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Squad with Autonomous Teammates - Challenge

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Author Note: Cadets Brooks, Chaussey, Coulson, Gordon, Maude, Mcnerney, Sanders, and Tyler are seniors at the United States Military Academy. They will commission as Second Lieutenants in the United States Army in May of 2019. LTC Christopher Korpela, the director of the Robotics Research Center, and Mr. Edward Londner, a visiting professor in the department of Systems Engineering, are the advisors for this capstone project. The client and sponsor for this project is the Office of Naval Research (ONR) located in Arlington, Virginia.

Abstract: The Office of Naval Research has petitioned the cadets of the United States Military Academy's Squad with Autonomous Teammates-Challenge (SWAT-C) team to develop a system integrating unmanned aerial systems into a modern-day infantry squad to help further promote and develop the science and technology programs of the United States military. As cadets who are not subject matter experts in any set discipline, the team has the distinct advantage over our senior counterparts of being able to think of unconventional solutions to conventional problems. Through an iterative design process, the SWAT-C team has developed a system where humans will be interacting with unmanned aerial systems (UAS) and unmanned ground sensors that will provide a marked advantage against a near-peer force, encouraging the development of Tactics Techniques and Procedures (TTPs), as well as Standard Operating Procedures (SOPs) for the future operating environment.

Keywords: Unmanned Aerial Systems, Infantry Squad, Iterative Design Process

1. Introduction

Currently, U.S. military forces are looking to further develop doctrine, operational familiarity, and tactics, techniques, and procedures (TTPs) for employing unmanned aerial, surface, and subsurface systems in conjunction with human forces. This gap between cutting edge technology and its utility to an operational infantry squad requires full spectrum experimentation across a range of operating domains to gain familiarity in manned-unmanned teaming. The next step in this domain is to develop TTPs, plan operations, and create doctrine for human and machines to operate in conjunction with each other.

Such a situation requires rapid experimentation and knowledge dissemination for military forces to learn to work with unmanned systems. The research conducted by those unburdened with expert knowledge in this field may provide a unique perspective and add valuable research to future developments. For this reason, the Office of Naval Research (ONR) has sponsored both a group of cadets at the United States Military Academy and a group of midshipmen at the United States Naval Academy to participate in a competition and controlled experiment.

SWAT-C, Squad with Autonomous Teammates Challenge, is a capture the flag competition between teams of fourteen cadets at the United States Military Academy and fourteen midshipmen at the United States Naval Academy, utilizing autonomous equipment to provide surveillance and reconnaissance to conduct offensive and defensive operations. The project includes two competitions: one in the fall of 2018 and one in the spring of 2019. The first competition occurred in early December of 2018. Just like the fall competition, the spring competition, conducted from April 26 to April 29, utilized airsoft weaponry. The competition area for the event will be a one kilometer by one-kilometer square, located on the grounds of Marine Corps Base Quantico, Virginia. The fall competition resulted in one victory for the United States Military Academy and one victory for the United States Naval Academy.

1.1 System Definition

SWAT-C is exploring methods of integrating autonomous systems into an infantry squad. The project sponsor, ONR, has expressed that SWAT-C will be at least a three-year research project for them. The systems should provide a marked advantage against a near-peer force, encouraging the development of TTPs and Standard Operating Procedures (SOPs) for the future operating environment. This will be accomplished through the employment of aerial drones and operators, as well as unmanned sensor systems, as a force multiplier to an infantry squad. These assets must not hinder squad movement or inhibit effectiveness on the battlefield. The final system will utilize the PD-100 Black Hornet drone in conjunction with unmanned ground sensors to relay live video feed of the opposition force and their flag to the Android Tactical Assault Kit (ATAK) carried by six squad members enabling dynamic planning and reaction in the conduct of operations, as can be seen in Figure 1.

2. System Context and Literature Reviews

The ONR Code 30 Autonomy Program Officer has obligated funds to support The USMA and the USNA SWAT-C faculty and student teams with preparing to conduct the challenge, while adhering to preestablished guidance, to enable a rifle platoon squad leader to fight and lead a squad in combat. The context of the organization, weapons, capabilities, and limitations is based off of the task organization of a Marine rifle squad.

Unmanned systems in the military sector that are currently used at the squad level are largely teleoperated or used with pre-programmed missions. In contrast, there has been much development in unmanned system technology in terms of autonomy, GPS denied navigation, and control in academia and the private sector. While this development is new, many of these technologies have not been tested for their ability to benefit a tactical unit. In order to bridge this gap, ONR Code 30 is sponsoring efforts that will validate the utility of these unmanned system technologies with the end state of improving mission effectiveness. It is not enough for the technology to exist, it must actually integrate effectively in order to enhance the ability of our Soldiers, Sailors, Airmen, and Marines conducting operations.

SWAT-C is designed to encompass the contemporary train of thought in regard to electronic warfare combined with context of the uncertain cyber domain at the tactical level in the modern multi-domain battlefield.

To focus our efforts, the team utilized the Defense Advanced Research Projects Agency's (DARPA) Squad X Core Technologies (SXCT) program as a case study to outline our efforts (Root). Squad X aims to develop novel technologies that could be integrated into user-friendly systems that would extend squad awareness and engagement capabilities without imposing physical and cognitive burdens. The goal is to speed the development of new, lightweight, integrated systems that provide infantry squads unprecedented awareness, adaptability and flexibility in complex environments, and enable dismounted Soldiers and Marines to more intuitively understand and control their complex mission environments.

As a part of the capstone project, the SWAT-C team has decided to hone in on two of the four key technical areas that Squad X focuses on. For this the team focused on Squad Sensing and Squad Autonomy. Since this is a three-year project, operations are based using the premise of projected success in these areas according to the time table developed. With the key technical area of Squad Sensing, the desired end-state capability is to detect potential threats at a squad-relevant operational pace. Capabilities of interest to supplement this include multi-source data fusion and autonomous threat detection. With the key technical area of Squad Autonomy, the desired end-state capability is to increase squad members' real-time knowledge of their own and teammates' locations in GPS-denied environments through collaboration with embedded unmanned air and ground systems. Capabilities of interest to supplement this include robust collaboration between humans and unmanned systems.

3. System Development Approach

For this project, the SWAT-C team approached the challenge using two different methods: the top-down and bottom-up. These two methods provide different views on how the project will meet its stated requirements and the desires of the personnel utilizing the overall design. The requirements were only to gather GPS information. However, the competition required 14 personnel to conduct squad level tactics in a 1x1 km area of restricted terrain. These conditions imposed challenges on the broadcasting of signals and movement of autonomous machines and people. The competition required 3.5 hour long iterations, which put constraints on our systems for battery life. All of these requirements, conditions and constraints caused us to approach the system from the top-down and bottom-up.

The top-down approach for the system, as seen in Figure 2, focused on the requirements of having GPS and utilizing drones for autonomous teammates. The GPS aspect focused on gathering GPS information for each device and person throughout the competition. The system used commercial off the shelf equipment to accomplish this goal by obtaining

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devices to attach to members and potential electrical systems. The other aspect of the drones for autonomous teammates came from the aspect of using drones for reconnaissance, attacking, and ground support. The system focused on these three areas in developing and acquiring specific drones to fulfill these roles.

The bottom-up ways for the system came from the feedback after the fall competition and potential assets provided, these subsystems of the main system can been seen in Figure 3. The first issue apparent was the lack of communications throughout the competition. Members of the team needed some way to communicate with other members of the squad in order to properly attack and defend. Therefore, the SWAT-C team decided to pursue basic Army methods for completing this by seeking to acquire AN/PRC-148 Multiband Inter/Intra Team Radios (MBITRs) and Advanced System Improvement Program radios (ASIPs) to cover the basic voice connection with each other. The other issue noted in the competition was the lack of situational awareness in the environment. Due to the personnel limitations, the squad needed a method to determine where enemy personnel were approaching. The SWAT-C team thought of designing a system that could provide eyes and notifications of people coming from specific directions. Therefore, SWAT-C team needed to design a system of cameras that could connect back to individuals and relay the information if something approached us. The idea required computers and camera systems that could report back to a centralized node and update all members of the squad. Therefore, SWAT-C team determined to create a network, utilizing multiple computer systems and devices to receive these updates. This created the network design aspect, ATAK system incorporation, and Raspberry Pi development.

The work with ATAK development afforded the opportunity to incorporate the drone feed into the system. The ATAK system could allow the individual users to have more eyes from the different drones in the air and provide more information to the user that would not distract from the mission.

Therefore, the primary means of development focused on the bottom up approach from what the individual members of the squad required, since the project was fairly open in the requirements aspect, Figure 4 illustrates how each subsystem relates to the main system's first level functions. However, the top down approach showed potential outside the box ideas. These ideas were then incorporated into the system based on available resources and applicability to the squad as seen from their perspective.

4. System Design

This OV-1 Diagram displays the overarching concept of the operations for how our SWAT-C team will integrate unmanned systems and technologies into an infantry squad sized element. Squad members will be using the ATAK system to receive live video feed from both the UAS systems deployed as well as the unmanned ground sensors. Squad members will use this information to determine both offensive and defensive courses of action, while the command center will be monitoring the squad member's movements and maintaining communications through a radio mesh network.

Figure 1. OV-1 Diagram

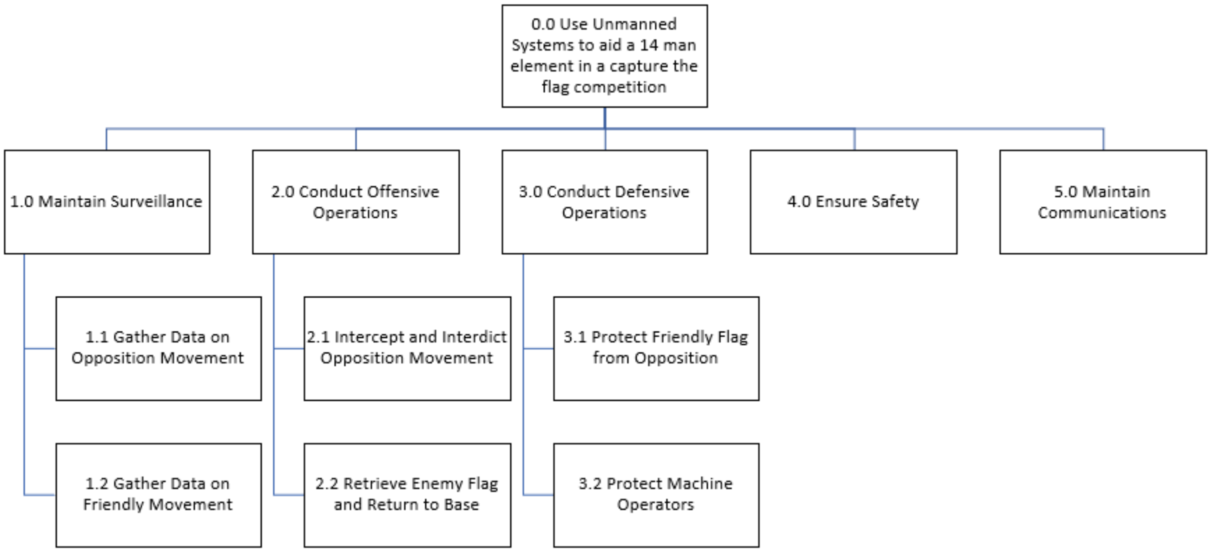

Figure 2. Functional Hierarchy

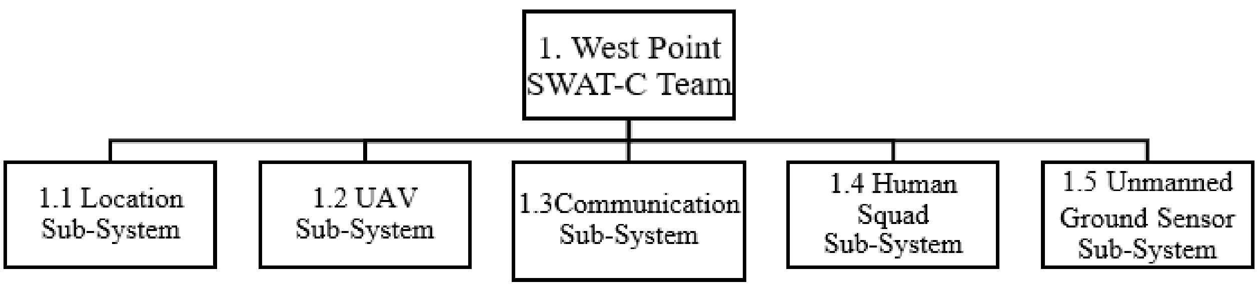

Figure 3. Internal Block Definition Diagram

	Maintain Surveillance	Conduct Offensive Operations	Conduct Defensive Operations	Ensure Safety	Maintain Communication
Location Sub-System	X	X	X	X	
UAV Sub-System	X		X		X
Communication Sub-System		X	X	X	X
Human Squad Sub-System	X	X	X	X	X
Unmanned Ground Sensor System	X		X		

Figure 4. N-2 Diagram

5. Hardware

The United States Military Academy SWAT-C team has access to a variety of organizations and facilities in preparing for this competition. For software development in house, the team is working with the West Point Robotics Research Center. The research center provides Linux platforms for development in addition to references and “read-me” files for utilizing common software packages in the Linux environment.

In-house hardware development is done with the USMA Electrical Engineering Support Group. Their shop provides access to 3D printers, lathes, soldering equipment, and assorted connectors, wires, and enclosures for product development. Additionally, they provide common components such as batteries for our products.

Through the grant from ONR, the SWAT-C team has acquired several components of the system in addition to components from the Department of Electrical Engineering and Computer Science that are being utilized for testing purposes. The SWAT-C team purchased a batch of single board computers and related sensors in development for the ground sensor network. Additionally, the team is in the process of purchasing end user devices for the Android Tactical Assault Kit. Ubiquiti commercial networking equipment as well as different ruggedized laptops have been tested, both on loan from the department

In addition to resources within West Point, the team worked with several outside organizations to get hands on experience with the solutions currently being fielded. The PD-100 Black Hornet from U.S. Army Natick Soldier Systems Center was used. The team used their software to integrate the Black Hornet into the ATAK network. Additionally, the team coordinated with the Army Cyber Institute for tools to hack enemy drones.

Finally, the team has developed an ongoing relationship with the Rapid Equipping Force. The team was able to use their InstantEye quadcopter platforms as well as anti-UAS platforms and are currently working to acquire more of these systems for testing.

6. Field Testing

The team wrote a series a tests to ensure that the subsystems meet the individual requirements, derived through a detailed analysis, before attempting to merge them all together into a final, complete system. The system was broken down into these components: power supply, Raspberry Pi, compass, GPS, and long range Wi-Fi.

The requirements for the power supply included being able to power a Raspberry Pi under load, in a field environment for 3 hours. Additionally, the power supply needed to be as light and as small as possible, since it needed to be placed inside a discrete weatherproof box, carried by a dismounted infantryman. Ideally, it would weigh less than 400 grams and have dimensions less than or equal to 150mm by 75mm by 75mm for the length, width and height respectively. Assuming the maximum possible power draw from the system, the battery will last a minimum of 5 hours, meeting the 3 hour requirement. The battery weighed 372 grams, had a length of 107 mm, width of 40 mm, and height of 35 mm, meeting all of the requirements.

The Raspberry Pi needed to be able to withstand temperatures between 10 and 120 degrees Fahrenheit, humid conditions, rain, winds of up to 30 miles per hour, weigh less than 200 grams, and be able to function after being jostled around by a soldier running with it in a backpack for 400 meters.

The compass must weigh less than 200 grams, have dimensions less than or equal to 50mm by 50mm by 25mm for the length, width and height respectively, and give a compass heading accurate within +/- 5 degrees of the true value. The compass meets these requirements. It was taken to Range 11 where it was referenced against an iPhone's compass. The team found that it provided headings accurate within the established tolerance. Ten trials were conducted, and the compass passed to the standard every time.

The GPS must weigh less than 200 grams, have dimensions less than or equal to 50mm by 50mm by 25mm for the length, width and height respectively, and give a GPS reading accurate to the millisecond measurement with a less than 5 second delay. The GPS met the size and weight requirements, and was tested on local grounds at West Point, with 2 of theteam members walking and running around campus.

The long range Wi-Fi must weigh less than 1 kg, have dimensions less than or equal to 1000mm by 100mm by 50mm for the length, width and height respectively, assign an IP address to an end user device automatically, and be able to reach a user 500 meters away. The team will be attempting to implement a few of these Wi-Fi boosters. The routers and their corresponding antenna meet the height and weight requirements but have not been tested yet. Testing ended 30 MAR 2019.

7. Ongoing and Future Work

There is much ongoing and future work being done in this problem space. Currently, Squad X represents a very expensive ongoing effort by DARPA to develop capabilities and procedures within the context of a squad.

The results of this project will enable future SWAT-C teams to identify unconsidered or unexplored routes in a relatively constrained cost environment, similar to how many adversaries often operate cost constrained. This context offers the potential for efficient, sustainable solutions for the future. Furthermore, this project will ideally enable better learning about how individuals learn. Whether successful or not, the documentation of the pursuit of meaningful ideas will provide the Army valuable feedback in creating efficient and effective learning and feedback loops, as the rate of changes which the Army will have to continue to keep adapting to is only increasing.

In terms of fully realizing and exploring the problem space, there are still vast gaps in knowledge. With the rate of technology increasing and the constant updates and changes in commercial off the shelf capabilities, constant refinement and testing must always be done. However, as core principles and procedures emerge for the modern squad, then there naturally arise questions of scale.

How can the tactics and procedures which have been developed for an Infantry squad be adapted to be effective for a tank or mechanized force? How can a squad's tactics be integrated within a whole platoon or company? How do these tactics change the previous assumptions and timelines for operations which have been planned within the Army forged through the past decades of warfare?

8. Conclusion

The work and system the SWAT-C team is creating has real world applications. The Office of Naval Research is studying the decisions made and tactics used by both sides during the competition to inform the defense community of new ways to look at squad level warfare in the future. The fall competition was informative in that it showed both sides what strategies and technologies are viable in the field. The plan for the spring competition is to take those lessons learned and present a solution to the field problem given. Moving forward into the spring competition, the SWAT-C team will record its findings and research to aid the next group working on this system.

9. References

LTC Root, Philip. *Squad X Core Technologies (SXCT) (Archived),* Defense Advanced Research Projects Agency.