Turbo-Multirotor Drone

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Contents

1 Introduction

1.1 Purpose

Drones are becoming very common today in many industries. For example Amazon is starting a project to use drones for delivery [1]. However, propellers on multirotors easily break when it comes into contact with anything hard. It tears skin when it hits flesh. Our project aims to make drones safer. Instead of using propellers, our project will use a centrifugal fan for thrust. Doing so will make the drone safer than a typical drone with expose propellers or even propeller guards on it. The exposed propeller case is obvious since the propellers will have a chance to damage anything that comes into contact with it. Our project will be safer than a drone with propeller guards most propeller guards will still flex and during a crash, the propellers will hit the surface resulting in plastic shrapnel. Our design will have the impeller enclosed such that people will not be able to accidentally touch the fast spinning impeller. Also, since the impeller is enclosed in the shell, it will be less likely to be damaged and shrapnel when it crashes.

1.2 Objectives

- Design a drone the flies without propellers
- Design a more robust drone than ones on the market

1.3 Function and Features

- Flies like a commercial drone
- Interpret sensor data and determine stability
- Safely bring back drone when signal is lost
- Lightweight and portable
- Balanced design for stability
- Long flight time
- State feedback control
- Low power, High thrust

2 Design

2.1 Block Diagram

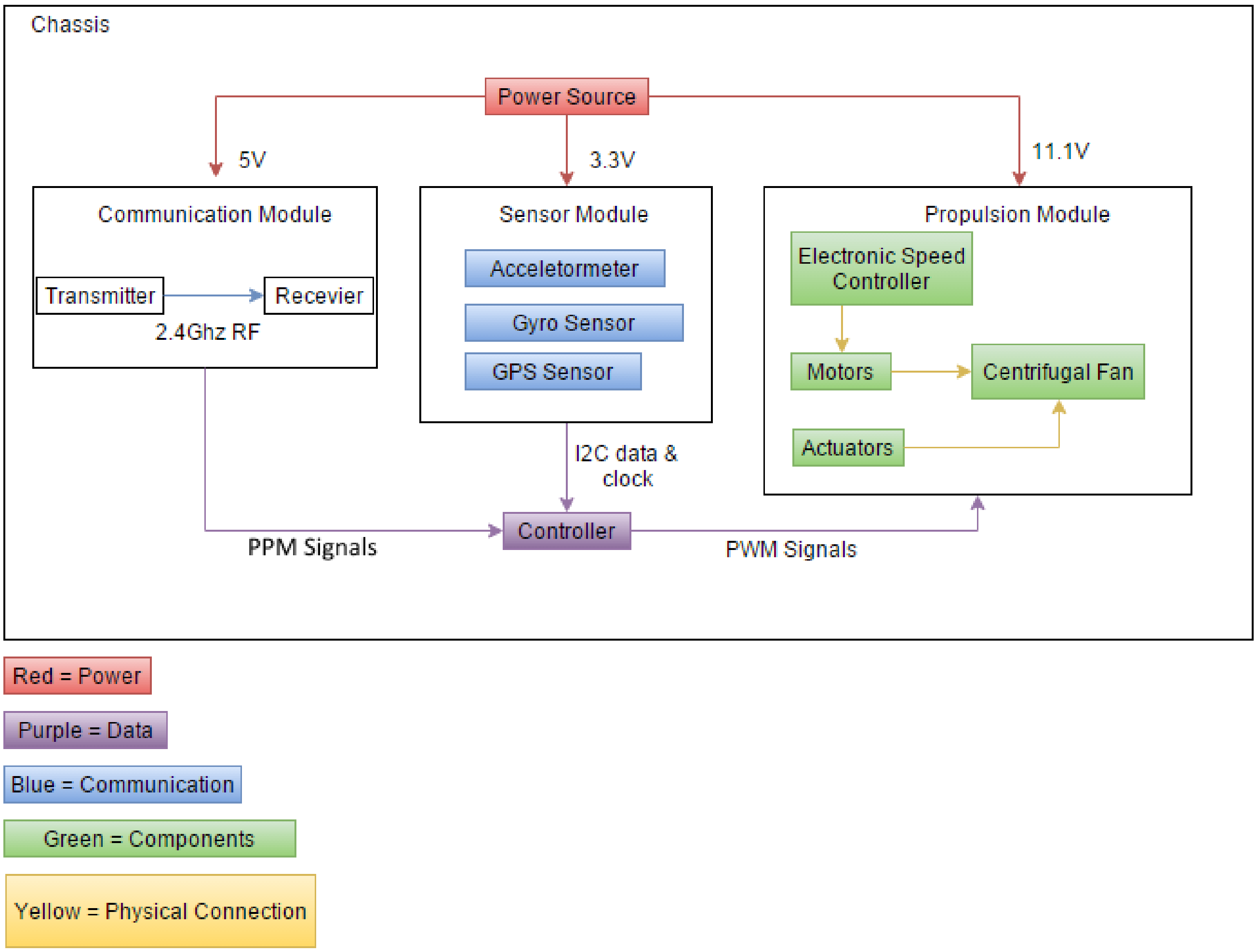

Figure 1: Block Diagram with the modules

2.2 General Schematic

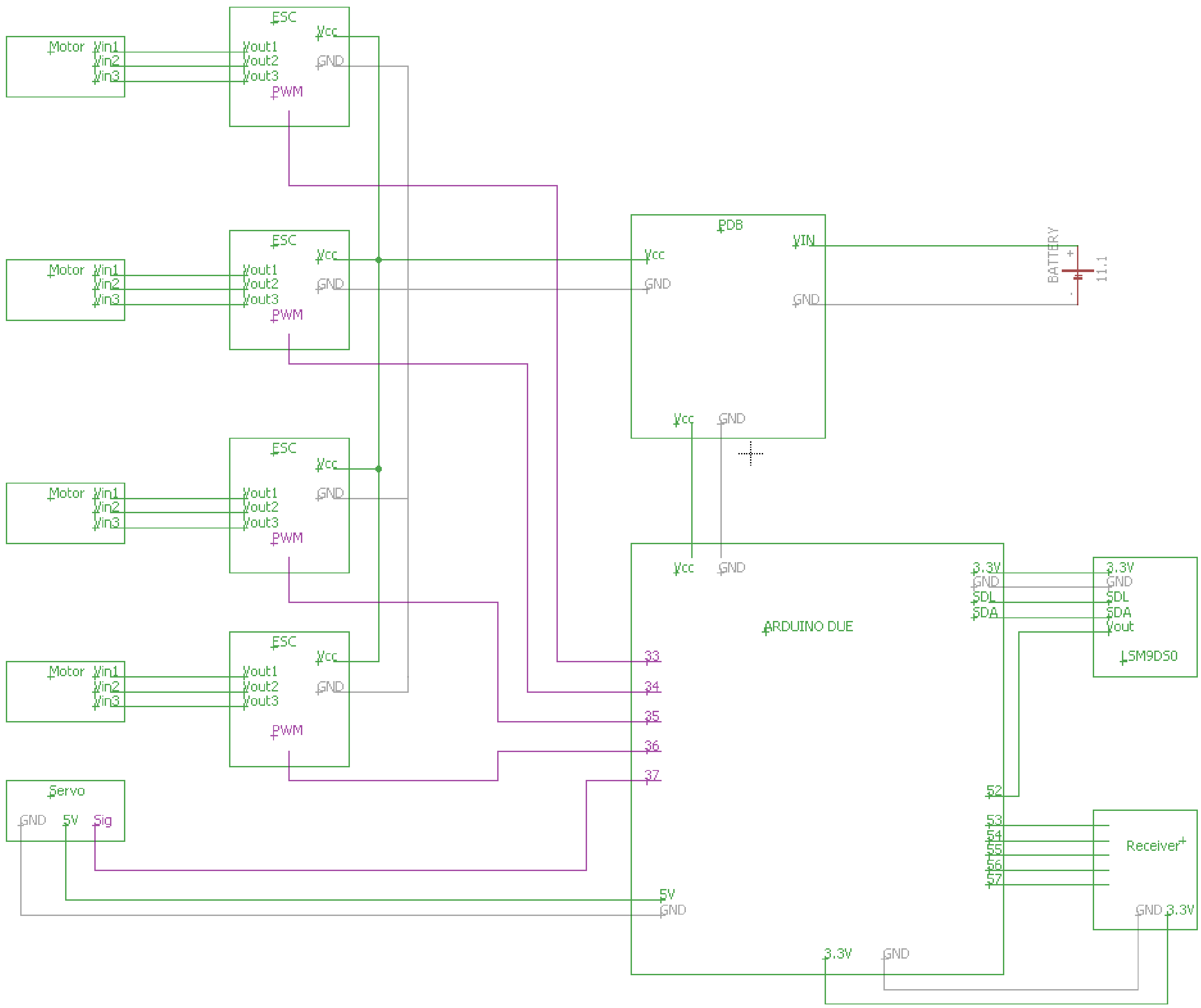

Figure 2: Genera Schematic for Drone

2.3 Block Descriptions

2.3.1 Power Supply

This will properly distribute power for all components in the system diagram. Lithium Polymer Batteries will be used for the advantageous Power/Weight Ratio. Since the power supply will distribute power to the machine, the voltage and current regulators must be able to simultaneously handle the current draw of every module at maximum output. The estimated requisite battery will have to meet this demand as well, and as such a high current discharge lithium polymer battery will be selected. For this project, we will be using a Turnigy Bolt 2200mAh 3S 65-130C 25.08Wh. This battery operates at 3S or 11.1V with a capacity of 2200mAh and a 65-130C Discharge.The mAh stands for mili-Ampere-Hours which is the amount of electric charge the battery can provide. The C rating is the maximum safe continuous discharge rate of the battery. This means that the battery will output a continuous current of $2200mAh * 65C = 143A$ and a peak current of $2200mAh * 130C = 286A$.

2.3.2 Transmitter

The transmitter will allow the operator to control the machine at a distance by transmitting signals (Pulse Position Modulation) to the receiver on the machine. For this project, we will be using a Spektrum Dx6i Transmitter. The Spektrum Dx6i transmitter uses the 2.4Ghz band and the DSM2 modulation[6]. This transmitter supports up to 6-channels where our project will only use 4. This transmitter was chosen for this projects as it provides a reliable communication to the receiver and is a similar type of controller used for typical drone and plane operation.

2.3.3 Receiver

The receiver is the component that will receive the signals transmitted by the transmitter and send the data to the microcontroller. It will need to be able to handle a minimum of 4 separate channels of data. We will be using a Spektrum AR600 Receiver. The Spektrum AR600 Receiver was chosen along with the Spektrum Dx6i transmitter as it operates on the DSM2 modulation as well as the 2.4Ghz Band[7]. The receiver also supports up to 6-channels such that we will be able to expand upon our project in the future with the unused channels. This product is from the same manufacturer and will be compatible with the transmitter for the project.

2.3.4 Electronic Speed Controller

The electronic speed controllers (ESC) are the components that are calibrated to a range of PWM (Pulse Width Modulation) or PPM (Pulse Position Modulation) signals, and uses these to determine the speed at which they should be driving the motors. Each must have current-handling capabilities that include a safety factor in order to properly drive each motor on the drone without jeopardizing the integrity of the overall control system. For this project, we will be using the HobbyKing SS Series 50-60A ESC. This ESC is able to control the speed of a brushless motor and can handle up to 50A continuous and 60A. This ESC is perfect for our project because it has many features included like overheating protection as well a smooth linear throttle response and a auto-shutoff when signal is lost.

2.3.5 Motors

The motors are the elements that will allow the machine to move. Large brushless outrunner motors with a kV rating of greater than 2670. kV rating is the RPM generated per volt applied to the motor. Therefore, if we apply 11.1V to a 3400kV motor, the motor will be spinning at 44400 RPM. Brushless motors are chosen due to less light weight, lower operating costs, lower friction, higher efficiency, and high power they provide. This motor will need to be able to handle a great amount of torque for it to not burn during operation of the drone. For this reason, the NTM Rotor drive 450 Series 3400kV/500W motor is chosen. This motor pulls from 30A continuous and 46A burst. This means that the power supply must be able to output $30A * 4Motors = 120A$ continuous and $46A * 4Motors = 184A$ burst.

2.3.6 Centrifugal Fan

The centrifugal fan is the key component in the project. The centrifugal fan give the project its uniqueness. This and the use of the servo creates an alternative propulsion method for drones of this size. The centrifugal fan is similar to an automotive intake compressor found in cars equipped with turbines or belt-driven compressors. It has a circular hole on its large face which takes in air and then a spinning circular blade compresses the air and pushes it out the nozzle on the side of the round housing. This part will be custom-made. The part will be made with cardboard impeller and a foamboard housing. These materials are chosen mainly due to their weight. The following is their drawing of their CAD models.

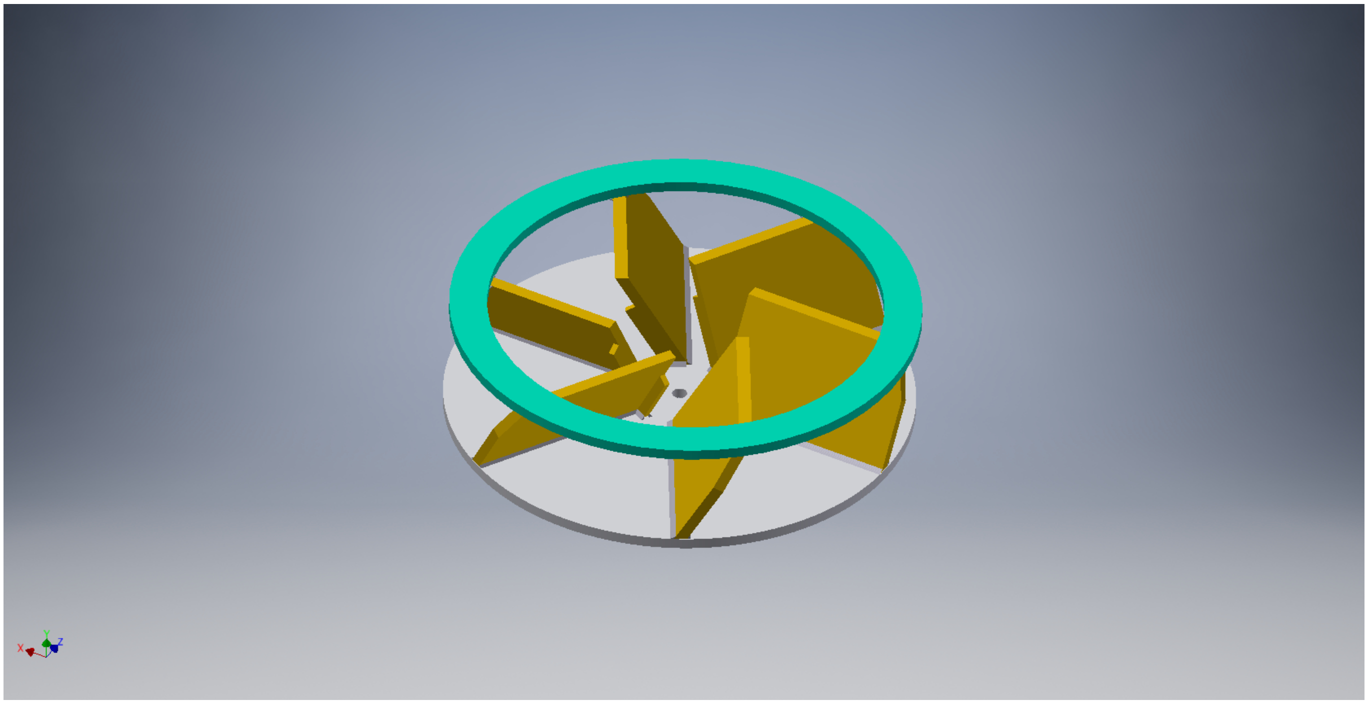

Figure 3: CAD model for Centrifugal Fan Impeller

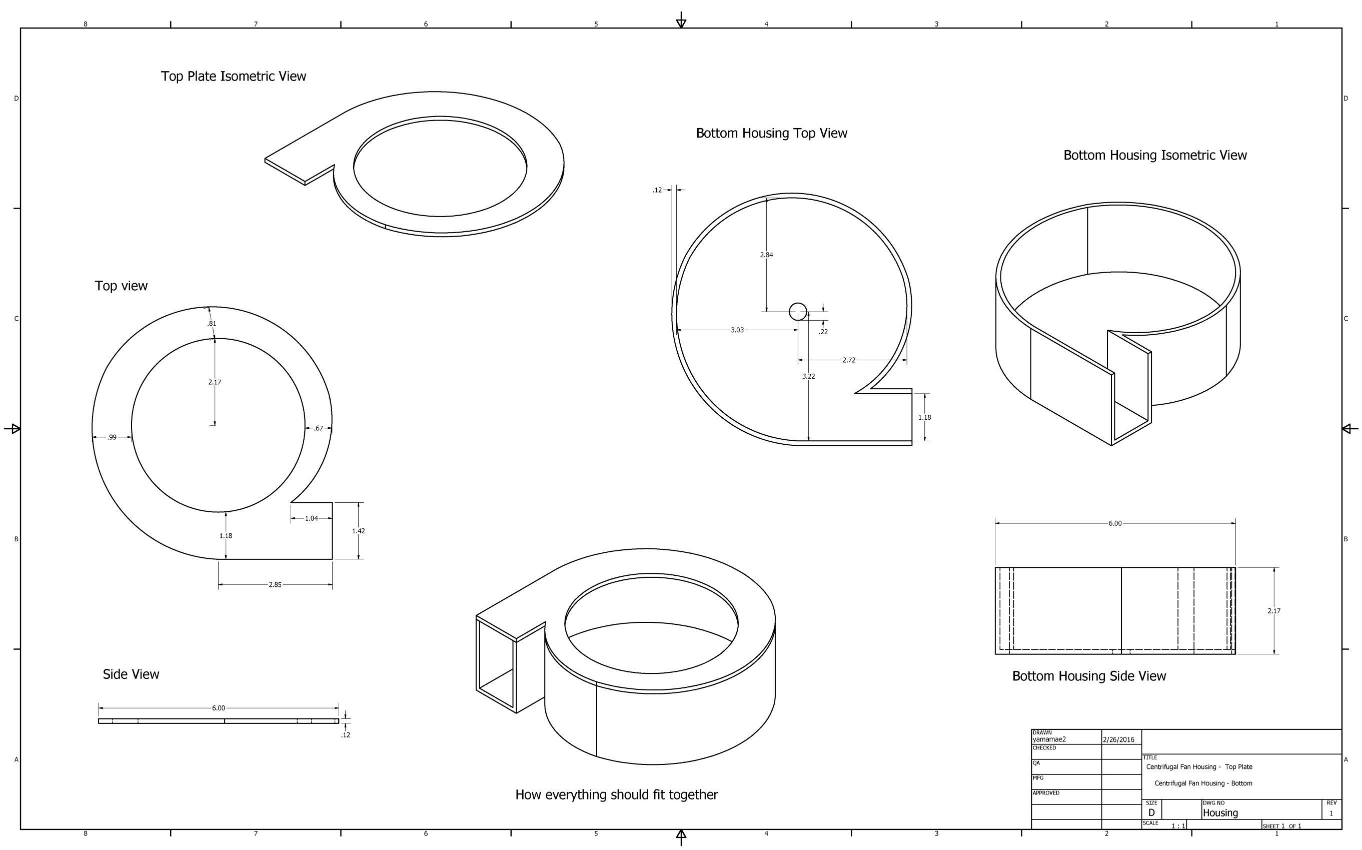

Figure 4: CAD model for Centrifugal Fan Housing

2.3.7 Controller

The controller is the brain of the machine. This takes in pulseIN signals from the receiver and L2C sensor data from the gyro sensor and the Accelerometer. Then the controller outputs PWM or PPM (Pulse Width Modulation or Pulse Position Modulation) signals to the electronic speed controllers. The device we will be using in this project will be the Arduino Due since the Arduino Uno does not have enough pins for the project nor the computation time. Compared to the Arduino Mega,the Arudino Due has faster computational speeds as well as have as many available pins[9].

2.3.8 Gyro sensor

This sensor measures the axes of tilt of the drone, which are its yaw, pitch, and roll. This data is sent to the controller in order to stabilize the drones motion. The sensor will automatically to be calibrated when turned on, though the gain response will be calibrated on a per-drone basis. For this project, we selected the Adafruit 9-DOF Acc/Mag/Gyro + temp breakout board which uses the LSM9DS0. This sensor was chosen since it can be easily integrated to the Arduino board and because it contains both the accelerometer and the gyro sensor. The gyro sensor is able to measure from $\pm 245/\pm 500/\pm 200$ degrees-per-second.

2.3.9 Accelerometer

This sensor measures the acceleration forces upon the drone. The data from the sensor will be used along with the gyro sensor unit to stabilize the drone. As mentioned above, we will be using the Adafruit 9-DOF Acc/Mag/Gyro + temp breakout board which uses the LSM9DS0. The LSM9DS0 can measure $\pm 2/\pm 4/\pm 6/\pm 8/\pm 16g$ linear acceleration full scale. these values is the maximum swing the chip is able to detect. For example, to measure the earth's gravitational acceleration, a $\pm 1.5g$ should be enough but if the sensor will experience sudden stops or starts, a $\pm 5g$ must be handled. The g we are referring to is the g-force which is $9.8\frac{m}{s^2}$ on Earth.

2.3.10 Actuator

The actuator is the component that is used to angle the centrifugal fans in order to yaw the drone. This is most-likely be a brushless or coreless servo motor due to its power to weight ratio requisites. The servo will will take in a PWM signal and 5V from the controller. The servo will be able to turn 125 degrees of rotation and should be able to output 20oz-in of torque. For this project, we will use the Sparkfun generic sub micro-size servo since we will use the servos to turn the shutters on the centrifugal fan's output port to direct the air flow.

2.4 Software Flowchart

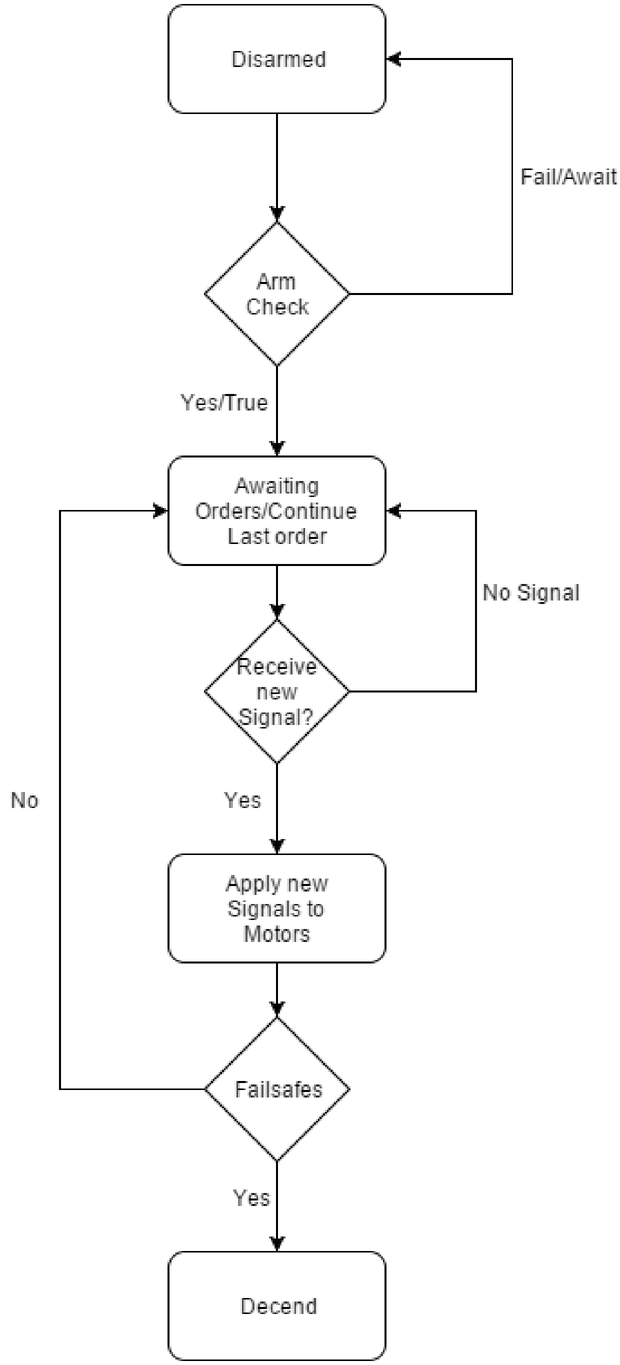

Figure 5: Flowchart for drone

2.5 Custom Hardware

2.5.1 Circuit Schematic

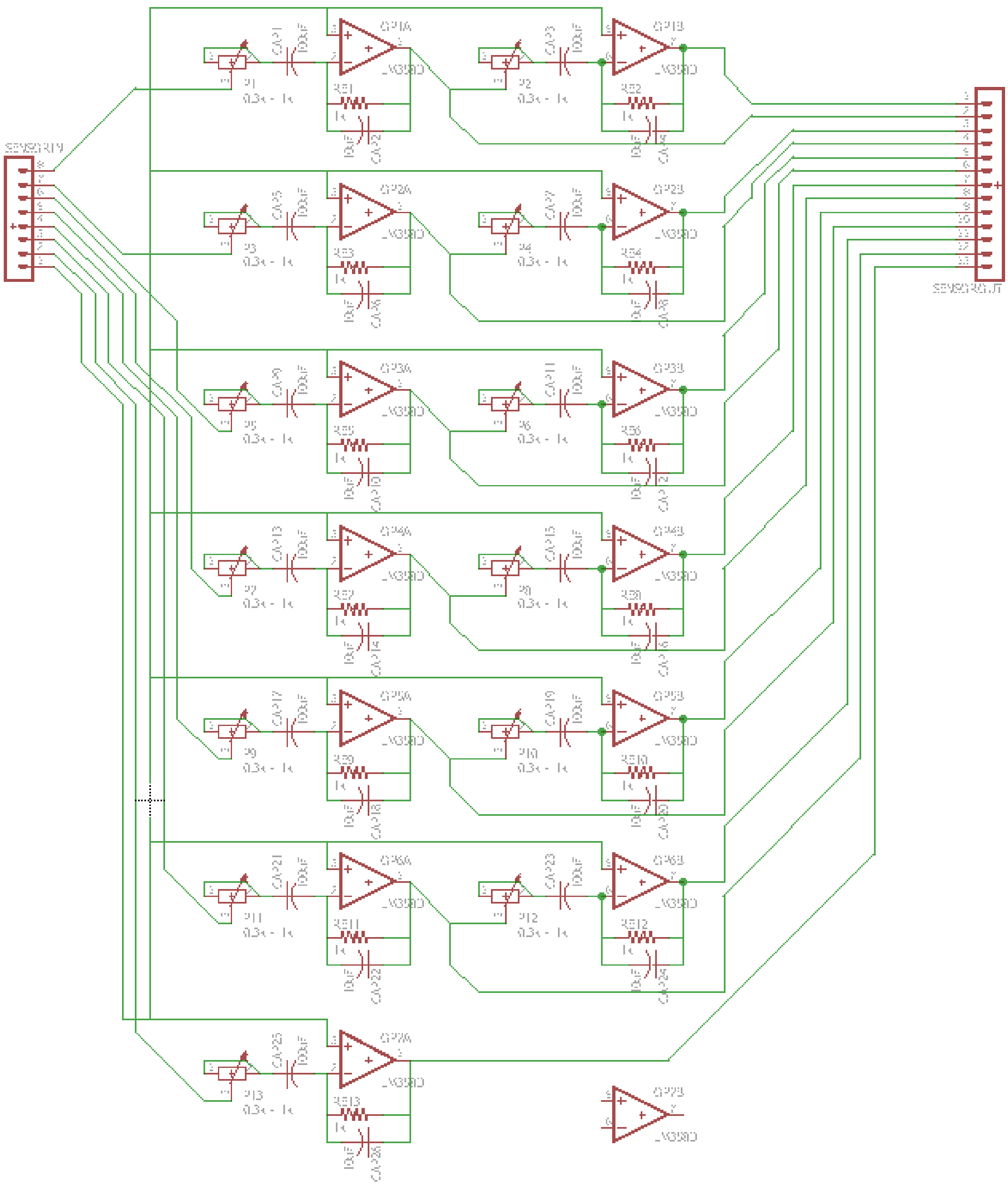

Figure 6: The data conditioner of the PID controller schematic

2.5.2 PCB Design

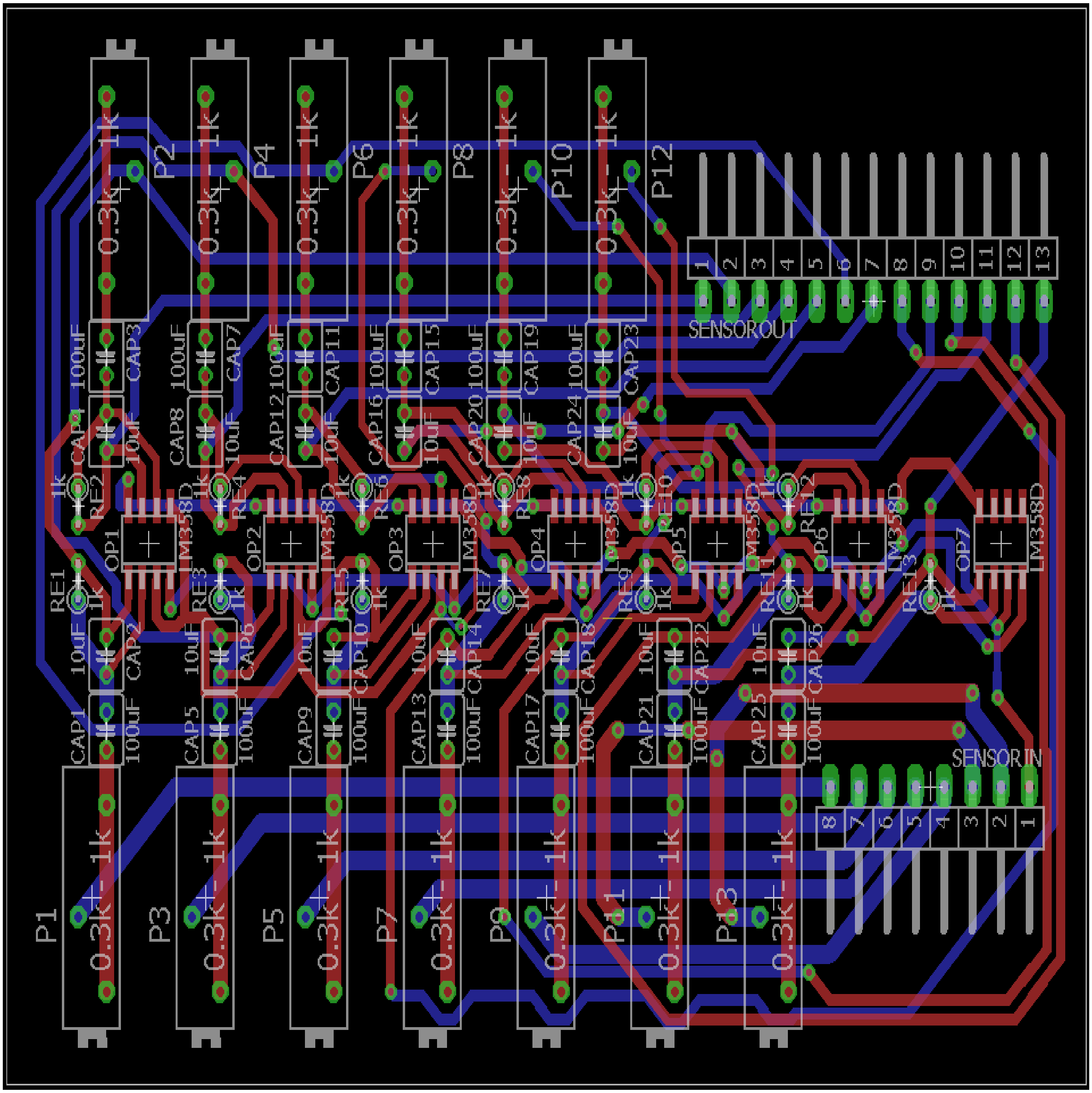

Figure 7: The data conditioner of the PID controller PCB design

2.6 Calculations

Dynamics Calculation:

Specifications:
Drone Mass

$$m_g = 1.25kg \tag{1}$$

Motor's Thrust

$$625gf \tag{2}$$

We have assume the worst conditions possible within the requirement and verification values to give some tolerance to our calculations.

$$1Kgf = 9.8N \tag{3}$$

Top View

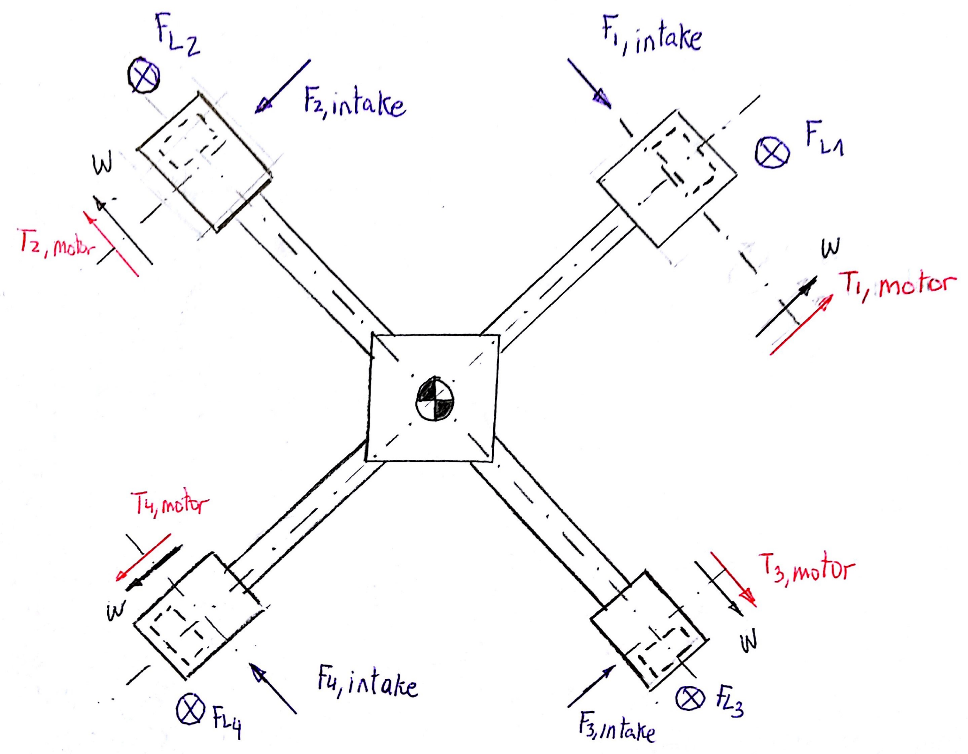

Figure 8: Top view

If ω is fixed then

$$T_{1,motor} = T_{2,motor} = T_{3,motor} = T_{4,motor} \tag{4}$$

$$\overrightarrow{T_{1,motor}} + \overrightarrow{T_{2,motor}} + \overrightarrow{T_{3,motor}} + \overrightarrow{T_{4,motor}} = 0 \tag{5}$$

The direction of F_{intake} will depend on in which side of the fan we put the intake. In this configuration all F_{intake} and T_{intake} are canceled.

$$\overrightarrow{F_{1,intake}} + \overrightarrow{F_{2,intake}} + \overrightarrow{F_{3,intake}} + \overrightarrow{F_{4,intake}} = 0 \tag{6}$$

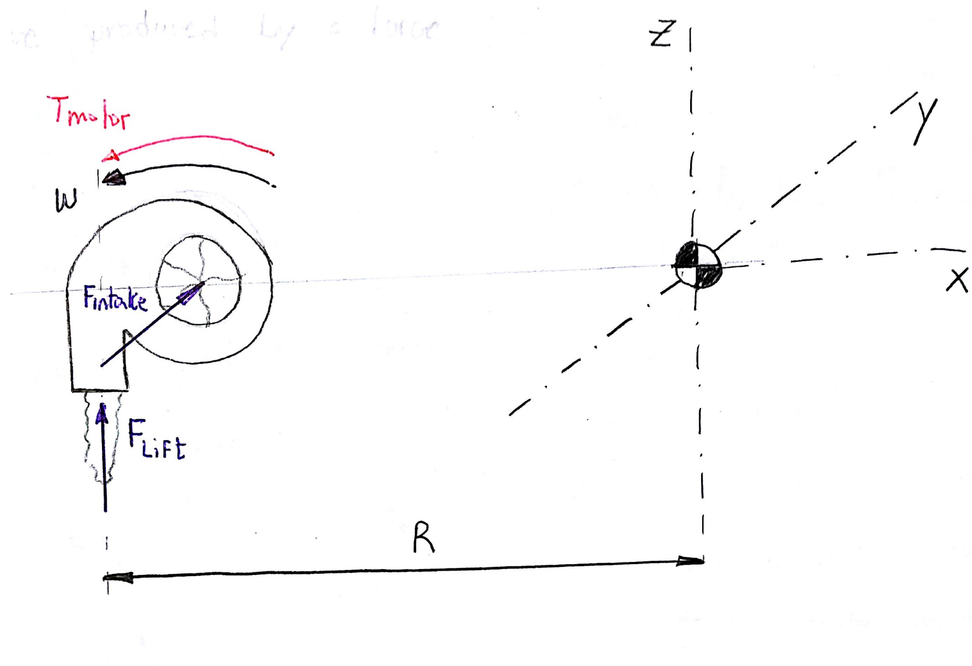

Figure 9: Torque produced by a force

Torques:

$$T_{Lift} = F_{1,lift} R \tag{7}$$

For y:

$$T_{motor} + T_{Lift} = T_y \tag{8}$$

For z (yaw):

$$F_{intake} R = T_z \tag{9}$$

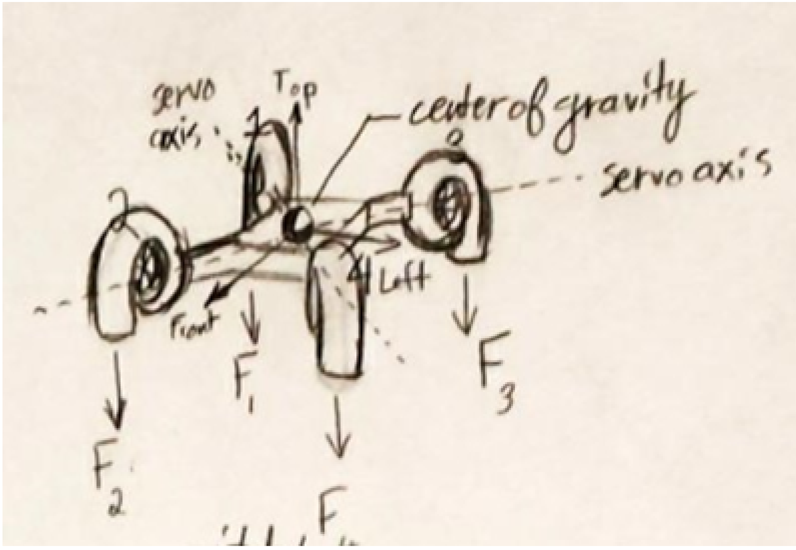

Figure 10: Isometric View: Pitch and Roll

Zero pitch, roll, and yaw: same ω for all motors

(zero roll and pitch)

$$T_1 = T_4 \tag{10}$$

$$T_2 = T_3 \tag{11}$$

In conclusion:

$$T_1 = T_4 = T_2 = T_3 \tag{12}$$

(zero yaw)

$$T_{1,intake} = T_{2,intake} = T_{3,intake} = T_{4,intake} \tag{13}$$

To maintain height:

$$4 * F_{lift} = m_d g$$
$$F_{lift} = \frac{m_d g}{4}$$
$$F_{lift} = \frac{1.25*9.8}{4} = 3.0625 \text{ N} = 0.3125 \text{ Kgf}$$

$$1\text{Kgf} = 9.8 \text{ N}$$

Take off:

$$4 * F_{lift} - m_d g = m_d a$$
$$a = \frac{4*625*9.8 - 1.25*9.8}{1.25} = 9.8 \frac{m}{s^2}$$

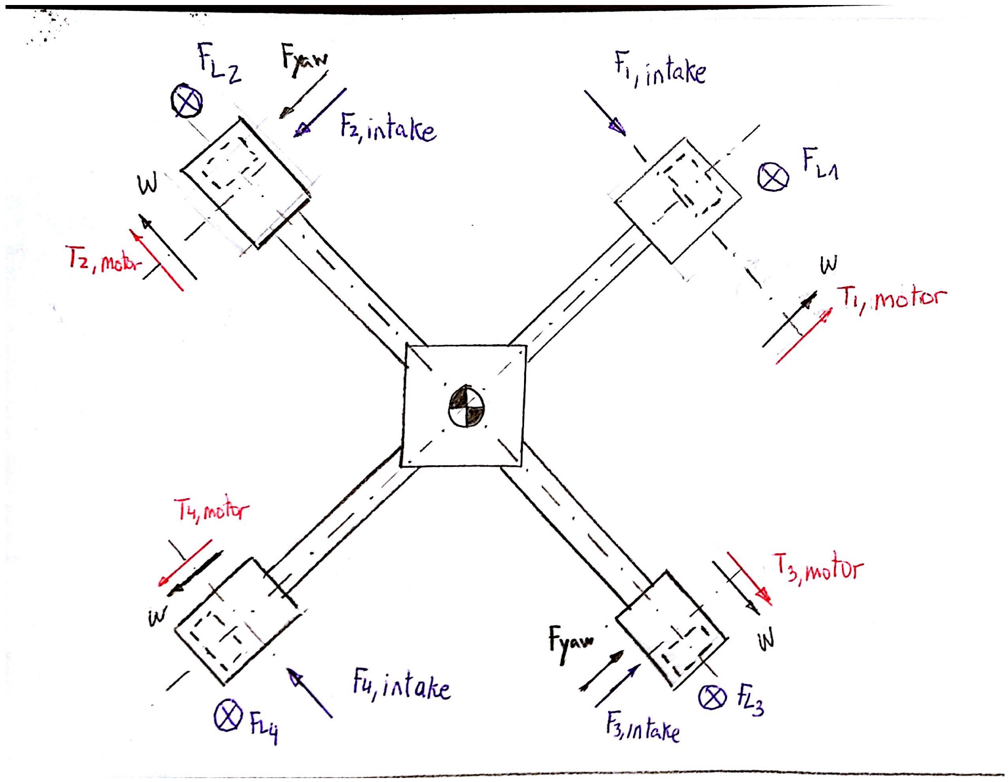

Figure 11: Top View: Yaw

Pitch Forward:

$$T_1 + T_3 > T_2 + T_4 \tag{14}$$

Pitch Rearward:

$$T_1 + T_3 < T_2 + T_4 \tag{15}$$

Roll Left:

$$T_1 + T_2 > T_3 + T_4 \tag{16}$$

Roll Right:

$$T_1 + T_2 < T_3 + T_4 \tag{17}$$

Level: Yaw Right/Left
To get yaw, we will use 2 servos to change the directions of he shutters located at the output port of the centrifugal fan which will change the direction of the airflow. Doing so will create 2 torques to get yaw.

$$F_{yaw} = F sin\theta \tag{18}$$

$$2F_{yaw}R = I\alpha_{yaw} \tag{19}$$

$$F_{lift} = F cos\theta \tag{20}$$

(Where θ is the angle between F and the vertical axis)

To maintain height

$$4F_{lift} = mg \tag{21}$$

Choice of Components:

Motor:

Lets estimate the motor necessary to obtain lift. For this calculation, we need to know the weight of our final design which is not build yet. Lets approx its weight to the higher tolerance specified in the RV table. In the drone mass, we are including all the components like motors, ESCs or the drone frame.

m_{drone} **= 1.25 kg**

T_{motor}**= thrust of the motor**

$$T_{motor} = \frac{m_{drone}}{4} = \frac{1.25}{4} = 312.5g \tag{22}$$

But with this calculation we are just compensating the gravity force so to achieve at least an acceleration like the gravity we have to achieve the double of thrust.

$$T_{motor} = \frac{m_{drone}}{4}2 = \frac{1.25}{4}2 = 625g \tag{23}$$

It will be easy to choose a motor+propeller if we were using an ordinary drone propelled by propellers because the thrust achieved by the ensemble is provided in datasheets. In our case, we will be using the data from the prototype tests where we achieved a maximum thrust of 300g with a 4000kV motor.

Figure 12: motor NTM Rotor Drive 450

Kv(rpm/v)	3400
weight (g)	96
Max Current(A)	46
Resistance(mh)	0
Max Voltage(V)	12
Power(W)	500
Shaft A (mm)	3.5
Length B (mm)	38
Diámetro C (mm)	29
Can Length (mm)	25
Total Length E (mm)	56

Figure 13: motor specifications

Battery: Then we need to choose a battery with a discharge rate that allows run every component at his maximum power.

$$I_{battery} = 4I_{maxmotor}(A) + Components(mA) \approx 4I_{maxmotor}(A) = 184A \tag{24}$$

The battery chosen is a Turnigy Bolt 2200mAh 3S 11.4V 65 130C High Voltage Lipoly Pack (LiHV)

Figure 14: Turnigy Bolt 2200mAh 3S 11.4V

Capacity(mAh)	2200
Configuration(s)	3
Discharge (c)	65
weight (g)	203
Max Charge Rate (C)	2
Lenght-A(mm)	113
Height-B(mm)	36
Width-C(mm)	26
Diameter C (mm)	29
Can Length (mm)	25
Total Length E (mm)	56

Figure 15: battery specifications

Figure 16: battery dimensions

$$Current_{max.discharge} = \frac{2200 * 65}{1000} = 143A \tag{25}$$

$$Current_{max.burst} = \frac{2200130}{1000} = 286A \tag{26}$$

Lets calculate how much time would last the battery at maximum load.

$$t_{bat} = \frac{2200mAh}{143A}\frac{1A}{1000mA} = 9.23min \tag{27}$$

2.7 Plot

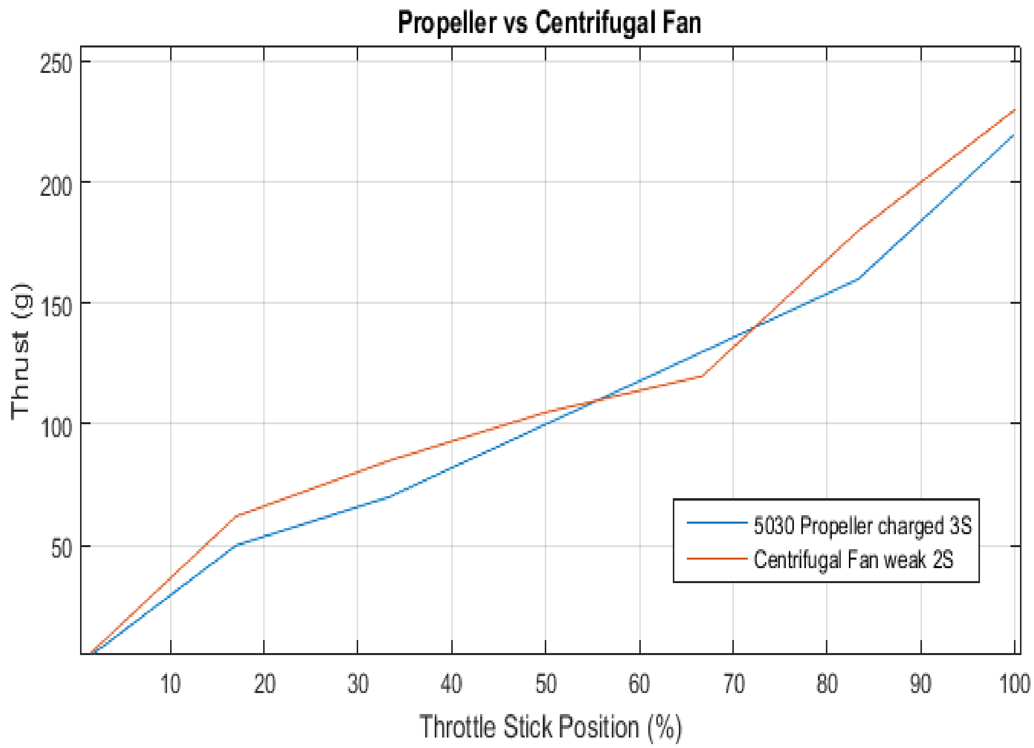

Figure 17: plot for throttle stick vs thrust for the original 5030 propeller

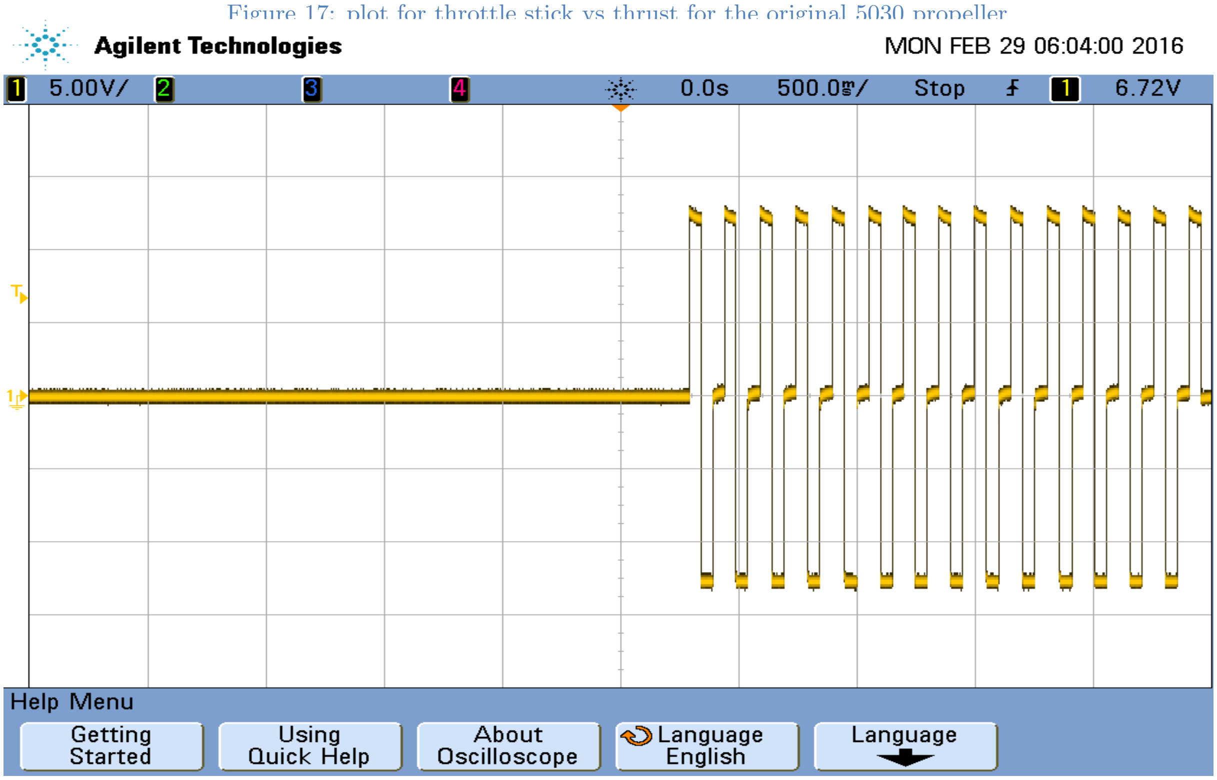

Figure 18: ESC output with throttle

3 Requirements and Verification

Table 1: System Requirements and Verifications

Requirement	Verification	Point Allocation
1. Power Supply (a) Capable of handling 286A burst output* (b) Supply 12.6V ± 0.25V when fully charged (c) Supply 143A± 0.25 A when fully charged	**1. Power Supply** (a) Record amperage and heat telemetry from all outputs when running all systems at 100% with standard current probes. Repeat 10 times and check that heat of system does not rise above 55 degrees Celsius. (b) Measure voltage difference across power source using a Digital multimeter placed in parallel with the power supply. voltage should read 12.6V ± 0.25V (c) Measure current difference across power source and maximum load using a Digital multimeter placed in series with the power source and load that would draw 143A. The current should read 143A ± 0.25A while maintaining the first tests temperature goals.	**15**
2. Transceiver (a) Capable range of 5+/-0.25 miles	**2. Transceiver** (a) Turn on transmitter from a distance of 5 miles and attempt to fly and hover drone. Repeat for 5.25 and 4.75 miles	**5**
3. Microcontroller (a) Capable of receiving 6 signals from the transmitter using a receiver* (b) Capable of outputting PWM signals to the ESC	**3. Microcontroller** (a) Use function $PulseIn()$ from the Arduino library to determine if the microcontroller can read signals from the transmitter using the receiver. (b) Hook up PWM outputs to oscilloscope and test if output signal looks right, and then connect this signal to an ESC/motor to check that it correctly modulates the motors speed.	**5**
Continued on next page		

Table 1 – continued from previous page

Requirement	Verification	Point Allocation
4. Gyro Sensor (a) Consume less than 3.6V ± 0.25V* (b) Consume less than 7mA ± 0.25mA* (c) Ranges ± 500° ± 5°per second (d) Has an accuracy of 5±1°	4. Gyro Sensor (a) Place sensor in series with a test voltage source (Arduino 5V) and use a Digital Multimeter to measure the voltage drop across sensor. It should be less than 3.6V ± 0.25V. (b) Place sensor in in series with a test voltage source and use a Digital Multimeter to measure the current across sensor. It should be less than 7mA ± 0.25mA. (c) Hook up sensor to a microcontroller and spin the assembly on a test rig at 500 degrees per second and see if the microcontroller outputs the correct data ± 5 degrees/second. (d) Hookup sensor to microcontroller and read the output angle and measure the angle using a protractor	10
5. Accelerometer (a) Consume less than 3.6V ± 0.25V* (b) Consume less than 7mA ± 0.25mA* (c) Accurate to 1±$0.1g$ of force	5. Accelerometer (a) Place sensor in series with a test voltage source and use a Digital Multimeter to measure the voltage drop across sensor. It should be less than 3.6V ± 0.25V (b) Place sensor in in series with a test voltage source and use a Digital Multimeter to measure the current across sensor. It should be less than 600 μA ± 25μA. (c) Hook up sensor to a microcontroller and spin the assembly on the test rig to the speed required to simulate 1g of acceleration at the accelerometer ± 0.1 m/s^2	10

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Table 1 – continued from previous page

Requirement	Verification	Point Allocation
6. Actuator (a) It must be able to rotate 160 degrees with a precision of ± 0.05°. (b) It must consume less than 6.0V ± 0.25V	**6. Actuator** (a) Give the servo the signal for its zero degree position, measure with precision angle measurement tool, then feed the servo the signal for its 90° position. Measure position again with the same tool. find the difference in angle and compare with the theoretical 90°. (b) Hook up the servo to a voltage source and use a Digital Multimeter to determine the voltage drop across the servo.	**5**
7. Centrifugal Fans (a) Must generate a thrust of 625g ± 5g in conjunction with its motor running at 100% power. (b) Must weigh less than 100g ± 5g (c) Each of the centrifugal fans must weigh within ± 5 grams of each other	**7. Centrifugal Fan** (a) Attach motors to centrifugal compressors and determine thrust by measuring force (in Newtons) of each individual compressor-motor pair on a stationary force sensor pad with the compressor thrusting itself against the pad. (b) Weigh module on a scale to determine mass meets requirements (c) Compare mass measurements between each module	**15**
8. Electronic Speed Controller (a) Capable of driving a motor with at least 46± 2.5A (b) Must consume less than 0.5V ± 0.1V	**8. Electronic Speed Controller** (a) Attach motor with a draw current of 46 Amps and spin up motor for at least 10 minutes without stalling or rising above 93C. (b) Place ESC with one of the selected motors connected in series with test voltage source and use a Digital Multimeter to measure the voltage drop across ESC as it runs the motor at full power. It must be less than 0.5 V ±0.1 V	**15**

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Table 1 – continued from previous page

Requirement	Verification	Point Allocation
9. Motors **(a) Capable of providing 625g of lift overall in junction with centrifugal fan** **(b) Must draw less than 46A ± 2.5A**	**9. Motors** **(a) Attach motors to centrifugal compressors and determine thrust by measuring force (in Newtons) of each individual compressor-motor pair on a stationary force sensor pad with the compressor thrusting itself against the pad.** **(b) Place Motor in series with a test voltage source and measure the current across the motor. It must be less than 46A ± 2.5A**	**15**
10. Chassis Frame **(a) Capable of withstanding a fall of 1m ± 0.1m** **(b) Must weigh less than 1kg ±0.25kg**	**10. Chassis Frame** **(a) Drop drone from 1.1m and repeat at 0.9m** **(b) Weigh drone on a scale. It must weigh less than 1kg±0.25kg**	**5**
Total		**100**

*1.a The battery must handle 286A transiently. When you turn a motor on, it draws between 3 to 5 times its nominal current until it achieve steady state.

*3.a The six signal corresponds to the six commands that you have in our transceiver.

*4-5.a,b Circuit to check gyro+accelerometer specifications

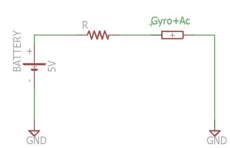

Figure 19: circuit to test gyro voltage drop

$$7mA = \frac{1.4}{R} --> R = 0.2k\Omega \tag{28}$$

4 Tolerance Analysis

4.1 Centrifugal Fan Performance Tolerances

For this project, the one engineering sub-system that most affects the performance of the project is a piece of the propulsion module. The unique method of propulsion sets this project apart from the other projects and is therefore a key component. For the success of this sub-system, the combination of the centrifugal fans must be able to produce double the weight of the drone. This means that each individual centrifugal fan must be able to produce 500g max thrust when supplied with 12.6+/-0.25V. The thrust total of double the weight or 2kg is important for the purposes of providing upward lift, and as an operating safety margin in the case of reduced power. The method to test this tolerance is to have a voltage supply at 12.85V and connect it to our centrifugal fan module. Using the thrust measuring apparatus, we can able to measure the thrust from the centrifugal fan module supplied with this voltage. Repeating the measurement with the voltage source reduced to 12.35V. If the output of each fan at all tests measures at least 500g of thrust, we can verify that the sub-system is meets the tolerances.

4.2 Electronic Speed Controller Tolerances

The Electronic speed controller as this is the component that determines the RPM of the motor that is spinning the centrifugal fan. This means that the ESC must be able to handle at least 50+/-2.5A. If the ESC cannot handle the current draw of the motors, the electronics are very likely to overheat causing a loss of power best and at worst, cause a fire. To test this, we will connect the ESC to a motor which draws 52.5A and monitor the ESC for failure or overheat over 10 minutes. Then we will repeat the test with 49.5A and confirm if the device operates as intended. If it passes both tests, we can conclude that the crucial subsystem is up to tolerance.

5 Cost Analysis

5.1 Parts

Table 2: Parts Costs

Part	**Manufacturer**	**Model**	**Quantity**	**Cost/unit ($)**
Brushless Motor	NTM	NTM Prop Drive 450	4	30
Battery	Turnigy	Bolt 3S	1	30
Microcontroller	Arudino	Due	1	45
Gyro + Accelerometer	Adafruit	Breakout Board	1	25
Transceiver	Spektrum	Dx6i/AR600	1	120
Actuator	Sparkfun	Generic Sub-micro	2	10
ESC	Hobby King	Hobby King 50A ESC	4	20
Chassis Frame	Hobby King	Color	1	15
PID Controller	-	-	1	25
Total				$ 480

6 Schedule

Table 3: Schedule

Week	Task	Responsibility
9-Feb	1. Finalize Proposal 2. Study dynamics of drone 3. Prepare mock design review	1. Leo and Bree 2. Bree and Ignacio 3. Everybody
15-Feb	1. CAD Centrifugal fan 2. Design ESC 3. Prepare design review	1. Ignacio and Leo 2. Bree 3. Everybody
22-Feb	1. Purchase microcontroller 2. Purchase sensors and test 3. Purchases motors and test 4. Purchase centrifugal fan materials and prototype 5. Finalize Design Review	1. Leo 2. Bree 3. Ignacio 4. Leo 5. Everybody
29-Feb	1. Assemble Control Mechanism 2. Reiterate centrifugal design 3. Assembly prototype propulsion mechanism 4. Assemble acutuation and Chassis	1. Leo 2. Leo 3. Ignacio 4. Bree
7-Mar	1. Prepare mock demo 2. Finalize PCB Design 3. Run more tests on control 4. polish centrifugal fan design	1. Ignacio 2. Bree 3. Leo 4. Leo
14-Mar	1. Finalize mock demo 2. Polish drone design 3. Run final test on drone capability 4. Prepare individual progress report	1. Everybody 2. Bree and Ignacio 3. Leo 4. Everybody
4-Apr	1. Fix any remaining issues 2. Prepare presentation 3. Prepare demonstration	1. Leo 2. Bree 3. Ignacio

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Table 3 – continued from previous page

Week	Task	Responsibility
11-Apr	1. Prepare Final paper 2. Finalize presentation 3. Finalize demonstration	1. Everybody 2. Bree 3. Ignacio
2-May	1. Finalize Final paper 2. Lab checkout	1. Everybody 2. Leo

7 Ethical / Legal Considerations

7.1 IEEE Code of Ethics Considerations

Since this drone will be airborne, this will involve the first code of the IEEE Code of Ethics where we must consider the decisions that we make which will involve the safety, health, and welfare of the public [2]. This is because even if the drone is safer than those that uses propellers, it may still fall from the sky and cause injury or property damage, cause injury or property damage from flight motions, catch fire if overheated, or catch fire if the battery is punctured. This is a concern that regarding the clause 9 in the IEEE code of ethics to avoid injuring others, their property, reputation, or employment by false or malicious action. Because since the drone will be capable of carrying and delivering a payload, we must deter its usage for malicious intent through its specifications.

7.2 Legal Obligations

A legal consideration that we must consider is the FAA regulations on Model Aircraft Operations. The FAA recently released the guidelines on flying for hobby or recreation, which restricts recreational model flight to below 400 feet, away from other people or stadiums, et cetera. The regulation that most applies to this drone states that one may not fly within 5 miles of an airport without clearance from the airport and control tower before flying [3]. This applies to our drone because the University of Illinois at Urbana-Champaign is within the 5-mile radius of the University of Illinois Urbana-Champaign Willard Airport. This means that before any testing is being done on the drone, we must contact the control tower at the Willard Airport for clearance. In addition, the University of Illinois has also placed regulations and restrictions on drone use on campus. Another legal issue that concerns our project is the registration of our drone. FAA has made it mandatory for anyone who has a unmanned aircraft that is heavier than 250g but lighter than 25kg to register their drone on their website to fly outdoors[9]. Our drone will weigh close to 1kg which falls into this category.

However, to be able to test the system without having to go out to an airfield every time, we will have the test apparatus as shown below.By doing this, the project will not be technically a drone and should be safe enough to be tested from yaw, pitch, roll, stability even indoors.

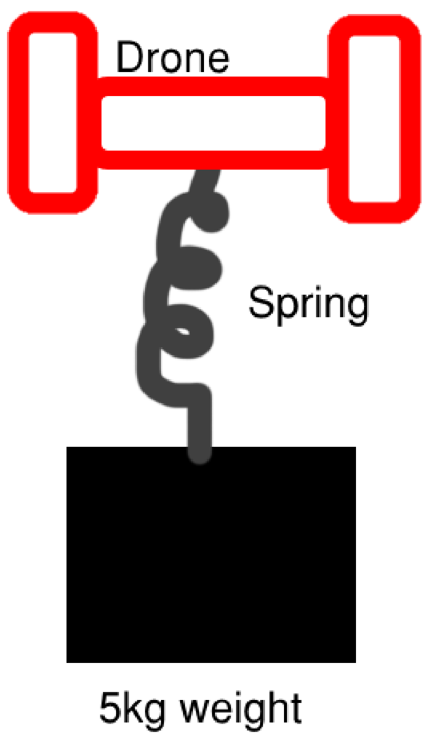

Figure 20: Testing apparatus for on-campus testing

7.3 Safety Statement

In this project, there are many safety considerations that must be taken into mind. This is because the project is a drone which upon completion will be flying. Not only that,during the build phase, there are many step that pertains safety concerns. The fact that the project is a drone is one safety concern that we have to address according to the first and second IEEE code of ethics. The first statement is to to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.[1] This is a factor we need to consider because even though our drone will be safer than a drone that uses propellers, the drone could still damage people or property when it falls from a height. Also the drone will be powered by a Lithium-Polymer (Li-Po) battery which by itself is a safety concern. This is because a Li-Po has many factors that could cause it to explode releasing harmful chemicals. Some events that could cause the battery to explode include but is not limited to charging using an incorrect battery charger, shorting wires, puncturing cells, and overcharging[4]. The second statement in the IEEE code of ethics needs to be considered because as we are flying a motorized object within 5-miles of an airport, we must let the airport control tower know that we will be flying a drone[3].

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