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# Drone Optimization on the Modern Battlefield

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**Author Note:** Rich Jaramillo, Jasier Marquez, Tracer Roberts, and Salvatore Rasizzi are cadets at the United States Military Academy. The team is comprised of a Systems Engineering Major, two Systems Decision Science Majors, and an Engineering Management Major. This work is the authors' academic Capstone project in the Department of Systems Engineering (DSE). Lieutenant Colonel Matthew Mogensen, Ph.D., an assistant professor in the Department of Systems Engineering, serves as this Capstone project's faculty advisor. The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

**Abstract:** This work seeks to model the additive contribution of future unmanned aerial vehicles (UAVs), referred to in this paper as drones, to light infantry platoons in order to increase the lethality of a Light Infantry Brigade Combat Team (IBCT). We used Infantry Warrior Simulation (iWARS) as the simulation platform to simulate, assess, and provide insight into the utilization of drones as a force multiplier. Insights gathered in this paper show the degree to which the lethality of a light infantry platoon, measured by times to find and destroy the enemy, enemy casualties inflicted, and friendly casualties incurred, is enhanced when future drone systems are used. We found that gains in lethality are marginal when only range and loiter time are increased, but are greatly enhanced when future drone systems are also equipped with a kinetic payload.

*Keywords*: Lethality, Unmanned Aerial Vehicles (UAV), Systems Decision Process (SDP), Infantry Warrior Simulation (iWARS)

## 1. Introduction

Cadets studying in the Department of Systems Engineering (DSE) at the United States Military Academy (USMA) collaborate with faculty members in the Systems Design and Management course to tackle real-world issues presented by clients, enabling them to gain a comprehensive understanding of engineering design (USMA Redbook, 2022). The Capstone group, named Drone Optimization on the Modern Battlefield (DOOM-B), comprised of Cadets Rich Jaramillo, Jasier Marquez, Tracer Roberts, and Salvatore Rasizzi, guided by Lieutenant Colonel Matthew Mogensen, Ph.D., as their faculty advisor, explores methods to enhance lethality within the Infantry Brigade Combat Team. DOOM-B collaborated with MITRE Corporation and Army Futures Command (AFC) to build upon previous research and aims to offer pertinent and timely insights into concepts related to modern military drone use.

## 2. Background

### 2.1. Military Application of Aerial Drones

One of the most prominent drone capabilities currently in use in the U.S. Army is their ability in providing real-time and comprehensive surveillance, enhancing a military force's situational awareness. With the potential incorporation of artificial intelligence (AI) technologies, drones could gain capabilities such as visual perception, speech, facial recognition, and decision-making tools, eventually operations without human intervention (Johnson, 2020). Additional kinetically equipped drones can use conventional or loitering attack ammunitions (LAMs), commonly known as "kamikaze drones". These drones are capable of pursuing targets (such as enemy radar, ships, and tanks) based on pre-programmed targeting criteria, expanding the range of military operations (Johnson, 2020).

### 2.2. Aerial Drones in Modern Warfare

In the ongoing conflict between Russia and Ukraine, drones have emerged as critical tools reshaping the modern battlefield. Both sides extensively employ various types of drones, showcasing their diverse roles and impact on modern warfare. Small drones, often repurposed from commercial models, play a significant role in providing crucial reconnaissance and artillery targeting capabilities for ground forces (Kunertova, 2022). These agile and adaptable drones enable troops to gather real-time intelligence, spot enemy positions, and navigate artillery fire with precision, significantly enhancing combat effectiveness.

On the other hand, larger drones like the Bayraktar TB2, have gained attention for their ability to deliver firepower over long ranges and strike behind enemy lines (Kunertova, 2022). However, their effectiveness is contingent upon air superiority, a factor often absent in active conflict zones. Furthermore, the use of loitering munitions, also known as kamikaze drones, presents a daunting offensive capability. These drones, though limited in intelligence gathering capability, offer a one-way attack option, capable of loitering in target zones before impact, posing a significant threat to enemy forces and infrastructure.

The proliferation of drone technology in war highlights the evolving nature of modern warfare and the need for adaptive strategies in both offensive and defensive tactics. As drones continue to play a pivotal role in military operations, drone capabilities must be continually refined to address the challenges posed by this rapidly advancing technology on the battlefield.

### 2.3. Stakeholders

The main stakeholders for drone operations in the Light Infantry Brigade Combat Team are the drone operators themselves and Infantry Brigade Combat Team soldiers. A secondary stakeholder, as the research and development arm enabling rapid fielding to the force, is U.S. Army Futures Command (AFC). AFC is currently leading the modernization of Infantry Brigade Combat teams (Army, 2024). They are looking at current small-scale drone capabilities and analyzing how these drones can be applied to maximize the lethality of smaller units. Traditionally, these tactics have been studied at the division cavalry level. Our final stakeholder is MITRE Corporation, who provides funding and assists the team by facilitating conversation between AFC and other stakeholders to provide research, software, and people necessary to study this problem (MITRE, 2024).

## 3. Methodology

### 3.1. Design Process

The methodology used to guide our capstone team was the Systems Decision Process (SDP). The Systems Decision Process is a collaborative, iterative, and value-based decision process that can be applied in any system life cycle stage (Parnell, Driscoll, & Henderson, 2011). The process consists of four phases: Problem Definition, Solution Design, Decision Making, and Solution Implementation (Parnell et al., 2011). The work developed in this process carries over to the Solution Implementation phase once the solution decision has been made by relevant stakeholders. This final phase, however, is not included in our decision process given it is outside of the capstone team's scope for this research.

### 3.2. Problem Statement

Following the completion of the Problem Definition Phase of the SDP, the team created a redefined problem statement. The redefined problem statement was informed by the team's understanding of the concerns, objectives, and constraints found in the Problem Definition Phase and was validated by a stakeholder survey administered in the Fall of 2023. The redefined problem statement is as follows:

*Inform the choice of drones fielded to a light infantry platoon in order to increase the lethality of a Light Infantry Brigade Combat Team.*

### 3.3. Value Model

After concluding stakeholder meetings, solidifying a specific problem statement, and conducting our research, the team developed a qualitative value model. Figure 1 presents the qualitative value model, outlining the unique functions and associating each function with its respective value measure. The qualitative value model begins by defining a core objective function, representing the system's overarching goal. Then, the team identified smaller functions aimed at accomplishing the core objective function and linked each function to a specific objective. In order to assess each alternative (where different drones will be

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used), the team established value measures for each objective through stakeholder analysis, as elaborated on in future sections of this paper.

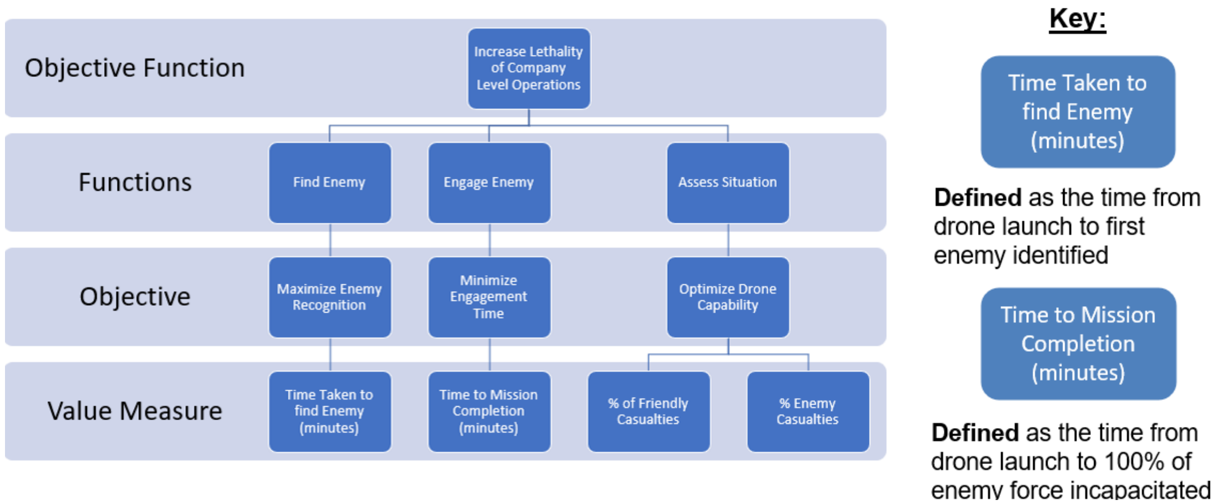


Figure 1: Qualitative Value Model

### 3.4. Value Measure Functions

The value measure scoring process offers a systematic approach to comparing alternatives, and the value measure's contribution in achieving the fundamental objective. Considering the simulation's capabilities, the team assessed the feasibility of gathering specific value measures from the simulation software output. We established four value measure functions that contribute to an overall value measurement of lethality: time taken to find the enemy, time to enemy incapacitated (100%), percent of friendly casualties, and percent of enemy casualties.

In consultation with stakeholders and informed by the stakeholder survey, we formulated four value measure functions (one for each value measure) to convert raw simulation output data into unit-less quantitative values. Subsequently, we applied each value measure function to the simulation outputs to calculate a weighted value score for each alternative iteration. This method provides scores that are instrumental in comparing the lethality of friendly forces across alternatives.

### 3.5. Global Value Weights

In conjunction with the four value measure functions, we established four global value weights to incorporate the relative importance of each value measure, informed by the stakeholder survey results. To do this, we compiled all value measures and their associated weights into a swing weight matrix. The swing weight matrix ranks and values each measure by variability and importance to stakeholders in terms of measuring lethality. In the survey, stakeholders rated each respective value measure against an opposing value measure. This process is known as the pairwise comparison method, which produces every possible comparison of value measures in a series of A-vs-B to turn the qualitative information into quantitative data. The team then normalized the swing weights to establish the global weights used to score each simulation run in a given alternative (Table 1).

Table 1: Global Value Weights

| Value Measure | Global Value Weight |
|---|---|
| Time taken to find the enemy | 8/30 |
| Time to mission completion (100% enemy incapacitated) | 5/30 |
| % enemy casualties | 6.5/30 |
| % friendly casualties | 10.5/30 |

### 3.6. Lethality Value Function

The Lethality Value Function $L(v, x, y, z)$ gives a measure of lethality of a simulation run, as a function of each value measure function, $f(v)$, $g(x)$, $h(y)$, $i(z)$, and global weights $w_f, w_g, w_h, w_i$ (Equation 1).

$$L(v, x, y, z) = w_f f(v) + w_g g(x) + w_h h(y) + w_i i(z) \tag{1}$$

$w_f$ is the global weight for the time taken to find the enemy
$w_g$ is the global weight for the time to mission completion
$w_h$ is the global weight for % enemy casualties
$w_i$ is the global weight for % friendly casualties

$f(v)$ is the value for $v$ minutes taken to find the enemy
$g(x)$ is the value for $x$ minutes to mission completion
$h(y)$ is the value of $y$% enemy casualties
$i(z)$ is the value for $z$% friendly casualties

## 4. Simulation Modeling

### 4.1. Infantry Warrior Simulation (iWARS)

To model different alternatives, the team utilized Infantry Warrior Simulation as its simulation program. This software is a stochastic, agent-based, force-on-force combat simulation focused on individual and small unit dismounted combatants and their equipment used to assess operational effectiveness across a spectrum of missions, environments, and threats. We chose Infantry Warrior Simulation as its primary simulation program given it allowed for stochastic modeling for Monte Carlo simulation, batch runs for efficiency in producing data, and the team's accessibility to in-house subject matter experts.

### 4.2. Alternatives

We modeled three alternatives where the only variability is the type and capability of the drone assigned in support of the light infantry platoon. This platoon is composed of three maneuver squads, one weapons squad and consists of two M240Bs machine guns, and six M249 squad automatic weapons (SAW). Enemy forces are simulated as an organic infantry rifle squad. The squad has two M249 SAWs (used as an analog to a Russian PKM), and is postured defensively with minimal cover and concealment. Key assumptions the team made for our simulations include the each drone's line of sight, battery life, and kinetic payload capability (Alternative 3 only). Alternative 1 represents the base case, or status quo available today to a light infantry platoon as it utilizes an already fielded drone system (Raven). The Company UAS used in alternatives 2 and 3 represents a potential future drone system informed by Army Futures Command directed requirement. Importantly, these drones are not designed to be recovered by friendly forces following their use. The alternatives are depicted in the Simulation Run Matrix of Table 2.

Table 2: Simulation Run Matrix

| Alternative | Drone System | Drone Capability | Simulation Iterations |
|---|---|---|---|
| Alternative 1 (Base Case) | 1x Raven | Reconnaissance: 10km of reach and 1.5 hours of battery life.<br>Payload: None | 30 |
| Alternative 2 | 1x Company UAS | Reconnaissance: 10km of reach and 8 hours of battery life.<br>Payload: None | 30 |
| Alternative 3 | 1x Company UAS | Reconnaissance: 10km of reach and 8 hours of battery life.<br>Payload: 40mm Grenade with Blast Radius of 10m | 30 |

## 5. Results

### 5.1. Lethality Value Scores

After conducting the simulation using iWARS, we scored each iteration (30 iterations for each alternative) using our lethality value function (Section 3.6). The results are displayed in Figure 2, showing the median lethality value score of each alternative as well as the range of results. Alternative 2 provided only a marginal improvement over Alternative 1. Alternative 3 exhibited a consistently higher lethality value score compared to both Alternatives 1 and 2.

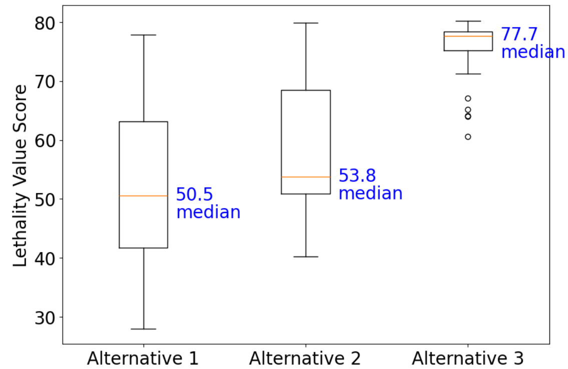


Figure 2: Simulation Results by Alternative

## 5.2. Sensitivity Analysis

We conducted Monte Carlo simulation on the global weights to see how changes in weights would affect our results. To do this, we sampled a result uniformly from each alternative, then generated random variates (which were normalized) from a uniform distribution for the global weights. This process was repeated one million times to generate *value score difference* distributions for each pair-wise set of alternatives. Table 2 shows the percent of time a alternative outperforms the other in a pair-wise comparison (every simulation run uses new random random global weights for both alternatives), with the greatest difference shown between Alternatives 1 and 3.

Table 3: Sensitivity Analysis on the Global Weights

| Pair-Wise Alternatives | Alternative 1 Outperforms | Alternative 2 Outperforms | Alternative 3 Outperforms |
|---|---|---|---|
| 1 and 2 | 29.0% | 71.0% | N/A |
| 1 and 3 | 8.5% | N/A | 91.5% |
| 2 and 3 | N/A | 24.3% | 75.7% |

Each pair-wise alternative comparison results in a probability distribution. For example, when comparing Alternatives 3 and 1, the area to the right of zero depicts all simulation runs where Alternative 3 had a higher lethality value score (91.5% of the time), and the area to the left of zero depicts all simulation runs where Alternative 1 had a higher lethality value score (8.5% of the time) (Figure 3).

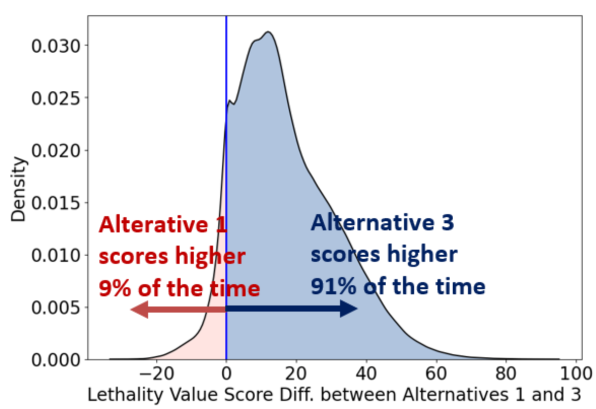


Figure 3: Alternative Value Score Difference Distribution (Between Alternatives 3 and 1)

### 5.3. Cost-Benefit Analysis

A cost-benefit analysis allows stakeholders to determine if the added benefit of a system is justified by its increase in cost, over some baseline alternative (Alternative 1). This analysis is particularly interesting if we consider *benefit* as a single value measure in isolation: *percent friendly casualties*, since this value measure arguably contributes to lethality but also has a direct effect on unit morale given its force protection aspect. In this section, we examine the increase in cost from the Company UAS (with and without payload), measured against the number of friendly casualties avoided, when compared to the base case alternative (Alternative 1). We used the *cost per friendly casualty avoided* metric ($C_{FCA}$) which evaluates the monetary cost paid for each additional friendly casualty avoided, over Alternative 1. This metric is calculated using Equation 2.

$$C_{FCA} = \frac{\text{Difference in Cost}}{\text{Difference in Expected Friendly Casualties}} \tag{2}$$

While this metric only takes into account one value measure from the performance of the overall model, it should be of particular interest to decision-makers who must judge the marginal benefits of fielding a potential new drone system given its additional cost. We used reasonable assumptions of system costs for each system, informed by our stakeholder and subject-matter experts (Table 4).

Table 4: Estimated System Costs

| **Alternative** | **System** | **Estimated Cost per Unit** |
|---|---|---|
| 1 | Raven | $35,000 |
| 2 | Company UAS | $300,000 |
| 3 | Company UAS with kinetic payload | $310,000 |

Alternative 2 has a cost per friendly casualty avoided of $10,460,526 over Alternative 1, Alternative 3 has a cost per friendly casualty avoided of $204,816 over Alternative 1, and Alternative 3 has a cost per friendly casualty avoided of only $7,591 over Alternative 2. The main takeaway for decision-makers is that if you consider the Company UAS as a future system, the marginal benefit to force protection (in terms of friendly casualties avoided) is minimal unless you arm the drone with a kinetic payload.

## 6. Conclusion

This paper will help decision-makers understand which drone assets will make their formations more lethal, and in simulation, the Company UAS proved to be a more lethal force multiplier throughout an enemy engagement. However, since the non-payload Company UAS provides minimal friendly casualty avoidance benefits over the base case alternative, we emphasize the importance of prioritizing payload integration in drone technology for enhancing the effectiveness of military operations and the lethality of platoons. The lethality value scores of the Company UAS with kinetic payload were consistently higher in simulation than the other two drone alternatives, showing the advantages of having a rapidly deployable, man-portable drone that can be used not only as a reconnaissance platform but also as a weapons system.

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