

Drone It Yourself!

MAKING AND DESIGNING A TOY DRONE  
THROUGH MULTIDISCIPLINARY  
COLLABORATIVE WORK  
Project no. 2015-1-ES01-KA202-015925

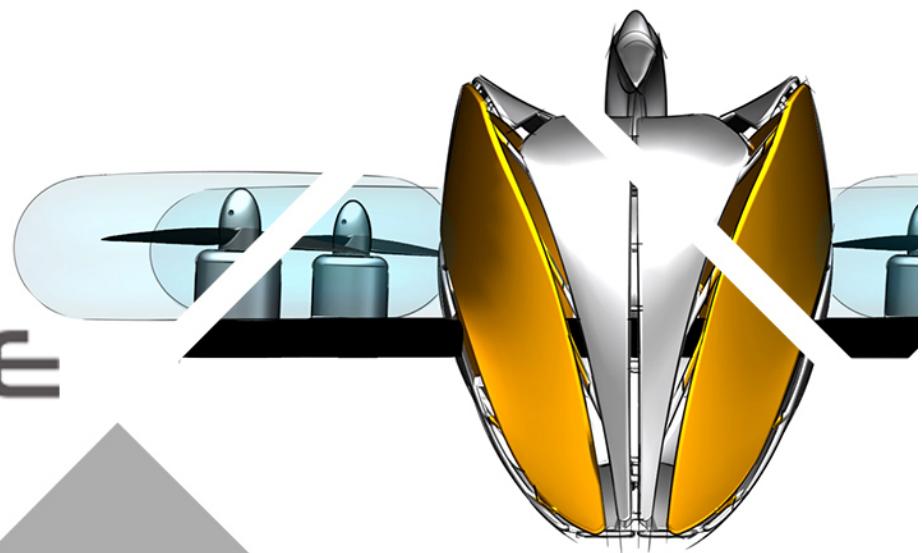


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Drone It Yourself! consists of the following modules:

0. INTRODUCTION TO THE DRONETEAM PROJECT
- 1. BASIC TOY DRONE FRAME**
2. MODULE OF FLIGHT CONTROL
3. MODULE OF COMMUNICATION CONTROL
4. MODULE OF ADVANCED FRAME
5. MODULE OF GPS-COMPASS CONTROL
6. MODULE OF PROBLEM MANAGEMENT
7. MODULE OF FLIGHT STABILIZATION SYSTEM
8. MODULE OF FIRST PERSON VIEW
9. DRONETEAM E-LEARNING PLATFORM
10. OTHER DEVELOPMENTS
11. GLOSSARY



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## BASIC TOY DRONE FRAME

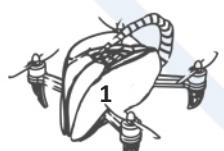
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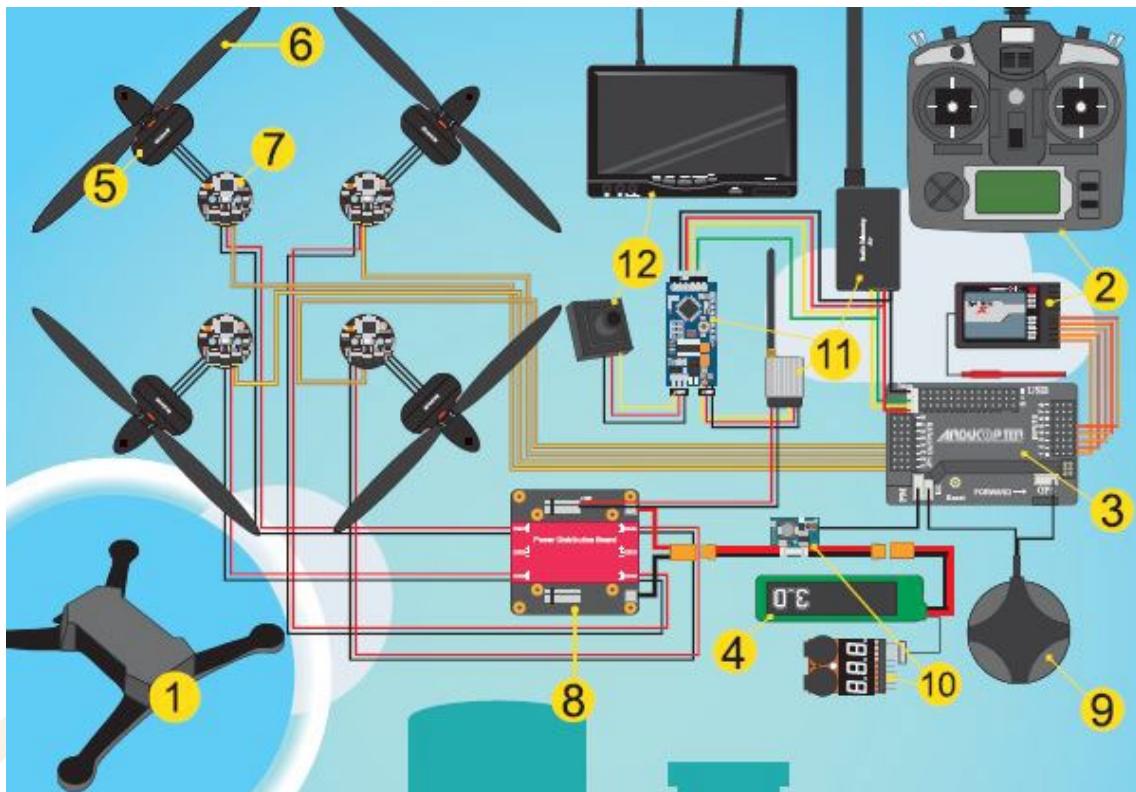


# 1 BASIC TOY DRONE FRAME

## 1.1 DRONE COMPONENTS

### 1.1.1 INTRODUCTION

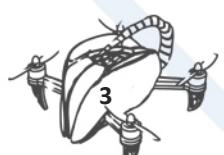
Unmanned aerial vehicles (UAV) or Drones can fly by using the remote control of a pilot or computer. Drone sector is evolving rapidly and that has multiple applications. Learning about its components is essential to understand its operation and get into this sector of great relevance.



Learning about all drone components. You can find all the information about basic components according to your budget or your needs.

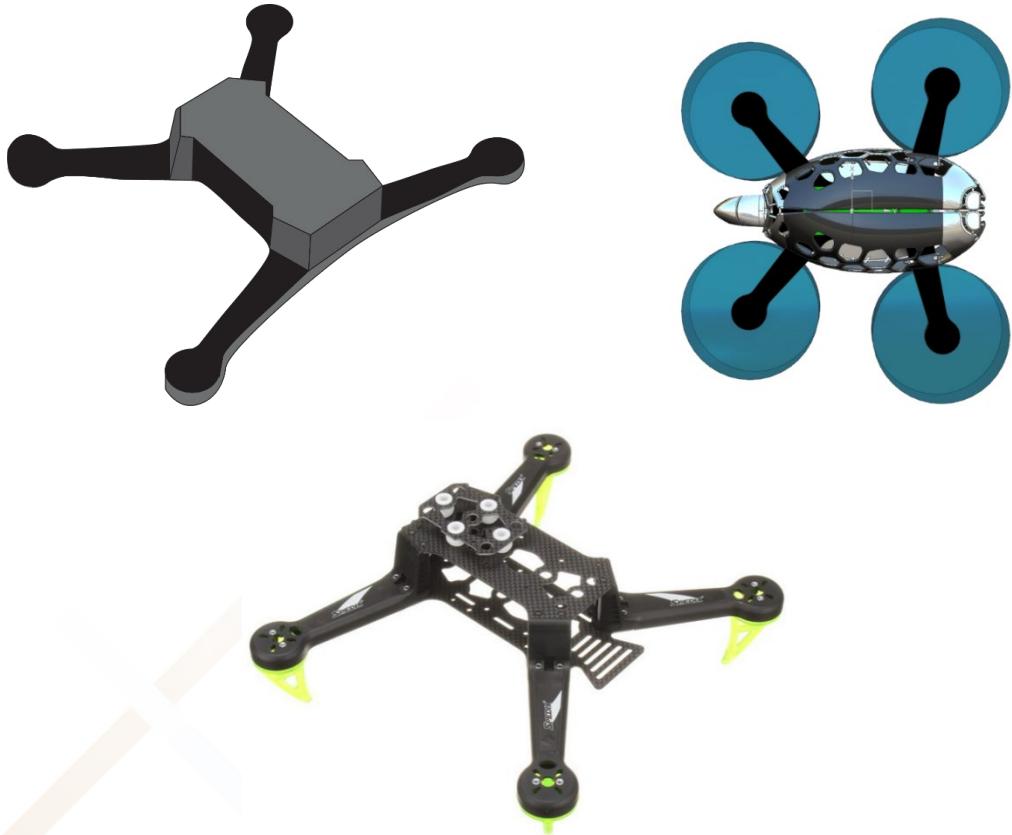
First eight components are necessary to have a Basic Drone that can fly.

Download the Component Poster. Link: <http://www.droneteamproject.eu/results/download-area2/231-posters-on-drone-components>



### 1.1.2 FRAME

The Frame is the base on which the other components are assembled. The most common are 4 motors (quadcopter). For heavy drones is advisable 6 (hexacopter) or 8 motors (Octocopter).



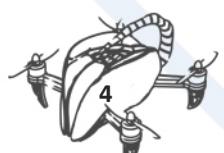
### 1.1.3 RADIO TRANSMITTER

Radio Transmitter is used to control the motors of the drone. We need to bind the transmitter with the receiver of drone. In advanced drone, we can use another system to control.



Transmitter (TX)

Module (RF)



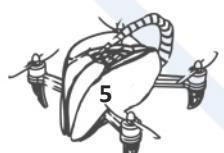
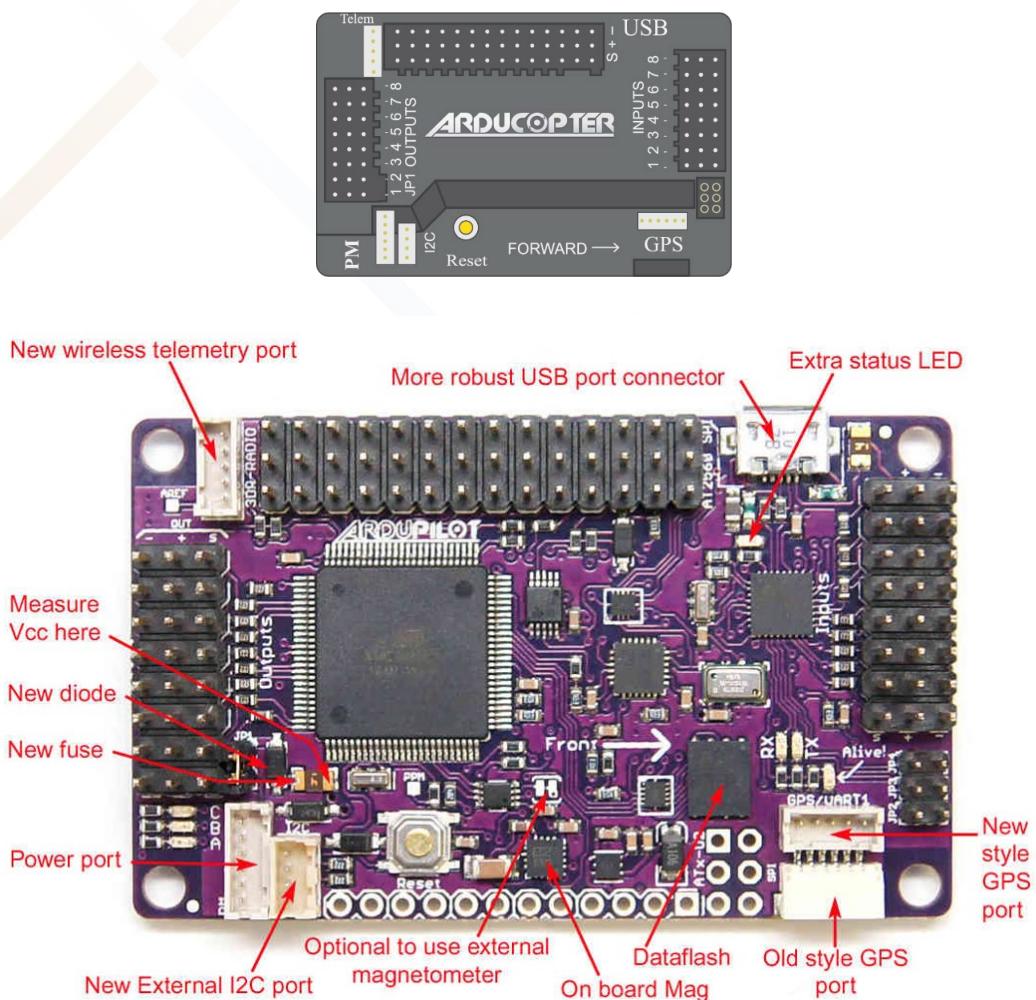
(Note: This component can now be replaced by a smartphone that incorporates an application for managing the drone. Using a Wi-Fi network between the phone and the drone, it is possible to control it by means of a simple application).

In the DroneTeam project we have used the Turnigy 9X model.

The radiofrequency is defined in Hertz (Hz), which is the unit of measurement for electromagnetic waves that are emitted in a defined radius and with a frequency also defined. The typical frequency used by these systems is 2.4 GHz. For professional use it is possible to use lower frequencies that will allow a greater range and make flights at a greater distance from the transmitter. The 2.4 GHz frequency is typical for Wi-Fi networks and therefore may be saturated at certain points and could cause interference. Or we simply meet other users of drones, where it is important that there are no interferences between the different drones. Therefore, to avoid them, these transmitters come equipped with a control software that changes frequency when it detects interference. You can make this change several times per second, which avoids these possible interferences.

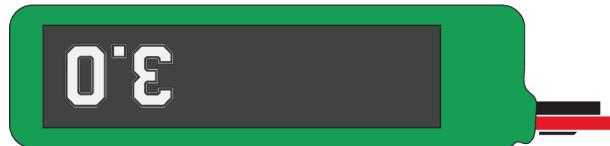
#### 1.1.4 FLIGHT CONTROLLER

Flight Controller (FC) Is the brain of drone. It receives sensor inputs provides orders to stabilise the drone. Advanced controls permit autopilot: take-off, waypoints, and landing.



### 1.1.5 BATTERY

Battery capacity is related to the flying time. Voltage should be according to the other components. Discharge rate (C rating) should be optimal, usually LiPO (lithium polymer).



The batteries currently used in drones are LiPo type (Lithium and Polymer) that offer better performance than those of NiCd (Nickel / Cadmium) since they weigh almost half and offer a greater discharge.

Choosing the right battery depends on the characteristics of the drone, according to the following reference parameters: weight and desired flight time. For the case of the basic drone assembled in DroneTeam, these parameters would be:

Total weight of drone with installed battery: 1.5 Kg

Desired flight time: 15 -- 20 min

### 1.1.6 MOTORS

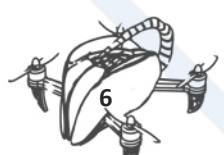
Motors, brushless type which is more efficient. Motors and propellers should theoretically push 2.5 times the weight of drone to fly. The key parameter to know is KV (Kilo volt).



#### The brushless motor

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

The rotor part of a brushless motor is often a permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor.



Brushless motors may be described as stepper motors; however, the term stepper motor tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position. This page describes more general brushless motor principles, though there is overlap.

Two key performance parameters of brushless DC motors are the motor constants Kv and Km.

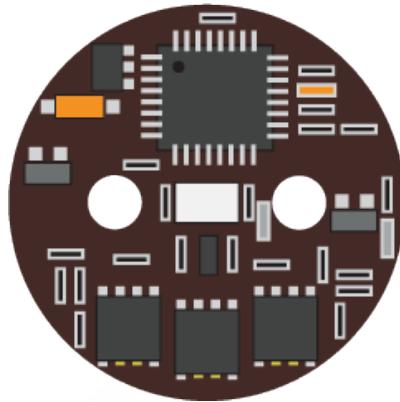
### 1.1.7 PROPELLERS

Propellers. Pitch parameter: distance in one turn. Bigger pitch implies increase motor KV. The "R" propellers are fitted with the CW (Clock Wise) rotation and the "L" with CCW.



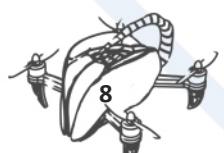
### 1.1.8 ESC

Electronic Speed Controller (ESC) defines the speed of rotation of a brushless motor by the generation of pulses. It receives the power through the PDB and the orders from Flight Controller.



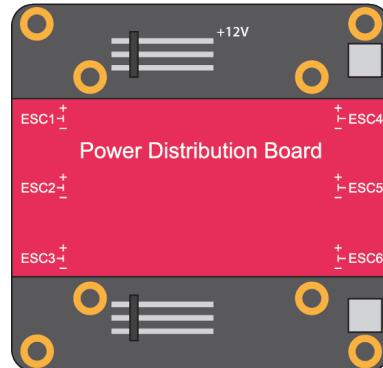
Electronic Speed Controller Known as ESC by its acronym is a small board whose mission is to control the speed of the engine. An ESC is needed for each motor since the rotation speed is independent.

The ESC connects directly to the flight controller (for example, CC3D or Ardupilot) by means of a cable so that it transmits the orders accurately. That is why compatibility with the motor is essential.



### 1.1.9 PDB

Power Distribution Board (PDB) distribute the power from the battery to all ESC. It has positive pads for red wires and negative pads for black wires. It can include two voltage circuits (5V & 12V)



This component facilitates the connection of the other components to the battery and also has the function of adapting the voltage to the needs.

Several components that are assembled in the drone need a constant voltage of 5V, others operate at 12V. As the batteries offer a higher voltage and also the voltage they offer depends on the load of the same and requirements of the rest of the components at all times, especially the motors, a system that ensures the constant voltage is required. This system is known as BEC (from English Battery Eliminator Circuit) and its function is to adapt the voltage that comes from the battery to have a constant voltage of 5V and / or 12V.

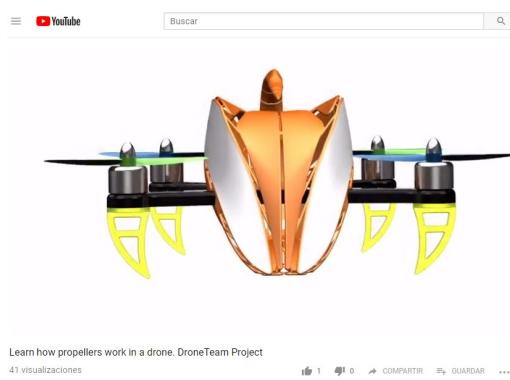
The BEC can regulate the voltage in two ways: linearly or in a switched form (which are specified as SBEC of the English Switching BEC or also as UBEC of Ultimate BEC).



## 2 WHY DOES A DRONE FLY?

### 2.1 INTRODUCTION

To understand why a drone flies you have to know some basic concepts that have to do with aerodynamics: Newton's equations and Bernoulli's principle. In this section these basic concepts are explained, as well as the concepts about the different configurations of a multirotor or drone.



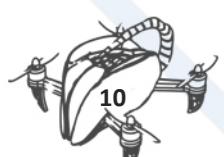
<https://youtu.be/TzoSF0OsoXA>

### 2.2 AIR CHARACTERISTICS

First, it must be understood that air is composed of gases and, therefore, has, like anybody, a certain mass and weight. The main quality is that it is a fluid that is subject to the changes that are produced by pressure and temperature. These changes allow the air to expand or contract depending on the pressure and temperature. This relationship is described by Charles's Law that relates the volume of a given gas with the proportional increase in temperature: the higher the temperature, the greater the volume. This is because the movement of the molecules increases with temperature and the gas expands.

On the other hand, the temperature decreases with increasing height. This phenomenon is known as a Vertical Temperature Gradient. It is estimated that every 100 meters, the temperature decreases  $0.65^{\circ}\text{C}$ . This is because the surface of the Earth transmits solar radiation to the closest layer of air in the atmosphere: the troposphere which is about 11 km.

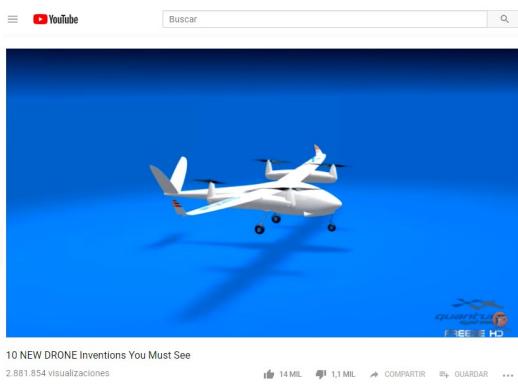
As we can see in this case, the temperature should not affect so much the drone since, in 120 meters, the variation will not be greater than one degree and, therefore, the density of the air, although less dense, the variation for this height will be priceless. This is so, except when the thermal inversion occurs, where the hot air is located at higher altitudes. This meteorological phenomenon occurs especially in winter, in anticyclonic situations where the night rapidly cools the ground and it cools the air closer, becoming denser than the one that is just in the upper layer. The Thermal Inversion, therefore, occurs in cold mornings and will break as soon as the sun warms the air in contact with the ground, restoring the vertical gradient of normal temperature.



Another parameter that is usually taken into account is the so-called Atmospheric Pressure. This pressure varies according to the height. The higher the height, the lower the pressure. It is estimated that for every 9 meters we climb, the pressure drops 1 millibar. Taking into account that the drones have a limit of 120 meters of height to fly (according to the regulation of majority of countries), the variation of atmospheric pressure will be 13 millibars between the ground and the maximum 120 that must reach the drone on your flight.

Wind Conditions are important because with the height it can be stronger and if there are gusts of wind, the drone can lose stability and the battery will be consumed more quickly since engines are continually forced to try to maintain the stable drone. In windy conditions and possible storm, it is advisable, logically, not to fly.

## 2.3 NASA VIDEO ABOUT THE TURBULENCE OF A DRONE:

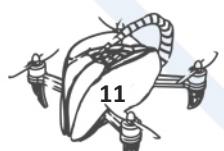


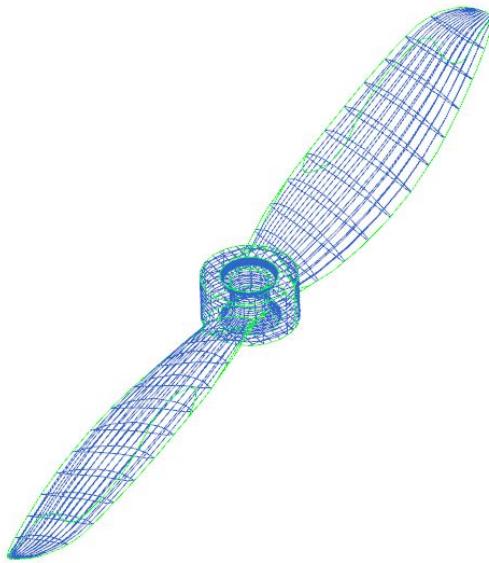
<https://youtu.be/hywBEaGiO4k>

For decades, NASA has used computer models to simulate the flow of air around aircraft in order to test designs and improve the performance of next-generation vehicles. At NASA's Ames Research Center in California's Silicon Valley, researchers recently used this technique to explore the aerodynamics of a popular example of a small, battery-powered drone, a modified DJI Phantom 3 quadcopter. This simulation reveals the complex motions of air due to interactions between the vehicle's rotors and X-shaped frame during flight. In the video, airflow interactions are shown as undulating lines. Pressure changes are shown using colour. Areas of high pressure are red; low are blue.

## 2.4 BUT, WHY DO DRONES FLY?

First, it is convenient to understand that an object that presents little thickness and weight, with a flat shape, placed against the wind, will cause it to rise and plan or sustain itself. This is how we get the kites to fly. The wings of the airplanes have aerodynamic designs very studied to make the most of the lift they offer in their forward movement. A helicopter also has blades that form an aerodynamic surface in its circular rotation without needing to move forward to rise. This same concept of circular movement is applied to drones: the blades of the propellers have a rounded shape and, therefore, aerodynamics that allow them to penetrate the air and take advantage of the speed change that occurs in their movement. Therefore, the design of the angled blades of the propellers allows dividing the air generating a thrust and a lift.

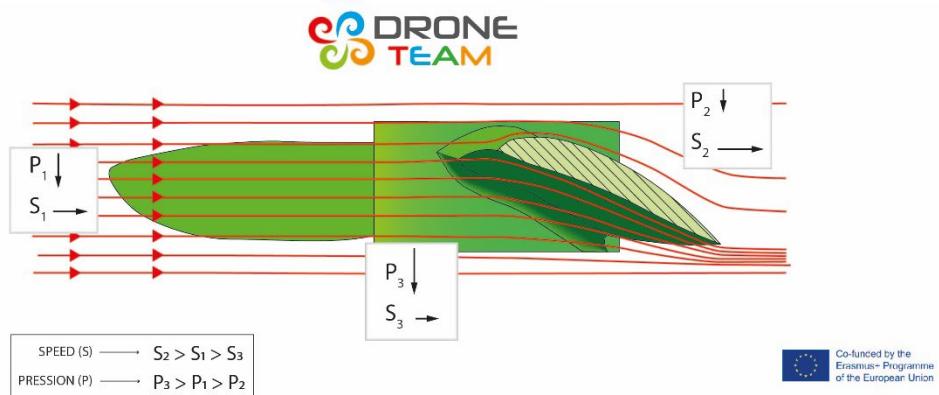




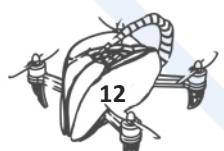
Air, like any other body, has three possible effects for energy: kinetic energy due to air velocity, gravitational or potential energy, which is due to the height of the air and the energy that air has due to the pressure the one that is submitted. Bernoulli conducted experiments that allowed to relate these three states and verify that the pressure of a fluid is inversely proportional to the speed. That is to say, if the velocity of the fluid increases, the internal pressure of the fluid decreases and furthermore it specifies that the sum of the pressure ( $p$ ) and the speed ( $s$ ) permanence constants ( $k$ )

Applying the Bernoulli Theorem to the blade of the Helix of the Drone, we have the point on the surface of the blade will be fulfilled that  $p + s = k$

The following figure explains this Theorem, where the rotational movement of each drone's propeller causes a change in the air in the upper part and the lower part of the blade:



The movement of the blades causes a change of speed in the air, therefore, the pressure must change to maintain the constant  $k$ . The aerodynamic design of the shovel with the angled shape allows the flow of air to circulate at the top of the speed of the speed, while the one that pushes down the speed. Fulfilling Bernoulli's Theorem creates a differential pressure between the part of the blade (more pressure) and the upper part of the blade (less pressure). When the force exerted by the pressure under the blades of all the blades is greater than the weight of the weight, at that moment the tooth begins to rise. This force is known as thrust or lift force.



# 3 HOW TO CHOOSE THE RIGHT MOTOR FOR MULTICOPTER

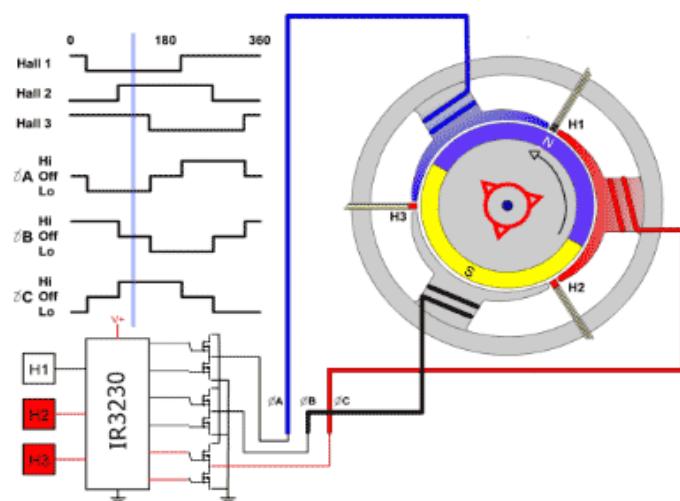
## 3.1.1 THE BRUSHLESS MOTOR

**Brushless DC electric motor (BLDC motors, BL motors)** also known as **electronically commutated motors** (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

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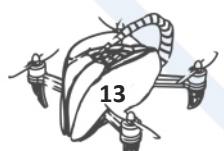
Two key performance parameters of brushless DC motors are the motor constants  $K_v$  and  $K_m$ .



## 3.1.2 THE MOTORS OF DRONE

The motors of drone are what propellers are connected to which cause them to spin around and generate thrust to enable drone to fly. In the case of fixed wing aircraft, the motors generate a forward thrust to push your plan forwards through the air. In the case of multirotors, the motors generate upwards thrust which keep drone such as a quadcopter flying.

Brushless motor contains a bunch of electromagnets (coils) which are connected together in specific pairs. The motor controller (commonly known as electronic speed controller or ESC) is



the device that controls the motor by activating and deactivating specific sections if electromagnets in the motor at very specific times to cause the rotor of the motor to spin due to the magnetic force. These electromagnets are connected into three main sections which is why all brushless motors have **3 wires coming out of them**.



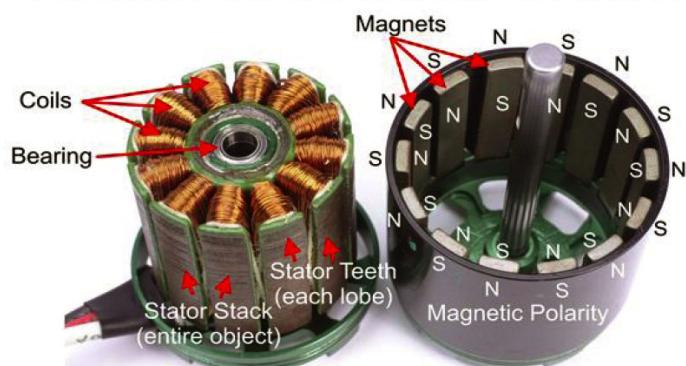
*Picture 1: Brushless motors*

### 3.1.3 BRUSHLESS MOTOR COMPONENTS

A brushless motor consists of two main sections:

- **Rotor** – the part that rotates and has the magnets mounted in a radial pattern.
- **Stator** – the part that does not rotate, and has electromagnets.

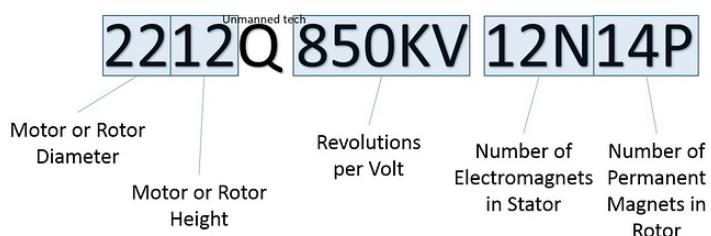
## OUTRUNNER COMPONENTS



### 3.1.4 INRUNNER AND OUTRUNNER MOTORS

There are two categories of brushless motors however with multirotors and most fixed wing aircraft you will only encounter out runner motors are pictured above. The difference between this two is that **out runners** have the rotor on two **outer area of the motor**, and **in runner motors** have the **rotating part on the inside** while the outer shell remained stationary. In runner motors are often used with R/C cars as they can spin much faster than out runner motors. However **out runner** motors are able to produce more torque which allows them to drive larger propellers used on aircraft and multicopters.

### 3.1.5 WHAT DO THE NUMBERS MEAN?



Most motors have a few letters followed by 4 numbers. The letters hold no significance (usually a model or series name, such as MT series motors, or Q series for quadcopter), whereas the numbers tell you the essential measurements of the motor.

Generally, **the first two numbers indicate the diameter** of the entire can of the motor OR the diameter of the stator (the inner part of the motor) only. Please see the picture at the below for clarification.

The second pair of numbers can indicate either **the height of the entire motor**, or only the height of the stator. In this case of the MT2204 motors that unmanned tech, these numbers indicate the stator diameter and height, and so we have an 22mm stator diameter, and a 4 mm stator height.

The size of the motor can give you an idea about what size drone you will use with the motor. Typical FPV racing miniquads will use 1806 or 2204 motors, whereas larger quadcopters that are designed to carry a Gopro camera will typically be around the 2212 size.



### 3.1.6 GUIDE TO CHOOSING YOUR FIRST BRUSHLESS MOTOR

No one standard exists for measuring the speed of the brushless motor. Some manufacturers measure the speed by turns. Other manufacturers use a KV rating. These terms are important because they will help to choose your motor's speed. A sensored motor is marked by the amount of turns it has: 21.5, 10.5, 9.5, 8.5 -- the lower the turn counts the faster the rotor spins. But a sensorless motor is referenced by KV. With KV, the higher the number the faster the rotor spins. As a comparison, a 10.5 sensored motor is similar to a 4300kv sensorless motor. When you look at specifications supplied by the manufacturers, you will see that they are very close in performance. A 10.5 brushless motor is roughly the same as a 3800-4300 KV motor, depending on the manufacturer.

#### Brushless Advantages

- 1      Higher efficiency
- 2      Longer runtime
- 3      More power
- 4      Maximum RPM

Better acceleration and performance

#### kV Rating

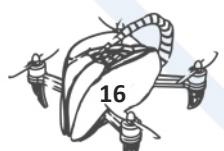
The Kv rating of a motor.

When a motor is supplied with a voltage, it spins. As the voltage increases, so does the rate of the spin; logical. This rate of spin is quantified using revolutions per minute i.e. rpm, and this Kv rating gives you the rpm a motor will spin at full throttle, given a certain voltage. This value is also assuming that the copter is unloaded. The Kv rating gives you the rpm of the motor in the following way:

### 3.1.7 RPM = KV X VOLTAGE

**Note:** The ideal number of rpm of a motor for you is dependent on what type of copter you're looking for. For example, if you're looking for a high performance, acrobatic copter, a high rpm motor is the one for you, meaning of course a high Kv rating. This is intuitive because these acrobatic copters are generally of the smaller variety, meaning a smaller motor, leading to smaller propellers. When you have these smaller propellers, the motors need to produce more rpm in order to produce the necessary thrust. However, this means that these motors use up more power than others, and so are less efficient.

On the other hand, if you would like your copter to use the least amount of power as possible, and so last longer and be more stable, then **motors with lower rpm are ideal**. An example for when these types of motors would be useful is in taking aerial photos. Again, this is partly due to the fact that the type of copters used for these tasks are bigger in order to carry the



necessary equipment, meaning larger propellers, which will create more thrust when rotated. They therefore require fewer rpm.

### 3.1.8 MAGNET CONFIGURATION

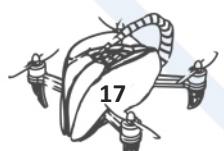
The configuration number tells you **how many electromagnets there are on the stator**, and the number of permanent magnets are on the rotor. The number before the letter N shows the number of electromagnets there are in the stators. The number before the P shows how many permanent magnets there are in the rotor. Most out runner brushless motors follow the 12N14P configuration. There are some special low KV multirotor motors which have a higher number of electromagnets and permanent magnets which allow the motor to create more torque more efficiently, however due to the added number of magnets these motors are more expensive.

### 3.1.9 THRUST - THE MAIN PARAMETER

Knowing the weight of your drone is the first thing you need to know. With multirotors are important to make sure that your motors can produce **around 50% more thrust** than the total weight of your drone.

So if your total weight of your drone is **800g**, your motors on a drone will need to produce **1.6Kg** of thrust in total, or **400g max thrust per motor**.

Motor type	The voltage (V)	Paddle size	current (A)	thrust (G)	power (W)	efficiency (G/W)	speed (RPM)
MT1806-2280KV	7.4	5030 Carbon Fibre Prop	4.4	210	32.6	6.4	13530
		APC 6*4	6.8	280	50.3	5.6	12030
		5*4.5 three-blade prop	6.2	240	45.9	5.2	12330
	11.1	5030 Carbon Fibre Prop	8	380	88.8	4.3	18510
		APC 6*4	11.3	460	125.4	3.7	15160
		5*4.5 three-blade prop	10.6	410	117.7	3.5	15910



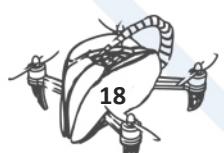
### 3.1.10 THE BEST CHOICE FOR DRONETEAM PROJECT

High performance brushless T- Motor MS2216 1100KV for quadcopter



Technical Datas		Recommended Prop(inch)				
		Standard	3S-1045/1047	Max thrust	3S-1155	
KV	1100					
Configuration	12N14P					
Stator Diameter	22mm					
Stator Length	16mm					
Shaft Diameter	3mm					
Motor Dimension(Dia. * Len)	Φ27.7×33.5mm					
Weight(g)	75					
Idle current(10)@10v(A)	0.9A					
No.of Cells(Lipo)	2-3S					
Max Continuous current(A)180S	23A					
Max Continuous Power(W)180S	253W					
Max. efficiency current (8-17A)>76%						
internal resistance	103m Ω					
Tested with Tiger motor 20A ESC						
Prop	Volts (V)	Amps (A)	Watts (W)	Thrust (g)	Efficiency (g/W)	Efficiency (oz/W)
1045	7.4	10.6	78.44	580	7.39	0.26
	8.5	13.8	117.3	730	6.22	0.22
	10	17.9	179	960	5.36	0.19
	11	20.2	222.2	1170	5.27	0.19

**T-MOTOR**  
High Performance Brushless Motors



4pcs Emax MT2213 935KV 2CW 2CCW Brushless Motor or DJI F450 F550 Quad Hex Octo Copter



**Framework:.....12N14P**  
**KV:.....935KV**  
**Length:.....39.7mm**  
**Diameter:.....27.9mm**  
**No. of cells:....3-4S**  
**Max. thrust:....720g**  
**Shaft:.....3mm**  
**Propeller:.....8"-10"**  
**Weight:53g**

Reference: internet, dronetest, manufacturer manual.



## 4 CHOOSING THE RIGHT BATTERY FOR A DRONE

### What we want

- Total weight of drone with installed battery: 1.5 Kg
- Desired flight time: 15 -20 min

### What we must know

- Battery is related to other components of drone.
- The battery is dependant
- LiPo (lithium polymer) battery

### Size of battery

- Flying time is related to battery capacity.
- Larger the capacity, longer the flight time.
- Battery size is important.

### Number of batteries

- Pros of more batteries:
  - backup battery
  - Probably longer flight time
- Cons of more batteries:
  - more weight
  - price
  - more complex to mount

### Battery Voltage

- Higher voltage:
  - produce more power
  - are heavier
  - motors are more efficient and powerful
- You must chose depending on number of motor.
- Motors and other electronics must support the voltage of your battery.

### Battery connectors

- Soldering battery connectors can be hard
- Easy swapping to another drone



### Battery Discharge Rate and its Capacity

- Battery discharge C rating should be optimal
- Discharge rate (C rating) that is too low, can result in damaged battery
- Batteries with higher C rating, have extra unnecessary weight

### C rating

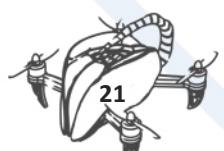
- So quadcopter will hover when each motor produces about 0.375 Kg of thrust
- So when using 10 inch propellers each of our four motors will draw little less than 10 A from LiPo 3S battery (40A motors + 1A everything else)

The voltage (V)	Paddle size	current (A)	thrust (G)	power (W)	efficiency (G/W)	speed (RPM)	Working temperature (° C)
11	EMAX8045	1	110	11	10.0	3650	
		2	200	22	9.1	4740	
		3	270	33	8.2	5540	
		4	330	44	7.5	6200	
		5	390	55	7.1	6700	
		6	440	66	6.7	7150	
		7.1	490	78.1	6.3	7400	36
13.8	EMAX1045	1	130	11	11.8	2940	
		2	220	22	10.0	3860	
		3	290	33	8.8	4400	
		4	370	44	8.4	4940	
		5	430	55	7.8	5340	
		6	480	66	7.3	5720	
		7	540	77	7.0	5980	
		8	590	88	6.7	6170	
		9	640	99	6.5	6410	
		9.6	670	106	6.3	6530	43

[MT2213 Motor33](#) Thrust table for a 3S LiPo battery

### Calculating capacity

- Battery should have enough capacity to supply our drone continuously with 16 A current for 20 minutes of flight.
- Battery capacity [Ah] = Current [A] \* Flight time [h]
- Battery capacity =  $16 \times 0.333 = 5.3 \text{ Ah} = 5300 \text{ mAh}$



**Which one?**

Technical data:

Brand	Tattu	Tattu	Gens ace
Capacity(mAh)	5100	5300	5300
Voltage(V)	11.1	11.1	11.1
Discharge Rate (C)	10	35	30
Max Burst discharge Rate (C)	20	70	60
Configuration	3S1P	3S1P	3S1P
Net Weight(±20g)	334	429	406.3-410.6
Length(±5mm)	137	138	137
Width(±2mm)	42	44	42
Height(±2mm)	26	34.1	32
Connector Type	XT-60	EC5	Deans
Wire Gauge	AWG12#	No	12#
Wire Length(mm)	50	No	120mm
Balancer Connector Type	JST-XHR	JST-XH	JST-XHR



## References

<http://dronepic.co.in/blog/how-to-choose-battery-for-quadcopter-miltirotors-uavs.html>

<http://www.uavdronemarket.com/how-to-choose-a-battery-for-your-quadcopter/>

<http://www.dronetrest.com/t/lipo-batteries-how-to-choose-the-best-battery-for-your-drone/1277>

<http://blog.oscarliang.net/how-to-choose-battery-for-quadcopter-multicopter/>



## 5 PROPELLERS TEST

### 5.1.1 STUDY

After checking web pages of some experts in drones, several conclusions are reached:

- a. Propeller types, depending on their use, are classified as:
  - Slow Fly (SF). Planned to operate at low speed. Good for light drones. Speeds up to 8500 rpm
  - Thin electric (TE). The most commonly used for electric drones with speeds up to 23000 rpm.
  - Multi-blade (MB). Usually 3-blade propellers. They may be shorter and therefore good when you have to reduce the space, but they are less efficient and generally not recommended.
  - Pusher prop (PP). Only suitable for vertical position.
  - Counter rotating (CR). Rotate clockwise.
  - Contra rotating (CR2). Rotate counter clockwise.
  - Folding prop (FP). Folding blades.
- b. The most commonly used materials in the manufacture of propellers for drones are:
  - Plastic Composite (countless formulas). Generally fragile and easily deformable.
  - The carbon fibre. The best quality but exceeds the object of the project since it was decided to use plastics.
  - Nylon fibre reinforced with carbon. Good quality, high strength and stiffness.
  - Nylon reinforced with fiberglass. A little lower performance than the ones above.
  - The ABS. Widely used. The best in quality/price ratio. Less rigid than nylon, but easier to manufacture since it is not necessary to dry the raw material before moulding it.

Properties	ABS	NYLON + 30 GF
Density	1,04 g/cm <sup>3</sup>	1,35 g/cm <sup>3</sup>
Hardness Rockwell R	105	120
Flexural yield strength	68,9 MPa	220 MPa
Charpy notched impact strength	19 kJ/m <sup>2</sup>	20 kJ/m <sup>2</sup>

- c. Parameters which define a type of propeller are:
  - The diameter. It is the distance between tips of an opposite pair of blades.
  - Pitch. It is the theoretical distance the propeller would move forward in one turn.
- d. The dimensions of the propeller are based on the engine characteristics and those of the drone, mainly by its weight.
- e. A balance control should be made on the propellers before mounting them on the drone. A bad balance can cause undesirable vibrations and even severe damage to engines and electronic equipment.
- f. There is the possibility of designing the drone so that all the blades rotate in the same direction, but this design often gives yaw problems (unwanted rotation of the drone on its vertical transverse axis). Although some experts say these problems can be compensated by bending the rotation axis of the propeller and electronically controlling this inclination, the team of La Foia considered that the complexity of this solution far exceeds the one which



may result from the manufacture of propellers for both directions, and therefore this design is rejected.

As example for propeller dimensioning, a calculation can be made as follows:

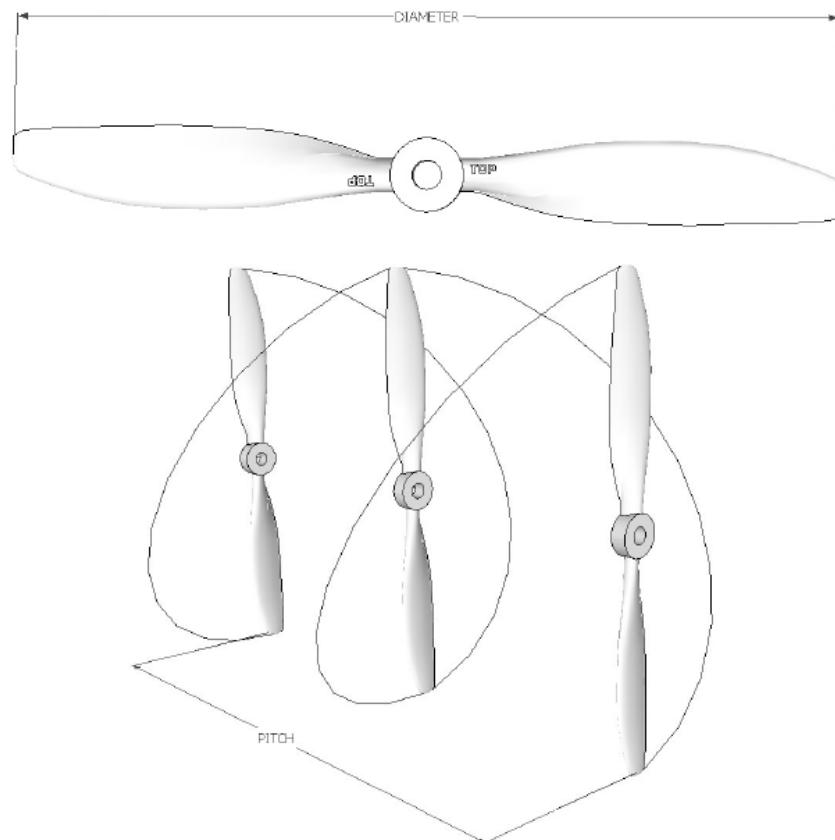
For a drone with a total estimated weight of 1,5 kg.

The motor assembly (supposed to be 4 engines in this case) has to be able to sustain in the air 2 times the weight of the drone, so that:

$$\text{Total thrust} = 1,5 \times 2 = 3\text{kg}$$

This weight is shared by the 4 engines, that gives 750 g/motor.

The first proposal could be a motor for 960 g thrust, with **10" diameter and 4.5" pitch propellers**.



Images taken from [www.robotshop.com](http://www.robotshop.com)

### 5.1.2 FIRST PROPOSAL FOR PROPELLERS

Once the previous study has been done, the team of IES La Foia intends to make two prototypes of propellers with the following characteristics:

- A. SF or TE (depending on the finally chosen motor) propeller, manufactured in ABS and in the final measures.
- B. SF or TE propeller, made of nylon reinforced with fiberglass and same size as the ABS one.

Obviously, in both cases two pairs of propellers should be made: one for clockwise rotation and a one for counter clockwise rotation.

Once they are manufactured and mounted on the drone, wind tunnel tests can be made to compare performances.

Due to the complexity of the design, a pair of carbon fibre propellers should be bought in order to get a 3D design by using reverse engineering.

## 6 3D CAD MODELLING

### 6.1.1 INTRODUCTION

A CAD system (a Computer Aided Design system) is a software that allows to make designs of elements using different tools. CAD systems can be 2D or 3D, although the systems used and advanced are those that work in three dimensions.

Many are advanced 3D CAD systems that allow you to design any part of a car or plane, for example. But these advanced systems have expensive professional licenses. Some systems have educational licenses with different costs and it is even possible to find free educational licenses. Although the partners of the DroneTeam project use different advanced CAD systems (Inventor, CATIA, Siemens NX, SolidWorks), it is also interesting to offer the possibility of accessing an open and free 3D CAD system, such as FREECAD. This system offers the possibility of multiplatform installation and also does not need activation of educational licenses. Therefore, it is recommended that, if no CAD system is available for 3D design, FREECAD is used to start designing 3D parts that can then be printed and used in the development of a customised drone.

FREECAD, is a parametric system. But what is a parametric CAD system?

This aspect is very interesting to be able to design 3D parts, since it is very common to make modifications or small adjustments in their dimensions. Parametric systems allow the operations to be saved together with the essential parameters with which they have been created. That is, in a parametric system we can access the parameters or values given to each operation and modify them simply, so that the design is updated with the new parameters introduced. In summary, it is possible to access the operation history and edit them to make changes in the design parameters. This aspect is very interesting to be able to design and adjust our design to the needs.

For example:

It is possible to return to the operation of Extrusion of a sketch (operation of thickened of a profile) by editing its Extrusion parameter and changing it:



### 6.1.2 FREECAD

FreeCAD is a free open source parametric CAD that allows you to design 3D parts. Being a system that saves the design parameters, it will allow its modification in a simple way when accessing the operation history, editing and changing the design parameters.

Being an open source system allows customisation and programming using scripts created in Python.

FreeCAD is multiplatform (Windows, Mac and Linux), it allows to import from the main CAD formats: STEP, IGES, STL, etc.

FreeCAD is also a solid modeller, that is, we design parts that have their thicknesses and can be printed in 3D. A surface modeller allows to design complex shapes of the pieces, but they do not have thickness and therefore cannot be sent to a 3D printer. It will be necessary to make a thickening of the part, or the step from surfaces to solid, so that it is possible to obtain a physical part.

To start with FreeCAD you have to keep in mind that you must create the body. It will be the solid that will act as a container for operations. The environment offered by FreeCAD is always related to the design object, so if we are in the Design of Parts, we will have prepared the necessary tools environment, which simplifies the search for tools.

### 6.1.3 REVERSE ENGINEERING

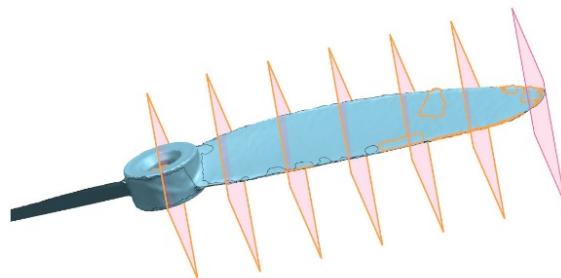
The process of creating a CAD model from a physical model is known as reverse engineering. It is called reverse engineering because it is part of a piece already developed, it is digitised with a 3D scanner and the model is reconstructed in CAD for its subsequent modification, being a reverse process to the usual one. This is done because we do not have the three-dimensional (3D) information of the model that we intend to modify. An exercise is developing a propeller starting from a plastic propeller. With a 3D scanner you get a cloud of ordered points that are saved in STL format. We work on this model to obtain the part in 3D CAD. Later we will obtain the other blade in the opposite direction and we can make the modifications to adapt it to the needs and be able to manufacture them for example in 3D printers. For example, modifying the length of the propeller, or the type of helix we want ("Bullnose", hybrids), or the "Pitch" (or inclination of the blade).

From a digitized propeller and it is possible to redraw the 3D geometry to design our own custom propeller. The three-dimensional information of the points obtained can have more or less dark areas not captured by the 3D scanner or by reflections that can make some points captured not suitable. The CAD system does not have automatic tools that transform the information of points in a parametric modelling and it is necessary to carry out a process of reconstruction of surfaces and generation of the corresponding solid.

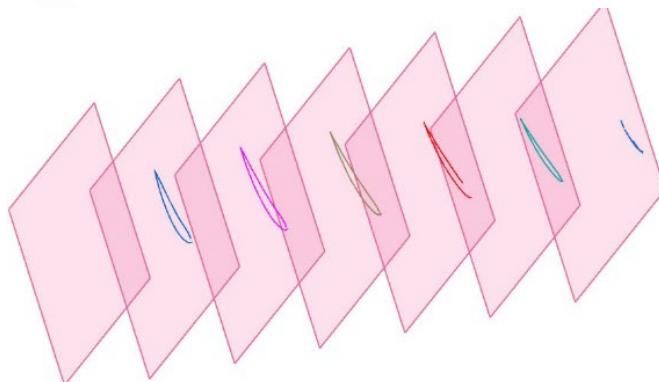




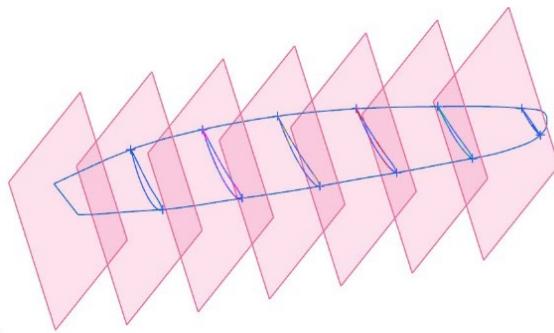
The objective is to extract the necessary three-dimensional information to reconstruct the part surfaces. The first step is to locate the centre of the part for the flat surface of the cylinder. From this origin, parallel reference planes will be generated that will be used to cut one of the blades:



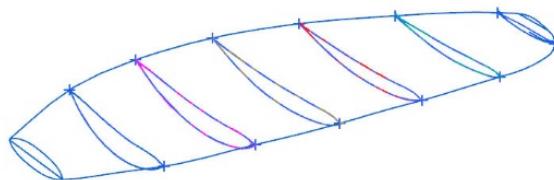
Each reference plane cuts the piece and the points that must be used to create the base curves are obtained. In those reference planes in which the dark parts were not captured by the scanner, it will be necessary to carry out a design work of the curve that reconstructs the part.



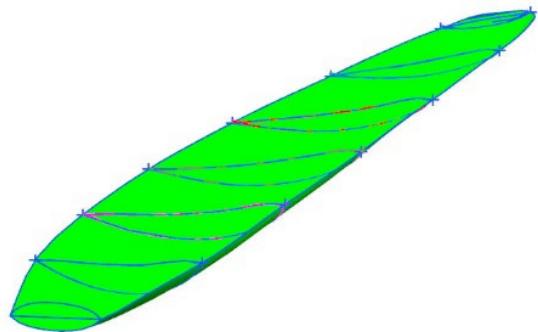
Several design techniques can be applied in this work. For example, it is possible to project another curve of a reference plane that is complete and rely on this information to repair the necessary points. In this case the information of the 3D scanner is quite complete and it is very easy to obtain curves from the extracted points



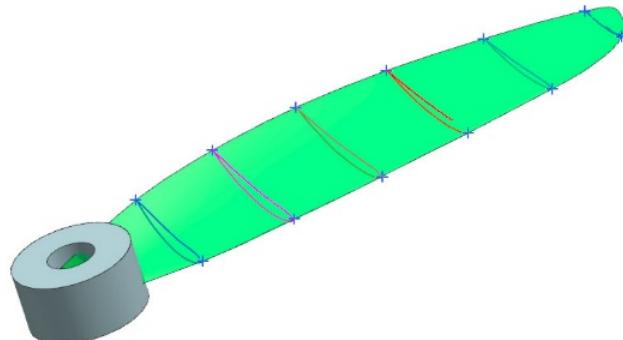
The goal is to generate a mesh of curves that are the skeleton of the design. It must be ensured that the curves are cut at a point with the transversal curves that are designed to close the model.



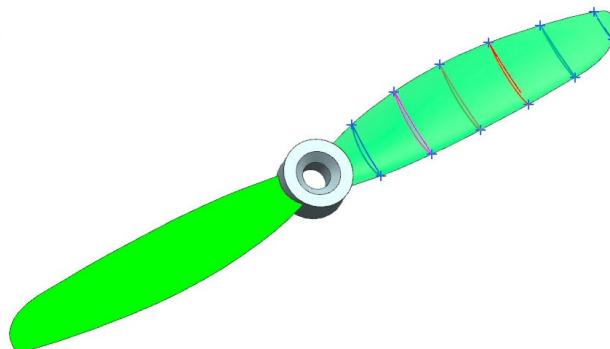
From these curves, the mesh surface is generated, which will allow us to obtain the "skin" of our CAD model.



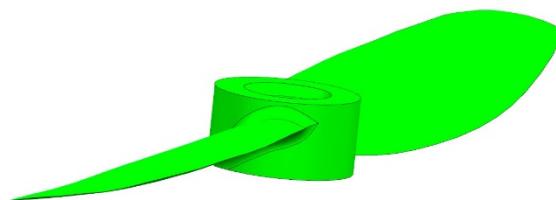
These surfaces obtained must be analysed to ensure that they have the appropriate quality and adapt to the scanned model. The next step is to generate the central cylinder of the propeller that will allow closing and thickened the propeller, converting it into a solid.



The last step is to generate the copy of the blade. For this purpose, a copy with rotation with a 180° rotation must be made it in the CAD system.



We perform the Boolean operations of Union of all parts of the propeller and apply rounding. The propeller is complete. Obtaining the propeller that rotates in the other clockwise direction is relatively simple by using symmetry with turns that allows to make the necessary changes to have the new propeller model.



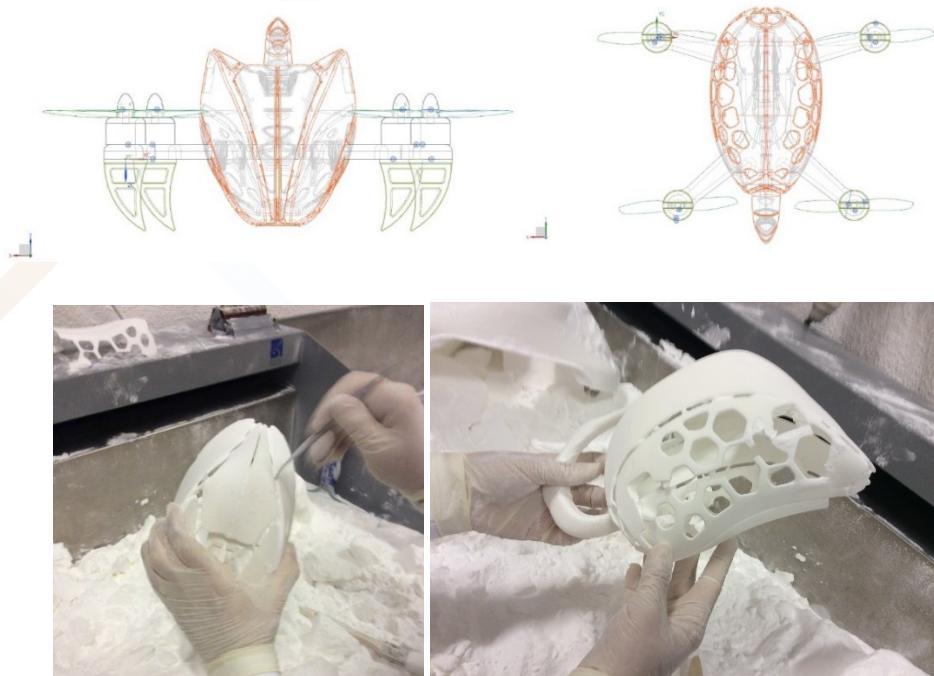
You can download the propeller in some CAD formats and in STL format prepared for 3D printers in the DroneTeam webpage, Download Area in Results section.

### 6.1.4 DRONE FRAME DESIGNING

The frame or "frame" of the drone is the element that contains all the components, gives it the form and must be light and resistant, which is why the efficient design must also take into account the materials and the manufacturing process of the vehicle. It is therefore possible to have carbon fibre or plastic chassis such as ABS (acronym for Acrylonitrile Butadiene Styrene), it is also possible to create housings that cover all the elements. It is a creative exercise to design a frame at the same time as the development itself. It is an R & D process using various rapid prototyping technologies, from the simple use of a 3D printer to the use of advanced rapid prototyping machines, such as selective laser sintering.

All the possibilities have been used in the DroneTeam project. From the simplest to the most complete machines. This is how the DroneTeam model of the drone chassis was obtained.

As an example, a chassis and a drone carcass is generated that has an effect of a creative design in the form of a flying insect with a stinger prepared to house the antenna of the drone transmitter that connects with the radio control station.



The CAD 3D files are ready to download from the DroneTeam website (<http://www.droneteamproject.eu/>), inside Results Section, Download Area.

## 7 BASIC DRONE ASSEMBLY

### 7.1 INTRODUCTION

Two options to start. If you have a 3D printer, you can start designing and assembling parts. Our advice is to start with a kit and then customize parts with the 3D printer. A designed and printed frame is possible. A carbon fibre frame costs € 10 and is more impact resistant than 3D printed in ABS. However, as an academic exercise, the development of own products and their modifications is always interesting. In DroneTeam project, we started with Spedix S250 Kit and next sections are the tutorial to assembly and configuring the drone. Keep in mind that the documentation is quite vague or non-existent. We have made this work within the project investigating how to properly connect the various components to this kit.

#### **Operates safely:**

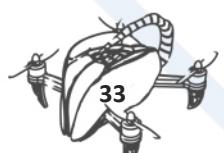
- The propellers can cause injuries therefore never use the Drone/Quadcopter nearby persons or situation in which losing the control of the Quadcopter can produce an accident by hitting a person or a car.
- Never place the propellers on the Quadcopter until you are totally sure that they turn in the proper direction, are properly attached and can be controlled in a safe manner.
- Never leave the batteries charging and unattended or exposed directly to the sun.
- Never allow the voltage per cell in the battery to go lower than 3.3V in a discharge.

### 7.2 KIT CONTENT

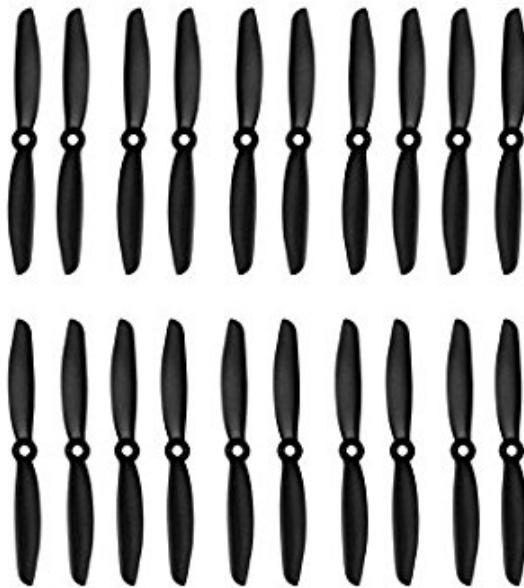
#### **Kit Spedix S250:**



1. BASIC TOY DRONE FRAME



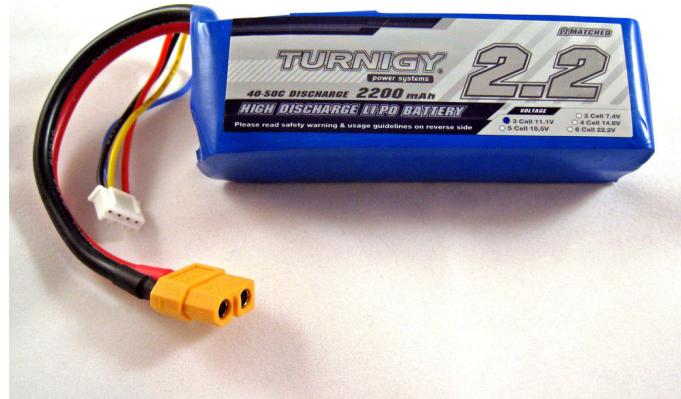
**Extra propellers (2 couples) 5x4.5 Black (CW/CCW):**



**Turnigy 9X 9Ch Transmitter (RC control) & Module 8ch Receiver:**



**Battery Turnigy 2.2 Amps 11.1V(3S) 1.5C (For the receiver):**



**Battery Multistar 3.0 Amps 11.1V(3S) 20C (For the quadcopter):**



**HobbyKing® B3AC Compact Charger:**



### 7.2.1 TOOLS REQUIRED FOR ASSEMBLING

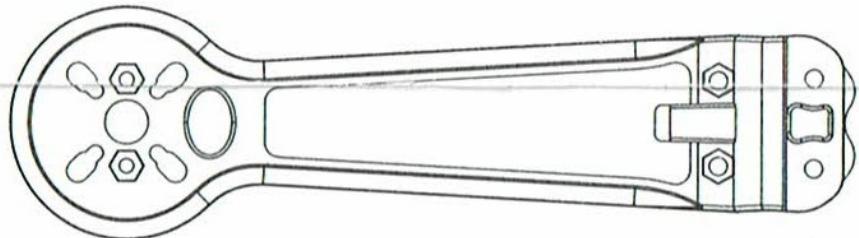
- Allen Keys (1,4 mm y 2mm)
- Small tip screwdriver.

#### 7.2.1.1 FRAME ASSEMBLY

In order to assemble the chassis of our drone, we need the following components:

Bag1

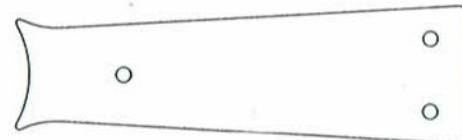
4x



4x

Stickers

4x



M2x8(12x)

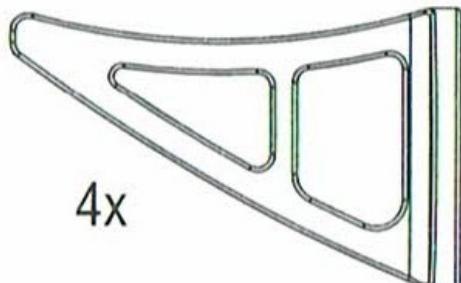


Ø2xØ5x0.5(8x)



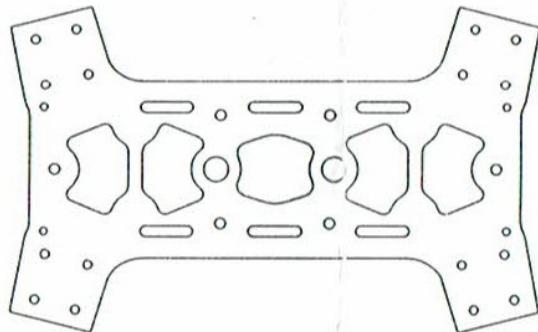
Bag2

4x

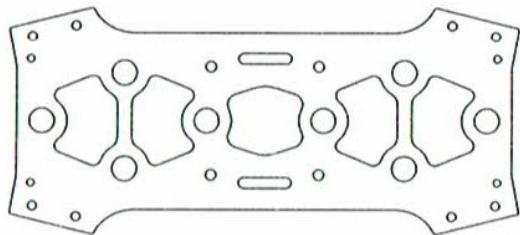


M2x12(8x)

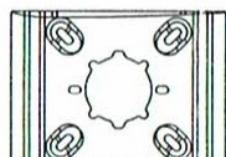
### Bag3



Bottom Board (1X)



Top Board (1X)



1x



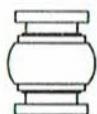
PB2x5(4x)



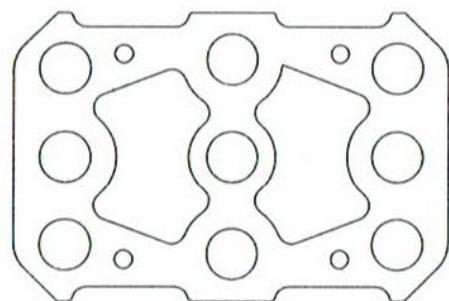
M2.5x10(24x)

### Bag4

4x



1x

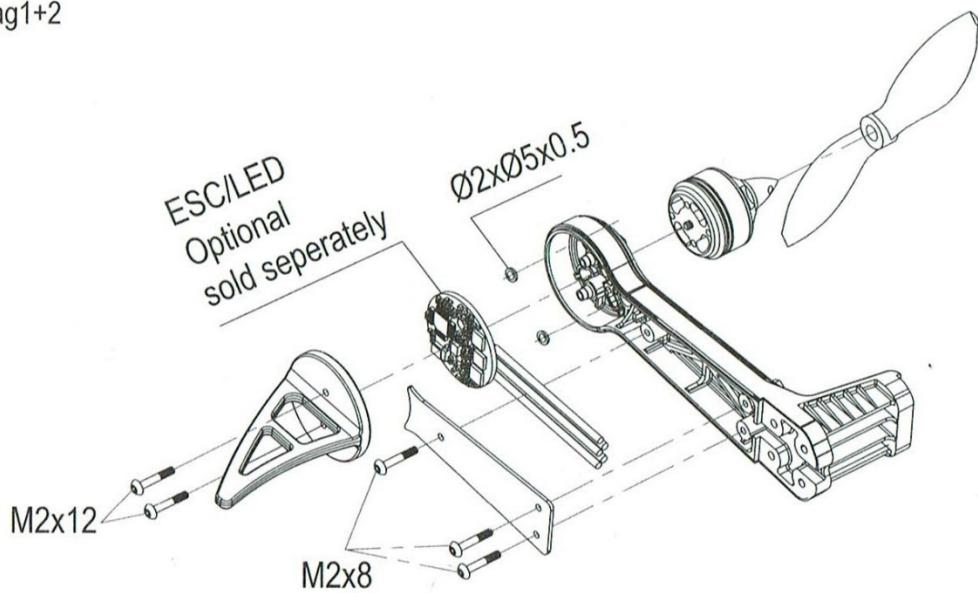


Next, we proceed to mount the chassis of the drone following the order of the following images:

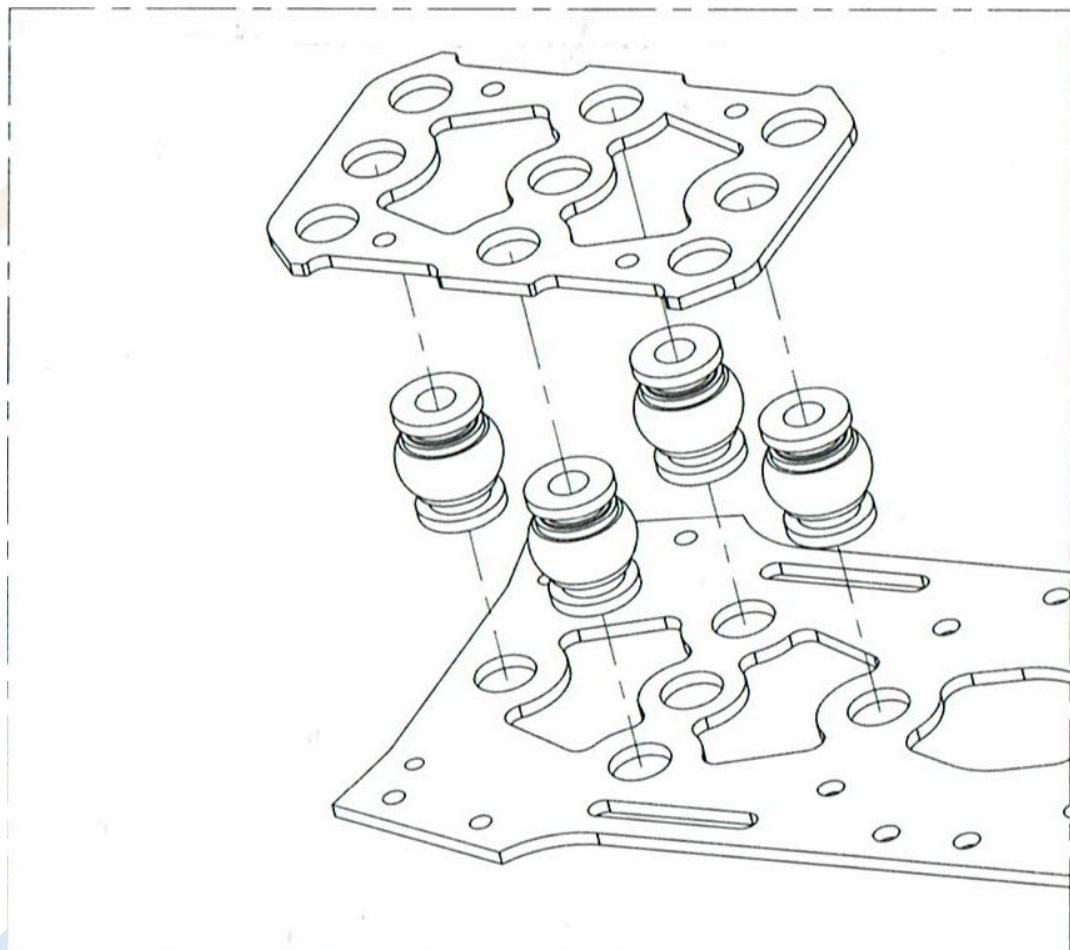


### Step 1

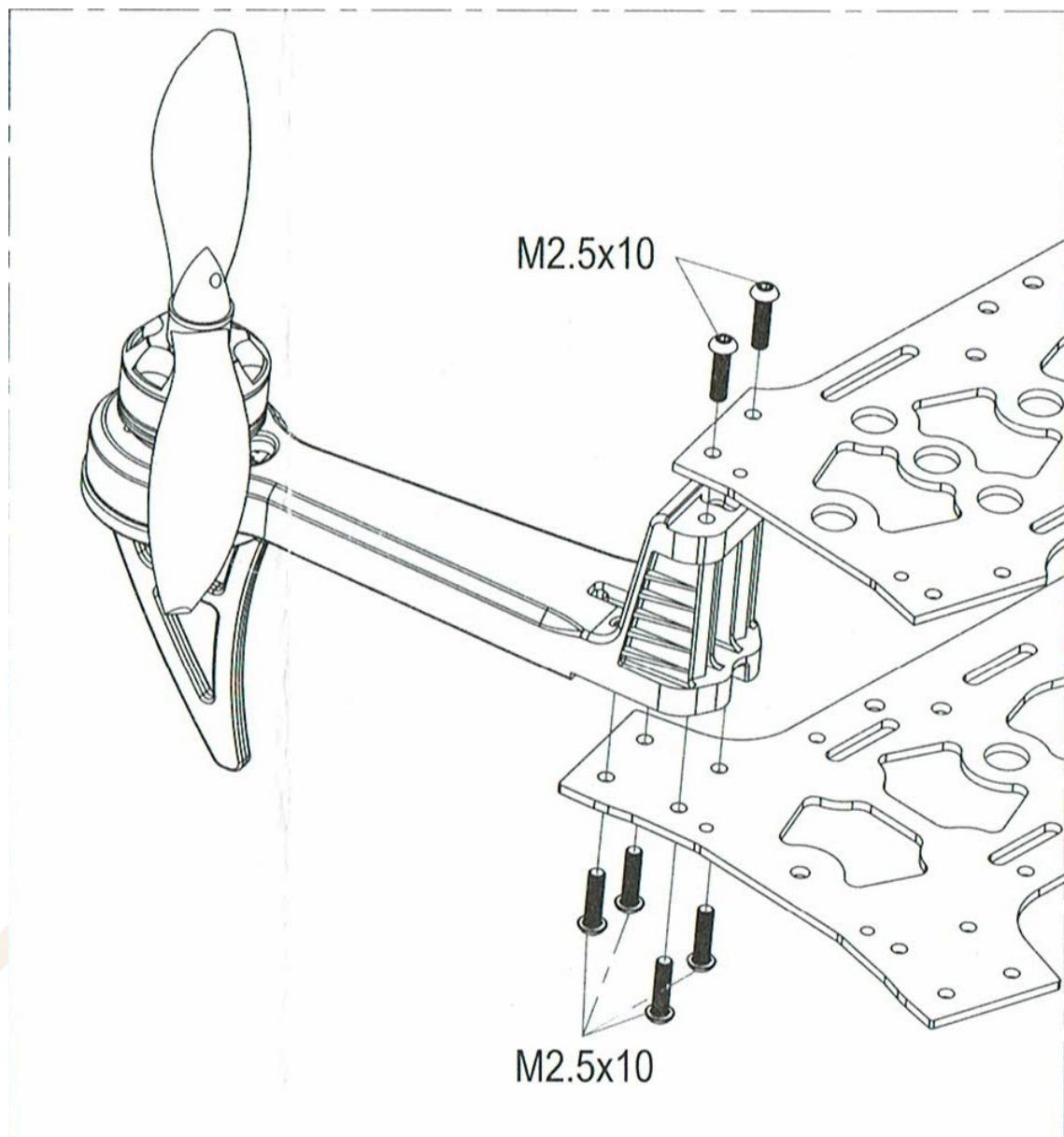
Multirotor Arms  
Bag1+2



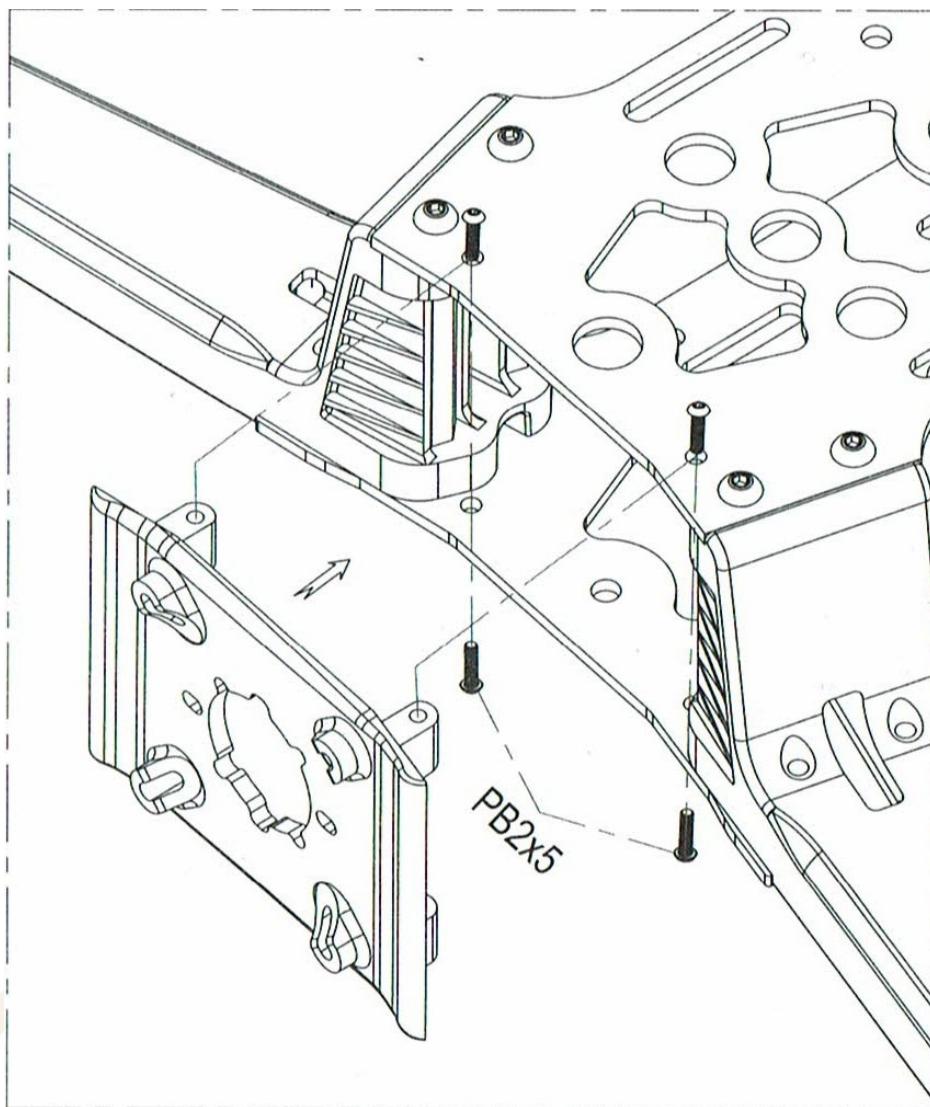
### Step 2



**Step 3**



**Step 4**



Once assembled, it will be such that:



### 7.2.2 HOW TO ASSEMBLE A DRONE.

10 easy steps to assemble a basic drone and put it in the air, based on SPEDIX s250

## The frame



## Other basic components



## Assembling the drone

1<sup>st</sup> step. Attach a motor in each arm of the drone following the sequence shown in the image.



Mark which arms are mounted on a motor that rotates clockwise to distinguish them from those rotating counterclockwise.

## Assembling the drone



## Assembling the drone

2<sup>nd</sup> step. Attach the ESC (Electronic Stability Control) in each arm of the drone



## Assembling the drone

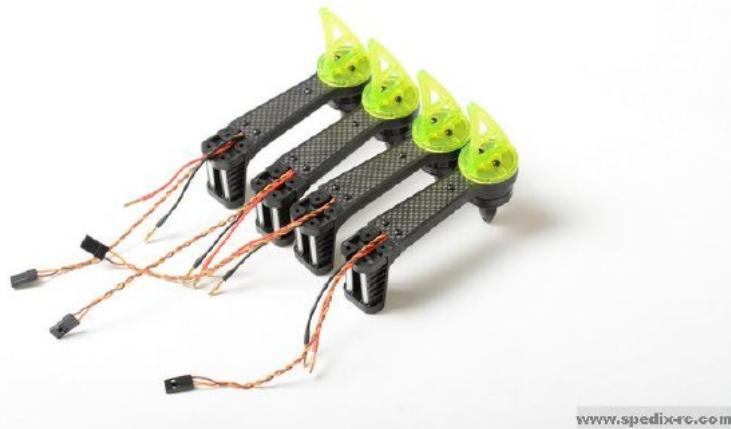


Close the rear part of each arm with the carbon fiber cover plate, to hide the wire and to strengthen the arm.

Without these plates, the arm would be too flexible.

## Assembling the drone

3<sup>rd</sup> step. Attach a landing gear in each arm of the drone. The final result should look as shown in the picture.

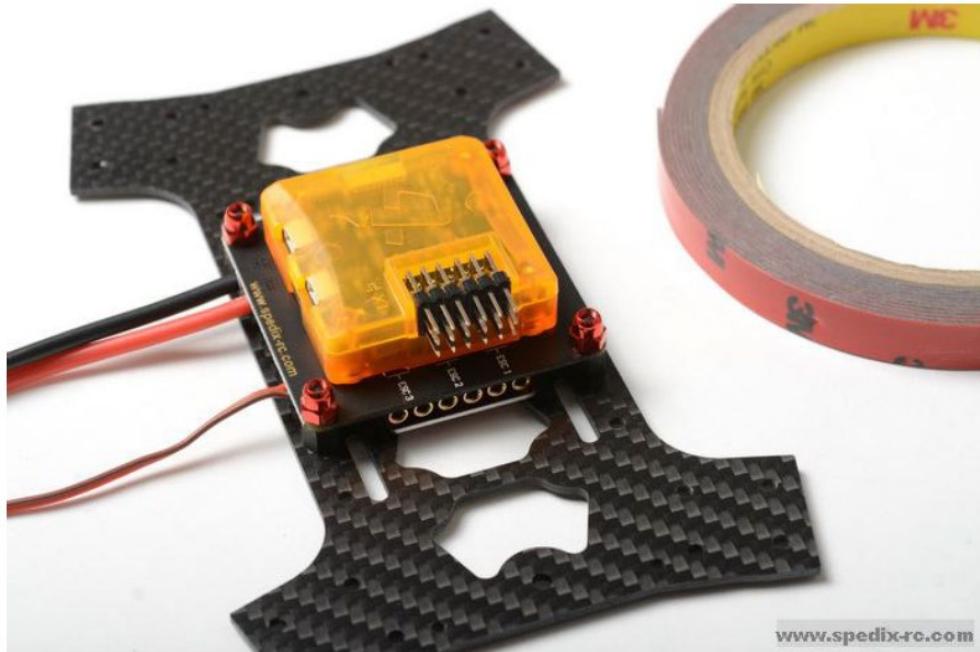


## Assembling the drone

4<sup>th</sup> step. Fix the power distribution board and the CC3D controller on the lower central board.



## Assembling the drone



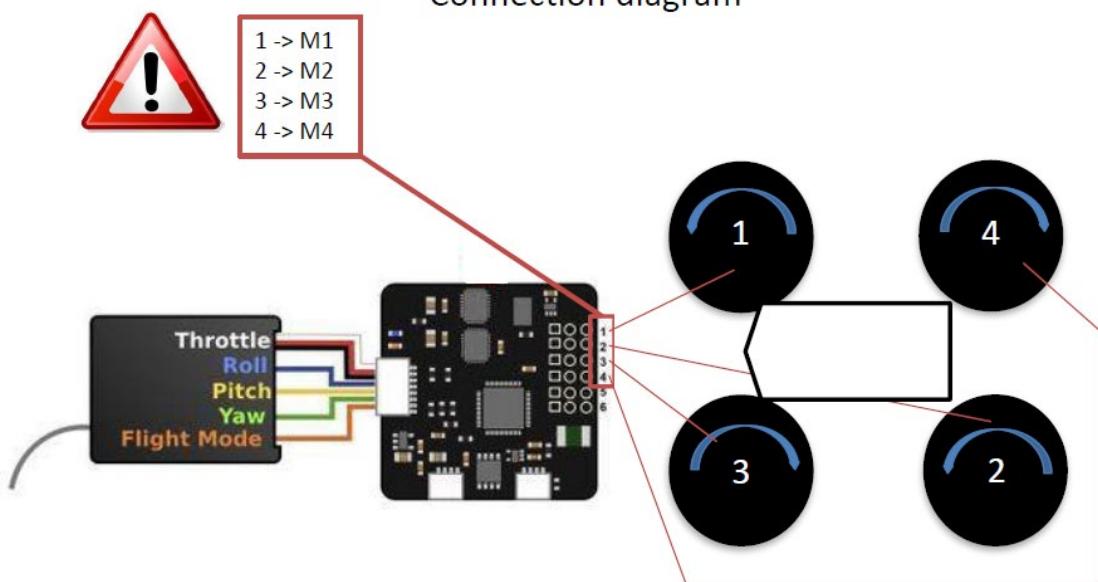
## Assembling the drone

5<sup>th</sup> step. Connecting.

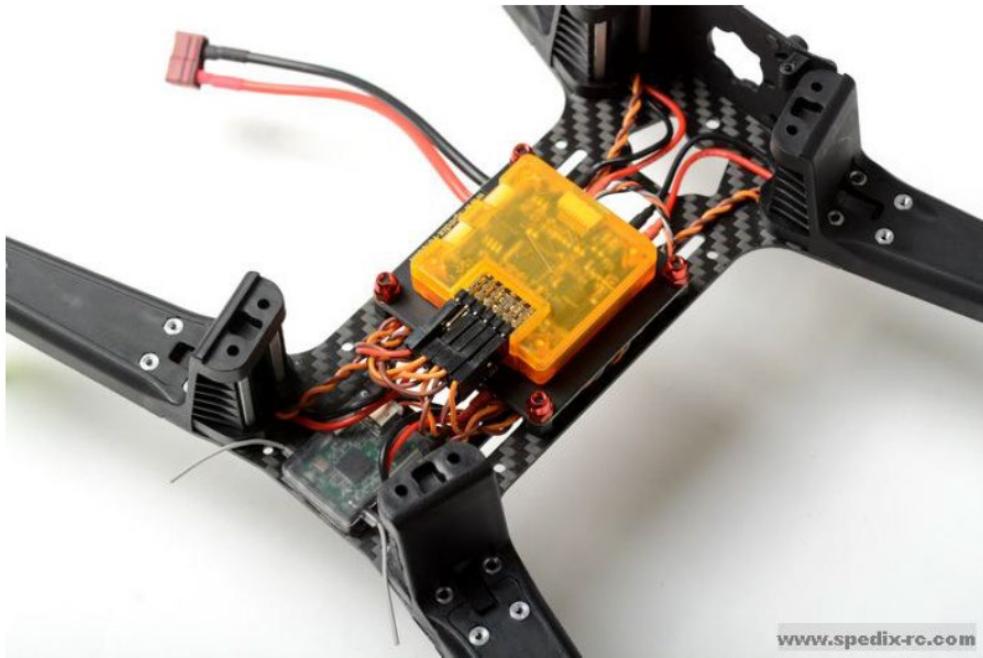


## Assembling the drone

Connection diagram



## Assembling the drone



## Assembling the drone

6<sup>th</sup> step. Fix the arms on the plate and close with the upper central board.



## Assembling the drone

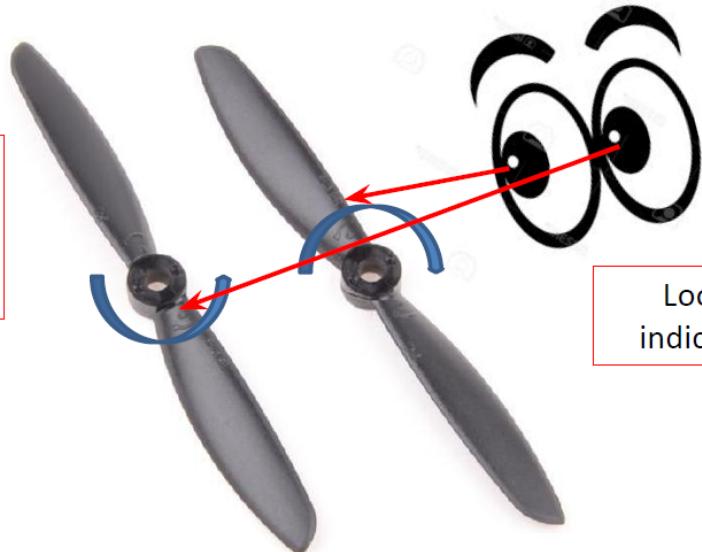
7<sup>th</sup> step. Propellers



## Assembling the drone

CW?... CCW?... Which is which?

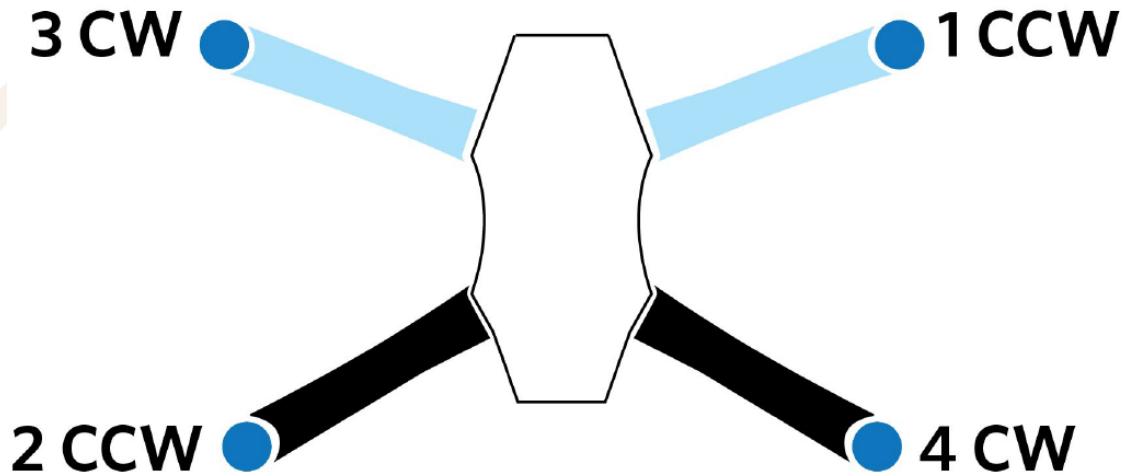
The direction of the blades can help to identify the propellers.



Look for indications.

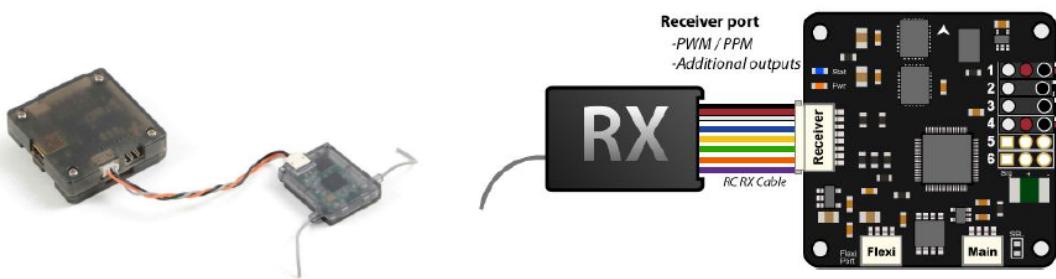
## Assembling the drone

Propellers and motors must match in CW or CCW.



## Assembling the drone

8<sup>th</sup> step. Connecting the radio receiver.



## Assembling the drone

The drone is almost ready to fly



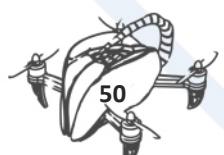
## Assembling the drone

9<sup>th</sup> step .Hold the battery with the strip included in the kit and connect it.



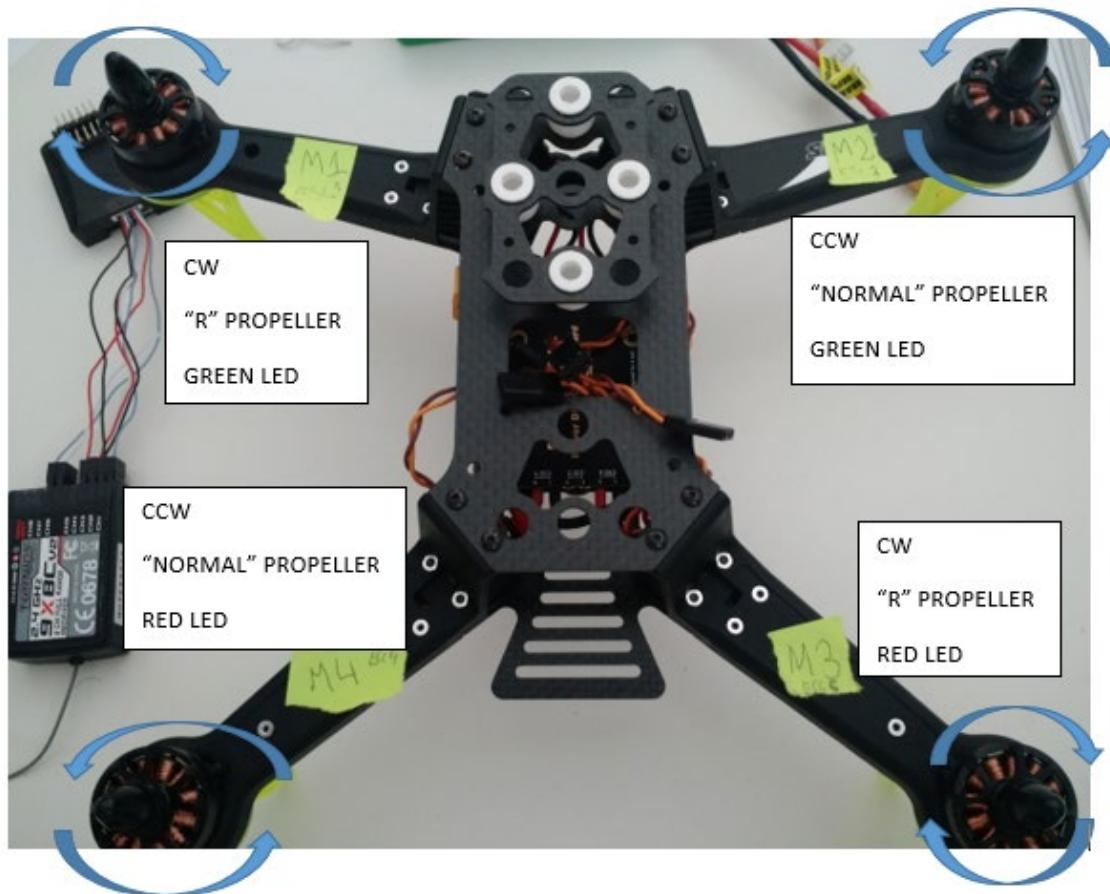
## Assembling the drone

Last step: get a radio control and bind it with the drone.

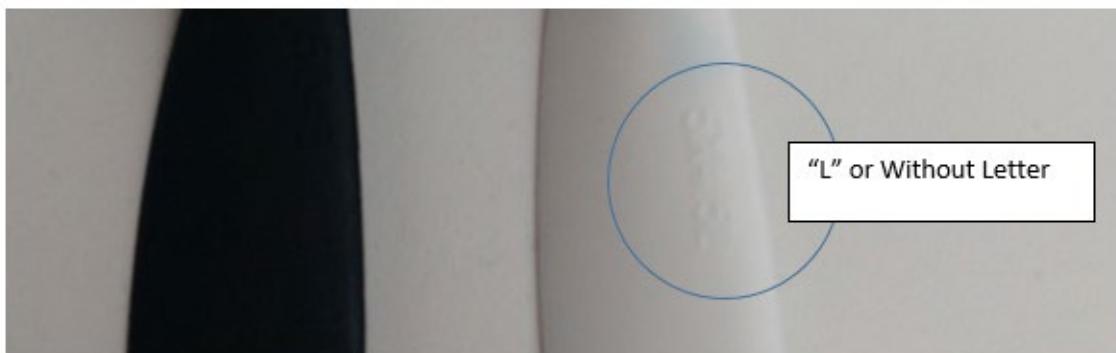


### 7.2.2.1 MOTORS ROTATION AND CONNECTIONS

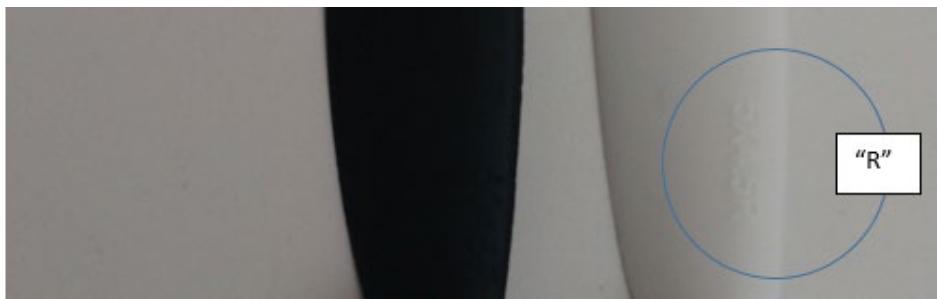
MOTORS ROTATION & PROPELLERS (Motor numbers and rotation)



NORMAL OR "L" PROPELLERS:



“R” PROPELLERS:



LED'S

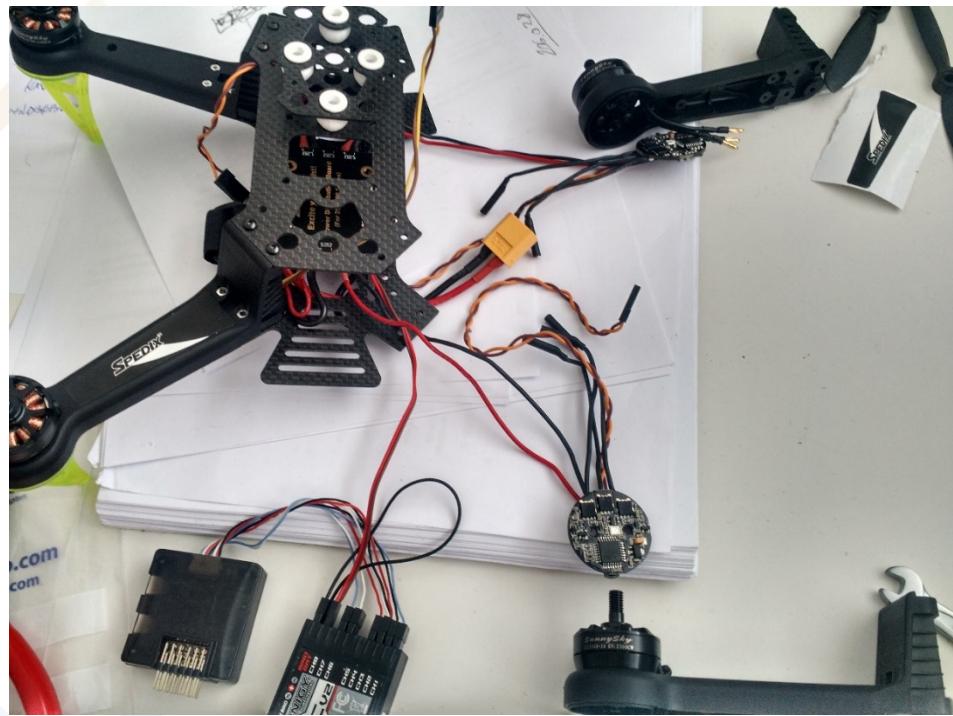


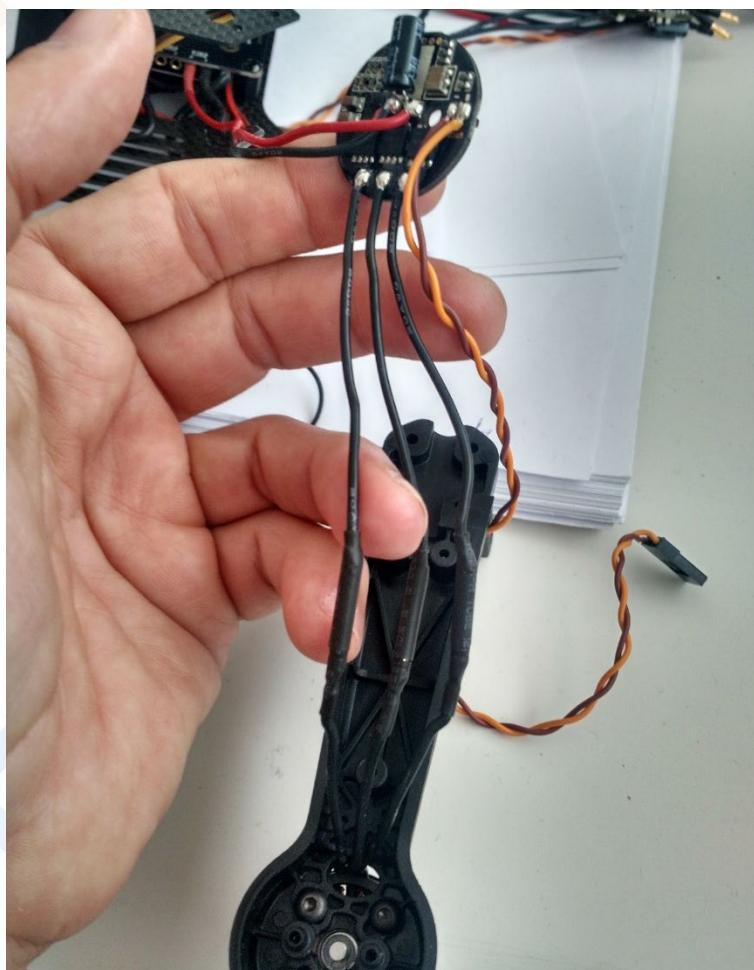
GOOD!!!



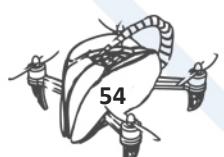
### 7.2.2.2 MOTORS AND ESC CONNECTIONS

CW – Clock Wise

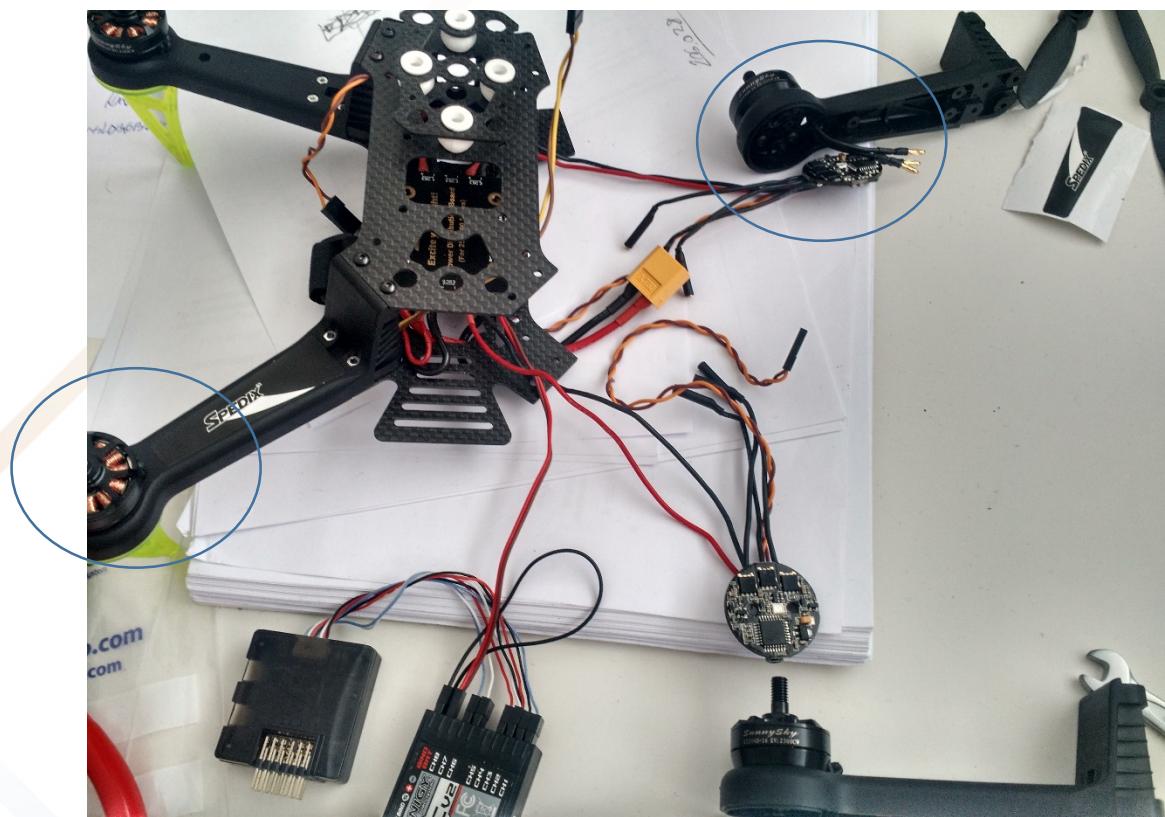


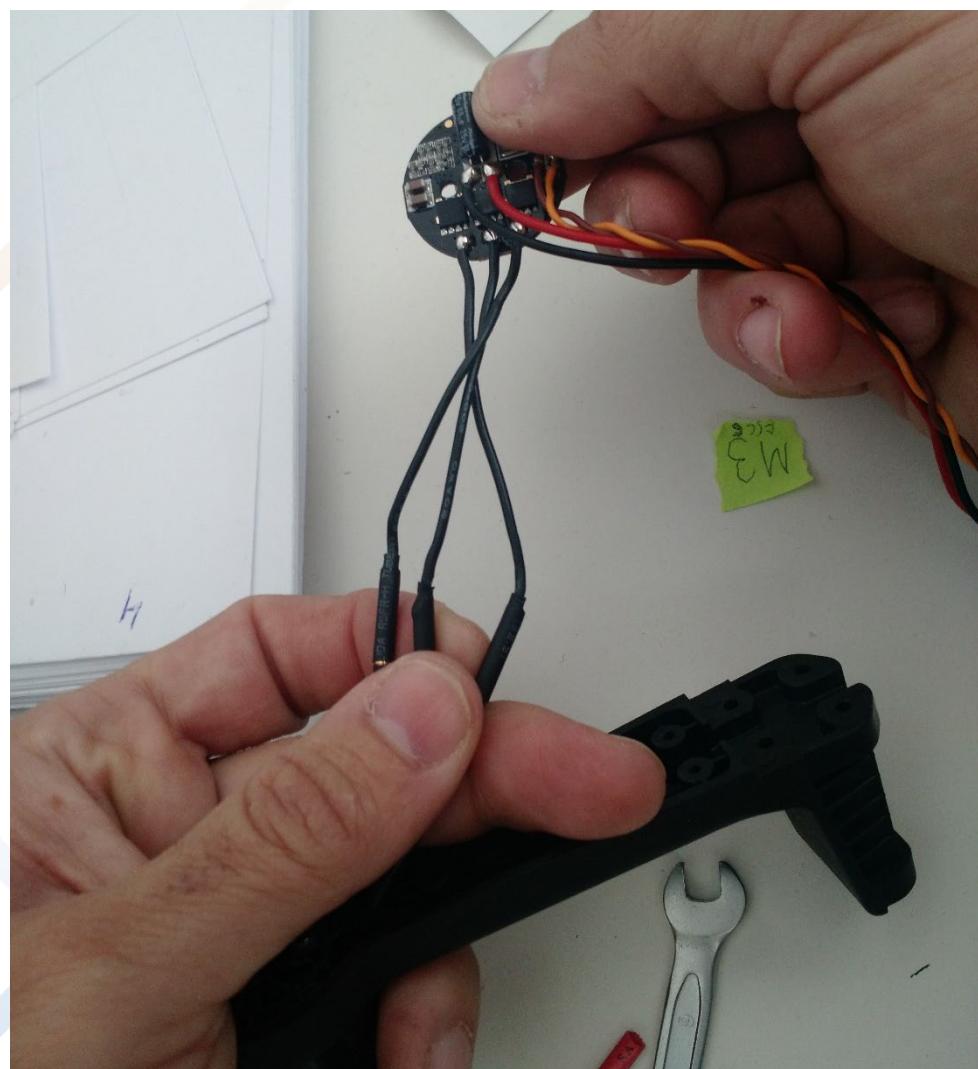
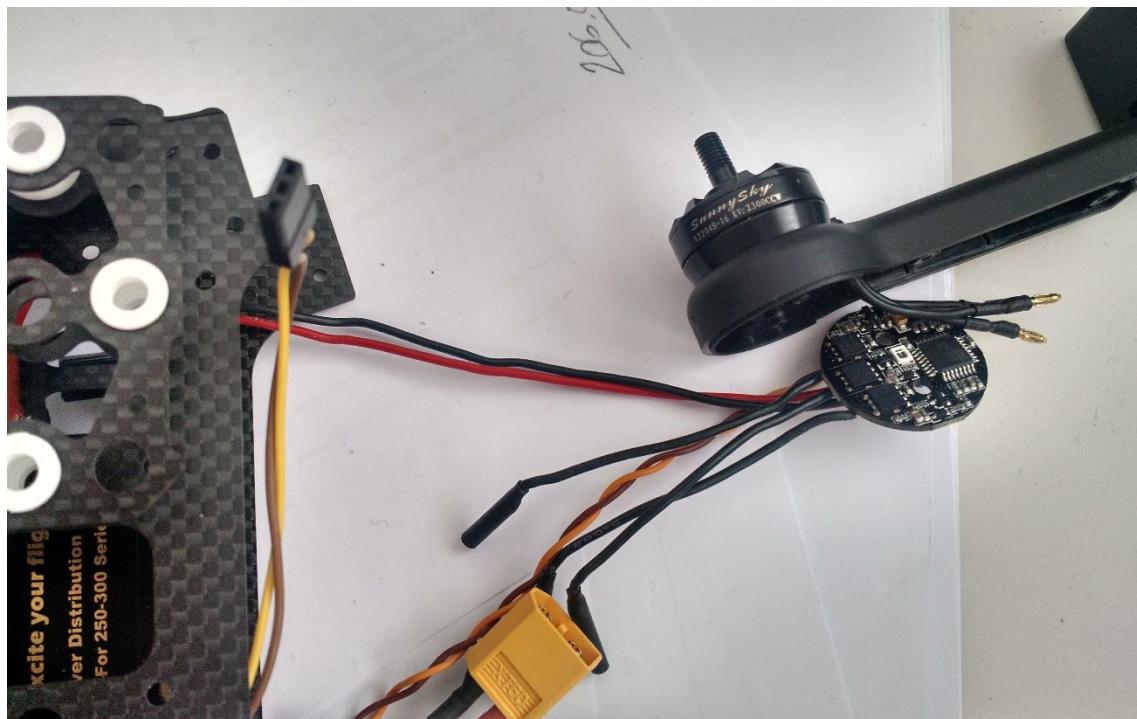


1. BASIC TOY DRONE FRAME

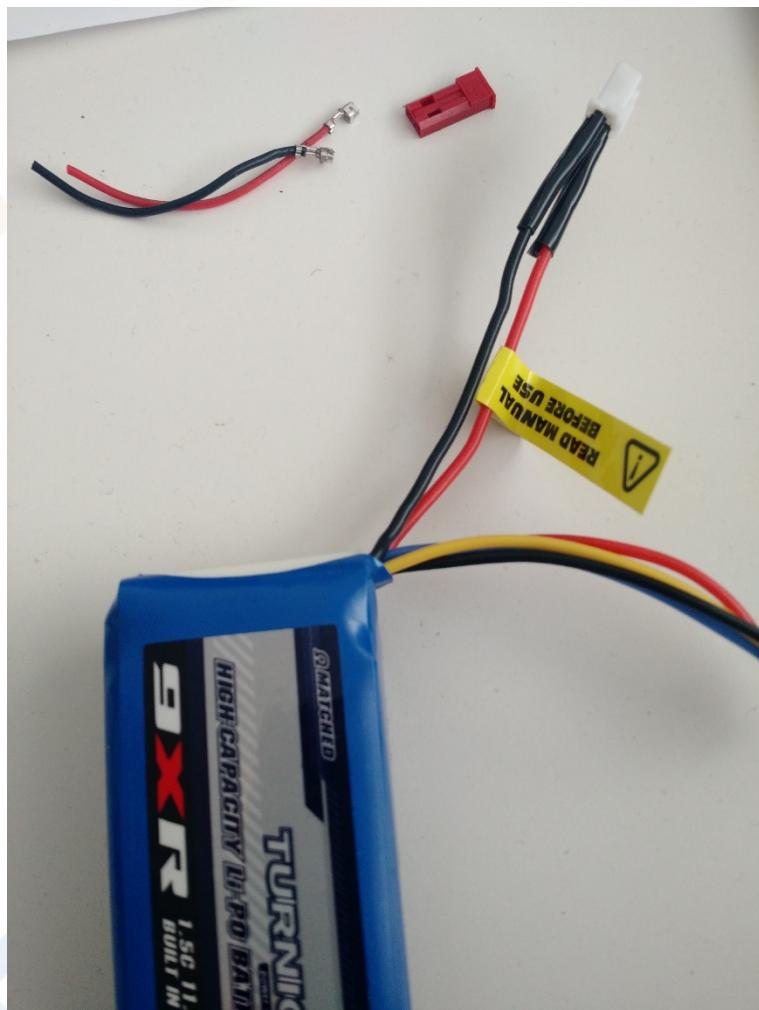


CCW -Counter Clock Wise motors



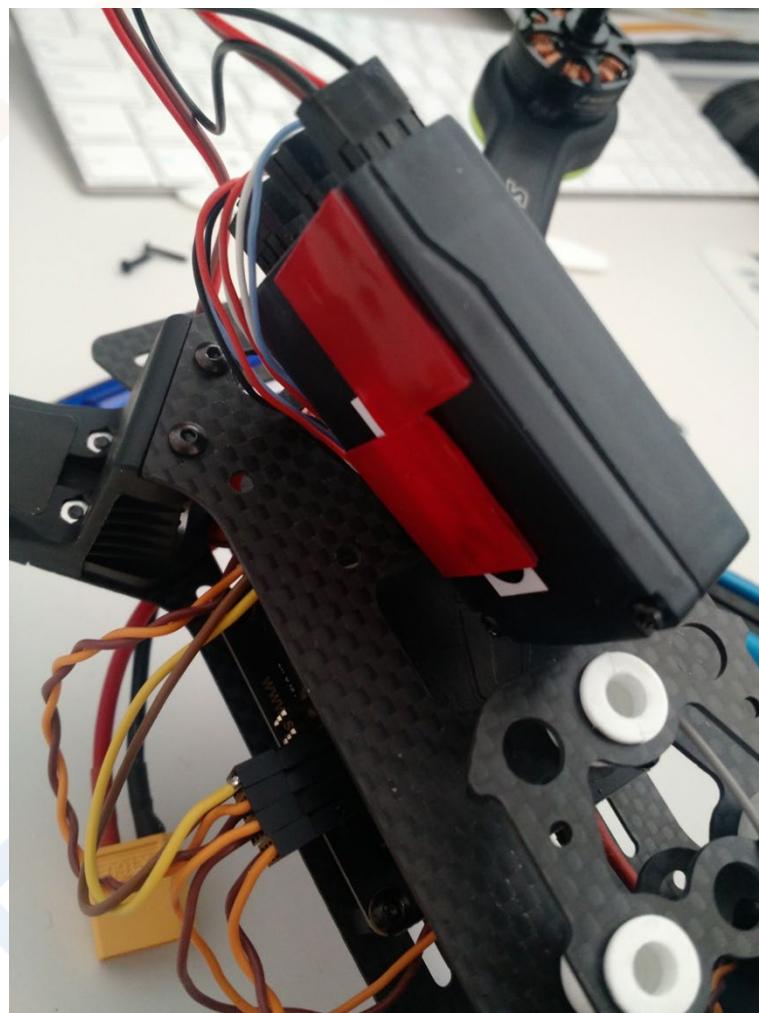


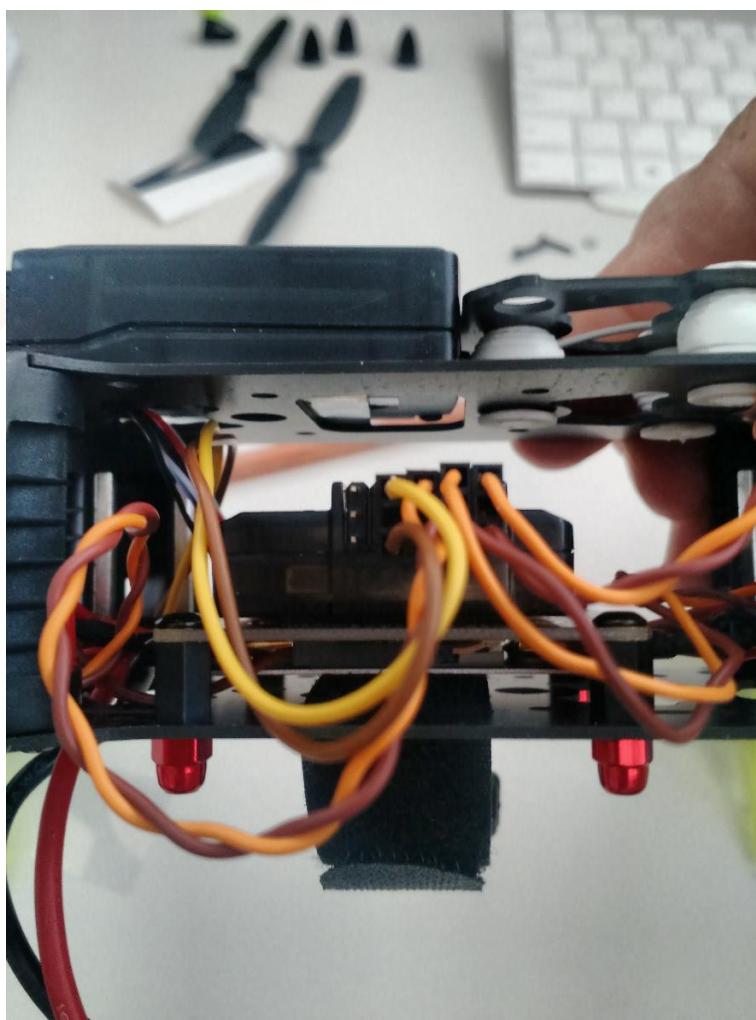
BATTERY ASSAMBLY ON REMOTE CONTROL





#### OTHER ISSUES TO MOUNT





### 7.2.2.3 S250 CONNECTIONS

#### S250 CONNECTIONS - CC3D - TURNIGY 9X

**Turnigy 9x rx channels are as follows:**

Channel 1: Aileron 1 (fins).

Channel 2: Depth (elevator).

Channel 3: Throttle (throttle).

Channel 4: Management (Rudd).

Channel 5: Train returning (Gear).

Channel 6: Shutters (Flaps).

Channel 7: Auxiliary 1 and fins 2 (for differential)

Channel 8: Auxiliary 2.

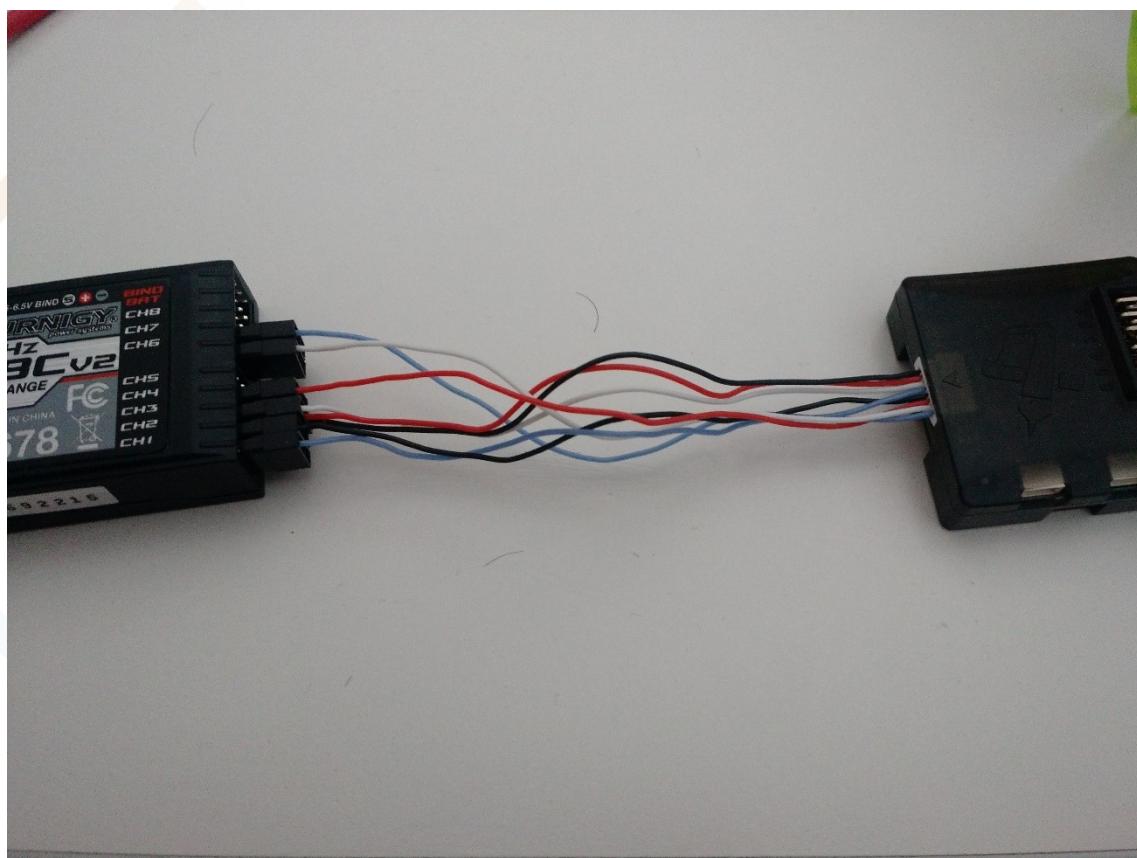
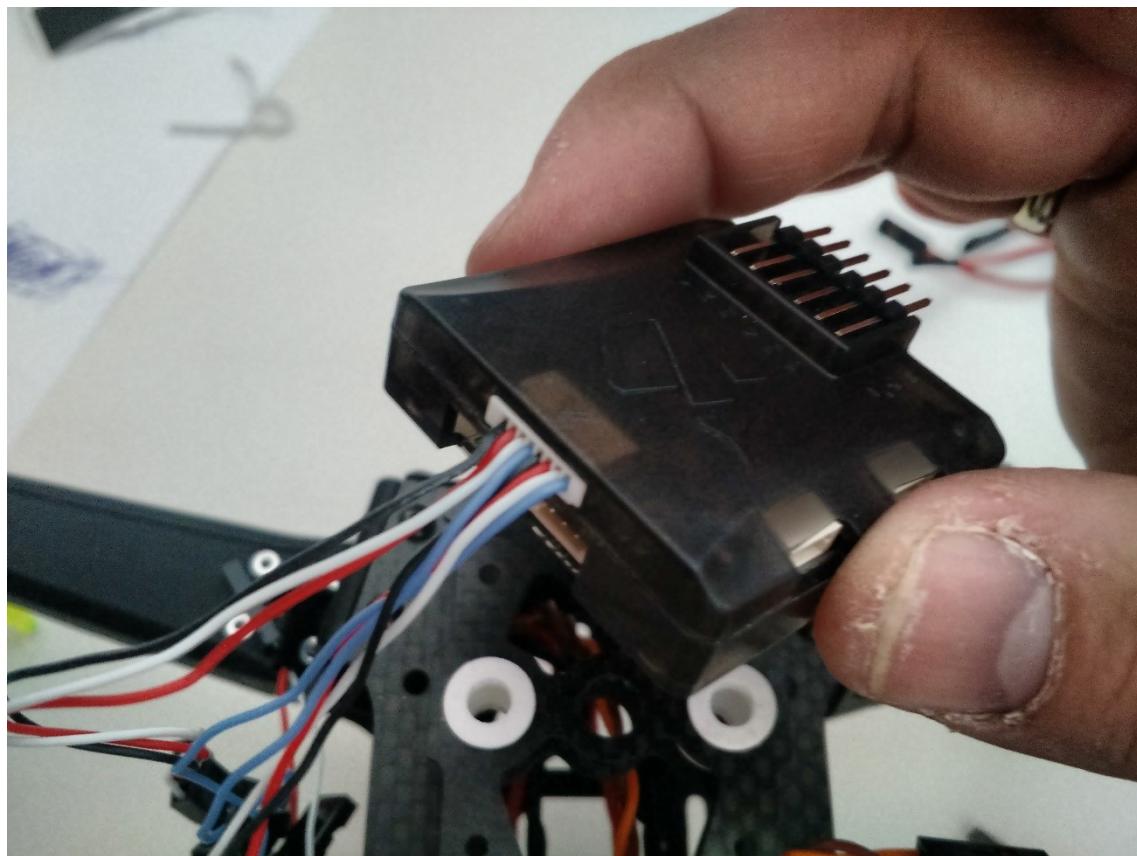
BAT: Battery

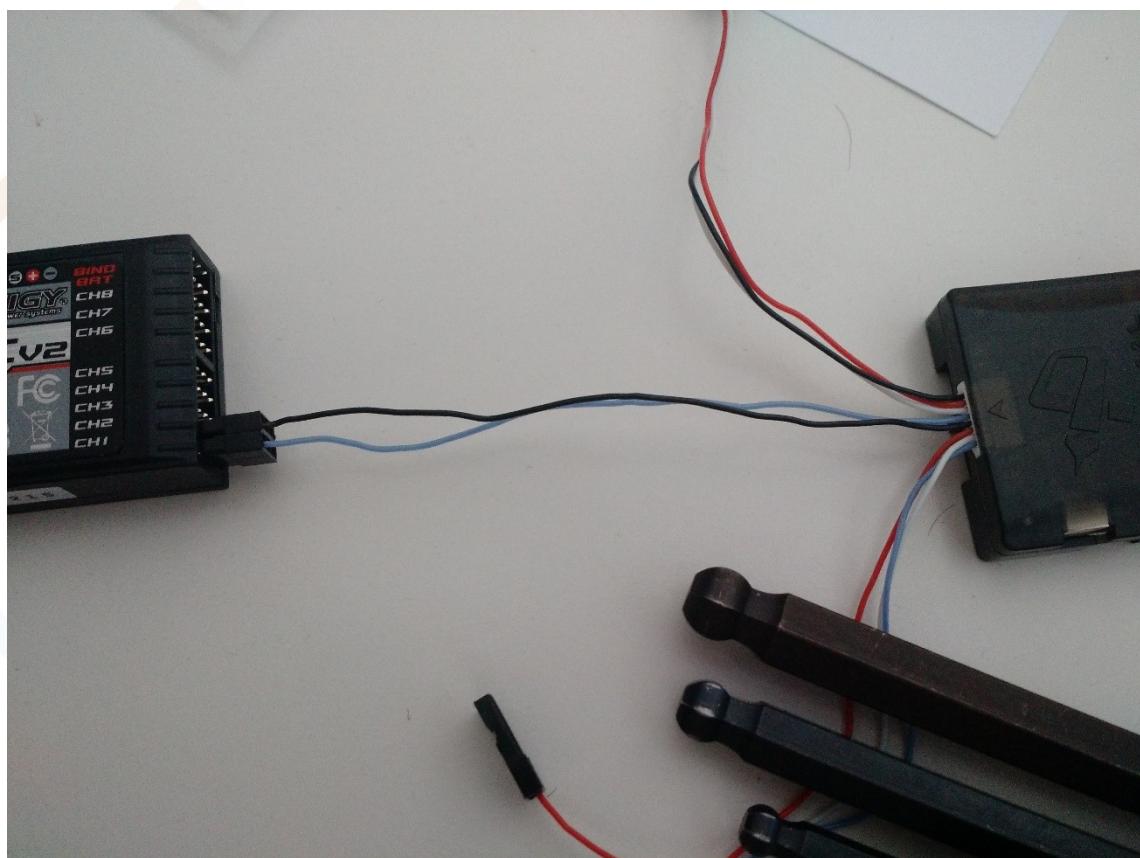
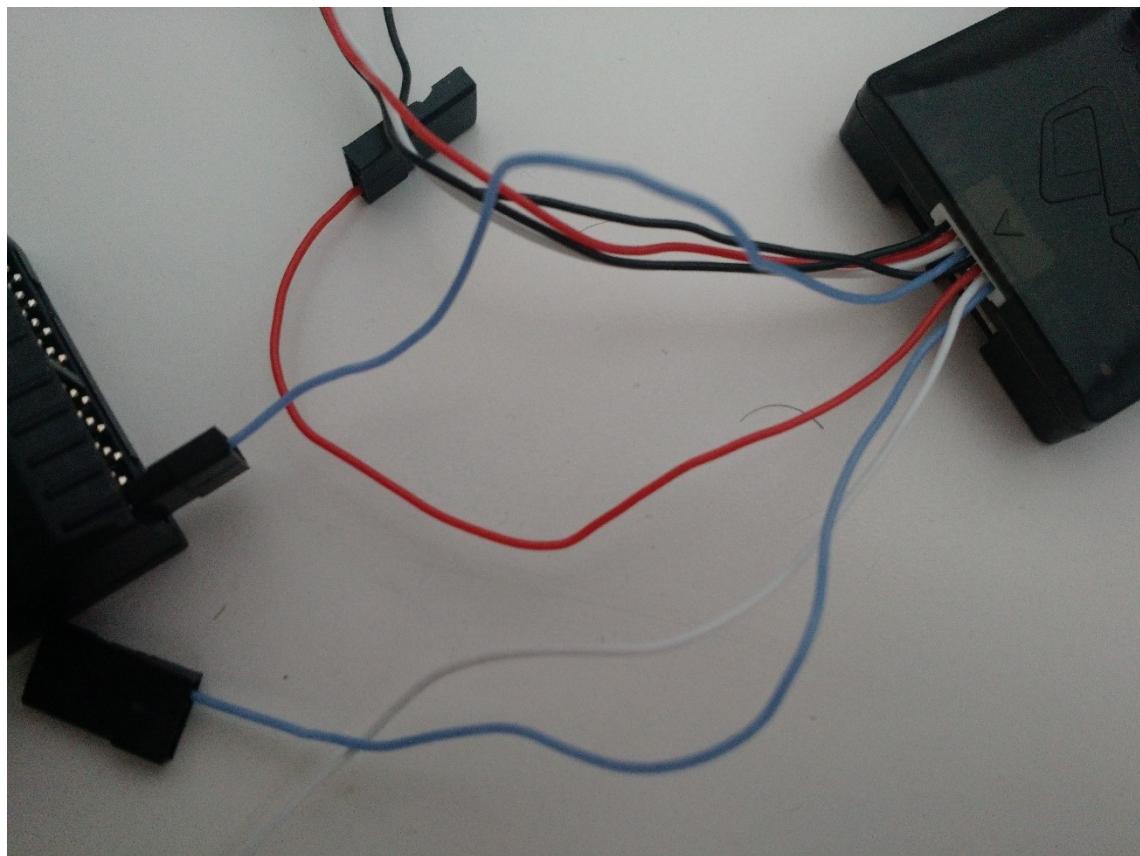
BIN: binder

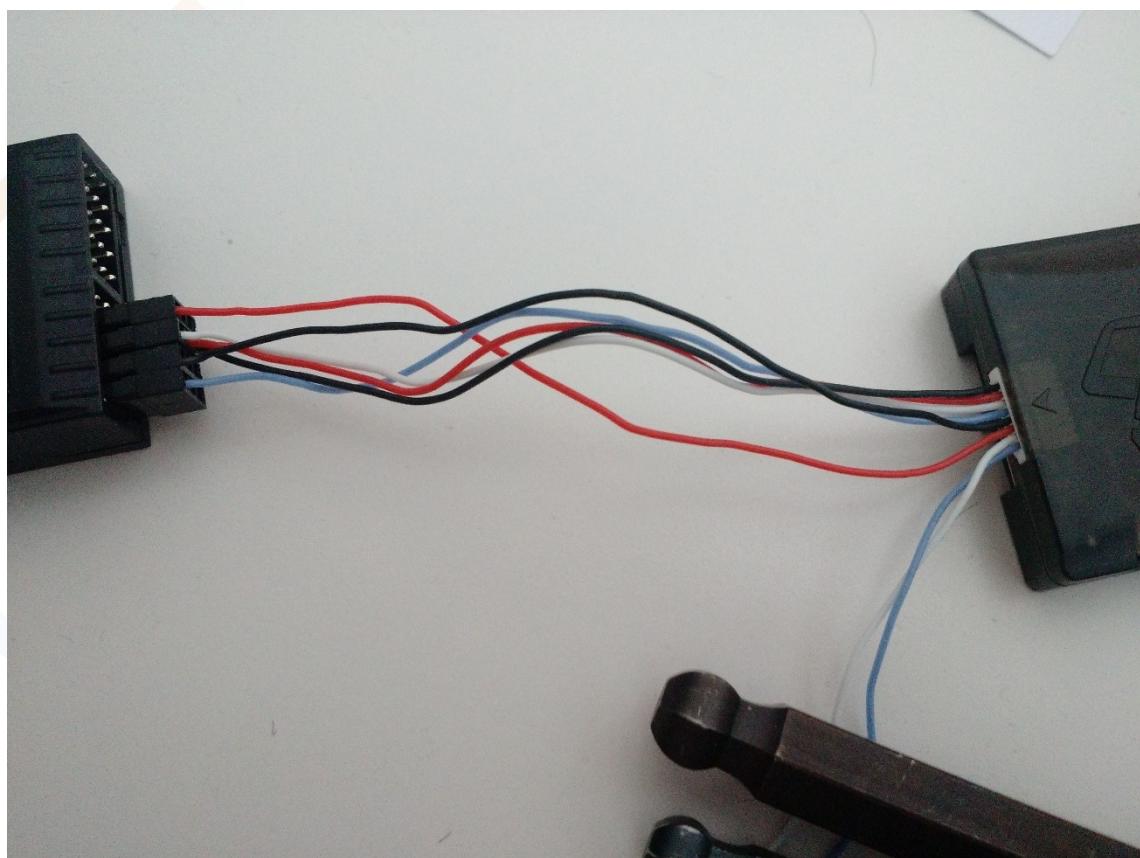
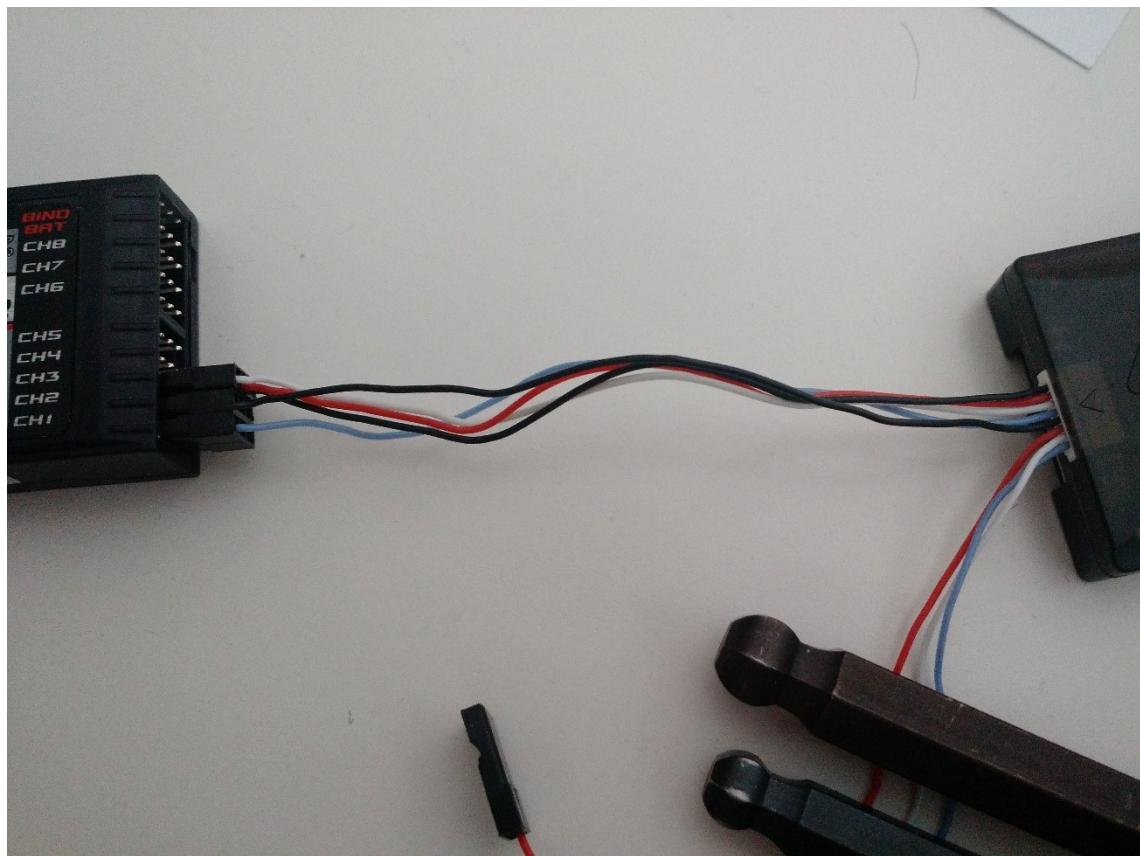
**Receiver module CC3D cables to Turnigy 9x:**

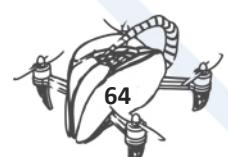
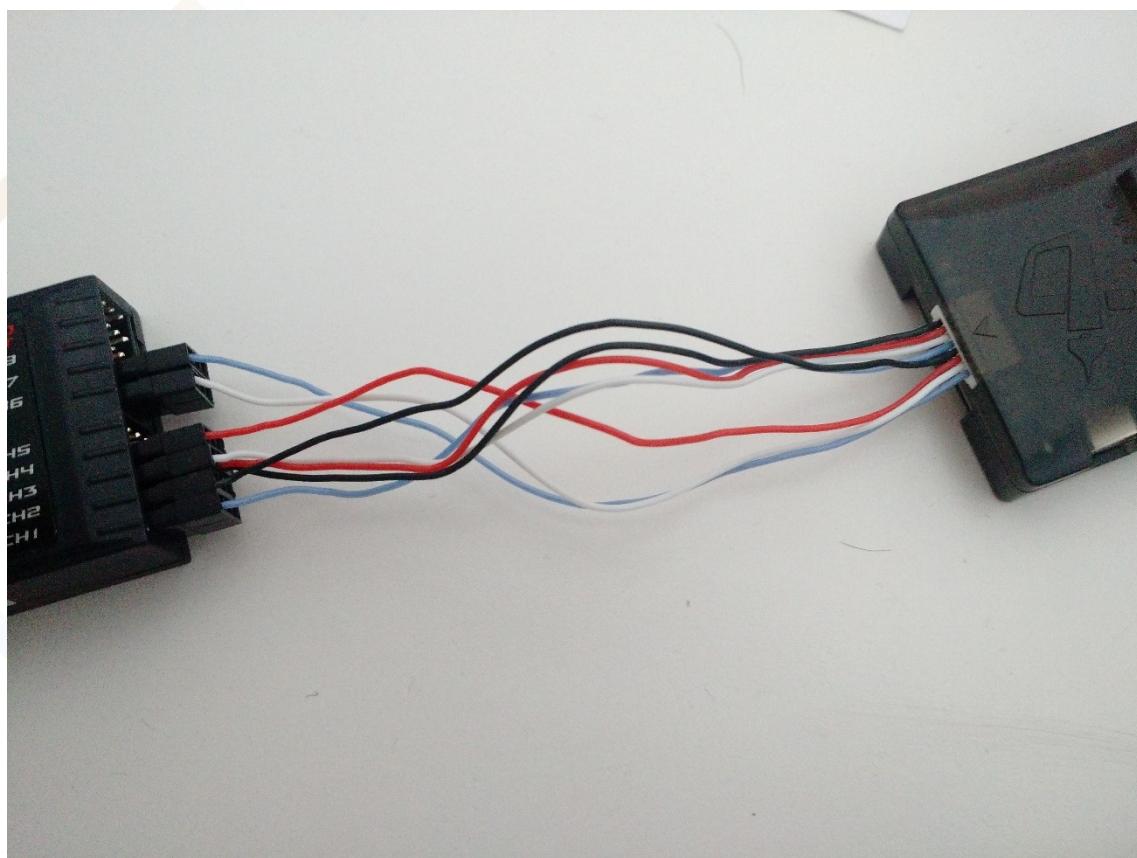
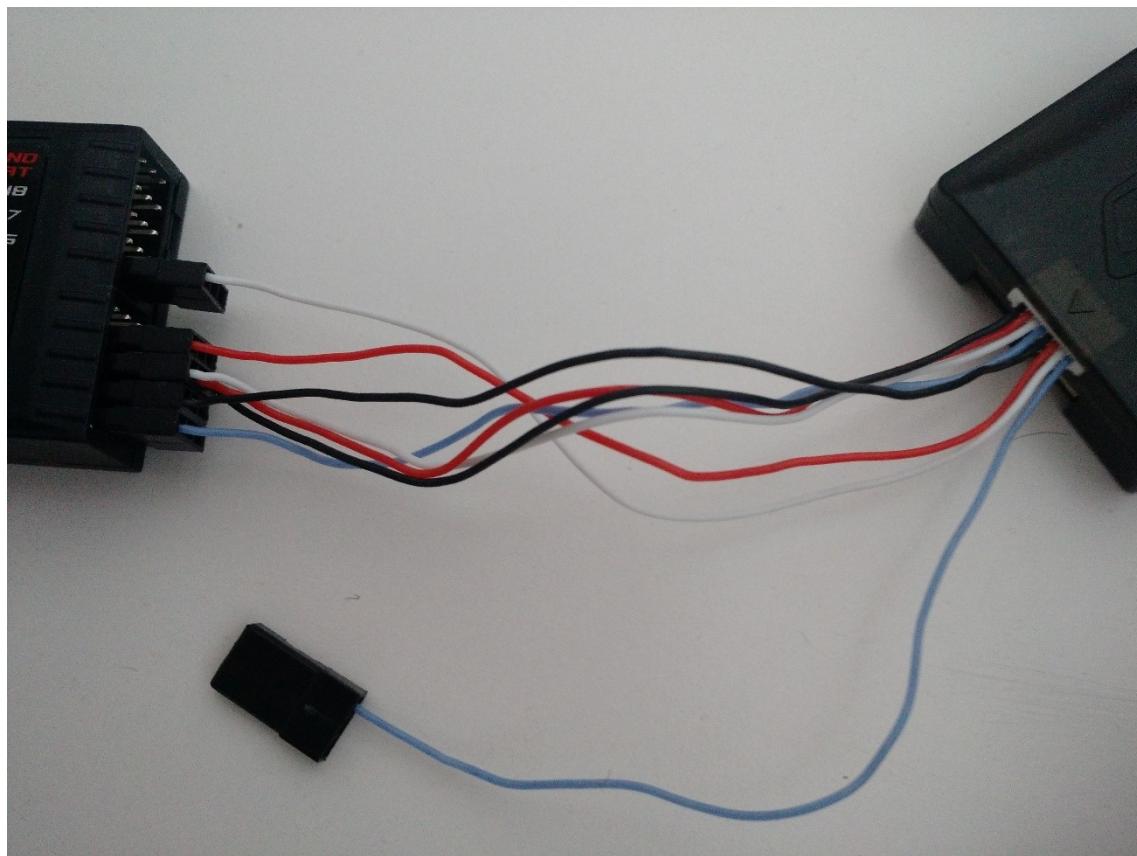
<u>Receiver module</u>	<u>CC3D cables</u>
RX 1	Blue 5
RX 2	Black 4
RX 3	Red/White/Black 1
RX 4	Red 3
RX 5	Free
RX 6	White 2
RX 7	Blue 1

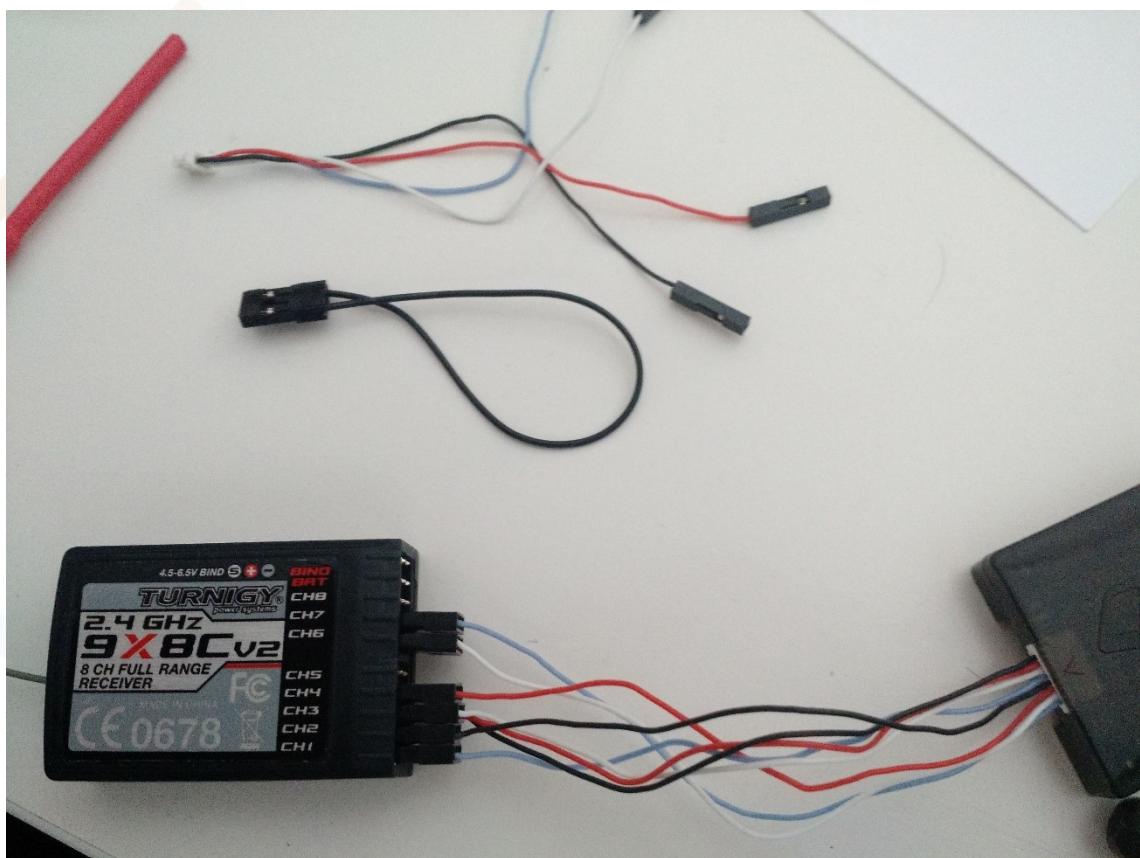
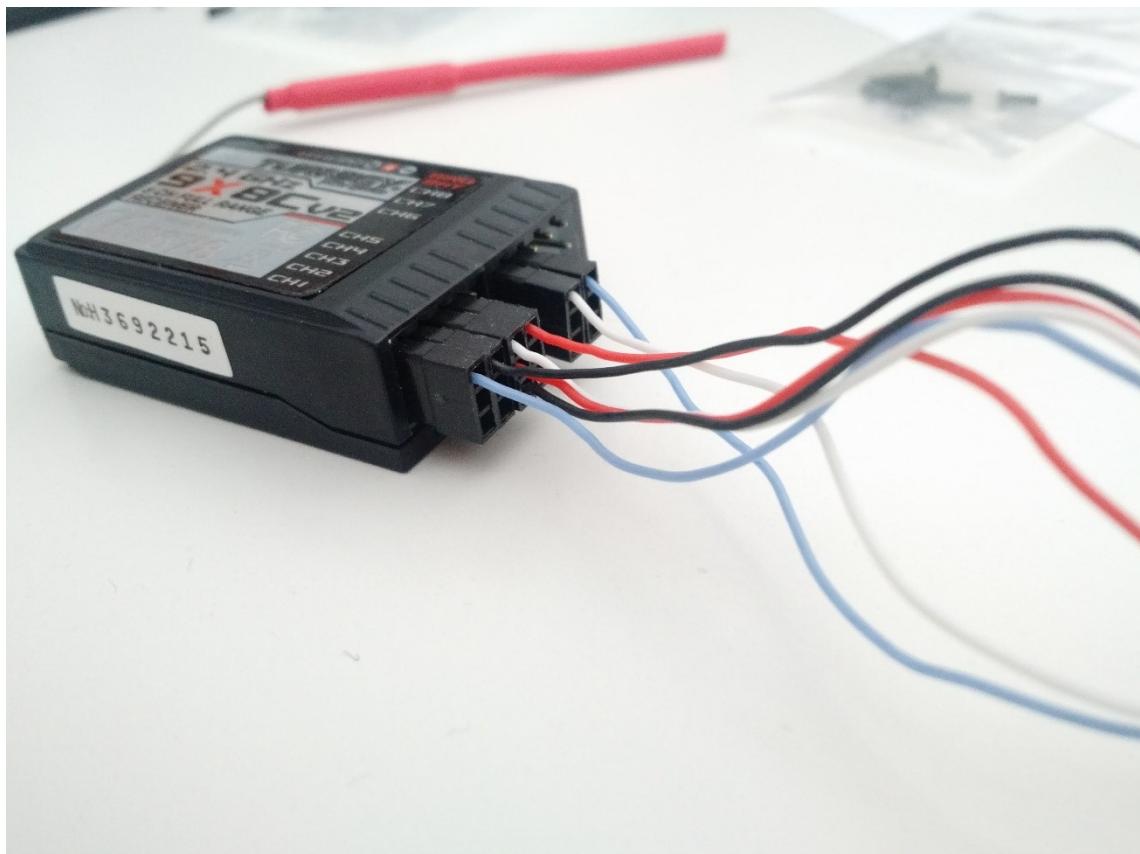


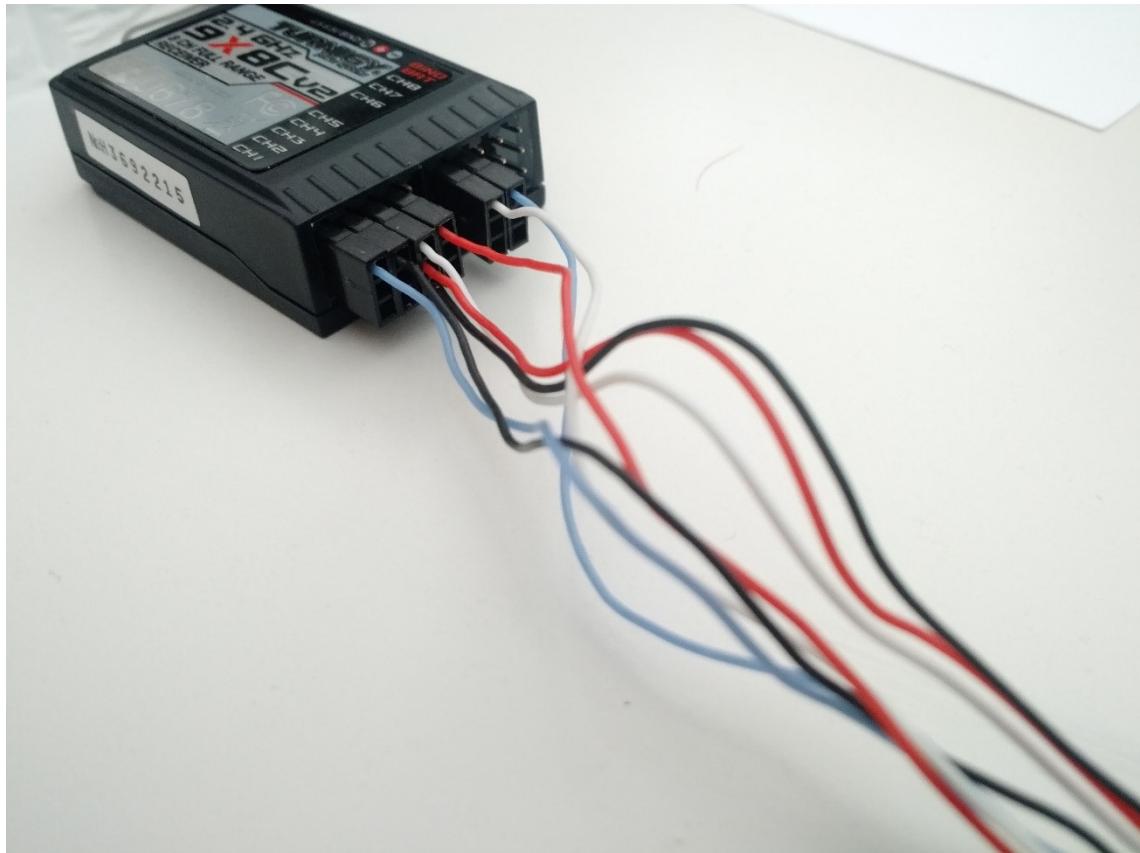




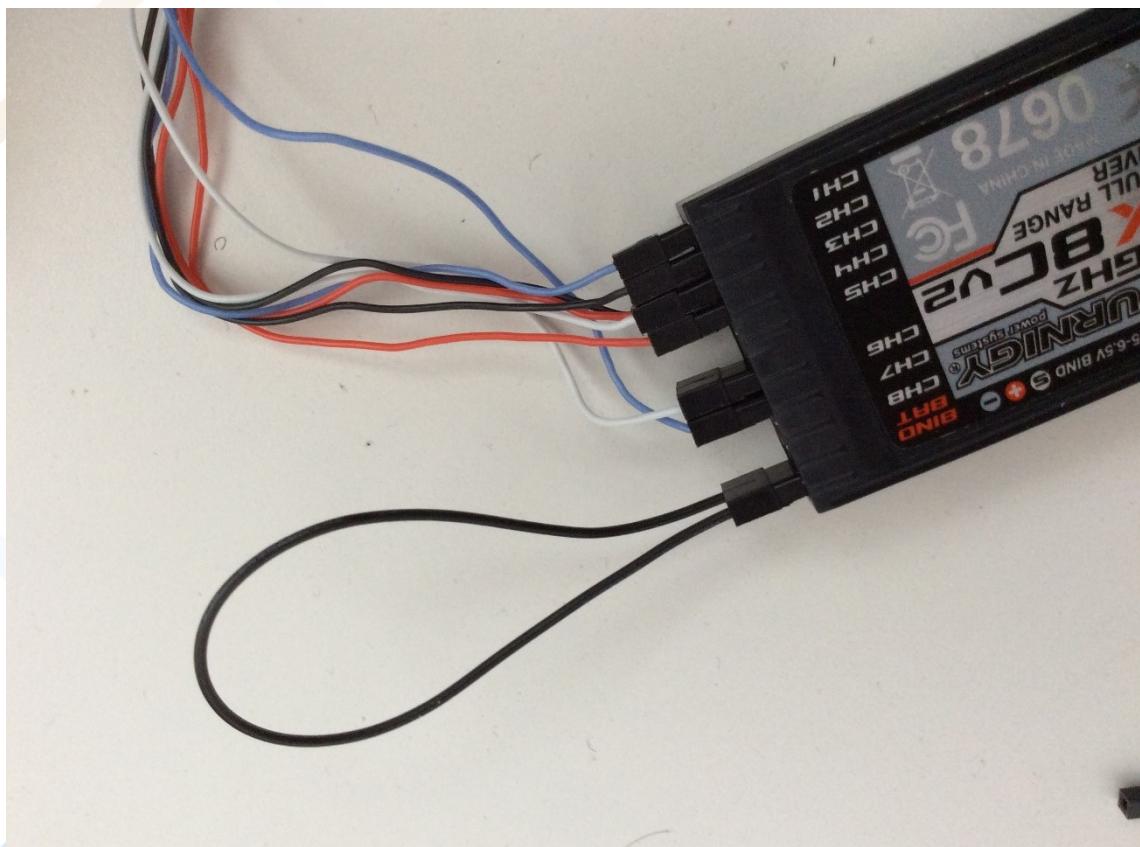


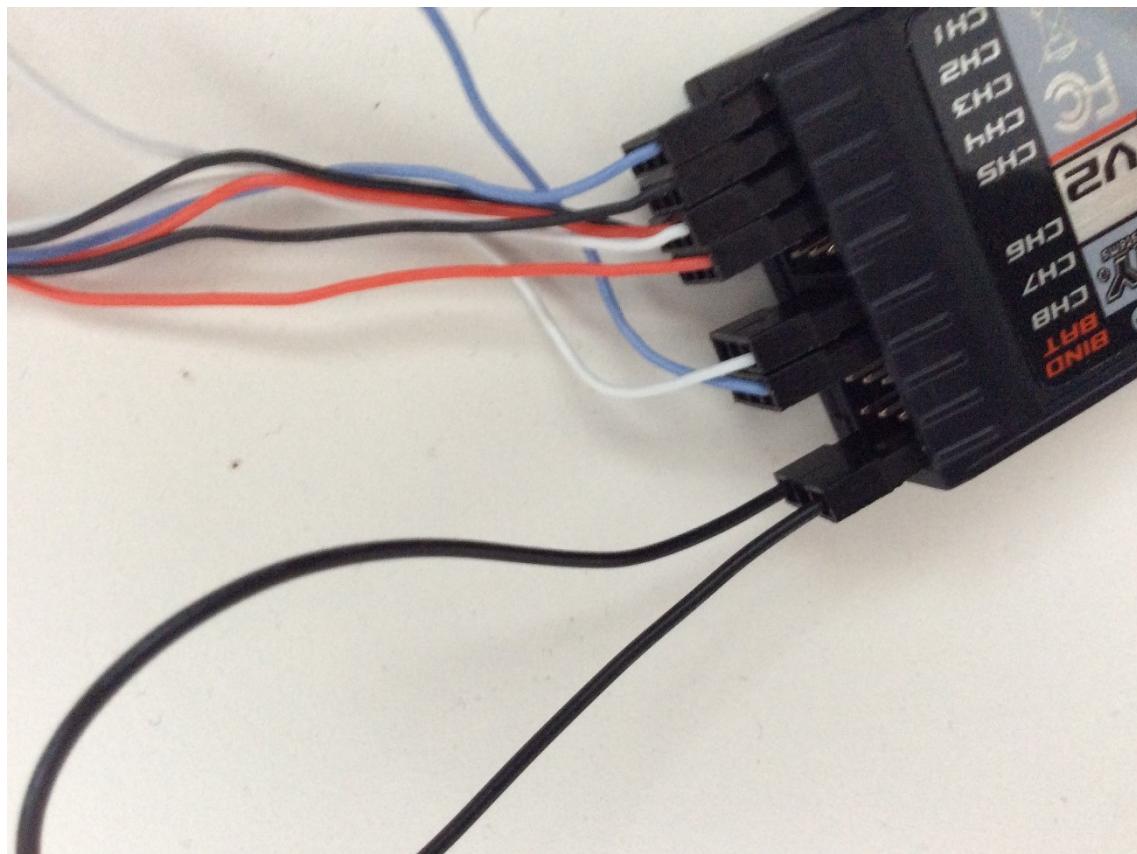






BINDING - Looping wire in BIN connector

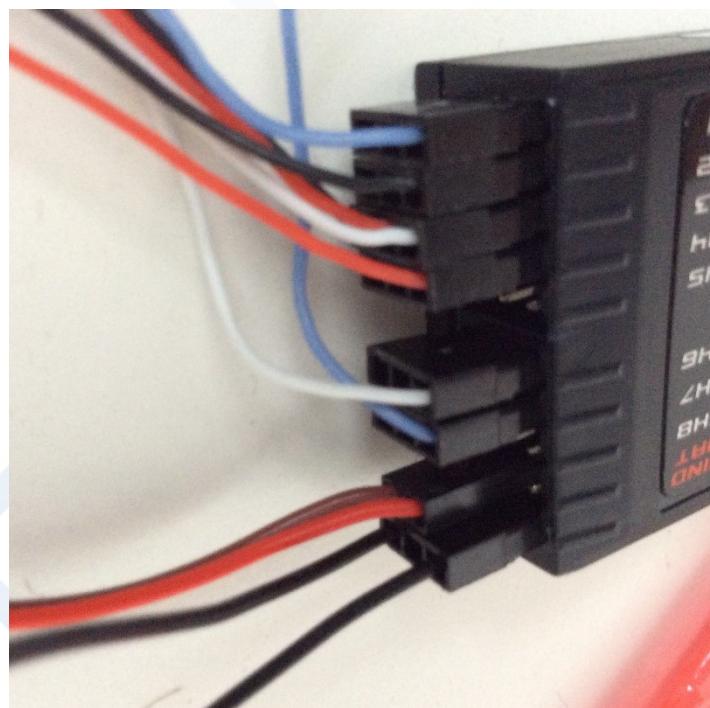


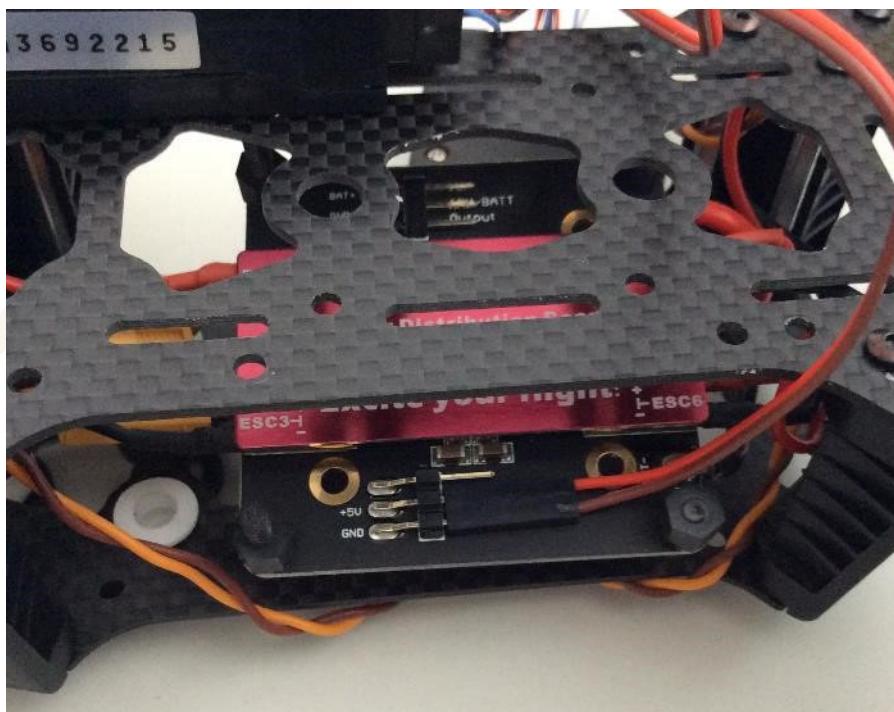
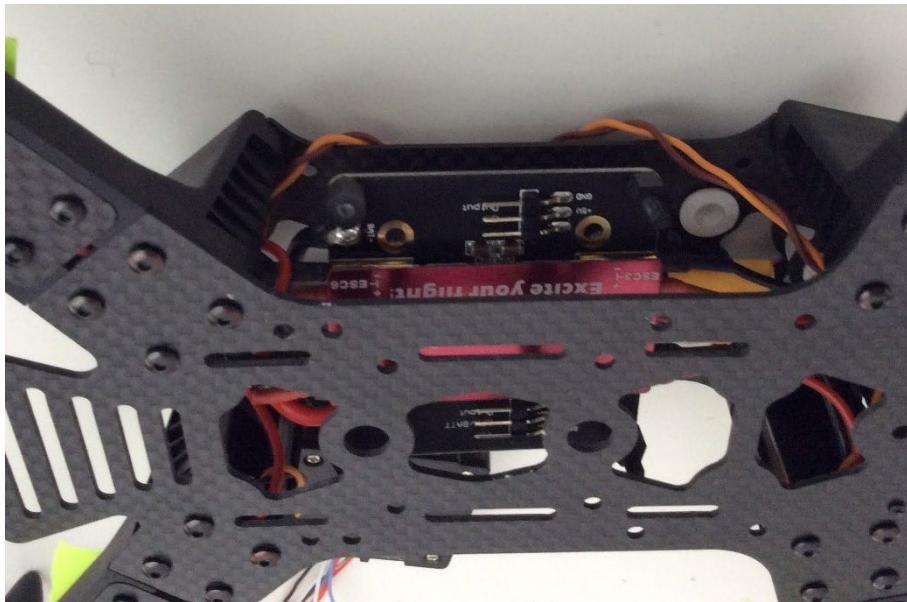


#### 7.2.2.4 FROM POWER DISTRIBUTION BOARD TO TURNIGY 9X:

Use double wire to connect +5 v and GRD from POWER DISTRIBUTION BOARD TO TURNIGY 9X: connecting in BAT connector:

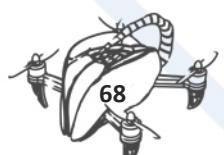
+5v will be in the middle and ground on button in TURNIGY 9X



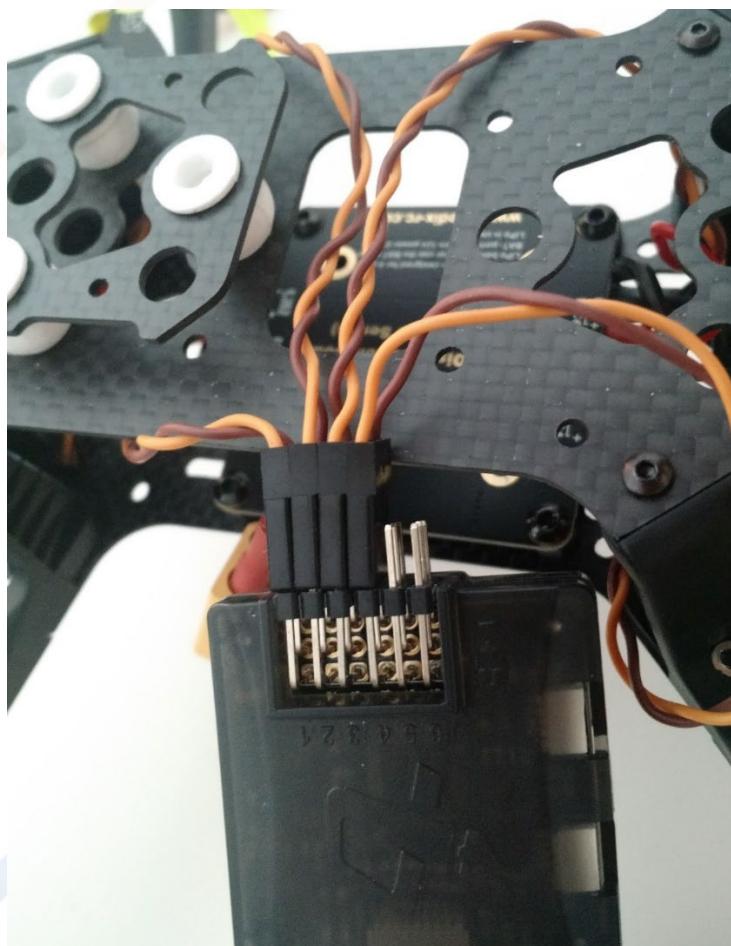


PCB position inside the frame. Pay attention to +5V or +12V.

**These connections will burn some components if they are connected in +12V**



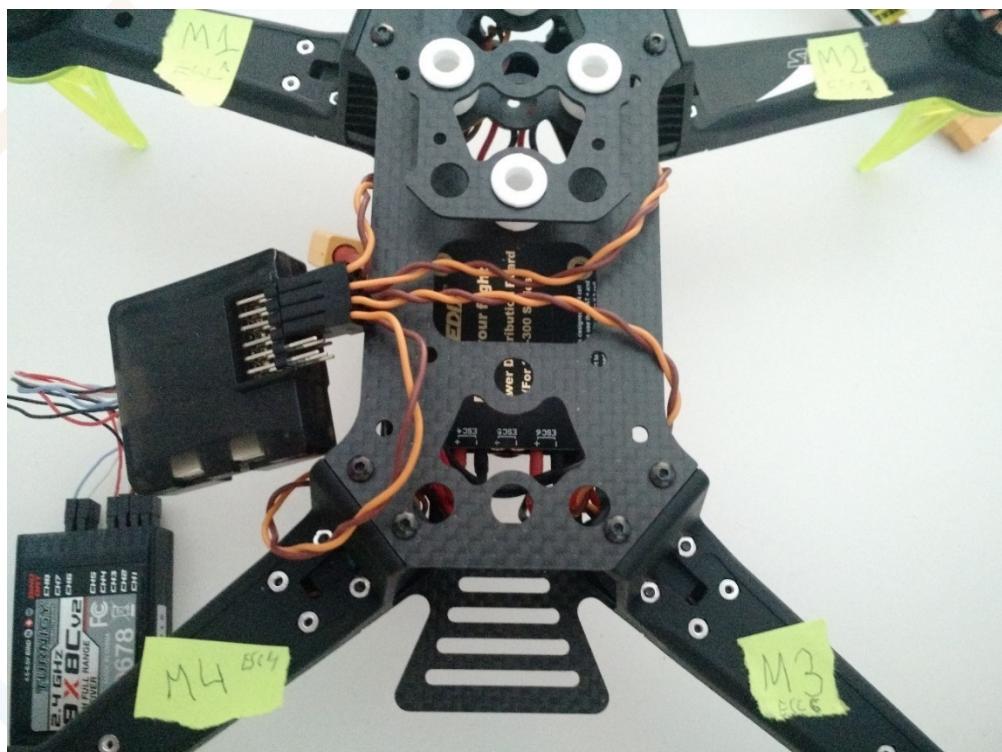
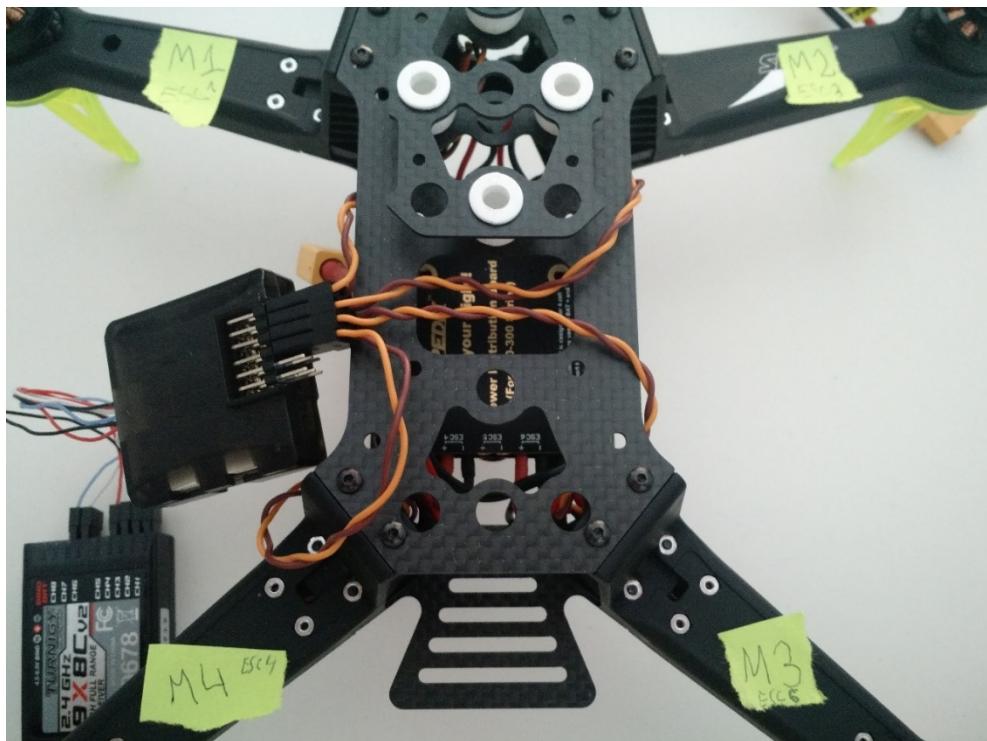
### CC3D TO DRONE ENGINE/MOTOR



Connections to CC3D controller. Review them. It is important. The CC3D must be oriented properly.



It is important identify the four motor: Although it is basic, a simple sticker allows to identify them while assembling the components:

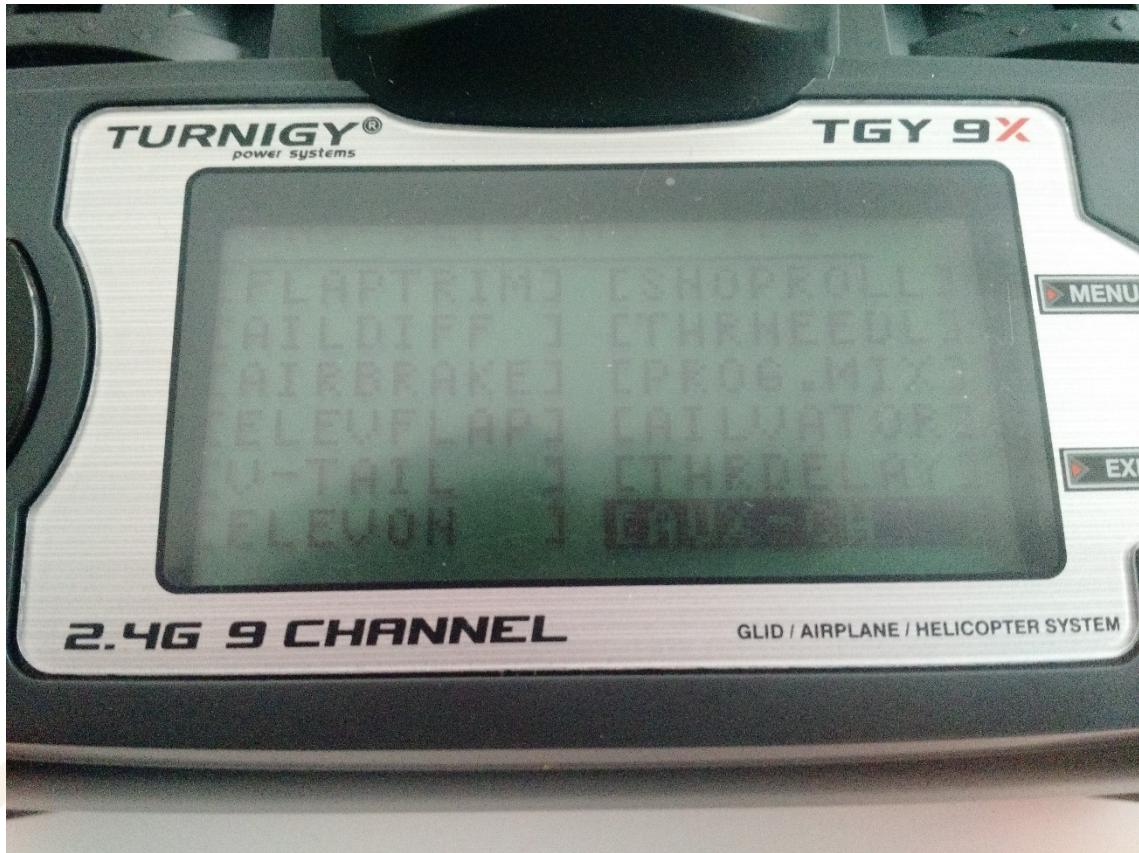


## 7.3 TRANSMITTER

**Transmitter configuration:**

SET transmitter TYPE HELI

Moving across the menu, go to setting, and then to the option AUX-CH



**Check CH6 is NULL**

Then go back into the main Settings menu, and choose the option PIT/CV

Move the AUX3 F mode on transmitter



Switch in the transmitter to the top position(NOR), and put all the values to 0.0 on transmitter



Once are set the values to zero save the data pressing MENU button.

Move the AUX3 Fmode

Switch in the transmitter to the medium(ID1) position, and put all the values to 50.0.



Once are set the values to zero save the data pressing MENU button. Move the AUX3 Fmode

Move the AUX3 Fmode

Switch in the transmitter to the bottom(ID2) position, and put all the values to 100.0



Once are set the values to zero save the data pressing MENU button.

## 7.4 BINDING

RC Transmitter-receiver communication

Transmitter-receiver binding

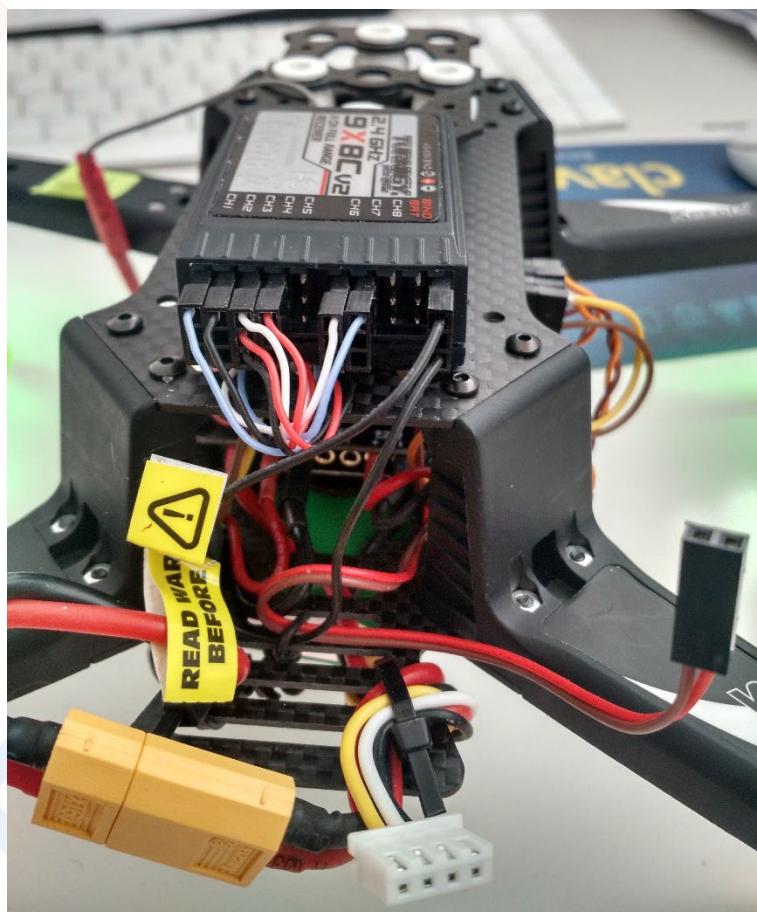
Binding is necessary to teach the receiver the code of the specific transmitter so that they can talk to each other.

NOTE: This would be not necessary if you are using the Transmitter-Receiver that are packed in the same box.



1. Connect the Turnigy 2.2 battery into the Transmitter (Don't turn on the transmitter).

2. Connect the binding wire(Jumper) in the bind port of the Receiver.



3. Using the Transmitter (power off) hold the button (Bind range test) and switch on the transmitter.

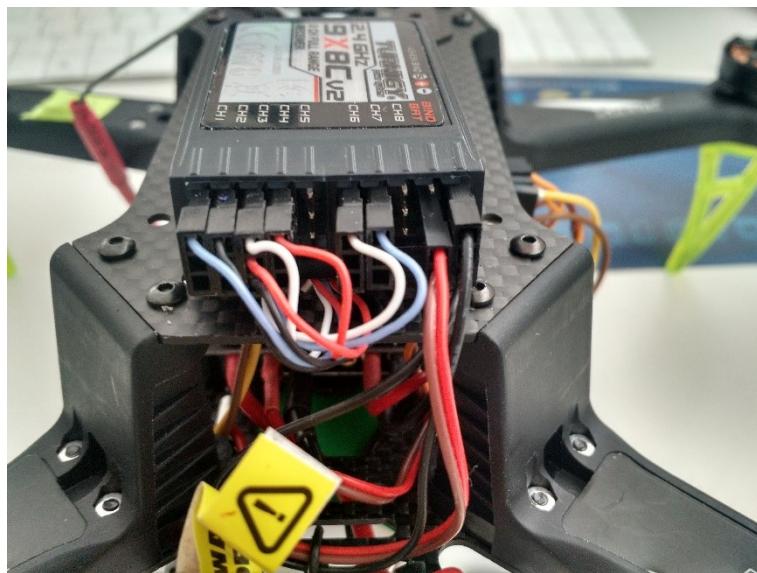


4. Keeping the Bind Range Test held go to the next step.

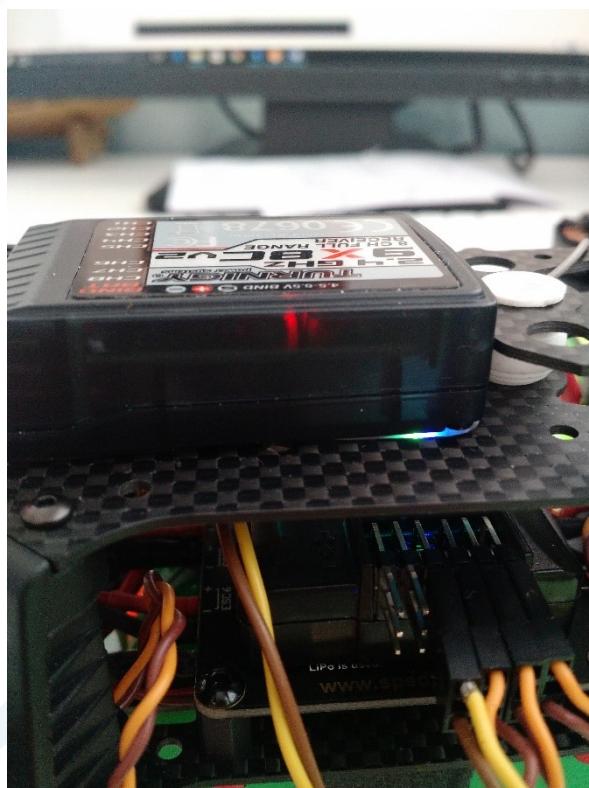
5. Power up the Receiver, using the 3 wire cable connector and plug it into the Receiver power port.



6. Turn off the transmitter, take off the power cable of the receiver and take off the bind cable of the receiver as well.



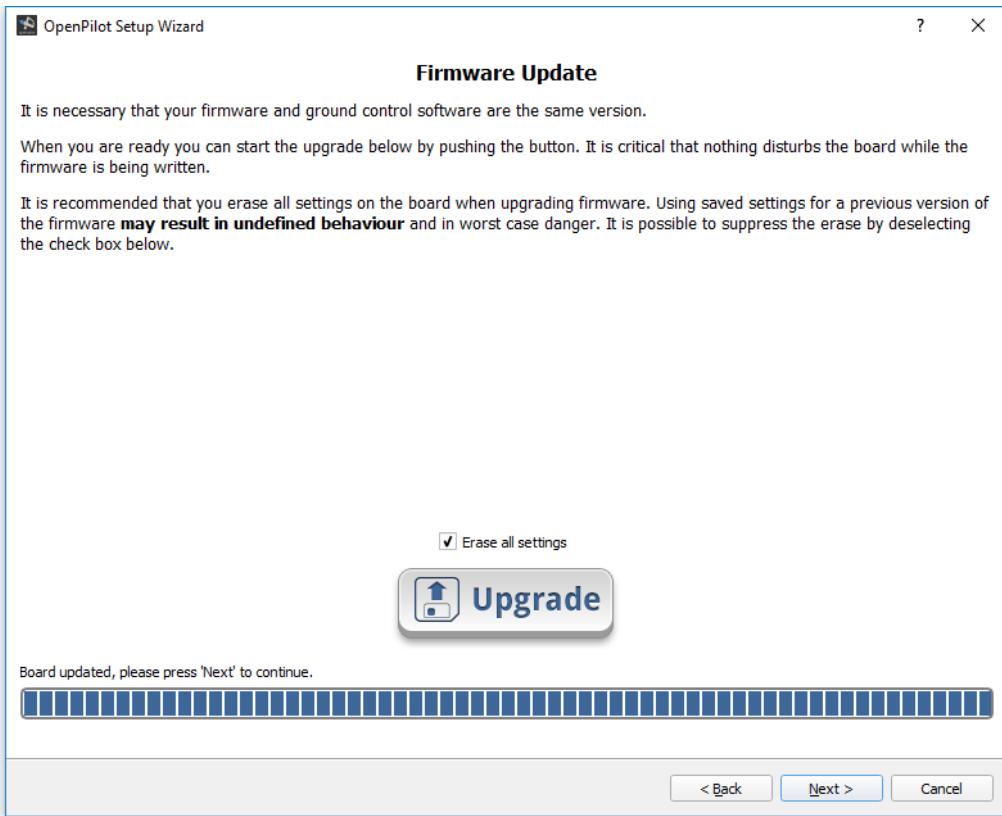
7. If this step has been made properly whenever you turn on the transmitter the led in the receiver should go on (steady red light), or off if you turn off the transmitter.



## 7.5 OPENPILOT

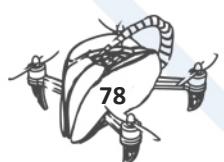
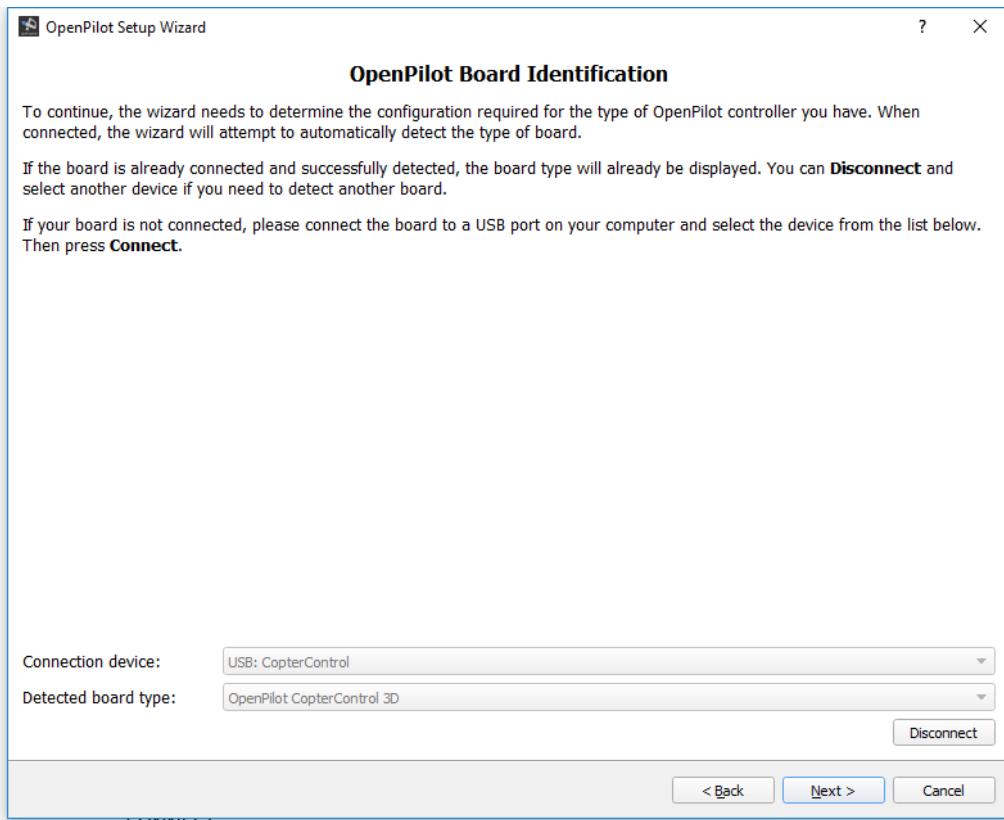
Open source software to control de basic drone. Next steps to configure the OpenPilot software.

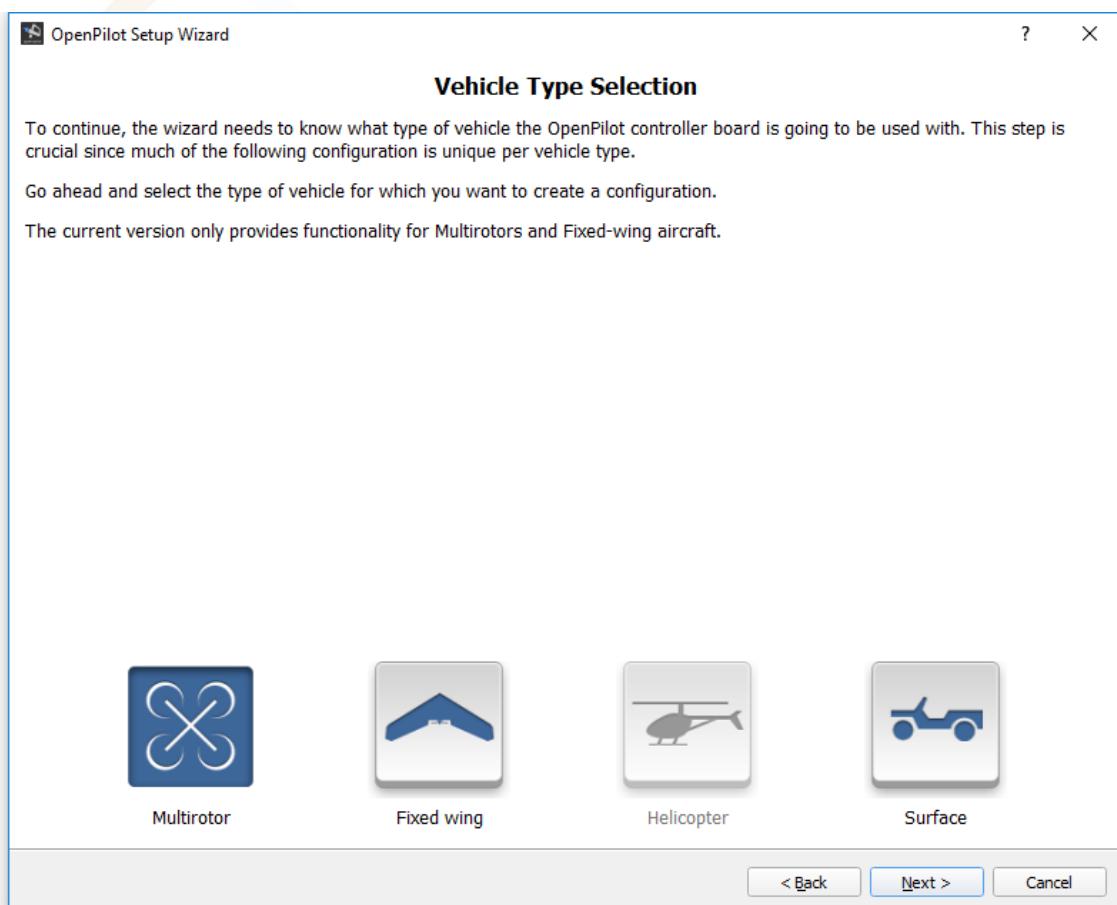
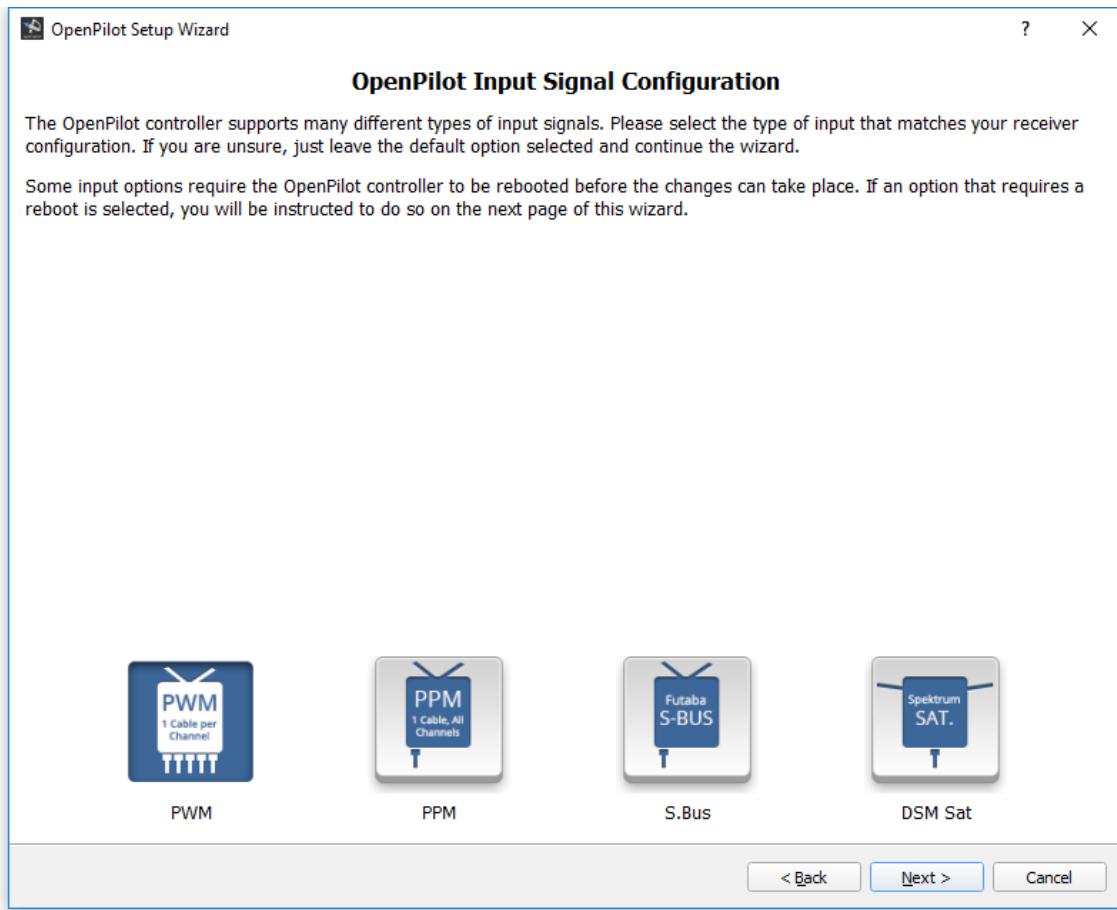
Note, CC3D controller is not supported for last versions of Open Pilot. You need 15.02.02 or below release.

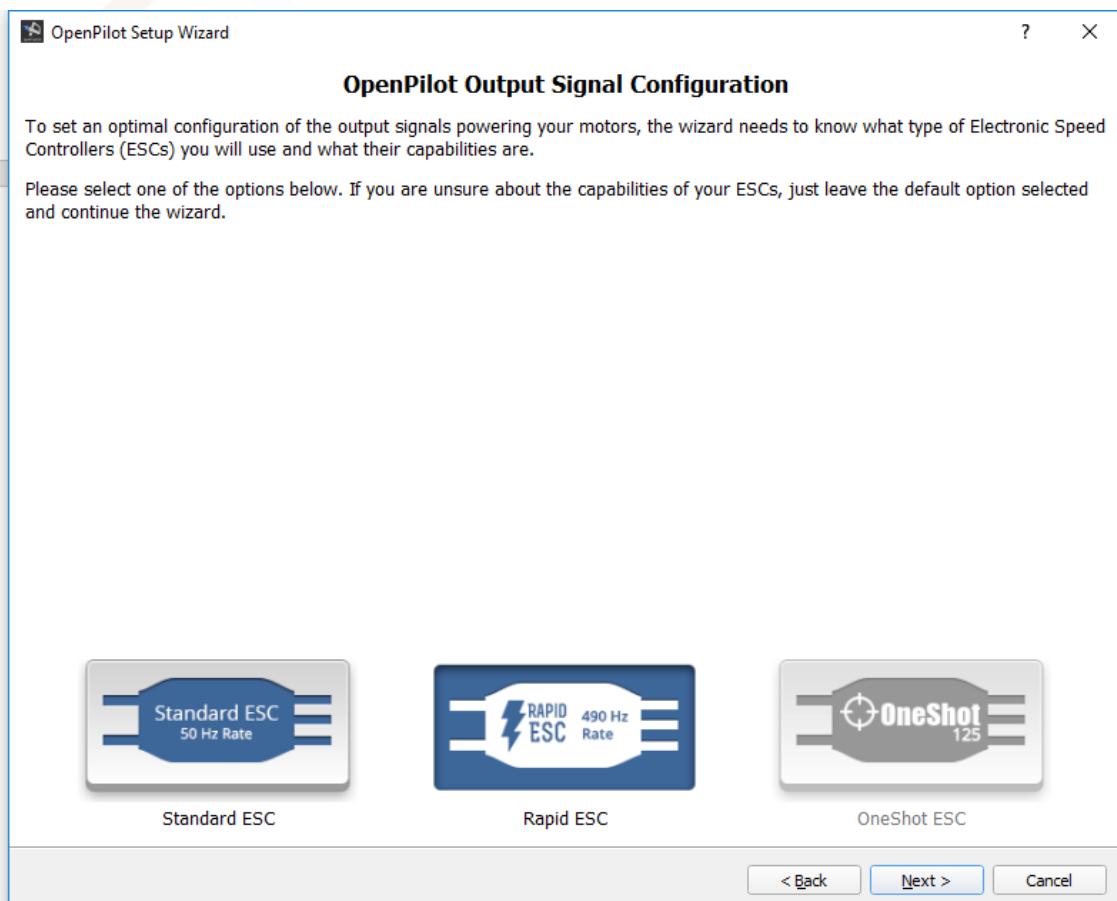
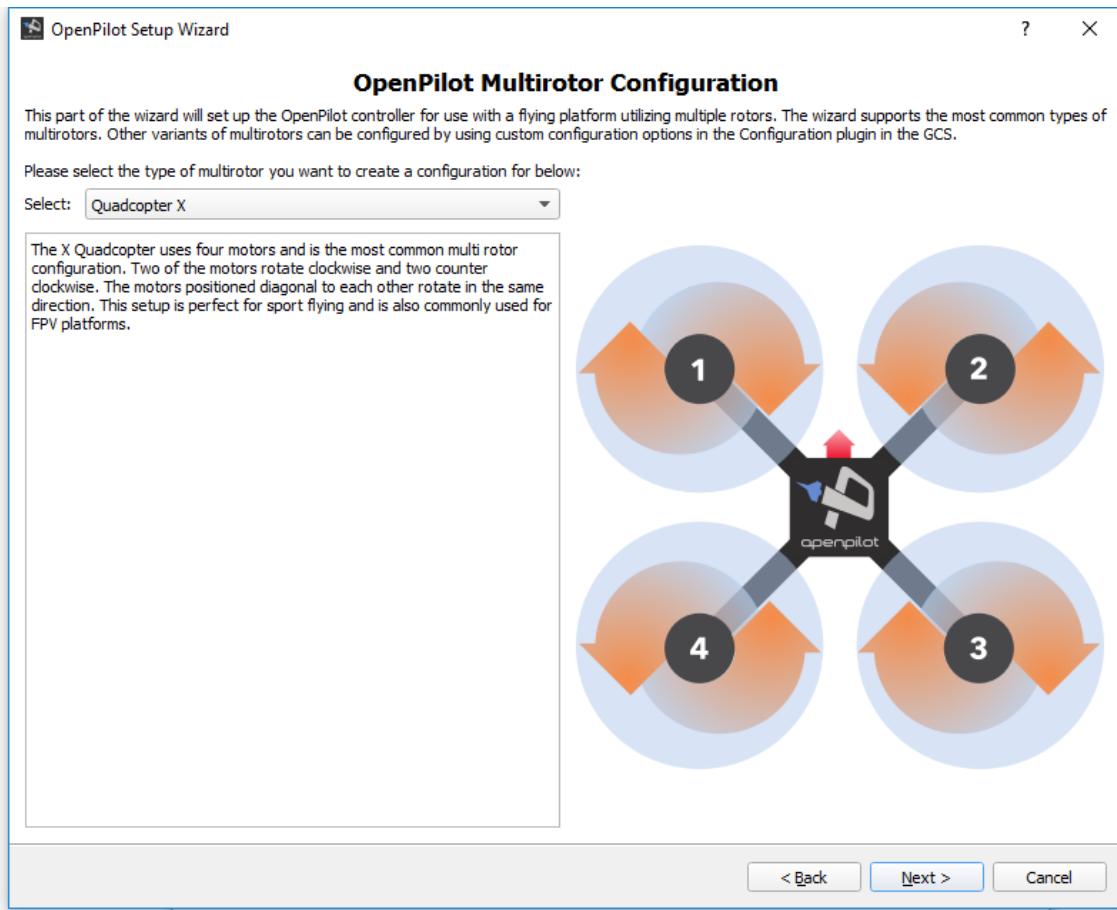


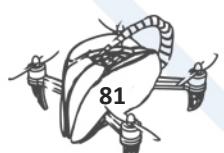
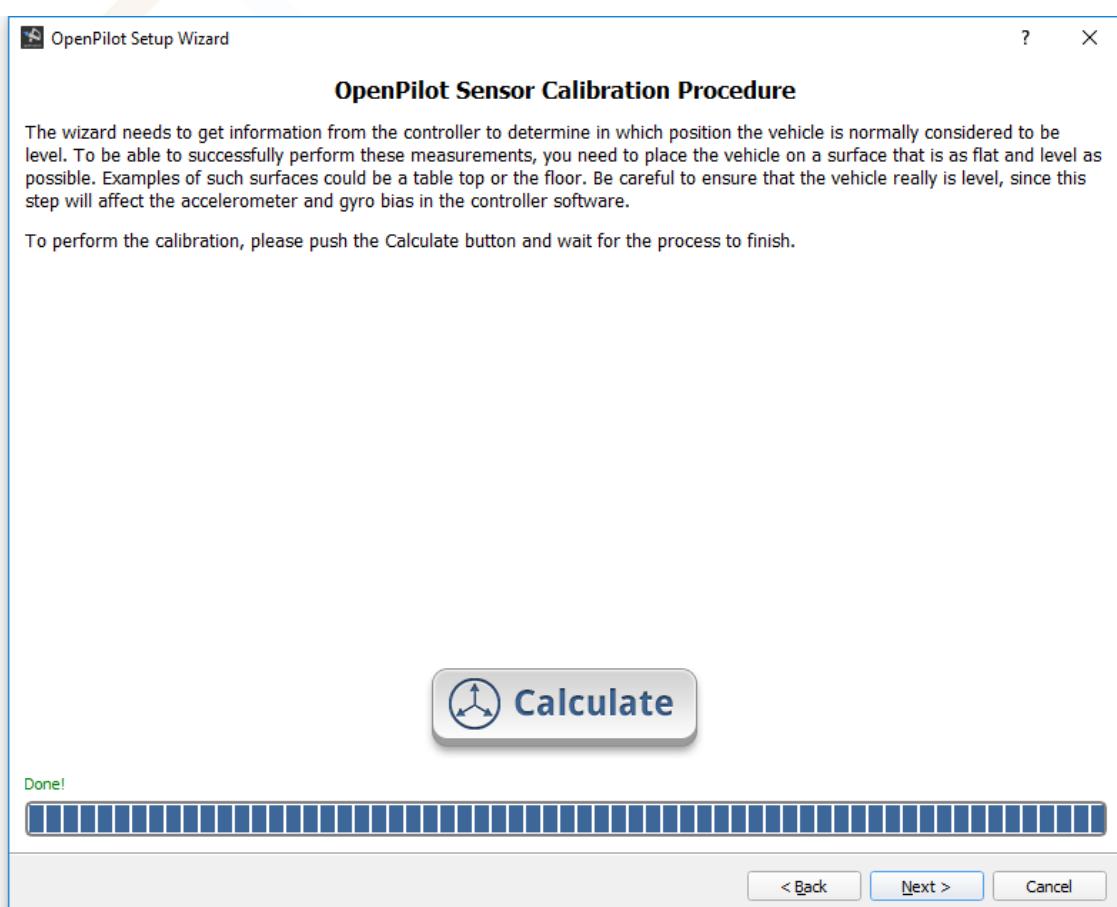
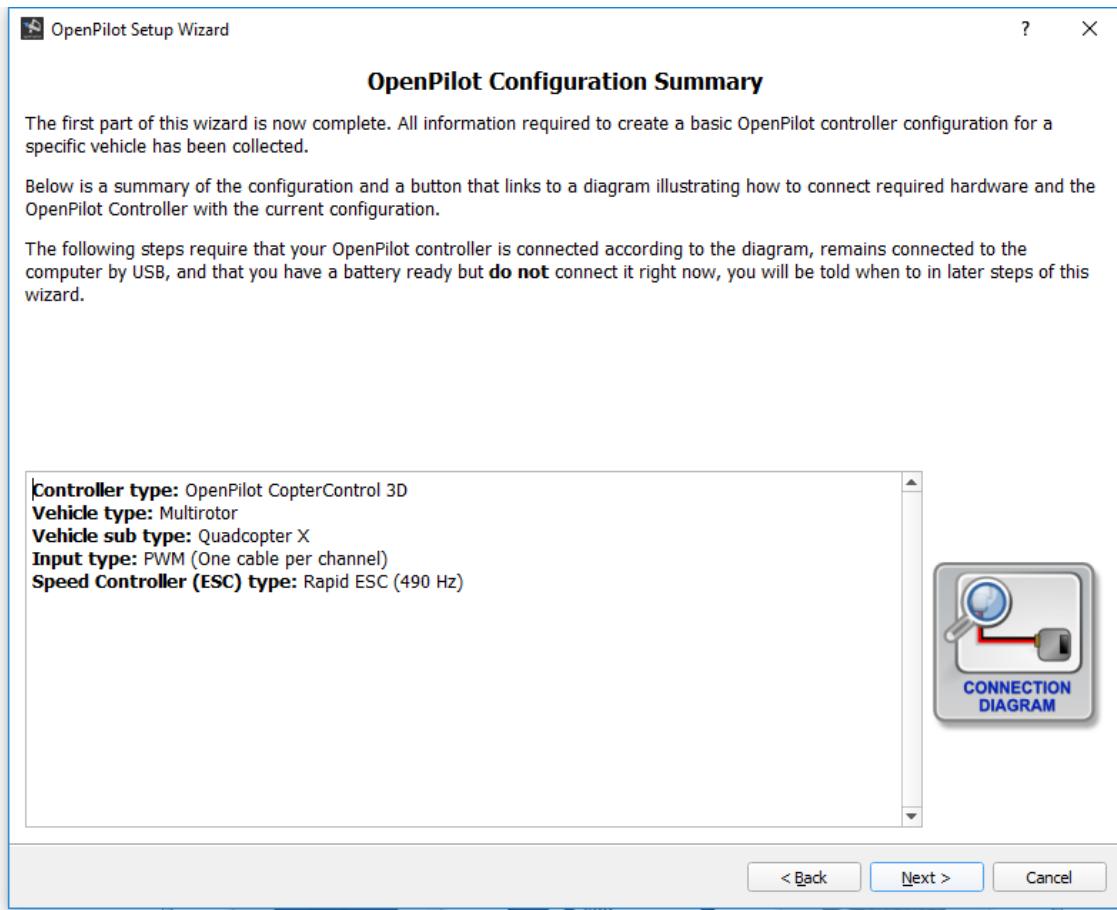
CONNECT mini-USB from CC3D to PC **without BATTERY** connection on CC3D.

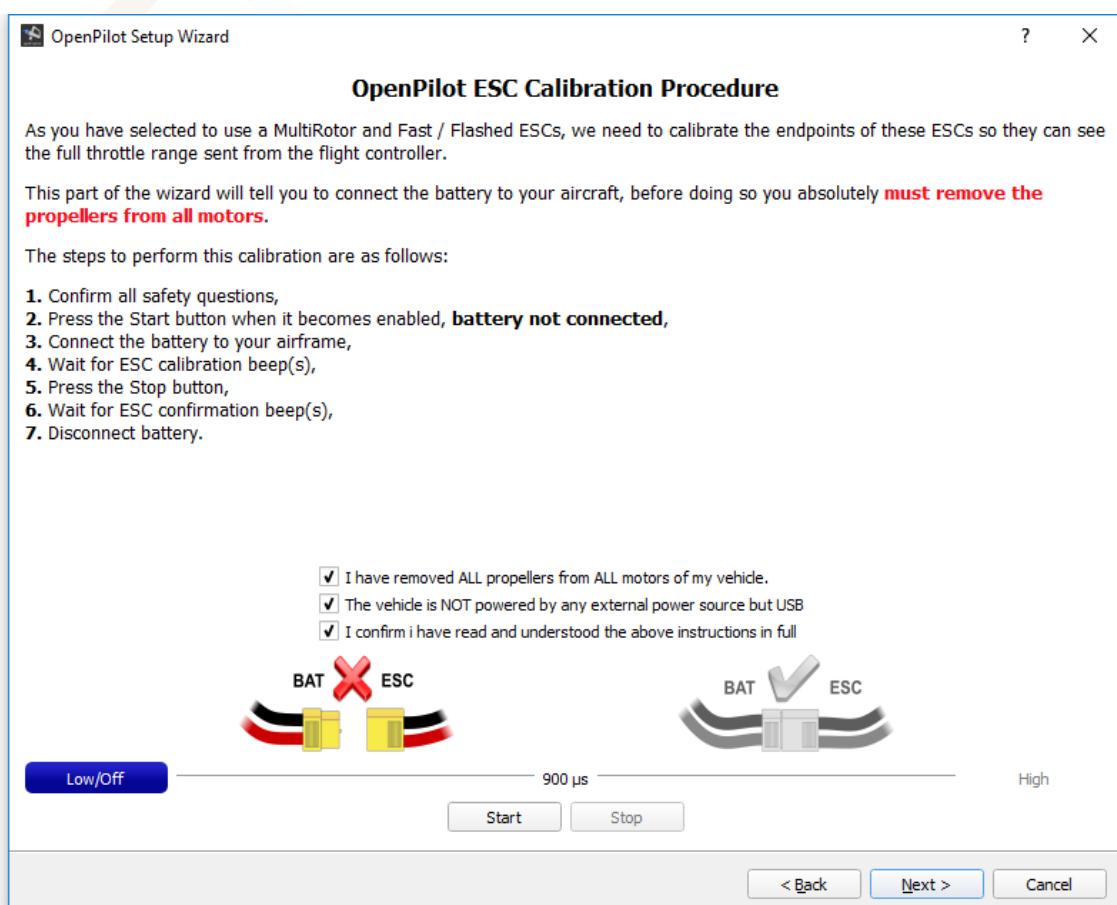
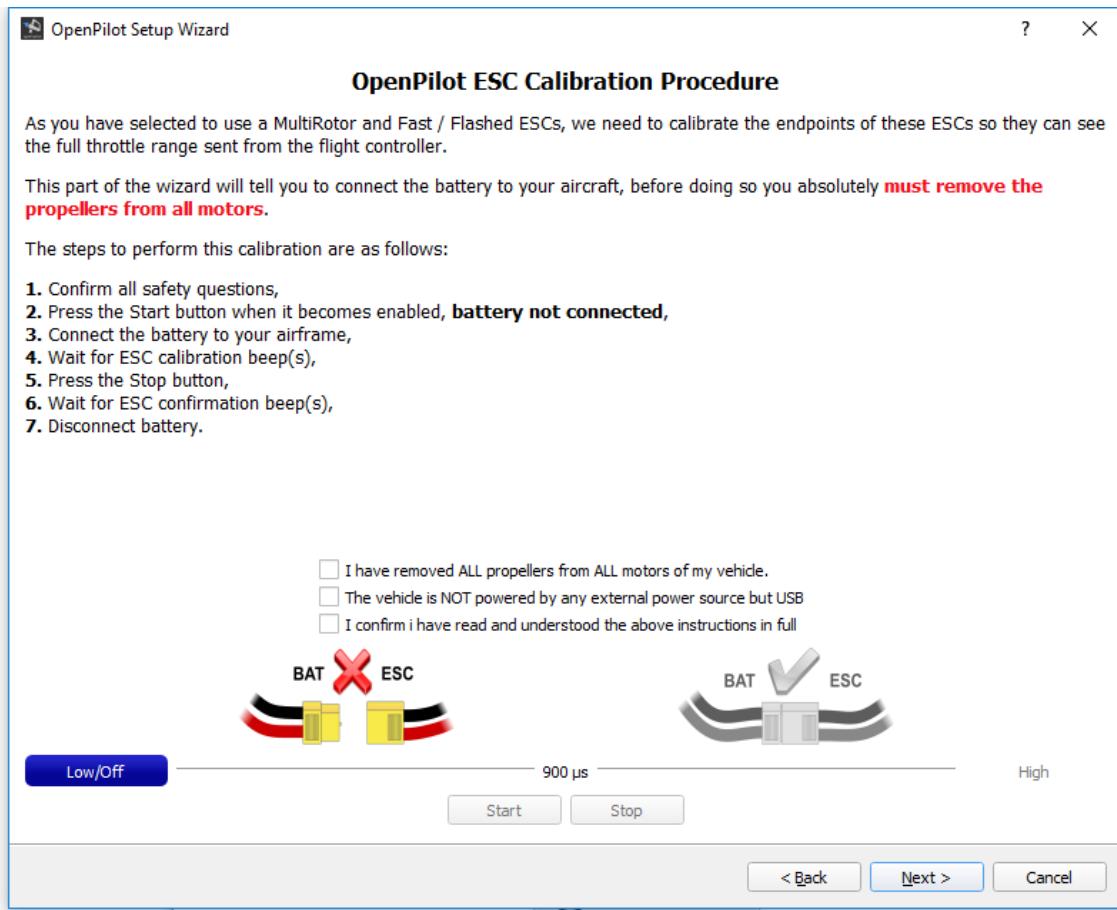




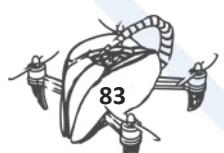
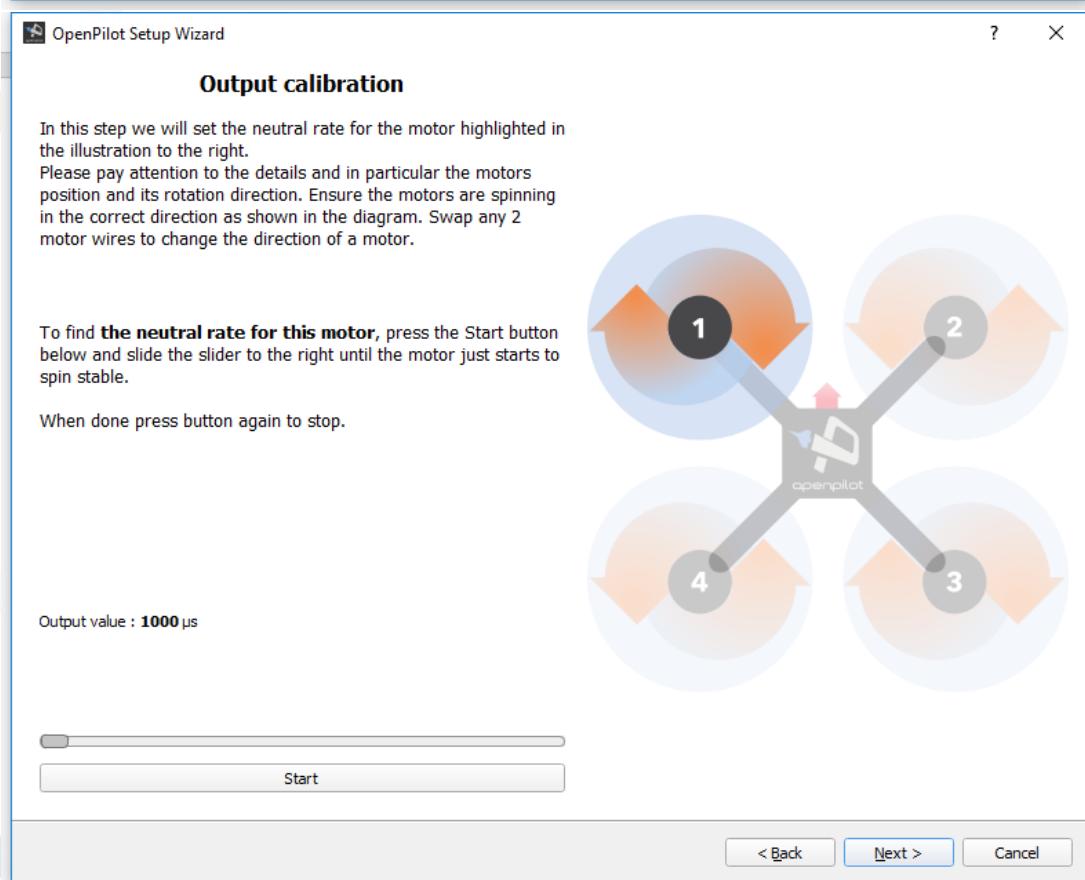
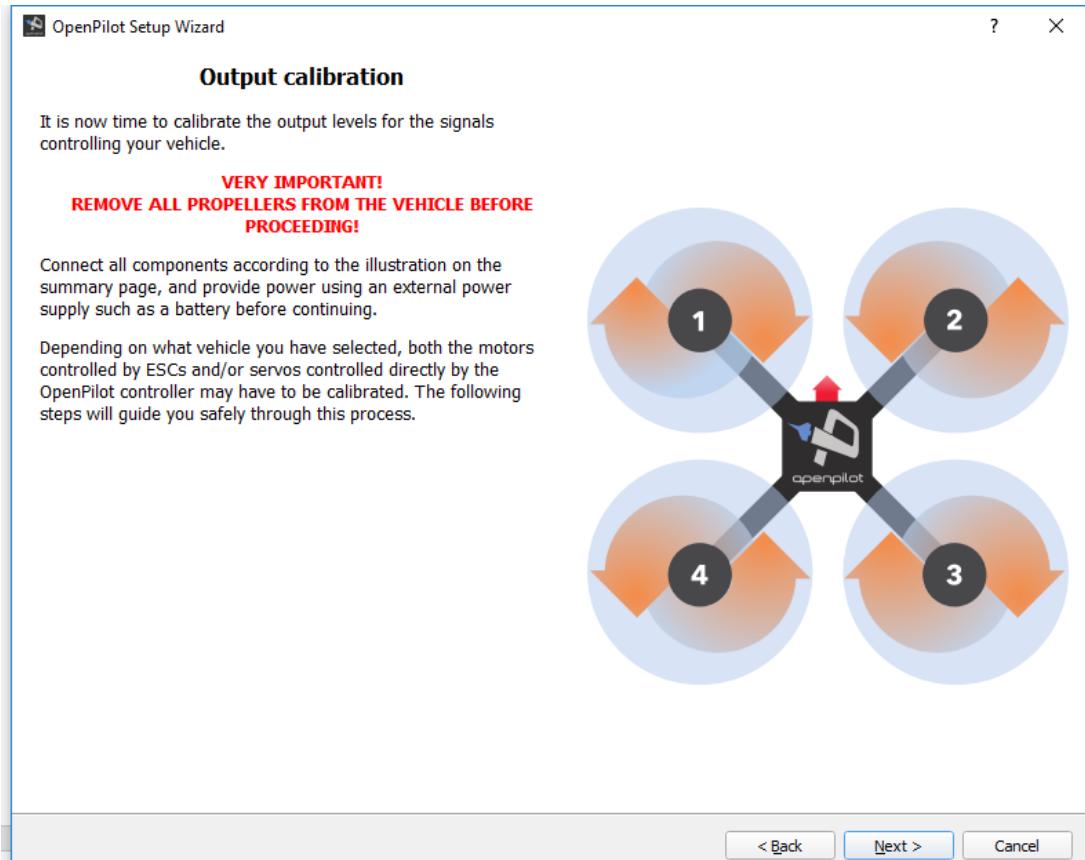


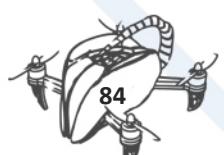
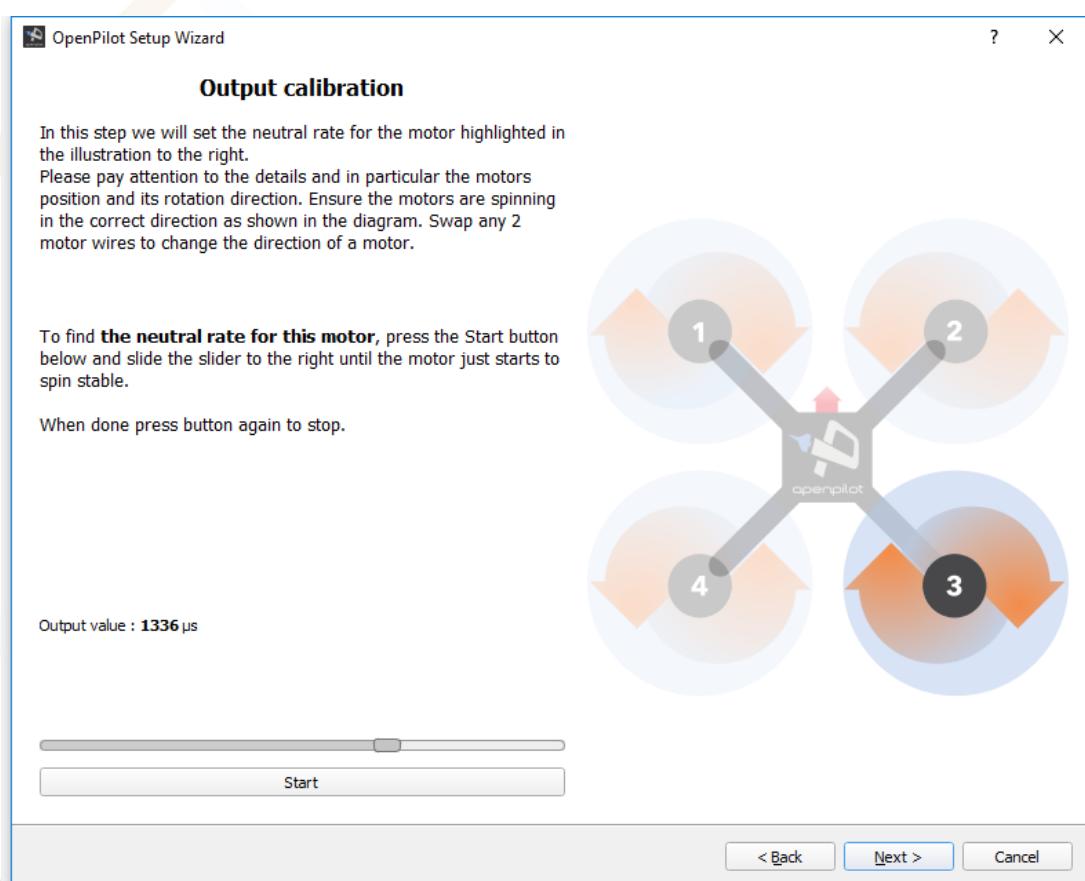
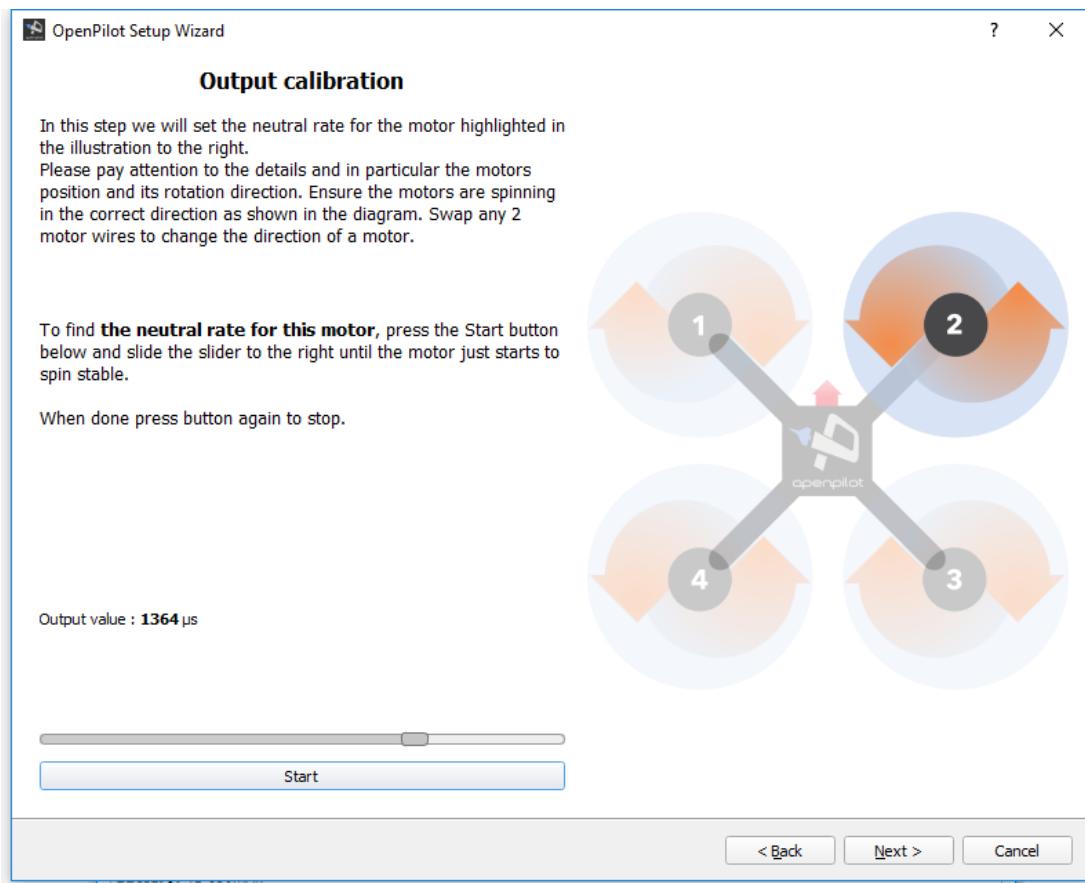


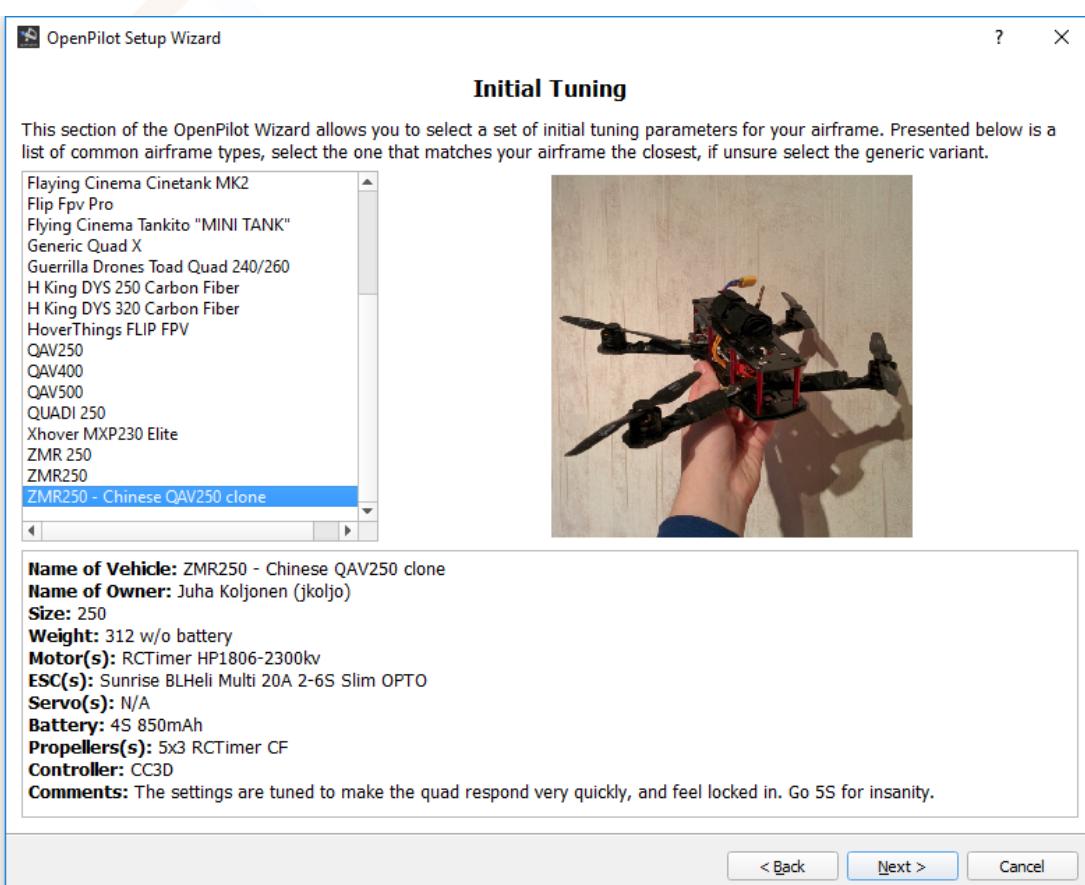
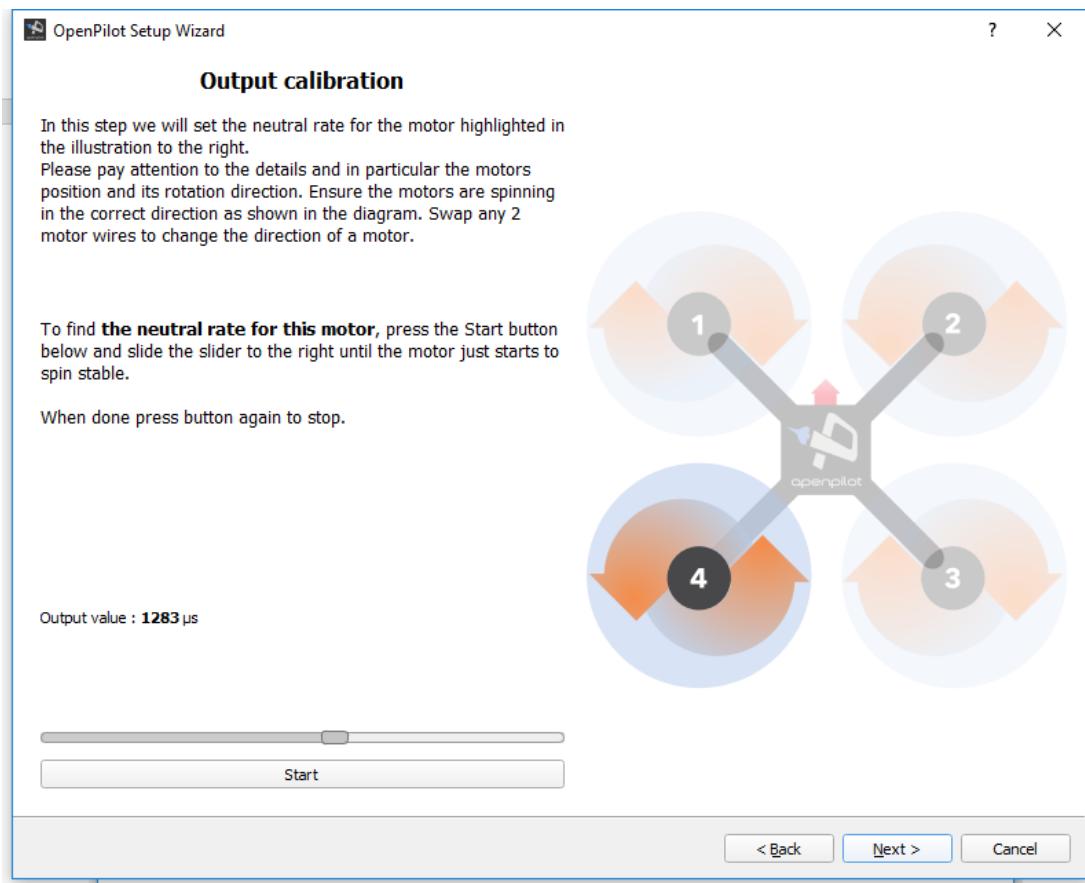




PRESS START, LATER PRESS STOP





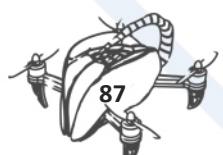
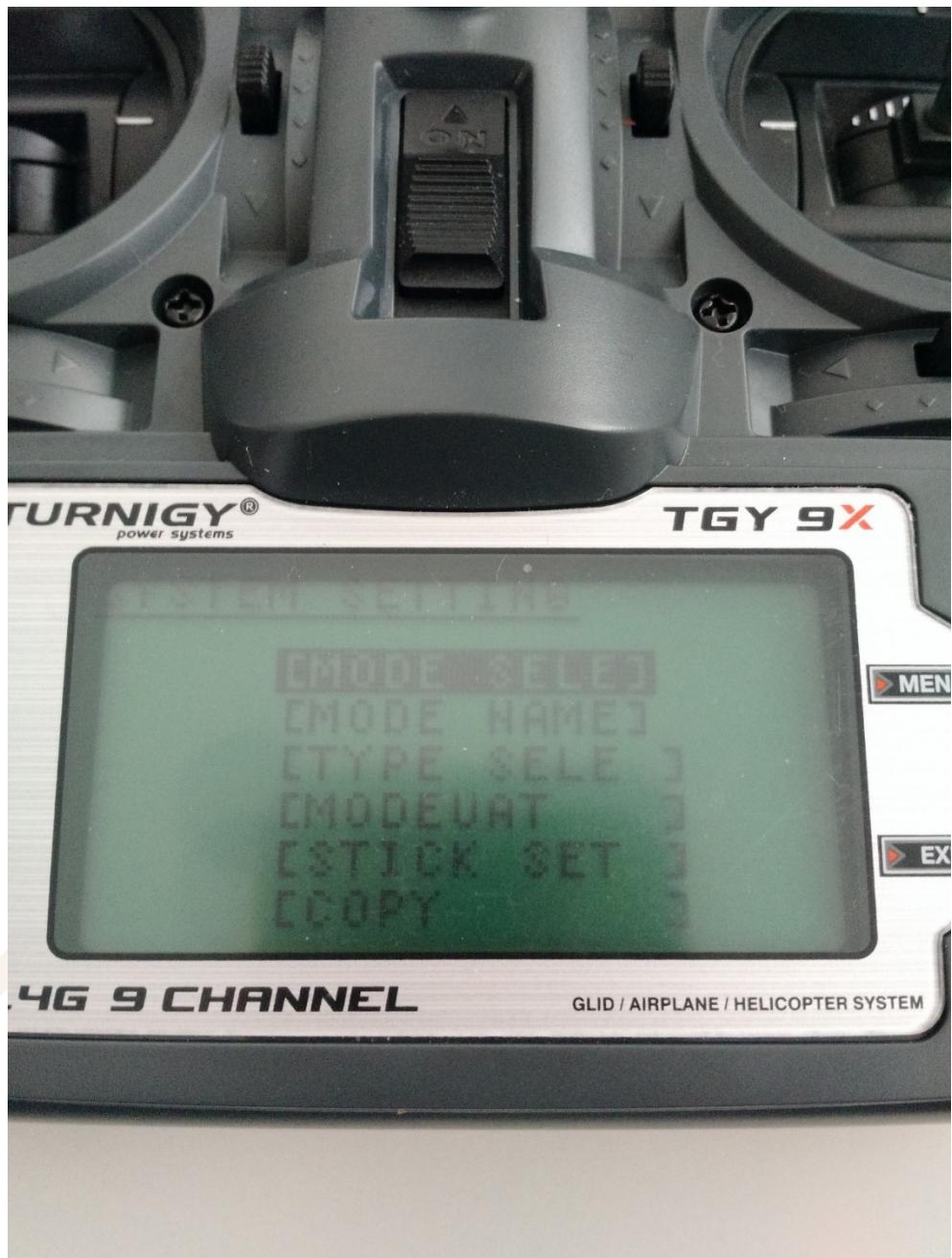


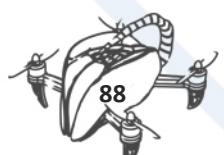
## RECEIVER/TRANSMITTER SETUP

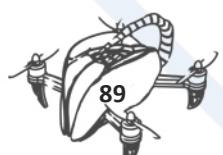
### TRANSMITTER SETUP

Step by step configuration:



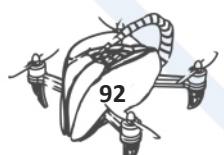




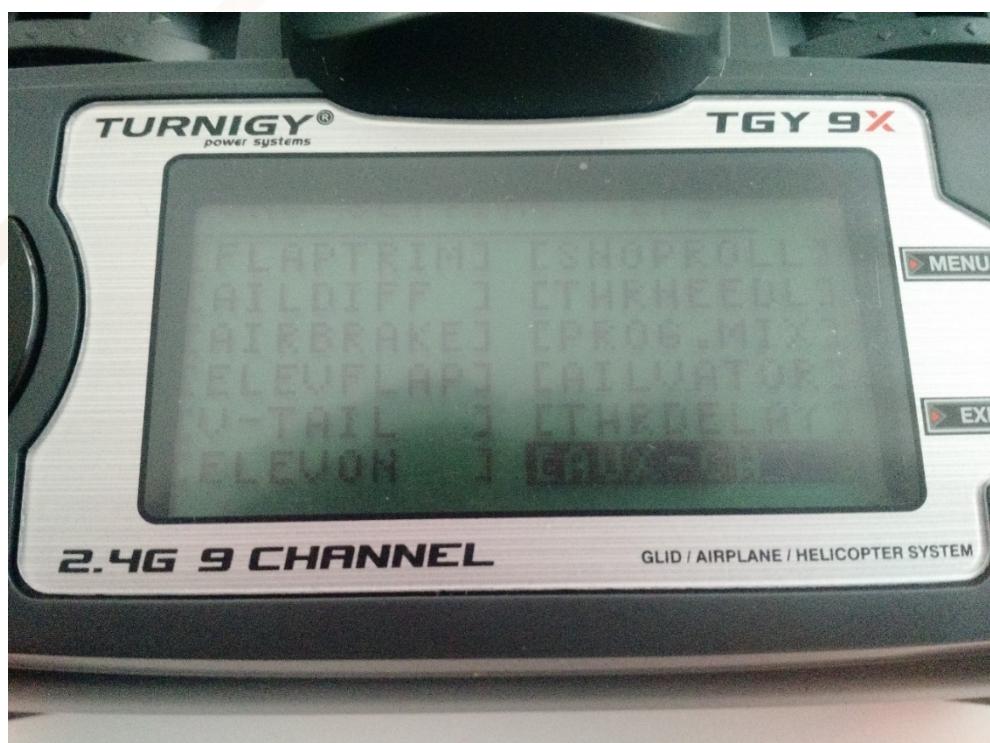


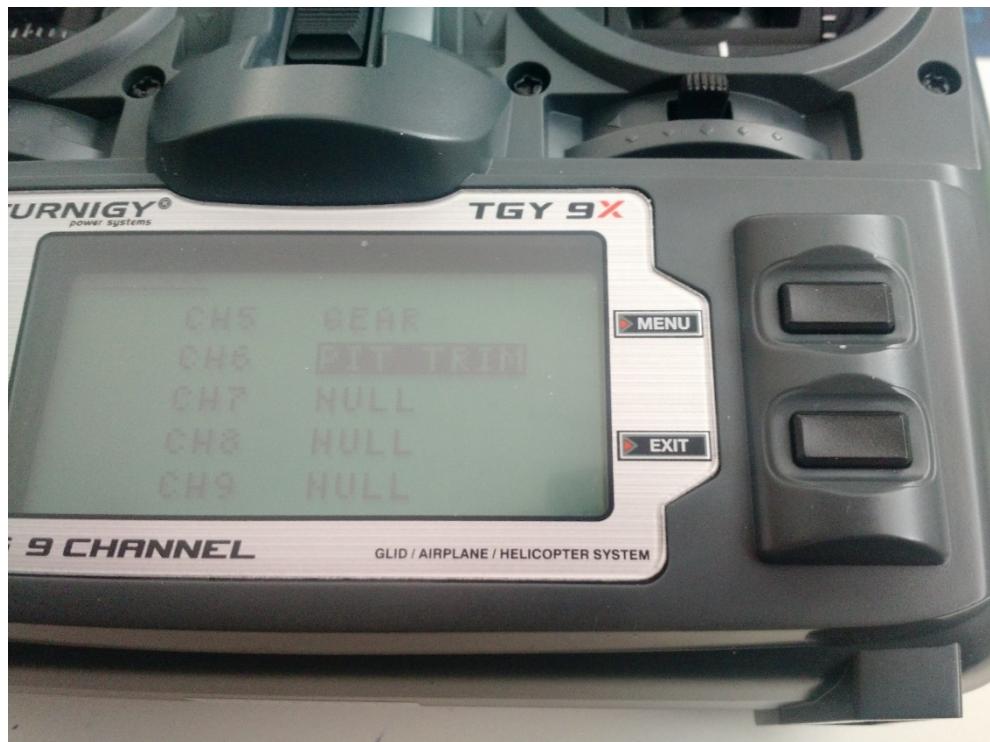










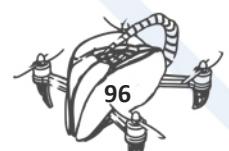
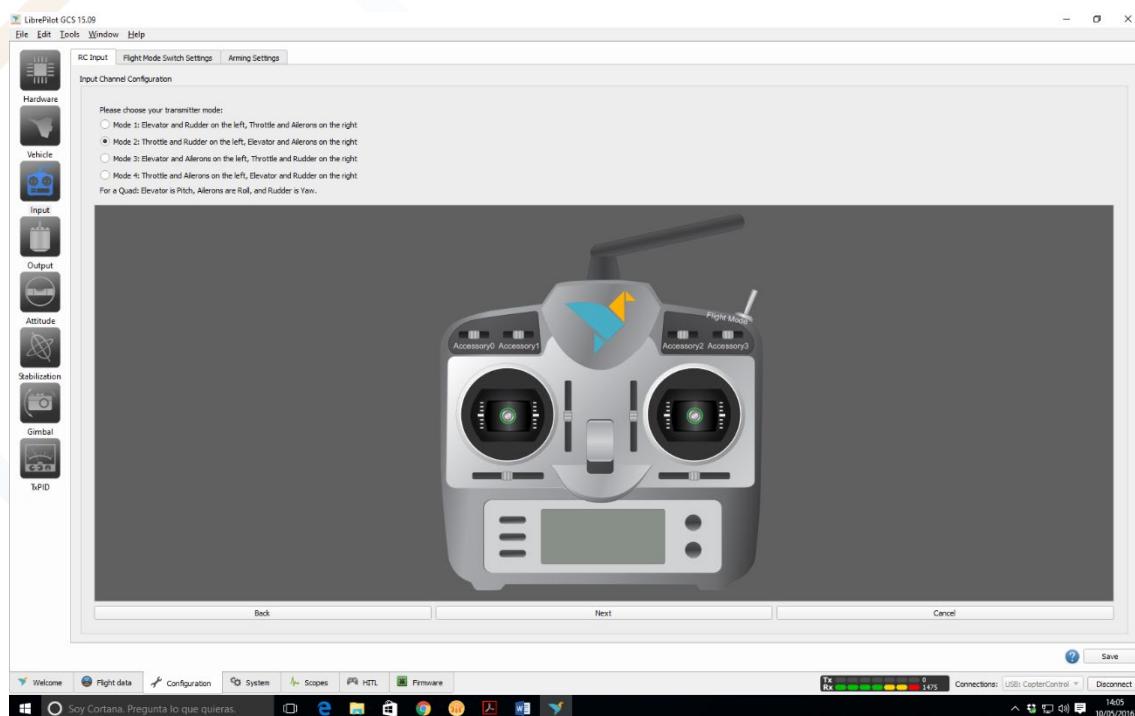
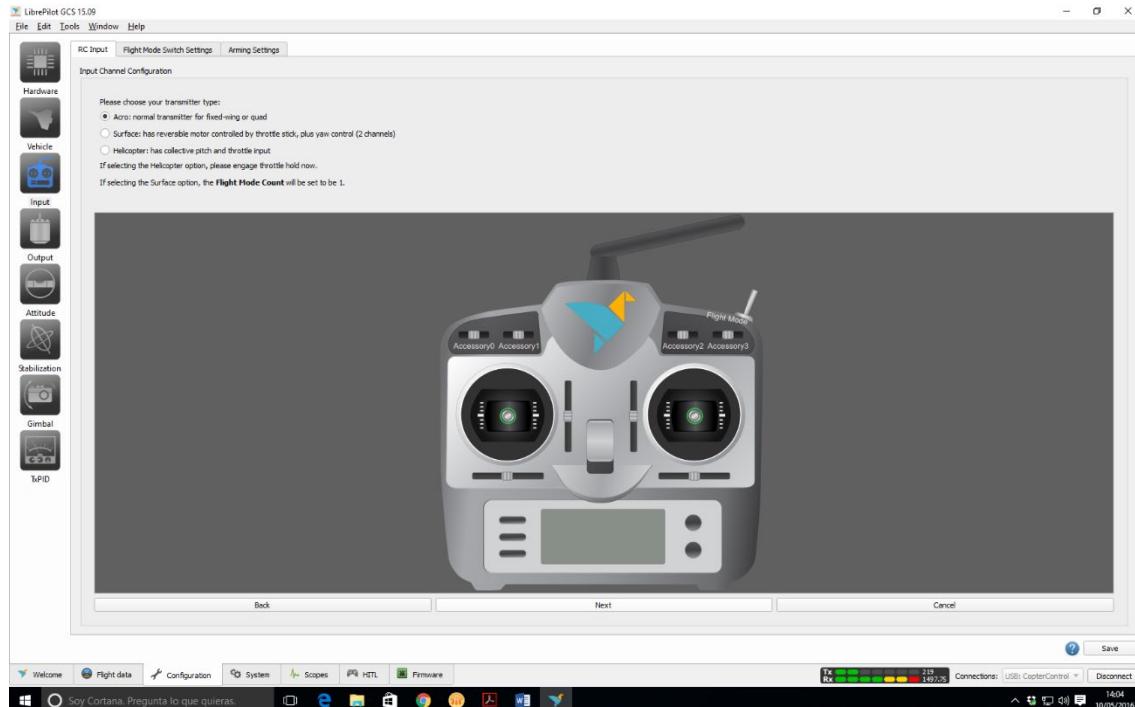


## 7.6 LIBREPILOT

LibrePilot is an open source software to control drones.

Download link: <https://librepilot.atlassian.net/wiki/spaces/LPDOC/pages/4128780/Downloads>

After some experiences, some configurations are ready for uses depending the flight:



MOVE CONTROLLERS AS INDICATION IN SCREEN

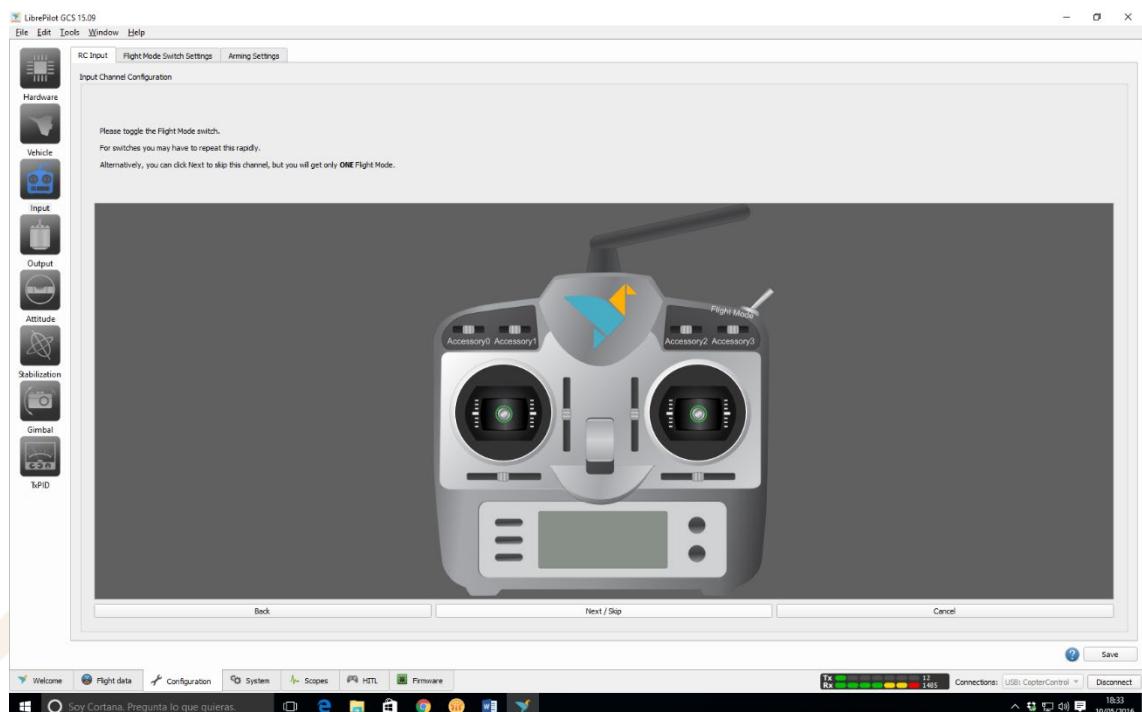
SKIP FLIGHT CONTROLLER SETUP

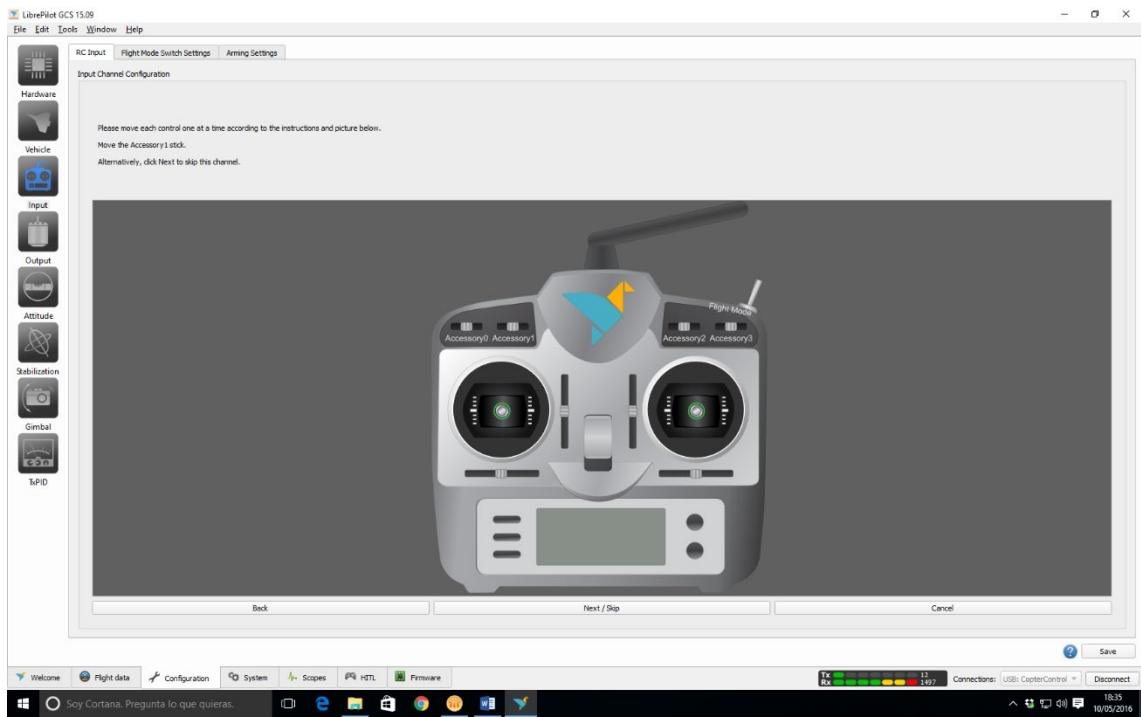
SKIP ACCESSORIES 01 SETUP

SKIP ACCESSORIES 02 SETUP

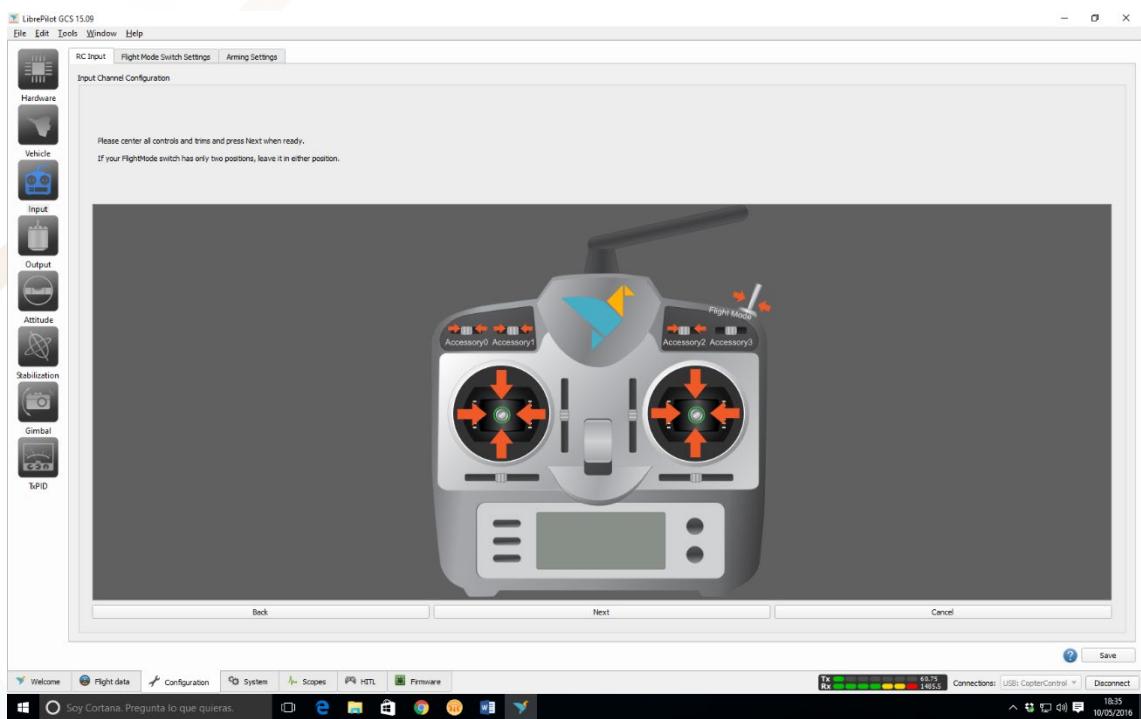
SKIP ACCESSORIES 03 SETUP

SKIP ACCESSORIES 04 SETUP

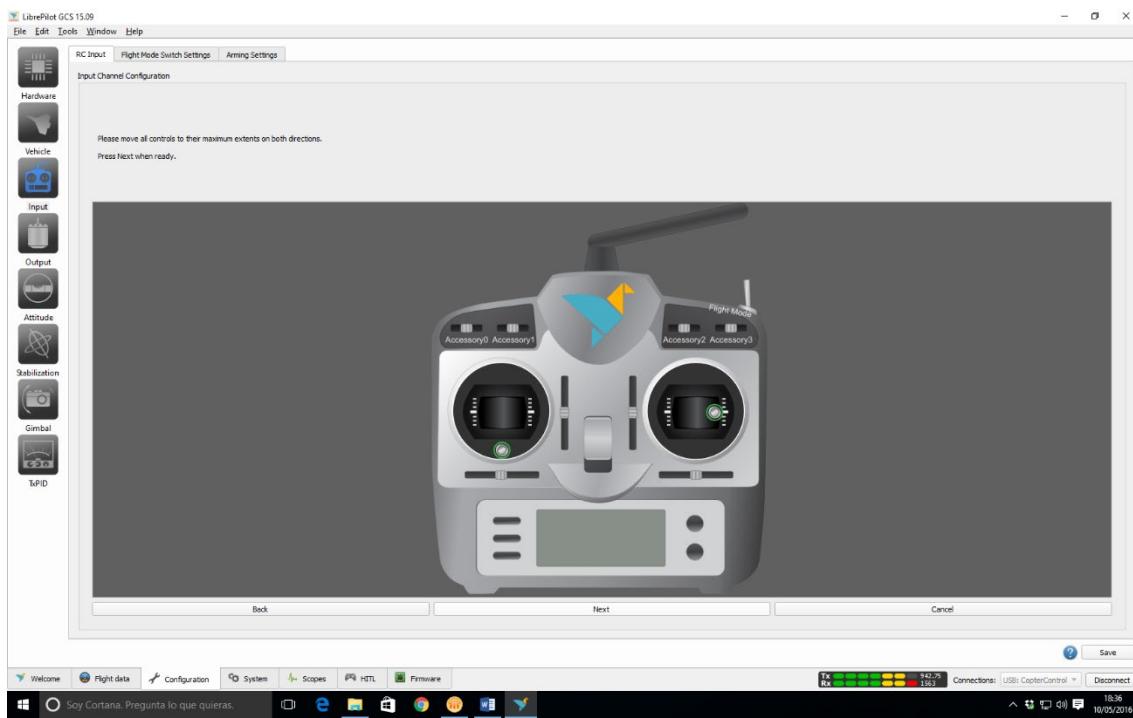




## CENTER STICKERS



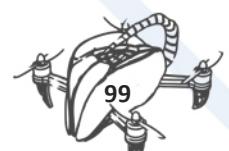
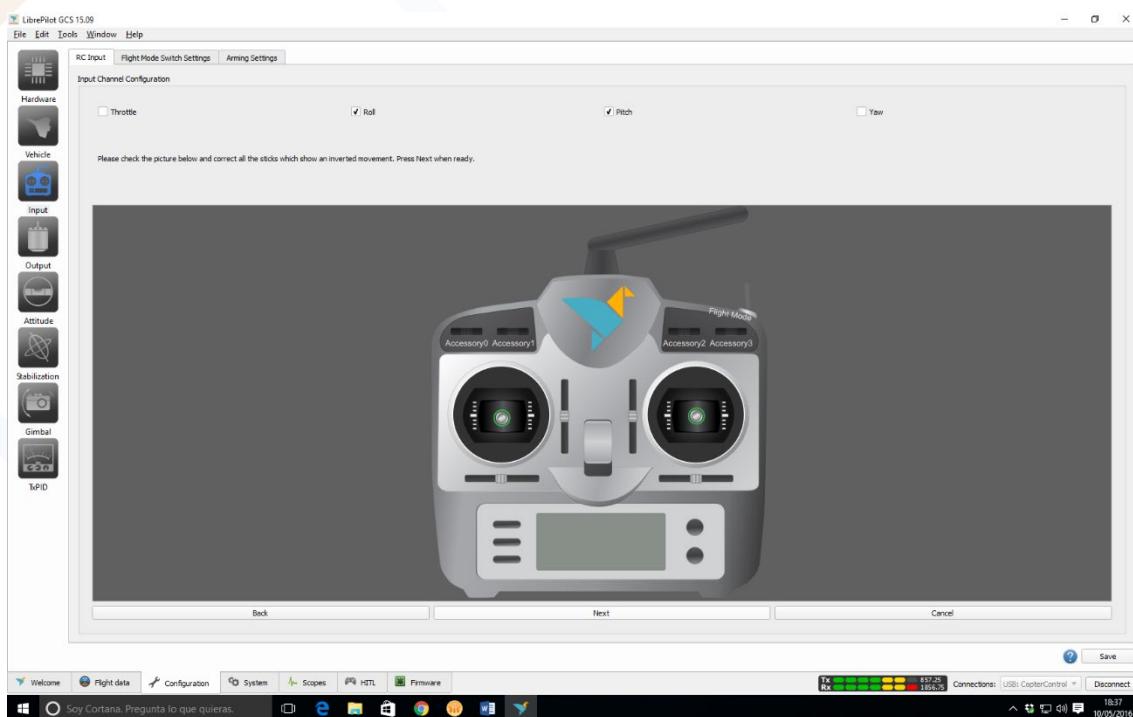
MOVE STICKERS TO BE SURE THAT MOVE IN CORRECT DIRECTION



IF ANY STICKER MOVE INVERTED, IN NEXT STEP YOU CAN REVERSE STICKERS MOVEMENT JUST CLICK IN CHECKING BOX

(THROTTLE (UP/DOWN), YAW (LEFT/RIGHT) --> LEFT STICKER)

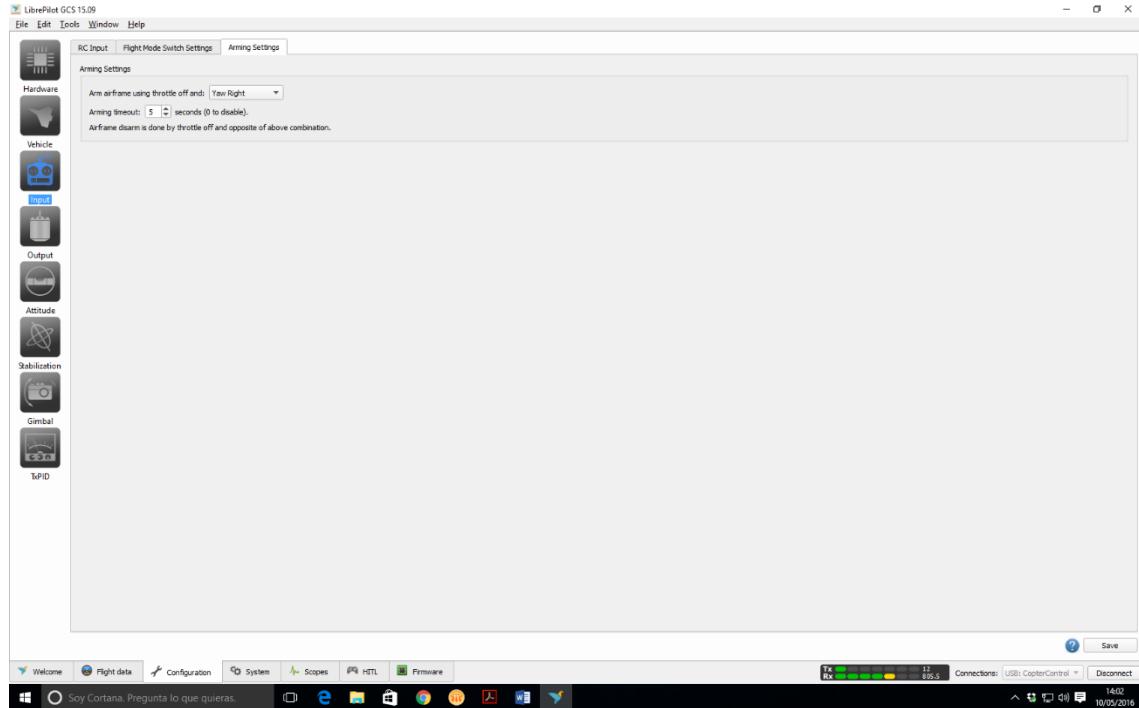
(PITCH (UP/DOWN), ROLL (LEFT/RIGHT) --> RIGHT STICKER)



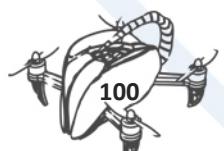
## LAST STEP IS RELATED TO ARMING MOTORS

IN ARMING SETTING, ARM AIR FRAME USING THROTTLE OFF AND "YAW RIGHT"

TIMEOUT "5" SECONDS



ARMING MOTORS (5 seconds)



## DISARMING MOTORS (5 seconds)



**WARNING:** Some firmware versions are not compatible with the CC3D board, we recommend for now to don't upgrade the firmware and just skip that step in the Wizard.

Once you have finished the wizard you should add the following for the PID settings.



### 7.6.1 HOW TO NAVIGATE IN LIBREPILOT

The LibrePilot is organized into tabs and pages for easy navigation. You can find them on the bottom of window. There are:

#### **Welcome Tab:**

The greeting tab which shows you the latest project information and activity, provides buttons for the other pages, as well as containing the start button for the Vehicle Setup Wizard.

#### **Flight Data Tab:**

Displays live data from the flight controller.

The Flight Data Tab consist of:

1. Map
2. Model View
3. PFD - The Primary Flight Data display all information from current board connected to GCS.
4. SystemHealth
  1. **Atti**  
Shows the status of the board's attitude data. If all is well with gyroscope and accelerometer, it turns green after gyroscope calibration upon power up, or if you are using "GPS Navigation (INS13GPSOutdoor)" stabilization mode, when the Inertial Navigation System's Extended Kalman Filter (EKF) has fired up. EKF is a sophisticated sensor fusion algorithm that takes data from relevant sensors and creates a best possible estimation of the board's angle, velocity and position.
  2. **Stab**  
Shows whether the board is capable of stabilizing flight. This status goes very much hand in hand with Atti.
  3. **GPS**  
Shows the status of the GPS that can be connected to an OpenPilot flight controller. GPS is required for autonomous missions and more sophisticated flight modes.
  4. **Input**  
Input module handles the data that is coming from your receiver.
  5. **Output**  
Output module takes motor speed and servo position data from stabilization algorithms, and feeds it into output channels.
  6. **I2C**  
I2C is a bus that connects on-board or auxiliary sensors and handles the data transmissions. I2C is designed for communications internal to a PCB, and does not work well via wire connections. It is okay to use for LED controls and similar functions, but is absolutely not recommended for flight-critical sensor connections.
  7. **Telemetry**  
Shows the status of Telemetry communications module.



**8. Batt**

Battery status shows whether you have enough voltage in the battery to fly. Set limits for this in FlightBatt (CHECK this) settings. It requires a battery voltage sensor to work. Battery monitoring module can be enabled in system settings' optional modules.

**9. Time**

Shows whether you have enough energy in the battery left for flying, and requires a battery voltage and current sensor to work. Currently has a bug when not using a current sensor; set the battery capacity to 0. This disables the estimated flight time counter and associated alarms.

**10. Config**

Shows whether your flight controller board has been properly set up.

**11. Boot**

Shows that a board reboot is required, or fail-safe settings have been loaded upon boot.

**12. Mem**

Displays the status of remaining memory (RAM) that are used by processes internal to the flight controller.

**13. Stack**

Shows the status of the microcontroller's stack, which is a place where low-level functions store data.

**14. Event**

Shows the status of event system. A very heavy load can cause the event system to be overloaded.

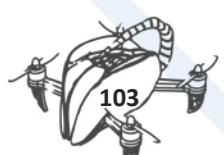
**15. CPU**

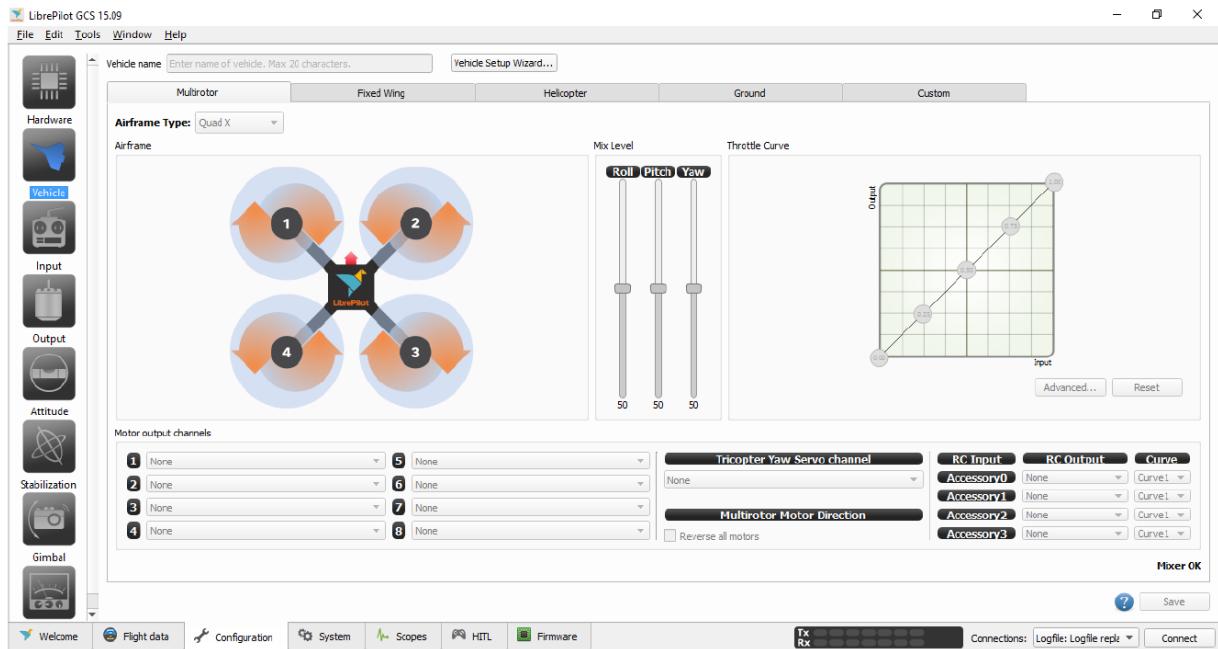
Indicates CPU load.

**Configuration Tab:**

This tab contains subpages which enable you to configure major elements of the flight controller using simple graphical interfaces. None of the subpages are active unless a flight controller is connected to GCS.

(**Important tip:** Before you start changing configuration you can save the current state in menu File -> Export UAV Settings. It is good for beginners - it could happen that after some changes your drone stop flying. In that situation you can Import UAV Setting and fly again.)





*Here you can configure your board.*

### **System:**

A configurable interface for viewing and modifying advanced settings, live data, GPS data and more.

### **Scopes:**

Real-time graphing of flight controller data. Care should be taken to not let auto-scaling fool you into thinking you have a problem where there is none. The longer a scope is functioning, the tighter the scale may get, and a very small deviation in a value may look significant when it's not.

### **HTML:**

An interface for the GCS to act as a bridge between a flight simulator, and either actual hardware running through the telemetry link or simulated hardware running on the computer.

### **Firmware:**

Inspect the current firmware version, and upgrade the bootloader/firmware of the flight controller.



## 7.7 FLIGHT MODES

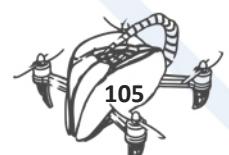
### Smooth flight Configuration



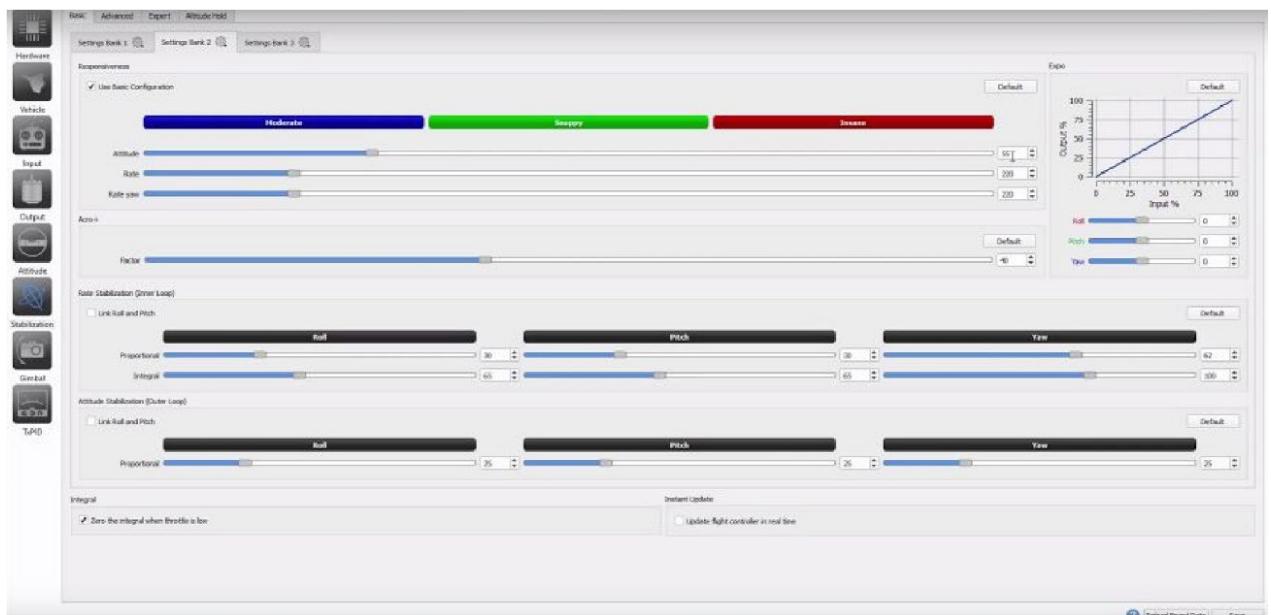
<u>Attitude</u>	<u>Rate</u>	<u>Rate way</u>
55	200	180

	<u>Roll</u>	<u>Pitch</u>	<u>Yaw</u>
P	30	30	35
I	30	30	35

	<u>Roll</u>	<u>Pitch</u>	<u>Yaw</u>
I	25	25	25



## More aggressive flight Configuration:



	<u>Attitude</u>	<u>Rate</u>	<u>Rate way</u>
	70	275	210

	<u>Roll</u>	<u>Pitch</u>	<u>Yaw</u>
P	30	30	35
I	30	30	35

	<u>Roll</u>	<u>Pitch</u>	<u>Yaw</u>
I	25	25	25



## Acrobatic flight Configuration:



<u>Attitude</u>	<u>Rate</u>	<u>Rate way</u>
75	400	300

	<u>Roll</u>	<u>Pitch</u>	<u>Yaw</u>
P	22	22	60
I	40	55	52

	<u>Roll</u>	<u>Pitch</u>	<u>Yaw</u>
I	25	25	25

