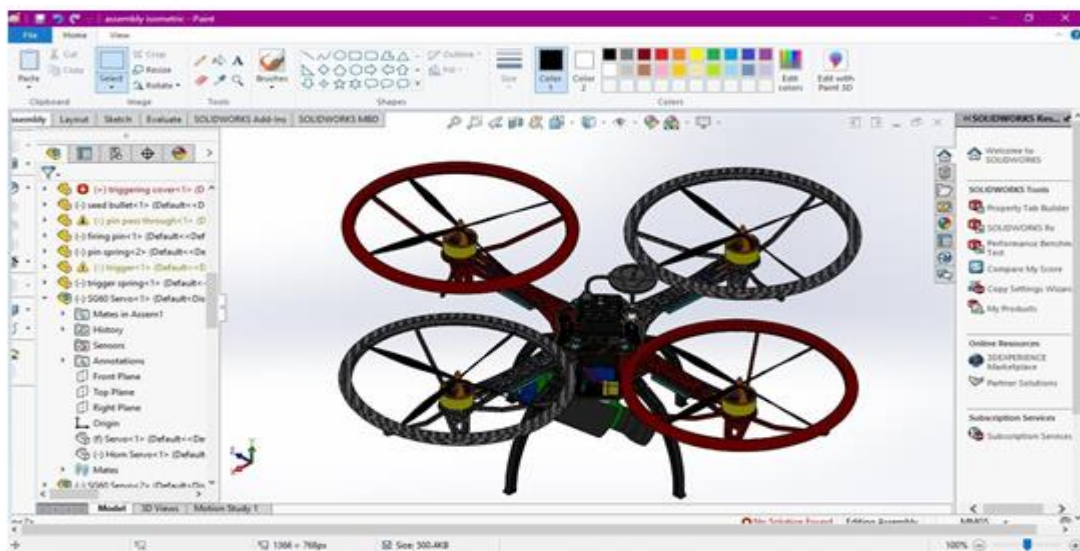**Fig: Final assembly: Top view**

Fig: Final assembly: Isometric view

Mathematical Modelling of Dynamic forces acting on Frame

Various forces acting on the drone are mentioned as follows

- Mass and acceleration of drone

$$F_{int} = m_{total} \begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{bmatrix}$$

- Gravity pulls the drone in downward in z direction i.e. towards the negative z axis. Here R_{NB} the normal reactant force due to gravity.

$$F_{gb} = m_{total}.R_{NB} \cdot \begin{bmatrix} 0 \\ 0 \\ g \end{bmatrix}$$

- Propulsion forces

Propulsion forces is the thrust provided by the propeller and always acts against the gravitational force. There is no propulsion forces in X and Y direction while the drone is in hovering mode. F_{M1}, F_{M2}, F_{M3}, F_{M4}, F_{M5}, F_{M6} are the thrust acting in downwards direction due to 6 motors.

$$F_{thrust} = \begin{bmatrix} 0 \\ 0 \\ F_{M1} + F_{M2} + F_{M3} + F_{M4} + F_{M5} + F_{M6} \end{bmatrix}$$

- Drag force

Drag force acts when the drone is accelerating or is in motion in the air. It always opposes the motion of drone.

$$F_{drag} = \frac{1}{2}.\rho.V^2.S_w.C_D$$

Where: ρ: Air density
V: Velocity
S_W: Reference Area
C_D: Drag Coefficient

Drag force is caused by the friction of drone with air.it is determined by the following formula -

Other disturbance forces-

Other unknown forces also act on the drone and they are denoted by, F dist.

Total force
The cumulative forces and the total acceleration acting on the drone can be given by the formulas-

$$F_{total} = F_{gravity} - F_{thrust} + F_{dist} + F_{drag}$$
$$m_{total}\ddot{r} = F_{gravity} - F_{thrust} + F_{dist} + F_{drag}$$

$$\begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{bmatrix} = \ddot{r} = \frac{1}{m_{tot}}(F_{gravity} - F_{thrust} + F_{dist} + F_{drag})$$

Calculations Using FormulaeModel Weight Calculation

1. Weight of motors = 342*4g = 1368g = 1.368kg
2. Weight of batteries=2076g=2.076kg
3. Weight of the frame = 1.5kg
4. Weight of the payload = 4 kg
5. Weight of props = 30*4 = 120g = 0.12kg
6. Weight of ESC = 90*4 = 360g = 0.36kg
7. Weight of PDB = 256g =0.256kg Total Weight, W Total = 9.68kg(21.34lb)

Assumptions Made

1. Efficiency, n = 0.80
2. Input Power, P_{in} = 1512kW = 2.055HP.
3. Model RPM = 7000 rpm
4. Throttle Condition: Full

Constant Values

1. Number of Motors, N_{Motor} = 4.
2. Diameter of propeller, D = 18inch.
3. Pitch of the Propeller, P = 6.5inch.
4. Current Rating of motor, I_{Motor} = 60A

IV. LIFT REQUIREMENTS RELATED CALCULATIONS

- **Propeller Sweep Area**

1. A = 0.25 X π X D^2 = 254.502 $inch^2$
2. Aft = 1.767 ft2

- **Power Loading Equation**

Pl = P_{in} X n/ Aft = 455.87 W/ft2 = 0.626 HP/ft2

- **Thrust loading equation**

TL = 8.6859 X $PL^{-0.3107}$ = 5.9218 lb. /HP

- **Lift Per Motor**

Lift = TL X (P_{in} X n) = **9.735 lb**.(4.41kg)

- **Total Lift of the HLAV**

Lift Total = Lift X N motor = **58.37 lb.** (26.48kg)
- **Common Thrust-to-Weight Ratio to generate needed**

lift

Lift Total req. = 2 X W Total = **42.68 lb.** (19.36kg)

- **Actual T/W ratio**

Lift Total / W total = **1.905 (Including all losses)**

- **Power relation involving motor efficiency**

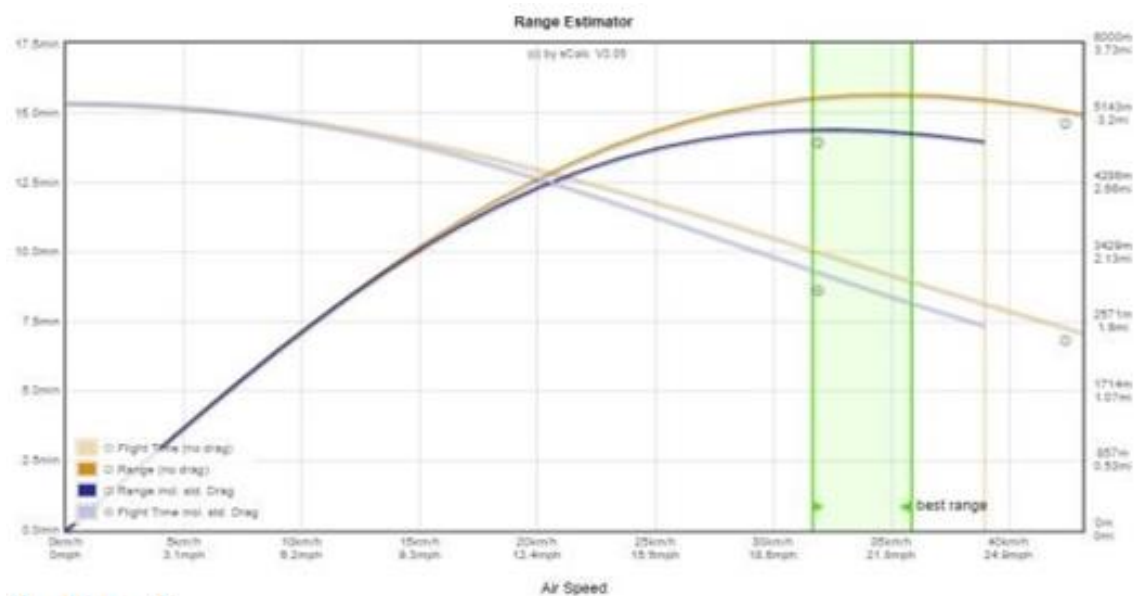P out Watts = Pin Watts X n = 1510.1564 W

- **Total Current Requirement by the UAV**

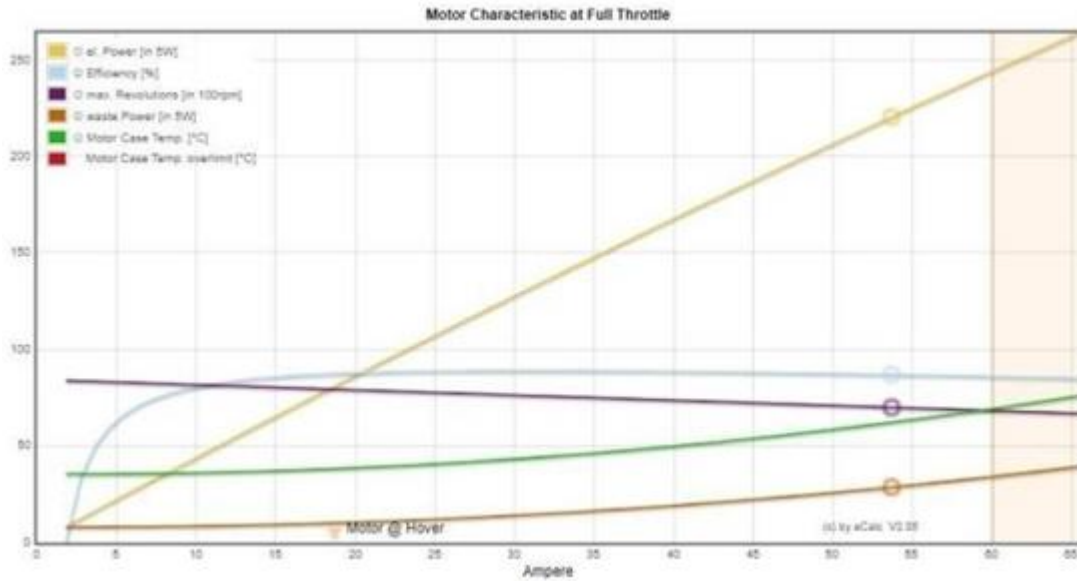I total = I motor X N motor = 240A

Calculation Done By ECalc.

Graph 1: Various Parameters

Graph 2: Time Vs Speed

Graph 3: Motor Characteristics at Full Throttle

V. RESULT

The above calculations proves that our selected components will serve our purpose of heavy lifting with ease.

Seed ejector calculations:

The Background: (x) and (y) Components of Velocity

Say, the seed is moving at a speed of 10 meters per second at a 30-degree angle to the horizontal, the x-component of the velocity is:

$$v_x = v \cos (\theta) = 10 \text{ m/s} \times \cos (30°) = 8.66 \text{ m/s}$$

Where (v) is the speed (i.e., 10 meters per second), and you can put any angle in the place of the (θ) to suit your problem. The (y) component is given by a similar expression:

$$v_y = v \sin (\theta) = 10 \text{ m/s} \times \sin (30°) = 5 \text{ m/s}$$

These two components make up the original velocity.

Basic Trajectories with the Constant Acceleration Equations

The projectile stops moving forwards when it hits the floor. If the seed is fired from 1 meter in the air, when the acceleration due to gravity takes it down 1 meter, it cannot travel any further. This means the y-component is the most important thing to consider.

The equation for the y-component displacement is:

$$y = v_{0y} \, t - 0.5gt^2$$

We can simplify this if the bullet is fired perfectly horizontally, so it doesn't have a speed in the (y) direction. This makes the equation:

$$y = -0.5gt^2$$

In this equation, (y) means the displacement from the starting position, and we want to know how long it takes the bullet to fall from its starting height (h). In other words, we want

$y = -h = -0.5gt^2$

Which you re-arrange to:

$t = \sqrt{2h} \div g$

This is complicated because technically, the drag reduces the speed, which in turn reduces the drag, but you can simplify things by just calculating the drag based on the initial speed of 400 m/s. Using a flight time of 0.452 s (as before), this gives:

x= 400 m/s × 0.452 s - [0.295 × 1.2 kg/m³ × (4.8 × 10⁻⁵ m²) × 400² m²/s² × 0.452² s²] ÷ 2 × 0.016 kg

= 180.8 m - (0.555 kg m ÷ 0.032 kg)

= 180.8 m - 17.3 m = 163.5 m

So, the addition of drag changes the estimate by about 17 meters.

This is the time of flight for the bullet. Its forward velocity determines the distance it travels, and this is given by:

$x = v0x \; t$

Where the velocity is the speed it leaves the muzzle at. This ignores the effects of drag to simplify the math. Using the equation for (t) found a moment ago, the distance traveled is:

$x = v0x\sqrt{2h} \div g$

If the seed is fired at 400 m/s and is shot from 1 meter high, this gives:

$x = 400 \text{ m/s} \sqrt{[(2 \times 1 \text{ m}) \div 9.8 \text{ m/s}^2]}$

$= 400 \text{ m/s} \times 0.452 \text{ s} = 180.8 \text{ m}$

So, the seed travels about 181 meters before hitting the ground.

Incorporating Drag

The equation for the force due to drag is:

$F_{drag} = -C\rho Av^2 \div 2$

Here (C) represents the drag coefficient of the bullet (C = 0.295 taken), ρ is the air density (about 1.2 kg/cubic meter at normal pressure and temperature), (A) is the cross-sectional area of a bullet (A = 4.8×10^{-5} m², the value for a .308 caliber) and

(v) is the speed of the bullet. Finally, you use the mass of the bullet to turn this force into an acceleration to use in the equation, which is taken as m = 0.016 kg.

This gives a more complicated expression for distance traveled in the (x) direction:

$x = v_{x0}t - C\rho Av^2 \, t^2 \div 2m$

Ignoring wind resistance to calculate the distance traveled by the seed bullet,

$x = v0x\sqrt{2h} \div g$

Where (v0x) is its starting speed, (h) is the height it's fired from and (g) is the acceleration due to gravity.

This formula incorporates drag:

$x = v_{x0}t - C\rho Av^2 \, t^2 \div 2m$

Here, (C) is the drag coefficient of the bullet, (ρ) is the air density, (A) is the area of the bullet, (t) is the time of flight and (m) is the mass of the bullet.

VI. ELECRTICAL AND PROPULSION SYSTEM

Motor

Fig: BLDC Motor

A BLDC out runner motor is used because it is an efficiently high caliber motor, which has quality double shielded bearings. Higher the K_V of the motor, lesser is the torque produced. Since our aim is to heavy lift, this motor

also has high loading capability up to 60A, which means bigger propellers can be loaded on this motor with ease. We did not go for even smaller KV due to following reasons:

1. Lesser KV motor provides less linear speed to the drone.
2. High cost.
3. It requires high current.
4. ESCs will become more expensive.

Therefore, after considering all the factors, keeping the cost in mind, this motor can serve our purpose i.e. keeping the drone cost effective and compact in size.

Motor Specifications

7.2V to 12V (2 to 3 Li-poly or 6to10 NiCad) current:0.5Amp for 60Sec maximum current:13Amp
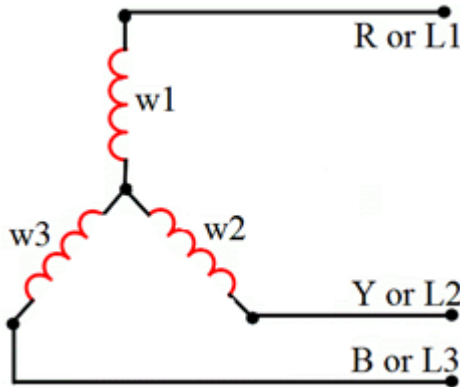
The maximum wattage is 150 watts.

Motor weight: 50-60 grammes

+80°C is the maximum operational temperature.

Because of the three-phase connection, complete speed control is possible.

There are no moving contacts, hence there has a long life expectancy.

Fig: Motor internal connection

Battery

Fig: Lithium-Polymer Battery

The drone uses a LIPO battery. A rechargeable battery of lithium-ion technology upgraded to use polymer electrolyte instead of a liquid one. The battery gives the whole system a flight time of at least 8-10 minutes. It the latest battery technology which has the highest energy density among all the batteries available in the market.

6cell, 16000 mAh, LiPo in parallel, which will act as the equivalent source to 32000m Ah with each LiPo having a discharge rate of 15C and 25C in burst mode.

Features of the Lipo battery a
1. Electrical load sharing.
2. No overloading to single battery.
3. Symmetrical placing of the batteries.
4. Reduces stress on the frame.
5. Less chances of complete power failure.
6. Reduces point loading on the frame.

Battery	Tattu	Orange	Turnigy
Availability	5	3	0
Weight	3	4	5
Cost	4	2	2
TOTAL FIGURE OFMERIT	12	9	7

Table 4 – FOM of Battery

Battery Specifications
❖ Capacity: 16000mAh
❖ Series: 6S
❖ Parallel:1S
❖ Discharge Rate: 15/25C

❖ Weight: 2076g

Propeller

Fig: Carbon Fibre Propeller

The main lift generating part our HLAV is called Airscrew or Propeller. The propellers in our drone are of 18X6.5 inch fixed pitch type propeller made of carbon fiber in order to keep the drone lightweight and increase durability. The propellers chosen for our drone are also of the smallest possible dimension, making the drone more compact without compromising the thrust with respect to the power rating of the motor. These propellers also provide high thrust, easily replaceable and remove any required gearing. The reason for selecting carbon fiber propeller is gives least vibrations and have less blade tip losses. Our selected propeller fits on T-Motor Mount, which ensures the safe operation of the propeller and holds the propeller tightly.

PROPELLOR	Metallic	Nylon	CarbonFibre
Strength	5	3	4
Weight	2	3	5
Cost	3	4	3
TOTAL FIGURE OFMERIT	10	10	12

Table 5 – FOM of Propeller

Propeller Specifications

- ❖ Diameter=18inch
- ❖ Pitch=6.5inch
- ❖ Mount type: T motor mount.
- ❖ Material: Carbon Fibre

7.4 Electronic Speed Controller

Fig: Electronic Speed Controller (ESC)

The term ESC stands for an "electronic speed control is an electronic circuit used to change the speed of an electric motor, its route and also to perform as a dynamic brake. These are frequently used on radio controlled models, which are electrically powered, with the change most frequently used for brushless motors providing an electronically produced 3-phase electric power low voltage source of energy for the motor. An ESC can be a separate unit which lumps into the throttle channel of the receiver or united into the receiver itself, as is the situation in most R/C aircrafts. Some R/C producers that connect exclusive hobbyist electronics in their entry-level vehicles, containers or aircraft use involved electronics that combine the two or on a sole circuit board.
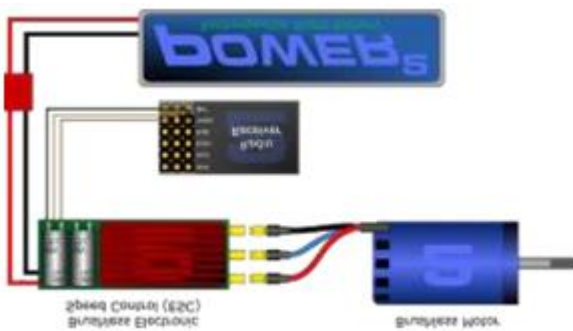
Fig: Block Diagram for ESC Connection

ESC should have the following features-

1. Should be able to hold maximum motor current that is 60A.
2. Required current rating is satisfied.
3. Programmable ESC.
4. High switching frequency.
5. Good heat dissipation
6. Lightweight.

| ESC	Hobbyking	Turnigy
Current Rating	5	5
Weight	4	3
Cost	5	3
TOTAL FIGURE OF MERIT	14	11

Table: FOM of ESC

Power Distribution Board

Power Distribution Boards or commonly known as PDB's are often an overlooked area of multirotor dronebuilding, mainly because they are fairly simple but despite this they are a crucial part of your drone and if you do not choose the right one you could end up losing your drone. As the name suggests, a PDB distribute the power on your drone, and provides a neat and tidy way of connecting your battery to all of your ESC's on your aircraft. A PDB has positive pad s/terminals, which are all connected, and negative terminals/pads, which are all, connected. This way when you solder all of the red wires from your ESC's and battery to the positive pads on the PDB, and the black wires to all the negative pads, they will all become connected so your batterycan provide power to all of your ESC's as shown in the image below.

7.5.1 PDB Specifications

- ❖ Scope of application: Up to six-axis
- ❖ Weight: 256g
- ❖ Size: 150*16mm
- ❖ ESC Plug: XT60
- ❖ ESC signal line: Rearward
- ❖ Power supply:2*6s
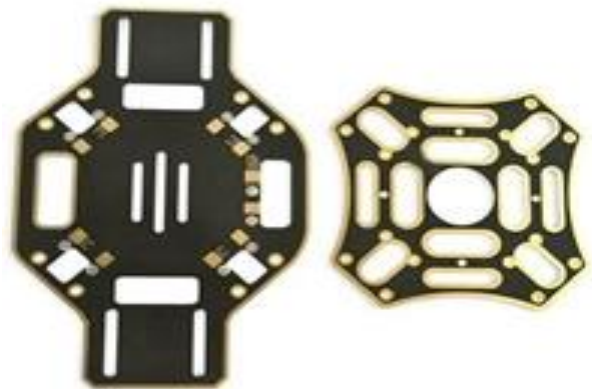
Fig: Power Distribution Board

VII.   WIRELESS AND COMMUNICATION

8.1 Pixhawk Hardware Interfacing:

8.1.1   LIDAR

The LIDAR rangefinder is a low-cost optical distance measurement solution with a 12m range under most operating conditions, low power consumption and small formfactor.

8.1.1.1 Pixhawk-Lidar Interfacing:

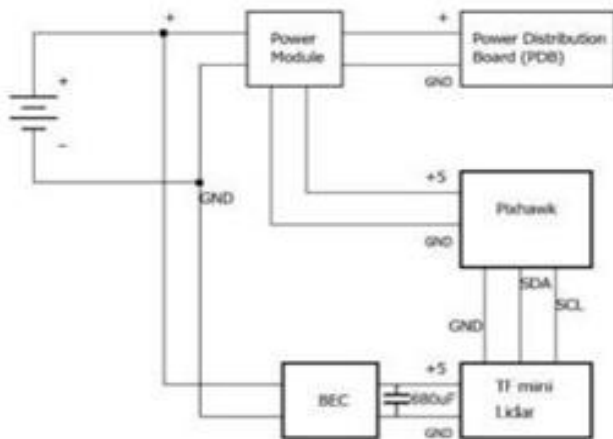There are two types connections which can be used for

interfacing PIXHAWK andLIDAR:
(i) **Connection of Lidar to the I2C port of Pixhawk.**
(ii) **Connection of Lidar using PWM mode**

Using I2C port:
The power for the TF-mini Lidar rangefinder will be supplied using a BEC as shown below:

Figure 17: LIDAR Connections to PIXHAWK

A battery eliminator circuit is used to deliver electrical power without the use of multiple batteries. The overall circuit will be as given below:

Circuit Diagram Connecting to PIXHAWK using PWM:
This is an alternate method for the Lidar connection. This method is ideal since it avoids the GPS interference, which may occur in the I2C method. The connection forthis is shown below:

Figure 19: PWM Connections of LIDAR to PIXHAWK

8.1.3 Arming Switch
Allows the user to power on and off the UAV. It is connected to the switch port of thePixhawk.
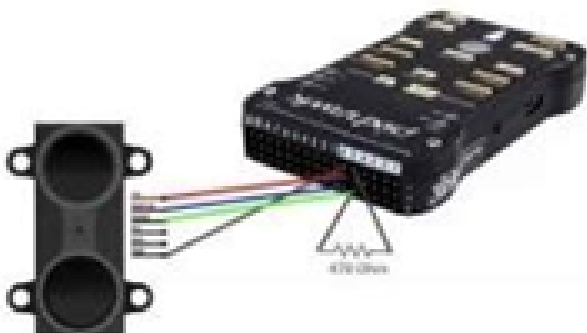
Figure 21: Arming Switch

8.1.4 Telemetry
Pair of two devices. One of them will be connected to the telemetry port of the PIXHAWK board. The other one will be connected to a tablet which will be operatedfrom the ground.

Figure 22: Telemetry Kit

8.1.5 GPS
It is connected to the GPS port of the PIXHAWK board. It will be placed at the centre and top of the drone away from the Lidar in order to avoid electrical interference. It isconnected to the I2C port of the PIXHAWK.

Figure 23: GPS

Attopilot Module
The power module provided with the PIXHAWK is

only compatible with 4S (16.8V) or less batteries. Since for our heavy lift aircraft we will be using 6S battery the power modul e will ensure safe operation of PIXHAWK Flight Control Board. So in order to operate PIXHAWK with 6S battery we will be using the power module called Attopilot. This ensures the safe operation of the drone. Since we are using a supply of 25.2V, we have to step down the voltage using a Power Converter, before we connect it to the PIXHAWK. It supplies power to the PIXHAWK from the LIPO as shown below:
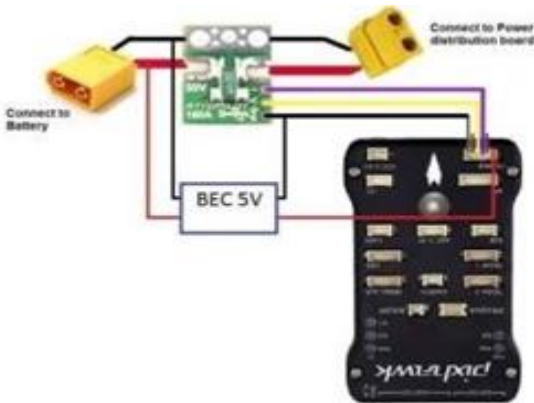

Figure 25: Attopilot Module Connections to PIXHAWK

Servo motor

A Servo Motor is a low-speed, high-torque motor that comes in a variety of sizes. Unlike the DC and Stepper motors the Servo Motor does not normally spin a full 360 degree rotation. Instead it is limited to a range of 180, 270 or 90 degrees.

A control signal is sent to the servo to position the shaft at the desired angle. This arrangement with a single signal makes it simple for servos to be used in radio and remote controlled designs, as well as with microcontrollers.

```
1 /*
2       PCA9685 PWM Servo Driver Example
3       pca9685-servomotor-demo.ino
4       Demonstrates use of 16 channel I2C PWM driver
board with 4 servo motors
5       Uses Adafruit PWM library
6       Uses 4 potentiometers for input 7
8       DroneBot Workshop 2018
9       https://dronebotworkshop.com
10 */
11
12 // Include Wire Library for I2C Communications 13
#include <Wire.h>
14
15      // Include Adafruit PWM Library
16      #include <Adafruit_PWMServoDriver.h>
17
18      #define MIN_PULSE_WIDTH       650
19      #define MAX_PULSE_WIDTH       2350
20      #define FREQUENCY     50
21
22      Adafruit_PWMServoDriver       pwm       =
Adafruit_PWMServoDriver(); 23
24 // Define Potentiometer Inputs 25
```

```
26 int controlA = A0; 27 int controlB = A1; 28 int controlC =
A2; 29 int controlD = A3; 30
31 // Define Motor Outputs on PCA9685 board 32
33      int motorA = 0;
34      int motorB = 4;
35      int motorC = 8;
36      int motorD = 12;
37
38 void setup()
39 {
40
41
42 }
43
44 pwm.begin(); pwm.setPWMFreq(FREQUENCY);
45 void moveMotor(int controlIn, int motorOut) 46 {
47
48
49
50
51
52
53
54
55
56
57
58
59 }
60 int pulse_wide, pulse_width, potVal;

//    Read    values    from    potentiometer    potVal    =
analogRead(controlIn);

// Convert to pulse width
pulse_wide = map(potVal, 0, 1023, MIN_PULSE_WIDTH,
MAX_PULSE_WIDTH);              pulse_width              =
int(float(pulse_wide) / 1000000 * FREQUENCY * 4096);

//Control Motor pwm.setPWM(motorOut, 0, pulse_width);
61 void loop() { 62
63      //Control Motor A
64      moveMotor(controlA, motorA);
65
66 //Control Motor B moveMotor(controlB, motorB);
67
68 //Control Motor C moveMotor(controlC, motorC);
69
70 //Control Motor D moveMotor(controlD, motorD);
71
72
73 }
74
75
76
```

VIII. DRONE AVIONICS INITIAL SETUP AND TUNING

1. Setting up Flight modes:

In autonomous terrain following application of the Hexacopter drone, we need various flight modes to achieve the required objectives. Some of them are, Altitude hold, loitering, manual override etc.

The controller setup that we are using consists of FS-i6 transmitter-receiver and Pixhawk flight controller.

The following steps are followed in order to achieve our required configuration.

1. We will be using the 3-position switch (SWC) and the 2-position switch (SWD). This will provide us the reliability of accessing six modes.
2. The first part of the configuration is done directly on the transmitter itself.
3. Click OK to get out of the home screen, now use the navigation switches to enter the SETUP MENU.
4. Select AUX.CHANNELS.
5. Keep pressing OK to cycle through the channels until the pointer is on Channel 5.
6. Use UP and DOWN buttons until Channel-5 shows SWC+D.
7. Cycle to Channel-6; assign Channel-6 as SWD.
8. Click and hold CANCEL until the transmitter beeps and returns to the previous screen. This means that the current setup is saved.
9. Go to END POINTS and then click OK.
10. Click OK to cycle down to Channel-5.
11. Use UP or DOWN button to adjust the END POINT values of Channel-5.
12. While doing this, have SWC and SWD in their first position and have your mission planner open at INITIAL SETUP/MANDATORY HARDWARE/RADIO CALIBRATION and have your MP connected to your quad via MAVLINK. It may be helpful, before doing this to click on INITIAL SETUP/MANDATORY HARDWARE/FLIGHT MODES and write down the PWM values for each flight mode to save you having to constantly click back to it during the next step.
13. As you adjust your END POINT, watch the value of CHANNEL 5 on your MISSION PLANNER and adjust it, until it falls within the PWM value required for FLIGHT MODE-1.
14. Repeat the above step for all the other modes.
15. The following is the required setup:

SWC Pos1	/	SWD Pos1	=	Flight	Mode	One
SWC Pos2	/	SWD Pos1	=	Flight	Mode	Two
SWC Pos3	/	SWD Pos1	=	Flight	Mode	Three
SWC Pos1	/	SWD Pos2	=	Flight	Mode	Four
SWC Pos2	/	SWD Pos2	=	Flight	Mode	Five
SWC Pos3	/	SWD Pos2	=	Flight	Mode	Six

Once the END POINTS are set, click and hold CANCEL until the TX beeps and returns to the previous screen.

Now, our switches have been programmed and we are ready to assign each and every MODE some specific task.

9.1.1 Setting up Altitude Hold:

One of our flight modes will be Altitude hold mode. When it is selected the throttle is automatically controlled to maintain the current altitude. Automatic altitude hold plays a major role in other modes like loiter. The values tuned in here will be used by the loiter mode too for its operation.

9.1.1.1 Tuning:

The Altitude Hold P is used to convert the altitude error to a desired climb or descent rate. The Throttle Rate converts the desired climb or descent rate into a desired acceleration up or down. The Throttle Accel PID gains convert the acceleration error into a motor output. The 1:2 ratio of P to I should be maintained. Since we are using this in a heavy lift application drone, we may get a better response by reducing both by 50% (i.e. P to 0.5, I to 1.0)

9.1.2 Setting up stabilize mode:

This mode is very important as it allows the pilot to have a manual control over the aircraft while the vehicle self-levels the roll and pitch axis.

➢ This mode is generally used in order to ensure a stable flight.
➢ Different yaw inputs change the heading of the aircraft. Once the controls are released the aircraft follows the heading at that particular instant.
➢ The altitude of the aircraft is controlled manually by giving throttle inputs.
➢ This mode is a backup human override when the aircraft loses control in autopilot due to external factors.

9.1.2.1 Tuning:

- ANGLE_MAX: controls the maximum lean angle (default-45 deg).
- ANGLE_RATE_MAX: controls the maximum requested bank in roll and pitch (default-180deg.).
- ACRO_YAW_P: This decides the responsiveness to yaw input given by the pilot (default-4.5 -200deg/sec).
- Stabilize Roll/Pitch P: This is same as ACRO_YAW_P but it is for roll and pitch. The default of 4.5 will command a 4.5deg/sec. This gain can be varied according to our needs. A higher gain allows more responsiveness.
- Considering our case, the heavy drone would need the gain to be between 5-7.
- Rate Roll/Pitch P, I and D: terms control the output to the motors based on the desired rotation rate from the upper Stabilize (i.e. angular) controller. These terms are generally related to the power-to-weight ratio of the copter with more powerful copters requiring lower rate PID values. For example, our copter with high thrust might have Rate Roll/Pitch P number of 0.08.

9.1.3 Setting up LOITER mode

The Loiter mode automatically tries to maintain the location, heading and altitude of that particular instant. The operation will be just as a complete manual flight, but as soon as the control is released the aircraft hovers in that particular location. A good GPS setup and lessinterference is essential for this mode. The pilot can control the copter's position with the control sticks:

➢ Horizontal location can be adjusted with the Roll and Pitch control sticks with the default maximum horizontal speed being 5m/s. When the pilot releases the sticks,the copter will slow to a stop.

➢ Altitude can be controlled with the Throttle control stick just as in Alt. Hold mode

➢ The heading can be set with the Yaw control stick.

9.1.3.1 Tuning:

➢ WPNAV_LOIT_SPEED: max horizontal speed is 5m/s. In default condition the acceleration is ½ of the loiter speed.

➢ WPVAV_LOIT_MAXA: This decides the maximum acceleration of the drone. Higher values cause the drone to stop or accelerate more quickly.

➢ WPNAV_LOIT_MINA: This decides the minimum acceleration. Higher values stop the aircraft more quickly when the stick is centred, but cause a larger jerk when the copter stops. Since we will be carrying a heavy payload, it is very important that thisvalue is moderate.

➢ WPNAV_LOIT_JERK: This is for the maximum change in acceleration. Higher numbers will make the vehicle more responsive, lower numbers will make it smoother.

➢ POS_XY_P: converts the horizontal position error to a desired speed towards thetarget position.

➢ VEL_XY_P: converts the desired speed towards the target to a desired acceleration. The resulting desired acceleration becomes a lean angle, which is then passed to thesame angular controller used by Stabilize mode.

9.1.6 Command List:

The following commands need to be specified while planning the mission. These parameters will be given according to the arena provided for the observation. Take-off Waypoint

Delay Lat, LonAlt

The altitude can be varied in such a way that the aircraft attains various altitudes throughout the different waypoints. But in our condition, we will be keeping the altitude constant so that our sensors work on their capability to maintain the required altitude with respect to the terrain rightbelow it.

9.2 Drone Sensors Calibration

1. The first step is to select the type of Frame. In our case, we will be going with the HEXA'X' class.

2. **Compass Calibration:**

a. Go to Mandatory Software and select Compass.'

b. Select the flight controller configuration to automatically enter the information for theboarding up

c. Select the button Pixhawk/PX4

d. Perform OFF board Calibration.

i. Click on the Live Calibration button, a window pops up showing the status of the livecalibration.

ii. The platform is then rotated in all the possible directions until a complete sphere forms onthe screen.

iii. The calibration is completed when the device has the information of all the positions.

3. **Accelerometer Calibration:**

a. Go to Initial Setup and select Acceleration Calibration from Mandatory Hardware.

b. Once the Accelerometer Calibration window opens click on Calibrate Acceleration. There are six different positions namely: Level, Left side, Right side, Nose down, Nose up and backside.

c. Proceed through all the above given positions.

d. The Mission planner will display "Calibration Successful" once you have completed the calibration process.

4. **Radio Calibration:**

a. Once the initial setup window is open, click on Radio Calibration in mandatory hardware.

b. Click on "Calibrate Radio". A dialogue box appears stating that the battery isdisconnected. Click on the OK button.

c. A new window with all channels to be calibrated appears. Move the sticks and switches on your remote such that they indicate the maximum and minimum values.

d. Select the "Click when done" button once done. A new dialog box appears indicating allthe channels with the minimum and maximum values.

S. No	Component	Quantity	Price/unit	Total Price(Rs.)
1.	Aluminium Tubes	6 metre	Rs. 250/kg	3000
2.	Aluminium Plates	~3kg	Rs.200/kg	600
3.	Miscellaneous (Connectors, wires and fixtures)	-	-	5000
4.	Motor(BLDC)	6	Rs.6000	36000
5.	ESC	6	Rs.3000	18000
6.	LIPO battery	3	Rs. 22000	44000
7.	PIXHAWK Kit	1	Rs. 20000	20000
8.	Attopilot	1	Rs. 1700	1700
9.	Propellers set	3	Rs.7500	17500
10.	LIDAR Rangefinder	1	Rs. 3000	3000
11.	CNC Milling and Laser Cutting	-	Rs. 5000	5000
	Total			153800

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