Integration of 3-D Printed Drone Project in General Engineering Curriculum

Gavin Garrett Tipker, Indiana University Purdue University, Indianapolis
Mr. Michael Golub, Indiana University Purdue University, Indianapolis

Michael Golub is the Academic Laboratory Supervisor for the Mechanical Engineering department at IUPUI. He is an associate faculty at the same school, and has taught at several other colleges. He has conducted research related to Arctic Electric Vehicles and 3D printed plastics and metals. He participated and advised several student academic competition teams for several years. His team won 1st place in the 2012 SAE Clean Snowmobile Challenge. He has two masters degrees: one M.S. in Mechanical Engineering and an M.F.A. in Television Production. He also has three B.S. degrees in Liberal Arts, Mechanical Engineering, and Sustainable Energy.

Mr. Tejesh Charles Dube, Indiana University Purdue University, Indianapolis

I am a Mechanical Engineering graduate student interested in structural and material science application in the field of mechanical engineering.

Dr. Jing Zhang, Indiana University Purdue University, Indianapolis

Dr. Jing Zhang's research interests are broadly centered on understanding the processing-structure-property relationships in advanced ceramics and metals for optimal performance in application, and identifying desirable processing routes for its manufacture. To this end, the research group employs a blend of experimental, theoretical, and numerical approaches, focusing on several areas, including:

1. Processing-Microstructure-Property-Performance Relationships: thermal barrier coating, solid oxide fuel cell, hydrogen transport membrane, lithium-ion battery 2. Physics-based Multi-scale Models: ab initio, molecular dynamics (MD), discrete element models (DEM), finite element models (FEM) 3. Coupled Phenomena: diffusion-thermomechanical properties 4. Additve Manufacturing (AM) or 3D Printing: AM materials characterization, AM process (laser metal powder bed fusion, ceramic slurry extrusion) design and modeling

(http://www.engr.iupui.edu/~jz29/)

Integration of 3D printed Drone Project in General Engineering Curriculum

Abstract
We recently developed a new project-based 3D printing module in general engineering curriculum. Specifically, students are required to make a drone using 3D printed components. The revised engineering course with the new module has received extensive interests and positive feedback from students. They learned how to apply the fundamentals, applications, and implications of 3D printing or additive manufacturing (AM) in a real-world project.

1. Introduction

With technology getting better every year, it is imperative that students are taught the latest technologies. One great advancement in engineering is the invention of 3D printing. It is used in many different engineering industries to create prototypes, validate designs, and to produce final products. 3D printing is actually much older than most people think. According to Goldberg (2018), 3D printing began as early as 1981 when Hideo Kodama "published his account of a functional rapid-prototyping system using photopolymers." This was the birth of 3D printing, and it has been growing slowly until more recent years. The growth of 3D printing quickly increased after RepRap Project released an open-source 3D printer that had the capabilities to almost build itself (Goldberg, 2018). This allowed more and more people access to 3D printers and opened up more opportunities for ideas and innovative ways to use 3D printers. These ideas have gone from just simple thoughts to full blown human tissue printers, 3D metal printers, and many other innovations (Molitch-Hou, 2018). Almost every engineering company has started to use 3D printers to make prototypes, and some are even using them to produce final projects. This is because 3D printers do not require any cost for tooling or molds, and companies can save lots of money by printing prototypes or components that will only need to be produced a small number of times.

Another technology that is sweeping the engineering world is unmanned vehicles. These range from small remote controlled helicopters to large drones the size of small airplanes. These can be used for simple things like taking aerial photos and delivering packages or more serious tasks such as military surveillance. Some companies, like Tesla, have even taken ideas from these unmanned vehicles and incorporated them in self-driving automobiles. These two engineering feats have been combined, and people are starting to make 3D printed unmanned aircraft and other vehicles. With these two engineering aspects becoming so popular, teaching students about 3D printing and unmanned vehicles is a great way to get them involved and excited for their future degree while also teaching them important and relevant information.

2. Project Background

This project is part of the curriculum for a freshman engineering class at our university. It was started in 2015 by a young mechanical engineering student who was actually in the class. He met with the professor, Dr. Peter Orono, who told him he would like to do a quadcopter project but did not know much information about quadcopters. That student agreed to help him get a project set up for the students. This required him to create an instruction manual, decide on what parts to order, and help the students test, assemble, and fly their quadcopters. That project is still done each semester and has even been incorporated into university's freshman engineering class.

3. Design of Drone Components

The components the students use are selected for them to save money and make it easier to order parts. If the components are still in working condition after the project is over they are reused for the next semester's class. Below is some of the parts used to build the quadcopter.

Components

1 x Frame
4 x ESC
4 x Motor
2 x Set of props
1 x Battery Strap
1 x Flight Controller
1 x Radio Receiver
1 x Power Distribution Board

Figure 1: Components

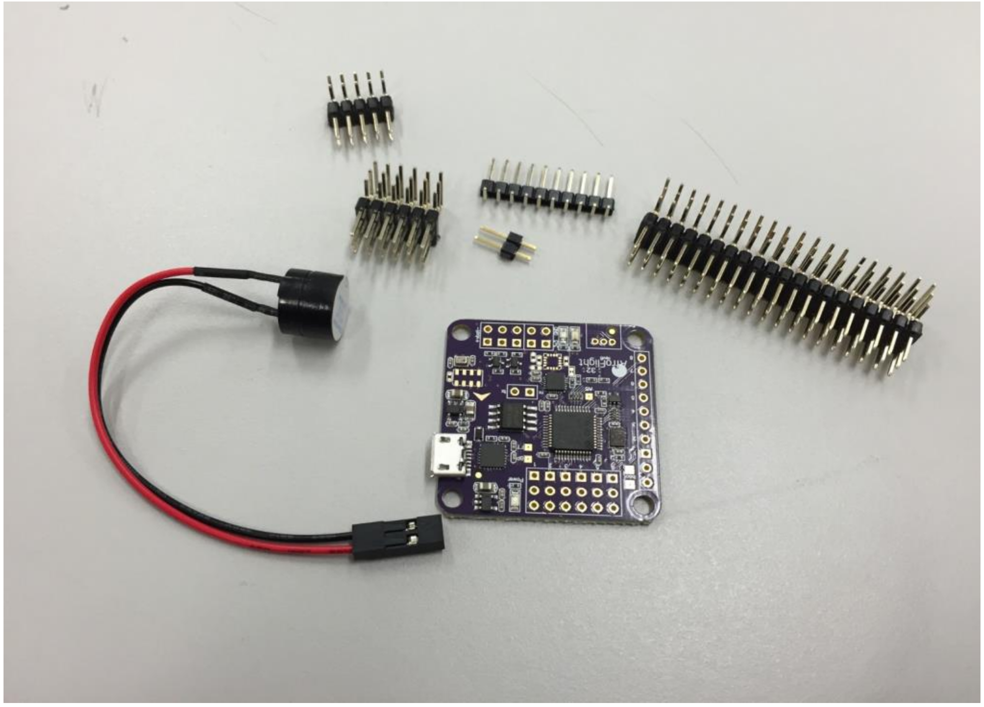

Figure 2: Flight Controller and Piezo Buzzer

Figure 2 shows the flight controller and piezo buzzer that is installed on the quadcopter. The flight controller is the brains of the quadcopter. It is equipped with a 32bit processor, accelerometer, gyroscope sensor, barometer, and magnetometer (Acro Naze32, n.d.). With all these systems feeding information into the processor the quadcopter knows exactly which way it is facing, its acceleration, and even its altitude. All this information turns the quadcopter from four randomly spinning propellers to an easy to fly quadcopter.

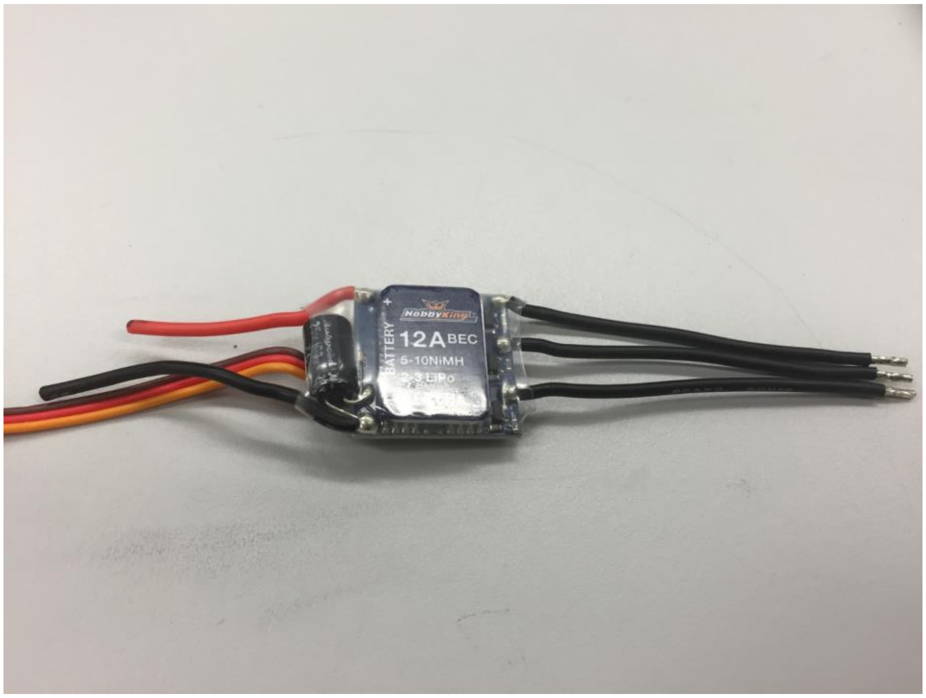

Figure 3: Electronic Speed Controller (ESC)

Figure 3 shows the ESCs that are used for the quadcopters. The ESC receives power from the battery and sends it to the motor. The amount of power that is sent to the motor is determined by the flight controller shown in Figure 2. The flight controller determines this by combining the input from the controller with the input from the multiple sensors on the flight controller. Each quadcopter is equipped with four of these, one for each motor. This is due to the fact that each motor needs to rotate at its own individual speed to keep the quadcopter stable.

Figure 4: Motor

Each quadcopter for this project is equipped with four motors. They receive power from the ESC to control the quadcopter. Two motors spin clockwise and two motors spin counterclockwise. This is to prevent the quadcopter from spinning due to Newton's third law of motion. The flight controller uses this to its advantage to control the quadcopters yaw.

3.1 Step 1: Design and Printing

The first step in this project is designing the quadcopter frame. This requires the students to use the computer automated design (CAD) skills they have learned in the class. The students have the freedom to choose multiple different design patterns for their frame. They can make H frames which are the most common. They can also make X frames which are basically H frames with a square base plate instead of a rectangular one. Below are a few different frames that have been made throughout the years.

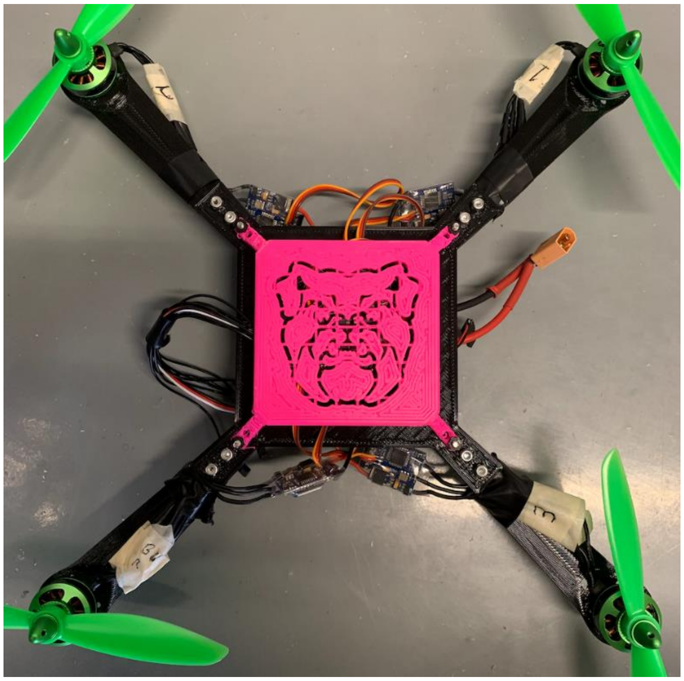

Figure 5: X Frame Design

Figure 6: H Frame Design

As you can see from the above photos, the students can get quite creative with their designs as long as they can be 3D printed and are the correct size. A quadcopter cannot be too big because it will weigh too much, and, also, the parts would be too big for the 3D printer. If the frame is too small, the blades will hit each other rendering the quadcopter useless.

After the students have finished designing their frames, they must assemble them in Creo. This is to make sure that the holes will line up and everything will fit together the way it should. The arms are a very critical part, and the students use pre-designed arms for this. This is because the arms have to be a certain length to prevent the blades from hitting components on the quadcopter. Length is also a consideration due to the fact that the motors produce a slight magnetic field that can interfere with the sensors on the flight controller. The arms also have to be the right thickness to handle the force exerted on them from the motors. The students are required to create a CAD model of the arms but they do not get printed off.

Once the students have finished drawing their parts and have checked to make sure they fit, the teacher's assistant prints them off. If the students have access to their own 3D printer or would like to print it elsewhere they are allowed to do that to learn more about 3D printing. The components are 3D printed by a printer that has been donated to our university's freshman engineering department. Printing them in-house not only saves money, but it also allows the students to create their own frame designs. This keeps them more engaged while allowing them to experiment with what kind and size frame they would like.

3.2 Step 2: Assembly and Testing

Assembling and testing the quadcopter is the majority of the project. The students spend most of their time on this part of the project, especially testing. This step requires the students to assemble their 3D printed frame and then put all the electronics and motors on the quadcopter. The first part of this step is to assemble the base plate. This is done by bolting the legs to the bottom of the base plate as shown below.

Figure 7: Base Plate with Legs

Once the legs are attached to the base plate, the electronics can be attached to the frame. Before attaching the electronics, the students must lay them on the base plate and cut the wires to the correct length. After that, the wires must be soldered together and then have shrink wrap put over the connected wires. Once this is all done, the electronics can be attached to the base plate.

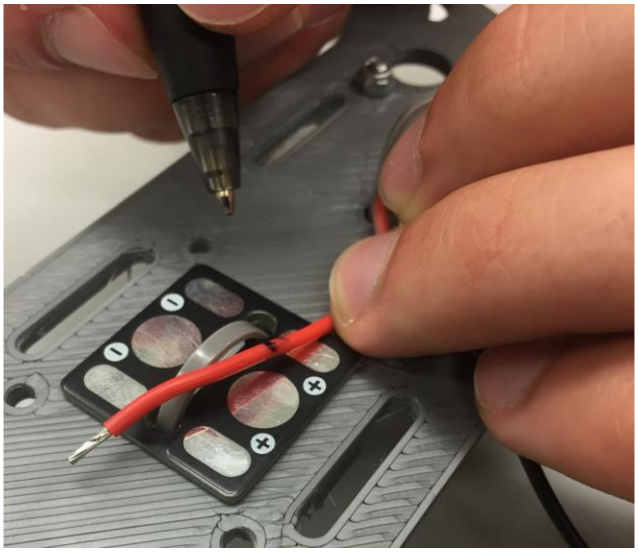

Figure 8: Measuring the Wires

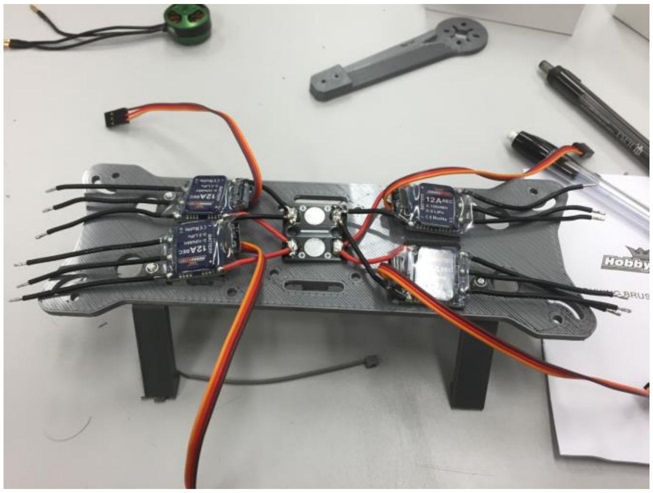

Figure 9: Electronics Attached to Base Plate

After the electronics are attached to the frame, the students must solder the pins to the flight controller. This is because the flight controller will be needed in the next step. The pins can actually be soldered to the flight controller at any point before this, but it is recommended that the students do this after they solder some other components due to the precision needed to solder the pins.

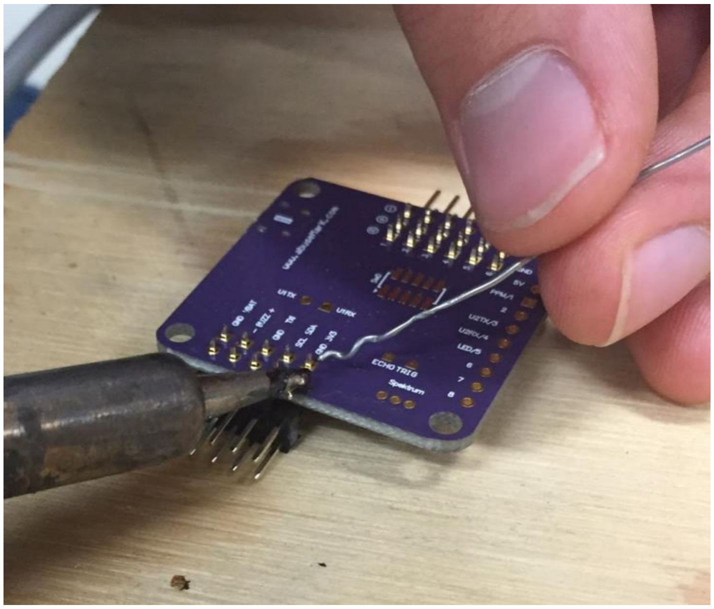

Figure 10: Solder the Pins to the Flight Controller

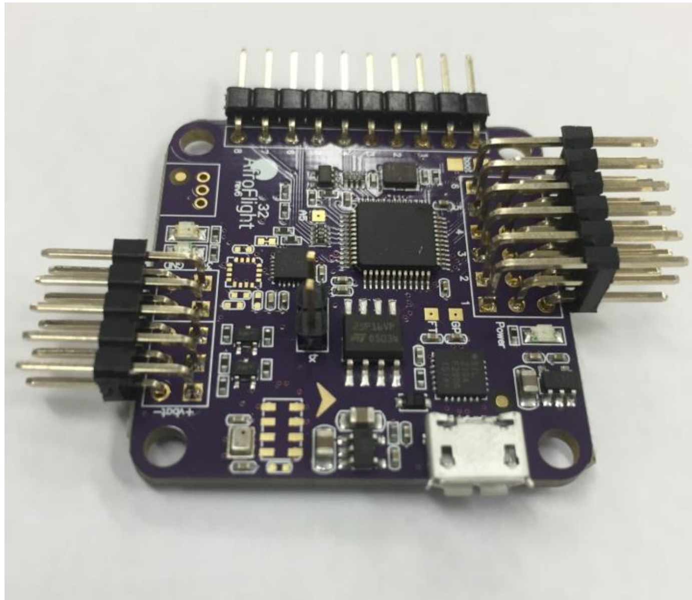

Figure 11: Completed Flight Controller

After the flight controller is soldered, the motors can be soldered to the ESCs. The reason the flight controller must be assembled first is because after soldering the motors to the ESCs, they must be tested to make sure they are spinning in the right directions. If they are not spinning in the right direction, the two outside wires coming from the ESC must be switched. To test which way they are spinning, the control wires from the ESCs must be attached to the correct spots on the flight controller and then the flight controller must be plugged into the computer. Once this is done, the battery can be plugged into the battery leads. Then using BaseFlight on your computer the motor directions can be tested.

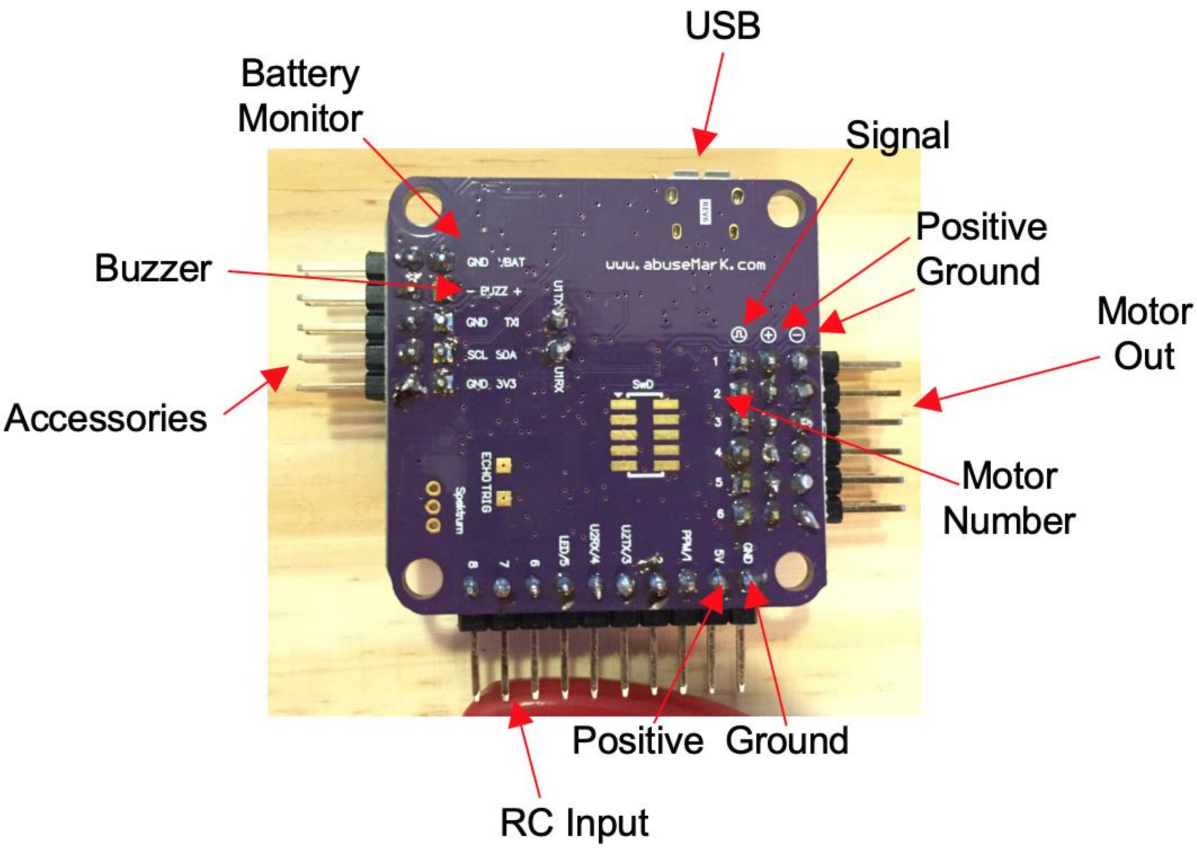

Figure 12: Flight Controller Setup

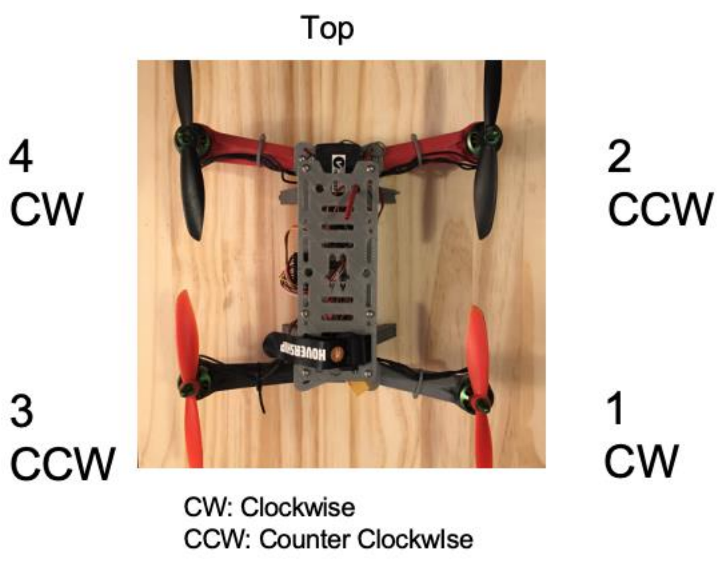

Figure 13: Motor Numbers and Directions

After the motors have been tested, they can be bolted to the arms, and the rest of the wires can be attached to the flight controller. This is a very critical step because if the wires are attached wrong it can completely ruin the flight controller. This is the last step before attaching the rest of the frame.

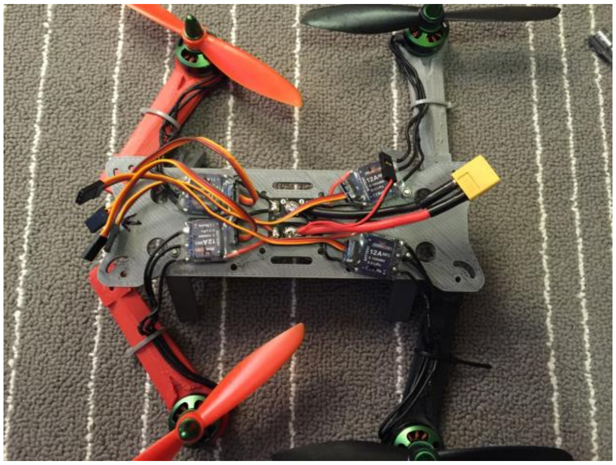

Figure 14: Motors Attached to the Arms

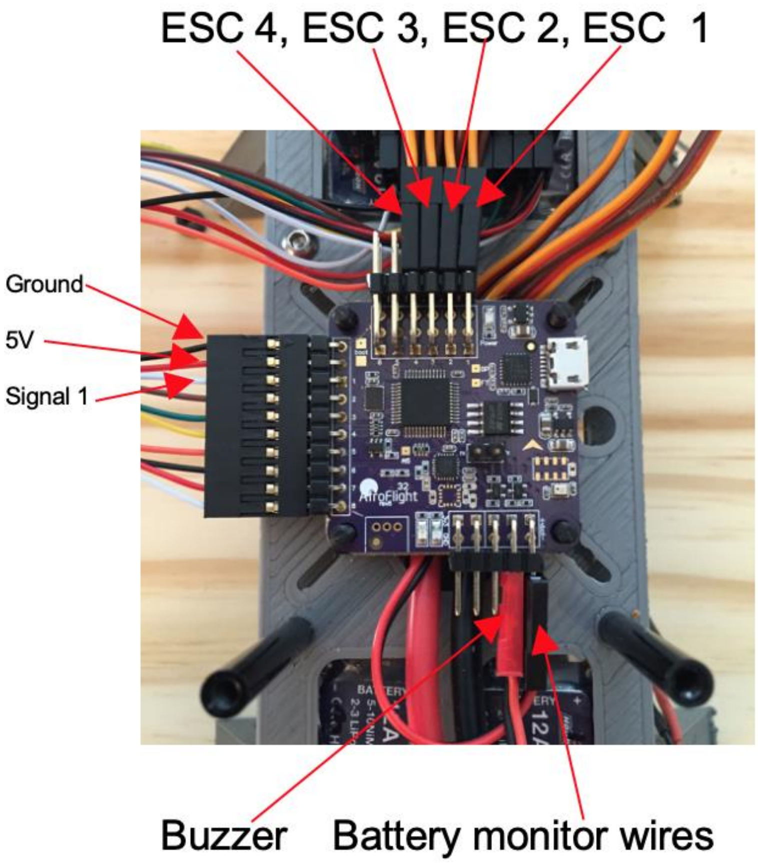

Figure 15: Wire Connections to Flight Controller

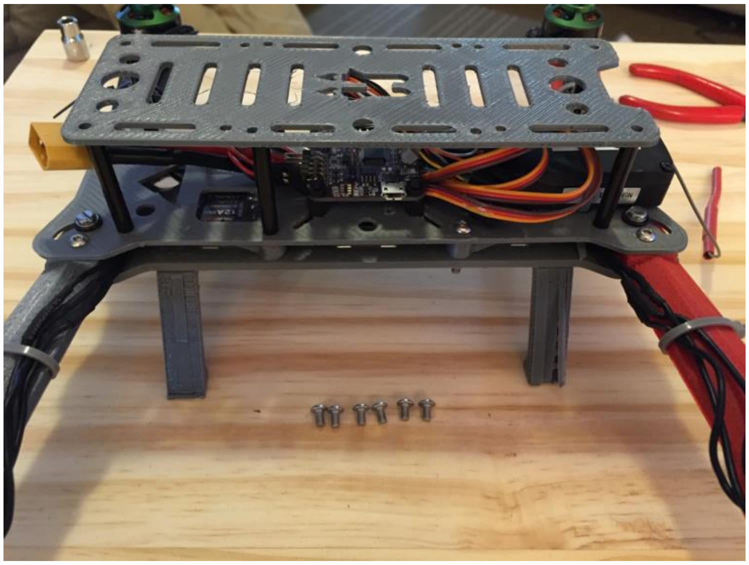

Figure 16: Attaching the Top Plate of the Frame

Once all these steps on done, the quadcopter is almost ready to fly. Before it is completely ready to fly, the propellers should be removed and the quadcopter should be tested one more time. This is done by plugging the battery into the quadcopter, powering on the controller, and making sure the motors spin the directions they should and that they respond correctly to the input that is being put into the controller.

3.3 Step 3: Flying Tests

Flying the quadcopter is the most exciting step and, also, the students' favorite step. To prepare the students to fly the quadcopters, they are trained on miniature pre-built quadcopters. These teach them the basic controls that they will need to know to fly their own quadcopters. Once they have finished assembling their quadcopter and have tested it, they are allowed to fly it. They could have the TA fly it instead, if they would prefer. The students are not penalized if their quadcopter does not fly, they just have to explain why it did not fly in their report and what they did to try to fix this issue.

4. Student Report Requirements

Below is a description of the student report format requirement. All students prepared their reports using the following format.

Introduction

- General description of a quadcopter
- Overview of how a quadcopter works
- Applications of real world quadcopter

Description of your quadcopter

- Electronic components
  i. Purpose of each and how they interact
  ii. Important specifications taken into consideration
- Structural parts
  i. Design strategy (including electronic component considerations)
  ii. Drawings for the structural parts made on the 3-D printer
- Assembly
  i. Assembly steps
  ii. Mounting of motors and propellers in proper direction
  iii. Picture of assembled quadcopter
- Software used and its purpose

Flight

- Description of how motion is controlled

Performance Evaluation

- Performance of your quadcopter
- Reasons for any shortcomings

Discussion/Wrap-up

- Overall evaluation of project
- Suggestions for improvements in your quadcopter
- Suggestions for improvements in project

5. Conclusion

Quadcopters, and all kinds of unmanned technology, are quickly on the rise. Introducing students to these technologies early on can help them in their future engineering careers. Overall, this project is a favorite among most students. A lot of students go on to make their own quadcopters after learning how to make one in their freshman engineering class. Combining unmanned technology with the advancements of 3D printing is not only a great way to teach students about them, but it is also a great way to get them engaged and excited about their degree.

References

Acro Naze32 Flight Controller rev6. (n.d.). Retrieved January 25, 2019, from https://www.getfpv.com/acro-naze32-flight-controller-rev6-w-pin-headers.html

Goldberg, D. (2018, April 13). History of 3D Printing: It's Older Than You Think. Retrieved January 21, 2018, from https://www.autodesk.com/redshift/history-of-3d-printing/

Molitch-Hou, M. (2018, July 12). Bioprinter Preps for ISS to 3D Print Beating Heart Tissue. Retrieved January 21, 2019, from https://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/17268/Bioprinter-Preps-for-ISS-to-3D-Print-Beating-Heart-Tissue.aspx