SMALL UNIT UNMANNED WEAPON SYSTEM FOR TODAY'S ARMY

CDT Julia D. Carier,, CDT Earnest D. Smith, CDT Andrew M. Wade, CDT Paul S. Walker, LTC Michael J. Kwinn Jr. PhD

Abstract— **While engaged in the Global War on Terror, our soldiers have discovered the need at the small unit level for a non-line of sight, man portable, lethal, unmanned device that could be used to gain entry into a building by blowing the door, kill enemy personnel or disable soft skinned vehicles without a soldier ever exposing himself to the enemy and while minimizing collateral damage [1]. This capability could potentially save soldiers lives and increase the combat effectiveness of our units currently deployed in combat zones. Our project team will evaluate several alternatives and provide a recommended solution for such a device to provide these capabilities to the soldier on the ground.**

Currently, the US Army – specifically Special Operations Command (SOCOM) and the US Marine Corps operate with small and unmanned surveillance equipment such as the Raven B, DRAGON Eye, FPASS, Pointer, and Silver Fox [2]. None of these systems however have a lethal component. Additionally, they are currently all operated primarily at the company or battalion level. Other Unmanned Ariel Vehicles are equipped with a lethal capability such as the MQ-1B Armed Predator (Hellfire Missiles), but they are too heavy and require too large a launch footprint to be effectively employed by small unit ground forces. FMI 3-04.155 (Army Unmanned Aircraft System Operations) is the current field manual which outlines the effective employment of current UAS in the inventory [3]. Currently, there is a noticeable capability void which can be best addressed by a system which incorporates the flexibility of a smaller man portable UAV with the lethality of one of the larger systems. Our study seeks to find a solution which will address this capability void.

I. INTRODUCTION

Recently, while engaged in the Global War on terror a capability Gap has been discovered at the small unit level. Platoons and squads do not have the organic fire support capability that would allow them to react to and destroy the enemy in a timely and easily coordinated manner. The use of Unmanned Ariel Vehicles (UAVs) in today's modern military is ubiquitous. The United States currently employs several different systems with different mission focuses and capabilities, but most are oriented toward the mission of providing surveillance capabilities to the ground commander. This capability is extremely important, but once the commander identifies a threat, what options does he have? If the threat is too serious or poses to high of a risk to expose his troops to hostile fire, then his only other options are to go through joint channels in order to request fire support or close air support from adjacent units. This can often be time consuming, frustrating, and dangerous for the commander to rely on others for fire support. In the time that it takes for approval or for the fires to arrive, the threat may have moved on or been able to take cover. Conversely, if the ground commander had an organic, accurate, and reliable fire support capability he would be able to react to and neutralize threats in a timely and deadly manner.

Our project team was assembled with the goal of designing a system for the Army that would fill this capability gap. Our project team includes one Systems Engineering major, one Operations Research major, and two Engineering Management majors. Based on our systems engineering backgrounds, good looks, and a common inclination towards value focused thinking, we will utilize the Systems Decision Process (SDP) in order solve this problem.

II. BACKGROUND

As recently as five years ago (2002), UAVs were not considered an important capability for ground troops. From 1988 until 2002, UAV research and development received a steady $200 million per year from the department of defense. In the last 6 years however, the amount of spending has risen significantly and this year DoD is spending over $2 billion on UAV research and development. The two biggest factors responsible for these changes are the nature of modern combat, and advancements in technology which enable contractors to meet the needs of the soldiers in combat in new ways. UAVs are currently used in combat zones all around the world and domestically carry out missions including border security, coast guard/maritime missions, transportation security, and protection of critical infrastructure. The most recent trend in UAV research and development has been investigating the possibility of developing armed small UAVs that can carry out the traditional surveillance mission, but at the same time provide a lethal capability. The only armed UAV to date is the Predator, which carries a payload of hellfire missiles. This UAV is very effective; however it is massive, weighing in at 2,250 pounds. The Predator is far too large to be organic at the small unit level, and so the goal of this project will be to design a UAV that can be employed by a platoon or squad.

III. APPROACH

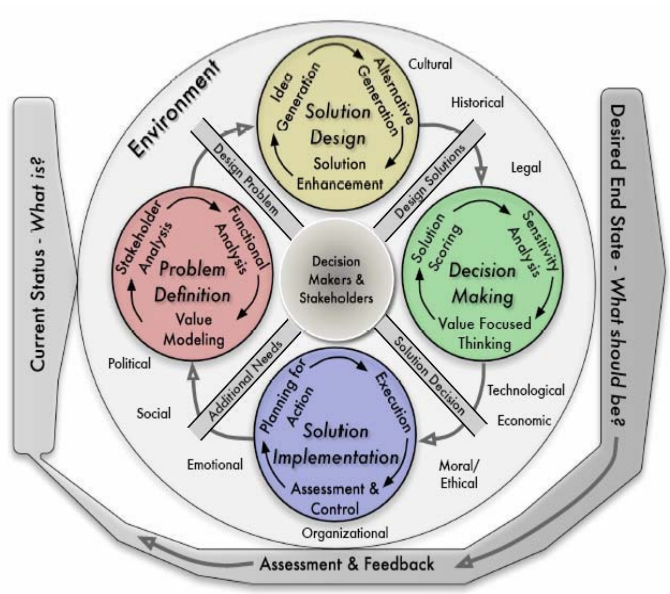

Figure1. The Systems Decision Process [4]

The Systems Decision Process (SDP) is a four phase process developed by the Department of Systems Engineering at the United States Military Academy. The process is a value focused method to determine the best possible solution to a problem. The process is broken down into four phases; problem definition, solution design, decision making, and solution implementation [4].

The key tasks in the problem definition phase are to conduct a stakeholder analysis, functional analysis, and value modeling. It is also important during this phase to develop a revised problem statement that satisfies the client and effectively encompasses the problem. Before proposing a focused problem statement the project team needs to conduct significant background research so that they will understand the problem better than the client [4].

In solution design the project team will develop a set of feasible alternatives based on their value model. The value model needs to be stressed in this phase because of the value focused nature of the SDP. A project team will often conduct a Pareto analysis during this phase so that they can more closely examine the problem and determine the significance of different factors.

The three main tasks of the solution design phase are score candidate solutions, conduct sensitivity analysis and improve solutions. During this phase the project team will confirm their weights and measures and model simulation results in order to build their argument for their recommended solution. At the end of this phase the project team will present to the decision maker their solution for a final decision [4].

The solution implementation phase may or may not be required in certain projects. The project team should provide a recommendation for how to implement their solution because they will have the greatest understanding of the capabilities of the system, but ultimately implementation will be handled through other channels using the feedback provided by the project team [4].

IV. WORK COMPLETED

A. Problem Definition

Stakeholder Analysis- We began the problem definition phase with background research and interviews of stakeholders. We spoke with and surveyed soldiers, officers, project stakeholders, and manufacturers to determine the needs and possible capabilities of the system. Though each stakeholder had a variety of different wants and needs, we developed three primary findings: soldiers need increased capabilities beyond the current system (surveillance based UAVs in conjunction with fire support), current systems would not be cost effective at a platoon or squad level, and there is a capability gap in the small unit's organic ability to survey and destroy the enemy. Along with these larger scale findings, we also received almost unanimous insight on the physical structure and capabilities of the UAV. All our stakeholders agreed that it needed to be man portable (light enough for a soldier to carry in their backpack, meaning no more than 25 lbs) [5], quickly and discreetly launched, easily maneuvered, and capable of providing limited surveillance capabilities with a lethal component approximately equal to that of a 40-60mm mortar round. These findings gave us the basis for our revised problem statement and functional analysis.

Functional Analysis- Based on the information obtained during our stakeholder analysis, we were able to determine the basic functions that our system needed to perform. From start to finish we must be able to transport the system (backpackable, lightweight, durable), launch the system (easy setup, small footprint), operate the system (react to commands, trainable), maneuver the system (ability to operate in restricted space), achieve the desired effects (surveillance and lethality), and then end the mission safely. Each of these events contains sub functions or concerns (in parentheses following each basic function) that affect the systems ability to perform the event. The functional flow diagram allows us to display a logical sequence of the events that will occur during the deployment of our system. This is an effective means of modeling the system because it allows us to analyze each aspect of the system and what functions go into each phase. Certain aspects of the system that are important in the "launch" phase are not important during the "achieve desired effects phase," and so the functional flow diagram allows us to examine in depth each phase of our systems deployment and ensures that each is analyzed with the equal and appropriate scrutiny. Without a functional flow diagram it may become easy to accidentally ignore a certain aspect of the system.

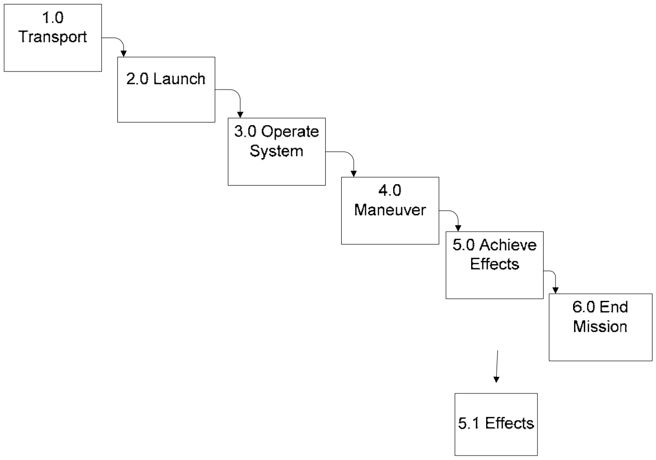

Figure 2. Functional Flow Diagram

From the functional flow diagram, we were then able to break down each individual function and determine the objectives that we want to achieve with each function. The product of this process was our revised problem statement and functional hierarchy.

Revised Problem Statement- The initial problem statement given to us by the UAS project office was [6]; "Identify potential solutions to provide a lethal unmanned aircraft system (UAS) capability in non-line-of-sight (NLOS) applications to the small unit (platoon/squad) leader." After conducting significant background research and conducting our stakeholder analysis, we used our initial problem statement to create our revised problem statement; "Develop a small unit (platoon/squad) unmanned device that is man-portable, quickly launched, maneuverable, easily controlled, will achieve the desired effects of providing surveillance and lethality, and safely and effectively end mission." We believe that our revised problem statement effectively outlines the needs that became apparent while conducting our stakeholder analysis. Our client approved our revised problem statement and agreed that a system that met these requirements would surely be a valuable asset in today's army.

The functional hierarchy is a rather cumbersome presentation of all of the objectives, value measures, and value curves for each function. Beginning with transporting the system, we know that we want the system to be reliable and portable by foot soldiers. We can achieve this objective by maximizing the reliability of the system, minimizing the system weight, and minimizing the compacted dimensions. In launching the system, we know that we have to prepare the system to launch and operate the system with a small launch footprint. We can do this by minimizing personnel requirements, minimizing time from arrival to launch, minimizing required launch area, and minimizing the launch noise. To effectively operate the system, it must be easy to train the operators and it must be able to be controlled at a distance. To achieve this we must minimize the training time and maximize the operational range. In maneuvering the system, we must avoid obstacles, move quickly, and operate with a small maneuver footprint. We can do this by maximizing agility, maximizing speed to target, minimizing flight noise, and minimizing visual detection. There are many effects that the system needs to achieve. When conducting surveillance of the enemy, the system must operate in urban environments, provide a quality picture, have endurance and provide accurate surveillance. To achieve these effects, we must maximize terminal position, maximize resolution, maximize flight time, and maximize accuracy of video tracking. When providing lethality as an effect, the system must detonate reliably, destroy the objective, and avoid collateral damage. To achieve these objectives, we must maximize reliability of detonation, maximize consistency of explosion on impact, and minimize collateral damage. Lastly, we must end the mission by either recovering the system or reusing the system. This can be achieved by either maximizing ease of recovery or maximize the reuse of the system. The functional hierarchy depicts exactly what the system needs to do and what functions need to be maximized and minimized in order to achieve the desired results. From this point, we added values to the different functions and developed our value hierarchy.

Value Hierarchy- Our value hierarchy is a visual and mathematical depiction of what functions are more valuable than others. This is important because once weights are added to the functions our different alternatives will be scored which will yield our optimal solution based on our value model. We used swing weighting to give each of our functions and sub functions weights. Weights identify the most important and variable functions in relation to one another. The weights are then converted into a value that identifies how important each function is in relation to the entire system. The top five most valuable objectives in order of most valuable to least valuable are; minimize system weight, minimize launch noise, maximize reliability of detonation, maximize reliability of system, and minimize collateral damage. We developed these weights based on the conclusions drawn from our stakeholder analysis. We weighted those functions that were more important to the stakeholders more heavily then those that were negligible. We also took variability into account while swing weighting. Even though one objective may be very valuable, such as number of operators necessary, it was not weighted as heavily because all of the alternatives require a similar number of operators and so the weight of that specific objective is meaningless because all of the alternatives will score very similarly.

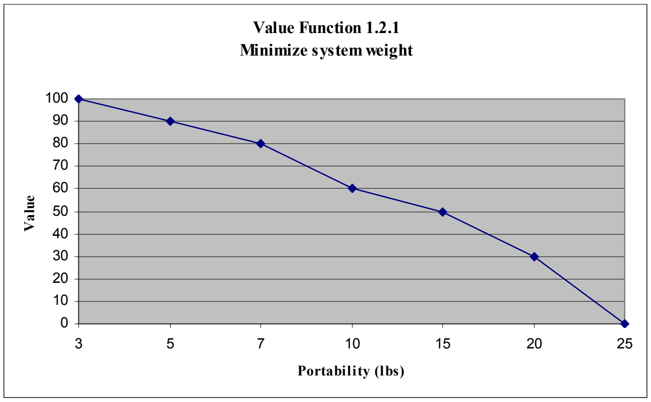

Figure 3. Example Value Curve

Each Objective is measured in different metrics. Figure three shows how we account for this and the increasing or decreasing value that the measure yields. The example shows Weight. We screened out all alternatives which weighed above 25 pounds. We then determined the value that each reduction of weight would yield. With those numbers we developed the value curve. Once the value curve was created we could insert the data on each alternative, and receive a balance value amount from the curve.

One problem that arose while developing our weights became what the overall “idea” of the system would be. We needed to determine if the system was going to resemble more of a fire and forget - “smart” mortar round that had a surveillance capability, or would it be a recoverable system that would drop or fire a payload and then return for follow on missions? Given that minimizing system weight was the biggest concern for our stakeholders, during a meeting with our client and with input from the Infantry Center based out of Huntsville Alabama, we determined that the final product would need to be more similar to a fire and forget round in order to assign appropriate weights to our measures. System weight is the biggest concern for our stakeholders; therefore many tradeoffs are necessary in order to get the system down to an appropriate weight.

B. Solution Design

In the solution design phase we developed and enhanced alternative solutions to the problem. In order to develop potential alternatives, we took different components from existing systems and created alternative systems which were compared by the application of our value hierarchy. Some of the existing systems from which we gathered components include; the Raven, Swift, and Switchblade. Once we generated and compiled components from various systems, we screened the components in order to determine their suitability for our ultimate system. Some of the screening criteria included the weight of the specific component, and its ability to interface with other components. There were also some legal issues that had to be dealt with. We discovered that it is a violation of the Geneva Convention to use catapults as lethal weapons in war [6]. Some small UAVs use a catapult mechanism in order to launch the system, and so since our UAV will be lethal we had to screen out the catapult as a potential means to launch the system.

After we compiled our list of alternative systems, we began to screen them out. Our alternatives are not entirely aerial systems. We also included some ground based systems. We agree with out client that a UAV will be the best solution, but we analyzed ground systems as well in order to strengthen our analysis in order to provide a greater confidence in our proposed solution. Once we screened out some of the alternatives, we created a raw data matrix on all of the remaining alternatives. We developed the raw data matrix by compiling all the data from the individual components of each system. After the raw data matrix was complete, we went back and re-analyzed our value curves from our value model and made sure that we were ready to use them to convert our raw data into scores that will give us values for each different alternative solution.

V. FUTURE WORK

A. Decision Making

The next step in our project will be in the decision making phase. Once we have finished improving our alternative solutions, we will score each system using our weights from our value model in order to determine the best system. Before we make any final decisions however, we will use common sense value focused thinking and conduct a sensitivity analysis in order to determine if the optimal solution really is the best solution. Once we are confident that we have solved the problem with the best system we will recommend our solution to our client.

In order to ensure that our proposed solution is right for our client, we will conduct other steps within the decision making phase in order to strengthen our analysis. These steps will include component optimization, modeling and simulations, and operational testing.

We will conduct component optimization as a check on the solution that is recommended by our value model. In order to conduct component optimization we will score individual components separately, and then create a system that includes the optimal components. We will then screen the solution in order to ensure that the chosen components have the ability to interface with one another successfully. If the system created by our component optimization reflects the optimal alternative as scored by our value model then we will be highly confident in the legitimacy of our recommendation.

After we have a potential solution, we will utilize the System Engineering Departments modeling and simulation capabilities in order to establish greater fidelity in our system. We will require the potential solution conduct operations in a variety of environments with different condition in order to test the capabilities and discover the weaknesses of our system. This will allow us to improve our system before we enter into the last phase which will be operational testing.

B. *Solution Implementation*

While the solution implementation will not be controlled by our team, as creators of the system we will provide recommendations of how we feel the system can be best and most effectively employed. Proper implementation of our system will be crucial because no matter how capable or reliable a UAV is, it needs to be employed and managed properly in order for it to operate to its full potential and to provide the user with the best results. Our recommendation will primarily be involved with trying to ensure that the system is organically employed at the platoon level or lower. We believe that this is necessary because the goal of the system is to provide quick and deadly firepower for the small unit ground commander. If the small unit ground commander is not in control of the system, then he will not be able to implement it swiftly because he will have to go through higher channels in order to employ the system. If this is necessary the system is no longer more effective then calling in for close air support or artillery fire. If the commander can own and operate the system however, he will have the flexibility to neutralize threats quickly and without ever having to expose his troops to hostile fire.

VI. CONCLUSIONS

It is our hope that the Army recognizes the work that we have done in this project and can eventually employ our system or one that provides similar capabilities. As future officers, we recognize the life saving capabilities that our system could provide and would hope to have this capability as platoon leaders who could be leading soldiers in combat in less than one year.

REFERENCES

[1] TRADOC. Advanced/Joint Concept Technology Demonstration (AC/JCTD) FY07 Candidate. Squad Level Lethal Munition (SLLM). 15 February 2006.

[2] Weatherington, Dike, D. Department of Defense Unmanned Aircraft Systems (UAS). Presentation. 2005.

[3] Headquarters, Department of the Army. FMI 3-04.155, Army Unmanned Aircraft System Operations. April 2006.

[4] Parnell, G., Driscoll, P. and Henderson, D.
(2007). Systems Decision Making in Systems Engineering and Management. John Wiley & Sons
Inc., New York, NY.

[5] Klupacs, Lewis; Lead Analyst, MTC Technologies, Infantry Center. POC at Infantry Center. Provided input for weighting objectives. 706-545-9849.

[6] Charlton, Jim. Senior Systems Engineer, Aerodyne, inc. Army UAS Project Office, Contractor Support. POC for our Client, PEO Aviation. 256-313-5322.

[7] Swanson, Kyle; Assistant General Manager, SUAV, Aerovironment. Discussion during meeting at Aerovironment. October 2006. 706-545-9849.

[8] General Pace, Peter; Krieg, Kenneth; Cambone, Stephen; Wells, Linton. Office of the Secretary of Defense. UAS Roadmap 2005-2030. Memorandum. 4 August 2005.

[9] Matrisciano, Vincent. Us Army ARDEC, Picantinny Arsenal. POC for Picittany Arsenal. Provided information regarding munitions.