Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
April 29, 2021
A Regional Conference of the Society for Industrial and Systems Engineering

The Effects of Increasing the Size of the Infantry Squad

William Webber and Vikram Mittal

United States Military Academy
Department of Systems Engineering
West Point, NY

Corresponding author's Email: william.webber@westpoint.edu

Author Note: William Webber is a senior at the United States Military Academy (USMA) pursuing a Bachelor of Science degree in Engineering Management with Honors distinction. Upon graduating on May 23, 2021, William will commission as a Field Artillery officer. Dr. Vikram Mittal is an Assistant Professor in USMA's Department of Systems Engineering.

Abstract: After major conflicts, the United States Army re-evaluates the optimal size of its infantry squads, given changes in military technology and enemy strategy. The Army is currently evaluating changing the size of the infantry squad from nine to thirteen. This analysis sets out to analyze the change in soldier survivability and lethality from this change. The Lanchester equations, the standard attrition models used in military modeling, provided initial insight into these changes. The Lanchester equations indicated that the squad would have an increase in survivability and mission effectiveness. A more detailed analysis used the Infantry Warrior Simulation (IWARS) to simulate four standard infantry missions and evaluate the overall changes in mission performance. This model indicated that across the mission sets the infantry squad saw an increase in lethality and a decrease in survivability when shifting from nine to thirteen soldiers.

Keywords: Combat Modeling, Infantry Squad, Next Generation

1. Introduction

The squad is the Army's integral building block within formations. It is important to maximize the effectiveness of this unit. This study investigates the current size of the infantry squad to determine if increasing the size to thirteen-members will be more effective for future combat operations. Figure 1 presents the current structure of the squad, which contains a squad leader and two fire teams, Alpha and Bravo. This study evaluates a proposal to increase the size to thirteen members by adding an additional fire team, Charlie, visually depicted in Figure 1.

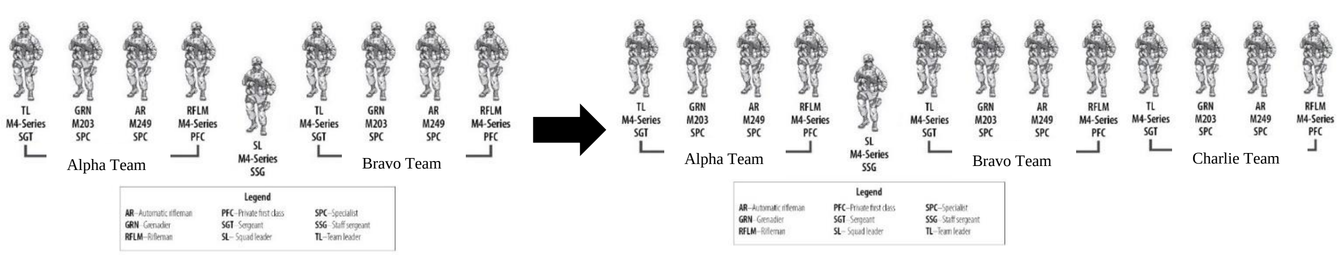

Figure 1. The Proposed Modern Infantry Squad Formation

This paper begins with background information, including the justification for changing the squad size. It then uses the Lanchester model, a standard mathematical attrition model, to gain additional insight on force-on-force combat. This analysis then presents a series of detailed simulations using the Infantry Warrior Simulation (IWARS) to further analyze the effects of changing the infantry squad. Finally, the paper concludes with a discussion of the limitations, future work, and the recommendation.

2. Background

Many consider the infantry squad to be the decisive force of the US Army (Brown 2011). At a minimum, the infantry squad can be considered as the critical building block of the Army's strength and combat power. The formation of the infantry squad has evolved many times throughout history as the characteristics of conflict have changed. The last change to the infantry squad came in 1983 at the beginning of American involvement in Afghanistan with the invasion of the Soviets in the Iranian hostage crisis (Hughes, 1994). This change was from a unit with eleven personnel to nine personnel because of the introduction of the Bradley Infantry Fighting Vehicle (BFV), which could only transport nine personnel (Hughes, 1994). As the Army's focus shifts from the Global War on Terror to near-peer adversaries, such as Russia and China, it must prepare for larger scale combat with a large nation. Key leaders within the United States Army have publicly voiced the need for change in the structure of units. MAJ. General Patrick Donahoe, former commander of the Army Maneuver Center of Excellence, stated the likely move from brigade combat team focus to a divisional structure will better serve the Army for future combat. He stated "We understand that large-scale combat operations [are] no longer a brigade-centric fight. The brigade will not have enough combat power. The brigade will not have the ability to synchronize all the elements of combat power that will be required to fight and win in large-scale combat operations" (Cox, 2020). This shift provides an opportunity to shift the size of the squad to support the need for increased combat power.

To prepare for these large-scale conflicts, the Army is evaluating changing the size of the rifle squad from nine to thirteen members (South, 2020). There are many proposed benefits to increasing the size of an infantry squad. The idea to shift to a thirteen-member squad is based on adding one fire team to the squad, moving from two fire teams and a squad leader to three fire teams and a squad leader. Figure 1 shows the addition of the Charlie Fire Team that will be added to the existing Alpha and Bravo Teams. The fire team can serve as a base-of-fire or a maneuver element, and adding one additional team would allow the squad to use this team as either an additional maneuver element or strengthen the support by fire (Potočnik, 2018). The additional fire team can act as an independent team which will cause little change in current strategy and doctrine and allow for an easy transition. Not only is this a benefit in the ability for the squad to plan and act as an independent unit, but it also simply increases the fire power of the unit by adding additional personnel and more weapon systems (Cox, 2020).

While there are current limitations to increasing the size of the squad specifically due to the size of the BFV, within the next two years there will be the addition of three new pieces of technology to the squad level. First, the Integrated Visual Augmentation System (IVAS) provides a plethora of information to the soldier to include navigation, targeting, communication, bio-tracking and facial recognition (South, 2020). Second, the Next Generation Squad Weapon (NGSW) will be added to replace the M4 carbine which will add extended range, accuracy, and lethality (South, 2020). Lastly, the Optionally Manned Fighting Vehicle (OMFV) is intended to replace the BFV to allow for greater flexibility in future conflicts. The BFV lifecycle is ending, and the Army has requested proposals for future vehicles from industry (Judson, 2020). These three new technologies, specifically the OMFV will remove the limitation that was a result of the capacity of the BFV. The addition of these new technologies provides an opportunity to change the current squad formation by adding an additional fire team.

3. Lanchester Model

Lanchester's laws are the standard attrition model used for modeling an engagement between two armies (Johnson, 1990). Lanchester's Linear Law is the most basic predator-prey model that uses differential equations to represent the strength of each side. This law is appropriate to use for a series of one-on-one duels. The Lanchester Square Law modifies the first Linear Law to include concentration of forces and better replicates modern combat (Johnson, 1990). The model labels a red and blue side for each respective equation and uses time to calculate the loss of life. In combat modeling, blue is commonly used for friendly forces and red is used for enemy forces. The following equations represent the model with B_0 and R_0 representing the initial size of the force, β_R and β_B represents the strength of the force and the rate at which the opponent can attrit it, and lastly t represents the time step in the model.

$$B(t) = (B_0 - \beta_R t) \quad and \quad R(t) = (R_0 - \beta_B t) \tag{1}$$

The results of the Lanchester equation, when applied to the growth of the US Army Infantry Squad, are depicted in Figure 2. The two metrics being compared are the time required for the Blue force to defeat the Red force and the number of Blue forces deaths that occurred. This is depicting both the survivability in the death parameter and lethality in the time parameter of the Blue force. Figure 2 shows that both the survivability and the lethality of the blue force increase from the nine to thirteen-member squad when facing an enemy element of 5 personnel. The number of blue deaths decrease from the nine to the thirteen member squads resulting in a higher survivability. The time that was required for the blue force to remove all the red force also decreased which results in a higher lethality of the blue force.

Figure 2. Results of Lanchester Model Including Both the Time and Blue Deaths

The Lanchester Model is a very simplistic simulation technique that only considers the strength and size of the friendly and enemy forces. However, despite its simplicity it provides important information before the IWARs simulation is run. The IWARs simulation should produce similar results but will take into consideration more of the combat characteristics and provide more insight on how the extra fire team operates within the squad.

4. Base Models

4.1 Combat Simulation

The analysis in this research will utilize Infantry Warrior Simulation (IWARS) to compare the effectiveness of the different squad size. IWARS is an agent-based, force-on-force combat simulation program. It represents individual soldiers, squads, and small-unit operations in different environments, including military operations in urban terrain (IWARS Methodology Guide, 2014). Within the simulations friendly and enemy death will be used to determine survivability and lethality. The measurement in IWARS that captures this information is Blue and Red killed in action (KIA).

4.2 Overview

The nine-member squad and the thirteen-member squad will be tested through four different simulations that match common infantry tasks. While there are many factors that will play a role in the ideal size of an infantry squad, this research studies the combat effectiveness of the infantry squad based on size. The overall combat effectiveness will be determined by simulating the infantry squad completing common infantry operations based on FM 3-90 to include movement to contact, attack with ambush, react to contact, and area defense (Dept of Army, 2019). The objective of each scenario will be to eliminate the enemy fire team which would result in four Red KIA. In the event that all four are not eliminated the most value will be given to the maximum number of Red KIA. The smaller number of Blue KIA is best with the ideal outcome being zero. The nine-member squad has an advantage because it requires less manpower and has a lower level of risk to human life. If both the thirteen- and nine-member squad are equally effective the nine-man squad will be considered more advantageous.

The simulation will be run within the McKenna MOUT terrain. This terrain is depicted in Figure 3. This terrain contains multiple avenues of approach with three roads entering the area of operation. Within the area of operation there are many different sized buildings. This terrain was chosen because of the similarity that it has to an urban environment. It is likely that conflict in the future will take place within an urban environment with buildings and structures involved (Judson, 2020). The missions that are conducted within the simulations will utilize the avenues of approach and the cover of the buildings to achieve the success of the missions.

Figure 3. McKenna Mobile Operations in Urban Terrain (MOUT) Site in IWARS.

4.2 Structure of the Squads

There are two squads that are used within the simulations. The first is a nine-member squad that represents the current infantry squad. The structure of the nine-member squad is depicted in Figure 1. The second is a thirteen-member squad that has been created to simulate the effect of the new thirteen-member squad. The new thirteen-member squad is the same as the nine-member squad with an additional fire team, Charlie team, also depicted in Figure 1. This addition was made to the personnel; however, the other aspects of the squad have remained the same as the nine-member squad. The formations are the same with the facing direction and the field of regard of the personnel equal between the two squads. There are also no changes in the equipment between the two squads as both the communication and the techniques for engaging the enemy are identical.

4.3 Mission Simulations

There are four types of missions that will be used to determine the effectiveness of the two squads. These four missions are commonly executed infantry missions including react to contact, movement to contact, attack, and area defense. Each of these missions will be simulated with both a nine-member and thirteen-member squad. The layouts for all the missions and both size squads are depicted in Figure 4. The blue force represents the friendly personnel, and the red force represents enemy personnel.

The first mission is reacting to contact. In this mission the blue force will begin in the north portion of the map at the entrance to the village. In this mission the blue force does not know the position of the red force and is tasked with moving from the north end of the village to the south end by using the road that runs through the village. The movement route can be seen in Figure 4 with the pink line being the path of the blue force. The red force is positioned in the middle of the village with cover and ready to ambush the blue force when they move past their location. The blue force will return fire and continue to move to the south end of the village after coming under contact. In this simulation the blue force will move as a squad file.

The next mission is movement to contact. Similar to the react to contact mission, the blue force will begin in the north portion of the village and move through the village to end in the south. In this mission, the squad moves in a squad column. The main difference from the react to contact is that the blue force knows the location of the red force and is moves to that position to engage with the red force and then continue to the north end of the village. The red force does not know the positioning of the blue force.

The attacking mission is a simple simulation. The blue force is in a line formation within an unobstructed view of the red force. Both the blue and red force will engage each other while the blue force moves closer to the red force position. The red force is placed with slight cover in a building; however, the blue force is still able to engage as they move towards the red force position.

The last mission is area defense. In this mission the blue force will not move throughout the simulation and remain in a defense formation along the main road of the village. The red force will begin in the north portion of the village and move through the village using the main avenue of approach, the main road. The blue force is not outlined in a specific formation; however, they are arranged by fireteam in defensive positions with cover from the road. As the red force moves through, the blue force will engage, and the red force will return fire and continue to move to the south end of the village.

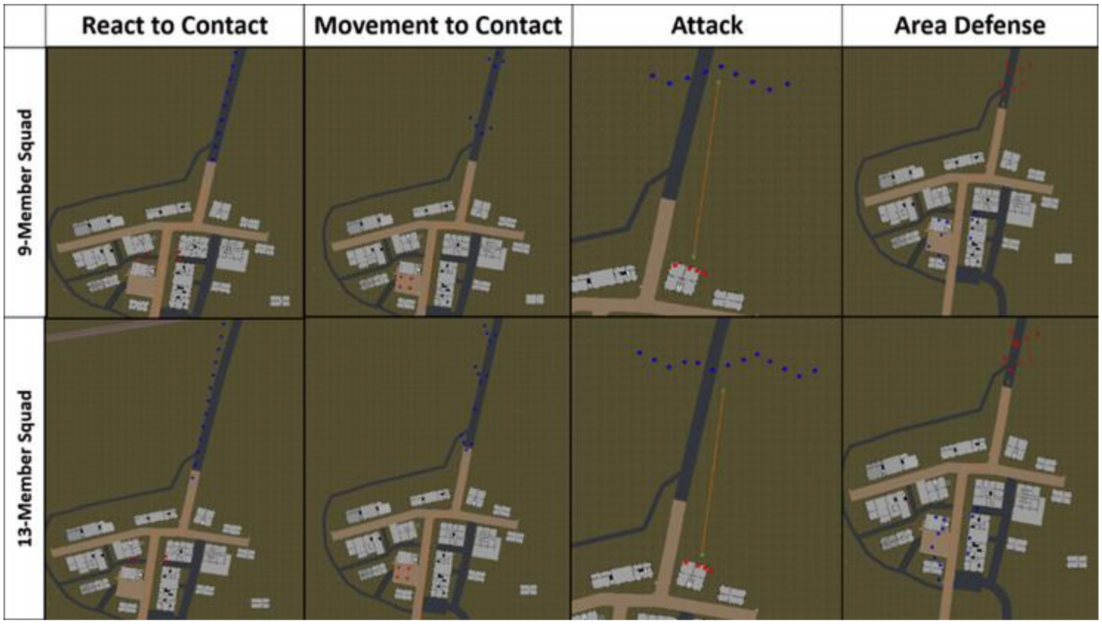

Figure 4. Simulation Formations of Red and Blue Forces

4.4 Batch Run Analysis and Simulation Studio (BRASS)

The completed missions were analyzed using Batch Run Analysis and Simulation Studio (BRASS). BRASS is an organizational tool used to perform the design of experiments and explore statistical significance for different factors. It allows the simulation to be run multiple times in IWARS to account for the stochastic nature of combat (IWARS User Guide, 2014). Within this study, the Output Analysis captured the number of Red and Blue KIA for each run.

Running the simulation multiple times accounts for variability because IWARS is a stochastic simulation model. Equation 2 determines how many times the simulation needs to be run to be within a certain percent of the mean (Mittal, 2021). In equation 2, *n* is the number of required runs, *DRP* is the desired relative precision, *s* is the estimated standard deviation, and *t* is the t-table value corresponding to the desired confidence level and sample size. For this analysis, *DRP* was set at five percent. Using equation 2, it was determined that each simulation had a unique number of runs required to meet the desired relative precision. Each simulation was executed twenty times to generate a standard deviation value. Table 1 lists the standard deviation and then the calculated value for number of runs for each simulation. Using equation 2, the t-value and DRP was the same for all the simulations, 2.262 and 0.05, respectively. The only variable that changed was the standard deviation value to obtain the unique number of runs.

$$n^* = \left(\frac{s \times t_{n-1,1-\alpha/2}}{DRP}\right) \quad (2)$$

Table 1. Data for Calculated Number of Runs for Each Simulation

Mission	Area Defense		Attack		React to Contact		Movement to Contact	
Squad Size	9	13	9	13	9	13	9	13
SD	0.92	1.54	0.66	1.10	1.01	1.30	1.00	1.37
n	42	70	30	50	46	59	46	63

5. Results and Analysis

5.1 Simulation Results

While the results of the simulation are not conclusive between all four of the simulations, there is still key takeaways based on the specific results of each mission. Over the four missions, in all cases the increase in squad size from nine to thirteen resulted in both an increased in lethality (a higher Red KIA) and a decrease in survivability (a higher Blue KIA). Across all the four different missions, the same results were achieved, however, each mission had a unique effect on the magnitude of the results. The output of the results is presented first in Figure 5 which displays the mean KIA over all the simulation runs with the confidence intervals depicted in black error bars. The output is also displayed in numeric form in Table 2.

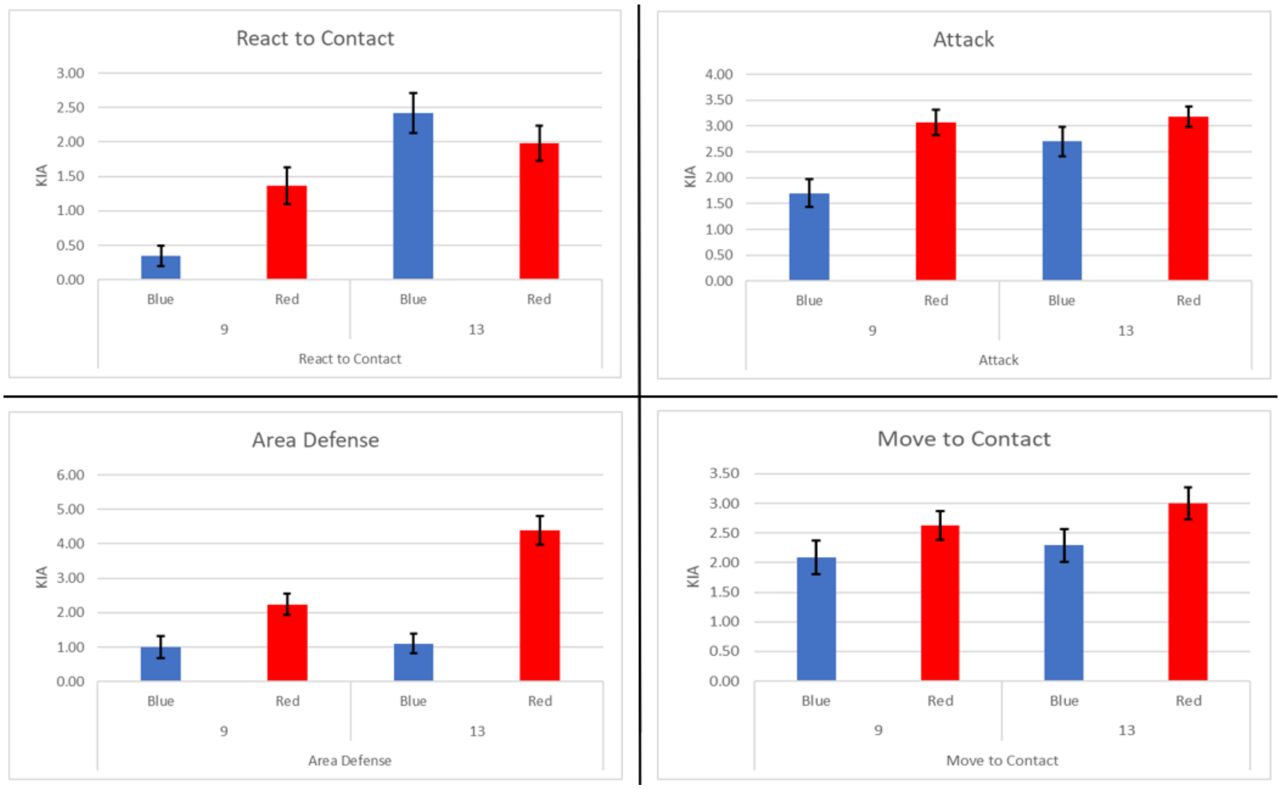

Figure 5. Graphs of the Simulation Results Displaying the Number of Red and Blue KIA

Figure 5 depicts the change in both the Red and Blue KIA based on the size of the squad. The react to contact results in a large change in Blue KIA from 0.347 to 2.42. This is the largest difference between the two squad sizes for all the simulations. This change was expected because of the increase of the size of the Blue force which increases the potential KIA. The magnitude of the change may result from the Red force in this mission knowing the positioning of the Blue force and the Blue force entering the ambush zone unaware of the Red force positioning resulting in the Red force able to capitalize on the time required for Blue force to return contact. The number of Red KIA also increased with the larger Blue force squad. This was expected because of the increase in firepower of the Blue force.

The results from the movement to contact mission match the expectations. The survivability decreased with an increase in Blue KIA, and the lethality increased with a higher number of Red KIA when comparing the nine-member squad to the thirteen-member squad. The magnitude of the change in Red and Blue KIA are similar. The difference in the mean Blue KIA is about 0.2, while the difference in Red KIA is about 0.4. The Blue KIA variation is smaller in this mission because the known position of the Red force during the mission allowing them to better utilize their fire power and not be caught off guard.

The results from the attack mission show limited benefit in the additional Blue force. There is a drastic change in the survivability with Blue KIA and a very slight change in lethality with Red KIA. The change from the nine- to thirteen-member squad resulted in an increase of average Blue KIA of 1.0 while the shift in Red KIA was only 0.06. This shows, that while there was a slight increase in success of the Blue force, it came at a great cost of a large increase in Blue KIA.

The results from the area defense mission show the greatest benefit from the increase size in the Blue force squad. There is a large increase in the lethality of the Blue force increasing Red KIA by 2.15 and only slightly decreasing survivability by 0.1. This is the best result from all the missions because the Blue force can utilize the increase strength by increasing the lethality at a great magnitude. At the same time, they do not see the negative results of the increase strength by maintaining the survivability. In this mission, the blue force remains in the same concealed positions which is likely why there is not a large change in the survivability.

Table 2. Numeric Results from Simulation

	Movement to Contact				*React to Contact*				*Attack*				*Area Defense*			
	9		*13*		*9*		*13*		*9*		*13*		*9*		*13*	
Sample	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*	*Blue*	*Red*
Mean	**2.09**	**2.62**	**2.29**	**3.00**	**0.35**	**1.37**	**2.42**	**1.98**	**1.70**	**3.07**	**2.70**	**3.18**	**1.00**	**2.23**	**1.10**	**4.39**
Stand. Dev	**0.97**	**0.83**	**1.12**	**1.06**	**0.53**	**.93**	**1.13**	**1.01**	**0.75**	**0.69**	**1.02**	**0.72**	**1.08**	**1.01**	**1.21**	**1.75**
Number of Runs	**45**	**45**	**62**	**62**	**46**	**46**	**59**	**59**	**30**	**30**	**50**	**50**	**42**	**42**	**70**	**70**
Confidence Interval	**2.37**	**2.86**	**2.56**	**3.26**	**0.49**	**1.63**	**2.71**	**2.24**	**1.96**	**3.31**	**2.98**	**3.37**	**1.32**	**2.54**	**1.38**	**4.79**
	1.80	**2.37**	**2.01**	**2.73**	**0.19**	**1.10**	**2.13**	**1.72**	**1.43**	**2.81**	**2.41**	**2.98**	**0.67**	**1.93**	**0.81**	**3.97**

The four missions all have similar results with different magnitude of change between the nine- and thirteen-member squad. In every mission, there was an increase in lethality and a decrease in survivability. The results were all not conclusive, and the magnitude of difference was not the same. For example, react to contact resulted in a large increase in friendly KIA while only a small increase in enemy KIA. This mission would not benefit from the thirteen-member squad because it would result in too many friendly deaths. The attack mission had similar results with a large jump in friendly death and small change in enemy death meaning the thirteen-member squad advantage is not worth the large increase in death. The most likely reason for these disadvantageous results from the increase in size of the squad is because, within these two missions, the friendly forces did not know the positioning of the enemy. Both missions required Blue force to receive contact and then respond with return fire allowing the Red force to take advantage of this time. If the Red force was able to kill blue personnel initially before the Blue force could return contact, the advantage of extra personnel is weakened. The other two missions had the opposite outcome in terms of magnitude of change in Blue and Red KIA. The movement to contact and area defense mission saw a large increase in Red KIA while only resulting in a small increase in Blue KIA. This is the most advantageous result because the friendly forces were able to kill more of the enemy forces while only suffering a small increase in casualties. This is because in the movement to contact mission the Blue force knows the position of the Red force which allows the Blue force not to be surprised by the Red force contact and utilize all the increase in fire power. In the area defense mission, the Blue force is in concealed positions making it difficult for the enemy to eliminate friendly forces despite the increased number of targets. Both these missions saw the most advantageous results with area defense having the best results of all four missions.

6. Conclusion

6.1 Analysis Limitations

While the results from the simulation are similar and convincing, there are several limitations for this model that should be discussed. The first limitation is that only four missions were conducted. While these are the most common missions within infantry units, there are other missions that, if run, could provide more insight. As mentioned in the background, the United States Army is going to institute new technology with new vehicles and weapons in the near future. The simulation was conducted with the M4, which is the weapon system currently used. There is a possibility that the new technology would produce different results. While IWARS is a great simulation technology with many benefits, it is completely run by AI, meaning that some of the actions of the personnel are not realistic. For example, in the simulations there was a path prescribing the movement of the personnel, and, after encountering enemy fire, the personnel will return fire and continue on the path. In most real-world situations, personnel would seek cover and alter movement based on enemy location.

6.2 Future Work

There is still more information that would provide great insight as to whether the thirteen-member squad is more advantageous that was not gained with the simulations run in this research. This research investigated running four of the more common infantry missions, whereas a future study could investigate the effects on other missions. While adding an additional fire team is likely to produce the greatest results, the Marine Corps is looking into a squad size of fifteen, and a future study could investigate the effects of a number greater than thirteen. In addition to changing the size, the layout of the formations could be studied further. For this study, an additional fire team was placed in the exact layout as the other two fire teams, however, there might be a more advantageous layout of personnel. In this simulation the friendly forces were operating against an enemy fire team. The size of the enemy formation could generate different results.

6.3 Final Findings

The conclusion of the simulation provided great insight into the outcomes of increasing the infantry squad from nine to thirteen members. There are certain advantages based on the type of mission, however, there are results that can be generically applied to all infantry operations based on the abilities of each individual squad. In all four missions, there was an increase in friendly lethality. The increase in personnel and fire power allowed for the friendly force to eliminate more enemy personnel. While this advantage is great in every simulation, the number of friendly casualties also increases because of more friendly targets. Certain missions, to include react to contact and attack, saw a greater magnitude in the increase in friendly casualties than enemy kills, revealing that the thirteen-member squad was not advantageous. The other two missions, movement to contact and area defense saw greater magnitude changes in enemy kills versus friendly casualties, meaning the thirteen-member squad is more advantageous.

6.4 Recommendation

The results are not conclusive, and the application of the findings are not as simple. While, in all the missions, the friendly force was more lethal and able to kill more of the enemy, it also resulted in more friendly casualties. It is not clear the value of friendly personnel life making it difficult to determine the acceptable increase in friendly casualties. However, the results of this simulation support the increase in friendly casualties is worth the increase in enemy casualties in the area defense mission. This is supported because of the increase in enemy kills is greater in magnitude compared to the magnitude of change in friendly death. Of the four missions simulated in this study, only area defense produces result that would support utilizing the thirteen-member squad.

7. References

Army Techniques Publication (ATP) 3-21.8, Infantry Platoon and Squad, April 2016.
Brown, Robert. The Infantry Squad: Decisive Force Now and in the Future. *Military Review.* Dec 2011.
Cox, Matthew. The Army Is Looking at Changing Up the Size of Its Infantry Squads. *Military Advantage.* 6 November 2020.
Department of the Army. (2019). *Army Doctrine Publication (ADP) 3-90: Offense and Defense.* Department of the Army.
Hughes, Stephen E. The Evolution of the U.S. Army Infantry Squad. *School of Advanced Military Studies.* Fort Leavenworth, Kansas. 17 December 1994.
Johnson, Ronald. Lanchester's Square Law in Theory and Practice. *School of Advanced Military Studies.* Fort Leavenworth, Kanas. 21 August 1990.
Judson, Jen. Solicitation for Bradley replacement offers flexibility for foreign participation. *Defense News.* 18 December 2020.
Mittal, Vikram. Combat Modeling Notes. *Department of Systems Engineering.* United States Military Academy. Fall 2021.
"Preface," *IWARS 5.1 Methodology Guide*. April 2014.
Potočnik, Viktor. Basic Infantry Building Block. *U.S. Army Command and General Staff College*, Fort Leavenworth, Kansas. June 2018.
South, Todd. Will the Army change the size of the infantry squad? *Army Times.* Sightline Media Group. 5 November 2020.
"UDOP," *IWARS 5.1 User Guide.* April 2014.