Take Flight Robotics: A STEM Education Workshop for High School Students

Miss Elyse Hill, University of Guelph

I am a first year PhD student with current interests in control and estimation theory and pedagogy research. I hope to obtain a faculty position in mechanical engineering post-PhD and combine my interests into a new field of research.

Mr. Andrew Lee, University of Guelph

Lee has applied his mechanical engineering knowledge and STEM teaching skills as a camp assistant in the Take Flight Robotics program, a summer experience designed to engage and inspire high school interested in STEM fields. In 2015, Lee helped participants build and program their own small drones, and in 2016 he developed a new program to help them modify remote controlled cars using coding skills and microcontrollers.

Ms. Amy Domenique Gadsden, University of Alberta

Amy Domenique completed her Bachelor of Fine Arts at Mount Allison University (New Brunswick) and a Bachelor of Education at Nipissing University (Ontario) in 2012. Following this, she completed a Master of Education at Nipissing University in Special and Inclusive educational praxis in 2014. Amy Domenique is a certified teacher and has worked as an elementary and secondary classroom teacher in both the province of Ontario and Alberta. She is a member of the Ontario College of Teachers and the Alberta Teachers Association. She is an experienced university instructor, guest speaker, and graduate teaching assistant. Amy Domenique has also worked as a research assistant in the JP Das Centre for Developmental and Learning Disabilities (Alberta) as well as the Western Canada Centre for Deaf Studies (Alberta). Concomitant with her relevant professional working experience, she is a member of a variety of organizations that promote and advocate for the inclusion of students with special needs. Amy Domenique is also a Director of the Learning Disabilities Association of Alberta, and a member of its Ontario organization. Currently, Amy Domenique is a doctoral student in the department of Educational Psychology at the University of Alberta, conducting research in Special Education.

Dr. Stephen Andrew Gadsden, University of Guelph

Andrew completed his Bachelors in Mechanical Engineering and Management (Business) at McMaster University in 2006. In 2011, he completed his Ph.D. in Mechanical Engineering at McMaster in the area of estimation theory. Andrew worked as a postdoctoral researcher at the Centre for Mechatronics and Hybrid Technology (Hamilton, Ontario, Canada). He also worked as a Project Manager in the pharmaceutical industry (Apotex Inc.) for three years. Before joining the University of Guelph in 2016, he was an Assistant Professor in the Department of Mechanical Engineering at the University of Maryland, Baltimore County. Andrew worked with a number of colleagues in NASA, the US Army Research Laboratory (ARL), USDA, NIST, and the Maryland Department of the Environment (MDE). He is an ASME and IEEE member, and a Professional Engineer. Andrew was an Associate Editor for the Transactions of the Canadian Society for Mechanical Engineers and is a reviewer for a number of ASME and IEEE journals and international conferences. Andrew is a 2018 Ontario Early Researcher (ERA) award winner (on intelligent condition monitoring strategies), and has been nominated for the 2018 University of Guelph Faculty Association (UGFA) Teaching Award.

Dr. Stephen Andrew Wilkerson P.E., York College of Pennsylvania

Stephen Wilkerson (swilkerson@ycp.edu) received his PhD from Johns Hopkins University in 1990 in Mechanical Engineering. His Thesis and initial work was on underwater explosion bubble dynamics and ship and submarine whipping. After graduation he took a position with the US Army where he has been ever since. For the first decade with the Army he worked on notable programs to include the M829A1 and A2 that were first of a kind composite saboted munition. His travels have taken him to Los Alamos

where he worked on modeling the transient dynamic attributes of Kinetic Energy munitions during initial launch. Afterwards he was selected for the exchange scientist program and spent a summer working for DASA Aerospace in Wedel, Germany 1993. His initial research also made a major contribution to the M1A1 barrel reshape initiative that began in 1995. Shortly afterwards he was selected for a 1 year appointment to the United States Military Academy West Point where he taught Mathematics. Following these accomplishments he worked on the SADARM fire and forget projectile that was finally used in the second gulf war. Since that time, circa 2002, his studies have focused on unmanned systems both air and ground. His team deployed a bomb finding robot named the LynchBot to Iraq late in 2004 and then again in 2006 deployed about a dozen more improved LynchBots to Iraq. His team also assisted in the deployment of 84 TACMAV systems in 2005. Around that time he volunteered as a science advisor and worked at the Rapid Equipping Force during the summer of 2005 where he was exposed to a number of unmanned systems technologies. His initial group composed of about 6 S&T grew to nearly 30 between 2003 and 2010 as he transitioned from a Branch head to an acting Division Chief. In 2010-2012 he again was selected to teach Mathematics at the United States Military Academy West Point. Upon returning to ARL's Vehicle Technology Directorate from West Point he has continued his research on unmanned systems under ARL's Campaign for Maneuver as the Associate Director of Special Programs. Throughout his career he has continued to teach at a variety of colleges and universities. For the last 4 years he has been a part time instructor and collaborator with researchers at the University of Maryland Baltimore County (http://me.umbc.edu/directory/). He is currently an Assistant Professor at York College PA.

Take Flight Robotics:
A STEM-Education Workshop for High School Students

Summer activities and programs are important to attract students to careers in science, technology, engineering, and math (STEM). Take Flight Robotics (TFR) was a youth outreach workshop and program that ran for one week during the summer in 2015 and 2016 at the University of Maryland, Baltimore County (UMBC). The camp was very well received by about 15 high school participants each year. This paper provides a comprehensive summary of the TFR program, a look at the student experience and activities, and lessons learned. Suggested guidelines, program activities, and technical descriptions of unmanned aerial vehicles are provided. This paper provides enough information for interested instructors and educators to replicate the program at their home institutions.

Introduction

Take Flight Robotics (TFR) was a weeklong summer enrichment program that took place in 2015 and 2016 at the University of Maryland, Baltimore County (UMBC). The purpose of the program was to introduce local high school students to a possible academic or industrial career in STEM-based fields. This experience aimed to introduce the basic concepts of unmanned aerial vehicles (quadcopters) to co-ed high school students. A number of other quadcopter-based programs were discovered in literature [1, 2, 3]. The program taught students how to design, build, and fly their very own quadcopter. At the end of the week, the students would be able to take their quadcopter home with them. This provided a sense of accomplishment and talking points with their friends. A number of key engineering concepts were covered in this program, and included: aerospace and aerodynamics (lift, drag, thrust, etc.), engineering design, 3-D printing, mechanical and electrical systems, and computer programming. Each day, brief lectures were accompanied with demonstrations, and were reinforced by participants working together on their own quadcopter. A significant amount of learning was based on active and hands-on experience. Activities also included guest lectures from local industry and government research labs. A friendly indoor quadcopter race was held on the last day of the program.

The program introduced and taught a number of important engineering and technical skills, including:

- Principles of 3-D printing (demo)
- Laser cutting and engraving (demo)
- Fabrication and assembly of parts
- Soldering circuitry and power cables
- Programming
- Basic concepts of aerodynamics and flight
- Training on virtual flight simulators
- Real-life flight control training
- Manufacturing in industry (field trip)
- Teamwork and communication

Figure 1. Fabrication of the quadcopters by the high school students.

The program was very well received by the students and their parents. In fact, at the end of the first offering (in 2015), nearly half (7 out of 15) of the students requested to sign up again for the following year (2016). Of the 7 students who requested to return in 2016, only three students registered. These three students helped the new students in the class and were very engaged in the activities. Out of the approximately 15 students that attended each year, only about half (8 out of 15) of the students were originally interested in STEM. By the end of the week, every single student that took part in the program (15 out of 15) wanted to pursue studies in a STEM-based discipline. This information was obtained by asking the students a number of questions throughout the last day of the program. This was a significant achievement, and was the main goal for the program. After describing STEM to the students, the students were asked which program interested them the most. Most of the students (11 out of 15) wanted to explore mechanical and electrical engineering, as well as programming or computer sciences (4 out of 15).

In addition to the informal questions on the last day, two surveys were circulated throughout the program: one on Wednesday and another on Friday. The survey questions are available in the Appendix. The majority of the questions focused on student experience with flying drones and hardware fabrication prior to the program. Other questions looked at what aspects student's enjoyed the most. The majority of the students (12 out of 15) liked the student panel the best. This was most likely because the high school students were looking to gain an insight into what to expect at the university level. Not surprisingly, 14 out of 15 students stated that they liked the fact that they could take their UAV (drone) home with them at the end of the program.

It is possible that the hands-on nature of the summer enrichment program led to a more dynamic learning environment. The students were very engaged in the program, and were encouraged to follow technical instructions independently with minimal guidance. This created a sense of accomplishment and helped build confidence in a new area. Furthermore, the advanced students would often help other students who could not solder or assemble their quadcopter as easily. The program was very dynamic and no student appeared to be bored or disengaged from the activities.

This brief paper describes the activities at the TFR program, lists required parts to build the quadcopter, summarizes the main findings and outcomes, and provides detailed instructions on how to build and program the quadcopter for other program offerings.

Description of Activities

Take Flight Robotics was a weeklong program (Monday to Friday) and lasted from 9:00 am until 4:00 pm. The following figure summarizes the main schedule of activities. Most students arrived earlier in the morning, at around 8:00 am. This gave the students time to become comfortable with each other and familiarize themselves with their surroundings in a university setting.

<table>
<tr><th></th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>9:00</td><td>Welcome/ Speakers</td><td rowspan="3">Demonstration UAV Starter Kit</td><td>Guest Speaker</td><td rowspan="4">Field trip (to UAV company)</td><td rowspan="3">Warming Up</td></tr>
<tr><td>10:00</td><td rowspan="2">What are UAVs?</td><td rowspan="2">Building UAV – Groups</td></tr>
<tr><td>11:00</td></tr>
<tr><td>12:00</td><td>Lunch</td><td>Lunch/Student Organizations</td><td>Lunch/Student Panel</td><td>Lunch/STEM</td></tr>
<tr><td>1:00</td><td>Basic Concepts of Aerodynamics and Flight</td><td rowspan="3">Building UAV – Groups</td><td rowspan="3">Initial Demonstrations – What Can Go Wrong?</td><td rowspan="3">Flight Simulations – Finishing UAV</td><td rowspan="2">Competition</td></tr>
<tr><td>2:00</td><td rowspan="2">UAV Designs</td></tr>
<tr><td>3:00</td><td>Closing Ceremony</td></tr>
</table>

Figure 2. Take Flight Robotics daily activities.

The first day involved a number of icebreakers for the students. In addition, quadcopters were introduced, different designs were discussed, and the basic concepts of aerodynamics and flight were taught by a trained pilot. For the TFR program, a UAV starter kit was designed and created. The kit was handed out on the second day in the morning. The custom kit consisted of the following:

- Carbon fiber frame (Makerfire H250)
- Standard propellers (Crazepony GemFan 5030)
- Carbon fiber propellers (US 5030 5x3)
- Clockwise and counter-clockwise motors (MX1806 2280KV brushless)
- Electronic speed controller (Hobbypower SimonK)
- Power distribution board (RipaFire)
- Flight controller (Andoer Open Pilot)
- Transmitter and receiver (Hobby King 6 channel)
- Battery (Zippy Flightmax Li-Po 2200 mAh)
- Charger (Turnigy 12V 2-3S)
- Power adapter (BV-Tech DC12V 1A)
- Battery connector (Nylon XT60 male/female)
- Battery voltage checker (Hobby King)

Each student was given a kit and detailed instructions (as shown in the Appendix). Fabrication began on the second day. Three to four university student volunteers helped guide construction of the quadcopters, step-by-step. The high school students were taught a number of important fabrication techniques. Soldering proved to be the most difficult task. Since this task involved electricity and a hot solder iron, high school students were carefully assisted at a designated workstation. Most students were able to complete the soldering portion correctly after two attempts. Although challenging, every student gained experience soldering wires and connections, and found it very rewarding.

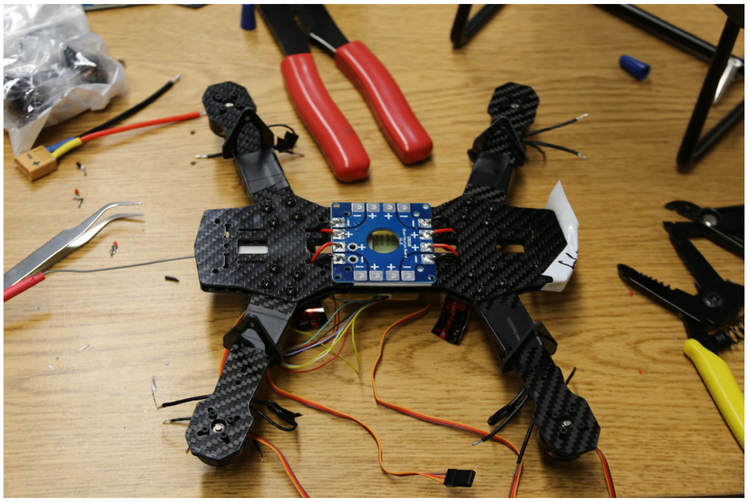


Figure 3. Part of a quadcopter during the soldering stage.

Special lunch sessions were organized on the second and third days of the program. The first lunch session involved a graduate student panel. The students discussed their experience entering university from high school, and answered a number of important (and sometimes personal) questions asked by the TFR program students. The second special lunch session included an industry panel. Industry members were invited to speak to the high school students about their careers in STEM (e.g., how and why they chose that specific career path). These sessions were very well received by the students, and some of the parents remarked the importance of the experience for their children.

Figure 4. Take Flight Robotics students taking part in a lunch panel discussion.

During fabrication of the quadcopters, students were provided training on flight simulation software. This was a good break between constructions and provided some basic flight control experience prior to flying their own quadcopter. Flight simulation drastically reduced the number of quadcopter crashes. It is important to note that every student had a working quadcopter at the end of the week (even after his or her own flights). Mini-competitions were designed to engage the students in the flight simulator, and made the experience even more rewarding.

Figure 5. A student practicing quadcopter flights in one of the simulations.

A field trip was organized to a local (about 15 minute drive) manufacturing company. This company makes custom unmanned aerial vehicles (UAVs) for the government and private industry. The students were provided a tour of the facility and manufacturing areas, and were given flight demonstrations. The trip was a good opportunity for students to see what type of careers are possible with an education in a STEM-based program.

The final day consisted of the quadcopter races and challenges. This was a very fun experience for both the students and the volunteers. The TFR program students were able to fly quadcopters that they fabricated and programmed. The last day also consisted of a few brief talks by university students who decided to pursue education in STEM. It was a good opportunity for the high school students to ask questions to other students who are only a few years older. The TFR program was truly a unique experience, and increased the high school students' interest in STEM careers.

Concluding Remarks

Take Flight Robotics was a summer enrichment program offered to high school students in 2015 and 2016 at the University of Maryland, Baltimore County (UMBC). There were about 15 students per program offering, of which 11 were male and four were female. A high school teacher attended both years and replicated the program for his own high school students. At the start of the program, each student was asked if they were interested in a STEM career. Only about half were originally interested. However, at the end of the program, every student was strongly interested in pursuing STEM-based education for university or college. This was a significant achievement, and the main goal of the program (besides having fun!). If an instructor or professor is interested in replicating this type of program, there are some lessons to be learned. The biggest challenge for the program was the soldering and fabrication stage. Although each student eventually was able to build his or her own quadcopter, the skill level for each student was vastly different. As such, it is important to have sufficient activities for the advanced students to occupy their time while the slower students catch up in building their quadcopter. Furthermore, a sufficient number of spare parts should be ordered in case of soldering failures or crashes due to flight control inexperience.

References

[1] C. H. Lai and C. M. Chu, "Development and Evaluation of STEM Based Instructional Design: An Example of Quadcopter Course," in *Emerging Technologies for Education*, Rome, Italy, 2016.

[2] P. Doroshenko, A. Hebert, A. Khare, C. Parikh, C. Sweeney, J. M. M. Marrocco and A. Pandit, "Hillsborough high school iSTEM club's 2016 project: Quadcopter," in *IEEE Integrated STEM Education Conference*, Princeton, New Jersey, USA, 2016.

[3] C. Molina, R. Belfort, R. Pol, O. Chacon, L. Rivera, D. Ramos and E. I. O. Rivera, "The use of unmanned aerial vehicles for an interdisciplinary undergraduate education: Solving quadrotors limitations," in *IEEE Frontiers in Education Conference*, Madrid, Spain, 2014.

[4] J. Kim, K. Chang, B. Schwarz, A. S. Lee, S. A. Gadsden and M. Al-Shabi, "Dynamic Model and Motion Control of a Robotic Manipulator," *Journal of Robotics, Networking and Artificial Life,* vol. 4, no. 2, pp. 138-141, 2017.

[5] M. Al-Shabi, A. Cataford and S. A. Gadsden, "Quadrature Kalman Filters with Applications to Robotic Manipulators," in *IEEE International Symposium on Robotics and Intelligent Sensors*, Ottawa, Ontario, 2017.

[6] J. Kim, S. A. Wilkerson and S. A. Gadsden, "Comparison of Gradient Methods for Gain Tuning of a PD Controller Applied on a Quadrotor System," in *SPIE Unmanned Systems Technology XVIII*, Baltimore, Maryland, 2016.

Appendices

The appendix includes three parts. The first two are the survey questionnaires that the students completed on Wednesday and Friday during the week (2015 in this case). The third is a step-by-step instructions for any student, teacher, or professor who would like to reproduce the program. This program could be offered by other instructors or professors at their home institutions.

Appendix A: Take Flight Robotics Survey, Wednesday 8/5/2015

This survey has two uses. First, your answers help us improve the TFR program; second, to help with research about how people feel about UAVs (unmanned aerial vehicles) and how to make robotics more exciting and approachable. You *do not* have to participate – this is strictly optional!

☐ I want to participate, *and* I have turned in my consent form saying it's okay to use my answers for research.

☐ I don't want to participate.

All questions are optional.

Gender:
☐ Male ☐ Female ☐ Other ☐ Prefer not to say

What is your age (in years)?
_____

Have you ever flown a UAV/UAS before?
☐ Yes ☐ No

If you answered YES: To your best judgment, what is your skill level at flying drones?
☐ Beginner
☐ Intermediate
☐ Expert
☐ Professional

How many hours a week do you play video games on average?
☐ 0-3
☐ 4-7
☐ 8-11
☐ 12-15
☐ 16-18
☐ 19-22
☐ 23+

How did you hear about the TFR program?
☐ I or a family member heard about it at work
☐ Through PLTW
☐ From friends
☐ From the Internet
☐ High school counselor
☐ News or radio programs
☐ Other: ________

What part of the program were you most interested in?

- ☐ Learning about robots generally
- ☐ Learning about UAVs
- ☐ Building a UAV
- ☐ Programming
- ☐ Flying the UAVs
- ☐ Meeting robotics professionals
- ☐ Meeting other students with the same interests
- ☐ Taking your UAV home afterwards
- ☐ Other: ____

Is there something else that made you interested in attending TFR?

What have you enjoyed most so far?

What are you looking forward to?

Is there anything you have disliked, or are concerned or nervous about?

How would you describe your level of experience with robots, including UAVs?

☐ No previous experience
☐ I've played with or worked with a robot or a toy robot before
☐ I've been involved in building robots from a kit
☐ I've participated in FIRST or another robot design and building program
☐ I've worked or volunteered in a robotics research group
☐ Other: ____

How would you describe your experience with hardware?

☐ I've assembled other things from a kit (a computer, a robot, a circuit board)
☐ I've assembled other things components I purchased separately
☐ I've built a piece of hardware, including wiring and soldering
☐ None of the above
☐ Other: ____

How much do you agree with the following statements?

I expect flying the quadcopter to be difficult.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I am nervous about flying the quadcopter.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I expect building the quadcopter to be difficult.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

Quadcopters and UAVs are mostly very expensive.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I am worried about damaging my quadcopter.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I am looking forward to the flying competition on Friday.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I will be disappointed if I break my quadcopter.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I am nervous about being around other people flying UAVs or quadcopters.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I think UAVs, including quadcopters, are fun.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I think UAVs, including quadcopters, will be useful in the near future.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

Appendix B: Take Flight Robotics Survey, Friday 8/7/2015

This survey has two uses. First, your answers help us improve the TFR program; second, to help with research about how people feel about UAVs (unmanned aerial vehicles) and how to make robotics more exciting and approachable. You *do not* have to participate – this is strictly optional!

☐ I want to participate, *and* I have turned in a consent form saying it's okay to use my answers for research.

☐ I don't want to participate.

All questions are optional.

Gender:
☐ Male ☐ Female ☐ Other ☐ Prefer not to say

What is your age (in years)?
_____

Have you ever flown a UAV/UAS before?
☐ Yes ☐ No

If you answered YES: To your best judgment, what was your skill level at flying quadcopters before TFR?
☐ Beginner
☐ Intermediate
☐ Expert
☐ Professional

How would you describe your level of experience with robots, including UAVs?
☐ No previous experience
☐ I've played with or worked with a robot or a toy robot before
☐ I've been involved in building robots from a kit
☐ I've participated in FIRST or another robot design and building program
☐ I've worked or volunteered in a robotics research group
☐ Other: ____

How would you describe your experience with hardware?
☐ I've assembled other things from a kit (a computer, a robot, a circuitboard)
☐ I've assembled other things components I purchased separately
☐ I've built a piece of hardware, including wiring and soldering
☐ None of the above
☐ Other: ____

What part of the program did you find most rewarding?

- ☐ Learning about robots generally
- ☐ Learning about UAVs
- ☐ The student panel
- ☐ The industry panel
- ☐ Building a UAV
- ☐ Flying the UAVs
- ☐ Meeting robotics professionals
- ☐ Meeting other students with the same interests
- ☐ Taking your UAV home afterwards
- ☐ Other: ____

Is there something else that was fun or rewarding that you'd like to tell us about?

What was the best part of the program?

Is there anything you disliked, found boring or pointless, or had concerns about?

Do you have any suggestions for us?

How much do you agree with the following statements?

Flying the quadcopter was difficult.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I was nervous while flying the quadcopter.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

The interface affected how easy it was to fly the quadcopter.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I tried to complete the flight courses as quickly as possible.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

Building the quadcopter was difficult.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

Quadcopters and other UAVs are mostly expensive.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I am more concerned about damaging the quadcopter than I am with flying quickly.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I was nervous about being around other people flying UAVs or quadcopters.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

I think UAVs, including quadcopters, will be useful in the near future.
☐Strongly agree ☐Somewhat agree ☐Somewhat disagree ☐ Strongly disagree

What suggestions do you have for making quadcopters and other UAVs easy to control? More entertaining? More useful?

Do you have any ideas for improving the TFR program?

Appendix C: Assembly Instructions

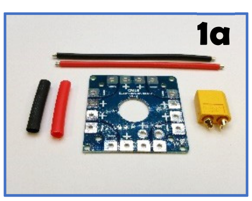
OPEN YOUR BOX

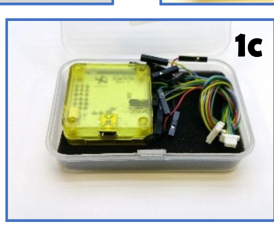
Note: Make sure to open the box carefully! You can use the box as a means of holding your parts!

1. CHECK YOUR STUFF

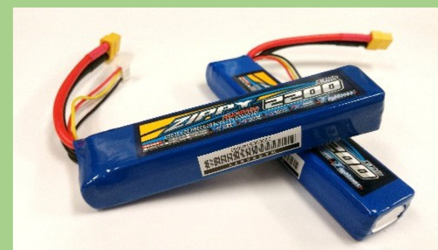
Check to see if all parts are present. Use the checklist below to expedite the process!

- ❑ One Frame Kit (with mounting screws)
- ❑ Two silver capped motors (Counter Clockwise rotation)
- ❑ Two black capped motors (Clockwise rotation)
- ❑ Four Propellers
- ❑ Four Electronic Speed Controllers (ESCs)
- ❑ One power distribution board [1a]
- ❑ One flight controller [1b]
- ❑ One Hobbyking 6 channel transmitter
- ❑ One Hobbyking receiver [1c]
- ❑ Eight double AA batteries
- ❑ Lipo voltage alarm





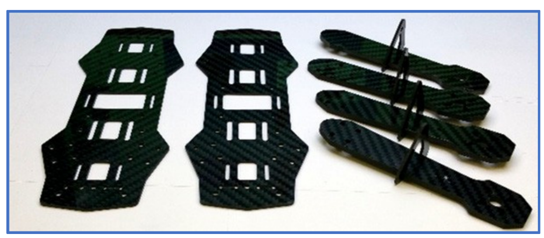
WARNING!!!



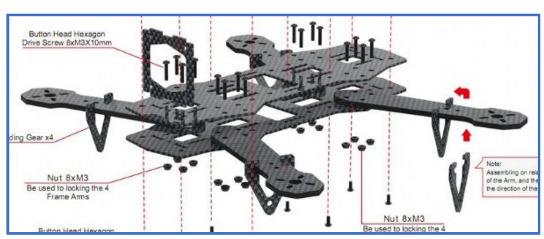
Lithium Polymer Batteries, otherwise known as Lipos, have the potential to be very dangerous. Improper usage and handling of Lipos can lead to Explosions and toxic gases! Be sure to read the Lipos safety guide at the end of this manual to learn how to properly handle

2. Assemble the Frame

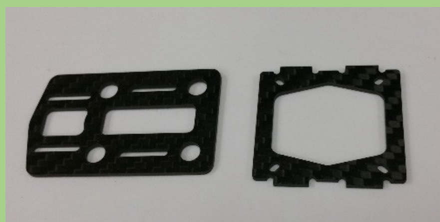
A Before assembly, start by organizing all of your frame parts. Make sure that all frame parts and screws are present. Use a solo cup to hold all of the screws and small parts and set that aside for now.



B Using the included frame assembly instructions, start by assembling the bottom half of the frame as depicted below.

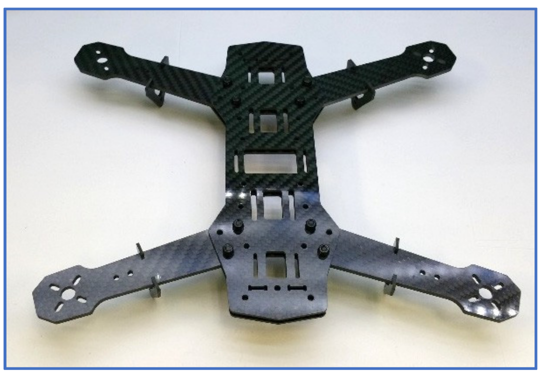


Read this!



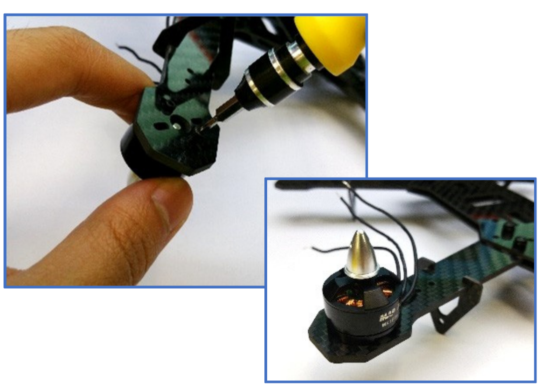
Given that this quad will not be equipped with first person view (FPV) cameras, these two frame pieces (shown above) are unnecessary and can be omitted from the assembly process. But remember to save them anyways in case you decide to get FPV

The assembled bottom half of the frame.

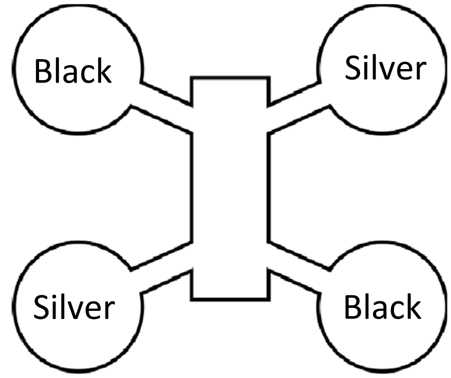


3. Attach the Motors!

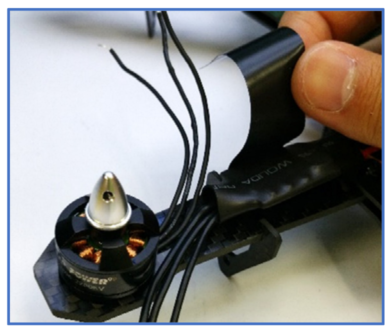
A Begin attaching the motors to the quadcopter frame using the thin motor screws that come with each motor. Make sure to tighten the screws as much as possible!!!



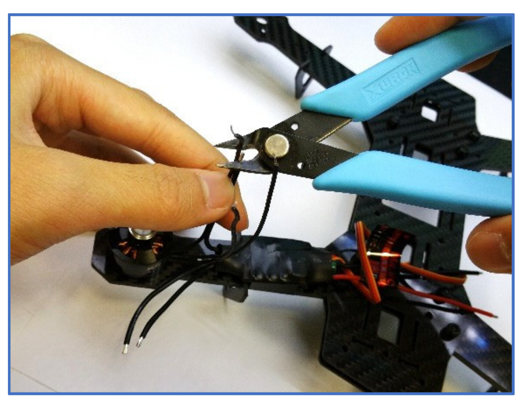
B Use the diagram below to ensure the motors are mounted in the correct pattern.



C Attach the ESCs to the quad frame with the side with three wires facing out towards the arms and the side with red and black wires facing towards the main body. Then use a length of electrical tape and wrap it around the ESC and the frame arm. Take care to ensure that each ESC is securely attached to each arm.



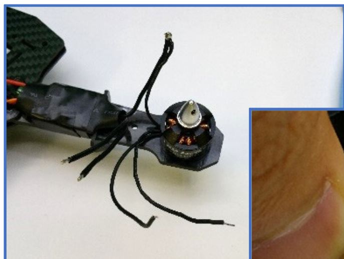
D Use wire cutters to match the length of the motor wires to the ESC wires. Then use wire strippers to remove some insulation on the motor leads to prep for soldering. Repeat this step for each motor/ESC pair.

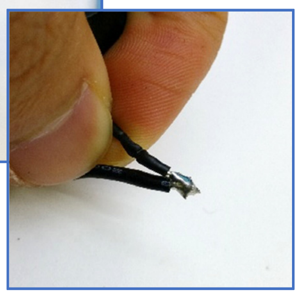


NEXT UP: Soldering stuff together!!!

4. Solder the motors Part 1

In each Motor/ESC pair, take one motor lead and one ESC lead and solder them together. It's important that you only solder one pair of wires in each Motor/ESC pair together because that'll save you a bit of trouble later on.



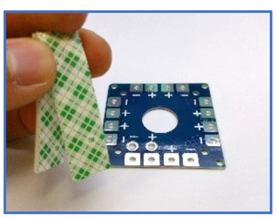


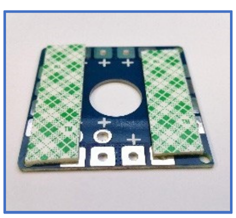
Repeat this step for each Motor/ESC pair

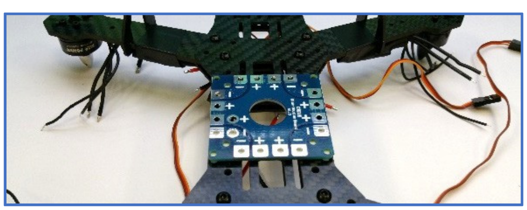
Note: Make sure to use the soldering smoke ventilator while soldering

5. Power Board Part 1

A Using a few small strips of double sided foam tape, secure the power distribution board (PDU) to the bottom of the quadcopter frame.

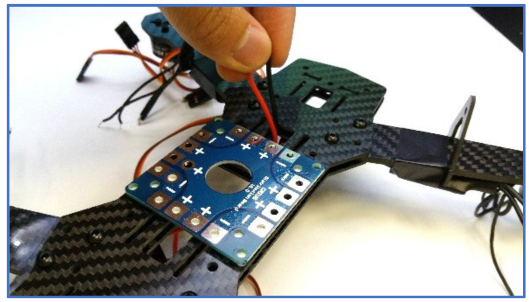




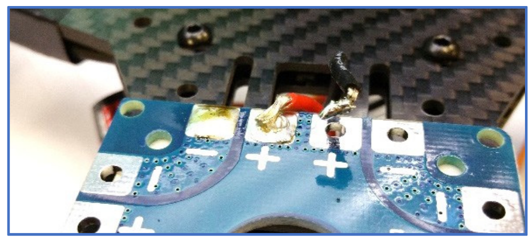


Aside from the picture above, the power distribution board (PDU) can be oriented such that the two circular pads are perpendicular to the length of the frame. This makes for cleaner wire management later on

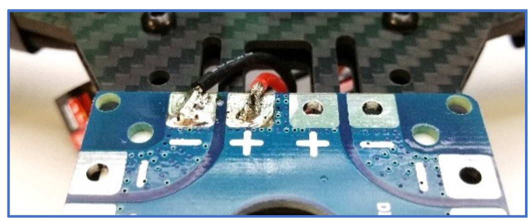
B Take the red and black wires from each ESC and thread them through one of the central holes in the frame.



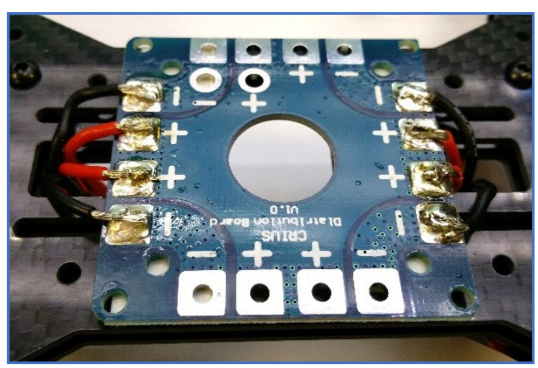
C Add solder to the PDU by heating the square silver pad with the iron and slowly feeding solder into the tip of the iron. See the picture below for a good example of how the end result should look like.



D When the puddle of solder on each pad is hot and shiny, use tweezers to press the wires into the solder. Attach the red wire to the positive pad and the black wire to the negative pad.



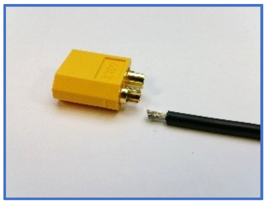
Your PDU should look like this once you have finished soldering the ESC wires.

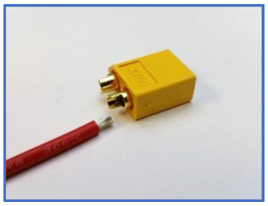


5. Power Board Part 2

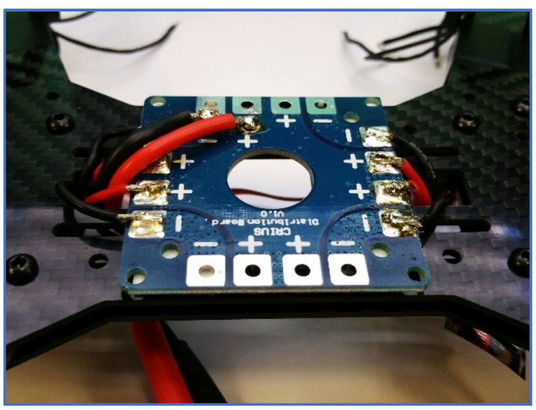
A Solder the yellow battery connector to the

thick red and black wires. The red wire goes to the side with the positive marking and the black wire goes to the side with the negative marking.



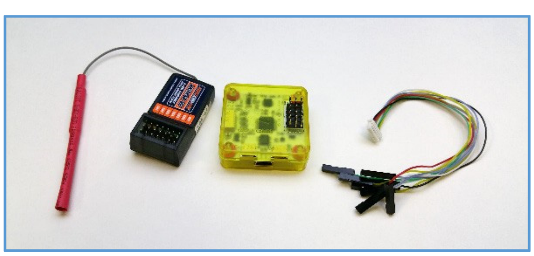


B Thread the battery connectors through one of the holes in the frame. Solder the connector wires to the circular pads on the PDU. Red to positive and black to negative.

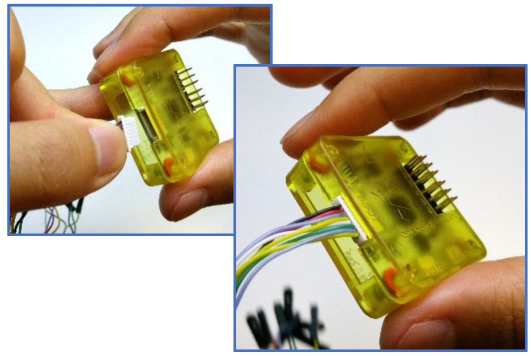


6. Prep the Flight Controller

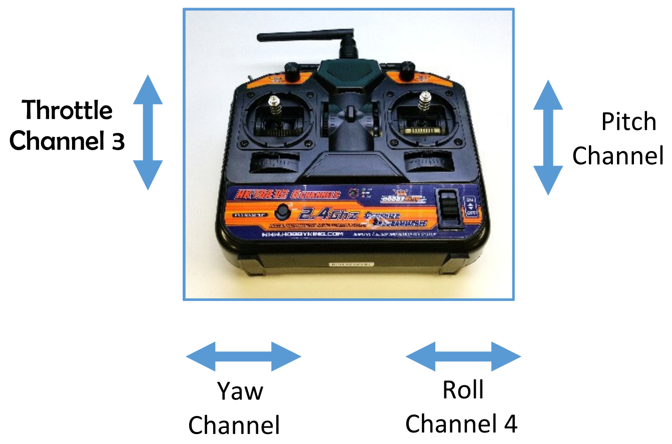
For this next part, you'll need your flight controller, radio receiver and a set of multicolored wire connectors.



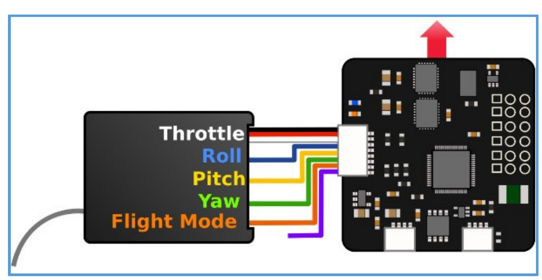
A Take the multicolored cable and plug it into the matching slot on the flight controller



B This next part can be a little bit tricky. It is important to understand which channels are connected to each control stick on the transmitter. For the Hobbyking 6 channel mode 2 controller the control scheme is as follows:

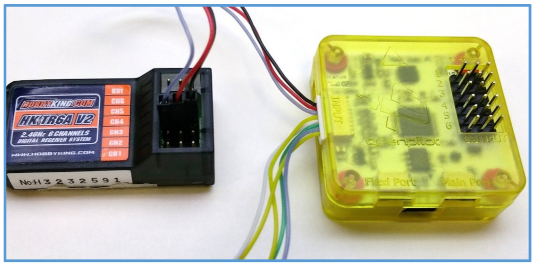


C Use the follow diagram as a reference for the wires coming from the flight controller. The colors of the wires may not match your wires, but the order of the wires is the same.

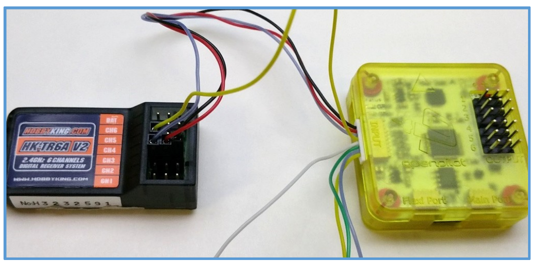


7. Connect the Flight Controller to the receiver

A Take the first three wires (red, black, blue) and connect them to the channel three on the receiver. The blue wire goes to the left most column, the red wire to the middle column and the black wire to the right most column.



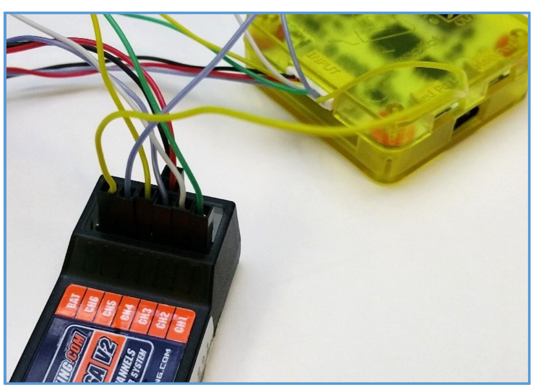
B take the next wire, the yellow wire, and connect it to channel 4 in the left most column on the receiver.



C Using the same column of pins as the yellow wire, do the following:

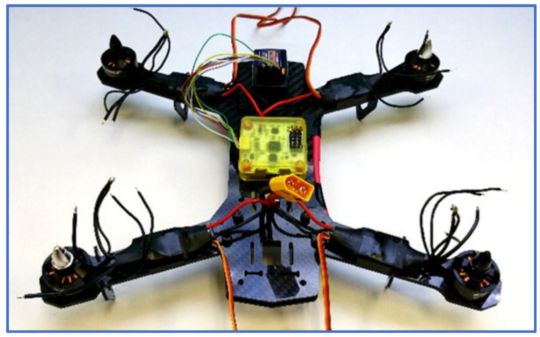
1. Connect the next white wire to channel 2
2. Connect the green wire to channel 1
3. Connect the next blue wire to channel 5
4. Connect the last yellow wire to channel 6

If done correctly, your receiver should look like this:

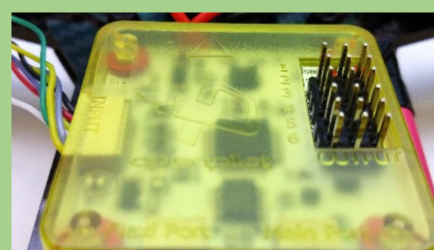


8. Attach the Flight Controller to the Frame

Using a few short piece of double sided foam tape, attach the flight controller and the receiver to the frame. Take care to ensure that the side with the pins is facing up.



Read this!



There is a small arrow embossed on the top face of the flight controller. This arrow denotes the forwards orientation of the quadcopter. It is important that you have the arrow pointing in the direction parallel to the

NEXT UP: Calibrating the Flight Controller

9. Download Software

Using your favorite internet browser, preferably chrome, navigate over to https://www.openpilot.org/. Click on the link to the software downloads located in the dropdown menu Docs & Software.

The flight controller you are using is called the CC3D. At the time of writing this manual, the CC3D flight controller is not supported by the latest version of OpenPilot . As a result, you'll need to download the 15.02.02 version of OpenPilot .

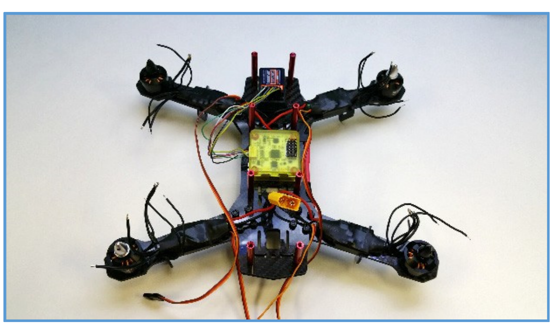
Once you've download OpenPilot , install it on your computer!

Note:

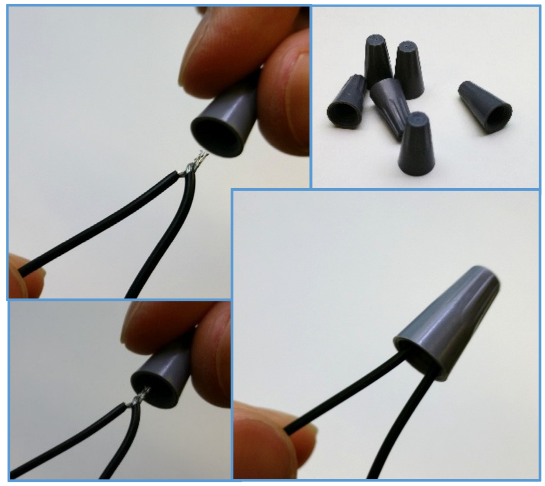
The CC3D may not be currently supported by the latest software release, but watch out for future versions of the software just in case they bring back support!!!

10. Run the Vehicle Setup Wizard

1. Run the OpenPilot software and connect your flight controller to the computer.
2. Once the computer detects the flight controller, click on the vehicle setup wizard button.
3. The software will prompt you to erase all settings and upgrade the firmware. Check the checkbox and click upgrade.
4. After upgrading, click on the next button until you reach the window titled, "OpenPilot Sensor Calibration Procedure". Click on the calculate button and do not touch your quad until the process is completed. Click next when finished.



Using wire nuts to temporarily secure the loose motor/ESC wire pairs. Do this for all remaining wire pairs on each arm of the quad frame.



5. Once all of the loose wire pairs have been secured by the wire nuts, proceed to the next screen on the wizard, the ESC Calibration screen, and run through the instructions.
6. Follow the next few steps in the wizard carefully. Make sure that the propellers are not connected. Then connect the battery.
7. When you arrive at the output calibration screen, you need to move the slider until the motor just starts to spin, not the lowest value that the motor will spin at after it has started spinning.

Attention!

Make sure that your motor is rotating in the correct direction as indicated by the on screen diagram. If you find that your motor is rotating the in wrong direction all you need to do is switch any two (of the three) wires

8. After you ensure each motor is rotating in the correct direction, solder the appropriate wires together.
9. Once you get to the initial tuning screen select the ZMR250 drone profile, click next and press save.

NEXT UP: Calibrating the Transmitter

11. Calibrate the transmitter

Immediately after the vehicle setup wizard, the software will direct you to the transmitter calibration wizard. Make sure that your props are disconnected and your battery is connected. Follow the on screen steps to calibrate the transmitter.

12. Complete the frame!

Attach the red aluminum rods to the frame using the frame screws. Then use the remaining screw to attach the top frame to the quad

13. Attach the Props

Attach the props to your quad. Attach the clockwise props to the black motors and the counter clockwise props to the silver motors.

Clockwise props are indicated by a 5030R embossed on the propeller itself. Counter-Clockwise props have just 5030 embossed on them.

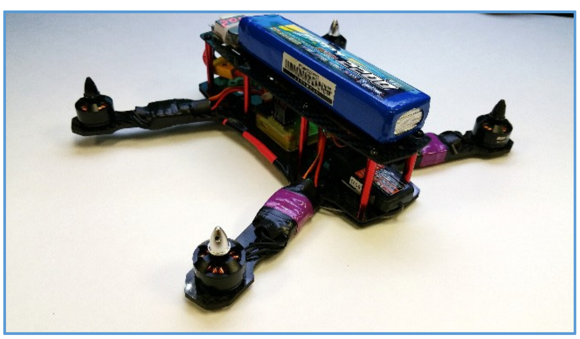
Note:

Silver motors have normal screw threads, as in, right to tighten and left to loosen. Black motors are reverse threaded. Left to tighten and right to loosen.

14. Finishing Touches

A Using a ziptie, attach a Lipo voltage alarm to the front or rear of the quadcopter frame. Use the holes in the frame to secure the ziptie and lipo alarm.

B Use adhesive Velcro strips and attach them to the top of the frame and the battery.



15. You're done, Go fly.