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FEASIBILITY STUDY FOR REPLACING THE MK19 AUTOMATIC GRENADE LAUNCHING SYSTEM

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ABSTRACT

The Army's MK-19 weapon system is an automatic grenade launcher capable of destroying thin-skinned vehicles and dismounted targets at ranges up to 2200 meters. Since its first use in the 1960s, the MK-19 has remained largely unchanged while technology has improved. This research will determine if an alternative weapon system provides a significant improvement in lethality over the MK-19. The Joint Combat and Tactical Simulation (JCATS)is used to test weapon variants against a variety of enemies in terrain similar to current operating environments. The results of these tests – along with the weapon's mobility, user interface, and logistics footprint – are analyzed, weighted, and scored through the use of the Systems Decision Process (SDP) developed by the U.S. Military Academy's Department of Systems Engineering. Ultimately, this report provides a recommendation to the Army's Program Manager of Advanced Crew Served Weapons on which weapon provides the greatest value to our troops in theater.

1 INTRODUCTION

Due to the nature of the Global War on Terrorism (GWOT), U.S. forces deployed in Iraq and Afghanistan have been forced to fight on an asymmetric battlefield against a well trained and indiscernible enemy. Since engagements are often fought in urban terrain favoring the enemy, new capability requirements for weapon systems used by U.S. ground forces have developed. Pushing these capability requirements is the need to minimize collateral damage as well as the need to quickly and accurately engage enemy targets in defilade. The purpose of this study is to analyze the feasibility of a new prototype weapon the Army is considering, the XM307 Automatic Grenade Launching System, and compare it to two existing alternatives. The end state of our study is to provide a recommendation to the Program Manager for Advanced Crew Served Weapons on which is the best of our three alternatives: the MK19 MOD 3, MK47 MOD 0, and XM307.

Based on our analysis, the best performing alternative for an improved automatic grenade launcher for Army ground forces is the XM307.

2 BACKGROUND

2.1 MK19MOD 3

Development of the MK19 began in the 1960's with the MK19 MOD 0. After several modifications and extensive testing, the MK19 was adopted by the U.S. Navy in 1978 and the U.S. Army in 1983. The MK19 is a 40mm automatic grenade launcher with a maximum effective range of 1600 meters and an average rate of fire between 325 – 375 rounds per minute. The MK19 can be used in both dismounted and mounted roles, but is most often mounted to vehicles presently. The MK19 is capable of firing several different types of ammunition, most notably armor piercing grenades as well as high explosive dual purpose grenades. Each 40mm grenade has a casualty radius of 15m. Although it is designed for use against lightly armored vehicles, it can be used against dismounted troops when necessary.

The MK19 has several limitations. The weapon system weighs 72.5 pounds with an additional 44 pound tripod when used in a dismounted role. This limits mobility and constricts dismounted use significantly. Additionally, when fired from a tripod, the tripod must utilize sandbags for support, due to the immense recoil of the weapon system. This adds to set up time, and limits the weapon's mobility. Furthermore, the lack of optics or a fire control system significantly reduces the first round hit probability on targets,

forcing the user to "walk in" rounds on target. This increases the likelihood of unnecessary collateral damage and increases ammunition use (FM 23-17, 1988).

2.2 MK47 MOD 0

The MK47 MOD 0 is a 40mm automatic grenade launcher designed as a replacement for the MK19 MOD 3. Development for this weapon system began in the late 1980's, but prototypes did not appear until the mid-1990's. In 1997, the MK47 integrated a fire control system, which calculates a ballistic fire solution, into its operation. In 2003, the United States Special Operations Command (USSOCOM) adopted the MK47. Presently the MK47 is fielded overseas with USSOCOM units, and has seen limited fielding with the U.S. Marine Corps (Popenker, 2007).

The MK47 is lightweight, about half the weight of the MK19, weighing only 39.6 pounds. The maximum effective range is 2,000m and the rate of fire is between 250 – 300 rounds per minute. This is slightly slower than the MK19. The integrated fire control system (FCS) not only increases first round hit probability, its helps decrease both collateral damage and ammunition use by eliminating the need to "walk in" rounds on target. Additionally, the FCS gives the MK47 the ability to use air-bursting rounds, which enables the weapon to engage targets in defilade. Air-bursting technology uses a range finder to determine the range from the weapon to the target. The FCS then programs the outgoing round to detonate at that range, sending shrapnel below the line of sight onto the target. Although this is a significant improvement over the MK19's capabilities, air-bursting rounds are not currently in use due to the expense of the rounds and reliability of the technology.

The MK47 can be used in the same dismounted and mounted roles as the MK19. However, the MK47 does not need to be sandbagged when dismounted due to significantly reduced recoil. This, and the lighter weight, allows dismounted troops more mobility with the weapon and fast set up time, increasing the MK47's ability to be used by dismounted troops. The MK47 also possesses a shot counter, which acts as an odometer for the weapon to monitor maintenance. This increases reliability and reduces maintenance costs. The MK47 currently uses the same ammunition as the MK19.

2.3 XM307

The XM307 is a 25mm automatic grenade launching system currently in development by General Dynamics. The XM307 is designed to replace the MK19 and MK47, and is designed to utilize new 25mm air-bursting ammunition. The XM307 was specifically designed to incorporate air bursting technology into its operation. Requirements for this technology were outlined in the Counter Defilade Target Engagement (CDTE) Initial Capabilities Document (ICD). In addition the XM307 can be transformed into a new lightweight .50 caliber machine gun, the XM312, by changing just four parts. A trained crew can change the weapon system from the XM307 to the XM312, or vice versa, in less than two minutes. This helps decrease the logistical footprint associated with supporting two separate weapon systems and adds unique capabilities to the XM307. Currently the XM312 is a DOD funded program, but the XM307 is not.

The XM307 25mm automatic grenade launcher has a maximum effective range of 2000m and has a rate of fire of 260 rounds per minute. The XM307's recoil is greatly reduced compared to the MK19 and weighs just 50 pounds, including the fire control system and tripod mount. Additionally, the XM307 is capable of firing several types of 25mm ammunition to include high explosive air-bursting, armor piercing, and training ammunition.

The use of the integrated fire control system not only allows the XM307 better first round accuracy, but is also capable of programming the time until detonation for each air-bursting round leaving the weapon. The range finder determines the distance to target, which is sent to the FCS. The FCS calculates the fire solution and how long it will take the round to reach the target. An electronic chip within each 25mm round receives this time, and determines when the round should detonate while on its trajectory. This effect sends shrapnel tearing through the target, even into positions in defilade.

The XM307 can be used in both mounted and dismounted roles. Its light weight and low recoil ensures that dismounted troops can carry it with relative ease, and that it does not require sandbagging before firing. The XM307 is light enough to be carried within squad size units, unlike the MK19 and MK47. Since the weapon is still in the prototype phase of the design process, the full extent of its capabilities and limitations are still unknown.

3 PROBLEM DEFINITION

3.1 Initial Problem Statement

This paper provides statistical analysis for the feasibility of replacing the MK19, the Army's primary suppressive weapon for combat support and combat service support units. The replacement weapon is evaluated on its ability to improve mobility, lethality, and reliability, while simultaneously reducing the logistics footprint and simplifying the user interface. Consideration is also given to employing a new system beyond the current tactics, techniques, and procedures.

3.2 Stakeholder Analysis

The purpose of the Stakeholder Analysis is to identify the wants and needs of the client, what the client feels is important, and revise the problem. Based upon the feedback we received from several stakeholders, including the Infantry Training Center at Fort Benning, we performed a functional analysis on the system, breaking it down into its main functions. We then identified the objectives each function must perform in the system, and how each objective will be evaluated.

Development of a MK19 replacement system falls under the Program Executive Office (PEO) Soldier, a government agency that overseas the development and procurement of weapons and material for U.S. Soldiers. This research project was directly supported by one of PEO Soldier's program managers. The project's goal is to analyze possible alternatives to the MK19 using value focused thinking and present the findings to the PM for Advanced Crew Served Weapons (PM ACSW).

The XM307 is currently an unfunded project. The focus of this study was to conduct a complete weapon system analysis based on the desired capabilities to determine if future development is a worthwhile endeavor for the U.S. Army or if an existing weapon system is better suited for to replace the MK19.

PM ACSW provided a series of responses from civilian and military personnel with backgrounds in automatic grenade launchers that had been collected during initial development of the prototype system. The information received outlined comments by users on the limitations of the MK19 and what they would like to see in a new grenade launching system. From this data, the group determined four main functions the weapon system must perform: improved mobility, improved lethality, decreased logistical footprint, and improved user interface.

The comments allowed the group to identify the most important and reoccurring complaints with the current weapon system, draw conclusions, and create recommendations. Based upon these recommendations and the comments, our group developed a survey that forced the surveyed individual to weight the functions by importance. Furthermore, we developed a series of possible measurable sub-functions for each function, which were included in the survey and weighted by level of importance to the user. The survey was sent to the Infantry School in Fort Benning, Georgia. We received responses by military and civilian personnel who are familiar with the MK19, MK47 and other grenade launching systems.

The survey responses indicated that mobility and lethality were the most important functions, while the logistical footprint was less of a concern. Additionally, the sub-functions were weighted by importance, which can be seen in our Value Hierarchy as well as each evaluation measure. From the survey responses, the capstone team developed three possible courses of action. The MK19 represents a "do nothing" recommendation, and acts as the baseline for evaluation. The MK47 is a newer weapon with limited use in the military, and serves as an alternative to the MK19 with several improved grenade launching capabilities. The XM307 represents the newest alternative to the MK19 integrated with the latest air-bursting and FCS technology. All alternatives are American developed and produced grenade launchers, and were developed to support similar missions.

Additionally, the group conducted a thorough literature review of each of the alternatives to identify the performance capabilities and limitations of each system. The literature review included each weapon's development, doctrinal employment, capabilities, limitations, and performance data. This information not only expanded the understanding of the problem, but also provided invaluable information to evaluate the weapon system's user interface, mobility, and lethality.

3.3 Value Hierarchy

Based on information received through survey results provided by the Infantry School, we were able to weight the importance of our identified functions, and sub functions into a value hierarchy. Our value hierarchy is shown in Figure 1. At the top of the value hierarchy is the primary objective of the system, in this case what the grenade launcher must accomplish. The primary objective is supported by four distinct functions that the system must perform. Below the functions are the system objectives.

Under each system objective is a list of performance measures. Each performance measure consists of how it will be measured, the units of measure, whether a value of more or less is better, annotated by MIB or LIB respectively. Lastly, each performance measure is weighted with a global weight. Global weights were calculated from the survey results based on how individuals ranked each function, objective, and performance measure. Although the functions and objectives are also weighted, these weights are relative to only that level within the hierarchy. Global weights extend across objectives and functions, providing a mathematical representation of importance for the performance measures in the system as a whole. These weights represent a percentage of value within the entire system, and likewise will sum to 1 for each level of the value hierarchy.

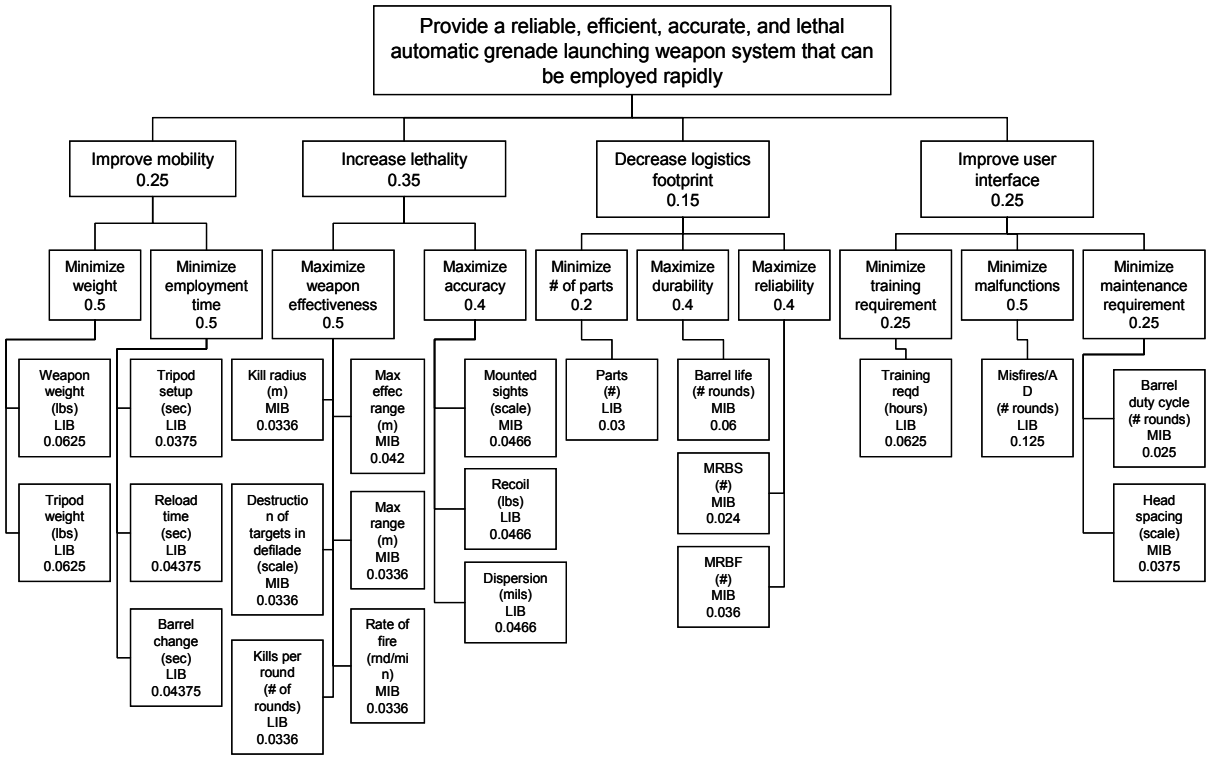


Figure 1: Automatic grenade launcher value hierarchy

4 SOLUTION DESIGN

4.1 Alternative Generation

During the Solution Design phase, the group analyzed several automatic grenade launchers and potential alternatives for recommendation. The list of alternatives was narrowed down to the MK19, MK47, and XM307 automatic grenade launchers since they most closely met the performance objective and provided the greatest overall value to the stakeholder. All of these grenade launchers have similar missions and capabilities. The MK19 serves as the baseline for comparison and is widely used across the Army. The MK47 is newer, lighter replacement to the MK19 that has seen limited fielding. The XM307 is the newest alternative that integrates revolutionary technology designed to replace both the MK47 and MK19.

4.2 Modeling and Analysis

In order to compare the alternatives, both a scoring method and simulation modeling were used. The scoring method utilizes the value hierarchy to evaluate the historical data and weapon characteristics. This method compares what we know of the alternatives based upon the characteristics of weight, reliability, maximum effective range, and rate of fire. The results from this method are gathered into a raw data matrix, scaled, and used to determine the alternative that presents the decision maker and stakeholders with the greatest value.

Modeling and simulation was also used to compare alternatives. The Joint Conflict and Tactical Simulation (JCATS), a Monte Carlo-based combat simulation, primarily used by the Department of Defense was used to compare the capabilities of each alternative weapon system in several different scenarios. JCATS simulates many environmental and human variables in combat, in order to accurately model the uncertainties of battle. Data that modeled the characteristics for each weapon was gathered from the Army Materiel Systems Analysis Activity's (AMSAA) Soldier System Branch. Since JCATS is probability based, it can differ greatly between runs. Each scenario was run 100 times for each weapon system. Additionally, we developed two scenarios to model different situations in an urban environment.

In order to isolate the performance of each grenade launching system, we modeled the movement of U.S. forces through Baghdad, Iraq to seize a bridge. The U.S. forces consisted of mounted and dismounted personnel, since grenade launchers are used currently on mounted vehicles only. The insurgent opposing forces consist of thin skinned vehicles, dismounted rifleman in open terrain and defilade, and some insurgents carrying rocket propelled grenades (RPG). We chose a variety of enemy units in dif-

ferent levels of cover and concealment to see how effective each weapon system was at engaging and destroying the enemy. Based on the number of enemy and friendly units killed, we analyzed our data to determine which weapon was most effective.

Although three weapons were analyzed, the group developed two versions of the XM307. The first version identified enemy personnel in defilade as having 15% of their bodies exposed. This is the same for both the MK19 and MK47. However, this did not take into account the air-bursting technology of the XM307. The group also used historical data to make the assumption that air-bursting technology would increase the exposure of the target's body to 50%. Since this would significantly increase the performance of the XM307, both the 15% and 50% versions were run in JCATS as separate scenarios.

5 DECISION MAKING

5.1 Results

The data generated from JCATS allowed for three key factors for analysis to determine if there is a significant statistical difference between the weapon systems. Analyzing the final number of friendly dismounts killed, friendly vehicles destroyed, and enemy forces killed shows how effective each weapon is at both protecting friendly combatants and killing enemy combatants when employed in combat. A lower ratio of friendly casualties to enemy casualties is the desired outcome.

MiniTab 15, statistical analysis software, was used to analyze the JCATS data. Because of the multiple data populations and two factors, a two-way analysis of variance test was selected to determine whether evidence exists to suggest that the population means are significantly different. A difference in the means would indicate a significant statistical difference in the weapon systems at a 95% confidence level. Friendly dismounts killed, friendly HMMWVs killed, and enemy killed were all tested versus the weapon and the scenario.

The resulting p-values shown in Table 1, reveal two key pieces of information. First, the "Scenario P-Value" of 0.15 for "Friendly Dismounts Killed" indicates that there is no significant difference between the scenarios. Second, the remaining p-values are all well under the 0.05 level of significance, indicating that the null hypothesis of the population means being the same can be rejected, or that there is a significant difference between the MK 19 and the other weapon systems.

Additionally, the individual plots of the three factors show the density of casualties from both scenarios. These plots reveals that mean total of friendly killed is at its lowest and the mean total of enemy killed is at its highest for the XM307 50%, while the opposite is true for the MK 19.

Table 1: Statistical Results of Casualties vs. Weapon and Scenario

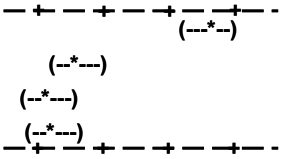
	Friendly Dismounts Killed	Friendly HMMWV Killed	Enemy Dismounts Killed
Weapon P-value	0	0	0
Scenario P-value	0.15	0	0
Interaction P-value	0	0	0
R-sq	0.3037	0.6876	0.7445
R-sq Adjusted	0.2976	0.6848	0.7423

Finally, when the weapons are compared in a one-way ANOVA where the type of scenario is not considered. Like in the two-way test, the means of friendly dismounts, friendly HMMWVs, and enemy dismounts killed were examined (though, as expected, no significant difference was found for the mean enemy killed). For friendly dismounts killed, there is a significant difference between the MK 19 and the other three weapons, as seen by the lack of an overlap in the confidence intervals in the diagram in Appendix A. The confidence interval for the MK 47 overlaps with the two confidence intervals for the XM307, showing there is no significant difference between them.

Table 2: Confidence Intervals for Friendly Dismounts Killed

Individual 95% CIs for Friendly Dismounts Killed

Level	N	Mean	StDev
MK19	100	8.060	9.847
MK47	100	1.230	3.768
XM307 15%	100	0.080	0.800
XM307 50%	100	0.060	0.600



However, for the friendly HMMWVs killed, there is a confidence interval overlap only between the XM307 15% and the XM307 50%. The MK 19 and the MK 47 confidence intervals do not overlap with any other confidence interval. Since the mean number of HMMWVs killed is the lowest for the two versions of the XM307, and since their confidence intervals are not overlapped by the MK 19 or the MK 47, it can be determined that the XM307 15% and 50% perform significantly better than their counterparts at protecting friendly HMMWVs.

In addition to the analysis from the data gathered in JCATS, we compared the weapon specifications using the evaluation measures established in the value hierarchy. After the data was tabled into a raw data matrix, the data was scaled in order to be able to compare different specifications. Using the global weights and the scaled value scoring of the weapon specifications, the group calculated a total value score (TVS) for each alternative. This TVS took

into account the weapons weight, range, rate of fire, and other evaluation measures. The value matrix is tabled in Table 3.

Table 3: Value Matrix and Total Value Scores

		Weapon		
Evaluation Measure	**Global Weight**	**MK19**	**MK47**	**XM307**
Weapon weight	0.081	31	81	95
Tripod weight	0.081	15	15	92
Weapon setup time	0.081	20	50	100
Kill radius	0.108	100	100	63
Maximum effective range	0.135	80	100	100
Maximum range	0.108	100	100	91
Rate of fire (cyclic)	0.081	100	86	74
Rate of fire (sustained)	0.108	80	80	100
Recoil force	0.108	38	38	94
Destruction of targets in defilade	0.108	15	15	50
Total Value Score		**60**	**68**	**86**

The results of the TVS calculations show the MK19 receiving the lowest TVS of 60, the MK47 receiving a TVS of 68, and the XM307 receiving a TVS of 86. Calculating the TVS provides a quantitative way to compare alternatives. Using the TVS for each alternative and the costs of each grenade launcher provided by General Dynamics, we are able to perform a cost benefit analysis, which is located in Appendix B. According to the cost benefit analysis, the XM307 provides the most value to the stakeholder, for $41,000 less than the MK47. However, the MK19 costs only $14,000, without optics, mount, or fire control system, which is included in the costs of the MK47 and XM307. Since the XM307 provides the most value for a moderate cost, the value scoring method also recommends the XM307 as the optimal solution.

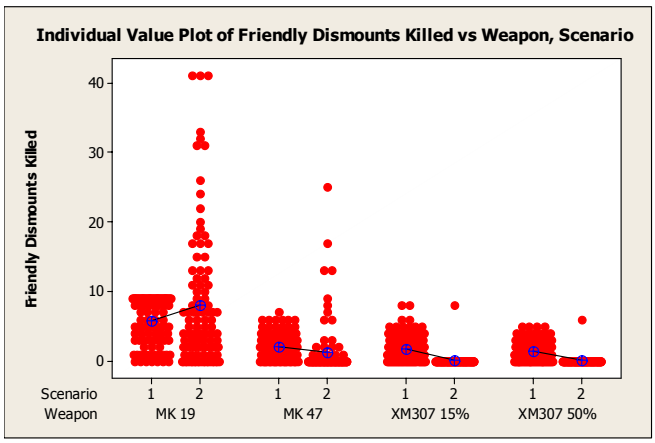
5.2 Recommendations

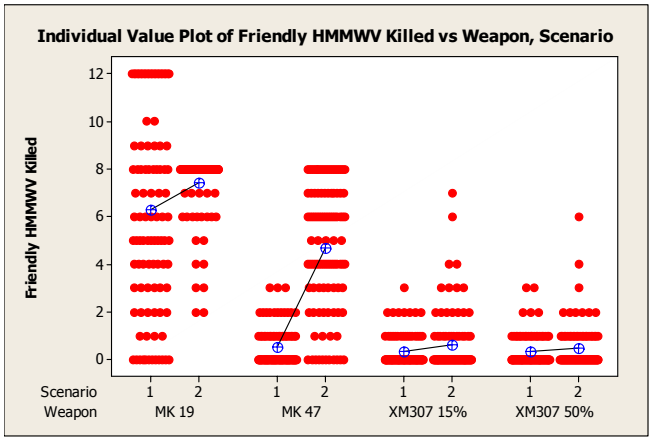
Based upon the analysis conducted from historical data, weapon characteristics, and modeling through JCATS, our research has determined that the XM307 is a weapon that the Army could consider as a replacement for the MK19 in the future. Although this is the recommended weapon, the XM307 uses new 25mm ammunition that is not currently in use by the U.S. military, which was not accounted for in the cost benefit analysis. The XM307 offers some major advantages over the MK19; however the procurement cost of the weapon is significant. Furthermore, there are other alternate grenade launchers that were not analyzed in this study, which may perform better than the XM307.

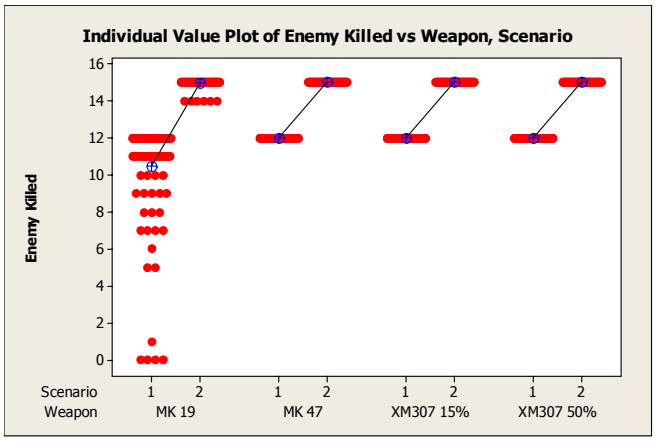
6 ACKNOWLEDGMENTS

We would like to acknowledge the efforts of PM Advanced Crew Served Weapons for allowing us to perform this analysis. The Capstone Course conducted in the Department of Systems Engineering at West Point is a largely academic course that allows cadets to research real world projects. The findings and recommendation presented in this paper do not reflect the official recommendations or conclusions from any government agency and consist of only a portion of the research that is required to complete a thorough investigation of a MK19 replacement.

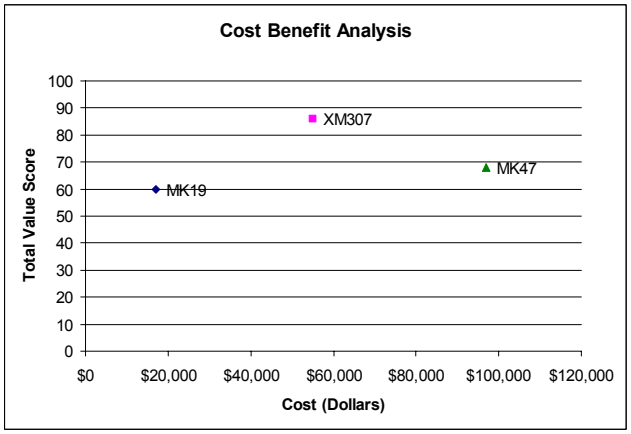
A INDIVIDUAL VALUE PLOTS







B COST BENEFIT ANALYSIS



REFERENCES

FM 23-27, 1988. *MK 19, 40-mm Grenade Machine Gun, MOD 3*. Headquarters, Department of the Army. Washington, D.C.: Department of the Army, 1988.

General Dynamics Armament and Technical Products, 2007. *Gun Systems*. Internet. Available via http://www.gdatp.com/Products/gun_systems/default.htm [Accessed 19 September 2007].

Popenker, Max R., 2007. *MK47 (Mark 47) Striker 40 automatic grenade launcher / machine gun (USA)*. Available via http://world.guns.ru/grenade/gl23-e.htm [Accessed September 2007].

General Dynamics Armament and Technical Products, 2005. *XM307 Fact Sheet.* Available via http://www.gdatp.com/Products/PDFs/XM307.pdf [Accessed 18 September 2007].

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