SKYHAWK DELTAWING VTOL

(Vertical Takeoff & Landing Drone)

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CERTIFICATE FOR CORRECTNESS AND APPROVAL

Certified that work contained in the thesis- Skyhawk Delta wing VTOL carried out by Muhammad Noman Afzal , Adnaan Ashraf , Muhammad Hassan Ali and Nimra Iftikhar under supervision of Dr. AhmedMuqeem Sherifor partial fulfillment of Degree of Bachelors of Software Engineering, in Military College of Signals, National University of Sciences and Technology during the academic year 2019-2020 is correct and approved. The plagiarism is 13 %.

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Dr. Ahmed Muqeem Sheri
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DECLARATION

Noparcelof the workdisplayedin thisthesishas been submitted inbackof anothergrantorcapabilityeither at this institution orsomewhere else.

DEDICATION

In the name of Allah, Most Gracious, Most Merciful. To ourguardians, without whosedeterminedbackand unstinting cooperation, a work of thissizewould not have been possible to oursupervisor Dr. Ahmed Muqeem Sheri who has given usawesomebolsterandprofitableproposalsall throughtheusageprocess. Andat lastto ourCompanionsfor their encouragement.

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Abstract

Present day drones accessible in the market are all around created and they are utilized in innumerable applications. Drones are having constraints in flight, time and range. Fixed-wing air vehicles can fly for significant distance however, they large area is required for their flight or the runways for their vertical takeoff and landing. Then multirotor drones have progressively flexibility, yet they devour more vitality. Drones have very less flight time averagely of 15 mins and their weight is approximately 1280 grams. To avoid this, we have designed a VTOL that has the flight time of 1 hour as a minimum with a median pace of 30 kilometer per hour that's two times as a Quadcopter.

The report is a detailed description of the work and procedures carried out for various tasks related to design, analysis & flying of Vertical Takeoff and Landing Unmanned Aerial Vehicle. This includes project plan and methodologies followed, timeline, literature review, results and calculations required and future work. For design and analysis different software such as ANSYS Fluent for CFD Analysis, MAT Lab for optimization and plotting different graphs, RDS for initial weight estimation and aerodynamic analysis, AAA for stability analysis and Ecalc for component matching. Also, study of control board PIXHAWK 2.4.8 and ground station software Mission Planner is undertaken. The structure of the wing is also analyzed for carrying designed loads through FSI and images obtained through telemetric link can also be classified on workstations.

Key Words:VTOL, Multirotor, Quadcopter, Qground

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CHAPTER 1: INTRODUCTION

The Unmanned air vehicles specially the vertical takeoff and landing vehicles are the flying robots using autopilots. The drone is controlled by the adjustment of the angular velocities of the rotors that the electric motors spin. The armatures are skywards heading,put in square development,equivalent good ways from the focal point of mass of quadrotor. Besides, quadcopter have exceptionally basic structure they are utilized in observation (military and civil surveillance, salvage and search purposes, rural and development purposes) and in a few different applications. Quadcopter is of extraordinary enthusiasm as it has opened enormous territories of enthusiasm for innovation. The essential model and dynamic structure of the quadcopter is the primary concerns everything being equal. There are distinctive control techniques for the quadcopter, which have been researched which incorporates PID controllers (Proportional Integral Derivative), LQR controllers and the Backstepping controllers and so forth.

UAVs have found a widespread application in both civil and military airspace. They are increasingly used for reconnaissance in dangerous area, rescue operations, meteorological monitoring, fish finding, power line maintenance, survey and inspection of various sites. These multipurpose UAVs are found in every size, various configuration and complex systems. However, if the UAVs are large, they are costly, needing large runways and infrastructure for maintenance. Small UAVs are affordable and used for aerial photography with high resolution. Microprocessor and micro-electro-mechanical systems (MEMS) made small UAV design possible. Although these small UAVs also require space for runway no matter how much portable. This limitation for runway requirement is overcome through Vertical takeoff and landing mechanism. First built VTOL aircraft was a helicopter which had poor cruise performance such as flight speed, range and endurance. Recently there is a considerable attention given to make fixed wing aircrafts vertically take off and land. These have characteristics of both traditional aircraft and take off and land without requiring a runway. Tilt rotor and thrust vectoring techniques are used in larger and sophisticated aircrafts. However, for VTOL UAVs there are multiple frame configurations. They include mounting rotors in either X-, I- or H- configuration. Each has its own merits and demerits. Moreover, X configuration is comparatively easier to fabricate and analyze. Four motors with rotors mounted are placed at 90 degrees, two pairs of rotors clockwise and counterclockwise to balance the torque at each side. This configuration has better stability and lifting capability.

The fundamental reason for this exploration is to introduce the essential model of the quadcopter and the Vertical Takeoff and Landing drone. This is sought after with the main mean to contemplate the numerical model of the quadcopter and VTOL. In this report, we will see the differential conditions of movement for quadcopter that will be gotten from the Newton Euler and Euler-Lagrange conditions. The conduct of the model is inspected by incitement of the drone. We use PID controllers for the adjustment of the drone. This strategy is anything but difficult to execute and is utilized to control the drone. The drone will comprise of four engines for vertical drive, a solitary engine for flat impetus and a to level the flight servomotor will be added on the control surface. The vertical impetus engines would be connected to the fixed delta wing stage to create a cross breed VTOL framework.

Not at all like the tilt-rotor VTOL, vertical drive engines won't tilt to work appropriately and satisfy the vertical flight mode and the level engine will be utilized for the flat flight.

As various flight modes are constrained by the different actuators as the framework's multifaceted nature will be diminished. Later, the detailed plan procedure of the drone will be given in which the estimations, counts, choice of the materials, 3D model and the theoretical structure of the drone will be clarified. After this the model of the drone and a progression of programming reproduction real flights and get together procedure of the drone will be portrayed which will be trailed by a progression of programming reenactments and real flight tests to help the idea of non-inclining drone. The working of the fixed-wing automaton and multirotor is straightforward. Creating of the required coordination of flight qualities both the quadcopter and the multirotor stages. Thus, it is essential to have separate comprehension of general hypothesis of fixed-wing flight and quadcopter just as the control methods to balance out the drone. The essential point of the undertaking is to build the flight time by expanding the battery time of the automaton. Right off the bat, drone is structured and manufactured utilizing the logical methods. After this various flight,we will perform the tests under various climate conditions to evaluate the soundness of the automaton during float, winged flight and progress. The optional point is to recognize the flight time as contrast with others drone accessible in showcase.

1.1. Purpose of this document

The purpose of this document is that we get to know about the components and modules and their relations in our developed prototype. It will further tell us the interrelationships between subsystems. We will get a clear understanding of system architecture and structures. This document also serves the reusability in terms of product design, manufacturing and implementation. In addition to that, design decision for components are also mentioned in detailed.

1.2. Problem Statement

The main idea behind the project is to provide a drone to people interested in a drone which has much more flight time than a normal drone. Drone will fly with a speed of 30 km/h. Due to high efficiency; this drone can cover a larger area as compared to normal drones.

1.3. Scope of the development project

This drone will have a greater flight speed as compare to the others available in market, which is almost 50kmph, and it will cover a range of 10km. Our drone will be used for several purposes i.e., in Agriculture, Military and Civilian Surveillance.

1.4. System Overview

SKYHAWK VTOL will accomplish both fast forward flight (glide mode) and hover as well. Rotors generate lift during take-off and landing. After takeoff, it'stransitionsfrom vertical mode to forward flight mode (glide mode) in which life will be produced with the help of delta wing. It extends the capabilities of Quadcopter by incorporating additional (push/pull) propeller systems. Lithium polymer battery is used in this drone for enhancing battery lifetime as they can last up to 2 to 3 days after full charging. This drone will be able to communicate with the user and its internal parts for better performance. It has capacity of carrying almost 1kg payload for at least half an hour in the air. There will be no background information, as no previous work has been done on this project.

1.5. Product Functions

The main features of SKYHAWK DELTAWING DRONE are highlighted below:

1. The drone can fly and gild.
2. The drone has a speed of 30 km/h
3. The drone can carry a payload of 1kg
4. The drone utilizes less power.

1.6. User Interfaces

Users will be able to view the current location of the drone, distance travel from the takeoff position, information related to flight and can configure the setting of the drone.

CHAPTER 2: Literature Review

2.

2.1. Theoretical Backgroundof Drone

Vertical takeoff and landing aircrafts had always been a quest for aeronautical engineers in all ages. It can be seen in the sketches of Da Vinci as Aerial screws, in twin propeller model of Lomonosov and Paul Cornu’s first helicopter just to mention a few. The difficulty in lifting a heavier than air vertically and to sustain hover were major issues until Paul Cornu hailed his first helicopter in air for 20 seconds. It gave a kick to design of VTOL aircrafts.

Vertical takeoff and landing aircrafts developed until now are of three main configurations fixed wing, helicopter or ducted type. Fixed wing configuration was the oldest and most used type. Either the entire wing of an aircraft moves, or nozzle of an aircraft provides thrust vectoring, or it has a frame with motors mounted in quad configuration with tiny rotors. Helicopter types are common and include a main rotor to provide lift while ducted type includes a ducted rotor.

Most of the initial aircrafts built were of short run or jump vertical takeoff and landing vehicles a few examples worth to mention are Harrier, V22 Osprey and Yak 38 Forger. Harrier P1127 jump type aircraft built in Britain 1960 and used in military could take off and land vertical under its maximum loading limit. Yakovlev Yak 38 Soviet Navy VTOL aircraft looked like P1127 but had different working mechanism with two smaller engines. V22 Osprey was a tilt rotor aircraft with both VTOL and V/STOL evaluated in June 2005.

Going to Unmanned aerial vehicle capable of vertical takeoff and land had its roots in the attempts made to liftoff vertically. There are various Vertical takeoff and landing UAVs built recently that includes Falcon V, Pigeon V, Alti, Sky hawk and many others worth to mention. These UAVs have different Maximum takeoff weight, flight time, range and maximum altitude but the common features among them are the rotors for vertical takeoff in Quad configuration. Latest UAVs built are made from carbon fiber or composites to make them light in weight. Also, these UAVs are versatile and can carry significant payload.

However, the design of VTOL UAVs is difficult. Major problem is to achieve higher thrust to weight ratio keeping the weight as low as possible. For achieving greater thrust high-powered batteries are to be used that have their own weight and larger sized propellers are to be used increasing the overall weight of the UAV. Thus, the design is usually a compromise between its weight and maximum thrust attainable. It can be resolved by component matching technique. Other problem in VTOL UAVs is of transition from hover to forward flight. When UAV attains a specific altitude in hover and is ready for forward flight the rotors in quad configuration are turned off and power is switched to main propeller. While this transition the delay in power switching may cause the UAV to crash. It can be avoided using several methods that reduce the delay in this transition.

A VTOL drone has capacity to fly like a fixed wing plane and simultaneously drift in air like a multirotor. Flight elements for the most part utilizes body-fixed organize framework where the arrange framework is fixed comparative with the drone though for the multirotor airplane moving the three turn pivots are namedas :

1. Roll: This is pivot of x-pivot
2. Pitch: This is pivot of y-pivot
3. Yaw: This is pivot of z-pivot

Following figure is indicating the pivot revolution of the drone.

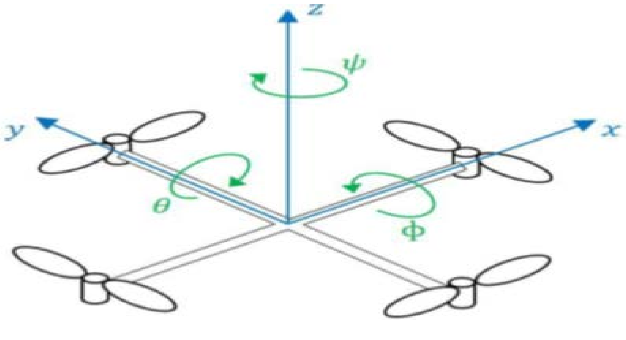
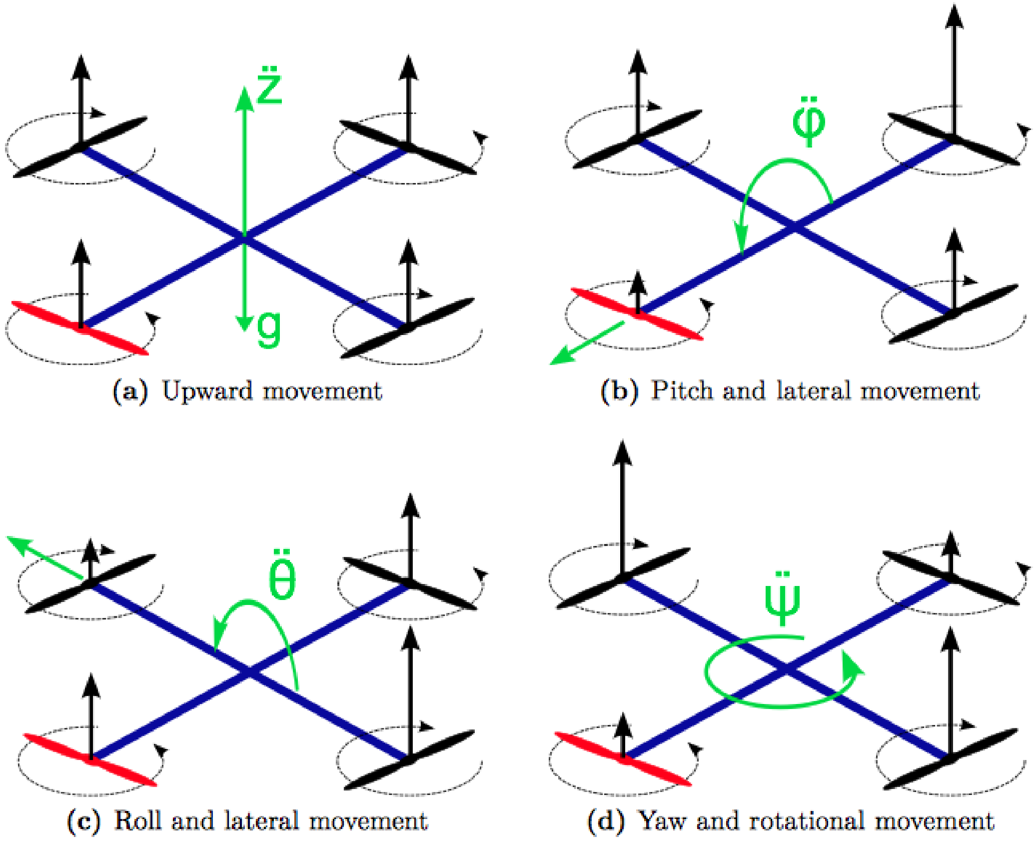


Figure 1. Coordinate System in a multirotor aircraft

A multirotor propeller design comprises of four propellers, which are known as quadrotor. There are other multirotor propellers arrangements also, for instance trirotor, hexarotor and octorotor.

Every one of these setups has diverse territory of utilizations and furthermore has varieties as far as execution, flight time, solidness, payload limit and nimbleness. The principle undertaking of the propeller is to create sufficient lift power to lift the drone upwards towards sky and convey enough push to move its present situation to in reverse, upward, right and left. There are four essential movements of the multirotor.



(a) Upward movement
(b) Pitch and lateral movement
(c) Roll and lateral movement
(d) Yaw and rotational movement

Figure 2. Body Movement change and altitude in drone

By stable flight, we imply that the pitch and the move turns must be first offset. If these tomahawks are not controlled sufficiently, the multirotor will be at a risk of crash and spilling. Flight Control Unit has gyroscopes and accelerometer for the affirmation of the disposition of roll and pitch tomahawks. Without a doubt, it is less fundamental to offsetting the turn if the multirotor is controllable If the yaw pivot is shaky it would somewhat float the multirotor body in that hub, yet it tends to be adjusted by utilizing the radio controllers.

The sort out structure resembles the multirotor for a fixed wing drone. The basic contrast among drone and the plane is that the planes uses charges that are changed in accordance with the fuselage for the forward drive as showed up in the figure 3 underneath. The smoothed-out weight differentiate among the lower end surfaces and upper end surfaces of wing produces lift. The lead of automaton is how better you use the control surfaces added to essential wing, vertical and level tail wing. So there are three control surfaces if there ought to be an event of the plane are mentioned below:

1. Controlling the pitch turn: Elevator
2. Controlling the yaw turn: Rudder
3. Controlling the move turn: Aileron

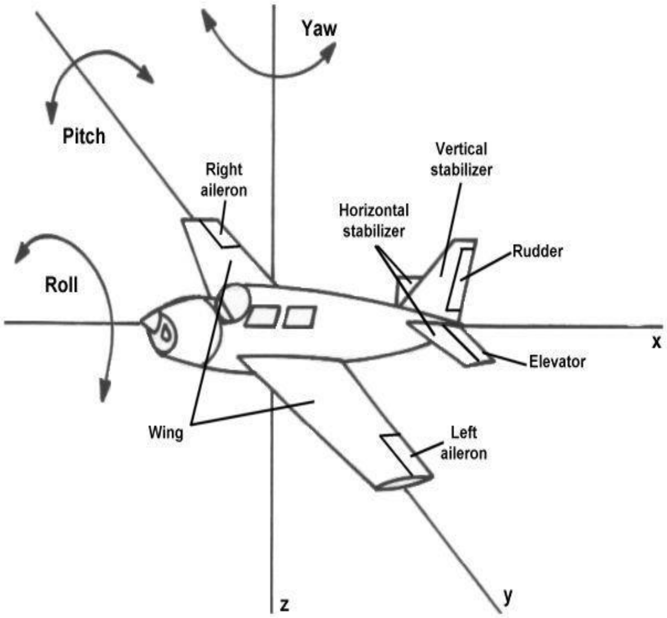


Figure 3. Coordinate system in a fixed-wing airplane

In the fixed-wing plane like the multirotor, x and the y pivots must settle appropriately for straight and the level flight. Direct trimming of the ailerons and the elevators can help in the case of full-scale manned aircrafts. While in Small-scale unmanned fixed wing drones, mentality sensors, for example, spinner and accelerometer help in the roll and pitch axes adjustment.

These dynamics can be made complex because of propulsion units for the vertical as well as longitudinal movements. In order to keep it basic the drone is accepted to obey the flight elements of the multirotor framework during its vertical flight, though in the flat flight mode it is normal that the drone will obey fixed-wing flight elements. The drone will be in changing states during its progress flight mode and the gravity will defeat by both longitudinal and vertical impetus units until the successful completion of the change mode. Controlling engine yields appropriately will be required for the improvement of the height of drone. The elevation will be seriously diminished if the base slow down speed isn't accomplished because of absence of vertical engine yields in the change to level flight mode. While on the move to vertical flight mode, decreasing the longitudinal engine yield beneath least slow down speed before the vertical engines accomplish enough push would lead lessening altitude/elevation. The extreme velocity is restricted to the appraised intensity of the longitudinal propulsion unit.

2.2. Advantages of VTOL:

1. No long-paved landing or takeoff stripes required
2. Very efficient for tracking, surveillance and airborne data acquisition
3. Coastal surveillance, defense intelligence gathering and environmental monitoring
4. In highly vulnerable to attack airbases it provides with a very quick time response
5. Simple to Operate & Deploy
6. Operational flexibility in remote areas
7. Mineral exploration and environmental monitoring in remote areas
8. They are also used for inspection of power utility assets and power industry infrastructure inspection
9. Point way navigation systems
10. Low cost
11. A very promising UAV configuration having both VTOL capability and efficient cruise performance
12. Efficient horizontal flight promises significant advantage over other vehicles for any mission

13. Fixed Wing UAS can operate at very low power to weight ratio as compared to conventional VTOLs
14. Fixed Wing VTOL can have tremendously high endurance than conventional VTOLs like quad copters, Hexa-copters, Octocopters, Helicopters or Tail sitters
15. Like conventional VTOLs, fixed wing VTOL does not suffer performance penalties like dash speed, range and endurance because of very efficient cruise flight mode
16. Fixed Wing VTOL UAS can use both fully electric propulsion systems as well as hybrid systems for high endurance
17. Technique of using Hybrid systems in fixed wing VTOL UAS make its operational range and endurance surpass any conventional VTOL UAV range and endurance
18. High operational benefits with high reliability unlike quadcopters or hexacopters.

2.3. Software & Hardware:

2.3.1. Pixhawk 2.4.8

Pixhawk is an integrated, single board flight controller. It has sufficient inputs and outputs for many applications without expansion. This version of Pixhawk 2.4.8 has improved ease in use, sensor performance, microcontroller resources and increased reliability with reduced integration complexity. It has key design points such as it has all in one design and lots of ports. On board battery backup and separate power supply for FMU and input/ output.

Figure 4. Pixhawk Components and structure

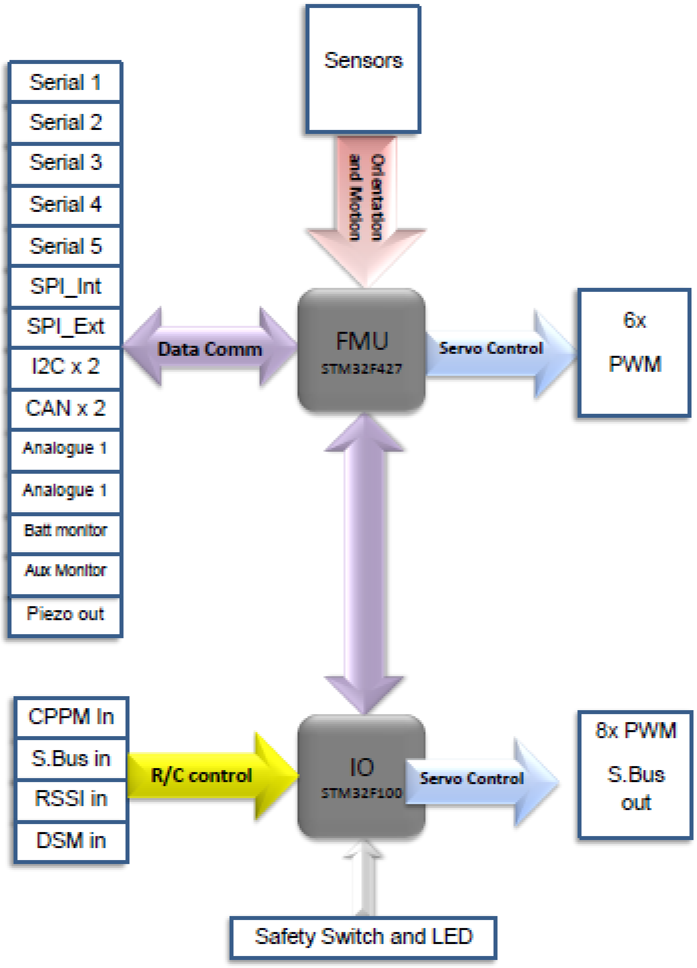


Figure 5. Pixhawk Components and its connections Architecture

Figure 6. Pixhawk Specifications

2.3.2. Mission Planner

It is a full featured ground station application for Qground for plane, copter and rover. Only companionable with windows. There are a few steps followed to make use of Mission Planner:

- Load this firmware in autopilot (PX4) to control the vehicle
- Tune, setup and configure performance of autonomous vehicle
- Plan, save and load the mission on Google entry map by click away
- To make a full UAV simulator interface it with a PC flight simulator
- With proper telemetry hardware:
  a) Vehicle status in operation can be known.
  b) Telemetry logs can be recorded and analyzed that contain much useful information.
  c) Vehicle can be operated in first person view.

Steps for its use are:

- Install mission planner directly from internet

- After installation mission planner can be:
  a) Connected to autopilot to get telemetry and control vehicle
  b) Or can be loaded

First connect autopilot to PC using a data cable or USB or Bluetooth, Radios or IP connection. Then select the connection and data rate. For radio link data rate is 57600 and for USB 115200. After this press connects button parameters will automatically be downloaded from autopilot and button will change to disconnect.

- Install firmware
- Go to initial setup and select structure closest to design. Unplug the control board (Pixhawk) and then plug it back.
- To test that the firmware has been installed tilt the board and HUD will appear over PC screen.
- Set up the home position. Home position is the place where the UAV will return after its autonomous flight (RTL). For different configurations home position is different. For plane the home position is where the GPS is first locked.
- Select the flight plan icon and define the mission profile. Way points are to be defined on the Google map and respective altitude are fed. The altitude is relative to the launch position.
- Write the mission profile by selecting write and to modify it select read.
- Multiple mission profiles can be saved by selecting Save WP File or read file by selecting Load WP File
- To define an automatic mission profile in which aircraft has to map the area then select a polygon over the area in map then select Auto WP, Grid. Mission planner will automatically allocate waypoint at given altitude.
- A filtered list of commands is also provided in Mission Planner where user can provide values. Like LOITER_TURN command in which number of turns are given by the user.
- Frame of reference can be set accordingly using commands:

MAV_FRAME_GLOBAL_RELATIVE_ALT

MAV_FRAME_GLOBAL_TERRAIN_ALT

- There are also few navigation commands:

MAV_CMD_NAV_WAYPOINT

MAV_CMD_NAV_TAKEOFF

MAV_CMD_NAV_LOITER_UNLIM

MAV_CMD_NAV_LOITER_TURNS

MAV_CMD_NAV_LOITER_TIME

MAV_CMD_NAV_RETURN_TO_LAUNCH

MAV_CMD_NAV_LAND

MAV_CMD_NAV_CONTINUE_AND_CHANGE_ALT

MAV_CMD_NAV_SPLINE_WAYPOINT

MAV_CMD_NAV_GUIDED_ENABLE

MAV_CMD_NAV_ALTITUDE_WAIT

MAV_CMD_NAV_LOITER_TO_ALT

MAV_CMD_DO_JUMP

MAV_CMD_CONDITION_DELAY

MAV_CMD_CONDITION_CHANGE_ALT

SKYHAWK DELTAWING VTOL

- If gimbaled cameras are employed then its tilt, yaw and roll can be set using commands:

DO_SET_ROI

DO_MOUNT_CONTROL

- Rally points can also be set for geo fencing.

2.3.3. QGroundControl (QGC)

QGroundControl (QGC)is a combination of hardware and firmware. Hardware acts as UAVs brain, ear and eyes. The firmware is a set of code that runs on the hardware that configures it for type of vehicle under use. An easy firmware update repurposes hardware into different role. Software is an interface to the hardware. It provides point and click interaction to define the mission profile. Fixed Wing aircraft mode is chosen for mission profile. It is safer in air. Also, they can carry greater payload for longer distances. This mode is however not suitable for precision mission. The QuadPlane supports several arrangements of frame quad copter, hex copter, and octacopter and octaquadmulticopter frames.

In quad copter frame there are different configurations on which motors are placed.

- Chanel 5: Front Right motor, Counterclockwise
- Chanel 6: Rear left motor, Counterclockwise
- Chanel 7: Front left motor, Clockwise
- Chanel 8: Rear right motor, Clockwise
- There are extra five modes in quad plane
- QSTABILIZE: that stabilizes the quad plane when subjected to disturbance
- QHOVER: that holds the altitude

- QLOITER: that helps to loiter

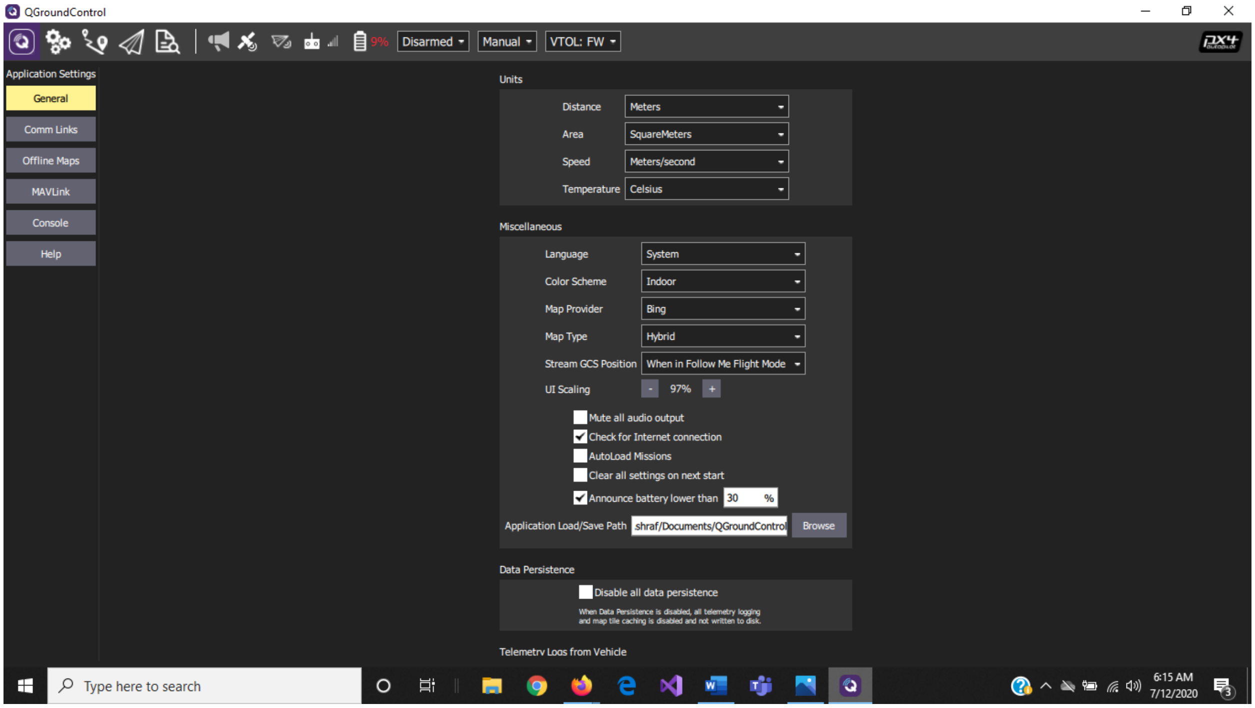
- QLAND: landing assistance

- QRTL: return to launch

Transition in a quad plane is of primary concern where the aircraft is flying from VTOL to conventional fixed wing aircraft. Transition can be both ways from VTOL to fixed wing or vice versa. It can also be manual or automated.

- If transition is manual the motors will stop immediately.
- If transition to any fixed wing mode quad will supply lift and stability until minimum fly by wire airspeed is reached.
- Once this airspeed is reached quad motor will slowly drop in power over Q_Transition_ms i.e. 5000ms by default and will switch after this.

The working of QGroundControl can be seen by the screenshots attached below:



Units

Distance: Meters
Area: SquareMeters
Speed: Meters/second
Temperature: Celsius

Miscellaneous

Language: System
Color Scheme: Indoor
Map Provider: Bing
Map Type: Hybrid
Stream GCS Position: When in Follow Me Flight Mode
UI Scaling: 97%

☐ Mute all audio output
☑ Check for Internet connection
☐ AutoLoad Missions
☐ Clear all settings on next start
☑ Announce battery lower than 30 %

Application Load/Save Path: shraf/Documents/QGroundControl

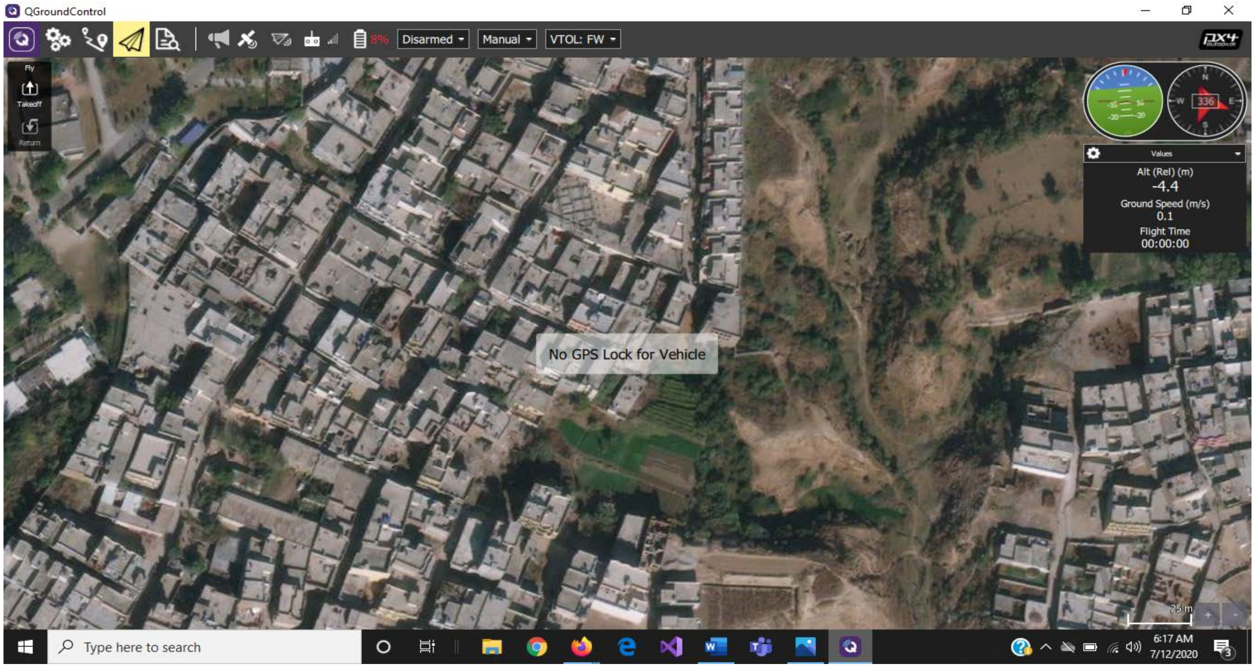
Data Persistence

☐ Disable all data persistence

When Data Persistence is disabled, all telemetry logging and map tile caching is disabled and not written to disk.

Telemetry Logs from Vehicle

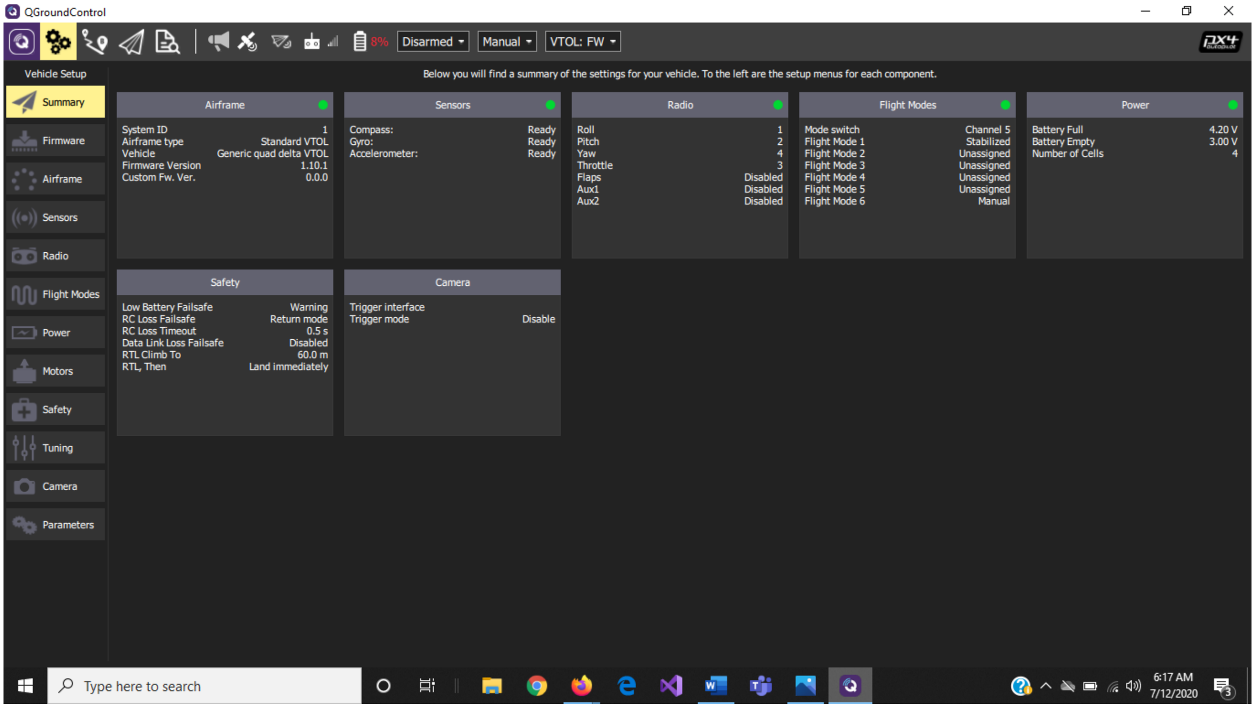
Figure 7. General Details of Q Ground Control



Alt (Rel) (m)
-4.4
Ground Speed (m/s)
0.1
Flight Time
00:00:00

No GPS Lock for Vehicle

Figure 8. GPS Mode Showing Altitude, Speed and location map



Below you will find a summary of the settings for your vehicle. To the left are the setup menus for each component.

Airframe

System ID	1
Airframe type	Standard VTOL
Vehicle	Generic quad delta VTOL
Firmware Version	1.10.1
Custom Fw. Ver.	0.0.0

Sensors

Compass:	Ready
Gyro:	Ready
Accelerometer:	Ready

Radio

Roll	1
Pitch	2
Yaw	4
Throttle	3
Flaps	Disabled
Aux1	Disabled
Aux2	Disabled

Flight Modes

Mode switch	Channel 5
Flight Mode 1	Stabilized
Flight Mode 2	Unassigned
Flight Mode 3	Unassigned
Flight Mode 4	Unassigned
Flight Mode 5	Unassigned
Flight Mode 6	Manual

Power

Battery Full	4.20 V
Battery Empty	3.00 V
Number of Cells	4

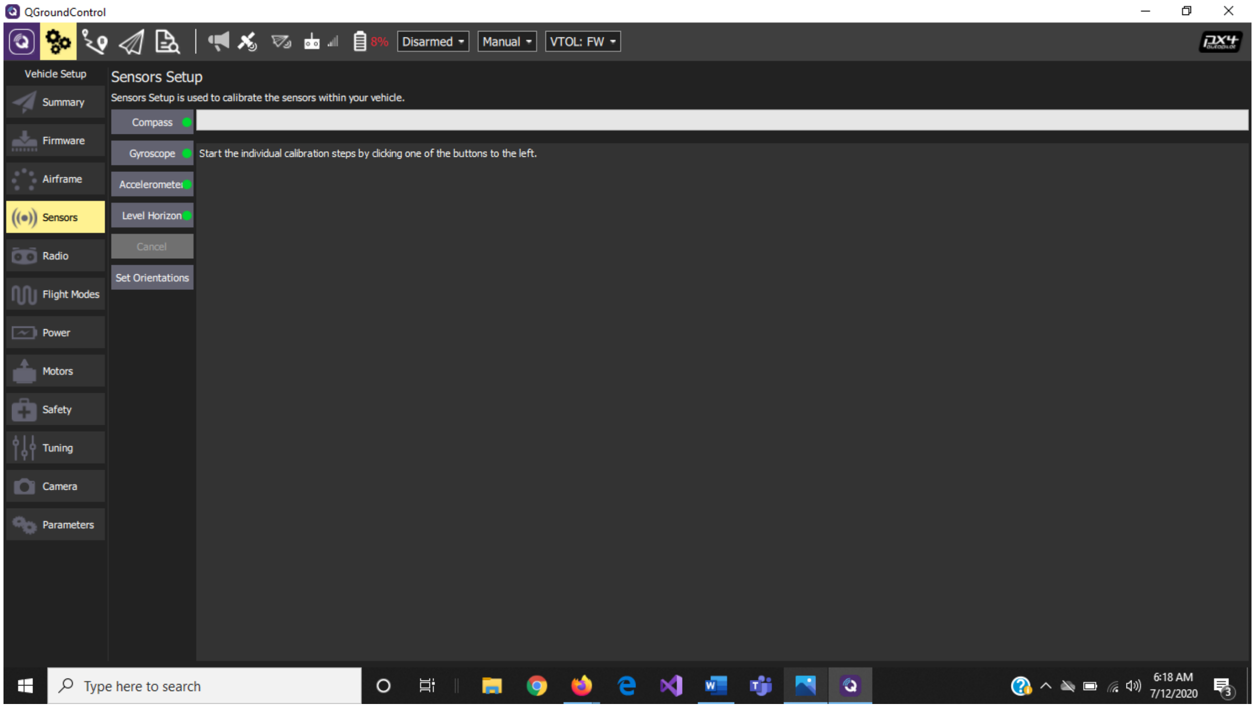
Safety

Low Battery Failsafe	Warning
RC Loss Failsafe	Return mode
RC Loss Timeout	0.5 s
Data Link Loss Failsafe	Disabled
RTL Climb To	60.0 m
RTL, Then	Land immediately

Camera

Trigger interface	
Trigger mode	Disable

Figure 9. Summary of the device (VTOL) attached

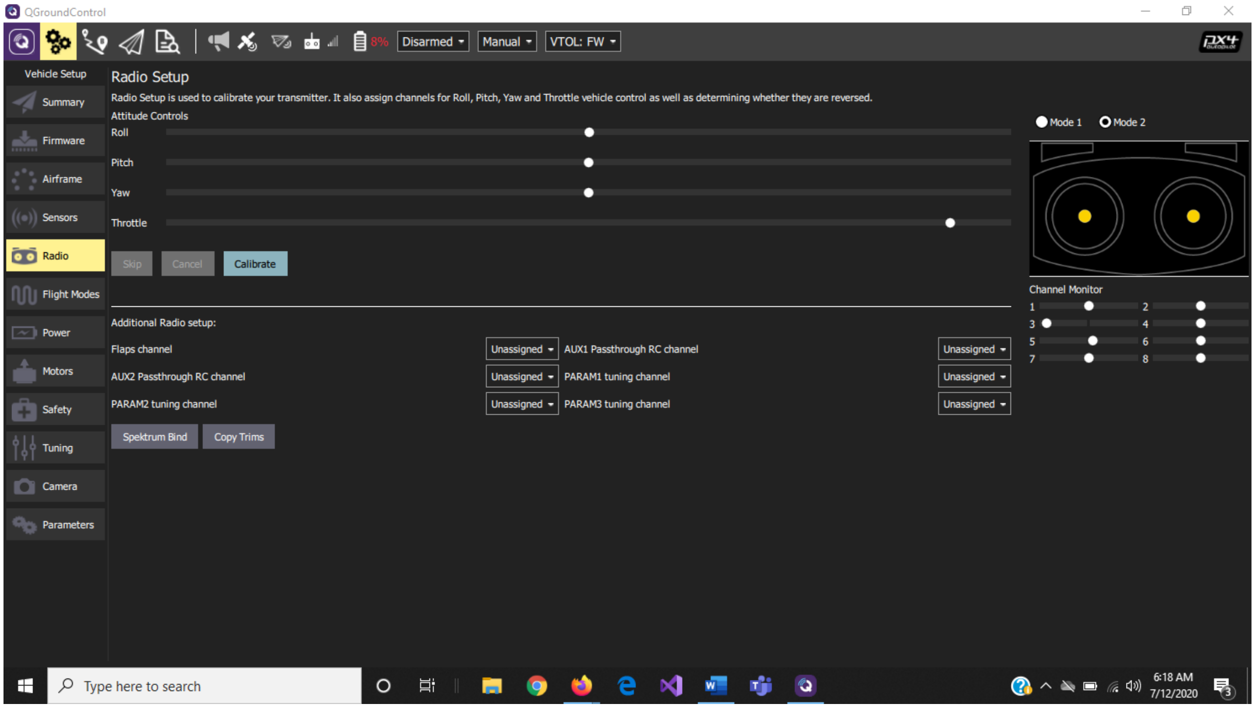


Sensors Setup

Sensors Setup is used to calibrate the sensors within your vehicle.

Start the individual calibration steps by clicking one of the buttons to the left.

Figure 10. Details of Sensors attached



Radio Setup

Radio Setup is used to calibrate your transmitter. It also assign channels for Roll, Pitch, Yaw and Throttle vehicle control as well as determining whether they are reversed.

Attitude Controls

Roll

Pitch

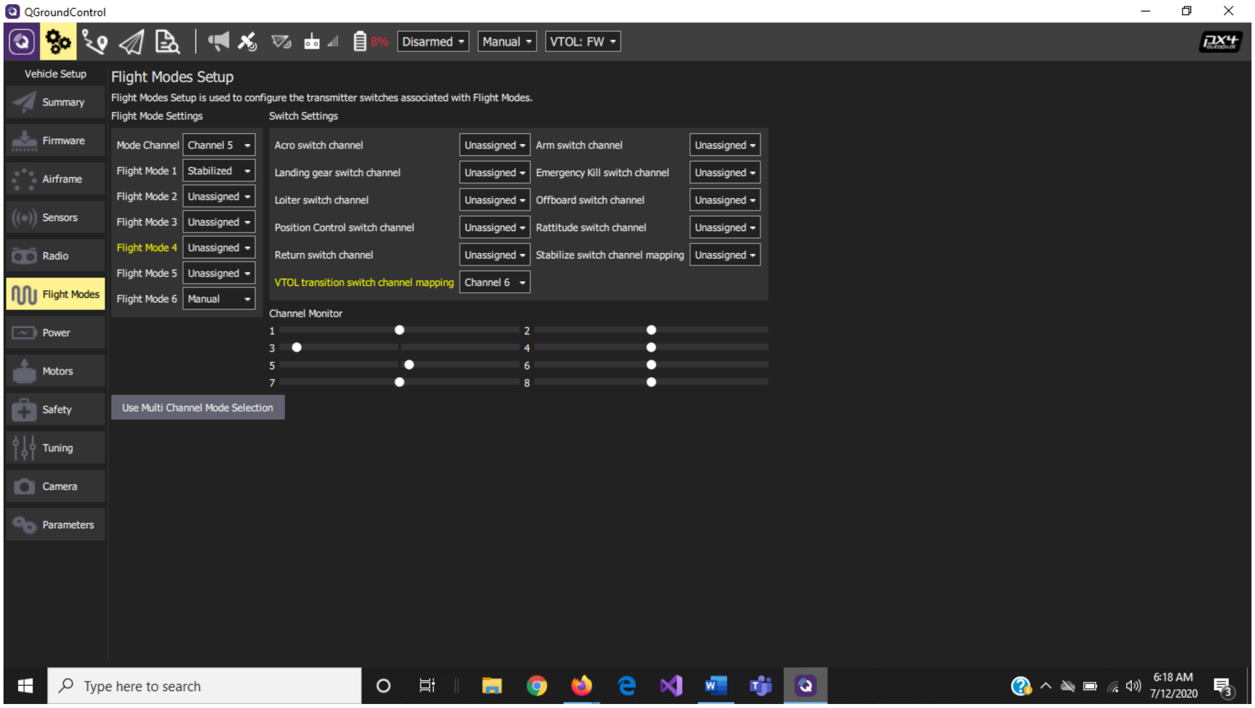
Yaw

Throttle

Additional Radio setup:

Flaps channel	Unassigned	AUX1 Passthrough RC channel	Unassigned
AUX2 Passthrough RC channel	Unassigned	PARAM1 tuning channel	Unassigned
PARAM2 tuning channel	Unassigned	PARAM3 tuning channel	Unassigned

Figure 11. Details of Radio Controller



Flight Modes Setup

Flight Modes Setup is used to configure the transmitter switches associated with Flight Modes.

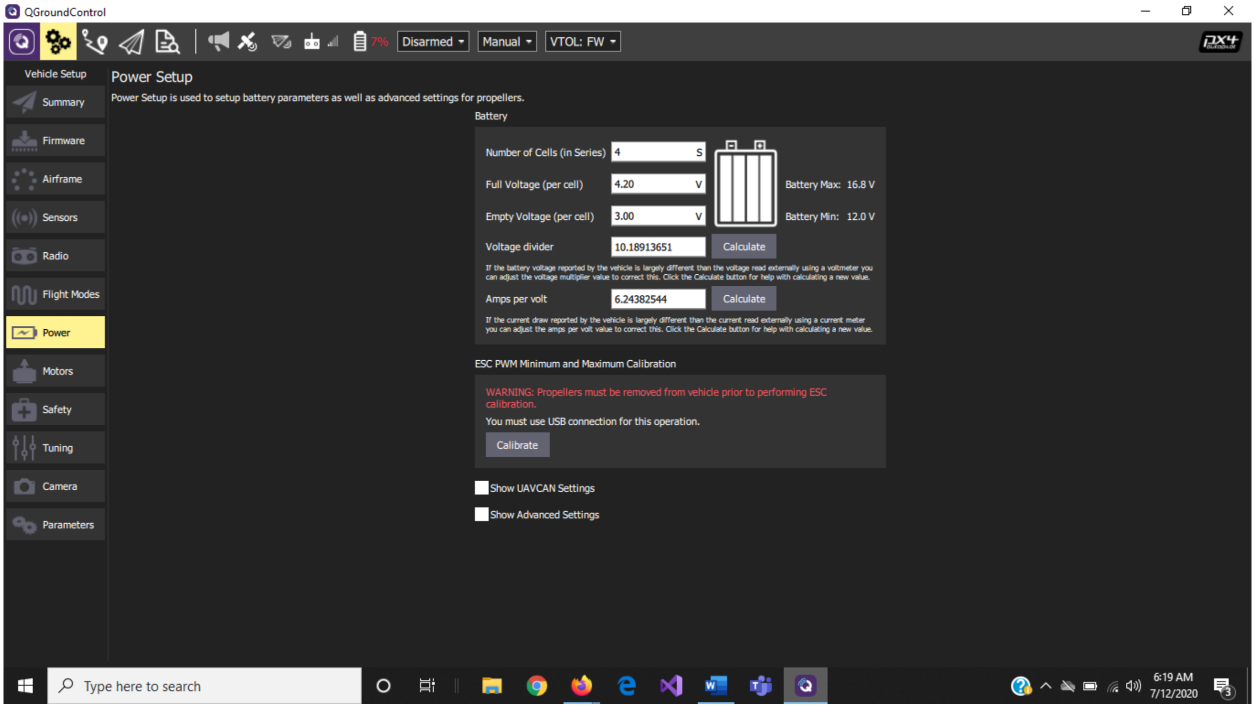
Flight Mode Settings

Mode Channel	Channel 5
Flight Mode 1	Stabilized
Flight Mode 2	Unassigned
Flight Mode 3	Unassigned
Flight Mode 4	Unassigned
Flight Mode 5	Unassigned
Flight Mode 6	Manual

Switch Settings

Acro switch channel	Unassigned	Arm switch channel	Unassigned
Landing gear switch channel	Unassigned	Emergency Kill switch channel	Unassigned
Loiter switch channel	Unassigned	Offboard switch channel	Unassigned
Position Control switch channel	Unassigned	Rattitude switch channel	Unassigned
Return switch channel	Unassigned	Stabilize switch channel mapping	Unassigned
VTOL transition switch channel mapping	Channel 6		

Figure 12. Details of flight Modes



Power Setup

Power Setup is used to setup battery parameters as well as advanced settings for propellers.

Battery

Number of Cells (in Series): 4 S

Full Voltage (per cell): 4.20 V

Empty Voltage (per cell): 3.00 V

Battery Max: 16.8 V

Battery Min: 12.0 V

Voltage divider: 10.18913651

If the battery voltage reported by the vehicle is largely different than the voltage read externally using a voltmeter you can adjust the voltage multiplier value to correct this. Click the Calculate button for help with calculating a new value.

Amps per volt: 6.24382544

If the current draw reported by the vehicle is largely different than the current read externally using a current meter you can adjust the amps per volt value to correct this. Click the Calculate button for help with calculating a new value.

ESC PWM Minimum and Maximum Calibration

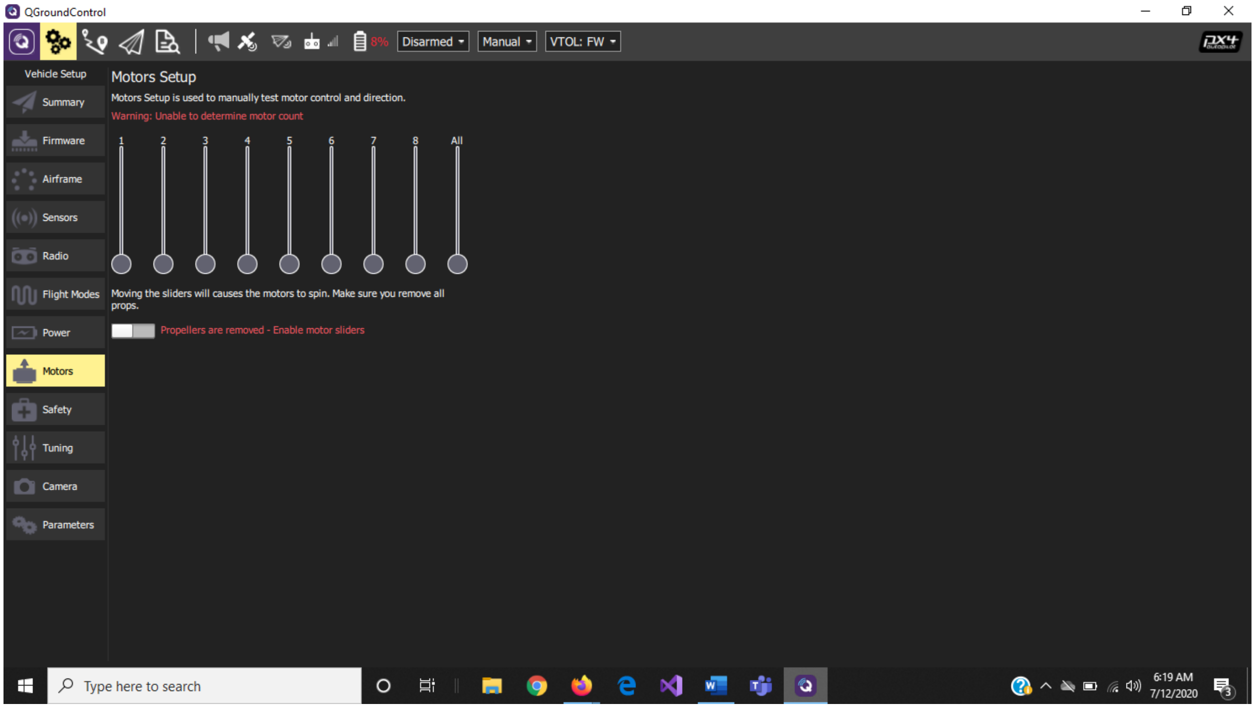
WARNING: Propellers must be removed from vehicle prior to performing ESC calibration.

You must use USB connection for this operation.

☐ Show UAVCAN Settings

☐ Show Advanced Settings

Figure 13. Configuration of Battery through Q Ground Control



Motors Setup

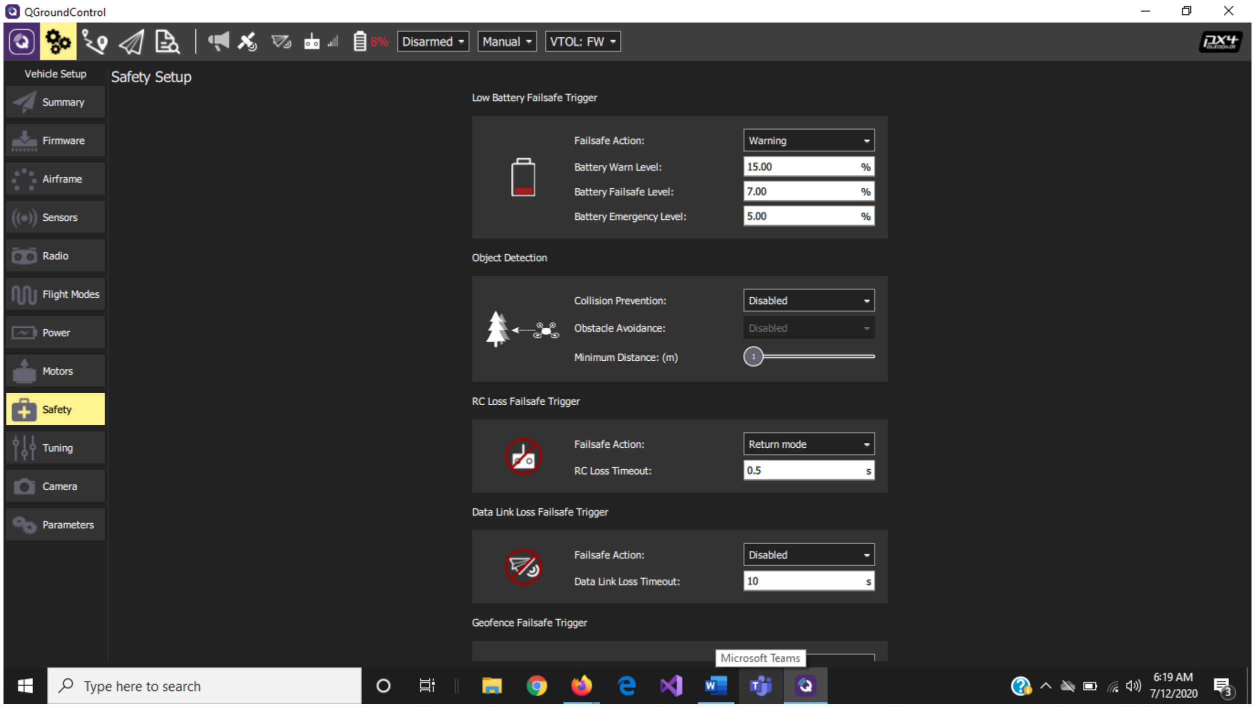
Motors Setup is used to manually test motor control and direction.

Warning: Unable to determine motor count

Moving the sliders will causes the motors to spin. Make sure you remove all props.

Propellers are removed - Enable motor sliders

Figure 14. Status of Motors



Safety Setup

Low Battery Failsafe Trigger

Failsafe Action: Warning
Battery Warn Level: 15.00 %
Battery Failsafe Level: 7.00 %
Battery Emergency Level: 5.00 %

Object Detection

Collision Prevention: Disabled
Obstacle Avoidance: Disabled
Minimum Distance: (m) 1

RC Loss Failsafe Trigger

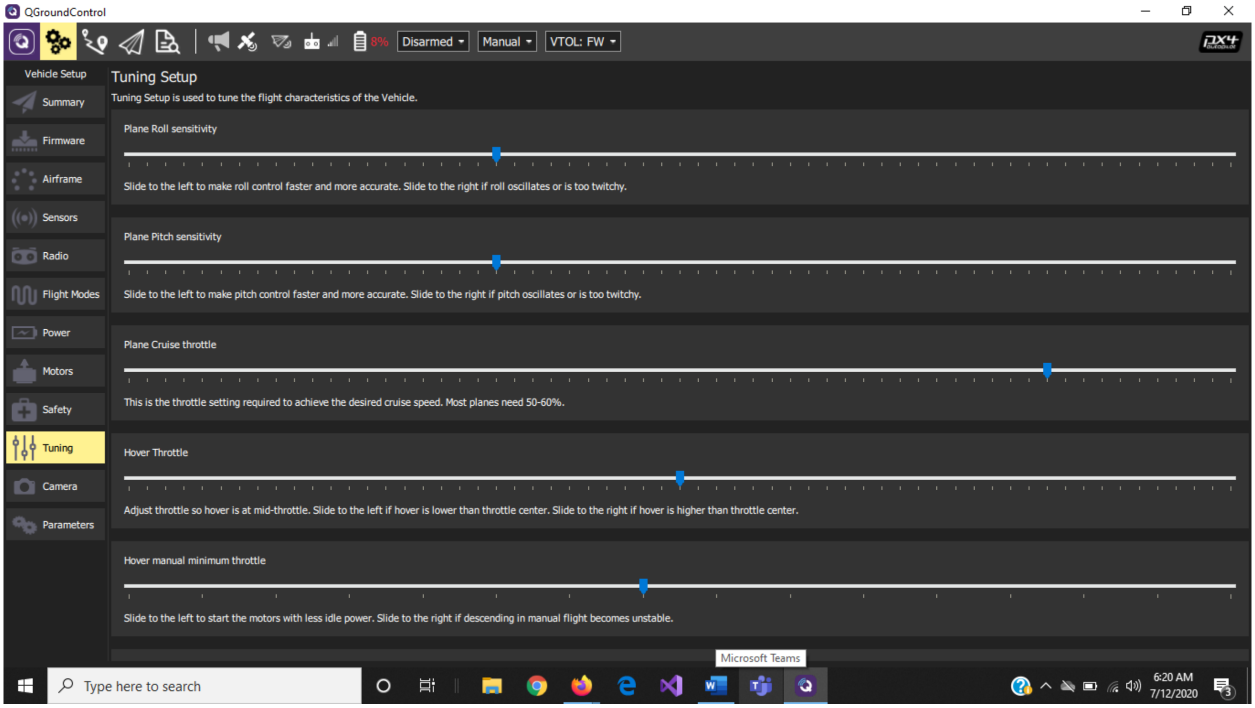
Failsafe Action: Return mode
RC Loss Timeout: 0.5 s

Data Link Loss Failsafe Trigger

Failsafe Action: Disabled
Data Link Loss Timeout: 10 s

Geofence Failsafe Trigger

Figure 15. Details of Safety features



Tuning Setup

Tuning Setup is used to tune the flight characteristics of the Vehicle.

Plane Roll sensitivity

Slide to the left to make roll control faster and more accurate. Slide to the right if roll oscillates or is too twitchy.

Plane Pitch sensitivity

Slide to the left to make pitch control faster and more accurate. Slide to the right if pitch oscillates or is too twitchy.

Plane Cruise throttle

This is the throttle setting required to achieve the desired cruise speed. Most planes need 50-60%.

Hover Throttle

Adjust throttle so hover is at mid-throttle. Slide to the left if hover is lower than throttle center. Slide to the right if hover is higher than throttle center.

Hover manual minimum throttle

Slide to the left to start the motors with less idle power. Slide to the right if descending in manual flight becomes unstable.

Figure 16. Manual tuning of parameters

2.3.4. Ecalc

ECALC is online available software used for selecting electric drive and propellers. The operating conditions, weight and geometry of the airplane is fed into the software. Battery cells are selected, and its configuration is set. Similarly, controllers and motors are selected along with a propeller. This will in turn calculate whether the components used would be able to fulfill the requirements and how much thrust to weight will be provided. ECALC is used for two configurations of the designed UAV. One for Vertical takeoff and landing configuration and the other for plane configuration. Different sets of propellers and motor pairs were coupled, and best pair was then selected that fulfills the requirement of both configurations.

2.3.5. Advance Aircraft Analysis (AAA)

It is industry software used to design aircraft up to standard and to analyze the stability, aerodynamics and performance of different configurations of aircraft. It is used worldwide in Universities, hobbyist and civil aircrafts as well as military aircrafts design. It uses high fidelity methods that are based upon physics principle and uses semi empirical technique to design both conventional and unconventional aircrafts. This software provides a platform for iterations and non-unique process for preliminary design. It works by taking initial weight and geometry of aircraft by the design engineer and analyze open and closed loop stability and sensitivity keeping the design with in weight and cost constraint. It is also used to design fighter aircrafts and high-speed airplanes. The module for detailed drag allows simulation of supersonic flow. However, the stability and control only deal with subsonic flow less than Mach 0.7. It can be used for design of small (civil), military and transport airplane. This program is designed to aid in the design learning that is necessary for creative design judgement.

CHAPTER 3: Analysis of VTOL

3.

In this section the aircraft is analyzed to check its performance suitability. The following analysis are undertaken and discussed through-out.

Analysis includes:

- Aerodynamics
- Propulsion
- Weights
- Stability, Control and handling qualities
- Performance
- Cost Analysis
- Optimization

3.1.Aerodynamic Analysis

Figure below shows the only two ways the air mass and the airplane can act upon each other. As the aircraft moves, it pushes the air molecules aside creating a boundary layer and varying the relative velocity of the air about the aircraft on the upper and lower boundary surfaces. This varying velocity results in varying pressure distribution across the body of the aircraft especially on the upper and lower surfaces of the wing that creates high pressure on the lower side of wing with decreased velocity while a very low pressure on the upper side with increased velocity thus creating an upward force that is called lift, to compensate the change in dynamic pressure.

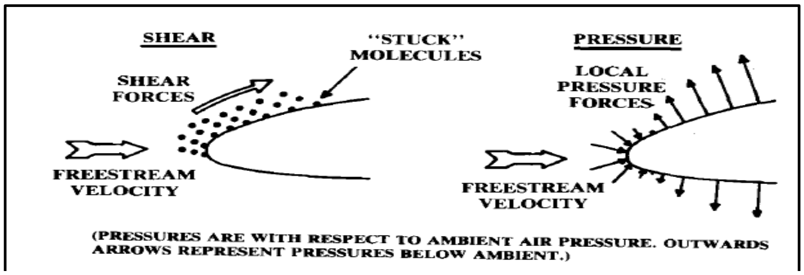
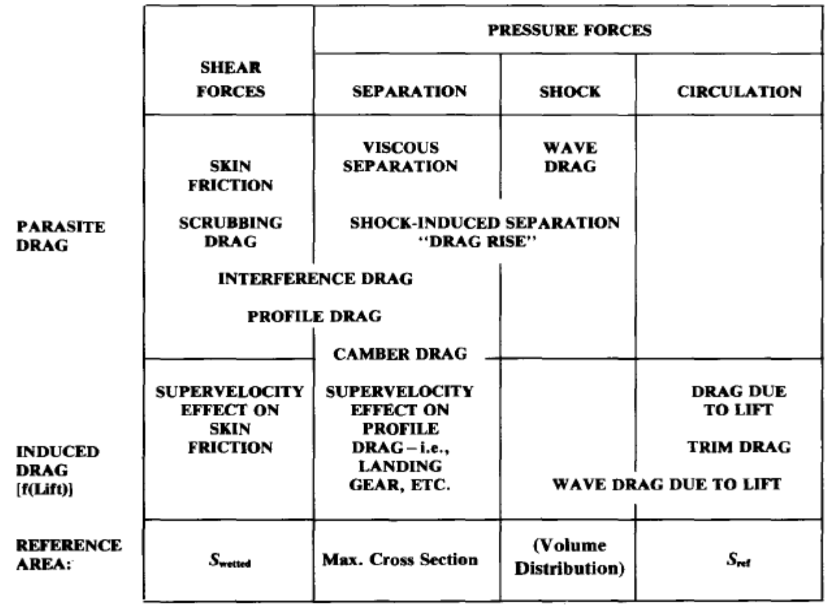


Figure 17. Aerodynamic forces developed due to shear and pressure difference

Table below shows some of the drag forces acting on an aircraft whether due to separation, shock or circulation.



	SHEAR FORCES	PRESSURE FORCES		
		SEPARATION	SHOCK	CIRCULATION
PARASITE DRAG	SKIN FRICTION SCRUBBING DRAG	VISCOUS SEPARATION	WAVE DRAG	
		SHOCK-INDUCED SEPARATION "DRAG RISE"		
	INTERFERENCE DRAG			
	PROFILE DRAG			
		CAMBER DRAG		
INDUCED DRAG [f(Lift)]	SUPERVELOCITY EFFECT ON SKIN FRICTION	SUPERVELOCITY EFFECT ON PROFILE DRAG – i.e., LANDING GEAR, ETC.		DRAG DUE TO LIFT TRIM DRAG
			WAVE DRAG DUE TO LIFT	
REFERENCE AREA:	S_{wetted}	Max. Cross Section	(Volume Distribution)	S_{ref}

Figure 18. Table of Different types of drags due to shear and pressure effect

Airfoils used in the wings have some drag due to flow separation and this separation increases as the angle of attack is increased. This is due to the viscous effects on the airfoil which creates a boundary layer that in result causes flow separation. This viscous separation drag is also called form drag. The location of that point where separation starts, depends upon the curvature of the airfoil and can also be affected by the amount of energy in the flow. As turbulent flow has more energy so it will tend to delay the flow separation than the laminar flow nuts the overall effect on drag for turbulent flow will be greater than laminar flow.

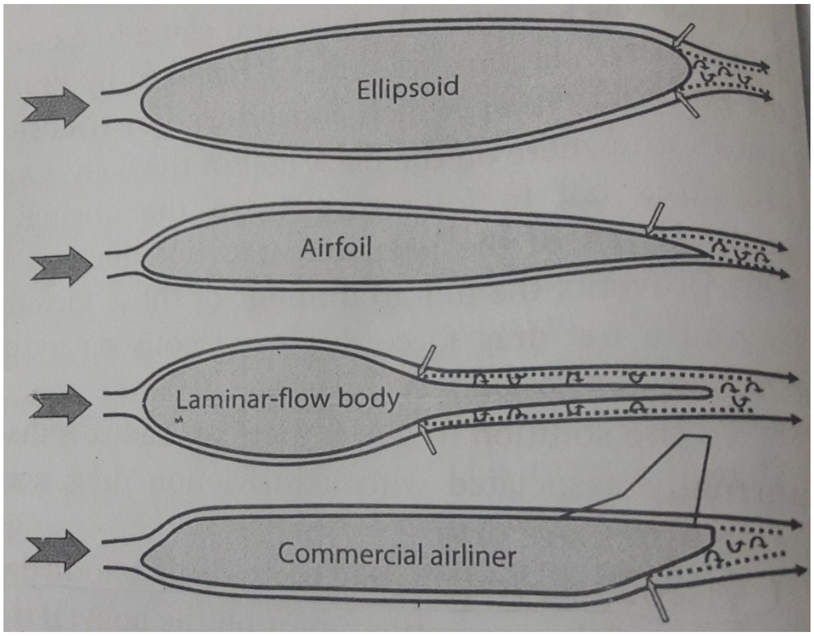


Figure 19. Different fuselage configurations and flow field

3.1.1. Subsonic Lift Curve Slope

The equation that ismentioned below is a form of semi empirical formula which is used for the complete curve slope of wing lift measured in per radians.

$$C_{L_\alpha} = \frac{2\pi A}{2+\sqrt{4+\frac{A^2\beta^2}{\eta^2}\left(1+\frac{\tan \Lambda_{max\ t}}{\beta^2}\right)}}\left(\frac{S_{exposed}}{S_{ref}}\right) F.$$

Where:

$$\beta = \sqrt{1 - M^2} = \sqrt{1 - 0.1^2} = 0.9949$$

$$\eta \approx 0.95$$

$$F = 1.07\left(1 + {}^{d}/_{b}\right)^2 = 1.07\left(1 + {}^{0.4469}/_{7.2357}\right)^2 = 1.2062$$

Fir under design UAV maximum thickness is at quarter chord at which sweep angle is 5 degrees, so we have:

$\Lambda_{\text{max t}} = \text{Wing sweep at maximum thickness} = 5° = 0.08726\ \text{rad}$

$A = \text{aspect ratio} = 6$

As suggested by Raymer, product of fuselage lift factor and area ratio is assumed to be 0.98, so:

$$\frac{S_{\text{exposed}}}{S_{\text{ref}}} = \frac{0.98}{8.7258} = 0.1123$$

Hence, the subsonic lift curve slope will become:

$$C_{L_\alpha} = \frac{2\pi(6)}{2 + \sqrt{4 + \frac{(6)^2(0.9949)^2}{0.95^2}\left(1 + \frac{\tan(5)}{0.9949^2}\right)}}(1.2062 * 0.1123)$$

$$C_{L_\alpha} = 5.7677\ \text{rad}^{-1}$$

Maximum lift without high lift devices

For a high aspect ratio, maximum lift co-efficient can be found using the following formula:

$$C_{L_{\text{max}}} = C_{l_{\text{max}}}\left({C_{L_{\text{max}}}}\middle/{C_{l_{\text{max}}}}\right) + \Delta C_{L_{\text{max}}}$$

$$C_{l_{\text{max}}} = 2.13$$

3.1.2. RDS Analysis

Through RDS aerodynamic analysis is made and its accurate keeping assumption in account. All the required parameters are either computed or known through standards or historical trends are given as an input to RDS that gives the total drag of the aircraft. All the parts of aircraft and external equipment are catered for analysis.

3.2.Performance Analysis

While various aspects of our aircraft design have been investigated, including the structural and stability analysis, the epitome of this report focuses on the final performance of the aircraft. Aircraft performance is the main parameter that is looked at while judging any aerial vehicle, hence this section will focus on evaluating the primary characteristics of our aircraft's performance.

3.2.1. Steady level flight

An aircraft undergoing at a constant altitude un-accelerated is said to be under steady level flight. Therefore, If the aircraft is in steady level flight, then the flight path angle and all the forces and moments are zero. The force balance equations simply state that thrust equals drag and lift equals weight.

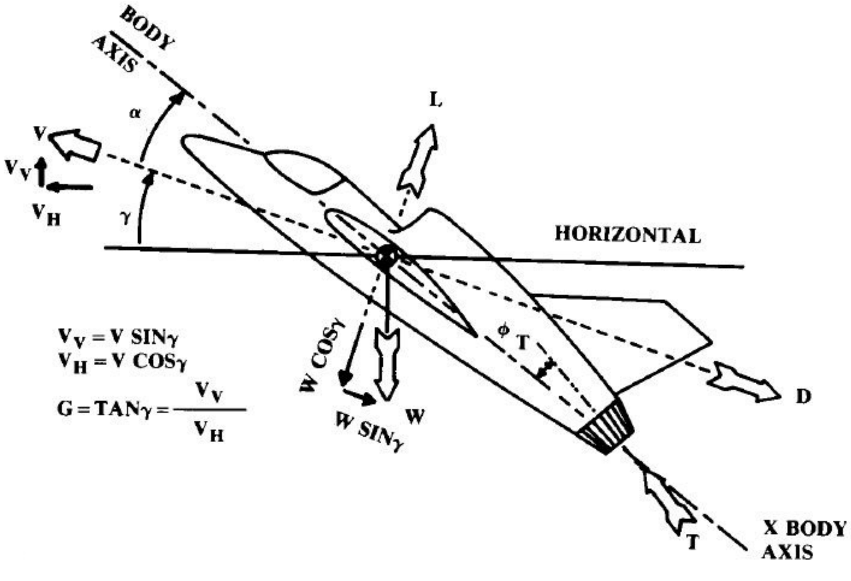


Figure 20. Different forces on an aircraft in climb

Hence, the translational equations of motions featured on page 457 (Raymer, 1992) reduce to:

$$T = D = qS\left(C_{D_0} + KC_L^2\right)$$

$$L = W = qSC_L$$

L/D Vs Velocity Curve

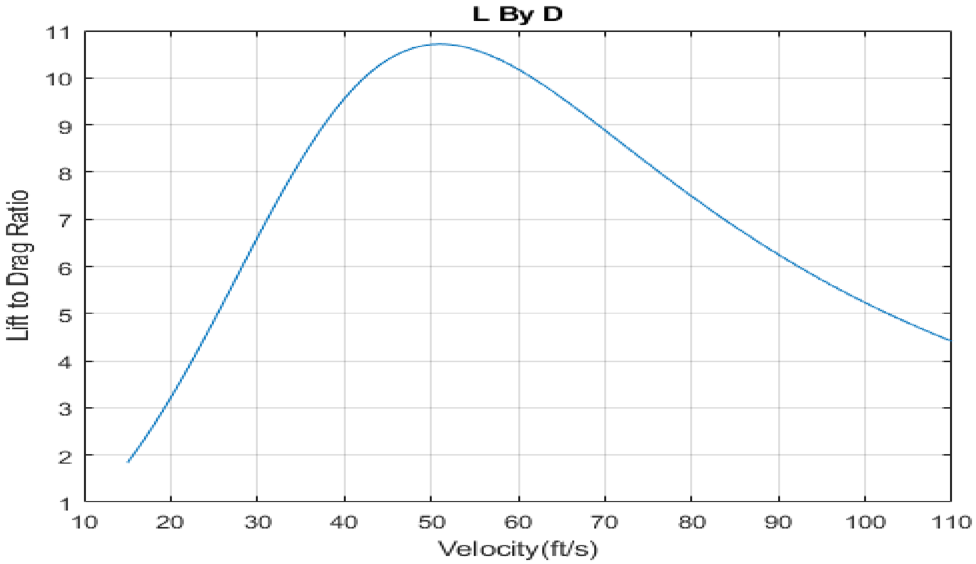


Figure 21. L/D Vs Velocity Curve in MAT lab

The graph above shows the variation of aerodynamic efficiency with the range of velocities at 64 ft/s it is maximum hence it is taken as the cruise velocity.

3.2.1.1. Minimum thrust required in level flight

The required thrust in steady level flight must be equal to the drag encountered by the aircraft at any given time. Thrust required, as the term indicates, is the minimum amount of thrust needed to overcome the drag that is opposing the forward motion of an aircraft at a given speed and altitude. Analytically, the minimum thrust required during level flight can be estimated using the expression featured on page 458 (Raymer, 1992) given below:

$$D_{\min\ thrust} = qS\left[C_{D_0} + \left(\sqrt{\frac{C_{D_0}}{K}}\right)^2\right] = 2qSC_{D_0}$$

- Velocity at minimum thrust/drag

$$V_{min\ T} = \sqrt{\frac{2W}{\rho S}\sqrt{\frac{K}{c_{D\,0}}}}$$

$$V_{min\ T} = \sqrt{\frac{2*3.105}{0.00238}\sqrt{\frac{0.0539}{0.0427}}} = 54.1436ft/s$$

- Lift coefficient at minimum thrust /drag in level flight

$$c_{L_{min\ T}} = \sqrt{\frac{c_{D\,0}}{K}} = 0.8900$$

Since the required thrust equals the drag in this case,

$\mathrm{T}_{\mathrm{R}_{\min}} = 2.9609$ lbf

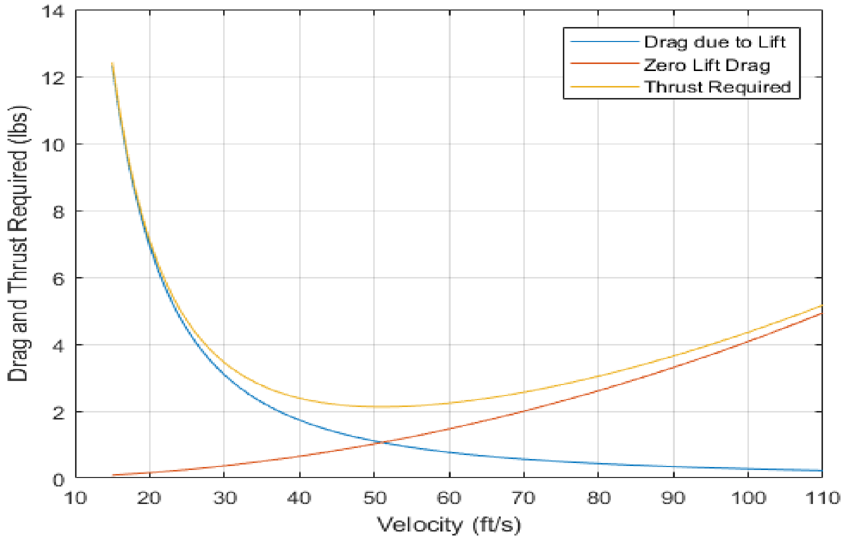


Figure 22. Minimum Thrust required in level flight Vs Velocity in MAT lab

Note: It can be seen that the graphical results with $T_{R_{min}} \approx 3lbf$ and $V_{T_{R_{min}}} = 53\ \mathrm{ft}/s$(After conversion from Mach) are similar to the analytical results.

3.2.1.2. Minimum Power required in level flight

Power is usually defined as the product of velocity(v) and force(F) but since the force in question equals the amount of drag under steady level conditions(D), the expression is modified to:

$$\mathrm{P} = \mathrm{DV}$$

In order to evaluate the minimum power required, the velocity to be used is 0.76 times the velocity required for minimum thrust, therefore, as per the expression on page 457 (Raymer, 1992):

$$\mathrm{V}_{\text{min power}} = \sqrt{\frac{2W}{\rho S}\sqrt{\frac{K}{3C_{D_0}}}} = 40.6019\ ft/s$$

Analytically, the minimum power required during level flight can be estimated using the expression featured on page 458 (Raymer, 1992) given below:

$$D_{\min\ power} = 4qSC_{D_0} = 3.3301\ lbf$$

Hence,

$$P_{R_{\min}} = 135.2098\ \text{lbft/s}$$

A similar value can be obtained using the graphical method which involves using a MATLAB code featured in the appendix. The resulting figure is given below:

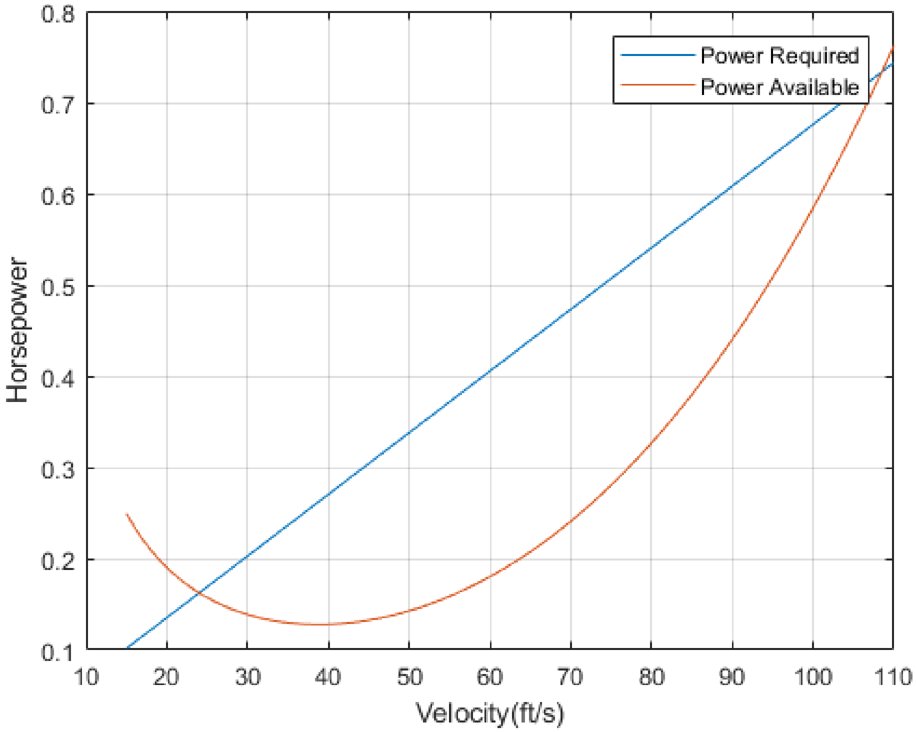


Figure 23. Power required and Power available in MAT lab

3.2.1.3. Range

Range can be defined as the distance an aircraft travel on that fuel. It depends upon the type of the aircraft and the role it is made for. Range can be determined using Breguet Range equation

]

$$R = \frac{2}{C}\sqrt{\frac{2}{\rho S}}\left(\frac{C_L^{\frac{1}{2}}}{C_D}\right)_{max}\left(W_0^{\frac{1}{2}} - W_1^{\frac{1}{2}}\right)$$

$$R = 69.13 \text{ nm}$$

3.2.2. Climb Performance

3.2.2.1. Maximum Climb Angle

Another important parameter while analyzing the climb performance of an aircraft is its maximum climb angle. The maximum climb angle and the maximum rate of climb do not necessarily coincide as shown in the figure featured on page 464 (Raymer, 1992), given below:

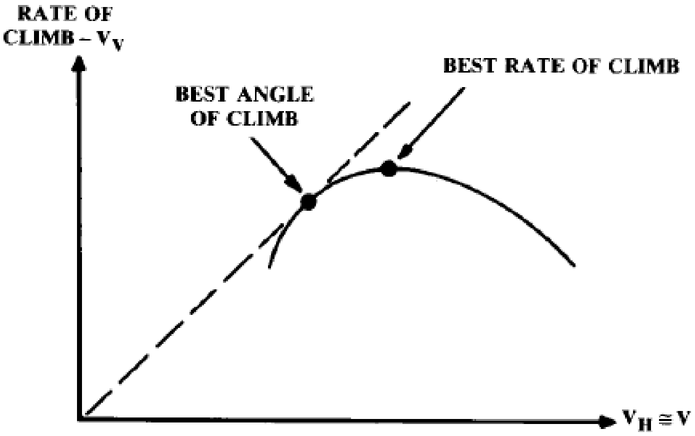


Figure 24. Best Rate of Climb through hodograph

Hence, in order to estimate the analytical maximum climb angle of the aircraft, the expression featured on page 271 (Anderson, 1999) can be used, given below:

$$\sin\theta_{max} = \left(\frac{T}{W}\right) - \frac{1}{\left(\frac{L}{D}\right)_{max}}$$

Hence,

$$\theta_{max} = 5.0424°$$

Similar to the method used above, the expression on page 464 (Anderson, 1992) can be used to estimate the velocity of the aircraft while operating at the maximum climb angle.

$$V_{\theta_{max}} = \sqrt{\frac{\left(\frac{W}{S}\right)}{3\rho C_{D_0}}\left[\left(\frac{T}{W}\right) + \sqrt{\left(\frac{T}{W}\right)^2 + 12C_{D_0}K}\right]}$$

Hence,

$$V_{\theta_{max}} = 34 \text{ ft/s}$$

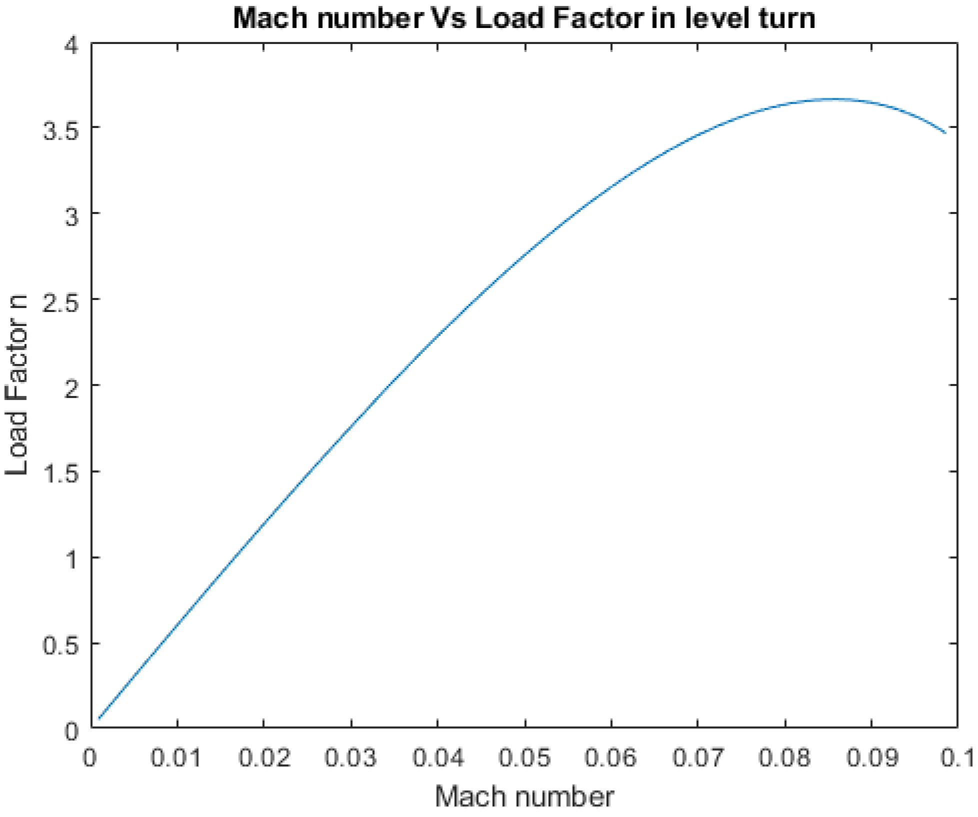


Figure 25 Load Factor Vs Mach number in MAT lab

The graph above shows how the load factor varies with Mach. As the Mach number goes higher the load factor increases.

3.3.OPTIMIZATION

Aircraft design is a compromise between certain competing factors, constraints and market requirement to produce best aircraft. Optimization paves way for an aircraft that meets all the customer requirements and best performance for specified factors. With the advancement of computation and simulation techniques possibility of quantifying and exploiting tradeoffs is done to create finely tuned aircrafts. Aerospace industry is a competitive market where need for more and more robust aircraft which can work well in off design conditions and is fail safe is becoming a necessity.

There are different ways and techniques to make an aircraft more robust and best suited for the required specification. It’s called multidisciplinary optimization. There are various methods associated with it. Three of them discussed here are Orthogonal Steepest Descent (full factorial stepping search), Monte Carlo (mutation based Evolutionary algorithm) and variants of Genetic algorithm. These techniques are applicable for advanced multirole export fighter, commercial airliner, UAVs and general commercial airliner design

Orthogonal steepest descent method is used when the minimum possible of a function is not possible to find analytically. It uses gradient vector at each point as search direction for each iteration. This gradient vector is orthogonal to the iso-surface of the plane. This method helps in minimizing function with several variables to a single variable and optimizing where the minimum possible value of that variable keeping the rest constrained is attained. It reaches local minima in zigzag manner.

Monte Carlo algorithm is a random algorithm whose output can be inaccurate with certain probability. It relies on repeated random sampling they are preferably used in cases where analytical or numerical solutions are difficult to find. It determines the statistical property of the inputs, generates multiple inputs following this property, performs deterministic calculations with these sets and analyzes the result.in optimization this technique is preferable because it finds a better minimum.

Genetic algorithm is a method that mimics biological evolution and based on natural selection process it solves constrained and unconstrained optimization problems. This algorithm randomly selects parameter from a set of data and use it as a parent to produce children for next generation. These iterations result in an optimum solution of the problem. Highly non- linear, stochastic, discontinuous and non-differentiable problems can be solved using this technique.

Optimization can generally be classified as linear or non-linear programming or optimization. Linear optimization is a way for obtaining best solution of a mathematical model whose requirements are a linear relationship. A linear relationship with equality and inequality constraints is plotted as a polyhedron. Linear programming algorithm finds a point on this polyhedron where the maximum or minimum of that relation lies. Non-linear programming is a process of optimization having an objective functions and constraints that can be non-linear.A typical nonlinear problem may be of the form:

Minimize: $f(x)$

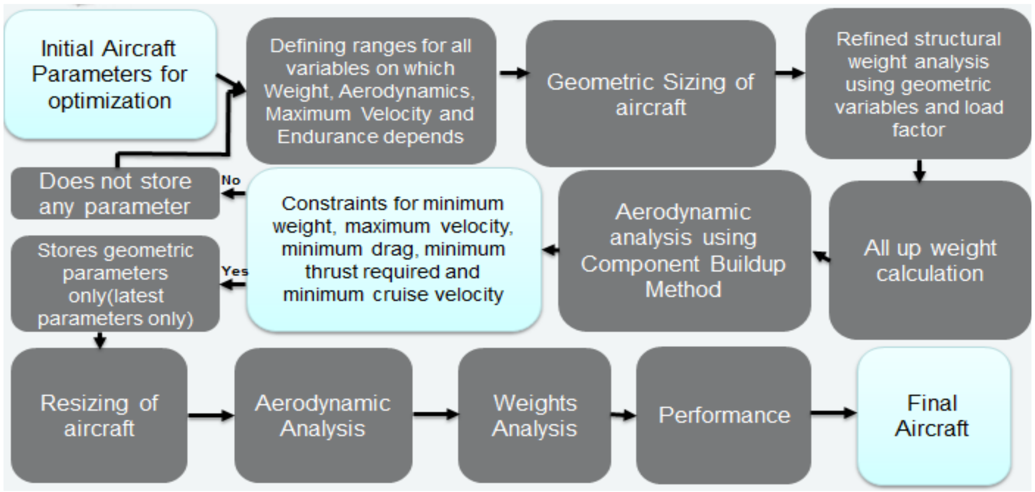
Where constraints are: $h(x) = 0$

$$g(x) \leq 0$$

Here $f: R^n \to R, h: R^n \to R^m$ and $g: R^n \to R^p$. These types of problems frequently arise in various applications like in science, industry, engineering and management. Here constraints can be quadratic and non-linear, but the function is linear. Basic gist of SQP is to model a problem and assume a solution x by quadratic programming sub problem and then to solve for a better approximation this is then iterated to produce a sequence of solutions leading to one that will give optimum solution. With a proper choice of quadratic sub problem this method resembles Newton's method. It has rapid convergence if the initial guess is correct otherwise the solution may diverge. The constraints present make this method quite complex. Also, it is a non-feasible method the starting point or any point in iteration may not be feasible that is may not be satisfying the constraints. Also, the accuracy of solution depends upon the algorithm used to solve that problem. Quadratic programs moreover are easier to solve as there are easier procedure to solve them. If there is one equality, then solution reduces to a linear problem. This method is employed to optimize UAV for achieving maximum endurance.

3.3.1. Algorithm for Optimization

This algorithm shows a set of steps for sequential quadratic programming. First the parameters that are to be optimized are enlisted. Then the variables upon which parameters depends are weighted and the aircraft is geometrically sized. It is then analyzed and if constraints are not met it is iterated again.



CHAPTER 4: Requirement Specifications

4.

4.1.Flow Diagram

The flowchart of overall research design is given following which is explaining our work. This flow chart was made at start of project. Following flow diagram has two segments, first one covers the specifications and design while the second one explains the flight tests and the fabrication of the drone.

The Purpose of this research is to check the performance of the drone recorded during different flight tests.

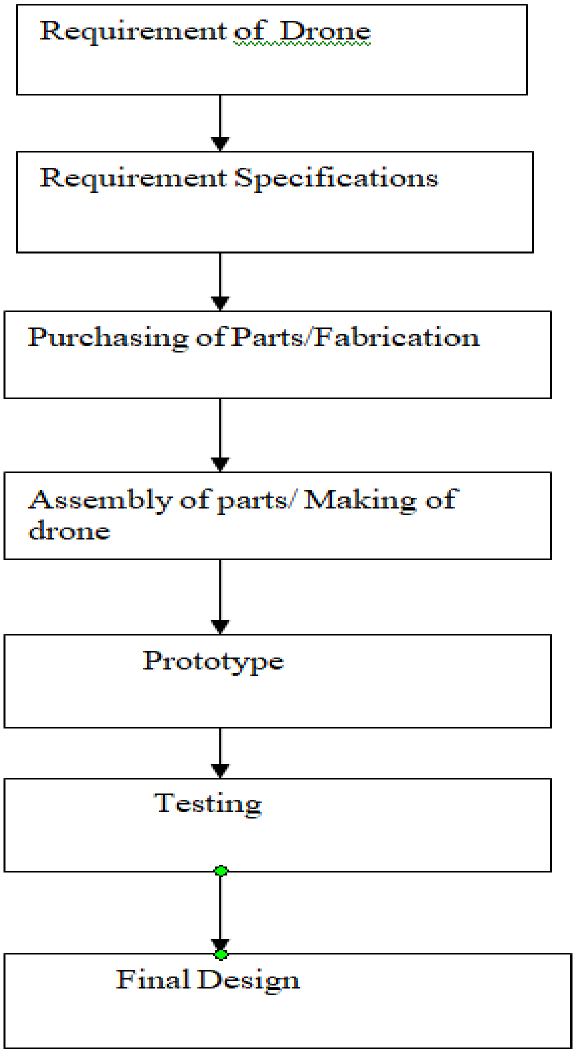


Figure 27. Flow Chart

4.2.Requirement Specification

The essentials of the proposed drone are set up ensuing to looking into the information got from a composing study drone. These necessities are set in such a way that drone is in every way that really matters conceivable in term of structure, creation, flight test and final flight. There are two or three central drone necessities developed in this assessment. To begin with, drone, which includes standard fixed wing plane got together with four vertical rotors that are fixed to be melded in the drone structure. Drone should be adaptability at tight and restricted spaces like a helicopter. Drone should be prepared for performing VTOL exercises with commendable prosperity and steadfastness properties. The change of flight mode from the fixed-wing flight and the opposite way around is to be managed genuinely or self-governingly. Five-rotor system that includes four verical rotors like quadcopter and one at the back of frame like fixed delta wing for steadfastness and also lessening in multifaceted nature. The typical journey speed extent of about 15 to 20 m/s. The log jam speed is in like manner should be nearly around the 70% of base excursion speed. At last, for more better performance it would be outfitted with adaptable flight controller prepared to manage manual controls and perform self-overseeing missions. Last type of drones for the most part showed up below where later on, minor changes may be essential.

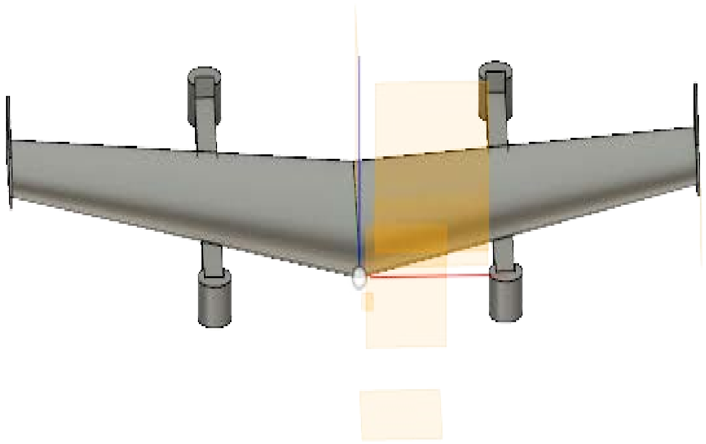


Figure 28. 3D Structure of Skyhawk VTOL designed using Auto Fusion 360

4.3. External InterfaceRequirements

4.3.1. UserInterfaces

Users will be able to view the current location of the drone, distance travel from the takeoff position, information related to flight and can configure the setting of the drone.

4.3.2. HardwareInterfaces

- Flight controller provides the platform for the connection of other hardware components of the drone
- The flight controller is linked to the motors and other hard components
- The flight controller is configured through the firmware.
- Firmware is installed on Flight Controller.

4.3.3. SoftwareInterfaces

- Flight Controller provides the platform for software interface
- The software of Qground is installed on Flight Controller.
- Mission planes are configured on Qgroundfirmware.

4.3.4. Communications Interfaces

- The drone operates using the radio controller.
- Transmitter sends the signal to the receiver mounted on the drone.
- Drone act accordingly instructions given by the user using a radio controller.

4.4.Functional Requirements

4.4.1. Description and Priority

S/No.	Module	Priority (5 for highest 1 for lowest)
1	Flight Controller	5
2	Independent yet centered Flight	4
3	1kg Payload	4
4	GPS Positioning	3
5	Value-Based motion without direct control	2
6	Faster Wi-Fi communication and Secure	2

Table 1. Description and Priority

4.4.2. Stimulus/Response Sequences

S/No.	Functionality	Description
1	**Ascend**	SKYHAWK DELTAWING VTOLshall rise and hover
2	**Descend**	SKYHAWK DELTAWING VTOL shall lower and settle down
3	**Directional Motion**	SKYHAWK DELTAWING VTOLmove in direction Specified
4	**Path Travel**	SKYHAWK DELTAWING VTOLshall move to a specified location without directly controlling.

Table 2. Stimulus/Response Sequnces

4.4.3. Requirements Detail

REQ-1: Basic Ascend Descend

REQ-2: Basic 4-way motion

REQ-3: GPS Locating

REQ-4 (TBD): Autonomous Flight

4.5.Other NonfunctionalRequirements

4.5.1. PerformanceRequirements

Execution is indispensable in ventures that require constant calculations and that contain equipment segments. This announcement is additionally valid for our venture. A basic part of our venture is the calculation that will permit the VTOL to float in space without losing its equalization. This calculation will run on the Radio Controller and it will be liable for the turn and speed of the engines through the ESCs. Therefore, the presentation of this calculation is very basic, since a little postponement may make the VTOL rapidly lose its equalization, fall over and may bring about material harm just as put the close by human lives in harm's way.

4.5.2. ResponseTime

The SKYHAWK DELTAWING VTOL shall response a request at most 0.2 seconds.

4.5.3. Platform

The SKYHAWK DELTAWING VTOL shall be compatible with the Pixhawk flight controller.

4.5.4. Controlled environment

The drone must be operated in a controlled environment, i.e. no wind/rain, etc.

4.5.5. Lighting and visibility conditions

The environment must be well lit and there must not be anything that might hurt visibility. Specific values TBD.

4.5.6. Safe/clear route

The path marked for the drone must be completely free of obstacles.

4.5.7. Efficiency

The SKYHAWK DELTAWING VTOL can fly for 30 mins at least with an average speed of 30 km/h which is twice as fast as a Quadcopter. This increase in range and speed will be achieved but incorporating a fixed-winged flight mode which requires less power and naturally produced higher ground speeds.

4.6.SecurityRequirement

Since our task won't manage touchy private information, security is anything but a genuine concern. The main matter of enthusiasm for the security point of view is the information dealt with by the Xbee remote communicators. However, since the Xbees scramble the information that they send/get, no gatecrasher may meddle with our information.

4.7.Software QualityAttributes

4.7.1. Usability

Our objective clients generally incorporate scientists and security offices, yet we will even now make a basic enough interface for a very long time more prominent than 15. This interface will consent to structure interface guidelines that make the client's association as straightforward and productive as could reasonably be expected.

4.7.2. Accuracy

The system shall provide 90% accuracy in order to make the project more useful for carrying out different operations and slightly less accuracy will result in the downfall of VTOL.

4.7.3. Legal

SKYHAWK DELTAWING VTOL should follow customer privacy policy strictly.

4.7.4. Reliability

Our framework is for the most part contingent upon equipment. Thus, the unwavering quality of our undertaking exceptionally relies upon the dependability of the solitary equipment segments and their interfaces. The framework isn't relied upon to deal with any sort of disappointment aside from handling the automaton securely if there should be an occurrence of a crisis. These equipment dependability necessities are: Communication between equipment must be valid in any event 99% of the time. Communication must be done all things considered 0.2 seconds.

4.7.5. Ease ofUse

By understanding the flight controller VTOL will be very easy to use and fly.

4.7.6. Maintainability

The VTOL practicality is somewhat harder to achieve since it contains fragile parts and might be liable to harm if is presented to different items. The battery's life is another worry since the battery life of a LiPo battery keeps going around 1 year.

CHAPTER 5: Design Specifications

5.

5.1.Use case Diagram

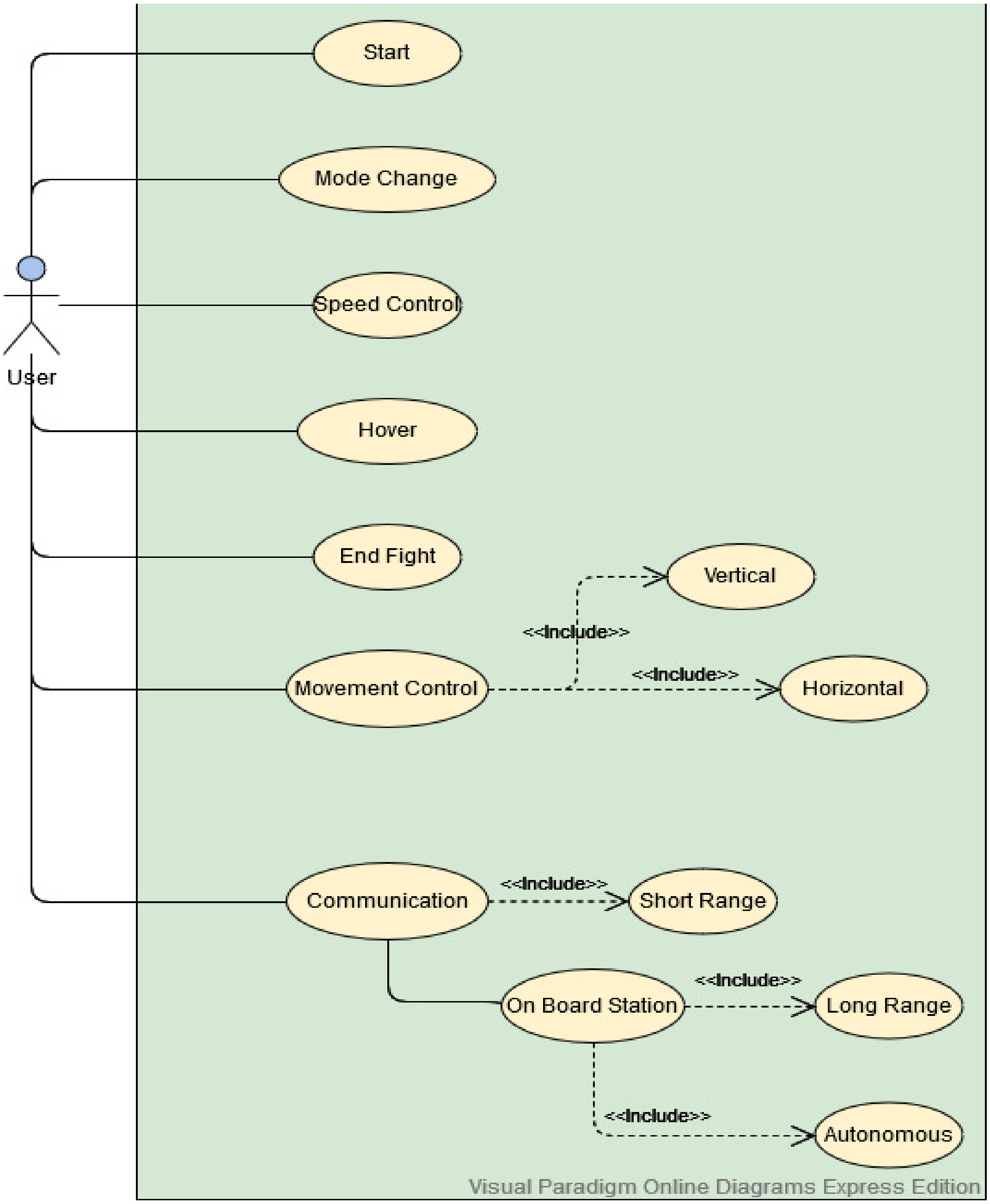


Figure 29. Use Case Diagram

5.2.Use Case Specifications:

Use Case id	1
Use Case	**Start Flight**
Primary Actor	User
Description	The flight will be started
Pre-condition	Drone was in rest condition
Normal flow	User will power on the drone and will give the command to start the flight. The drone will move vertically upward. In this scenario diagonal motors will move in same direction clockwise and anticlockwise.
Alternate Flow	If some components do not work properly drone will not start
Post-condition	Drone is flying vertically

Table 3. Start Flight Use Case Specification

Use Case id	2
Use Case	**Mode Change**
Primary Actor	User
Description	Movements of the drone will be controlled by user commands
Pre-condition	Drone is in rest state,on stand initially
Normal flow	User will control the movement of drone using Radio Controller. Once the drone has reached its vertical height user will give the command to change the mode in which drone will start its horizontal flight from the vertical flight.
Alternate Flow	Transmitter and Receiver of RC controller may get disconnected and eventually user won’t be able to move drone in desired direction.
Post-condition	Drone will not be crashed and will be on stand

Table 4. Mode Change Use Case Specification

Use Case id	3
Use Case	**Speed Control**
Primary Actor	User
Description	Average speed of the drone will be 50mph
Pre-condition	Drone is in rest state, mounted on stand initially
Normal flow	User will control the speed of drone using Electronic Speed Controller (ESC). When the user will give command the speed of drone will increase or decrease as per required.
Alternate Flow	If ESC is not connected with the flight controller and motor the drone speed cannot be controlled by user
Post-condition	Drone will not be crashed and mounted on stand

Table 5. Speed Control Use Case Specification

Use Case id	4
Use Case	**Hover Mode**
Primary Actor	User
Description	Flight will hover.
Pre-condition	Drone was landing vertically
Normal flow	User will give the command to drone to hover the flight and drone will not change its position in the air with the help of all running motors
Alternate Flow	If there is some technical fault or bad weather interference drone might get crashed.
Post-condition	Drone is in rest condition at its stand

Table 6. Hover Mode Use Case Specification

Use Case id	5
Use Case	**End State**
Primary Actor	User
Description	Drone will come to rest position on its stand.
Pre-condition	Drone was moving with some payload
Normal flow	User will give the command to stop the flight of drone and drone will move vertically downward and eventually will come to rest on its stand.
Alternate Flow	If there is some technical fault or bad weather interference drone might get crashed.
Post-condition	Drone is in rest condition without any payload

Table 7. End state Use Case Specification

5.3.State Diagram

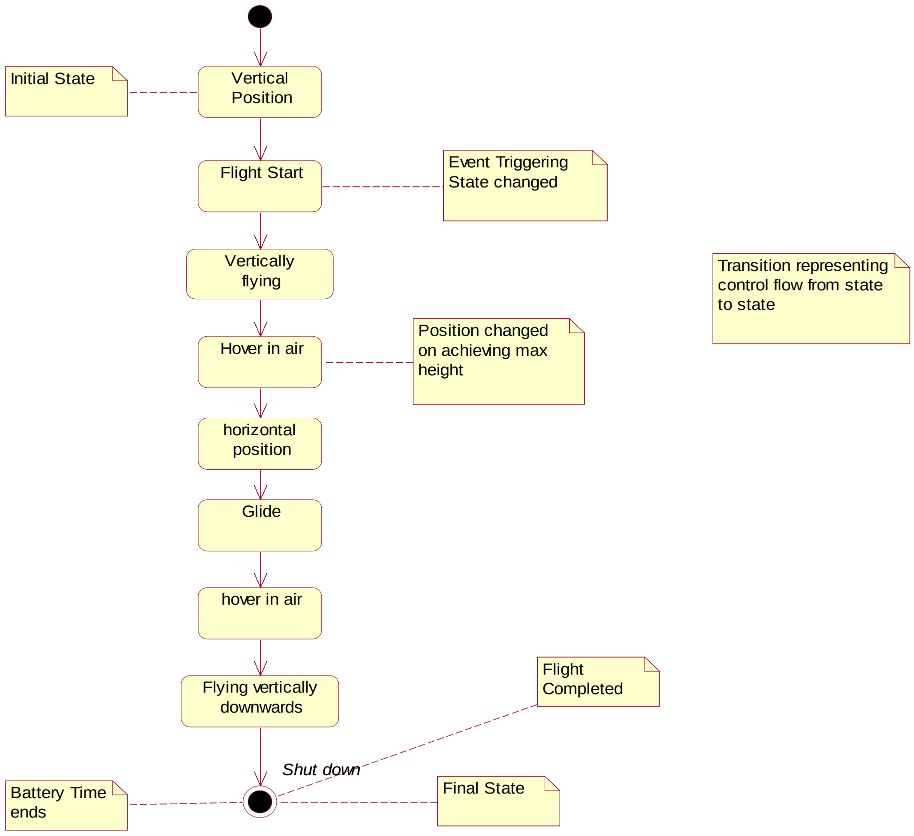


Figure 30. State Diagram

5.4.Activity Diagram

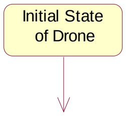


Figure 31. Activity Diagram

CHAPTER 6: 3D Model Creation

6.

Autofusion 3D Model

Three dimensional view of drone is created using Autofusion program.Diverseparts, forcase, the plastic and aluminumtracesare lessbasictoillustrateon the grounds that the quality of these parts is fair enough and due to high quality, itamidgenuineflight test and would try to successfullyhandle the light crashes.The real time 3D modelshowingfor wingfragmentand tailrangeareshowed upunderneathseparately.

When it comes to the airfoil modeling, therecommendedairfoil for this VTOL would be the NACA 3414 airfoil family. It hasmany features such as the lower surface isexceptionallylevelandsubsequentlywouldprovideawesomeLift-Dragextentfor theassessed velocities.

6.1.Delta Wing:

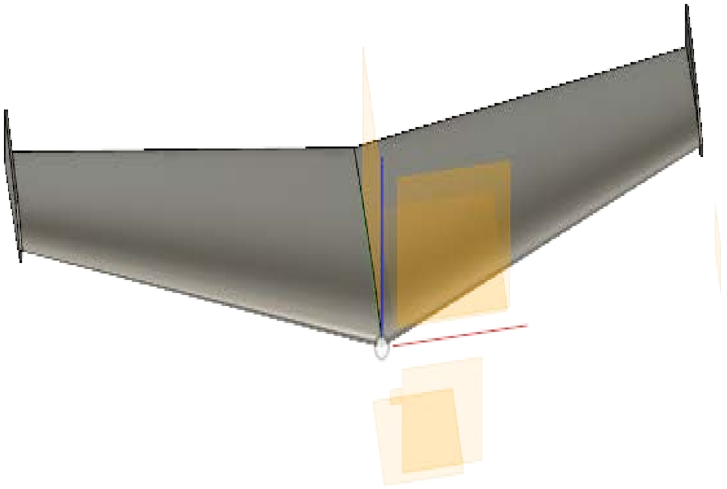


Figure 32. 3D Structure of Fixed Delta Wing designed using Auto Fusion 360

6.2.Quadcopter:

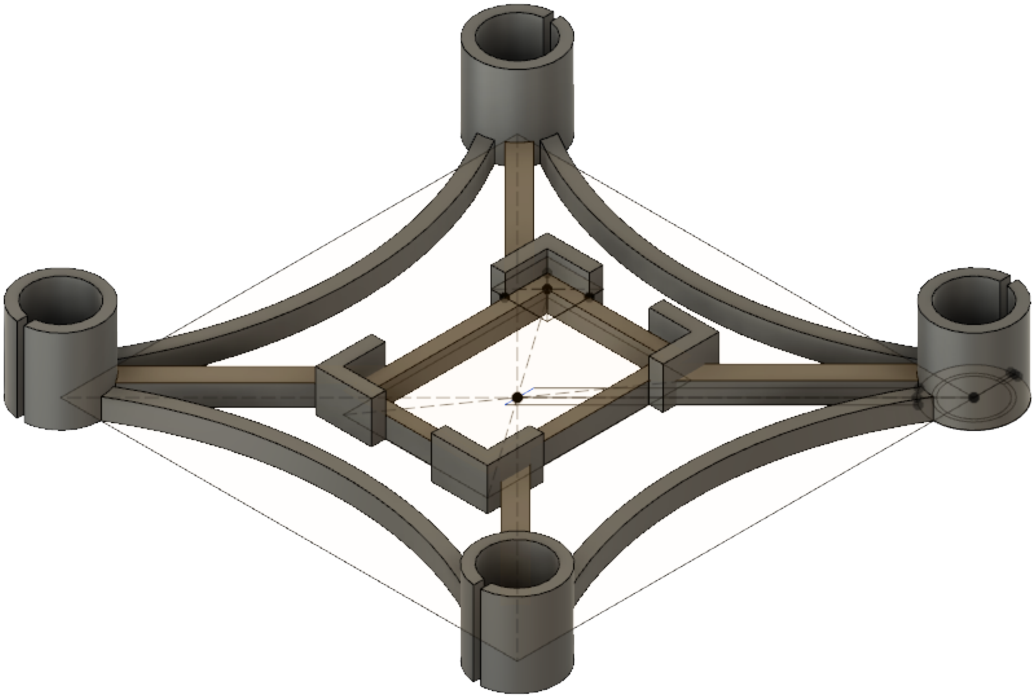


Figure 33. 3D Structure of Quadcopter designed using Auto Fusion 360

6.3.VTOL:

6.3.1. Front View:

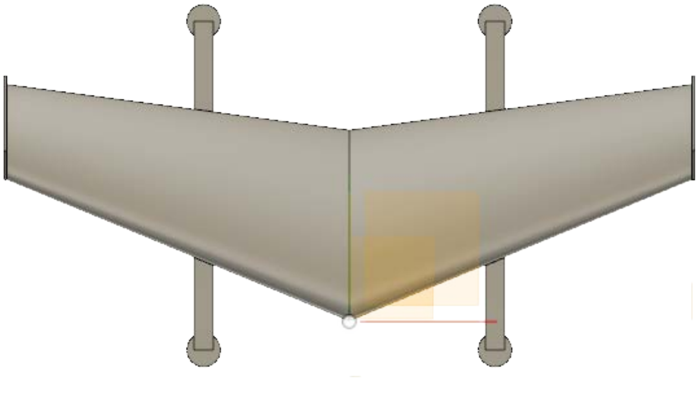


Figure 34. 3D Structure of Front View designed using Auto Fusion 360

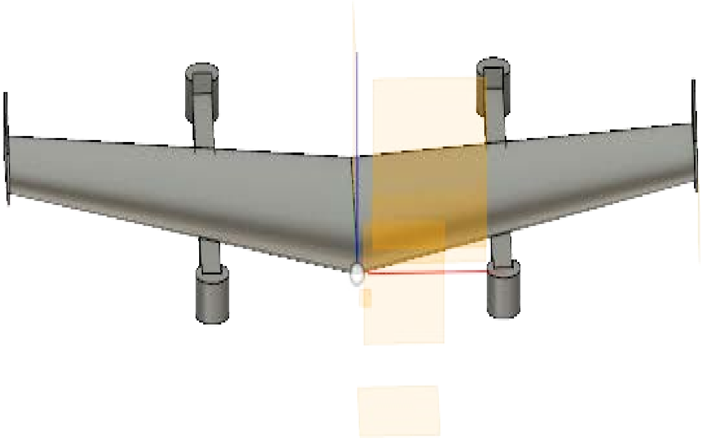


Figure 35. 3D Structure of front view designed using Auto Fusion 360

6.3.2. Side View:

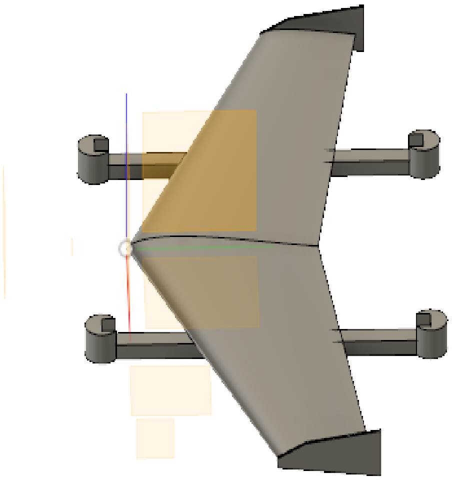


Figure 36. 3D Structure of side view designed using Auto Fusion 360

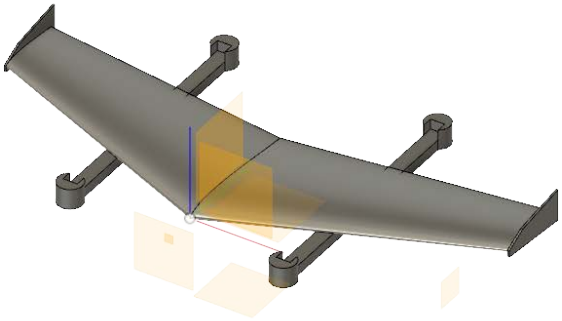


Figure 373D Structure of side view designed using Auto Fusion 360

CHAPTER 7: Developement Process

7. Developement Process

7.1.Designing Parameters

To plan a little scope drone, it is imperative to confine certain boundaries of sizes to a for all intents and purposes sensible figure so different boundaries concerning measurements would be practical for creation. The structure boundaries picked ought to likewise comply with known hypothetical ideas and conditions to affirm that the drone will have the option to achieve stable and wellbeing trips over the entirety of its flight modes.

Determining the length and actual size of the tail wing and its good ways from the primary wing These generic methods will be utilized to assess the length and size the model. After being manufactured and conduction of flight tests, the genuine measurements will be balanced as needs be.

7.1.1. Fuselage Design

The fuselage doesn't have a particular computations, the model utilizes F450 quadcopter outline as the base fuselage. This present edge's streamlined shape can be improved to cook for even flight mode by covering the inside center utilizing light materials and joining shape that can improve lift and decrease drag. Covering the middle center likewise secures the uncovered primary hardware.

7.1.2. Estimation of Weight

Before manufacturing the model, a few parts which are promptly accessible was gauged while the heaviness of parts that should have been work is assessed. This is on the grounds that typically, the final product weight will be slighly or simly more than the underlying weight estimations. Evaluating the additional weight likewise increment the edge for the extra payload. Then, it is essential to decide the privilege All up Weight (AUW) for the model as the aftereffect structure counts depend totally on this boundary check the table below.

Item	Weight	Quantity	Total Weight
Motors	85g	5	425g
ESC	65g	5	325g
Battery 5200 mAh	400g	1	400g
GPS, power module, receiver	120g	1	120g
Propeller	15g	5	75g
Servo	60g	4	240g
Consumables (bolts, nuts, cable ties, glues, etc)	150g	1	150g
Foam Board	400g	1	400g
Base Board	200g	1	200g
Total Estimated Weight of Drone			2335g

Table 8. Estimation of Weight

7.1.3. Selection of Material

Key and basic boundaries in the structure of such drones is decision of material. Each and every piece of the littlest thing, for example let’s take a wing, then we are sure that weight is the basic factor that can’t be neglected at any cost. Preferably,lightest material but then roust against its mechanics (drop, stun) and condition (height/lower weight, compound tainting/consumption) will be chosen. Such drones that regularly utilizes in cruel condition will follow some worldwide standard of protest in order to guarantee the item is hearty and may be utilized in any mode of use/circumstance. More and more interest in structure/creation and capability test will be envisioned. Notwithstanding, the last decision of material and decision of assembling/manufacture methods is likewise relying upon cost moderateness and amount to be delivered. What generally significant in these type of investigation is the drone, is truly working (totally functional) and verifiable. Material that must be used for the fixed wing ought to be sufficiently light and effectively accessible.

7.1.4. Brushless DC Motor

Most significant in the determination of this engine are a detail of RPM versus gracefully voltage and sturdiness and furthermore some spec of waterproof and temperature. Long flight length could cause heat issue and somewhat, it could liquefy the protection of the engine curls and causing a short out. It is prudent not to go through the engine to extreme constraint of the voltage gracefully. For genuine structure for business use, waterproof or sprinkle confirmation is an unquestionable requirement for this engine. For this investigation, which is verification of idea venture, a prerequisite, for example, IP65 is not generally thought of.

7.1.5. Batteries

For this versatile application, limit thickness (how vitality put away in particular volume/weight) can be coonsidered basic. The smaller the size and on the the other hand higher vitality thickness is the favored innovation. Li-polymer is better in term of vitality limit and with an adaptable shape yet is progressively costly. NiCd is outdated innovation and Lead Acid is for car application.

Battery-powered Li-Polymer battery is the most ideal decision, modest and great vitality limit and current rating esteem. In expansion, this player has a decent life cycle (charge/release) 1000 cycle, dependable use.

7.2.Electronics Layout and Operations

The diagram shown below is the wiring outline on the electric piece of drone.The center motor of framework is the Pihawx 4 Flight Controller and a control processing unit. It will help to control the revolution or RPM of the engine during departure, when its landing or even development of drone.

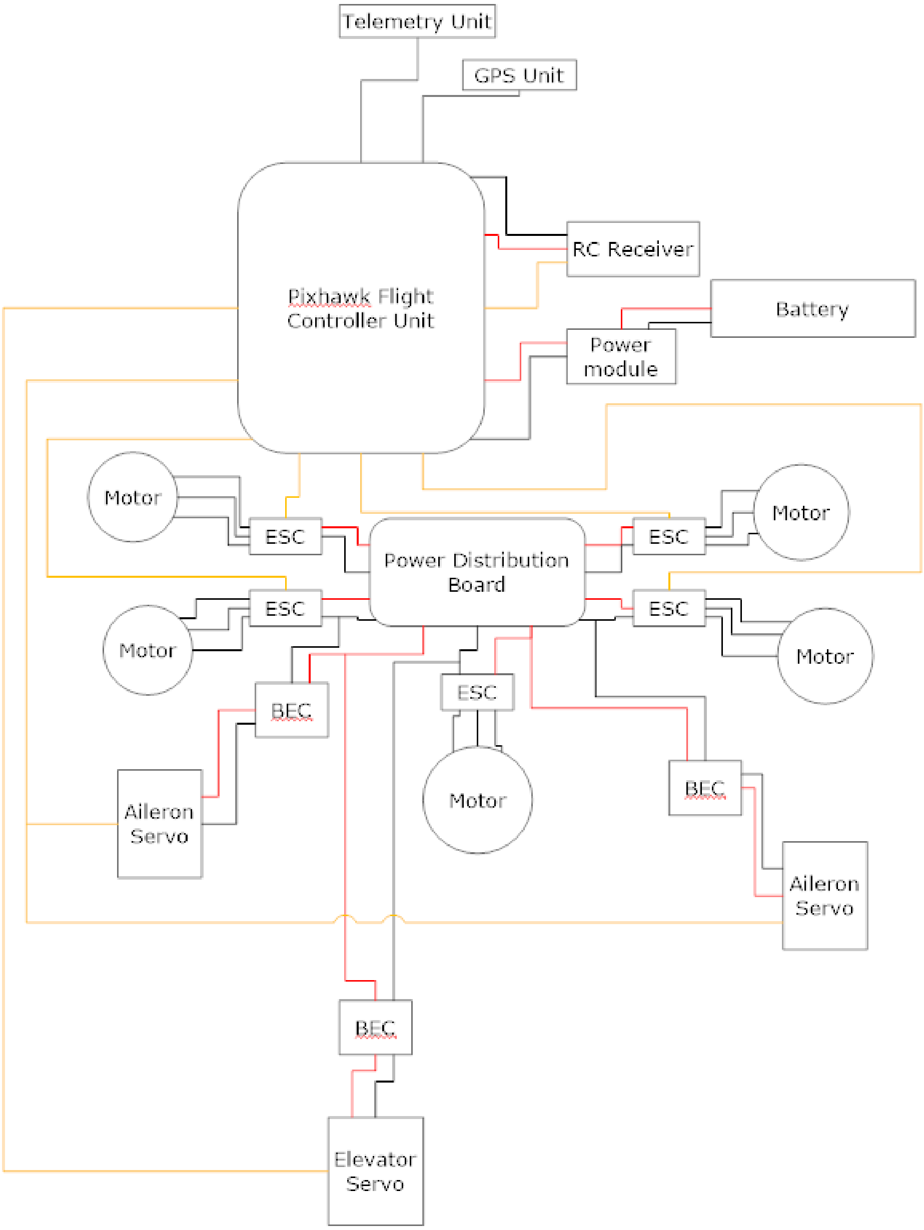


Figure 38. Wiring Diagram

7.3.Development Phase:

Figure 39. VTOL after attaching all components except back propeller

7.4.Vertical Take off and Landing Methodology

The main component toensuredrone’scapacityof 4motorswithrotatingsharp edgedauntlessnessto lift up thepile.Every turning cutting edges will be at acomparablevelocity (Turneachminute) andexpandingspeed rate forcasechanging the RPMbeginningwith one stateat that pointonto anotherstate.Extendingthe RPMsuggestsgrowingthestatureorflightarrange.Lesseningthe speed orRPMcrueldiminishingthetallnessor toarrive. AcomparativeRPM for all the vertical cutting edge and its weightadjustare the main points toensurerobustnessamidtakeofflanding andleveladvancement. Leveladvancement(speed oframble) is bycruelof controlling the RPM ofat that pointlevel engine/propeller.

7.5.Software Setup

Strategic programming is utilized to arrangement autopilot. The product transfers right firmware into Pixhawk to coordinate model's vehicle type, in our case its half breed drone. It is likewise used to tune the Proportional Intrgral Derivative control additions to accomplish ideal solidness. It should be possible during genuine flight tests where increases are balanced likewise by the a group of experienced pilot or can be set previously before flight tests and Trial-and-Failure technique is utilized to acquire best outcome. As alrady mentioned we are using Q ground Controller.

Channels	Functionalities
Mode 1	Left stick operates elevator, right stick operates throttle & ailerons.
Mode 2	Left stick operates throttle, right stick operates elevator & ailerons.
Mode 3	Left stick operates elevator & ailerons; right stick operates throttle.
Mode 4	Left stick operates throttle & ailerons; right stick operates elevator.
Dual Rates	These enable the control surface deflection limits to be changed, while still retaining full stick movement
Servo Reverse	Allows the direction of servo movement to be fully reversed, ideal for times when a servo can only be installed in the aircraft in a way which isn't conducive to the required direction of movement.
Control Surface Mixing	A single pair of control surfaces is made to act as two separate pairs would. A common example of control surface mixing is to combine elevator and aileron deflection in to 'elevons', on a flying wing type RC aircraft
Channel Mixing	This is when two separate channels are made to operate in conjunction with one another
Expo	Short for exponential, this lets you adjust the sensitivity of the control surface deflection around smaller TX stick movements.
Travel Adjust	Also called End Point Adjustment, and a few other names. This lets you set the travel limits of each servo, normally as a percentage of the servo's normal travel

Table 9. Functionalities of RC Controller

CHAPTER 8: Testing Phase

8.

Drone will depature in vertical upward flying mode, by then change to forward flying mode, fly forward like a fixed wing and level to a specific relegated waypoint, by then progress to vertical downward flying mode and land the drone safely. In a manual flight mode, a ground customer will coordinate the drone by methods for radio control transmission. The strategy is simply envisioned underneath.

The greatest test is to play out the transition between theforward flight to vertical flight mode and the other way around. Thus, level engines need to deliver enough push to quicken the drone rapidly for the wings to supplant the vertical engines in producing lift. An additional technique to address this conceivable elevation lose is to build up a viable control framework where the vertical engines would keep on creating enough lift while experiencing significant change until it passed the base slow down speed.

Figure 40. A testing Flight

8.1.Flight Log Analysis

Figure 41. Manual Control inputs graph

Figure 42. Power consumption and distribution graph

Figure 43. Altitude estimation graph

8.2.Crashed Wing

On 20th June during a normal testing flight the Skyhawk VTOL got crashed and was on fire.

Figure 44. Crashed Wing after a testing flight

8.3.Repairing of Wing

We started to repair the wing so that it becomes functional again.

Figure 45. Repairing of the wing

Figure 46. Repairing of wing

CHAPTER 9: Further Researches

9.

According to the methodology followed only assembly of fabricated parts is remaining. As per the timeline fully fabricated VTOL UAV will be delivered that would be capable of two hours endurance, gimbaled camera for surveillance and can be operable manually or can be made autonomous. The proposed VTOL will use a quad configuration for vertical takeoff and landing, using efficient electric motors with high thrust to weight ratio. It will be fabricated in such a way that it can be assembled and disassembled anywhere in a very short time, making it portable and easy to operate from anywhere. Most of the low-cost UAVs available in market have very low endurance. To achieve high endurance, the aircraft will use a single electric pusher propeller instead of multiple propellers, thus consuming low energy and increasing endurance. To save energy quad configuration motors will be turned off during cruise. For fabrication of this VTOL only a few new equipment will be required and advanced techniques in VTOL fabrication will reduce the cost. Cost will also be reduced due to learning curve effect. As most of the work is done using advanced software that Institute owns and low cost.

The VTOL has a huge impact on society. It can be used for multiple purposes such as surveillance. Crime rate in Pakistan has significantly increased. Hence instead of guards performing duties these VTOLs can be deployed on roads and through telemetric links the culprit can be captured easily. It can also be used by separate industries such as construction industry to inspect their work, agricultural industry for spraying, aviation to check maintenance of the aircraft. It has positive environmental impact as no fuel is consumed due to use of electric motors, no emission of injurious gases such as NOX and CO2. It also opens the new arena of future of aviation. VTOL was an inspirational concept and further research can be made upon this idea to vertically take off and land commercial and fighter aircrafts.

CHAPTER 10: Conclusion

10.

In view of the hypotheticalexamand flightstatisticsresearch, the proposedcrossbreed drone frameworkmightaccomplish theanticipatedflight execution assome distanceas solidness and flight run. Thisexamskilledsomedifficultieswheretheadventof theversioncan'tbecompletedwithin thepredefined timedue topostponement, getting newelement(engines)due toimperfection.Furthermore,sourcingthe properfabricfor wing.

10.1. Results and Discussion

The creation became carried out efficaciously and the ultimate model was attempted to be completely realistic. After entire manufacture and get together were performed, physical evaluation alongside subsystems and complete framework assessments had been finished. Aside from this, the facts streak logs from real flight assessments have been correctly recorded for added exam. Utilizing the stepped forward FCU which is ready installed the framework, one-of-a-kind sort of information can be recorded. Anyways, the statistics which might be of enthusiasm. The project incorporates the proportional derivative Integral response execution inside 3 tomahawks revolution, vibration degree of 3 tomahawks. The flight modes that have been utilized when the statistics became recorded are balanced out, top preserve and stand round mode. In settle mode, the placement and elevation manipulate is done physically. In stand around phase, both peak and position hold is managed self-ruling. These types of 3 modes have the accelerometer locally to be had the FCU is therefore balanced out wherein least patron intercession is required to handle the UAV in a perfect float. This chart suggests flight time of around one moment to facilitate perception of diagrams. In synopsis, security execution in a roll and special tomahawks changed into at worth tiers wherein response of framework, recorded inside the unit of m/s/s, accompanied close to the ideal information resources both from the patron or the FCU itself because it tried to car-settle the tomahawks consistently. Regarding the vibration tiers, the features recorded likewise fell inner an adequate diploma of vibrations in all tomahawks.

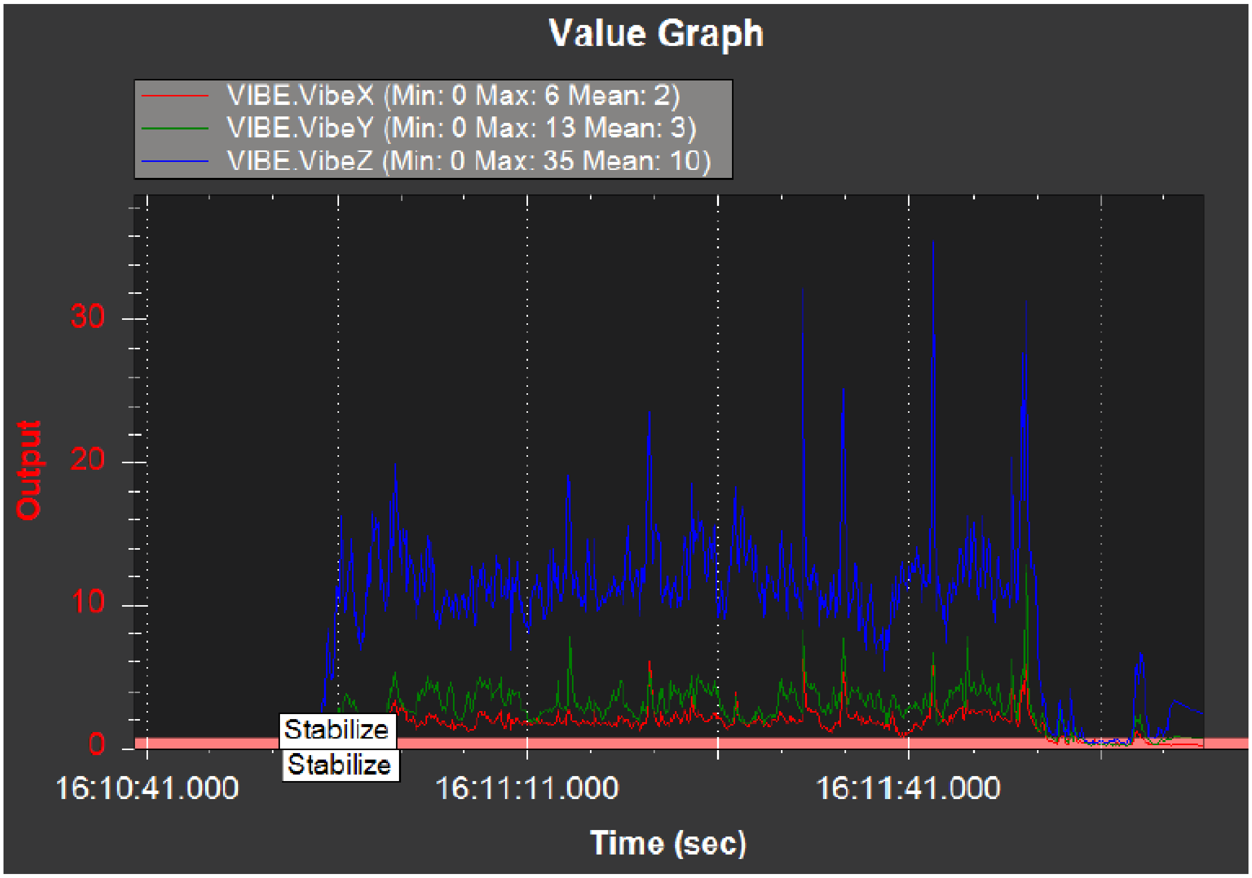


Figure 47. Vibration Level Graphs in each axes

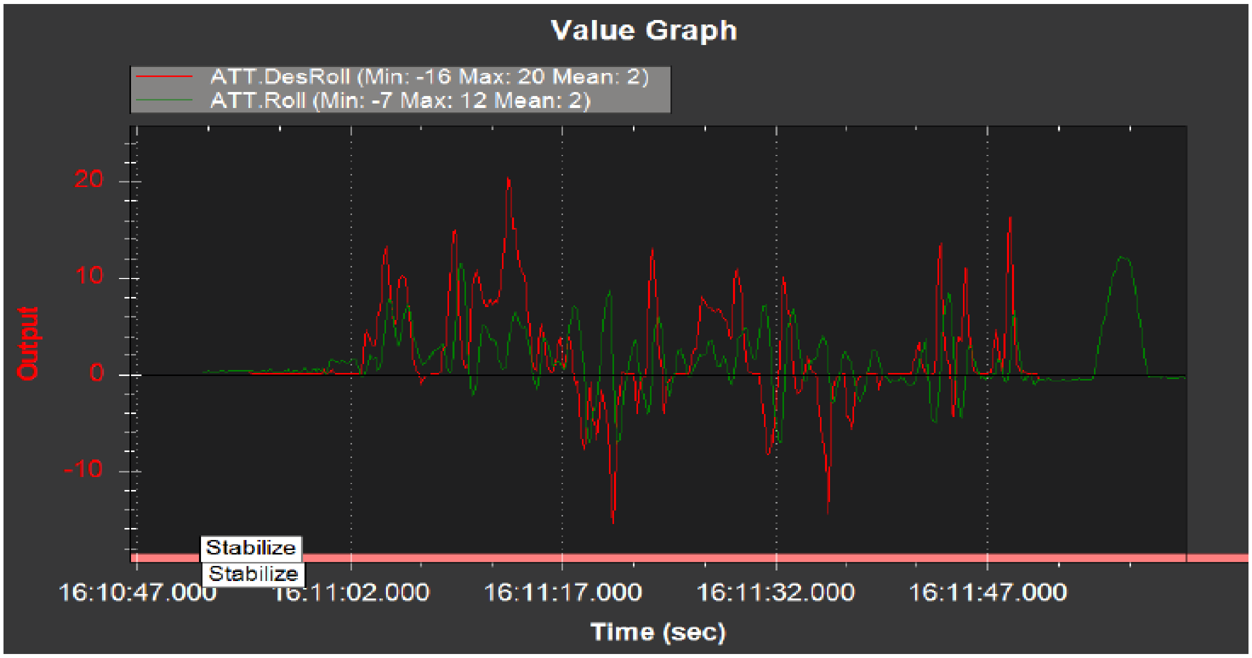


Figure 48. Diagram for wanted roll and move reaction pivot

10.2. Final Product:

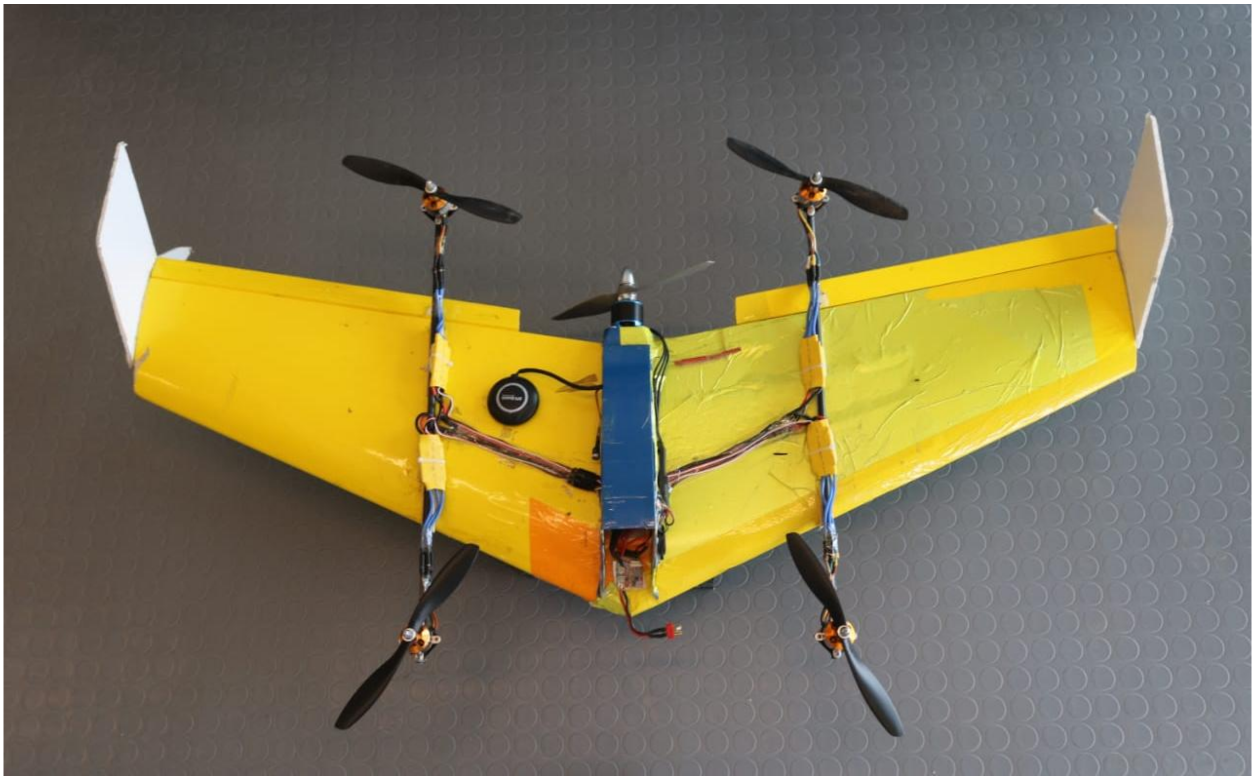


Figure 49. Skyhawk VTOL after repairing

Bibliography

Abd Rehman, Y. H. (2018). *Design and fabrication of small vertica; take off and landing unmanned arial vehicle.*

Company, T. C. (n.d.). *AIN_Online*. Retrieved April 21, 2017, from http://www.ainonline.com/aviation-news/defense/2017-03-09/northrop-grumman-tests-ms-177-sensor-global-hawk.

Daniel.P.Raymer. (1992). *Aircraft Design A Conceptual Approach.* Washington D.C: American Institute of Aeronautics and Astronautics, Washington D.C. 20024, 1992.

Daniel.P.Raymer. (2012). Aircraft Design: A conceptual Approach. In *Aircraft Design.* Virginia: AIAA.

Gundlach, J. (2012). *Designing Unmanned Aircraft Systems.* Virginia: American Institute of Aeronautics and Astronautics, Virginia 20191-4344, 2012.

Intelligence, A. (2011, May 05). *Avionics*. Retrieved April 21, 2017, from http://www.aviationtoday.com/2011/05/01/starlite-vision/

Operations, C. T. (n.d.). Retrieved from http://carbonix.com.au/wp-content/uploads/2017/06/17-06-19-Carbonix-Volanti-Information-Brochure.pdf

Roskom, D. J. (1985). *Airplane Design.* Roskom Aviation and Engineering Corporation, 1985.

Update, D. (2002, November 11). *Defense Update*. Retrieved April 21, 2017, from http://defense-update.com/20161111_avenger-er.html

Appendix

[1] John, S. (2013) Artificial Intelligent-Based Feedforward Optimized PID Wheel Slip Controller. *AFRICON*, 12 September 2013, Pointe-Aux-Piments, 1-6.

[2] Lee, K.U., Kim, H.S., Park, J.-B. and Choi, Y.-H. (2012) Hovering Control of a Quadroto. 12*th International Conference on Control*, *Automation and Systems* (*ICCAS*), 17-21 October 2012, 162-167.

[3] Li, J. and Li, Y. (2011) Dynamic Analysis and PID Control for a Quadrotor. *International Conference on Mechatronics and Automation* (*ICMA*), 7-10 August 2011, 573-578.