Palos Verdes High School

PVIT UAV TEAM

2018 SUAS Competition

Abstract

This technical design paper is a compilation of the processes conducted by the PVIT UAV Team for the AUVSI Student UAS Competition 2018. The Palos Verdes Institute of Technology (PVIT) Unmanned Aerial Vehicle (UAV) team is comprised of 8 high school students from Palos Verdes High School (PVHS), as well as a faculty advisors and an industry mentor. This document covers the system engineering approach, system design, and safety procedures that were used and will be used for the Condor II. Enhancing upon the hexacopter Condor I (the UAV used in the 2017 competition), the team launches a more powerful (1) octocopter featuring optimized propulsion, improved autonomous guidance, and longer flight time. Through extensive analysis of the previous platform, the new system was systematically designed to include a (2) custom-designed server-connected navigation, detection and avoidance ground-based Automated Mission Planner (AMP), (3) 3D printed parts for aerial delivery, an (4) enhanced longer distance antenna system with automated ground antenna-tracker, and (5) a test-bed for a future object recognition system. All differences between the Condor I and the Condor II have led to advancements in the mission demonstration for AUVSI's SUAS Competition 2018. Additionally, a test platform, the Condor Mini quadcopter, was developed to test individual components before implementing them on Condor II.

1.Systems Engineering Approach

The Condor II is designed, assembled, and tested to perform an autonomous fire extinguishing mission within the parameters of the AUVSI SUAS competition all while prioritizing safety. The system is designed to execute autonomous flight, object avoidance, and air delivery.

1.1Requirement Analysis

The team broke up the requirements by priority and difficulty to evaluate and focus on the best approach to reach the highest possible score.

Table 1

Task	**Description**	**Priority (1=High)**	**Difficulty (1=Hard)**	**Percent of Total**
Timeline (10%)	• Setup Time • Mission Time (80%) • Timeout (20%)	1	3	6%
Autonomous Flight (30%)	• Autonomous Flight (40%) • Waypoint Capture (10%) • Waypoint Accuracy (50%) • Out of Bounds Penalty (-10%) • TFOA (-25%) • Crash Penalty (-35%)	1	2	18%
Obstacle Avoidance (20%)	• Stationary Obstacle Avoidance (50%) • Moving Obstacle Avoidance (50%)	1	1	12%
Object Detection, Classification, Localization (20%)	• Characteristics (20%) • Geolocation (30%) • Actionable (30%) • Autonomy (20%)	2	1	12%
Air Delivery (10%)	• *max*(0, (150*ft-distance*)/150*ft*)	1	2	6%
Operational Excellence (10%)	• Professionalism • Team Communication • Reaction to System Failures • Attention to Safety	1	2	6%

1.2Design Rationale

The team is composed entirely of high schoolers: three freshmen, three sophomores, and two juniors. All of the members continuously devote their weekends and often weekdays in order to propel the team forward. Depending on the work needed to be done that weeked, more or less time is devoted into the creation of the copter throughout the week.

After last year's failed attempt of Condor I at the AUVSI SUAS 2017 Competition due to limited flight time, communication loss, and manual mission planning, the team sincerely reconsidered the benefits and detriments to the hexacopter. Thus, Condor II is completely redesigned to better complete the tasks that the team's previous drone could not. PVIT UAV's new drone, Condor II, is now an octocopter and will help the team efficiently execute desired tasks. The octocopter possesses many new devices that are attached in order to instill both a safe and efficient flight of copter. According to the team's calculations related to the weight of the vehicle, octocopters are more efficient and more stable than different sized copters, like last year's hexacopter. The octocopter increases the capacity of weight allowed onto the drone, while maintaining stability and safety.

The eight man team is broken into three sub groups: hardware, software, and mechanical. There is a team leader, two members dedicated to hardware, three focused on mechanical, and two other team members working on software. The hardware team is focused on improving the drone itself from last year including, but not limited to, the frame, battery, gps, and flight controller using an improved pixhawk. The members working on the mechanical portion are in charge of the moving parts, specifically the a new drop mechanism and a new antenna tracker. The two working on software are creating a new Automated Mission Planner program (AMP) for connection with the ground server, providing object avoidance and the link to the ground station.

Before assembling and testing Condor II, the team's performance in the 2017 flight demonstration was evaluated and the Condor II was built learning from successful teams of that year. PVIT UAV decided to upgrade most of the UAV's main components: the pixhawk flight controller for stability, the batteries for duration, and customized air delivery. The team also improved connections to the ground station by running multiple wireless connections through one wireless internet connection. In addition to these changes the drone was switched to a much larger octocopter frame as opposed to the obsolete hexacopter of the past for greater payload capacity.

As the main foundation, the PVIT UAV team's key objectives this year are to accomplish priority 1 mission objectives. As mentioned above, different tasks are allocated to different people, allowing for the group to efficiently work on multiple parts of the competition at once. Given the large amount of work needs to be done and efficiently implemented, the team works diligently and effectively to complete the redesigned copter.

2.System Design

2.1Aircraft

The vehicle, Condor II, is built using the Tarot Iron Man 1000 frame (Figure 2) built of carbon fiber. The team came to a conclusion based on other teams' past successes with octocopters (specifically the Iron Man 1000 frame) and decided upon this frame in order to possess the optimal weight capacity, speed, and efficiency. The Iron Man 1000 is an octocopter frame with an approximate weight of 1.6 kg and stands 380 cm tall. Because of the high complexity of the frame, it poses a high resistance to the vibrations created by the motors.

Figure 1

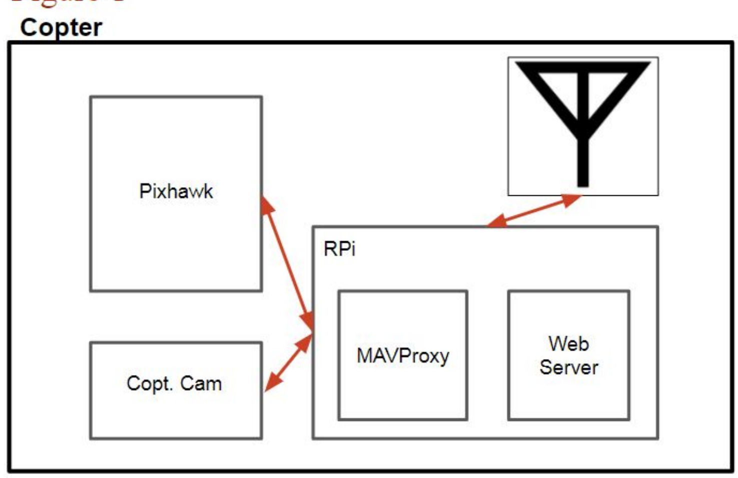
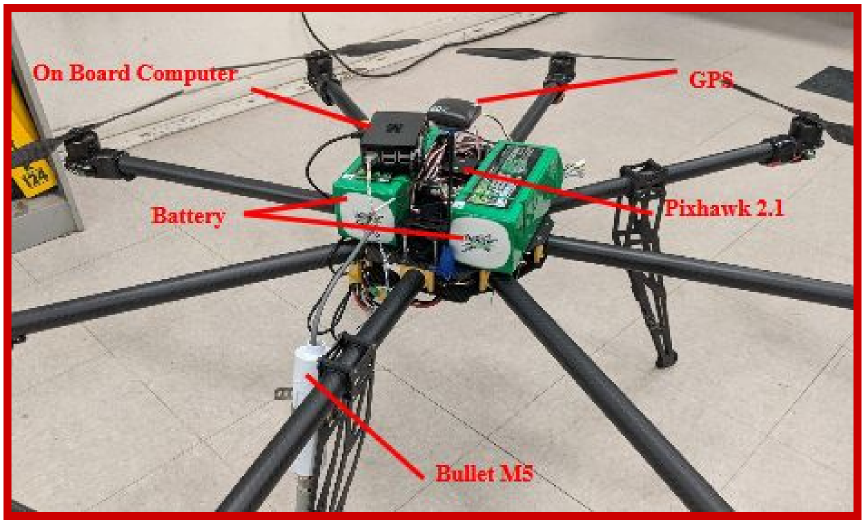


Figure 2



Using the provided weight of items from sellers, the team complete this mass budget (later confirmed by weighing the assembled UAV) to help influence later decisions like the choice of motors and propellers. These devices are crucial to the seamless flight of the copter.

Table 2: Mass Budget

Item	Number on UAV	Weight of each (lbs)	Total weight (lbs)	Item	Number on UAV	Weight of each (lbs)	Total weight (lbs)
Pixhawk 2.1	1	0.08	0.08	Motors	8	0.3696	2.96
Raspberry Pi	1	0.1	0.1	Bottle	1	0.5	0.5
Raspberry Pi camera	1	0.07	0.07	Propellers	8	0.1	0.8
Wifi Bullet	1	0.4	0.4	Power distribution board	1	0.1	0.1
GPS	1	0.02	0.02	Drop mechanism	1	0.5	0.5
Frame	1	3.53	3.53	ESC	8	0.0572	0.46
Batteries	2	3.35	6.7	RC air	1	0.02	0.02
Wifi air omni	1	0.1	0.1	DF13 cables	1	0.02	0.02
Dog collar	1	0.5	0.5	other small parts	N/A	3.87	3.87

	Total	Weight :	20.67	lbs

With the addition of a new frame, the team purchased both new motors and propellers to accommodate the size and weight of an octocopter. One of the first trades considered was the choice of motor and propeller, as these parts are crucial to the implementation of a successful mission.

Table 2 and Table 3 was created based on information from the seller and manufacturer in order to decide upon the most ideal purchase. After completing the mass budget of the UAV, the team calculated that the needed thrust from each motor would need to be around 1.5 kilograms. Using this weight and provided information from the manufacturer, the group determined the thrust of each possible combination of motors and propellers options.

Table 3: Motor and Propeller Choice Trade

Item	option #1	option #2	option #3	option #4
Motor	Tarot 5008	Tarot 5008	Tarot 4114	Tarot 4008
Motor cost	$515	$398.75	$340	$360.04
Propellers	1660	TL2822	TL2812	TL2813
Propeller cost	$388	$374.32	$284.10	$284.10
Propeller diameter (in)	16	18	15	15
Pitch	6	5.5	5	5
Thrust (g)	1400.9	3010	1500	1740
Total cost	$1018.6	$938.6	$744.73	$685.98

After comparing the positives and negatives of each combination, the team reached a consensus on the Tarot 4114 and the Tarot TL2812 (1550 fixed paddle) propellers, as they were the best choice (Table 3). The conclusion was reached based on the parts' success of other past teams and the fact that the propellers are the most cost efficient fit to the Ironman 1000 frame.

Table 4: Specifications of The Tarot 4114 and TL2812

Thrust (Kg)	Voltage (V)	Current (A)	RPM	g/W	W/Kg
1.0	25	5.2	4370	7.69	130.00
1.5	25	7.4	5045	8.11	123.33

The hardware team calculated raw data and determined the necessary battery capacity to fly effectively. Using an estimated flight time of 30 minutes, the team budgeted the power usage of the flight to ensure that the UAV had enough power to last a flight of that length. Using a voltage of 20V and an estimated energy total of 2106900J (based off weight and flight time) the group determined the needed battery capacity to be 29262.5mAh. The needed battery capacity is about 1.8 of our two 16000mAh batteries.

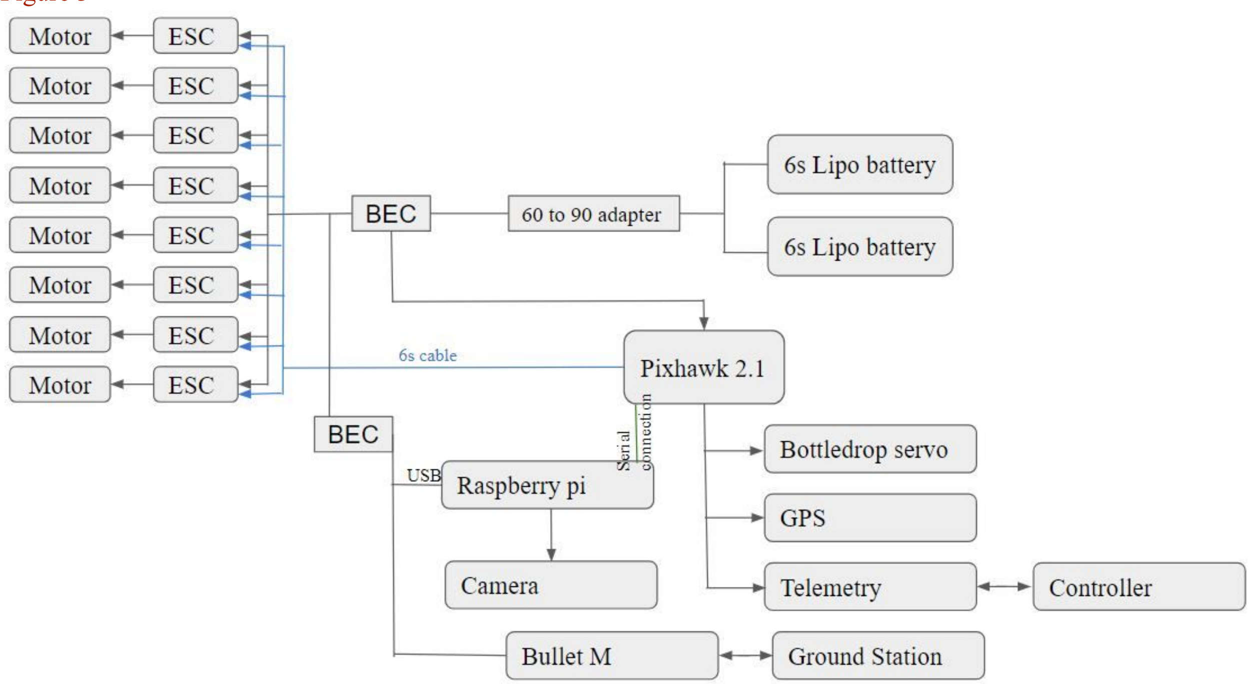
Table 5: Electrical Budget

Item		Units
Flight time	1800	s
Energy	2106900	J
Voltage	20	V

Capacity needed	29262.5	mAh
Battery size	16000	mAh
Batteries	1.82890625	

Throughout last year's attempt, the team did not possess many crucial devices, such as the raspberry pi and a second battery. In addition, the team struggled with connection loss from the ground station to the copter. The new improvements to the drone made by the team required a complete redesign of the electrical diagram. Now, the Condor II is powered by two 16000mAh batteries which are attached to the first BEC connector which splits off some power to the pixhawk. The majority of power continues to a second BEC which splits power to the raspberry pi and bullet. The remaining power goes to the eight 4114 tarot motors. The raspberry pi and pixhawk also power devices like the camera, bottledrop servo, GPS, and telemetry. In addition to the connection between the batteries and motors, the pixhawk is also connected to the ESC to control the flight. A diagram of the system is shown in Figure 3.

Figure 3



The PVIT UAV team had not previously attempted object-recognition and interoperability (including obstacle avoidance) due to a lack of onboard computing power. This year, the team attaches a Raspberry Pi to function as the onboard computer. The Raspberry Pi is communicating with the Pixhawk via the Telemetry 2 Port on the Pixhawk 2. The hardware team then connects a Ubiquiti 5G wifi antenna system to the Raspberry Pi, which communicates with the ground station. With the team's new antenna system, the team is able to achieve many more data transmission capabilities, including MAVlink command and telemetry, camera, and computer. The team can then send information to the onboard computer to enhance copter control. Along with MAVLink data, PVIT UAV uses the wifi antenna system for future object-recognition systems.

2.2Air delivery

The air delivery system has two parts: the payload and the drop mechanism. The payload is the portion attached to the 6 ounce water bottle to break and release the water. The drop mechanism is used to release the water bottle at the appropriate position. After a couple tests from approximately 50 feet up, it was determined that the water bottle without a payload was capable of breaking on both grass and asphalt. However it could not break on turf, and other options were given more attention for this reason. Table 6 shows the trades made between different payload designs. Ultimately the dog collar design was chosen.

Table 6: Water Bottle Drop Trade

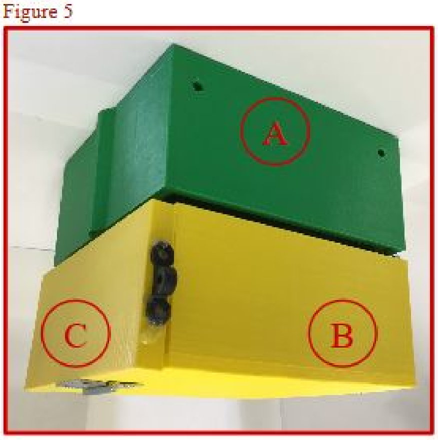
Traits	Iron Maiden	Guillotine	Acorn	Dog Collar	None
Safety	poor	fair	fair	exceptional	exceptional
Size	bulky	bulky	bulky	small, compact	only bottle
Weight	10 ounces	7 ounces	6 ounces	7 ounces	0 ounces
Destructive Power	exceptional	exceptional	fair	exceptional	fair
Complexity	over-complex	fair	over-complex	simple	simple
Test results (rate of success)	90%	70%	60%	90%	60%

The water bottle has a metal dog choke collar around its side. This collar is designed to have dull, but damaging tips. This gives the water bottle a better chance of being torn, instead of sliced on impact. Due to the nature of the drop mechanism (the bottle slides out of the box) the bottle will begin to spin when it starts to fall. The spin in addition to the heftiness of the dog collar and the approximate 8 ounce weight will increase the chance of it landing on the side of the bottle with the label, the proper side (see Figure 4). This is the proper side because if the collar makes impact on the ground first, its prongs will be forced up into the bottle, tearing it open. When the team tested this and the dog collar made impact first, it made a significant tear in the bottle 100% of the time. However, occasionally when the collar does not hit the ground first, little to no damage is done. This is due to the collar's weight being unevenly balanced on all sides of the bottle when not spinning, causing it to land on either the cap or bottom of the bottle.

Figure 4

The drop mechanism provides a way for the payload to easily attach and be released from the drone. The mechanism is a box comprised of three parts. Part A is half a box (a hollow cube cut in half) with a long cylindrical puncture for a small metal rod. Part B is the other half to the box, identical to the first except the side is missing that lines up with the side of part A that has the hole for the rod. The two halves are attached by a hinge. Part C fits into this empty side in part B, with a hole for the rod. This piece is attached to part B by a hinge, but is not directly attached to part A. Part A and part C are attached by the rod. Part C is there to ensure the payload doesn't get caught on the sides of Part B because if the drop mechanism only had two parts there is a chance the collar could get caught on the sides of Part B, because part B does not fold all the way back, rather it falls perpendicular to part A when it is released. The top piece (Part A) will have a small servo motor attached to it. The rod will be attached do the servo. This is the rod that will be fit down the two holes in parts A and C so that the box is held together and the hinges are not able to move. When over the drop zone the the rod is pulled out via servo, causing the rod to be released from the hole in Part C,

Figure 5



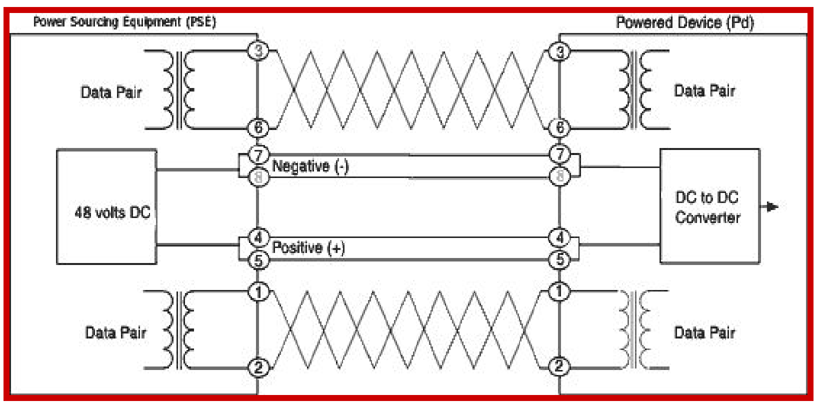
therefore allowing both hinges to turn and the bottom of the box open so the payload can drop.

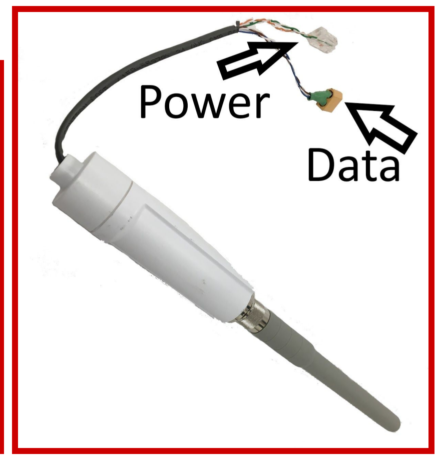
The team conducted numerous trials on the drop mechanism, in order to test the durability and the efficiency of the device. These tests were conducted on various surfaces including turf grass, average lawn grass, and asphalt. Every test conducted resulted in a success, as the bottle was penetrated, and the box remained intact. Modification to the device were applied throughout the year, yet these were purely to increase the efficiency and durability of the device, as the drop mechanism proved to be successful each trial.

2.3Communications

On the copter, the team the Bullet M5 with a "whip" antenna. The Bullet M5 is connected to a battery and a Raspberry Pi via an ethernet cable. PVIT UAV used Power over Ethernet (PoE) injector wiring. Data and power is sent to and from the Bullet with an Ethernet cable split into two cables. The Bullet M5 serves as a bridged connection, meaning the IP address of the copter is passed to attached devices. It has a longer range and higher gain compared to our choice from last year. The diagram below shows how the power is moved over ethernet.

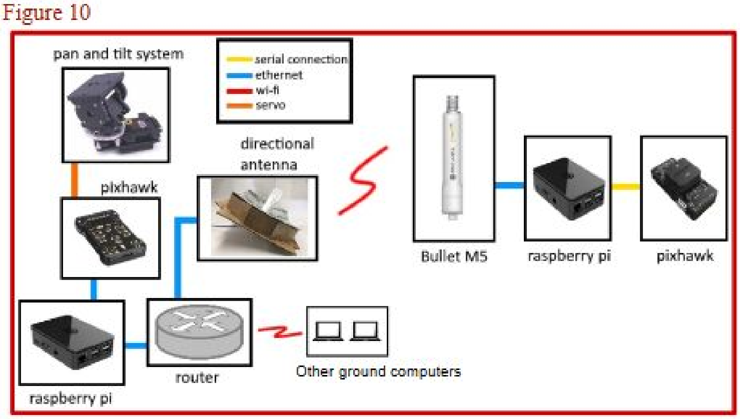
Figure 6 and 7





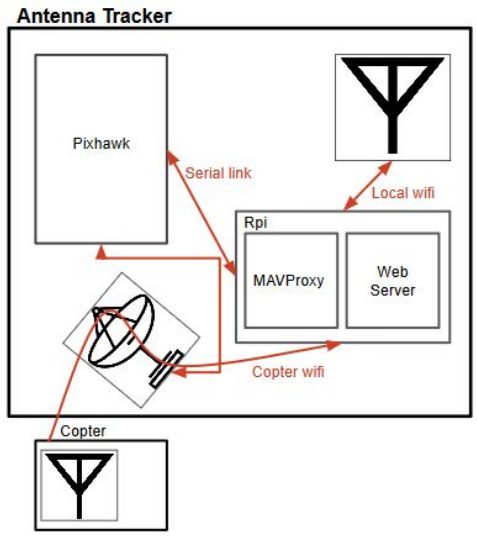
The ground antenna is pointed at the copter. In the future, the PVIT UAV Team hopes to create an antenna tracker that will automatically point to the copter to ensure the accurate, precise aiming of the antenna. The team is currently working on this device, and will hopefully implement this system in future competitions. The team uses a pan and tilt servo system to aim the antenna in multiple directions: sideways, up, and down. The servos are controlled by the pixhawk on the ground, which adequately receives positioning data from transmitters on the ground and on the octocopter. The antenna can be powered by battery or directly from an outlet.

Figure 10



Unfortunately, the antenna frame is too heavy for the pan and tilt servos. The UAV team solves this problem by creating a model of the frame made of cardboard and aluminum foil. This is achieved by taking measurements of the frame and drawing the outline on a piece of cardboard. After this is done, the cardboard is cut out and attached onto a cardboard base. The team measures and cuts small pieces of cardboard and covers the pieces in aluminum foil before taping them onto the base. Aluminum foil was chosen by the team because of its lighter weight. The weight of the antenna is significantly reduced by using a cardboard frame, and has proven to be highly beneficial in both transport and durability. Despite using aluminum foil and cardboard the team has not lose any signal, according to the team's tests.

Figure 8 and 9



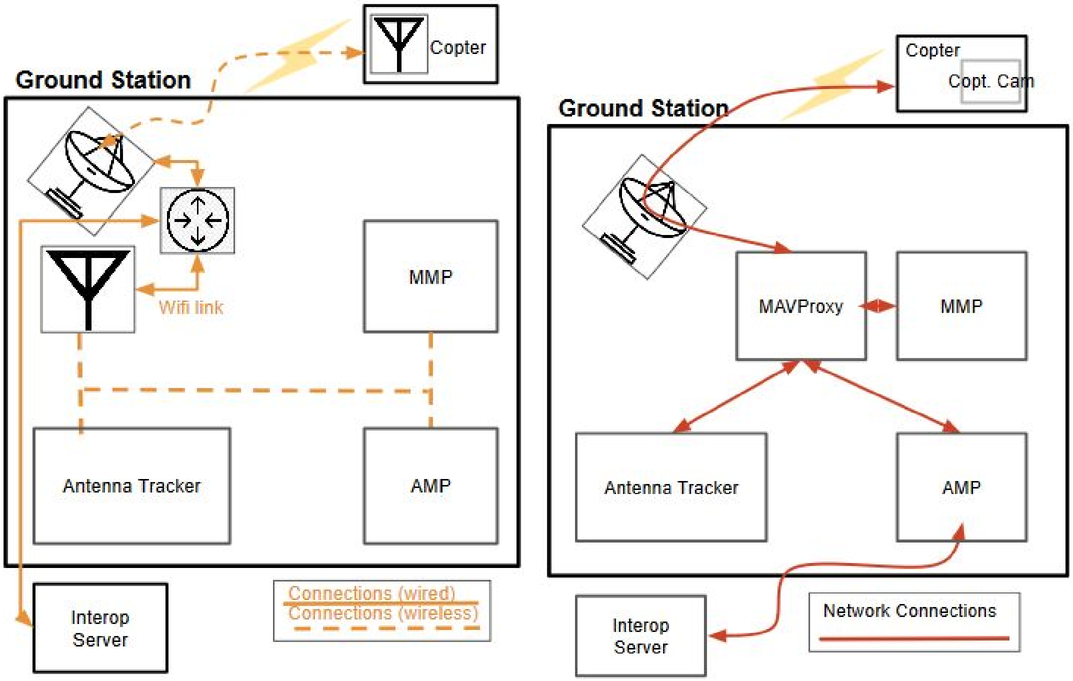
2.4Autopilot

The PVIT UAV team's ground station consists of seven people each assigned to different tasks in order to effectively and successfully complete the missions. Positions include AMP manager, an Interop manager, a wireless link controller, Manual Mission Planner (MMP) crewmen, safety manager, and an antenna controller. The two AMP crewmen will constantly confirm that the automatic mission planner is correctly calculating a route past obstacles. Next, the interop manager will check that telemetry is correctly giving information to the interope server. There is a bidirectional connection between the AMP and the interop server. The team's wireless link controller will check that the wireless link to the copter is maintained. Two MMP crewmen will be checking values given by the copter for realistic values, battery power, and other basic functions of the drone. The safety manager ensures that all members are properly communicating (a problem the team experienced in the past). The last member of the ground station is the antenna controller who will manually point the antenna to the drone, unless the team can finish the antenna tracker-in-progress which can do it automatically. In addition to the seven members in the ground station, one member of the PVIT UAV Team will be the safety pilot, managing the copter's movements. The safety pilot will also will talk to the safety judge in order to confirm that the copter maintains connection. The diagrams below demonstrate the connections between different devices in and out of the ground station.

To maintain complete cyber security the team decided to be sure that the UAV responds only to the controller, ground station, and make sure collected data is private using standard wifi encryption. The UAV team has ground station diagrams and connections below. Figure 10 shows physical connections of the devices, and Figure 11 diagrams the logical connections.

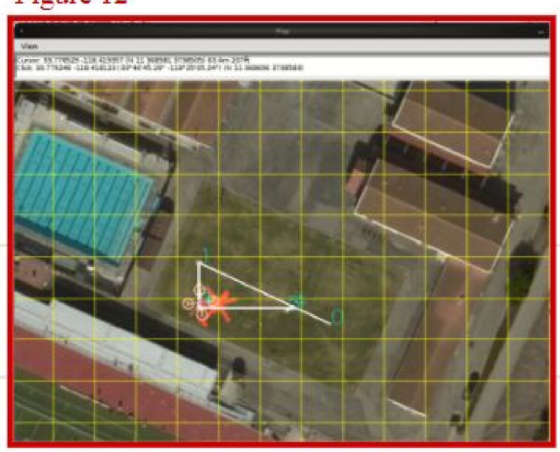
This year, much effort was placed in the programming of the obstacle avoidance software. The team utilized the Software-in-the-Loop (SITL) program in order to seamlessly connect simulations of the SUAS interop server to the ground control station (GCS) with displays on Mission Planner, APM2, and Google Earth. The connection allows effective information sharing such as the location of both the static and dynamic objects.

Figure 11a and 11b



There were several autopilot systems in the market such as APM, Pixhawk, CC3D, and Erle-Brain that the team evaluated. After considering the benefits of each, in addition to the team having used the PX4 Pixhawk last year, the team decided to use a pixhawk flight controller. The pixhawk and subsequent Pixhawk2 serves a crucial role in autonomous flight. It offers substantial support to multiple common sensors, thus making the implementation of simultaneous testing of different systems both highly efficient and affordable. In addition, the Pixhawk's autopilot mechanisms provide numerous features that help meet the competition's safety requirements. Since 3DR did not produce anymore 3DR flight controllers, the PVIT UAV team decided to go with the newly developed Pixhawk 2.1. With the addition of the cube on the Pixhawk 2, the team has more processing power to accomplish more tasks that was not able to be accomplished by the older Pixhawks. Even though the older 3DR Pixhawks were damaged, they were still able to transmit and read data to send data back to the ground station. With this functionality, the team used the 3DR Pixhawks on the smaller, pre-built test quadcopter, the Condor Mini and for the antenna tracker. With this, PVIT UAV was able to fly the quadcopter to perform developmental tests while the current octocopter was being built. The quadcopter was tested to assess both the antenna tracker system and the wifi-telemetry system.

Figure 12



The PVIT UAV team runs the most popular choice, ArduPilot in coordination with the pixhawk because it is capable of developer support, and has many essential flight features required for autonomous flight. Its mechanisms allow the vehicle to navigate through the waypoints precisely to earn the most points on the waypoint navigation task. Moreover, ArduPilot is able to formulate both autonomous takeoff and autonomous landing in order to avoid being penalized for manual interference. An important advantage of ArduPilot as opposed to other mission planners is that it is an open source system, allowing the team to customize the firmware as needed.

When initially starting PVIT UAV's Automated Mission Planner program, or AMP, the team converts the boundary points into Cartesian grid points to more easily calculate the boundary lines, and later the calculated path for the copter grid for the copter, Condor II. A 3D grid is formed, in feet, from these boundary points, and the maximum height set by the competition's given maximum height (750ft). This allows for the team to create a fixed three dimensional Cartesian coordinate map of the competition with the boundaries and the stationary obstacles indicated—points it cannot intersect. This grid is viewed in a window opened by the AMP made of simple blocks showing the x-y plane.

The team starts MAVProxy in the AMP, opening its map right away to view the boundaries and waypoints in the system. The MAVProxy is designed to include both the Mission Planner function that links and can broadcast the MAVLink commands from the copter to other software, like interop server and GCS. This allows for minimal, yet effective support the MAVLink protocol.

2.5Obstacle Avoidance

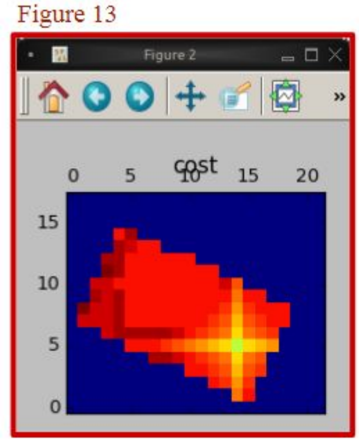
In order to successfully complete the Obstacle Avoidance task, the team proposes and implements a new, innovative method. The formulative system aims to predict collision-free paths around the UAV by employing models that test the probability of the current path, and adjust accordingly if the path is deemed as unsafe. Throughout the mission, the location of the moving obstacles are continuously computed. Should the location of the obstacle collide within the radius of the drone (which includes a buffer of 10% of the radius), the path will be recalculated and the drone will continue its mission on the newly calculated path. Although the moving obstacle may collide with the path behind the vehicle, the path will only be recalculated when crossed ahead, in order to maximize the time given and promote stability. On the MAVProxy map, the moving obstacles appear as other UAVs to visualize their approximate position on the x-y plane. This was done by giving them their own MAVLink messages to the MAVProxy.

To simplify calculations, and to reduce the risk of colliding with obstacles, PVHS uses entire grid spaces occupied by obstacles and boundaries as spaces which the copter cannot fly. This minimizes complex calculations that are required to get around spherical objects or cylinders, which would have taken more computation time. Although this can occasionally result in longer-than-necessary trips to avoid obstacles, it was determined that for the algorithm explained below, this was the better option. Grid spaces are scaled 40ft for every 1 grid space in X and Y, and Xft per z space, as the Z max is relatively shorter than the X and Y max.

PVHS utilizes the Dijkstra Algorithm, which operates based on a minimal cost system (based on distance and number of waypoints) that determines the path taken by choosing the path that would lead to the given waypoint the most cost efficiently and effectively. Between the current position and the next waypoint, the path is drawn for the copter to fly. Intermediate waypoints are created at each vertex of the path so the copter will accurately fly along it. Because the system allows for the autonomous adjusting of the path, the vehicle is able to update its direction based on each circumstance to adequately avoid moving obstacles that collide in the path.

The PVIT UAV team's Dijkstra Algorithm has been modified so it works in the 3D plane needed to utilize all pathway options and find the most efficient way to go (see Figure 13). Likewise, all prediction vectors are three dimensional. Although working in a three dimensional plane does require higher computational complexity (slow down the updating time), this was seen to be the better option of the alternative, working in a two dimensional plane.

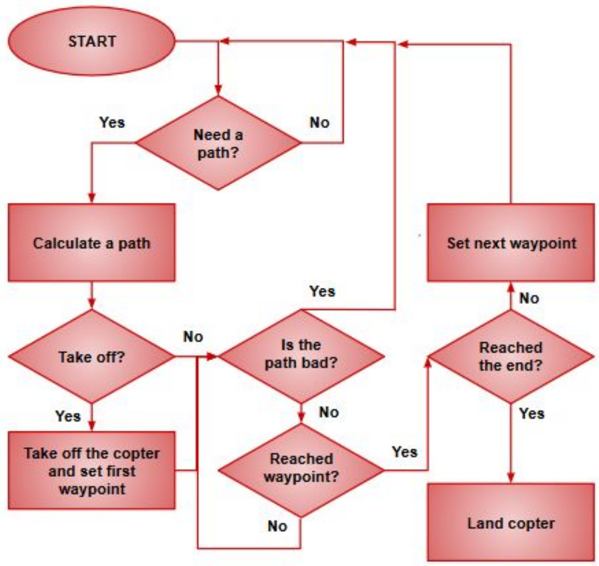
Figure 13



The obstacle avoidance is calculated on the ground, and then uploaded to the copter if a path is needed to change. If the path does not need to change, the information is not sent to the copter as it does not need to make any adjustments.

If the predicted moving obstacle does collide with the path, the dijkstra algorithm recalculates a path for Condor II. The copter hovers in place while waiting for its new directions. Next year, PVHS hopes to have the copter continue moving, if it can, while the new path is calculated, but for now the copter sits in place since it is uncertain of how far the threat is before it. This new path is then sent to the copter so it knows the new path to fly, to the MAVProxy so it may be appropriately updated, and to the Mission Planner so it can also be updated. The grids PVHS produce of the path are all updated to reflect the new path as well.

Figure 14



Originally, the team had the Condor II's information being sent directly to a MAVConnection, due to the belief that it would filter out unnecessary information and promote smooth transmissions of information. However, after a few tests, the team discovered that the information originally sent to the MAVConnection was crucial for the proper functioning of the MAVProxy. Thus, the PVIT UAV team decided that the best way to send information would be to send it through the MAVProxy. Although it adds additional steps in the information sharing process, this was seen as the better alternative as it allows the team to accurately deliver information to the copter and back.

2.6Object recognition

Due to the team's new copter design and team members, the PVIT UAV team decided it would be more strategically beneficial to focus on other portions of the competition rather than the object recognition.With the addition of new sectors, the team had much to consider and work through in order to promote success of Condor II. Considering that this is only the team's third time enrolling in the AUVSI SUAS competition, and most of the tasks had never been attempted, the amount of points and the amount of work that had to be done for this portion was weighed, but finally decided to not be attempted until next year. Instead of implementing Object Recognition into the mission, the team focused on different aspects, such as Object Avoidance, which was also newly attempted this year.

3.Safety, Risks, & Mitigation

3.1Developmental Risks & Mitigation

During the developmental stages of the competition, many problems have arrosed that set back the progress of the team. The table below discusses common issues and setbacks as well as the mitigation strategies that were established in order to strategically progress the copter throughout the numerous trials.

Table 7: Developmental Risks and Mitigation Strategies

Risk	**Description**	**Probability**	**Impact**	**Mitigation Method**
Flight Test Crash	A crash can result in significant damage to the frame.	medium	severe	Stronger frame and spare parts
Communication loss	Loss of connection between the copter and the rc and/or ground station	medium	severe	Longer range directional antenna with automated antenna tracker and manual backup. Fence limits defined for automatic return to launch.
Mission Planning	Manual system unable to match the speed of other mechanisms	low	severe	Automated Mission Planner with visual feedback

Limited flight time	Lack of battery power and space on the copter to complete missions	medium	moderate	Extra capacity (octocopter is larger than team's other copters; dual high-power batteries)
Limited testing time with single octocopter	Having inadequate time to practice missions prior	high	moderate	Leverage Software-in-the-Loop (SITL) for development. Condor mini provides second copter.

3.2Mission Risks & Mitigation

Since a complete redesign of all sectors of the program was established, including the team, copter, and plan of action, it is expected that the team will run into previously unexperienced issues. The team established a list of problems that could occur throughout the duration of flight, see the table below (Table 8). The table explains experienced and possible risks the team may experience during the mission in competition. In addition, it addresses the mitigation methods that will be instilled in the case of the copter experiencing these risks. Knowing first-hand the danger of unsafe flight, PVIT UAV wants to ensure that a close eye is kept on any potential problems to mitigate risks in the event that a problem does occur.

Table 8: Mission Risks and Mitigation Strategies

Risk	**Description**	**Likelihood**	**Impact**	**Mitigation Method**
Crash	A crash will result in the end of our mission flight	medium	major	Calmly recover the drone and discuss methods for improvement
Communication loss	Loss of connection between the copter and the rc and/or ground station.	medium	major	The safety pilot will be given instructions by the team captain to land the drone either by means of return to land or complete manual
Drop Mechanism Early Release	The mechanism malfunctions and releases the payload early.	low	medium	Never fly overhead people. The safety pilot will differ to the instructions of the safety judge. The team will be prepared to land or continue the mission excluding the drop depending on the response
Limited flight time	Battery lacks the capacity to complete the rest of the mission	low	major	Battery loss will be indicated by mission planner at the ground station or by the battery checker on the drone. The Team Captain will notify the safety pilot to land the drone
Falling Object	An object falls off of the copter while in flight	low	medium	Never fly overhead people. The safety pilot will defer to the instructions of the safety judge. The team will be prepared to land or continue the mission depending on

				the response

PVIT UAV decided that it would be very beneficial to implement a new guideline of safety measures for the team to follow this year and following. To avoid injury, the team wanted to create a precautionary procedure that the team follows very strictly before every takeoff or test. Safety is always considered of the utmost importance to the group in order to ensure successful and safe flights. The checklist is shown in the table below (Table 9). The table addresses each member of the team and how they will contribute to the safety management of Condor II at all times before, during, and after flight.

Table 9: Safety Checklist

Item	**Procedure**
GPS	MMP Crewmen will check and confirm that the Condor II's location matches the position that the GPS indicates on Mission Planner
Telemetry	MMP Crewmen will check and confirm that the Condor II's Raspberry Pi and Pixhawk are connected to the ground station notifying the Antenna Controller of any discrepancies. In addition, the connection to the interop server will be checked and confirmed with the interop manager
Battery Levels	Battery levels will be checked by the Hardware Team and confirmed by the MMP Crewmen on Mission Planner.
Flight Mode	The flight modes will be checked and confirmed by the MMP Crewmen. The information will be reported to the Team Captain to notify the Safety Pilot.
Altitude	MMP Crewmen will check and confirm that the Condor II's altitude matches the height indicated on Mission Planner
Onboard Components	The Hardware Team will check and confirm that all onboard components are safely secured and pose no controllable risk of unexpectedly falling off of the Condor II
Drop Mechanism	The Hardware Team will check and confirm the mechanism, servo, water bottle, and dog collar are secure and pose no controllable risk of prematurely falling off of the Condor II
Team Check	The Team Captain will confirm that all members of the team have completed the Pre-Flight checks and are prepared to fly.

Depending on the issue, either the Hardware or Software Captain will be notified. If the issue poses a significant threat (possibility of crashing or harming people) the Captains will be notified. The team and the captains will discuss the extent of the risk at hand. The Captain will make the final decision of whether to continue the mission or conduct a premature landing. However, the opinion of the safety judge and team mentor will overrule the Team Captain's decision if they do not align.

4.Conclusion

In conclusion, the team has had a enthusiastic, educational, and exciting experience building, improving, and executing the UAV in its missions. The team implemented many new tactics to achieve the goals PVIT team had as a vision this year for the AUVSI SUAS Competition. Although many of the team's members are new to the team, and it is composed of very busy highschool students, the team is feeling confident about this year's competition, and is looking forward to competing in June.