Verification and Validation of the Infantry Warrior Simulation (IWARS) through Engagement Effectiveness Modeling and Statistical Analysis

Joshua Eaton, Ryan Kalnins, Mitchell McKearn, Preston Wilson, and Andrew Zecha
United States Military Academy, joshua.eaton, ryan.kalnins, mitchell.mckearn, preston.wilson, mndrew.zecha@usma.edu

Abstract - The United States Military uses simulations extensively in order to conduct detailed cost benefit analysis, facilitate the procurement, development and testing of systems, and to train and educate service members. The models that the military uses are only beneficial as long as they accurately mirror reality based on known data. As combat evolves, simulations must improve at a matched rate in order to stay relevant.

Currently, the Infantry Warrior Simulation (IWARS) program has been through limited validation processes concerning its data on body hit distributions in the simulation versus the body hit distributions from actual combat.

The IWARS models are developed through firsthand accounts collected through extensive research and stakeholder analysis. Common aspects of current engagements are then combined into a number of scenarios that the project team will simulate through IWARS. The project team will then use statistical analysis to compare the real and virtual data sets to determine to what degree the simulation matches the collected historical data. The project team will run multiple scenarios and trials in order to create statistically significant data. At the conclusion of this research project and through detailed statistical analysis, the design team will validate the IWARS output against historical data.

Index Terms - Combat Modeling, Infantry Warrior Simulation, Body Part Hit Distribution, Army Material Systems Analysis Activity, Validation, Verification, Statistical Analysis

INTRODUCTION

Combat modeling and simulation provides critical insight into the modern battlefield and enables decision makers to assess and act on situations at the tactical, operational, and strategic levels of warfare. Combat modeling offers descriptive analysis on weapon systems, soldiers, and combat situations [1]. There are three main types of combat models: constructive, virtual, and live. Figure 1 below illustrates the differences between the classes of models and simulations.

Accurate simulations not only facilitate action on current situations, it also allows proper preparation for future events in a constantly evolving, international domain. However, in order for the simulations to be of any use to the military decision making authority, the simulations must be constantly vetted and re-evaluated to ensure the most accurate reflection of reality. The goal of our research and analysis is to confirm or reject the validity of the munitions delivery methodology within the Infantry Warrior Simulation (IWARS) program. Specifically, the team is attempting to identify the specific distribution of which body part each bullet impacts within IWARS. The team will accomplish this by comparing the body part hit distribution of the simulation output to actual data taken from the conflicts in Vietnam, Iraq, and Afghanistan. The results of our study will help us identify the accuracy of IWARS along with any potential areas for improving the effectiveness of the IWARS database.
I. Background

The IWARS program is used in conjunction with multiple other modeling tools such as One Semi-Automated Forces (oneSAF) and Virtual Battle Space (VBS) to provide a full spectrum analysis of current and future military scenarios. Each of these combat modeling programs has its specific strengths and weaknesses. IWARS in an analysis driven, entity-based multi-sided simulation program that focuses on individual and small-unit combatants and their equipment. “This program is used to assess the operational effectiveness across the spectrum of missions, environments and threats” to address problems facing the military today [3]. IWARS’ primary function is to model military operations at the platoon level (roughly forty soldiers) and smaller. The focus on smaller unit operations and engagements is due to the massive analytic capabilities of the IWARS database. The database captures a large spectrum of data ranging from each soldier’s hydration levels, heart rates, and movement speeds to the trajectory of each individual round being shot.

IWARS excels in allowing analysts to quantify and investigate individual soldier responses in a variety of military operations. This model utilizes a database of known properties and effects of numerous weapon systems and environmental considerations that it combines with complex algorithms to simulate reality. With such a broad scope of analyses available through the IWARS program, our validation is focused on the delivery accuracy portion of the simulation. Munitions delivery within IWARS correlates to the body part hit distribution of blue force soldiers in the simulation. This data can be taken and analyzed for similarity to real world hit distributions that have been collected from past and present conflicts.

One of the many outputs of the IWARS database is the body part hit distribution. This distribution will be the focus of our study. The body part hit distribution is broken up into six major body regions. They are the Head and Neck, Thorax, Abdomen, Pelvis, Arms, and Legs. A visual representation of the different regions can be seen in Figure 2 below.

![Figure 2](image)

**FIGURE 2**
IWARS Body Part Hit Distribution [4]

Body part hit distribution is important for analysts because it is indicative of casualties and incapacitation in combat. Ensuring the distribution is accurate has secondary effects within the incapacitation data that is produced from the models. Incapacitation of blue forces is one of the most vital pieces of information that simulations can provide in relation to military operations. As a result, this distribution can be incredibly useful in helping protect American soldiers. Accurate models will allow analysts and scientists to develop body armor that protects the most frequently hit body parts. In addition, these simulations will help identify different hit distributions based upon the different missions executed by US forces in combat and will also help develop different types of body armor for different types of missions. An effective IWARS model will aid researchers in creating the most effective solution to keep soldiers safe in whatever mission they are executing.

The hit distribution information is critical in determining soldier incapacitation on the battlefield. In IWARS and the military, incapacitation is defined as the inability for an individual to complete their mission due to any physical or psychological wounds [5]. Identifying which body parts produce the greatest risk to incapacitation allows military personnel, as well as researchers, to create new doctrine and strategies to mitigate the exposure of these more vulnerable body parts. Our project team has been working on this project in conjunction with the Army Materiel Systems Analysis Activity (AMSAA) to try and enhance the usefulness of IWARS. AMSAA works extensively with combat modeling in order to improve the survivability and lethality of American military forces with a specific focus on the United States Army. The body hit distribution data from Vietnam, Iraq, and Afghanistan is provided by AMSAA and they are critical in the simulation development and support.

II. Research Motivation

The primary motivation for the research is to assist in creating more accurate models that will allow analysts to make better informed decisions. Simulations are useful in analyzing possible courses of action on the battlefield to help make a better decision. These simulations will always be limited in the amount of information they can provide to the tactical decision maker due to the fact that the validity of the output is directly correlated to the accuracy of the model. As a result, our goal is to make the IWARS database as accurate as possible with respect to hit distributions. This will afford researchers, engineers, and soldiers a more accurate insight into how different combat scenarios will unfold so that US soldiers can be better protected. Although addressing the delivery methodology by itself is only a small portion of the IWARS database, the benefits of a more accurate model can significantly influence both research and soldiers fighting on the ground.

**Methodology**

IWARS is a unique program that creates combat scenarios and simulates them to gather data and results from the designed situation. It can be used to generate data
about a number of data points to include soldier deaths, time until enemy detection, range of contacts, impacts of varying terrain and hundreds of other variables within the system.

The program is created to operate in an entity flow based system. In this system, an entity ranges from an individual soldier to a platoon sized element to vehicles. This provides the user the ability to control very detailed aspects of the entity’s movement, responses, and inputs. There are two main aspects of IWARS that the user encounters. The first is the entity interface. In this area the user creates and places the desired entities onto the map.

The user can control basic formations, types of entities, location, and basic movement patterns. Interface allows the user to easily click on the desired unit type and place them wherever they want on the map. This interface can be seen in Figure 3 to the left.

For the project team’s scenarios, constructing the entity layout and basic movement plan was critical. Each different type of mission is executed very differently and as a result, great detail must be put into the specific layout of the scenario. This was necessary to create the desired engagement distance, the size of the friendly and enemy forces, and the engagement location. The user must then construct the specific mission that they want each entity to execute in the scenario. This is done in the Mission Builder, which is a decision tree based structure that shows the flow from one movement to the next. The mission builder is what determines how an entity will act throughout the scenario. For example, in Figure 4 in the bottom left, the entity will move in formation along a path and engage the enemy. The Mission Builder can cause a soldier to react in a different way once he spots an enemy or receives fire and it is very important in building the most realistic scenario to mirror actual combat happening overseas.

Once a scenario is executed, IWARS responds based upon the information within its extensive database. The database is a collection of data points from real world analysis and different distributions with a random number generator incorporated. To determine specific outcomes, IWARS runs the simulation through a series of algorithms and returns the results. Hundreds of results through the use of algorithms mentioned above are calculated every second and are the foundation of how the simulation creates accurate results when replicated.

I. Assumptions

One of the major assumptions made in this project is that the sample data collected from actual soldiers in combat accurately depicts the population hit distributions seen overseas today. Additionally, there is an assumption that the data sets containing more body regions than the six used in IWARS can be compiled into the standard six regions used in this project. For instance, one set of data included the body region shoulders, which was then grouped with the thorax region. The default IWARS database was used and was not altered for the preliminary evaluation of the IWARS validation. Bursting munitions are not evaluated because IWARS doesn’t attribute a hit distribution to individuals hit by bursting munitions, they are simply incapacitated or unaffected.

II. Evaluating Hit Distribution in IWARS Methodology

To effectively evaluate the hit distribution in IWARS the project group set out to capture the complete mission set of the US Army. Each different type of mission will result in a different hit distribution based upon the size of the engagement, the distance of the
engagement, and the location of the engagement. To effectively capture these differences the team created a scenario to represent each type of mission. Currently, there are six disparate scenarios created to represent some of the most frequently conducted missions that include an ambush, a battle damage assessment, a key leader engagement, a reconnaissance patrol, a security patrol, and a room clearing mission. The team is still working in order to better evaluate the scope of the US Army mission set. Once the design team created and finalized each scenario, the team collected the desired data from each simulation. The team ran each simulation to completion 100 times. This large number of replications is used to gather more data points that will allow the design team to create more accurate distributions.

The probability of accepting the model as valid is positively correlated to the sample size. The data categories in the scenario are: the scenario name, the agent hit, the specific body part hit, the range from firer to target, and the time to incapacitation. Once IWARS completed the simulations, the team compiled the output data pertaining to hit distributions. To do this a table was created displaying the body part hit distribution for each individual scenario as well as a distribution of all of the scenarios combined. This can be seen in Table 1 below.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>IWARS BODY PART HIT DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Combined Grand Total</td>
</tr>
<tr>
<td>Abdomen</td>
<td>673</td>
</tr>
<tr>
<td>Arms</td>
<td>635</td>
</tr>
<tr>
<td>Head</td>
<td>637</td>
</tr>
<tr>
<td>Legs</td>
<td>705</td>
</tr>
<tr>
<td>Pelvis</td>
<td>494</td>
</tr>
<tr>
<td>Thorax</td>
<td>1018</td>
</tr>
<tr>
<td>Abdomen/Pelvis</td>
<td>1167</td>
</tr>
<tr>
<td>Grand Total</td>
<td>4162</td>
</tr>
</tbody>
</table>

The data in Table 1 highlights the combined hit distributions of all mission sets simulated. However, creating an individual average that combines all of the scenarios proves less accurate than maintaining individual scenario integrity. In order to create a more accurate distribution that combined all of the different mission sets, the project group developed a survey that will help capture the frequency with which each mission was executed within a deployment. The survey created asked combat veterans to provide a percentage of time that each different type of mission was run compared to the total number of missions run. It also provides room for these combat veterans to include different types of missions that were not specifically listed. This data allows the project team to determine which missions are run most frequently in a combat environment. The survey also asked respondents how frequently they made enemy contact while executing these different types of missions. This data helps determine the lethality of each different scenario in reference to friendly and enemy incapacitations, and it weights the hit distributions accordingly. For example, when a unit conducts a room clearing operation they take contact a very high percentage of the time. However, when a unit conducts a security patrol they receive contact much less frequently. These discrepancies need to be accounted for in such a manner that the final distribution is accurate and aligns with real combat situations. These survey results provide the project team with a weight for each of the scenarios being simulated for data collection.

After the creation of the IWARS mission set distribution, the team ran 1,000 iterations and collected results for comparison with the real world data obtained in Vietnam, Iraq, and Afghanistan. To make the differences in data easy to interpret and understand, the design group calculated the percent error between the real world data and the IWARS simulation data.

**ANALYSIS OF RESEARCH**

The project team compiled the results of the 1,000 simulations weighted to reflect the survey results collected from combat veterans. This data can be seen in Table 3 on the top of the following page.

The IWARS data was broken down by the different scenarios and then totaled up to create one overall average for the IWARS data. Table 3 shows the body part hit distribution for each specific scenario that provides insight not only into how IWARS is programmed, but also into the differences between the mission sets that are represented in the study. The real world data from Vietnam, Iraq, and Afghanistan can be seen in Table 4 on the following page. This table shows the body part hit distributions from the Vietnam War as well as the combined hit distributions in Iraq and Afghanistan for the years 2010, 2011, and 2012. To come up with an overall distribution, the design team averaged the four data sets together to get the total distribution.

Once the data was compiled, several differences were noted between the real world data and the IWARS data. A percent error chart further identifies these differences showing the error between the IWARS data and several different real world datasets. The results can be seen in Table 2 below.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>PERCENT ERROR</th>
</tr>
</thead>
<tbody>
<tr>
<td>IWARS Unadjusted to Real Data</td>
<td>IWARS Adjusted to All Real Data</td>
</tr>
<tr>
<td>Head/Neck</td>
<td>15.40%</td>
</tr>
<tr>
<td>Thorax</td>
<td>129.78%</td>
</tr>
<tr>
<td>Abdomen/Pelvis</td>
<td>8.14%</td>
</tr>
<tr>
<td>Legs</td>
<td>40.77%</td>
</tr>
<tr>
<td>Arms</td>
<td>5.42%</td>
</tr>
</tbody>
</table>
From the percent error table above, it can be seen that the Thorax is the one body region that consistently has a larger error than all of the other regions. The IWARS data produced a distribution for the Thorax that contained 24.46% of the total hits, while the real world data never had more than 21% of the total hits land in the Thorax. The IWARS distribution was, however, more accurate when compared to other body parts. The smallest difference between the simulated data and the real world data was in the arms region. IWARS produced a .52 percent difference from the actual conflict distributions. This is only a .48 percent error between the two distributions, which is an incredibly close correlation between any sort of combat simulation and reality.

Our clients at AMSAA expected a high degree of discrepancy between the simulation hit distributions and the conflict collected hit distributions. As a rough benchmark for their analysis into our research they concluded that having the simulation produce results within 40 percent error of the real data would indicate a high degree of accuracy within the simulation. Only the thorax percent error exceeded the 40 percent limit provided by our client. As shown below in Figure 5, the IWARS simulation yielded results in line with the 40 percent threshold of acceptable error with the exception of the thorax region.

The discrepancies between the IWARS data and the real world data are most likely due to faults in the IWARS database with regards to entity aiming errors. The IWARS database is structured so that each entity aims at the center of mass every time they shoot. The center of mass is the line between the thorax and the abdomen as seen in Figure 2. The IWARS database then accounts for two types of error, random and fixed in reference to the delivery accuracy methodology. Each time an entity shoots, the database randomly draws a number that determines the random error, specifically how far from center of mass will the bullet impact with respect to the horizontal and vertical error. The fixed error provides additional error for every shot and is likely the biggest reason for the discrepancy of the thorax hit distribution. The fixed error for the IWARS database is likely limiting the shot distribution too much, resulting in an unequal distribution between the real world data and the IWARS data. The design team will have to evaluate the random and fixed errors further to draw more concrete conclusions. One final and possible reason for the discrepancy between the thorax hit distribution produced by the simulation and the real world data is the lack of reporting hits when soldiers take rounds to their body armor. There have been indications from combat veterans that not all body hits are reported if they do not cause injury. The thorax is the primary protected region by soldier’s body armor. This would explain the abnormally high thorax hits in the simulation since all hits are reported in the model. This warrants further analysis into the validity of the study assumptions.
**Contributions and Future Research**

There are many contributions that this research can provide to AMSAA. First off, the analysis of the accuracy of the IWARS model shows that the model provides a feasible representation of real world conflicts in terms of simulated munitions delivery and body part hit distribution. Analysis of the accuracy allows AMSAA to conduct further research in other aspects of the simulation by providing a baseline analysis acting as a starting point. Secondly, our analysis identifies a possible problem that may exist in the simulation model. As the data illustrates, the model was most inaccurate in the hit distribution to the thorax and deltoids. It is possible that this problem might be isolated to within the thorax and deltoid portions of the model because the arms and abdomen/pelvis, which represented over 15 percent of the total hits had the two most accurate comparisons to the real world data. This indicates that when further analysis is conducted by AMSAA or another outside organization that it might be useful to focus their analysis around the thorax portion or the model. There is a possible connection between the munitions delivery algorithms and the agents changing body position during the simulation. A possible relationship between the two methodologies and coding could explain the anomalous data created by the thorax hit distributions. Later teams can assess these possibilities and conduct analysis to determine if there is an underlying flaw within the IWARS model.

**I. Future Research**

The next step to continue the research is to take the preliminary results and continue to improve the accuracy of the model in relation to the current combat environment. The project team will continue to gather data and re-evaluate the results by utilizing focus groups, and updating the results from continued survey collection. This will allow a more accurate scenario to be constructed as well as a more accurate distribution of how frequently each type of scenario should be run. In future analysis, the team needs to collect more surveys from a specified population. For the IWARS model, surveys collected from combat veterans will lead to better data and current conflict mission set representation. By continuing to extend our research to gain better insights into the operational environment of current engagements, the development of a well rounded validation process will be made possible.

In the focus group, the project team will gather combat veterans and display the layout of the simulation. These veterans will be asked to identify where both friendly and enemy units should be located, what distance the engagement should take place from, and where the engagement area should be. Tailoring the scenarios based upon the information gained by the focus group will allow the project team to have the most accurate scenarios possible.

Another aspect of the simulation that warrants further research is analyzing the change in body hit distribution based on the weapon system being fired. Within IWARS, each weapon system has its own set of data that governs the accuracy and munitions delivery methodology. It would be worthwhile to conduct future research to expand the model validation into multiple weapon systems.

**Conclusion**

Through these studies the project team determined that the hit distribution generated in IWARS is fairly accurate and within the 40% error allotted, except for the percent distribution on the thorax. In fact, it had a total of 129% error when compared to the real world data. The main driving factor for this large error is found in the delivery accuracy methodology of the IWARS database. It consists of random and fixed biases that are incorporated every time a munition is fired to generate the distributions the team is analyzing. However, all of these biases and errors are based off of targeting the center of mass of the body, or the thorax. As a result, a majority of the hits still end in the thorax region. In addition to this discrepancy, IWARS counts a hit as any time a bullet impacts the body regardless of whether or not the entity is wearing body armor. The real world data only accounts for wounds and doesn’t include hits to the body armor that didn’t result in a wound. These are the two main areas for discrepancies in the distribution of the thorax region.

**References**


**Author Information**

Joshua Eaton, Instructor, Department of Systems Engineering, United States Military Academy
Ryan Kalnins, Student, Department of Systems Engineering, United States Military Academy
Mitchell McKearn, Student, Department of Systems Engineering, United States Military Academy
Preston Wilson, Student, Department of Systems Engineering, United States Military Academy
Andrew Zecha, Student, Department of Systems Engineering, United States Military Academy