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METHODOLOGY AND ANALYSIS OF GROUND MANEUVER SYNCHRONIZATION AT THE NATIONAL TRAINING CENTER

by

Joel R. Parker

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Thesis Co-Advisors: Robert R. Read
David A. Dryer

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Methodology and Analysis of Ground Maneuver Synchronization at the National Training Center

by

Joel R. Parker
Captain, United States Army
B.S., University of Kansas, 1981

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Author: ______________________________
Joel R. Parker

Approved by: ______________________________
Robert R. Read, Co-Advisor

____
David A. Dryer, Co-Advisor

____
Laura D. Johnson, Second Reader

____
Peter Purdue, Chairman
Department of Operations Research

ABSTRACT

This thesis analyzes deliberate attack missions conducted at the U.S. Army National Training Center and checks for relationships between ground force synchronization at the mission critical point and a measure of effectiveness. This analysis should facilitate the development of similar or more in-depth studies of combined arms operations in desert warfare. Procedures are developed to quantify the core offensive doctrinal concepts addressed in U.S. Army Field Manual 100-5: Operations. The thesis also addresses current critical shortfalls in the National Training Center data collection process and identifies agencies which can potentially render corrective support.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

A. PURPOSE AND SCOPE

The purpose of this study is to develop a framework for quantifying proper **GROUND MANEUVER SYNCHRONIZATION**[1] in U.S. **BATTALION TASK FORCE** deliberate attack missions conducted at the United States Army's National Training Center[2]. Such an analytically supportable framework can then be translated to rules of thumb or general guides for battalion task force commanders and their staffs in planning and preparing similar, future deliberate attack missions. The proposed framework, or methodology, will consist of simple, objective[3], yet robust, techniques for quantifying U.S. offensive doctrinal concepts consistent with U.S. Army Field Manual 100-5 (Operations) [Ref. 3].

Because battlefield synchronization implies proper **COMMAND AND CONTROL**, it is imperative that any study of U.S. military synchronization include considerations of command and control. This paper meets this requirement by employing the concept of

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1 Bold, capitalized terms are defined in Glossary

2 Commonly referred to as NTC by U.S. Army personnel; See Section D of this Chapter for more information

3 The only subjective step in the methodology for quantifying ground maneuver synchronization is the identification of the mission critical region (see Chapter III,B).

This paper meets this requirement by employing the concept of **MOMENTUM** at the team, or company, level and synchronization at the battalion task force level as measures. Equally as important for the study of synchronization, are the military concepts of mass and speed together with time and space relationships. All are incorporated in this study.

In order to support clarity in this analysis-- because of the vast diversity and number of systems comprising any battalion task force conducting operations at the National Training Center-- this paper limits its study to mounted tank-killing systems only. By focusing on the tank-killing system, we concentrate on the heart of the task force commanders ground **PUNCH POWER**.

Although, platoons are the Army's basic maneuver element, this paper aggregates platoons to the team, or company level. Aggregating platoons into the 4 or 5 companies, or teams, of a task force allows for a much clearer picture of the battalion task force elements and their time and space relationships at the critical point in the mission.

A number of National Training Center battles were studied. No formal sample size analysis was conducted. A great deal of time was required in determining a feasible method for extracting individual samples from the Army Research Institute-Presidio of Monterey (ARI-POM) Combat Training Center's (CTC) archive located in Monterey, California.

The automated portion of the ARI-CTC archive lacks critical data required for in depth research of offensive operations at the National Training Center.

It is common to see a particular system killed, in simulation, several times in one National Training Center mission. Therefore, the earliest recorded "DEAD" time for any particular system (i.e. vehicle) in the **INGRES, MORTALITY FILE** is used as the system's simulated death in the deliberate attack mission.

The percentage of U.S. and opposing force system kills are most accurately recorded in the observer-controller generated Take Home Package (THP) produced at the conclusion of each task force training cycle at the National Training Center. Therefore, these figures are used to produce the respective task force mission measures of effectiveness (MOE).

The aggregation of momentum, and thus command and control, at the team level will not significantly dilute the accuracy of this study's findings. Recall that in accordance with U.S. Army doctrine, the lowest echelon of command and control lies with the platoon commander[4].

A sample of 17 battles serves to support our research findings. The data for each battle, or mission, in the sample is collected at five minute intervals. Periodically, through out this paper the terms snapshot or time-step will be

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[4] See Glossary: COMMAND AND CONTROL

substituted for "five minute intervals". Any of these terms refer to the time period immediately following the last data collection point in a given mission.

It is reasonable to assume that the average cross-country speed for tank-killing systems (i.e. vehicles mounted with organic tank-killing systems) given NTC terrain is approximately 24 kilometers per hour (i.e. 14.8 miles per hour). The importance of this assumption is addressed in Chapter III.

B. PROBLEM DESCRIPTION AND HYPOTHESIS

A significant portion of U.S. battalion task forces conducting deliberate attack missions at the National Training Center fail to optimally synchronize their tank killing, maneuver teams during the critical point in the mission. This synchronization factor, as developed in this paper, will be analyzed and its influence on mission success.

This done, we address the hypothesis: At the critical point in the mission, proper ground maneuver synchronization for U.S. battalion task forces conducting deliberate attacks at the National Training Center is one task force penetration of the opposing force's defensive belt. The attacking force's teams follow one behind the other at 5-minute intervals through the **BREACH**, with each team displaying a high level of momentum.

C. PRESENTATION

This document is written primarily for a reader who is familiar with U.S. Army doctrinal terms and concepts. However, for those readers lacking such a background, a glossary of terms and concepts is provided for assistance.

All terms and concepts unique or varied by the U.S. Army are presented as small capital, bold text as they are individually introduced in each chapter. For example the term **ORGANIC** will appear in the body of the text, as it does here, the first time it is introduced in each successive chapter. If the reader is unfamiliar with this term, the glossary will provide insight.

Chapter I contains a brief explanation of the military environment involved in this study; a thorough overview of this study's purpose and its relevance to specific U.S. Army doctrinal issues and what the reader's expectations should be when reading this report. Chapter II provides a discussion of the U.S. Army doctrinal concepts introduced in this study and how they are quantified. The analytical tools and methodology employed in this study to obtain a final data set are discussed in Chapter III. This set is used for statistical analysis in Chapter IV. Chapter IV is limited to the discussion of the final data sample set analysis.

Chapter V concludes the study by providing a summary discussion of any analytical results, their implications and how they support or refute the stated hypothesis and suggestions for future analysis in this area.

D. BACKGROUND AND INSIGHT

The United States (U.S.) Army's National Training Center (NTC) is located in southern California's desert region. The NTC's purpose is to provide U.S. Army maneuver task forces with the toughest, most realistic, simulated combat training offered anywhere in the world today. Army task forces throughout the continental United States deploy to NTC to conduct training at least every two years.

While at NTC, each task force plans and executes a series of assigned missions across NTC desert terrain. Of these assigned missions, the deliberate attack is considered to be of critical importance due to its offensive nature. The U.S. Army's Operations Field Manual 100-5 states,

> "...offensive action, whatever force it takes, is the means by which the nation or a military force captures and holds the initiative, maintains freedom of action and achieves results. It permits the political leader or the military commander to capitalize on the initiative, impose his will on the enemy, set the terms and select the place of confrontation or battle, exploit vulnerabilities and react to rapidly changing situations and unexpected developments. No matter what the level, the side that retains the initiative through offensive action forces the foe to react rather than to act." [Ref. 3:p 174]

It is because of the deliberate attack mission's importance in the scheme of military strategy and tactics, that it has been chosen as the representative mission for this study.

Many experienced observers of U.S. attacks at NTC indicate that a significant proportion of these missions are unsuccessful. A recent study by the RAND Corporation found that 39 of 52 U.S. attacks conducted at NTC were unsuccessful. [Ref. 5:p 11]

Why are so many U.S. attacks unsuccessful? Brigadier General William W. Crouch and Lieutenant Colonel Thomas V. Moreley, in their article for Military Review, contend that much of the problem lies with the respective task force commander and his staff's inability to properly command and control (C and C) their battalion task force (TF). [Ref. 1]

Captain David Dryer, in his thesis, quantified ground momentum concentration at the TF level and showed the correlation between the massing of tank killing maneuver systems at the battle's critical attrition point and mission effectiveness. In the NTC deliberate attack missions studied,

> "[this] massing of combat power is a prerequisite to mission success.... Once a task force's combat power is appropriately massed, [however], the unit has to convert this combat potential into enemy attrition and friendly survival through synchronized direct fire and maneuver, in combination with other combat multipliers." [Ref. 2:pp 69-70]

The present thesis builds upon Captain Dryer's work by further investigating proper U.S. ground maneuver synchronization as a major contributing factor to attack mission successes at NTC. A major factor contributing to poor synchronization is poor C and C.

> "Synchronization may and usually will require explicit coordination among the various units and activities participating in any operation. By itself, however, such coordination is no guarantee of synchronization, unless the commander first visualizes the consequences to be produced and how activities must be sequenced to produce them. Synchronization thus takes place first in the mind of the commander and then in the actual planning and coordination of movements, fires, and supporting activities [planned and executed by his staff]." [Ref. 3:p 17]

The above quote implies that proper C and C does not guarantee proper synchronization, however, it is safe to state that the achievement of proper synchronization without proper C and C is certainly a miracle.

With this premise well in hand, the central question for this study centers on, "What is the proper ground maneuver synchronization for any U.S. task force deliberate attack conducted at NTC"? For the purposes of this study, the analysis of ground maneuver synchronization is focused on the **CRITICAL POINT** of the TF deliberate attack mission.

Any conclusions drawn from this study must be viewed with caution. To paraphrase General Don Starry: In any military action there comes a turning point. A point were someone determines that, if we are to survive this ordeal, now is the time to act. It doesn't have to be the optimal course of action; in fact, it may be quite the opposite. But, the really important thing is that someone has taken charge amid all of the chaos. It is this action, on one person's part, that leads to victory under fire.

This paraphrase points to the key reason why analytical study of combat will probably never fully capture the characteristics of battle. While a good measure of effectiveness can capture what actually happens in the battle, and through data collection the researcher then can reasonably determine why certain things happen, there presently is no method available to accurately capture how the human interacted to achieve the end result. That is to say, researchers have no accurate means for measuring the synergistic effects of military action.

II. CONCEPTS

The following concepts are explained by relating them to the database system used in this research. That system is **GNATT** (General-purpose NTC Analysis of Training Tool), and it is a software package that provides a dynamic replay of each mission by employing the training exercise data on an MS-DOS computer with EGA monitor. It allows the user to follow each NTC historical mission by graphical playback on the computer monitor. The monitor displays the battle to the viewer as though he were observing the mission on a military topographical map, minus any contour lines, with graphical symbols representing vehicle types. The monitor dynamically displays the mission from beginning to end by continually updating the screen with 5 minute snapshots of the battle.

A. MASS

The U.S. Army's Operations Field Manual (FM) 100-5 states:

> "In operational and tactical dimensions, [**MASS**] suggests that superior combat power must be concentrated at the decisive place and time in order to achieve decisive results." [Ref. 3:p 174]

Mass for this study, in accordance with FM 100-5, measures force concentration at the **TEAM** level. For an example of team concentration and its relationship with **COMMAND AND CONTROL**

(C and C), consider the following: The team commander of A/1-016 (i.e. Company A, 1st Battalion of the 16th Infantry Regiment) controls three platoon commanders (PL's). In order to evaluate the team commander's C and C, the vehicles that are controlled by any of the three team PL's and are located within a given constant radial distance from the predetermined team centroid are summed. Figure 1 provides a graphical representation of this concept and figure 2 provides the formulation. The resulting sum is the value assigned to A/1-016 for team mass for one time-step.

A circle is used in limiting the geographical dispersion of the team's systems because it allows the team commander maximum freedom in arranging his vehicles. In figure 1, the two time-steps depict A/1-016's team configurations for two consecutive time-steps. Here the team commander has chosen to array his forces in the shape of a wedge formation. With a little imagination the reader can see that the commander can easily reposition his forces anyway he deems appropriate and still receive full credit for mass as long as all vehicles remain within close proximity of one another (i.e. within the given radial distance of the team centroid). For the earlier time-step the team has a mass of 4. The value of 4 is derived by summing the number of vehicles inside or on the circle. For the later time-step the team mass is 3.

The team commander failed to fully mass his available combat power for either time-step. In the earlier time-step

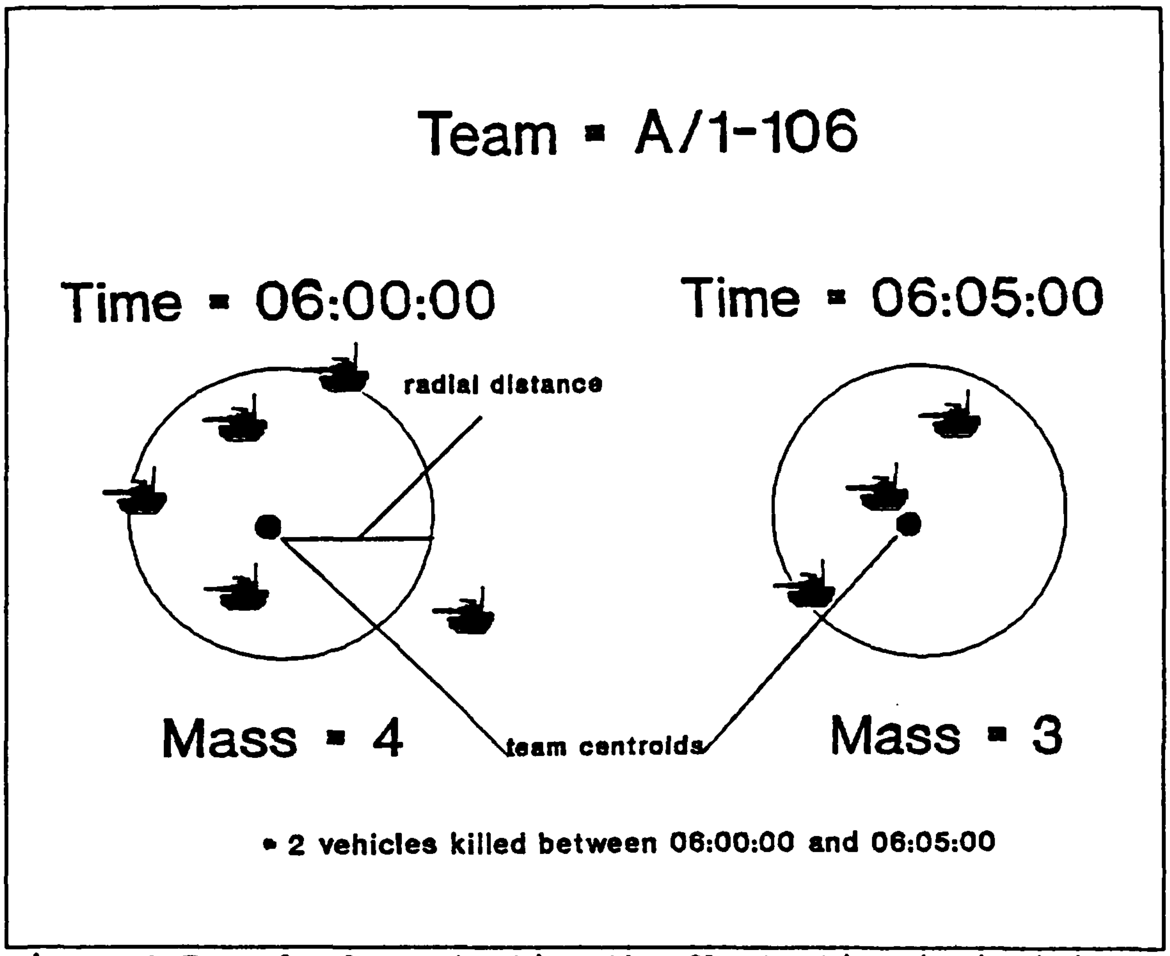

Figure 1 Example demonstrating the fluctuation in individual team mass between time-steps

there are 5 vehicles, but one is outside of the circled region. In the later time-step there are only 3 total vehicles, indicating that two vehicles died during the last time-step, and of the 3 remaining, all are inside or on the circled region.

The diameter and center of mass for the team during a given time-step are determined by the following methods. First, the diameter, throughout this study, is established at a constant 2000 meters (see figure 3) and is based on the

$$M_T(\Delta t_k) = \sum_{j=1}^{n} U_j, \text{ where}$$

$$U_j = \begin{cases} 0, \ IF \sqrt{[x_j(\Delta t_k) - x_T(\Delta t_k)]^2 + [y_j(\Delta t_k) - y_T(\Delta t_k)]^2} > 1000 \, meters \\ 1, \ OTHERWISE \end{cases}$$

Δt_k - k^{th} time-step

M_T - team mass for the k^{th} time-step

n - number of tank killing systems in the team at the start of k^{th} time-step

U_j - dumby variable representing j^{th} team system as 0 or 1

x_j - the j^{th} system's x-coordinate for the k^{th} time-step

y_j - the j^{th} system's y-coordinate for the k^{th} time-step

x_T - average team x-coordinate for k^{th} time-step

y_T - average team y-coordinate for k^{th} time-step

Figure 2 Team mass for time-step k

assumption that the upper bound on the total number of vehicles in any team for a given TF mission is 20. The value of 20 is based on the approximate number of tank killing systems (i.e. vehicles) in a regimental cavalry troop. By placing these 20 vehicles in a straight line and dispersing them at 100 meter intervals, a total length of 2000 meters results. The dispersion distance of 100 meters between vehicles is based on U.S. Army doctrine which recommends that vehicles be minimally spaced at all times by 50-100 meters in order to minimize the loss of friendly vehicles to enemy artillery.

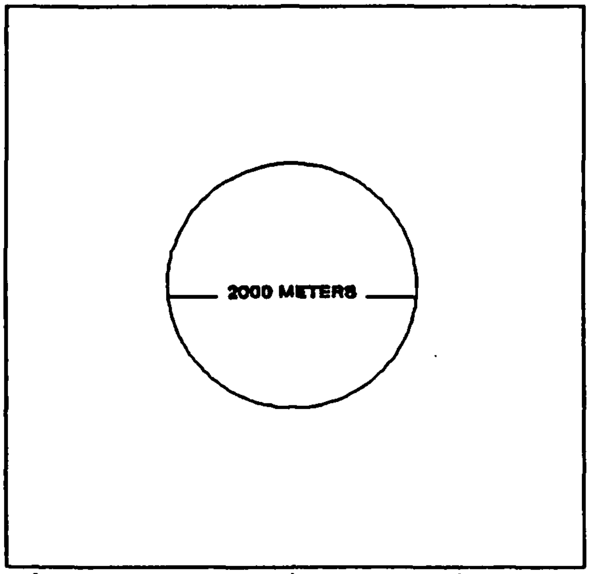

Figure 3 Team circular diameter

The team center of mass, or centroid, is determined using simple euclidean geometry. (see Figure 4) The GNATT database records all vehicle locations as x,y coordinates (i.e. euclidean). To determine the team center of mass for any time-step, simply sum all team vehicle x-coordinates and divide by the total number of vehicles in the team for the given time-step. Repeat the process for the y-coordinates. Once this procedure is complete, the team center of mass (i.e. team centroid) for one time-step is identified. It is important to note that centroids determined by this method, alone, are often biased by a vehicle, or vehicles, in the team that fails to keep up with the other team members. There are various reasons for this occurrence such as mechanical failure, crew disorientation or simply the act of following orders. What ever the reason, it is irrelevant for the purposes of this study. The main concern is how to overcome this bias. This issue is resolved through the use of clustering and is addressed in the following chapter.

$$\left.\begin{array}{l} x_T(\Delta t_k) = \dfrac{\sum_{j=1}^{n} x_j(\Delta t_k)}{n} \\ \\ y_T(\Delta t_k) = \dfrac{\sum_{j=1}^{n} y_j(\Delta t_k)}{n} \end{array}\right\} \quad (x_T(\Delta t_k)\,,\, y_T(\Delta t_k))$$

y_T - team center of mass, x-coordinate for k^{th} time-step

x_T - team center of mass, y-coordinate for k^{th} time-step

Δt_k - the k^{th} 5-minute, time-step

x_j - j^{th} system x-coordinate at the beginning of the k^{th} time-step

y_j - j^{th} system y-coordinate at the beginning of the k^{th} time-step

n - number of tank killing systems in the T^{th} team at the beginning of the k^{th} time-step

Figure 4 Team center of mass for one time-step

B. VELOCITY

VELOCITY in this study refers to the average speed of a particular team for a given time-step in the TF mission. To determine a team's velocity, take the team centroids for any two consecutive time-steps and determine their difference; then take the absolute value of this difference and divide by 5 minutes (i.e. one time-step). This provides the team's velocity for one 5-minute, time-step in meters per 5 minutes. In order to make this velocity value easier to interpret, the necessary conversion is instituted to provide the velocity in kilometers per hour. Figure 5 contains the equation used to quantify the average team velocity in kilometers per hour for a given time-step.

$$|C_T(\Delta t_k) - C_T(\Delta t_{k-1})| = D(\Delta_k)$$

$$\frac{D(\Delta_k)}{5\,minutes} * \frac{60\,minutes}{1000\,meters} = D(\Delta_k) * 0.012 = V_T(\Delta t_k)$$

C_T - team centroid

T - ATEAM, BTEAM, CTEAM, DTEAM, ETEAM

Δt_k - the k^{th} 5-minute, time-step

D - distance in meters

V_T - team velocity in kilometers per hour

Figure 5 Team velocity in kilometers per hour for time-step k

C. MOMENTUM

As stated in Chapter I the measurement of team **MOMENTUM** is the means by which this study determines each team commander's level of C and C for a given time-step in the TF mission. Team momentum is quantified by the product of team mass and team velocity. By quantifying momentum in this manner, the researcher provides a combined measure of a given team's force concentration and speed on the battlefield.

D. CRITICAL POINT AND DEFENSIVE BELT

For this study the "**CRITICAL POINT**" refers to the time and location in any deliberate attack mission where the attacking U.S. TF encounters the OPFOR, **STRONGPOINT**, **DEFENSIVE BELT**. Figures 7 and 8 in Chapter III provide a graphical presentation of these concepts.

A defensive belt is the region surrounding the OPFOR strongpoint. It is this region where the OPFOR intends to stall the momentum and deplete the mass of the attacking U.S. TF. A defensive belt will always be within direct fire and artillery range from the established strongpoint and normally will consist of extensive obstacles emplaced by OPFOR engineer assets.

E. GROUND MANEUVER SYNCHRONIZATION

Inherent in any military operation is the commander and his staff's desire to achieve and maintain proper SYNCHRONIZATION.

> "Synchronization is the arrangement of battlefield activities in time, space and purpose to produce maximum relative combat power at the decisive point." [Ref. 5:p 17]

In this paper, ground maneuver synchronization refers to the time and space between individual teams that possess tank killing systems and are part of the same U.S. TF.

The two dimensions, time and space, provide the basic elements of synchronization. However, recall from Chapter I that proper C and C is a requirement in order to stand a reasonable chance of achieving proper synchronization, and that this study utilizes momentum at the team level to address this requirement. Thus, a more comprehensive look at TF synchronization at the mission critical point consists of three dimensions: average time separation between teams in reaching the critical point, average distance between teams at the critical point and the cumulative team momentums at the critical point.

F. MEASURE OF EFFECTIVENESS (MOE)

The MOE in this study (figure 6) is based on the percentage of enemy tank killing systems destroyed (B) and the percentage of friendly tank killing systems alive (A) at the conclusion of the mission. While this MOE is not optimal for the study of offensive maneuvers, it is the best quantifiable measure currently available.

Optimally, an MOE for this analysis should incorporate the number of friendly systems that reach the mission geographical objective, however, such information is not currently available in the GNATT database, and is extremely difficult to accurately acquire through manual search of the ARI-POM CTC archive. [Ref. 7]

$$A = \frac{FRIENDLY\ SYSTEMS\ SURVIVING}{INITIAL\ FRIENDLY\ SYSTEMS}$$

$$B = \frac{ENEMY\ SYSTEMS\ KILLED}{INITIAL\ ENEMY\ SYSTEMS}$$

$$\frac{A + B}{2} = MOE$$

Figure 6 Measure of Effectiveness

By summing the percentages of enemy tank killing systems killed and friendly tank killing systems surviving and then dividing by two, the researcher obtains an MOE which ranges in value from 0 to 1. A value of 0.5 or greater indicates increasing degrees of success for the attacking U.S. TF while a value of 0.5 or lower indicates decreasing degrees of mission success.

III. METHODOLOGY

A. TOOLS

The analytical tools used in this study are the DBASE IV software package, a clustering program, the GNATT software package and the INGRES database management system.

The dBASE IV software package was employed to extract required data from each of the GNATT files used in the sample set. Two programs were coded in dBASE: MAIN11 and MAIN22. Both were verified by Elizabeth Attanasio, Computer Programmer/Analyst (GS-334-11), Department of Administrative Sciences.

For each U.S. TASK FORCE (TF) deliberate attack mission file, the MAIN11 program creates a new separate file for each of the TEAMS comprising the TF. Each of the rows in any of these team files contain data unique to a specific, individual vehicle for each 5-minute time-step during the TF mission. All rows contain the following fields: a euclidean location, unique player (i.e. vehicle) number, vehicle type, and ORGANIC unit designation. Only vehicles coded as alive for any 5-minute time-step are included in the team file. Each team is formed based on the mission TASK ORGANIZATION specified in the INITIALIZATION FILE for the particular TF mission, and the vehicles unique to each team are identified and grouped by matching the mission task organization with their respective **ORGANIC** unit designations.

The MAIN22 program, again for each U.S. TF deliberate attack mission file, executes computations to determine the centroid, mass and velocity for each team in the TF for each time-step. Once MAIN22 produces this information, it then determines and stores the **MOMENTUM**, time and euclidean location that each team first enters the defensive belt of the OPFOR's **STRONGPOINT**. MAIN11 and MAIN22 programs are listed in Appendices A and B.

A clustering technique is employed to identify and remove bias[5] from the individual team DBASE files created in the MAIN11 program. Clustering is conducted on each team of a TF for each time-step in the mission.

Bias in the dBASE files equates to tank-killing systems that overly distance themselves from the main body of a given team. For the purposes of this study it does not matter why a vehicle chooses to take this action; only that it has done so.

These overly distanced vehicles cause bias in the location of team centroids. Through trial and error it was determined that such bias prevented a significant portion of the TF teams from reaching the mission critical point. If the teams never reach the mission critical point, then the MAIN22 program has no data to capture for final analysis in this study. The

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[5] See Section B of this Chapter for an example of bias

clustering program was employed to identify and remove any outlying vehicles for each TF mission. That is, each team text file created by the program MAIN11, is subjected to a cluster analysis in order to remove any outlier vehicles. The filtered file is then imported into the program MAIN22 to determine the non-biased team centroids.

The essential question at this point of the study was the choice of a reasonable isolation distance for use in the clustering program. The clustering distance is the maximum distance that any vehicle, or set of vehicles, can be positioned from the main team cluster and be considered for analysis in the DBASE MAIN22 program.

As stated in Chapter I under Assumptions, a typical tank-killing system traveling over NTC cross-country terrain can be expected to average a speed of 24 kilometers per hour (i.e. 38.4 miles per hour). To determine a reasonable isolation distance for use in the clustering technique, the speed of 24 kilometers per hour is applied to the five minute, time-step. The resulting distance is 2000 meters. Thus, it follows that the clustering program retains any vehicle, of a given team and in a given time-step, that is within 2000 meters of the main team cluster centroid. All other vehicles from the original team text file for a given time-step are considered outliers and are deleted.

The clustering technique was originally coded by Major Jim Hoffman and Captain Derryl Hamilton, and later revised for use in this study by Captain David A. Dryer and Doctor Robert R. Read, all former students or current faculty of the Naval Postgraduate School. The program is coded in A Programming Language (APL) and is based on an algorithmic description found in a text book by Charles H. Romesbury [Ref. 6]. For a listing and summary explanation of the clustering program see Appendix C.

This study draws upon three of the GNATT software package's files in order to execute the mission simulation. These files[6] are Organization, Mortality and Player Location and are identified by the abbreviations ORG.DAT, MORTALTY.DAT and PL.DAT, respectively (also see GNATT in glossary). These files are co-located on one floppy disk for each TF mission. All GNATT files derive their contents from the ARI-POM CTC INGRES database.

GNATT only identifies platoons by their organic unit designation. Therefore, when these same platoons are reconfigured to form the teams of a TF, the GNATT database has no way of identifying which platoons are grouped to form the teams. Fortunately, this information is stored in the parent INGRES initialization file for each mission.

INGRES is a database management system employed by the Army Research Institute-Combat Training Center, Presidio of Monterey (ARI-CTC, POM) to collect, process and disseminate

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[6] See Glossary: GNATT

NTC instrumented data. The accuracy of these files has been verified by David Rainey, TACS Deputy Instrumentation Officer, NTC.

B. EXAMPLE

The methodology used in this study can best be explained by walking the reader through the procedures employed to determine the final data set for one representative team in a TF deliberate attack mission. In this example the GNATT mission is MA870626; and the representative team from the TF is, once again, A Company of the 1st Battalion, 16th Infantry Regiment (A/1-016). The INGRES initialization file for mission MA870626 specifies that the platoons of 1/A/1-016, 2/A/1-016 and 1/A/5-023 (i.e. organic unit designations) comprise team A/1-016. As stated above, for the remainder of this example only the data processing associated with A/1-016 will be discussed, however, keep in mind that any processing conducted on A/1-016 is simultaneously taking place on all other teams comprising the TF.

Given the GNATT, floppy disk containing the U.S. TF deliberate attack mission MA870626 and a personal computer containing DBASE IV, the program MAIN11 will produce a DOS text file entitled A1016 (i.e. A/1-016). This file will contain only the live U.S. mounted tank killing systems (i.e. tanks, Bradley fighting vehicles and TOWs) for the team segregated by 5-minute time-steps from the beginning of the deliberate attack mission until completion. Each time-step, for each vehicle, contains a euclidean location, unique player number, type of vehicle and organic unit designation.

The team A1016 text file, in its present form, may contain outliers. Therefore, every file is clustered to determine and remove any outliers. An outlier in the clustering program, is any tank killing system, or systems, which is located more than 2000 meters from the team's main cluster for any given time-step.

For example, picture a team of five tanks; four of the tanks are within 200 meters of one another. Suppose the fifth tank experienced a mechanical failure rendering the vehicle incapable of movement during any future time-steps. As each time-step expires the four operational tanks continue to move further away from the disabled tank increasingly distorting the team centroid for each progressive time-step. The clustering program determines at which time-step the disabled system is more then 2000 meters from the main cluster, and removes it from the team file for the given time-step.

Once the team A1016 text file has been clustered, the file now contains the accurate data necessary to determine the time, euclidean location, mass, speed and momentum of team A1016 at the **CRITICAL POINT** of the mission.

Recall that the critical point in the mission is the location where the attacking U.S. force encounters the OPFOR strongpoint defensive belt at a common time. After much thought and exploratory consideration, the only reasonable method available to ascertain the unique critical point for each mission was by visual inspection of the mission GNATT program.

To be more precise, the researcher loads, executes and views, through the use of a PC monitor, the GNATT mission. Based on what the simulation depicts and his military expertise, the researcher identifies the mission critical point. He then runs the simulation a second time in order to obtain a hardcopy depicting a snapshot of the attacking U.S. TF encountering the OPFOR defensive belt (i.e. mission critical point).

The battlefield hardcopy is divided into squares identical to those seen on a military topographical map. Each square represents one square kilometer. The tank killing systems for both the U.S. and the OPFOR are displayed at their respective geographical (i.e. euclidean) locations for the 5-minute time-step at which the hardcopy was produced.

With the hardcopy in front of him, the researcher now marks the point that will represent the center of mass for the OPFOR defensive belt. The point is chosen based on the researcher's visual interpretation of the OPFOR tank killing systems displacement, their configuration within the strongpoint and, most importantly, the direction that the attacking U.S. TF is approaching. It is this center of mass that enabled the analyst to position the defensive belt.

The defensive belt is simply a circle centered on the established center of mass and consisting of a diameter unique to each TF mission. Each mission's diameter is based on the OPFOR's vehicle dispersion within the strongpoint and limited by the maximum effective engagement range of 2500 meters that exist between OPFOR tank killing systems and their potential U.S. targets.

The three parameters of OPFOR vehicle displacement and configuration, and the direction of attack by the U.S. TF provide the essential input the researcher uses to make a professional judgement concerning the placement of the defensive belt center of mass and the defensive belt circle. It is important that the reader understand that the researcher has some freedom in placing the strongpoint center of mass; he is not tied to the traditional analytical centroid as formulated in Figure 4 of Chapter II. Recall that the analytical centroid is based solely on the individual vehicle locations in the strongpoint.

As an example, suppose the vehicles in the OPFOR strongpoint are arranged in a circular formation, the center of mass should be equivalent to the analytical center of mass (Figure 7). However, for various reasons, this is not always the case. Suppose that the OPFOR tank killing systems occupying the strongpoint are configured in a manner such that the attacking U.S. force entering the strongpoint defensive belt encounters an OPFOR force configured in an oblong formation (Figure 8). How then does the researcher choose the positioning of the defensive belt center of mass? In this particular case the strongpoint's left side (i.e. the side that the U.S. formation is approaching) is obviously the critical point for the ensuing battle because it is this area where the two opposing forces will confront one another.

Based on this scenario, the defensive belt's center of mass is determined to be on the strongpoint's left flank. The diameter of the defensive belt for this mission is established by the constant engagement range of 2500 meters and an additional 500 meters for dispersion among the OPFOR vehicles comprising the strongpoint's left flank. This results in a diameter of 3000 meters. The strongpoint vehicle dispersion is unique to each mission and will vary between 500 to 3000 meters.

From the above discussion it is clear that this study's analysis is unavoidably subjective for this phase of the data collection process. However, it is worthy of noting that the subjectivity is compensated by the researcher's military expertise in this area.

Now that the researcher has determined the defensive belt, he loads this information into the MAIN22 program along with the clustered text file A1016. After executing the program a DBASE file entitled MATRIX is produced. The MATRIX file contains the time, euclidean team centroid and the team momentum for the first time-step that the team entered the

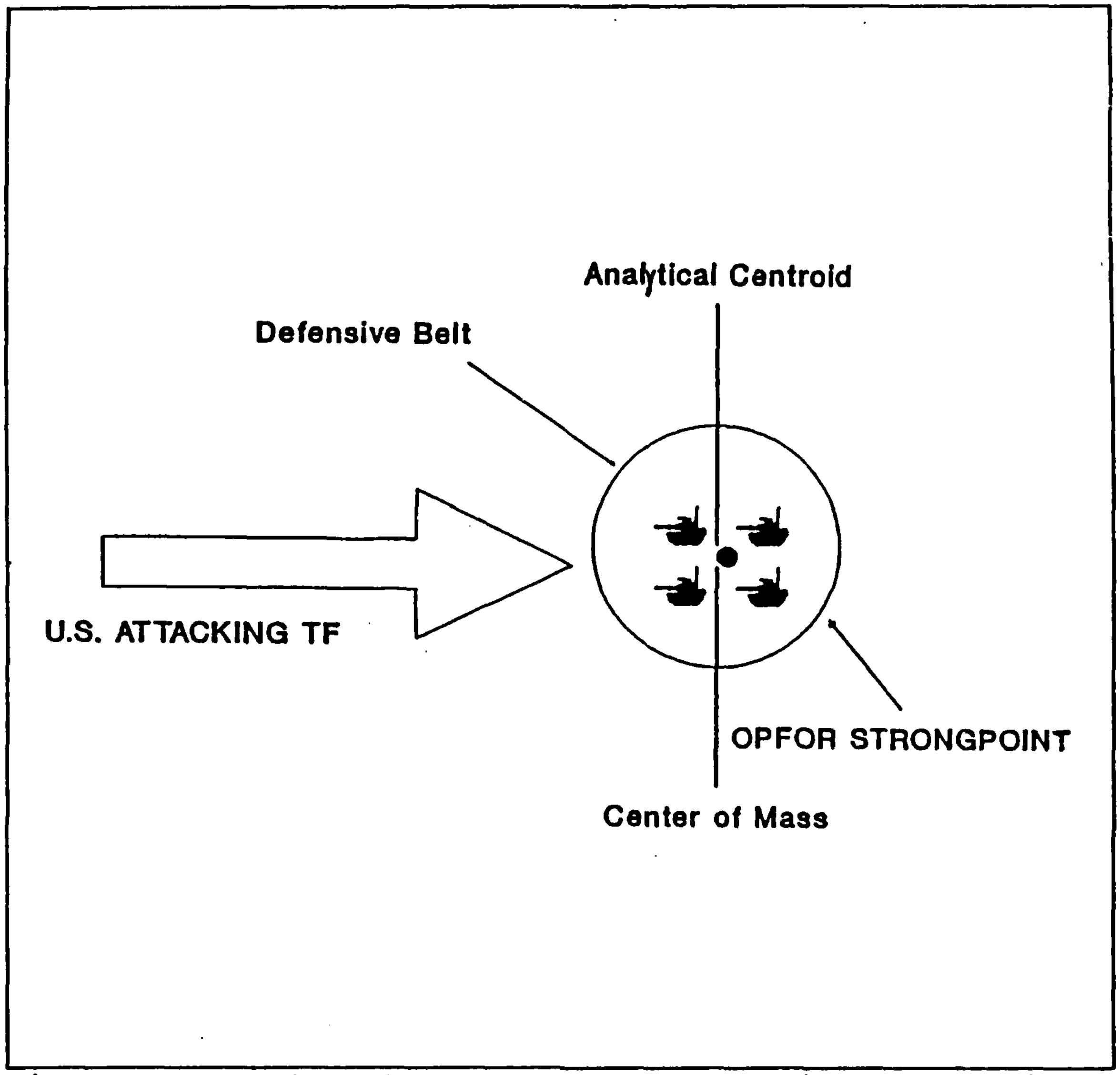

Figure 7 Example where researcher applies professional judgement; he determines that the defensive belt center of mass is equivalent to the analytical centroid of the strongpoint vehicles

OPFOR strongpoint defensive belt as well as the team name (see Table 2 in Chapter IV).

Keep in mind that for any sample mission the number of teams composing the TF will vary from 4 to 5. In order to standardize the final sample set, the DBASE program MAIN22

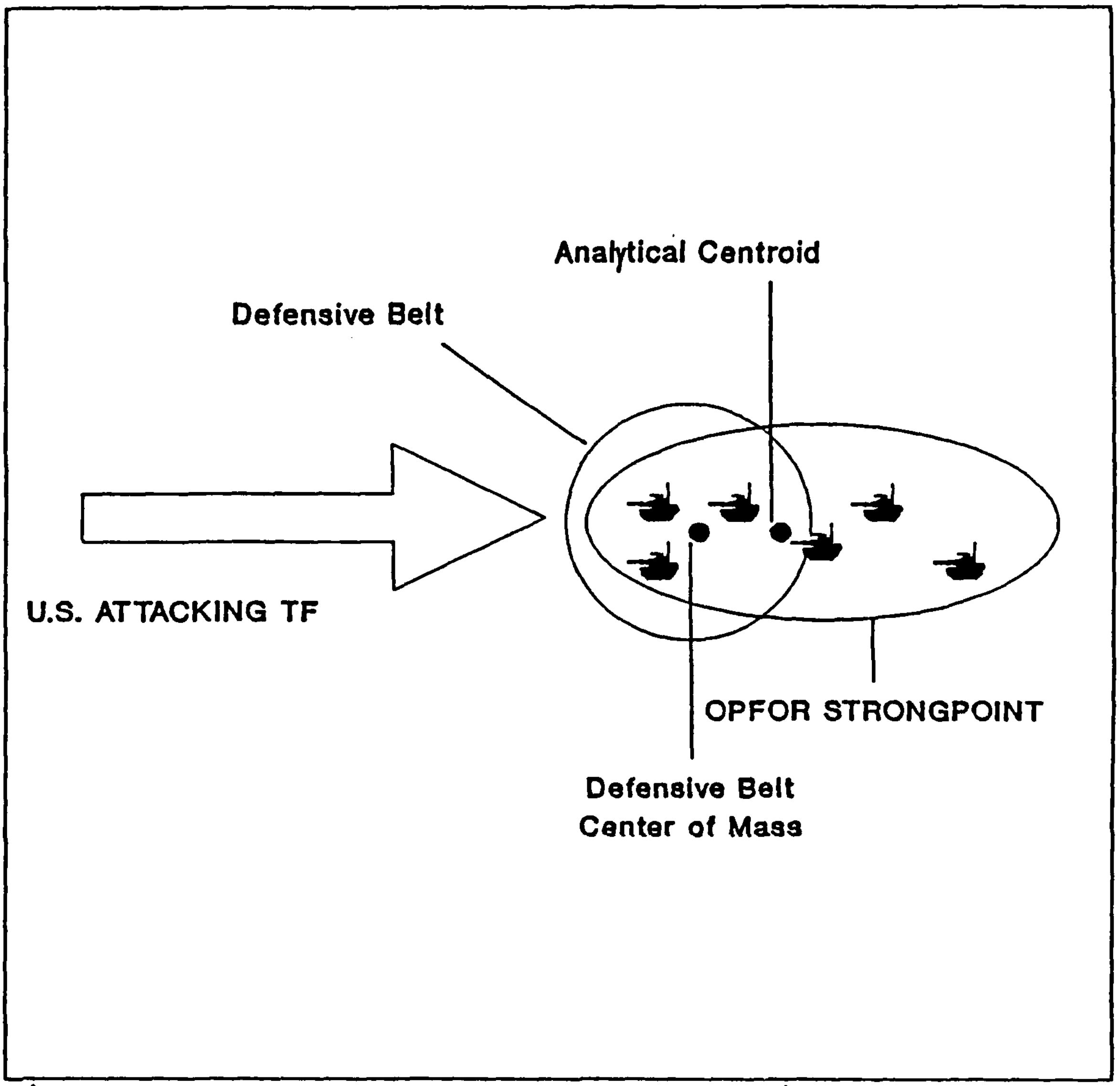

Figure 8 Example where researcher professionally determines that the defensive belt center of mass is not equivalent to the analytical centroid of the strongpoint vehicles

always produces 5 rows of data for each sample mission. Each row in a sample mission represents one team. Once the program completes its routine, the reader will normally see between 2 and 4 rows of data containing values other then zero. Those rows containing a team name (e.g. ATEAM) in the sixth column indicate teams that possess mounted tank killing systems. And those rows with blanks in the sixth column represent teams that had no mounted tank killing systems. Five rows of data are reserved for each team.

For this study, the described methodology is applied to 17 sample missions, and the final data set (i.e. MATRIX.dbf) will contain 85 rows of data with 5 rows of data per mission for 17 individual missions.

IV. ANALYSIS

A. SAMPLE SET MISSIONS

Table 1 lists the seventeen U.S. TF deliberate attack missions which form the sample for this study. The missions were selected from Captain Dryer's final thesis sample set. [Ref. 2:p 59] This set was selected as the initial screening set for this study because he had determined the percentages of U.S. and OPFOR system kills, by mission, based on the NTC observer-controller, generated take home packages (THP). These figures were considered more accurate in comparison to the kill figures generated by the DBASE program MAIN22 using the GNATT database, and were, therefore substituted for the GNATT figures in determining the respective MOE's for the missions of the sample set. The sample set is limited to seventeen missions simply because of the time required to produce the necessary output for analysis.

Table 1 MISSION SAMPLE SET

MISSION	US FORCE (Initial)	OPFOR FORCE (Initial)	INITIAL FORCE RATIO (US:OPFOR)	US KILLED (THP)	OPFOR KILLED (THP)
MA870212	41	14	2.9	24	13
MA870626	39	16	2.4	26	16
MA870604	42	17	2.5	21	9
AA871421	36	16	2.3	28	15
MA881053	38	38	1.0	32	38
MA871409	44	13	3.4	32	12
MA870319	33	14	2.4	22	12
MA880632	42	42	1.0	18	35
AA880324	32	30	1.1	21	5
AA871115	32	16	2.0	27	7
MA880220	27	34	0.8	12	11
AA870432	32	14	2.3	21	6
MA871233	33	18	1.8	24	16
AA880614	37	22	1.7	20	4
MA871308	40	22	1.8	29	2
MA870828	45	22	2.1	34	9
MA870806	40	162	0.3	30	58

B. FINAL DATA SET

Table 2 illustrates an abbreviated version of the actual mission critical point data extracted from the 17 sample missions. For a complete listing of the critical point data see Appendix D. The values contained in Table 2 represent the times, locations and momentums for the teams of each mission. The table is separated into 10 columns and 86 rows including the headings at the top of the table. The second column from the left repeatedly displays the numbers 1 through 5 down the column. Here, each group of 5 consecutive rows contains the individual team data for one TF mission (i.e. one cell). These same groups of rows coincide with the missions listed in column one. For example, the first mission listed in column one is MA870212, and it is related to the first five rows of the table.

A brief explanation of each of the column headings is provided to further clarify the data:

MISSION - The code used to identify each U.S. TF mission. The first two letters indicate type of TF and mission. For example, MA means mechanized infantry TF indicated by the first letter (M). If the first letter were (A), this would indicate that it is an armor TF. The remaining numbers indicate the FY year, rotation number and date of the mission.

TIME - The first two digits are hours followed by minutes; then seconds.

XCOORD - The euclidean x-coordinate indicating the latitudinal location of the vehicle on a U.S. Army topographical map.

YCOORD - The euclidean y-coordinate indicating the longitudinal location of the vehicle on a U.S. Army topographical map.

TEAM - Identifies teams that possess mounted tank killing systems. If a row within any cell has no team name, then that team does not possess any mounted tank killing systems for that particular mission.

MOMENTUM - The level of momentum for each team in the mission.

MOE - The measure of effectiveness described in Chapter II,F.

MOE2 - Component A of the above MOE.

MOE3 - Component B of the above MOE.

Table 2 MISSION CRITICAL POINT DATA SET

MISSION		TIME	XCOORD	YCOORD	TEAM	MOMENTUM	MOE	MOE2	MOE3
MA870212	1	07:44:16	41693	94185	ATEAM	48.47	0.67	0.42	0.93
	2	07:44:16	42000	93763	BTEAM	15.99			
	3	0	0	0		0.00			
	4	07:49:16	42070	93325	DTEAM	64.01			
	5	0	0	0		0.00			
MA870626	1	0	0	0		0.00	0.67	0.33	1.00
	2	06:10:01	38583	121168	BTEAM	214.00			
	3	06:15:01	40407	121138	CTEAM	107.70			
	4	06:25:01	39725	121225	DTEAM	215.00			
	5	0	0	0		0.00			
⋮		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
MA870806	1	0	0	0		0.00	0.30	0.33	0.36
	2	05:35:10	38146	109629	BTEAM	124.50			
	3	04:00:10	37940	108760	CTEAM	0.00			
	4	05:35:10	38146	109629	DTEAM	124.50			
	5	04:00:10	37431	109085	ETEAM	0.00			

C. ANALYSIS TOOLS

The computational tools employed to conduct analysis on the final sample set were APL in conjunction with GRAFSTAT. The following list of APL variables represent the independent and dependent variables used in this analysis:

AVDIF - Contains the vector of values representing the average time between teams arriving at the mission critical point for each of the 17 missions (see figure 10).

GOODMOM - Contains the vector of values representing the summed individual team momentums at the mission critical point for each of the 17 missions (see figure 9).

AVDIST - Contains the vector of values representing the average distance between teams at the mission critical point for each of the 17 missions (see figure 11).

FRATIO - Contains the vector of force ratio values of U.S. to OPFOR for each of the 17 sample set missions.

LRATIO - Contains the vector of logarithmic force ratio values of U.S. to OPFOR for each of the 17 sample set missions.

GOODMOE - Contains the vector values representing the MOE described in Chapter II,F for each of the 17 sample set missions.

MOE2 - Contains the vector values representing component A of above the above MOE (i.e. GOODMOE) for each of the 17 sample set missions.

MOE3 - Contains the vector values representing component B of above the above MOE (i.e. GOODMOE) for each of the 17 sample set missions.

$$\sum_{i=1}^{n} M_i = TF\ momentum\ (GOODMOM)$$

where M_i - *Mission critical point for team i in kilometers per hour*

i - $1,2,\ldots,n$

n - *No. of teams containing tank killing systems in U.S. TF*

Figure 9 Summed mission critical point momentums for teams of U.S. TF (GOODMOM)

Linear regression techniques were applied using GRAFSTAT to compare the independent (predictor) variables AVDIF, AVDIST, FRATIO, LFRATIO and GOODMOM against the dependent variables GOODMOE, MOE2 and MOE3. All possible combinations of the above independent and dependent variables were analyzed

--- STEPS ---

(1) *Convert raw time[(H)ours:(M)inutes:(S)econds)] to decimal values in hours*

$$\frac{H}{1} + \frac{M}{60} + \frac{S}{3600} = TT_i$$

where $i - 1,2, \ldots ,n$

n - *No. of teams containing tank killing systems in U.S. TF*

TT_i - *Mission critical point time for team i converted to a decimal value in hours*

(2) *Rank order* TT_i*'s*

$TT_1 = A$

$TT_3 = B$

$TT_2 = C$

(3) *Subtract consecutive pairs starting with largest value*

$A-B = d_1$

$B-C = d_2$

(4) $$\sum_{j=1}^{n-1} d_j = D$$

(5) $\frac{D}{n-1} =$ *Average time dispersion between teams at mission critical point(AVDIF)*

Figure 10 Average time dispersion between teams of a U.S. TF at the mission critical point (AVDIF)

using scatter plot, ANOVA and Coefficient Estimates.

Each of the predictor variables, AVDIF, AVDIST, FRATIO, LRFATIO AND GOODMOM when plotted against each of the MOE's

$$\frac{\sum_{i=1}^{n} \sum_{j=1}^{n} (| L_i - L_j |)}{n(n - 1)} = \text{Average team distance (AVDIST)}$$

where

$L_{i\,or\,j}$ - *Mission critical point location for team i or j (combined x,y coordinates)*

$i = j - 1, 2, \ldots, n$

$L_i - L_j = 0$, if $i = j$

Figure 11 Average distance between teams at mission critical point for U.S. TF (AVDIST)

correlation was between FRATIO and AVDIST with a value of 0.548 (see figure 14).

FILE: M3DIF1 DAT A1

TABLE OF COEFFICIENTS

17 OBSERVATIONS R-SQUARED = 0.1475 STANDARD ERROR = 0.32376
2 VARIABLES ADJ R-SQUARED = 0.09067

					0.95 CONFIDENCE LIMITS	
COEF	ESTIMATE	STD ERR	T STAT	SIG LEVEL	LOWER	UPPER
INTERCEPT	0.74595	0.121	6.1651	0.000018087	0.48803	1.0039
AVDIF	0.33368	0.20712	1.611	0.12801	0.7752	0.10785

Figure 12 Simple regression between MOE3 and AVDIF

FILE: 21AFATML DAT   A1

(21afatml)
dep var = moe2
indep var = avdif,avdist,goodmom,lfratio

TABLE OF COEFFICIENTS

17 OBSERVATIONS   R-SQUARED   = 0.25821   STANDARD ERROR = 0.12431
5 VARIABLES   ADJ R-SQUARED = 0.01095

COEF	ESTIMATE	STD ERR	T STAT	SIG LEVEL	0.95 CONFIDENCE LIMITS LOWER	UPPER
INTERCEPT	0.30446	0.075656	4.0243	0.0016865	0.13961	0.46931
AVDIF	0.024356	0.090448	0.26928	0.79229	0.22144	0.17272
AVDIST	0.000015173	0.000044687	0.33955	0.74006	0:00011254	0.000082196
GOODMOM	0.000062562	0.00027978	0.22361	0.82682	0.00054705	0.00067218
LFRATIO	0.10957	0.060347	1.8157	0.09447	0.021921	0.24106

Figure 13 Multiple regression between MOE2 and AVDIST,AVDIF,GOODMOM,LFRATIO

FILE: 3ADAFMRC DAT A1

SIMPLE CORRELATION COEFFICIENTS

	AVDIST	AVDIF	GOODMOM	FRATIO	MOE3
AVDIST	1	0.21377	0.23706	0.54769	0.30449
AVDIF	0.21377	1	0.30099	0.082595	0.38406
GOODMOM	0.23706	0.30099	1	0.18035	0.33215
FRATIO	0.54769	0.082595	0.18035	1	0.28357
MOE3	0.30449	0.38406	0.33215	0.28357	1

Figure 14 correlation

V. CONCLUSIONS

As stated, none of the regression analysis conducted produced significant support for the stated hypothesis. However, military history indicates that the hypothesis is analytically supportable because the doctrinal concepts addressed in FM 100-5 (Operations) are based on a thousand years of military outcomes. Therefore, it appears that other factors, not presently available for study, have a significant affect on the dependent variables (MOE's). Two primary candidates immediately come to mind. First, the sample size is small at 17 and should be significantly increased to support the reliability of the estimates introduced here. Second, ARI in conjunction with TRADOC ANALYSIS COMMAND, Monterey (TRAC-MTRY) and NTC should combine their efforts toward updating the present automated data gathering process used at NTC to specifically include further information such as actual engineer obstacle emplacement locations; yes or no responses to indicate the U.S. force performance in breaching each obstacle, as well as a method to determine the percentage of U.S. systems that either occupy or control the intended geographical mission objective(s) at the conclusion of each deliberate attack mission.

Of course the above proposed advances in the automated database will not guarantee success in supporting the proposed hypothesis, however, such actions will contribute to the understanding of the process and aid in any future research involving the study of general offensive operations at NTC.

Also, it is important to reiterate that this research effort has analyzed only one of the many factors influencing deliberate attack synchronization. That one factor being mounted tank killing systems. To date there exists little quantitative research incorporating additional factors such as close air support, aviation, infantry, air defense artillery or artillery.

Battle analysis is not necessarily limited to checking linear relationships. Non-linear, dynamic techniques need to be developed to more fully explore combat involving single and multiple variables. Graphical exploratory data analysis and higher order non-linear mathematical techniques are currently being explored at TRAC-MTRY to better fit these combat relationships. All of the above limiting factors in this study are worthy of follow-on research efforts.

GLOSSARY

The following definitions are provided to familiarize the reader with the military concepts and principles addressed in this study.

Battalion Task Force (TF). "[1.] A force generally organized by combining tank and mechanized infantry elements under a single battalion commander to conduct specific operations. A battalion task force may be tank-heavy, mechanized infantry-heavy, or balanced, depending on the concept and plan of operation.... An example is an infantry battalion headquarters; one or more of its **ORGANIC** companies; and the attachment of one or more of the following: a tank company, and armored cavalry troop, or an engineer company.... [2.] Based upon mission, a temporary grouping of units under one commander formed to carry out a specific operation or mission, or a semipermanent organization of units under one commander to carry out a continuing specific task". [Ref. 4:pp 1-110,1-71]

Organic. "Assigned to and forming an essential part of a military organization;.... [U]nits or personnel in an organization [which are] relatively permanent..." [Ref. 4:pp 1-54,1-7]

Company team (team). "A team formed by attachment of one or more nonorganic tank, mechanized infantry or light infantry platoons to a tank, mechanized infantry, or light infantry company either in exchange for or in addition to organic platoons." [Ref. 4:p 1-18]

Ground Maneuver Synchronization. (1) Inherent in any military operation is the commander and his staff's desire to achieve and maintain proper synchronization. (2) "Synchronization is the arrangement of battlefield activities in time, space and purpose to produce maximum relative combat power at the decisive point." [Ref. 5:p 17] (3) In this study, battalion task force, ground maneuver synchronization refers to the time and space between individual teams, and their respective momentums, for a particular period (time-step) during the mission.

Command and Control. In U.S. doctrinal terms, the phrases "the mind of the commander" and "the actual planning and coordination of movements, fires, and supporting activities", in the views of Crouch and Morley [Ref. 1], literally translate to command and control (C and C), respectively. Henceforth in this study the above phases will be referred to as C and C.

U.S. Army doctrine states that C and C starts at the platoon level. That is platoon commanders control platoons; team commanders control platoon commanders; TF commanders control company commanders, etc. The platoon is, by doctrine, the basic maneuver element for U.S. forces. The platoon and team commanders must C and C their respective organizations alone and unaided, while the TF commander, due to the size and complexity of his organization, employs a group of personnel referred to as his staff to convey his operational intentions to subordinate commanders.

U.S. Army Field Manual (FM) 101-5-1 defines command and control as, "The exercise of command that is the process through which the activities of military forces are directed, coordinated, and controlled to accomplish the mission...." [Ref. 4:p 1-16] Numerous methods are available to pass command and control information within the TF, but the most common are map graphical control symbols and written or oral orders specifying how the commander's intent is to be executed.

Critical Point. For this study the "critical point" refers to the time and location in any deliberate attack mission where the attacking U.S. force encounters the opposing force (OPFOR) strongpoint **DEFENSIVE BELT.**

Defensive Belt. A defensive belt is the region surrounding the OPFOR strongpoint. It is this region where the OPFOR intends to stall the **MOMENTUM** and deplete the **MASS** of the attacking U.S. TF. A defensive belt will always be within direct fire and artillery range from the established **STRONGPOINT** and normally will consist of extensive obstacles emplaced by OPFOR engineer assets.

For the purposes of this study, a defensive belt is a circle surrounding the OPFOR strongpoint. The diameter of the defensive belt is unique for each mission; it is based upon the dispersion of OPFOR vehicles within the strongpoint plus the maximum effective engagement range of approximately 2500 meters from the strongpoint tank killing systems out to their potential U.S. targets.

Momentum. Here momentum is quantified as **MASS** times **VELOCITY.** These respective parameters closely represent the two key C and C variables that every task force commander and his staff strive to optimize in any attack mission: "No commander envisions a slow, piecemeal attack. No plan is ever written that is predicated on a unit's destruction. Yet the failure to use mass and speed against enemy defenses [produces] this lack of success." [Ref. 1:p 1]

This definition of momentum provides an efficient means of measuring the command and control that each team commander possesses for each time-step of the mission from beginning to end.

Mass. U.S. Army FM 101-5-1 defines mass as, " The concentration of combat power at the decisive time and place.... The military formation in which units are spaced at less than normal distances and intervals." [Ref. 4:p 1-45] For the purposes of this study, mass is a means for measuring force concentration at the team level.

Speed or Velocity. For the purposes of this study, velocity is based on the aggregate ground movement of each team in the TF. It is a means for measuring individual team movement during mission execution. The aggregate team velocity is calculated for each team at each 5-minute time-step.

INGRES. A database management system employed by the Army Research Institute-Combat Training Center, Presidio of Monterey (ARI-CTC, POM) to collect, process and disseminate NTC instrumented data.

GNATT (General-purpose NTC Analysis of Training Tool). A software package that provides a dynamic replay of each mission by employing the training exercise data on an MS-DOS computer with color. Allows the user to follow each NTC historical mission by graphical playback on the computer monitor. The monitor displays the battle to the viewer as though he were observing the mission on a military topographical map with graphical symbols representing vehicle types. The monitor dynamically displays the mission from beginning to end by updating the screen every 5 minutes.

The GNATT package employs a unique floppy disk for each historical mission. Each disk contains six data files. Of these six files, this study employs three which are tied together by the common field of time: Organizational (i.e.ORG.DAT), Mortality (i.e. MORT.DAT) and Player (i.e. PL.DAT):

- The ORG.DAT file identifies all platoons composing the TF. Each platoon is specified by its organic unit designation.

- The MORTALTY.DAT file is described in the glossary under Mortality File.

- The PL.DAT file identifies each vehicle belonging to the TF by a unique number.

Strongpoint. "A key point in a defensive position, usually strongly fortified and heavily armed with automatic weapons, around which other positions are grouped for its protection." [Ref. 4:p 1-167]

Punch Power. "Punch" power is commonly referred to as the true strength of any maneuver force on the battle field. The task force commander and his staff constantly strive to aim their massed "punch" power at the OPFOR's weakest point, and propel this concentrated force through the enemy's defensive belt as rapidly as possible.

TACS. The data collection center for NTC. Contains a complex data collection system designed to support the NTC mission. The TACS primary function is to monitor, record and disseminate pertinent information pertaining to each mission conducted at NTC. All data collected is transported to ARI-CTC located at Monterey, California.

Initialization File. This is an INGRES file which specifies the task organization for each historical NTC mission. It contains the TF's platoons by their organic designations, and associates each platoon with its respective team.

Mortality File. A GNATT file, specifically ORG.DAT, which contains a listing of the vehicles "killed" during the historical NTC mission listed by time, unique player number and type of vehicle.

Task Organization. "A temporary grouping of forces designed to accomplish a particular mission. Task organization involves the distribution of available assets to subordinate control headquarters... " [Ref. 4:p 1-71]

Breach. The employment of any means available to break through or secure a passage through an enemy defense, obstacle, minefield, or fortification. [Ref. 4:p 1-12]

APPENDIX A: dBASE IV Program (MAIN11)

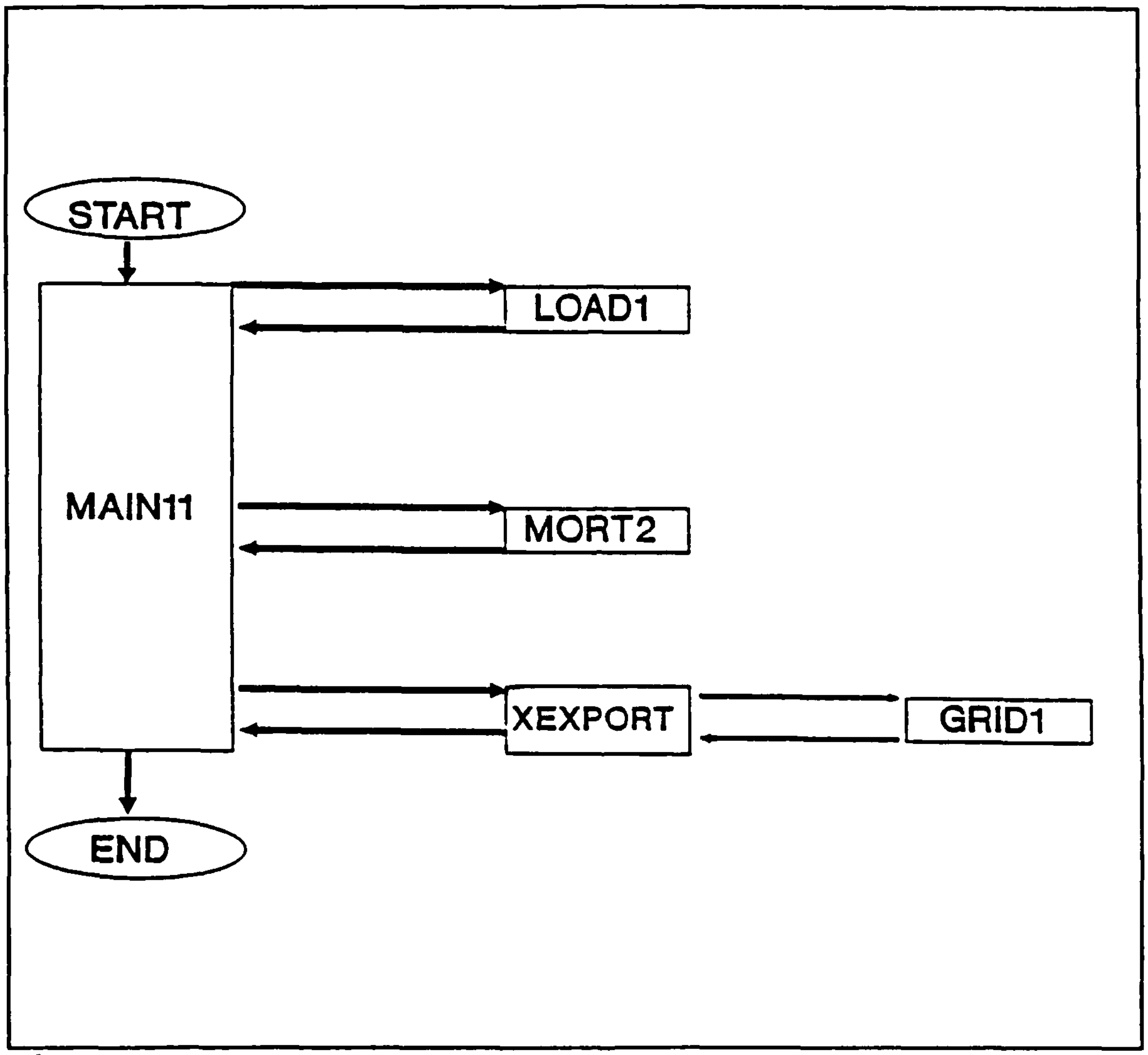

Figure 15 dBase IV program: MAIN11

```
****************************MAIN11.PRG*******************
*Program.....LOAD1.PRG
*Project.....Thesis
*Purpose.....main program for gnatt sort\format of .dat
*            files
*********************************************************

CLEAR ALL
SET TALK OFF

*-------------public variables---------------------------
PUBLIC mmoe
PUBLIC mmission
PUBLIC mateam,mbteam,mcteam,mdteam,meteam
PUBLIC matmpl1,matmpl2,matmpl3,matmpl4
PUBLIC mbtmpl1,mbtmpl2,mbtmpl3,mbtmpl4
PUBLIC mctmpl1,mctmpl2,mctmpl3,mctmpl4
PUBLIC mdtmpl1,mdtmpl2,mdtmpl3,mdtmpl4
PUBLIC metmpl1,metmpl2,metmpl3,metmpl4


          mmoe=0
          mmission="AA870220"

          mateam = "A5032"
             matmpl1 =' "2/A/5-032" '
             matmpl2 =' "3/A/5-032" '
             matmpl3 =' "1/C/5-032" '
             matmpl4 =' " Z        " '
          mbteam = "C5032"
             mbtmpl1 =' "2/C/5-032" '
             mbtmpl2 =' "3/C/5-032" '
             mbtmpl3 =' "1/A/5-032" '
             mbtmpl4 =' " Z        " '
          mcteam = "D5032"
             mctmpl1 =' "1/D/5-032" '
             mctmpl2 =' "2/D/5-032" '
             mctmpl3 =' "3/D/5-032" '
             mctmpl4 =' " Z        " '
          mdteam = "D3019"
             mdtmpl1 =' "1/D/3-019" '
             mdtmpl2 =' "2/D/3-019" '
             mdtmpl3 =' "3/D/3-019" '
             mdtmpl4 =' " Z        " '
          meteam = " Z   "
             metmpl1 =' " Z        " '
             metmpl2 =' " Z        " '
             metmpl3 =' " Z        " '
             metmpl4 =' " Z        " '
```

```
*------------------end public memory variables---------

   DO LOAD1      &&creates .dbf files from manually loaded
                 &&.dat files
   DO MORT2      &&modifies pl's;keeps earliest dead times
                 &&per pl
   DO XEXPORT    &&sorts\modifies .dbf files into player.dbf,
                 &&then creates a <<team>>.txt file for
                 &&each team
                 &&in the mission. next, .txt files
                 &&(i.e. export
                 &&files) are exported into apl for
                 &&clustering.
                 &&once clustering is complete, the
                 &&new modified .txt files are imported
                 &&back onto dbase\dump directory where the
                 &&programmer executes main2.prg to further
                 &&manipulate the data
```

```
************************************************************
*
*Program.....LOAD1.PRG
*Project.....Thesis
*Purpose.....Creates player/org/mort.dbf files and copies
*            records from pl/org/mortalty.dat files into
*            dbase IV
************************************************************

*------creates player.dbf andloads pl.dat data----------

USE PSHELL                    &&data structure shell for
                              &&player.dbf
COPY STRU EXTENDED TO PSHELL2 &&copies structure shell
                              &&to pshell2.dbf

USE                           &&closes pshell.dbf file

*------creates org.dbf and loads org.dat data----------
CLEAR
@12,15 SAY "CREATING PLAYER.DBF"
CREATE PLAYER FROM PSHELL2
APPEND FROM PL.DAT DELIMITED WITH BLANK

USE OSHELL
COPY STRU EXTENDED TO OSHELL2
USE
CLEAR
@12,15 SAY "CREATING ORG.DBF"
CREATE ORG FROM OSHELL2
APPEND FROM ORG.DAT DELIMITED WITH BLANK
REPLACE ALL ORG WITH SUBSTR(ORG,2,22)

*------creates mort.dbf and loads mortality.dat data---

USE MSHELL
COPY STRU EXTENDED TO MSHELL2
USE
CLEAR
@12,15 SAY "CREATNG MORT.DBF"
CREATE MORT FROM MSHELL2
APPEND FROM MORTALTY.DAT DELIMITED WITH BLANK


USE
RETURN

*--------------------end LOAD1.PRG------------------
*--------------------return to MAIN11.PRG-----------
```

```
***********************************************************
*Program....MORT2.PRG
*Project....Thesis
*Purpose....Front loads all pl's (i.e ingres lpn's)
*           with 0's if not three digits in length already
*           example: pl = 37 replaced by pl = 037
*           another example: pl = 137 replaced by pl = 137
***********************************************************

  CLEAR
  @12,15 SAY "DELETING ALIVE RECORDS"
  USE MORT
     INDEX ON PL TO MORT
     DELE FOR COND<>'DEAD'
     PACK
  USE
  @14,15 SAY "FIXING DATA IN MORT.DBF"
  USE MORT INDEX MORT
     DO WHILE .NOT. EOF()

        MPL = PL             &&mpl is a memory variable

                             &&val(mpl) changes mpl from
                             &&character stirng to
                             &&number  if<00 front loads a
                             &&0 always removes trailing
                             &&blanks from character
                             &&expression:
        IF VAL(MPL)<100
           REPLACE PL WITH "0" + TRIM(MPL)
        ENDIF

        SKIP                  &&moves pointer to next record
     ENDD

*------------creates mort1.dbf sorted by pl and time-------
     @16,15 SAY "SORTING MORT.DBF ON PL AND TIME"
     SORT ON PL,TIME TO MORT1

  USE                         &&closes mort.dbf

  USE MORT1
      SET UNIQUE ON           &&includes one record for each
                              &&unique pl in mort1.dbf
                              &&displaying only the earliest
                              &&dead times per pl
      INDEX ON PL TO MORT1
  USE
  RETURN
*--------------------return to MAIN11.PRG-----------
```

```
**********************************************************
*Program.....XEXPORT.PRG
*Project.....Thesis
*Purpose.....This program combines the three mission-
* # .dat files (pl,org,mortalty) into one
* required <<team>>.txt file for each team in the
* mission.
**********************************************************

*-----------------linking files------------------------
  CLEAR
@12,15 SAY "LINKING FILES"
  SELECT 3
    USE MORT1 INDEX MORT1
  SELECT 2
    USE ORG
        INDEX ON PL TO ORG
        SET RELA TO PL INTO C
  SELECT 1
    USE PLAYER
        SET RELA TO PL INTO B

               &&keeps vehs of type 1,3,29;keeps blue
               &&players;keeps live-times for
               &&each veh throughout mission.
        CLEAR
        @14,15 SAY "DELETING ALL NON-BLUE PLAYERS"
        DELE ALL FOR B->FORCE<>'B' .OR.;
           (B->VEH<>1 .AND. B->VEH<>3 .AND. B->VEH<>29);
           .OR. ( C->TIME<=TIME)
        PACK
    USE

    DO GRID1        &&corrects ycoords<70000

    USE PLAYER
        SET RELA TO PL INTO B
*---------------end linking files---------------------

*---------------creating and formating.text files------
*---------------creates .dbf file for each &_team------
            CLEAR
            @18,15 SAY "CREATING TEXT FILES"
            SET ALTERNATE TO &mateam
                SET ALTERNATE ON

               &&refer to public memory variables for data
               &&used in below &m_tmpl_'s


                LIST TIME,PL,XCOORD,YCOORD,B->VEH,;
```

```
              B->ORG OFF FOR B->ORG= &matmpl1 ;
              .OR. B->ORG= &matmpl2 .OR.;
              B->ORG= &matmpl3 .OR. B->ORG= &matmpl4
        CLOSE ALTERNATE

          &&creates listing of live vehicles in a team
          &&for each deltaT throughout mission #

        SET ALTERNATE TO &mbteam
            SET ALTERNATE ON
            LIST TIME,PL,XCOORD,YCOORD,B->VEH,;
              B->ORG OFF FOR B->ORG= &mbtmpl1 ;
              .OR. B->ORG= &mbtmpl2 .OR.;
              B->ORG= &mbtmpl3 .OR. B->ORG= &mbtmpl4
        CLOSE ALTERNATE
        SET ALTERNATE TO &mcteam
            SET ALTERNATE ON
            LIST TIME,PL,XCOORD,YCOORD,B->VEH,;
              B->ORG OFF FOR B->ORG= &mctmpl1 ;
              .OR. B->ORG= &mctmpl2 .OR.;
              B->ORG= &mctmpl3 .OR. B->ORG= &mctmpl4
        CLOSE ALTERNATE
        SET ALTERNATE TO &mdteam
            SET ALTERNATE ON
            LIST TIME,PL,XCOORD,YCOORD,B->VEH,;
              B->ORG OFF FOR B->ORG= &mdtmpl1 ;
              .OR. B->ORG= &mdtmpl2 .OR.;
              B->ORG= &mdtmpl3 .OR. B->ORG= &mdtmpl4
        CLOSE ALTERNATE
        SET ALTERNATE TO &meteam
            SET ALTERNATE ON
            LIST TIME,PL,XCOORD,YCOORD,B->VEH,;
              B->ORG OFF FOR B->ORG= &metmpl1 ;
              .OR. B->ORG= &metmpl2 .OR.;
              B->ORG= &metmpl3 .OR. B->ORG= &metmpl4
        CLOSE ALTERNATE
  USE
 SELECT 2
  USE
 SELECT 3
  USE

*-------------------end creating and formating .text files--

 RETURN
*-------------------return to MAIN11.prg-------------------
```

```
*****************************************************
*Program....GRID1.PRG
*Project....Thesis
*Purpose....Converts actual map grid coordinates to
*           compensate for --00-- y-grid line depicted
*           on the National Training Center topographic
*           map.
*****************************************************

* val(my) changes my from character to number
* string; if <70000 front loads a 1; else front loads
* a 0; always removes trailing blanks from character
* expression
*@16,15 SAY "CORRECTING FOR -00- & QUALITY CONTROL IN
PLAYER.DBF"

  USE PLAYER
      DO WHILE .NOT. EOF()
     my = YCOORD
     DO CASE
        CASE VAL(my)<1
         REPLACE YCOORD WITH "000000" + TRIM(my)
        CASE VAL(my)<10
         REPLACE YCOORD WITH "00000" + TRIM(my)
        CASE VAL(my)<100
         REPLACE YCOORD WITH "0000" + TRIM(my)
        CASE VAL(my)<1000
         REPLACE YCOORD WITH "000" + TRIM(my)
        CASE VAL(my)<10000
         REPLACE YCOORD WITH "00" + TRIM(my)
        CASE VAL(my)<100000
         REPLACE YCOORD WITH "0" + TRIM(my)
        ENDCASE

        SKIP
      ENDDO
   USE

  USE PLAYER
    DO WHILE .NOT. EOF()
       mx = XCOORD
       DO CASE
          CASE VAL(mx)<1
           REPLACE XCOORD WITH "000000" + TRIM(mx)
          CASE VAL(mx)<10
           REPLACE XCOORD WITH "00000" + TRIM(mx)
          CASE VAL(mx)<100
           REPLACE XCOORD WITH "0000" + TRIM(mx)
          CASE VAL(mx)<1000
           REPLACE XCOORD WITH "000" + TRIM(mx)
          CASE VAL(mx)<10000
```

```
        REPLACE XCOORD WITH "00" + TRIM(mx)
        CASE VAL(mx)<100000
        REPLACE XCOORD WITH "0" + TRIM(mx)
        ENDCASE

        SKIP
  ENDDO
USE
USE PLAYER
    DO WHILE .NOT. EOF()

   my = YCOORD              &&my is a memory variable
   DO CASE
      CASE VAL(my) => 100000
      @ 12,12 SAY "GRID ALREADY HAS -00- COMPENSATION?"
      @ 14,12 SAY RECNO()
      WAIT
      *EXIT
      CASE ((033000 < VAL(my)) .AND. (VAL(my) < 087000))
      @ 12,12 SAY " GRID NOT WITHIN NTC NORTH/SOUTH;

                BOUNDARY"
      @ 14,12 SAY RECNO()
      WAIT
      *EXIT
      CASE VAL(MY) <= 033000
      my2 = VAL(MY) + 100000
      REPLACE YCOORD WITH STR(my2,6,0)
      ENDCASE
   SKIP                  &&moves pointer to next record
   ENDDO                    &&returns to top of do loop
USE

  RETURN
*--------------------returns to XEXPORT.PRG------------
```

APPENDIX B: dBASE IV Program (MAIN22)

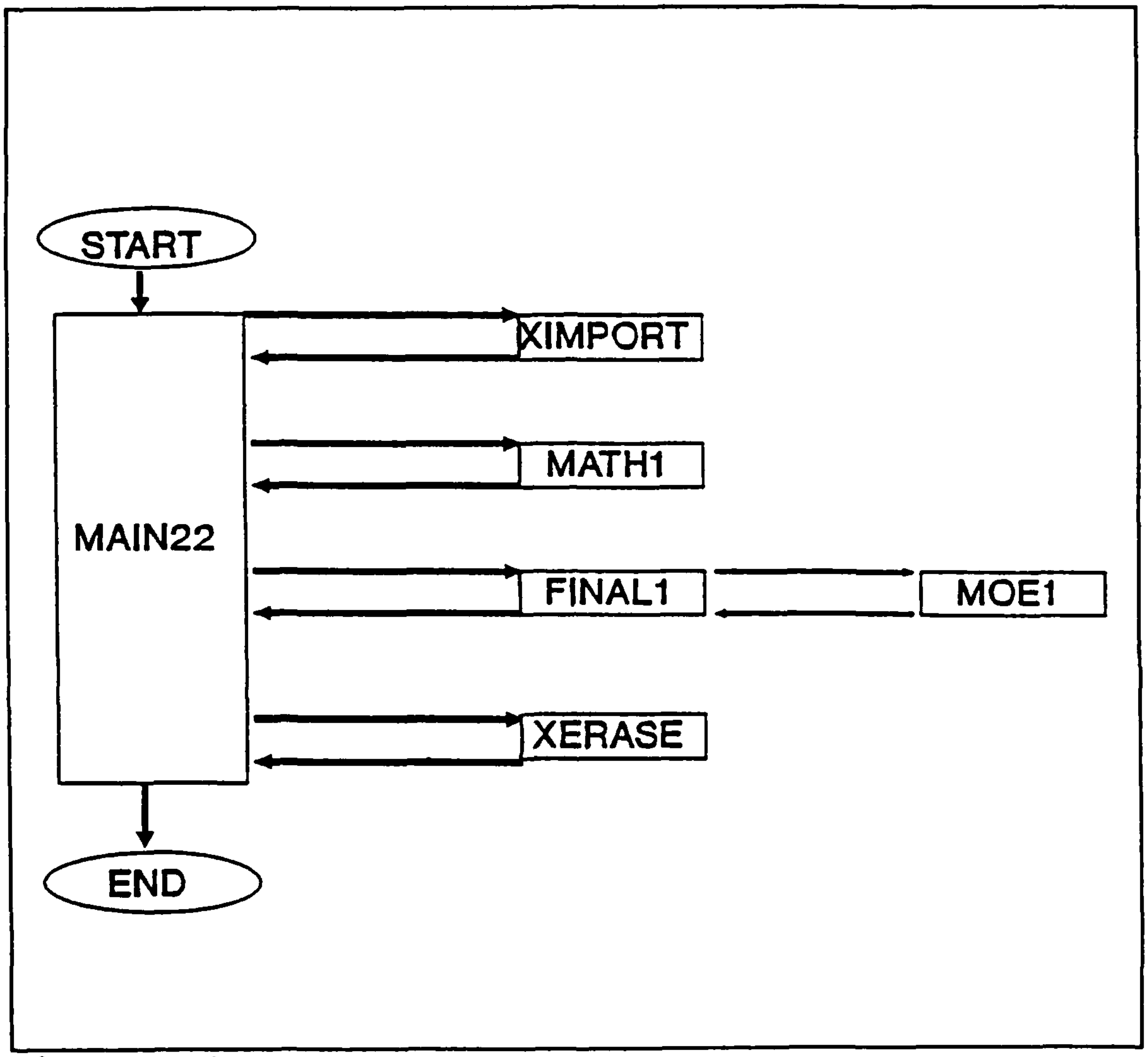

Figure 16 dBASE IV program:MAIN22

```
***********************************************************
*Program....MAIN22.PRG
*Project....Thesis
*Purpose....Uses clustered .txt files to produce
*           final statistical analysis matrix for each
*           mission from sample set(i.e. by running this
*           program, you add a new mission data subset to
*           the matrix.dbf file).
***********************************************************

*------------public variables--------------------------
PUBLIC mmoe
PUBLIC mmission
PUBLIC mobstcle
PUBLIC mateam,mbteam,mcteam,mdteam,meteam
PUBLIC matmpl1,matmpl2,matmpl3,matmpl4
PUBLIC mbtmpl1,mbtmpl2,mbtmpl3,mbtmpl4
PUBLIC mctmpl1,mctmpl2,mctmpl3,mctmpl4
PUBLIC mdtmpl1,mdtmpl2,mdtmpl3,mdtmpl4
PUBLIC metmpl1,metmpl2,metmpl3,metmpl4
PUBLIC mxredcrd, myredcrd

      mobstcle= .0
      mxredcrd= .0
              &&red-force strong point x-centroid
      myredcrd= .0
              &&red-force strong point y-centroid

          mmoe=0
          mmission="AA870220"

          mateam = "A5032"
             matmpl1 =' "2/A/5-032" '
             matmpl2 =' "3/A/5-032" '
             matmpl3 =' "1/C/5-032" '
             matmpl4 =' " Z         " '
          mbteam = "C5032"
             mbtmpl1 =' "2/C/5-032" '
             mbtmpl2 =' "3/C/5-032" '
             mbtmpl3 =' "1/A/5-032" '
             mbtmpl4 =' " Z         " '
          mcteam = "D5032"
             mctmpl1 =' "1/D/5-032" '
             mctmpl2 =' "2/D/5-032" '
             mctmpl3 =' "3/D/5-032" '
             mctmpl4 =' " Z         " '
          mdteam = "D3019"
             mdtmpl1 =' "1/D/3-019" '
             mdtmpl2 =' "2/D/3-019" '
             mdtmpl3 =' "3/D/3-019" '
             mdtmpl4 =' " Z         " '
```

```
          meteam = ' " Z        " '
          metmpl1 =' " Z        " '
          metmpl2 =' " Z        " '
          metmpl3 =' " Z        " '
          metmpl4 =' " Z        " '

*------------------end public memory variables---------
  SET SAFETY OFF
  SET TALK OFF
  DO XIMPORT &&imports clustered .txt files and renames to
       &&original .dbf file names

  DO MATH1   &&calculates velocity,mass and momentum

  DO FINAL1  &&determines time,location,momentum and moe for
       &&each blue team's entrance into the red force's
       &&strong-point circle for each mission(i.e. loads
       &&above information into matrix.dbf for each team
       &&in a given mission)

  DO XERASE  &&erases unnecessary dbase\dump directory files

  CLEAR ALL
  SET TALK ON
```

```
*****************************************************
*Program....XIMPORT.PRG
*Project....Thesis
*Purpose....Import clustered .txt files into
*           dbase\dump directory
*****************************************************

*------------------- importing .txt files-------

*                            creating and formating
*                            .dbf files to accept
*                            imported .txt data
*                            (ex. &_team represents
*                            .txt file; _team
*                            represents .dbf file)
  CLEAR
  @12,15 SAY "IMPORTING  CLUSTERED .TXT FILES"
  USE TSHELL
      COPY STRU EXTENDED TO TSHELL2
  USE
  CREATE ATEAM FROM TSHELL2

         COPY STRU TO BTEAM
         COPY STRU TO CTEAM
         COPY STRU TO DTEAM
         COPY STRU TO ETEAM
  USE ATEAM
     APPEND FROM &mateam DELIMITED WITH BLANK
     DELE FOR LEN(TRIM(TIME))<8
     PACK
  USE BTEAM
     APPEND FROM &mbteam DELIMITED WITH BLANK
     DELE FOR LEN(TRIM(TIME))<8
     PACK
  USE CTEAM
     APPEND FROM &mcteam DELIMITED WITH BLANK
     DELE FOR LEN(TRIM(TIME))<8
     PACK
  USE DTEAM
     APPEND FROM &mdteam DELIMITED WITH BLANK
     DELE FOR LEN(TRIM(TIME))<8
     PACK
  USE ETEAM
     APPEND FROM &meteam DELIMITED WITH BLANK
     DELE FOR LEN(TRIM(TIME))<8
     PACK
USE
*--------------end importing .txt files------
RETURN
*--------------return to MAIN22.PRG----------
```

```
***********************************************************
*Program....MATH1.PRG
*Project....Thesis
*Purpose....To calculate momentum,mass and velocity for
*           each team.dbf file; then create a mission#.dbf
*           file with required information from all teams
*           operating in this mission.
***********************************************************

*-----------------private memory variables-------------

mradius= 1000.0    &&arbitrary circular radius
mcount=0.0         &&counter
mtcount=1.0        &&counter
mxcoord= 0.0       &&team average x-centroid coordinate
mycoord= 0.0       &&team average y-centroid coordinate
mvelocty= 0.0      &&team average velocity over deltaT
mmomntum= 0.0
mmass= 0.0         &&team mass for deltaT
mtime=SPACE(8)     &&delatT time variable holder
mteam=SPACE(5)     &&organic team name variable holder
mrecord=0.0        &&variable holder
mxdif= 0.0         &&x-difference between team and individual
veh
mydif= 0.0         &&y-difference between team and individual
veh
mdis= 0.0          &&euclidian distance in meters
mxsub= 0.0         &&variable holder
mysub= 0.0         &&variable holder

*--------------end private memory variables------------

*--------------create empty mission#.dbf file---------------
CLEAR
@12,15 SAY "CREATING MISSION FILE"
USE MATHSHEL
    COPY STRU EXTENDED TO MATHSHL2
USE
    CREATE &mmission FROM MATHSHL2
USE
SELECT 3
    USE &mmission           &&alias: is mmission
    SET SAFETY OFF
    ZAP                     &&removes all records but leaves
                            &&database shell intact

                            &&leaves empty mission#.dbf file
                     &&open to receive data

*-------------choose a team.dbf file to work with------
CLEAR
```

```
DO WHILE mtcount <= 5.0
   SELECT 2                    &&alias: one of
                           &&(ateam,bteam,cteam,dteam)

                           &&chooses each team.dbf file,
                           &&listed below (i.e. ateam),
                           &&once for use in this subroutine
   DO CASE
      CASE mtcount = 1.0
         USE ATEAM               &&uses ateam.dbf file on
                                 &&dbase.directory
         mteam =  "ATEAM"       &&recall these are memory vars
      CASE mtcount = 2.0
         USE BTEAM              &&uses bteam.dbf file on
                                 &&dbase.directory
         mteam = "BTEAM"
      CASE mtcount = 3.0
         USE CTEAM              &&uses cteam.dbf file on
                                 &&dbase.directory
         mteam = "CTEAM"
      CASE mtcount = 4.0
         USE DTEAM              &&uses dteam.dbf file
                                 &&on dbase.directory
         mteam ="DTEAM"
      CASE mtcount = 5.0
         USE ETEAM              &&uses eteam.dbf file
                                 &&on dbase.directory
         mteam ="ETEAM"
   ENDCASE
*---------completes selecting one team.dbf file to work with

*---------conducts calculations on above team.dbf file----

   *@14,15 SAY "PERFORMING CALCULATIONS ON " + mteam
   DO WHILE .NOT. EOF()
      mtime=TIME
              && tells you at what record the pointer
              && is locating:
      mrecord=RECNO()
              && averages all team coordinates for a
              && single deltaT and stores value in
              && x-memory variable(i.e.mxcoord) and
              && y-memory vaiable (i.e.mycoord):

      AVERAGE XCOORD,YCOORD FOR TIME= mtime
      TO mxcoord,mycoord

                           &&returns pointer to this memory var
                           &&value:
      GO mrecord
```

```
    DO WHILE TIME=mtime
                         &&mass calculations:
   mxdif=XCOORD-mxcoord
   mydif=YCOORD-mycoord
   mdis=FIXED(SQRT((mxdif*mxdif)+(mydif*mydif)))
   IF mdis<=mradius
      mmass=mmass+ 1.0
   ENDIF
   SKIP
    ENDDO
                         &&velocity calculations:
    IF mxsub<> 0.0 .AND. mysub<> 0.0
       mxdif=mxcoord-mxsub
       mydif=mycoord-mysub
       mdis=FIXED(SQRT((mxdif*mxdif)+(mydif*mydif)))
    ELSE
       mdis= 0.0
    ENDIF


    mvelocty=mdis* 0.012 &&above block discusses mvelocty
    mmomntum=mvelocty*mmass
*------------------------------------------------------------

           &&completes calculations for one delta
           && form above team.dbf file
           && loads required data for one deltaT
           && from above team.dbf file mission#.dbf
           && file
    SELECT 3
    @16,15 SAY "STORING DATA FROM ONE deltaT"

    APPEND BLANK    &&adds single blank record to database

    REPLACE TIME WITH mtime,XCOORD WITH mxcoord
    REPLACE YCOORD WITH mycoord,TEAM WITH mteam
    REPLACE MASS WITH mmass,VELOCITY WITH mvelocty
    REPLACE MOMENTUM WITH mmomntum
    mxsub=mxcoord
    mysub=mycoord
    STORE 0.0 TO mxcoord,mycoord,mvelocty,mmomntum,mmass
    SELECT 2
  ENDDO
*---------ends calculations for one team.dbf----

  mtcount=mtcount + 1.0          &&gets next team
  @12,15 SAY SPACE(60)
  @12,15 SAY SPACE(60)
  @12,15 SAY SPACE(60)
  mysub = 0
  mxsub = 0
```

```
ENDDO
*---------ends choose a team.dbf-----------------

SET SAFETY ON
SELECT 3
USE
SELECT 2
USE
RETURN
*-----------return to MAIN22.PRG-----------------------
```

```
*************************************************************
*Program....FINAL1.PRG
*Project....Thesis
*Purpose....Loads required data into matrix dbf for first
*           time
*           entry into opposing force's strong-point
*           circular radus.
*************************************************************


*--------------private memory variables----------------


mcount= 1.0          &&counter
mrecord= 0.0         &&teamrecord counter
mexit= 0.0           &&inter-loop exit
mtxdif= 0.0          &&x-difference between team and
                     &&strong-point-
                     &&x-centroid in meters
mtydif= 0.0          &&y-difference between team and
                     &&strong-point-
                     &&   y-centroid
mtdis= 0.0           &&euclidian distance
mtxsub= 0.0          &&variable holder
mtysub= 0.0           &&variable holder
*--------------end private memory variables-----------

   CLEAR
   @12,15 SAY "RECORDING MATRIX DATA FOR MISSION"
   STORE FILE ("MATRIX.DBF") TO mthere
   IF .NOT. mthere
      USE STATSHEL
         COPY STRU EXTENDED TO STATSHL2
      USE
      CREATE MATRIX FROM STATSHL2
      USE
    ENDIF
   DO MOE1

   SELECT 1
     USE MATRIX
   SELECT 3
     USE &mmission
        DO WHILE mcount <= 5.0
           mexit = 0.0
           DO CASE
              CASE mcount = 1.0
                 COPY TO AFINAL FOR TEAM = "ATEAM"
                 SELECT 2
                 USE AFINAL
                     mrecord= 1.0
```

```
        CASE mcount = 2.0
           COPY TO BFINAL FOR TEAM = "BTEAM"
           SELECT 2
           USE BFINAL
               mrecord= 2.0
        CASE mcount = 3.0
           COPY TO CFINAL FOR TEAM = "CTEAM"
           SELECT 2
           USE CFINAL
               mrecord= 3.0
        CASE mcount = 4.0
           COPY TO DFINAL FOR TEAM = "DTEAM"
           SELECT 2
           USE DFINAL
               mrecord= 4.0
        CASE mcount = 5.0
           COPY TO EFINAL FOR TEAM = "ETEAM"
           SELECT 2
           USE EFINAL
               mrecord= 5.0
     ENDCASE

     DO WHILE mexit = 0.0 .AND. (.NOT. EOF())
        mtxdif = XCOORD - mxredcrd
        mtydif = YCOORD - myredcrd
     mtdis =
       FIXED(SQRT((mtxdif*mtxdif)+(mtydif*mtydif)))

        IF mtdis <= mobstcle  &&only want to record
                              &&the first time this
                              &&is true, then leave
                              &&_final.dbf
           mtxsub = XCOORD
           mtysub = YCOORD

           SELECT 1
             APPEND BLANK
             REPLACE TEAMRECORD WITH mrecord
             REPLACE TIME WITH B->TIME,XCOORD WITH
               mtxsub
             REPLACE YCOORD WITH mtysub,TEAM WITH
               B->TEAM
             REPLACE MOMENTUM WITH B->MOMENTUM
             REPLACE MOE WITH mmoe
             mexit = 1.0
        ELSE
             SKIP
        ENDIF
     ENDDO

IF mexit = 0.0
```

```
            SELECT 2
              GO TOP
            SELECT 1
              APPEND BLANK
              REPLACE TEAMRECORD WITH mrecord
              REPLACE TIME WITH "0",XCOORD WITH 0,YCOORD
               WITH 0
              REPLACE TEAM WITH B->TEAM,MOMENTUM WITH 0
              REPLACE MOE WITH mmoe
         ENDIF
       mcount = mcount + 1.0
       SELECT 3
       ENDDO
  SELECT 3
  USE
  SELECT 2
  USE
  SELECT 1
  USE
  RETURN
  *--------------------return to MAIN22.PRG-------------
```

```
*************************************************************
*Program....MOE1.PRG
*Project....Thesis
*Purpose....Calculates mission moe and passes to final1.prg
*************************************************************

*----------------private memory variables--------------------
mbtotal=0.0
mototal=0.0
mbfinal=0.0
mofinal=0.0
malpha=0.5
mbeta=0.5

*---------------end private memory variable---------------
CLEAR
@12,15 SAY "CALCULATING MISSION MOE"
USE ORG
    COUNT FOR FORCE='B' .AND. (VEH=1 .OR. VEH=3 .OR.
       VEH=29);
     TO mbtotal
    COUNT FOR FORCE='O' .AND. (VEH=1 .OR. VEH=4) TO mototal
USE
SELECT 2
    USE MORT1 INDEX MORT1
SELECT 3
    USE ORG
    SET RELA TO PL INTO B
    COUNT FOR PL<>B->PL .AND. FORCE='B' .AND.;
         (VEH=1 .OR. VEH=3 .OR. VEH=29);
         TO mbfinal
    COUNT FOR PL<>B->PL .AND. FORCE='O' .AND.;
         (VEH=1 .OR. VEH=4) TO mofinal
USE
mmoe=malpha*(mbfinal/mbtotal) + mbeta*(mofinal/mototal)

RETURN

*---------------return to FINAL1.PRG-----------
```

```
************************************************************
*Program....XERASE.PRG
*Project....Thesis
*Purpose....Erases unnecessary files from dbase\dump
*           directory
************************************************************
mmiss=0

CLEAR
@12,15 SAY "ERASING UNNECESSARY FILES"
ERASE OSHELL2.DBF
ERASE TSHELL2.DBF
ERASE PSHELL2.DBF
ERASE MSHELL2.DBF
ERASE STATSHL2.DBF
ERASE MATHSHL2.DBF
ERASE PLAYER.DBF
ERASE ORG.DBF
ERASE MORT.DBF
ERASE PL.DAT
ERASE ORG.DAT
ERASE MORTALTY.DAT
ERASE ORG.DAT
ERASE ENG.DAT
ERASE CMT.DAT
ERASE MORT1.NDX
ERASE MORT1.DBF
ERASE MORT.NDX
ERASE ORG.NDX
ERASE ATEAM.DBF
ERASE MAIN11.PRG
ERASE MAIN22.PRG
ERASE MAIN11.DBO
ERASE BTEAM.DBF
ERASE CTEAM.DBF
ERASE DTEAM.DBF
ERASE ETEAM.DBF
ERASE AFINAL.DBF
ERASE BFINAL.DBF
ERASE CFINAL.DBF
ERASE DFINAL.DBF
ERASE EFINAL.DBF
ERASE mmission + ".DBF"
ERASE mmission + ".ARC"
ERASE trim(mateam) + ".TXT"
ERASE trim(mbteam) + ".TXT"
ERASE trim(mcteam) + ".TXT"
ERASE trim(mdteam) + ".TXT"
ERASE trim(meteam) + ".TXT"
```

APPENDIX C: Clustering

The following programs constitute a cluster analysis technique that is based on an algorithmic description found in a textbook by Charles H. Romesburg [Ref.6]. The cluster method used is non-standardized, euclidean distance, average linkage method. Major Jim Hoffman and Captain Derryl Hamilton wrote the original function MASTER, and sub-functions CLUSTER, CLMETHOD, and MINKOWSKI in A Programming Language (APL). Captain David Dryer and Professor Robert R. Reed modified these functions and added function DRYER to interface this clustering method with the cluster requirements for this thesis. These functions have not been verified by an independent source and use of them in other research is at the user's own risk.

The beginning comments of function DRYER state the input file TM.TXT inputs the x and y coordinates of a team's vehicles. The clustering method weeds out vehicles or groups of vehicles that are located at greater distances than the specified input distance (YLIMIT) in meters. The heart of the method is the production of a matrix called ZMOD and a vector Y. A sample of each follows:

ZMOD	Y	YLIMIT = 2000(meters)
1 2 3 4 5	0	
1 2 3 3 5	505.3	
1 2 3 3 1	610.1	
1 2 2 2 1	1801.9	
1 1 1 1 1	3987.4	

The columns of ZMOD represent the different vehicles. If vehicles have the same number, then they have been clustered together at the distance specified in Y. Since YLIMIT is 2000 meters in this case, vehicles 2,3 and 4 are clustered together and vehicles 1 and 5 are eliminated since they cluster with the main body at 3987.4 meters. The YLIMIT used in this study is 2000 meters for the reasons specified in Chapter III,A and B, respectively. For more information on this clustering method, read Chapter 2 of Reference 6.

```
     ⎕CR 'DRYER'
DRYER YLIMIT
⍝THE FUNCTION TAKES CPT PARKER'S INPUT TEAM DATA FILE, WEEDS OUT VEHICLES
⍝WITH A CLUSTER LEVEL HIGHER THAN YLIMIT, IN METERS.  THE CLUSTER METHOD
⍝USED IS NON-STANDARDIZED, EUCLIDEAN DISTANCE, AVERAGE LINKAGE METHOD.
⍝THIS FUNCTION CALLS FUNCTION MASTER, WHICH IN TURN CALLS SUBFUNCTIONS
⍝MINKOWSKI, CLUSTER, AND CLMETHOD TO EXECUTE THE CLUSTERING METHOD.
⍝THE INPUT FILE SHOULD BE CALLED TM.TXT AND NEEDS TO HAVE A BLANK LINE
⍝FOLLOWING THE LAST DATA LINE AS THE END DELIMETER.  THE OUTPUT FILE WILL
⍝BE CALLED TMMOD.TXT.
⍝
⍝TIE NATIVE INPUT FILE, ERASE/CREATE NATIVE OUTPUT FILE
'C:\APL\PARKDAT\TMMOD.TXT' ⎕NERASE ¯2
'C:\APL\PARKDAT\TMMOD.TXT' ⎕NCREATE ¯2
'C:\APL\PARKDAT\TM.TXT' ⎕NTIE ¯1
⍝INITIALIZE ALL FUNCTION COUNTERS
I←0
K←0
L←1
M←52
N←1
O←1
P←1
⍝INITIALIZE LAST NO. OF CLUSTER OBJECTS (LCLSTRNO) WHICH IS USED IN LOOP
⍝L8
LCLSTRNO←0
⍝READ FIRST LINE OF INPUT FILE INTO VAR. CHAR
CHAR←⎕NREAD ¯1 82 50 0
⍝READ FIRST CHARACTER TIME INTO VAR. ITIME
ITIME←CHAR[1 2 3 4 5 6 7 8 9 10]
⍝INITALIZE MATRIX OF CHARACTER TIMES (TIMEMAT)
TIMEMAT← 1 10 ⍴ITIME
⍝READ FIRST UNIT AND INITIALIZE MATRIX OF UNITS (UNITMAT)
UNITMAT← 1 9 ⍴(CHAR[29 30 31 32 33 34 35 36 37])
⍝READ FIRST LPN INTO VECTOR LPN
LPN←⍎CHAR[11 12 13]
⍝READ FIRST XCOORDINATE INTO VECTOR XCORD
XCORD←⍎CHAR[15 16 17 18 19 20]
⍝READ FIRST YCOORDINATE INTO VECTOR YCORD
YCORD←⍎CHAR[22 23 24 25 26 27]
⍝IF YCORD IS ABOVE OO GRID LINE, ADD 10000 TO FIVE DIGIT GRID
→(YCORD≥70000)/LA
YCORD←YCORD+100000
LA:
⍝SAVE ITIME AS LTIME TO CHECK WHEN NEXT TIME INCREMENT OCCURS
LTIME←ITIME
L1:
I←0
L2:
⍝LOOP L2 CONTINUES TO READ DATA, UNTIL CURRENT TIME (ITIME) ≠ PREVIOUS
⍝TIME (LTIME), THEN GO TO L3:
CHAR←⎕NREAD ¯1 82 50 ,M
ITIME←CHAR[1 2 3 4 5 6 7 8 9 10]
→(ITIME≠LTIME)/L3
UNITMAT←UNITMAT,[1](1 9 ⍴(CHAR[29 30 31 32 33 34 35 36 37]))
LPN←LPN,(⍎CHAR[11 12 13])
XCORD←XCORD,(⍎CHAR[15 16 17 18 19 20])
YTEMP←(⍎CHAR[22 23 24 25 26 27])
→(YTEMP≥70000)/LB
YTEMP←YTEMP+100000
```

```
LB:
YCORD←YCORD,YTEMP
LTIME←ITIME
I←I+1
M←M+52
→L2
L3:
LTIME←ITIME
⍝BUILD MATRIX OF TIME INCREMENTS
TIMEMAT←TIMEMAT,[1](1 10 ⍴ITIME)
K←K+1
→(K>1)/L4
⍝ADD ONE TO THE FIRST NUMBER IN VECTOR COUNT, SINCE FIRST LINE OF DATA
⍝WAS NOT READ IN LOOP L2.  COUNT CONTAINS THE NUMBER OF VEHICLES
⍝CONTAINED IN EACH TIME INCREMENT
COUNT←I+1
→L5
L4:
COUNT←COUNT,I ⍝BUILD VECTOR COUNT (SEE LINE 52 ABOVE)
⍝CHECK FOR LAST BLANK LINE OF FILE.  IF LAST LINE, GO TO L6
→(ITIME[4]≠':')/L6
L5:
→L1
L6:
⍝REINITIALIZE COUNTERS
N←1 ⍝TRACKS CLUSTER LEVELS IN Z CLUSTER MATRIX
O←1 ⍝TRACKS OBJECT NUMBERS IN ZMOD CLUSTER MATRIX
P←1 ⍝COUNTS NUMBER OF CLUSTERED OBJECTS IN OUTPUT FILE LOOP L14
⍝INITIALIZE VALUE WHICH TRACKS HIGHEST NUMBER OF CLUSTERED OBJECTS IN THE
⍝SELECTED ROW OF THE ZMOD CLUSTER MATRIX
OBJSV←1
LCSTRNO←0 ⍝REINITIALIZE LAST NUMBER OF CLUSTERED OBJECTS
TIME←TIMEMAT[L;⍳10] ⍝READ CURRENT TIME FROM TIMEMAT
⍝READ CURRENT X AND Y COORDINATES FOR ALL VEHICLES IN CURRENT TIME
⍝INCREMENT INTO MATRIX DATA
A←(2,COUNT[L])⍴((COUNT[L])↑XCORD),((COUNT[L])↑YCORD)
LPNTEMP←COUNT[L]↑LPN ⍝READ CURRENT LPNS INTO VECTOR FOR OUTPUT USE
⍝READ CURRENT XCOORDINATES INTO VECTOR FOR OUTPUT USE
XCORDTEMP←COUNT[L]↑XCORD
⍝READ CURRENT YCOORDINATES INTO VECTOR FOR OUTPUT USE
YCORDTEMP←COUNT[L]↑YCORD
⍝READ CURRENT UNITS INTO MATRIX FOR OUTPUT USE
UNITEMP←((COUNT[L]),9)↑UNITMAT
⍝IF ONLY ONE VEHICLE, SKIP CLUSTERING AND GO TO L12
→(COUNT[L]=1)/L12
⍝CLUSTER DATA MATRIX USING FUNCTION MASTER, AND SUBFUNCTIONS MINKOWSKI,
⍝CLUSTER, AND CLMETHOD.  PRODUCES Z MATRIX, ZMOD MATRIX (WHICH TRACKS
⍝ACTUAL VEHICLE CLUSTERS, AND Y (THE LEVELS FROM THE Z MATRIX)
Z←MASTER DATA
⍝READ HIGHEST CLUSTER LEVEL NUMBER INTO YMAX
YMAX←Y[COUNT[L]]
⍝IF NO CLUSTER DISTANCE > YLIMIT (INPUT VALUE), GO TO →L12
→(YMAX≤YLIMIT)/L12
L7:
⍝LOOP L7 FINDS 1ST CLUSTER LEVEL (N) > YLIMIT (INPUT VALUE)
→(Y[N]>YLIMIT)/L8
N←N+1
→L7
⍝LOOPS L8, L9, L10, L11 FIND THE LARGEST CLUSTER OF VEHICLES AT LEVEL
⍝YLIMIT AND STORES THIS IN BOOLEAN VECTOR CSTRBOOL
```

```
L8:
⍝CSTRNO TRACKS NO. OF OBJECTS OF NUMBER 'O' AT LEVEL 'YLIMIT' IN
⍝MATRIX ZMOD
CSTRNO←+/CSTR←(ZMOD[(N-1);]=O)
⍝IF THE NUMBER OF CLUSTERED VEHICLES IS NOT TIED, OR THIS IS THE FIRST
⍝CLUSTER DETERMINED, GO TO L9 AND DO NOT BREAK CLUSTER TIES
→((CSTRNO≠LCSTRNO)∨(O=1)∨(L=1))/L9
⍝NEXT FIVE LINES BREAK CLUSTER TIES WITH THE CLOSEST CLUSTER TO THE
⍝PREVIOUS CLUSTER WINNING
CENTRD←(+/(CSTR/DATA))÷(+/CSTR)
LCENTRD←(+/(LCSTR/DATA))÷(+/LCSTR)
DIST←(((CLCENTRD[1]-CENTRD[1])*2)+((CLCENTRD[2]-CENTRD[2])*2))*0.5
LDIST←(((CLCENTRD[1]-LCENTRD[1])*2)+((CLCENTRD[2]-LCENTRD[2])*2))*0.5
→(DIST<LDIST)/L10
→L11
L9:
→(CSTRNO<LCSTRNO)/L11
⍝IF NUMBER OF VEHICLES IN CLUSTER 'O' IS > CLUSTER 'O-1' OR A TIE IS
⍝BROKEN IN FAVOR OF CLUSTER 'O', UPDATE CSTRBOOL AND LCSTRNO
L10:
CSTRBOOL←CSTR
LCSTRNO←CSTRNO
L11:
O←O+1
⍝SAVE CSTRBOOL IN LCSTR FOR POSSIBLE USE IN BREAKING CLUSTER TIES
LCSTR←CSTRBOOL
⍝CHECK ALL CLUSTERS (1 THROUGH 'O') AT LEVEL 'YLIMIT' IN MATRIX ZMOD
→(O≤COUNT[L])/L8
→L13
L12:
⍝IF ONLY ONE OBJECT, OR ALL OBJECTS CLUSTER AT A LEVEL ≤ YLIMIT,
⍝MAKE A CSTRBOOL OF ALL ONES
CSTRBOOL←(COUNT[L])⍴1
L13:
⍝DETERMINE CLUSTER CENTROID FOR POSSIBLE USE IN BREAKING CLUSTER TIES
CLCENTRD←(+/(CSTRBOOL/DATA))÷(+/CSTRBOOL)
⍝NEXT FOUR LINES UPDATE OUTPUT VARIABLES BASED ON CLUSTER
LPNTEMP←CSTRBOOL/LPNTEMP
XCORDTEMP←CSTRBOOL/XCORDTEMP
YCORDTEMP←CSTRBOOL/YCORDTEMP
UNITEMP←CSTRBOOL⌿UNITEMP
PMAX←+/CSTRBOOL
L14:
⍝OUTPUT CLUSTERED DATA TO FILE, NEXT TWO LINES COMMENTED OUT TO PRINT
⍝(TIME,' ',(⍕LPNTEMP[P]),' ',(⍕XCORDTEMP[P]),' ',(⍕YCORDTEMP[P]),' ',
⍝(UNITEMP[P;]),⎕TCNL,⎕TCLF)⎕NAPPEND ¯2
P←P+1
→(P≤PMAX)/L14
'TIME'
TIME
'Y'
Y
⍝NEXT FOUR LINES DELETES CURRENT TIME INCREMENT DATA TO PREPARE FOR NEXT
⍝LOOP STARTING AT L6
LPN←(COUNT[L])↓LPN
XCORD←(COUNT[L])↓XCORD
YCORD←(COUNT[L])↓YCORD
UNITMAT←((COUNT[L]),0)↓UNITMAT
L←L+1
→(L≤⍴COUNT)/L6
```

```
AONUNTIE ¯2 AUNTIE NATIVE OUTPUT FILE
END:
```

```
     ⎕CR 'MASTER'
Z←MASTER DATA
⍝'THE DATA MATRIX IS CALLED DATA (Rows ARE Attributes)'
⍝'NO Standardizing Required'
⍝'Euclidean Distance'
Z←2 MINKOWSKI DATA ⍝ EUCLIDEAN
⍝'CHOOSE A LINKAGE METHOD '
⍝'Average'
Z←CLUSTER Z
Y←Z[;4] ⋄ Y←¯1⌽Y ⋄ →END
END:
```

```
     ⎕CR 'CLUSTER'
Z←CLUSTER X;ROW;COL;LEVEL;RED;KEEPER;I;N;IND;CC;KR;KC
⍝ INPUT IS A RESEMBLENCE MATRIX. OUTPUT THE Z MATRIX
⍝ ZMOD IS GLOBAL OUTPUT IN CAPT. DRYER'S FORMAT
Z←((N←1↑⍴X),4)⍴0 ⍝ Z IS AN EMPTY MATRIX WHOSE COLUMNS ARE:
⍝ ITERATION, ROW, COLUMN, LEVEL
KEEPER←Z[;1]←⍳1↑⍴X ⍝KEEPER TRACKS THE TRUE OBJECTS
ZMOD←(N,N)⍴IND←⍳N ⋄ I←1 ⍝ZMOD COLLECTS ALL OBJECTS IN CLUSTERS
LIN:X←CLMETHOD X
Z[I;1+⍳3]←(KR←KEEPER[ROW]),(KC←KEEPER[COL]),LEVEL
RED←(⍴KEEPER)⍴1
RED[COL]←0 ⍝ RED IS THE REDUCTION VECTOR TO ELIM AN ELEMENT OF KEEPER
KEEPER←RED/KEEPER
CC←(ZMOD[I;]=KC)/IND ⋄ ZMOD[I+⍳N-I;CC]←KR
I←I+1 ⋄ →LIN×⍳1≠1↑⍴X
```

```
      ⎕CR 'MINKOWSKI'
Z←P MINKOWSKI X;I;J;N
⍝_FORMS THE RESEMBLENCE MATRIX USING MINKOWSKI METRIC (EUCLIDEAN P=2)
N←1↓⍴X ⋄ ⍝  N IS THE NUMBER OF COLUMNS (OBJECTS)
I←1
Z←(N,N)⍴0 ⋄ ⍝ Z IS AN EMPTY MATRIX OF OBJECT×OBJECT DIMENSION
LO:J←I+1
LI:Z[I;J]←+/(|X[;I]-X[;J])*P
→LI×⍳N≥J←J+1
→LO×⍳N>I←I+1
Z←Z*1÷P
Z←Z+⍉Z ⍝  Z IS A RESEMBLENCE MATRIX
```

```
      ⎕CR 'CLMETHOD'
ANS←CLMETHOD X;P;V;DD;I;J;NEWCOL;XX
⍝ INPUT IS A RESEMBLENCE MATRIX. OUTPUT THE REDUCED RESEMBLENCE MATRIX
P←1↑⍴X ⋄ ⍝ P IS DIMENSION OF THE MATRIX
V←(⍳P)∘.>⍳P ⋄ ⍝ V IS LOWER TRIANGULAR MATRIX OF ONES
DD←(,V)/,X ⋄ ⍝ DD LOWER TRIANGULAR MATRIX IN VECTOR FORM
I←(,V)/⍳P*2 ⋄ ⍝ I IS THE INDICES MATRIX OF DD
LEVEL←⌊/DD ⋄ ⍝ CHOOSE SMALLEST NUMBER IN MATRIX
J←1↑(DD=LEVEL)/I ⋄ ⍝ CHOOSE THE INDEX OF LEVEL
ROW←P|J ⋄ ⍝ ROW OF UPPER MATRIX INDEX NUMBER
COL←⌈J÷P ⋄ ⍝ COL IS THE OTHER INDEX
NEWCOL←X[;ROW]LINKMETHOD X[;COL] ⋄ ⍝ L... COMP NEW COLUMN AND ROW
XX←(P,P)⍴1
XX[;COL]←XX[COL;]←0 ⋄ ⍝ XX IS A MATRIX OF 1 EXCEPT THE ELIMINATED COL
X[;ROW]←X[ROW;]←NEWCOL
ANS←((P-1),(P-1))⍴(,XX)/,X ⋄ ⍝ ANS IS NOW LESS ONE ROW AND COLUMN
ANS←ANS×((P-1),(P-1))⍴0,(P-1)⍴1 ⋄ ⍝ ENSURE ANS HAS DIAG OF 0
```

APPENDIX D: Critical Point Data

MISSION		TIME	XCOORD	YCOORD	TEAM	MOMENTUM	MOE	MOE2	MOE3
MA870212	1	07:44:16	41693	94185	ATEAM	48.47	0.67	0.42	0.93
	2	07:44:16	42000	93763	BTEAM	15.99	0.67		
	3	0	0	0		0.00	0.67		
	4	07:49:16	42070	93325	DTEAM	64.01	0.67		
	5	0	0	0		0.00	0.67		
MA870626	1	0	0	0		0.00	0.67	0.33	1.00
	2	06:10:01	38583	121168	BTEAM	214.0	0.67		
	3	06:15:01	40407	121138	CTEAM	107.7	0.67		
	4	06:25:01	39725	121225	DTEAM	215.0	0.67		
	5	0	0	0		0.00	0.67		
MA870604	1	08:30:57	43282	88250	ATEAM	6.94	0.51	0.50	0.53
	2	09:20:57	44538	88525	BTEAM	63.00	0.51		
	3	0	0	0	CTEAM	0.00	0.51		
	4	0	0	0	DTEAM	0.00	0.51		
	5	0	0	0		0.00	0.51		
AA871421	1	0	0	0	ATEAM	0.00	0.60	0.22	0.94
	2	06:58:41	45506	100143	BTEAM	123.4	0.60		
	3	07:23:41	45688	99850	CTEAM	12.57	0.60		
	4	0	0	0		0.00	0.60		
	5	0	0	0		0.00	0.60		
MA881053	1	05:25:12	44104	115232	ATEAM	64.49	0.58	0.15	1.00
	2	05:15:12	44158	114510	BTEAM	32.21	0.58		
	3	05:35:12	44079	115650	CTEAM	36.31	0.58		
	4	05:20:12	44146	114375	DTEAM	21.53	0.58		
	5	0	0	0		0.00	0.58		

MA871409	1	07:00:54	39350	100650	ATEAM	8.39	0.60	0.27	0.92
	2	07:05:54	38146	95821	BTEAM	65.20	0.60		
	3	07:00:54	36033	95108	CTEAM	248.6	0.60		
	4	05:10:54	37246	97488	DTEAM	0.00	0.60		
	5	0	0	0		0.00	0.60		
MA870319	1	07:10:38	46782	103669	ATEAM	10.63	0.59	0.33	0.86
	2	06:45:38	49838	101755	BTEAM	30.65	0.59		
	3	0	0	0		0.00	0.59		
	4	06:45:38	49838	101755	DTEAM	30.65	0.59		
	5	0	0	0		0.00	0.59		
MA880632	1	12:55:27	37851	114988	ATEAM	31.49	0.70	0.57	0.83
	2	13:15:27	37744	114494	BTEAM	30.58	0.70		
	3	0	0	0		0.00	0.70		
	4	12:35:27	38413	114700	DTEAM	9.19	0.70		
	5	13:10:27	38785	114357	ETEAM	12.54	0.70		
AA880324	1	07:55:34	32607	95650	ATEAM	38.95	0.25	0.34	0.03
	2	0	0	0	BTEAM	0.00	0.25		
	3	08:15:34	33238	94932	CTEAM	69.39	0.25		
	4	09:00:34	32582	94988	DTEAM	69.41	0.25		
	5	0	0	0		0.00	0.25		
AA871115	1	0	0	0		0.00	0.30	0.16	0.44
	2	05:55:58	41567	95859	BTEAM	32.72	0.30		
	3	06:00:58	41688	97150	CTEAM	6.74	0.30		
	4	06:50:58	41769	96813	DTEAM	7.79	0.30		
	5	0	0	0		0.00	0.30		
MA880220	1	0	0	0		0.00	0.44	0.55	0.32
	2	07:31:12	43704	109958	BTEAM	13.61	0.44		
	3	0	0	0		0.00	0.44		
	4	08:01:12	43613	109596	DTEAM	48.13	0.44		
	5	08:56:12	43600	110388	ETEAM	14.80	0.44		
AA870432	1	06:25:01	32625	91488	ATEAM	11.67	0.39	0.34	0.43
	2	06:45:01	33207	91032	BTEAM	3.20	0.39		

	3	07:15:01	31808	91568	CTEAM	51.93	0.39		
	4	0	0	0		0.00	0.39		
	5	0	0	0		0.00	0.39		
MA871233	1	06:32:34	50619	100994	ATEAM	19.78	0.58	0.27	0.89
	2	0	0	0		0.00	0.58		
	3	07:27:34	52032	98777	CTEAM	31.65	0.58		
	4	06:47:34	52088	99119	DTEAM	26.23	0.58		
	5	06:27:34	51213	99194	ETEAM	29.35	0.58		
AA880614	1	04:48:54	36019	105126	ATEAM	16.72	0.32	0.46	0.18
	2	0	0	0		0.00	0.32		
	3	05:23:54	35898	105168	CTEAM	28.65	0.32		
	4	02:03:54	35057	102613	DTEAM	0.00	0.32		
	5	0	0	0		0.00	0.32		
MA871308	1	06:15:16	33125	90380	ATEAM	45.39	0.18	0.28	0.09
	2	06:10:16	33704	91017	BTEAM	36.10	0.18		
	3	0	0	0		0.00	0.18		
	4	06:05:16	33414	91017	DTEAM	85.51	0.18		
	5	0	0	0		0.00	0.18		
MA870828	1	06:20:53	34575	90900	ATEAM	9.80	0.33	0.24	0.41
	2	0	0	0		0.00	0.33		
	3	06:05:53	35095	94058	CTEAM	147.3	0.33		
	4	06:20:53	34717	90779	DTEAM	52.45	0.33		
	5	05:40:53	34586	94232	ETEAM	18.03	0.33		
MA870806	1	0	0	0		0.00	0.30	0.33	0.36
	2	05:35:10	38146	109629	BTEAM	124.5	0.30		
	3	04:00:10	37940	108760	CTEAM	0.00	0.30		
	4	05:35:10	38146	109629	DTEAM	124.5	0.30		
	5	04:00:10	37431	109085	ETEAM	0.00	0.30		

REFERENCES

1. Crouch, William W.,Brigadier General, U.S. Army, and Lieutenant Colonel Thomas V. Morley. June 1989. U.S. Army. Failed Overwatch: A Lack of Mass and Speed in the Offensive. Military Review.

2. Dryer, David A., Captain, U.S. Army. September 1989. An Analysis of Ground Maneuver Concentration During NTC Deliberate Attack Missions and its Influence on Mission Effectiveness. Thesis, Naval Postgraduate School, Monterey, California.

3. Field Manual 100-5: Operations. May 1986. Headquarters Department of the Army.

4. Field Manual 101-5-1: Operational Terms and Symbols. October 1985. Headquarters Department of the Army.

5. Goldsmith, Martin and James Hodges.October 1987. Applying the NTC Experience: Tactical Reconnaissance. RAND Corporation.

6. Romesbury, Charles H.. 1984. Clustering Analysis for Researchers. Lifetime Learning Publications, Belmont, California.

7. Zimmerman, Ray A. and James T. Root. August 1988. A Unit Effectiveness Measurement System at the National Training Center. BDM Corporation. Report Number BDM/ARI-TR-0016-87.

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   Attn: ATRC-W (Dr. Collier)
   White Sands Missile Range, NM 88002-5502

13. Director 1
   TRAC-FLVN
   Attn: ATRC-F (Dr. LaRocque)
   Fort Leavenworth, KS 66027-5200

14. Director 1
   TRAC-LEE
   Attn: ATRC-LC
   White Sands Missile Range, NM 88002-5502

15. Commander 1
   U.S. Army TRADOC Analysis Command
   Attn: ATRC-ZD(Mr. Bauman)
   Fort Leavenworth, KS 66027-5200

16. Director 1
   Attn: Mr. E.B. Vandiver III
   U.S. Army Concepts Analysis Agency
   Bethesda, MD 20814

17. U.S. Army Armor Center 1
   Attn: ATSB-CD-SD (CPT T. Schwartz)
   Fort Knox, KY 40121

18. U.S. Army Infantry Center 1
CATD
Attn: ATSH-B
Fort Benning, GA 31905-5000

19. Bell Hall Library 1
U.S. Army Combined Arms Center
Fort Leavenworth, KS 66027

20. Captain Joel R. Parker 1
PSC Box 1901
APO Miami 34003 (Panama)