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DESIGN AND FABRICATION OF PESTICIDE SPRAYING QUADCOPTER

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ABSTRACT

The purpose of this paper is to put basis information and parameters which are required for the actual detail designs of a Quadrotor. We propose a ESSTI model pesticide spraying Quadrotor in which all the four engines (motor-propellers) are situated on the above of the frame. All the airframe designs and parameters are new and customized in domestic products. The electronic/electrical components to be customized and calibrated to satisfy the performance of the new Quadrotor. Regarding to the dynamic, kinematic and aerodynamic modeling they are performed after detail design phase and complete 3D model. The Quadrotor basic airframe dimensions are determined including the individual components. All the necessary equipments, weight analysis and cost estimation are tabulated and calculated which helped greatly while designing the Quadrotor. The main features of this design are to manufacture a pesticide spraying Quadcopter with four transverse bamboo sticks as a boom. The hollow bamboo can accommodate the ESC and wiring to motor-propeller assembly. The bamboo and other frame parts are found locally and make the cost cheaper. The detail design, mathematical analysis and 3D modeling are analyzed in result and discussions. We take some estimation to design the Quadrotor.

Keywords: Quadcopter, Pesticide Sprayer, Design Analysis, Quadcopter Motion, Mathematical Modeling.

I. INTRODUCTION

A Quadcopter, also called a Quadrotor helicopter are a multicopter that is lifted and propelled by four rotors. The lift is generated by a set of revolving narrow chord airfoil. A quadrotor is a multicopter that is lifted and propelled by four rotors [1]. The airframe design types of a quadrotor differs depending the number of arms (booms) and motor assembly such as tricopter, Quadcopter (with x and + configurations), Hexacopter, Octocopter and other configurations. Nowadays there are different designs of Quadrotor which are used for different purposes [2].

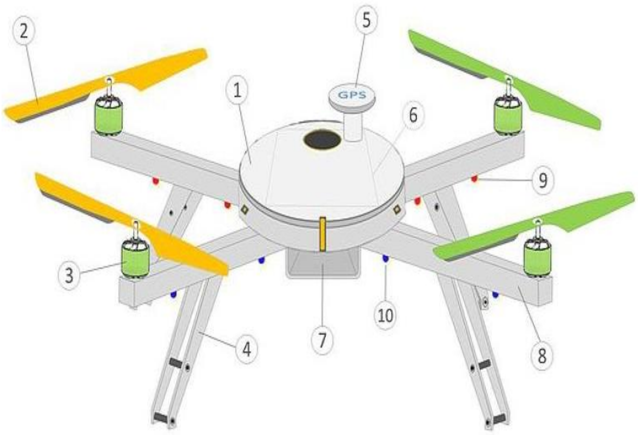

Figure 1: Main components of a Quadcopter [3]

1-Canopy 2-Blade (propeller) 3- Brushless motors 4- Landing skid 5- GPS antenna 6- Control board7- Li-Po battery 8- Frame 9- LED lights (front) 10- LED light (Back)

Manual spraying of pesticide and fertilizers cause a number of chronic diseases [4] to rural areas. Agriculture is the backbone of the Ethiopian economy and is not modernized very well. There are modern technologies that greatly help Ethiopia's farmers such as the drone applications with various benefits like farm assessments and preserving farm conditions namely checking for weeds, watering, seed spray, bacteria, and chemical spray e.t.c. In the current need of the country, the project is of Quadcopter pesticide sprayer is found to be important. It will have dual benefits for agricultural fields and prevention of locust infestation as optional. The major objective of this project is to create a quadrotor system which has a better agility, stability, endurance with optimal payload capacity of spraying pesticides which can cover visible areas. The Quadcopter pesticide sprayer system consists of; The Quadcopter and the spraying mechanisms with a brushless motor [5]. From the function of the Quadrotor, it is wise approach to map systems and subsystems. This made easier to design a Quadcopter which fulfill the basic function and the basic equipments [6].

a) Basic components

The flight controller transmits signals to Electronic Speed Controllers (ESCs) and the transmitted data changes the motors rotational speeds which in-turn is responsible for the stability of the Quadrotor. They are designed to control the speed and direction of a motor and there are different features for various applications [7]. The ESC has wire ports in both sides namely; the power input wires, 3 bullet connectors and 3-pin R/C servo control.

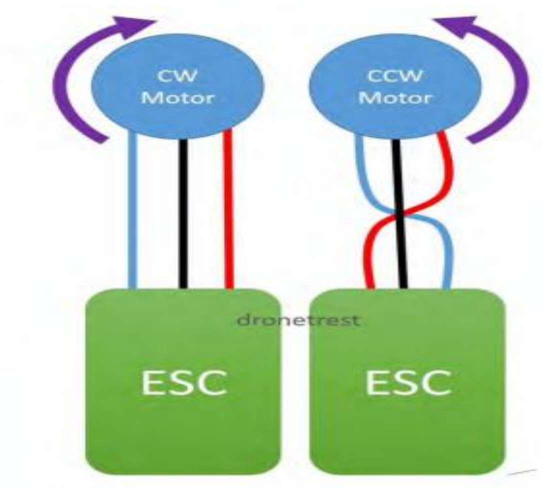

Figure 2: Brushless ESC [8]

Battery used in quad rotors nowadays is Li-Po (Lithium-Polymer) batteries. Li-Po has high capacity-low weight with a high discharge rates. Small battery packs range is 0.1Ah (100mAh) though the medium sized drones 2-3Ah (2000mAh-3000mAh) [9]. The receiver on a quadrotor is an electronic device that uses built-in antennas to receive radio signals from the Quadcopter controller. Receiver is connected to the flight controller which should be programmed to receive RC signals [10]. A flight controller is a circuit board that manages the drone's flight and has DCU support for Quadcopter, Hexacopter and Octocopter agriculture spraying GPS. The flight controller consists of T-1A, GPS, PMU, DCU and LIU [11].

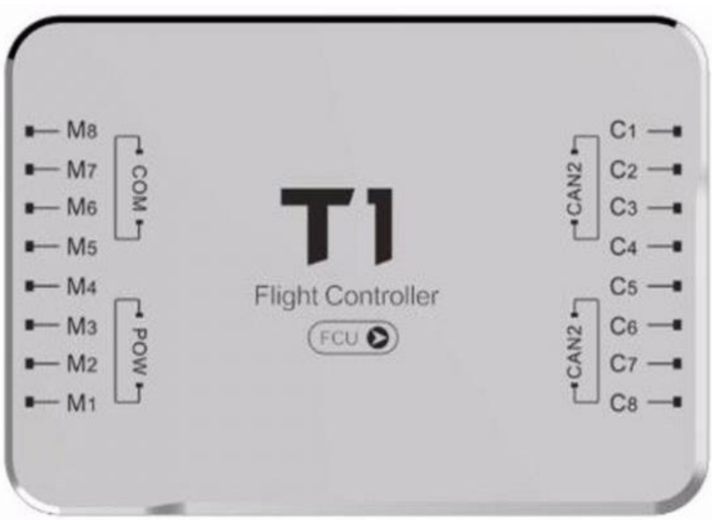

Figure 3: Flight controller T1A

The flight controller is basically the nervous system of the drone and receives raw information from the drone. It is transmitted via the receiver and then makes the corresponding movement to the drone's rotors. Some flight controllers are configured and programmed by operator, but this requires a fairly in-depth level of knowledge [12]. Flight drone controllers are typically titled to include their main microprocessors model and STM electronics 32-bit microprocessors are more popular. The STM32 F1, F3, F4, and F7 are considered the most common models [13]. Radio transmitter is an electronic device that uses radio signals to transmit commands wirelessly via a set of radio frequency over to the radio receiver. It can also define as the device that translates pilot's commands into movement of the multi-rotor.

Radio transmitter transmits commands via channels an every switch or knob on the transmitter uses one channel to send the information through to the receiver [14]. A receiver and radio transmitter are compatible products; this means the same brand of Rx and TX need to be purchased in order to establish a communication [15]. The motors have an impact on the Quadcopter payload which it can support and the flight time. The Quadrotor motors in which the propellers are connected are made them to spin around to generate thrust. They are connected into three main sections which are why all brushless motors have 3 wires coming out of them [16]. Propellers are either designed to rotate clockwise or counter-clockwise and it is important to understand which part of the propeller is intended to upwards. Technically, the top of the propeller always face to the sky [17]. The opposing yaw motion cancels each other out in flight [18]. The pre-Loaded trajectory provides the real time coordinates to flight controller loaded program and as a result GPS coordinates the microcontroller navigates a Quadcopter [19].

b) Precision Agriculture

Precision agriculture helps the way farmers manage their crops to yield product using drone technology for pesticide spraying, watering and fertilizer. In order to maximize the productivity, quality, and yield, it is recommended to minimize pests, unwanted flooding, and disease.

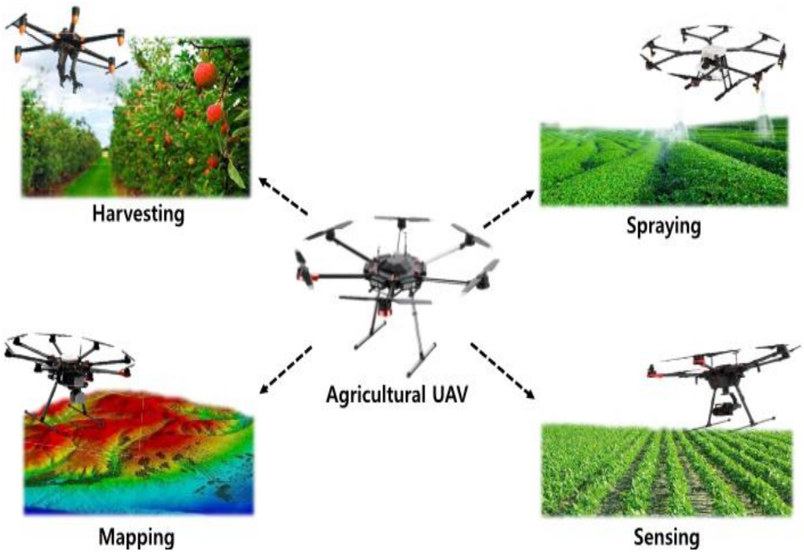

Figure 4: Multiple types of agricultural UAVs: harvesting UAV, spraying UAV, conventional UAV, mapping UAV and sensing UAV [20]

According to the Food and Agriculture Organization of the United Nations (FAO) and the International Telecommunication Union (ITU), the world should increase the food production by 70% by 2050 due to population growth. This problem can be solved with PA done by the Unmanned Aerial Vehicles (UAVs) and Wireless Sensor Networks (WSNs) which can lead to valuable and at the same time economic Precision Agriculture (PA) applications. This includes aerial crop monitoring and smart spraying tasks [21]. Yamaha RMAX was the first drone for spraying crops with far more precision than a traditional tractor. There are many different quadrotor designs used in pesticide spraying applications [22].

Top XGun robotics has produced a professional flight controller T1-A is a combining main function of agricultural UAV in current market. It can be installed on a variety of models and has the functions such as intelligent mode, dose detection, resume spray function, precision spraying, and low voltage protection, fail safe and go home. Schematic diagram for the recommended sprayer is shown below [11].

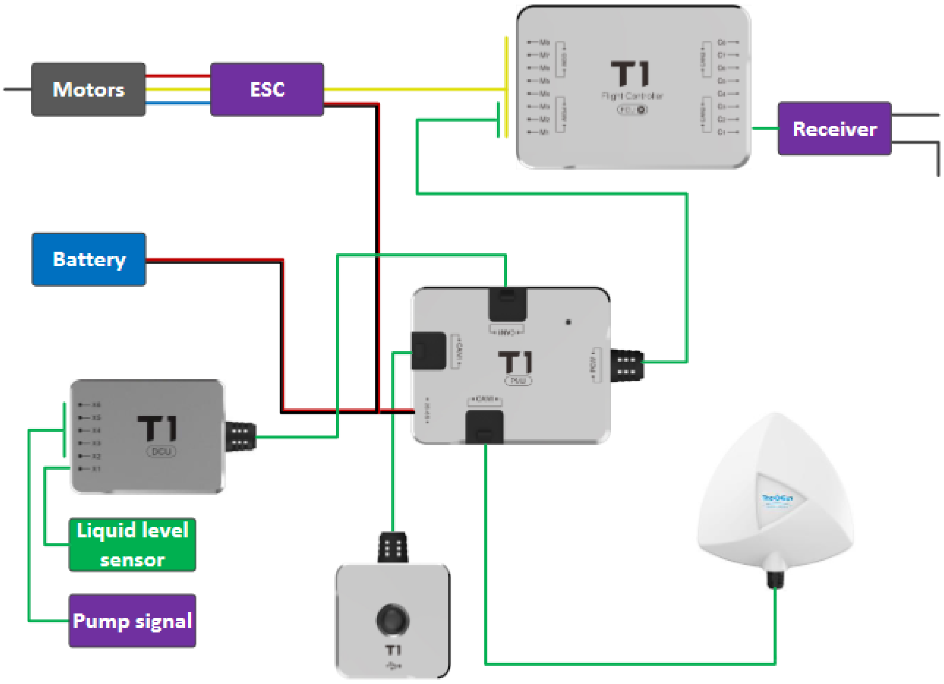

Figure 5: T1 Hardware connection diagram

Quadcopters can range from small drones that fly on a single charge for 10 minutes to big Quadcopters that can fly much longer and cost much. Some of the drones are operated by controllers, while others by operator's smartphone or tablet. Basic elements in drones are frame, propellers, BLDC motor, battery, electronic sensors, GPS, payload (camera or spraying system).

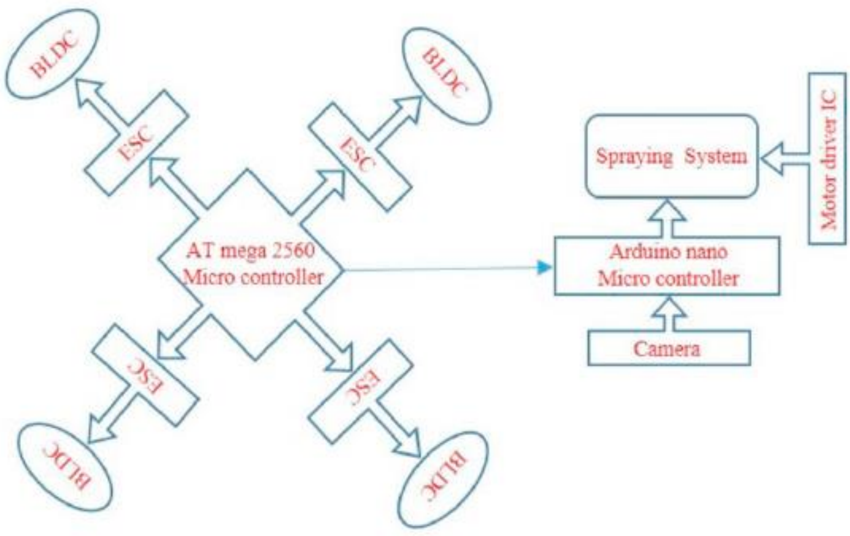

Figure 6: Block diagram of a Model pesticide spraying Quadcopter [23]

c) Quadrotor Pesticide Spraying System

For the pesticide spraying mechanism we use main tank, with submersible DC motor pump, battery, and switch, pipes fitted to T-split and mini nozzles. As soon as the switch is turned on, the motor pumps the pesticides through the pipe. The pipes then supply the pesticides to the nozzles via the T-split so that it sprays with a certain pressure and uniformity by avoiding wastage [24]. A model pesticide spraying Quadcopter mainly consists of the following components as shown in the figure below.

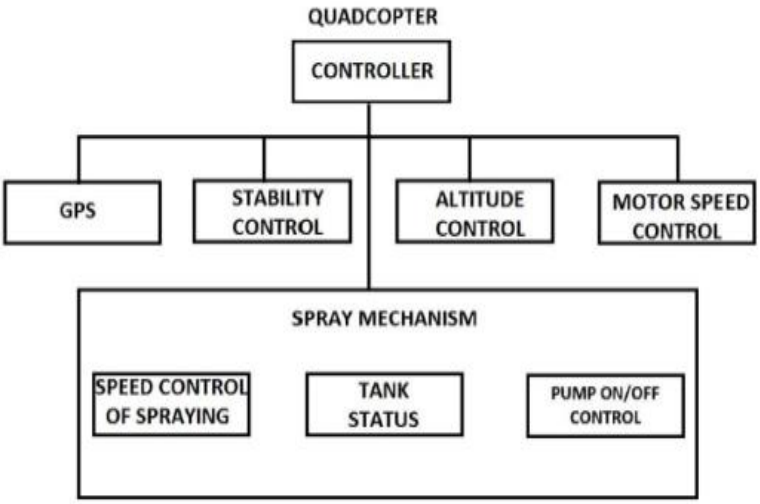

Figure 7: Block Diagram of an Automatically Controlled Drone Based Aerial Pesticide Sprayer

The motor driver circuit is used to control the speed of spraying and pesticide level indicator circuit with buzzer for detecting the level of pesticide fluid. There are many challenges in Agri-drone development in Africa and listed out as follow [25];

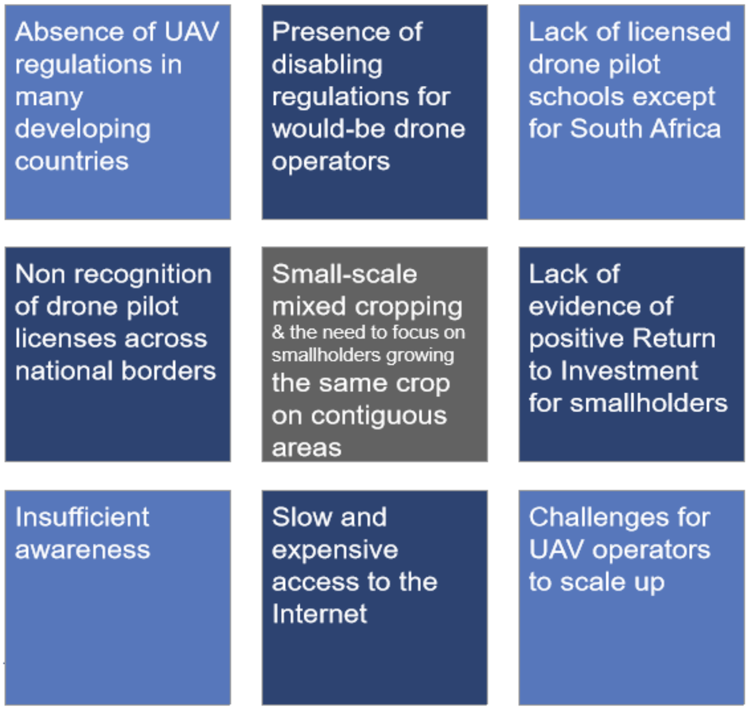

Figure 8: Agri-drone development challenges in Africa [25]

II. METHODOLOGY

The major task of this project is to design a quadrotor system which has a better stability, agility, endurance with better payload capacity of spraying pesticides which can cover visible areas effectively. It started with new Quadcopter Concept design system & subsystem mapping, identifying each component in the drone. Estimating the performance parameters of the new model. The new model will operate with fixed brushless motors installed on main bamboo transverse beams fixed on the central frame (casing). The covers of the quadrotor can be made from composite sheets. All its aerodynamic cover is easy to manufacture and assemble. In order to assure its stability a balancing holes will be available for weight balance. All the necessary part & 3D model designs, simulation and mathematical modeling done to get best and smooth operation of spraying.

a) Mapping of systems and subsystems

From the function of the quadrotor, we map systems and subsystems so that we can easily design in order to fulfill the basic function. So the quadrotor will be designed from this mapping point of view. (See figure below).

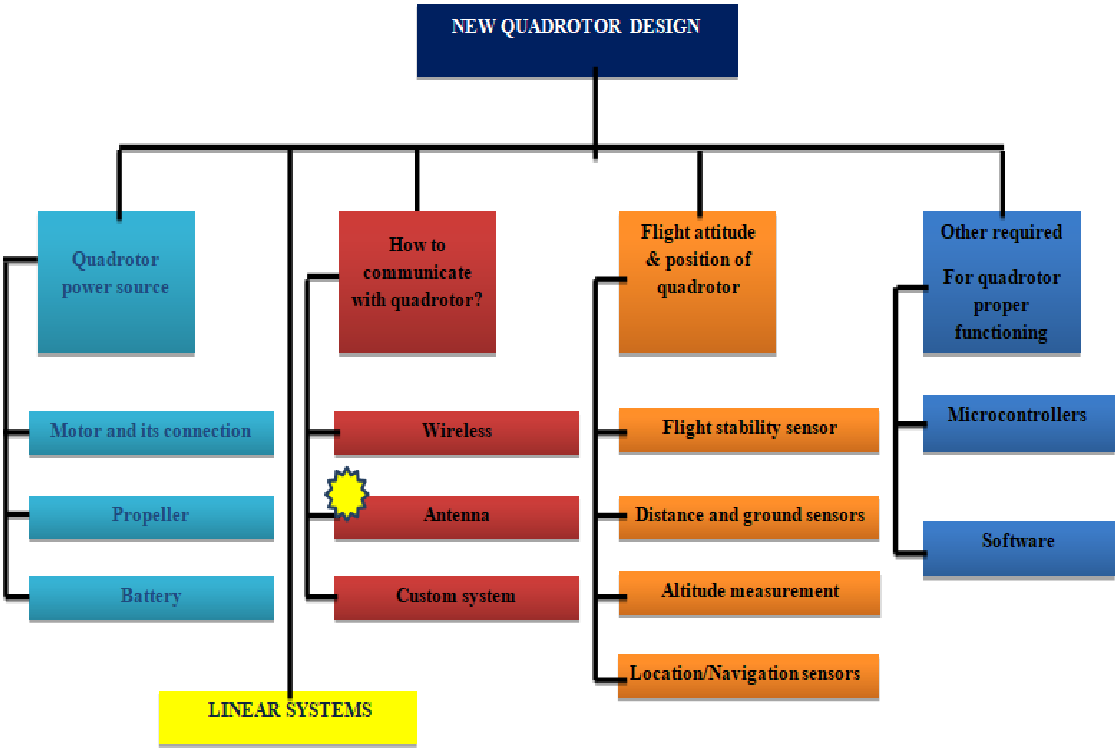

Figure 9a: Quadcopter sub-systems

b) Simple Quadcopter Systems Mapping

The newly designed pesticide spraying Quadrotor is assumed to have some basic components to accomplish its main spraying tasks and the main components included in the model project are shortly put diagrammatically.

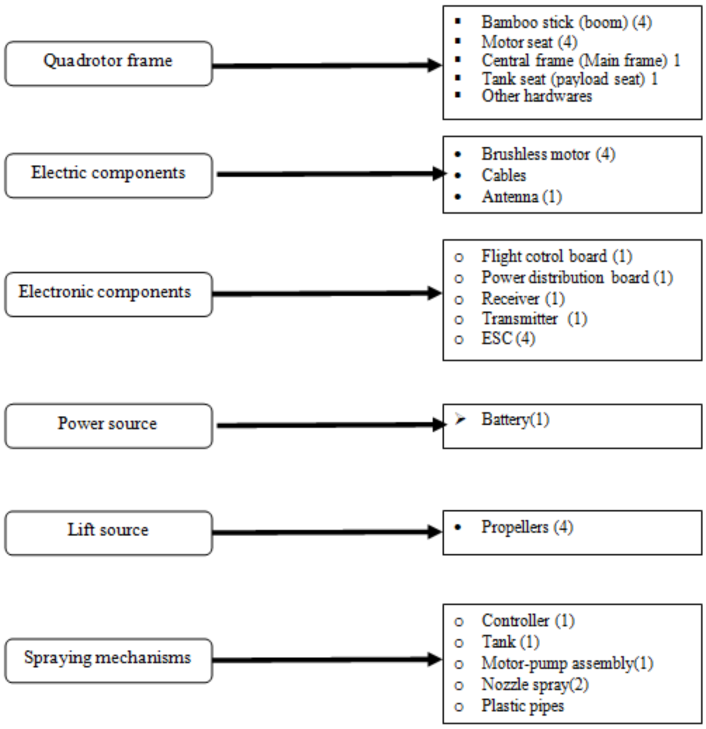

Figure 9b: Quadcopter components mapping

c) Model estimated parameters

ESSTI model Quadcopter design configuration, requirements and parameters.

Table 1. Basic Quadrotor Model Parameters (Expected Parameters)

Basic data	Values	Remark
Weight	8 Kg	Total weight Maximum. The range can be from 3Kg-9Kg depending on electronic equipments
Payload	5Kg	Maximum
Altitude	7 m	Maximum
Range	Radius of 400m	For the control signal
Speed	90kph	Capable of hovering, slowing down, speed up depending on its task
Wind speed	54kph	Not preferable if it exceeds this value
Endurance	20 min	

III. MODELING AND ANALYSIS

a) Quadcopter Motion

Basically the motion can be clearly described in 3-axes. The yaw, pitch and roll motion and they can be controlled by ESC with desired changes in motion and direction of the Quadrotor. The motion digram below shows how speed change by ESC can control the motion with help of transmitter control [26].

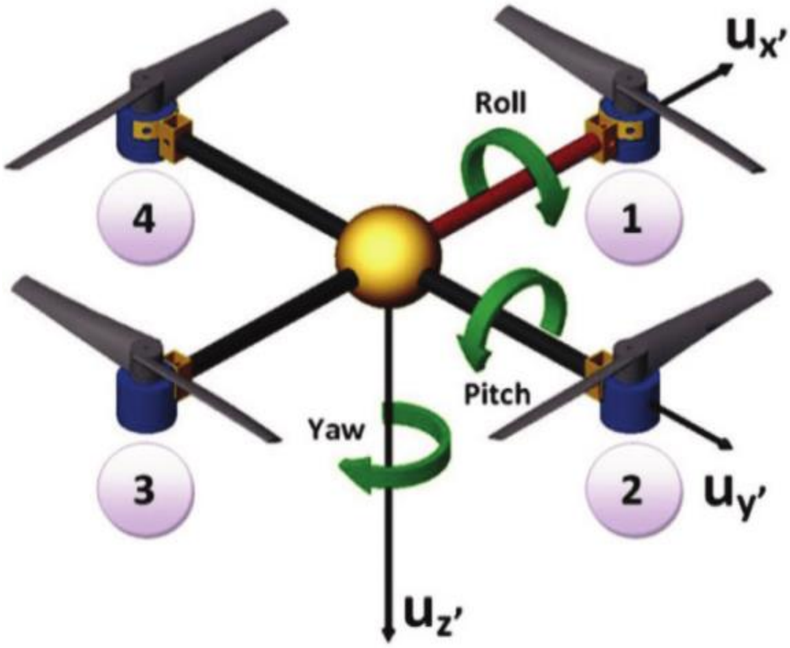

Figure 10: Quadcopter motion

b) Reference Frames

The ESSTI Quadcopter modeling environment is illustrated in the figure below where E is the earth frame and B is the body frame reference point shown in the figure. This frame is related to the modeling motion and forces in which the model is flown and is orientated so the XY-plane is in the floor (earth reference) with the z-axis pointing upwards. The vector reference in the E frame will be referred as E_a and those in the B frame as B_a. Theoretically, the model is able to rotate around all three body-axis and the sign of the rotations have been defined based on relation to the input commands from the wireless link. It is logical that the positive inputs result in positive right-hand rotations and vice versa [27].

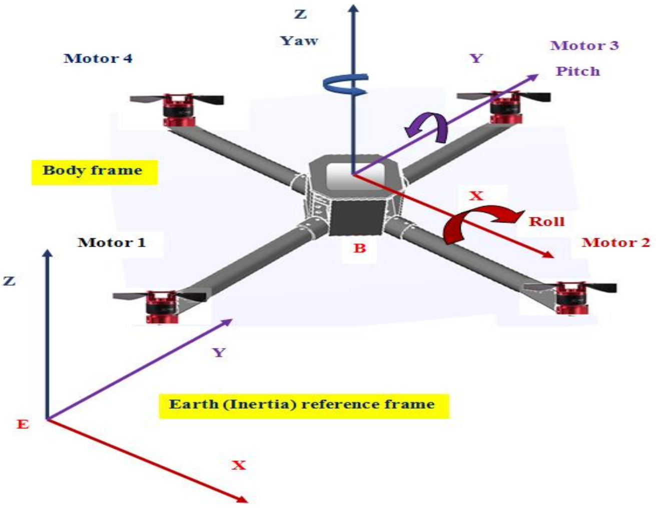

Figure 11: Body and earth reference frames of the model Quadcopter

The Quadcopter translational motion requires tilting the platform toward the desired axis and the reference angle of the Quadcopter is given by the pitchθ, roll Ø, and yaw ψ with the convention of movement in three dimensions in 3D. Changing the speed of one of the pair of motors as to cause motion in six degrees of freedom (6DOF). This made the Quadcopter to move in six DOF and be controlled just with four inputs [28].

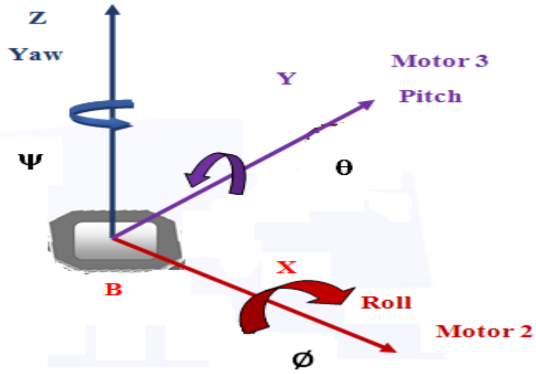

Figure 12: Quadcopter model Movement in 3D

c) Quadcopter Maneuvering

Rotors 1/3 are rotating clockwise where as 2/4 rotate counterclockwise. Newton's second law of motion are given at 1 and converted to rotational analogue to the law 3.2.

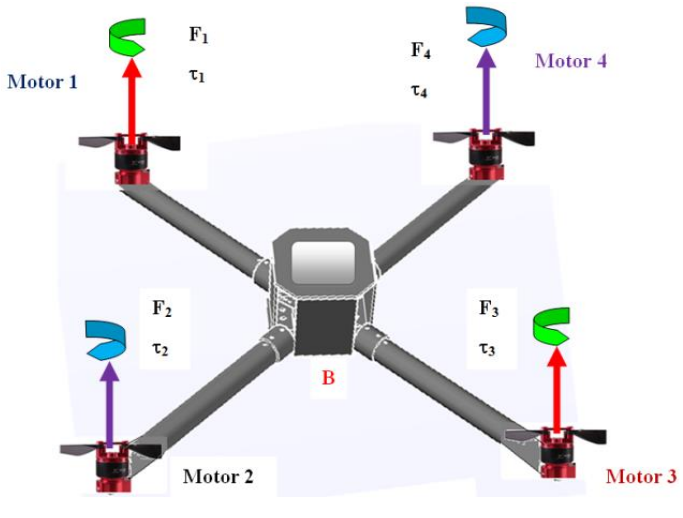

Figure 13: Quadcopter hovering

F is the total applied force to a rigid body and a is the linear acceleration with m as the mass of the body. **τ**, J, α is the total torque exerted at the body, body moment of inertia and the angular acceleration respectively.

$$\sum F = m.a \qquad (1)$$

$$\sum \tau = J.\alpha \qquad (2)$$

When the model is in perfect hover, it is in both perfect force and torque balance of rotors. Since the rotors are of the same design and equal angular velocity, it will result in equal thrust and torque.

Roll is when the model performs a rotation around the x-body axis. This is achieved by changing the angular velocity of the rotors. The roll on y-body axis is by rotor 2 and 4 while maintaining the same angular velocity on rotor 1 and 3.

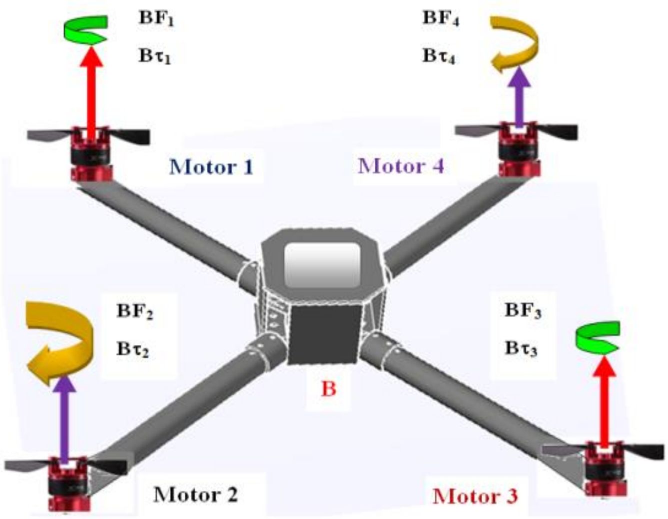

Figure 14: Rotation around the x-body axis or roll

Pitch is when the model performs a rotation around the y-body axis and this is achieved by changing the angular velocity of the rotors on the x-body axis. This is done when rotor 1 and 3 maintain the same angular velocity on rotor 2 and 4. When the pitch is increase the angular velocity of rotor 1 and decreasing the angular velocity of rotor 3 results in rotation around the y-body axis [27].

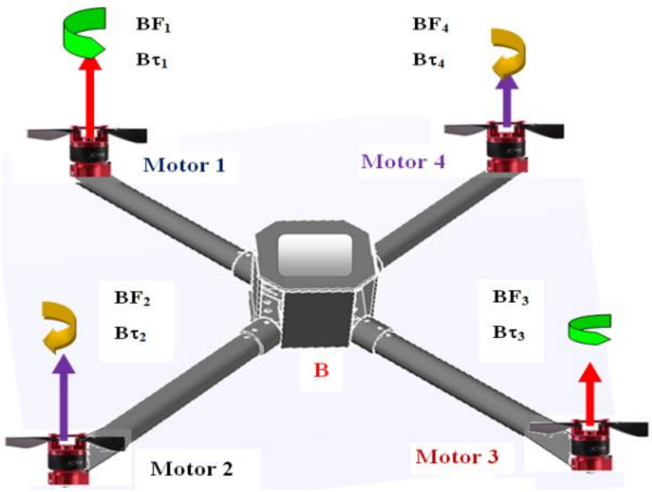

Figure 15: Rotation around the y-body (Positive pitch)

Yaw is when the model performs a rotation around the z-body axis by mismatching the torque generated by the model rotors and the net torque acting on the platform body is zero during flight. If the torques applied along the axis is mismatched the platform will perform a rotation around the z-body axis. If the desired rotation is positive the yaw is performed by increasing the angular velocity of rotor 2 and 4 while decreasing angular velocity of rotor 1 and 3.

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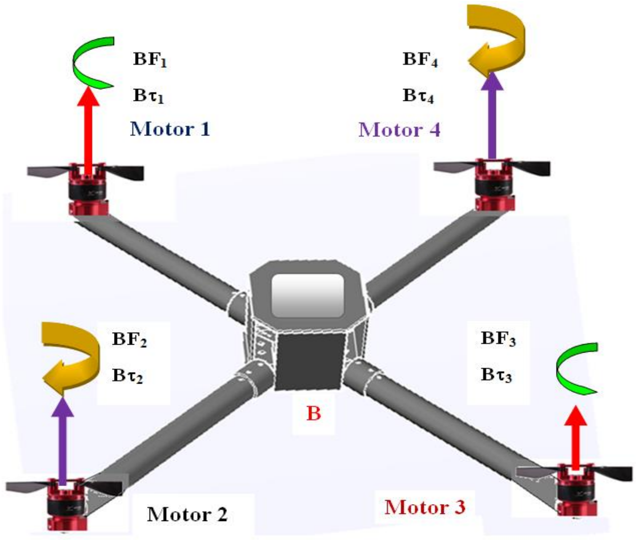

Figure 16: Rotation around the Z-body axis (Positive yaw)

d) Forces and moments

The forces and moments on the Quadcopter on the Figure 16 are created primarily due to the gravity on the four propellers. As a result each motor exerts an upward force F and a torque τ and the total force of the Quadcopter is given by the sum of all the forces represented as;

$$F_t = \sum_{i=1}^{4} Fi \quad (3)$$

The same principle applies to the torque;

$$\tau_t = \sum_{i=1}^{4} \tau i \quad (4)$$

Considering this the rolling, pitching and yawing torques are defined as;

$$\begin{bmatrix} \tau_\phi \\ \tau_\theta \\ \tau_\psi \end{bmatrix} = \begin{bmatrix} l(F_d - F_b) \\ l(F_a - F_c) \\ (\tau_d - \tau_b) - (\tau_d - \tau_b) \end{bmatrix} \quad (5)$$

e) Quadcopter Ideal Modeling

The mass model of the Quadcopter components are estimated as single integral parts.

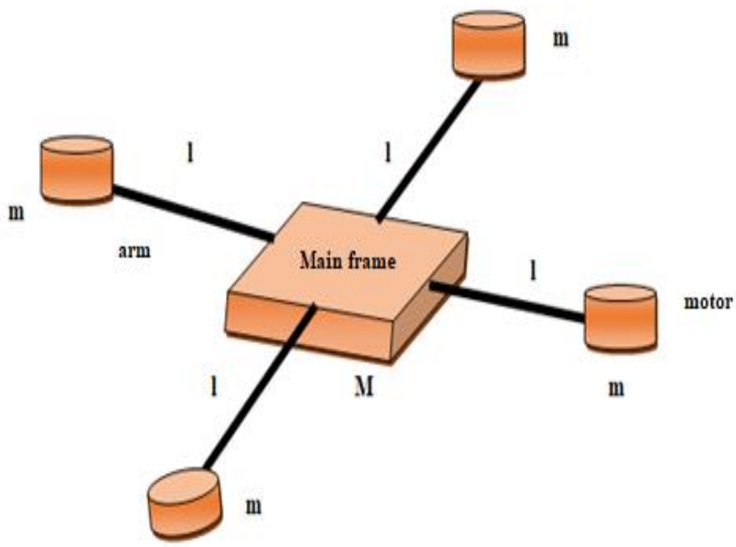

Figure 17: Quadcopter ideal models

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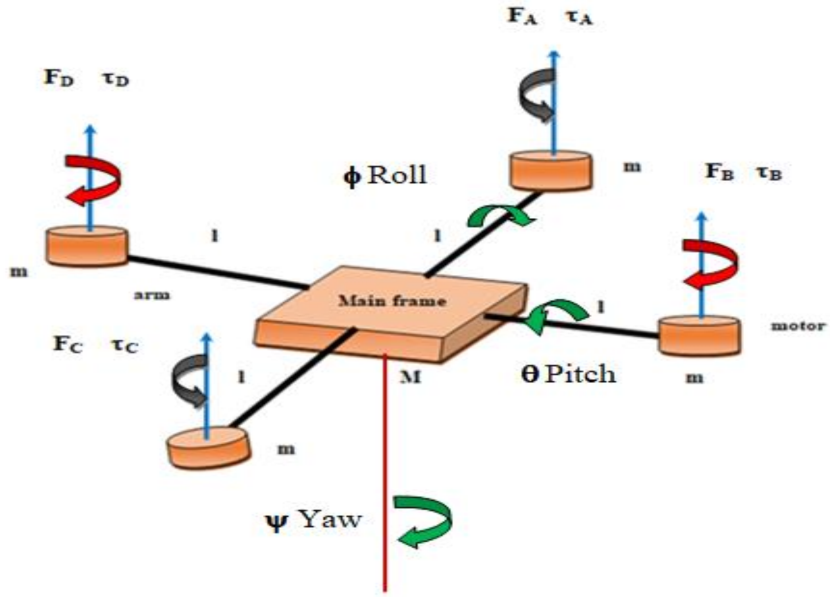


Figure 18: Forces and moments on the Quadcopter (ideal)

The force of gravity is also exerting a force on the vehicle frame Fv of the Quadcopter and has an influence on the z direction. In order to match this force with body frame F_b, it is necessary to multiply by the respective rotation matrix [29].

$$F_g^v = R_v^b F_g^b \rightarrow F_g^v \begin{bmatrix} (mgsin)\theta. \\ mgcos)\theta.sin)\phi - \\ mgcos)\theta.cos)\phi - \end{bmatrix} \quad (6)$$

Finally rewriting eq. 13, we express the linear acceleration on the body frame as eq. 3.7

$$\begin{bmatrix} \dot{V}_x^b \\ \dot{V}_y^b \\ \dot{V}_z^b \end{bmatrix} = \begin{bmatrix} V_y^b r - V_z^b q \\ V_z^b p - V_x^b r \\ V_x^b q - V_y^b p \end{bmatrix} + \begin{bmatrix} -gsin\theta \\ gcos\theta sin\emptyset \\ gcos\theta.cos\emptyset \end{bmatrix} + \frac{1}{m}\begin{bmatrix} 0 \\ 0 \\ \sum F \end{bmatrix} \quad (7)$$

f) Mathematical Modeling

Brushless motors are more preferable for Quadrotor due to their high efficiency and motors can be modeled as a permanent magnet DC motor inside the framework of a three-constant model and requires the knowledge of the supply voltage, current through the motor coils and the back-electromotive force with additional required parameters such as the armature resistance, and the shaft angular velocity [30].

Supply voltage (V) -V_k

Motor coil current (A) - i_a

Back electromotive force (V) - e_a

Armature resistance (Ω) - R_a

Shaft angular velocity (rad/s) - ω

Therefore the motor equations can be expressed as:

$$V_k = e_a + i_a R_a \quad (8)$$

$$e_a = Ke\ \omega = K_T\ \omega = N/KV \quad (9)$$

Where

Ke is the motor back EMF constant (Vs/rad),

KT is the motor torque constant (Nm/A),

N is the motor rpm, and KV is motor speed constant (rpm/V).

KT is related to KV by:

$$Ke = K_T = 30/(\pi KV) \quad (10)$$

The output torque is given by:

$$M_{mot} = K_T (i_a - i_o) \quad (11)$$

Where i_o is the current at zero load

The motor input power is described by:

$$P_m = V_k \, i_a \quad 3.12$$

The motor output power is:

$$P_{mot} = M_{mot} \, \omega = K_T (i_a - i_o) \, \omega = (V_k - i_a R_a)(i_a - i_o) \quad 3.13$$

The motor speed in rpm is expressed by:

$$N = (V_k - i_a R_a) \, KV \quad (12)$$

The thrust coefficient is given by:

$$C_T = T / \rho \, (N/60)^2 \, D^4 \quad (13)$$

Where

T is thrust (N), ρ is air density (kg/m3), N is propeller speed (rpm), and D is propeller diameter (m).

The power coefficient is given by:

$$Cp = 2 \pi \, CM = P / \rho \, (N/60)^3 \, D^5 \quad (14)$$

Where

P is power (W) and CM the torque coefficient.

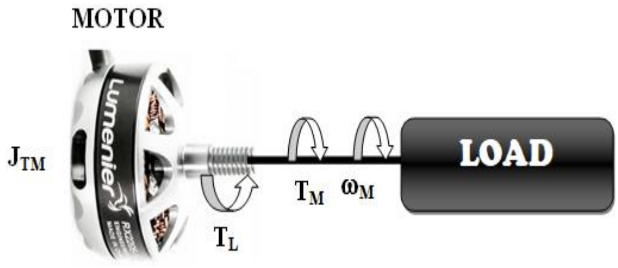


Figure 19: Simplified motor system

J_{TM} The total motor moment of inertia

$\dot{\omega}_M$ [rad s−2] is the motor angular acceleration,

T_M [N m] is the motor torque and

T_L [N m] is the load torque.

K_E [V s rad−1] is called the motor constant

$$v = Ri + K_E \dot{\omega}_M \quad (15)$$

$$J_{TM} \dot{\omega}_M = T_M - T_L \quad (16)$$

The motor torque T_M is proportional to the electrical current i through K_M [N m A−1]: $T_M = K_M$ i. Hence equation (3.18) can be rewritten according to equation (3.19).

$$J_{TM} \dot{\omega}_M = K_M i - T_L \quad (17)$$

By connecting equations (3.17) and (3.19) a differential equation in ω_M can be derived.

$$J_{TM} \dot{\omega}_M = -\frac{K_E K_M}{R} \omega_M - T_L + \frac{K_M}{R} v \quad (18)$$

It must be pointed out that the two constants K_E and K_M have the same value even though the units of measurement differ. This difference comes from the electric P_E [W] and mechanic P_M [N m s−1] power balance.

$$P_E = P_M \begin{Bmatrix} P_E = ei = K_E i \omega_M \\ P_M = T_M \omega_M = K_M i \omega_M \end{Bmatrix} \Rightarrow K_E = K_M \quad (19)$$

g) Aerodynamic Modeling

The aerodynamic modeling gives a brief overview on how to calculate the thrust b [N s2] and the drag d [N m s2] factors generated from the propellers motion using a combination of momentum and blade element theory.

The rotation of the propeller creates aerodynamic and mechanical contributions to the structure [32]:

- Thrust is the aerodynamic force which is produced in the direction of the propellers and this required to overcome the drag and weight forces. This made the drone to sustain the forward flight of the vehicle.
- Drag torque acts on the blade elements around the rotor shaft and is a result of the aerodynamics forces.

The Figure below shows how these force components act on a propeller. The thrust force, T_{BET} [N] and the drag torque, Q_{BET} [N m] according to the blade element theory. ωP [rad s−1] is the angular speed of the propeller.

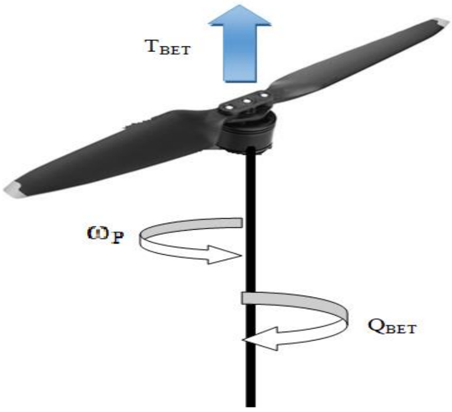


Figure 20: Aero thrust torque

The thrust factor b can be estimated with different approaches. At the end of this chapter a mean of these components will be done to get the average value of the thrust factor in order to estimate b with blade element theory (b_{BET} [N s2]), is necessary to describe the thrust T_{BET} as a function of ω_P in the equation below.

$$T_{BET} = N_B \rho_A a c \omega_P^2 R_P^3 \left(\frac{\theta_{IO}}{6} - \frac{\theta_{Itw}}{8} - \frac{\lambda}{4}\right) \quad (20)$$

Since the thrust T_{BET} is proportional to the square of the angular speed of the blade ω_P, it is possible to determine the ratio of T_{BET} to ω^2_P, which is the definition of the thrust factor.

$$b_{BET} = \frac{T_{BET}}{\omega_P^2} = N_B \rho_A a c R_P^3 \left(\frac{\theta_{IO}}{6} - \frac{\theta_{Itw}}{8} - \frac{\lambda}{4}\right) \quad (21)$$

The value of b can be also be evaluated by applying the momentum theory. The thrust factor with momentum theory b_{MT} [N s2] in hovering is simply the ratio of the weight carried from one propeller W_P to the squared propeller speed ω^2_H as shown in equation (6.48).

$$b_{MT} = \frac{W_P}{\omega_H^2} \quad (22)$$

To estimate the drag factor d, is necessary to describe the torque acting on the shaft Q_{BET} in function of the angular speed ω_P. Equation (6.49) shows this relation.

$$Q_{BET} = N_B \rho_A c \omega_P^2 R_P^4 \left(\frac{C_D}{8} + a\lambda \left(\frac{\theta_{IO}}{6} - \frac{\theta_{Itw}}{8} - \frac{\lambda}{4}\right)\right) \quad (23)$$

As for the propeller thrust T_{BET}, the torque Q_{BET} is proportional to the square of the angular speed of the blade ω_P. It is possible to determine the ratio of Q_{BET} to ω^2_P, which is the definition of the drag factor d. The numeric result can be provided by equation (6.50).

$$d = \frac{Q_{BET}}{\omega_P^2} = N_B \rho_A c R_P^4 \left(\frac{C_D}{8} + a\lambda \left(\frac{\theta_{IO}}{6} - \frac{\theta_{IW}}{8} - \frac{\lambda}{4}\right)\right) \quad (24)$$

Unlike the b, the drag coefficient d was estimated just with blade element theory; hence, no subscript was applied [31]. Model and Material which are used is presented in this section. Table and model should be in prescribed format.

IV. RESULTS AND DISCUSSION

a) Mass Estimation

All the components required on the pesticide spraying Quadrotor are identified. Total weight of the Quadrotor (weight of the airframe and components) are put in detail in the following table. This helped to select motor and propeller types.

Table 2: Weight Distribution for Calculating Hover Power

PART	TOTAL MASS (G)
Frame(All)	3400
Receiver	210
Controller	
4x Multi rotor Speed Controller	90
Propellers (2xCW, 2xCCW)	120
Li-Po battery	340
2x Pin headers	50
2x Pin header rows for TBS	56
4x brushless motors (with	670
Pesticide tank and plastic hoses	270
Total pesticide payload	5000
Sprayer	100
Other hard-wares	120
Total mass	**10426gm**

b) Takeoff weight calculation

Takeoff weight of the Quadcopter is the overall gross weight, which includes payload weight battery weight, structural weight including all the electrical harnesses and electronic systems.

Table 3: Quadcopter Model Basic Parameters

Total weight (TW)	10.426 kg
Flight time (FT)	20 minutes
Thrust to weight ratio (TWR)	2

The solution derived is by iterative process of assuming the value and finding the unknowns.

$$TW = PW + BW + AW + ECW + \cdots = 10.426Kg \quad (25)$$

$$Thrust = TW \times TWR = 20.852Kg \quad (26)$$

For 20.852 Kg thrust with best-case scenario of 200 Wh/kg energy density and 10000mAh/25C charging rate; the required voltage of 44.4V/10Ah battery is suitable.

c) Propeller and Motor selection

The total weight of the Quadcopter is 10426 gm and the propeller wind sweep area should carry a lifting force of 2606.25gm minimum for each props. The total lifting force is 10426 gm. Considering many external forces with some safety margins taken as 35% the actual weight supported will be 14075gm of design value. Referring to the motor-propeller performance table of manufacturers' data sheet for the required motor type and propeller sizes, the brushless DC motor EA100 EAGLEPOWER T10 with maximum thrust of 20Kg is used for large load agricultural drone. The selected propeller is UP2280 (22*8) model which has a length of 558.8mm with pitch 22 inch. Each of these motors and propeller combination will have best wind sweep area to carry the load supported by arm.

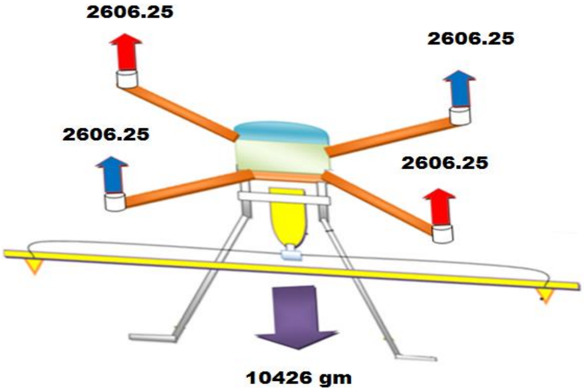


Figure 21: Quadcopter weight supported by each propeller at stand still

d) Selection of ESC

The motor speed as well as motion control of the Quadcopter is controlled by ESC. The four ESCs for four motors have specific ranges of current to be set according to motor performance parameters. For the specific selected motors, these values were 14.8 - 22.2V power supply which support a maximum of 18.6 A.

e) Bamboo stick

Bamboo trees are known for their strength to weight ratio and they have a wide applications in different areas and easily affordable. It is a preferred material to be used in our Quadcopter airframe as a boom to carry the motor-propeller assembly and total weight of the machine.

Figure 22: Bamboo boom used for Quadrotor

f) System Diagram

The ESSTI model design of the Quadcopter is primarily for pesticide spraying. This consists of the Quadcopter and pesticide spraying systems.

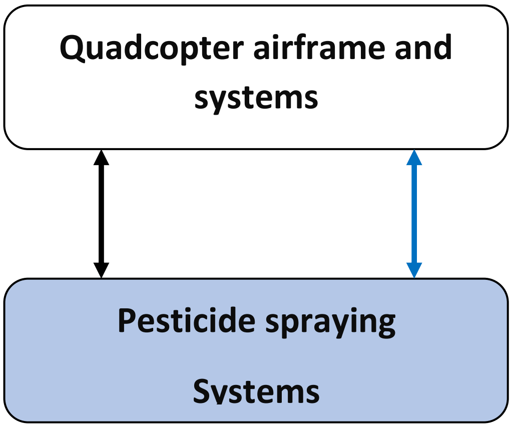
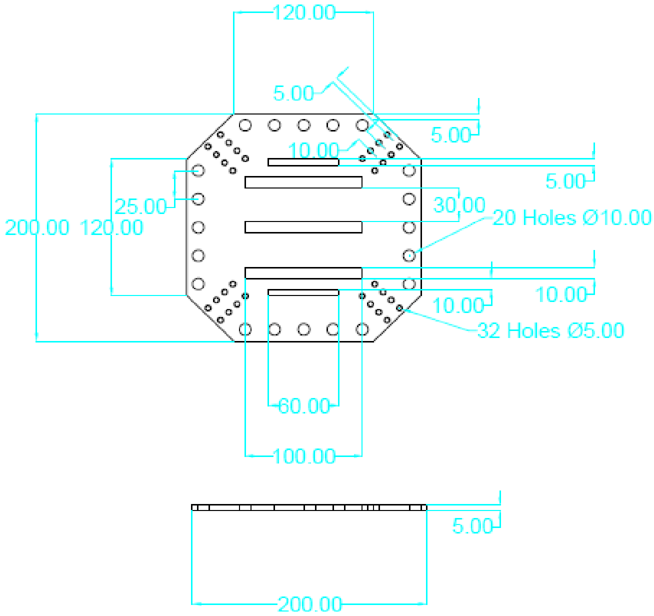


Figure 23: Quadcopter model system main block diagram

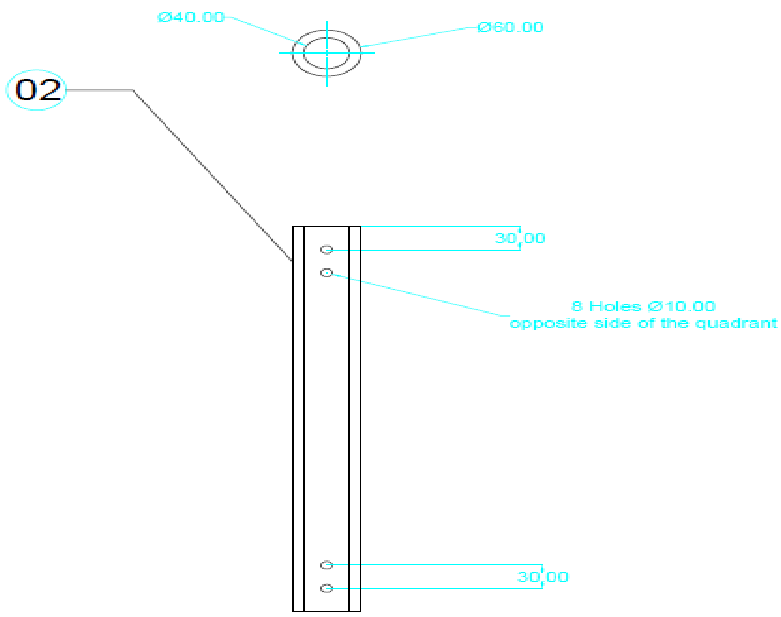
1. ESSTI Model Quadcopter Detail Parts Drawing



Item Number	Item description	Dimension	Material	Quantity	Weight
01	Electronic seat	200X200	Steel	01	

Designed by	Lijalem G/hiwet	Technology owner	Ethiopian Space Science Technology Institute							
Drawn by	Lijalem G/hiwet	Department	ESSTI Space Engineering R & D							
Checked by	Yashurun Alemayehu	Project type	Design of Quadcopter pesticide sprayer							
Approved by	Yashurun Alemayehu	Drawing title	Central upper chassis (Main frame)	Quantity	01					
Date	05/03/2020	Unit	mm	Scale	1:1	Drawing No.	01	Sheet No.	1 of 10	

Figure 24a: ESSTI Model Quadcopter



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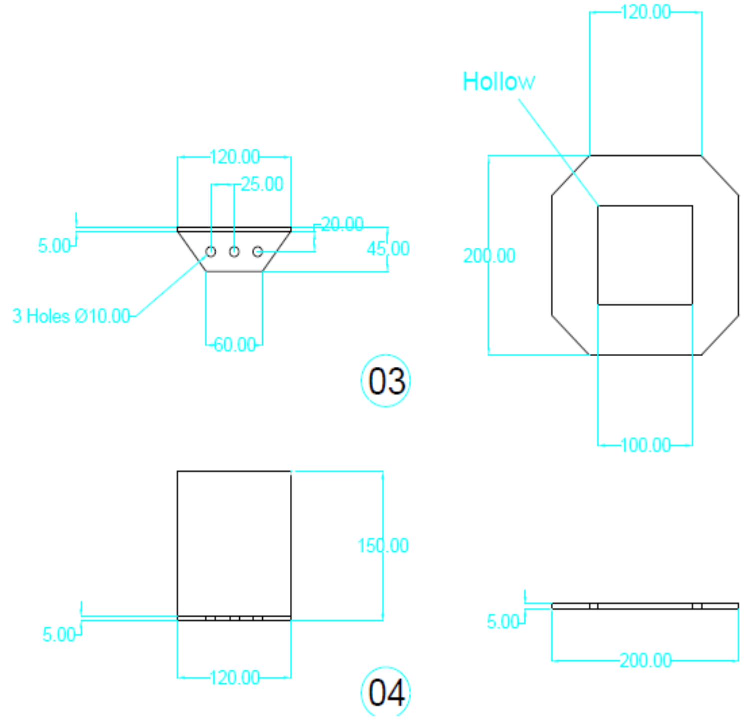
Item Number	Item description	Dimension	Material	Quantity	Weight
02	Bamboo stick	500X60	bamboo	04	

Designed by	Lijalem G/hiwet	Technology owner	Ethiopian Space Science Technology Institute						
Drawn by	Lijalem G/hiwet	Department	ESSTI Space Engineering R & D						
Checked by	Yashurun Alemayehu	Project type	Design of Quadcopter pesticide sprayer						
Approved by	Yashurun Alemayehu	Drawing title	Bamboo stick (Quadcopter boom)				Quantity	04	
Date	05/03/2020	Unit	mm	Scale	1:1	Drawing No.	01	Sheet No.	1 of 10

Figure 24b: ESSTI Model Quadcopter



Item Number	Item description	Dimension	Material	Quantity	Weight
04	Upper casing cover	120x200	steel	01	
03	Upper casing side panel	120x150x45	steel	04	

Designed by	Lijalem G/hiwet	Technology owner	Ethiopian Space Science Technology Institute						
Drawn by	Lijalem G/hiwet	Department	ESSTI Space Engineering R & D						
Checked by	Yashurun Alemayehu	Project type	Design of Quadcopter pesticide sprayer						
Approved by	Yashurun Alemayehu	Drawing title	Electronic housing (Upper casing)				Quantity	04/01	
Date	05/03/2020	Unit	mm	Scale	1:1	Drawing No.	01	Sheet No.	3 of 10

Figure 24c: ESSTI Model Quadcopter

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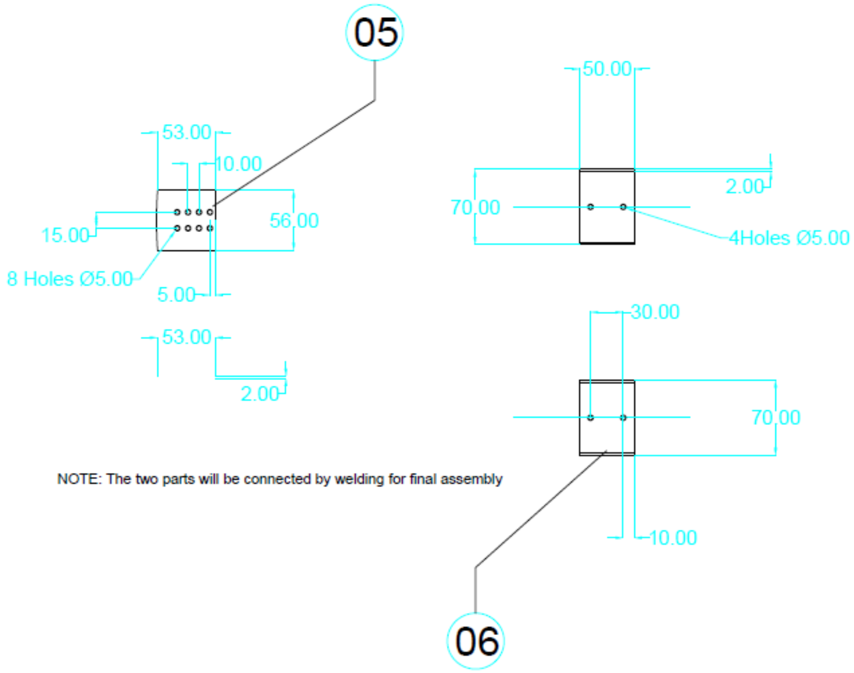
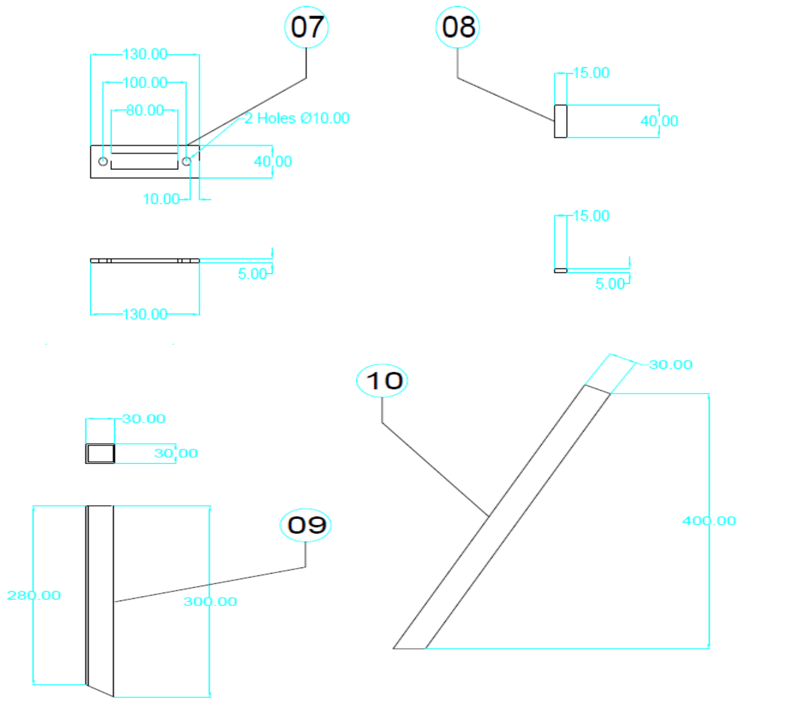


04	Upper casing cover	120x200	steel	01	
03	Upper casing side panel	120x150x45	steel	04	
Item Number	Item description	Dimension	Material	Quantity	Weight

Designed by	Lijalem G/hiwet	Technology owner	Ethiopian Space Science Technology Institute						
Drawn by	Lijalem G/hiwet	Department	ESSTI Space Engineering R & D						
Checked by	Yashurun Alemayehu	Project type	Design of Quadcopter pesticide sprayer						
Approved by	Yashurun Alemayehu	Drawing title	Electronic housing (Upper casing)				Quantity	04/01	
Date	05/03/2020	Unit	mm	Scale	1:1	Drawing No.	01	Sheet No.	3 of 10

Figure 24d: ESSTI Model Quadcopter



10	Lower landing hollow bar	30x30	steel	09	
09	Upper landing hollow bar	30x30x300	steel	04	
08	payload seat bar	15x40	steel	04	
07	central frame attachment	40x130	steel	02	
Item Number	Item description	Dimension	Material	Quantity	Weight

Designed by	Lijalem G/hiwet	Technology owner	Ethiopian Space Science Technology Institute				
Drawn by	Lijalem G/hiwet	Department	ESSTI Space Engineering R & D				
Checked by	Yashurun Alemayehu	Project type	Design of Quadcopter pesticide sprayer				
Approved by	Yashurun Alemayehu	Drawing title	Landing attachment frames/lower parts	Quantity	2/4/4/4		
Date	05/03/2020	Unit	mm	Scale	1:1	Drawing No. 05	Sheet No. 5 of 5

Figure 24e: ESSTI Model Quadcopter

2. AUTODESK 3D design development for the model Quadcopter

The software design used for this particular Quadcopter is AUTODESK and the simulations of some components and the whole frame is transported to SOLIDWORK to perform some analyses and dynamic effects. The detail components of any Quadcopter models include different basic parts. The Quadcopter model detail parts drawing with AUTOCAD are shown in Appendix F.

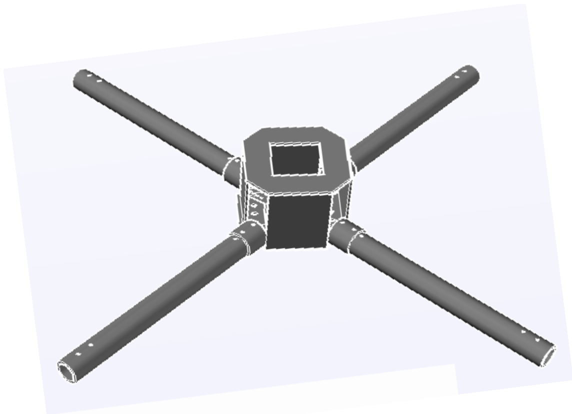


Figure 25a: Developing Quadcopter 3D model

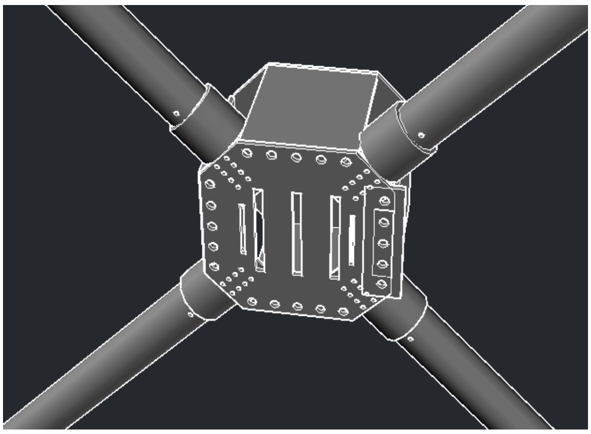


Figure 25b: Developing Quadcopter 3D model

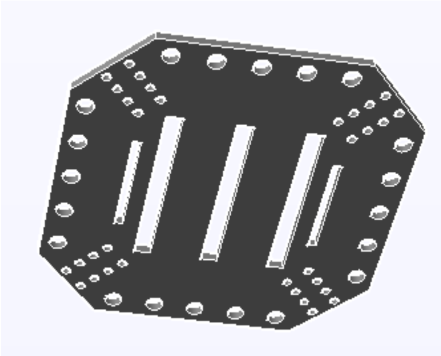


Figure 25c: Developing Quadcopter 3D model (central frame)

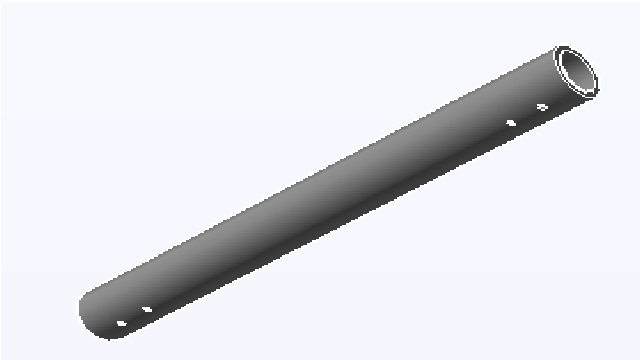


Figure 25d: Developing Quadcopter 3D model (arm)

g) Selected Quadcopter components for the model

With detail mathematical modeling and weight analyses, the basic components that fit the airframe of ESSTI model Quadcopter is tabulated from the reverse engineering.

Table 4. Lists of Equipment (Hardware Components)

S/N	NAME	DESIGNATION	QTY
1	Motor (Brushless) & ESC	EA100 EAGLE POWER T10	4motor/ 4ESC
2	Propeller (folded)	UP2280 (22*8) model	4
3	Li-Po battery	Li-Po 10000mAh/25C (44.4V/10Ah)	1
4	Transmitter or remote controller	2.4GHz Futaba T8F (Futuba T8FG)	1
5	Main circuit boards -Receiver-Flight controller -LED -Compass - GPS receiver& antennae	R6208SB Receiver Full set of Eagle brother 3WD-TY-D10 model	SET
6	Beep alarm	Agriculture drone spray system accs Nozzle + pump + Buck type governor adapter + Pipes combo for 10L Agricultural UAV	1
8	Pesticide tank		1
	Drone sprayer (pump)		1
9	Spraying nozzle		4pcs
10	Tank-nozzle accessories		Set

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11	Spraying bar (stick)	Width: 1600mm	2
12	Battery charger	For Eagle brother 3WD-TY-D10 model	1
14	Other cables ,connectors and adapters	For Eagle brother 3WD-TY-D10 model	sets

V. CONCLUSION

The main purpose of this paper is to design new pesticide spraying Quadcopter which will have great benefits for Ethiopian farmers for the health of their farms and other crop protection methods. It is easily manufactured structures and compatible to the farm sizes. The spraying mechanism selected is more efficient with almost zero losses to save the cost of chemical wastage and efficient spraying. The main outcome of the project is to develop a Quadcopter with a controller to control its attitude in accordance with the wind speed and other environmental factors the affect spraying. The components are compatible to each other for effective operation of the Quadcopter. The actual selection of motor-propeller matching smoothes the vehicle dynamics. Structural simulation is also performed to visualize the smooth stability of Quadcopter which will be more addressed in other paper. The design, modeling and selected components assure stability of the vehicle in all direction. In the future the vehicle can be upgraded with software for autonomous flight. Smart spraying will be research will be adopted to select the affected areas or farms.

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ESSTI Aerospace Engineering R & D directorate participated in this project

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