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A New Cyber Enemy and How to Beat It

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Abstract: A problem that the United States Army faces is with the use of Unmanned Aerial Systems (UAS) flown by enemy units. These UAS's can tactically drop airborne improvised explosive devices over a standard infantry platoon conducting a mission as well as having the potential to be used to call for indirect fire. To combat this new problem the United States Army needs to adopt a counter UAS jamming system will allow a standard infantry platoon to continue on mission even if spotted. The capstone team was told to transition from creating counter UAS solutions to creating a baseline experiment that could better assist companies in creating an optimal counter UAS system. This paper outlines the research and experiment conducted by the team in an effort to create a series of requirements and testing capabilities for the United States Army to r inform their decision on purchasing a dismounted counter-UAS system.

Keywords: Counter Unmanned Aerial System, Soldier Survivability, Infantry Platoon

1. PDR Summary

The problem facing the Army as a whole is that Enemy UASs are attacking units at the platoon level while current counter UAS systems are too bulky to be carried by a person on a patrol. Potential solutions are created and debated with data to back it up along with other pertinent information in a PDR or Preliminary Design Review. A Preliminary Design Review or PDR is what is first presented before any major decisions are made by the Army. This is the first thing created in order to serve as a baseline for the entire project. Our capstone group was tasked with finding a way to combat Enemy UASs without hindering the soldier load. This was done by using the PDR development process in order to better understand what it was that was demanded of us.

1.1 Background

The Army currently faces a low effort cyber problem in that the Enemy has low level drones such as the DJI Phantom and will mount a grenade on it to drop over troops. In reality the current time standard associated with acquiring new systems for Soldiers is drawn out. In today's battlefield there are constant updates to ever changing technologies and tactics applied with these technologies. A well-defined baseline of requirements could reduce overall time consumed in the acquisition process. The main stakeholders were identified in this evolving problem are Army Cyber Institute, the Soldier, Training and capabilities command and others. The need statement associated with this problem is; The United States Army needs a counter UAS system to increase soldier survivability at the squad level. An Operational View (OV-1) "provides a graphical depiction of what the architecture is about and an idea of the players and operations involved" (Department of Defense).

The OV-1 shows the operational context for a counter-UAS system. It would start with boot up and scan in which the system passively scans for enemy UASs. Once an enemy UAS is detected the system will rely that info to the user through the screen. Once the user had made a decision a course of action is made and chosen on the screen which can vary from either passively hiding from the drone to directly eliminating it. The system will then enact the course of action and check for how effective it was. Once completed the system will revert back to the stand- by mode and scan for additional UASs.

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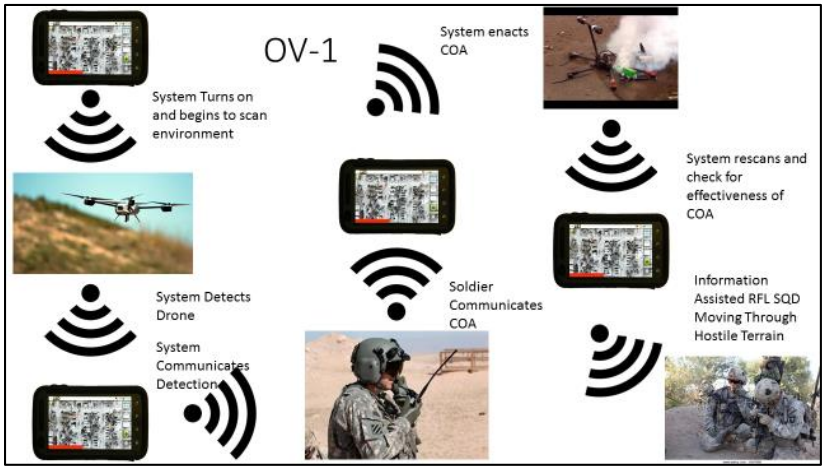

Figure 1. OV-1

1.2 Requirements and Concepts

Functional Analysis consists of the functional hierarchy and the functional flow block diagram and the internal block definition diagram. Functional Hierarchy is a top down model on the must statement. In this instance it was soldier survivability, from there branches are made going into smaller things that the system will do. This all goes down to the smallest possible thing or breaking it into the simplest of terms.

The Functional flow block diagram is what breaks the system down into the things it will do, so at the top level you have that it will monitor the surrounding area which leads into the user receiving threat data. Those are two top level things that are done but does not go into detail of what it takes to get into that next stage, the flow block diagram fills in those gaps in order to give a better understanding of the system. This is shown below.

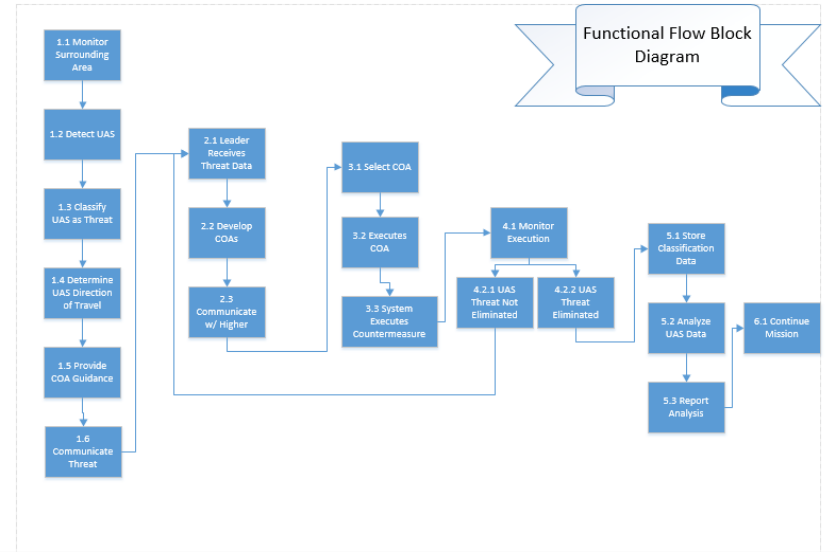

Figure 2: Functional Flow Block Diagram

The system requirements are the must, needs, wants of the entire system. This is broken into what the system must do such as countering a UAS, the needs of the clients such as “I need it to detect counter UAS at least 500m out,” and the wants are non-mission essential such as “I want the system to have a camouflage paint job.” The team works through these requirements in that order and breaks them into a list that was put into the final PDR. Some examples are “Software shall

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determine if threat is UAS or not," "Software shall classify level of threat based on metrics," "Software shall develop COA's base on threat level," "Software shall to delete irrelevant data," "Software shall be able to determine completion of COA."

Concepts are the initial 10 ideas that were created for an initial proposal to fulfill the requirements. These would be narrowed done multiple times until a decision was reached to test counter UAS technology. The ideas ranged from very impractical such as an Electronic Magnetic Pulse to more practical such as a Counter- UAS drone that could detect the command and control location as well as take down the Enemy UAS. Through feasibility analysis we were able to narrow down the list 5 and then eventually the one solution.

This feasibility matrix lists the five concepts generated and evaluates them on five categories: technology, human performance, mission performance, maintenance and sustainability, and life cycle cost. The five concepts created at this point were an Invisibility cloak, which would hide a platoon from enemy UAS, a stalker drone which was a more direct attack method against enemy UAS's, drone communication which would use drones to extend friendly radio capability, Army Waze which was a app that would allow friendly units to see likely attacks based on an algorithm, and an invisibility laser which would blind an enemy UAS. A low technology score indicates that the technology either does not exist or is impractical in application and a high score indicates the technology exists and is already proven to be effective. A low human performance score is defined as the inability for the system to be used effectively by the soldier in such a way that he or she is not removed from the squad's fighting force, while a high score indicates the soldier being able to use the system as well as remain in the fight. A low mission performance score is defined as the inability for the system to perform under mission conditions, while a high score means the system performs well under pressure and harsh conditions. A low maintenance & sustainability score indicates the system will be difficult to maintain and or require significant time off-line, and a high score indicates a minimal amount of maintenance will be needed to keep the system online. A low life cycle cost implies that the system will be expensive from design to retirement, and a high score implies this cost will be low in comparison to the other concepts.

	Concept	Technology	Human Performance	Mission Performance	Maintence & Sustainability	Cost (Life Cycle 20 yrs.)
1	Invisibility Cloak	5	6	8	9	8
2	Stalker	7	1	7	6	5
3	Drone Comms	8	8	6	4	4
4	Waze for Army	6	8	8	7	7
5	Invisibility Lazer	7	2	5	6	2

Figure 3: Feasibility Matrix

1.3 PDR Conclusion

In conclusion, The Counter UAS system is an amalgamation of the stalker and Army waze in which it will detect a threat, convey it to the user through the blue force tracker and allow the user to issue a response whether it be passive or aggressive. The Counter UAS System does this by being low cost and easily repairable while still being light weight and portable for squad movements. The Counter UAS System operates in any physical condition (e.g. temperature, precipitation) all year round. The system requires minimal maintenance and sustainability, all while remaining extremely reliable. The way this is achieved is with the soldier being able to complete simple repairs as well as carrying extra parts on his person during a mission. The counter UAS system would be an improvement over anything that the Army has currently. The reason being that it is portable and able to be used at the squad level.

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2. Technical Performance Measures

TPMs or technical performance measures are a set of testing measures that are created from the requirements. Figure 5 shows a set of technical performance measures derived from the PDR's counter-UAS requirements. Figure 5 shows a set of technical performance measures derived from the PDR's counter-UAS requirements.

TPM ID	TPM	Requirement	Test Objective	Success
1	System does not interfere with soldiers' ability to perform basic soldier tasks	System shall not detract from the abiltiy of the Soldier to complete their primary mission	Verify that the wraqe and transportation of the system doer nat detract from the soldiers' ability ta perform their primary duty in the squad	Score will be assigned based off weight and configuration on Soldier, as the weight increases by 2lbs it decreases in score. Anything over 20lbs will receive a 1. In regards to configuration, Soldier will be tested in full range of motion, score will be 10 if soldier
2	System jams or diables enemy UAS at specified distances and altiudes	Accurately executes defined counter UAS attack 95% of time	Counter UAS System effectively jamr ar dirabler Enemy Dranes uithin 600m	Score uill be arrigned ta system if drane ir succesrfully attacked at each angle from each dirtancr. A full score af 10 will be arrigned if system can jam the drane at all 4 angler at all dirtancer, r core af 5 will be arrigned if system can anly jam half af the dirtancer.
3	Power usage, used by the jammers and transmiter, measured in watts	Accurately executes defined counter UAS attack 95% of time	Determine the pauer level required ta jam ar dirable UAS at specified dirtancer and altiudes	Score uill be arrigned based off pauer ured by the system. The leart amount af pauer ured that succesrfully attacks the drane uill receive the highest score af 10.
4	System does not interfere with established US Army communications systems	System shall be compatible with current Army communication technologies	Verify that uhen the system ir jamming dranes that it daes nat alra jam US Army communications systems	Ar the system ir being ured messages uill be sent acrass current Army communication technalagies. Interference nat arsociated uith technalagy capabilities uill reduce the score arrigned ta this system.
5	System turn on time is less than 30s	System turn on time <30s	Verify and validate that the counter UAS system can baat up in lear than 30 secandr.	Score uill be arrigned based an turn an time, ar time pralangs score uill increare. A 10 will be arrigned if system can be ured uithin 3 secandr af turn an.
6	System cuts enemy UAS video at specified distances and altiudes.	System shall effectively cut video feed of enemy UAS.	Verify and validate that the counter UAS system can effectively cut the enemy UAS feed at the specified range.	Video cannection betueen the UAV and Controller ir lart. The langer the lart cannection the better, score uill increare every 2 minutes that cannection ir lart. Score uill be maximum af 10 uhen cannection lart far aver 15 minutes ta allau simulation af platoan leaving location.

Figure 4: Technical Performance Measure Table

3. Test Plan

The Capstone group was tasked with creating and conducting a field test for current counter UAS capabilities. The current test has the systems counter UAS capabilities being tested at 500m increments and being jammed from the UASs four different possible directions. This is to ensure that the jammer can still effectively jam the UASs antenna regardless of flight path. One consideration that had to be taken into account was that GPS jamming was considered but could not be done due to the potential to interfere with aircraft. Another consideration was that one of the frequencies used by the jammer is also the emergency frequency for local emergency services and cannot be used.

Data will be collected using the spreadsheet shown below which has the UAS being jammed from four directions which tests the effectiveness against the onboard antenna for the UAS.

Once the data has been collected for the jammer it will be calculated against power received from the controller. If it is stronger than the signal from the controller and the receiver sensitivity, then the signal will be jammed. Based on the calculations in the table below the UAS should be successfully jammed at all distances because the jammer is more than capable of creating those power levels at the specified distances.

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Distance from Start Point (m)	Lowest Power Level From LP (dBm)	FSPL	Lowest Power Level From LP (W)	Distance from Jammer (m)	Lowest Power Level at UAV to Jam (dBm)	FSPL	Power From Jammer (dBm)	Lowest Power Level From Jammer (W)
401.1234224	-68.1175685	92.1175685	1.54256E-07	1329.595427	-88.1175685	102.5263983	1.408829815	0.001383194
659.223786	-72.43266544	96.43266544	5.71128E-08	939.4147114	-92.43266544	99.5091552	-5.923510241	0.000255652
943.9412058	-75.55090695	99.55090695	2.78554E-08	633.309561	-95.55090695	96.08432895	-12.466578	5.66686E-05
1236.486959	-77.89579886	101.8957989	1.62338E-08	441.5529413	-97.89579886	92.9516637	-17.94413516	1.60541E-05
1329.595427	-78.52639831	102.5263983	1.40398E-08	401.1234224	-98.52639831	92.1175685	-19.40882981	1.14582E-05

Figure 2: According to the theoretical calculations above, the jammer should have enough power to jam the drone at all of the specified distances. Furthermore, the jammer should be able to complete the attack with a fraction of its lowest power setting of 1W.

The intent of this experiment is to validate counter UAS system requirements with an end state of developing a baseline for system requirement design for future development.

4. Equations

The following two formulas were used to double check the calculated for loss due to free space. No obstacles were included in these calculations.

Distance: the distance used were calculated using the Pythagorean Theorem, with the parameters being the horizontal distance along the ground and the altitude of the drone

$$\mathrm{D} = \sqrt{ground\ distance^2 + altitude^2} \quad (1)$$

Free Space Loss Calculation: The below equations were used to calculate the declining strength of the signal based on its frequency and the distance that the signal travels.

$$\mathrm{L(fs)} = 20 * \log d + 20 * \log f + C \quad (2)$$

$$\mathrm{FSPL} = 10 * \log((\frac{4\pi df}{c})^2) \quad (3)$$

Link Budget Calculation: This equation was used to calculate the power received at the UAS from the controller, the jamming system, and the system used to cut the UAS' video feed. The power received from the drone controller and the system cutting the video feed were calculated without the Fade Margin parameter.

$$\mathrm{P} = G_T + G_R + P_T - L_T - L_R - \mathrm{L(fs)} - \mathrm{Fade\ Margin} \quad (4)$$

5. Moving Forward

5.1 What this means to the Army

What the data we collect can provide the army is a starting point. It can show how effective current counter UAS technology is, as well as showing how the test was ran. The data collected could then provide a template for future tests to be ran. It can

also show the manufacture where to improve, because if for example the system is very effective against Enemy UASs but very heavy then a soldier cannot effectively use it. The companies have cyber defeats for the UAS as well as a simple solution that is more "point and shoot." The data collected will help them in their endeavors in creating a better system for the soldiers dealing with this. In the long run this could mean less time in-between approval times. These short approval times would mean less time in which the enemy has an effective UAS system against soldiers.

With Soldier's having to deal with an ever changing enemy having a baseline test which shows how tests should be ran in the future it would be able to speed up the process in which new methods are approved. This would help the Army in being able to get new counter UAS methods on the field faster. While this does not solve the current counter UAS problem it does give us a starting point to get to a hundred percent solution.

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