# PRINCE MOHAMMAD BIN FAHD UNIVERSITY
## College of Engineering
## Department of Mechanical Engineering
## Spring 2020 -2021

Senior Design Project

**Milestone 7: Final Report**

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## *Abstract.*

Nowadays, there is a growing need for flying drones with diverse capabilities for both civilian and military applications. There is also a significant interest in the development of novel drones which can autonomously fly in different environments and locations and can perform various missions. In the past decade, the broad spectrum of applications of these drones has received most attention which led to the invention of various types of drones with different sizes and weights. In this review paper, we selected a commercial drone frame QAV ZMR 250. This frame will be tested and redesign to achieve better efficiency and more flight time with less power consumption. The redesign process we will focus in area of weakness of the design as well as changes in the drone components to reach better efficiency and long flight time. This Quad Copter is independently designed and helps you to monitor footage's. Controller-Quad-Copter communications take place primarily using the FS-I6 wireless communication system. The equilibrium state of the Quad-copper is sensed by the sensors integrated KK-2.1 controller. The KK microcontroller board processes all sensor signals K. K. board microcontroller performance used by Quad-copter propellers to control. We Develop a wing equipped with legs to be more valuable and more stability to the design that can sit with different applications under one design. And maximized the flight time for drone with low cost and minor changes in design to develop a better usage for those who are using the drone for long time such as monitoring proposes.

Moreover, we understood the design of propeller angels and numbers can create a change in the drone flight efficiency, which can help those are working with the drone to deliver packages or unexpected increase of weight. Also improvement in Sensors selection optimization & Analysis of the performance requirements of Quadcopter are required. We studied the changes in the system and get the best valuable result in improving the design based on the experiment that will implements will help the future researcher or drone manufacturers make their drone project with based data can guide them to make the best design without studying the project from zero and make their testing just for the data.

## *Acknowledgment.*

First of all, we would like to express our appreciation to our advisor Dr. Nassim Khalid for his unlimited support for our project and his encouragement. Also, we express thanks to Eng. Nedaal Bembi, for his continued support and encouragement.

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## Chapter 1: Introduction:

UAVs have been used in a variety of applications from the first pilotless aircraft to today's DIY drones. Unmanned aerial vehicles (UAVs) are planes that have no pilots or passengers on board. They can be remotely piloted aircraft or autonomous ‘drones' (RPVs). UAVs can fly for long stretches of time at a regulated speed and height, and they play a part in a variety of aviation applications. During World War I, Britain and the United States produced the first pilotless cars. The Aerial Goal, a small radio-controlled aircraft developed by the British, flew for the first time in March 1917, while the Kettering Bug, an American aerial torpedo, flew for the first time in October 1918. Despite showing success in flight tests, neither was used in combat during the war. Unmanned aircraft production and research continued throughout the interwar era. The British developed a series of radio-controlled aircraft to be used as training targets in 1935. The word 'drone' is believed to have first been used around this time, perhaps as a result of the name of one of these models, the DH.82B Queen Bee. In addition, radio-controlled drones were made in the United States and were used for target practicing and testing. Reconnaissance unmanned aerial vehicles (UAVs) were first used in vast numbers during the Vietnam War. Drones started to be used in a variety of new ways, such as decoys in battle, firing missiles at fixed targets, and dropping leaflets for psychological operations. Drones, which were initially designed for military use, have seen exponential development and advances and have found their way into commercial electronics. Originally, they were used as weapons, in the form of remotely-guided aerial missile launchers. Drones, on the other hand, have a wide range of civilian applications today, especially in the form of small quadcopters.

(Parihar, 2016)

## 1.1 Project Definition

Assessment of multiple 3D print designs of a drone. Optimizing and testing of several control designs. Implementation of a design of experiment (DOE) and recording flight time from fully charged battery. Select the optimal design of the drone. Modeling flight time using relation between battery voltage and flight time and selecting the optimum design based on efficiency of power consuming and flight time.

## 1.2 Project objective

The objective from designing the Quad copter and make research & consider problem solving and start to do several experiments to approach:

- Develop a wing equipped with legs to be more valuable and more stability to the design that can sit with different application under one design.
- Maximize the flight time for drone with low cost and minor changes in design to develop a better usage for those who are using the drone for long time such as monitoring proposes.
- Understand the design of propeller angels and numbers can create a change in the drone flight efficiency, which can help those are working with the drone to deliver packages or unexpected increase of weight.
- Improve Sensors selection optimization & Analysis of the performance requirements of Quadcopter.
- Studying the changes in the system and get the best valuable result in improving the design based on the experiment that will implements will help the future researcher or drone manufacturers make their drone project with based data can guide them to make the best design without studying the project from zero and make their testing just for the data**.**

## 1.3 Advantages of Quadcopter

One of the coolest invention is drone technology (because it is useful environmentally and economically) I.e Agriculture revolutionizes drone or Unmanned Air Vehicle (UAV), such as the use of remote sensing in agriculture. Essentially, the use of precision drones Worldwide agriculture, agriculture, pesticides and weed control are exploding.

### 1.3.1 Environmentally:

- Due to their mobility and connectivity to the distant regions, more focus has been paid to unmanned aircraft (UAVs, drones) used as delivery vehicles.
- Drones have also been used often in logistics, taking advantage of the sensors and the mobility to rough terrains of cameras and sensors by drones. In December 2013 for instance, in Amazon, America's largest online retailer, 'Amazon Prime Air' used self-developed drones known as the 'Octocopters' in order to distribute merchandise within 30 minutes to a customer over 16 km. Amazon has also tested drones many times and obtained a UAV delivery system patent.

### 1.3.2 Economically:

- In order to assess the volume of pollution and the environmental effects of the distribution process, shipping distances and fuel efficiency were considered. The study excluded from the reach details on some factors inaccessible for drones, including drone price and repair costs, the latest advancement of technologies, the delivery failure rate and the environmental conditions, for focusing on the delivery stage to compare a traditional and a drone delivery system.
- The use of drones for supply makes landless or difficult to enter places easier and the delivery time is reduced by preventing traffic congestion; however, a small battery life and power prevents the use of drones for long-distance use or significant freight capacity.

## 1.4 Project Specification:

Specifications include:

- BLDC= 20500 rpm
- Power system operates on 12V
- Remote distance is about 200m
- Action time will be about 30 Minute-3 hour.

| | |
|---|---|
| Lithium Polymer Battery 1300 mah | Capacity of 1300 mah - cell number 3S |
| 3 phase Brush-less motors | 2300kv with XMC 1302 |
| Fly sky FS-i6x | 2.4 GHz : 6 Channels |
| Electronic speed controller | PINUS 35A |
| Flight controller FC | 5V, 12V in DC |
| Propellers | 5 inch glass made propellers |
| GPS WIFI Bluetooth | 16MP |
| Low voltage warning | Less than 5V |

Table 1.1

## 1.5 Applications

In the following fields, the Quad-Copter security system has applications:

1. Military/Army
2. Large Production places e.g big industries/ large complexes
3. Shopping centers /malls /big markets
4. Colleges/Universities.
5. Hospitals/ clinics.
6. Aerial photography and surveying

# Chapter 2: literature Review

## 2.1 Project Background

The United States military was one of the first to see the benefits of unmanned aerial vehicles. Miniaturization, technology maturation, more efficient processors, and more accurate and less expensive sensors have all aided research and investment in these machines. Miniaturization favored the development of mini UAVs, also known as micro UAVs, which weigh less than a kilogram. This has prompted the development of advanced vehicles in both the private sector and academia, with several universities focusing on the potential of vertical takeoff and landing (VTOL) vehicles in particular. In recent years, there has been a surge of interest in drones for both industrial and military uses, resulting in the launch of a number of commercial “complete packaged” quad-copter systems that are now available on the market. The quad-copter is a common drone due to its unique characteristics. The Quad-main copter's benefits are its ability to float or stay still in the air, as well as its VTOL capabilities. This enables the Quad-copter to fly in almost any situation, like incomplete flight or confined spaces with little maneuverability. Many of the characteristics of a Quad-copter are shared by a conventional helicopter with one main rotor and one tail rotor. However, apart from the spinning engines and propellers, the Quad-copter has no moving components, whereas a traditional helicopter needs a complex hub to rotate the rotor axis to induce a translating wave. The Quad-copter is thus less susceptible to vibrations and has greater flexibility in terms of center of gravity positioning. Since rotors are smaller, they can be shielded more comfortably, making flying indoors safer. Except for the propellers, there are no moving parts in a traditional quad-copter configuration. The motors and propellers are attached to the board, and the only way to trigger lateral motion is to tip the whole thing. The Quad-copter, unlike a traditional helicopter, does not have a tail rotor to control the yaw motion. Two of the quad-four copter's motors rotate clockwise, while the other two spin counterclockwise. A moment would be generated along the yaw axis if the pair of clockwise motors rotate at a different rate than the pair of counterclockwise motors. Our project can be seen as a small step toward optimizing and enhancing the reliability of UAVs in terms of power consumption and flight time.

## 2.2 Quadcopter

A quad-rotor helicopter (quadcopter) has four evenly spaced rotors arranged at the corners of a square body. The quadcopter is a kind of helicopter that is more sophisticated. A helicopter is a moving aircraft that uses two quickly rotating rotors to propel air downward. There are four rotors on the quadcopter. Since the quadcopter has four rotors, controlling them without any electronic assistance is very complicated. A quadcopter is made up of four thin airfoils or lift generators that are arranged in a perfect square formation at the four corners. These lift generators are powered by a high-speed motor and precision-balanced propellers, which force the air flow down and produce thrust to lift the Quadcopter above the ground. We can customize the scale of the quadcopter to fit our needs. It can be made as compact as we like by using the small components we'll need to put it together.

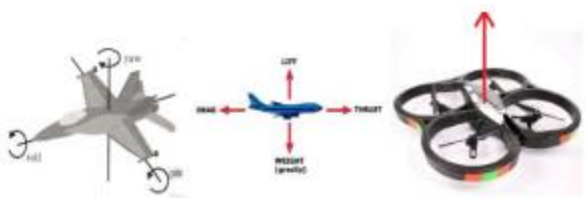

Figure 1: A Quadcopter (Borah, 2016)

## 2.3 Modelling of a quadcopter dynamics

The fundamental dynamics of Quadcopter are presented here. The following figure shows the fundamental concept of the Quadcopter movement. The figure shows that the Quadcopter is easy compared with helicopters in its mechanical nature. Action in the horizontal frame is accomplished by inclining the platform and vertical rotation by adjusting the overall driving force of the engines. However, Quadcopter arises with certain control design problems.

A specific type of controller is used to control the altitude. The propeller speed is changed as the controller is moving up or down, allowing the quadcopter to gain or lose height. There is also a way to change the thrust of the rotors using voltage supply to conduct normal flight operations and to put the quadcopter into some angular orientation based on the circumstances of a specific flight routine. One kind of force is thrust. When a system accelerates mass in one direction, the accelerated mass causes the system to experience a force of equal magnitude but in the opposite direction. Thrust is a force that is applied to a surface in a direction that is perpendicular or normal to the surface. Two of the propellers on a quadcopter are designed to spin in the opposite direction to the other two propellers. The first pair of propellers rotates in one direction to maintain X-axis balance, while the other pair rotates in the opposite direction to maintain Y-axis balance. To eliminate rotation in the Z dimension, rotate in the opposite direction. The rotational speed of each of the thin airfoils determines the aircraft's movement; changing the rotational speed affects the position. The aircraft is largely controlled by the three main axes of pitch, roll, and yaw. The motion of a quadcopter may be disrupted by a variety of forces in space. As a result, balancing the powers acting on the quadcopter is critical. To comprehend these powers, we must first comprehend the three axes.

### 2.3.1 Yaw

It's the vertical axis that runs along the quadcopter's geometric core. When the rotational force vectors of all four motors operate at the same time and cancel out at the same geometric center, the quadcopter rotates clockwise or anticlockwise around this axis. When they don't cancel out and the resulting vector has net positive or negative amplitude, the quadcopter rotates clockwise or anticlockwise around this axis.

### 2.3.2 Pitch

It's the axis that runs horizontally parallel to the quadcopter's plane, extending towards the front and back ends. The quadcopter goes forward or backward depending on whether the resultant of the rotational force vector is positive or negative.

### 2.3.3 Roll

It's the line that runs horizontally parallel to the quadcopter's plane as it moves from left to right. The quadcopter goes in the right or left direction depending on whether the resulting rotational force vector is positive or negative.

**Mathematical Calculations of thrust force for motor and propeller:**

$$Drone\ +\ battery = mg(drone) + mg(battery)$$

$$= 10 \times 20500 \times \frac{2(3.14)}{60}$$

$$= 21456$$

Thrust1/Weight1

10N/1Kg=10

Thrust2/Weight2

Thrust =1034 g

W (rpm) =20500 rpm

10.4/1.2=8.6

Power 1 Mass=200g

Power 2 Mass=150g

### 2.3.4. Motors and rotate regulators

A motor with a high thrust is required by the quadcopter. Strong AC brushless motors work well for this. Using PWM bursts, the thrust can be regulated indefinitely. PWM pulses for motors are produced by a kit's output ports, which are then sent to each motor's ESC (Electronic Speed Control). The location of the motor's rotor is required by the ESC. As compared to DC motors with the same efficiency, AC motors are 30-50% lighter. These AC motors are used in the construction of smaller, longer-flying versions. It's important to check the ESC's output when choosing motors. (Borah, 2016)

### 2.3.5 Assumptions of quadcopter

The Quadcopter has the following assumptions:

- The structure should be rigid. It is presumed that the Center of Gravity and the fixed frame origin coincide.
- Thrust and drag are commensurate with the square speed of the propeller. The propellers should be rigid.
- The axis should be symmetrical in shape.
- using Euler angles φ- roll angle, θ- pitch angle, ψ- yaw angle. − About by φ, by θ and by ψ

The body rate measured p, q, r of a body-fixed frame and the Tait-Bryan angle speed expressed in the Earth-fixed framework should be given special consideration. The transformation matrix from [ **φ θ ψ**]**T** to [***p q r*** ]**T** is displayed by:

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} 1 & 0 & -\sin\theta \\ 0 & \cos\emptyset & \sin\emptyset\cos\theta \\ 0 & -\sin\emptyset & \cos\emptyset\cos\theta \end{bmatrix} \begin{bmatrix} \emptyset \\ \theta \\ \varphi \end{bmatrix}$$

In addition, the rotation matrix of the body of the Quadcopter must be compensated Regulation of place. The reward is obtained by transposing the rotation matrix.
(Luukkonen, 2011)

$$R(\emptyset,\theta,\emptyset) = R(x,\emptyset)R(y,\theta)R(z,\varphi)$$

$$R(x,\emptyset) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\emptyset & -\sin\theta \\ 0 & \sin\emptyset & \cos\emptyset \end{bmatrix}$$

$$R(y,\theta) = \begin{bmatrix} \cos\theta & -\sin\varphi & 0 \\ \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R(z,\varphi) = \begin{bmatrix} \cos\varphi & -\sin\varphi & 0 \\ \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

# CHAPTER 3: SYSTEM DESIGN

## 3.1 DESIGN CONSTRAINTS AND DESIGN METHODOLOGY:

Once we began our designing and schedule for the project, we encountered certain difficulties, there was shortage of few parts and hard to get them in short time period for our project like specific kind of motors including control system to facilitate the lifting of the design. Besides that, the majority of the parts were purchased from abroad because they are not available on the local market and even the big cities because of that the various companies which refuse to design because they do not have proper freedom to design them. Finally, company has agreed only to make the concept in shape without any control device programming also the weight of the design and the thrust force of the engine should be taken into account in order to increase our design without overloading, so that we can fly it quickly. We came across few limitations while working on CAD model in SOLID WORKS. These limits are the propeller length, which defines the arm length.  The engine rotor diameter and the electronic speed controller distance, which relate to the determination of drone arm size, are few electrical devices during which the flight controls and distribution boards decide the fuselage dimension.

### 3.1.1 Sustainability:

We had a sustainability challenge because of the possibility of little movement Since we used smaller fans with high efficiency to be suited to the engine movements in the thrust due to its thickness and direction of the fan blades to avoid this issue.

### 3.1.2 Safety:

Safety is the key because protection of parts is an integral aspect of our structure. This would maximize the performance and keeps the efficiency high the fan's motion constant if the motor does not run overloaded.

### 3.1.3 Ethical:

In this project we took an idea from older projects so it appears a little like the older type of project. We have therefore sought general ideas to develop the design with our safety, economic and sustainability ideas and because of these ideas it makes our report exceptional and different from all previous reports.

## 3.2 DESIGN ENGINEERING STANDARD:

While designing this project we must follow the engineering standards. So in this part of our project, each item chosen was identified properly. (multirotor, 2016)

| COMPONENT | ENGINEERING STANDARD | DETAILS |
|---|---|---|
| Lithium Polymer Battery 1300 mah | Capacity of 1300 mah - cell number 3S | Power supply for our drone |
| 3 phase Brush-less motors | 2300kv with XMC 1302 | Motors to rotate the propeller and left the drone |
| Fly sky FS-i6x | 2.4 GHz : 6 Channels | To control the drone wireless. |
| Electronic speed controller | PINUS 35A | 4 Speed controller |
| Flight controller FC | 5V, 12V in DC | To monitor the drone operations |
| Propellers | 5 inch glass made propellers | To generate the thrust power |
| GPS WIFI Bluetooth | 16MP | To transfer the vision |
| Low voltage warning | Less than 5V | To reduce the power consumption |

Table 2

### 3.3 THEORY AND THEORATICAL CALCULATION:

Quadcopter estimation based on the following seven factors:

1. **Forces and Moments on Quadcopter:**

$$Fi = kf * \omega i^2$$

$$Mi = km * \omega i^2$$

Four propellers generate the Fi thrust perpendicular to the propeller rotation axis. This thrust is directly proportional to the square of the angular propeller velocity. If a propeller rotates, it produces MI on the Z axis quadcopter.

$$Mi = km * \omega i^2$$
$$My = (F1 - F2) * L$$

This moment of reaction is proportional to the angle square. Propeller angular speed. Thrust created by opposite pairs of MX and My propellers. Different strengths x length between two propellers give the moment.

$$MX = (F3 - F4) * L$$

$$Weight = mg$$

Finally, the force of gravity that is still downwards. A second law of Newton's motion will study the motion of the quadcopter. (Biczyski, 2020)

2. **Newton's Second law of motion:**

The motion of Quadcopter can be analyzed by newton's second law of motion.

*For linear motion*

*Force = mass x linear acceleration.*

** for rotational motion:*

*Torque = Inertia x angular acceleration*

**3. Hover Condition:**

The drone requires a net upward force to rise off the ground. As a quadcopter is constant in the air, it needs to be balanced. The drone engines provide a thrust larger than the quad copter weight, which causes the quad to move upward.

$$mg = F1 + F2 + F3 + F4$$

$$All\ Moments = 0$$

The overall thrust of the propeller F1 + F2 + F3 + F4 shall be equal to the quadcopter weight, and all the times of the quadcopter shall be equivalent to 0.

While Equation of Motion for hovering condition is:

$$Mr = F1 + F2 + F3 + F4 - mg$$

$$Mr = 0$$

**4. Rise Motion:**

In Rise motion case thrust generated by all four propellers are more than the weight.

$$Mg < F1 + F2 + F3 + F4$$

$$All\ Moments = 0$$

Equation of motion while rising all four forces are:

$$Mg = F1 + F2 + F3 + F4 - mg$$

$$Mr > 0$$

Electric motors produce thrust. When the movement rises, it exceeds the weight of the quadcopter by the net push produced by all propellers.

**5. Drop motion:**

In Drop motion case thrust generated by all four propellers should be less than the weight.

$$Mg > F1 + F2 + F3 + F4$$

$$All\ Moments = 0$$

Equation of motion while dropping all four forces must be less than zero

$$Mr = F1 + F2 + F3 + F4 - mg$$

$$Mr < 0$$

This leads to a quadcopter output movement which is mr>0 in this situation.

The net thrust provided by all the propellers in the case of increase motion is more than the quadcopter's weight. This results in a quadcopter performance movement, which is mr>0.

6. **Yaw Motion:**

Yaw movement is the lateral axis rotation of a quadcopter. Two of them rotates in clockwise rotating propellers, and the other 2 anti-clockwise rotating propellers.

$$mg = F1 + F2 + F3 + F4$$

$$All\ Moments \neq 0$$

7. **Pitch and roll motion:**.

Pitch and roll movement is the quadcopter rotating along the horizontal axis and in this situation, the opposite propeller pairs generates uneven force, resulting in net non-zero moments.

$$mg < \square 1 + F2 + F3 + F4$$

$$All\ Moments \neq 0$$

### 3.3.1 THRUST APPLICATION:

The strength that pushes a plane through the air is Thrust. Thrust is used to control the aeroplane drag and to surmount a rocket's weight. Thrust is produced by some other propulsion system by the aircraft engines.

**How to calculate thrust for motors?**

$Basic\ life\ Formula\ - ball\ bearings$

Life in Hours = ( C / P )3 * 106 = ( C / FY)3 * 106

In above given equation

**C** represents Thrust rating from chart for 106 revolutions of life.

**F** represents actual thrust applied plus weight of rotor.

**Y** represents Bearing thrust factor from chart

**N** represents RPM of motor.

**Theoretical Calculations for Selecting out motors thrust power**

Weight of drone = approx. 700g

$\text{Calculated weight} = 2 \times 700 = 1400\text{gapprox}$

$$\text{Total weight} = 1400 + 20\% = 1680\text{g}$$

$$\text{thrust for each motor} = \frac{1680}{4} = 420$$

Thrust1/Weight1

10N/1Kg=10

Thrust2/Weight2

Thrust =1034 g

W (rpm) =20500 rpm

10.4/1.2=8.6

Power 1 Mass=200g

Power 2 Mass=150g

**STATIC THRUST**

We calculate the power to measure the thrust first. Power transferred from the motor to the propeller in rpm.

$$\boldsymbol{POWER = propeler\ constant \times RPM^{power\ factor}}$$

**DIFFERENT EFFECTS ON PROPELLER EFFICENCY AND THRUST:**

***‘‘According to Bernoulli's equation, the pressure is low where the airspeed is high, and high where the airspeed is low in the case of a flat sheet or aero-foil.’’***

Drones using the rotors — a propeller linked to a generator, that means the drone's downward pull would be the same as its gravity, Climbing up if another pilots raise their speed even before rotors generate a length higher than the gravity.

The air flowing in the upper part of the air film, in comparison with the bottom part of the aerobic foil, where the stress is greater, is high, creating a decrease in pressure. This is because the friction differential makes the aero-foil boost.

The propeller is constructed from multiple blades connected to the hub or boss either by Forging or welding. The aero-foils are tilted and arranged so that the blades are rotated in either direction, based on how the thrust is to emerge. Such blades act similarly as wings moving across the air causing the air to be lifted as the air passes across the air and the effect causes a wing to be lifted. Propellers acts according to the Newton’s third law of motion which states

***“Action and reaction are equal in magnitude but opposite in direction”***

According to Bernoulli's air passing by from the top surface pretty quickly than the lower one in case of aero-foil.

### 3.3.2 Brushless motor and reason for using it instead of normal motors:

Brushed DC motors are dependent on a mechanical system to pass current, whereas electronic current control mechanisms are used by AC and brushless DC motors. In our project we prefer using brushless motor because of the following reasons:

- ✓ Motor Construction:
- ✓ Efficiency:
- ✓ High Speed Operation:

### 3.3.3 Calculation Thrust For Motors:

Motor thrust shall be determined by the process below:

1) First, measure the weight of the drone and the things it carries in flight. To find minimum thrust, multiply Drone's weight by two. Again, to get overall weight, add 20% of the measured weight.

$$\boldsymbol{calculated\ weight} = \mathbf{2} \times [\boldsymbol{weight\ of\ drone} + \boldsymbol{weight\ of\ carried\ objects}]$$

$$\boldsymbol{total\ weight} = \mathbf{2} \times [\boldsymbol{weight\ of\ drone} + \boldsymbol{weight\ of\ carried\ objects}] + [\mathbf{0.2} \times \boldsymbol{calculated\ weight}]$$

2) Lastly divide all the weight by no. Of motors

$$\frac{\boldsymbol{calculated\ weight} + (\mathbf{0.2} \times \boldsymbol{calculated\ weight})}{\boldsymbol{Number\ of\ motors}}$$

### 3.3.4 Power lift calculation:

If a body is passing through a fluid, fluid often imposes a force on the flowing body's surface. One part of the applicable force is lifting. lift mostly applied in the direction perpendicular to the object's movement. On the airfoil, the stream lines at the top pass through the air are closer than the lower ones. It will act accordingly linear or streamline flow as the lines get closer pressure decrease.

$$\boldsymbol{power\ of\ life} = \frac{\boldsymbol{CI} \times \boldsymbol{\rho V}\text{^}\mathbf{2} \times \boldsymbol{A}}{\mathbf{2}}$$

**CI** stands for lift co-efficient ,

***p*** stands for density of fluid

**V** stands for speed

**A** stands for area that cover wings

**3.3.5 Flight Time calculation formula for our drone:**

The following formula can be used to determine flight time:

$$\boldsymbol{time\ of\ flight\ of\ drone = t = \frac{battery\ capacity\ \times battery\ discharge}{Average\ amp}}$$

In Above given formula:

**t** is time of flight in hours (For minutes divide the calculated time by 60)

Average amp is for amperes of battery

FOR EXAMPLE:

$$time\ of\ flight\ of\ drone = t = \frac{10 \times 0.6 \times 60}{55}$$

= 6 minutes 54 seconds

= **6’54’’.**

**3.3.6 Relation of Power Consumption in drone and number of propellers blades:**

The number of blades of propellers highly depends on the carry load/weight condition. Higher proportion of blades of propellers add to the carrying load. The power consumption of drone will also rise as drone load increases. Smaller portion of blades is mounted on the motors with low capacity and high KV rating. Larger fan blades with low KV engines are mounted. (Biczyski, 2020)

**3.3.7 Making Graph And Data Table of thrust power and power consumption to get flight time data:**

The following formula can be used to measure drone power consumption:

$$\boldsymbol{power\ consumption\ =\ Battery\ capacity\ \times\ Battery\ discharge}$$

A graph can be drawn by power consumption at y-axis and average ampere at x-axis. The slope of the graphs gives the time of flight of Drone.

**3.3.8 Stability and body rigidity:**

Two laws should be taken into account for a smooth flight while building drone.

1) Having a rigid body is the first norm. Whether the body was fastidious. Flying is not going to be safe and the drone is going to undergo much unmatched movement and angular movement. If

the body is fixable because it is a low-cost alternative which greatly increases reliability and rigidity, a rigid harness support can be attached to the drone.

2) The support we used for harness in our drone is X-shaped with 5mm thickness and of fiberglass and its working is to help and support the drone system properly.

3) The key point is to mount the flight control board to be fully attached in it so that It cannot rotate or tilt throughout the whole flying processor even only by moving it freely and it would respond after tilt slightly by raising motor power to the degree at which it was celebrated.

**NOTE:**

The drone's arms are autonomous and intended to remove force from the fuselage. In this way, in case of faults or injuries, the electronic components will be at their minimum risk

**Fuselage**: the fuselage is indeed the core of all electronics parts on the drone. Flight controllers, power delivery boards, receivers, ESC etc. For example. DYS FC pro omnibus, Matek XT-60 PDB can be accommodated in this fuselage. A housing is designed to shield the components while the crash landing or crash is carried out to avoid damage to the electronic components of the fuselage.

## 3.4 Risk Factors

- ESC has been burned repeatedly.
- Flipping over.
- Smooth landing challenging.
- Motor and smashed weapons damage, landing gear and propeller damage.
- And during processing, its batteries was destroyed.

### 3.4.1 Product Risk Factors

- **Lack of Oversight:** In several nations there are almost no regulations on drone safety measures mostly in regional, local or international field. It covers ordinances on sustainability. This leads to grave dangers, as these un personalized aircraft share flights with civilian, commercial as well as fighter planes.
- **Colliding:** Far more hazard of accident with drones is a pilot aircraft which flies beneath 500 feet. This covers commercial aircraft, helicopters, agricultural aircraft and gliders upon landing/start. A drone colliding on a commercial plane may cause physical harm in excess of $5 million

- **User Error:** The majority of drone pilots are hobbyists, including many youngsters. There is a significant concern about the lack of regulatory supervision and mandatory safety training for hobbyists.
- **Losing control** : Contact with the drone may be disrupted if it flies far beyond radar strength and fails in its system. There have been several incidents like these, making it a high risk.
- **Cyber Attack**: As drones are monitored by Wi-Fi radio waves, internet who rob the data gathered from the drone may be hacked. Drones may also be "spoofed," which means hackers took control of the plane and control on the drone's radio signals.
- **Liability**: High dollar litigation charges toward suppliers (exposure to product liability), firms (exhibition of general liability) and property operators (exhibition of financial damage) will be made when rules are in place.
- **Malice**: Drone terror attacks were also a serious risk; drones flying over power plants and nuclear stations have already been reported. Drones also can quickly reach audiences from arenas, marches, music events, respectively.
- **Data protection:** During 2016, the FAA published privacy guidance and other drone risks. In 2016, the National Telecommunications and Information Authority also launched Best Practice Guidelines on privacy for local individuals. However, they are voluntary rules, and the absence of legislation leads to a significant risk of violation of privacy and infringement.
- There has been absolutely no ethical decision for public health drone designers.and recommend that it should be adopted Because of the context critics and the role of bioethics to structure the field of medical services, drones (or any other robot for such) used in health contexts and procedures should also be assessed as an integral factor.
- A small but crucial part of that effort is that during the risk analysis process a large number of people blend restrictions and risks. (ALLOUCH, 2019)

## 3.5 Risk Analysis:

A system was built in and tested. Those are the results:

- To prevent burning the ESC, the PI values would have to be corrected for optimal flight
- Sender enabled with success.
- ESC coded smoothly.
- Formatted KK board with achievement.

### 3.5.1 Overall Risk Analysis For Drones:

- An ethical guideline strategy incorporates it's use drones in methods that satisfy the need for another surgeons and clinicians for both the instrument (achievement) and that have no directly relationship with the patient. For instance, medical supplies and sampling between hospitals are transported. This task, however, may be better studied using **CCVSD** and carried out by a human , such as a drone, which carries drugs directly to a patient at home. Here, instead of the caregiver, the patient communicates directly with the drone and there is a possibility of devaluation of the treatment practice.
- Conceptual investigation phase of the **VSD** process is another factor that can be extremely helpful for risk analysis. The ethical frameworks are not intended as a sign list but as a base for ethical reflection on technological growth, which could be used for a variety of design executions as prescribed by VSD. Its Guidelines is indeed an implemented technique to morality designed to structure problems and possibilities to be considered and mitigated, respectively, by designers and implementers if possible. (ALLOUCH, 2019)

## 3.6 Economic Evaluation of Project

This section of report comprises of three parts:

1. Table
2. Cash Flow Diagram
3. Payback period chart

| YEAR | INVESTMENT | Operating cost | REVENUE FROM SALES | Profit | Payback period | Months |
|---|---|---|---|---|---|---|
| 0 | -1200 | 0 | | | | |
| 1 | -12000 | 0 | 15000 | 3000 | 0.8 | 9.6 |
| 2 | -24000 | 0 | 30000 | 6000 | 0.8 | 9.6 |
| 3 | -36000 | 0 | 45000 | 9000 | 0.8 | 9.6 |
| 4 | -48000 | 0 | 60000 | 12000 | 0.8 | 9.6 |
| 5 | -60000 | 0 | 75000 | 15000 | 0.8 | 9.6 |

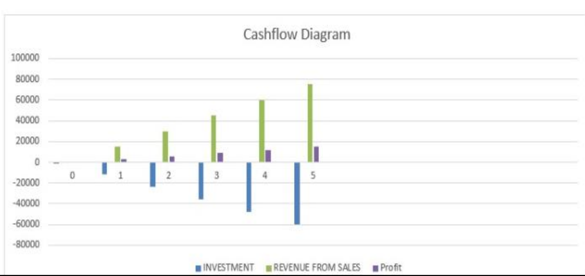


Figure 2: Table and Cash Flow Diagram

1. From the table we can say that in the year 0, I made an investment of 1200 SR while there is no operating cost. In the year 1, I made ten products so investment is of 12000 SR. We

assumed that one product will be sold of the 1500 SR then in first year I sold ten products then cost will be of 15000. So, his revenue is of 15000 SR with a profit of. 3000 SR. In the same way, the table works.

2. From the cash flow diagram, It can be seen that the green bars are in the positive quadrant while blue bars are in the negative quadrant. As investment shows outflow of cash that's why these bars will be in the negative quadrant and revenue will show cash inflow so they will be in the positive quadrant. As in the year one, there is investment of 12000 and revenue generated 15000 in this year while profit for this first year will be 3000 that is shown by purple bar in the positive quadrant. In the same way, during coming years the blue bars will indicate investments, green bars will show revenue from sales while purple bars will show profit in the positive quadrant.

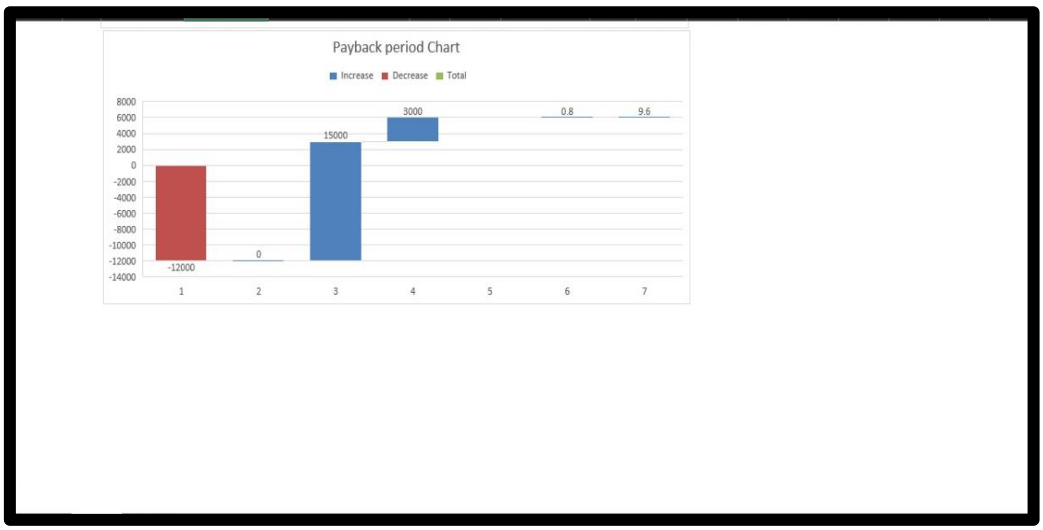


Figure 3: Payback Period Chart

3. In the payback period chart, The first bar is showing the investment of 12000, operating cost of zero in the second column, a revenue of 15000 in the third column, a profit of 3000 in the fourth column, while the column six is showing that he will get all his money back in 0.8 years and 9.6 months.

# Chapter 4: System Testing and Analysis

## 4.1 Stick Scaling

These settings enables us to adjust the sensitivity of the transmitter stick. A higher number gives a more sensitive response. It is used in preference to increasing the rates in our transmitter. The default values are low for beginners that may not appreciate how sensitive the transmitter sticks can be in controlling a quadcopter.

• If we want to flip and roll, we need to increase the Roll and Pitch values.

• Increase the Yaw value to yaw to our liking.

• Throttle should be at 90. If we increase it too much, full throttle on the transmitter will run the motors at maximum and leave no headroom for the PI control loop to adjust the motors to keep it steady. If we set the value to a negative value, it will reverse the transmitter channel. This is to enable the use of transmitters that don't allow us to change the direction for a channel. It only works for roll, pitch and yaw.

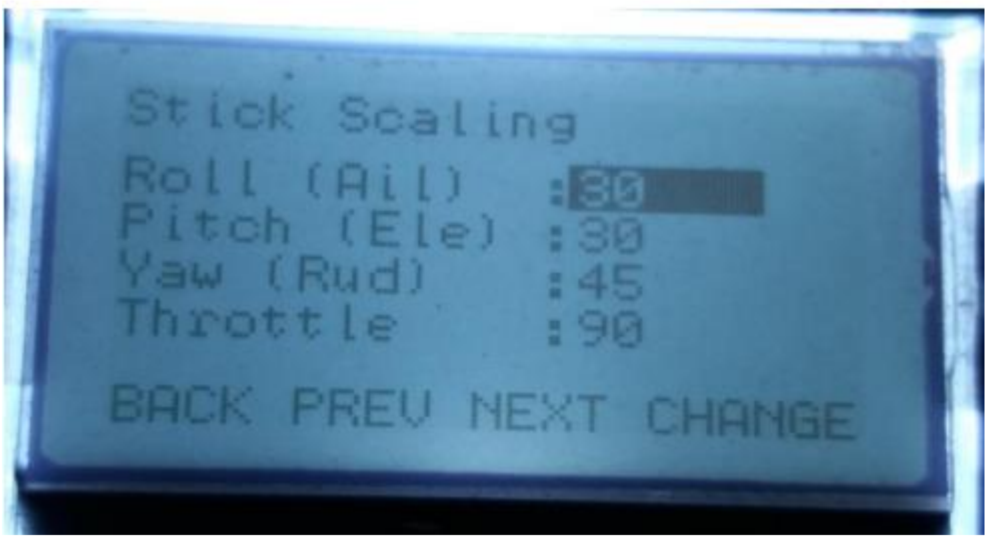


Figure 4: Stick Scaling Menu

Stick Scaling Roll: 30

Pitch: 30

Yaw: 45

Throttle: 90

**4.2 Misc. Settings 1**

Various settings

• **Minimum throttle** – ensures all motors start at the same rate. If some motors do not start when armed, we increase this value. This value also allows us to change the motor speed if we have Spin on Arm enabled. We set it at 10.

• **Height Dampening** – Compensates for the drop in height when the quadcopter is banked in a turn. Normally, the pilot will compensate for this dropping effect by increasing the throttle slightly. The default is 0 (disabled). We set it at 10.

• **Height D. Limit** – The percentage of motor power that can be used to apply the correction.

• **Alarm 1/10 volts** – When the flight battery +ve terminal is connected to the KK2.1.5 battery monitor pin, this sets the voltage alarm threshold when the buzzer sounds. If we want the buzzer to sound at 11.0 volts or less, set this value to 110. The default is 0 (disabled).

• **Servo Filter** – Software filter that smooths out the control signal to servos. Set this value at 50

• **Acc. SW filter** – Software filter in the KK2.1.5 code that smooths out the accelerometer reading. This value can be increased to mask vibrations. The default is 8 which results in a low pass filter coefficient of 0.03 (8/256).

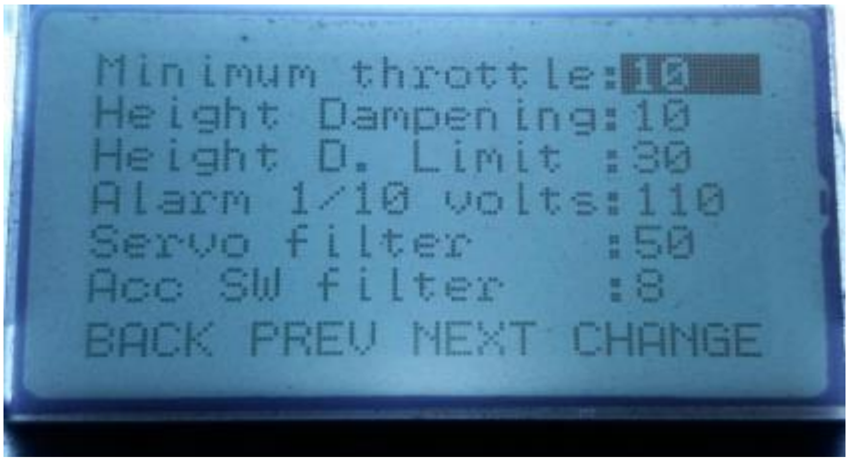


Figure 5: Misc. Settings 1

Minimum Throttle: 10

Height Dampening: 10

Height D. limit: 30

Alarm 1/10 volts: 110

Servo filter: 50

Acc SW filter: 8

### 4.3 Misc. Settings 2

- **Board Offset**

o 0 – Zero degrees offset. KK2.1.5 board faces forward.

o +45 or -45 – KK2.1.5 board is mounted at 45 degrees.

o +90 or -90 – KK2.1.5 board is mounted at 90 degrees.

o 180 – 180 degrees offset. KK2.1.5 board faces backwards.

- **Spin on Arm**

o No – When armed, with throttle at zero, motors are stopped.

o Yes – When armed and throttle is at zero, motors run at the speed set by Minimum Throttle. This is useful if you want to fly and never want your motors to stop in flips and rolls for example.

- **SS Gimbal**

o No – A normal camera gimbal is being used with one servo for Pitch and one for Roll.

o Yes – Super Simple Gimbal is used where both servos work together to move Pitch and Roll in a differential configuration.

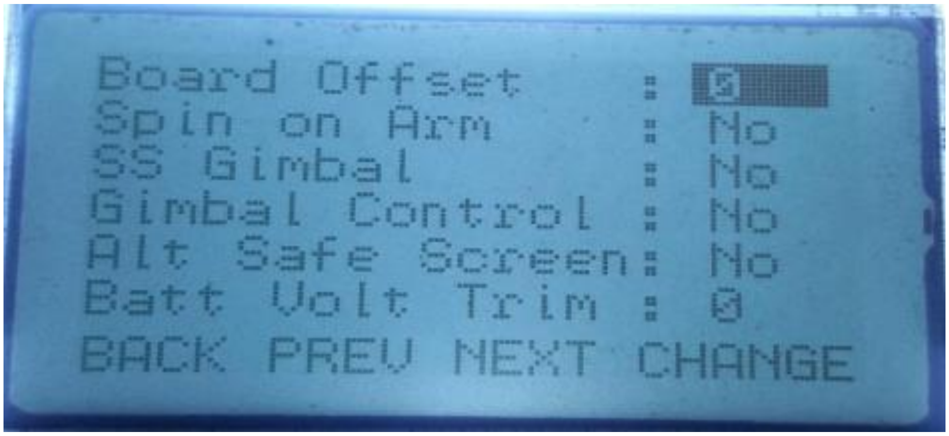


Figure 6: Misc. Settings 2 Menu

- Gimbal Control

o No – Gimbal offset is fixed as set in Camera Stab Settings.

o Aux – Gimbal Pitch offset can be changed using the Aux channel. This enables you to change the Pitch offset with a Standard PPM receiver.

o 6&7 – Gimbal Pitch and Roll offset can be changed using the receiver Channel 6 and 7 outputs. Note that you will need to use this feature with a CPPM receiver, satellite receiver or SBus receiver.

- Alt Safe Screen

o No – Standard SAFE screen layout

o Yes – Alternative SAFE screen layout which displays the last Motor Layout selected

- Batt Volt Trim

o Enables us to adjust the battery voltage reading by 0.1 volt increments if we are not satisfied with the value shown with the default trim value of 0. The range is +/0.6 volts. The value shown is 1/10th of a volt so a value of 6 is 0.6V.

**4.4 Self-Level Settings**

Self-Level Settings are independent from normal PI settings.

• **P Gain** – The power of the self-levelling. Higher number is stronger. Too high will cause oscillations. To low and it’s slow to self-level. Higher number gives the operator more stick control. Lower number reduces the operator stick control.

• **P limit** – Limits the max power of self levelling. Higher number is higher limit.

• **ACC Trim Roll** – compensates for self-level drift when the KK2.1.5 had the ACC calibrated when it wasn’t exactly level.

• **ACC Trim Pitch** – compensates for self-level drift when the KK2.1.5 had the ACC calibrated when it wasn’t exactly level. It’s better to calibrate the ACC with the KK2.1.5 level rather than use the trims. Make sure the KK2.1.5 is mounted level in the quadcopter.


Figure 7: Self Level Settings

P Gain: 75

P Limit: 20

Acc Trim Roll: 0

Acc Trim Pitch: 0

**4.5 Sensor Test**

Displays the raw gyroscope and accelerometer sensor values.

• Must show "OK" when stationary.

• If it says “Not OK” when stationary, the sensor chip is faulty.

• Move the KK2.1.5 around to see that the numbers change.

In this case, it is fine if the sensors start reading “Not OK”.

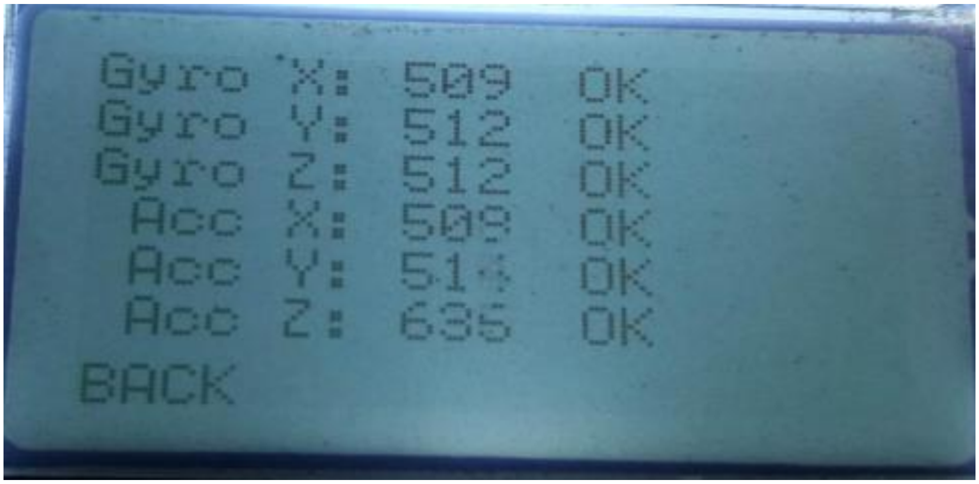


Figure 8: Sensor Test for Gyroscope and Accelerometer

**4.6 Show Motor Layout**

Displays a graphical representation of the motors and servos

• Can be used to check the Motor direction and which outputs to connect the ESCs and Servos to. Note that this does not set the motor direction. That is set by the wires connected between your motor and ESC. If needed to reverse the motor, reverse two of the three motor wires.

• Enables us to see which Motor Layout we have selected and any changes we make in the Mixer Editor.


Figure 9: Motor Layout

# Chapter 5: Project Management

## 5.1 Project Plan and Contribution of Team Members

In our project, there are many tasks included. Each task is assigned to one or more members. The details about division of whole work is being presented below:

| Task | Start Date | Days to complete | Responsible |
|---|---|---|---|
| **Task 1: Plan** | | | |
| Project Identification/Allocation | 20/1/2021 | 4 | Sultan Al Rashidi, Ali Al Zahrani |
| Objective Identification | 25/1/2021 | 2 | Najem Al Joufi, Bander Al Otaibi |
| Gannet Chart | 29/1/2021 | 3 | Mishal Al Nasser |
| **Task 2: Report Establishment** | | | |
| Report Formatting, Table of Context & Acknowledgement. | 2/2/2021 | 1 | Sultan Al Rashidi, Ali Al Zahrani |
| Chapter # 1: Introduction | 4/2/2021 | 2 | Najem Al Joufi |
| Chapter # 1: Objectives | 7/2/2021 | 1 | Najem Al Joufi |
| Chapter # 2: Background | 9/2/2021 | 2 | Mishal Al Nasser |
| Chapter # 2: Previous Work | 12/2/2021 | 2 | Bander Al Otaibi |
| Chapter # 2: Comparative Study | 15/2/2021 | 2 | Mishal Al Nasser |
| **Task 3: System Design** | | | |
| Chapter #3: Design | 20/2/2021 | 3 | Sultan Al Rashidi, Ali Al Zahrani |
| Chapter #3: Calculations | 24/2/2021 | 2 | Everyone |
| Chapter #3: 3D Modelling | 27/2/2021 | 2 | Najem Al Joufi, Bander Al Otaibi |
| Material Selection / Machining | 2/3/2021 | 14 | Everyone |
| Gathering Parts | 16/3/2021 | 2 | Everyone |
| **Task 4: Midterm Presentation** | | | |
| 1st Monthly Progress Report | TBA | 1 | Everyone |
| PP Presentation | 19/3/2021 | 5 | Everyone |
| **Task 5: Testing & Data Collection** | | | |
| Prototype Assembly / Completion | 19/3/2021 | 4 | Everyone |
| Pre-Testing Observation | 23/3/2021 | 4 | Sultan Al Rashidi |
| Chapter #4: System Testing | 27/3/2021 | 5 | Ali Al Zahrani |
| Chapter #4: System Analysis | 1/4/2021 | 5 | Najem Al Joufi |
| Chapter #5: Project Management | 6/4/2021 | 4 | Bander Al Otaibi |
| Chapter #6: Project Analysis | 10/4/2021 | 4 | Mishal Al Nasser |
| **Task 6: Deliverables & Final Presentation** | | | |

| | | | |
|---|---|---|---|
| 2nd Monthly Progress Report | 13/5/2021 | 1 | Everyone |
| Final Project Report | 12/5/2021 | 3 | Everyone |
| Brochure | 15/5/2021 | 2 | Sultan Al Rashidi, Ali Al Zahrani, Najem Al Joufi |
| Poster | 17/5/2021 | 2 | Bander Al otaibi, Mishal Al Nasser |
| Final Presentation PP | 19/5/2021 | 2 | Everyone |

Table 3: Plan of Work

### 5.2 Project Execution Monitoring

During our project, for the successful accomplishment of goals, regular meetings and sittings were arranged to ensure the continuous monitoring and meeting deadlines. Following is the list of events and meetings being conducted during this whole period of project formulation:

| Time/ Date | Activities/ Events |
|---|---|
| Once time a week | Assessment class |
| Biweekly | Meeting with supervisor |
| Weekly | Meeting with group members |

Table 4: List of activities being performed for monitoring project progress

### 5.3 Challenges and Decision Making

Following are the issues and challenges being encountered during the execution of project:

1. **Issues in equipment's:**

   As far as sustainability is concerned for the prototype, it was made sure that selection of components, like propeller and brushless motors and Cam adapter and power distribution board and supporting frame were made according to choice of the proper materiel. Also, our concerns are there is a limitation for our prototype like the capability of it have the maximum possible flight time. Also, another concern is corrosion that can affect the prototype because it can be exposed to erosion so we must consider to control the corrosion by use barrier coatings like paint.

2. **Testing and Safety Concerns:**

   When working, there are certain risks like fault in circuitry or a malfunction in motor that can leads to damage to property, injury to life and loss of this precious piece of technology that we developed after hours of hard work and investment of money.

3. **Design Problems:**

During the fabrication and assembling of quadcopter, we faced challenges in the matting of parts because of wrong tolerances we maintained in the first attempt. Then we redesigned chain sprockets and bearings to meet the close tolerances to ensure a close fit during assembly. Moreover, we faced problem in designing complex parts like propeller etc. But later on, things get smooth when we successfully done with the testing of quadcopter.

### 5.4 Project Bill of Materials and Budget

The table below is showing the cost of parts that we purchased and the one we designed. Moreover, it also illustrates about the cost of material of which we designed this quadcopter.

| Items | name | quantity | cost | total |
|---|---|---|---|---|
| 1 | Udemy course | 1 | 150 | 150 |
| 2 | Frame Kit | 1 | 72 | 72 |
| 3 | Brushless Motor | 8 | 145 | 1160 |
| 4 | Electronic Speed Control ESC 3A | 6 | 60 | 360 |
| 5 | Power Distributor Board | 2 | 80 | 160 |
| 6 | Flight Controller Board | 1 | 180 | 180 |
| 7 | 11.1V LiPo Battery | 1 | 240 | 240 |
| 8 | Propellers | 30 | 1 | 30 |
| 9 | FLYSKY FS-i6X 10CH 2.4GHz RC Transmitter Controller | 1 | 202 | 202 |
| 10 | FLYSKY FS-i6X 10CH 2.4GHz RC Transmitter Controller | 1 | 60 | 60 |
| total | | | | 2614 |

Table 5: Overall cost of project analysis

# Chapter 6: Project Analysis

## 6.1 Life-long Learning

When we were working in our project, we gained diverse knowledge about different things, be it software skills, hardware skills, time management skills and project management skills. By working as a team we learnt that how to manage tasks by ensuring time management and good communication skills with members of team. In this part, we will explain the number of skills we gained since we worked on this project.

### 6.1.1 Software Skills

In this project, we gained hand on experience of working on softwares like MS Word, MS PowerPoint and Solidworks. For designing of quadcopter, we used the software of solidworks which helped us polishing our skills in this designing software. In addition to this, we learnt about using word and PowerPoint while writing report and making brochure.

### 6.1.2 Hardware Skills

During our project, we learnt about assembling the designed parts to fabricate our desired project of quadcopter. We also have a hand on experience of the skill of welding. Moreover, I also learnt about doing sound calculations before moving towards fabrication part of project because a small difference in calculations can result into a huge difference while fabrication of project.

### 6.1.3 Management Skills

During project work, we learnt about time management that how deadlines can be met efficiently during the execution of project. Moreover, there are many skills like distribution of work, team work and leading the team in the right direction that I learnt during the completion of project.

## 6.2 Impact of Engineering Solutions

Following are the social, economic and environmental impacts of our project:

### 6.2.1 Social Impacts of project

Since most of the projects are carried out to develop product and contribute to making the industry better and efficient by using the minimum amount of resources as possible to develop this product, this product is very helpful in the agriculture sector for seed sowing and also for gaining a bird eye view of the crops and for evaluating the progress regarding watering and harvesting of crops by installing cameras in quadcopters.

### 6.2.2 Economic Impacts of project

In the economic side it helps to save energy because it doesn't require any type of energy cost. So that will help the users for not thinking about the energy consumption. Also, it is efficient enough to replace the thousands of labors for sowing seeds and many other purposes.

### 6.2.3 Environmental Impacts of project

As this project machine has zero power consumption so it will have zero emissions and will not cause any environmental concerns for the public.

## 6.3 Contemporary Issues Addressed

The most significant issue that this project is addressing is following contemporary issues:

1. Developed a wing equipped with legs.
2. Maximizing the flight time.
3. Improving the efficiency of flight.

# Chapter 7: Conclusion and Future Recommendations

## 7.1 Conclusion

A surveillance device using a quadcopter may improve protection, especially in areas where human intervention is strictly prohibited. Surveillance of terrestrial areas is important in all civilized countries. The main goal is to look at the whole quadcopter design process from an engineering standpoint and improve the stabilization and stabilization mechanism. It would also aid in the analysis of different parameters such as height, temperature, and humidity, among others. With the aid of a microphone, it can even be used to do live video streaming. Nowadays, quadcopters are in use in various disciplines where these are performing different duties. While the quadcopter we designed is a wing equipped with legs to be more valuable and more stability to the design that can sit with different application under one design. We maximized the flight time for drone with low cost and minor changes in design to develop a better usage for those who are using the drone for long time such as monitoring proposes. We understood the design of propeller angels and numbers can create a change in the drone flight efficiency, which can help those are working with the drone to deliver packages or unexpected increase of weight. We improved Sensors selection optimization & Analysis of the performance requirements of Quadcopter.

Figure 10: Our Final Prototype of Quadcopter

## 7.2 Future Recommendations

By adjusting camera phone to the phone holder at quadcopter, it can be utilized in following domains:

Remote Reaching

Aerial Photography

Security etc.

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