Autonomous Drones with Swarm Capabilities

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Old Dominion University

MAE 434W Project Management and Design I

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Abstract

With numerous applications in civilian and military environments, research into autonomous drone swarms is a growing field. Full autonomous flight of multiple drones flying in close proximity to one another is a difficult task to accomplish; with collision avoidance being the major obstacle to overcome. The purpose of this project was to develop a drone capable of swarm integration. The design of a multi axis positioning and anti-collision system was tested to ensure the effectiveness of the drone's swarm capability. Through the use of Mission Planner and Ardupilot, flight data was collected and drone operation was achieved. The results from the test flights show the capability of self-correcting autonomous drone flight. This drone design model is now ready for further swarm integration and testing.

Introduction

Unmanned aerial vehicles (UAVs), or drones, are becoming a key part of daily life for many people around the world. From the military to medicine to routine package delivery, drones are being researched for many different industries. Currently, the non-military drone industry is worth more than 2.5 billion dollars, and is continuing to grow. Drones are used industrially most often for photography and filming, but are also being developed to carry cargo to deliver information and supplies [1].

Drones are not a new development. The first wirelessly operated flying vehicle was the “Hewitt-Sperry Automatic Airplane” developed in 1917. The first drones in the military were test flown before World War 2 by Great Britain in 1935 and the United States in 1937. In fact, the word “drone” comes from the “Target drone” which was thought to be named by the US as word play after the development of the “Queen Bee” by the British. However, it took until 2001 to develop a UAV that could achieve full autonomous control. With drones that were able to operate fully autonomously, we are now able to achieve drone swarming, a procedure in which autonomous drones use sensors, GPS trackers, and other systems to fly in a group without collision. [2]

Drone swarming serves many purposes in many different industries. For the military, drone swarms are preferred over manned vehicles as drone swarms are cheap and much more expendable than human beings. They are also much faster to deploy than manned vehicles, and can be used for weapons, communication, battle damage assessments, and strategic planning. [3] In non-militaristic settings, drone swarms also have many uses. For example, drone swarms can be used in disaster settings to deliver medical supplies to people in need or identify missing people in the wreckage. UAVs can also deliver supplies much more quickly, especially in urban environments where high traffic impacts the response time of emergency vehicles. Currently, research is being done on drones delivering automated external defibrillators to patients in cardiac arrest, which is a situation where just a few minutes saved in response time can mean the difference between life and death. [4] Drone swarming can also be used in non-emergency, everyday scenarios such as for package delivery. Using drones to deliver packages as opposed to human delivery drivers is not only quicker, cheaper, and more convenient, but also more environmentally friendly as many drones are electric and do not rely on expensive and CO_2-producing gasoline. Drones also provide safety from contamination, so they can be used to safely and conveniently deliver at-home tests to people in quarantine. Shipping companies like USPS and FedEx can also take advantage of drone delivery, especially in rural or remote locations where delivering mail and packages via human drivers is inconvenient and expensive. Single drone usage can be used for delivering mail and single, small packages, however drone swarms are required for delivering heavy packages and/or multiple items to one location to distribute the load and prevent individual drone failure. [5] The purpose of this project is to research autonomous drone swarming, which is not an easy task to accomplish and is still under much development in the industrial and militaristic world. Autonomous swarming requires the coordination of multiple sensors and systems to avoid collisions with nature, obstacles, and one another. Our team is working on the building of two drones to swarm to understand and optimize the process.

	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resour
1		**Autonomous Swarm Drone**	**166 days?**	**Fri 9/9/22**	**Fri 4/28/23**		
2		**I. Research Aurdo-Pilot/Copter**	**166 days?**	**Fri 9/9/22**	**Fri 4/28/23**		
3		**II. Collaborate with instructors weekly**	**166 days?**	**Fri 9/9/22**	**Fri 4/28/23**		
4		A. Meet with advisor	166 days	Mon 5/1/23	Mon 12/18/2	6,13,19,23,26,29,	
5		B. Meet with ODU Drone Club	149 days	Mon 5/1/23	Thu 11/23/23	6,32,29,35	
6		**III. Materials**	**11 days?**	**Fri 9/23/22**	**Fri 10/7/22**	**23,29,32,13,19,3**	
7		A. Frame	11 days	Fri 9/23/22	Fri 10/7/22		
8		B. Motors	11 days	Fri 9/23/22	Fri 10/7/22		
9		C. Propellers	11 days	Fri 9/23/22	Fri 10/7/22		
10		D. Speed Controllers	11 days	Fri 9/23/22	Fri 10/7/22		
11		E. GPS	11 days	Fri 9/23/22	Fri 10/7/22		
12		F. Blade Guards	11 days	Fri 9/23/22	Fri 10/7/22		
13		**IV. Budget**	**16 days?**	**Fri 10/7/22**	**Fri 10/28/22**	**23,26,29,32,35**	
14		A. Smart Transmitter/Receiver	16 days	Fri 10/7/22	Fri 10/28/22		
15		B. Cube Orange Pixhawk	16 days	Fri 10/7/22	Fri 10/28/22		
16		C. Battery/ Battery Charger	16 days	Fri 10/7/22	Fri 10/28/22		
17		D. Sensors	16 days	Fri 10/7/22	Fri 10/28/22		
18		E. Replacement Parts	16 days	Fri 10/7/22	Fri 10/28/22		
19		**V. Sensors**	**16 days?**	**Fri 9/30/22**	**Fri 10/21/22**	**13,23,26,29,32**	
20		A. Optical Flow/ Hear Flow	16 days	Fri 9/30/22	Fri 10/21/22		
21		B. Non-GPS Navigation	16 days	Fri 9/30/22	Fri 10/21/22		
22		C. Object Avoidance	16 days	Fri 9/30/22	Fri 10/21/22		
23		**VI. Software**	**16 days?**	**Fri 10/28/22**	**Fri 11/18/22**	**26,29,32,35**	
24		A. Mission Planner	16 days	Fri 10/28/22	Fri 11/18/22		
25		B. Q-Ground Control	16 days	Fri 10/28/22	Fri 11/18/22		
26		**VII. Drone Schematics**	**11 days?**	**Fri 10/28/22**	**Fri 11/11/22**	**29,32,35**	
27		A. Brush Motors	11 days	Fri 10/28/22	Fri 11/11/22		
28		B. Brushless Motors	11 days	Fri 10/28/22	Fri 11/11/22		
29		**VIII. Prototype**	**26 days?**	**Fri 11/11/22**	**Fri 12/16/22**		
30		A. Assmebly	12 days	Mon 5/1/23	Tue 5/16/23	31,32,35	
31		B. Pre-Test	15 days	Mon 5/1/23	Fri 5/19/23	32,35	
32		**IX. Flight Testing**	**40 days?**	**Mon 1/9/23**	**Fri 3/3/23**	**35**	
33		A. Indoor	19 days	Mon 1/9/23	Thu 2/2/23		
34		B. Outdoor	22 days	Thu 2/2/23	Fri 3/3/23		
35		**X. Final**	**11 days**	**Fri 4/14/23**	**Fri 4/28/23**		
36		A. Demonstation					
37		B. Presentation					

GANTT CHART

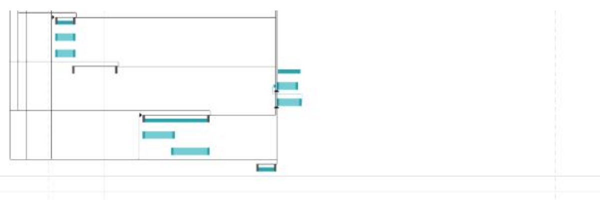

Table (1)

Methods

Materials

In this project, a preconstructed drone with the base set of parts was provided. This includes the base frame of a quadcopter drone that would have 4 propellers and motors. Additionally, 4 speed controllers were already incorporated into the drone as well. One Cube Orange autopilot flight controller was provided, this would act as "the motherboard" of the drone responsible for connecting the sensors and drone parts and allowing the drone to function as a whole. This is shown in Figure 11, where each component of the drone is wired into the Cube Orange, including the respective sensors, GPS, battery, and additional parts listed in the figure and will be further discussed in sensors and coding. The drone was also provided with a Radiolink GPS which would allow for flight control, destination, and location tracking using the Ardupilot software [6]. Finally, a Tattu 5200 mAh battery is provided with the drone. The battery is an effective option as it efficiently outputs power to the drone and therefore would allow for approximately 20 minutes of uninterrupted flight time.

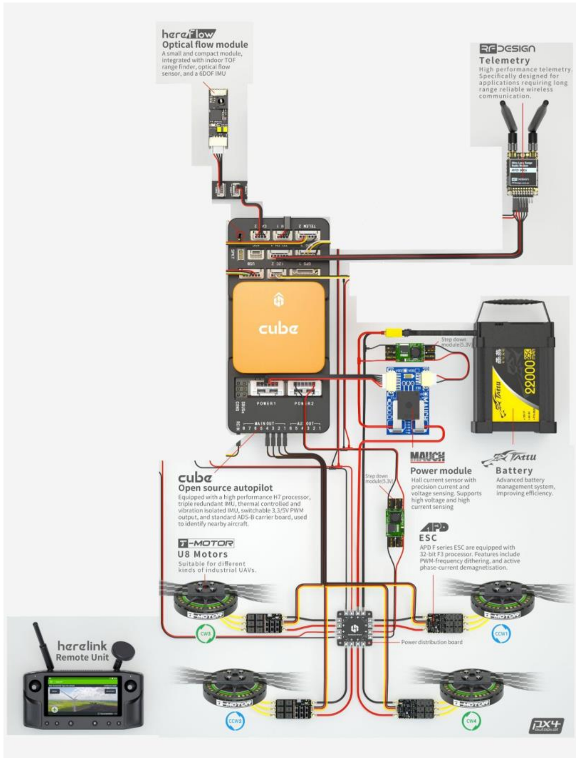

Figure 12. Cube Orange with Attachments

Sensors and Coding

Ardulpilot is the most prominent software that is utilized in drone flight and coding for this specific project. Ardupilot software will be downloaded onto the Pixhawk in order for specific functions to be enabled. Mission Planner will be utilized alongside Ardupilot so that the drone can be monitored while in flight. Mission Planner will show mission logs, the drone’s location, and will allow for loading of autonomous missions. An example of this is shown in figure 18.

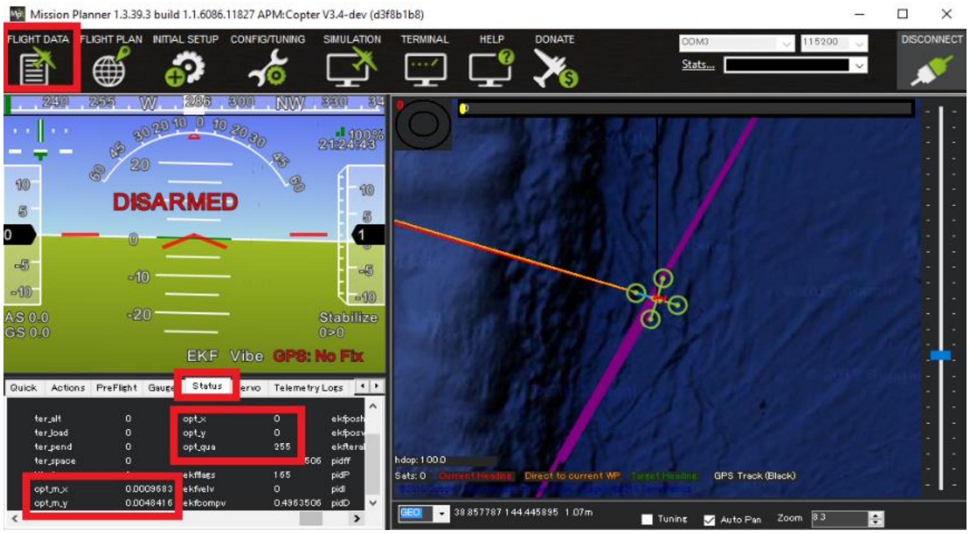

Figure 7. Mission Planner with Highlighted Status of Drone

The primary drone being constructed is still in its early stages of development, and does not have all the sensors to accomplish the goal set for this project. Several other sensors that will be included in the drone construction include the rob sense, the sonar rangefinder, and the hereflow. These sensors are listed as Figures 3-6 below.

Figure 3. Cube Orange

Figure 4. Robsense

Figure 5. Sonar Rangefinder

Figure 6. Hereflow Sensor

Design and Construction

In terms of design and build, the project guidelines strictly followed a quad frame build of the main drone. As most of the materials were provided to the team for the initial drone, AutoCAD or other modeling software were not necessarily required. Instead, most sensors and parts were ordered and will be utilized in the final construction of the drone. The drone frame is initially desoldered from the top and bottom circuit plates that would connect with several wires. The top plate of the drone would house the Cube Orange resting right on it. The GPS sensor will need to be placed outside of the drone frame facing upward in order to make proper contact with our Mission Planner.

Engineering Standards

1. Safety
    a. The Recreational UAS Safety Test (TRUST)

The Federal Aviation Administration provides guidelines for fliers that are looking to man a UAV for recreational purposes in certain environments. This also serves as a safety measure for the public in case any form of drone flight does prove to be of any harm. TRUST is a law that requires all recreational fliers pass an aeronautical knowledge and safety test and provide proof of passage if asked by law enforcement or FAA personnel. If an individual's drone weighs more than .55 lbs, it must be registered through the FAA. [7]

b. ASME & IEEE Safety Codes & Standards

There are a wide range of safety measurements and standards put into place by both the American Society of Mechanical Engineers and the Institute of Electrical and Electronics Engineers. This includes ethical guidelines that serve to ensure projects that engineers take part in are moral and whether those products they put out are safe to the public. In regards to this project, certain safety codes include, but are not limited to, the Mobile Unmanned Systems rules which sets guidelines for engineers in the inspection, maintenance, and repair of UAVs to ensure the health and safety of its owners that fly them. [8] The IEEE follows similar guidelines and regulations and provides descriptions of maintenance procedures for electronic circuit boards and other electrical parts that should be safe for the environment when utilized in the construction of products. [8]

2. Restrictions

a. Flight

For recreational fliers, there are strict rules and regulations set by the FAA to ensure the safety of others and the flier. This includes No Drone Zones and certain Airspace restrictions. Drone flights are strictly prohibited in areas such as stadiums & sporting events, airports, military bases, national landmarks, critical infrastructure such as power plants, and Washington, DC. [8]

Results

Our expected results are determined through UAV Log Viewer using a drone provided by the graduate project assistant that has a design similar to that we wish to create. The tests shown were conducted at the ODU Football Stadium. Within Table (1), we can see that the desired sensor for gravity is -9.81 m/s^2. This is because anything less or more will cause the drone to make corrections that are unneeded. For example, if the gravity was determined to be 0 m/s^2, then the drone would fly away and ultimately crash. The analysis also shows that the vertical acceleration (GPS.VZ) is having a mean value of -0.00 in Table (2). This is due to the vertical acceleration being 0 as the drone hovers in place. In Table (3), the graph shows that the drone's mean altitude is 6.07 meters from sea level. This shows the height that the drone was capable of consistently hovering at, as shown in Figure 17.

Figure 19. Drone Flight in UAV Log Viewer

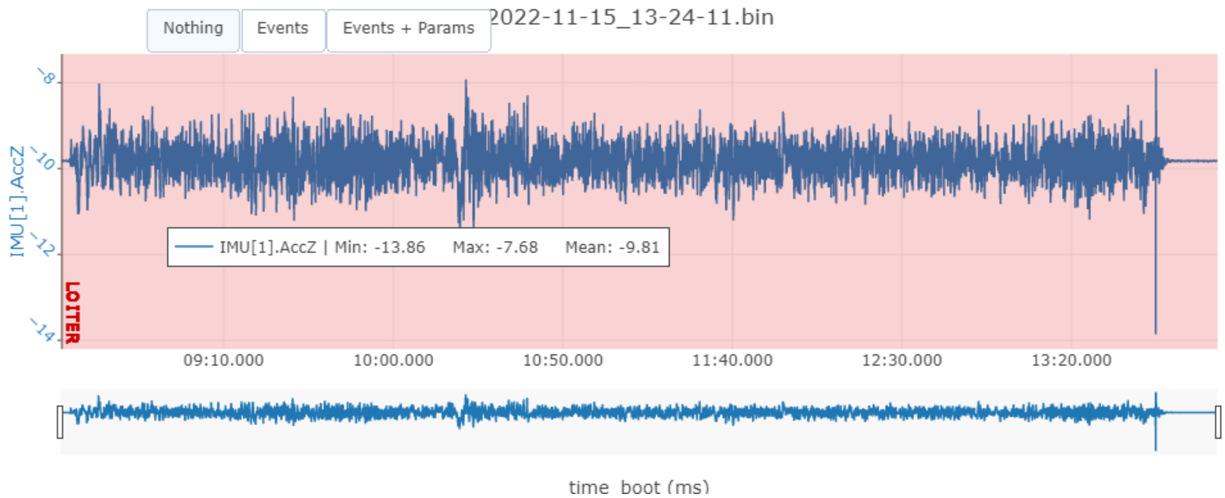

Table (1) Gravity Analysis

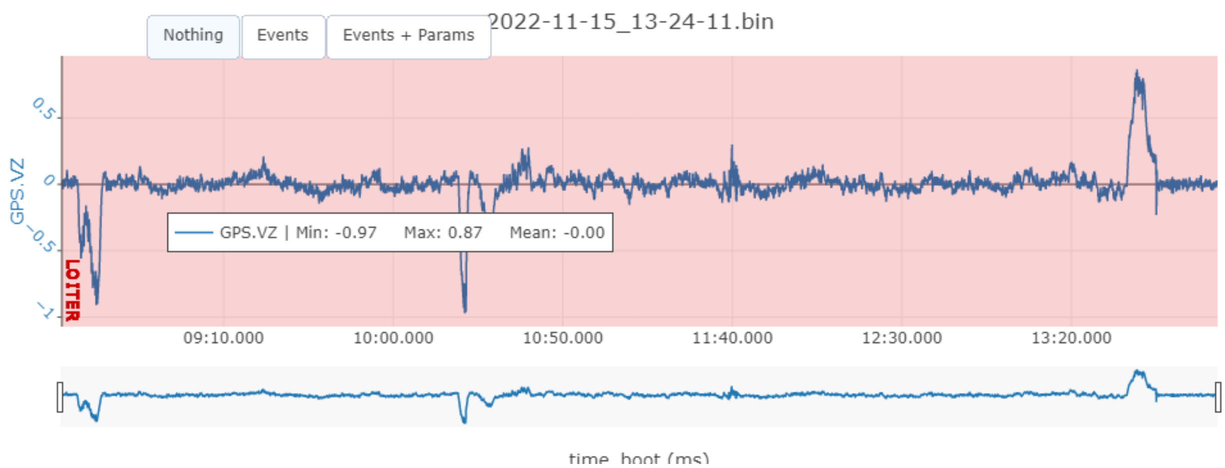

Table (2) Vertical Acceleration

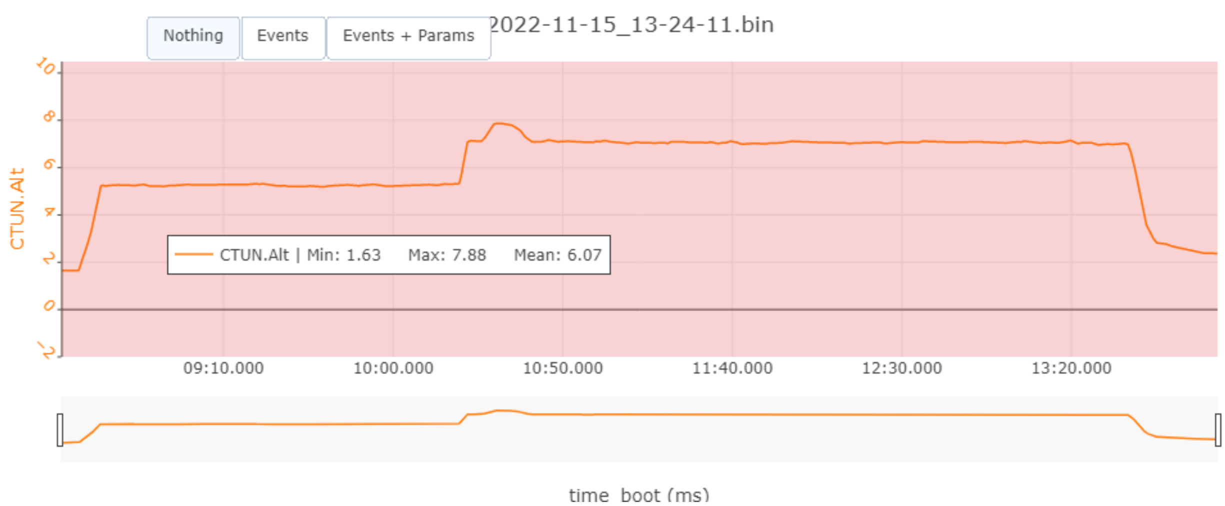

Table (3) Altitude Analysis

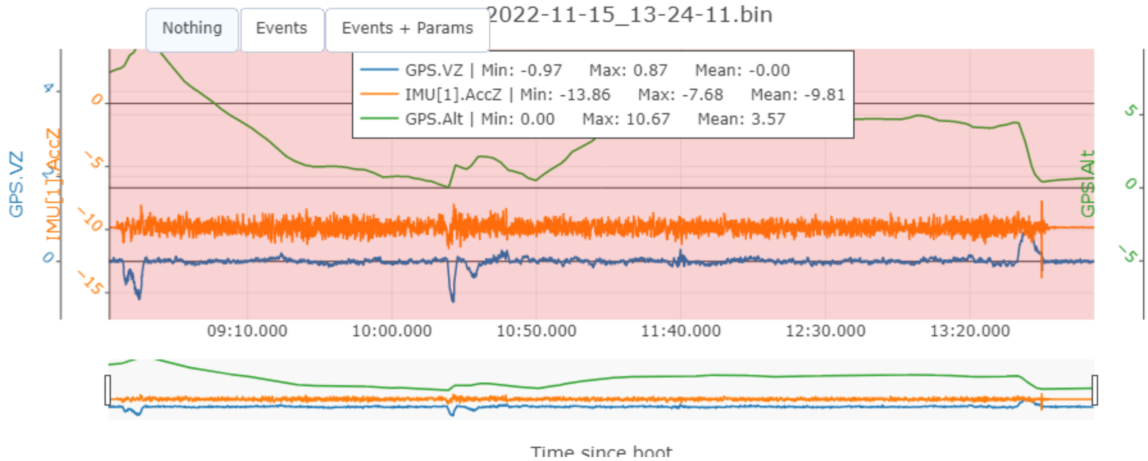

Table (4) Full Analysis

Discussion

Table (5)To demonstrate the swarm capabilities of our drones we are planning to start out by designing one drone to run and fly fully autonomously both indoors and outdoors. We have agreed to make one fully functional drone before we make the swarm to give us time to figure out everything and iron out the kinks of the process as well as allowing us to save some of our budget so that when we have one autonomous drone we know exactly what we need to spend our funding on. We plan on having our drones fly indoors and outdoors to have more flexibility while conducting our tests since it can be hard to have outdoor flight since a lot of the area around us is a restricted flying area. Our graduate project assistant, Rob Stewart, has helped us identify flight sensors that we could attach to our Cube Orange to provide safe and operable autonomous flying both indoors and outdoors environments.

Next we needed to research and decide on the parts that will allow our drone to achieve the goals mentioned above. Fortunately spare drone parts such as the frame, power distribution board, motors, speed controllers, props, and GPS were provided for use. Knowing what we had and after researching additional parts that are needed to complete the drone we needed to purchase a Cube Orange, battery, range finder, and hereflow sensor. The HereFlow and rangefinder sensors will allow the drone to be able to fly indoors while also allowing for more accurate positioning flying outdoors. The Cube Orange is the brains of the drone and will be able to process and compute the information from the sensors adequately in real time. After obtaining these parts the drone will be able to be fully built and ready for the ardupilot system integration.

Since we have not fully built our own drone, our graduate project assistant Rob Stewart allowed us to fly one of his own drones at the ODU stadium. Although the drone Rob was allowing us to use could fly autonomously, we manually operated it. This practice flight got our team acquainted with how to operate a drone as well as allowing us to get a better sense of how long we could fly a drone due to the battery capabilities. This flight also gave us the opportunity to look at and mess around with the UAV Logger View Program that we will be using with our own drones to track the data of our flights. When we ran the tests we were able to make the drone take off, hover and land safely. By next semester when we have our own drones built we should be able to run the exact same test but without operating the drones manually.

Currently we are completing the drone build with the parts already acquired. We have made wire connectors and extensions to power the sensors and cleaned and attached the frame, power board, motors, speed controllers, and props. We have been able to do this by stripping wires and adding the new connectors to them so that they will be compatible with the desired sensors as well as soldering the wires to the power board for the correct distribution of power. This knowledge and experience will allow us to build out the rest of the drone quickly and efficiently once the additional parts arrive. Also, every member of the team will know how to fix the drone in the inevitable event of a crash so we can focus on perfecting the autonomy and then integrating the swarm capabilities next semester.

Conclusion

During our project, our team has been able to acquire a deep understanding of the requirements needed to not only make an autonomously piloted drone swarm work, but what is required to build and assemble one as well. Our team has made sure to cover all bases of operation needed for a fully functional drone swarm, from proper wiring and soldering to a deep understanding of the programs needed for the drones to be able to communicate with each other. Our team understands that with the many applications autonomous drones possess, we must do our best to ensure that the drones we construct are not only able to function properly, but are also capable of performing the tasks that we assign them. (WIP)

References

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Appendix

Fig. 1 Battery to charge the drone.

Fig. 2 Propellers for Drone

Fig. 3 Cube Orange that is the brain of the drone.

Fig. 4 Robsense sensor to allow for indoor and more accurate outdoor flight.

Fig. 5 Sonar range finder to allow the drone to fly outdoors on its own.

Fig. 6 Hereflow sensor to allow for indoor and more accurate outdoor flight.

Fig. 7 Image of what mission planner software looks like.

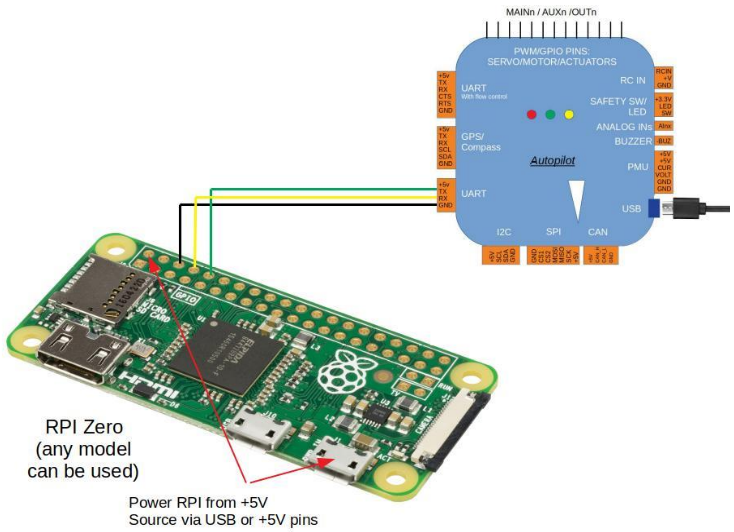

Fig. 8 Image of the circuit that reads outputs from the ardupilot

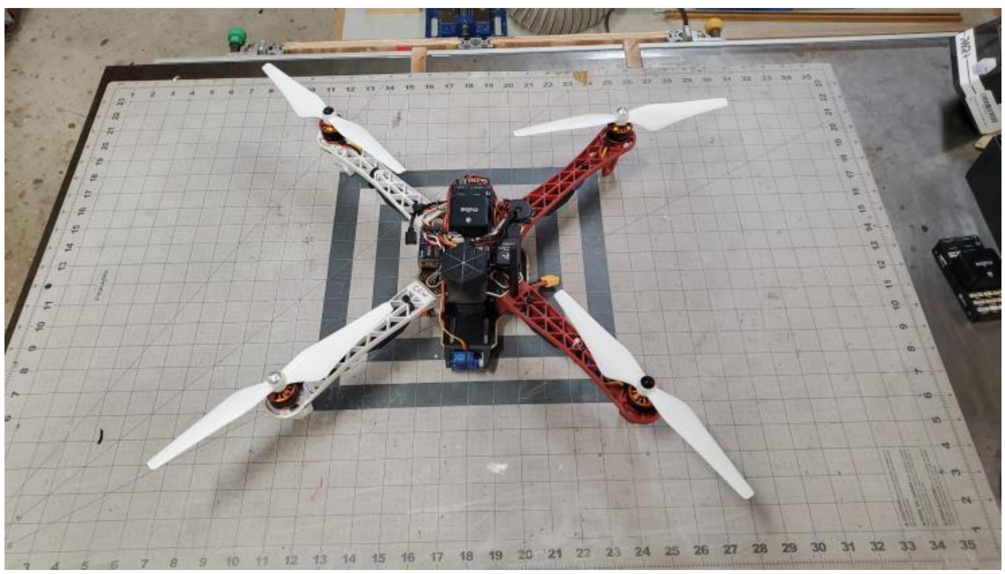

Fig. 10 Image of the drone.

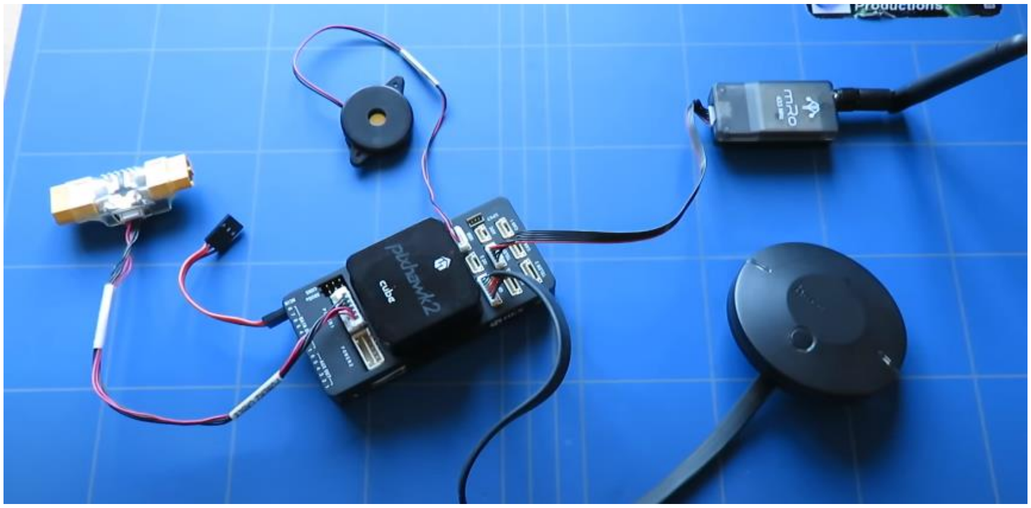

Fig. 11 Image of what the cube orange will look like with the sensors connected.

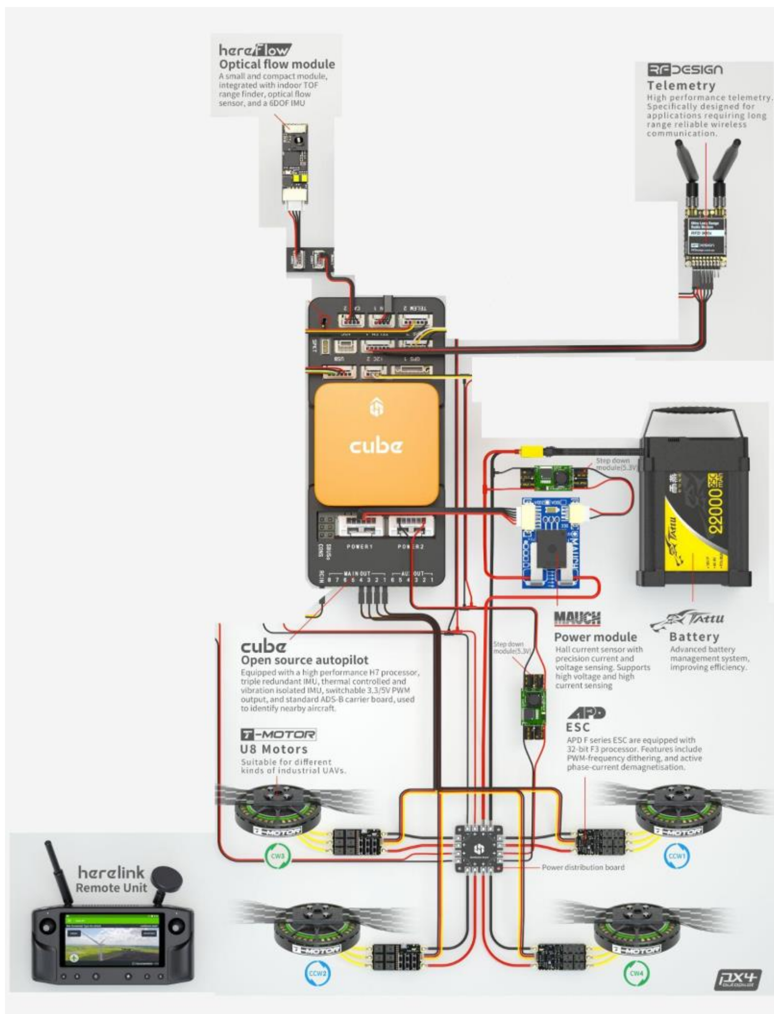

Fig. 12 Example diagram of the cube orange and all the sensors that plug into the cube orange in order to safely operate the drone.

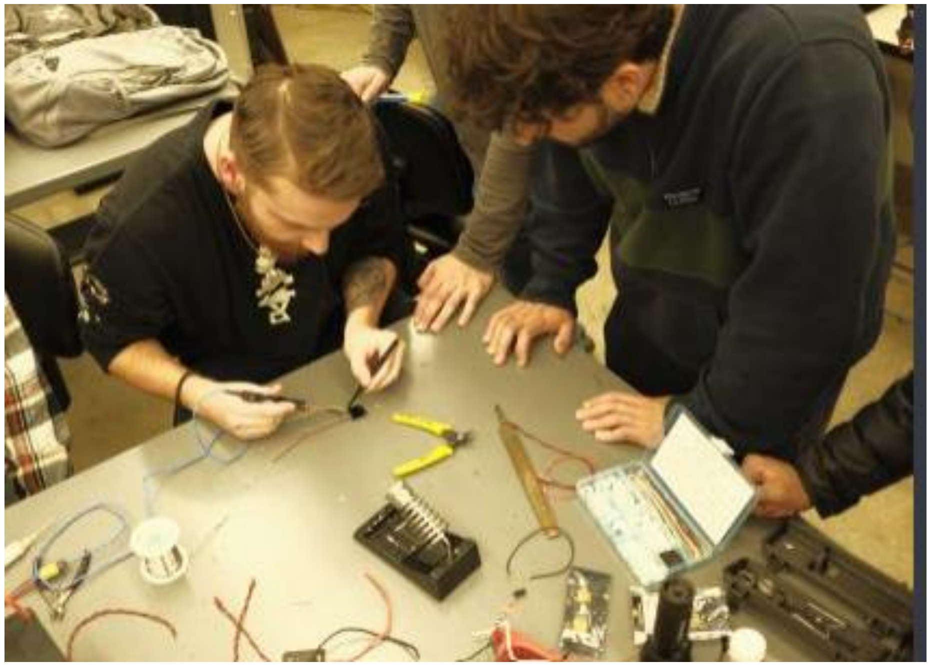

Fig. 13 Two team members learning how to solder components.

Fig. 14 A group of students gather around while our team leader launches a drone while one in the background gets ready to operate it in flight.

Fig. 15 Team stands by as one member gets practice flying a drone at the stadium.

Fig. 16 Team member learning and perfecting soldering.

Fig. 17 Team member putting her newly found soldering skills to use .

Fig. 18 Image of our end goal which is several drones flying in a swarm

Fig. 19 Using ardupilot mission planner this image shows our practice flight and data recorded at the ODU stadium.

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