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Spring 2018

Budget Quadcopter Kit

Connor Bailey
cab216@zips.uakron.edu

Taylor Stephens
tjs32@zips.uakron.edu

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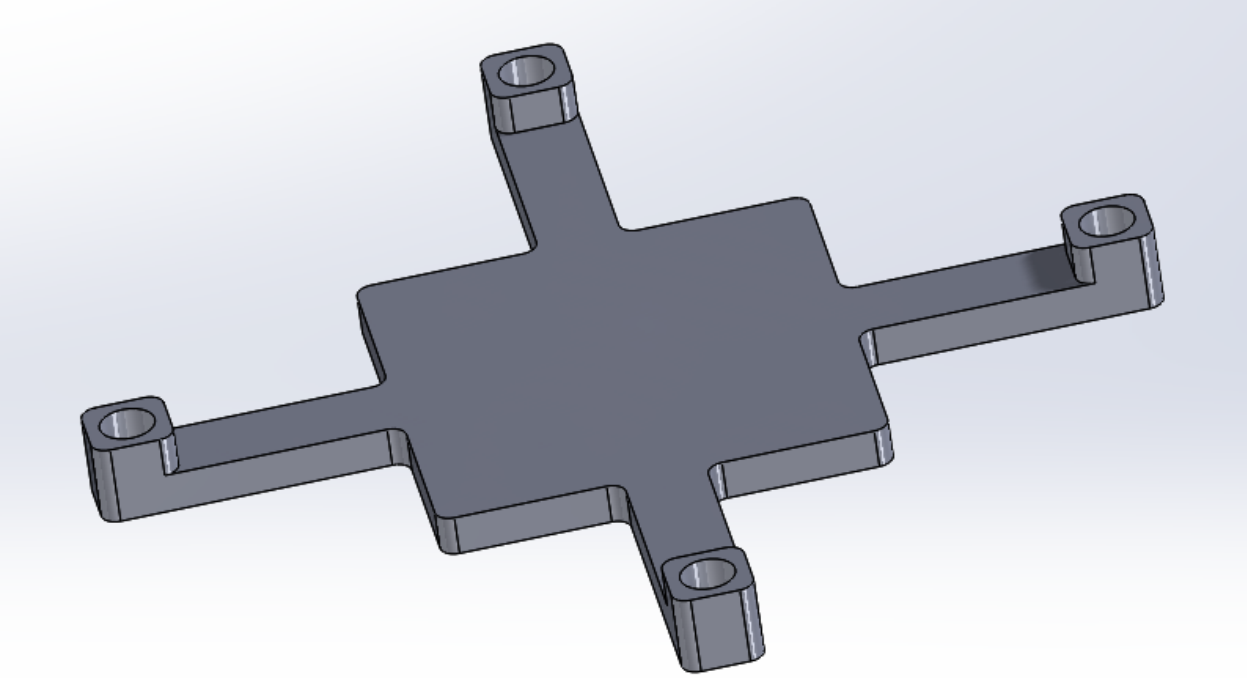
2018



Senior Design Report

BUDGET QUADCOPTER KIT

CONNOR BAILEY & TAYLOR STEPHENS

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Introduction

Over the past few years quadcopters, also known as drones, have really started to take off in a recreational market. The technology has come a long way over the past decade and as with most technology, as it has matured it has become cheaper and more accessible to everyday people. So much so that anyone can go online and purchase a small quadcopter for under $20. They are relatively easy to fly and can even be flown indoors due to how safe they are as well. However, buying a quadcopter online doesn't really allow the consumer to develop a true understanding of how quadcopters are build and how they function. It is possible to purchase a kit online in order to build a quadcopter and develop that better understanding but these kits can be more expensive than the average consumer would like to spend. It is also possible to build a quadcopter from different parts purchased online but this can also get expensive as well as incredibly confusing. The goal of this project was to solve those issues, and make the quadcopter building experience both simple and affordable for a consumer who may want to learn more about quadcopters and have a quadcopter of their own.

Background

A quadcopter is very similar to a helicopter in that it flies via rotary blades and motors. However, a quadcopter has four motors as opposed to the one helicopters have, hence the prefix, quad. In order to fly the quadcopter with accuracy, two of the motors rotate clockwise while two of them rotate counterclockwise (Figure 1). This is how the copter

prevents from spinning as the motors counteract each other's torque.

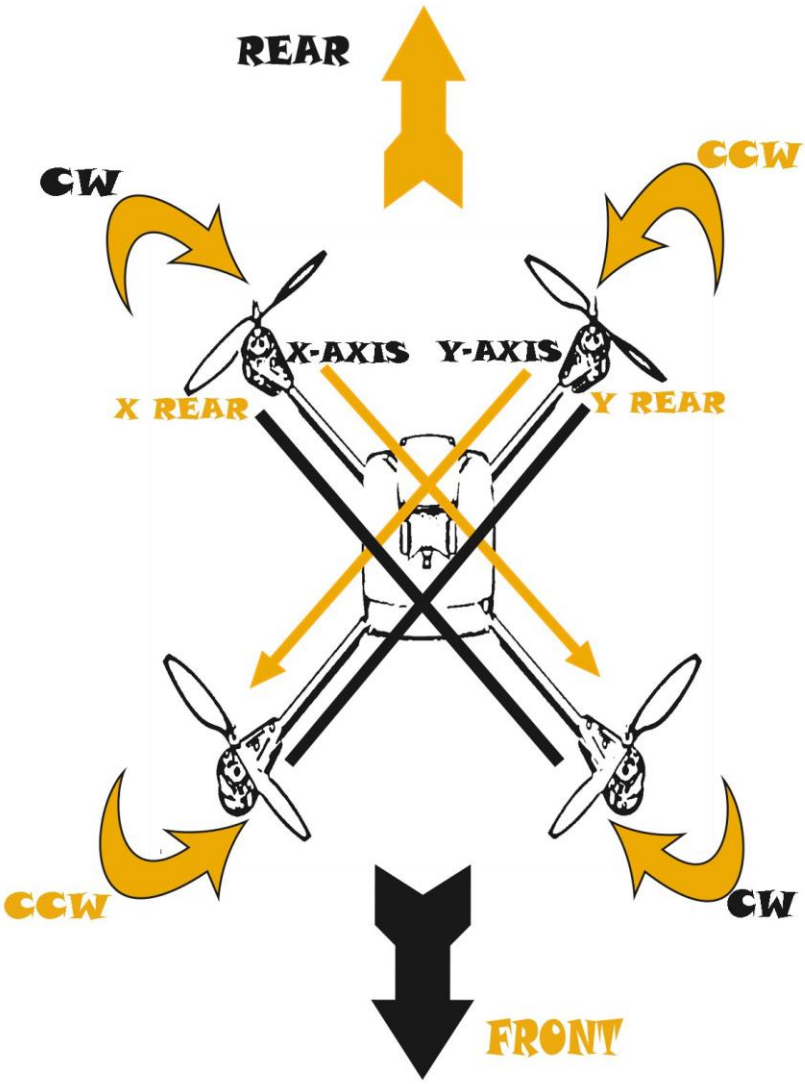

Figure 1: Quadcopter Configuration

If all motors are rotating at the same speed and enough lift is generated to counteract the copters weight it can hover in place. To gain altitude all motors must increase speed and conversely to lose altitude all motors must decrease speed. In order to maneuver

the motor speeds would have to change speed variably depending on the desired maneuver.

System Design

The system to be designed includes the items listed in the appendix. The goal of the system is to all fit on the required parts on the custom designed and 3D printed body. The 3.7 V battery would feed into the powerboost in order to supply a constant voltage of 5 V. The powerboost would then be connected to the central computer which would be coded to disperse the power to four brushed motors. These four motors would be interfaced with the propellers causing them to spin then lift the quadcopter. This would all be controlled by a controller app from a smartphone which is coded to disperse variable power to the motors for maneuverability (Figure 2).

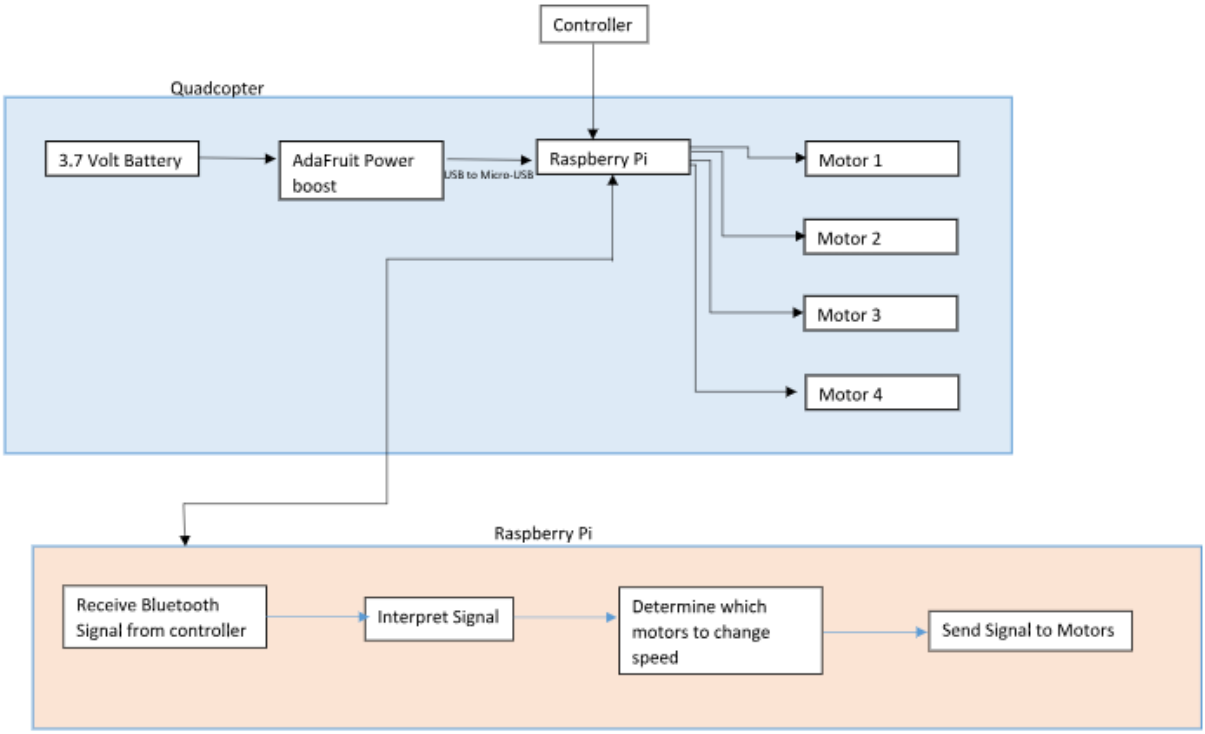

Figure 2 - The Control System Design

The Design Process

Quadcopter Body:

In order to keep costs down it was decided that the body of the quadcopter should be 3D printed. While 3D printers themselves are expensive, if the consumer has access to one in some capacity, 3D printing the body of the quadcopter would be very cheap, as it would be fairly small and printing material is inexpensive. That being said, requiring the body to be 3D printed sets a limit on just how big the quadcopter can be, while the printer available for this project had a print volume of 8”x8”x8”.

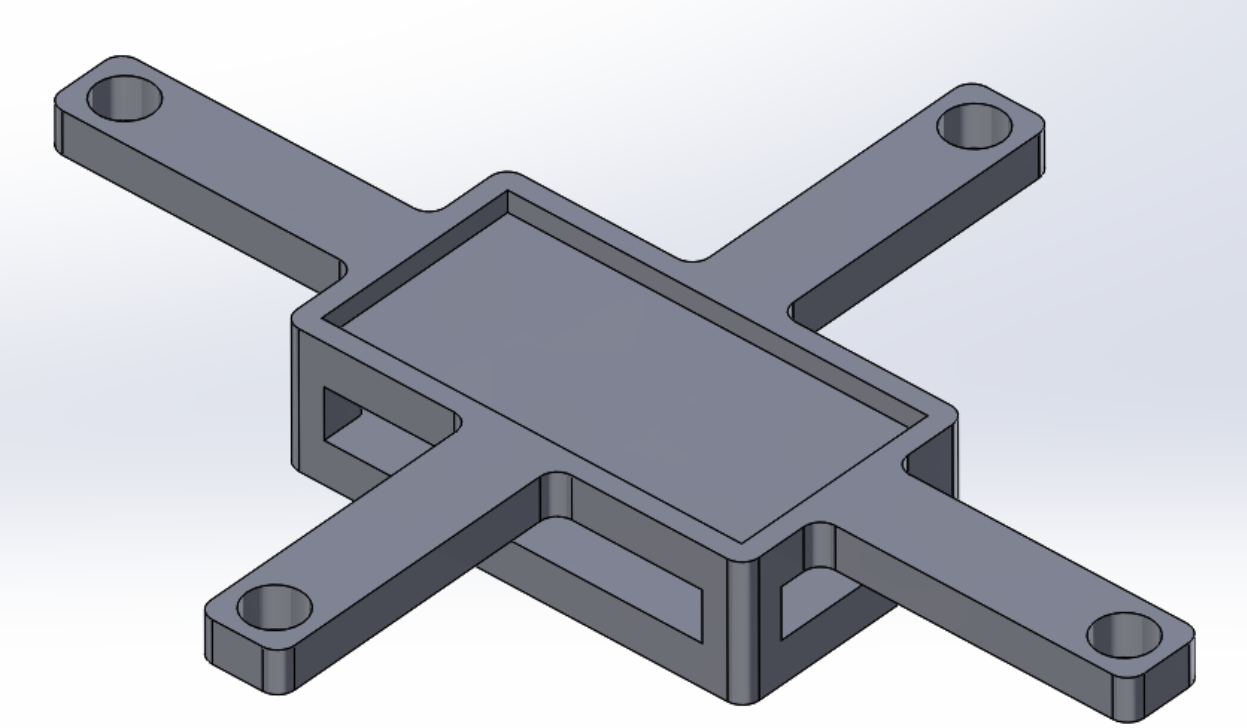

Figure 3: Iteration 1

The first iteration of the design (Figure 33) incorporated a two level asymmetric design. It was determined that a raspberry pi would be controlling the machine so the center platform of the quadcopter would have to be large enough to hold it. A lower shelf was

also included in the center of the design as a place to safely store the battery that would power the machine. The length of the arms were determined by the propellers so that they would not collide during operation. This design was printed but the print failed due to a bad connection in the printer's hot bed causing the design to move off center and stop the print. While the print failed, a valuable lesson was still learned, it was determined that the supports differentiating the two layers of the design were not sturdy enough as they broke off while attempting to remove the support material from the print (Figure 44). It was also determined that there was no good way to remove the support material generated in the indent designed to house the raspberry pi so that was another thing that would need changed in rev two.

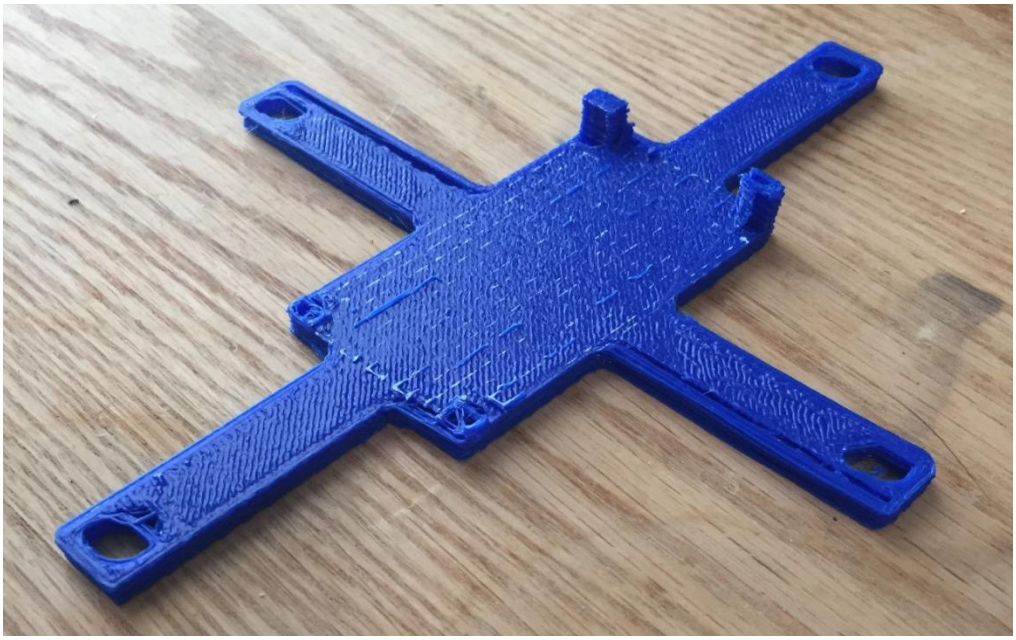

Figure 4: Iteration 2 Printed

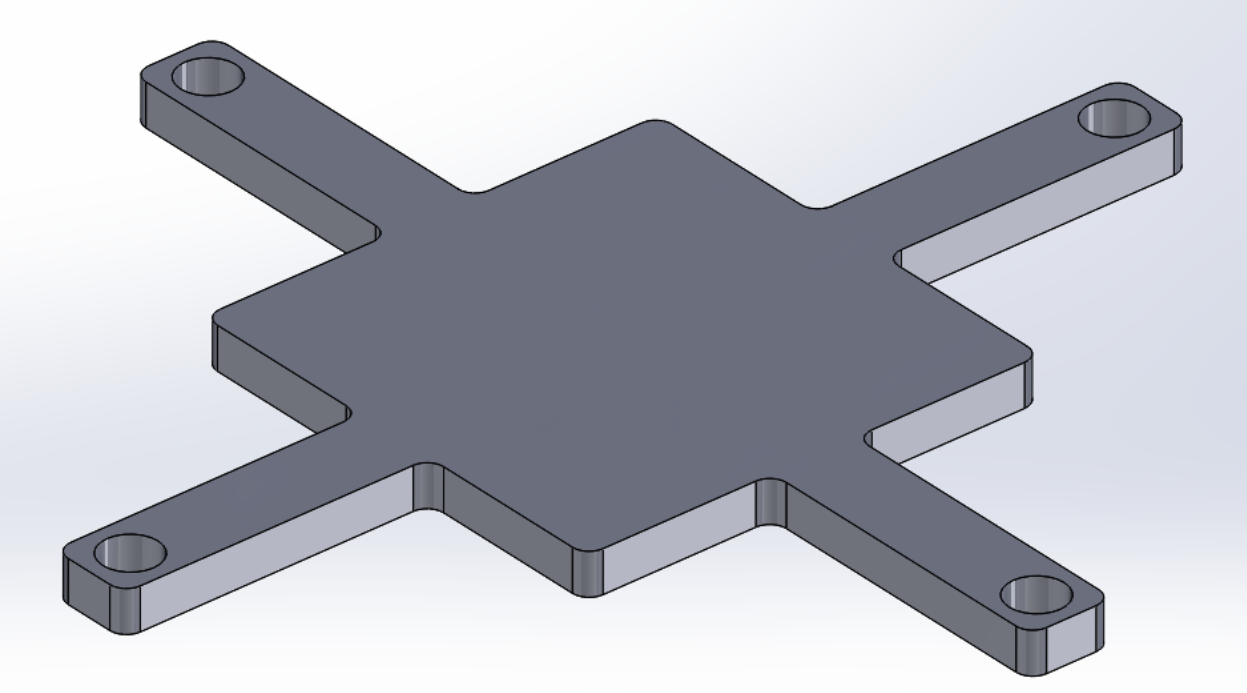

Figure 5: Iteration 2 CAD Model

The second iteration of the design process (Figure 55) was meant to fix the aforementioned issues with the first design, as well as something that was never previously a concern until more research was conducted. The second iteration of the body of the quadcopter was a one level symmetric design. This one level design was introduced because it would greatly increase the ease of the print and eliminate any need for the printer to generate support material. This design was also made symmetric because otherwise the thrust generated by the motors at the end of each arm would not be equal, preventing the quadcopter from flying. This design was not printed for this project as the hot bed issue on the printer had not been fixed and the ordered motors were not yet delivered in order to confirm width.

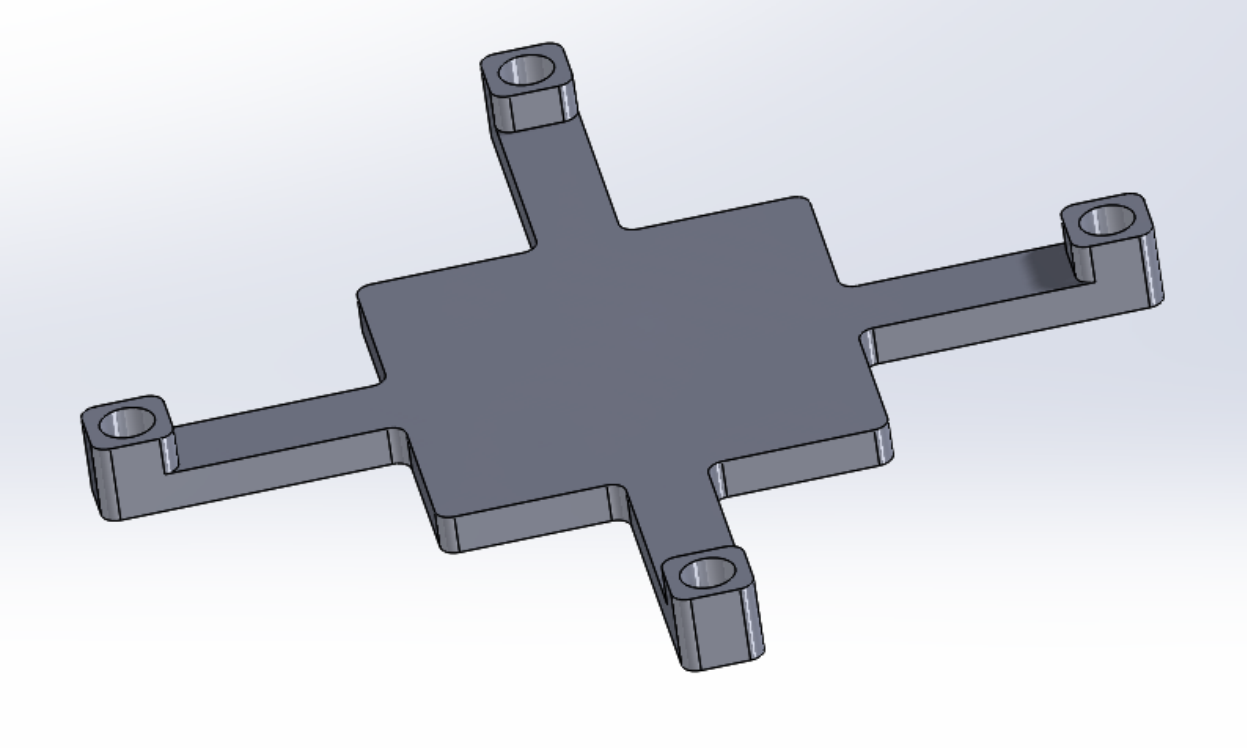

Figure 6: Iteration 3 CAD Model

The third iteration of the design (Figure 66) is very similar to the second but included one small modification in order to increase design robustness. This third design included raised areas around the motor holes to account for the total length of the motor and better hold them vertical once the quad copter is assembled. This design was printed without any issues and was the first printed body available for this project (Figure 77).

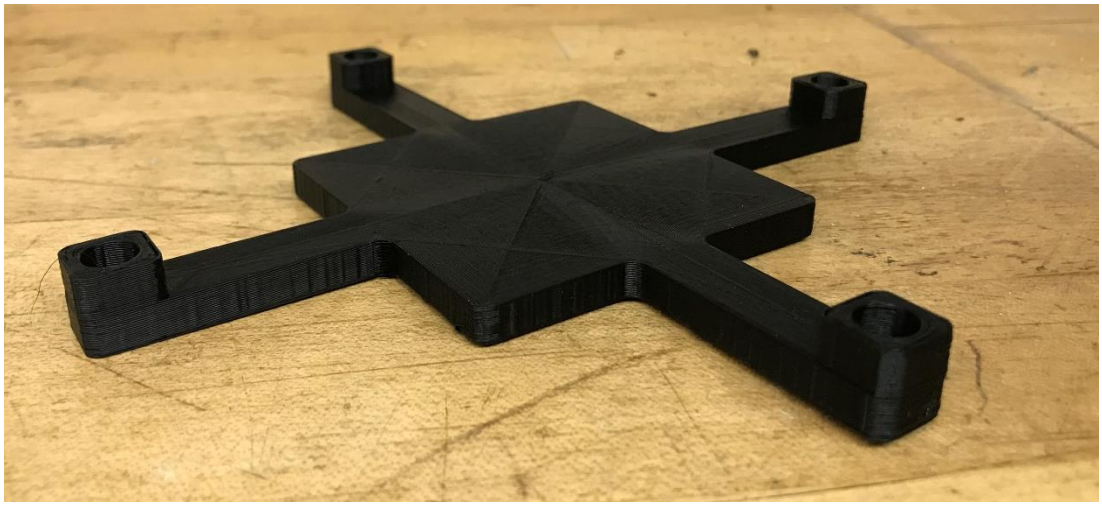

Figure 7: Iteration 3 3D Print

Power Plants:

One of the first questions when designing and building a quadcopter is brushed or brushless motors. Brushed motors have a simplified wiring system and can be controlled by a simple switch which makes them lower cost. However, they are slightly less efficient than brushed motors. Brushless motors are slightly more complicated and require an encoder to function properly. Therefore, for the sake of cost, brushed motors were selected for this project. This was a significantly cheaper option because not only are the motors themselves cheaper, but encoders are also unnecessary. A relatively cheap set of brushed motors with propellers was found on amazon.com that was thought to be perfect for this project (Figure 88).

Figure 8: Motors and Propellers

The generated thrust of these motors would later have to be tested as it was extremely difficult to find accurate propeller specs in order to calculate thrust.

Control System

A very basic computer would be able to control this quadcopter which is why the Raspberry Pie Zero W was chosen for this project. It is very small, cheap and has Wi-Fi and Bluetooth capabilities (Figure 99).

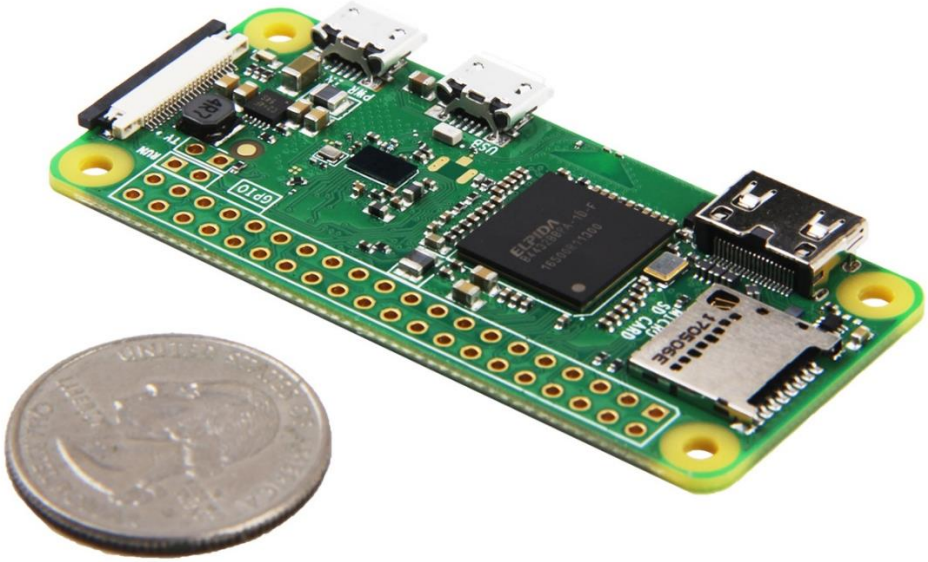

Figure 9: Raspberry Pi Zero W

Generally Raspberry Pi's are powered by being plugged into some sort of power outlet but that is not possible for a quadcopter application as it has to move freely in space. So, lithium-ion polymer (LiPo) batteries were chosen to power the pi instead. LiPo batteries are cheap and relatively lightweight which makes them perfect for this application. The batteries' power also had to line up with that of the motors to insure they would receive sufficient power without burning them up. Therefore, a set of 3.7V, 350 mAh batteries were purchased for the copter (Figure 1010).

Figure 10: Lithium-Ion Polymer Batteries

It was quickly determined that these batteries would not be able to provide the consistent five volts of current that the pi required to function and something had to be done. In order to have one battery be able to power the copter a DC/DC boost converter was required. Adafruit is a company that specializes in such converters which take a battery that has a voltage of 1.8 volts or higher and coverts it to a constant 5.2V DC for running any 5V project like this one. The selected boost converter was the PowerBoost 500 Basic (Figure 111).

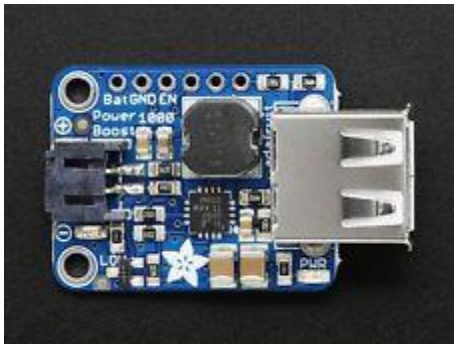

Figure 11: PowerBoost 500 Basic

In order to communicate with the quadcopter, a third party app was purchased. The app sent a Bluetooth signal to the raspberry pi where it could be interpreted and turned into something that the PI could interpret and tell the copter what to do. The signal would then tell the motors to spin faster or slower. For more advanced projects, a gyroscope could be put on the drone, turning the control system into a feedback loop. An input to the pi would be given to go in some direction and the gyroscope would give a constant signal telling how much more the quadcopter has to react before it reaches the desired input. Both versions of the control system are shown below.

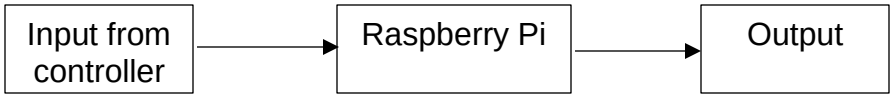

Figure 12: Basic Quadcopter Control System

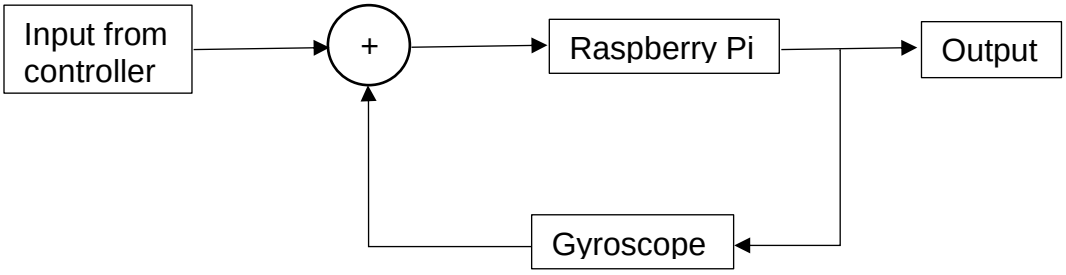

Figure 13: Advanced Quadcopter Control System

Testing

The first thing that needed to be tested for this project was the thrust of the motors that were purchased. In order commence this testing some sort of rig needed to be created to allow the thrust to be tested on a simple scale.

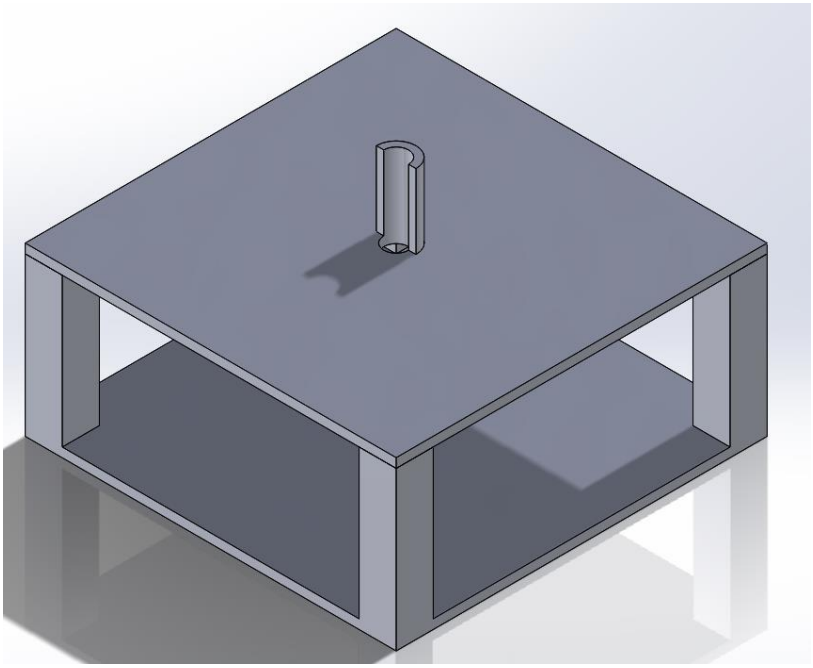

Figure 14: Thrust Test Rig

A rig was designed in SolidWorks that would allow the motor to be tested in a downward configuration pushing into the scale to get an accurate thrust reading (Figure 144). This rig consisted of a baseplate with supports for a test platform with a hole in it the size of the motor. The platform also features an extruded half circle so that the motor could be fastened in securely with rubber bands or tape. This rig was to be 3D printed on an Anet A8 3D printer purchased earlier in the year for recreational purposes. This is where the project ran into a few snags. The heated bed of the printer meant to keep the print itself adhered to the printer was experiencing connectivity issues causing the print to go horribly awry (Figure 155).

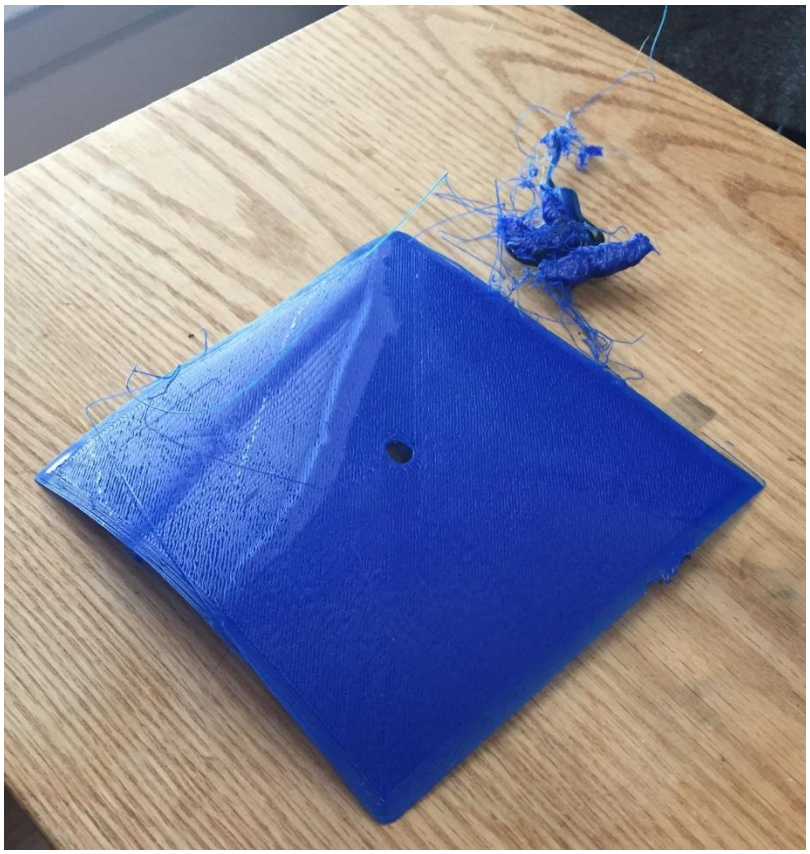

Figure 15: Thrust Test Rig Failed Print

The print started successfully with the heated bed staying on for the first few layers of the print while the base stayed in one place, but eventually the bed became disconnected causing the test rig to slide off the printer altogether ultimately ruining the print. This was a significant setback for this project as other 3D printers available had long queue times and the turnaround time for a print was multiple weeks. While an inquiry was made this delayed testing and the project as a whole significantly.

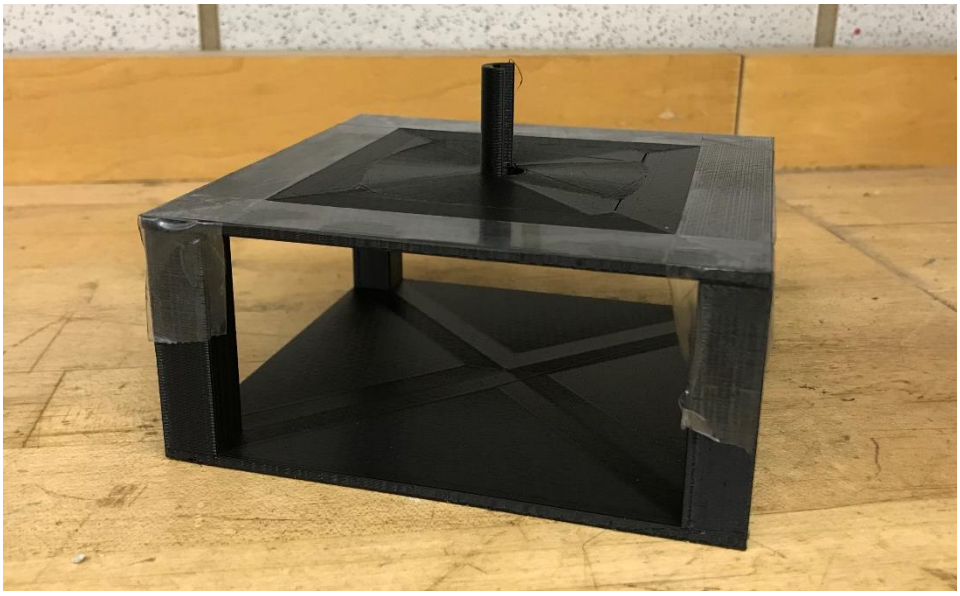

Figure 16: Thrust Rig Successful Print

Eventually the test rig was printed and ready for testing (Figure 166) but by this point there was not enough time to make any significant design changes if something were to not work as expected.

Thrust testing was now able to start and was set up using the printed test rig, one of the purchased motors and propellers, the raspberry pi, and some various wiring (Figure 17).

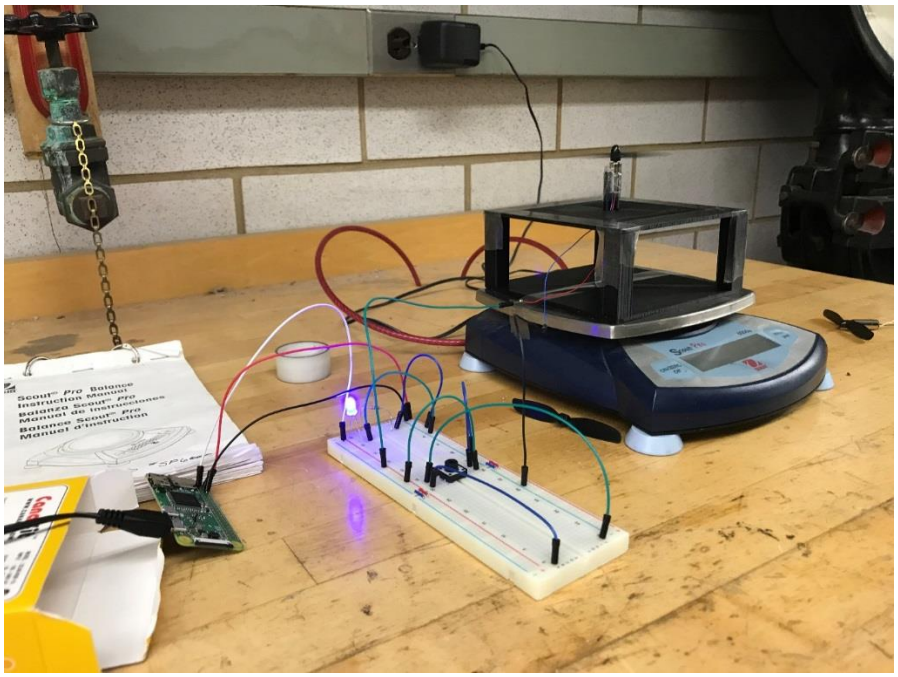

Figure 17: Thrust Testing

In Figure 177 it is clear that the motor is actually in an upward position rather than a downwards one as previously mentioned. The hole for the motor was slightly too small and a file or sand paper was not available at the time to increase the size of the hole so a change had to be made and the thrust was tested the other way. This is when the hidden glaring issue with this project was realized. The previously selected motors and propellers were unable to generate enough thrust for the quadcopter to properly function with all of the hardware required (Figure 188**)**.

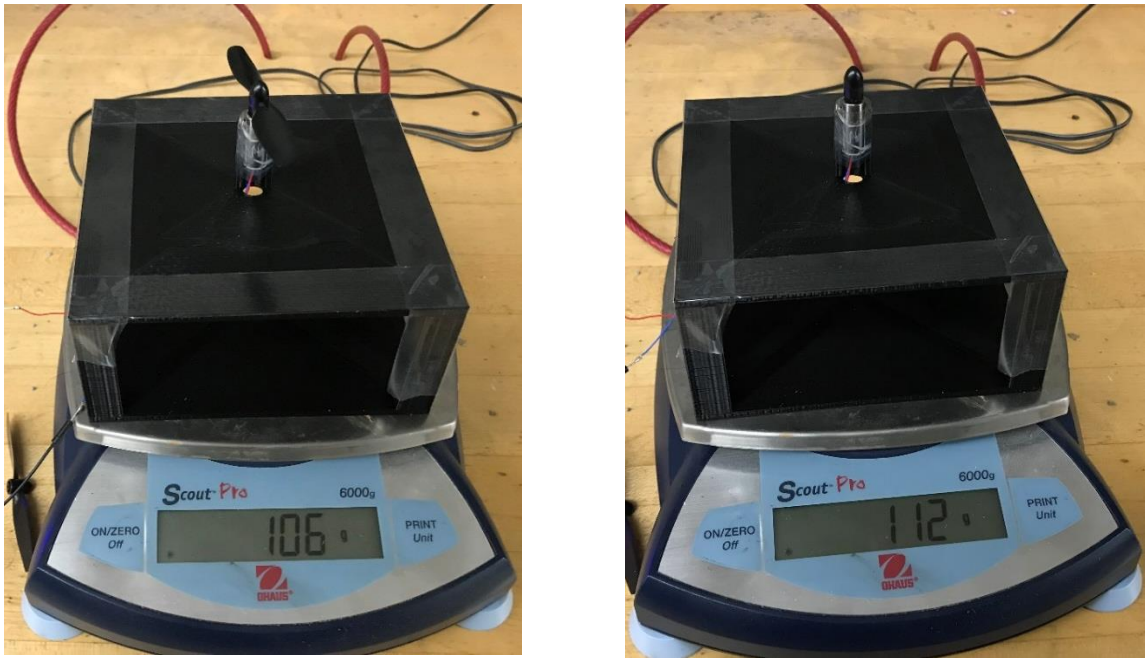

Figure 18: Thrust Testing Results

The motor generated approximately six grams of thrust which when multiplied by four would not be enough to have the quadcopter operational.

Lessons Learned

There were many lessons to be learned in this project, especially from the perspective of a systems engineer. The first issue that led to the quadcopter's downfall was the lack of clearly stated requirements. When the project originated it was clear that the purpose was to create an easily accessible build your own quadcopter for a reasonable price. However, no values were set to these goals and that made success hard to measure. The idea of a camera being mounted to the copter was also brought up but never clearly stated as a requirement which made size and required thrust of the device to be too ambiguous.

The project was also improperly planned, no Gantt chart or any form of scheduling was created so it was impossible to know if the project was on track at any given point. This is a failure from a systems perspective as a schedule needs to be defined at the beginning of a project to insure integrity throughout the process.

This project is a perfect example of how the Aerospace Systems Engineer should be used. In order for a project to be successful, the requirements must be laid out before the project is started. Some examples of these requirements would be;

System Requirements

1. The assembled drone shall weigh less than 200 grams.
2. The total thrust produced by the system should be 50 grams more than the total weight.
3. The system will use a Raspberry Pi as the flight controller
    a. The Raspberry Pi will use Python coding language to interpret commands
4. Four (4) brushed motors and propellers shall be used as the propulsion system for the drone
5. Each propeller shall be equal or less than 1.5 inches in diameter
6. The system shall be less than 8”x8”x8”, which is the maximum 3D printable space.

Requirements like these would have allowed us to define the scope of the project with more accuracy. Another tool that we should have used was a Gantt chart, or a

schedule. The scheduled would have defined dates that we would have to complete things.

Conclusion

The value of the systems engineer is to define the system well enough so that the technical engineers know exactly what to do when they build the subsystems. During this project, the lack of systems engineering caused us to fall behind on our project plans and eventually not complete the project. Using the systems engineering approach would have allowed us to, in theory, not only complete the project but to do it in a timely matter. In the future, because of this project, there will be a higher respect for what the systems engineer does, and how valuable to the team that they are during all engineering projects.

Appendix

	Item	Cost	Purpose
1	3.7 V 350 mA LiPo Batteries	10.99	Power option 1
2	Spare Propellers	10.95	Propeller Option 2
3	3.7 V 400 mA LiPo Batteries	18.99	Power Option 2
4	Motors and Propellers	14.95	Motors and Propeller Option 1
5	Raspberry Pi Zero W Kit	24.99	$5 for Pi, 25 for kit
6	Gyroscope	5.99	For advanced control
7	AdaFruit Powerboost	11.79	Constant 5V

Links:

1. https://www.amazon.com/Powerextra-350mAh-Battery-Hubsan-Quadcopter/dp/B071Y6BP4G/ref=sr_1_1?s=toys-and-games&ie=UTF8&qid=1519413125&sr=1-1&keywords=350+mah+3.7+lipo+battery

2. https://www.amazon.com/Pairs-KingKong-Propellers-Coreless-Motor/dp/B077WS9DY7/ref=pd_sim_21_6?_encoding=UTF8&pd_rd_i=B077WS9DY7&pd_rd_r=MYQN7BB1PJ8Q5C25K378&pd_rd_w=XRVNX&pd_rd_wg=NOnV9&psc=1&refRID=MYQN7BB1PJ8Q5C25K378

3. https://www.amazon.com/Keenstone-400mAh-Battery-6-Port-Charger/dp/B00S8VEH3E/ref=sr_1_1?ie=UTF8&qid=1519412976&sr=8-1&keywords=400+mah+3.7+lipo+battery

4. https://www.amazon.com/USAQ-Coreless-Brushed-8-5x20mm-Propeller/dp/B06Y11C2HL/ref=sr_1_6?s=toys-and-games&ie=UTF8&qid=1516649065&sr=1-6&keywords=brushed+motor

5. https://www.amazon.com/CanaKit-Raspberry-Wireless-Official-Supply/dp/B071L2ZQZX/ref=sr_1_4?s=electronics&ie=UTF8&qid=1519413253&sr=1-4&keywords

6. https://www.amazon.com/kwmobile-acceleration-digital-gyroscope-Raspberry/dp/B01LZAY28Q/ref=sr_1_10?ie=UTF8&qid=1516654170&sr=8-10&keywords=gyroscope+raspberry+pi

7. https://www.amazon.com/Adafruit-PowerBoost-500-Basic-ADA1903/dp/B00OKJFKEI/ref=sr_1_3?s=electronics&ie=UTF8&qid=1525976296&sr=1-3&keywords=adafruit+powerboost+500