University at Buffalo

Quadcopter Setup

Hardware Assembly and Software Configuration

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CONTENTS

1 INTRODUCTION

This documentation will act as a detailed guide for constructing the copter, integrating the electronics as well as setting up the flight controller. The physical assembly of the copter should be direct and easy to follow but it may not be so for the flight controller set up. This document is not meant to cover everything about the APM but it is meant to cover the very basics. Any further questions on general topics can be found easily in the Arducopter wiki pages and anything specific can be directed to me personally and I will be happy to help.

2 STRUCTURAL ASSEMBLY

2.1 PERPENDICULAR TUBE CONNECTOR SUBASSEMBLY

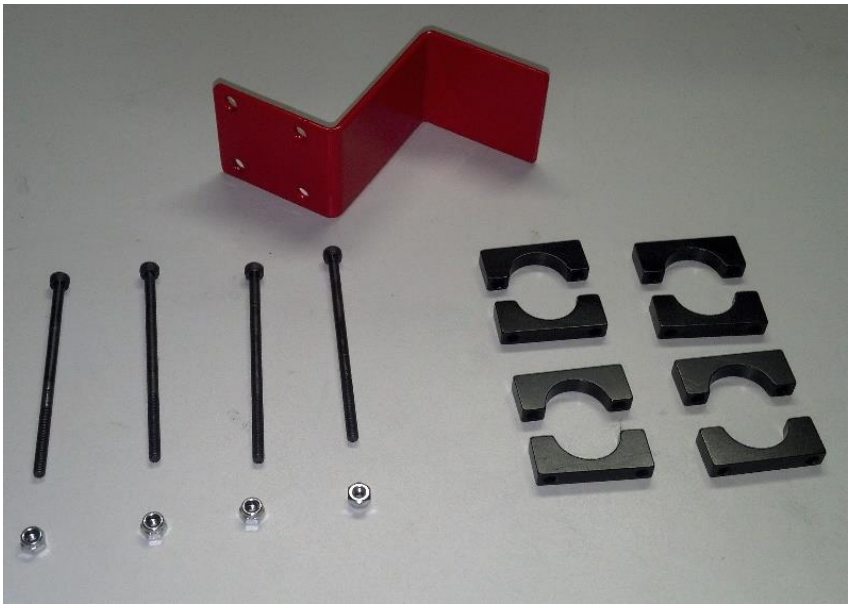

Figure 1

Items in Figure 1:

1 x Z-bracket (1.25” x 1.5” x 2.0”)

4 x bolts (3mm and 60mm long)

4 x nuts (3mm)

4 x tube clamp pairs (16mm dia.)

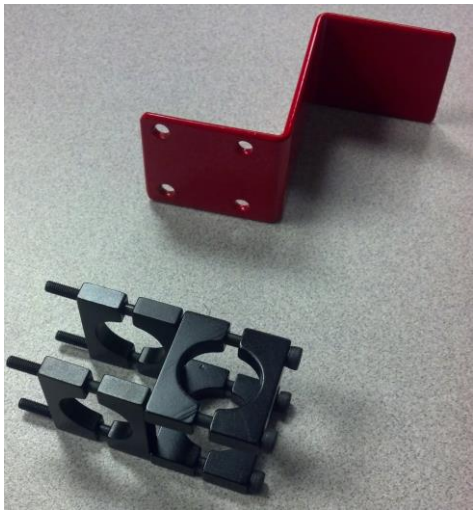

Figure 2: Perpendicular tube connector assembly

Figure 3: Landing gear attached to perpendicular clamp connector

Do not fully tighten the nuts fully until further instructions. Build 4 of this subassembly.

2.2 FUSELAGE SUBASSEMBLY

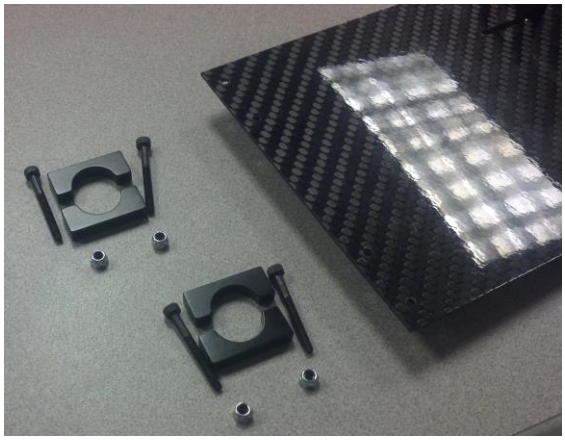

Figure 4

Items in Figure 4:

Carbon fiber base plate (5” x 12”)

Bolts (3mm and 30mm long)

Nuts (3mm)

Tube clamps (16mm)

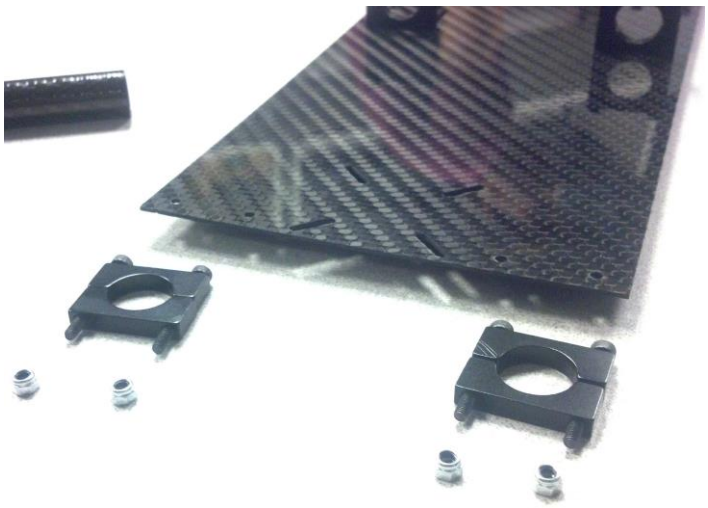

Figure 5: Assembling tube clamps to base plate part 1

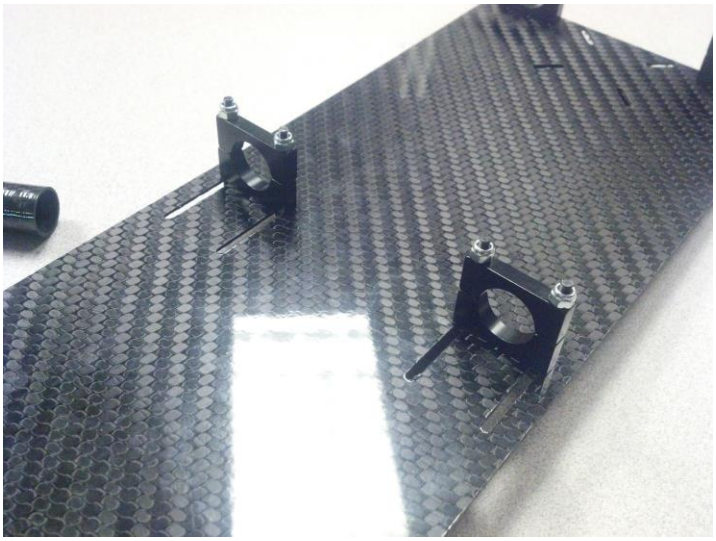

Figure 6: Assembling tube clamps to base plate part 2

As shown in Figure 6, ensure that the nuts for the middle two clamps are on top. Also note that the bolts used for those clamps must be the **low profile 3mm bolts.** Otherwise the bolt heads will push the batteries out from the dual lock fastener that will be placed underneath.

Figure 7: Assembling tube clamps to base plate part 3

Figure 8: Pass the 16” tubes through the clamps

As shown in Figure 8 measure the distance from both ends of the tubes to the clamps and try to get them to be approximately equal on both ends.

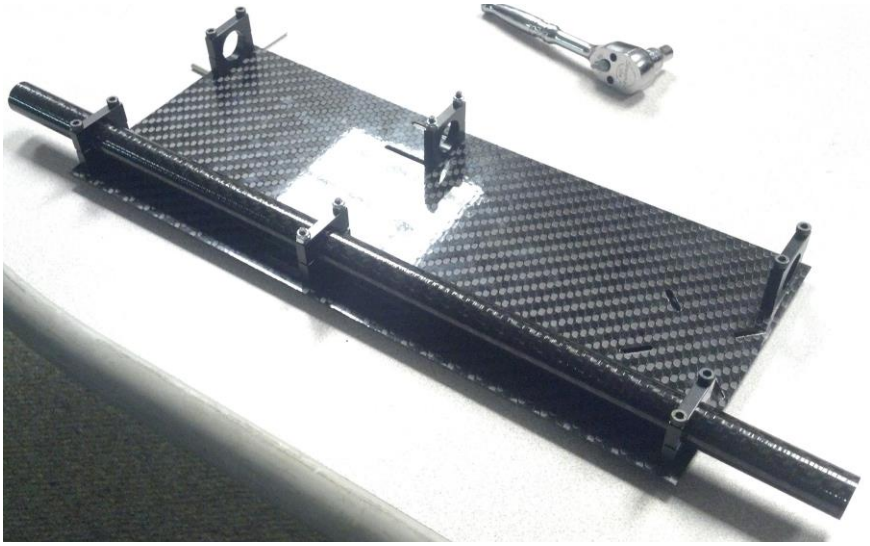

Figure 9: Tighten the nuts on the end clamps and repeat with the second tube

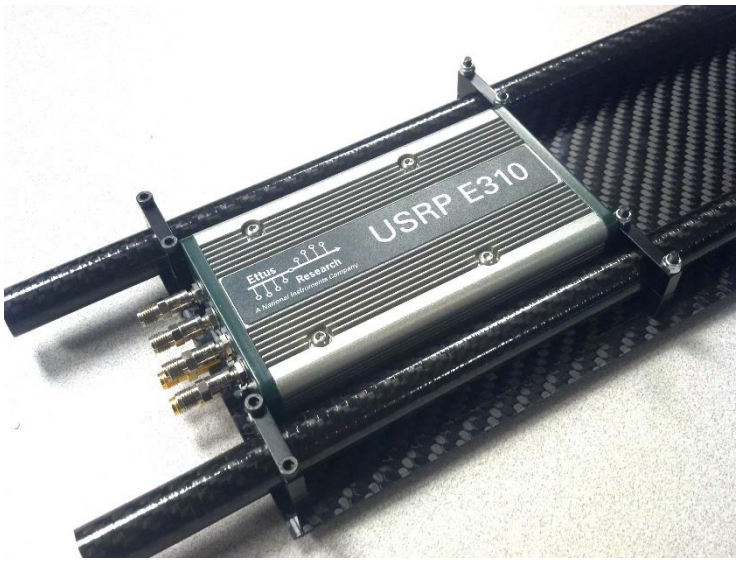

Figure 10: Place the USRP E310 between the 4 clamp sets and slide them together until the USRP fits fairly snug

Do not overtighten the USRP between the clamps since that will make it very difficult to remove and reinsert them after Velcro straps are added later.

2.3 FULL FRAME ASSEMBLY

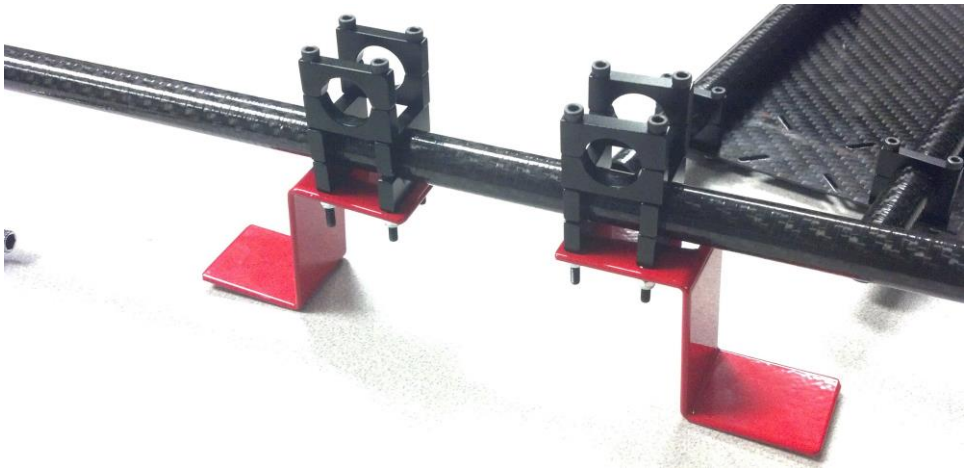

Figure 11: Pass a 20" tube through two landing gear subassemblies as shown

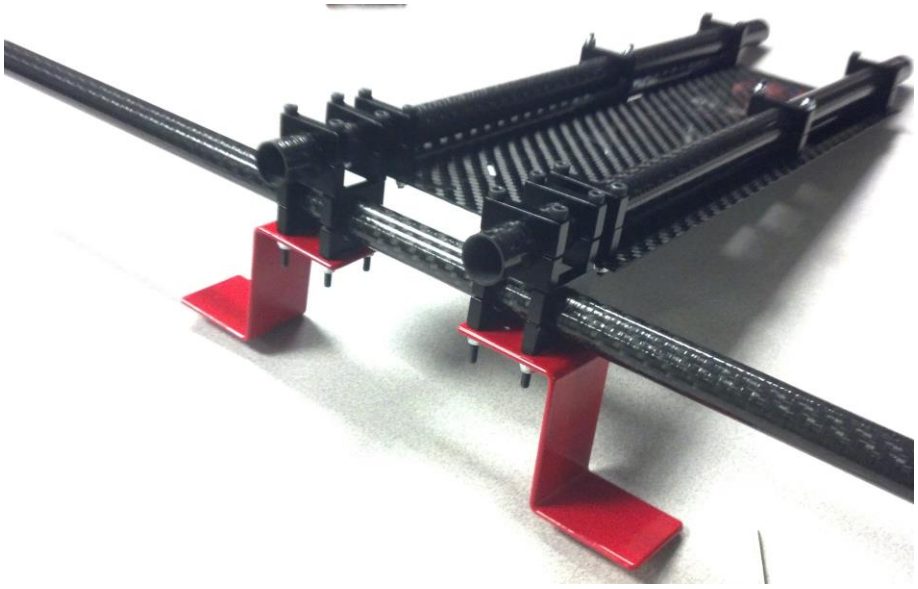

Figure 12: Connect it to the fuselage subassembly and loosely tighten nuts

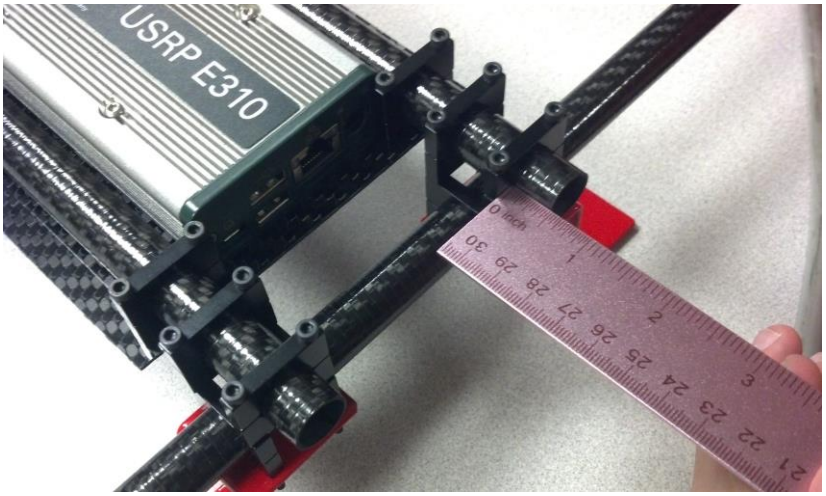

Figure 13: Measure out the distance from the clamp to the tube end to be approximately 1cm as shown

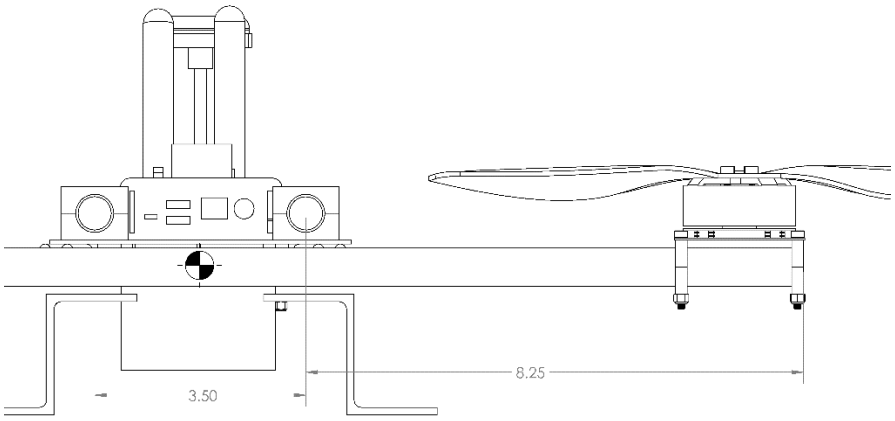

Figure 14: Distance in inches between tube midpoints and endpoints

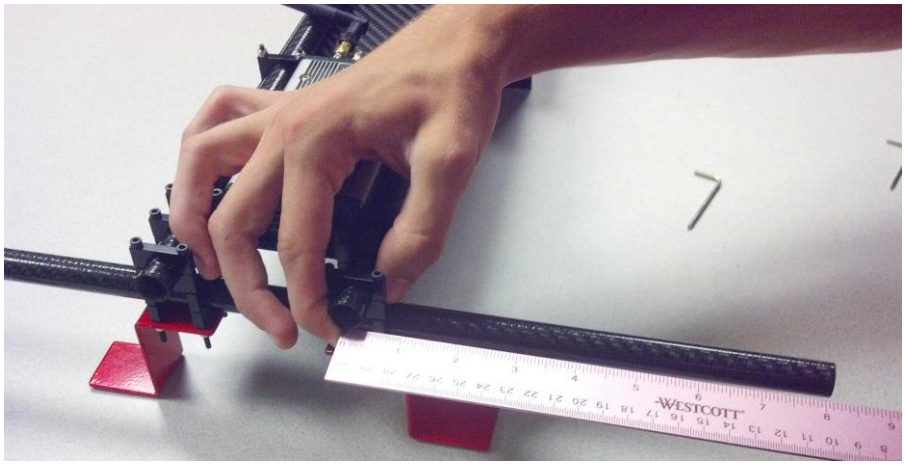

Figure 15: Approximate the distance as 8.25" as shown in the image above

Figure 16: Repeat all prior steps that are relevant until this stage is reached

The basic frame structure is now completed. Ensure that all nuts are tightened and everything is secured properly with no concerns.

2.4 MOTOR ASSEMBLY

Figure 17: Items required for a motor mount minus the 3mm nuts

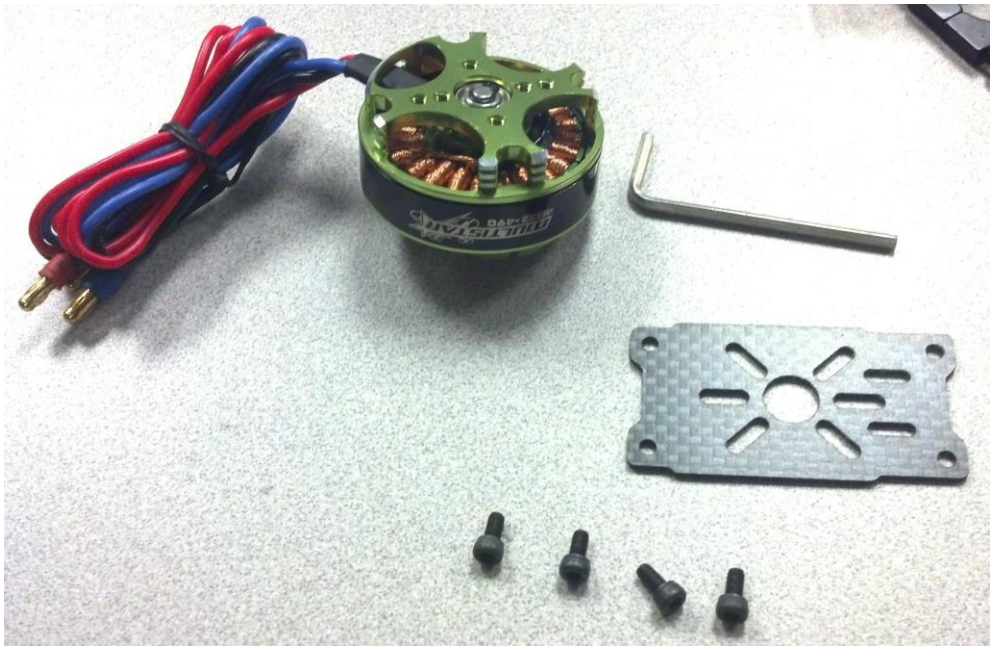

Figure 18: Items needs for mounting the motor to the mount plate

The hex key in Figure 18 is of the 2.5mm size.

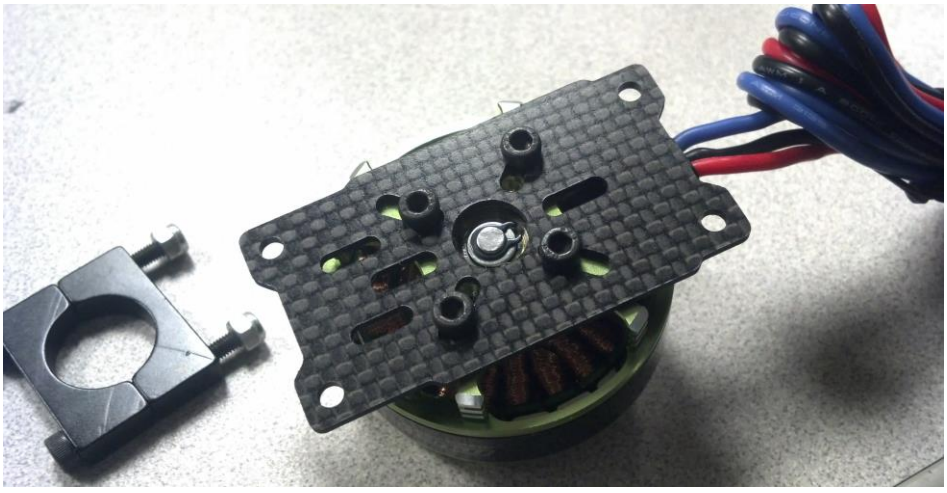

Figure 19: Mount the motor such that the wires come out in the direction as shown

Ensure that the thread locking solution is applied between the screws and motors when completing the assembly in Figure 19. The motor will come loose from it after certain number of uses otherwise, due to vibration, and will cause catastrophic crashes.

Figure 20: Loosely attach the clamp pairs to the plate as shown

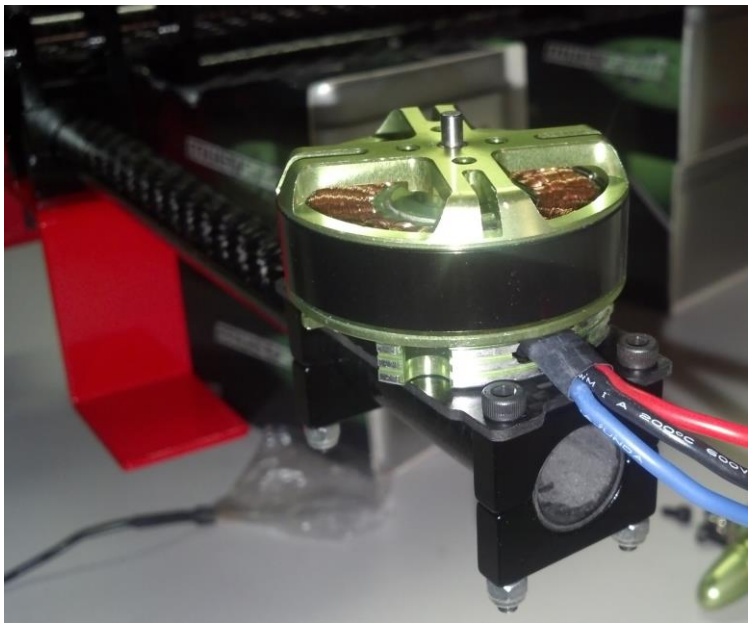

Figure 21: Attach the motor/motor mount to the motor-tube as shown and tighten into place

Ensure that the motor and motor mount is parallel to the rest of the horizontal surfaces of the copter.

Also not shown here is that the leads from the motor are shortened appropriately to make the assembly cleaner and reduce weight.

3 ELECTRONICS ASSEMBLY

The wiring diagram for the APM shown in Figure 22 is the basis for everything that follows in this section. Note that this image does not show the power module being between the battery and the ESC power splitter cable.

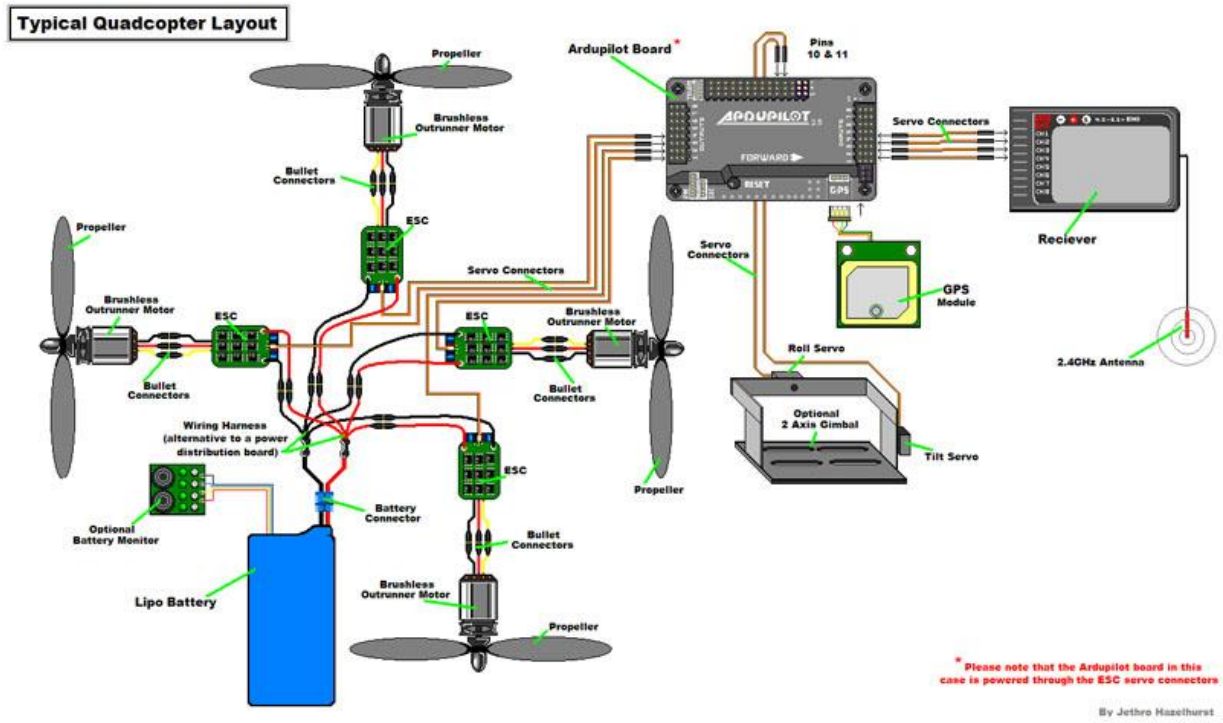

Figure 22: http://copter.ardupilot.com/wiki/initial-setup/assembly-instructions/connecting-the-apm2/

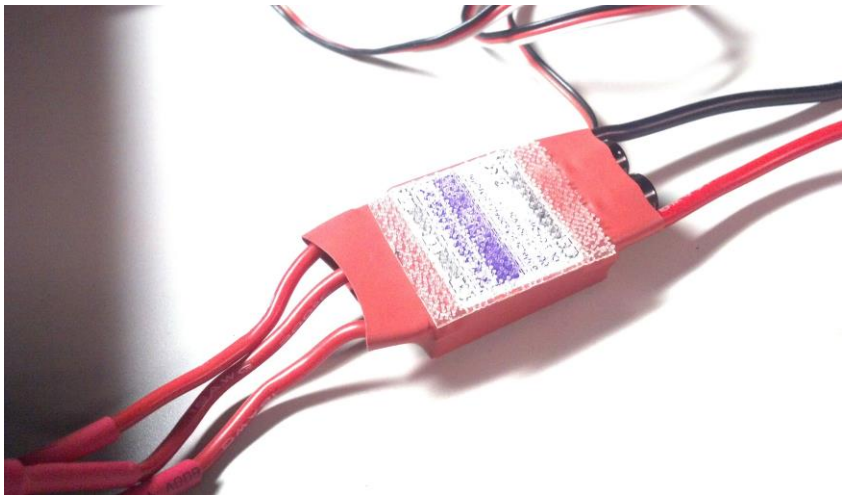

Figure 23: Electronic Speed Controller (ESC) with dual Lock fastener

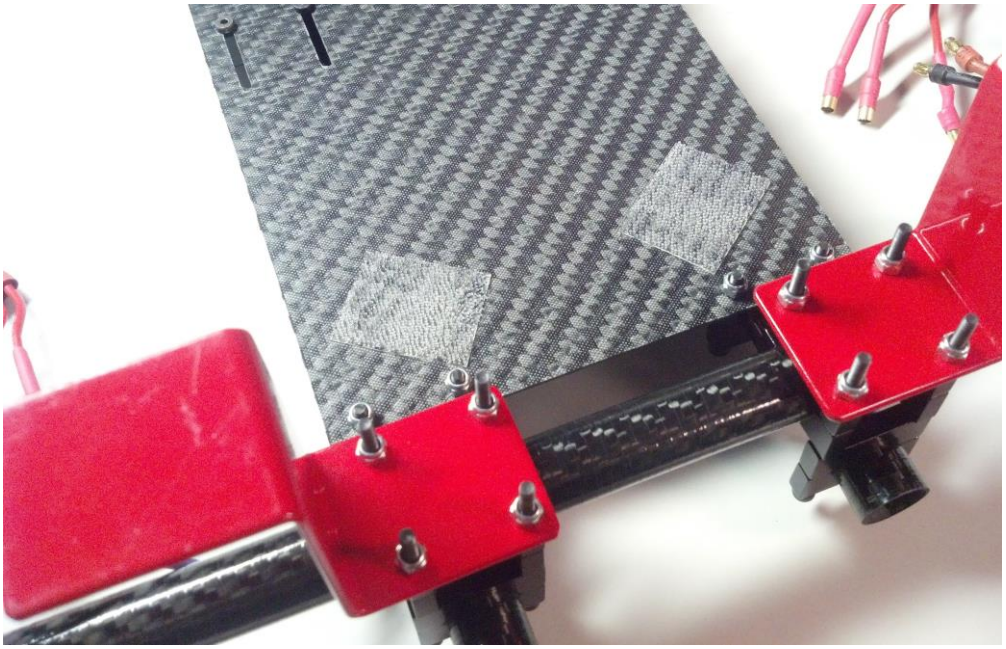

Figure 24: Apply dual lock on the mount plate to complement the ones on the ESCs

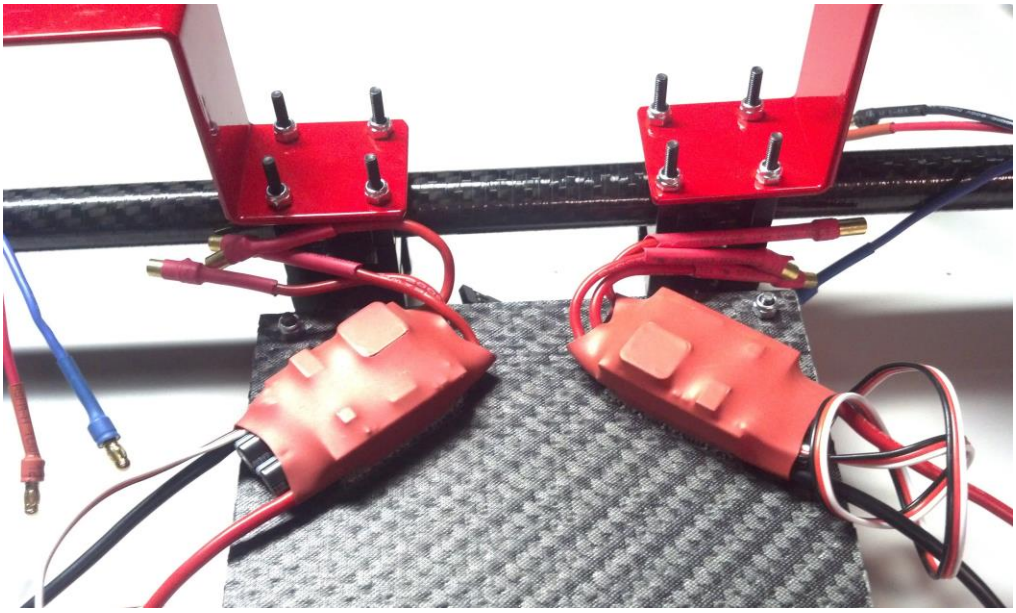

Figure 25: Attach the ESCs to the dual lock

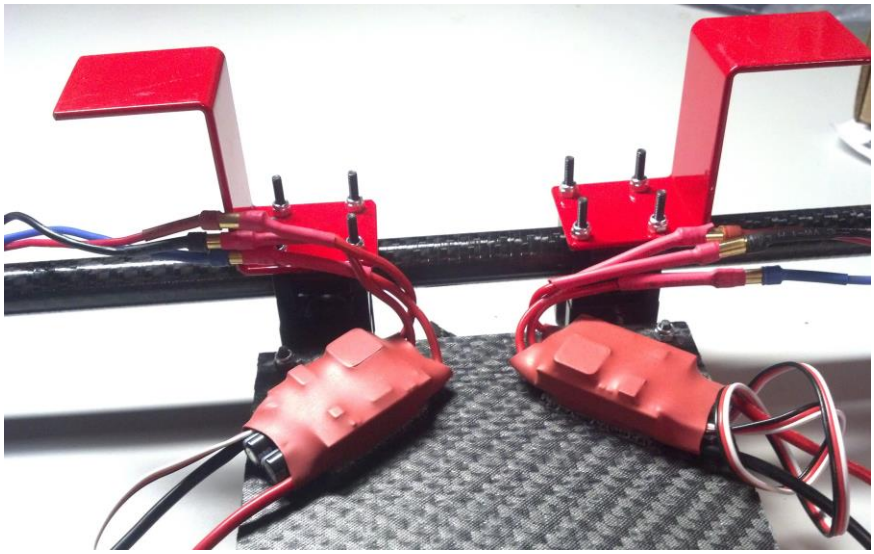

Figure 26: Connect the motor leads to the ESC

They must be left uninsulated for the time being until the APM is configured and motor spin directions are set.

Motor spin directions for each frame type can be found here:
http://copter.ardupilot.com/wiki/connecting-the-escs-and-motors/

Switching any two cables on the ESC will reverse the spin direction of the motors.

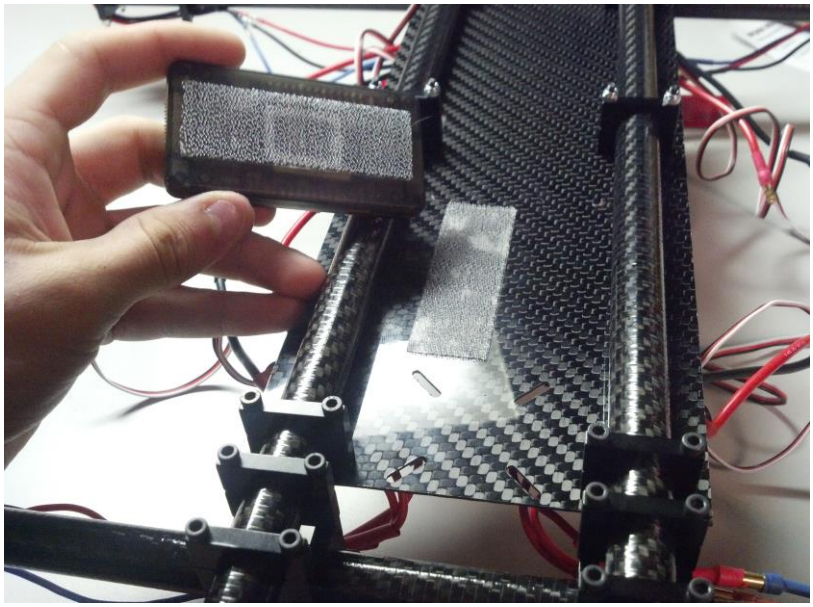

Figure 27: Use dual lock to apply the APM to the frame as shown

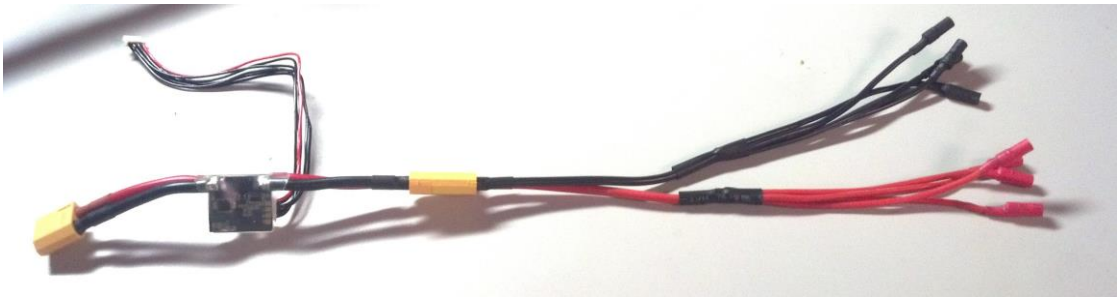

Figure 28: Power module connected to the power splitter cables

The power module for this copter is not the one provided by the APM manufacturer. The original power module is limited to the voltage of a 4 cell battery (16.8V). Since the battery that is being used has a cell count of 6 (25.2V) a modified power module is used. Make sure to avoid using the lower rated power module when using the 6 cell battery on any new copters that will be built.

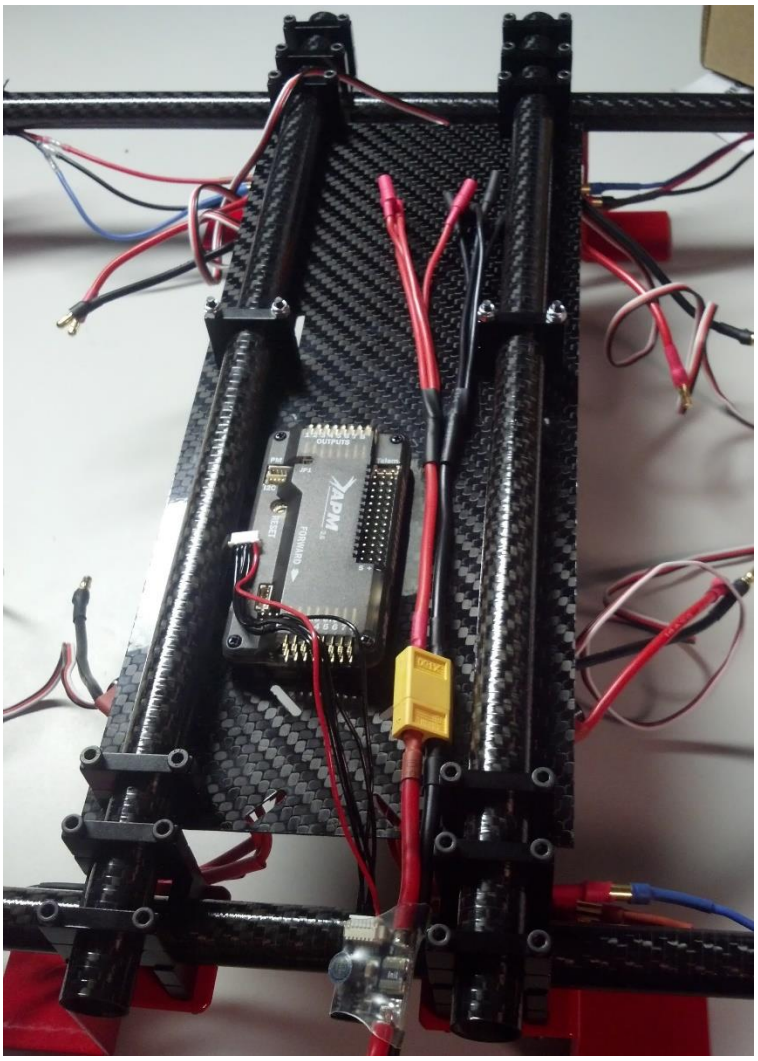

Figure 29: How all the electronics mentioned up until now must be laid out

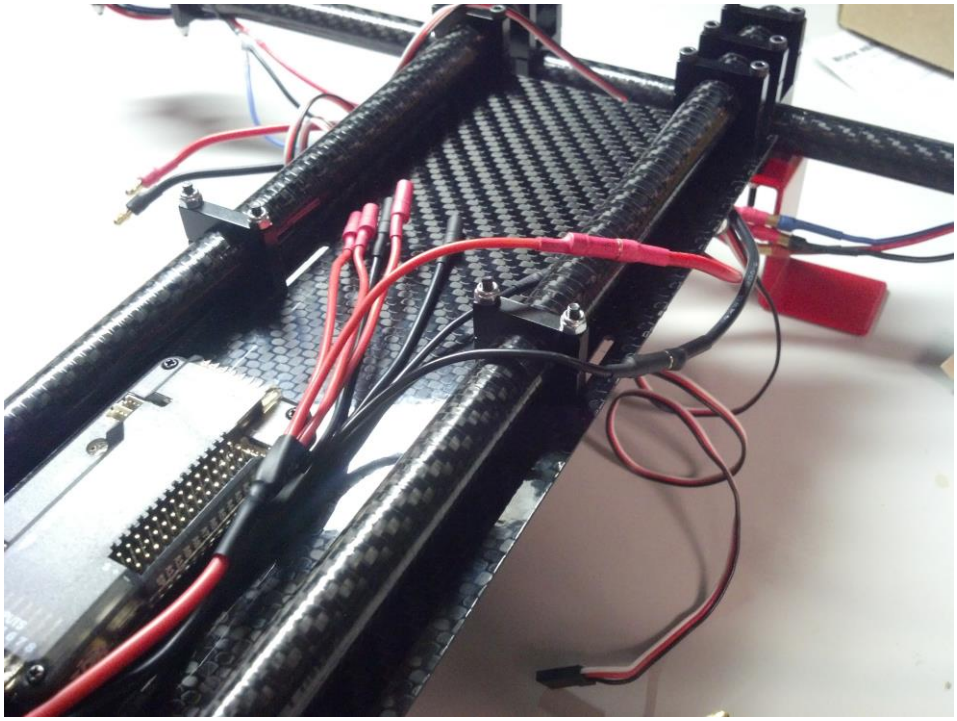

Figure 30: Start connecting each ESC to pairs of the power splitter cable

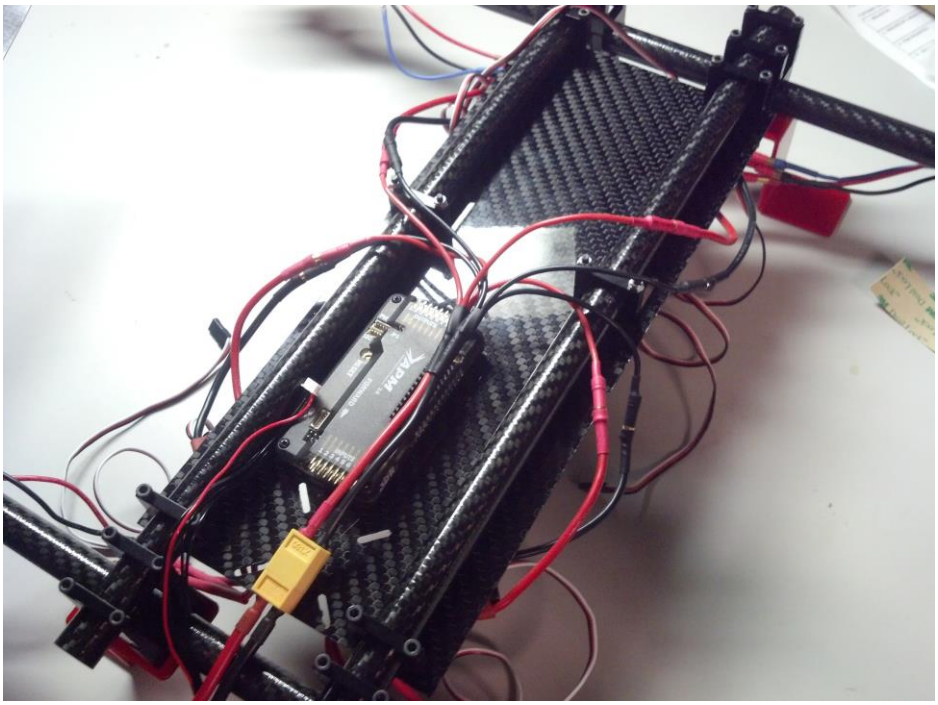

Figure 31: All ESCs connected to power module

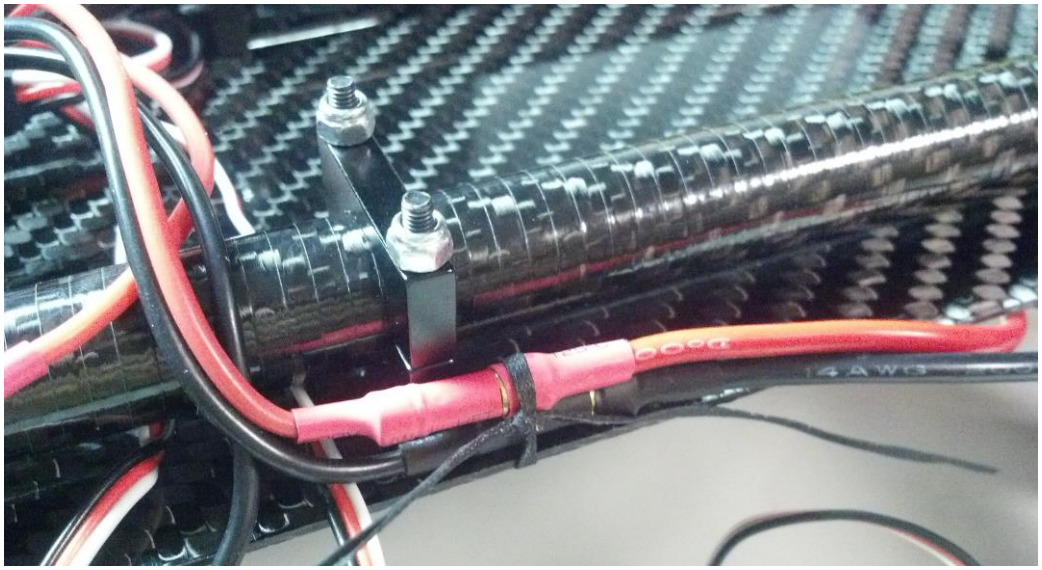

Figure 32: Tie down the cables to the plate slot

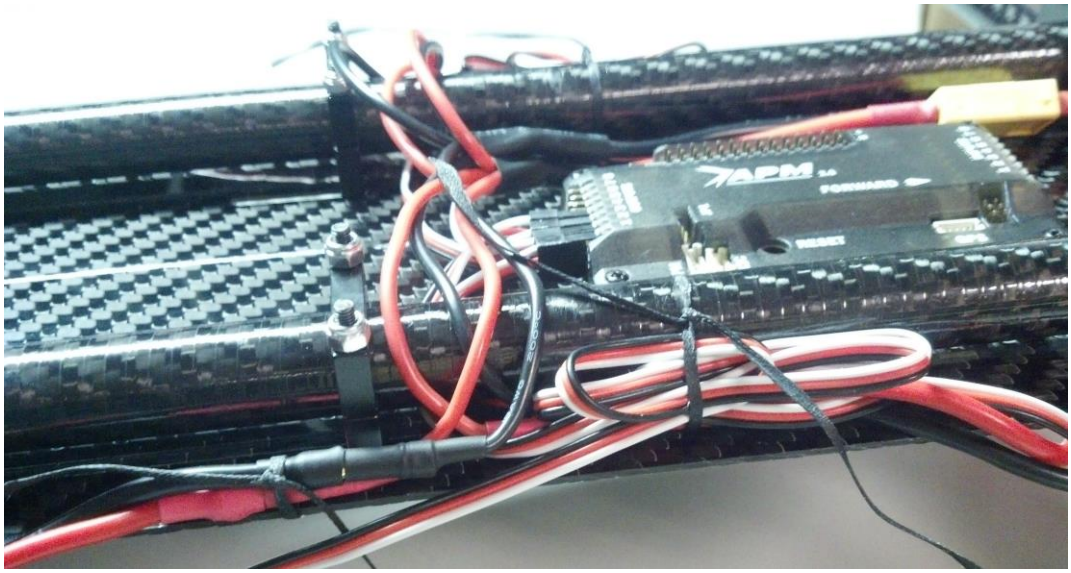

Figure 33: Tie down cables to the fuselage tubes

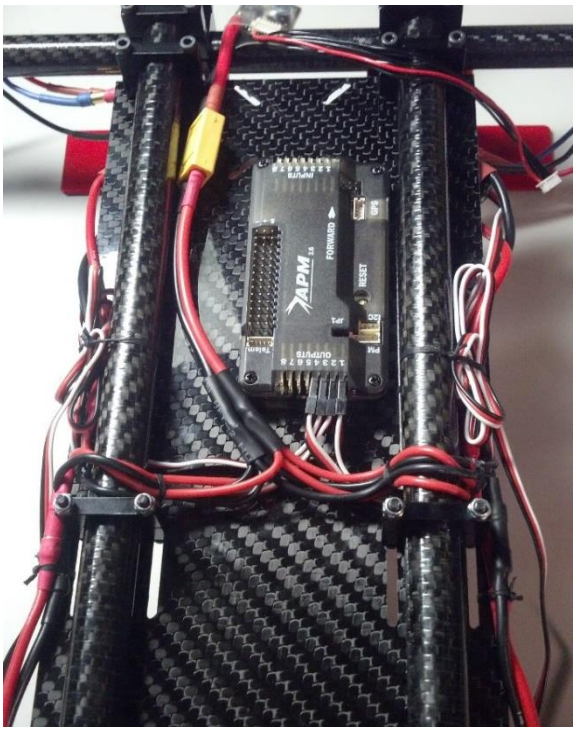

Figure 34: Make sure the cables are tied up in the section outside URSP mount location

Figure 35: Place Dual lock along the center for the batteries as well as at the side for the receiver

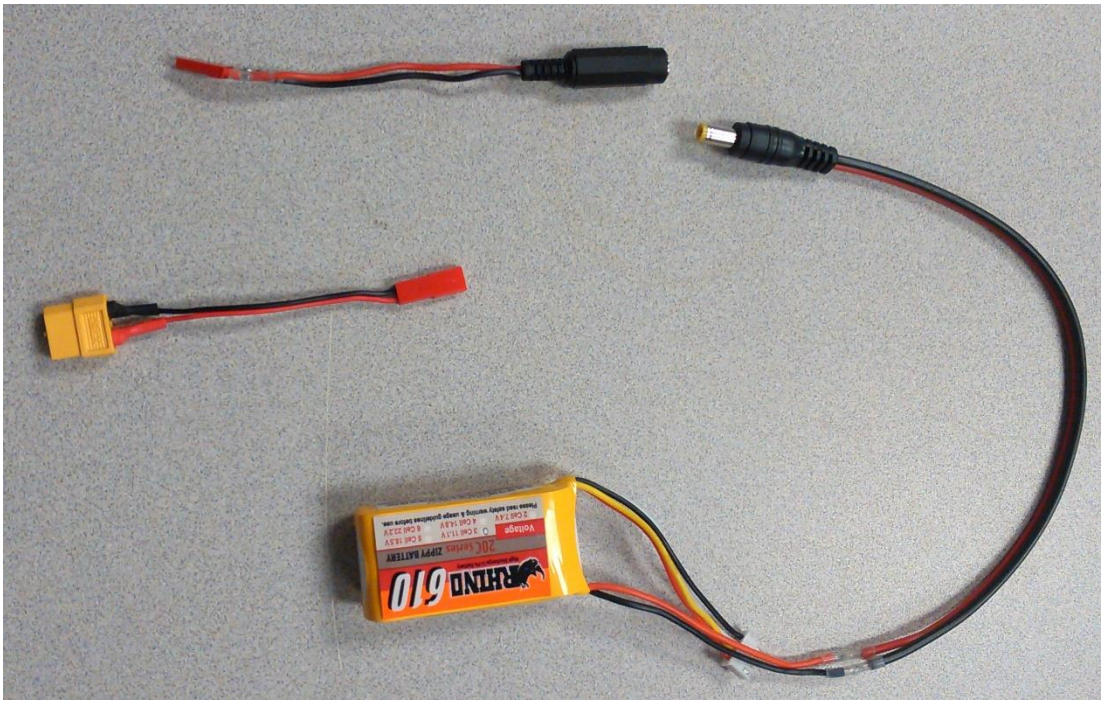

Figure 36: LiPo Battery modified for use with the USRP and custom charger adapters

Quick note on all batteries; make sure that they are not charged at a rate faster than 1C unless specifically mentioned by the manufacturer. 1C charge or discharge rate will empty or charge a battery within an hour.

Make sure to read up further on battery care

4 RADIO AND SOFTWARE SETUP

4.1 SETTING UP RC RECEIVER

The current radio receivers for the copter are flashed to be used with the PPM setup. This means that if connected in the appropriate manner, it can provide the functionality of all 8 channels through just a single channel. The advantage to this is that only one servo connector will need to be used to connect the Receiver to the APM. This provides weight reductions as well as a cleaner frame.

Note that these receivers do not come with PPM functionality. The specific firmware has to be flashed to any new ones that is purchased. This process will not be covered here and must be researched if needed. The following images however will show how to connect the APM and receiver to access the PPM setup. For future models, receivers with PPM built-in can be bought to avoid the need to flash the firmware.

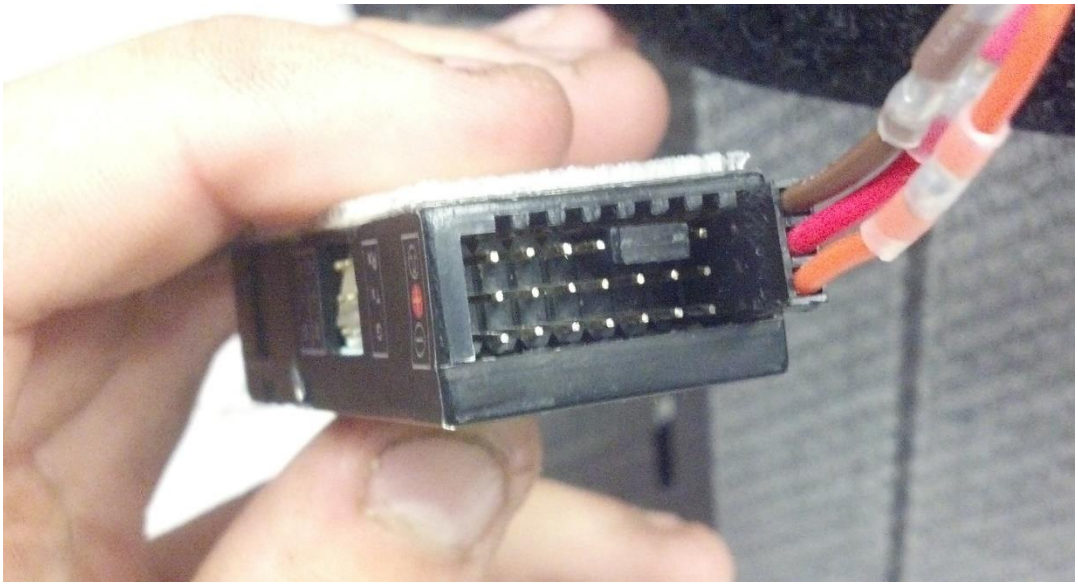

Figure 37: Place the jumper on the 3rd and 4th signal pins on the receiver

Figure 38: Plug in the servo connector to 1st channel on the receiver

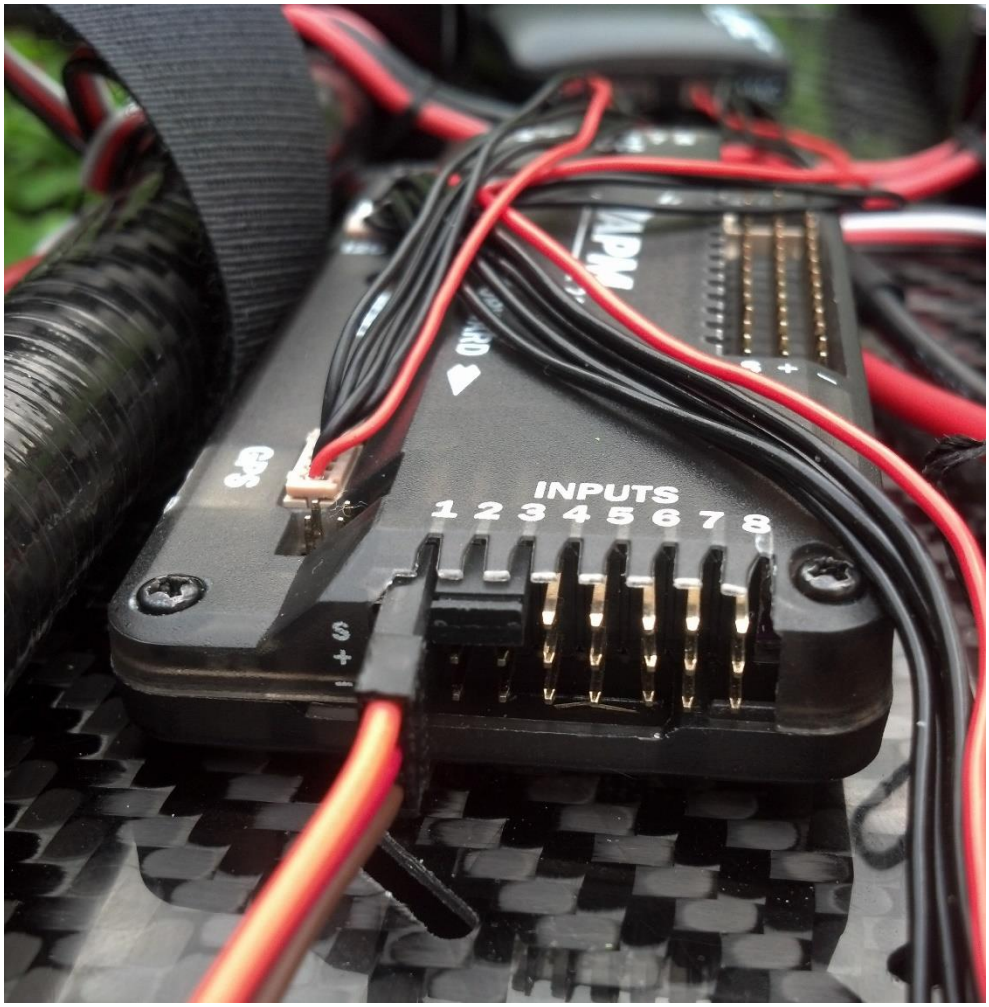

Figure 39: Plug the servo connector into channel 1 and jumper on signal pins 1 and 2 on the APM

If using PWM mode, look in the *Documentation* folder for "Channel Setup PWM" file to see corresponding channels for APM and the Receiver for proper control.

4.2 TRANSMITTER SETUP

The copter is armed by holding the throttle down and to the right for 5 seconds. Disarmed by holding the throttle down and to the left for 5 seconds.

The props will start spinning when armed for 10 seconds before disarming itself Keep clear!

You can only arm if the copter if the Mode is set to Stabilize.

Go through the controller menu and ensure that they look as shown in Figure 40 and Figure 42 so that the switches that are labeled on the controller matches what the APM expects.

Figure 40: Channels 1-5 setup

Setting channel 1-4 should be straight forward. Channel 5 is what is used for switching between the flight modes. A 3 toggle switch is used to do this. The specific modes can be set through Mission Planner as shown in Figure 41.

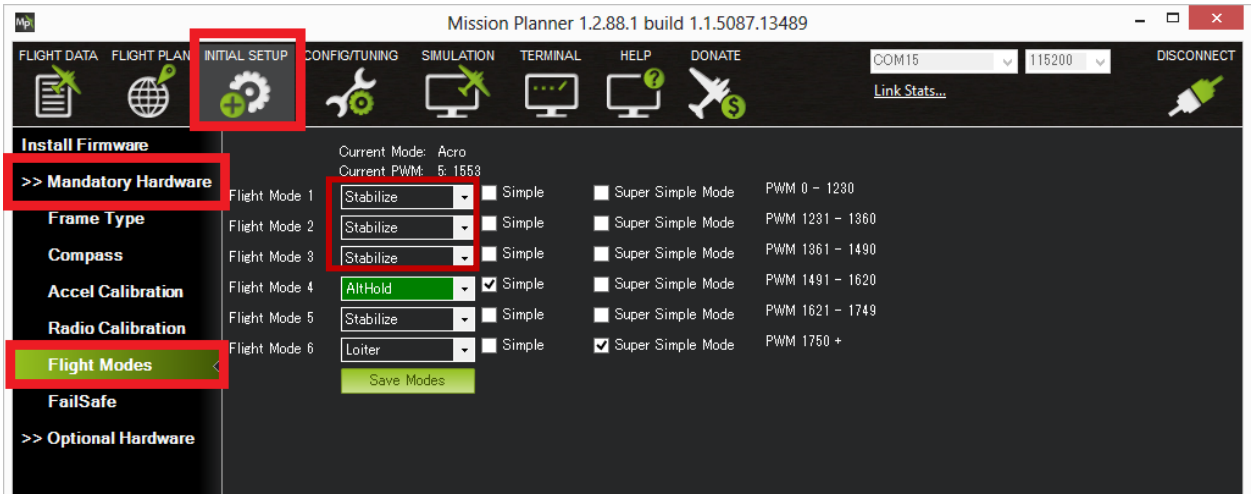

Figure 41: Flight Mode Setup

Figure 42: Channels 7&8 setup

Channel 7 and 8 modes can be set in Mission Planner as shown in Figure 43. 6 is omitted since it is not necessary feature and we would like to avoid the issue covered in the link below for new pilots:

http://diydrones.com/profiles/blogs/why-frsky-cppm-signal-is-so-disappointing?id=705844%3ABlogPost%3A984615&page=3

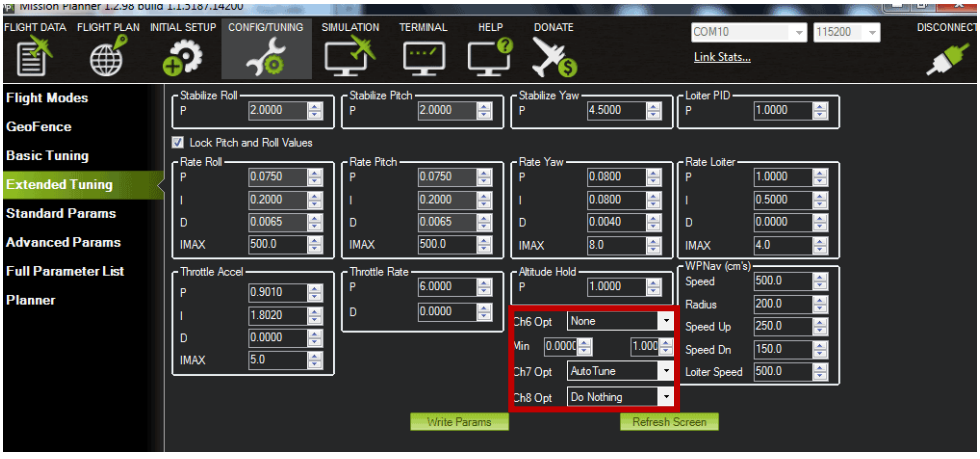

Figure 43: Tuning and setting channel 6 to 8

4.3 ESC SETUP

The ESC must be programmed independently to ensure that they respond to the flight controller as expected. Then they must be calibrated independently or together through the flight controller to

ensure that all of them spin up at the same time from the throttle. This is important so that it doesn't flip itself over by having uneven thrust during takeoff.

4.3.1 ESC PROGRAMMING

Plug in the servo connector from the ESC to the programming card as and set their values as shown in the following links.

https://www.youtube.com/watch?v=xm8GMAJhPjY

http://copter.ardupilot.com/wiki/initial-setup/esc-motor/

Note that, to do this for an ESC that is already set up on a copter, just power the copter as usual, and then take the servo connector plugged into the APM and just plug that into the programming card.

4.3.2 ESC CALIBRATION

Instead of explaining this here, the original source is below since no single picture will explain this clearly. If any of the ESCs are replaced, this must be redone for the copter.

http://copter.ardupilot.com/wiki/initial-setup/esc-motor/

4.4 PARAMETERS

The basic parameters that are important to know will be mentioned here but won't be covered in depth since preset parameter files are provided for different scenarios with these already taken care of. These files can be found in the APM/Parameters folder. These and other parameters can be individually modified once their definitions are well understood.

4.4.1 AIRFORCE INDOOR TESTING SPEED LIMIT

The autopilot speed requirements for indoor testing of this experimental copter is limited to be within 1 to 2 meters per second in all directions. Figure 44 shows max speed settings for way point navigation for the APM set to be at 1.5 m/s.

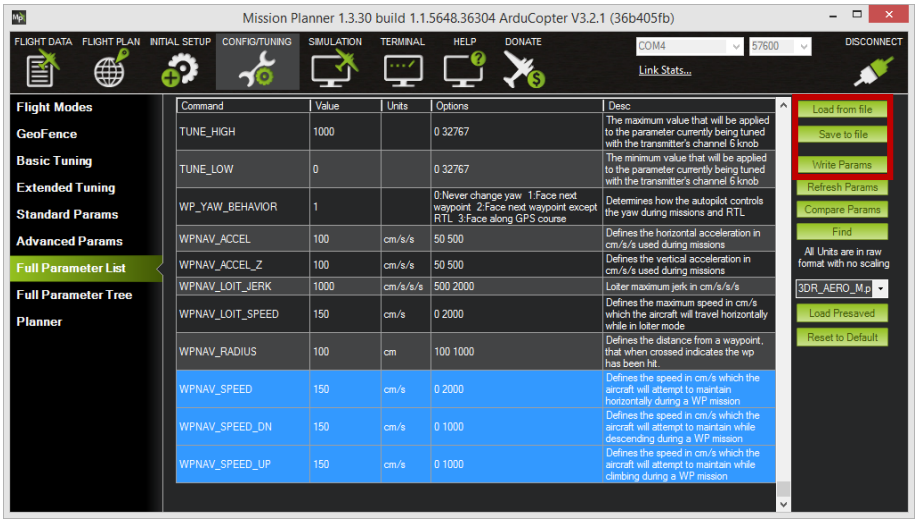

Figure 44: Autopilot speed parameters

If there seems to be any control issue from the copter, the known working parameters can be loaded and written to the copter from the APM/Parameters folder using the buttons that are boxed in.

4.4.2 PID CALIBRATION AND AUTOTUNING

PID values for roll and pitch must be calibrated for copters as their mass and weight distribution change. The PID coefficients are extremely important for proper response from the copter. This can be done manually or can be automated. The manual method is very painstaking and can be inaccurate so the auto-tuning process link is given below to do this in an automated manner.

http://copter.ardupilot.com/wiki/autotune/

The PIDs are already tuned for the empty weight of the copter for each of the batteries and saved in the *APM*/*Parameters* folder. But it must be redone with the USRP E310 onboard once the copter is ready for testing.

5 FLIGHT MODES AND FAILSAFES

There are a number of flight options to choose from for the APM, but for this project only the basics will be needed. The default modes that are set up to be toggled between are Stabilize, AltHold and Land, in that order. Stabilize is the mode where the pilot has full control of the copter and the flight controller's primary concern is only with maintaining the stability of the platform in flight. Stabilize is also the only mode in which the copter can be armed. AltHold stands for altitude hold and it will maintain the copter at approximately the altitude that the pilot activated it at. The pilot still maintains full directional control. Land mode will bring the copter down at a preset speed until it reached the ground. The pilot still maintains directional control during this mode.

The advanced counter parts of the three above modes are Auto, Loiter and RTL. In Auto mode, a preset mission can be uploaded to the flight controller and have it complete it with no human input as shown

in Figure 45. Loiter mode combines the Altitude hold and Position hold function using the onboard Barometer and GPS. When activated, this will hold the copter in a fixed position in hover both laterally and vertically. RTL or return to launch is one of the most useful tools available because once activated, it will fly the copter back to where it was armed for the given mission and land it there, all on its own.

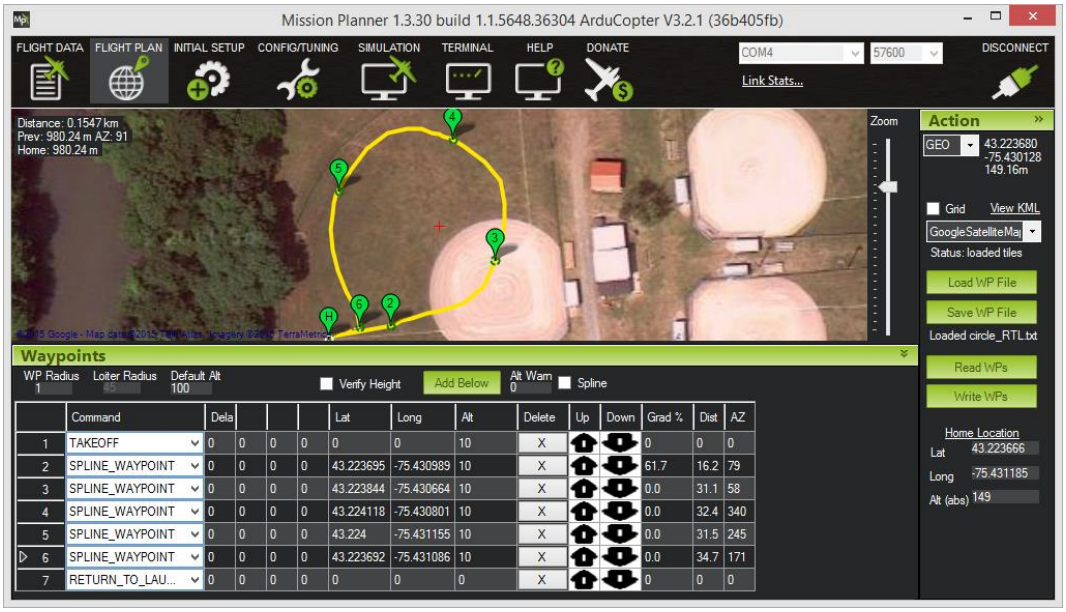

Figure 45: Sample Auto Flight Plan

Note that the way-points are based on google earth longitudes and latitudes and are fixed to a given location. If the copter is given this specific waypoint mission and had Auto mode activated, it will try to fly to Rome NY. So be aware of this and must make waypoints for the location that it will be flown at. Seems like an obvious point but it is worth making.

5.1.1 GEO FENCE

This is a very important feature for anyone that is not an expert. This allows the user to set a maximum height ceiling and horizontal radius that the copter should not go outside. The failsafe should be set to RTL in the case that this might happen. Without this feature, the likelihood of retrieving the copter safely by a pilot disoriented by distance and altitude is very slim.

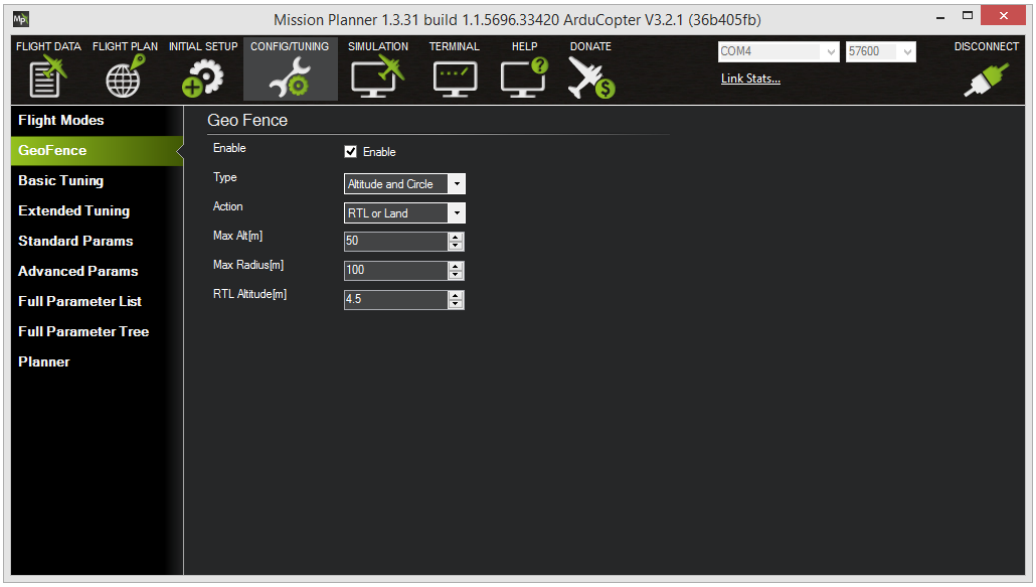

Figure 46: GeoFence Parameters

5.1.2 BATTERY FAILSAFE:

For the 6 cell battery, use 20.2V and 2000MAH

For the 4 cell battery, use 13.45V and 2000MAH

5.1.3 RADIO FAILSAFE:

This activates if the copter loses contact with the transmitter. This doesn't work correctly right now. ***It only activates if the transmitter loses contact with the copter and then turns back on***. *If it only loses contact, the copter will basically power down mid-flight and crash.*

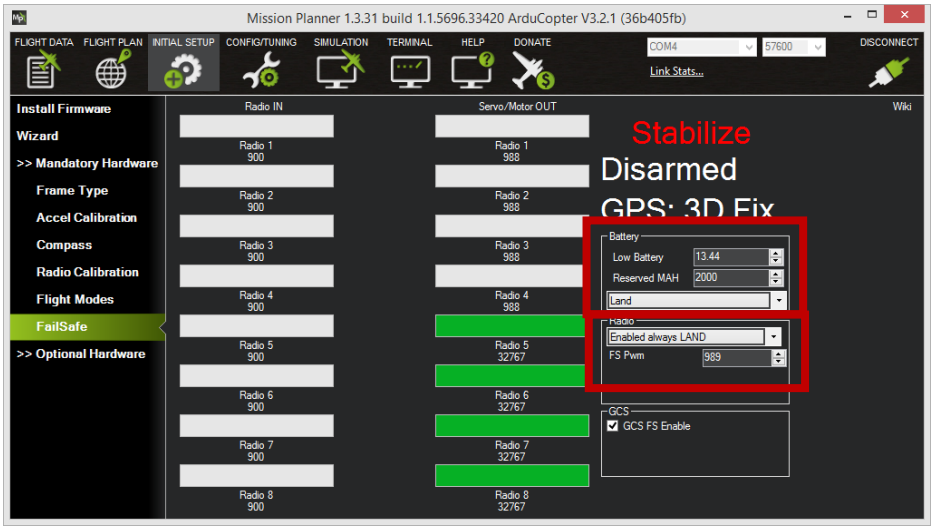

Figure 47: Battery and Radio Failsafes

6 FLIGHT CHECKLIST

There are lots of things that can go wrong when working with aircrafts but the risks can be lowered significantly by following safety checklists. Table 1 is the preflight checklist that is to be gone over prior to at least the first flight of the day for each individual copter. DO NOT SKIP ON THIS.

Table 1: Flight Safety Checklist

	#	**Steps**	
Stage 1	1	Weather Check	
	2	Laptop Battery Level	
	3	Transmitter turned on	
	4	Transmitter Battery Level	
Stage 2	5	Airframe/Electronics Visual Check	
	6	Payload Secured	
	7	Move battery until CG is centered	
	8	Battery Secured	
	9	Props mounted/oriented correctly	
	10	Nothing is in spin zone of props	
Stage 3 (Control Check)	11	Hard Arm, confirm boot by audible feedback	
	12	Ensure Radio Telemetry	
	13	Battery Voltage Check	
	14	Confirm GPS	
	15	Check Flight Mode presets	
Stage 4 (Failsafes)	16	Battery voltage and and mAh Failsafe	
	17	Radio loss failsafe check	
	18	GPS loss Failsafe check	
	19	Geo Fence Parameters check	
Stage 5 (Flight)	20	Adequate room to fly, Clear of Bystanders	
	21	Soft Arm	
	22	Ensure all motors are rotating evenly	
	23	Takeoff and Execute Mission	

This is also not a final checklist. Things can and should be modified in them as more mission constraints need to be dealt with.

7 COPTER TESTS COMPLETED

7.1.1 LANDING SPEED (HARD SURFACE):

30 cm/sec and 50 cm/sec without issues in land mode.

Recommended 30 cm/sec

7.1.2 LANDING SPEED (GRASS):

Up to 1m/sec comfortably in fully manual control.

Almost free fall from between 5 and 8 meters high. All landing gear damaged with one motor mount twisted. NOT RECOMMENDED.

Did not recover from a back to back flip from 20 meters in time and copter hit the ground on all landing gear. There was no damage then but instantaneously bounces back up and does 3-4 front flips 2 feet above the ground and smashed into the ground breaking off one motor arm on impact. All other components were safe.

7.1.3 MAX HEIGHT:

60 meters high before wind speeds make the copter unstable. Don't recommend above 30 meters under manual control since the copter because unstable and harder to orient higher up in the air. *There is video footage.*

7.1.4 RETURN TO LAUNCH:

Activated at an altitude of 42 meters and 100 meter radius when copter became hard to orient. Came back to launch point autonomously without issues. *There is video footage.*