Integrating Autonomous Systems into Military Units

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Abstract: Autonomous systems are the future of military warfare and must be carefully employed to hold the advantage in technological advances. In an effort to measure the capabilities of autonomous systems within military units, this study analyzes the effects an autonomous system has while integrated into an Army Infantry unit. Using combat modeling software, a constructive reality modeled breaching and fires mission scenarios to determine the effects an autonomous system may have within a unit. Within the model limitations, statistical analysis supported that an autonomous system has a general impact on increasing a unit's lethality and survivability. These statistically significant conclusions support that autonomous systems should be integrated within military units since these systems have a strong, positive impact on unit effectiveness. Additional data analysis and extending the analysis to other combat scenarios is crucial in applying these conclusions outside of the tested scenarios.

Keywords: Autonomous System, Combat Modeling, Warfighting Function

1. Introduction

Autonomous systems are rapidly being integrated into society, especially within the military. Within the U.S. Army, autonomous systems have often been allocated towards augmenting specific soldier tasks. These tasks can be classified under the warfighting functions. The six warfighting functions are mission command, movement and maneuver, intelligence, fires, sustainment, and protection (Headquarters, Department of the Army, 2019). All six of these warfighting functions encompass a wide range of subfunctions to cover different abilities to remain competitive in the modern-day multi-domain operations environment. Multi-domain operations require the military construe future armed conflict and prepare its members to effectively deter that conflict through the integration of various warfare domains.

Using combat modeling software, autonomous systems can be integrated into a constructive reality and analysis can be done on their impact on warfighting functions. The software can vary the levels of autonomy depending on the different warfighting functions it is programmed to support. The purpose of this paper is to further explore the capabilities of autonomous systems within military units.

2. Usage of Autonomous Systems by the Army

2.1. Capability by Warfighting Function

The Army has often allocated autonomous systems towards augmenting specific soldier tasks. There are numerous autonomous system capabilities possible, but through stakeholder input, the following warfighting functions were commonly supported: Intelligence, Movement and Maneuver, Fires, and Protection (Herbert, 2020; Polczynski & Zenone, 2020). Various unit capabilities and tasks cover these warfighting functions (Ryan & Mittal, 2019). Depending on the environment and other contextual features, the method of completing the tasks may vary. Some of these capabilities include using sensors to identify personnel and their location, load carriage to lighten the physical load on soldiers, breaching obstacles, and controlling fires missions.

DOI: https://doi.org/10.37266/ISER.2020v8i1.pp59-67

First, being able to detect, identify and/or locate enemy personnel would greatly increase unit lethality and survivability (Lovell et al., 2019). Soldiers are required to quickly identify personnel and distinguish friendly from foe. Combatants are required to observe, orient, decide and act constantly during their missions. In a combat scenario, the combatant that identifies their enemy first inherently owns the advantage. Sensor capabilities fall under the intelligence warfighting function. The better a soldier's intelligence, the more confident he or she is in completing the mission and properly executing tasks.

Second, reducing a soldier's physical load could increase the unit's overall lethality. Infantry units are often burdened by a heavy equipment load of 95 to 120 pounds. Moving around with a heavy load puts a large strain on soldiers since it requires greater energy expenditure to do carry various mission essential equipment and items. This burden falls into the categories of movement and maneuver. Lightening a soldier's load could greatly increase the mobility of an Infantry unit.

Third, the ability to efficiently breach an obstacle gives friendly forces the advantage of surprise which allows units to more effectively execute their mission. Breaching operations fall under the movement and maneuver and protection warfighting functions. Breaching requires time which is often constrained. Minimizing time in these operations allows for units to hold the element of surprise and allows for a quick, effective clearance of the obstacle and what lays beyond it.

Fourth, fires missions are very common within an Infantry unit. In these missions, indirect fire is called on a specific target to provide suppression, obscuration, or other means that assist in a mission. The Forward Observer (FO) and/or Fire Support Officer (FSO) manages these missions to lessen the load for the unit leaders. However, despite planning and training for quick execution, calling fires still requires time. Fires control falls under the fires and protection warfighting functions. By decreasing the time spent on requesting fires, a unit's lethality and survivability could be greatly increased.

2.2. Levels of Autonomy

Autonomous systems can enhance all of these capabilities. These autonomous systems can have a range of different levels of autonomy. Systems on the lowest level of autonomy are remotely operated by personnel, systems on the intermediate level follow "bread crumbs," or a digital footprint left by a guide, and systems on the highest level are fully autonomous, allowing them to operate as an independent entity (Anderson et al., 2017). An example of the low-, intermediate-, and high-level autonomy systems would be a toy remote control helicopter, vehicle-following capabilities within modern vehicles, and a robot with artificial intelligence that can make its own environment input-informed decisions, respectively (Fairbrass et al., 2018).

2.3. Different Potential Autonomous Capabilities

Table 1 below outlines the discussed capabilities and levels of autonomy that will be used to create varying models to analyze an autonomous systems impact on unit lethality and survivability within the different warfighting functions.

Table 1. Autonomous System Capabilities and Autonomy Levels

Capability	Autonomy Level
Sensor	Remote Control (Low)
Load Carriage	"Bread Crumbs" (Intermediate)
Breaching	Fully Autonomous (High)
Fires	

If each of these capabilities and autonomy levels were independent of each other, there would be 12 possible permutations assuming each system has one capability and autonomy level. Though there are 12 possible permutations with the listed capabilities and autonomy levels, some permutations lack logical or feasible solutions. An example of an infeasible system would be an autonomous system with breaching capabilities and an intermediate autonomy level. This solution would be infeasible because the intermediate level autonomy limits the system to following another entity. In this case, the entity would have to move beyond the breaching obstacle for the autonomous system to reach the obstacle to perform the breach.

DOI: https://doi.org/10.37266/ISER.2020v8i1.pp59-67

Additionally, an autonomous system is bound by its autonomy level, but it is not bound by its numbers of capabilities. Below is a list of logical permutations with descriptions outlining their capabilities combinations:

1. Autonomous System with Sensor and Breaching Capabilities (Remote Control)
2. Autonomous System with Sensor and Breaching Capabilities (Fully Autonomous)
3. Autonomous System with Load Carriage and Fires Capabilities ("Bread Crumbs")
4. Autonomous System with Load Carriage and Fires Capabilities (Fully Autonomous)

For this study, sensor and breaching capabilities were paired because of the most logical order of functions within the system. Obstacles are emplaced by combatants to give them a lethal advantage. Obstacles are assumed to observed by enemy forces meaning a breaching operation often leads to enemy contact. Being able to sense and identify these combatants after a breaching operation would allow for friendly forces to gain the advantage.

Load carriage and fires capabilities were paired because the autonomous system with these capabilities would be further away from combat and potential danger. Calling for fires is normally done by an FSO or FO. The autonomous system would eliminate the need for these soldiers' duty. Load carriage would be an added benefit to the soldiers since the autonomous system would bear most of the heavy loads that physically fatigue soldiers.

The low level of autonomy can be used with an autonomous system with sensor and breaching capabilities since these operations benefits the soldier behind the remote control device. The medium level of autonomy can be used for the autonomous system with load carriage and fires capabilities because this system will be away from direct combat, so the system only needs to follow the unit. The high level of autonomy can be applied to both autonomous systems, eliminating the need for the unit to worry about controlling the system.

3. Base Models

Two separate base models were developed to use as a foundation for autonomous system integration analysis. The first base model is a breaching scenario in which an infantry team breaches and clears a room in an urban environment. The second base model is a fires scenario where an infantry squad is ambushed and calls in fires to eliminate the enemy force.

3.1 Breaching Scenario

The first base model involves an infantry team breaching and clearing a room in urban terrain. This scenario is represented in Figure 1. In the figure, there are two different colored dots, each representing a different entity. The blue color represents friendly forces whereas red represents enemy forces. The green (light blue in right picture) dots (nodes) interconnected with red lines (arcs) represent different paths for each entity or group of entities.

The infantry team enters the building in a stacked formation and once set, the rear soldier moves toward the room door to prepare the breach. Once the breach is set, the soldier moves back to his original position and prepares to enter and clear the room with the team. When the door is breached by a C4 explosive charge, the team moves into the room and clears the room with the first soldier, the point man, moving immediately to their left and engaging the enemy in the corner. The second soldier follows closely and moves opposite of the first soldier and engages the enemy to his right. The third soldier enters and continues to the farther corner while engaging the other enemies. The fourth soldier enters last and engages the remaining enemies. The infantry squad is unaware of enemy locations while entering the room.

Upon breach, the enemy immediately crouches in response to the explosion. The enemy soldier in the adjacent room responds quickly by moving into the main room and engaging friendly personnel as they enter. The main advantage the enemy has in this scenario is that they know where friendly forces will be coming in from.

3.2 Fires Scenario

The second base model has an infantry squad ambushed by an enemy squad and the friendly squad leader calling in a fires mission on the ambush location. This scenario is represented in Figure 2. All blue and red dots represent the same entities described in the previous scenario; however, entities labeled with a "P" indicate that the agent is in the prone posture. This model includes additional elements such as the node network and area features. The node network, depicted by the interconnected purple lines overlaying the green dots, dictate various paths an entity can follow to reach a specific waypoint. Additionally, an area feature, depicted as a purple rectangle with green dot corners, designates an indirect fire target zone.

The friendly infantry squad is moving through the urban terrain and gets ambushed between two major buildings. In response, they rush back behind the buildings. Alpha team moves behind the western building and Bravo team moves behind

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the eastern building with the squad leader. The squad leader calls in a fires mission on the ambush location afterward. After 30 seconds, the squad leader calls ceasefire and has Bravo team clear the ambush location.

The enemy squad waits for the arrival of the friendly force in the ambush location. The enemy forces quickly get into a V-Shaped ambush and engage the friendly force from the prone position. They continue engaging until they cannot see the friendly forces anymore after their retreat. Once the enemy squad is hit by indirect fire, they quickly recover from the initial shellshock and evacuate to the East and attempt to flank the friendly bravo team behind the building.

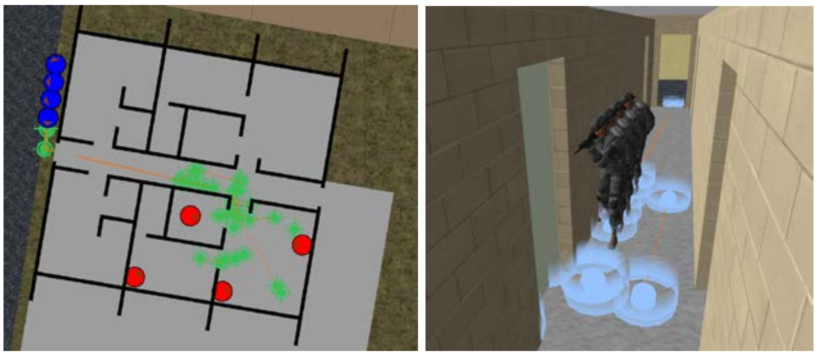

Figure 1. Base Breaching Scenario

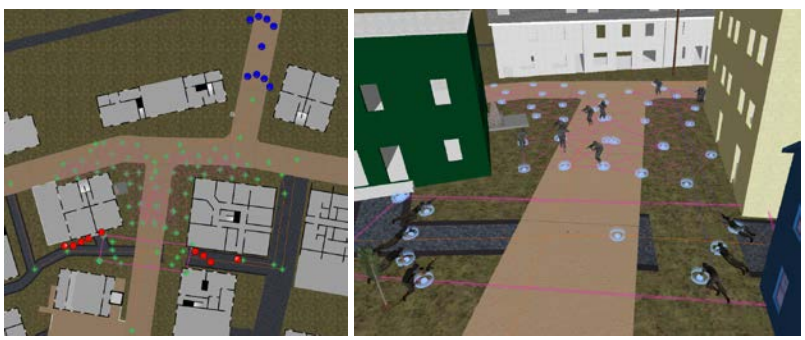

Figure 2. Base Fires Scenario

4. Modified Models to Reflect Autonomous Systems

The base models were updated with the addition of an autonomous system. That autonomous system operated within its given autonomy level to perform its assigned functions. Some of these functions replaced functions previously assigned to the soldiers. Additionally, the system sometimes performed additional functions that the soldiers did not perform previously.

4.1 Breaching Scenario Integrating an Autonomous System with Remote Control Autonomy

In this model, once the infantry team has stacked outside the door, the rear formation soldier calls in the system using a remote-controlled device. The system enters the building and approaches the door. The soldier uses the remote control to have the system perform a manual breach. The breach takes some time, but once the door is breached, the system moves into the room and scans the surrounding area. Once the system has identified all the enemy combatants, it relays that information to the squad. The breach team then moves into the room with the fourth soldier lagging due to the time it takes to put the remote control away and re-arm. Since each soldier knows the identification and location of the enemy, they enter in a more efficient formation. The point man immediately moves in toward the enemy SAW gunner and engages him. The second soldier moves straight into the room engaging the two enemies in his line of sight. The third member follows and turns immediately to his right to engage the soldier is the smaller room. The fourth member files in last after re-arming himself and engages any remaining enemies. This breaching method was recommended by an experienced Infantry Officer (Bell, 2020).

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4.2 Breaching Scenario Integrating an Autonomous System with Full Autonomy

This scenario is similar to the “bread crumb” autonomy scenario, with the final friendly soldier entering the room with the rest of the team. Figure 3 shows the integrated autonomous system in this scenario. The label “2” is assigned to the autonomous system. Additionally, the agents labeled with “C” are in a crouching position.

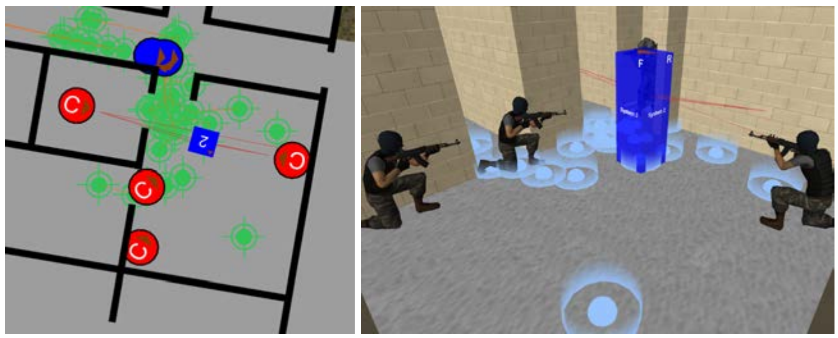

Figure 3. Breaching Scenario with Autonomous System

4.3 Fires Scenario Integrating an Autonomous System with “Bread Crumbs” Autonomy

This model expanded on the base fires scenario by adding an autonomous system that follows the bravo team leader. The purpose of this system is to provide load carriage reducing the load carried by the soldiers. This scenario modeled ideal conditions with reduced load carriage decreasing the soldiers’ exhaustion level and increasing their movement speed. The friendly unit moves through the ambush zone, but with reduced load carriage, friendly forces can move away much faster. The friendly unit sprints away at a rate of 5 meters per second which allows them to incur fewer friendly injuries due to the decreased time in the enemy’s kill zone. Additionally, at the time of ambush, the autonomous system starts calling in immediate suppression indirect fire. The indirect fire does not impact until after the friendly forces have retreated safely behind the building. The indirect fire is also more accurate in this model since the autonomous system can precisely pinpoint the enemy ambush location. The remainder of the model remains consistent with the base model. Figure 4 displays the positioning of the autonomous system relative to the unit. Its appearance in the model is identical to that previously established in the breaching scenario (the “B” and “L” labels represent the back and left side of the system, respectively).

4.4 Fires Scenario Integrating an Autonomous System with Full Autonomy

This model is like the “bread crumbs” autonomy scenario except this system has full autonomy, allowing it to move freely as its own entity. It can react to the ambush once initiated rather than following the bravo team leader. The system still bears the soldier’s heavy load and calls in for indirect fire.

4.5 Model Validation

To ensure these models closely represented real-world scenarios, the breaching and fires models were validated by an infantry and field artillery officer, respectively. The models were formed around the officers’ expertise and experience.

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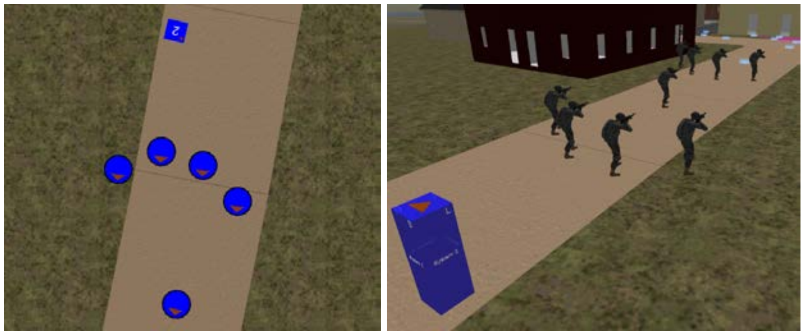

Figure 4. Fires Scenario with Autonomous System

5. Data Analysis

To assess each scenario's force lethality and survivability, data was collected on each forces' casualty count from 50 independent runs on every scenario. The scenario data was then filtered and aggregated to analyze summary statistics and perform different statistical tests to determine the benefits of integrating an autonomous system with an infantry team.

5.1 Breaching Model

Within the breaching scenario, variability was introduced with the autonomous system. It changed some of the soldier's mission sets and for the remote control autonomy scenario, inhibited a soldier's performance. This variability was accounted for as results were drawn from statistical analysis.

5.1.1 Methodology, Results, and Assumptions

BRASS, a program used to batch run multiple iterations of IWARS scenarios, was utilized in collecting data from the model (IWARS Methodology Guide, 2010). The aggregate breaching model scenarios' data was collected and filtered by force casualty count. The analysis of the summary statistics established a foundation for examining the difference of data averages and standard deviations. Figure 6 displays a boxplot of each forces' casualty count for the different scenarios.

Based on the summary statistics, there is a noticeable difference in each scenarios' variance. The difference of means was analyzed using a two-sample t-test to determine if there was a statistical significance for the difference of means. The tested null hypothesis was there was no difference in means. Using a 5% level of significance, there was a statistical significance (with a p-value of 0.04118) between the blue casualty rate for the base and remote control models, therefore rejecting the null hypothesis; however, this t-test supported the conclusion that more blue casualties were sustained by the friendly force when integrating the autonomous system. The base scenario generated an average of 3.64 friendly casualties whereas the remote control scenario generated an average of 3.88 friendly casualties. All other t-test conclusions supported that there was no statistical difference between the casualty means, therefore rejecting the null hypothesis.

Strictly looking at summary statistics, less variance was found in casualty ratings when the autonomous system was utilized. This implies that the autonomous system was able to give accurate data allowing the friendly force to generate more casualties; therefore, friendly forces' lethality increased with the autonomous system. However, a t-test on the friendly force casualty rate indicated that both forces' survivability decreased. The scenarios themselves put the friendly force at a great disadvantage. Additionally, in the remote control scenario, the fourth soldier enters the room late, resulting in the friendly forces initially engaging the enemy in a 3-on-4 situation which puts the friendly unit at an even greater disadvantage.

Multiple assumptions and implications dictated the results. Within this model, two four-man teams with the same individual capabilities, weaponry, and equipment were compared. Inherently, the enemy force held the advantage given the friendly force must enter from one doorway and the enemy is surrounding the friendly force as they enter. The soldiers would also fire on the first acquired target or the highest-level threat. Although the model attempts to capture accurate individual behavior, it cannot account for specific unit standardized operating procedures which could vary from the model.

5.1.2 Discussion

These results suggest that although an autonomous system may provide useful combatant information, it may not help benefit soldiers in an engagement. In real-world combat scenarios, an autonomous system may benefit soldiers as an additional sensor to provide them with critical information. For breaching scenarios, soldiers should plan to incorporate a

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fully autonomous system so they can receive real-time information and have no worries regarding controlling the system. The focus should be on the mission. The autonomous system addition in the breaching scenario is meant to relieve some of the cognitive load on the soldier and allow them to perform confidently in their given situation.

5.2 Fires Model

Like the breaching scenario, the fires model incorporated an autonomous system that augmented calling for fires and shared some of the soldiers' heavy load of equipment.

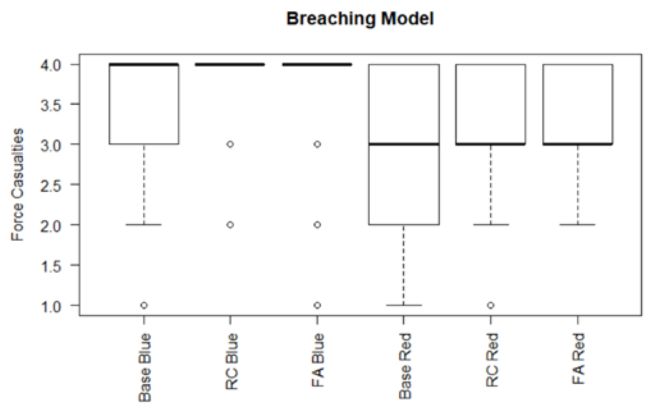

Figure 5. Boxplot of Force Casualties in each Breaching Scenario

5.2.1 Methodology, Results, and Assumptions

The same methodology as the breaching model was used for analysis on the fires model. Summary statistics were collected and based on those conclusions, a two-sample t-test was used to interpret the difference of means. Figures 5 and 6 displays a boxplot of the force casualty ratings for each of the modeled scenarios.

The same null hypothesis from the previous model was analyzed in this scenario. The t-test between each forces' base and autonomous system scenarios yielded statistically significant difference of means. The friendly casualty base and "bread crumbs," friendly casualty base and fully autonomous, enemy casualty base and "bread crumbs," and enemy casualty base and fully autonomous model mean comparison yielded p-values of 0.004078, 0.01477, 0.002163, and 0.02298 respectively, therefore rejected the tested null hypothesis. No statistical difference was evident between the friendly and enemy "bread crumbs" and fully autonomous model casualty ratings, therefore failing to reject the null hypothesis. Based on these yielded statistical conclusions and summary statistics, friendly force lethality and survivability increased when integrating an autonomous system. No statistical differences were found between the "bread crumbs" model and fully autonomous models since the system performs the same functions and its actions performed are not hindered based on whether it is following the unit or moving as its own entity.

There were numerous assumptions in this model to include: ground and air clearance is pre-established, mission processing time including initial transmission is negligible, a 45-second time of flight for indirect fire based on a round from a 81mm mortar, using precision-guided enabled munition, no rule of engagement or civilian casualty restrictions, and that immediate suppression is allowed (Olson, 2020). An additional assumption was for the load carriage capabilities, based on a 20-second 100-meter sprint, the soldiers could run at five meters per second after the initial ambush initiates.

5.2.2 Discussion

This model yielded many strong statistical conclusions that support using an autonomous system in fires missions. Since there was no statistical difference between the "bread crumbs" and fully autonomous scenarios, the specific autonomy level for the system does not matter when assisting in fires missions. Regardless of the autonomy level, the system would allow for accurate and effective fires missions to be delivered. However, FO and FSOs may still be required since an autonomous system would be limited to its programming whereas a person can more readily adapt to a dynamic environment.

Additionally, the load carriage capability assisted in drawing these conclusions. Load carriage allows for the physical load to be taken off the soldiers, allowing them to conserve their energy so they can maintain maneuverability during engagements. An autonomous system could carry the physical burden of a soldier in harsh operating environments. These systems should be integrated to assist in relieving the heavy load soldiers manage across mission sets.

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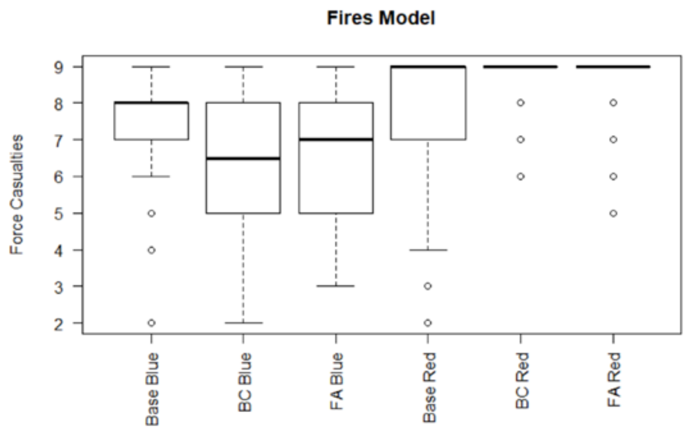

Figure 6. Boxplot of Force Casualties in each Fires Scenario

6. Model Limitations

Although the model developed strong statistical conclusions, the conclusions are limited to only the modeled scenarios, which contain less variability than reality. These models were developed under ideal conditions. For example, communication with the autonomous system is 100% reliable, an assumption unlikely in warfare conditions.

Additionally, the autonomous system is modeled in two very specific missions. In the breaching scenario, the ammunition, weapons, soldiers, soldier’s path, soldier’s reaction, and many other variables are fixed and held constant throughout the models which is not the case in normal breaching operations. Similarly, no additional munitions, such as a grenade, were utilized in this breaching scenario which would normally be incorporated in a breaching scenario with a higher number of enemy combatants present (Bell, 2020). In the fires scenario, many assumptions make the model almost seem unlikely. The entire fires process is assumed to be completely automated, allowing for the indirect fire to hit as soon as possible. Like the breaching scenario model limitations, this is highly unlikely (Olson, 2020).

Another limitation of this model is that the data analysis is based on 50 replicates of each scenario. Given the complexity of each scenario, running 50 replicates took a considerable amount of time for BRASS to iterate and in more ideal conditions, more iterations would collect more accurate data for stronger statistical conclusions. If this model were rerun, it would be beneficial to determine the optimal number of runs necessary to obtain reasonable statistical conclusions.

Finally, since the scenarios were modeled with combined capabilities, such as load carriage and calling for fires in the fires scenario, there is no way of differentiating which capability had an impact on the force casualty rating. A future study could model these separately to realize stronger results and conclusions.

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7. Conclusion and Future Work

The United States Army continues to explore how to integrate autonomous systems into warfare. Autonomous systems can augment specific soldier tasks to ease the physical and mental load of a soldier in the military. Warfare is constantly changing, and autonomous systems are a major part of the next step in keeping the advantage in modern-day warfare. By implementing autonomous systems, friendly force survivability and lethality can increase. The Army will be able to better protect their soldiers and focus on the mission with autonomous system integration. Combat modeling should continue to be developed to incorporate a wide range of possible warfare environments.

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