73 Easting VR-Forces Model Simulation and Results

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1. Introduction

The Battle of 73 Easting, a tank battle between the American and Iraqi forces during Desert Storm, occurred on February 26, 1991. Due to the technology advancements, the significance of the battle, its relatively recent occurrence, and the availability of detailed records of the battle, 73 Easting was used to demonstrate the capability of VT MÄK's VR-Forces and VR-Vantage to implement a combat model over a distributed simulation network using the Distributive Interactive Simulation (DIS) protocol.

The model of the battle was implemented utilizing two VR-Forces simulation engines on separate computers, one engine simulating the Iraqi forces while the other engine simulates the American forces. The two simulation engines are coupled with a Graphical User Interface (GUI) for each engine and a single VR-Vantage Viewer Client on a separate computer from the VR-Forces simulation engines.

After the initial implementation of the of the battle in the simulation network the battle was simulated and the model was refined until the average American casualties over a set of 30 runs resulted in 2 losses and the final Iraqi casualties was within 1 to 2 losses of their complete demise. These final results of the model closely resemble that of the actual historical battle where 2 American Vehicle casualties occurred and the Iraqi forces suffered a complete loss of their armored troops.

2. Historical Background

The Battle of 73 Easting refers to a series of engagements between American armored cavalry units of the 2nd Regiment and the Tawakalna Division of the Iraqi Republican Guard which occurred on February 26, 1991 during the Persian Gulf War. The battle occurred near 73 Easting, a north-south grid line roughly 30 kilometers west of the Iraq-Kuwait border after American and British forces had entered southeastern Iraq through Saudi Arabia. The 2nd ACR's objective was to move east and fix Republican Guard units, but the 2nd ACR ended up also engaging and annihilating two brigade-sized units of the Republican Guard. The 2nd ACR was split north-south into three areas of operation, with each area assigned to a squadron. The primary 2nd ACR units involved in the battle were Eagle and Ghost Troops of the Cougar Squadron and Iron Troop of the Wolfpack Squadron. Killer Troop of the Wolfpack Squadron provided support to Iron Troop.

As the 2nd ACR approached 68 Easting around 1525, Eagle Troop spotted a village complex, captured a small group of Iraqi soldiers, and received small arms fire from the complex's vicinity. Eagle Troop returned fire with 25mm cannon fire and a volley of 120mm rounds, silencing the enemy fire [2, pg. 133-136]. Suspecting more enemy positions to the east, Eagle Troop transitioned into a wedge formation in which tanks were on point and continued to advance. Scout sections of Bradleys were positions on the north and south flanks to maintain contact with Ghost and Iron Troops respectively.

Iron Troop, also advancing east in a wedge formation, received fire from the southern edge of the village and returned fire until Iraqi forces in the village ceased fire. After reaching 70 Easting, Iron Troop halted.

To the north and around 67 Easting, the 1st Platoon scout section of Ghost Troop encountered two T-72s, which they destroyed with TOW missiles [2, pg. 153].

Approaching 73 Easting at 1618, Eagle Troop swung south and then north, encountering a battalion-sized unit of Iraqi armor. The Iraqi unit, mainly composed of T-72s and BMPs, was defending in depth on the reverse slope of a dune that Eagle had just crested. The Iraqi unit had been taken by surprise and was slow to respond, and the few shots fired by Iraqi vehicles missed. Eagle Troop annihilated the battalion and then began firing on a group of T-72s and BMPs which were left in reserve roughly 2 kilometers northeast of the battalion. These Iraqi forces were also annihilated. After these engagements, Eagle Troop halted on a rise and set up defensive positions near 73 Easting.

At roughly the same time as Eagle was engaging the Iraqi armored battalion and reserves, Ghost Troop encountered a group sixteen Iraqi vehicles. Ghost Troop neutralized 13 BMPs and 3 T-72s and proceeded to also set up defensive positions along 73 Easting.

Roughly 40 minutes after Eagle's and Ghost's attacks, Iron Troop advanced to 73 Easting and encountered sixteen T-72s. Supported by Killer Troop, Iron Troop eliminated all of the T-72s and then fell back to 70 Easting, which was the ordered limit of advance.

At 1700, Iraqi forces launched a counterattack consisting of waves of T-72s, BMPs, BRDMs (amphibious APCs), and infantry. Ghost Troop split up into scout-tank teams in which Bradley crews spotted for the Abrams crews. Ghost Troop repelled three waves of Iraqi troops with tank fire, 25mm cannon fire, TOW missiles, mortar fire, and artillery support. During this counterattack, Ghost Troop took its only casualties due to enemy fire when a Bradley was severely damaged.

3. VR Forces Model

3.1.Terrain

The terrain used in the scenario model was the MÄK Earth terrain model retrieved from VT MÄK's VR-TheWorld Online streaming terrain server. Due to the simulation environment being on an isolated network, the terrain data was retrieved in two different ways. Initially, cache files of terrain data were copied from an external machine. The primary issue encountered was mismatched elevation data resulting in some entities being underground or falling through the terrain during movement. These inconsistencies in the terrain data required temporarily connecting the machines running VR Forces and VR Vantage Stealth to the internet using wireless adapters in order to download the terrain data again. Once these issues were resolved, 25 Hut Brick Mud 1 building props were added to the terrain near the location of 68 Easting to represent a complex of buildings encountered by Eagle Troop and Iron Troop. The final terrain file consisted of the MÄK Earth terrain data and the additional buildings.

3.2.Weather

The weather feature of VR Forces was used to account for poor and varying visibility present in the battle due to a sandstorm. The weather feature sets environment conditions for a specified area selected on the map. VR Forces provides various presets for weather conditions, but there is no sandstorm preset present in the stock software. As a result Custom weather conditions were created for the simulation of the Battle of 73 Easting. Four areas were created to cover the scope of the battle, three of which have the same weather parameters to represent low visibility, from the sandstorm, and encompass the village complex, Iron Troop's area of operation, and Ghost Troop's area of operation. The low visibility sandstorm areas set the visibility parameter to 750 meters and the wind speed parameter to 75 kilometers per hour. Due to accounts of the sandstorm subsiding in the area of Eagle Troop's engagement of with the battalion-sized Iraqi armored unit, the fourth weather area was created in the area of Eagle's Troops main engagement [2, pg. 140-142]. This area had visibility set at 2 kilometers and wind speeds set to 30 kilometers per hour. The four weather coverage areas can be seen in Figure 1.

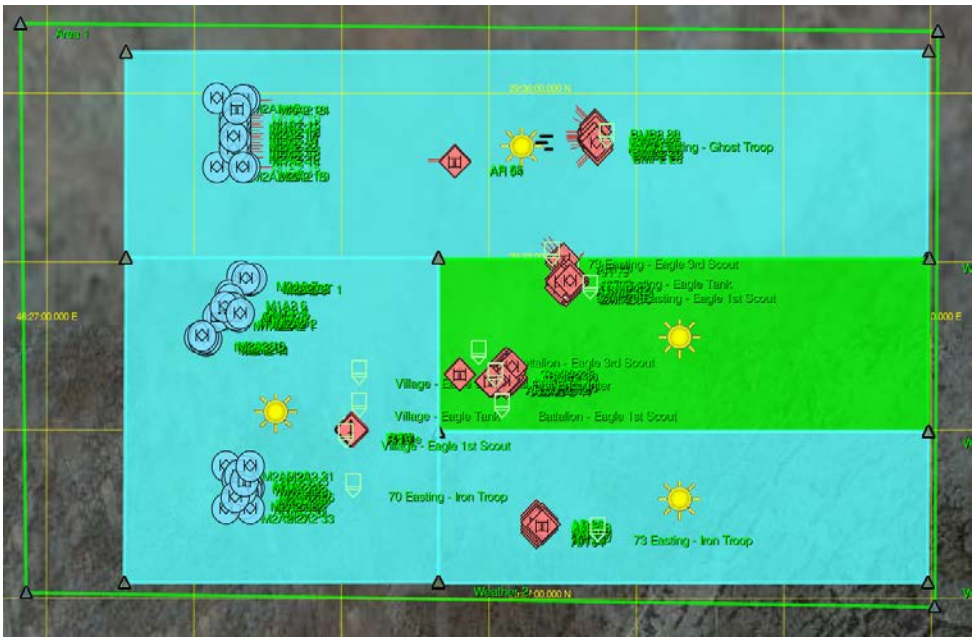

Figure 1 Weather Conditions

3.3.Entities

VR-Forces 4.4 provides two utilities to facilitate the editing of entities, models, and model parameters called the Simulation Object Editor and the OPD Editor. The Simulation Object Editor is the primary editor for a Simulation Model Set, the set of entities and aggregate groups that are used within a simulation. The Simulation Object Editor allows for the creation of new model sets and entities as well as the modifications of entities in the model sets. The Object Editor was used to create four aggregate group entities, Eagle Troop, Eagle Scout Plt, Iron Troop, and Ghost Troop, and their formations. The editor was also used to create the Grom Gun for the BMPs. The OPD Editor is the primary editor for VR-Forces parameter files written in XML, this includes hit probability tables as well as other entity attributes. The OPD Editor was used to modify the Bradleys and Iraqi Soldier target priority lists and ammo selection table to enable the Bradleys and Iraqi Soldier to engage each other.

3.3.1. M1A1 Abrams

The entity used in the model to represent the M1A1 Abrams in the Battle of 73 Easting was the M1A2 Abrams entity provided with the stock version of VR-Forces 4.4. The main gun used by the M1A2 Abrams model is the 120mm Main Gun which includes 3 mounted machine guns. The ammunition for the 120mm main gun includes both M829A1-AP Rounds and M830-HEAT Rounds. No modifications were made to the M1A2 stock weapon models. The sensors used with the M1A2 Abrams model include both the IR and Visual Sensors. Neither the M1A2 stock sensors nor the sensor attributes were modified in the model. The visual model for the M1A1 Abrams is provided in Figure 2.

Figure 2 M1A1 Abrams Visual Model

3.3.2. M3 Bradley

The entity used in the model to represent the M3 Bradley in the Battle of 73 Easting was the M2A2 Bradley entity provided with the stock version of VR-Forces 4.4. The main gun used by the M2A2 Bradley model is the 25mm Gun. A secondary weapon, the TOW Missile Launcher, was added to the model to reflect that the M3 Bradleys in the battle were equipped with a TOW Missile Launcher. The 20 TOW missile rounds were also added to the model as ammunition for the added missile launcher. The sensors used with the M2A2 Bradley model includes both the IR and Visual Sensors. Neither the M2A2 stock sensors nor the sensor attributes were modified in the model. The visual model for the M3 Bradley is provided in Figure 3.

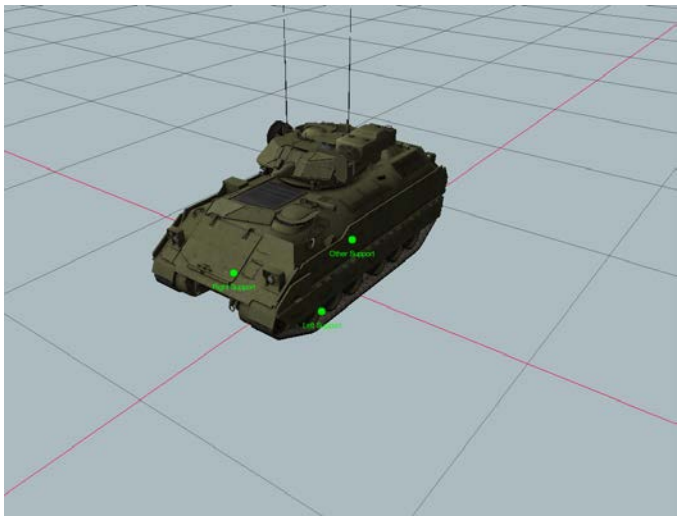

Figure 3 M3 Bradley Visual Model

3.3.3. M7BFIST

VR-Forces 4.4 provides a stock entity for the M7BFIST vehicle. The vehicle has a 25mm gun and utilizes visual sensors. No modifications were made to the stock entity. The visual model for the M2BFIST is provided in Figure 4.

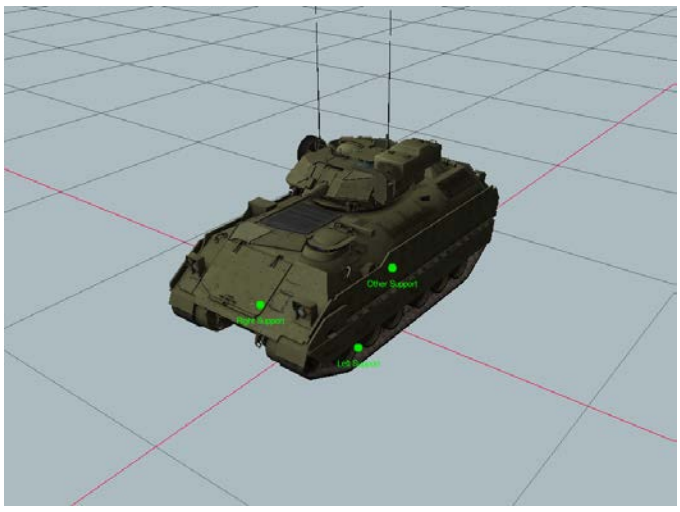

Figure 4 M7BFIST Visual Model

3.3.4. M577A2 Command Post

VR-Forces 4.4 provides a stock entity for the M577A2 Command Post vehicle. The vehicle does not utilize weapons and only has visual sensors. No modifications were made to the stock entity. The visual model for the M577A2 Command Post is provided in Figure 5.

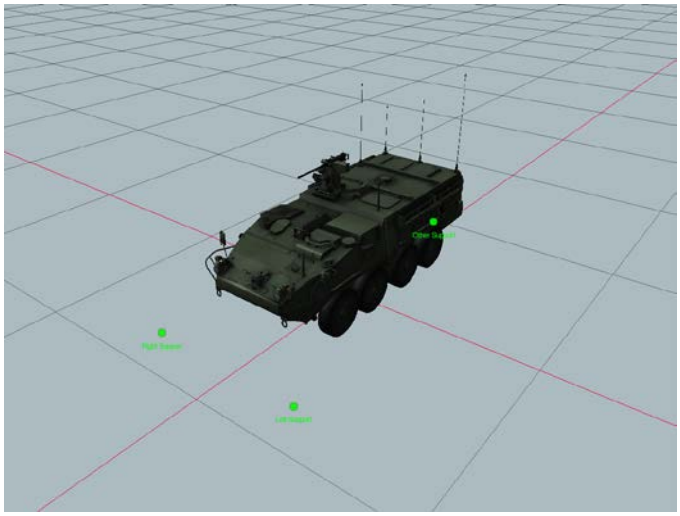

Figure 5 M577A2 Command Post Visual Model

3.3.5. M113 APC

VR-Forces 4.4 provides a stock entity for the M113 APC vehicle. The vehicle has an MHB Machine Gun which utilizes a Turreted M2 .50 Caliber Machine Gun, which utilizes 12.7mm rounds. The vehicle only utilizes visual sensor. The visual model for the M113 APC is provided in Figure 6.

Figure 6 M113 APC Visual Model

3.3.6. T-72

For the T-72 tanks used by the Tawakalna Division, a new entity named Iraqi T-72 was created from the T-72 entity already existing in VR Forces. A few modifications were made to the existing variables taken from the original T-72 entity. The turret slew rate was changed to 0.3 radians per second and the load and unload speeds were both initially set to 5 seconds each [1]. Iraqi T-72s were not equipped with IR sensors. The default probability of hit values were used for the first preliminary runs. The munition types and number each munition type were left at default values of 20 BM-9-AP rounds and 19 BM-14m-HEAT rounds. During preliminary simulation runs, the load and unload speeds were increased and the hit table values were decreased to account for the inaccurate fire and slow response of the T-72 crews present in the Battle of 73 Easting. The visual model for the T-72 is provided in Figure 7.

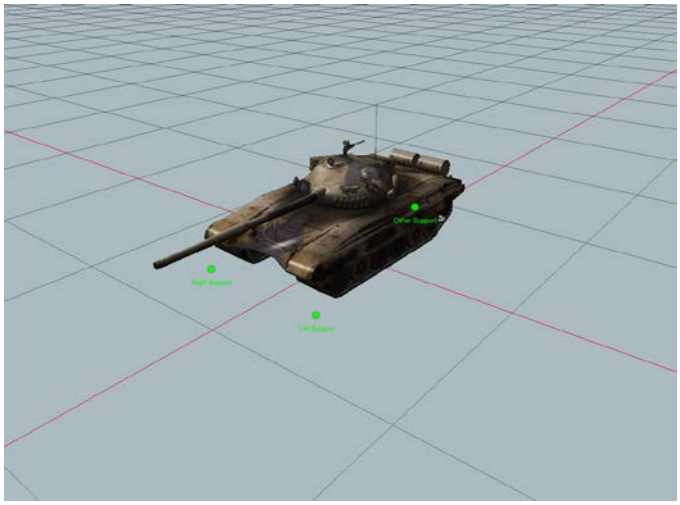

Figure 7 T-72 Visual Model

3.3.7. BMP

An entity named Iraqi BMP was created using the BMP-2 as a basis. Since the older BMP-1 design was in use by Iraqi forces, the 30mm cannon was replaced with a 73mm 2A28 Grom Gun. The 73mm 2A28 Grom Gun was created from the T-72's 125mm gun and then modified. Initial probability of hit values from a previous recreation were used and the muzzle speed was lowered to 400 m/s [1]. The 2A28 Grom is a magazine-fed semi-automatic gun, so the magazine size was changed to 40. The ammo loadout for the Grom was set to 24 PG-15V HEAT rounds and 16 OG-15V HE-Frag rounds, both of which were implemented by modifying the entity type of the BM-9-AP and BM-14m-HEAT rounds used by the T-72.. The sustained rate of fire was set to 6 rounds per minute and the burst rate of fire was set to 8 rounds per minute. In a similar fashion to the alterations to the T-72's 125mm cannon, the Grom's hit table values and rate of fire were decreased through a series of preliminary simulation runs.

The ATGM launcher and Sagger guided missile were also created for the Iraqi BMP. The ATGM launcher was created from the TOW missile launcher and then modified. The initial and unload speeds were 5 and 10 seconds respectively, and the number of total missiles was set to 4. The Sagger missile, like the ATGM launcher, was created from its TOW counterpart. Its maximum range was set to 3 km, its velocity set to 115 m/s, and its weight set to 10.9 kg. The load and unload speed of the ATGM launcher were increased during preliminary simulation runs. It was also configured to be initially unloaded and able to be suppressed by enemy fire. This latter modification was done to replicate minimal reports of Sagger missiles being fired during the battle.

Like the T-72, the BMP-1 was not equipped with IR sensors. The visual model for the BMP is provided in Figure 8.

Figure 8 BMP Visual Model

3.3.8. ZSU-23-4 Shilka

The ZSU-23-4 Shilka is already present in VR Forces. Only one modification was made to the existing Shilka entity: forcing it to fire upon ground platforms. This was done by adding ground platforms to the 14.5mm Quad Gun's target priorities list. The 14.5 mm Quad Gun's ammo select file already contained an entry for firing on ground platforms. Default hit tables were used throughout all runs. The visual model for the ZSU-23-4 Shilka is provided in Figure 9.

Figure 9 ZSU-23-4 Shilka Visual Model

3.3.9. Iraqi Soldier

Iraqi infantry were also modeled using a pre-existing entity in VR Forces, Iraqi Soldier. Iraqi soldiers in VR Forces do not fire on tanks and APCs by default, contradicting events of the Battle of 73 Easting. Ground platforms were added to the Iraqi Soldier target priorities list, and an entry was added to the ammo select file so that Iraqi Soldier entities would select ammunition when ground platforms were detected. After these changes, Iraqi soldiers would fire on American armored vehicles. The AK-47 was selected as the weapon system for Iraqi Soldier entities, and all of the AK-47's attributes and settings were left at default values. The visual model for the Iraqi Soldier is provided in Figure 10.

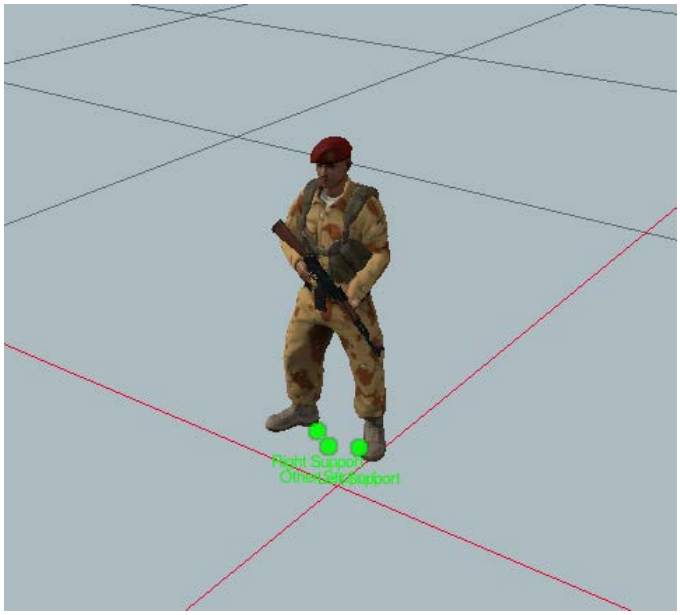

Figure 10 Iraqi Soldier Visual Model

3.4.US Forces

3.4.1. Eagle Troop

Eagle Troop is modeled as 3 Aggregate groups, 1 for the 2nd and 4th tank platoons (Eagle Tank), and a single aggregate group for the 1st Scout Platoon and 3rd Scout Platoon.

The 2nd and 4th tank platoon aggregate group contains 4 M1A1 Tanks per platoon and also includes 2 M113 APC's the M577A2 Command Post, an M1A1 with the 2nd Armored Calvary Division Commander and another M1A1 with Eagle Troop's Commander. The 1st Scout Platoon aggregate group contains 4 M3 Bradley's with 1 M7BFIST vehicle. The 3rd Scout Platoon aggregate group contains 6 M3 Bradley Vehicles. The three Eagle Troop aggregate groups can be seen in the scout formation in Figure 11.

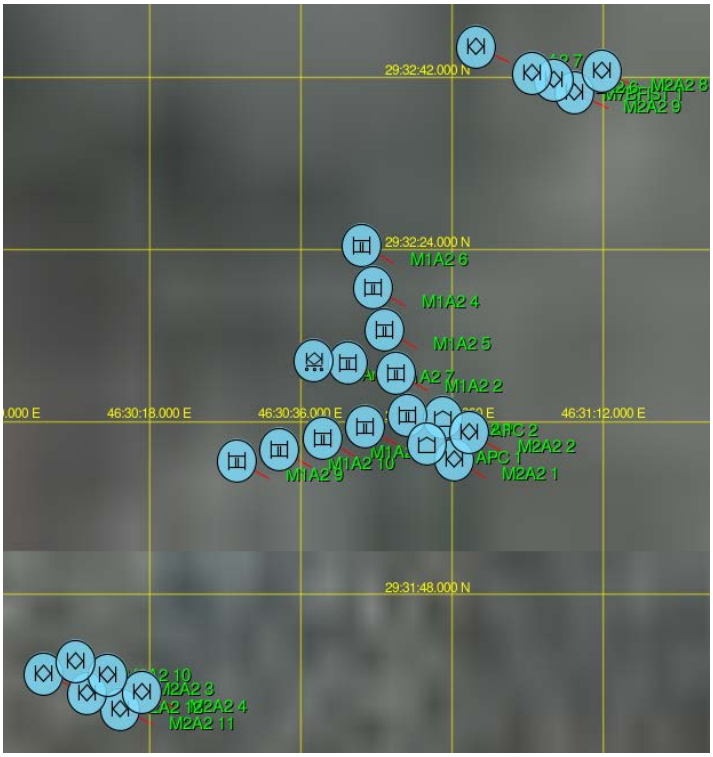

Figure 11 Eagle Troop

3.4.2. Iron Troop

Modeled as a single aggregate group utilizing a tank front wedge formation. The aggregate group contains 2 M1A1 Tank platoons (4 Tanks each) and 2 M3 Bradley platoons (6 Fighting Vehicles each) as well as the Troop commander for a total of 9 M1A1 Tanks and 12 M3 Bradley Vehicles. 1 Bradley platoon is used as scouting vehicles along the northern and southern boundary of Iron Troop (3 vehicles on both the northern boundary and southern boundary). Iron troop in the attack formation can be seen in Figure 12.

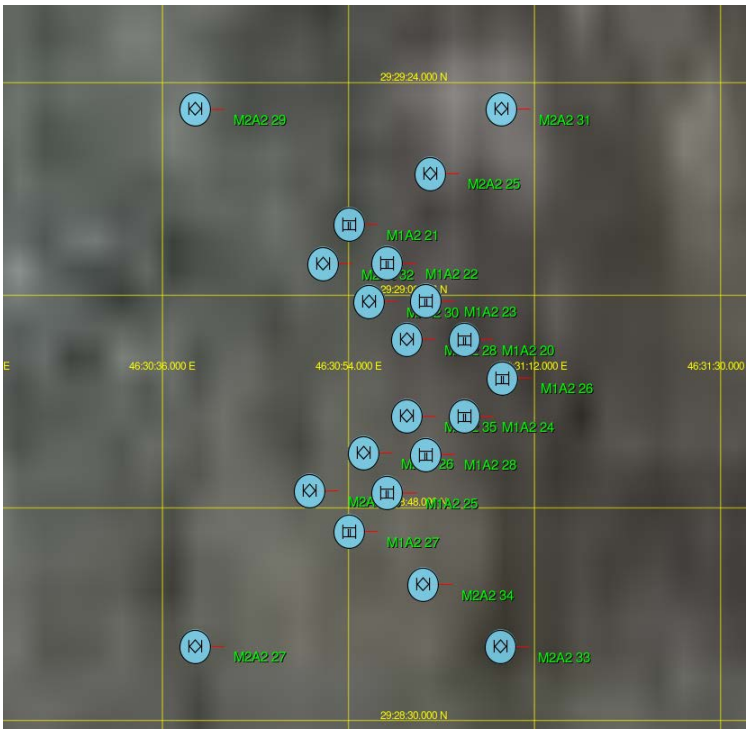

Figure 12 Iron Troop

3.4.3. Ghost Troop

Modeled as a single aggregate group utilizing a line formation. The aggregate group contains 2 M1A1 Tank platoons (4 Tanks each) and 2 M3 Bradley platoons (6 Fighting Vehicles each) as well as the Troop commander for a total of 9 M1A1 Tanks and 12 M3 Bradley Vehicles. 1 Bradley platoon is used as scouting vehicles along the northern and southern boundary of Iron Troop (3 vehicles on both the northern boundary and southern boundary). Ghost Troop in the scout formation can be seen in Figure 13.

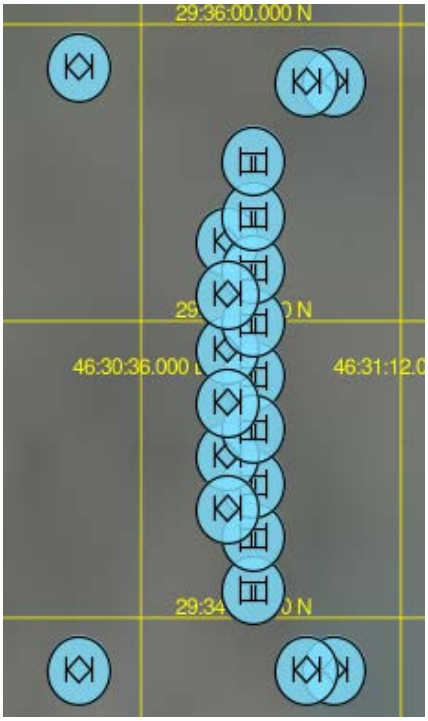

Figure 13 Ghost Troop

3.5.Iraqi Forces

3.5.1. Village

The village encountered by Eagle and Iron Troop is modeled using 25 buildings using the Hut Brick Mud 1 prop design provided with VR Forces. The configuration of the houses is largely unknown so the in the recreation the houses are randomly placed in a localized vicinity of the expected location of the village. The Iraqi troops in the village include 20 Iraqi soldiers and two ZSU-23-4 Shilka's which is used to mimic the forces encountered by Eagle and Iron Troop when they engaged the forces in the village during the battle. Figure 14 shows the Iraqi village in both a planning view and stealth view (3-dimensional view).

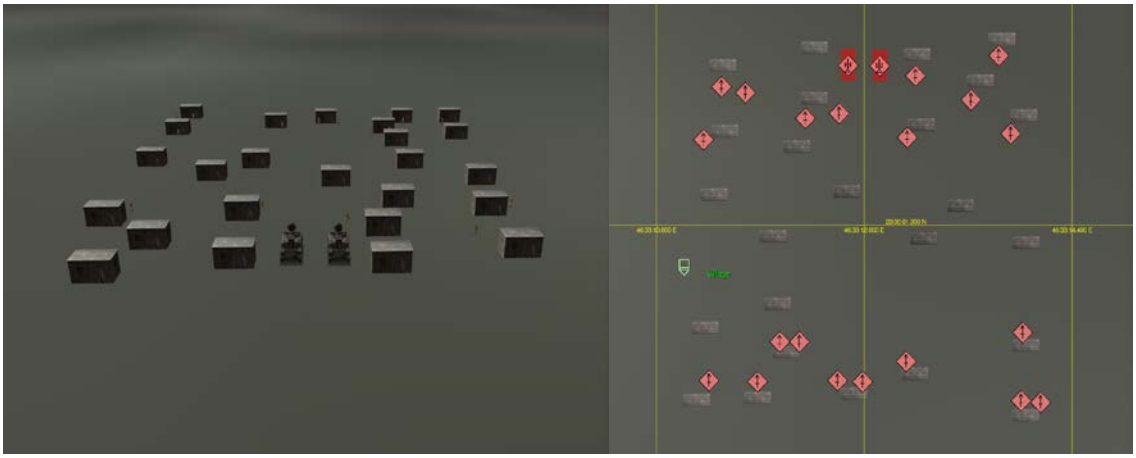

Figure 14 Iraqi Village Stealth and Plan View

3.5.2. Southern Iraqi Scouts

The southern Iraqi Scouts are the small forces that Eagle Troop encounters prior to reaching 73 Easting. These units were scouting for the Tawakalna Republican Guard Division of the Iraqi forces positioned to engage the US forces along the 73 Easting. The scout consists of one Iraqi T-72 and one Iraqi BMP.

3.5.3. Iraqi Battalion

The Iraqi battalion is Eagle Troop's main engagement during the battle of 73 Easting. The battalion is the main force from the Tawakalna Republican Guard Division positioned to engage the US forces to prevent them from entering Kuwait and Iraq. The battalion consists of one ZSU-23-4 Shilka, 28 Iraqi T-72s, and 11 Iraqi BMPs [2, pg. 142, pg. 153] [6]. Iraqi entities are positioned in depth, with the majority of the force oriented to the west. The core of the formation consists of T-72 arranged in staggered lines. BMPs cover the flanks and rear, and the Shilka is positioned in the rear-center behind the T-72s. All entities are spaced between 50 and 100 meters from each other; however, there is little source information regarding the exact spacing and positioning of this unit.

There are eight T-72s located southwest of the main formation and oriented south. These tanks are the first Iraqi combatants engaged by Eagle Troop after cresting the ridge blocking their view between the troop and this unit [2, pg. 319]. The Iraqi Battalion formation can be seen in Figure 15.

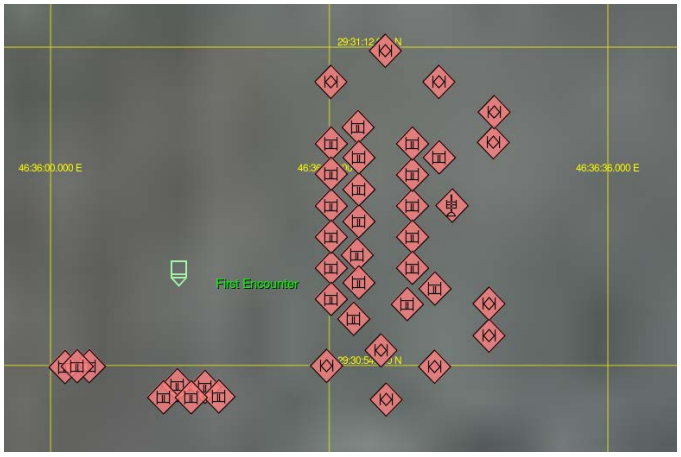

Figure 15 Iraqi Battalion

3.5.4. Iraqi Coil Reserves

The Iraqi coil reserves are positioned in a coil formation, a formation where the vehicles are positioned in a circle and oriented outward. Seventeen T-72s make up the outer ring of the formation while 15 BMPs make up the inner ring of the formation. Three additional BMPs are positioned just south of the formation and oriented south. This formation is positioned roughly 2 kilometers north-northeast of the battalion encountered by Eagle [2, pg. 142]. As with the armored battalion, the entities are spaced from 50 to 100 meters of each other. This unit was engaged by Eagle Troop as they moved north after engaging the Iraqi battalion. Figure 16 shows the Iraqi Coil formation at the 73 Easting.

Figure 16 Iraqi Coil

3.5.5. Iraqi Tanks, North of Reserve

There are three T-72s positioned northwest of the reserve unit. These tanks were also engaged by Eagle troop as the moved north back into their zone of control after engaging the Iraqi battalion.

3.5.6. Northern Iraqi Flank

Two T-72s located near 68 Easting in Ghost Troop's area of operation were engaged by Ghost Troop scouts. This was the first engagement which involved Ghost Troop. The Northern Iraqi Flank can be seen in Figure 17.

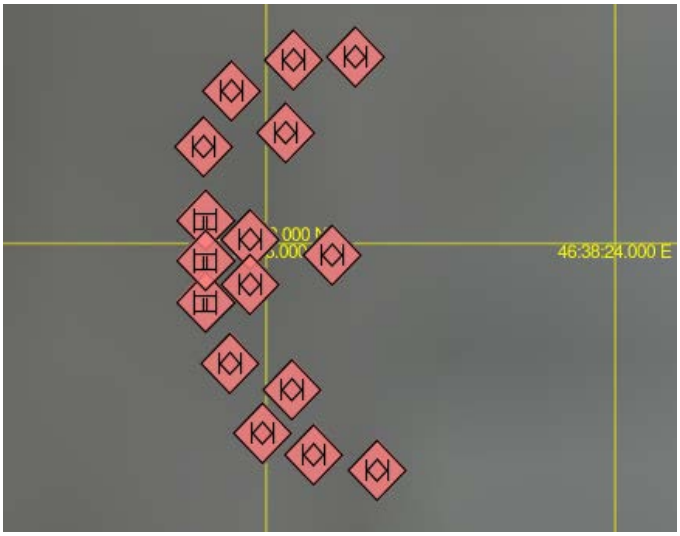

Figure 17 Iraqi Northern Flank

3.5.7. Northern Iraqi Scouts

The northern Iraqi flank consists of three T-72s and 13 BMPs located near 73 Easting [2, pg. 153]. The tanks are in the center of the formation with two BMPs positioned behind them. The other eleven BMPs are positioned on both sides of the tanks. This unit was engaged by Ghost Troop.

3.5.8. Southern Iraqi Flank

The southern Iraqi flank consists of 16 T-72s positioned in depth which were engaged by Iron Troop [7]. The Southern Iraqi Flank troops can be seen in Figure 18.

Figure 18 Iraqi Southern Flank

3.6.Combat Model Layout

Due to time constraints of the project and lack of reliable automated scenario testing, the counterattack launched by Iraqi forces is not included in this model and the lapse of time between Cougar Squadron's attacks and Wolfpack's attacks is significantly shortened.

3.6.1. US Forces

Based on the progression of the battle the US forces are initially placed around the 65 Easting and during the course of the battle progress toward the 73 Easting.

3.6.1.1.Initial Troop Placement

Eagle Troop

Eagle Troop's initial placement is along the 65 Easting at about 29.51° Latitude at about a 115° heading from North. The 115° heading orients eagle troop toward the village they first encounter in the battle preventing the simulation from forcing the Troop to initially orient toward the Village and then proceed to the village.

The main force of Eagle Troop, the Eagle Tank group, starts in the "Scout" formation which puts the Bradley and M113 Vehicles in front of the M1A1 Abrams. In this formation the Abrams are positioned in a wedge formation where one platoon forms one side of the wedge while the other platoon mirrors the first and forms the other side of the wedge. Eagle Troop's commander forms the point of the wedge while the 2nd Armored Division Commander and M577A2 Command Post are positioned behind the tank wedge formation.

The Scout platoons are placed to the left and right of the Eagle Tank formation so that The 1st Scout Platoon is approximately just northeast of the main force while the 3rd Scout Platoon is just south west of the main force.

Iron Troop

Iron Troop's initial placement is along the 65 Easting at about 29.50° Latitude with a 90° heading from North. This positions and orients the troop south of Eagle Troop toward the 73 Easting, the destination of their advancement. This placement was chosen due to the location of the Village, which both Eagle and Iron Troop engage during the battle.

Ghost Troop

Ghost Troop's initial placement is along the 65 Easting at about 29.48° Latitude, approximately 5 km north of Eagle Troop's main force.

3.6.1.2. Combat Plans

Eagle Troop

Eagle Troop engages the Iraqi troops with a fire-at-will rule of engagement. The model plan for Eagle Troop directs the troop to engage the village from a north westerly direction then proceed on to encounter the main battalion of the Iraqi forces. After the main battalion is engaged and destroyed the force then proceeds on to engage the Iraqi reserve forces in the coil formation. Eagle Troop’s modeled route taken during the battle can be seen in Figure 19.

Figure 19 Eagle Troop Route

Iron Troop

Iron Troop engages the Iraqi troops with a fire-at-will rule of engagement. The model plan for Iron troop makes Iron Troop delay going toward 73 Easting by 4 minutes since they are slightly behind Eagle during the battle. The troop then proceeds onward to engage the village that was previously engaged by Eagle Troop. After Iron Troop passes the village it then continues to 73 Easting to engage the southern Iraqi forces. After Iron Troop reaches 73 Easting they then return to 70 Easting. Iron Troops route through the battle is provided in Figure 20.

Figure 20 Iron Troop Route

Ghost Troop

Ghost Troop engages the Iraqi troops with a fire-at-will rule of engagement. The model plan for Ghost Troop delays their movement for 5 minutes as they lag behind both Eagle and Iron troop during the battle. Ghost Troop's plan then directs them to go directly to 73 Easting where they will engage the northern Iraqi Forces. Figure 21 shows the route Ghost Troop takes during the battle.

Figure 21 Ghost Troop Route

3.6.2. Iraqi Forces

The majority of the Iraqi forces are placed along the 73 Easting. Additional Iraqi forces are placed, as scouts, between the 67th and 73rd Easting as well as several units being placed at the 67th Easting in the Village encountered by Eagle and Iron Troop.

The Iraqi forces maintain defensive positions and do not move during the simulated battle. Iraqi aggregates are set to fire when fired upon to account for a reported element of surprise and delayed response. The only exception to this is the infantry and anti-aircraft guns in the village complex, since American forces were fired upon first in that particular engagement.

Figure 22 provides a large scale view of the Battle of 73 Easting, showing entity initial locations and waypoints.

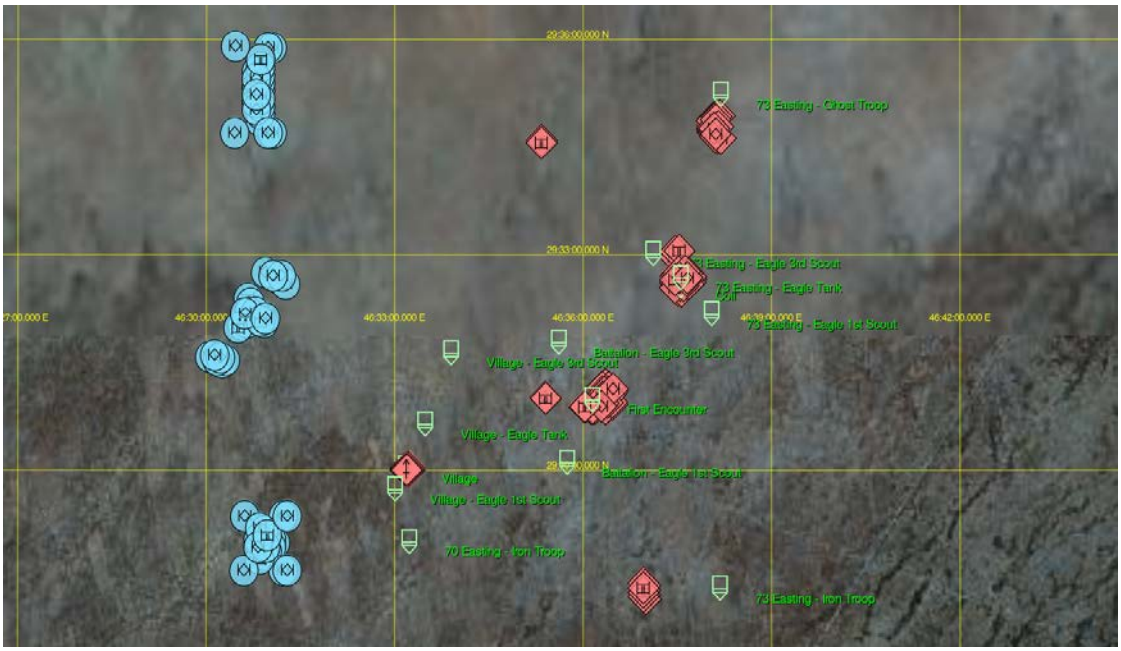

Figure 22 73 Easting Model Layout Overview

4. Simulation Results

4.1.Key Engagements

4.1.1. Eagle Troop

Village Engagement

The Eagle 3rd Scout Platoon engaged the Iraqi village in every scenario. This resulted in the demise of all Iraqi infantry and Shilka units (approximately two runs did show all but 1 infantry demise, this was likely due to the Bradley Vehicles initially missing the infantry unit and then losing line of sight due to the building placement). The Village Engagement can be seen in Figure 23.

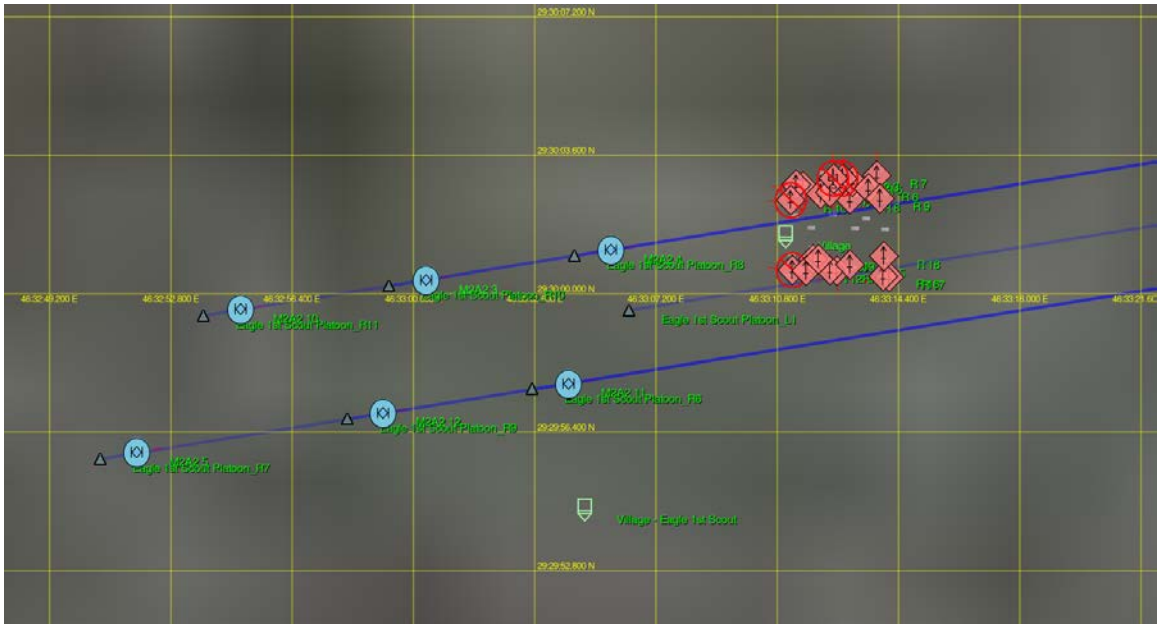

Figure 23 Eagle 3rd Scout Platoon Engagement of Iraqi Village

Battalion Engagement

The entire Eagle Troop engaged the Iraqi Battalion forces, first starting with the two scouting platoons and then followed up by the main Eagle Tank force. This engagement typically resulted in 0 to 2 American Tank casualties and the complete demise of the Iraqi forces. This engagement impacted the final outcome of each of the runs of the simulation as the loss of the lead tanks of the formation would result in the possible loss of additional American units (likely the Bradleys from the two scout platoons) during the Coil formation engagement. Figure 24 shows the engagement between the Iraqi Battalion and Eagle Troop.

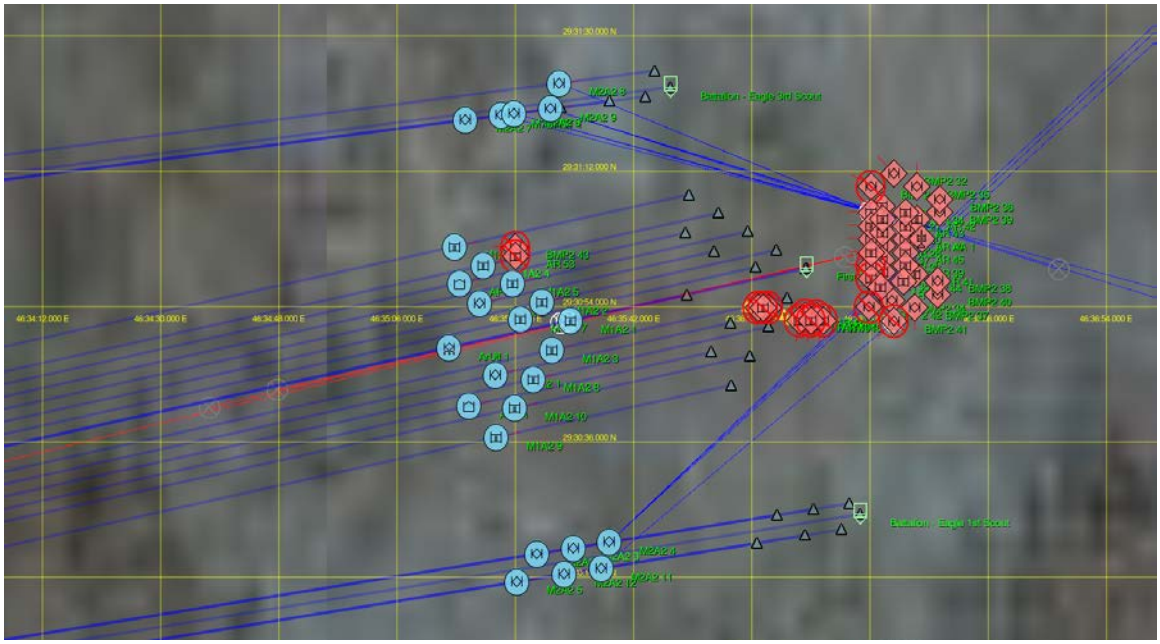

Figure 24 Eagle Engagement of Iraqi Battallion

Coil Engagement

The entire Eagle Troop engaged the Iraqi Coil formation, first starting with the main tank force, followed by the two scouting platoons. This engagement typically resulted in 0 to 2 American Tank casualties and the complete demise of the Iraqi forces. Eagle Troop's engagement of the Iraqi Coil at 73 Easting can be seen in Figure 25.

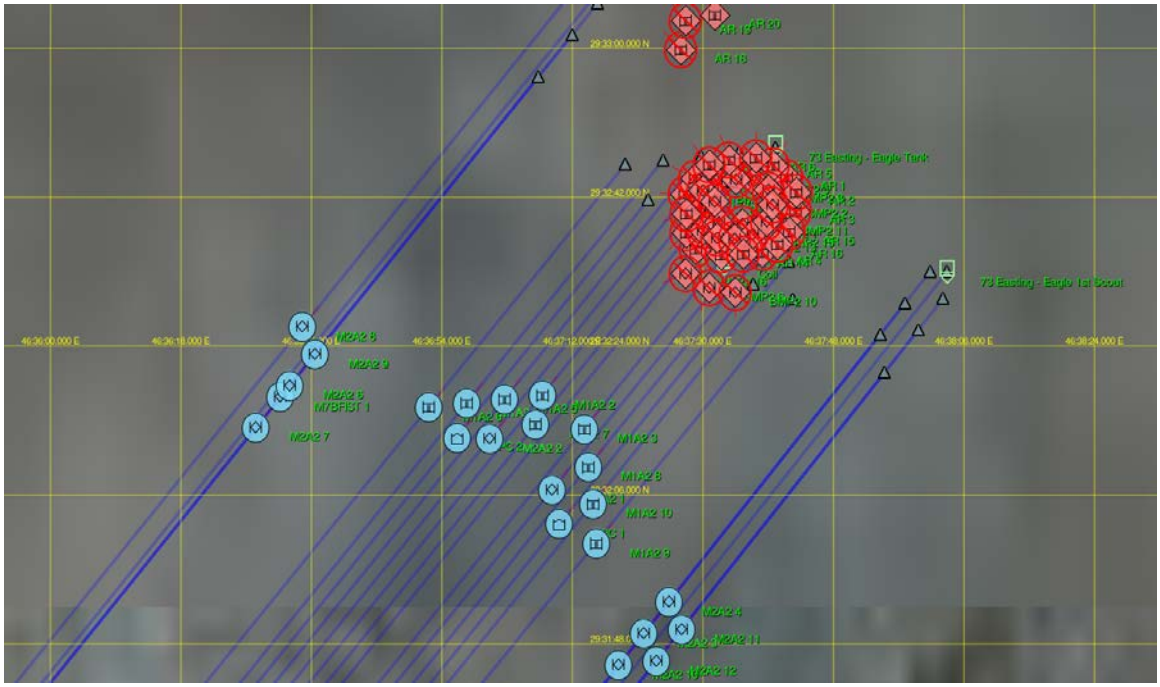

Figure 25 Eagle Engagement of Iraqi Coil

4.1.2. Ghost Troop

Ghost Troop engagement of the Iraqi Northern Flank resulted in the demise of all Iraqi Units for all runs. Periodically Ghost Troop obtained 1 to 2 casualties in the runs due to friendly fire. Ghost Troop's engagement of the Northern Iraqi Flank can be seen in Figure 26.

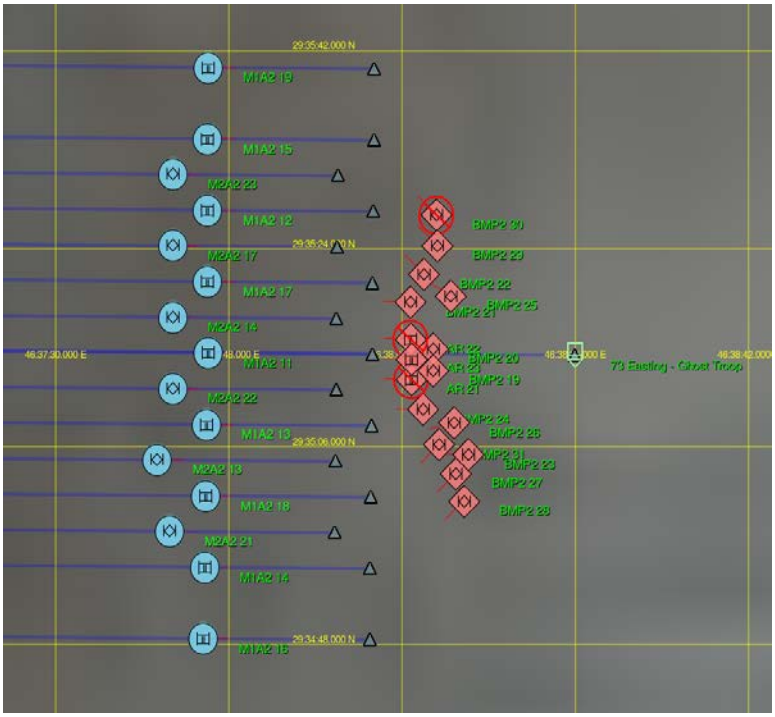

Figure 26 Ghost Engagement of Iraqi Northern Flank

4.1.3. Iron Troop

Iron Troop engagement of the Iraqi Southern Flank resulted in the demise of all Iraqi Units for all runs. Periodically Iron Troop obtained 1 to 2 casualties in the runs due to friendly fire. Iron Troop's engagement of the Iraqi Southern flank can be seen in Figure 27.

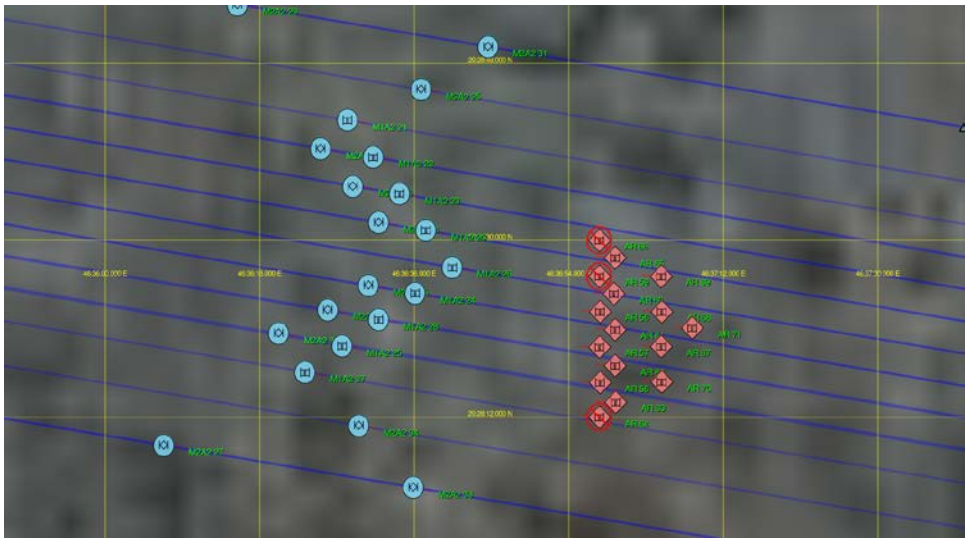

Figure 27 Iron Engagement of Iraqi Southern Flank

4.2. Validating the 73 Easting Combat Model and Final Results

Several runs of the model were conducted to compare to the expected results of 1 to 3 American causalities and 100% demise of the Iraqi forces. After the initial couple of runs small incremental adjustments were made to hit probability tables, formation waypoints, weather, etc. to adjust for differences between the expected results and the simulation. This process of running a simulation or set of simulations and making small adjustments based on the results was repeated about 20 times, ultimately resulting in a model of the battle that, over a set of 30 runs, achieved a mean American casualty count of 2 and a consistent 100% Iraqi casualty count for all runs. Detailed preliminary and validation runs can be found in Section 9.

5. Potential Model Improvements

5.1. VR Forces Improvements

During the development of the scenario used to simulate the Battle of 73 Easting, it was found that VR Forces lacked certain resources which would have been useful for more accurately modeling the battle and more efficiently executing the simulation runs.

Common Military Props

American forces encountered Iraqi infantry positioned in trenches and bunkers, but it was not easy to model these structures since VR Forces does contain props corresponding to trenches, bunkers, and other common military fortifications. Because of this, the majority of Iraqi infantry units present during the battle were omitted from the model. While it could be argued that Iraqi infantry had a negligible effect on the battle's outcome, the presence of these props would have allowed for a realistic representation of these infantry units and their emplacements.

Unit Quality Parameter

Through a series of preliminary simulation runs, the attributes and specifications of weapon systems and platforms used by Iraqi forces had to be modified to account for the slow response and low accuracy of their Iraqi operators. In terms of efficiency and realism, a parameter related to unit quality would have been preferred. This would allow the scaling the performance of specified entities, avoiding permanent modifications to weapon systems and platforms. A unit quality parameter would also be conceptually more appropriate in modeling the human elements attached to weapon systems and platforms.

Batch Mode Operation

While VR-Forces provides the capability to operate in batch mode for single backend simulations and multiple backend simulations the results of operating in batch mode between the two was inconsistent. Specifically, during several attempted operations of conducting 30 batch runs with the distributed simulation, the batch mode operation would only conduct a single run of the 30 requested runs. This was observed to be due, in part, to simulation engine critical runtime errors, simulation engine loading errors, and in some cases no observed causes of the failure was observed. In order to determine potential configuration errors of the model when running in batch mode, one of the stock batch mode files was run and compared to the operation of the 73 Easting model running in batch mode. No discernible difference was noted between the initial run in batch mode of the 73 Easting model with the stock batch file. However, the stock batch file operated nominally, loading each scenario contained in the batch. The only difference in the 73 Easting batch file and stock batch file was the specific scenario to run and how many times to run the scenario.

Logger Remote Control Operation with Batch Mode

In relation to batch mode operation of the simulation, the MAK Logger program was used to capture the simulation data through the remote control by the simulation engines. The starting, stopping, and clearing functionality of the logger worked as expected, according to the VR-Forces User Guide [5]. The only anomalous functionality with the remote control of Logger through the simulation engines was the saving functionality after each run of the simulation, as specified by the VR-Forces User Guide [5]. This condition was able to be worked around by having the Logger not be controlled by the engines but instead save at periodic intervals.

5.2. 73 Easting Implementation Improvements

During implementation of the model, several detailed portions of the 73 Easting Battle were determined not to be feasible to implement within the time constraints of the project. The additional characteristics and detailed portions of the battle that were not implemented include, but are not limited to, specific (scripted) actions by entities, historic terrain, and additional troops not significantly contributing to the outcome of the battle. These items would further enhance the accuracy of the model and are described here in detail.

Detailed Implementation of American Forces

Further development of the model would allow a more detailed implementation of the Iron and Ghost Troop Aggregate Entities and formations similar to how Eagle troop has been implemented. This would allow for more independent actions of the scout platoons of the two troops from the tank platoons. Additionally the routes for the two troops could be enhanced, specifically for Iron Troop to have them engage the Iraqi Village then pause at 70 Easting prior to proceeding to 73 Easting. For Ghost Troop additional scripting would be needed to send a single tank platoon to start the engagement of the Northern Iraqi Flank.

Further additions could be implemented to better recreate several events specifically for Iron Troop which would include a 40 minute wait for Iron troop to start advancing toward 73 Easting as well as the incorporation of Killer Troop and other units which bring up the flank of the American forces during the battle. The addition of the units bringing up the flank would be necessary to implement if the Iraqi Counter Attack were to be incorporated into the model of the battle.

American Friendly Fire

Friendly fire among American forces was occasionally observed during simulation runs. Such cases resulted from Bradley IFVs firing TOW missiles into the rear or sides of Abrams tanks. It is also worth noting that TOW missiles tended to be inaccurate when fired. Both of these issues could be avoided by creating scripts which order Bradley IFVs to come to a halt before firing TOW missile, as it is unrealistic that wire-guided missiles would be fired while the vehicle is moving.

Additional Iraqi Entities

There were some aspects of the Iraqi forces which were omitted in the final model, primarily due to lack of preexisting resources. Hundreds Iraqi infantrymen were present in the battle and fired on American armored vehicles with small arms and rocket propelled grenades with minimal effect. Due to the lack of fortification props in VR Forces and the lack of detailed information about infantry positions, the majority of Iraqi infantry units were omitted from the model. A small number of other vehicles were reported to be present in Iraqi forces during the battle: two T-55 tanks, one SA-13 SAM platform, three MT-LB tracked APCs, and one BTR-60s wheeled APC [2, pg. 153]. None of these vehicles have models in VR Forces, and due to time constraints new models were not created and included in the overall model of the battle. While these additional infantry and vehicles would likely have a negligible effect on the outcome of simulations of the Battle of 73 Easting, their inclusion would nonetheless result in a model with higher fidelity.

Iraqi Formations

With the exception of the coil formation of the Iraqi armored reserve unit, information describing the positioning and spacing of Iraqi armor was vague and difficult to find. The primary guide in the design of the Iraqi formations used in the model was the recurring theme of depth in their defense. Further research into Iraqi positions would be a point of interest in future studies attempting to develop a more accurate model.

Historical Terrain

The age or date of the terrain data retrieved from the VR-TheWorld Online server is not known, but it is most likely fairly recent data. This can result in some inconsistencies due to wind erosion that could have occurred between 1991 and the date the elevation data was recorded. Since elevation data played a role in the outcome of the historical battle, newer elevation data may be notably different than it was in 1991 elevation data. One way to fix this would be to overlay older elevation data with the current MÄK Earth data or import a complete set of terrain data recorded in 1991.

6. Sources

[1] Daniels, William and Petty, Mikel D. Recreating the Battle of 73 Easting in a Constructive Combat Model. Center for Modeling, Simulation, and Analysis. University of Alabama in Huntsville: Huntsville, 2011

[2] Macgregor, Douglas. Warrior's Rage: The Great Tank Battle of 73 Easting. Naval Institute Press: Annapolis, 2009.

[3] Bourque, Stephen A. *Jayhawk! The VII Corps in the Persian Gulf War*. United States Army Center of Military History: Washington DC, 2002.

[4] Guardia, Mike. The Fires of Babylon: Eagle Troop and the Battle of 73 Easting. Casemate Publishing: Havertown, 2015.

[5] VR Forces User Guide

[6] McMaster, H.R. Battle of 73 Easting

[7] Atkinson, Rick. *Crusade: The Untold Story of the Persian Gulf War.* Houghton Mifflin Company: New York, 1993. Pg. 144.

7. Appendix A - Simulation Environment

7.1. Environment Setup and Software Installation

The simulation environment consisted of three machines connected to an isolated network. VR Forces was installed on two machines, and VR Vantage was installed on the third. The installation process for both machines are similar; an installation file is first executed to install the chosen application, and then a second file is executed to unpack the application's model data.

7.2. VR Forces

VR Forces consists of two programs: VR Forces Simulation Engine and VR Forces GUI. Model development and simulation runs were performed using two VR Forces simulation engines and two VR Forces GUI clients distributed across the isolated network using the distributed interactive simulation (DIS) protocol. VR Forces required minimal configuration to set up a DIS-based simulation, only requiring that unique IDs be assigned to each simulation engine and GUI client. Iraqi forces were modeled and simulated on one simulation engine, labeled 3001, and American forces were modeled and simulated on the other simulation engine, labeled 3002. The GUI clients were labeled 3101 and 3102, with GUI client 3101 and simulation engine 3001 running on the same machine. The simulation connection configuration settings for the 3002 engine, 3001 engine, 3101 GUI, and 3102 GUI can be seen in Figure 28, Figure 29, Figure 30, and Figure 31 respectivly.

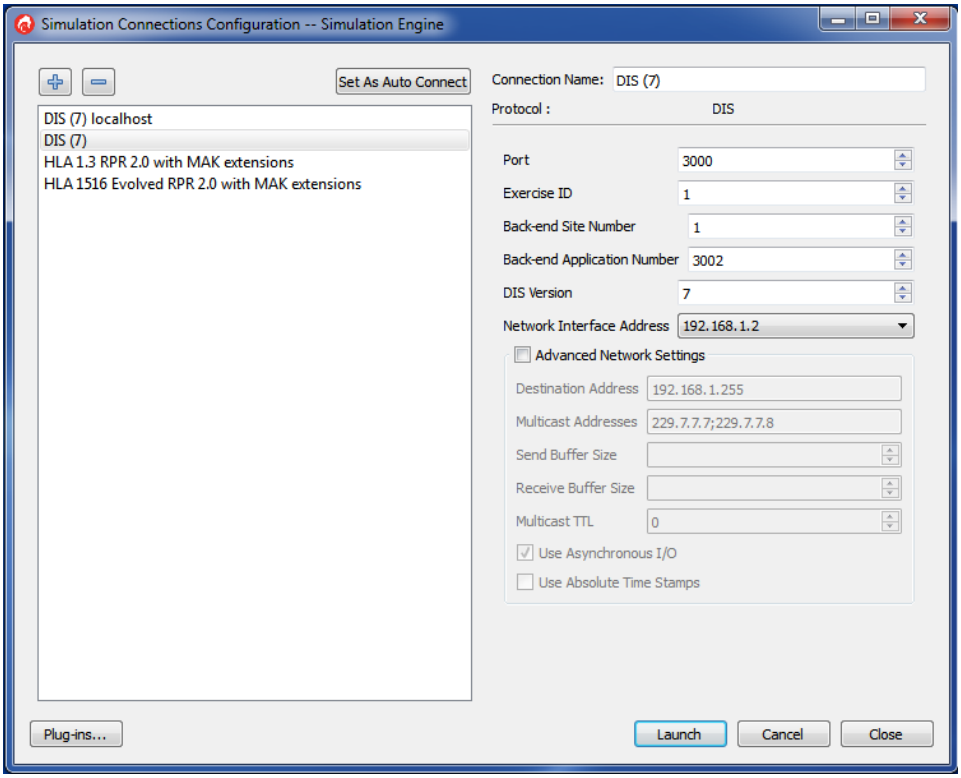

Figure 28 Back End 3002 Simulation Connection Configuration Settings

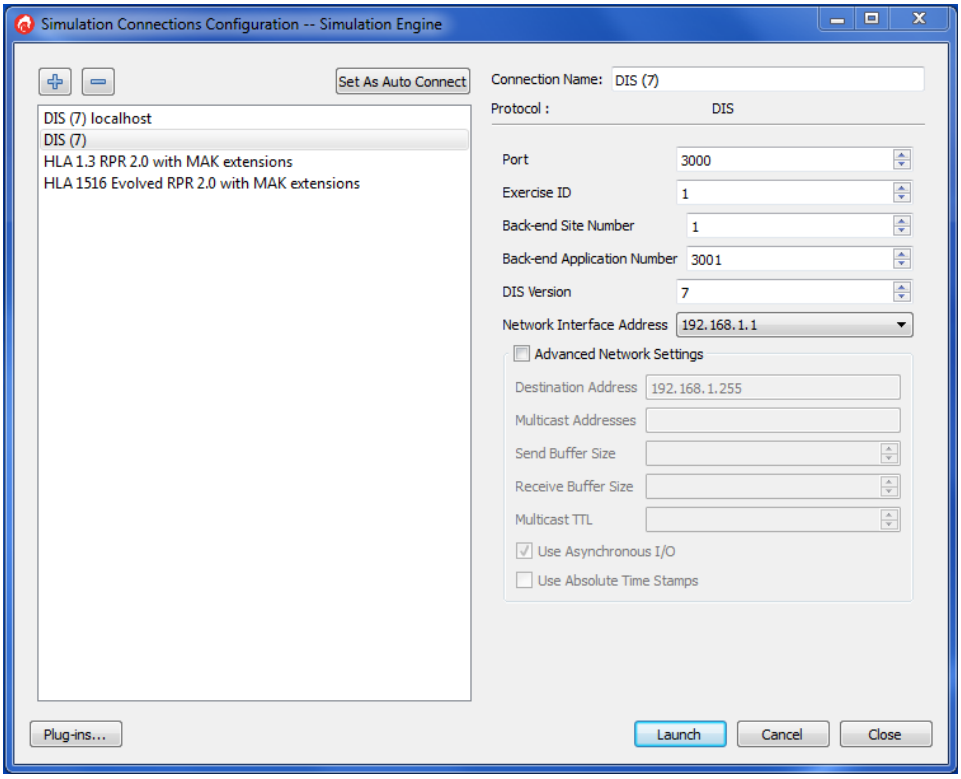

Figure 29 Back End 3001 Simulation Connection Configuration Settings

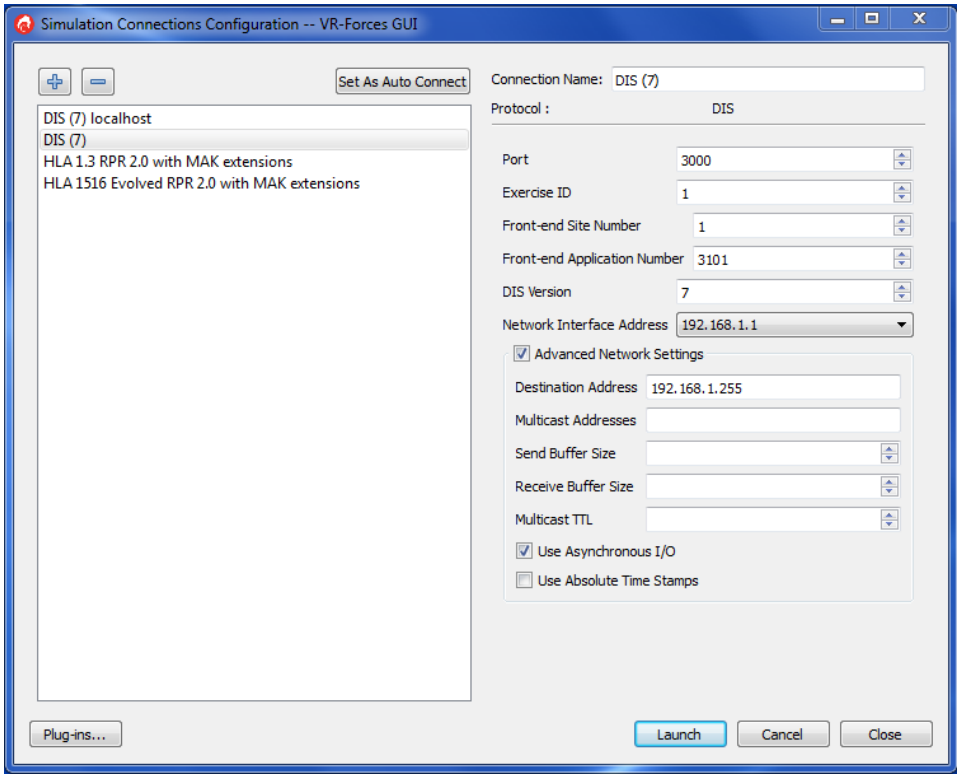

Figure 30 GUI 3101 Simulation Connection Configuration Settings

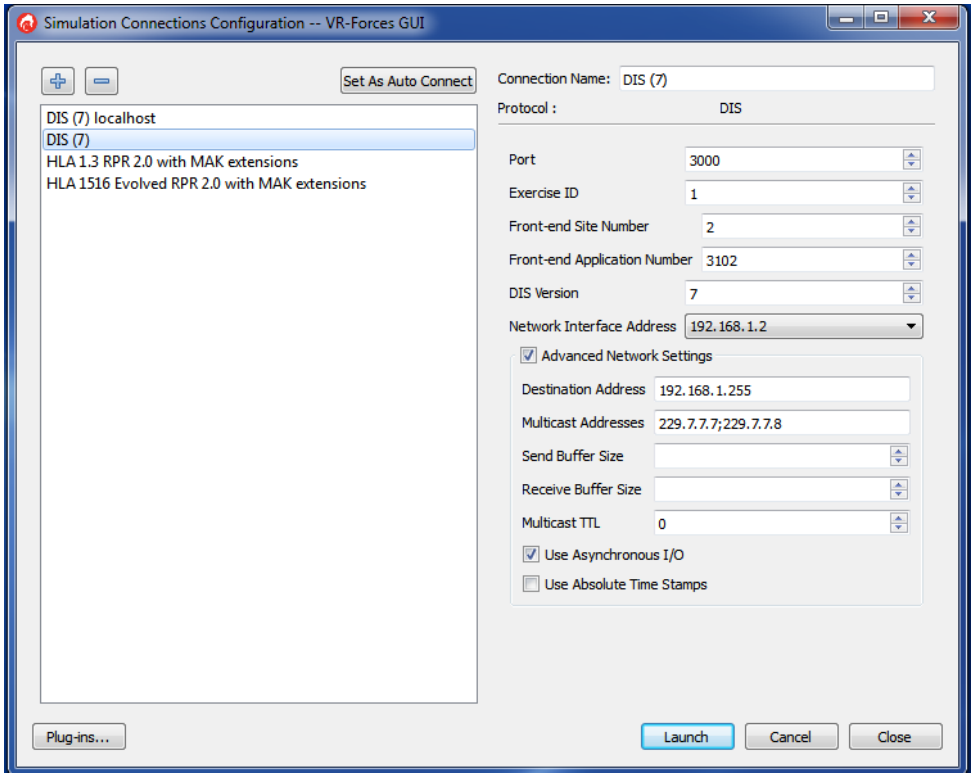

Figure 31 GUI 3102 Simulation Connection Configuration Settings

7.3. VR Vantage Stealth

VR Vantage Stealth is a viewer client which provides various views of a scenario. One VR Vantage Stealth client was run on a third machine on the isolated network. Setup required a VR Forces scenario to be open, starting the VR Vantage Stealth client, and manually opening the appropriate terrain. Model and simulation data is loaded automatically by VR Vantage Stealth. VR Vantage Stealth was primarily used as a third viewer during demonstration simulation runs. Plan view and stealth view were the modes primarily used during simulation runs. Plan view provides a 2D map view, while stealth view provides a 3D view of the battle in which you can attach the camera to a particular entities or manually control the camera angle.

8. Appendix B - Detailed Model Layout

8.1. US Forces

US Forces were simulated on the VR Forces 3002 Simulation Engine.

8.1.1. Eagle Troop Tank Aggregate Group

The Eagle Troop Tank Aggregate group is positioned with a heading of 120° from North at 29.535828° Latitude and 46.512356° Longitude.

8.1.1.1. Aggregate Group Composition

Table 1 Eagle Troop, Tank Aggregate Group Composition

Entity Position	Entity Type	Role in Battle
1	M1A2 Abrams	Eagle Troop Commander
2	M1A2 Abrams	Eagle Troop Tank
3	M1A2 Abrams	Eagle Troop Tank
4	M1A2 Abrams	Eagle Troop Tank
5	M1A2 Abrams	Eagle Troop Tank
6	M1A2 Abrams	Eagle Troop Tank
7	M1A2 Abrams	Eagle Troop Tank
8	M1A2 Abrams	Eagle Troop Tank
9	M1A2 Abrams	Eagle Troop Tank
10	M1A2 Abrams	2nd Armored Cavalry Division Commander
11	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
12	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
13	M577A2 Command Post	2nd Armored Cavalry Division Command Post
14	M113 APC	Eagle Troop Mortar
15	M113 APC	Eagle Troop Mortar

8.1.1.2. Formation Configurations

Table 2 Eagle Troop, Tank Aggregate Group Formations

Entity Position	Entity Type	Scout Formation (m)	Attack Formation (m)
1	M1A2 Abrams	(0,0)	(0,0)
2	M1A2 Abrams	(-100,-100)	(-100,-100)
3	M1A2 Abrams	(100,-100)	(100,-100)
4	M1A2 Abrams	(-200,-200)	(-200,-200)
5	M1A2 Abrams	(200,-200)	(200,-200)

Entity Position	Entity Type	Scout Formation (m)	Attack Formation (m)
6	M1A2 Abrams	(-300,-300)	(-300,-300)
7	M1A2 Abrams	(300,-300)	(300,-300)
8	M1A2 Abrams	(-400,-400)	(-400,-400)
9	M1A2 Abrams	(400,-400)	(400,-400)
10	M1A2 Abrams	(-50,-250)	(-50,-250)
11	M2A2 Bradley IFV-TOW	(-50,200)	(-150,-350)
12	M2A2 Bradley IFV-TOW	(50,200)	(150,-350)
13	M577A2 Command Post	(0,-350)	(0,-350)
14	M113 APC	(-50,100)	(-250,-450)
15	M113 APC	(50,100)	(250,-450)

8.1.1.3. Entity Plan

Wait-Duration Seconds-To-Wait: 15
When (Entity-In-Area:SELF,,Entity:"" Area: "Area 1") do
    Set Current Speed=36.0 (km/h)
Endwhen
Set Current Speed=36.0 (km/h)
Set Speed=36.0 (km/h)
Move-To Waypoint: "Village – Eagle Tank"
Move into formation: formation: Attack loc: {29.507428, 46.555868, 251}heading: 85.0 (Deg)
Wait-Duration Seconds-To-Wait:30
Set Target="Iraqi Battalion"
Move-To Waypoint: "First Encounter"
Wait-Duration Seconds-To-Wait:1
Set Target="Iraqi Coil Reserve"
Move-To Waypoint: "73 Easting – Eagle Tank"

8.1.2. Eagle Troop Scout Aggregate Group

The Eagle Troop 1st Scout Platoon Aggregate group is positioned with a heading of 115 degrees from North at 29.535828° Latitude and 46.512356° Longitude. The Eagle Troop 3rd Scout Platoon Aggregate group is positioned with a heading of 115° from North at 29.545186° Latitude and 46.518124° Longitude.

8.1.2.1. Aggregate Group Composition

Table 3 Eagle Troop, 1st Scout Platoon Aggregate Group Composition

Entity Position	Entity Type	Role in Battle
1	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
2	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
3	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle

Entity Position	Entity Type	Role in Battle
4	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle

Table 4 Eagle Troop, 3rd Scout Platoon Aggregate Group Composition

Entity Position	Entity Type	Role in Battle
1	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
2	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
3	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
4	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
5	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle
6	M2A2 Bradley IFV-TOW	Eagle Troop Bradley Fighting Vehicle

8.1.2.2. Formation Configuration

Table 5 Eagle Troop, 1st Scout Aggregate Group Formation

Eagle Troop 1st Scout Platoon		
Entity Position	**Entity Type**	**Plt Scout Formation**
1	M2A2 Bradley IFV-TOW	(-100,50)
2	M2A2 Bradley IFV-TOW	(0,0)
3	M2A2 Bradley IFV-TOW	(0,-150)
4	M2A2 Bradley IFV-TOW	(0,-350)

Table 6 Eagle Troop, 3rd Scout Aggregate Group Formation

Eagle Troop 3rd Scout Platoon		
Entity Position	**Entity Type**	**Plt Scout Formation (m)**
1	M2A2 Bradley IFV-TOW	(-100,50)
2	M2A2 Bradley IFV-TOW	(0,0)
3	M2A2 Bradley IFV-TOW	(0,-150)
4	M2A2 Bradley IFV-TOW	(-100,-100)
5	M2A2 Bradley IFV-TOW	(-250,-100)
6	M2A2 Bradley IFV-TOW	(0,-350)

8.1.2.3. 1st Scout Platoon Entity Plan

Wait-Duration Seconds-To-Wait: 15

When (Entity-In-Area:SELF,,Entity:”” Area: ”Area 1”) do

Set Current Speed=36.0 (km/h)

Endwhen
When (Detect Entity “Village unit” with identification of at least “Detected ,,”) do
Set Data Request; Object: Eagle Tanks Request: Set Target=”Village unit”
Task Object Eagle Tanks Task: Fire Weapon Task: auto select weapon = True. Target = Village unit Rounds to fire = 5
Endwhen
When (Detect Entity “Iraqi Battalion” with identification of at least “Detected ,,”) do
Set Data Request; Object: Eagle Tanks Request: Set Target=”Iraqi Battalion”
Task Object Eagle Tanks Task: Fire Weapon Task: auto select weapon = True. Target = Village unit Rounds to fire = 20
Endwhen
Set Current Speed=36.0 (km/h)
Set Speed=36.0 (km/h)
Move-To Waypoint: “Village – Eagle 1st Scout”
Move-To Waypoint: “Battalion – Eagle 1st Scout”
Move-To Waypoint: “73 Easting – Eagle 1st Scout”

8.1.2.4. 3rd Scout Platoon Entity Plan

Wait-Duration Seconds-To-Wait: 15
When (Entity-In-Area:SELF,,Entity:”” Area: ”Area 1”) do
Set Current Speed=36.0 (km/h)
Endwhen
Set Current Speed=36.0 (km/h)
Set Speed=36.0 (km/h)
Move-To Waypoint: “Village – Eagle 3rd Scout”
Wait-Duration Seconds-To-Wait:150
Move-To Waypoint: “Battalion – Eagle 3rd Scout”
Wait-Duration Seconds-To-Wait:150
Move-To Waypoint: “73 Easting – Eagle 3rd Scout”

8.1.3. Iron Troop Aggregate Group

The Iron Troop Aggregate group is positioned with a heading of 90° from North at 29.483056° Latitude and 46.516105° Longitude.

8.1.3.1. Aggregate Group Composition

Table 7 Iron Troop Aggregate Group Composition

Entity Position	Entity Type	Role in Battle
1	M1A2 Abrams	Iron Troop Commander
2	M1A2 Abrams	Iron Troop Tank
3	M1A2 Abrams	Iron Troop Tank
4	M1A2 Abrams	Iron Troop Tank
5	M1A2 Abrams	Iron Troop Tank
6	M1A2 Abrams	Iron Troop Tank
7	M1A2 Abrams	Iron Troop Tank

Entity Position	Entity Type	Role in Battle
8	M1A2 Abrams	Iron Troop Tank
9	M1A2 Abrams	Iron Troop Tank
11	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
12	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
13	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
14	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
15	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
16	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
17	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
18	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
19	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
20	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle
21	M2A2 Bradley IFV-TOW	Iron Troop Bradley Fighting Vehicle

8.1.3.2. Formation Configurations

Table 8 Iron Troop Aggregate Group Formation

Entity Position	Entity Type	Attack Formation (m)
1	M1A2 Abrams	(0,0)
2	M1A2 Abrams	(200,0)
3	M1A2 Abrams	(-200,0)
4	M1A2 Abrams	(400,0)
5	M1A2 Abrams	(-400,0)
6	M1A2 Abrams	(600,0)
7	M1A2 Abrams	(-600,0)
8	M1A2 Abrams	(800,0)
9	M1A2 Abrams	(-800,0)
10	M2A2 Bradley IFV-TOW	(-100,-100)
11	M2A2 Bradley IFV-TOW	(100,-100)
12	M2A2 Bradley IFV-TOW	(-300,-100)
13	M2A2 Bradley IFV-TOW	(300,-100)
14	M2A2 Bradley IFV-TOW	(-500,-100)
15	M2A2 Bradley IFV-TOW	(500,-100)

Entity Position	Entity Type	Attack Formation (m)
16	M2A2 Bradley IFV-TOW	(1100,300)
17	M2A2 Bradley IFV-TOW	(1100,200)
18	M2A2 Bradley IFV-TOW	(1100,-650)
19	M2A2 Bradley IFV-TOW	(-1100,300)
20	M2A2 Bradley IFV-TOW	(-1100,200)
21	M2A2 Bradley IFV-TOW	(-1150,-650)

8.1.3.3. Entity Plan

When (Entity-In-Area:SELF,,Entity:"" Area: "Area 1") do
    Set Current Speed=36.0 (km/h)
Endwhen
Wait-Duration Seconds-To-Wait: 250
Set Current Speed=36.0 (km/h)
Set Speed=36.0 (km/h)
Move-To Waypoint: "70 Easting – Iron Troop"
Move-To Waypoint: "73 Easting – Iron Troop"
Wait-Duration Seconds-To-Wait:20
Set Target= "Southern Iraqi Flank"
Set Current Speed=36.0 (km/h)
Set Speed=36.0 (km/h)
Move-To Waypoint: "70 Easting – Iron Troop"

8.1.4. Ghost Troop Aggregate Group

The Ghost Troop Tank Aggregate group is positioned with a heading of 90° from North at 29.588174° Latitude and 46.513901° Longitude.

8.1.4.1. Aggregate Group Composition

Table 9 Ghost Troop Aggregate Group Composition

Entity Position	Entity Type	Role in Battle
1	M1A2 Abrams	Ghost Troop Commander
2	M1A2 Abrams	Ghost Troop Tank
3	M1A2 Abrams	Ghost Troop Tank
4	M1A2 Abrams	Ghost Troop Tank
5	M1A2 Abrams	Ghost Troop Tank
6	M1A2 Abrams	Ghost Troop Tank
7	M1A2 Abrams	Ghost Troop Tank
8	M1A2 Abrams	Ghost Troop Tank
9	M1A2 Abrams	Ghost Troop Tank

Entity Position	Entity Type	Role in Battle
11	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
12	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
13	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
14	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
15	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
16	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
17	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
18	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
19	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
20	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle
21	M2A2 Bradley IFV-TOW	Ghost Troop Bradley Fighting Vehicle

8.1.4.2. Formation Configurations

Table 10 Ghost Troop Aggregate Group Formation

Entity Position	Entity Type	Attack Formation (m)
1	M1A2 Abrams	(0,0)
2	M1A2 Abrams	(200,0)
3	M1A2 Abrams	(-200,0)
4	M1A2 Abrams	(400,0)
5	M1A2 Abrams	(-400,0)
6	M1A2 Abrams	(600,0)
7	M1A2 Abrams	(-600,0)
8	M1A2 Abrams	(800,0)
9	M1A2 Abrams	(-800,0)
10	M2A2 Bradley IFV-TOW	(-100,-100)
11	M2A2 Bradley IFV-TOW	(100,-100)
12	M2A2 Bradley IFV-TOW	(-300,-100)
13	M2A2 Bradley IFV-TOW	(300,-100)
14	M2A2 Bradley IFV-TOW	(-500,-100)
15	M2A2 Bradley IFV-TOW	(500,-100)
16	M2A2 Bradley IFV-TOW	(1100,300)
17	M2A2 Bradley IFV-TOW	(1100,200)

Entity Position	Entity Type	Attack Formation (m)
18	M2A2 Bradley IFV-TOW	(1100,-650)
19	M2A2 Bradley IFV-TOW	(-1100,300)
20	M2A2 Bradley IFV-TOW	(-1100,200)
21	M2A2 Bradley IFV-TOW	(-1150,-650)

8.1.4.3. Entity Plan

When (Entity-In-Area:SELF,,Entity:"" Area: "Area 1") do
    Set Current Speed=36.0 (km/h)
Endwhen
Wait-Duration Seconds-To-Wait: 300
Set Target= "Northern Iraqi Flank"
Set Current Speed=36.0 (km/h)
Set Speed=36.0 (km/h)
Move-To Waypoint: "73 Easting – Ghost Troop"

8.2. Iraqi Forces

Iraqi Forces were simulated on the VR Forces 3001 Simulation Engine.

8.2.1. Village

8.2.1.1. Troop Placement

Table 11 Iraqi Village Troop Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Shilka			
AA 2	0	29.500836	46.553461
AA 3	0	29.500835	46.553538
Iraqi Infantry			
R 1	0	29.500792	46.553158
R 2	0	29.500779	46.553215
R 3	0	29.500725	46.553359
R 4	0	29.500735	46.553441
R 5	0	29.500815	46.553623
R 6	0	29.500764	46.553757
R 7	0	29.500857	46.553825
R 8	0	29.500685	46.553604

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
R 9	0	29.500693	46.553853
R 10	0	29.500681	46.553114
R 11	180	29.500175	46.553126
R 12	180	29.500173	46.553244
R 13	180	29.500175	46.553436
R 14	180	29.500173	46.553496
R 15	180	29.500215	46.553601
R 16	180	29.500133	46.553877
R 17	180	29.500129	46.553925
R 18	180	29.500275	46.553882
R 19	180	29.500257	46.553345
R 20	180	29.500257	46.553297

8.2.2. Iraqi Battalion

8.2.2.1. Troop Placement

Table 12 Iraqi Battalion Troop Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Iraqi BMP			
BMP 32	315	29.519951	46.606008
BMP 33	300	29.519464	46.605039
BMP 34	270	29.515253	46.605928
BMP 35	0	29.519465	46.606978
BMP 36	0	29.518987	46.607957
BMP 37	180	29.514991	46.606897
BMP 38	270	29.515974	46.607865
BMP 39	270	29.518518	46.607947
BMP 40	180	29.515478	46.607865
BMP 41	225	29.514477	46.606021
BMP 42	240	29.515009	46.604948
Iraqi T-72			

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
AR 24	270	29.518500	46.605039
AR 25	270	29.518022	46.605039
AR 26	270	29.517526	46.605040
AR 27	270	29.518283	46.605524
AR 28	270	29.517282	46.605524
AR 29	235	29.515003	46.600697
AR 30	270	29.517778	46.605524
AR 31	270	29.515749	46.605433
AR 32	270	29.516754	46.605497
AR 33	190	29.514684	46.602762
AR 34	270	29.518500	46.606493
AR 35	270	29.516064	46.605040
AR 36	270	29.516551	46.605040
AR 37	270	29.517038	46.605040
AR 38	270	29.516317	46.605524
AR 39	270	29.516552	46.606494
AR 40	270	29.517526	46.606494
AR 41	270	29.516227	46.606896
AR 42	270	29.518283	46.606978
AR 43	270	29.518013	46.606493
AR 44	270	29.515983	46.606401
AR 45	270	29.517039	46.606494
AR 46	270	29.514522	46.603010
AR 47	190	29.514521	46.602031
AR 48	190	29.514702	46.602278
AR 49	190	29.514522	46.602515
AR 50	235	29.514999	46.600476
AR 51	235	29.514993	46.600259
AR 52	270	29.518761	46.605514
Shilka			
AA 1	270	29.517526	46.607205

8.2.3. Iraqi Coil Reserve

8.2.3.1. Troop Placement

Table 13 Iraqi Coil Reserve Troop Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Iraqi T-72			
AR 1	50	29.545698	46.628226
AR 2	75	29.545197	46.628573
AR 3	90	29.544565	46.628558
AR 4	150	29.543186	46.627284
AR 5	30	29.546100	46.627696
AR 6	0	29.546351	46.627045
AR 7	340	29.546275	46.626004
AR 8	320	29.546115	46.625239
AR 9	295	29.545660	46.624701
AR 10	270	29.545136	46.624311
AR 11	250	29.544468	46.624373
AR 12	225	29.543844	46.624384
AR 13	210	29.543282	46.624720
AR 14	180	29.543113	46.626551
AR 15	100	29.543864	46.628319
AR 16	135	29.543437	46.627855
AR 17	180	29.543098	46.625706
Iraqi BMP			
BMP 1	175	29.544118	46.626516
BMP 2	100	29.544772	46.627680
BMP 3	75	29.545271	46.627524
BMP 4	270	29.544859	46.625465
BMP 5	30	29.545569	46.626989
BMP 6	200	29.541978	46.625249
BMP 7	0	29.545612	46.626290

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
BMP 8	270	29.544578	46.624873
BMP 9	290	29.545249	46.624996
BMP 10	180	29.541821	46.626246
BMP 11	125	29.544208	46.627458
BMP 12	195	29.544189	46.625603
BMP 13	180	29.543633	46.626224
BMP 14	190	29.543665	46.625538
BMP 15	165	29.543786	46.626910
BMP 16	245	29.542471	46.624338
BMP 17	200	29.543920	46.625012
BMP 18	305	29.545574	46.625508

8.2.4. Iraqi Tanks North of Reserve

8.2.4.1. Troop Placement

Table 14 Iraqi Tanks, North of Reserve Troop Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Iraqi T-72			
AR 18	315	29.549977	46.624168
AR 19	320	29.550948	46.624339
AR 20	325	29.551142	46.625466

8.2.5. Northern Iraqi Flank

8.2.5.1. Troop Placement

Table 15 Iraqi Northern Flank Troop Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Iraqi T-72			
AR 21	270	29.586714	46.635264
AR 22	270	29.587736	46.635253

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
AR 23	270	29.587234	46.635264
Iraqi BMP			
BMP 19	270	29.586935	46.635909
BMP 20	270	29.587490	46.635898
BMP 21	270	29.588662	46.635243
BMP 22	315	29.589358	46.635636
BMP 23	270	29.584809	46.636924
BMP 24	270	29.585948	46.635616
BMP 25	300	29.588821	46.636413
BMP 26	255	29.585614	46.636503
BMP 27	225	29.584330	46.636562
BMP 28	225	29.583636	46.636790
BMP 29	315	29.590091	46.636016
BMP 30	315	29.590863	46.635996
BMP 31	225	29.585059	46.636080

8.2.6. Northern Iraqi Scouts

8.2.6.1. Troop Placement

Table 16 Iraqi Northern Scouts Troop Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Iraqi T-72			
AR 54	270	29.579876	46.588277
AR 55	270	29.580429	46.588296

8.2.7. Southern Iraqi Flank

8.2.7.1. Troop Placement

Table 17 Iraqi Southern Flank Troop Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Iraqi T-72			
AR 56	270	29.473009	46.616006
AR 57	270	29.472006	46.616000
AR 58	270	29.471003	46.616007
AR 59	270	29.474007	46.616000
AR 60	270	29.473505	46.616455
AR 61	270	29.472502	46.616492
AR 62	270	29.471472	46.616492
AR 63	270	29.470451	46.616520
AR 64	270	29.470017	46.615997
AR 65	270	29.474532	46.616491
AR 66	270	29.475021	46.615988
AR 67	270	29.472018	46.617992
AR 68	270	29.473011	46.618010
AR 69	270	29.474012	46.617982
AR 70	270	29.471018	46.618010
AR 71	270	29.472539	46.618998

8.2.8. Southern Iraqi Scouts

8.2.8.1. Troop Placement

Table 18 Iraqi Southern Scout Placement

Entity Type	Entity Heading (Degrees from North)	Position	
		Latitude	Longitude
Iraqi T-72			
AR 53	270	29.516896	46.590007
Iraqi BMP			
BMP 43	270	29.517218	46.590019

8.3.Tactical Marker Layout

Table 19 73 Easting Waypoint Position

Waypoint	Position	
	Latitude	Longitude
Village - Eagle 3rd Scout	29.517024	46.555961
Village - Eagle Tank	29.507428	46.555868
Village	29.500411	46.553066
Village - Eagle1st Scout	29.498438	46.551412
70 Easting - Iron Troop	29.483484	46.553986
Battalion - Eagle 3rd Scout	29.523111	46.596564
First Encounter	29.516442	46.602306
Battalion - Eagle 1st Scout	29.507329	46.604578
73 Easting - Eagle 3rd Scout	29.552396	46.621443
73 Easting - Eagle Tank	29.546658	46.627783
Coil	29.542744	46.625833
73 Easting - Eagle 1st Scout	29.542485	46.634344
73 Easting - Ghost Troop	29.587307	46.639988
73 Easting - Iron Troop	29.470455	46.636901

Table 20 73 Easting Tactical Marker Locations

Areas	Points	Position		
		Latitude (m)	Longitude (m)	Altitude (m)
Area 1	Center Point	29.534695	46.596924	88
	Point 0	29.620722	46.440922	239
	Point 1	29.451772	46.443119	0
	Point 2	29.447487	46.751199	0
	Point 3	29.618429	46.752448	212

9. Appendix C - Modifications to Iraqi

Table 21 T-72 125mm Gun Load and Unload Times

	Load Time (in seconds)	Unload Time (in seconds)
Initial Values	5	5
Final Values	15	15

Table 22 Probability of Hit Tables for T-72 125mm Gun

Range (in meters)	Initial Probability of Hit	Final Probability of Hit
1000	0.9	0.08
2000	0.8	0.04
3000	0.75	0.02
4000	0.7	0.01

Table 23 Probability of Hit Tables for BMP-1 Grom Gun

Range (in meters)	Initial Probability of Hit	Final Probability of Hit
500	0.4	0.075
1000	0.5	0.125
1500	0.4	0. 075
2000	0.2	0.033

Table 24 Load and Unload Times of BMP ATGM Launcher

	Load Time (in seconds)	Unload Time (in seconds)
Initial Values	10	5
Final Values	45	45

10. Appendix D - Detailed Simulation Results

Table 21 Simulation Runs and Results

	American Casualties									Iraqi Casualties							
	Eagle					Iron		Ghost		Iraqi-Eagle			Iraqi-Iron	Iraqi-Ghost		Iraqi Village	
	Bradley	XM7FIST	M577A2	M113	M1A1	Bradley	M1A1	Bradley	M1A1	BMP	T-72	Shilka	T-72	T-72	BMP	Infantry	ZSU-23-4
MAX	12	1	1	2	10	12	9	12	9	30	50	1	16	5	13	20	2
P1	7	0	1	2	10	0	0	3	0	29	42	1	16	5	13	20	2
P2	12	1	1	2	10	2	0	2	4	20	35	1	16	5	13	20	2
P3	12	1	1	2	10	3	0	2	0	18	36	1	16	5	13	20	2
P4	0	0	0	0	2	1	0	2	1	30	49	1	16	5	13	20	2
P5	0	0	0	0	2	0	1	2	1	30	50	1	16	5	13	20	2
P6	0	0	0	0	3	0	1	0	1	30	50	1	16	5	13	20	2
P7	0	0	0	0	2	0	1	0	0	30	50	1	16	5	13	20	2
P8	2	0	0	0	2	1	1	0	0	30	50	1	16	5	13	20	2
P9	0	0	0	0	1	2	0	0	0	30	50	1	16	5	13	19	2
P10	0	0	0	0	3	1	0	1	0	30	50	1	16	5	13	20	2
P11	0	0	0	0	3	0	0	0	0	30	50	1	16	5	13	20	2
P12	0	0	0	0	1	1	0	1	0	30	50	1	16	5	13	20	2
P13	0	0	0	0	2	2	0	0	0	30	50	1	16	5	13	20	2
P14	0	0	0	0	0	0	0	0	0	30	50	1	16	5	13	20	2
P15	1	0	0	0	3	1	1	0	1	30	50	1	16	5	13	20	2
P16	0	0	0	0	2	2	0	0	0	30	50	1	16	5	13	20	2
P17	0	0	0	0	0	0	0	0	0	30	50	1	16	5	13	20	2
P18	0	0	0	0	2	0	0	0	2	30	50	1	16	5	13	20	2
P19	0	0	1	0	3	0	0	0	0	30	50	1	16	5	13	20	2
P20	1	0	0	0	2	0	0	0	1	30	50	1	16	5	13	20	2

Table 26 Detailed Results of Final Runs

	American Casualties per Unit									Iraqi Casualties per Unit							
	Eagle					Iron		Ghost		Iraqi-Eagle			Iraqi-Iron	Iraqi-Ghost		Iraqi Village	
	Bradley	XM7FIST	M577A2	M113	M1A1	Bradley	M1A1	Bradley	M1A1	BMP	T-72	Shilka	T-72	T-72	BMP	Infantry	ZSU-23-4
MAX	12	1	1	2	10	12	9	12	9	30	50	1	16	5	13	20	2
Run 1	0	0	0	0	1	0	0	0	1 (FF)	30	50	1	16	5	13	20	2
Run 2	0	0	0	0	1	0	0	1	0	30	50	1	16	5	13	20	2
Run 3	0	0	0	0	0	0	0	0	0	30	50	1	16	5	13	20	2
Run 4	0	0	0	1	2	0	0	0	0	30	50	1	16	5	13	20	2
Run 5	0	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 6	0	0	0	0	2	0	1 (FF)	1	0	30	50	1	16	5	13	20	2
Run 7	0	0	0	0	0	1	0	0	0	30	50	1	16	5	13	20	2
Run 8	0	0	0	0	0	0	0	1	0	30	50	1	16	5	13	20	2
Run 9	0	0	0	0	1	0	0	0	1	30	50	1	16	5	13	19	2
Run 10	1	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 11	0	0	0	0	0	0	0	0	0	30	50	1	16	5	13	20	2
Run 12	1	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 13	0	0	0	0	1	1	1	0	0	30	50	1	16	5	13	20	2
Run 14	0	0	0	0	0	1	0	0	1 (FF)	30	50	1	16	5	13	20	2
Run 15	0	0	0	0	1	0	0	0	1	30	50	1	16	5	13	20	2
Run 16	0	0	0	0	1	1	0	0	1	30	50	1	16	5	13	20	2
Run 17	1	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 18	1	0	0	0	1	0	1 (FF)	0	0	30	50	1	16	5	13	20	2
Run 19	0	0	0	0	1	0	0	1	0	30	50	1	16	5	13	20	2
Run 20	0	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 21	0	0	0	0	2	1	0	0	0	30	50	1	16	5	13	19	2
Run 22	0	0	0	0	0	0	0	0	1	30	50	1	16	5	13	20	2
Run 23	0	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 24	0	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 25	0	0	0	0	2	1	0	0	1 (FF)	30	50	1	16	5	13	20	2
Run 26	0	0	0	0	0	0	0	0	0	30	50	1	16	5	13	20	2
Run 27	1	0	0	0	1	0	0	0	0	30	50	1	16	5	13	20	2
Run 28	0	0	1	0	1	0	0	1	1	30	50	1	16	5	13	20	2
Run 29	1	0	0	0	1	0	0	1	0	30	50	1	16	5	13	20	2
Run 30	0	0	0	0	1	1	1	0	0	30	50	1	16	5	13	20	2

Note: Entries labeled (FF) refer to observed incidents of friendly fire.

Table 27 Detailed Results of Final Runs by Total Casualties per Force

	Total American Casualties	Total Iraqi Casualties (Vehicles Only)
	2	117
	2	117
	0	117
	3	117
	1	117
	4	117
	1	117
	1	117
	2	117
	2	117
	0	117
	2	117
	3	117
	2	117
	2	117
	3	117
	2	117
	3	117
	2	117
	1	117
	3	117
	1	117
	1	117
	1	117
	4	117
	0	117
	2	117
	4	117
	3	117
	3	117
Mean	2.00	117.00
Std. Dev.	1.13	0.00