# Autonomous Search and Rescue System (Project ASARS)

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***Abstract*– *The project outlines a project idea of creating an autonomous search and rescue system for unmanned aerial vehicles capable of long-range reconnaissance and payload delivery. Due to the scale of Search and Rescue (SAR) missions and the vast areas that they encompass, the system was designed for long range flight and mission times. Furthermore, the system was designed to be capable of fully autonomous flight, visual and data feedback for the operator. The system consists of a fixed-wing unmanned aircraft, the RMRC Anaconda, a fully equipped ground control system, and a long-range antenna tracking system.***

***Keywords*- *Search and Rescue, Ground Control Station, Antenna Tracker, Unmanned Aerial Vehicle, Drones, Unmanned Autonomous Systems***

## I. INTRODUCTION

According to Dr. Travis W Heggie in his paper, *Dead Men Walking,* search and rescue (SAR) efforts in 2007 cost an estimated $4,735,424 for 3,593 operations. More than half of these operations were in response to incidents that occurred during hiking. Dr. Heggie states that "Search and rescue operations in National Park Service units can be costly endeavors, with many of them occurring in undeveloped backcountry areas where normal emergency services are unavailable or inadequate." The average cost of land-based search and rescue personnel is roughly $25.00 per hour. While this is relatively cheap, the effectiveness and efficiency of land-based SAR attempts are limited, time-consuming, and inefficient. A much more efficient form of SAR can be conducted from the air using helicopters. However, this costs an estimated $1,600 per hour and is almost impossible in areas with limited helicopter accessibility due to the lack of refueling and landing locations.[1]

To combat this problem, we propose an autonomous aerial system capable of conducting long-range, high-efficiency aerial SAR missions at a massively reduced cost. This system will include an autonomous fixed-wing aircraft paired with a mobile ground station and an antenna tracker system. The fixed-wing aircraft will be capable of autonomous aerial scanning of the terrain below and will be able to identify and report to the operator if any objects of interest have been detected on the ground below. The ground station will allow operators to monitor, plan, and execute missions while receiving real-time information from the aerial platform. This will be possible due to cameras mounted on the aerial unit that relay first-person view (FPV) live video feed over the air (OTA) to the ground station. Our antenna tracking system on the ground station will track the movements of the aircraft in flight, using relative GPS coordinates, to ensure that transmitting and receiving antennas on the ground are always 2 pointed in the correct orientation for maximum signal reception; this increases the range and reliability of the system.

The idea for this project stems from our involvement in the American Unmanned Vehicle Society International (AUVSI) Student Unmanned Aerial Systems (SUAS) competition. This competition is a multi-part student challenge open to high school and college teams. The challenge incorporates the major aspects of aerial search including waypoint following, long-range flight, obstacle avoidance, package delivery, object recognition and identification, and classification.

## II. THE AUVSI SUAS COMPETITION

### *A. Competition Overview*

The AUVSI SUAS competition was designed to stimulate interest in unmanned aerial systems (UAS) technologies and engage students in a challenging UAS mission. This competition requires students to design, integrate, report on, and demonstrate a UAS capable of autonomous flight and navigation, remote sensing via onboard payload sensors, and execute a set of specific tasks. Each team consists of the development team, competition team, captain, advisor, and safety pilot.

The development team works in the creation of the ASAR system and the fixed wing aircraft that will be utilized for the mission demonstration. The competition team is the students who attend the competition and participates in the mission demonstration at the competition location. The team captain is tasked with being the primary point of contact for the judges. The safety pilot is a fully trained drone operator capable of taking back manual control if the autonomous control was to fail.

In this competition, teams are provided with 20 minutes to setup their entire system, 40 minutes to perform full mission, and 10 minutes to pack their system and leave the flight line area. In the setup time provided, the teams must be able to fully set up the ground control station, establish communication link between all components of the system and provide a pre-mission brief to the judges.

In the mission demonstration, the UAS must fly autonomously, and follow a sequence of waypoints that will be provided. The distance between each waypoint will be up to 4

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2019.1.1.494
ISBN: 978-0-9993443-6-1 ISSN: 2414-6390

miles in length. In order to receive the maximum points, teams must be able to follow the waypoints in sequence. During the flight mission, teams will also be given a set of stationary obstacles perpendicular to the ground and range from 30 ft. to 300 ft.

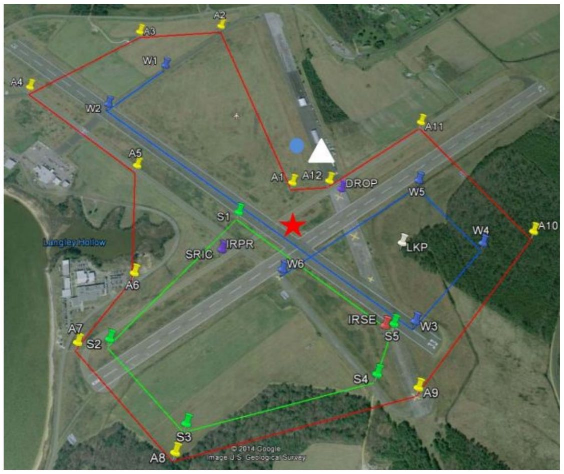

*Figure I. Sample Mission Map*

In the figure above a sample mission map shows the mission area and competition layout. In the map, the white triangle represents the pit area tents where teams can prepare for their mission demonstration and make any final adjustments to their systems. The red star signifies the flight line tents where the team will setup and perform the mission tasks and submit final mission reports to the judges. The red outline signifies the mission boundaries that the UAS cannot fly beyond. The yellow pins are the location of boundary judge stations for monitoring and ensuring that the aircraft does not pass the mission boundaries during mission execution. The blue outline represents the waypoint sequence and the green outline represents the search area where the objects are located. Furthermore, the blue circle and white pin represents the off-axis standard object and the last known position of the emergent target respectfully. Finally, the purple drop pin represents the air drop location that the aircraft must deliver the onboard payload.

### B. *Mission Objects*

The UAS must also search, detect, classify, and localize objects that are scattered throughout the search area. The objects that must be detected are classified into standard and emergent. The standard objects are colored alphanumeric symbols painted onto a colored shape. The standard objects are 1 foot wide with a 1-inch thick lettering. One of the standard objects is placed up to 250 ft. beyond the flight boundary. In the case that the off-axis object is out of the flight boundaries, the UAS system is not allowed to fly over the object. The emergent object on the other hand is a humanoid object engaged in an activity of interest. In total there are 20 standard and emergent objects that should be located within the search area. Each object detected must be photographed and submitted in the final mission report to judges at the end of the mission demonstration.

*Figure II. Standard and Emergent Object Examples*

In addition to detecting and documenting each object, it's set of characteristics must be identified. The characteristics that must be identified include shape, shape color, alphanumeric, alphanumeric color, and alphanumeric orientation. The characteristic traits of the emergent object that must be identified is a description of the person in need of rescue and the surrounding environment of the object. Lastly, teams are also awarded points for accurately providing the global positioning system (GPS) location of the objects. The distance reported must be the geodesic distance between the submitted GPS location and the object's true GPS location in feet.

### C. *Payload Air Drop*

A third crucial portion of the mission is to perform an air drop of a care package to a specified position. The payload package consists of a package carrying supplies and a standard 8oz. water bottle. At the start of the mission during setup period, the judges provide the team with the GPS coordinates of the drop location. To receive maximum points, the care package must land at the center of the target gently, with zero damage to the payload. Maximum points are awarded for deliveries within 5 ft. of the target. For drops within 25 ft of the target, half of the points are awarded. A quarter of the points are rewarded for drops within 75 ft. of the target location and zero points are allocated for drops beyond 75 ft. in distance.

### D. *Interoperability System and Object File Format*

The interoperability system utilized for this competition is an open source code repository, network, and web server that teams must interact with during the mission. The system provides the team and Anaconda drone with the mission details and receives mission deliverables for the judges. The system also utilizes the mission deliverables from the mission demonstration to calculate the points achieved by each team.

At setup time, teams connect to the system through an ethernet cable and log in using the account provided at the start of the competition day. During the mission, certain tasks require teams to upload valid UAS telemetry at a rate of at least 1 Hz while the drone is airborne. Furthermore, teams must submit objects detected, classified, and localized using the Interoperability system to earn points. The Object File Format is a folder containing object detection file. Each object submitted by the team gets two files in the folder which begins with a number unique to the object. The first file has an extension ".JSON" and lists the classification, characteristics, and geodesic location of the object as shown in the figure below. The second file is a JPEG image of the object that has been detected.

```
{
    "type": "standard",
    "latitude": 38.1478,
    "longitude": -76.4275,
    "orientation": "n",
    "shape": "star",
    "background_color": "orange",
    "alphanumeric": "C",
    "alphanumeric_color": "black"
}
```

*Figure III. JSON Object File Sample*

## III. ENGINEERING AND DESIGN REQUIREMENTS

1) Strength and Durability
    a. The ground control station must be able to function in the most difficult environments and weather conditions.
    b. The fixed wing drone must be capable of long-range sustained flight carrying high payloads.
    c. The antenna tracker must be able to support the full weight of all onboard receivers necessary for the ground control station to function.
2) Easily Deployable
    a. The system must be easily transported and deployed with minimal training.
    b. The ground station must be designed based on the needs of SAR personnel and park rangers.
3) Efficiency and Effectiveness
    a. The antenna tracker must effectively track the fixed-wing aircraft regardless of direction.
    b. The fixed-wing aircraft must be able to efficiently follow search waypoints and effectively deliver payloads.
4) Design
    a. The drone must be modified to be able to carry a payload of up to 48 oz.
    b. The total allowed weight of the aircraft cannot exceed the 55 lb. limit with payload.
    c. Use of exotic batteries or fuels will not be allowed.
    d. The ground station must be designed to provide all necessary information for SAR personnel and park rangers.
    e. The antenna tracker system must be able to move dexterously to maintain a connection with the aircraft.
5) Range
    a. The unmanned aerial vehicle must be powered by a battery source capable of sustaining long range flights.
    b. The antenna tracker system must be able to utilize high-gain antennas for superior range and penetration.
6) Autonomous Capability
    a. The UAS must be able to fly autonomously following pre-programmed coordinates.
    b. The fixed-wing aircraft must be capable of autonomous take-off and landing.

## IV. ANTENNA TRACKER

The mission range requires the use of high-gain antennas to provide superior range and penetration. This can be done only through a narrow communication beam as signal reception decreases significantly as the angle between the transmitter and receiver are increased. As a result, the antennas must constantly move to maintain a strong connection with the Anaconda drone. The antenna tracker system as a result provides a platform capable of such tracking by constantly updating position to ensure maximum signal reception. However, the system must remain smooth in actuation while remaining durable enough to hold an array of high-gain antennas and extra sensors that are required for the mission. Lastly, due to the application of the system, the antenna tracker must be seamlessly integrated with the ground control station while remaining light weight for transportation and easily deployed.

### A. *Hardware*

Given the requirements set forth by the competition and the team, there are several components necessary to provide the high-range connection and smooth transitions. At the centre of the system are two servo motors that used to actuate the pitch and YAW of the antenna tracking system. For this system, VEX EDR 393 Motors were chosen as they provided an output speed of 100 RPM and thrust of 1.67 N*m. Since the antenna tracker does not need to move relatively fast, the slower speed and torque allows for the required smooth movements necessary to keep the antennas aimed at the aircraft.

*Figure IV. VEX EDR 393 Motor*

Due to the high-range of SAR missions and potential environment that the SAR system will be deployed in, several antennas were chosen for each specific feature of the system. The YAGI 915 MHz Antenna provides a high gain with a 50° to 70° beam width. The Yagi antenna was chosen due to it's ability to filter almost all signal noise and provides a high-range communication connection with the transmitter on the aircraft. In our application, the YAGI antenna was used for the broadcast of mission information and receiving critical mission details. In addition to the Yagi antenna, a 5.8G Pagoda Omnidirectional Antenna and a 900MHz 3dBi Dipole Antenna were used to relay camera video feed and other mission data that were critical for the success of an SAR mission.

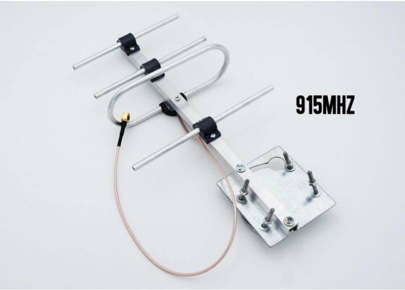

*Figure V. Blacksheep Yagi 915 MHz Antenna*

At the heart of the antenna tracker system is the Pixhawk 1 Flight controller. The Pixhawk is an advanced autopilot designed for autonomous flight control. However, in using the AntennaTracker package, the Pixhawk can be reconfigured to function as an antenna tracking module that calculates the position of a remote vehicle using its own GPS position and the GPS telemetry from a vehicle. Due to the availability of the AntennaTracker package, the system can be easily paired and configured for the SAR operation system.

While the antenna tracker controller receives telemetry information from the UAV, it requires its own global position and heading to be able to relate itself to the UAV. The AT controller is outfitted with one internal compass, one external compass and an external GPS module. Wireless communication is facilitated with an RFD 900X 900Mhz telemetry receiver. The telemetry receiver operates in a frequency range of 902-928 MHz at a UART data transfer rate of 57600k baud, using a 5-volt power source, and a outputs 1 W of power.

*Figure VI. RFD 900X 900Mhz Telemetry Receiver*

***B. Antenna Tracker Design***

Preliminary designs of the antenna tracker make use of 180° metal gear servos attached directly to the rotating components. The mechanism consisted of the following components: Base0, Yaw0, Tilt0, and Plate0. The first issue we found was the instability of the base which tends to tip over when the mechanism actuates rapidly. This makes the system difficult to be deployed outdoors in the field. Furthermore, the mechanism tended to wobble and bounce at the end of each actuation.

*Figure VII. Preliminary Design of Antenna Tracker*

The first modification done to the system was to increase stability and prevent the device from tipping over. This was done by integrating a tripod mount to the yaw component (Base0.5). While this made the device more portable and easily deployed in the field, the device was not robust as it wobbled during actuation and did not pan or tilt smoothly.

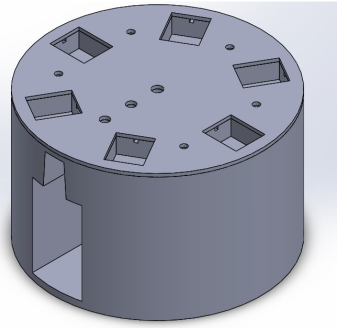

*Figure VIII. AT Base Solidworks Rendering*

While the initial design was simple and based on a direct-driven system where moving parts are connected directly to the actuator, the weight of the system rested directly on the servos. This meant that instead of only being responsible for the actuation of the mechanism, the servos played an integral part in maintaining the structure. The issue with this is that the servos are subjected to excess forces that increase the amount of work they must do and therefore reduce the expected life and reliability of the system. The simplest fix for this issue is to move load previously placed on the servos to a different area so that the servos are only responsible for actuation and no longer play a structural role.

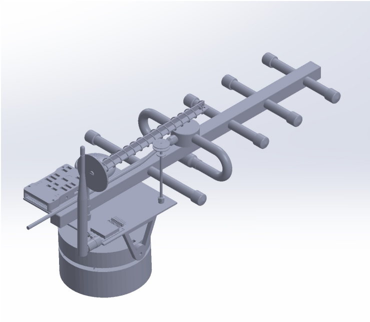

*Figure IX. AT Base Solidworks Rendering*

The final manufacturing process for the body of the antenna tracker was manufactured with the use of additive manufacturing. The Creality CR-10S 3D printer provides a 300x300x400 mm. print space that is able to fully print each component of the antenna tracker separately. Using an infill of 65% with a hexagonal pattern, the object maintains the structural strength required for long-term use as well as remaining as lightweight as possible for transportation.

### *C. Software*

There are two main methods that exist for antenna tracking; active and passive. Passive tracking happens through these main steps: Pan and tilt the antenna until a strong signal is found, once the strongest signal is found, move the antenna to the position of the strongest signal. Once the location of the strongest signal is found, restart panning and tilting till a stronger signal is found before moving antennas to face the direction of this newer, stronger signal. While this can be applied without the use of specialized equipment, the constant scanning means that antennas are always pointed in the general vicinity of the object being tracked and not at the exact location of the object. The constant scanning also causes increased wear on equipment over time as actuators need to work constantly even when the tracked object is directly in front of the tracker. Passive tracking makes use of a measure of signal strength known as RSSI (received signal strength indicator) which is a calculated value based on signal strength in decibels and noise.

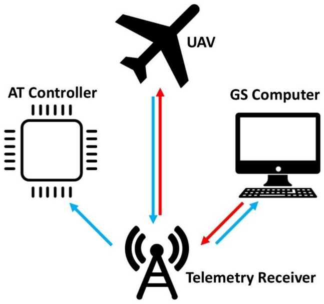

*Figure X. Telemetry Scheme for Antenna Tracker*

Alternatively, active systems make use of real-time information from the UAV such as location, heading, speed, and altitude to predict where the antenna should be pointing. This reduces the amount of work that needs to be done by the tracker as the system will only actuate when it needs to. This system will also be less prone to “losing” the UAV as it always knows where the aerial unit is in 3D space. If the telemetry connection is maintained, an active antenna tracker will reliably maintain communication with the UAV. The diagram below shows the overall communication scheme used to maintain control of the UAV Where Red represents instructions to the UAV and Blue represents telemetry information from the UAV. The AT controller only requires telemetry information from the UAV in order to operate and will not be capable of sending instructions to the aerial unit. On the other hand, the GS computer will be responsible for monitoring UAV telemetry and sending instructions to the UAV.

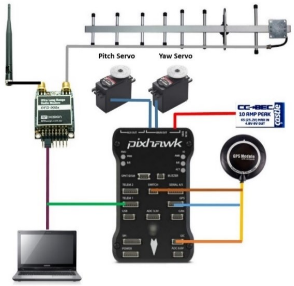

*Figure XI. Antenna Tracker Wiring Scheme*

While the AT controller is natively capable of reading information transmitted by the telemetry receiver, serial signals need to be converted via an FTDI interface before they can be read by a computer. Once connected to the GS computer, a connection between said computer and UAV must be established. This is facilitated using MAVProxy; a ground station software capable of forwarding telemetry information to multiple locations on a network. [7] In our case, MAVProxy can forward telemetry to autonomous code and a remote location (for example SAR command headquarters) simultaneously. This will allow operators to control the UAV in the field and allow headquarters to monitor the progress of the autonomous mission. The flow chart below shows how MAVProxy forwards telemetry information:

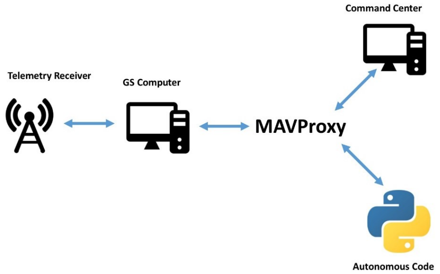

*Figure XII. MAVProxy Telemetry Schematic*

## V. GROUND CONTROL SYSTEM

The ground control station, or ground station for short, is essential for the functionality and communication between systems. The main goals for the ground station are to display the transmitted video feeds from the fixed-wing drone aircraft with a care package payload, assist with the autonomous flight path through the Intel NUC, as well as power the antenna tracker system that allows for long-range autonomous search and rescue missions.

### *A. Hardware*

The ground control station is the most critical component of the ASAR system. It provides the SAR personnel and park rangers with the ability to actively identify key information necessary for the mission success. Given the requirements for durability and transportation, the most effective design was utilizing a Pelican Air 1615 hard case to house all necessary electronics. The pelican case has an interior dimension of 30x15.5x9.4 inches with prebuilt mount holes that can be used to mount the necessary electronics.

*Figure XIII. Pelican Air 1615 Case*

To provide an interface for communicating with the aircraft, antenna tracker, and interoperability system, an Intel NUC computer was chosen. The Intel NUC provides enough power to run the Ubuntu software that will be used by the GCS operator to receive live feed information. The Intel NUC is connected to a wireless keyboard with a built-in trackpad and a 16” LED Monitor. In addition to the monitor for the NUC computer, two addition 7 in. LCD Monitors were used for monitoring the camera feeds of the two first person view (FPV) cameras on the aircraft. These monitors were connected to an AKK 5.8G FPV Receiver and a Aomway 5.8G FPV Diversity Receiver.

*Figure XIV. Intel NUC Computer*

Due to the communications requirement for the AUVSI SUAS competition, a NETGEAR Wireless Router and Ethernet Cable Extender Adapter were necessary to provide a means of communication with the Interoperability system. In addition, a 12V DC power supply was installed to provide a means of powering the ground control system. Due to the different power inputs and current draws of the components, the power supply was connected to a 12V to 5V converter through a 9 terminal power bar. Finally, a 120mm cooling fan system installed to prevent overheating of the enclosed system.

### *B. Design and Manufacturing*

For the ground control station (GCS), many parts had to be designed so that the final product was exactly to our needs for ASARS. Parts were designed first in computer-aided design software (CAD). The parts were designed so that they were either possible to 3D print or machine on a CNC machine.

The first few parts that were 3D printed were to keep the power rails isolated from shorting each other out. It took three iterations to get to the final item that was able to securely hold the bus bar using just three bolts. These bolts came in handy to attach the power rails to the base plate in the GCS to keep them stationary. The reason there were three iterations is that the 3D printing wasn’t done on a professional level printer and tolerancing issues called for redesigns. In the process, a slight design change was made- a part of the top casing was extended so that the two pieces had a better clamping force holding the bus bar in place. Of the two sizes of monitors placed inside the GCS, the smaller one had an odd mounting bracket, as seen in **Figure 2**. The included mount would’ve been too bulky to use, the monitor would’ve protruded more than optimally, possibly resulting in damage of the monitor.

*Figure XV. 9 Terminal Bar with Mount*

To overcome this problem, a bracket was designed so that the monitor could slide on and off easily off a mount that was bolted into the top plate of the GCS. After the prototype was 3D printed, it was evident that one of the dimensions need to be changed due to an odd circular hole that was present on the monitor. In addition, the opportunity for a reprint was taken and a rib was added for structural support. The larger of the three monitors had a common VESA 75 mounting pattern. The inserts in the monitor were for a screw size that wasn't present, therefore it was difficult to figure out the correct fastener to buy to mount the larger monitor. There are also two more 3D printed parts in the GCS- a holder for 5 ethernet plugs and a bracket. These two parts were designed and printed in Polyethylene Terephthalate Glycol (PETG) so that they would be stronger for the changes in load that they will experience.

To effectively cut sheets of Lexan (polycarbonate) and hardboard, test pieces had to be cut using the different bits at our disposal. The two main bits that were tested were a carbide 1/8" o-flute and a carbide 1/8" 2-flute wood bit. For the two different materials that were used in the GCS, proper speeds, feed rates, depth of cuts, stepovers, and work holding had to be determined so that parts could be cut efficiently. The first few things that were needed to be determined were the speeds, the rpm of the cutter, and the feeds, the linear speed of the cutter through the material, for Lexan and hardboard. A starting point was the parameters recommended by the manufacturer. **Equations 1 and 2** are the metric versions of the equations that were used to determine safe speeds and feeds to use based on the manufacturers recommended surface speed. There are both SI (Standarde Internationale) versions and English versions of the equation; the one to use would be dependent on the machine. Manufacturers typically recommend a range of surface speeds to use which is the speed along the circumference of the cutter.

**Equation 1:**

$$n = \frac{V_C * 1{,}000}{\pi * d}$$

Where:
n = spindle/cutter speed (rpm)
$V_C$ = cutting speed (m/min)
d = diameter (mm)

**Equation 2:**

$$F = n * f_z * Z$$

Where:
F = feed (mm/min)
$f_Z$ = feed per tooth (mm/tooth)
Z = number of flutes

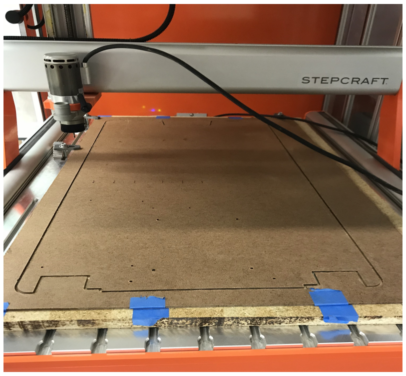

*Figure XVI. STEPCRAFT Base Board Manufacturing*

In another experiment to see how the depth of cut affected the time required to pocket a square that was just a few millimetres on each side, a larger depth of cut required a slower feed rate, the speed at which the cutter moves. When the depth of cut was smaller, the machine was able to run at a faster feed rate, in which case resulted in a quicker cycle time to finish pocketing the square. For the Stepcraft 840 that was used, we realized that due to the surface finish on the hardboard we were using, the cutter needed to run slower to cut through the top layer. The layers that were below that, were able to be cut at twice the feed rate. The optimal way to cut through 3mm thick hardboard was to have a depth of cut of 1mm. The first millimeter was cut at a speed of 4400 rpm and a feed of 45-90 mm/min. The next two passes, which would be 1mm each, was cut at a speed of 4400 rpm and a feed of 90-180 mm/min. The reason there is a range of values that work is because of work holding. If a piece was fully held down so that there were no vibrations in the flat piece of stock, the feed was able to run at its maximum range.

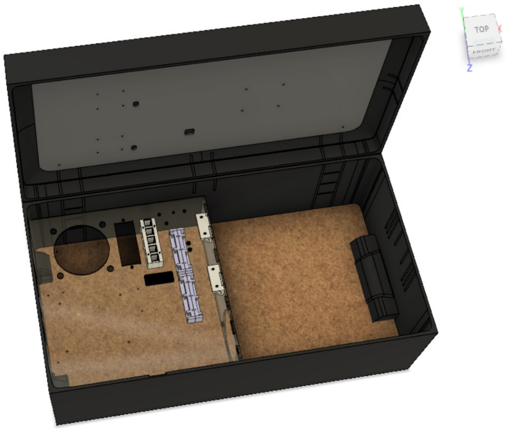

*Figure XVII. Ground Control Station Rendering*

## VI. UNMANNED AERIAL VEHICLE (UAV)

The unmanned aerial vehicle required for search and rescue operations must be capable of covering a large distance with long flight durations. Furthermore, the unmanned aerial vehicle must be able to carry a payload of survival necessities and medical supplies.

### *A. Hardware*

Due to the requirements of long flight duration and range, a multi-copter aircraft would not be the best solution. As a result, the best choice is a fixed-wing aircraft. A fixed-wing UAV is able to achiever high flight ranges, cover large areas in a shorter time, provides better control of flight parameters, and provide better quality for photographs. [2] As a result, the aircraft chosen for the SAR system was the Ready Made Remote Controlled (RMRC) Anaconda drone frame. The aircraft is powered with a Turnigy G60 500Kv brushless motor. The brushless motor provides an output of 2,850 grams of thrust when powered by a 6 cell Lithium Polymer battery and a 1380 propeller. Thus, providing enough thrust and power to maintain a stable flight as well as support the total weight of the final aircraft (2,475 grams). In addition, 8 Hitec HS-85MG servos were used to actuate the flaps of the aircraft.

*Figure XVIII. RMRC Anaconda Drone Frame*

Being an autonomous aircraft, an essential sensor onboard the aircraft is the LightWare LW20 Lidar. The Lidar sensor is a lightweight, compact sensor that functions as a laser rangefinder sensor providing the drone with accurate altitude monitoring. This proves to be most essential for the aircraft during autonomous take-off and landing. Another sensor incorporated in the aircraft is the Holybro Air Speed Sensor that provides accurate readings of the aircraft's speed during flight as well as during flight maneuvers.

At the center of the aircraft is a Pixhawk 2.1 Cube flight controller.[5] The flight controller was chosen due to its autonomous flight capabilities as well as its ability to communicate with different sensors and microcontrollers. The Pixhawk features a 32bit STM32F427 Cortex-M4F core, 256 KB of RAM, 14 PWM outputs, connectivity options for additional peripherals, and an external safety switch. The Pixhawk flight controller is connected to a RFD900x 900MHz Telemetry Modem with a 900MHz 2dBi Monopole Antenna. This telemetry module was chosen due to the antenna receivers located on the antenna tracker system. [4]

*Figure XIX. Pixhawk 2.1 Cube Flight Controller*

To provide the necessary video feeds, two Fatshark FPV cameras were attached to the Anaconda drone frame. In addition to the cameras, an AKK Video Transmitter providing real time feed to the ground control station monitors.

The final component of the unmanned aerial vehicle is the Taranis QX7 Controller used for manual override in the case of an emergency. The controller is modified with the attachment of a Dragon Link 3 transmitter module. The purpose of this module is to expand the range of the signal of the controller from the original 8 Km. range to a 50 Km. range.

*Figure XX. Dragon Link 3 Module*

### *B. Autonomous*

Once a mission is started, the aircraft progresses through the following mission chart:

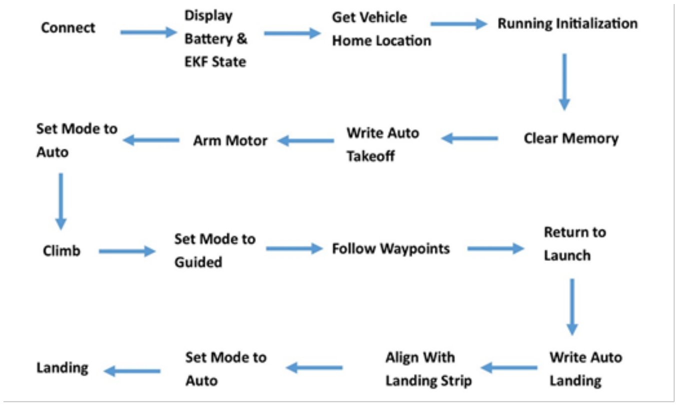

*Figure XXI. Autonomous Flow Chart*

As one can see from Figure XXI, once the vehicle completes its initial climb to a preset altitude, it will switch from Autonomous mode to Guided mode. With Pixhawk flight controllers, an autonomous mission is considered a pre-planned set of tasks that the vehicle will follow one after the other in sequence. Unfortunately, this “locks” the vehicle into a pre-planned mission which cannot be edited in real time. In Guided mode however, the vehicle is able to respond in real time to new mission requirements or tasks. For example, unlike in an autonomous mission with preset waypoints, a guided mission allows the UAV to respond to new waypoints that can arrive one after the other and will execute as long as it arrives before the previous one completes. This means that waypoints can be sent from a remote location (for example headquarters). This allows operators to change the UAV’s flight path in real time in order to react to situations as they come up. For example, the UAV can be rerouted to a different search area or requested to come back home in the event of mission cancellation.

The autonomous code is written in Python using the Dronekit API which transcodes instructions into MAVLink messages that are then forwarded through MAVProxy. MAVProxy and Dronekit work together to allow programmers to develop smart applications that consider various data points collected by the flight controller to intelligently instruct the UAV. It is important to note that MAVLink messages such as the MAV_CMD_NAV_TAKEOFF or vehicle.mode = VehicleMode(“RTL) are simply instructions that the UAV must follow based on a pre-programmed set of internal settings. [6] For example, when the vehicle receives a MAV_CMD_NAV_LAND instruction, internal programming preset in the flight controller govern how the vehicle executes autonomous landing. The FC is in charge of approach angle, speed, decent rate, flap deployment, and final flare to name a few. If the vehicle is unable to execute autonomous landing, the python script will send the MAV_CMD_DO_GO_AROUND command which will cause the vehicle to abort landing, pitch up, climb and circle at a set radius and altitude where the operator can decide between re-attempting autonomous landing or taking over flight and controlling the UAV manually.

## VII. CONCLUSION

The objective of the project was to develop an autonomous search and rescue system capable of long-range autonomous reconnaissance and payload delivery. Search and rescue operations currently cost $1,600 per hour and is almost impossible in areas where helicopter accessibility is limited or impossible. The ASARS system provides an alternative method of deploying a long-range fixed wing unmanned autonomous system that will be able to detect and relay coordinates of objects of interest to the operator at the ground control station. This long-rang, high efficiency aerial SAR system incorporates the use of a multi-system ground control station and a high gain antenna tracker module giving the aircraft the ability to increase the search radius. The ground control station provides an operational base where a SAR personnel or park ranger can monitor the aircraft flight through mission data and onboard camera feeds. In creating the system, the interface was designed to be as simple to use as possible. Furthermore, the ground control station was designed to be easily transported and deployed in any weather condition and environment.

## VII. APPLICATIONS

ASARS can be deployed to aid in a search and rescue mission where a missing person can be searched for from the air. Once located, a package containing a GPS beacon can be dropped from the UAV. This beacon can then be picked up by the missing person so that SAR workers can know the live location of the individual. Another application of the ASARS project is in forest fires. The UAV can be set to circle around the missing person, further helping SAR workers to locate said individual. ASARS can be deployed in a fire-prone location to constantly monitor the ground below. Due to the capability of this system, park rangers will be able to constantly keep the UAV in the air to act as an early detection system or to monitor a fire.

## ACKNOWLEDGMENT

The authors would like to thank Vaughn College of Aeronautics and Technology and the Department Chair of Engineering and Technology, Dr. Hossein Rahemi, for their enthusiastic efforts to consistently support the Unmanned Aerial Vehicles Club. Furthermore, we would like to thank the UAV Club faculty advisor, Dr. Amir Elzawawy, for his support and guidance.

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