Spring 2019

SWAT Operations Unmanned Vehicle

John K. Zelina
jkz3@zips.uakron.edu

Tyler Meadows
tem55@zips.uakron.edu

Ryan Cook
rmc99@zips.uakron.edu

Mathew Fellows
maf125@zips.uakron.edu

SWAT Operations Unmanned Vehicle

John Zelina
Tyler Meadows
Ryan Cook
Mathew Fellows

Department of Aerospace Systems Engineering

Honors Research Project

Submitted to

The Honors College

Approved:	Accepted:
Date 5/9/2019	Date
Honors Project Sponsor (signed)	Department Head (signed)
Daniel Raible	
Honors Project Sponsor (printed)	Department Head (printed)
Date May 9,19	Date
Reader (signed)	Honors Faculty Advisor (signed)
Reza Madad	
Reader (printed)	Honors Faculty Advisor (printed)
Date 9 May 2019	Date
Reader (signed)	Dean, Honors College
Nicholas Garafolo	
Reader (printed)	

Aerospace Design Project

STUDENT(S)

Name:	E-mail:
Ryan Cook	rmc99@zips.uakron.edu
Mathew Fellows	maf125@zips.uakron.edu
Tyler Meadows	tem55@zips.uakron.edu
John Zelina	jkz3@zips.uakron.edu

ADVISOR(S)

Name:	E-mail:
Dr. Daniel Raible	danielraible@yahoo.com

FINAL REPORT

The final report and project are submitted to the advisor with following comments.

Comments: None

Advisor Signature:

Date: 5/9/2019

University of Akron Senior Design Project:
SWAT Operations Unmanned Vehicle

Ryan Cook
Mathew Fellows
Tyler Meadows
John Zelina

Table of Contents

I. Introduction: Goals, Objectives, and Problem Statement

During SWAT operations, it is common to have a barricaded suspect who may be armed and a serious threat to SWAT team personnel. In these cases, sending a robot into harm's way to assess the situation as opposed to an operator has become the standard. To this end, Akron SWAT has consulted with the University of Akron to design a unmanned vehicle that can perform this task while mitigating potential harm to SWAT operators.

The current system used by Akron SWAT to perform this task is the RoboteX Avatar tactical robot, pictured in Figure 1 in the Appendix. This is a ground-based system that has a top mounted swivel camera, a fixed front mounted camera, and audio in and out capabilities. Anecdotal experiences from the members of Akron SWAT suggested that a ground based platform such as the Avatar is difficult to use in barricaded suspect scenarios. Obstacles as simple as a pile of clothing proved difficult to traverse as the treads would snag and slip on the loose surface. Additionally, the robot must be driven around barriers such as furniture in order to ensure a suspect isn't hiding on the other side. Upon testing, it was determined that the current platform also had difficulties with signal propagation specifically when line of sight is not feasible. During an experiment conducted at Goodrich Middle School, the Avatar was unable to send a reliable video or command-and-control signal from one room to another about 50 ft away. This range required the operator to close distance to the robot, putting them in potential danger in a field scenario. Furthermore, the Avatar experienced difficulty with climbing stairs and required direct visual on the robot to traverse a staircase in a timely manner. In a time-sensitive scenario, the robot requiring additional time to traverse these common obstacles could prove detrimental to the mission.

II. Requirements

Based off of feedback provided by SWAT members and testing performed on the current Robotex platform, the below list of requirements was generated in order to ensure Akron SWAT's needs would be met.

1. All communication signals need to be strong enough that the operator will have full visual and control of the system at all times.
2. The platform must be able to traverse an average two-story house.
3. The platform must have the ability to see over typical household obstacles without operator intervention.
4. System must be able to be operated long enough to clear every room in a standard two-story house.
5. System must be able to fit through a window that is eighteen inches wide.
6. The system should be able to send and receive a reliable video and telemetry/control signal through conventional building materials at a distance of at least one-hundred yards.
7. The system needs to be able to operate in low light conditions.

Requested Auxiliary Functions

In addition to the requirements listed above, there were additional functions that the SWAT team requested.

1. The video feed should be able to be cast to multiple devices.
2. The system should have audio in/out so operators can communicate with suspects.
3. The video feed should have infrared and/or FLIR capabilities.
4. The system should be able to deliver a payload. (Chemical munition, small object)

III. Methodology

a. Communications

The first aspect to be addressed was the signal bands used for transmitting controls and video. Communications were the highest priority aspect of the project because regardless of the platform, if a signal could not propagate through a house it was not useful to the SWAT team. It was determined that a significant aspect of signal loss seen on the current platform could have been due to its operating frequency. The current system Akron SWAT uses runs on a 2.4 GigaHertz (GHz) frequency. This is a very common band for remote control systems to operate in and is ubiquitous in the commercial market. A familiar 2.4 GHz signal such as a home WiFi network can work inside of a house, but to pick up a signal outside of the house is significantly more difficult due to attenuation of the signal as it passes through the external walls (Figure 6 in the Appendix). This is because when a signal is attenuated, it can be harder for the receiver to distinguish the meaningful signal from noise. By reducing the frequency the signal is operating at, the signal “sees” less of the barriers between the transmitter and receiver, which results in less attenuation. As a result, switching to a lower frequency such as 900 MegaHertz (MHz) can allow for a much more reliable signal in an urban environment.

Another issue that results from trying to propagate RF signals in urban environments is multipath. This occurs when the transmitting signal reflects off of surfaces that are common in buildings such as glass and metal. These reflecting signals make their way to the receiver and conflict, or occasionally destroy, the direct signal. This phenomena can be mitigated by dropping the frequency of the signal, but can never be completely eliminated.

Similar to the RoboteX Avatar that is currently in service, the proposed UAV will have a video feed; the key difference is it will leverage the capabilities of the lower frequency 900 MHz band instead of 2.4 GHz as discussed prior. The same principle will be used for the control signal; controls will be transmitted in the 433 MHz band instead of the 2.4 GHz band. Using a different band from the video signal will help mitigate any interactions between the two signals that could result in signal interference and loss of controls or video. The system will communicate video through a dual diversity ground station (visualized in Figure 4A and 4B in the Appendix) with built in redundancy for reliable video feed continuity. A pan tilt capable patch antenna will be able to track the GPS signal of the UAV and receive a high strength video feed while moving through a building.

Testing

To verify that a 900 MHz system exhibited superior performance compared to a typical 2.4 GHz system, a ground station and transmitter were placed a fixed distance away from the testing structure while a camera and receiver were carried into the structure. These systems were tested by traversing the structure and transmitting a videofeed while noting when the connection failed. In order to simulate the types of scenarios Akron SWAT would likely operate, the system was tested in two scenarios: a typical local townhouse, and a large concrete-walled apartment complex. Both buildings in question are featured as figures 7A and 7B in the Appendix.

Our observations during experiment 1 were as follows:

1. Base station and transmitter were both approximately 30 yards from the building
2. 2.4 GHz system lost signal in the basement behind the foundation; all other areas of the house kept a strong signal
3. Both systems were able to penetrate through the house and out to the street
4. 900 MHz videofeed gave a strong signal in the area that the 2.4 GHz system failed

Our observations during experiment 2 were as follows:

1. 2.4 GHz system lost signal on the 3rd floor landing
2. 2.4 GHz system lost signal by the elevator on each floor
3. 900 MHz system lost signal by the elevator on each floor
4. 900 MHz system lost signal on the 5th floor
5. 900 MHz system gave a noticeably weaker signal on the 4th floor

b. Mobility

To satisfy the improved efficiency criteria, it was necessary to identify a platform that would allow the user to quickly identify threats and clear rooms without having to drive around obstacles or worry about traversing rough or complex terrain such as stairs or cluttered floors. The best platform to perform this type of mission is a quad-copter style UAV similar to Figure 5 in the Appendix. This technology has been used extensively in recent years to support first responders and public safety personnel to great success. The platforms are inherently stable and easy to maneuver compared to other airframes which reduces time required to train new pilots on how to fly them. Switching to an airborne systems alleviates concerns of terrain obstacles and makes stairs much easier to maneuver. This platform is also highly customizable, which allows the SWAT team to install and uninstall cameras, sensors and lights to meet each particular mission's needs.

IV. Proposed Model

The system chosen to meet the requirements set by the Akron SWAT team was a quadcopter UAV that had separated signals for the controls and video feed. The system was modular in design to allow for making the UAV mission specific. The design was able to meet the set requirements with the auxiliary functions kept in mind if there was additional room in the budget.

V. Maintenance and Training

Training on the use of the system will be provided for the first users of the UAV. Detailed documentation will be provided for the maintenance of the UAV, the command station, and the controller in the event that any component is damaged and needs replaced. To make the ordering of replacement parts simpler, a list of all components will be provided with details such as each items source, description, and part number. In addition to the written instructions, video instruction will be provided for the more complicated operations such as assembly. If requested, duplicates of pre-assembled subsystems can be provided with additional funding.

VI. Feasibility

Feasibility had to be considered during all phases of the design process. There were many types of constraints that needed to be considered when questioning the feasibility of the design such as:

Technical Constraints: Can all components be found in the consumer market?

Legal Constraints: Are they any government regulations on indoor UAV operations?

Operational Deployment: Is the system simple enough to deploy that it will be used?

Time/Resources: Can this be produced with a limited budget and timeline?

After considering these constraints, the following conclusions were made for the chosen design:

Technical Constraints: All components required for the system could have been purchased either from Amazon.com or a manufacturer. One of the components required a Ham Radio License to obtain.

Legal Constraints: The FAA does not currently have any regulations that prohibit the use of UAVs indoors. However, the FAA does have procedures that government agencies like the SWAT Team are required to follow. There currently is limited legal precedent under FAA ruling for operating a UAV in this manner.

Operational Deployment: Setting up the system consisted of deploying the tripod, powering the tripod with a AC power source, powering the UAV, powering the transmitter, and turning on the monitor with the ground station. In addition, the SWAT Team would receive prior training to field deployment, including detailed instructions on system operations, design, and control. If any equipment happened to be damaged in the field, the modular design of the system made a quick replacement possible.

Time/Resources: This project was capable of being funded with $2500, and capable of being produced within 6 months.

Considering all of the above factors, the design was feasible, and was capable of working within all of the above constraints.

VII. Outcomes

The proposed system will operate as follows:

The main problem with the Akron SWAT's current platform is its inability to propagate a reliable signal through a building. In order to remedy this, the proposed design operates at a lower frequency due to better propagation characteristics. On top of this, the system has a separate signal at a lower frequency to prevent interference of video and controls as they pass between the UAV and command station. The ground station has dual diversity allowing it to switch in real time to the strongest signal. Implementing this approach satisfies requirements 1 and 6.

In addition to signal propagation, the Robotex platform is not well suited to traverse and operate inside a living space. To simplify operations of an unmanned vehicle indoors, the proposed design is based off of a quadcopter platform. A quadcopter is able to traverse steps easily, is not blocked with obstacles on the ground, and can see over typical household barriers such as couches and beds. This allow the UAV to traverse the structure more efficiently by giving a wider range of insertion points and reduce wait time for the forward team.This flight efficiency allows the UAV to clear the structure before the batteries are depleted. With a modular design in mind, the SWAT team had the ability to outfit the UAV to meet the specific requirements of the current mission (Low Light Environment, IR or FLIR, Payload). The system was constrained to fit within a 18” window and the quadcopter platform allows for an easy way to implement all the the required and desired components in a compact space. This platform change satisfies requirements 2-5 and 7 as well as keeping auxiliary functions 3 and 4 in mind.

Deploying the system in the field would be performed as described:

The operator would deploy a tripod that will have an antenna array, hardwired monitor, and receivers attached to it. They will then connect a battery to the tripod hardware to power the ground station. This ground array will also be capable of installing a laptop that can work in conjunction with a mobile hotspot to broadcast the video feed to all relevant personnel, fulfilling auxiliary function 1. After setting up the ground station, the quadcopter will be turned on and “zeroed” to the ground station. At this point, it will be ready to fly with the handheld controller and hardwired screen. A CONOPS diagram illustrating the process can be seen in figure 8 of the Appendix.

UAV Operation

Several systems need implemented on the UAV to aid the ease of operation. The UAV was given a constraint width of 18 inches to allow for clearance through a standard window in breaching protocol. This should allow the UAV to maneuver through a house, but there would still be challenges associated with flight inside a residential environment, thus the need for the following:

1. Propeller guards for safety and product longevity
2. Auto land on signal loss to prevent impacts
3. Throttled motion to aid in the control while operating in tight spaces
4. LED lighting to allow for use in dark conditions
5. Z-axis control to allow the pilot to better focus on maneuvering through the building

Deliverables

- One UAV outfitted with 900 Mhz transmitter and 433 Mhz receiver with First Person Video capabilities and GPS signal
- One command station with patch antenna on a pan tilt system and backup omnidirectional antenna for maintaining a strong video signal and transmitting video to multiple devices
- One 433 MHz Controller and Transmitter
- Written instructions for operation and maintenance of the UAV
- Video instructions for UAV assembly
- Extensive and explicite parts list for ease of component replacement

VIII. Reflections

This project was much more than just a design project. It was a lesson in municipal level bureaucracy, a two semester study of communication systems and a real example on working with non-technical individuals to produce a product they can use. The project utilized knowledge of system design and project modeling that we attained through several of our core engineering courses. Unfortunately, the design proposed was not fully realized due to budget constraints in the project. Thankfully we were able to produce adequate results from the borrowed communication system from Dr. Raible, as well as the Robotex Avatar with the SWAT team providing the requirements for the proposed system.

Appendix

Figure 1:Robotex Drone

Current System used by SWAT

Figure 2: Drone System Block Diagram

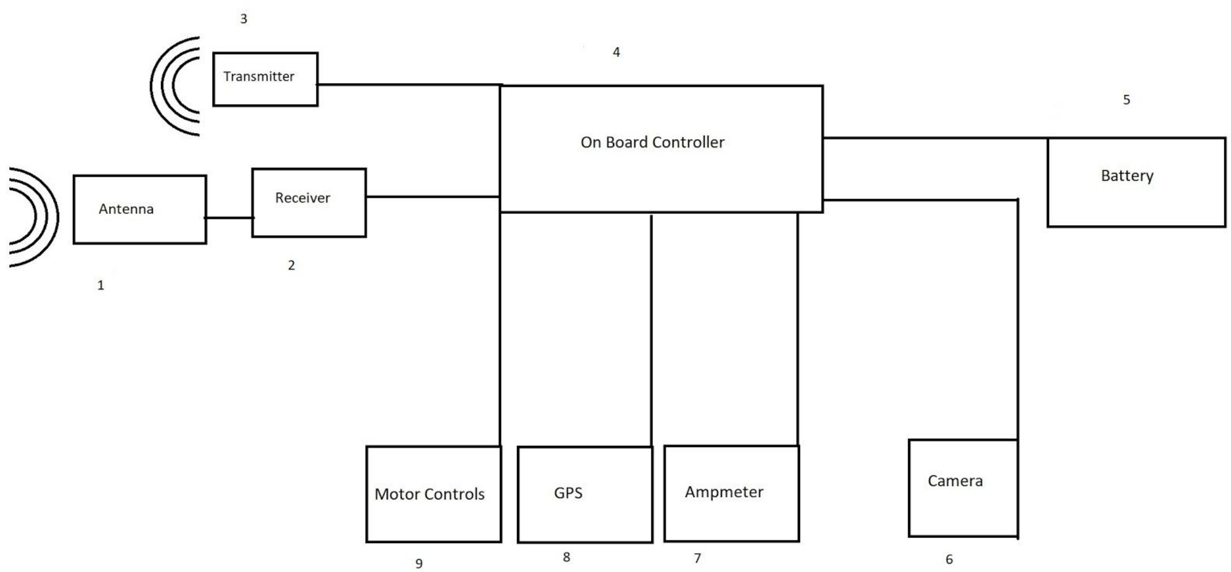


Figure 3: Command Station Block Diagram

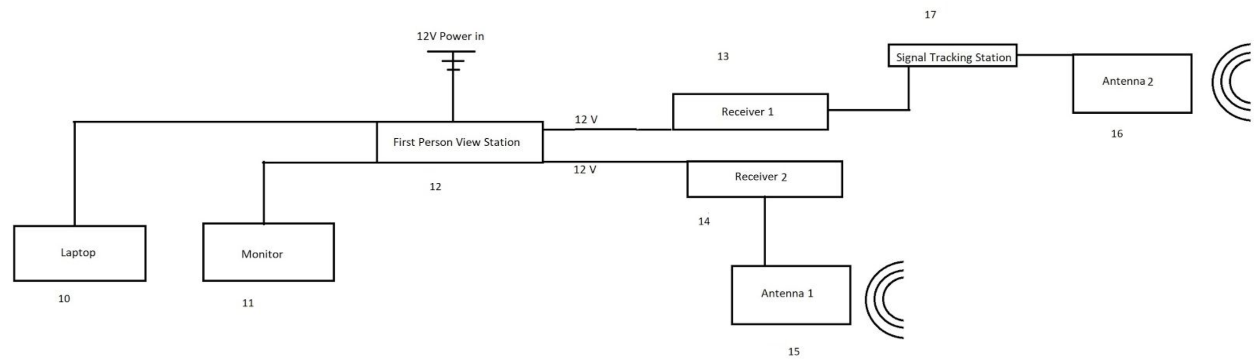


Figure 4a: Controls Transmitter

Example of Controller

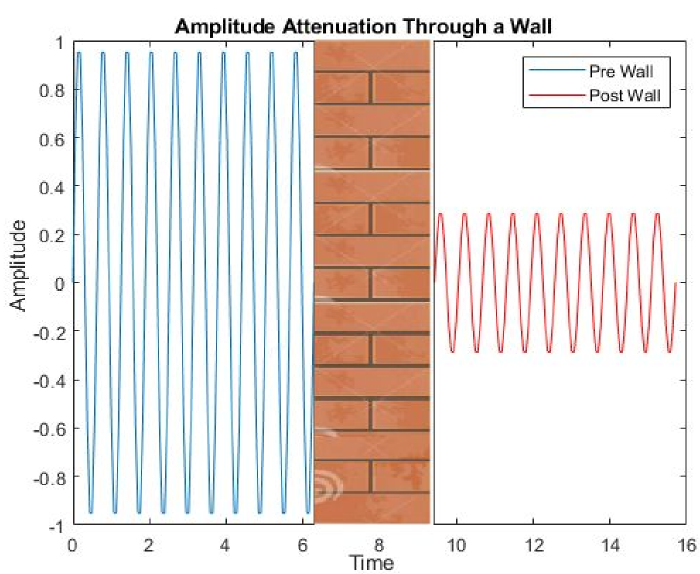
Figure 4b: Command Station Antenna Array

Example of Tripod Supported Antenna Array

Figure 5: UAV Body

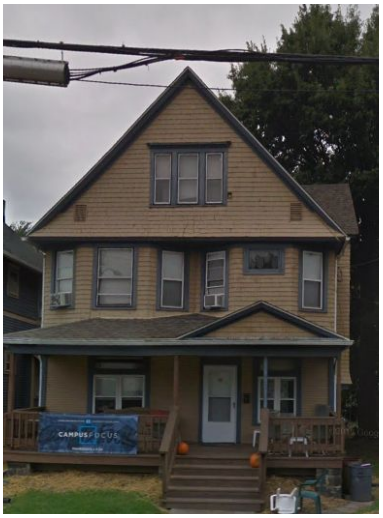
Example of UAV Structure with Motors Attached

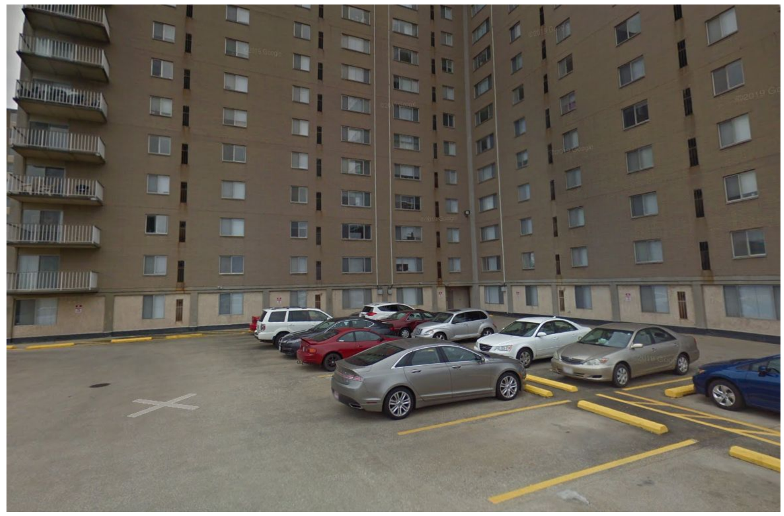
Figure 6: Example of attenuation through a wall.



Example what happens to signal as it passes through a solid object.

Figure 7: Test Sites





Test Site Alpha

Test Site Bravo

Figure 8: Concept of Operations