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Institut für Automobiltechnik Dresden - IAD
Lehrstuhl für Fahrzeugmechatronik

INTERNSHIP REPORT

Thema: Octocopter

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DIPLOMINGENIEUR

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Eingereicht am: Abgabedatum

Nur was ich selbst hervorgebracht

und immer wieder aufs Neue mir erwerbe, ist für mich Besitz.

Friedrich Schleiermacher (1768-1834)

ACKNOWLEDGEMENT

I would like to thank Professor Dr- Ing Bernard Baker for giving me the opportunity to work on this project and extending all necessary support. I would also like to thank my supervisors Dip – Ing Ronny Petersohn, Dip – Ing Sven Grunwald and Dip – Ing Kevin Krebs for helping me complete the project successfully and making this internship a true learning experience for me. I would also like to thank the technical staff of Lehrstuhl für Fahrzeugmechatronik for tirelessly helping us with some of the components without which the timely completion of the project would not be possible.

I would also like to thank IAESTE for giving me the wonderful opportunity to complete my internship in this institute.

ABSTRACT

The aim of this internship was to build a flexible flying platform that can be used for various applications. A detailed study of the various types of flying platforms was performed and a comparison was performed on their stability, robustness and cost and an octo-copter was chosen as the best suited platform. 3DR Pixhawk was chosen as the best suited flight controller for the drone owing to its processing capabilities, ease of programming, online support and compatibility with companion computers. Then an approximation of the weight was performed and suitable motors were selected. The Electronic Speed Controllers were selected according to the current requirements of the motor. A current approximation was performed, and accordingly a suitable power distribution board was designed. In order to increase the flight time, two batteries were connected in parallel. Then a suitable landing gear and protection mechanism was added, for a smooth landing.

The accelerometer and compass of the 3DR Pixhawk were calibrated using the wizard in the Mission Planner software. The various flight modes and failsafe modes were also implemented and tested on the drone. The data logs of the various flights and the aerial video footage using the GoPro camera were also recorded.

The second aim of this internship was to assist in fabricating a PCB for the battery test bench. My role was to assist in designing, fabrication, soldering and testing of the PCB and to program the microcontroller.

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1 Introduction

An **unmanned aerial vehicle** (**UAV**), commonly known as a **drone,** is an aircraft without a human pilot aboard.

The aim of this internship was to build a drone, that is stable, lightweight, robust,can pick up large payloads and have a long flight time. The drone built should be a flexible platform, suitable for surveillance operations as well has applications like finding parking spaces for cars.

The other aim of this internship was to assist in designing, fabricating and testing a PCB for a battery test bench.

This report first compares the type of drones and justifies why an octocopter was selected as the type of drone suitable for this application. Then, the report justifies the selection of components based on various factors.

The next part of the report talks about the calibration process for the Pixhawk controller and the initial setup for flying the drone. The next part of the report is about flying the drone and the various precautions and safety measures to be taken.

The last part of the report talks about the PCB for the battery test bench and the results obtained.

2 Types of Drones

The drones can be classified according to the number of motors. On the basis of number of motors, the drone can be of the following types:

1. Quad-Copters
2. Hex-Copters
3. Octo-Copters

A comparative study of these multi-copters was performed, by taking into account their pros and cons and the results are tabulated as follows:

Multicopter	Pros	Cons
Quad-copter	• Relatively cheap to manufacture. • Great manoeuvrability. • Powerful enough to add accessories. • Greater thrust and power versus tri-copters.	• Not as powerful as a hex-copter or octo-copter.

Hex-copter	• Greater overall power, speed and elevation. • Safety provided through additional motors. • Higher overall payload. • Great control and flight speed.	• Priced higher than a quad-copter. • Larger in size, making the copter harder to fly in tight spaces.
Octo-copter	• Very fast and agile. • Reach exceptionally high elevations. • Extremely powerful. • Can hold heavy camera equipment. • Very safe and stable.	• Big in size. • Expensive compared to the hex-copter and quad-copter. • Battery life is often far less.

According to the requirements of the project, the octo-copter was selected as the suitable type of drone for this application. An octo-copter ensures greater flexibility in terms of payload and more power as compared to other types of drones.

3 Description of Components

3.1 Selection of Flight Controller

A flight controller can control some or all these aspects of flying:

- **Gyro Stabilization** – the ability to easily keep the drone stable and level under the pilot's control. This is a standard feature of all Flight controller.
- **Self-Levelling** – the ability to let go of the pitch and roll stick on the transmitter and have the drone stay level.
- **Orientation mode**- The pilot can control the orientation of the drone.
- **Altitude Hold** – the ability to hover a certain distance from the ground without having to manually adjust the throttle.
- **Position Hold** – the ability to hover at a specific location.
- **Return Home** – the ability to automatically return to the point where the drone initially took off.
- **Waypoint Navigation** – the ability to set specific points on a map that drone will follow as part of a flight plan.
- **GPS** – the ability to record the data of flying, it will shorten the search time for next time.

A comparison was made among different flight controllers on the basis of flying style, price and specifications and the differences were tabulated as follows:

Flight Controller	Specifications	Price
APM 2.8	• Arduino Compatible • Onboard 4 MegaByte Dataflash chip for automatic datalogging • Optional off-board GPS, uBlox LEA-6H module with Compass. • Accelerometer/Gyro MPU-6000.	$96
KK2	An Atmel Mega644PA 8-bit AVR RISC-based microcontroller with 64k of memory.	$20
MultiWii Lite V1.0	• Can utilize a servo's output to trigger a camera button • FTDI/UART TTL socket for debug, upload firmware or LCD display • I2C socket for extend sensor • Separate 3.3V and 5V LDO voltage regulator • MPU6050 6 axis gyro	$27
DJI Naza-M Lite	• Advanced Attitude Stabilize Algorithm • Intelligent Orientation Control (IOC) • Motor Arm and Motor Dis-arm • Built-in Gimbal Stabilization Function • Multiple Flight Control Mode/Intelligent Switching • Support Futaba S-Bus and PPM Receiver • Remote Adjustment	$146
MultiWii SE V2.0	• Can utilize a servo's output to trigger a camera button • FTDI/UART TTL socket for debug, upload firmware or LCD display • I2C socket for extend sensor • Separate 3.3V and 5V LDO voltage regulator • ATMega 328P Microcontroller • MPU6050 6 axis gyro • HMC5883L 3-axis digital magnetometer • BMP085 digital pressure sensor	$47
3DR Pixhawk	• Pixhawk Flight Controller	$200

	• 3DR Power Module with XT60 and connector cable • Fully Autonomous Operations when using GPS • Mission Planner Ground Station • Safety Failsafes	

The final comparison was done between APM 2.8 and 3DR Pixhawk as both the controllers are capable of autonomous flying, the the results are tabulated as follows:

Feature/Characteristic	**Generic APM 2.X**	**3DR Pixhawk**	**Comment**
Size/Weight	Small	Larger	APM is available in 35x35x5 mm board. Pixhawk is 81x50x16 mm
Cost	Low	Higher, about 4X	APM with GPS ~$65
Quality	Variable	Better	Inspect a generic APM after you get it for poor soldering, loose USB..
Support	Good	Good	The best support is from peers on DIYdrones and APM forums
Flight Stability	Good	Good	
Accuracy	Good	Better	Pixhawk GPS is more accurate, Pixhawk has a more powerful processor and more memory
Onboard indicators	Poor	Good	Pixhawk has multiple LEDs and tones to tell you status, APM has a few LEDs
Ease of Setup	Moderate	Moderate	More components to interconnect on Pixhawk, but well documented. Cables and connectors often an issue with APM and documentation must be found on the Internet.
Ability to fly autonomous missions	Yes	Yes	
Mission Planner Ground Station Compatibility	Yes	Yes	
Flight logging Capability	Good	Better	Pixhawk logs more information and has a microSD for storage. APM has limited storage of most important variables.

Upgradeability	None	Yes	APM code is now frozen, but Pixhawk software with improvements still being released
Debugging difficulty	Good	More difficult	APMs seem to always work, Pixhawk is more finicky about ESCs, setup, etc.

APM 2.X works well with drones of smaller sizes and limited performance and features, but PixHawk is said to work with high performance drones, so, PixHawk was selected as the final choice for building the drone.

3.2 Pixhawk

3.2.1 Specifications

- **Processor**
  - 32-bit ARM Cortex M4 core with FPU
  - 168 Mhz/256 KB RAM/2 MB Flash
  - 32-bit failsafe co-processor
- **Sensors**
  - MPU6000 as main accel and gyro
  - ST Micro 16-bit gyroscope
  - ST Micro 14-bit accelerometer/compass (magnetometer)
  - MEAS barometer
- **Power**
  - Ideal diode controller with automatic failover
  - Servo rail high-power (7 V) and high-current ready
  - All peripheral outputs over-current protected, all inputs ESC protected
- **Interfaces**
  - 5x UART serial ports, 1 high-power capable, 2x with HW flow control
  - Spektrum DSM/DSM2/DSM-X Satellite input
  - Futaba S.BUS input (output not yet implemented)
  - PPM sum signal
  - RSSI (PWM or voltage) input
  - I2C, SPI, 2x CAN, USB
  - 3.3 and 6.6 ADC inputs
- **Dimensions**
  - Weight 38 g (1.3 oz)
  - Width 50 mm (2.0”)
  - Height 15.5 mm (.6”)
  - Length 81.5 mm (3.2”)

3.2.2 Basic Connections

The most important peripherals of the Pixhawk can be connected using the following wiring chart:

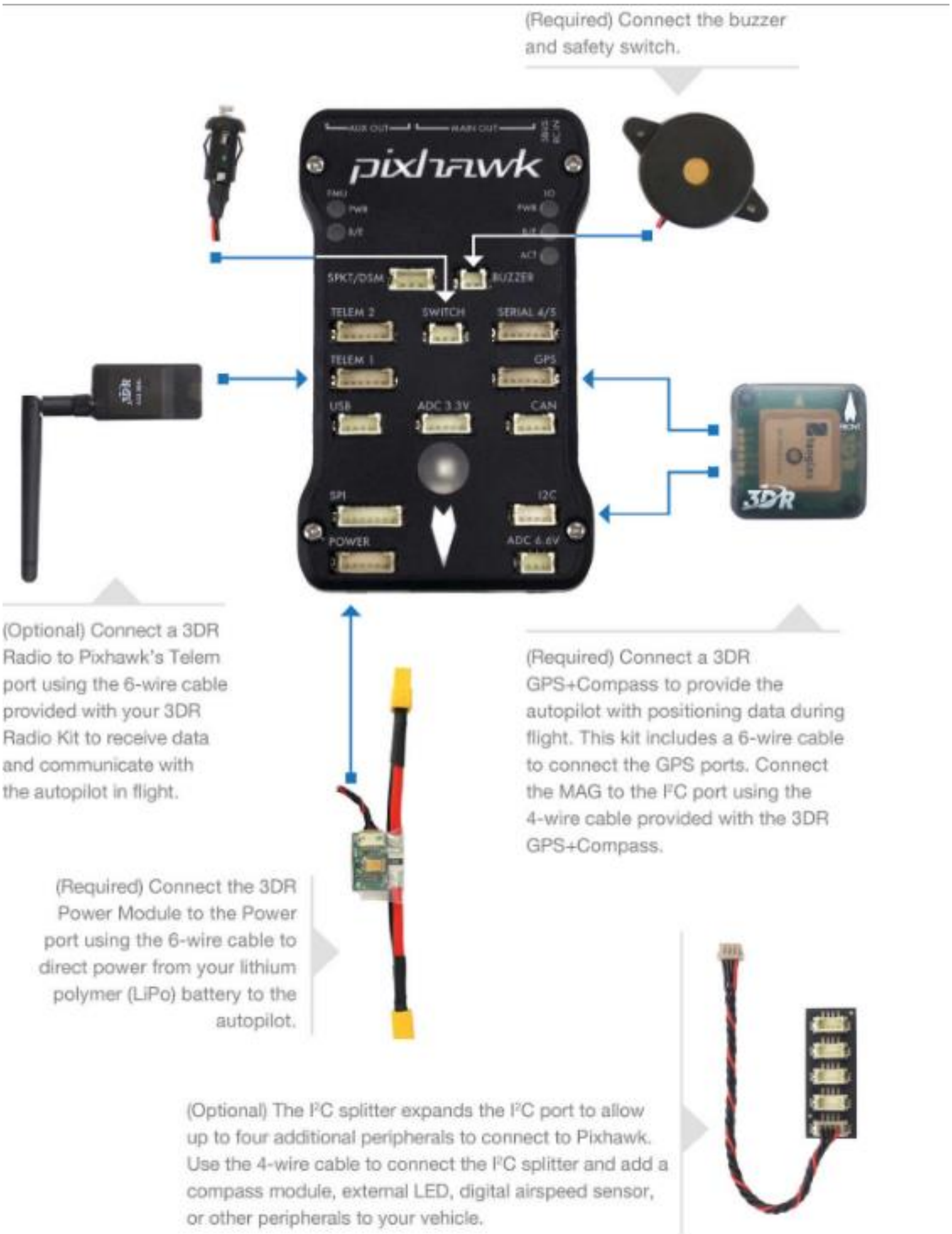


Image Source: Pixhawk

Connect the signal wires from the ESCs to the respective ports on the Pixhawk numbered as:

- Motor 1 → Pin 1

- Motor 2 → Pin 2
- Motor 3 → Pin 3
- Motor 4 → Pin 4
- Motor 5 → Pin 5
- Motor 6 → Pin 6
- Motor 7 → Pin 7
- Motor 8 → Pin 8

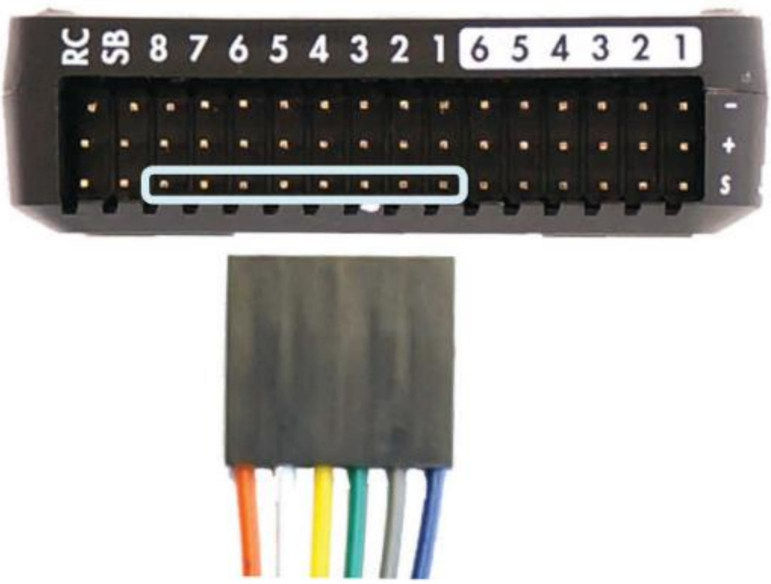


Image Source: Pixhawk

3.2.3 Powering the Pixhawk

The recommended way of powering the Pixhawk is using the 3DR power module. It is connected to the power port of the Pixhawk and provides a regulated 5V supply to it and allow the Pixhawk to measure the current/voltage of the main battery.

Pixhawk Power Port

Image Source: Pixhawk

The block diagram shown below gives an overview of the Pixhawk wiring with the power supply and the ESCs. In this diagram, a 3DR power module (or equivalent device) powers Pixhawk through its power port (primary source). One power source is enough but obviously not redundant if the power module fails to power this primary source. Therefore the diagram adds a second backup power source via a 5V BEC that wires to Pixhawk's output servo rail. If the primary source fails, Pixhawk will automatically switch to this second power source.

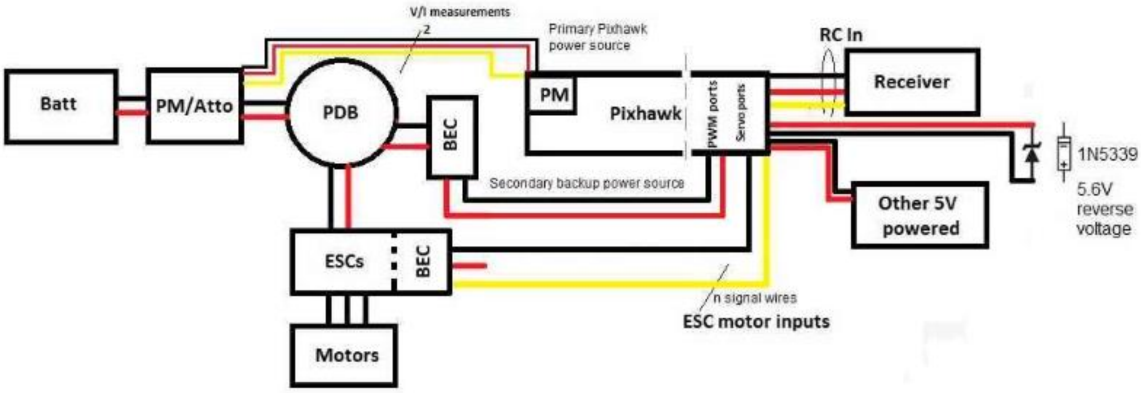


Image Source: RC Drone Good

Diagram Acronyms:-

- PDB = *Power Divider Board*
- PM = *Pixhawk Power Port*
- PM/Atto = *Recommended power module from 3DR*

3.3 Motors

3.3.1 Types of Motors

There are two kinds of motors that can be used for a drone: Brushed DC motors and Brushless DC motors. The basic principles of both the motors are discussed below.

Brushed DC Motor

In a brushed motor the winding's of the motor are fixed onto the shaft inside the case and spin when the current is supplied to the motor. The magnets inside the motor don't move and power is supplied to the motor winding's via the positive and negative brushes that push against the commutator on the shaft.

Brushless DC Motor

In a brushless motor there is no commutator or brushes, as the design basically turns the motor inside out, changing the way that the current uses the magnets to push the shaft so that it rotates

The pros and cons of both the motors are discussed below:

Motors	Pros	Cons
Brushed DC Motors	• Brushed motors may be re-buildable for extended life • Brushed motors operate in extreme environments due to lack of electronics • Brushed motors are cheaper to produce and buy • The wiring of brushed motors is simpler as they only have two wires to power them and they don't require any electronic commutation which means that you can use less complicated and less expensive Electronic Speed Controllers (ESC)	• The brushes and commutator must be cleaned periodically and eventually will wear out • Friction from the brushes will cause the motor to slow down, will lower the power to weight ratio and will result in shorter battery life which means shorter flight times • Brush arcing will generate noise causing electrical magnetic interference (EMI)
Brushless DC Motors	• Brushless motors are much more efficient than conventional brushed motors • Brushless motors do not have brushes or commutator that require maintenance or replacement which also increases the lifetime of the motor. • Brushless motors generate less noise causing electrical magnetic interference (EMI) • There is no friction being generated by brushes to slow the motor down which means that you have a better power to weight ratio, longer battery life and flight times and possibly higher speeds.	• Brushless motors are more expensive to produce and buy • The wiring of brushless motors is more complicated as they only have at least three wires to power them and they require electronic commutation which means that more complicated and expensive Electronic Speed Controllers (ESC) must be used.

3.3.2 Parameters for Brushless DC motors

Keeping in mind all the pros and cons of both the motors, brushless DC motor was selected for the drone. The specifications of a brushless DC motors can be described using the following terms:

1. **kV Ratings** – The RPM of the motor per volt with no load. Using a brushless motor with a kV rating of 1100 and 11V take the 1100, multiply by 11 to get 12,100 RPMs. This is the maximum RPMs that this motor can reach under no load.
2. **Motor Turns** – The number of wire windings around each of the motor's rotor poles.
3. **Current Rating (Amps)** – The maximum current rating is the maximum amount of current that a motor is able to handle safely. This current is measured in Amps. The continuous current rating of a motor is the Amps that a motor can handle safely over a long period of time.
4. **Watts** – The power rating or the horsepower equivalent of your brushless RC Motor..
5. **Motor Efficiency** – The more efficient the motor the more power it can produce before it overheats. An 80% efficient motor produces 80% power and 20% heat.

With multi rotors its important to make sure that the motors can produce around 50% more thrust than the total weight of the drone.

3.3.3 Motor Specifications

The motor used for the current project have the following specifications:

- Rpm/V: **1000kv**
- Shaft: **3.17mm**
- Voltage: **2S~4S (7.4v to 14.8v)**
- Weight: **52g**
- Watts: **210w**
- Max Current: **21A**
- ESC: **30A**
- Suggested Prop: **8x4 (4S) ~ 10x7 (2S)**
- Mounting Hole Bolt Circle: **16mm or 19mm**

Image Source: Hobby King

3.3.4 Motor Connections

The motors for the drone should be connected in the order shown:

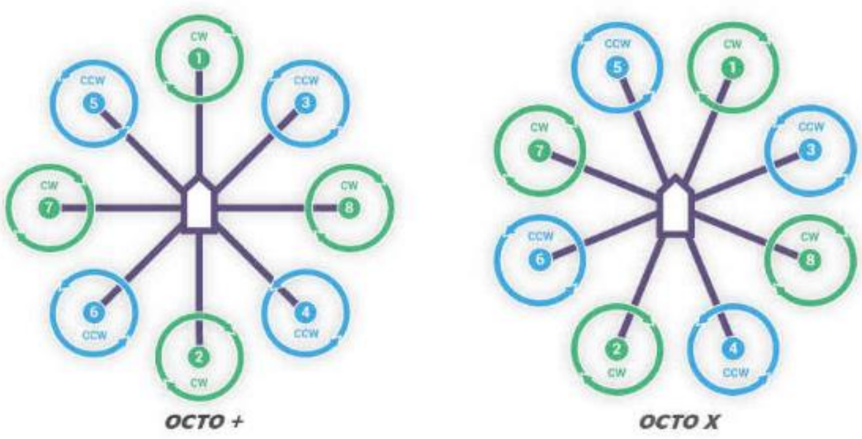


Image Source: Pixhawk

The two types of propellers namely clockwise and counter clockwise can be distinguished using the diagram shown below:

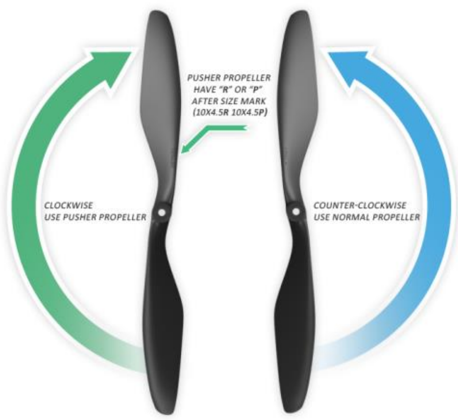


Image Source: Pixhawk

3.4 Electronic Speed Controllers

An electronic speed controller is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly act as an dynamic brake. Brushed ESCs are different from brushless ESCs.

Brushless ESCs are used for the project, since brushless DC motors have been used. Brushless ESC systems basically create a tri-phase AC power output of a limited voltage from a DC power source, to run brushless motors through a sequence of AC signals generated from the ESC‘s circuitry, employing a very low impedance for rotation.

Most modern ESCs incorporate a battery eliminator circuit (or BEC) to regulate voltage for the receiver, removing the need for separate receiver batteries. BECs are usually either linear or switched mode voltage regs in the broader sense are PWM controllers for electric motors. The ESC generally accepts a nominal 50 Hz PWM servo input signal whose pulse width varies from 1 ms to 2 ms. When supplied with a 1 ms width pulse at 50 Hz, the ESC responds by turning off the motor attached to its output. A 1.5 ms pulse-width input signal drives the motor at approximately half-speed. When presented with 2.0 ms input signal, the motor runs at full speed.

3.4.1 Selection parameters for ESCs

The following parameters are used to select a suitable ESC for a drone:

- **Maximum Ampere Rating:** The maximum current the ESC can handle should exceed the demands placed on it under peak conditions by all of the components connected to it.
- **Refresh Rate:** Flight controllers send signals to ESCs at a frequency of around 400Hz. So, ESCs selected should have refresh rates higher than this, so that the motors can respond the best to all the signals sent by the controller.
- **Firmware:** An ESC with appropriate firmware installed should be selected. The different types of firmware available are Traditional/Standard, SimonK and BLHeli.

3.4.2 Specifications

The ESC selected has the following features:

- Extremely low internal resistance
- Super smooth and accurate throttle linearity
- Over heat and over-load protection
- Auto shut down when signal is lost or radio interference becomes severe for more than 2 seconds
- Supports high RPM motors
- Power arming protection (prevents the motor from accidentally running when switched ON)
- New Advanced programming software

The specifications for the ESC are:

- Cont. Current: 30A
- Burst Current: 40A
- Battery: 2-4 Cell Lipo / 5-12 Cell Ni-XX
- SBEC: 5V/ 3A Output
- Size: 25*43*9mm
- Weight: 28g

The programming features include:

- Brake setting (we recommend using brake for only folding props applications)
- Battery type(LiPo or NiCd/NiMh)
- Low voltage cutoff setting
- Factory default setup restore
- Timing settings (to enhance ESC efficiency and smoothness)
- Soft acceleration start ups (for delicate gearbox and helicopter applications)
- Governor mode(for helicopter applications)
- Motor rotation(clockwise\counterclockwise)
- Switching frequency

- Low voltage cutoff type (power reduction or irnmediate shutdown)

The factory default settings are:

- Brake: off
- Battery type Detect: LiPo with Automatic Cell
- Low voltage cutoff threshold: Medium (3.0V/65%)
- Timing setup: Automatic
- Soft Acceleration Start Up: Medium
- Governor mode : OFF
- Frequency : 8kHz
- Low voltage cutoff type: Reduce power

Image Source: Hobby King

3.4.3 Connection of ESC

One end of the ESC is connected to the power divider board, which is connected to the battery. The other end has two connectors. One of them is connected to the Pixhawk where it is plugged into the appropriate channel for the motors. The other connector is connected to the motors. The three terminals of the ESC are connected to the three terminals of the motor in any particular order. After connecting the motor, the direction of the motor should be checked by connecting the ESC with a power supply. If the direction of motor is not appropriate, the connection of any two out of the three wires should be reversed.

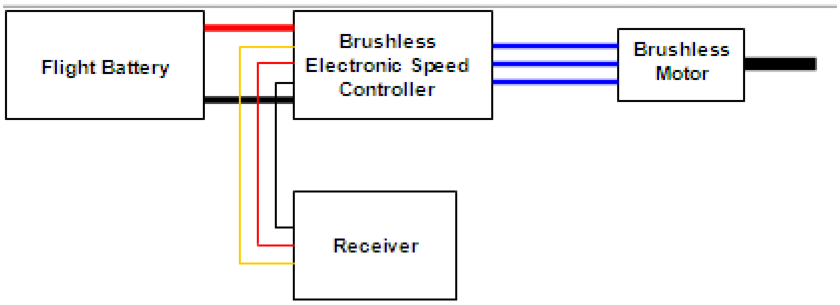


Image Source: Hobby King

Each of the 8 ESCs are connected to a power divider board, which is basically a parallel connection of all ESCs to the main power supply. The EAGLE schematic and layout for the board is shown below:

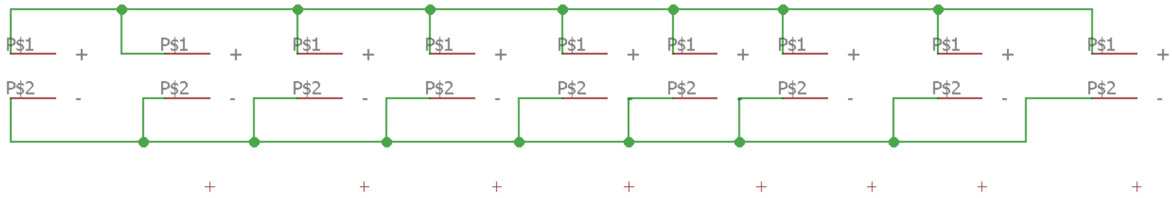


Figure: Schematic of the Power Distribution Board designed on EagleCAD

Figure: Layout of the Power Distribution Board designed on EagleCAD

3.5 Transmitter and Receiver

3.5.1 Transmitter and Receiver Specifications

The transmitter used in this project is a Spektrum DX6i 6 channel 2.4 GHz DSMX Aircraft System. It uses a wideband, frequency agile 2.4 GHz signal protocol. It has superior data quality and interference resistance for a wideband signal with the agility of frequency shifts.

The receiver used for this project is an Orange R615X 2.4GHz 6 channel receiver compatible with the transmitter described above.

3.5.2 Features of Spektrum DX6i Transmitter

- 10-model memory
- 1500mAh NiMH AA battery
- 150mA wall charger
- 2 programmable mixes

- Digital trims with dual speed trim scroll
- DSMX® technology
- ModelMatch™ technology
- ServoSync™ technology
- Airplane and helicopter programming
- Exponential throw
- Model copy
- Programmable dual rates
- Servo monitor
- Sub Trim
- Throttle cut
- Trainer mode
- Travel adjust
- 2-position flap
- 2 swash types 1 servo/3 servo CCPM
- 3 wing types
- 5-point graphic throttle curve
- Contrast adjustment
- Differential
- Graphic pitch curve
- Gyro adjust: normal, stunt & hold
- Integrated timer
- Revolution mixing
- Roller/selector-user interface
- Servo reverse
- Compatible with any existing DSM2® and DSMX receivers

Image Source: Hobby King

3.5.3 Channels

The 6 channels of the transmitter-receiver kit are:

1. Throttle
2. Aeileron

3. Rudder
4. Elevation
5. Gear
6. Auxillary

Roll/Aileron – Done by pushing the right stick to the left or right. Literally rolls the drone, which maneuvers the drone left or right.

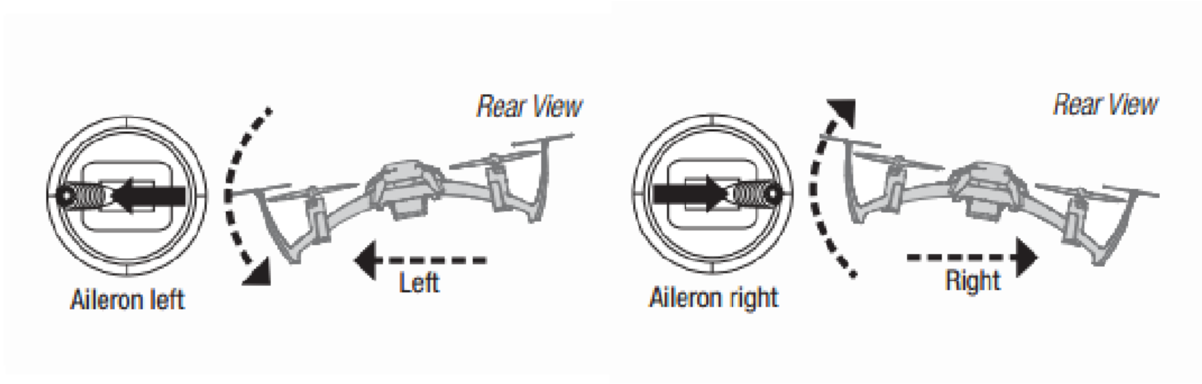


Image source: Best Quadcopter Spot

Pitch/Elevator – Done by pushing the right stick forwards or backwards. Tilts the drone, which maneuvers the drone forwards or backwards.

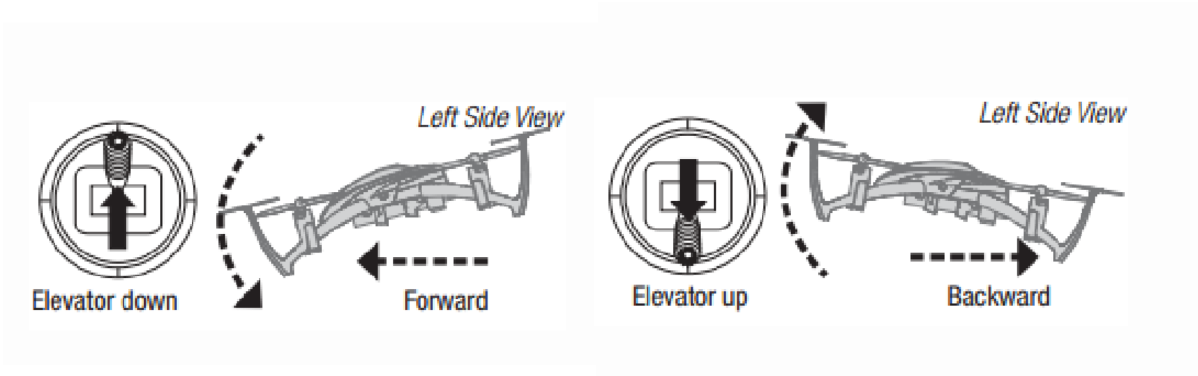


Image Source: Best Quadcopter Spot

Yaw/Rudder – Done by pushing the left stick to the left or to the right. Rotates the drone left or right. Points the front of the copter different directions and helps with changing directions while flying.

Throttle – Engaged by pushing the left stick forwards. Disengaged by pulling the left stick backwards. This adjusts the altitude, or height, of the drone.

Trim – Buttons on the remote control that help you adjust roll, pitch, yaw, and throttle if they are off balance.

By selecting modes in the transmitter, the different sticks can be used to control different channels.

3.5.4 Binding Steps for Transmitter and Receiver

Binding the transmitter and receiver is a tricky process. For binding, connect the ESC to any one of the channels of the receiver and provide a power supply with a voltage of 5V in order to power up the receiver. Connect the bind plug to the Bat/Bind port.

The sequence for binding should be

1. TX off and RX off.

2. Add bind plug to left most pins (Battery / Bind)

3. Switch on power to RX, RX light should blink rapidly.

4. With Bind switch pulled / pressed, power on the TX.

5. RX blinking light slows then goes solid on after ~15 seconds.

6. Bind complete. Remove bind plug from RX.

7. Power off RX.

8. Power off TX.

9. Power on TX and RX (with out bind plugs and switches) to check bind. Solid RX light indicates good bind.

While switching on the TX make sure that the throttle switch is pulled straight to the highest point and there is no other control that is activated. While binding, if the binding switch goes solid off instead of solid on, check that if the throttle is pulled straight. Any deviation in the throttle stick can cause improper binding.

3.5.5 Connecting the Receiver to Pixhawk

The receiver should be connected to Pixhawk to the RC In port, keeping in mind the polarity of the connections. The top line in Pixhawk is negative. If not connected in the correct way, the board can be spoit.

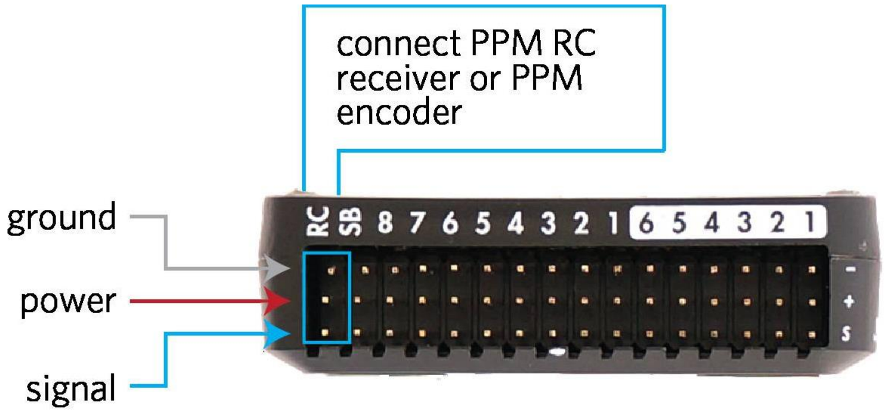


Image Source: Pixhawk

While calibrating the receiver in the Mission Planner IDE, if there are no green bars showing the values of the various channels of the transmitter, it means that proper connection has not been established between either Pixhawk and the receiver or the transmitter and receiver.

The drone uses the following components:

1. 3DR Pixhawk Kit
2. HobbyKing X930 Glass Fiber Octocopter Frame 895mm
3. Turnigy D2830-11 1000kv Brushless Motor
4. HobbyKing 30A BlueSeries Brushless Speed Controller
5. Spektrum DX6i 6-Kanal Full Range DSMX 2,4GHZ
6. OrangeRx R615X DSM2/DSMX Compatible 6Ch 2.4GHz Receiver w/CPPM
7. 4mm Gold Connectors 10 pairs
8. Turnigy B6 Compact 50W 5A Automatic Balance Charger 2~6S LiPoly
9. Turnigy 5800mAh 6S 25C LiPo Pack
10. Quanum Carbon Fiber Propeller 10x4.7 (CW/CCW)
11. uBlox GPS with compass

4 Calculations

4.1 Weight Calculation

The following table gives the approximate weight of the drone:

S.No	**Component**	**Weight**	**Quantity**	**Total Weight**
1	Turnigy D2830-11 1000kv Brushless Motor	52g	8	416g
2	HobbyKing 30A BlueSeries Brushless Speed Controller	28g	8	224g
3	Turnigy 5800mAh 3S 25C LiPo Pack	400g	2	800g
4	3DR Pixhawk Kit	100g	1	100g
5	HobbyKing X930 Glass Fiber Octocopter Frame 895mm	1000g	1	1000g
6	uBlox GPS with compass	30g	1	30g
7	Go – Pro Camera	50g	1	50g
8	Others(approximate)	500g		500g
	TOTAL			**3120g**

Maximum weight carried by each motor = 900g

Total payload capacity = 8 x 900g = 7200g

4.2 Current Calculation

Current through each motor = 21A

Maximum current through the Electronic Speed Controller = 30A

Maximum current entering the power distribution board (at full throttle) = 8 x 30A = 240A

Width of the traces on the power distribution board = 10 mm

Actual current reading at full throttle = 100A

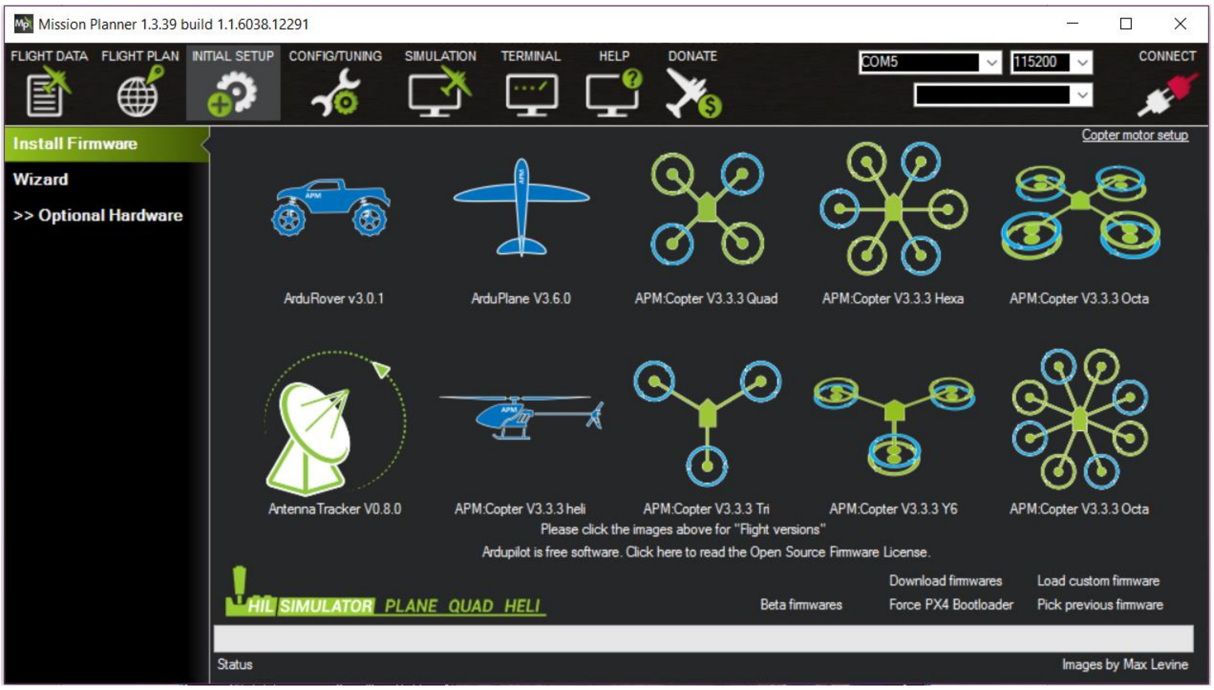
4.3 Cost Calculation

S. No.	**Component**	**Quantity**	**Total Cost**
1	3DR Pixhawk Kit (2.4) [9A012.b.2]	1	214.99
2	HobbyKing X930 Glass Fiber Octocopter Frame 895mm (EU Warehouse)	1	37.33
3	Turnigy D2830-11 1000kv Brushless Motor (EU Warehouse)	8	78.24
4	HobbyKing 30A BlueSeries Brushless Speed Controller (EU Warehouse)	8	92.24
5	Spektrum DX6i 6-Kanal Full Range DSMX 2,4GHZ	1	89.9
6	OrangeRx R615X DSM2/DSMX Compatible 6Ch 2.4GHz Receiver w/CPPM	1	10.34
7	4mm Gold Connectors 10 pairs (20pc)	2	5
8	Turnigy B6 Compact 50W 5A Automatic Balance Charger 2~6S Lipoly (EU Warehouse)	1	13.88
9	Turnigy 5800mAh 6S 25C Lipo Pack (EU Warehouse)	2	131.2
10	Quanum Carbon Fiber Propeller 10x4.7 (CW/CCW) (2pcs)	8	48.72
11	uBlox GPS with compass [7A994]	1	84.99
12	HKPilot Transceiver Telemetry Radio Set V2 (433Mhz)	1	37.2
			844.03

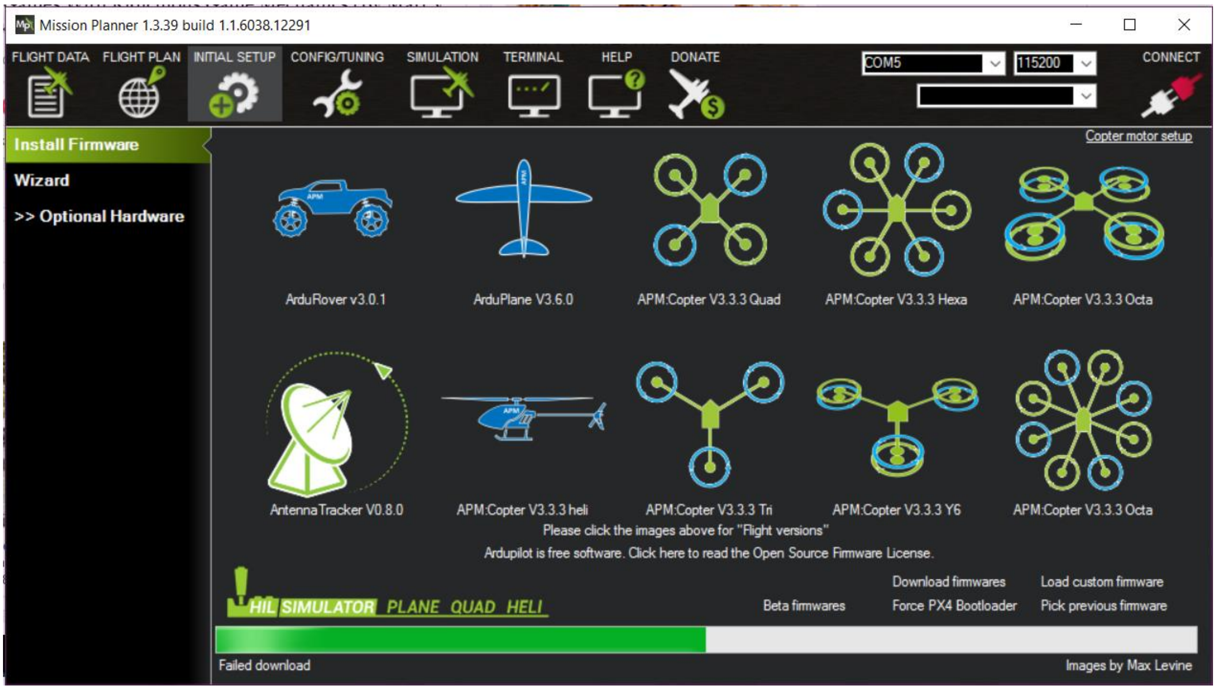
5 Calibration of Pixhawk

5.1 Installation of Firmware

Click on Initial Setup and Select Install Firmware from the menu on the left hand side.



Select the appropriate frame type and follow the instructions on the screen



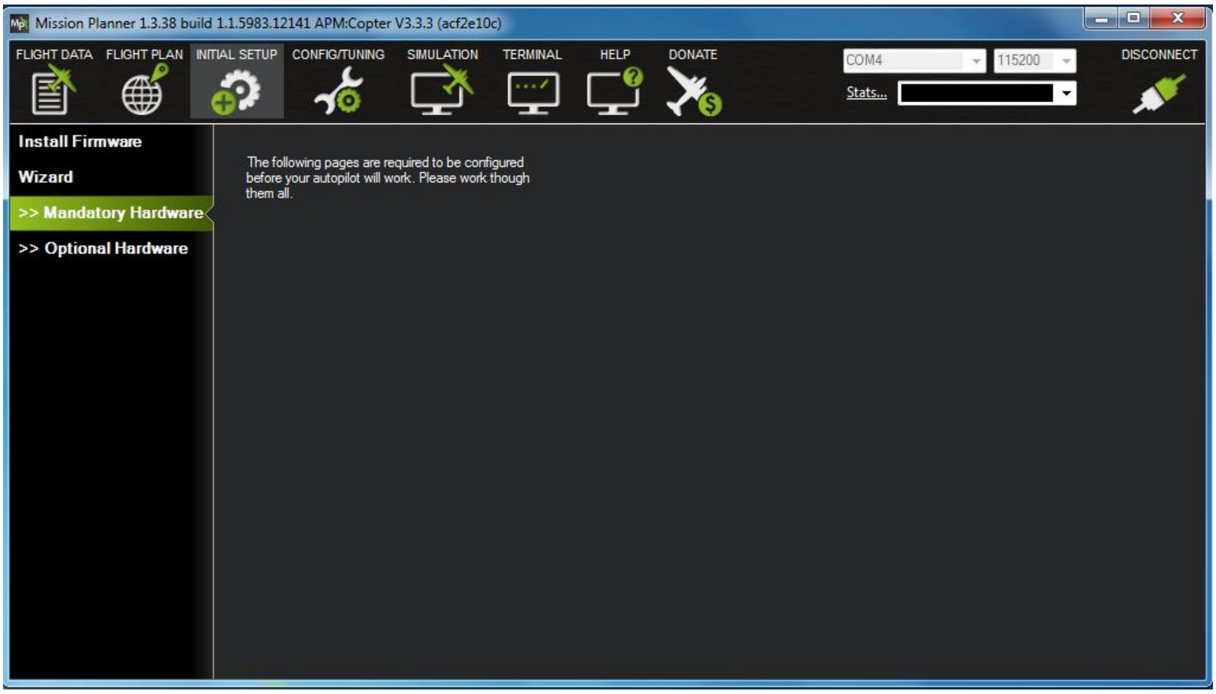
5.2 Initial Setup

Open Mission Planner. The basic flight data should appear on the screen.

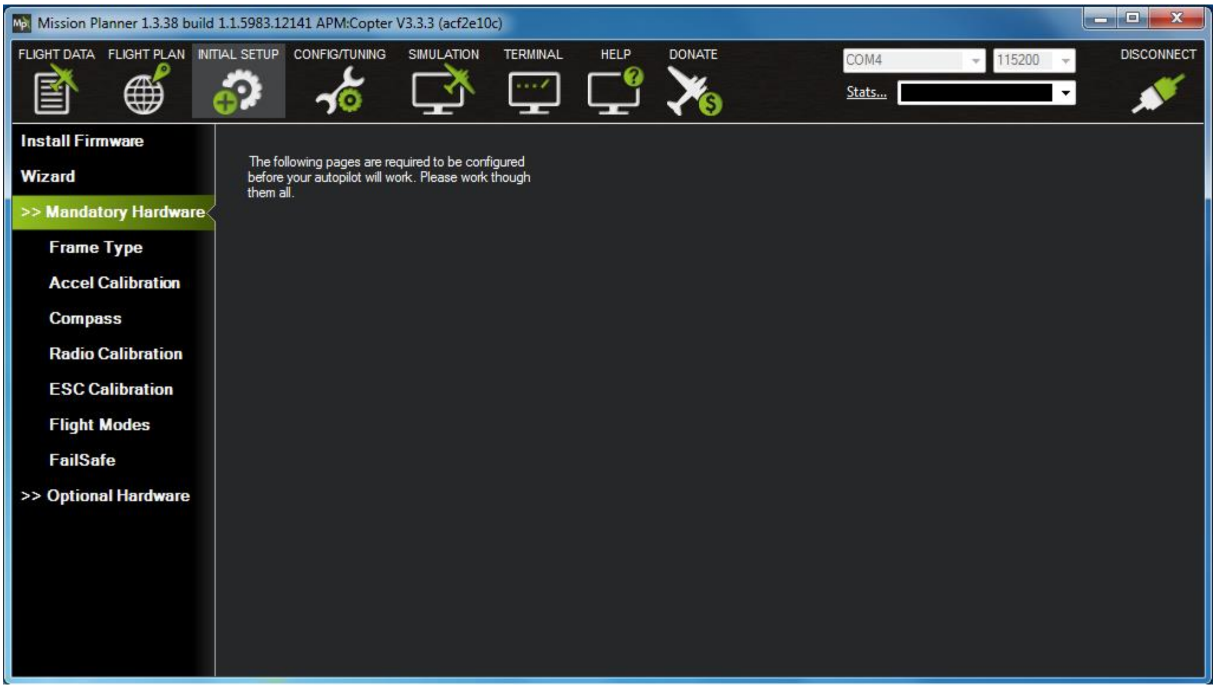
On the top right corner, select the suitable COM port and set the baud rate as 115200 and click on CONNECT.

After the board is connected, the values of the Altitude, Ground Speed, Yaw, Vertical Speed etc should change as the board is moved from its position.

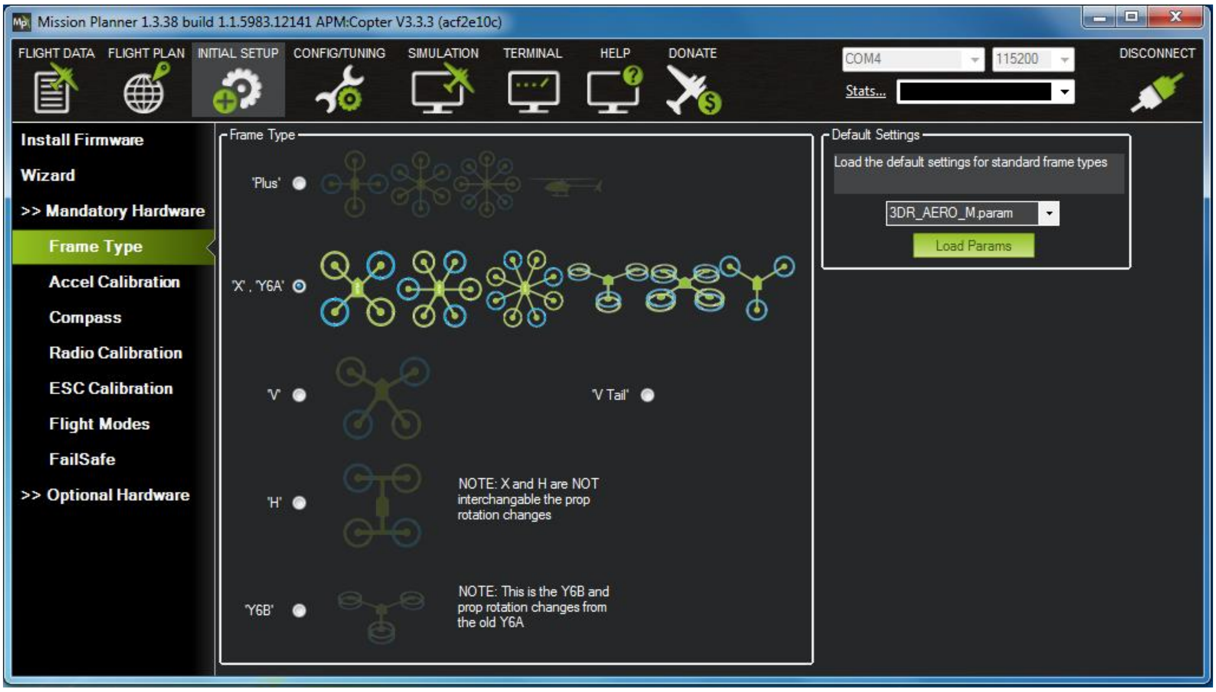
Click on Initial Setup in the top menu and select Mandatory Hardware from the menu on the left hand side.



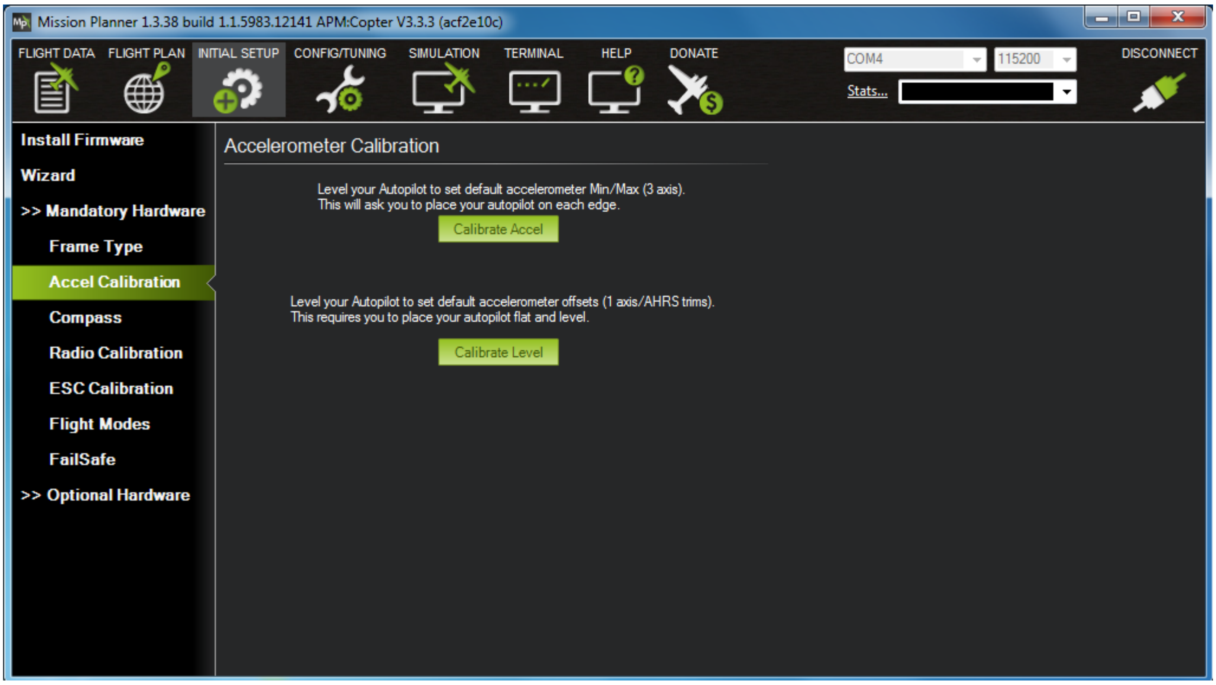
Click on Mandatory Hardware to see the Drop down menu.



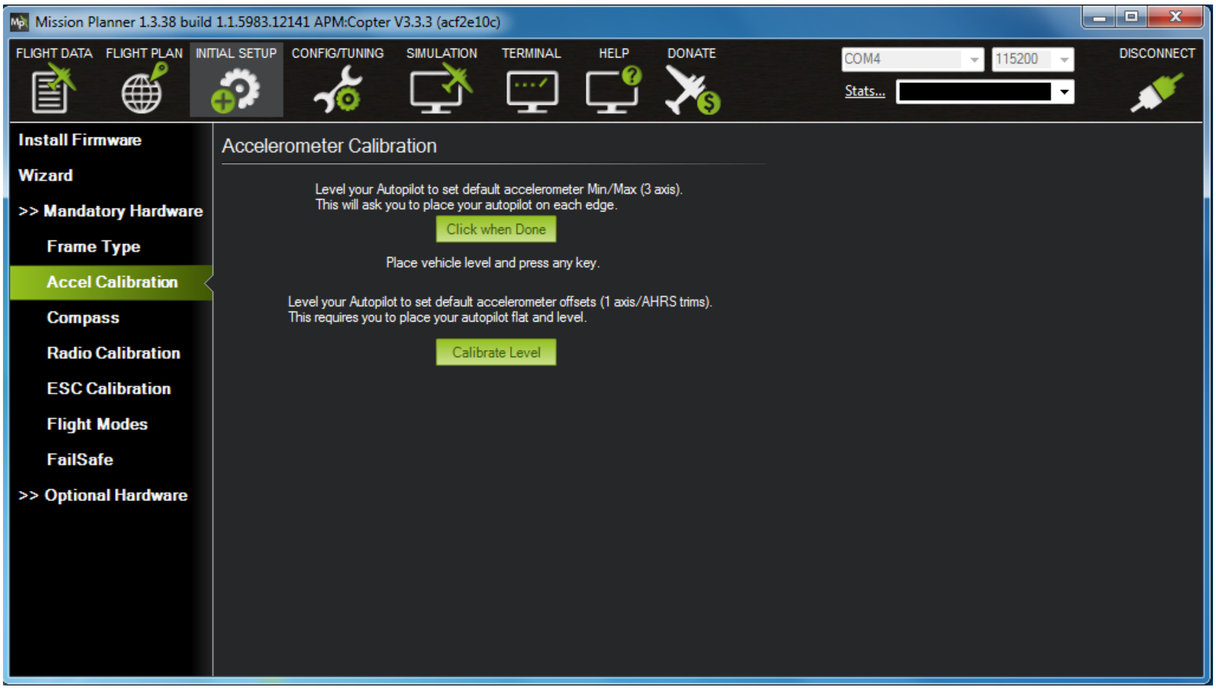
Select the suitable frame type. In this case an Octo – X frame is used, so the suitable option was selected.



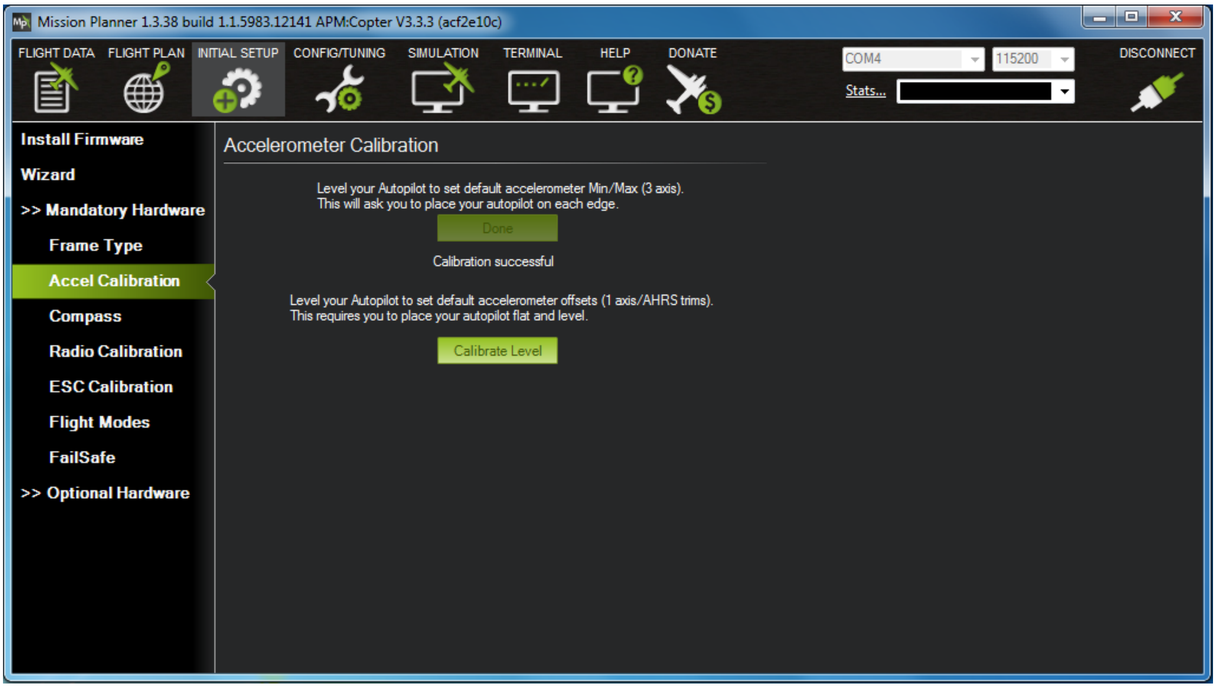
Click on Accel Calibration to calibrate the accelerometer.



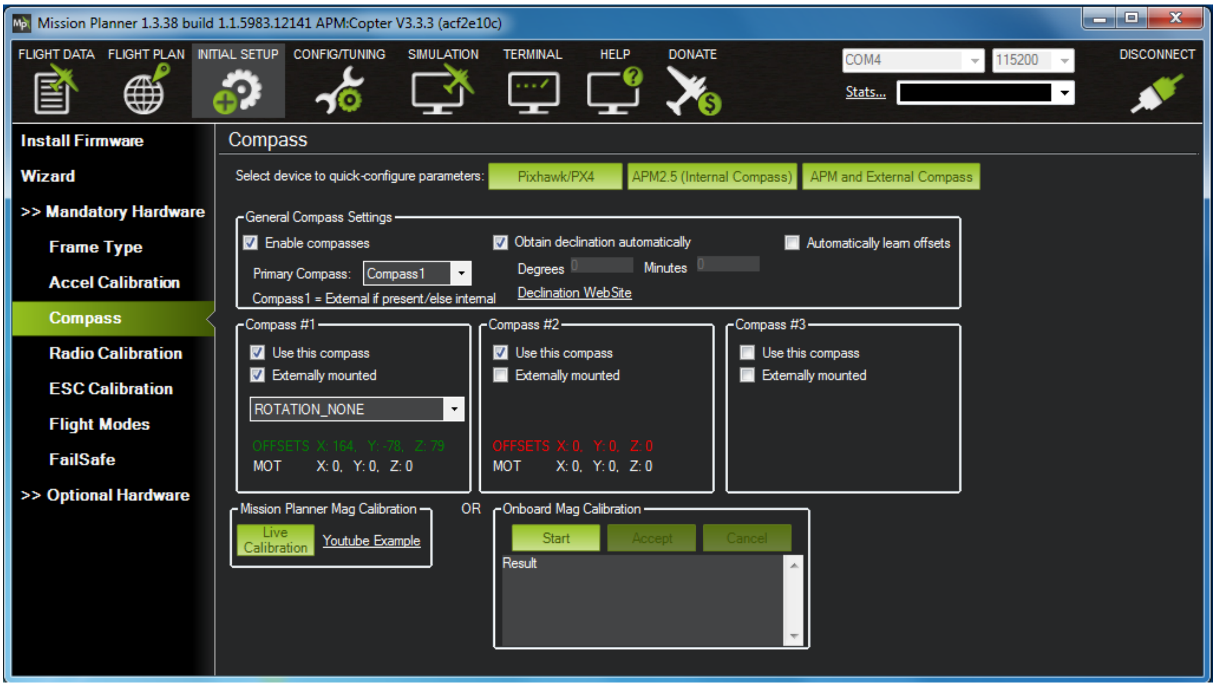
Click on Calibrate Accel and follow the instructions on the screen.



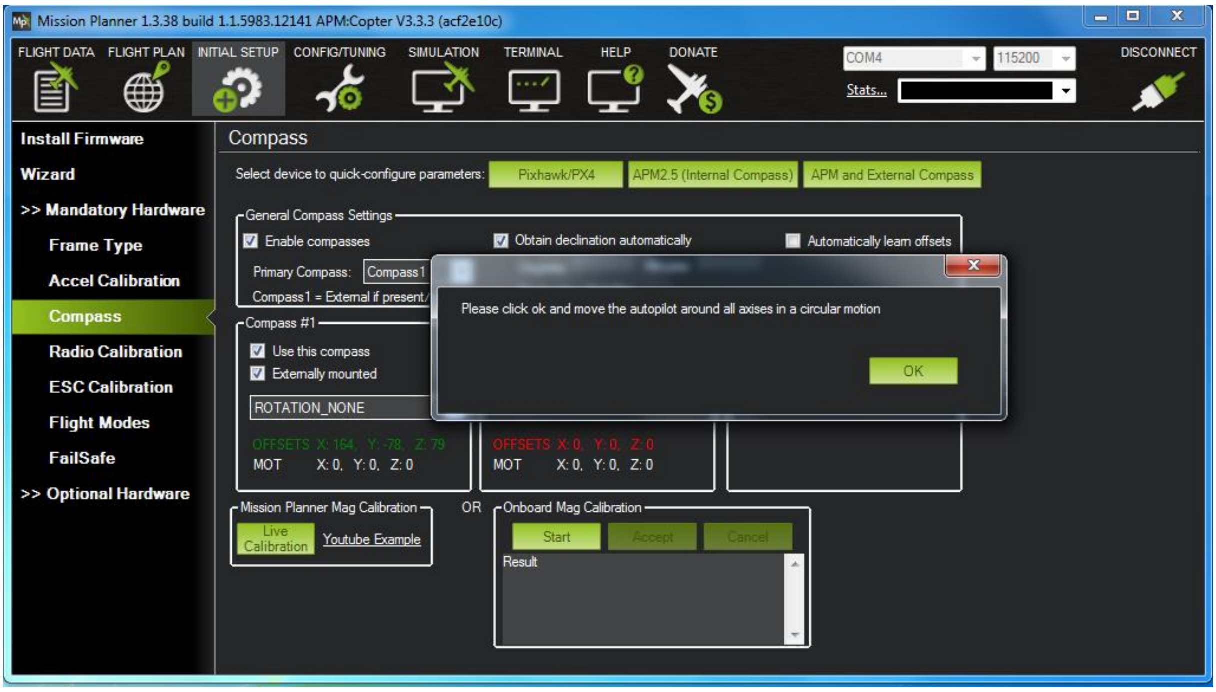
When asked to place the vehicle on the left, right, nose up, nose down and on its back, use a set square to ensure that the board is perfectly perpendicular to the surface and there is no movement of any kind. Otherwise, it results in a failed calibration.



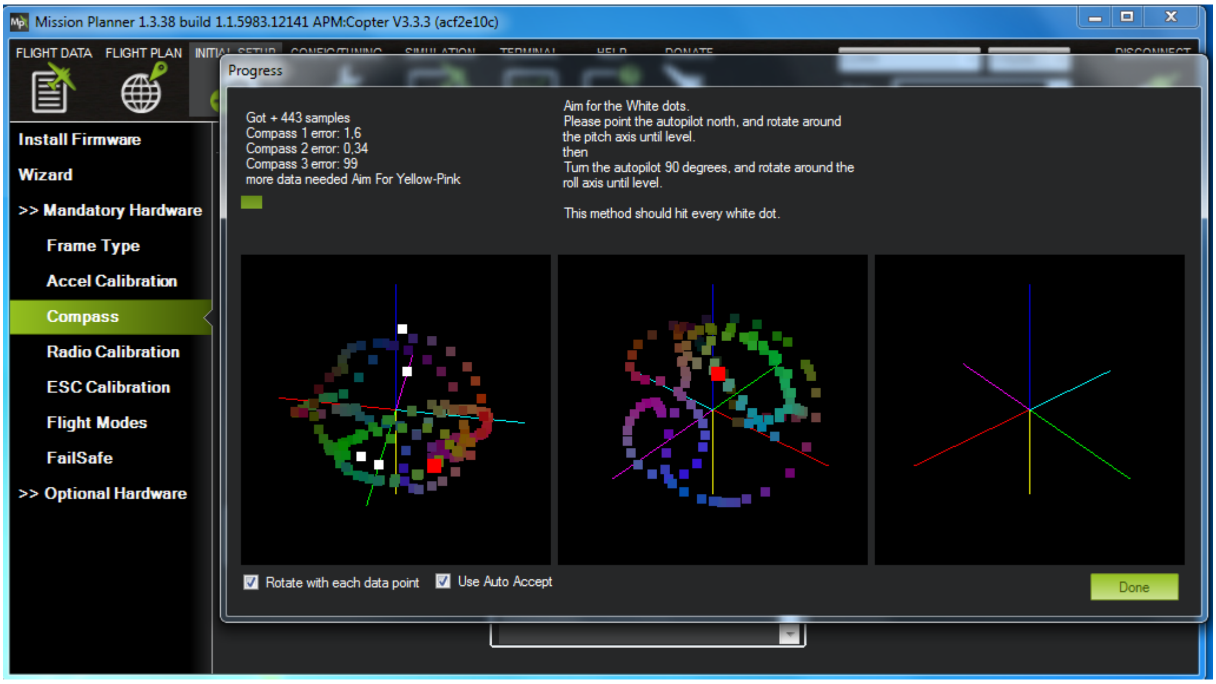
Click on compass to calibrate the inbuilt magnetometer and the magnetometer with the GPS module.



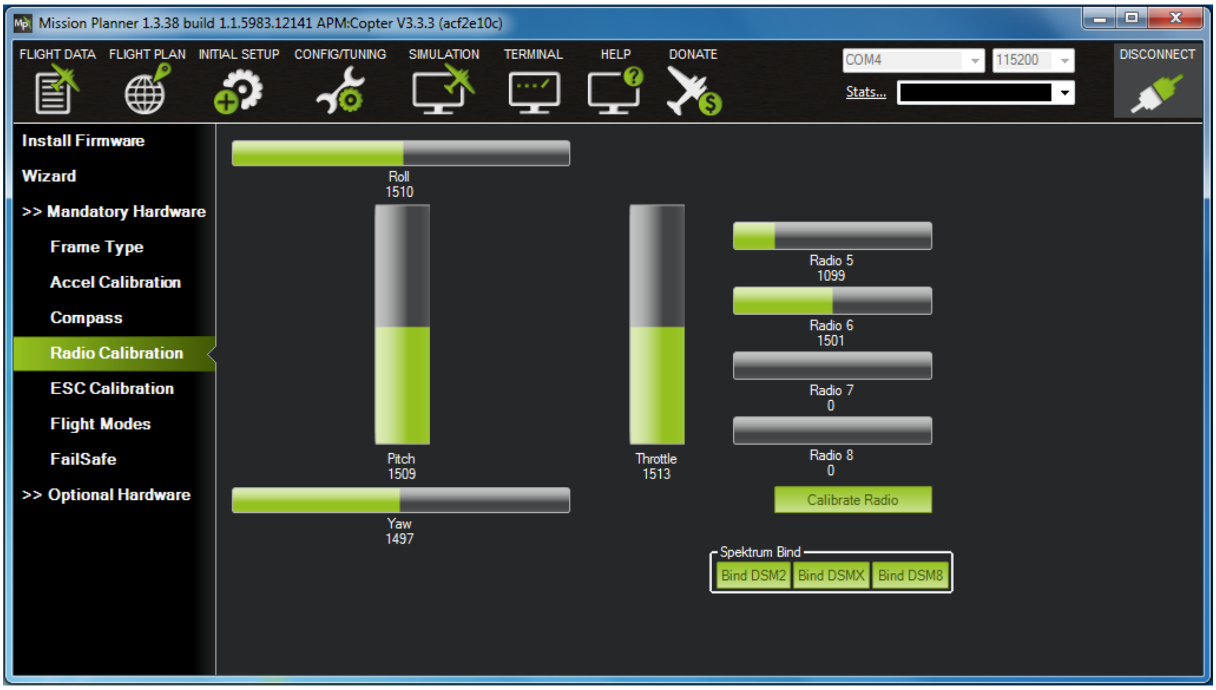
Click on Live Calibration and follow the instructions on the screen.



Move the board along all six axes until all the white dots are eliminated and sufficient number of samples are collected in all directions. For this step, ensure that the Pixhawk and the GPS module and fixed on a platform with their noses pointing in the same direction, so that both the modules can be moved together.

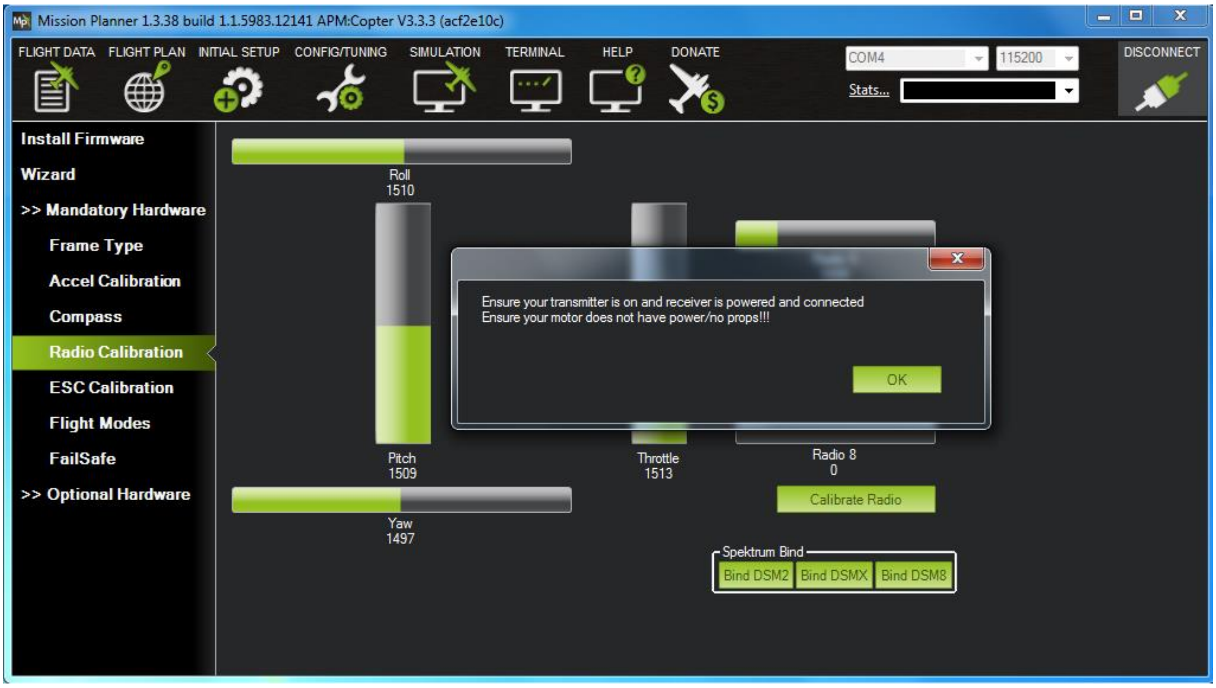


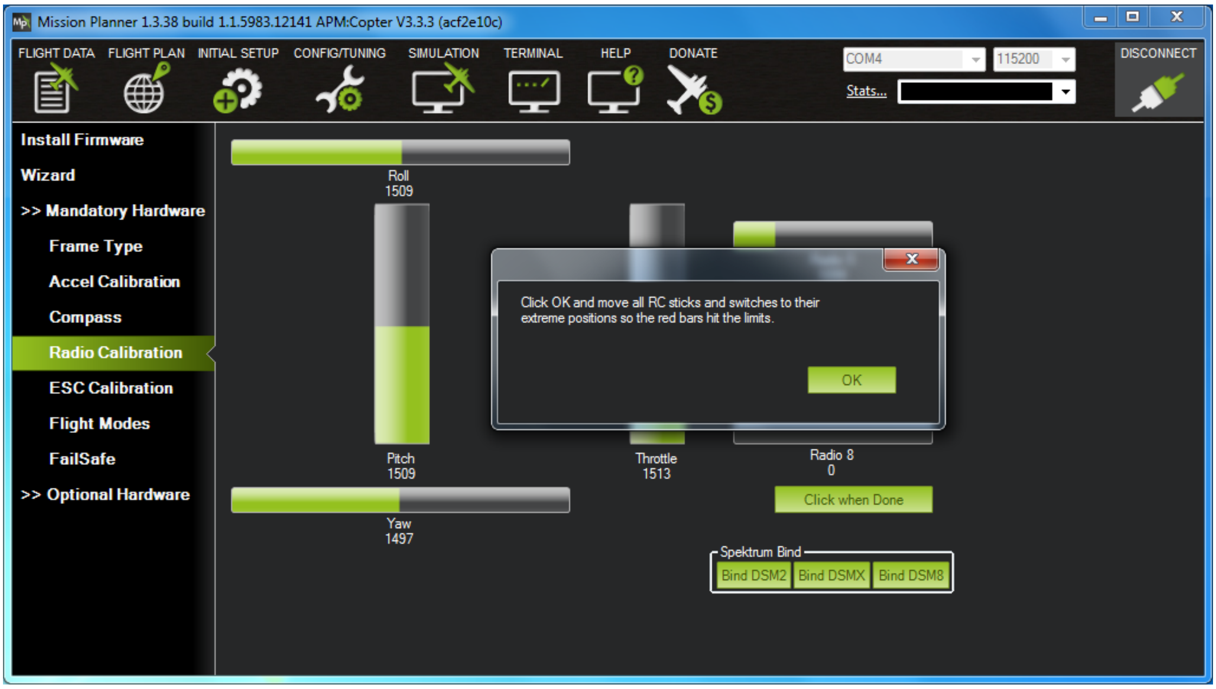
Click on radio calibration. Ensure the the transmitter and receiver are in a stable bind condition before performing this step.



If the bars for the different channels are not filled up with green, it means that there is a communication problem between either the transmitter and receiver or the receiver and the Pixhawk.

If the green bars appear, click on Calibrate Radio and follow the instructions on the screen.

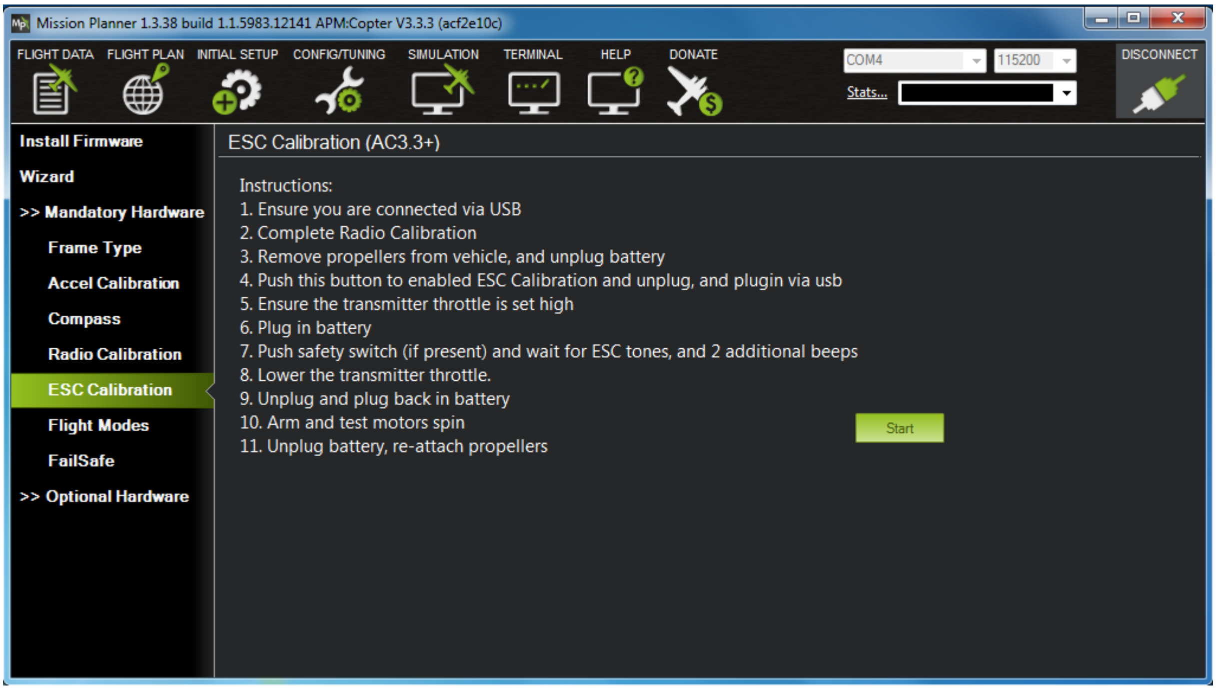




While doing this step, make sure that the green bars move in the same direction as the sticks of the transmitter. If they do not move in the same direction, reverse that particular channel from the transmitter menu.

After this step is done, the controller records the maximum and minimum value of each channel.

Click on ESC calibration and follow the instructions on the screen.


Mission Planner 1.3.38 build 1.1.5983.12141 APM:Copter V3.3.3 (acf2e10c)
FLIGHT DATA
FLIGHT PLAN
INITIAL SETUP
CONFIG/TUNING
SIMULATION
TERMINAL
HELP
DONATE
COM4
115200
Stats...
DISCONNECT
Install Firmware
Wizard
>> Mandatory Hardware
Frame Type
Accel Calibration
Compass
Radio Calibration
ESC Calibration
Flight Modes
FailSafe
>> Optional Hardware
ESC Calibration (AC3.3+)
Instructions:
1. Ensure you are connected via USB
2. Complete Radio Calibration
3. Remove propellers from vehicle, and unplug battery
4. Push this button to enabled ESC Calibration and unplug, and plugin via usb
5. Ensure the transmitter throttle is set high
6. Plug in battery
7. Push safety switch (if present) and wait for ESC tones, and 2 additional beeps
8. Lower the transmitter throttle.
9. Unplug and plug back in battery
10. Arm and test motors spin
11. Unplug battery, re-attach propellers
Start

6 Flying the Drone

6.1 Pre Arm Safety Checks

APM-Copter Flight Ops Checklist V1.0

PREFLIGHT

Groundstation

Laptop	Power On
Laptop Battery	Confirm Battery Lifespan
Mission Planner	Start
Telemetry Module	Connect USB
Telemetry Module Antenna	Orient Vertically
Com Settings	Com Port Select, Baud 57600

Aircraft

Airframe/Landing Gear	No Damage
Props	Secure, Undamaged, Correct Direction
Motors	Secure, Undamaged
ESCs	Secure, Undamaged
GPS Receiver & Cable	Secured
RC Rx & Connections	Secured
RC Satellite Rx and cable	Secured
Telemetry Module & Cable	Secured
APM	Secured
APM Connections	Verify All secured
Battery	Install in AV
Velcro Battery Straps	Secure

FLIGHT

RC Tx	Verify Throttle at Minimum
RC Tx	Power On
RC Tx	Verify Battery Voltage
RC Tx	Verify Correct Model Selected
RC Tx Mode Switch	Stabilize
Aircraft	Place at RTL Location
Battery	Connect (Don't move AV)
Telemetry Comms	Connect with MP
Battery Cables	Secure
RC Rx Antennas	Straight
Telemetry Antenna	Straight & Vertical
Telemetry Signal Strength	>75%
Pitch & Roll AV..	Ensure Correct response on AH
Airspeed	Verify 0 (+/-3)
Home Altitude	Set
Altitude	Verify 0 (+/-3)
Battery Voltage	Fully Charged
GPS	3D Fix
Flight Plan	Verify

Image Source: Pixhawk

6.1.1 Configuration

- Spin up the propellers on the ground and check they are all moving in the correct orientation.
- Check that your copter knows what level is. With the copter on a flat surface connect to Mission Planner and ensure the artificial horizon display shows level.
- Check all failsafe settings are enabled.

6.1.2 Flying

- Make sure you have a GPS lock before flying if you intend to use any auto modes. Even if you’re only flying in Stabilized mode this is a good idea so you can invoke Return To Launch if you get into trouble.
- Test RTL before sending your copter off on an auto waypoint flight. This is to check that the compass and GPS are working, and that it knows where home is before heading off on a more complex flight.
- Ensure that flight in Stabilize works well before you attempt any more complex flight modes. Ensure loiter works before trying RTL. Ensure RTL works before trying auto.
- Once armed stand 3m-6m away from the arming point as when in RTL the copter will be returning to this point.
- When testing more complex flight modes, be ready to switch back to Stabilize mode at any moment if it does anything strange. Stabilize or Acro are the only modes which can save you from a problem with the software or sensors. RTL is a good mode to save you from human error, but relies on the copter being able to locate and fly itself, so this should not be used as an emergency mode if other auto flight modes go wrong.
- Be sure you have a way of knowing when your battery is getting low, and land before you have used more than 80% of your battery capacity.
- If you’re about to crash into something, turn the throttle down to zero, so you don’t potentially destroy your drone, injure somebody, or injure yourself.
- Keep your fingers away from the propellers when they’re moving.
- Unplug/take out the battery of the drone before doing any work on it. If it turns on accidentally and the propellers start spinning
- Tie the drone down or surround it by a cage for some initial flights.

6.2 Flight Modes

Copter has 14 flight built-in flight modes, 10 of which are regularly used. There are modes to support different levels/types of flight stabilization, a sophisticated autopilot, a follow-me system etc.

Flight modes are controlled through the radio (via a transmitter switch), via mission commands, or using commands from a ground station (GCS) or companion computer.

The commonly used flight modes are:

6.2.1 Stabilize

- Pilot’s roll and pitch input control the lean angle of the copter. When the pilot releases the roll and pitch sticks the vehicle automatically levels itself.
- Pilot will need to regularly input roll and pitch commands to keep the vehicle in place as it is pushed around by the wind.
- Pilot’s yaw input controls the rate of change of the heading. When the pilot releases the yaw stick the vehicle will maintain it’s current heading.
- Pilot’s throttle input controls the average motor speed meaning that constant adjustment of the throttle is required to maintain altitude. If the pilot puts the throttle completely down the motors will go to their minimum rate and if the vehicle is flying it will lose attitude control and tumble.
- The throttle sent to the motors is automatically adjusted based on the tilt angle of the vehicle (i.e. increased as the vehicle tilts over more) to reduce the compensation the pilot must do as the vehicle’s attitude changes.

6.2.2 AltHold

When altitude hold mode (aka AltHold) is selected, the throttle is automatically controlled to maintain the current altitude. Roll, Pitch and yaw operate the same as in Stabilize mode meaning that the pilot directly controls the roll and pitch lean angles and the heading.

The pilot can control the ascent and descent rate of the drone using the throttle stick.

- If the throttle stick is in the middle(~40% to 60%), the drone will maintain its altitude.
- Outside the mid-throttle dead zone i.e. below 40% and above 60%, the vehicle will climb or descend depending on its deflection of the stick
- When the stick is completely down, it will descend at 2.5m/s and when it is completely up, it will ascend at 2.5m/s

6.2.3 Loiter

Loiter Mode automatically attempts to maintain the current location, heading and altitude. The pilot may fly the copter in Loiter mode as if it were in manual. Releasing the sticks will continue to hold position.

Good GPS position, low magnetic interference on the compassand low vibrations are all important in achieving good loiter performance.

The pilot can control the copter’s position with the control sticks:

- Horizontal location can be adjusted with the Roll and Pitch control sticks with the default maximum horizontal speed being 5m/s. When the pilot releases the sticks, the copter will slow to a stop.
- Altitute control is similar to AltHold mode.
- The direction can be set with the Yaw control stick.

6.2.4 Return to Launch (RTL)

RTL mode (Return To Launch mode) navigates Copter from its current position to hover above the home position. When RTL mode is selected, the copter will return to the home location. The copter will first rise to RTL_ALT before returning home or maintain the current altitude if the current altitude is higher than RTL_ALT. The default value for RTL_ALT is 15m.

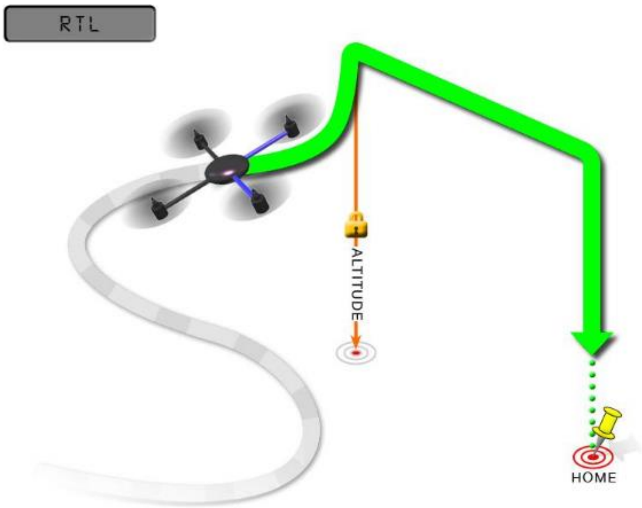


Image Source: Pixhawk

RTL is a GPS-dependent move, so it is essential that GPS lock is acquired before attempting to use this mode. Before arming, ensure that the Pixhawk's blue LED is solid and not blinking. For a GPS without compass, the LED will be solid blue when GPS lock is acquired. For the GPS+Compass module, the LED will be blinking blue when GPS is locked.

RTL will command the copter to return to the home position, meaning that it will return to the location where it was armed. Therefore, the home position is always supposed to be your copter's actual GPS takeoff location, unobstructed and away from people. For Copter if you get GPS lock and then ARM your copter, the home position is the location the copter was in when it was armed. This means if you execute an RTL in Copter, it will return to the location where it was armed.

In RTL mode the flight controller uses a barometer which measures air pressure as the primary means for determining altitude ("Pressure Altitude") and if the air pressure is changing in your flight area, the copter will follow the air pressure change rather than actual altitude

6.2.5 Auto

In Auto mode the copter will follow a pre-programmed mission script stored in the autopilot which is made up of navigation commands (i.e. waypoints) and "do" commands (i.e. commands that do not affect the location of the copter including triggering a camera shutter).

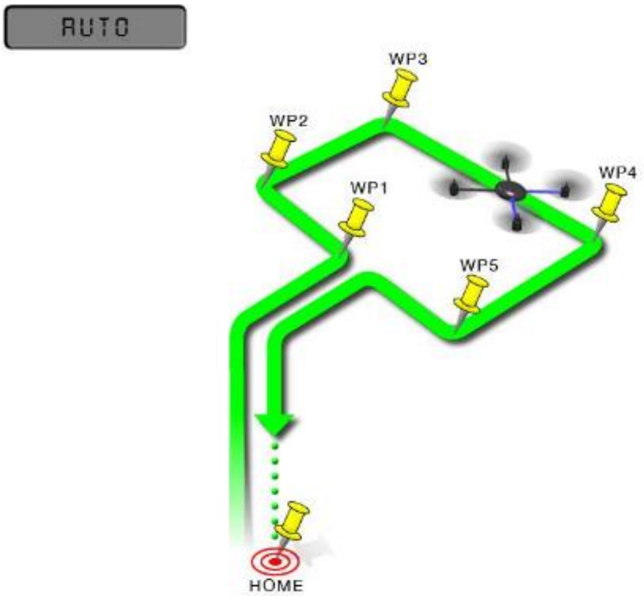


Image Source: Pixhawk

AUTO should be set-up as one of the Flight Modes on the flight mode switch.

- If starting the mission while the copter is on the ground the pilot should ensure the throttle is down, then switch to the Auto flight mode, then raise the throttle. The moment that the throttle is raised above zero, the copter will begin the mission.
- If starting the mission from the air the mission will begin from the first command the moment that the flight mode switch is moved to Auto. If the first command in the mission is a take-off command but the vehicle is already above the take-off command's altitude the take-off command will be considered completed and the vehicle will move onto the next waypoint.
- At any time the pilot can retake control from the autopilot by returning the flight mode switch to another flight mode such as Stabilize or Loiter. If the pilot then switches to AUTO again, the mission will restart from the first command.
- During the mission the pilot's roll, pitch and throttle inputs are ignored but the yaw can be overridden with the yaw stick. This allows the pilot to for example aim the nose of the copter (which might have a hard mounted camera on it) as the copter flies the mission. The autopilot will attempt to retake yaw control as the vehicle passes the next waypoint.

Missions should normally have an RTL as their final command to ensure the copter will return after the mission completes. Alternatively the final command could be a LAND with a different location. Without a final RTL or LAND command the copter will simply stop at the final waypoint and the pilot will need to retake control with the transmitter.

Remember that when using RTL, the copter will return to the "home" position which is the location where the copter was armed.

As the copter touches down at the end of the mission the pilot should move the throttle to zero at which point the autopilot will disarm the motors if it also believes that it has landed.

6.3 Safety Features

6.3.1 Calibration

The controller's inbuilt accelerometer and compass needs to be calibrated if the controller has been moved from its position. If any of the calibration steps fail, the drone will not arm and run into system error.

Image Source: Painless 360

6.3.2 Safety Switch

Once the drone is deemed fit for flying, it will not arm until the safety switch is pressed. This is beneficial as it will prevent injuries caused by sudden arming of the drone.

Image Source: Painless 360

6.4 Setting Failsafe

There are primarily two failsafe mechanisms to ease the vehicle recovery or prevent wandering in the event when the vehicle control is lost.

6.4.1 Radio Failsafe

Copter supports Return To Launch in cases where the contact between the Pilot's RC transmitter and the flight controller's receiver is lost.

If enabled and set-up correctly, the radio failsafe will trigger if:

- The pilot turns off the RC transmitter
- The vehicle travels outside of RC range
- The receiver looses power
- The wires connecting receiver to the controller are broken

When a radio failsafe is triggered one of the following will happen:

- Nothing if the vehicle is already disarmed
- Motors will be immediately disarmed if the vehicle is landed OR in stabilize or acro mode and the pilot's throttle is at zero
- Return-to-Launch (RTL) if the vehicle has a GPS lock and is more than 2 meters from the home position
- LAND if the vehicle has:
    a) no GPS lock OR
    b) is within 2 meters of home OR
    c) the FS_THR_ENABLE parameter is set to "Enabled Always Land"

The radio failsafe can be set by following these steps:

1. Disconnect the receiver from the controller.
2. Go to Mandatory Hardware -> Failsafe
3. Set the FSPWM to 990(A value less than the minimum value of the throttle channel)
4. In the transmitter menu, go to TravelAdj and decrease the value of the throttle channel till 118%
5. Rebind the transmitter to the receiver with this setting
6. Restore the transmitter settings to default value before flying.

The best way to check if radio failsafe is working is that whenever the transmitter is switched off when the receiver is connected to the controller, the buzzer connected to the controller beeps, indicating a loss of connection between the transmitter and receiver.

6.4.2 Battery Failsafe

The battery failsafe can be set-up to automatically trigger an RTL or LAND when the vehicle battery voltage or estimated remaining power has crossed a configurable threshold.

To use this failsafe the vehicle must have a Power Module or other voltage and (optionally) current monitor.

6.5 Getting the Drone Off Ground

- Push the throttle (left stick) up very slowly, just to get the propellers going. Then stop.

- Repeat this multiple times and until you're comfortable with the throttle's sensitivity.
- Slowly push the throttle further than before, until the copter lifts off the ground.
- Then pull the throttle back down to zero and let the drone land.
- Repeat this 3-5 times.
- Notice whether the copter is trying to rotate left or right (yaw), move left or right (roll), or move backwards or forwards (pitch).
- If you notice any movements happening without you making them happen, use the corresponding trim button to balance them out. For example, if you notice the copter moving to the left when you push the throttle, adjust the "roll" trim button next to the right stick.
- Keep adjusting the trims until you get a relatively stable hover off the ground by only using the throttle.

6.6 Hovering in Mid-Air and Landing

- Use the throttle to get the copter about a foot to a foot-and-a-half off the ground.
- Make tiny adjustments with the right stick (and the left, if necessary) to keep the copter hovering in position.
- When you're ready to land, cut back the throttle slowly.
- When the drone is an inch or two off the ground, cut the throttle completely and let the UAV drop to the ground.
- Repeat this until you get comfortable hovering off the ground and landing gently.

6.7 Moving the Drone Forward/Backward and Left/Right

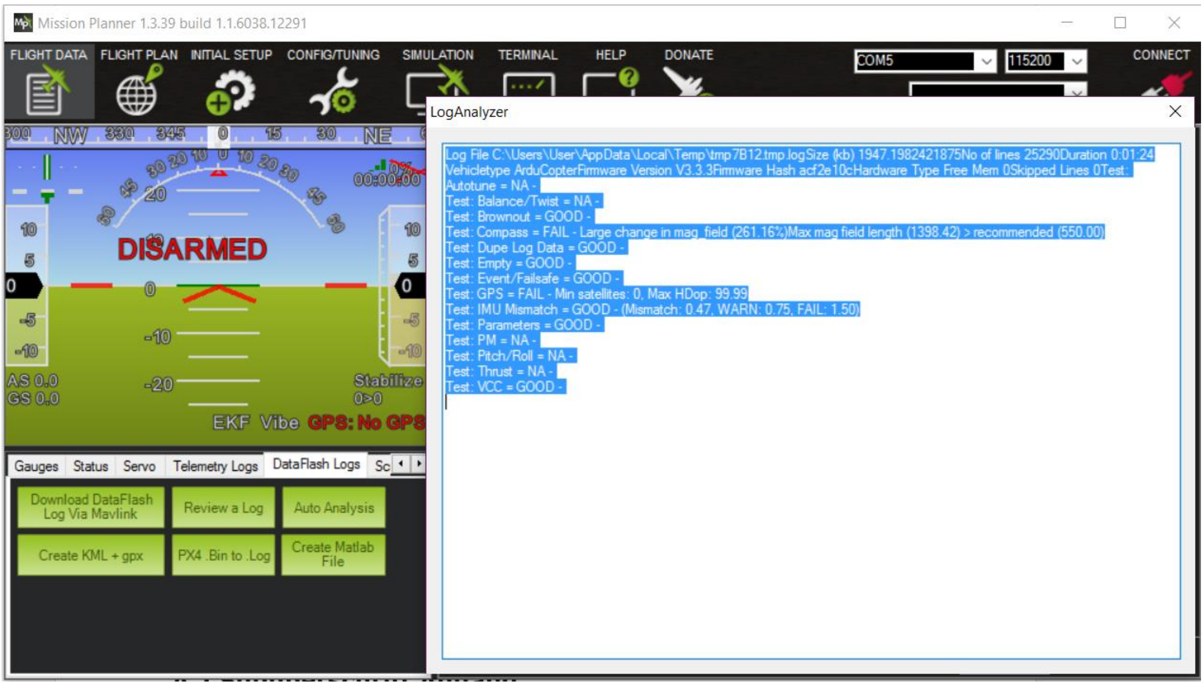
- Hold the throttle at a steady rate to keep it airborne.
- Use the right stick to maneuver the drone in the direction you want it to go.
- First, bring your copter to a hover.
- Push the right stick forward to fly it a couple feet forward.
- Pull the right stick back to bring it back to its original position.
- Now, move it further backwards a couple feet, and return it to its original position.
- Push the right stick to the left to move your copter a couple feet to the left.
- Move it back to its original position, then fly it a couple feet to the right.
- If it starts to rotate (yaw), adjust the left stick to the left or right to keep the copter facing the same direction.
- When you move in either direction, you will probably notice the quadcopter dropping in altitude. To keep the copter at the same altitude, push the throttle and give it more power whenever you turn or move

6.8 Checking Data Logs

The values of all the flight parameters during the flight can be checked using the following set of steps.

Click on Download DataFlash via Mavlink to download all the logs from the board to the computer. Click on Review a log to view the values of all parameters with respect to time in a graphical format.

Click on Auto-Analysis to obtain an overall summary of all the data during the flight.



7 PCB for Battery Test Bench

8 Results

The following results were obtained during the period of this internship:

- Created a flexible platform for further investigation
- Built a drone which is stable in air and robust in performance
- Achieved a payload capacity of about 8kg
- Achieved a flight time of about 20min
- Implemented various flight modes of the controller on the drone
- Designed a wireless charger for the lithium polymer batteries.
- Designed and fabricated a power distribution board for the drone
- Built a customised landing gear for the drone
- Fabricated, soldered and tested a PCB for the battery test bench

PARAMETER	DJI INSPIRE PRO	OUR DRONE
Price	4100€	1200€
Build	Quadcopter	Octocopter
Payload Capacity	3.5kg	8kg
Max. flight time	15min	20min
Customisability	Partial	Complete
Autonomous flying	Not possible	Possible

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