Building Smart Drones using ArduCopter and Telemetry

Make Human Life Easier with Smart Drone

CSCI 6838.03 Research Project and Seminar

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1. INTRODUCTION

Unmanned aerial vehicles (UAV) have been around for decades, but with small commercial drones in recent years they have gained the greatest prominence. The new so-called FPV (first person view) technology gave us a unique experience of flying and the advancement of GPS systems in drones opened a whole new world for passionate individuals.

This project aims to build a Smart Drone using ArduCopter, Telemetry and GPS by providing step-by-step tutorial for the high school students, which includes the whole process of assembling and building the drone with the Component list, Calibration, Assembly, Drone Building documents with the software used to control and fly the drone. It focuses on technical design and Architecture of Building a Smart Drone.

2. BACKGROUND

2.1 UAV Quadcopter

Quadcopter: Unnamed aerial vehicle (UAV) are capable of flying without an onboard pilot. It is the best way to target places where a human cannot be reached. UAVs are a component of an unmanned aircraft system (UAS); that includes a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers. In this project we build QuadCopter as UAV and the ground-based controller will be a Remote Controller and a Smart Phone. A quadcopter is an aerial vehicle that uses four rotors for lifting, steering, and stabilization. Unlike other aerial vehicles, the quadcopter can achieve vertical flight in a more stable condition.

While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific, recreational, agricultural, and other applications, such as policing and surveillance, product deliveries, aerial photography.

3. MOTIVATION

- Implementing a Smart drone using Arducopter will give a good learning experience in Control Systems, Artificial Intelligence and Computer Image processing.

- It is challenging to build the Quadcopter from scratch and to find the detailed tutorials about it.
- This project aims to provide a set of detailed tutorials for the high school students about this latest technology.

4. GOAL AND SPECIFICATIONS

Goal: To provide a step-by-step tutorial about building a Smart Drone using Radio Controller, Telemetry and GPS.

The tutorial needs to provide a detailed description of different types of Multicopter drones, motors, Principles of drone flight, Roles of propellers, flight controller, ESCs and how to bind a Radio Transmitter and Receiver in detail.

The final quadcopter design had to meet the following specifications:

1. The quadcopter must be calibrated successfully.

2. The quadcopter must be capable of flying and landing in stable manner using Radio Controller and Smart Phone.

3. The quadcopter must be capable of determining its current location using GPS data.

5. SCOPE

This project creates a platform to learn about unmanned aerial vehicles such as a quadcopter. This expands the scope of the computer engineering education to include the control and the understanding of the mechanical components. The quadcopter opens up the possibilities to broaden the understanding and applications of control systems, stabilization, artificial intelligence and computer image processing as it applies to the quadcopter.

6. MULTICOPTER DRONE BASICS

6.1 Introduction

The commonly known helicopter has one motor, while Multicopter is a unique type of aircraft that is equipped with two or more motors. Multicopters (also known as Multirotors) often use fixed-pitch propellers, so the control of vehicle motion is achieved by varying the relative speed of each motor. Radio controlled Multicopters are increasingly popular for aerial photography, and land surveying.

6.2 Types of Multirotor

There are many types of multirotor. They are generally categorized by the number of motors used, for example a three-motored Multicopter is a 6.called a Tricopter, and the configuration can also be referred to as Y3.

Multicopters can be divided into the following types:

- **Bicopter:** Bicopter could be the cheapest multicopter configuration to build among all because it only uses two motors and two servos. But it's also the most difficult platform to stabilize in flight. It has the least lifting power given the fact that it only has 2 motors.
- **Tricopter:** The Tricopter has 3 motors, and typically in a "Y" shape, where the arms are usually 120 degrees apart. Tricopters can sometimes be found in a "T" shape too. Two propellers on the front arms spins the opposite direction to counter each other out. The rear motor can be tilted left and right by a servo to enable the yaw mechanism.
- **Quadcopter:** A quadcopter has 4 motors mounted on a symmetric frame; each arm is typically 90 degree apart for the X4 config. Two motors rotate CW (clockwise), and the other two rotate CCW (counter-clockwise) to create opposite force to stay balance. Its frame can be two types: 'X' shape and '+' shape. In this project, we are using 'X' shape quadcopter. Quadcopter is the most popular multirotor configuration, with the simplest mechanical structure. It's widely used for drone racing in the form of "mini quad".
- **Pentacopter:** There isn't much information on this configuration because it's not a popular setup. But there have been people building this and verified the feasibility of this cool looking configuration. One obvious advantage of the pentacopter is the wide angle of the two front arm which allows the propellers to stay out of the camera view as far as possible.
- **Hexacopter:** The hexacopter has 6 motors mounted typically 60 degree apart on a symmetric frame, with three sets of CW and CCW motors/propellers.
- **Octocopter:** A typical octocopter has 8 motors on the same level with four sets of CW and CCW propellers.

The number of motors and configuration have impact on flight performance, and each has its own advantages. For instance, the more motors, the more power and lift capacity, which means you could carry more payload. More motors also mean better redundancy in case of motor failure. But the downside is decrease in power efficiency and increase in the cost of purchasing additional hardware and maintenance.

6.3 Working Principle:

It is the propeller direction along with the drone's motor rotation and speed, which make its flight and maneuverability possible. The quadcopter's flight controller sends information to the motors via their electronic speed control circuits (ESC) information on thrust, RPM, (Revolutions Per Minute) and direction. The flight controller will also uses GPS data before signaling to the quadcopter motors on thrust and rotor speed.

While the drone and quadcopter technology of today is all modern, they still use the old principles of aircraft flight, gravity, action and reaction pairs.

In the manufacture of quadcopters, propellers and motor design, the 4 forces which affect all flight (weight, lift, thrust and drag) are also important considerations.

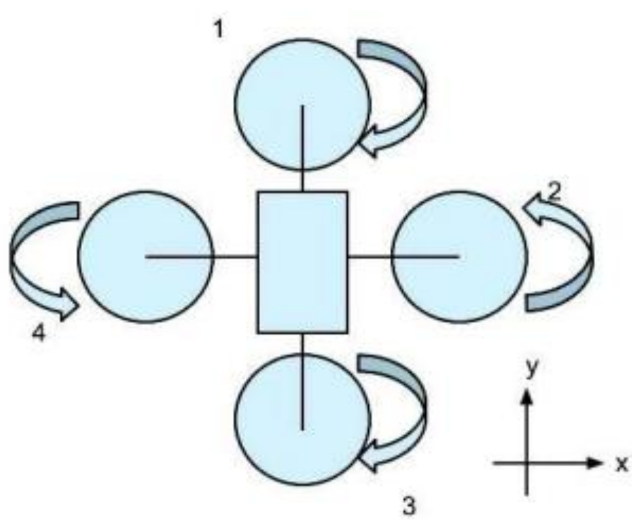

Figure 1: Motor rotation directions

A quadcopter consists of four motors evenly distributed along the quadcopter frame as can be seen in figure 1. The circles represent the spinning rotors of the quadcopter and the arrows represent the rotation direction. Motors one and three rotate in a clockwise direction using pusher rotors. Motor two and four rotate in a counter-clockwise direction using puller rotors. Each motor produces a thrust and torque about the center of the quadcopter. Due to the opposite spinning directions of the motors, the net torque about the center of the quadcopter is ideally zero, producing zero angular acceleration. This eliminates the need for yaw stabilization.

6.4 Roll, Pitch and Yaw

There is some terminology used for drone when it is flying forwards, backwards, sideways or rotating while hovering. These are known as Pitch, Roll and Yaw.

Yaw – Yaw is provided by increasing (or decreasing) the speed of the front and rear motors or by increasing (or decreasing) the speed of the left and right motors. This causes the quadcopter to turn along its vertical axis in the direction of the stronger spinning rotors. As the front and back motor slows down, the forces created by the corresponding rotors are less than the forces created by the left and right rotors. The quadcopter will begin to rotate in the same direction as the faster spinning rotors due to the difference in torque forces. This movement is represented by the red arrow.

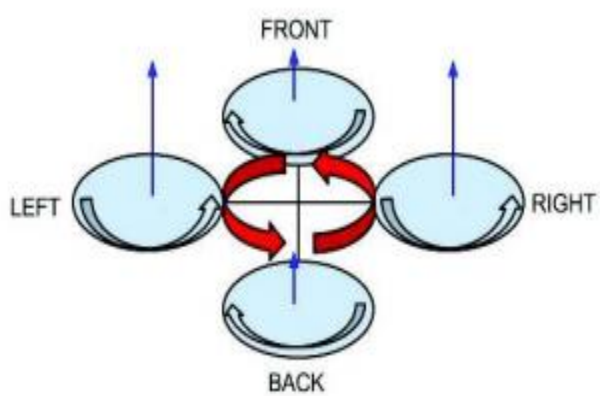

Figure 2: Quadcopter: Yaw movement

Pitch – Pitch is provided by increasing (or decreasing) the speed of the front or rear motors. This causes the quadcopter to turn along the x axis. The overall vertical thrust is the same as hovering due to the left and right motors; hence only pitch angle acceleration is changed. Figure shows an example of pitch movement of a quadcopter. As the front motor slows down, the forces created by the corresponding rotor are less than the forces created by the back rotor. These forces are represented by the blue arrows. These forces cause the quadcopter to tip forward and this movement is represented by the red arrow.

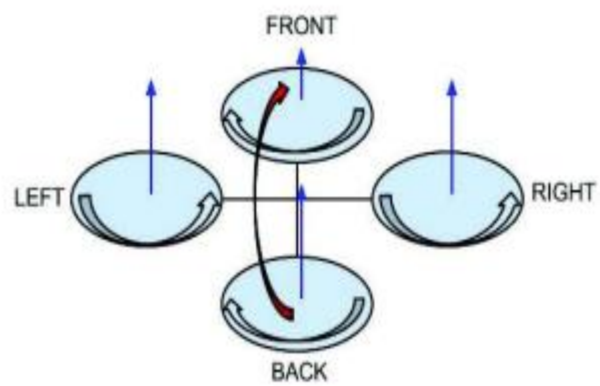

Figure 3: Quadcopter: Pitch movement

Roll – Roll is provided by increasing (or decreasing) the speed of the left rotor speed and right motors. This causes the quadcopter to turn along the y axis. The overall vertical thrust is the same as hovering due to the front and back motors; hence only roll angle acceleration is changed. Figure shows an example of roll movement of a quadcopter. As the right motor slows down, the forces created by the corresponding rotor are less then the forces created by the left rotor. These forces are represented by the blue arrows. This causes the quadcopter to tip to the right and this movement is represented by the red arrow**.**

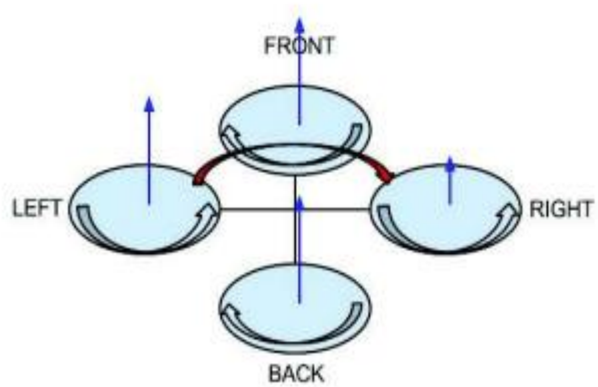

Figure 4: Quadcopter: Roll movement

7. DRONE PARTS – CHOOSING THE RIGHT COMPONENTS

So now you have a good idea what kind of drone you would like to build, the next step is to choose right components. Building the drone is going to vary person to person but almost all drones will have the same basic parts. In this section, the role of each component and its specifications is explained briefly.

7.1 Drone Frame

The frame of the quadcopter provides the physical structure for the entire aircraft. It joins the motors to the rest of the aircraft and houses all the other components. The frame must be large enough to allow all four propellers to spin without collision, but must not be too large and therefore too heavy for the motors. Drone frame used in this project is Hobby King S500 Glass Fiber Quadcopter Frame.

- Built with high quality glass fiber and polyamide nylon brass sleeves
- Weight: 405gms.
- Dimensions: 170mm height

Figure 5: Drone Frame

7.2 ESC

Speed Controllers: Every motor needs an individual electronic speed controller (ESC for short). These speed controllers accept commands in the form of PWM signals and output the appropriate motor speed accordingly. Every ESC has a current rating, which indicated the maximum current that it may provide the motor without overheating. Appropriate ESCs must be chosen to ensure that they can provide enough current for the motors.

- Type: Makefire VGOOD
- Current: 40A ESC
- Compatible with 2-4s input battery.
- Weight: 4gms
- Size: 40*13mm

Figure 6: ESCs (Speed Controller)

7.3 Motors

The motors spin the propellers to provide the quadcopter with lifting thrust. Quadcopters almost exclusively use brushless DC motors, as they provide thrust-to-weight ratios superior to brushed DC motors. However, they require more complex speed controllers.

- Crazepony EMAX RS2205
- It has a potential voltage of 2600kv
- Light, yields faster bell
- Rotational response, higher thrust.
- Weight: 30gms

Figure 7: Motor

7.4 Propellers

Propellers come in many sizes and materials. They are measured by their diameter and their pitch, in the format (diameter) x (pitch). Pitch is a measurement of how far a propeller will “travel” in one revolution. Propeller selection is important to yield appropriate thrust while not overheating the motors.

- USAQ carbon Fiber Propellers
- Low resin with high carbon fiber content for light weight
- Weight: 6 gms each
- Size: 8*4.5mm

Figure 8: Propellers

7.5 Flight Controller

The flight controller is the “brain” of the quadcopter, and performs the necessary operations to keep the quadcopter stable and controllable. It accepts user control commands from the Rx, combines them with readings from the attitude sensor(s), and calculates the necessary motor output.

- Includes 3-Axis Gyro, Accelerometer and Magnetometer, Along with a High-Performance Barometer.
- Onboard 4 Megabyte Dataflash Chip for Automatic Datalogging.
- Optional Off-Board GPS, Ublox LEA-6H Module with Compass.
- One of The First Open Source Autopilot Systems To Use Invensense's 6 Dof Accelerometer/Gyro MPU-6000.
- Barometric Pressure Sensor Upgraded to MS5611-01BA03, From Measurement Specialties.
- Atmel's ATMEGA2560 And ATMEGA32U-2 Chips for Processing and USB Functions Respectively.

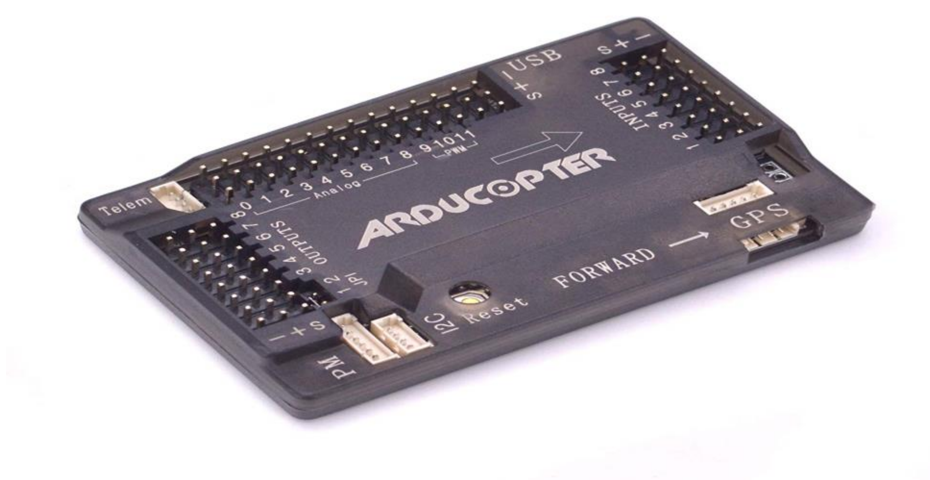

Figure 9: Arducopter V2.8

7.6 Battery Adapters/Chargers

Battery: The battery provides electrical power to the motors and all electronic components of the aircraft. Lithium Polymer (LiPo) batteries are used almost exclusively, because they have high specific energy. Hobby LiPo batteries have a capacity rating and discharge rating. The capacity rating, in milliamp-hours (mAh) indicates how much current the battery may output for one hour.

- Type: Gens ace
- Capacity: 3300mah
- Made with LiPo material.
- Weight: 283gms

Figure 10: Battery

Battery charger:

- Rapid charger/discharger for all kind of battery of RC hobby, with built in balancer.
- Individual cell balancing Li-ion, LiPo and LiFe capable Ni-Cd and NiMH capable.
- Microprocessor controlled Delta-peak sensitivity.
- Large range of charge currents Store function allows safe storage current.
- Input voltage monitoring. (Protects car batteries at the field)
- LCD display.
- Charge current range: 0.1~6.0A
- NiCd/NiMh battery cell count: 1~15cell
- Li-ion/Polymer cell count: 1~6series
- Pb battery voltage: 2v to 50v
- AC Adapter: Input: US plug, 100-240V, 50/60Hz. Output: 15V 6A

Figure 11: Battery Charger

7.7 Radio transmitter and receiver: A radio control system is made up of two elements, the transmitter you hold in your hands and the receiver you put inside your drone. Dramatically simplifying things here, your drone transmitter will read your stick inputs and send them through the air to your receiver in near real time. Once the receiver has this information it passes it on to your drone's flight controller which makes the drone move accordingly. A radio will have four separate channels for each direction on the sticks along with some extra ones for any auxiliary switches it may have.

- Channels: 6
- Model type: fixed-wing/glider/helicopter
- RF range: 2.405-2.475GHz
- Bandwidth: 500KHz
- Band: 142
- RF power: less than 20dBm
- Code type: GFSK
- Sensitivity: 1024
- Low voltage warning: less than 4.2V
- DSC port: PS2;
- output: PPM
- Charger port: no ANT
- length: 26mm * 2(dual antenna)

- Power: 6V 1.5AA * 4 (Not included)
- Display mode: Transflective STN positive type,128 * 64 dot matrix VA72 * 39mm, white backlight.
- Size:174 * 89 * 190mm
- Weight: 392g

Figure 12: Radio Transmitter and Receiver

7.8 GPS Module:

GPS Module is used to navigate the drone. It is connected to drone for the safe fly. It is also used to determine the path of the Drone.

- Main chip: 7M
- C/A code,1.023MHz
- Receiver Frequency: L1 [1575.42MHz]
- Locate Performance
- Drifting<0.02m/s
- Accuracy: 1us
- Coordinate System: WGS-84
- Max Attitude Height: 18000
- Max Speed: 515m/s
- Acceleration: <4g

Figure 13: GPS Module

7.9 Telemetry: Telemetry is used to communicate between the Smart phone and Drone. It consists of two modules; Ground Module and Air Module. Ground module is used to connect the Android smart Phone and Air module is used to connect the Drone.

- Frequency channel: 915MHz
- Receiving sensitivity: -117dBm
- Transmitted power: Up to 20dBm(100mW)
- Antenna Connector: RP-SMA
- Connector output power: 100mW(20dBm)
- Sensitivity can be adjusted between 1-20dBm
- Sensitivity interface: Standard TTL UART

Figure 14: Telemetry Air and Ground Module

8. REQUIREMENT ANALYSIS

8.1 Functional Requirements

This section provides a functional overview of the system.

ID	Requirements	Priority
F-01	Components have light weight frame, minimum battery voltage.	High
F-02	All components should be compatible with each other.	High
F-03	Components should be calibrating in right way for stable flight of drone.	High
F-04	All the components should be properly assembled.	High
F-05	Propellers should be balanced and unbroken for safe fly of drone.	High
F-06	Follow me drone should keep certain distance between smart phone and Drone.	High

Table 1: Functional Requirements

8.2 Non-Functional Requirements

ID	Requirements	Priority
N-01	*Guidelines:* Step by step tutorial have all the guidelines to build and fly the drone.	High
N-02	*Supportability:* Drone will be made from Ardupilot and Telemetry.	High
N-03	*Reliability:* It should have good quality and calibrated components. Testing should be done before the fly of drone happens.	High
N-04	*Range:* Drone should not fly over certain range.	Medium
N-05	*Perimeter:* Drone cannot fly in busy traffic areas.	Medium

Table 2: Non- Functional Requirements

8.3 Performance Constraints

- **Battery**: Battery will be charged at least 20 minutes of drone fly.
- **Path for Drone**: Chosen path should be clear and cannot have any obstacle.
- **Usability**: Flying the drone requires knowledge of establishing connection between smart phone and drone and giving the proper direction to drone from the remote controller/ transmitter.

8.4 Software Configurations

The calibration of the components can be done using different software's like Mission Planner, Droid Planner2 and QGround Controller. In this project, we used Mission Planner software for calibration.

- **Mission Planner:** Mission Planner is a full-featured ground station application for the ArduPilot open source autopilot project. Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for your autonomous vehicle.
- **Tower:** Tower is an Android mobile application used for controlling the drone.
- **Package:** Used "Copter.h" for implementing the function of Arming in the Arducopter using C++ programming language.

9. ASSEMBLING OF DRONE

For building the drone, we first need to assemble the components after gathering all the required components. This process can be done using the following steps.

9.1 Assembling the frame

The assembling of the drone frame can be done using the assembly guide which comes with the Hobbyking S500 Drone frame. It Includes assembling of frame arms, four leg plates, two rods for the base mount, one top plate, one bottom plate using screws and proper screwdriver. Do not keep any screws untightened or tilted. The following diagram shows the drone frame components before and after assembling.

Figure 15: Frame Before Assembling **Figure 16: Frame After Assembling**

9.2 Connecting the motors

To connect the motors, you need to place the motor on the frame arm as shown in the figure. Connect four motors to four drone frame arms using screws and drivers and connect each motor to each ESC (speed controller) with soldering.

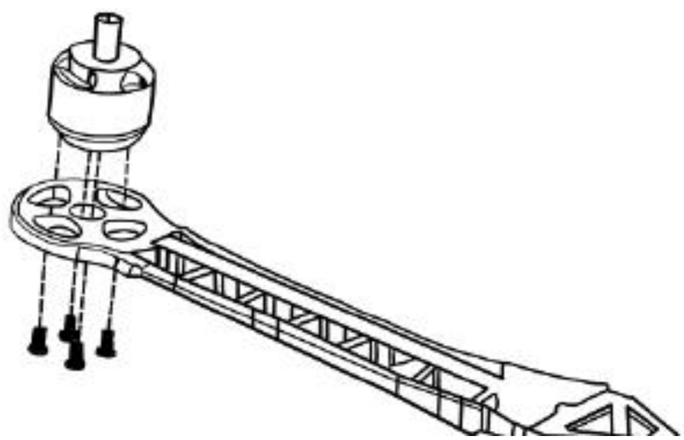

Figure 17: Connection of Motors to Drone frame Arm

9.3 Connecting the ESC

There are two types of ESCs available in market, it can be four-in-one ESC or four individual ESCs. In this tutorial, four different ESCs are used.

For the connection, the single ESC has 8 wires, from that 3 wires connect to motor, 2 wires connect to power board (bottom plate) and 3 other wires (signal, ground and power) connects to Arducopter output pins (with considering clock and counterclockwise directions).

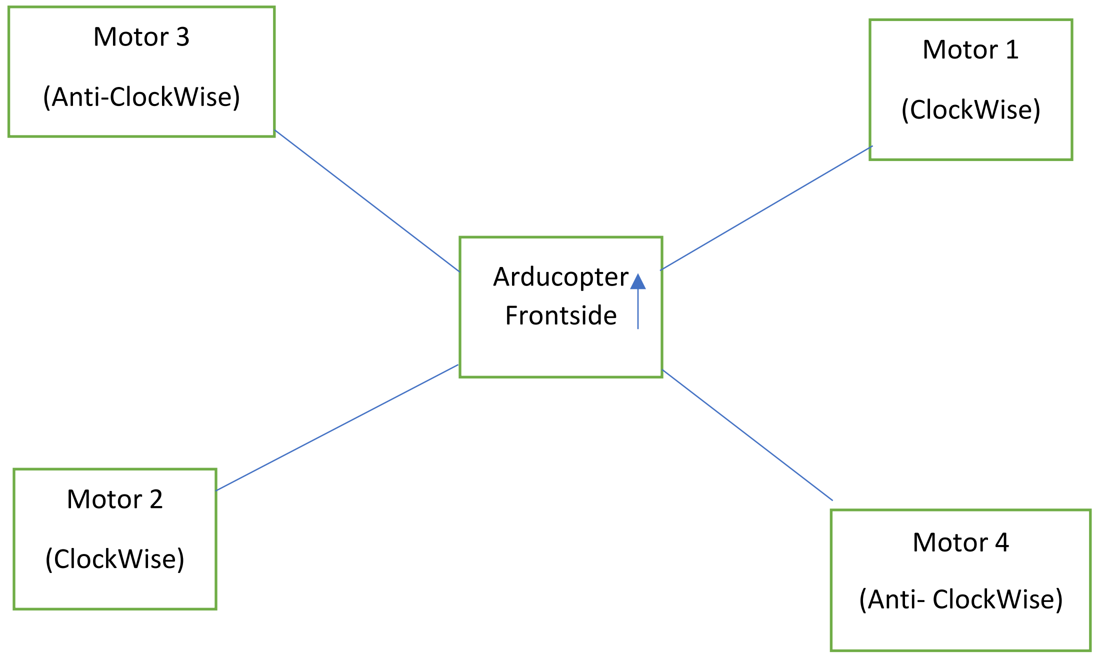

Figure 18: Direction of Arducopter and ESCs

Figure 18 describes the Arducopter's front direction and the connections to the four ESC's and motors.

Connections of the four ESC's to output pins of Arducopter.

Esc's Number	Arducopter Output Signal
1	Output 1
2	Output 2
3	Output 3
4	Output 4

Table 3: ESCs connections to Arducopter

9.4 Connection to Power Module:

Power Module has three ends, one end goes to PM pin of Arducopter, one goes to Power Board (bottom plate) and other one connects to the battery.

9.5 Connecting the Arducopter

- Arducopter requires power so it is connected to the power module through its PM pin.

- Connect 4 ESC's (Speed Controllers) by following the instructions in the above section "Connecting the ESC".
- Connect Radio Controller using the below section "Connecting the Radio".
- Connect Telemetry's air module to telemetry pin of Arducopter for handling the drone using smart phone.
- Connect GPS module to GPS pin and the four ESC's to output pins of Ardupilot.

9.6 Connecting the Radio: A radio control system is made up of two elements, the transmitter you hold in your hands and the receiver you put inside your drone.

Connect Radio Controller's receiver to Arducopter input pins

Radio Receiver Pins	Arducopter Input Signal
Channel 1 (Connect 3 wires)	Input 1
Channel 2 (Connect 1 wire)	Input 2
Channel 3 (Connect 1 wire)	Input 3
Channel 4 (Connect 1 wire)	Input 4
Channel 5 (Connect 1 wire)	Input 5

Table 4: Radio Receiver connections to Arducopter

9.7 Connecting the Battery: Connect battery to S500 frame using board and by soldering to supply the power.

9.8 Connecting the Telemetry: Telemetry contains two modules. One is ground module, which connects to smart phone using OTG connector and air module connects to Drone's Ardupilot.

10. CALIBRATION OF DRONE

- Calibration can be done using APM Planner software, Mission Planner software and Q-Ground Control. In this project, Mission Planner software is used for calibration.
- Download Mission Planner software for windows : http://ardupilot.org/planner/docs/mission-planner-installation.html

10.1 Configuring the QuadCopter:

- Connect Arducopter to laptop using USB cable.

➢ Open Mission Planner software and connect on any COM port and select AUTO with 115200. After successfully connected, disconnect arducopter by clicking the disconnect button.

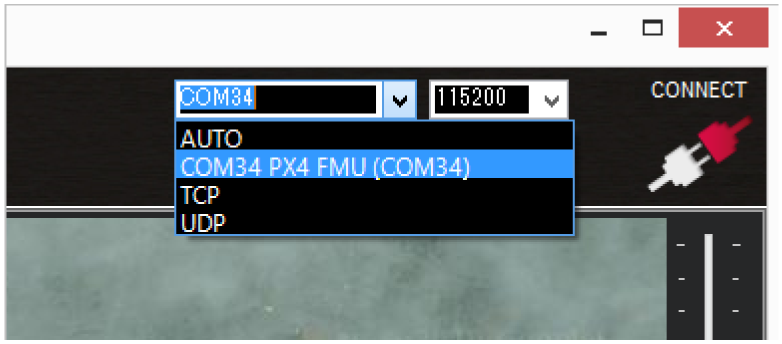

Figure 19: Settings to connect the Mission Planner through USB Cable.

➢ Then go to initial Setup install Firmware. Based on your choosen arducopter version choose firmware version, you can also install previous firmware version if arducopter has lower version. In this drone we used Arducopter 2.8 version.

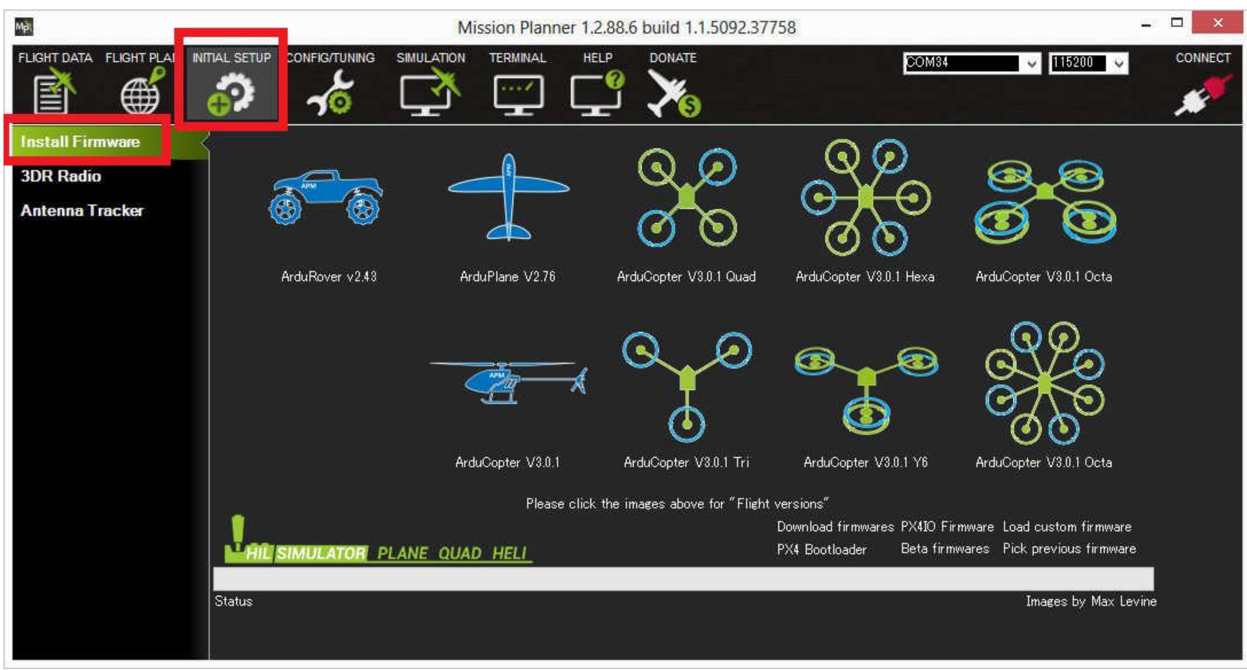

Figure 20: Installing the firmware in Mission Planner

➢ After installing firmware now connect again and then select frame type based on which type of multicopter you are making. In our drone it is Quadcopter.

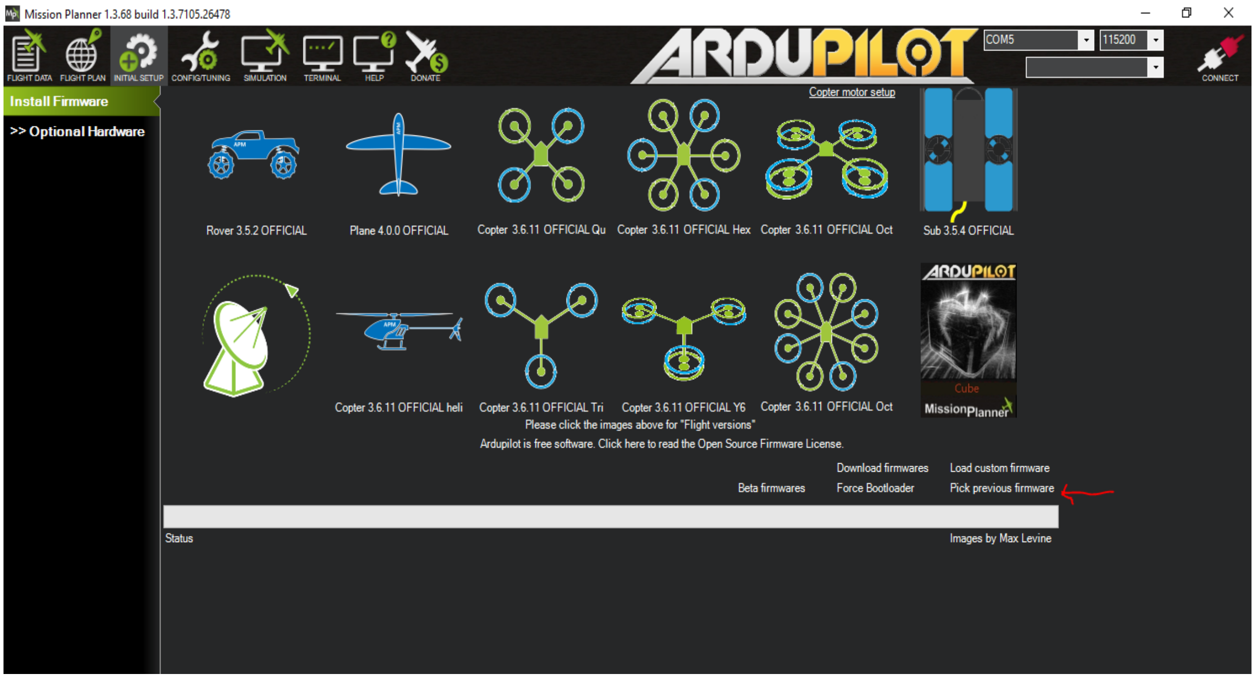

Figure 21: Mission Planner Calibration – Choosing the frame type

10.2 Accel calibration: Select orientation of the drone properly and calibrate according to the software instructions. It will ask you to put arducopter in different directions such as left, right, top, back etc means calibrate in each direction and once it pop up the calibration successful then we have completed Accelerometer Calibration.

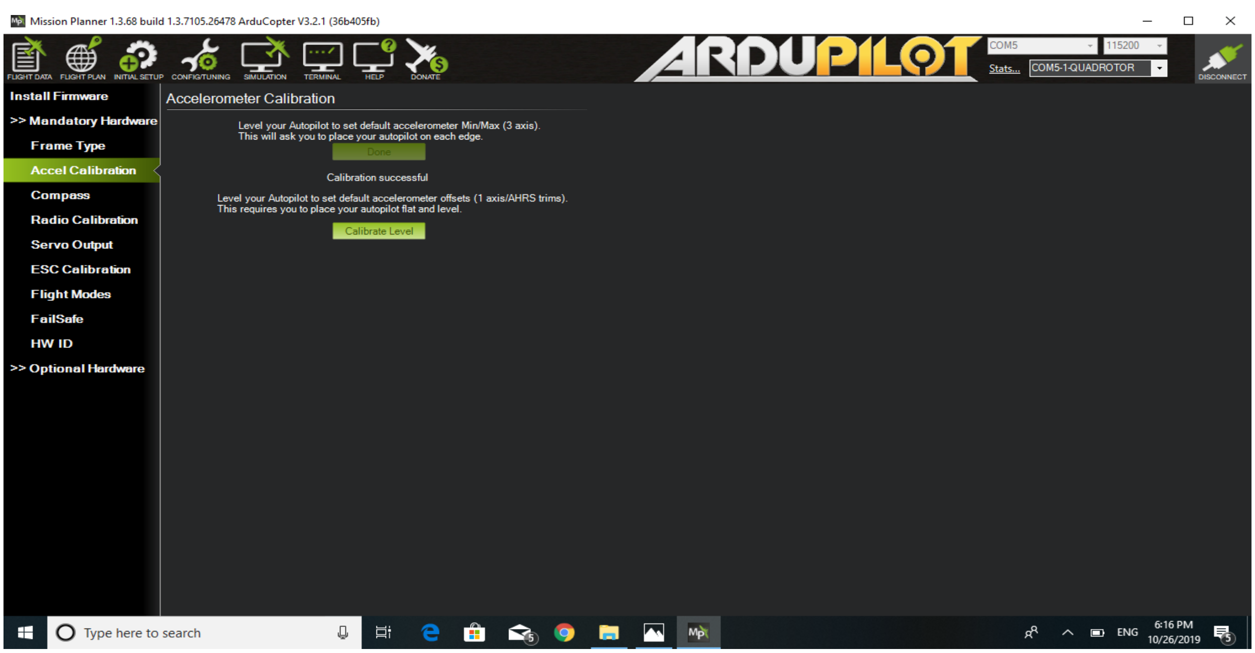

Figure 22: Mission Planner Calibration – Accel Calibration Successful

10.3 Compass calibration: In Mission planner software select compass option check “Enable” and “Auto Detection” options and click on Live calibration button, which will ask you to rotate arducopter in all directions for the calibration. Once the rotation covers all the points, calibration will be successful.

Figure 23: Mission Planner Calibration – Compass Calibration

10.4 Radio Calibration: Start radio transmitter and calibrate radio controller using Mission planner software by clicking “Calibrate Radio” button and moving all throttles and switch in all directions and do radio calibration in Mission Planner. For more details see in video tutorials.

Figure 24: Mission Planner Calibration – Radio Calibration Successful

10.5 ECS Calibration: ESC calibration is done manually without using mission planner software.

Step 1: Make sure all four motors are connected to drone frames and note that at this point you will not connect propellers; we will connect propellers at the end after the calibration part is completed successfully.

Step 2: Put throttle at lower (bottom direction) and connect battery to power module (some sound is produced).

Step 3. Disconnect battery from power module and take throttle up and again connect battery to power module (some sound is produced).

Step 4:

- Disconnect battery from power module and put throttle up again and connect battery to power module (some sound is produced). After finishing the sound then slowly take throttle up.
- Now the ESC Calibration is Done (Motors will start spin).

10.6 Flight mode calibration: Do calibration for the different flight mode such as RTL, Stabilize etc. The preferable flight modes are shown in Figure 22.

Figure 25: Mission Planner Calibration –Flight Modes Calibration

10.7 Failsafe calibration: This calibration helps to protect the drone when its loss the connection in communication. It helps to avoid crashes when it lost the connection. For this calibration. you can choose Return To Lunch (RTL) option.

11. TESTING

Each component was tested and verified to be working as intended. Test flights have been conducted and the results confirm that the quadcopter can fly in a stable manner.

11.1 Using Remote Controller

1. Each motor and Propeller should spin.
2. Each Motor should get same amount voltage.
3. Arming and Disarming of drone should work properly by using Remote Controller.
4. Drone should follow the directions given from the remote controller.
5. Drone should maintain certain height and modes at the time of flying.

11.2 Using Telemetry:

1. Check connection between telemetry ground module and air module
2. Check if the mobile application gets GPS signal (2D or 3D) or not.
3. Check in the mobile application (of handling drone) the map is showing correct position of drone or not?
4. Test Arming, Disarming and takeoff is working properly or not.
5. Check drone's height as per settings in the mobile application.

11.3 Safety Tips

When you want to fly your Drone, you must make sure that you are doing it properly. Here are some simple safety tips that we recommend.

- **Choosing the right environment:** First try to fly your drone in an open, preferably outdoor area instead of indoors, make sure the day you've selected is relatively wind free and the location has few trees. If necessary, take the permission of the land owner.
- **Be aware of your surroundings:** Take note of where other prople, objects, trees or roads are to assure a safe flight path and landing. Don't fly near an airport or over a large group of people. Be aware of powerful antennas and power lines as well.
- **Get permission:** If you are on someone else's property or in a public space, ask for permission to avoid invasion of privacy or other consequences.

- **Check the battery:** To avoid an emergency landing, Make sure your battery is fully charged. Do not charge overcharge the battery.
- **Learn the modes and channels:** Before flying learn the flying modes and settings as it can affect your drone and ability to control it.

12. SYSTEM DETAILS

This section explains in detail how the project was approached. All hardware and software components that will be used will be explained in this section of the report.

12.1 Design

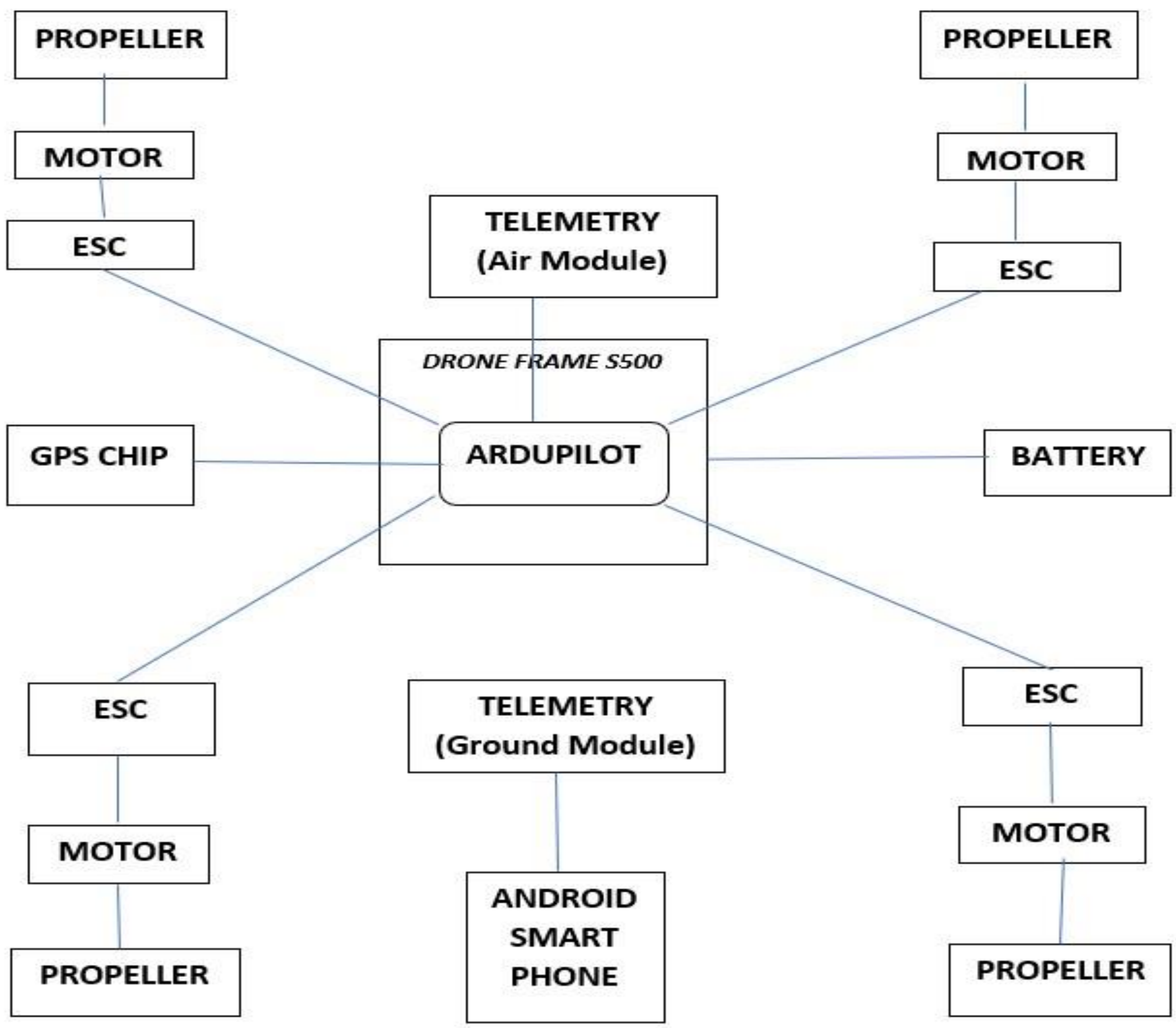

Figure 26: Architecture of Drone

Drone main functionality done by Ardupilot. It is responsible for the stability of the drone, providing connection between drone and smart phone. Ardupilot control the drone. Mount the motors and propellers on the drone frame's arms Then 4 single ESC (speed controller) connects to each motor with two of them are configured anti-clockwise and other two are configured clockwise. 4 ESC's signal, power and ground wires connect to output pins of ardupilot. Communication starts with control of the drone from the ground using smart phone with telemetry connected and send signal remote signal from ground telemetry module to air module of telemetry which is connected to drone's ardupilot, after that ardupilot is responsible for the further action by giving output to 4 ESC to move and ESCs do action using motors and battery's power supply.

12.2 Implementation

Arducopter is the important component of the drone which can be called as the brain of drone. So, Arducopter input signals are either radio receiver (If we control using radio controller) or telemetry (if we control drone using smart phone), output is 4 ESCc (ESCs connected to motors and motors are connected to propellers), Supplying power to arducopter by connecting power module to PM pin of Arducopter and power module is connected to the power board (S500) (which is connected to battery) and connect GPS to GPS pin of arducopter.

The process starts, when we give directions (say takeoff drone) from the ground (either by radio controller or by using smart phone mobile application), then arducopter's input signals: radio receiver or telemetry's air module receives signal based on ground control device, then arducopter send directions to four ESCs and then ESCs results in spinning the motors and then propellers. Finally, the drone will take-off.

The calibration of the components can be done using different software's like Mission Planner, Droid Planner2 and QGround Controller. In this project, we used Mission Planner software for calibration.

- **Mission Planner:** Mission Planner is a full-featured ground station application for the ArduPilot open source autopilot project. Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for your autonomous vehicle.
- **Tower:** Tower is an Android mobile application used for controlling the drone.

➤ **Package:** Used “Copter.h” for implementing the function of Arming in the Arducopter using C++ programming language.

PINS	CONNECTIONS
INPUTS	RADIO CONTROLLER RECEIVER
OUTPUT	FOUR ESC’S (SIGNAL, POWER AND GROUND CABLES)
GPS	GPS MODULE
12 C	12 C OF GPS MODULE
TELEM	TELEMETRY
POWER MODULE	BATTERY

Table 5: Pin Configuration for Arducopter

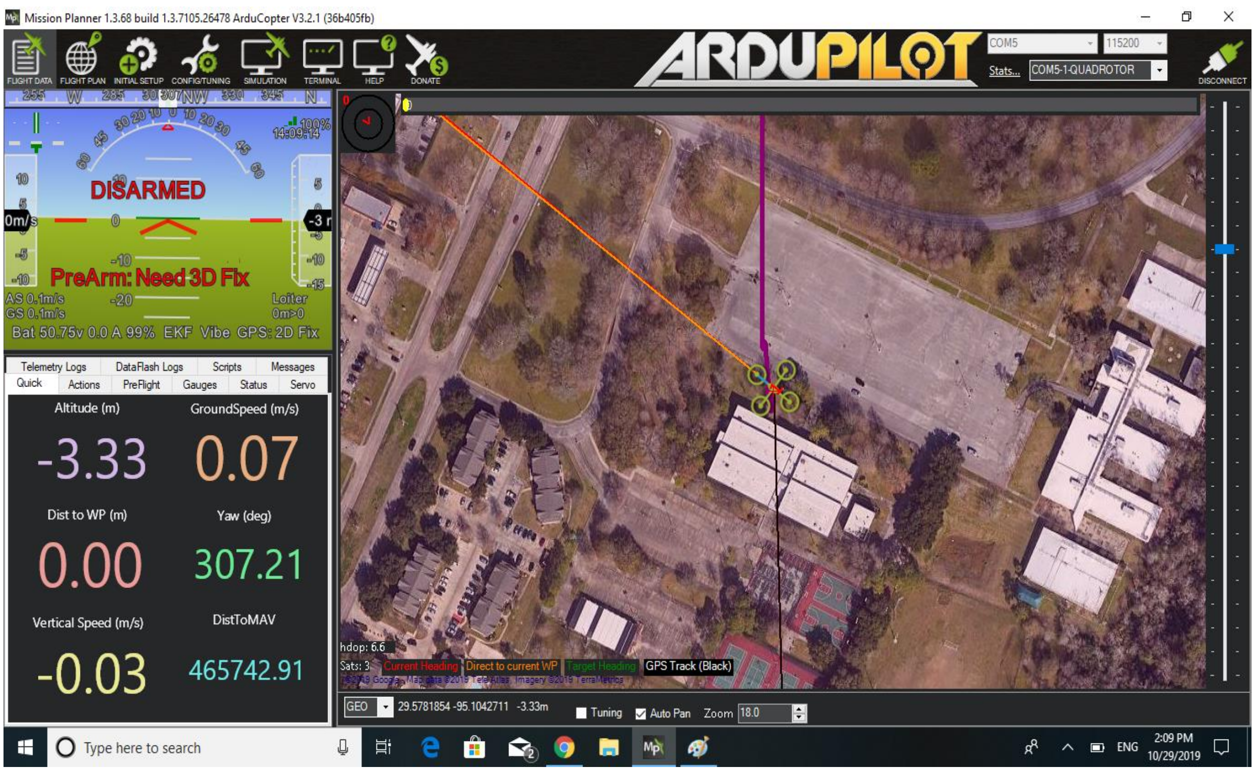

Figure 27: Mission Planner Calibration

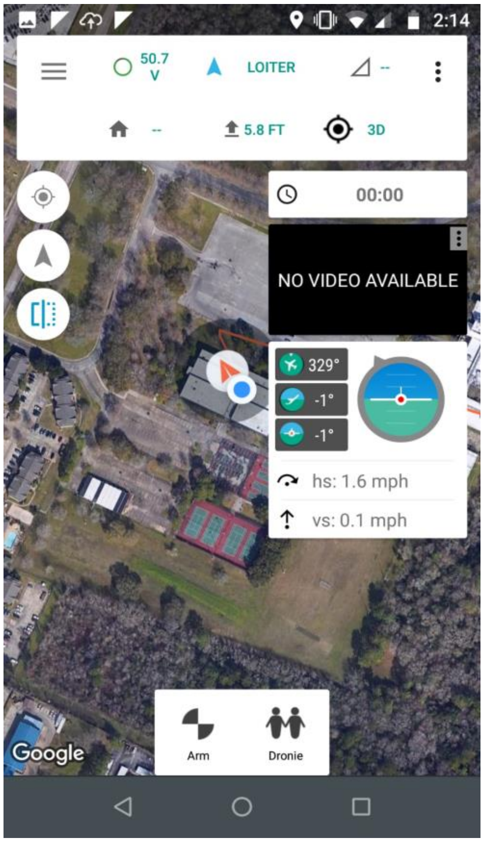

Figure 28: Handling Drone Using Mobile Application Tower

13. DISCUSSIONS

13.1 Challenges

In this section we briefly explain about the problems we faced at each phase and how we solved them by analyzing different scenarios.

PHASE I: GATHERING THE COMPONENTS

- Gathering the reliable and compatible components is one of the challenges we faced. We encountered delays in ordering some parts. To make up for this delay , we focused on other aspects of the project. We focused on learning the Mission Planner software and testing the components that had arrived.
- After gathering all the required components, we found that the propellers are not fitting in the motors, so we reordered the new propellers.
- On our research, we found the better-quality GPS module, so we returned the old GPS chip and ordered the new GPS.

- Due to the conflict between the vesions of the arducopter and the firmware that has to be installed in the Mission Planner, we returned the Arducopter version 2.6 and bought Arducopter vesion 2.8.

PHASE II: ASSEMBLING

Before assembling the components, we Checked the configuration of each components and their compatibility with the other components.

After doing a lot of research on assembling the components, we are successful with the following steps

- Assembling the frame
- Connecting the motors
- Connecting the propellers
- Connecting the ESC
- Connecting the ArduPilot
- Connecting the battery
- Connecting the Telemetry
- Connecting the Power Module

PHASE III: CALIBRATION

We tried calibration with different software's like APM Planner 2.0, Mission Planner and Q-Ground Control software's on Windows and MAC OS.

1. In Mission Planner, we had an issue conflicting the Mission Planner Default Firmware version with the Arducopter version. Firstly, we tried using the latest Mission Planner version which is 3.6.11 which didn't work, later we tried 3.2 through which we could install the parameters and firmware. We installed previous Firmware version which is compatible with the Arducopter APM 2.6. After loading the firmware, the Arducopter was connected and completed Frame type calibration but unable to do Accel calibration. In Accel calibration, we were able to calibrate only at Level (not left, right, top, bottom). In compass calibration, we tried several times to get the live calibration points.

2. We continued to do calibration through APM Planner. In APM Planner 2.0, we were not able to load configuration parameters and Accel calibration.
3. After research, we found Q-Ground Control is another software for calibration. So, started calibrating on Q-Ground control, the Arducopter is not connecting through USB cable.

We tried to find solutions for the above issues using the three software's but didn't work. we ordered the new version of Arducopter APM 2.8. With the new Arducopter APM 2.8, we are successful with the Frame type, Compass and Accel calibration. After the research we found that the Radio calibration is mandatory to proceed with the further steps. We ordered the radio controller and calibrated the Radio, ESC, Flightmode and Failsafe calibration.

PHASE IV: TESTING

There were many safety issues during testing the quadcopter with Motors. The spinning motors could spin quick enough to cause serious harm to a person. All the team members got injuries during this phase. Be careful while testing the motors. Before each test with the motor attached, no one would come into contact with the motors of the quadcopter. Due to the high speed of spinning the motors, the propellers may break, and the screw nuts may be missed. It is better to have extra propellers and screw nuts. The testing was done carefully starting at minimum throttle. If the quadcopter ran properly for a duration of time, then we would increase the throttle by 10%. This tedious process was used to ensure safety.

PHASE V: FLYING

After the successful calibration, we faced another challenge that the drone is able to spin the motors but it is tilting on one side and not taking off. We thought that the issue is with the stability of the drone. We tested few scenarios like

1. Whether the four motors are getting the same power.
2. The direction of the propellers.
3. Checked the space between the propellers and screws of the motor.

We fixed all the above scenarios in order to fly the drone with stability.

14. SECURITY PROTOCOLS FOR FLYING THE DRONE OUTSIDE

There are some rules by the government of the country where you fly things in the sky, specially the drone. Always check the security protocols. A few common rules are as follows:

- You cannot fly a drone within 5 miles of an airport
- You must keep the drone within your eyesight
- You are not allowed to go higher than 400 feet (around 0.12 km)
- You cannot fly a drone in busy traffic areas
- You must register your drone if you use it for business purposes or professionally; you must have a license
- Always know the local rules before flying a drone

15. CONCLUSION

15.1 Results

The result however is a drone custom to your requirements that you can be proud of. Even better if anything ever goes wrong or breaks, you'll know exactly how to fix it. Drone is a technology that is available in every industry for completing task in smart way and in less amount of time. It provides a good solution where human is not able to reach and find something. In this project, implementation is done specifically for the follow-me with Arducopter as flight controller and controlling the drone using Smartphone and Radio Controller.

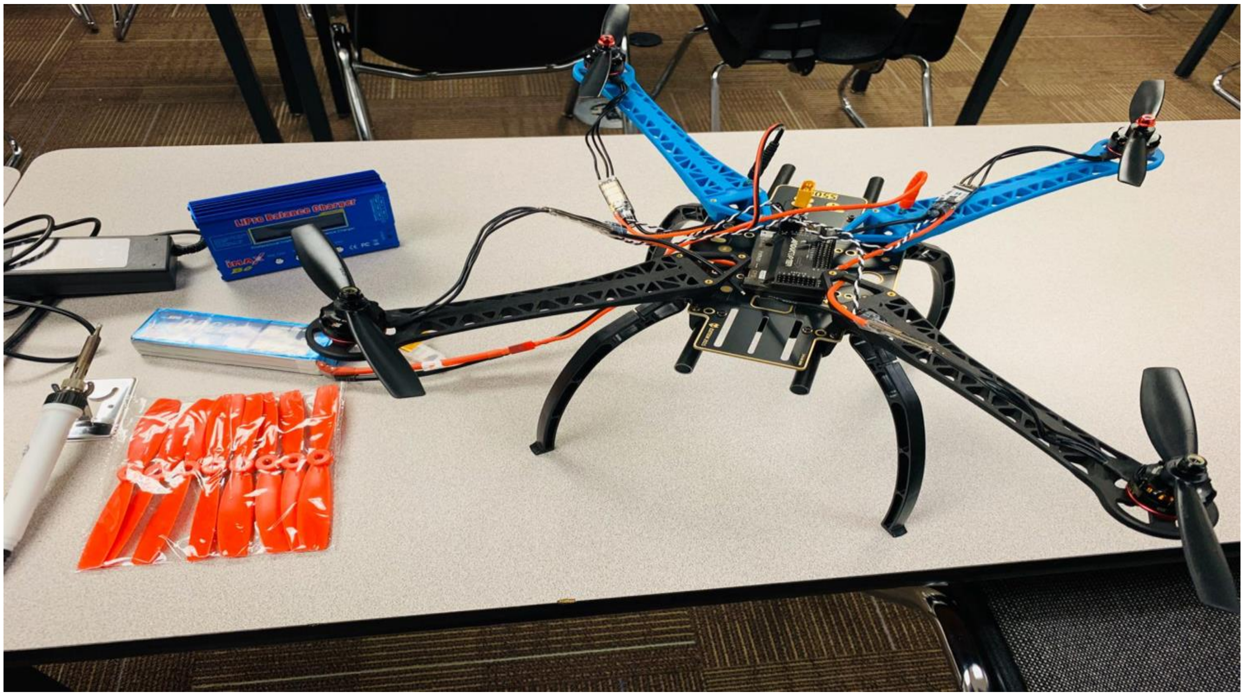

Figure 29: After Assembling, calibration and testing of Drone

- Detailed step-by-step description of the assembling, calibration and building of the drone with pictures and videos.
- Identified a set of right and compatible components with minimum cost.
- Recorded the details of a set of reliable vendors for purchasing the components
- Documented the software and code used to control and fly the drone.
- Successfully calibrated the components using Mission Planner software
- The parameters were adjusted, and stabilization of the quadcopter was achieved.
- Built the drone to fly and control using Remote Controller, Telemetry and GPS

15.2 Roadblocks

- Installing the correct firmware version in ArduCopter
- Setting up Modes and Channels of the remote controller for communicating to receiver of the drone
- Establishment and setting up the GPS for the Follow me drone
- Placing the motors in Clockwise and Counter-Clockwise direction

15.3 Future Work

- Make Selfie and video capable drone for capturing pictures and records videos from the sky, which will be a best application for the weather forecasting.
- Create drone using Arduino Nano and ESP 8266 Wi-fi module for the better performance of drone in terms of controlling the drone.

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[1] Sayed Omar Faruk Towoha “Building Smart Drones with ESP8266 and Arduino”, February 2018.

[2] Ty Audroins, “Designing Purpose-Built Drones for ardupilot Pixhawk 2.1”, December 2017, Packet Publishing Ltd.

[3] Drone tutorials: http://dronenodes.com/how-to-build-a-drone/

[4] Manitoba university, Final Report Design, Implementations and testing of UAV Quadcopter.

[5] Mission Planner Software: https://ardupilot.org/planner/docs/mission-planner-overview.html

APPENDIX A - LIST OF COMPONENTS

S.no	Component	Quantity	Total Price	Link to purchase
1	Drone Frame	1	26.3	https://www.amazon.com/HobbyKing-Glass-Fiber-Quadcopter-Frame/dp/B01N657QJ7
2	Speed Controller	4	39.99	https://www.amazon.com/Makerfire-Oneshort125-Controller-Multicopter-Quadcopter/dp/B07HRGNPC4/ref=asc_df_B07HRGNPC4/?tag=hyprod-20&linkCode=df0&hvadid=241938192625&hvpos=1o32&hvnetw=g&hvrand=8144513672191687087&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9027632&hvtargid=pla-636849736522&psc=1
3	Flight Controller	1	34.99	https://www.amazon.com/gp/product/B07MD3ZRKJ/ref=ppx_yo_dt_b_asin_title_o05_s00?ie=UTF8&psc=1
4	Propellers	4	11.99	https://www.amazon.com/gp/product/B01D2FWTDU/ref=ppx_yo_dt_b_asin_title_o09_s00?ie=UTF8&psc=1
5	Motors	4	56.99	https://www.amazon.com/RS2205-2600KV-Brushless-QAV250-Quadcopter/dp/B01CL6W7JC?tag=dronelabtrack-20
6	GPS Module	1	22.99	https://www.amazon.com/gp/product/B07MQ3S67N/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1
7	RC Transmitter and Receiver	1	47.00	https://www.amazon.com/gp/product/B07CXL9LCT/ref=ppx_yo_dt_b_asin_title_o03_s00?ie=UTF8&psc=1
8	Power Module	1	13.99	https://www.amazon.com/gp/product/B01CN62MZE/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1
9	Battery	1	37.99	https://www.amazon.com/Gens-ace-3300mAh-Battery-Glider/dp/B07C3MKZTS
10	Battery charger	1	32.99	https://www.amazon.com/dp/B07T29WQMQ/ref=sspa_dk_detail_0?psc=1&pd_rd_i=B07T29WQMQ&pd_rd_w=ohWbE&pf_rd_p=45a72588-80f7-4414-9851-786f6c16d42b&pd_rd_wg=8vWZR&pf_rd_r=7W94RRVY2WK4CAXKZ6FM&pd_rd_r=da251e2c-d4ab-4238-9fef-

				5479b2827b98&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEySE5RTzFMMVgwTEMyJmVuY3J5cHRlZElkPUEwNDkyMjYxSzdXOTNVT1NOSDNUJmVuY3J5cHRlZEFkSWQ9QTA5OTk5NDEyTUhGOEMxSVlWRFA2JndpZGdldE5hbWU9c3BfZGV0YWlsJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
11	Soldering kit	1	10.99	https://www.amazon.com/Soldering-Electronics-Adjustable-Temperature-Rarlight/dp/B07VLDZ7YW/ref=asc_df_B07VLDZ7YW/?tag=hyprod-20&linkCode=df0&hvadid=366418870502&hvpos=1o1&hvnetw=g&hvrand=2191724969670163129&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9027632&hvtargid=pla-835111130354&psc=1&tag=&ref=&adgrpid=74513983565&hvpone=&hvptwo=&hvadid=366418870502&hvpos=1o1&hvnetw=g&hvrand=2191724969670163129&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9027632&hvtargid=pla-835111130354
12	Cables	1	6.98	https://www.amazon.com/Elegoo-EL-CP-004-Multicolored-Breadboard-arduino/dp/B01EV70C78/ref=pd_bxgy_147_img_2/143-2759821-7736408?_encoding=UTF8&pd_rd_i=B01EV70C78&pd_rd_r=bed20e1c-643e-4bf6-9aa3-2000d5dcfe1e&pd_rd_w=UOPw3&pd_rd_wg=3E6mE&pf_rd_p=a2006322-0bc0-4db9-a08e-d168c18ce6f0&pf_rd_r=5C41PZ5CA73CJF82W9X5&psc=1&refRID=5C41PZ5CA73CJF82W9X5
13	Extra Motor Screw nuts (If needed not necessary)	1	9.34	https://www.amazon.com/gp/product/B073GXCWKK/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1
	Total		**$ 343.19**	

Table 6: Components List with Price and Vendor

APPENDIX B – DELIVERABLES

1. VIDEO TUTORIALS:

https://www.youtube.com/watch?v=rYFgCeF6ZVk&list=PL9Cn5btUDSZCOf0FaiiQB0IHaSKfl-Atc&index=10

A detailed explanation about the components, assembling, calibration, testing and flying of the drone was given in the videos which has been uploaded in the Youtube.

2.PRESENTATION:

http://dcm.uhcl.edu/capf19g7/Deliverables/Team_7_Final%20Presentation.pdf

An overview of the project is explained in the presentation slides.

3.WEBSITE: **http://dcm.uhcl.edu/capf19g7/#home**

This is the team website address where you can find more information about the team, project, code and documentation.