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THESIS

MODELING HOW INDIVIDUAL ENITIES REACT TO INDIRECT FIRE

by

D. Brent Streater

June 2004

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Current Army models and simulations provide limited representation of the actions and behaviors of the individual combatant (Soldier, Sailor, Marine, or Airman). As the Army transforms into the Future Force, more emphasis is being placed on modeling the actions and behaviors of the individual combatant. The Training and Doctrine Command Analysis Center – Monterey has initiated the Individual Combatant Research Project. One research area is modeling how individual entities react to indirect fire, which is the focus of this thesis. From a study of both historical examples and current U.S. Army doctrine, we derived the input factors and responses. We selected the most significant input factors and derived a general model to represent this phenomenon. From the general model we derived a specific model that we implemented as a behavior rule using the Combined Arms Analysis Tool for the 21st Century, CXXI. In order to determine the effectiveness of the model, we used the face validation method. Our data analysis consisted of a two-sample t-test, a Mann-Whitney test, and a two-way analysis of variance. From our analysis we concluded that implementation of our model in CXXI was an improvement that made CXXI more realistic and functional.

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MODELING HOW INDIVIDUAL ENTITIES REACT TO INDIRECT FIRE

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Current Army models and simulations provide limited representation of the actions and behaviors of the individual combatant (Soldier, Sailor, Marine, or Airman). As the Army transforms into the Future Force, more emphasis is being placed on modeling the actions and behaviors of the individual combatant. The Training and Doctrine Command Analysis Center – Monterey has initiated the Individual Combatant Research Project. One research area is modeling how individual entities react to indirect fire, which is the focus of this thesis. From a study of both historical examples and current U.S. Army doctrine, we derived the input factors and responses. We selected the most significant input factors and derived a general model to represent this phenomenon. From the general model we derived a specific model that we implemented as a behavior rule using the Combined Arms Analysis Tool for the 21st Century, CXXI. In order to determine the effectiveness of the model, we used the face validation method. Our data analysis consisted of a two-sample t-test, a Mann-Whitney test, and a two-way analysis of variance. From our analysis we concluded that implementation of our model in CXXI was an improvement that made CXXI more realistic and functional.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CASTFOREM	Combined Arms and Task Force Evaluation Model
CP	Command Post
CXXI	Combined Arms Analysis Tool for the 21st Century
DMI	Decision Module Interaction
FM	Functionality Module
HD	Hull Defilade
HE	High Explosive
IC	Individual Combatant
MCCDC	Marine Corps Combat Development Command
MS	Models and Simulations
SS	Sum of Squares
TRAC-WSMR	TRADOC Analysis Center White Sands Missile Range
TRADOC	Training and Doctrine Command

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EXECUTIVE SUMMARY

Current Army models and simulations provide limited representation of the actions and behaviors of the individual combatant (Soldier, Sailor, Marine, or Airman). As the Army transforms into the Future Force, more emphasis is being placed on modeling the actions and behaviors of the individual combatant. The Training and Doctrine Command Analysis Center – Monterey has initiated the Individual Combatant Research Project. One important research area is modeling how individual entities react to indirect fire, which is the focus of this thesis.

From a study of both historical examples and current U.S. Army doctrine, we derived the input factors and responses. We selected the most significant input factors and derived a general model to represent this combat phenomenon. We identified four of the most important input factors: training status, experience under fire, protective posture, and distance from the impact. Each of these four factors has two levels resulting in sixteen different cases. Using estimated values based on our military judgment we devised a probability matrix that depicts the probability of a response given a particular case. We identified four of the most likely initial individual responses: continue with the mission, run away from the impact, assume a more protective posture, and suffer temporary paralysis. In summary, the approach we used was to select the most significant factors and the most likely reactions, and then assign a probability of occurrence to each reaction base on a specific combination of factors.

From the general model we derived a specific model that we implemented as a behavior rule in the Combined Arms Analysis Tool for the 21st Century, CXXI. We determined that we could not incorporate all of the many factors that contribute to an individual's reaction to indirect fire. The primary reason is that CXXI, while still in the development stages, is currently not capable of modeling many of the factors we have identified as contributing to an individual's reaction.

With these limitations identified, we focused our effort on the two most significant factors that could be modeled in CXXI. These factors are protective posture and perceived proximity to the impact. Figure 5 is a graphic representation of the algorithm we implemented in CXXI.

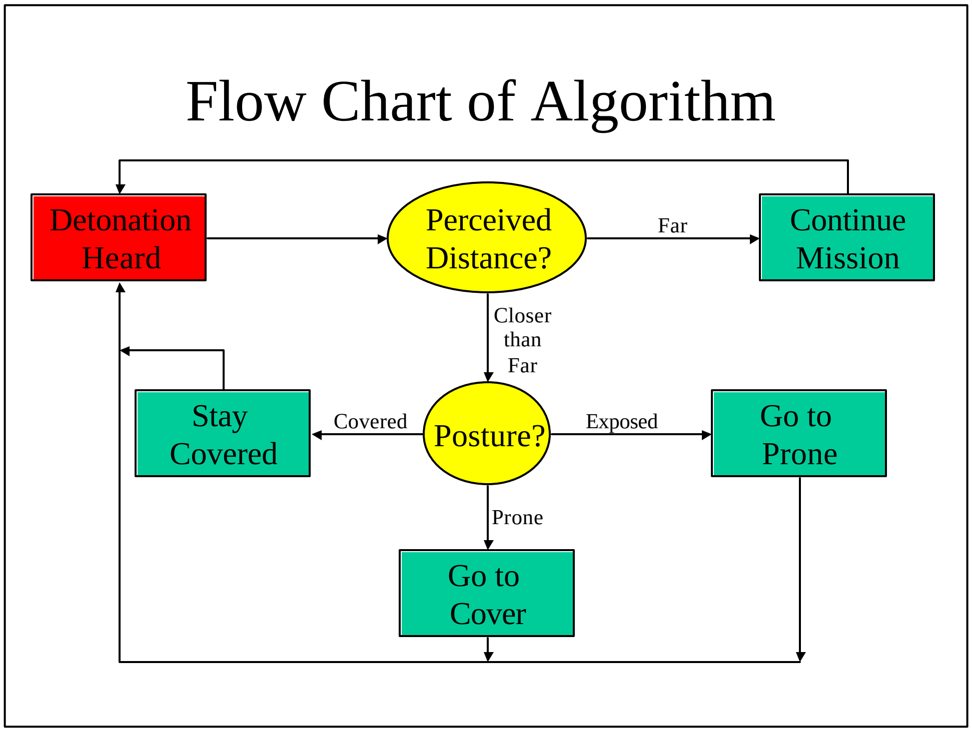

Figure 5. Flow Chart of Algorithm

We developed a scenario in CXXI that allowed us to test our algorithm and analyze the results. We executed a total of thirty runs and used Minitab for our analysis tool. Our data analysis consisted of a two-sample t-test, a Mann-Whitney test, and a two-way analysis of variance. We concluded that the difference in the mean number of kills between the base case with no "react to indirect fire" behavior and the alternative case with the behavior in place was both statistically and militarily significant.

Through the method of face validation, we determined that our model met the requirements for validity. The implementation of our model in CXXI is an improvement that has made CXXI more realistic and functional.

I. INTRODUCTION

Modeling combat phenomena is a complex undertaking. Soldiers under fire who may be cold, wet, tired, and scared react to situations differently based on a great number of factors. Modeling how an individual soldier reacts to indirect fire is a difficult undertaking. Take for instance this quote from a commander in the Israeli Army during the Yom-Kippur War responding to his ability to perform his duties while under indirect fire:

> **Thinking is impaired, one turns into a robot, you find yourself in a situation of traumatic anxiety and are unable to think…There were only a few brief moments when thought was outside the boundary of automatic response…In shelling, it is important that the noise not succeed in silencing the fragile voice of thought. [Ref 13]**

Current Army models and simulations (M&S) provide limited representation of the actions and behaviors of the individual combatant (Soldier, Sailor, Marine, or Airman). As the Army transforms into the Future Force, more emphasis is being placed on modeling the actions and behaviors of the individual combatant (IC). General Kevin Brynes, Commander of the US Army Training and Doctrine Command (TRADOC) stated:

> **Iraq and Afghanistan have showed us again that it is the caliber of the soldier not the caliber of the weapon that makes the difference in the battle. As such, the Soldier as a System (SaaS) is being given top priority in order to support Army Transformation goals and objectives. [Ref 16]**

One important area of interest is modeling how individual combatants react to indirect fire, which is the focus of this thesis. This thesis develops an algorithm to represent the individual combatant's reaction to indirect fire. This algorithm is implemented in a high-resolution combat simulation and analysis is based on a platoon-level scenario.

A. BACKGROUND

In an effort to meet these goals, the Training and Doctrine Command (TRADOC) Analysis Center – Monterey has initiated the Individual Combatant Research Project. One important research area is modeling how individual entities react to indirect fire. The suggested approach is to develop a model to represent this behavior. The desired end state would be a reusable product for integration into current and emerging simulations, such as the Combined Arms Analysis Tool for the 21st Century (CXXI).

CXXI is a high-resolution, closed-form, stochastic, analytical combat simulation. It is being developed by the TRADOC Analysis Center – White Sands Missile Range (TRAC-WSMR) and the Marine Corps Combat Development Command (MCCDC). CXXI is a replacement for the Combined Arms and Task Force Evaluation Model (CASTFOREM). [Ref 5]

TRAC-WSMR has identified a need to develop a react-to-indirect-fire capability in CXXI. This reaction to indirect fire can be implemented in the simulation using a set of behavior rules. The purpose of this analysis is to develop a general model that depicts how an individual entity reacts to indirect fire, and then implement a version of that model in CXXI using a set of behavior rules.

B. SCOPE AND ASSUMPTIONS

The reaction of individual combatants to indirect fire is a vague topic. We scoped the problem down to the essential elements and bounded the problem dimensions into four areas: doctrinal study of input factors, historical study of input factors, a general model derived from these two studies, and the implementation of a specific model in CXXI.

1. Doctrinal Study of Input Factors

The Reaction to Indirect fire is a combination of immediate actions taken by individuals and teams without orders from superiors and subsequent unit actions that are rapidly planned and executed. [Ref 12] With this in mind, our doctrinal study is divided into two areas: individual reactions and leader reactions. In studying an individual's reaction, it is expected that his behavior factors, such as personality, experience, training, and exposure will have a direct effect on his reaction to indirect fire. In terms of leader reaction, the type of mission a unit is conducting is one factor that will effect how the leader reacts and thus effect how all the individuals in his unit react to indirect fire.

2. Historical Study of Input Factors

We examined several historical examples from different conflicts to determine the most significant input factors. We specifically examined the Somme Offensive of July 1916 and the bombardment of the Bar-Lev Line on the outbreak of the Yom Kippur War of 1973. From our examination of these battles we were able to identify some of the important historical input factors.

3. A General Model

Considering the many factors that effect an individual's reaction, we developed a general model for this behavior. The approach we used was to select the most significant factors and the most likely reactions, and then assign a probability of occurrence to each reaction base on a specific combination of factors. These probabilities are subjective estimates. When possible the estimates are justified with data from historical studies. If deemed critical, these estimates could be substantiated from data gathered from actual combat studies.

4. Implementing the Behavior in COMBAT XXI

From the general model, we developed a specific behavior model that is appropriately matched to the current capabilities of CXXI. CXXI is a high-resolution simulation and is capable of providing a detailed reaction. Even with this state-of-the-art simulation, it cannot completely model every detail of this combat action, nor would that be necessarily beneficial. With this in mind, the general model was tailored to match the particular capabilities and limitations of the most current version of CXXI.

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II. DOCTRINAL STUDY OF INPUT FACTORS

The reaction to indirect fire is a combination of immediate actions taken by individuals and teams without orders from superiors and subsequent unit actions that are rapidly planned and executed. [Ref 12] With this in mind, our doctrinal study is divided into two areas: individual reactions and leader reactions.

A. INDIVIDUAL REACTIONS

To best understand the reaction to indirect fire, we begin with a doctrinal study to answer the question "how are soldiers trained to react to indirect fire?" The primary document to answer this question is the Soldiers Manual of Common Tasks for Skill Level 1 [Ref 10]. This manual breaks down the task into a set of conditions and standards with performance steps as shown in Figure 1. [Ref 10]

Conditions:

You are a member (without leadership responsibilities) of a squad or team. You are either in a defensive position or moving on foot. You hear incoming rounds, shells exploding or passing overhead, or someone shouting "incoming."

Standards:

React to each situation by shouting "incoming," following the leader's directions if available, and taking or maintaining cover.

Performance Steps:

Shout "incoming" in a loud, easily recognizable voice.

Look to you leader for additional instructions.

Remain in your defensive position (if appropriate); making no unnecessary movements that could alert the enemy to your location.

Take cover outside of the impact area (if you are in an exposed position or moving), keeping the body low if the leader is not in sight.

Figure 1. Task Conditions, Standards, and Performance Steps

Further exploration of doctrinal publications led us to categorize the factors into three areas: factors related to the conditions of combat, factors related to the soldiers task, and physiological factors. Below are some of the factors that may influence how an individual reacts to indirect fire. [Ref 6]

1. Factors Related to the Conditions of Combat

a. Protective Posture

The protective posture of the individual is one of the most significant factors. There are several methods to classify protective posture. One commonly used method is to classify a vehicular entity into one of the following categories: fully exposed, hull defilade (only the turret is exposed), and turret defilade. For an individual soldier the categories could be: standing, kneeling, prone, hasty fighting position, and standard fighting position with overhead cover.

b. Intensity of Fire

The intensity of fire is also a factor. The reaction to a heavy bombardment of large caliber rounds may be drastically different from the reaction to harassing fire from a small caliber mortar.

c. Unpredictability of Fire

Indirect fire can be delivered on a predictable schedule or at random. The more unpredictable the fire the more effective it may be.

d. Leadership Failure

Leadership is a key factor in determining how soldiers perform under fire. A leadership failure, or even a perceived leadership failure can directly effect how a soldier reacts to indirect fire. The following historical anecdote illustrates the effects of this factor:

> **In 1918, in the face of light indirect fire, an American infantry battalion serving as a regimental reserve broke and ran. The battalion commander was inspecting his positions when he was told to report to the regimental command post. Within earshot of his troops, he told his adjutant, "Come on, let's beat it," and began to run toward the CP and away from the enemy. The commander's men misinterpreted his words and actions as cowardice and panicked. Within a minute the battalion had passed the commander and ran for almost six miles before they were stopped. [Ref 8]**

e. Death or Replacement of the Leader

Similar to a leadership failure, the death of a leader can so demoralize the soldiers that they fail to do what they are trained to do and instead break and run. When a leader is replaced, the new leader may not yet have earned the trust of his subordinates. As a result, the soldiers under indirect fire may not follow the orders of the new leader.

f. Lack of Information

A soldier without information may think the worst of a situation. For example, a soldier receiving indirect fire and without information about his adjacent units may be more likely to leave his position than a soldier that is in continuous contact with his adjacent units and knows that they are holding their positions.

2. Factors Related to the Soldier's Task

a. Level of Military Training

Highly trained units know how to react to indirect fire. Their reaction is a battle drill, an action taken almost without thought. Untrained soldiers my freeze under fire.

b. Isolation from the Unit

The less isolated a soldier is from his unit, the more likely he is to take the correct action under indirect fire.

c. Near Misses

A near miss may cause a soldier to react in a unique way, possibly resulting in temporarily debilitation. The following anecdote illustrates how even a highly trained and proven small unit leader with two years of combat experience may react to indirect fire that is a near miss.

> **Shells from the mortars began coming in. Several landed near him, one very close. But he was only stunned, not hit. He managed to continue the fighting… but became tremulous and unable to hold his rifle. [Ref 6]**

This platoon sergeant with the 1st Division in Tunisia was evacuated to the aid station and returned to his platoon after two days.

d. Passive Role

A soldier that is in a passive role, such as a truck driver or technician, may react differently than a soldier that is in a more active role, such as a rifleman. The soldier in a passive role may be less mentally prepared for an attack than the soldier in an active role, which could affect his response.

e. Experience Under Fire

As a soldier gains more experience under fire his ability to assess the situation and react appropriately increases to a certain point. With indirect fire, continuous unrelenting fire, while increasing the soldier's experience, will eventually degrade his ability to react appropriately.

3. Physiological Factors

a. Food or Water Deprivation

Lack of food or water can effect how a soldier reacts to indirect fire. Lack of these essentials in effect, decreases a soldier combat effectiveness and as a result he may not react appropriately to indirect fire.

b. Exhaustion

Napoleon said it best in that "fatigue makes cowards of us all." A truly exhausted soldier does not have the strength to react appropriately to indirect fire.

c. Day or Night

There is historical evidence that shows that indirect fire weapons will cause greater fear if employed at night and this may effect how a soldier reacts. The fact that it is night may affect a soldiers reaction based on the night vision equipment he has. For example, a soldier with a night vision device may be more likely to move away form the impact than a soldier without a night vision device. [Ref 9]

4. Most Significant Factors

From this list of factors, we selected the four factors that appeared to be the most significant and most capable of being modeled. Our approach is general enough to accommodate additional factors. The four factors are: protective posture, distance from impact, level of training, and experience under fire. The four initial individual responses to indirect fire are: continue with the mission, assume a more protected posture, flee from the impact area, or paralysis.

B. LEADER REACTIONS

The leader's reaction to indirect fire is highly dependent upon a number of situational factors. While certainly not an all-inclusive list, here are some of the significant factors that effect a leaders decision as to how he will direct his unit to react to indirect fire [Ref 12]:

- Unit's current mission
- Current protective posture
- Restriction in the operational environment
- What effect the indirect fire is actually having
- Mission of adjacent and supporting units
- The quality and quantity of the fire

1. Unit's Current Mission

The leader must consider his current mission and the relative importance of maintaining his unit's position, direction of movement, or rate of advance. For example, if a unit is defending a decisive piece of terrain, the unit leader may decide that holding his unit's position despite receiving indirect fire is the best course of action.

2. Current Protective Posture

The leader must consider his unit's current protective posture. There are several methods to classify protective posture. As discussed earlier, one commonly used method is to classify a vehicular entity into one of the following categories: fully exposed, hull defilade (only the turret is exposed), and turret defilade. For an individual soldier the categories could be: standing, kneeling, prone, hasty fighting position, and standard fighting position with overhead cover.

3. Restriction in Operational Environment

The leader must consider the restrictions in the operational environment to include the rules of engagement, restrictive fire areas, and no fire areas. The rules of engagement are defined as the directives issued by competent military authority that delineate the circumstances and limitations under which United States forces will initiate and/or continue combat engagement with other forces encountered. [Ref 13] Restrictive fire areas are areas in which specific restrictions are imposed and into which fires that exceed those restrictions will not be delivered without coordination with the establishing headquarters. No fire areas are areas designated by the appropriate commander into which fires or their effects are prohibited. [Ref 13]

4. Effects of the Indirect Fire

The leader must consider what effect the indirect fire is having on this unit. The leader must determine if the indirect fire is producing significant casualties and damage. The leader should also determine if the indirect fire is only harassing fire.

5. Mission of Adjacent and Supporting Units

The leader must consider the mission of adjacent and supporting units. He should consider whether those units are in a position to support his unit or not. Positions and current control measures may restrict the leader's potential reactions. Boundaries may restrict his movement and the positions of friendly units may restrict his use of counter-fire.

6. The Quality and Quantity of the Fire

The leader must consider the quality and quantity of the fire his unit is receiving. He should consider how close the rounds are impacting and whether the rounds appear to be directed or adjusted by an observer. He should consider the volume and duration of the fire and categorize it as heavy, continuous, light, or sporadic. The type of weapons system firing, mortar or artillery, and the caliber, light, medium, or heavy, is also a consideration. [Ref 12]

III. HISTORICAL STUDY

We examined several historical examples from different conflicts to determine how soldiers have historically reacted to indirect fire and what were the most significant input factors. We examined the Somme Offensive of 1916 and the bombardment of the Bar-Lev Line during the start of the Yom Kippur War of 1973. From our examination of these battles we were able to identify some of the historical input factors and reactions.

A. SOMME OFFENSIVE

In July of 1916, British and French forces launched the Somme Offensive. [Ref 6] The general concept of the battle was to launch a massive artillery bombardment of the German positions lasting five days. The ground attack on the fifth day would be synchronized with close artillery support of the advance. Some estimates say that within the first few kilometer of the German sector "each 2500 square yards had received a ton of shells…and each 1000 square yards had received 30 shells. [Ref 6]

Despite this massive bombardment by the British and French, the Germans reaction was to maintain their positions and successfully defend their sector. Combined casualties for the British and French were 620,000 while the Germans had 450,000. Although the artillery was massive, it did not achieve massive effects at the decisive point on the battlefield. [Ref 6]

There are several factors that may have influenced German reaction to the indirect fire. For one, the artillery became predictable. Additionally, the Germans knew when to expect the indirect fire and took cover. The intensity of fire lessened at night. The Germans were able to predict the start of the ground attack and communicate that down to the squad level. The most significant factor was the artillery observer's inability to synchronize the creeping barrage to support the infantry ground attack. The Germans were able to stay in their covered position until the indirect fire stopped with time to reposition and effectively engage the attacking infantry. These are some of the more evident factors that influenced the German reaction to indirect fire during this battle. [Ref 6]

B. BAR-LEV LINE

Israeli forces suffered under a massive bombardment along the Suez Canal (the Bar-Lev Line) at the start of the Yom Kippur War of 1973. This bombardment was the Egyptian application of the Soviet doctrine of "artillery shock" in which over 10,000 shells were fired in the first minute. The aim of this massive bombardment was to temporarily neutralize the enemy's ability to react. [Ref 17]

The Israeli Institute for Military Studies conducted a study in 1992 that examined the psychological effects of intense artillery bombardment. This study was useful in identifying both input factors and reactions. [Ref 17] The study divided the input factors into three areas:

- Battlefield factors: surprise, intensity, duration, combination with ground attack, and severity of loss.
- Unit factors: combat readiness, presence of senior leadership, morale, cohesion, and duration in bunker.
- Individual factors: combat experience, level of training, rank, education level.

The study examined the combatants' responses to indirect fire. The responses were categorized by: physiological, emotional, and cognitive. The two most common physiological responses were heartthrobs and dryness of mouth. The following is an except from a combatant questionnaire:

> **Due to the shelling, I went into shock…dryness in the mouth was extremely pronounced and I sharply remember this right up to today. My entire body hurt from the strain of the muscles at the time I took shelter from the shells, and I remember that it was only with great difficulty that I succeeded in swallowing some food at the time of the break in the shelling. [Ref 13]**

The five most frequent emotional responses were: self-confidence, helplessness, excitement, anger, and fear. The study found that the differences in emotional responses were linked to the factors of type of service (conscript or reserve), rank, and location of the combatant at the time of the shelling. [Ref 17] The most frequent cognitive responses were "sharpness of thought" and "focusing on one thought" [Ref 17]

They also examined the influence the indirect fire had on the functioning of the combatants. Most soldiers reported that functioning decreased at first and then improved. Four percent of the soldiers reported suffering from temporary paralysis (they lost the ability to move) as a result of the indirect fire. [Ref 17]

The study concluded that the factors that distinguished highly-functioning soldiers from poorly-functioning ones were personal characteristics (character, personality), combat experience, level of training, role as a leader, and the type of soldier (combat or support). [Ref 17]

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IV. GENERAL MODEL

From the doctrinal and historical studies, we were able to identify many factors that affect how both individuals and leaders react to indirect fire. From these, we identified the most significant factors and developed a general model to represent this phenomenon.

A. INDIVIDUAL REACTION

Figure 2 shows the basic structure that we used to present the model in its most general form for the individual entity.

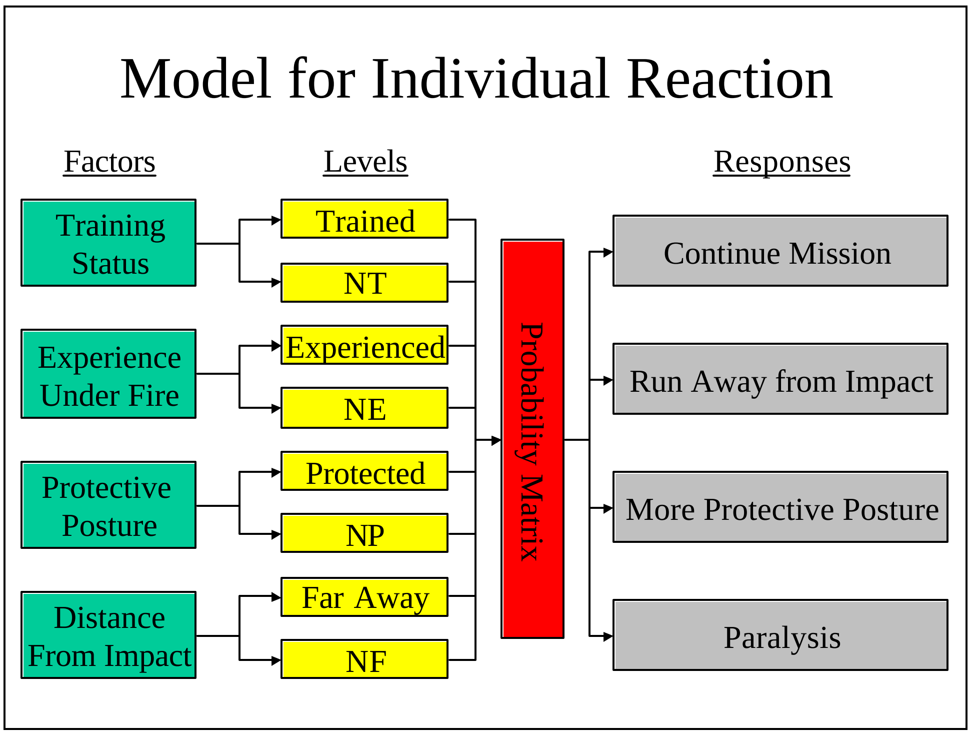

Figure 2. Individual Reaction to Indirect Fire.

We selected the input factors in Figure 2 based on our doctrinal study, historical study, and professional experiences. Essentially, we chose the four most significant factors and the four most realistic and historically documented reactions. We chose these factors for their importance and for their ability to be modeled. Each factor has two levels. The factors are: protective posture, distance from impact, level of training, and experience under fire. The four initial individual responses to indirect fire are: continue the mission, assume a more protected posture, run away from the impact area, and paralysis.

With four factors, each with two levels, there are sixteen different cases. The matrix in Figure 3 represents each of the sixteen different cases and the associated probability of a response given a particular case. For example, the entity that falls under case seven is trained, experienced under fire, is not in a protective posture, and is within the effective distance of the impact. This entity has a five percent probability of continuing the mission, a five percent probability or running away from the impact area, and a ninety percent probability of assuming a more protected posture. We devised this matrix using estimated values based on our military judgment. These are estimates that can be updated with actual values derived from future combat studies.

The table below shows four factors (if true 1, else 0) that compose the sixteen different cases:

	Cases														
Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Training Status (Trained or not)	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
Experience Under Fire (Experienced or not)	0	1	0	0	1	0	1	1	0	1	0	0	1	1	0
Protective Posture (Protected or not)	0	0	1	0	1	1	0	1	0	0	1	0	1	0	1
Distance from Impact (Within effective range or not)	0	0	0	1	0	1	1	1	0	0	0	1	0	1	1

The table below shows the probability of each response occurring given a specific case:

	Cases														
Responses	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Continue Msn (Stay in current posture)	0.05	0.025	0.95	0.1	0.99	0.96	0.05	0.98	0.4	0.1	0.8	0.3	0.9	0.05	0.5
Run Away from Impact	0.05	0.025	0.025	0.1	0	0	0.05	0	0.4	0.8	0.1	0.3	0.05	0.2	0.3
More Protected Posture	0.9	0.95	0.025	0.8	0.01	0	0.9	0	0.1	0.05	0.05	0.2	0.025	0.7	0.2
Paralysis (Without the ability to move)	0	0	0	0	0	0.04	0	0.02	0.1	0.05	0.05	0.2	0.025	0.05	0.1
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1.1

Figure 3. Probabilities for Each Case

B. LEADER REACTION

We selected the input factors and reactions for the leader, as seen in Figure 4, based on our doctrinal study, historical study, and professional military experiences. The fundamental decision the leader must make when reacting to indirect fire is whether to keep his unit in position or to move. As the focus of this thesis is on the individual entity, a more developed model for leader and unit reaction will be left for future research.

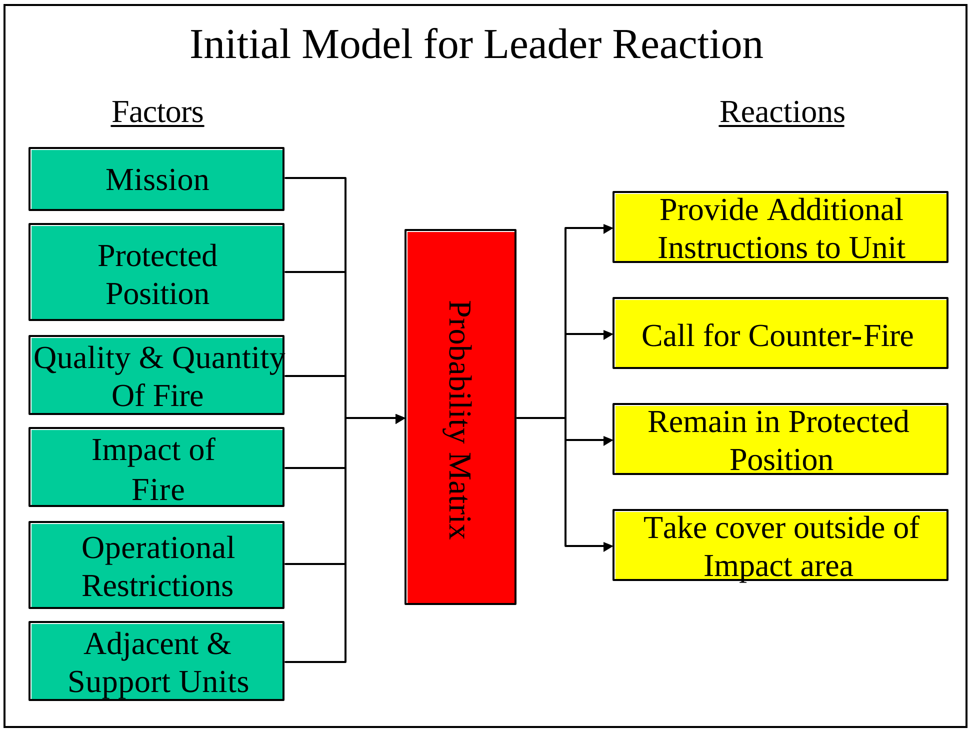

Figure 4. Leader Reactions to Indirect Fire.

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V. COMBAT XXI

A. OVERVIEW OF COMBAT XXI

CXXI is a high-resolution, closed-form, stochastic, analytical combat simulation. [Ref 5] It is being developed by the TRADOC Analysis Center – White Sands Missile Range (TRAC-WSMR) and the Marine Corps Combat Development Command (MCCDC). CXXI is a replacement for the Combined Arms and Task Force Evaluation Model (CASTFOREM). [Ref 5]

TRAC-WSMR has identified a need to develop a react-to-indirect-fire capability. This reaction to indirect fire can be implemented in the simulation using a set of behavior rules.

B. IMPLEMENTING THE MODEL IN COMBAT XXI

We met with the CXXI design team from White Sands Missile Range New Mexico. The team consisted of Mr. Dave Durda, Major Sergio Posadas, and Dr. Imre Balogh. Major Posadas is the Marine Corps Proponent for CXXI. Dr. Imre Balogh is the sensor and move developer, and Mr. Dave Durda is the team leader.

After discussing the thesis with the design team, two approaches were suggested. The first was to use the Behavioral language and to write rules to make the entities react to indirect fire. The second approach was to modify the source code and in essence "hard-wire" in the desired behaviors. After discussing both approaches with the design team, we decided that modifying the source code would be the most effective approach given the scope of the problem, the time requirements, and the infancy of the behavior language. We had originally planned to use the behavioral language to write the behavioral rules, but we were unable to due to the limited functionality of the language at this point in its development process. The behavioral language will be more usable in future versions of CXXI.

As we approached the problem, we determined that we could not incorporate all of the many factors that contribute to an individual reaction to indirect fire for several reasons. CXXI, while still in the development stages, is currently not capable of modeling many of the factors we have identified as contributing to an individual's reaction. With these limitations identified, we focused our effort on the two most significant factors that could be modeled in CXXI. These factors are protective posture and perceived proximity to the impact. These two factors will be used to determine how an individual entity reacts to indirect fire.

1. Creating the Behavior

We divided the problem into three areas: the code, the data, and the scenario. We determined that we could modify the following classes: DMI (Decision Module Interface) Actions, Detection FM (Functionality Module), and Ground Impact Mediator in order to implement the behavior we wanted.

Some important terms should be defined for our light infantry entities, referred to as Rangers. The term *posture* refers to whether the entity is exposed or in a prone position. The term *cover* means that the entity is in a covered position and his vulnerability to indirect fire is greatly decreased.

We modeled the behavior as a function of two factors: posture and perceived distance from the impact. Figure 5 is a graphic representation of the algorithm we developed to implement this behavior in CXXI. Here is an explanation of Figure 5:

- When an entity hears a detonation, it gets a perceived distance to that detonation. Those perceived distances are broken down as a function of range into five categories: very close, close, near, nearby, and far.
- If the perceived distance is closer than far, and the entity is not in a protective posture then assume a protective posture.
- Otherwise, if the entity is not in a covered position and the perceived distance is less than far, assume a covered position.
- There is no time component in this model. Each entity reacts immediately upon hearing a detonation and stays in his new posture indefinitely.

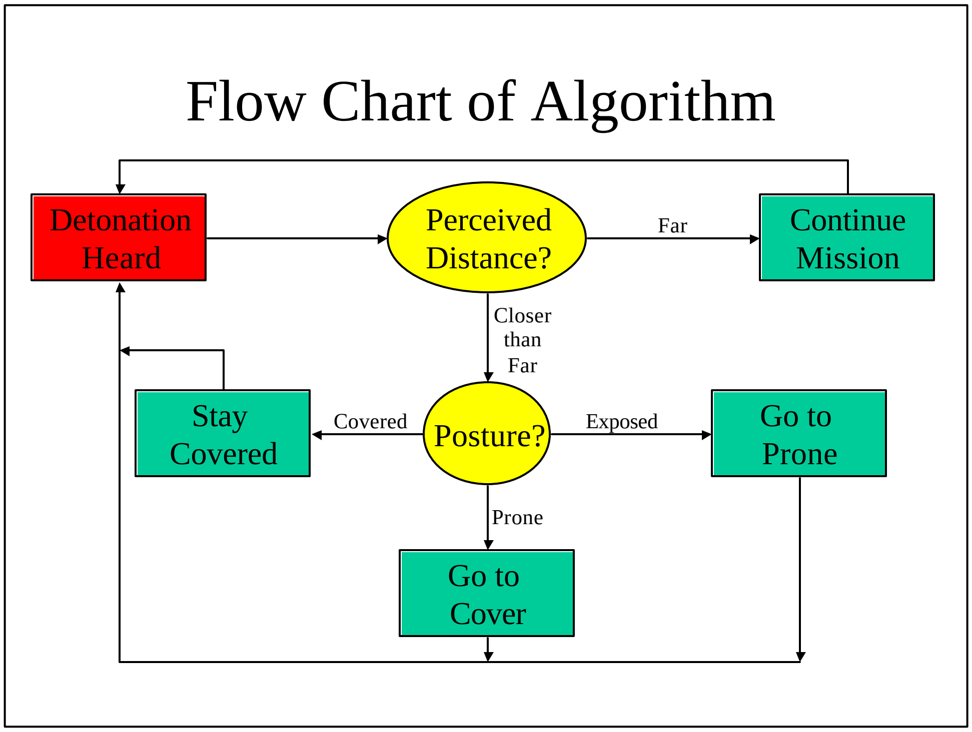

Figure 5. Flow Chart of Algorithm

This behavior was implemented in the Combat XXI source code in the DMI Actions class. The code in located in appendix B. We added a loop to implement the logic of our behavior. Figure 6 is an excerpt from that code:

```
if( (! hasProtectedPosture) && (! isFar))
{
   thisDetDMI.setHasProtectedPosture(true);
}
else if( (! isCovered) && (! isFar))
{
   thisDetDMI.setIsCovered(true);
}
```

Figure 6. Excerpt from DMI Actions Code

2. The Data

The data is a critical part of the model. The data is formatted in a Microsoft Access database. The table in Figure 7 shows the data for a high explosive (HE) artillery round fired against a specific target. The target in this case is the Ranger entities we created.

tgt_dspsn	tgt_mode	tgt_state	killcrit	environment	terrain	pxla_1
HD	DEPLOYED	SHIELDED	K	OPEN	FLAT	30
FE/STI	DEPLOYED	UNSHIELDED	K	OPEN	FLAT	1000
HD	DEPLOYED	UNSHIELDED	K	OPEN	FLAT	500
FE/STI	DEPLOYED	SHIELDED	K	OPEN	FLAT	30
FE/STI	DEPLOYED	UNSHIELDED	M/F	OPEN	FLAT	1000
HD	DEPLOYED	UNSHIELDED	M/F	OPEN	FLAT	1000
FE/STI	DEPLOYED	SHIELDED	M/F	OPEN	FLAT	30
HD	DEPLOYED	UNSHIELDED	F	OPEN	FLAT	500
HD	DEPLOYED	UNSHIELDED	M	OPEN	FLAT	500
FE/STI	DEPLOYED	UNSHIELDED	M	OPEN	FLAT	1000
HD	DEPLOYED	SHIELDED	F	OPEN	FLAT	30
FE/STI	DEPLOYED	SHIELDED	F	OPEN	FLAT	30
HD	DEPLOYED	SHIELDED	M	OPEN	FLAT	30
HD	DEPLOYED	SHIELDED	M/F	OPEN	FLAT	30
FE/STI	DEPLOYED	SHIELDED	M	OPEN	FLAT	30
FE/STI	DEPLOYED	UNSHIELDED	F	OPEN	FLAT	1000

Figure 7. Data Summary for HE Fired at a Ranger Entity

The first column, *tgt_dspsn*, describes the targets disposition. The two types of target disposition are hull defilade (HD) and fully exposed/standing (FE/STI). In terms of soldier entities, hull defilade is equivalent to the prone position. The next column, *tgt_mode*, refers to the target mode, which was DEPLOYED for our entities. The next column, *tgt_state*, has two settings SHIELDED and UNSHIELDED. SHIELDED targets are less vulnerable to fire than are UNSHEILDED targets. The column *killcrit* is the kill criteria. There are four categories: *K* for catastrophic kill, *M* for mobility, *F* for firepower, and *M/F* for mobility and firepower. For the next two columns, our Ranger entities were all in flat open terrain. The final column, *pxla_1*, is the most significant. This column lists the lethal area for a proximity fuse fired at one third or less of the max range. There are additional columns that list similar data for a point detonating fuse and for two thirds and max range. For our scenario we were only concerned with the columns shown in Figure 7.

We also had to create an entity that we could use in our scenario. We started with all the base settings for a light infantry entity from the CXXI database and modified his title. This gave us a unique entity that we could change freely without affecting any of the core CXXI entities.

Since we were firing at a newly created entity, we had to populate the data table for the specific weapon we were going to use. In our scenario, we are firing M198 howitzers at Ranger entities.

In choosing factors that could be modeled, we had to choose factors that corresponded to data available. In this case, the factor of posture relates directly to the data. Each entity includes input data that states his posture as shown in the first column, *tgt_dspsn*, and the third column, *tgt_state,* of Figure 7.

3. The Scenario

For the scenario, we chose flat open terrain. The Blue force consists of a light infantry platoon of 36 men. The platoon has occupied a triangular shaped assembly area to prepare for future combat operations. All soldiers are standing or kneeling while they are executing their priorities of work. Hasty fighting positions have been dug to provide cover. Figure 8 shows the Blue force disposition.

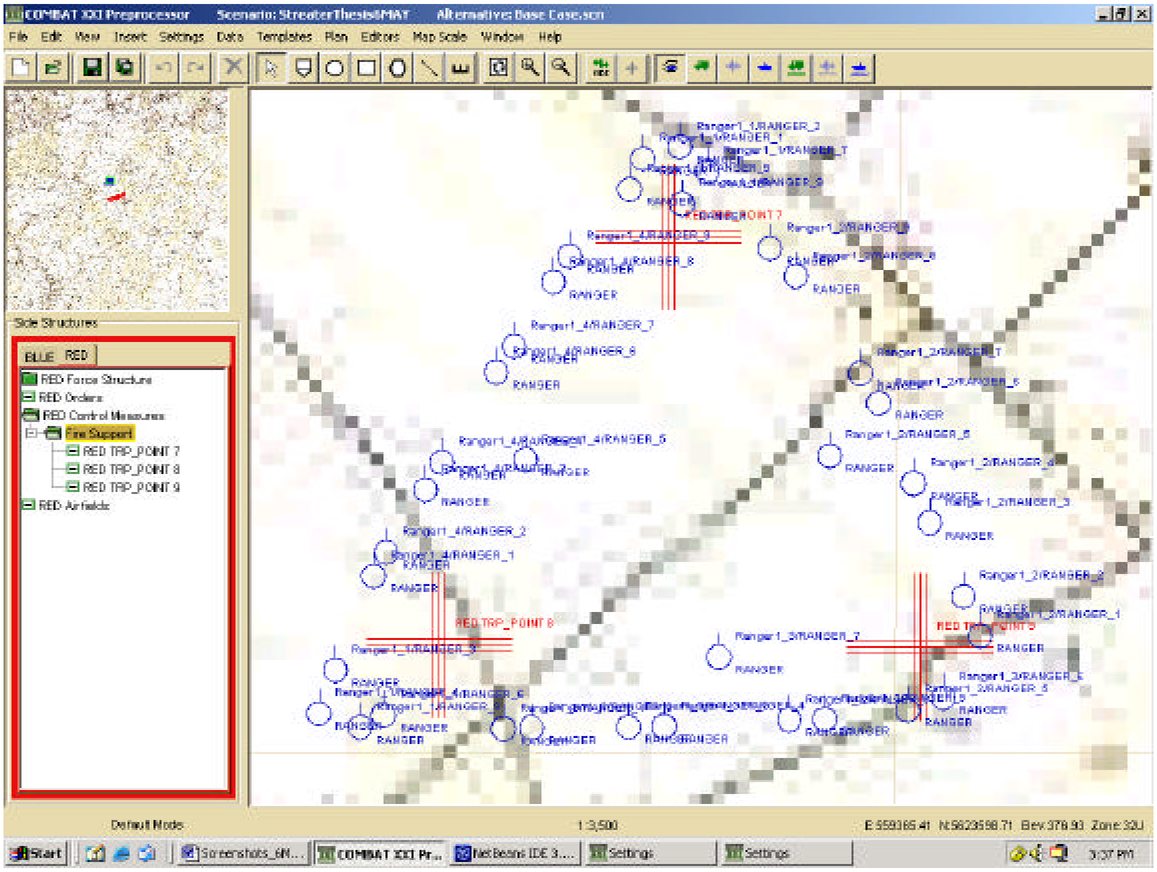

Figure 8. Blue Force Disposition

The red force consists of a nine-gun howitzer battery with three Fire Direction Centers. The battery has occupied a firing position and each section of three guns is laid on a point target within the Blue assembly area. Each gun will fire 10 rounds. Figure 9 shows the Red force disposition.

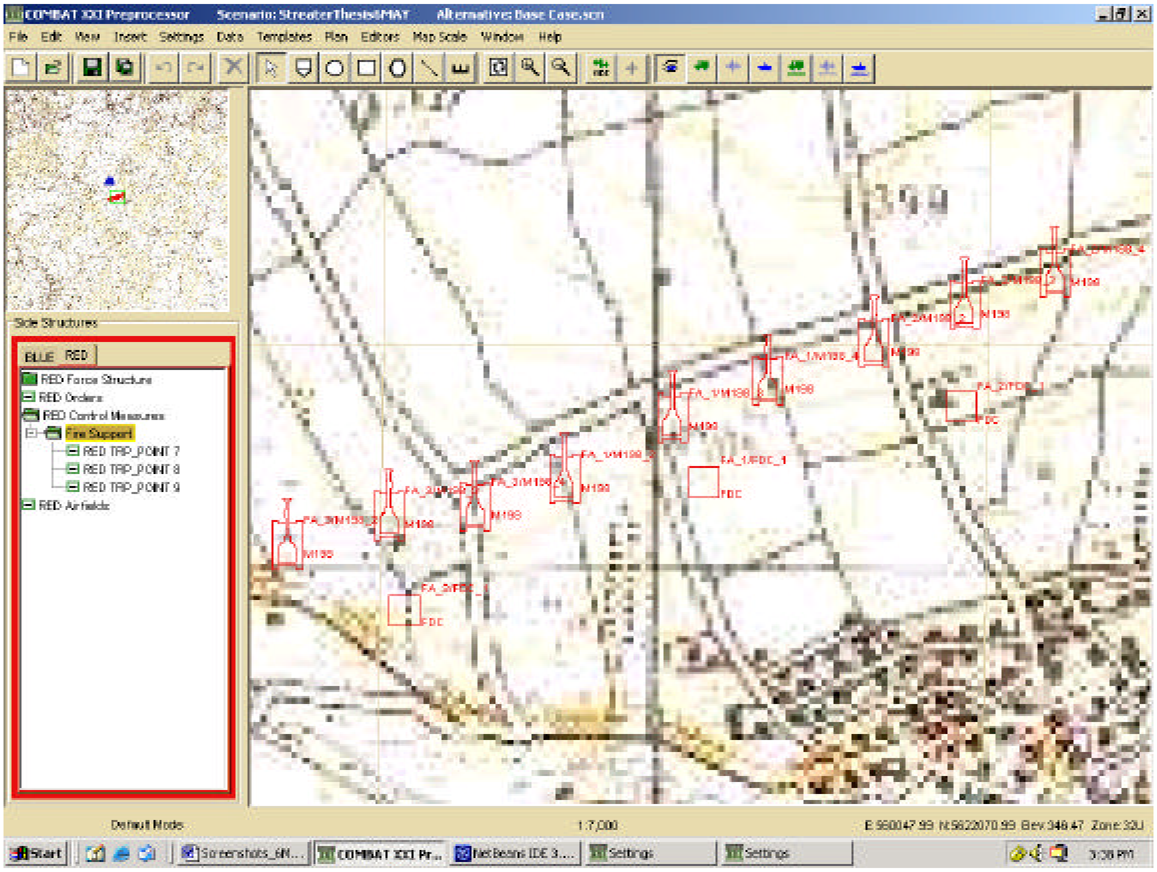

Figure 9. Red Force Disposition

4. Measures of Effectiveness

With the objective of the operational mission being to prepare for future combat operations and maintain/build combat power, we decided that the number of kills inflicted by indirect fire was the best measure of effectiveness. We collected the number of kills for both the base case (no behavior rule) and the alternative case (with the behavior rule) for comparison. CXXI currently only has K-kill (catastrophic kill) capability fully functional. Future versions with have mobility, firepower, and communication kills capability. Figure 10 shows indirect fire rounds impacting in the Blue assembly area. An "x" is placed over an entity when it is killed.

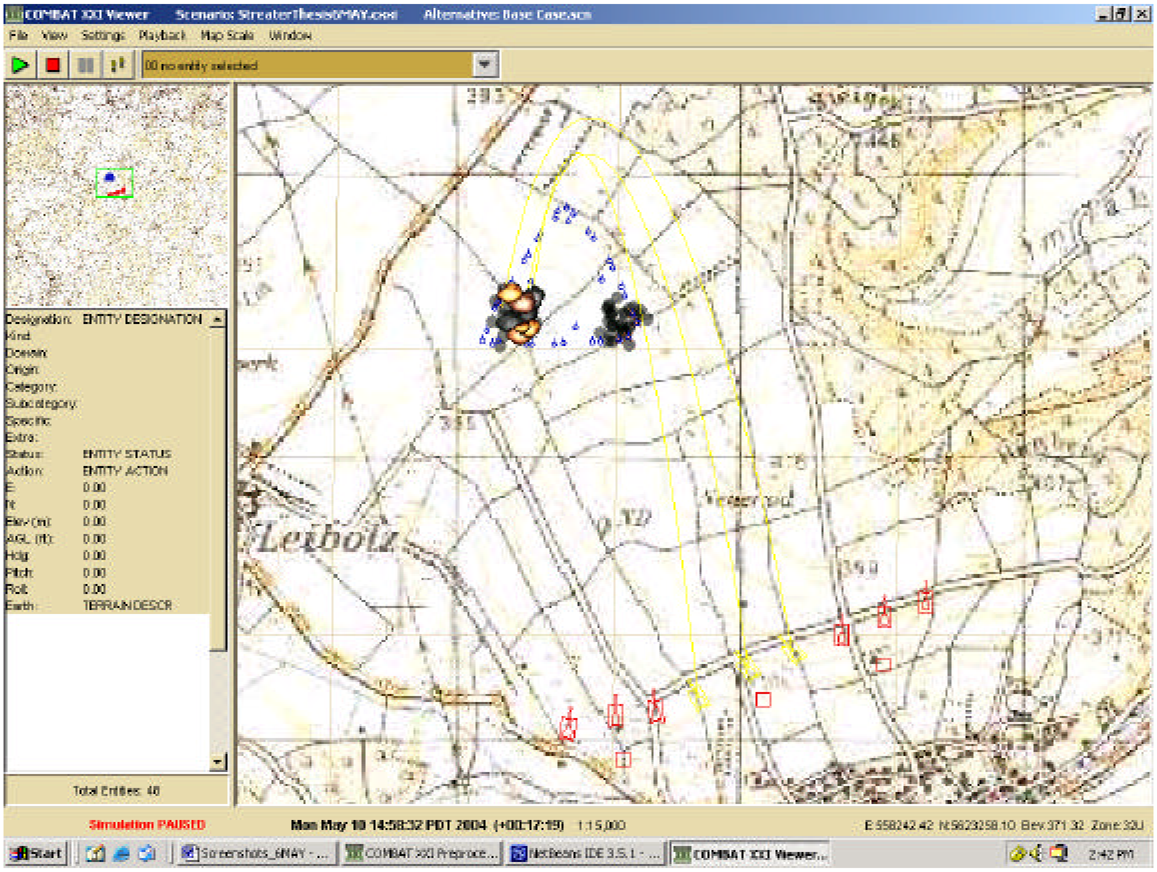

Figure 10. Rounds Impacting in Blue Assembly Area

5. Entity Reactions

In the alternative case the entity reactions are realistic. When an entity senses an impact, it executes the individual common task react-to-indirect-fire, which is to assume a prone position. If the entity is already in the prone position, then it assumes a covered position. These actions are more realistic than the base case in which the entities had no reaction at all to the indirect fire. The amount of time an entity stays in the new state is a topic for future research.

VI. EXPERIMENTAL DESIGN

A. OVERVIEW

To assess the impact of the new algorithm, we decided to conduct several runs of both the base case and the alternative case. We conducted five base case runs and five alternative runs.

B. BASE CASE (NO REACTION TO INDIRECT FIRE)

For the base case, there are no "react to indirect fire" behaviors in place. The blue force consists of a light infantry platoon of 36 men. The platoon has occupied a triangular shaped assembly area to prepare for future combat operations. All soldiers are standing or kneeling while they are executing their priorities of work. Hasty fighting positions have been dug to provide cover.

The red force consists of a howitzer battery with nine guns and a Fire Direction Center for each of the three sections. The battery has occupied a firing position and each section of three guns is laid on a point target within the blue assembly area. Each gun fires 10 rounds over a 20-minute period.

C. ALTERNATIVE (REACT TO INDIRECT FIRE BEHAVIOR IN USE)

For the alternative case, the react to indirect fire behavior rules are in place. The scenario has not changed from the base case expect that the behavior rules are in use.

D. VERIFING THE BEHAVIOR

To verify that each entity was executing the proper behavior, we created an output file to keep track of critical information. Figure 11 shows how entity Ranger 9 executed the behavior. Ranger 9's initial posture was not protected and not covered. After hearing a detonation that he perceived as near, his new posture became protected (he assumed the prone position).

```
DMI Actions... DETONATION HEARD for:
Ranger1_4/RANGER_9
Type: RANGER  ID: 508
Unit: BLUE SQUAD Ranger1_4 ID: 475
is entity in protected posture?: false
is entity covered?: false detdist NEAR
New protected posture: true
New covered: false
```

Figure 11. Output File for Ranger 9 First Detonation

Figure 12 shows that Ranger 9 heard a second detonation, also perceived as near, and changed to a covered position.

```
DMI Actions... DETONATION HEARD for:
Ranger1_4/RANGER_9
Type: RANGER  ID: 508
Unit: BLUE SQUAD Ranger1_4 ID: 475
is entity in protected posture?: true
is entity covered?: false detdist NEAR
New protected posture: true
New covered: true
```

Figure 12. Output File for Ranger 9 Second Detonation

VII. DATA ANALYSIS

A. OVERVIEW

We divided our data analysis into three parts: a two-sample t-test, a Mann-Whitney test, and a two-way analysis of variance. The t-test was chosen to determine if the difference between the base case average number of kills and the alternative case average number of kills was statistically significant. We conducted a total of ten runs, including five runs without the behavior (base case) and five runs with the behavior (alternative). With a small sample size, the assumption of normality was suspect. Therefore we also chose a nonparametric alternative to the two-sample t-test, the Mann-Whitney test. We conducted an additional twenty runs varying the intensity of fire for the two-way analysis of variance (ANOVA). The ANOVA was used to show the effect that varying the intensity of fire would have on each case.

B. TWO-SAMPLE T-TEST

We gathered our data from each of the runs and input it into Minitab. [Ref 14] Our null hypothesis is that there is no difference between the mean number of kills. Our alternative hypothesis is that there is a difference between the mean number of kills. The hypotheses are:

$$H_o : m_1 - m_2 = 0$$
$$H_1 : m_1 - m_2 \neq 0$$

1. Data Collected

For each run we collected the number of kills. Table 1 shows the data collected. In order to use the t-test we assumed the data was normally distributed. We also assumed the variances to be equal. [Ref 15]

Base Case Number of Kills	Alternative Number of Kills
14	4
14	5
15	3
16	4
19	4

Table 1. Data Collection Table

2. Key Findings

We found that the difference between the average number of kills was both statistically significant and militarily significant. Figure 13 is the Minitab output for the two-sample t-test with a 95% confidence interval. With a p-value of zero, there is essentially no chance that we would see such an extreme value for the test statistic (11.84) if the null hypothesis is true.

Two-Sample T-Test and CI: Base Case, Alternative

```
Two-sample T for Base Case Number of Kills vs Alternative Number of Kills

                  N   Mean  StDev  SE Mean
Base Case Number  5  15.60   2.07     0.93
Alternative Numb  5  4.000  0.707     0.32


Difference = mu (Base Case Number of Kills) - mu (Alternative Number of Kills)
Estimate for difference:  11.6000
95% CI for difference:  (8.8797, 14.3203)
T-Test of difference = 0 (vs not =): T-Value = 11.84  P-Value = 0.000  DF = 4
```

Figure 13. Two-Sample T-Test

The box plot in Figure 14 graphically shows that the difference between the sample distribution of the number of kills (the mean is indicated by the plus sign in a circle) in the base case and the sample distribution of the number of kills in the alternative case is quite clear. Specifically, all of the responses for the alternative case are less that the smallest response in the base case, further indicating a significant difference in the two settings.

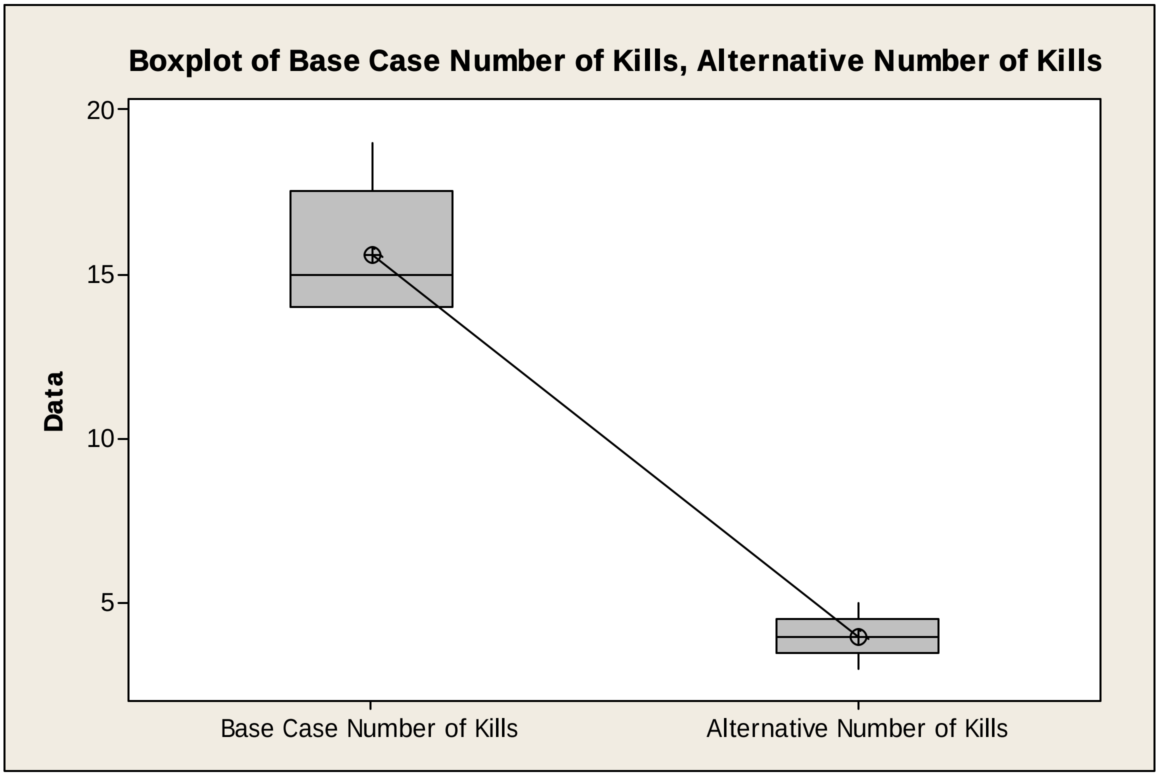

Figure 14. Box Plot

C. MANN-WHITNEY TEST

With a small sample size, the assumption of normality is a concern. To counter this, we chose the Mann-Whitney test. The Mann-Whitney test performs a hypothesis test of the equality of two population medians and calculates the corresponding point estimate and confidence interval. This test was used as a nonparametric alternative to the 2-sample t-test, and requires no assumption of normality. [Ref 15] An assumption for the Mann-Whitney test is that the data are independent random samples from two populations with the same shape and equal variances, and a scale that is continuous or ordinal (possesses natural ordering) if discrete. [Ref 14] The Mann-Whitney test is also known as the two-sample Wilcoxon rank sum test. The hypotheses are:

$$H_o : median_1 - median_2 = 0$$
$$H_1 : median_1 - median_2 \neq 0$$

1. Data Collected

For this test we used the same ten data points as used in the two-sample t-test found in Table 1.

2. Key Findings

Mann-Whitney Test and CI: Alt, Base

```
      N  Median
Base  5  15.000
Alt   5   4.000


Point estimate for ETA1-ETA2 is 11.000
96.3 Percent CI for ETA1-ETA2 is (9.999,14.999)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0122
The test is significant at 0.0109 (adjusted for ties)
```

Figure 15. Mann-Whitney Test and CI

We used Minitab to calculate the results of the Mann-Whitney Test, see Figure 15. The sample medians of the ordered data are 15.0 and 4.0. The 96.3% confidence interval for the difference in population medians (ETA1-ETA2) is [9.9 to 14.9], which does not include zero indicating a statistically significant difference between the medians. The test statistic W = 15 has a p-value of 0.0122 or 0.0109 when adjusted for ties. This is the lowest possible p-value for this test using only five samples from each population. Since the p-value is less than the chosen alpha level of 0.05, we concluded that there is sufficient evidence to reject H_0. Therefore, the data supports the hypothesis that there is a difference between the population medians.

D. TWO-WAY ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance (ANOVA) is used to investigate and model the relationship between a response variable and one or more independent variables. In analysis of variance, the independent variables are qualitative (categorical), and no assumption is made about the nature of the relationship (that is, the model does not include coefficients for variables). In effect, analysis of variance extends the two-sample t-test for testing the equality of two population means to a more general null hypothesis of comparing the equality of more than two means, versus them not all being equal. [Ref 14]

After analyzing the data from the first ten runs, we decided to determine what effect the intensity of fire would have on the number of kills for each case. A two-way analysis of variance tests the equality of population means when classification of treatments is by two variables or factors. [Ref 14] Therefore, our two variables are *case* and *intensity of fire*. Using the ten initial runs as the low intensity with 90 rounds fired in 20-minutes, we increased the number of rounds to 180 for medium intensity, and to 270 for high intensity. Table 2 summarizes the ANOVA factors and levels.

Intensity/Case	**Base Case**	**Alternative Case**
High	5	5
Medium	5	5
Low	5	5

Table 2. Number of Runs by Case and Intensity

An assumption of the ANOVA is that the random amount by which observed value differs from its expectation (residual) is assumed to be normal and independent with a common variance. [Ref 15] These assumptions appear reasonable based on the normal probability plot in Figure 16 showing that the residuals fall very close to or on the line, and the residual plot in Figure 17 showing no discernable pattern.

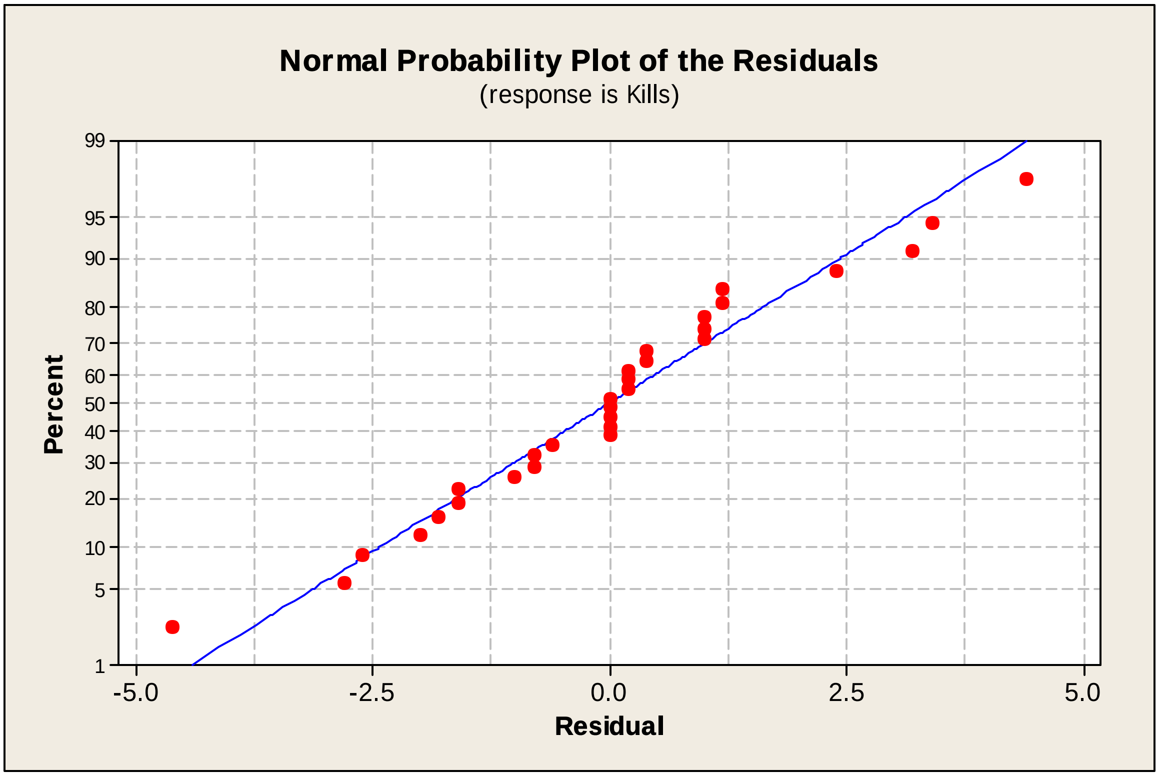

Figure 16. Normal Probability Plot of the Residuals

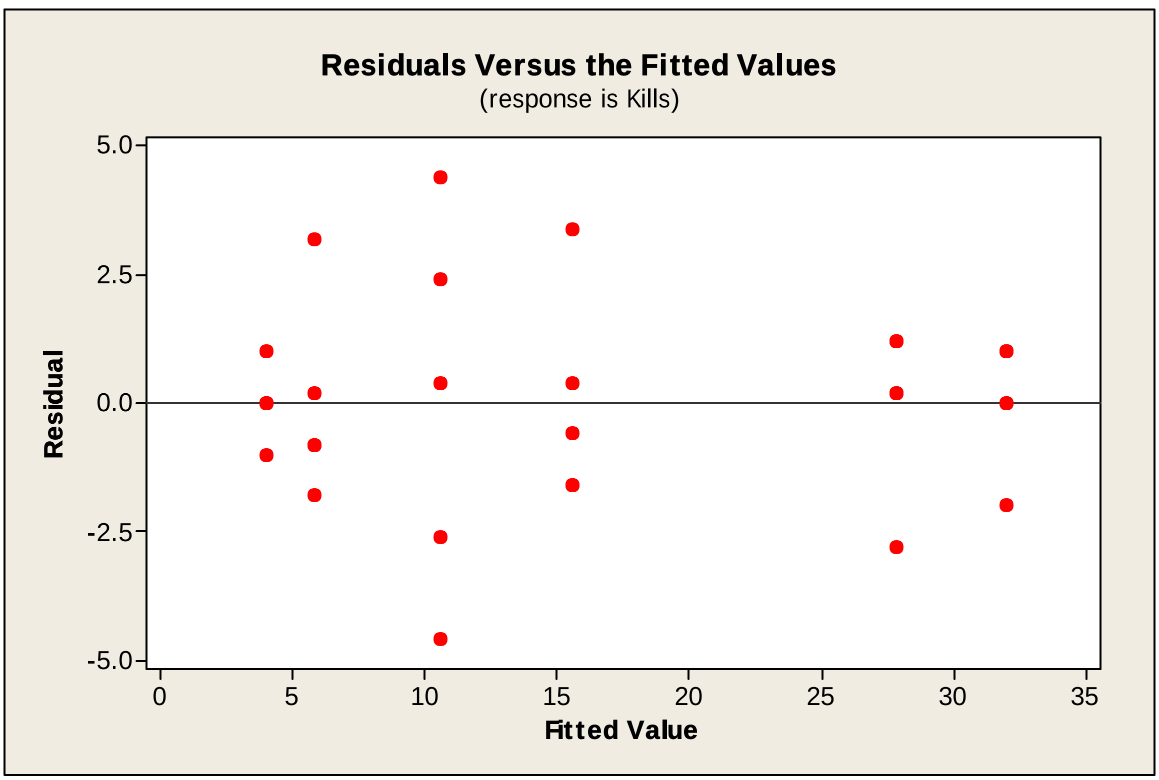

Figure 17. Residuals Versus the Fitted Values

1. Data Collected

Appendix A shows the data collected for all thirty runs broken down by case and intensity.

2. Key Findings

Figure 18 is a scatter plot of the number of kills for each run. Runs 1 through 15 are the base case and runs 16 through 30 are the alternative. An examination of this plot reveals that in the base case, the rate at which the average number of kills increases is greater than in the alternative case. This is significant and it supports our intuition that entities without the behavior in place would be killed at a higher rate than those with the behavior in place. In the base case, the number of kills increased rapidly as the intensity increased, eventually reaching a state in which all 36 entities would be killed. In the alternative case, however, the number of kills increases more gradually and would eventually reach the same state but at a much slower rate. These results were in keeping with our intuition on both cases.

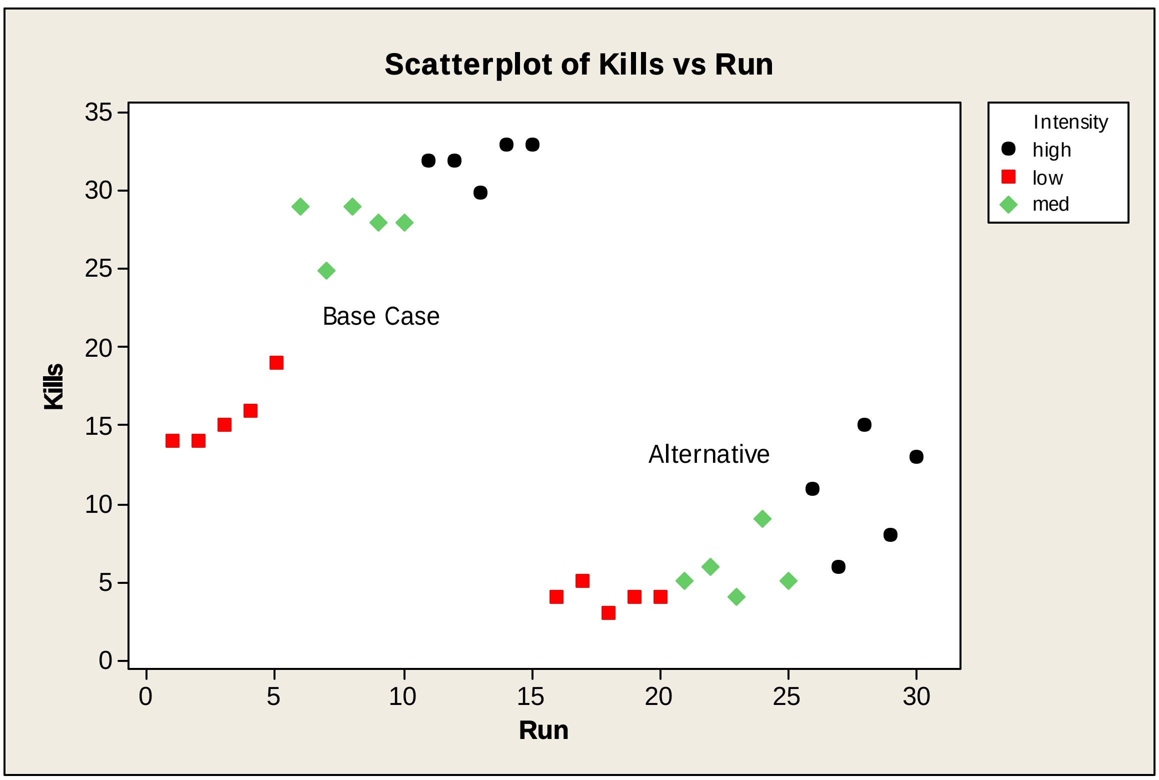

Figure 18. Scatter Plot of Kills vs. Runs

From our two-way ANOVA, we found that intensity, case, and interaction were all significant factors. Figure 19 shows the Minitab output of the two-way ANOVA for kills versus intensity and case. Case is the most important factor by far, with respect to explaining the variance in kills, as seen in the comparison of the relative sizes of the sum of squares (SS) of *Case*, SS *Intensity*, and SS *Interaction*.

Two-way ANOVA: Kills versus Intensity, Case

```
Source       DF       SS       MS       F      P
Intensity     2   671.67   335.83   77.50  0.000
Case          1  2520.83  2520.83  581.73  0.000
Interaction   2   170.47    85.23   19.67  0.000
Error        24   104.00     4.33
Total        29  3466.97

S = 2.082   R-Sq = 97.00%   R-Sq(adj) = 96.38%


                  Individual 95% CIs For Mean Based on
                  Pooled StDev
Intensity  Mean  ---------+---------+---------+---------+
high       21.3                               (--*---)
low         9.8  (---*--)
med        16.8                    (--*--)
                 ---------+---------+---------+---------+
                       12.0      16.0      20.0      24.0


                Individual 95% CIs For Mean Based on
                Pooled StDev
Case     Mean    -+---------+---------+---------+--------
alt    6.8000    (-*-)
base  25.1333                                 (-*-)
                 -+---------+---------+---------+--------
                6.0      12.0      18.0      24.0
```

Figure 19. Two-way ANOVA: Kills versus Intensity, Case

Graphic output from our two-way ANOVA produced the main effects plot in Figure 20. From this plot it is clear that both case and intensity are significant factors as seen by the slope of the lines.

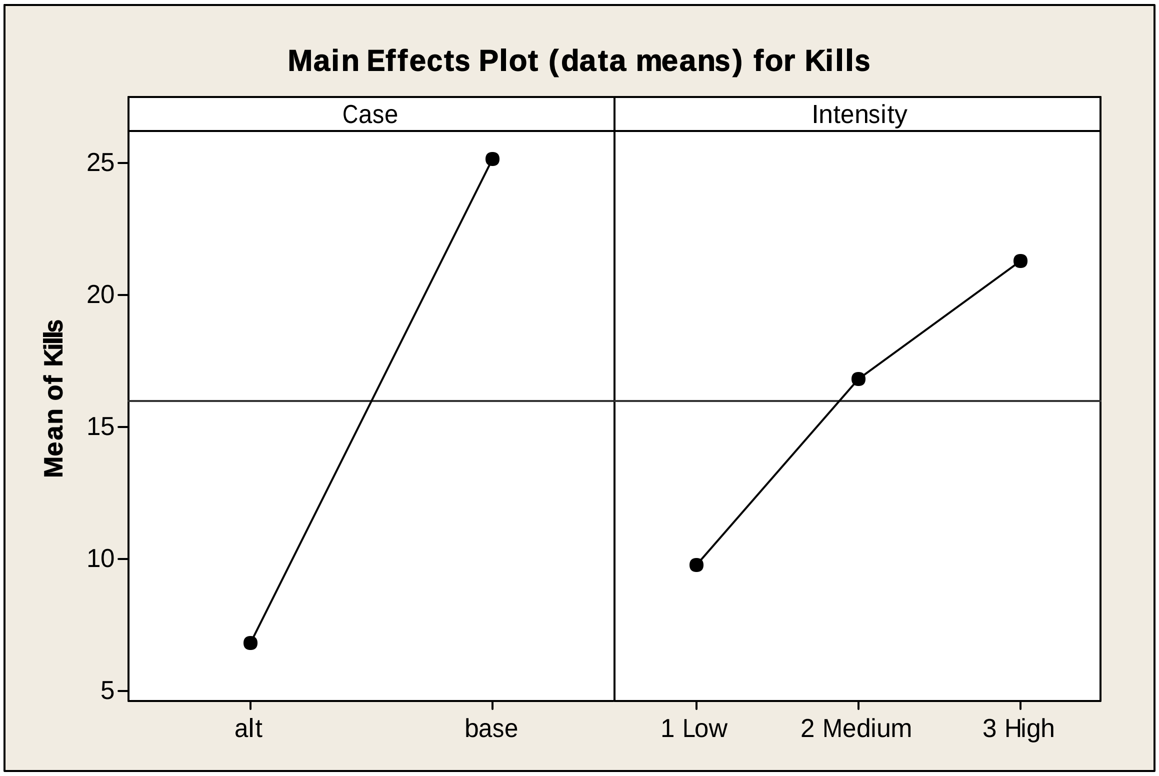

Figure 20. Main Effects Plot for Kills

Figure 21 shows the interaction plot among the factors of case and intensity. An interaction between factors occurs when the change in response from the low level to the high level of one factor is not the same as the change in response at the same two levels of a second factor. That is, the effect of one factor is dependent upon a second factor. We can compare the relative strength of the effects across factors. [Ref 14] Although intensity, case, and interaction were all significant factors, case was much more significant as evident by the largest Sum of Square of 2520.83, as described in Figure 19.

Figure 21. Interaction Plot for Number of Kills

VIII. CONCLUSIONS AND FUTURE STUDIES

A. FACE VALIDATION

In order to determine the effectiveness of the model, we used the face validation method. The office of the Deputy Under Secretary of the Army for Operations Research defines face validation as:

> **…the process of determining whether an M&S, on the surface, seems reasonable to personnel who are knowledgeable about the system or phenomena under study [Ref 2]**

Using this definition, we have determined that the behavior rules implemented in CXXI seem reasonable and meet the requirements for face validation.

B. SUMMARY

From the literature review, we determined both doctrinally how soldiers should react, and historically how soldiers have reacted to indirect fire. We then developed a general model from selected input factors and reactions. Using that model as a framework, we took the two most significant factors that could be implemented in CXXI, protective posture and perceived distance from impact, and developed a set of behavior rules. These behavior rules were implemented in the CXXI source code. We next modified the database for our entities and weapons system characteristics. With the behavior coded and databases updated, we develop a scenario that allowed us to do a face validation and determined that the rules were working in a realistic manner. We determined that the entity reactions are more realistic with the rules in place. From our data analysis consisting of a two-sample t-test, a Mann-Whitney test, and an ANOVA, we concluded that the difference in the average number of kills between the base case without the behavior rule and the alternative was both statistically and military significant. The model implemented through the use of the behavior rules has improved CXXI.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

There are several areas and aspects related to this topic that could be developed for future research. As CXXI completes its development, the behavioral language will continue to grow in capability. As it grows, it will become easier for users to develop their own behavior rules without modifying any source code. Future research should take the factors that influence the leader's reaction and develop leader behavior rules for react-to-indirect-fire. As the level of resolution continues to increase in future simulation s, the implementation of the model could be more detailed and include more of the input factors. Future research in this area should address suppression of the entity as a result of indirect fire. The amount of time an entity stays in the new state is also a topic for future research. Future researchers could change the scenario to include different missions such as a movement to contact or a deliberate attack.

APPENDIX A. DATA

This appendix contains the data for all thirty runs that were conducted.

Run	Case	Intensity	Kills
1	base	low	14
2	base	low	14
3	base	low	15
4	base	low	16
5	base	low	19
6	base	med	29
7	base	med	25
8	base	med	29
9	base	med	28
10	base	med	28
11	base	high	32
12	base	high	32
13	base	high	30
14	base	high	33
15	base	high	33
16	alt	low	4
17	alt	low	5
18	alt	low	3
19	alt	low	4
20	alt	low	4
21	alt	med	5
22	alt	med	6
23	alt	med	4
24	alt	med	9
25	alt	med	5
26	alt	high	11
27	alt	high	6
28	alt	high	15
29	alt	high	8
30	alt	high	13

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APPENDIX B. MODIFICATIONS TO CXXI SOURCE CODE

1. DMI ACTIONS

We modified this class in order to implement our react to indirect fire behavior. The DMI Actions class defines all tactical actions used by the CXXI core model DMI's. DMI Actions for each functionality are maintained in this class. This class is used for typical CXXI entities only. Certain assumptions are made about typical CXXI entities. The assumptions for the 'typical' CXXI entity are:

- It is a military platform
- It exists in a tactical environment which involves tactical units and a force hierarchy
- It is part of a unit and has a chain of command

The original author of this class is Dr. Imre Balogh. This is the block of Java code that was added to the CXXI core model DMI Actions Class.

```
//For Brent Streater's Thesis
//DETECTION HEARD EVENT
 else if (aSimEventName.equals("doDetonationHeard"))
 {
   if(false)
   {
     PerceivedDistance detDist  =
     ((PerceivedDistance)((SimEvent)aSimEvent).getParameters()[0]);

     boolean isVeryClose = false;
     boolean isClose = false;
     boolean isNear = false;
     boolean isNearBy = false;
     boolean isFar = false;

     if(detDist == PerceivedDistance.VERY_CLOSE)
     {
        isVeryClose = true;
     }
     else if (detDist == PerceivedDistance.CLOSE)
     {
        isClose = true;
```

```
        }
        else if (detDist == PerceivedDistance.NEAR)
        {
            isNear = true;
        }
        else if (detDist == PerceivedDistance.NEAR_BY)
        {
            isNearBy = true;
        }
        else isFar = true;

        PerceivedDirection detDir  =
        ((PerceivedDirection)((SimEvent)aSimEvent).getParameters()[1]);

        boolean isCovered = thisDetDMI.isCovered();
        boolean hasProtectedPosture = thisDetDMI.hasProtectedPosture();
         System.out.println("\nDMI Actions... DETONATION HEARD for:"+
          "\n"+thisEntity.getDescription()+
          "\nis entity in protected posture?: "+ hasProtectedPosture+
          "\nis entity covered?: "+ isCovered +  " detdist " +detDist);
         if( (! hasProtectedPosture) && (! isFar))
         {
             thisDetDMI.setHasProtectedPosture(true);
         }
         else if( (! isCovered) && (! isFar))
         {
             thisDetDMI.setIsCovered(true);
         }
           System.out.println(
          "\nNew protected posture: "+  thisDetDMI.hasProtectedPosture()+
          "\nNew covered: "+  thisDetDMI.isCovered());
      }
    }
    //NOT A VALID EVENT NAME
    else throw new InvalidSimEventNameException(
    "\nInvalid SimEvent Name!"+
    "\nThe name passed to Air Move Actions: " + aSimEventName);
}//try
catch(InvalidSimEventNameException e) {
    System.out.println(e.getMessage());
    System.exit(0);
}//catch
```

2. GROUND IMPACT MEDIATOR CLASS

This class handles the impact of munitions on ground entities. Impacts of Direct Fire munitions are handled differently than Indirect Fire munitions since Direct Fire munitions generally have a specific target associated with them. The target is retrieved from the Engagement Object and the mediator calls routines that compute the impact point on the target. For Indirect Fire munitions, the play board is consulted to find the entities that are within the influence of the munitions. Following the assessment of which target or targets are impacted, the appropriate information is then passed to the Damage Mediator class to actually determine the damage that occurred. The Damage Mediator class then passes the Damage State Vector to the entity in question to perform damage to itself. The original author of this class is David R. Durda.

This is the block of code that was added to the ground impact mediator class starting at line 646.

```
// GroundImpactMediator class

//For Brent Streater's Thesis
//                    adjustExposureParams(potentialTarget);

                   ///Go to damage mediator to determine the damage...
                   DamageMediatorIDF.assessIDFDamageToEntity(potentialTarget,
                                          anEngagementObject);

                 if (logger.isLoggingEnabled(DAMAGE_LOGPROPERTY))
                 {
                    String msg = Schedule.getSimTimeStr()+":"
                    +potentialTarget.getID()+":"
                    +potentialTarget.getAssignedName()+":"
                    +anEngagementObject.hashCode()+","
                    +"K-Kill";
                    logger.log(DAMAGE_LOGPROPERTY, msg, 1);
                 }
              }
          }
       }
       else  // target list is empty
       {
          if(debug)
```

```
            System.err.println( "No targets found near impact location!");
        }
    }  // end if eventName == IDFAssessImpact
```

3. DETECTION FM CLASS

The following code is for perceived distance. It is from Detection FM class. The entity is informed that a sonic event has occurred in its vicinity. This method should be called whenever an explosion occurs. This method causes this FM to schedule a "detonation heard" event to be scheduled with a time delay of zero. The input parameters should be modified based on the capabilities of the entity before the information is passed on to the DMI.

```
     * @param location the location of where the explosion occurred
     */
    public void detonationHeard(Location location);

     public void detonationHeard(Location aLocation)
     {
        Location myLocation = myPhysicalEntity.getCxxiWorldLocation();
        // compute the distance to the detonation
        double dist = myLocation.distanceTo(aLocation).getMeters();
        PerceivedDistance perceivedDist;
        if (dist < 25.0)
           perceivedDist = PerceivedDistance.VERY_CLOSE;
        else if (dist < 50.0)
           perceivedDist = PerceivedDistance.CLOSE;
        else if (dist < 150.0)
           perceivedDist = PerceivedDistance.NEAR;
        else if (dist < 200.0)
           perceivedDist = PerceivedDistance.NEAR_BY;
        else
           perceivedDist = PerceivedDistance.FAR;
```

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