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

by

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September, 1990

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

by

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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 \textit{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 \textit{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

\(^4\) 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
\[ M_T(\Delta t_k) = \sum_{j=1}^{n} U_j, \text{ where} \]
\[ U_j = \begin{cases} 
0, & \text{IF } \sqrt{(x_j(\Delta t_k) - x_T(\Delta t_k))^2 + (y_j(\Delta t_k) - y_T(\Delta t_k))^2} > 1000 \text{ meters} \\
1, & \text{OTHERWISE} 
\end{cases} \]

\( \Delta t_k \) - \( k^{th} \) 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

\( U_j \) - dummy 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.

![Diagram of team circular diameter](image)

**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. Whatever 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.

\[
x_T(\Delta t_k) = \frac{\sum_{i=1}^{n} x_j(\Delta t_k)}{n} \quad \text{(}x_T(\Delta t_k), y_T(\Delta t_k)\text{)}
\]
\[
y_T(\Delta t_k) = \frac{\sum_{i=1}^{n} y_j(\Delta t_k)}{n}
\]

\[y_T - \text{team center of mass, } x\text{-coordinate for } k^{th} \text{ time-step}
\]
\[x_T - \text{team center of mass, } y\text{-coordinate for } k^{th} \text{ time-step}
\]
\[\Delta t_k - \text{the } k^{th} 5\text{-minute, time-step}
\]
\[x_j - j^{th} \text{ system } x\text{-coordinate at the beginning of the } k^{th} \text{ time-step}
\]
\[y_j - j^{th} \text{ system } y\text{-coordinate at the beginning of the } k^{th} \text{ time-step}
\]
\[n - \text{number of tank killing systems in the } T^{th} \text{ team at the beginning of the } k^{th} \text{ time-step}
\]

**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.

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

\[
\frac{D(\Delta_k)}{5 \text{ minutes}} \times \frac{60 \text{ minutes}}{1000 \text{ meters}} = D(\Delta_k) \times 0.012 = V_T(\Delta t_k)
\]

\begin{itemize}
  \item \(C_T\) - team centroid
  \item \(T\) - \(A\) TEAM, \(B\) TEAM, \(C\) TEAM, \(D\) TEAM, \(E\) TEAM
  \item \(\Delta t_k\) - the \(k\)th 5-minute, time-step
  \item \(D\) - distance in meters
  \item \(V_T\) - team velocity in kilometers per hour
\end{itemize}

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]

\[
A = \frac{\text{FRIENDLY SYSTEMS SURVIVING}}{\text{INITIAL FRIENDLY SYSTEMS}}
\]

\[
B = \frac{\text{ENEMY SYSTEMS KILLED}}{\text{INITIAL ENEMY SYSTEMS}}
\]

\[
\frac{A + B}{2} = \text{MOE}
\]

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 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

---

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 files⁶ 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

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 than 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 than 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

<table>
<thead>
<tr>
<th>MISSION</th>
<th>US FORCE (Initial)</th>
<th>OPFOR FORCE (Initial)</th>
<th>INITIAL FORCE RATIO (US:OPFOR)</th>
<th>US KILLED (THP)</th>
<th>OPFOR KILLED (THP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAB70212</td>
<td>41</td>
<td>14</td>
<td>2.9</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>NAB70626</td>
<td>39</td>
<td>16</td>
<td>2.4</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>NAB70604</td>
<td>42</td>
<td>17</td>
<td>2.5</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>AAB71421</td>
<td>36</td>
<td>16</td>
<td>2.3</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>NAB81053</td>
<td>38</td>
<td>38</td>
<td>1.0</td>
<td>32</td>
<td>38</td>
</tr>
<tr>
<td>AAB71409</td>
<td>44</td>
<td>13</td>
<td>3.4</td>
<td>32</td>
<td>12</td>
</tr>
<tr>
<td>NAB70319</td>
<td>33</td>
<td>14</td>
<td>2.4</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>NAB80632</td>
<td>42</td>
<td>42</td>
<td>1.0</td>
<td>18</td>
<td>35</td>
</tr>
<tr>
<td>AAB80324</td>
<td>32</td>
<td>30</td>
<td>1.1</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>AAB71115</td>
<td>32</td>
<td>16</td>
<td>2.0</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>NAB80220</td>
<td>27</td>
<td>34</td>
<td>0.8</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>AAB70432</td>
<td>32</td>
<td>14</td>
<td>2.3</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>AAB71233</td>
<td>33</td>
<td>18</td>
<td>1.8</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>AAB80614</td>
<td>37</td>
<td>22</td>
<td>1.7</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>AAB71308</td>
<td>40</td>
<td>22</td>
<td>1.8</td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>AAB70828</td>
<td>45</td>
<td>22</td>
<td>2.1</td>
<td>34</td>
<td>9</td>
</tr>
<tr>
<td>NAB70806</td>
<td>40</td>
<td>162</td>
<td>0.3</td>
<td>30</td>
<td>58</td>
</tr>
</tbody>
</table>

### 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

<table>
<thead>
<tr>
<th>MISSION</th>
<th>TIME</th>
<th>XCOORD</th>
<th>YCOORD</th>
<th>TEAM</th>
<th>MOMENTUM</th>
<th>NOE</th>
<th>NOE2</th>
<th>NOE3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA870212</td>
<td>07:44:16</td>
<td>41693</td>
<td>94185</td>
<td>ATEAM</td>
<td>48.47</td>
<td>0.67</td>
<td>0.42</td>
<td>0.93</td>
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<tr>
<td></td>
<td>07:44:16</td>
<td>42000</td>
<td>93763</td>
<td>BTEAM</td>
<td>15.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>00:00:00</td>
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</tr>
<tr>
<td></td>
<td>07:49:16</td>
<td>42070</td>
<td>93325</td>
<td>DTEAM</td>
<td>64.01</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>00:00:00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>MA870626</td>
<td>00:00:00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.67</td>
<td>0.33</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>06:10:01</td>
<td>38563</td>
<td>121168</td>
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<td>214.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>06:15:01</td>
<td>40407</td>
<td>121138</td>
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<tr>
<td></td>
<td>06:25:01</td>
<td>39725</td>
<td>121225</td>
<td>DTEAM</td>
<td>215.00</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>00:00:00</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MA870806</td>
<td>00:00:00</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.30</td>
<td>0.33</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>05:35:10</td>
<td>38146</td>
<td>109629</td>
<td>BTEAM</td>
<td>124.50</td>
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<td></td>
</tr>
<tr>
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<td>04:00:10</td>
<td>37940</td>
<td>108760</td>
<td>CTEAM</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>05:35:10</td>
<td>38146</td>
<td>109629</td>
<td>DTEAM</td>
<td>124.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>04:00:10</td>
<td>37431</td>
<td>109085</td>
<td>ETEAM</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 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.

\[
\sum_{i=1}^{n} M_i = TF \text{ momentum (GOODMOM)}
\]

where \( M_i \) - Mission critical point for team \( i \) in kilometers per hour

\( i = 1, 2, \ldots, n \)

\( n \) - Nc. 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) \(\frac{D}{n-1} = \text{Average time dispersion between teams at mission critical point (AVDIF)}\)

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

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

where
\[i = j - 1, 2, \ldots, n\]
\[L_i - L_j = 0, \text{ if } i = j\]

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).

<table>
<thead>
<tr>
<th>COEF</th>
<th>ESTIMATE</th>
<th>STD ERR</th>
<th>T STAT</th>
<th>SIG LEVEL</th>
<th>LOWER</th>
<th>UPPER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.33360</td>
<td>0.20712</td>
<td>1.611</td>
<td>0.10785</td>
<td>0.460</td>
<td>1.0039</td>
</tr>
<tr>
<td>AVDIST</td>
<td>0.09067</td>
<td>0.121</td>
<td>0.12301</td>
<td>0.95</td>
<td>0.46803</td>
<td>1.0039</td>
</tr>
</tbody>
</table>

Figure 12 Simple regression between MOE3 and AVDIF
FILE: 21APATML DAT   A1

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

**TABLE OF COEFFICIENTS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Std. Err</th>
<th>T Stat</th>
<th>Sig. Level</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.30446</td>
<td>0.07686</td>
<td>4.024</td>
<td>0.00001</td>
<td>0.13618</td>
<td>0.47272</td>
</tr>
<tr>
<td>AVDIF</td>
<td>0.024356</td>
<td>0.090448</td>
<td>0.2692</td>
<td>0.79229</td>
<td>0.22144</td>
<td>0.44951</td>
</tr>
<tr>
<td>AVDIST</td>
<td>0.000015173</td>
<td>0.000044487</td>
<td>0.33955</td>
<td>0.74006</td>
<td>0.00001254</td>
<td>0.000012196</td>
</tr>
<tr>
<td>GOODMOM</td>
<td>0.000062562</td>
<td>0.000279778</td>
<td>0.22561</td>
<td>0.82402</td>
<td>0.000054705</td>
<td>0.000067218</td>
</tr>
<tr>
<td>LFRATIO</td>
<td>0.10957</td>
<td>0.060047</td>
<td>1.8157</td>
<td>0.09447</td>
<td>0.021921</td>
<td>0.24106</td>
</tr>
</tbody>
</table>

0.95 CONFIDENCE LIMITS

**Figure 13** Multiple regression between MOE2 and AVDIST, AVDIF, GOODMOM, LFRATIO
FILE: SADAFHRC DAT

SIMPLE CORRELATION COEFFICIENTS

<table>
<thead>
<tr>
<th></th>
<th>AVDIST</th>
<th>AVDIF</th>
<th>GOODMOM</th>
<th>FRATIO</th>
<th>MOE3</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVDIST</td>
<td>1</td>
<td>0.21377</td>
<td>0.28706</td>
<td>0.54769</td>
<td>0.30449</td>
</tr>
<tr>
<td>AVDIF</td>
<td>0.21377</td>
<td>1</td>
<td>0.30099</td>
<td>0.082595</td>
<td>0.38406</td>
</tr>
<tr>
<td>GOODMOM</td>
<td>0.23706</td>
<td>0.30099</td>
<td>1</td>
<td>0.18035</td>
<td>0.33215</td>
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<tr>
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<td>0.082595</td>
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<td>0.28357</td>
</tr>
<tr>
<td>MOE3</td>
<td>0.30449</td>
<td>0.38406</td>
<td>0.53215</td>
<td>0.28357</td>
<td>1</td>
</tr>
</tbody>
</table>

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
*------------------
public variables-----------------------------

PUBLIC mmoe
PUBLIC mmission
PUBLIC mateam, mbteam, mcteam, mdteam, meteam
PUBLIC matmpl1, matmpl2, matmpl3, matmpl4
PUBLIC mbtmp1, mbtmp2, mbtmp3, mbtmp4
PUBLIC mctmpl1, mctmpl2, mctmpl3, mctmpl4
PUBLIC mdtmp1, mdtmp2, mdtmp3, mdtmp4
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"
  mbtmp1 = "2/C/5-032"
  mbtmp2 = "3/C/5-032"
  mbtmp3 = "1/A/5-032"
  mbtmp4 = " Z"

mcteam = "D5032"
  mctmpl1 = "1/D/5-032"
  mctmpl2 = "2/D/5-032"
  mctmpl3 = "3/D/5-032"
  mctmpl4 = " Z"

mdteam = "D3019"
  mdtmp1 = "1/D/3-019"
  mdtmp2 = "2/D/3-019"
  mdtmp3 = "3/D/3-019"
  mdtmp4 = " 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

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

*-------creates player.dbf and loads 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 "CREATING MORT.DBF"
CREATE MORT FROM MSHELL2
APPEND FROM MORTALITY.DAT DELIMITED WITH BLANK

USE
RETURN

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

53
MORT2.PRG

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
ENDD

------------creates mortl.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 mortl.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,mortality) into one
* required <<team>>.txt file for each team in the
* mission.

---------------------

ing 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,;

55
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----------------------

56
*Program....GRID1.PRG
*Project....Thesis
*Purpose....Converts actual map grid coordinates to
*          compensate for 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
*
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)
 END CASE
 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)
 END CASE

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)

START

MAIN22

XIMPORT

MATH1

FINAL1

MOE1

XERASE

END

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 mbtmp1, mbtmp2, mbtmp3, mbtmp4
PUBLIC mctmpl1, mctmpl2, mctmpl3, mctmpl4
PUBLIC mdtmp1, mdtmp2, mdtmp3, mdtmp4
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"
    mbtmp1 = "2/C/5-032"
    mbtmp2 = "3/C/5-032"
    mbtmp3 = "1/A/5-032"
    mbtmp4 = " Z"

mcteam = "D5032"
    mctmpl1 = "1/D/5-032"
    mctmpl2 = "2/D/5-032"
    mctmpl3 = "3/D/5-032"
    mctmpl4 = " Z"

mdteam = "D3019"
    mdtmp1 = "1/D/3-019"
    mdtmp2 = "2/D/3-019"
    mdtmp3 = "3/D/3-019"
    mdtmp4 = " Z"
```plaintext
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 formatting .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----------

62
**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
mvelocity= 0.0       &&team average velocity over deltaT
mmomntum= 0.0        &&team mass for deltaT
mtime=SPACE(8)       &&deltaT 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 mtcnt <= 5.0
  SELECT 2
    &\text{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 mtcnt = 1.0
      USE ATEAM
      mteam = "ATEAM"
    CASE mtcnt = 2.0
      USE BTEAM
      mteam = "BTEAM"
    CASE mtcnt = 3.0
      USE CTEAM
      mteam = "CTEAM"
    CASE mtcnt = 4.0
      USE DTEAM
      mteam = "DTEAM"
    CASE mtcnt = 5.0
      USE ETEAM
      mteam = "ETEAM"
  END CASE
*---------* 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 variable (i.e. mycoord):
  AVERAGE XCOORD,YCOORD FOR TIME= mtime
  TO mxcoord,mycoord
    &returns pointer to this memory var
    &value:
  GO mrecord

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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 radius.

*************
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
   END CASE
   mcount= mcount + 1.0
DO CASE
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())
    mtxdf = XCOORD - mxreccrd
    mtydif = YCOORD - myreccrd
    mtdis =
        FIXED(SQRT((mtxdf*mtxdf) + (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
mcourit = mcourit + 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
* 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:
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.
DRYER YLIMIT
ATHE 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.
ATHE FUNCTION CALLS FUNCTION MASTER, WHICH IN TURN CALLS SUBFUNCTIONS
AMINKOWSKI, CLUSTER, AND CMETHOD TO EXECUTE THE CLUSTERING METHOD.
ATHE INPUT FILE SHOULD BE CALLED TM.TXT AND NEEDS TO HAVE A BLANK LINE
AFTER THE LAST DATA LINE AS THE END DELIMITER. THE OUTPUT FILE WILL
ABE CALLED TMMOD.TXT.

# ATIE NATIVE INPUT FILE, ERASE/CREATE NATIVE OUTPUT FILE
'C:\API\PARKDAT\TMMOD.TXT' UNERASE '2
'C:\API\PARKDAT\TMMOD.TXT' UNCREATE '2
'C:\API\PARKDAT\TM.TXT' UNTIE '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
AL3
LCLSTRNO+0

READ FIRST LINE OF INPUT FILE INTO VAR. CHAR
CHAR+ONREAD '1 82 50 0
READ FIRST CHARACTER TIME INTO VAR. ITIME
ITIME+CHAR'[1 2 3 4 5 6 7 8 9 10]
INITIALIZE MATRIX OF CHARACTER TIMES (TIMEMAT)
TIMEMAT+ 1 10 p ITIME
READ FIRST UNIT AND INITIALIZE MATRIX OF UNITS (UNITMAT)
UNITMAT+ 1 9 p (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 00 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+ONREAD '1 82 50 ,M
ITIME+CHAR[1 2 3 4 5 6 7 8 9 10]
→(ITIME+LTIME)/L3
UNITMAT+UNITMAT,[1](1 9 p (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+YTEMP(CHAR[22 23 24 25 26 27])
→(YTEMP=70000)/LB
YTEMP+YTEMP+100000

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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 pITIME)
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
LCSTNO+0 @REINITIALIZE LAST NUMBER OF CLUSTERED OBJECTS
TIME+TIMEMAT(L;110) @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])p((COUNT[L])T(CORD),((COUNT[L])tYCORD)
LPNTEMP+(COUNT[L])LPN @READ CURRENT LPNS INTO VECTOR FOR OUTPUT USE
@READ CURRENT XCOORDINATES INTO VECTOR FOR OUTPUT USE
XCORDTEMP+(COUNT[L])T(CORD
@READ CURRENT YCOORDINATES INTO VECTOR FOR OUTPUT USE
YCORDTEMP+(COUNT[L])T(CORD
@READ CURRENT UNITS INTO MATRIX FOR OUTPUT USE
UNITMAT+(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 CLMETHJ0. 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
+(YMAXsYLIMIT)/L12
L7:
@LOOP L7 FINDS 1ST CLUSTER LEVEL (N) > YLIMIT (INPUT VALUE)
+(Y[N]>YLIMIT)/L8
N+N+1
+L.
@LOOPS L8, 9, 10, 11 FIND THE LARGEST CLUSTER OF VEHICLES AT LEVEL
@YLIMIT AND STORES THIS IN BOOLEAN VECTOR CSTREBOOL
L8: ASRTNO TRACKS NO. OF OBJECTS OF NUMBER 'O' AT LEVEL 'YLIMIT' IN AMATRIX ZMOD
CSTRNO+->CSTR<-(ZMOD((N-1);1=0)
AIF THE NUMBER OF CLUSTERED VEHICLES IS NOT TIED, OR THIS IS THE FIRST
ACLUSTER DETERMINED, GO TO L9 AND DO NOT BREAK CLUSTER TIES
+((CSTRNOLCLSTRNO)V(O=1)V(L=1))/L9
ANEXT FIVE LINES BREAK CLUSTER TIES WITH THE CLOSEST CLUSTER TO THE
APREVIOUS CLUSTER WINNING
CENTRD+(+/CSTR/DATA)+(+/CSTR)
LCENTRD+(+/CSTR/DATA)+(+/CSTR)
DIST+((CCLCENTR[1]-CENTR[1])*2)+(CCLCENTR[2]-CENTR[2])*2)*0.5
LDIST+((CCLCENTR[1]-LCENTR[1])*2)+(CCLCENTR[2]-LCENTR[2])*2)*0.5
*(DIST<LDIST)/L10
+L11
L9:
+((CSTRNO<LCSTRNO))/L11
AIF NUMBER OF VEHICLES IN CLUSTER 'O' IS > CLUSTER 'O-1' OR A TIE IS
ABROKEN IN FAVOR OF CLUSTER 'O', UPDATE CSTRBOOL AND LCSTRNO
L10:
CSTRBOOL=CSTR
LCSTRNO=CSTRNO
L11:
O=0+1
ASAVE CSTRBOOL IN LCSTR FOR POSSIBLE USE IN BREAKING CLUSTER TIES
LCSTR+CSTRBOOL
ACHECK ALL CLUSTERS (1 THROUGH 'O') AT LEVEL 'YLIMIT' IN MATRIX ZMOD
+((COUNT(LI))/L8
+L13
L12:
AIF ONLY ONE OBJECT, OR ALL OBJECTS CLUSTER AT A LEVEL ≤ YLIMIT.
AMAKE A CSTRBOOL OF ALL ONES
CSTRBOOL=(COUNT(LI))*1
L13:
ADETERMINE CLUSTER CENTROID FOR POSSIBLE USE IN BREAKING CLUSTER TIES
LCENTRD+(+/CSTRBOOL/DATA)+(+/CSTRBOOL)
ANEXT FOUR LINES UPDATE OUTPUT VARIABLES BASED ON CLUSTER
LPNTMP=CSTRBOOL/LPNTMP
XCORDTEMP=CSTRBOOL/XCORDTEMP
YCORDTEMP=CSTRBOOL/YCORDTEMP
UNITMAT=CSTRBOOL/UNITMAT
PMAX+->CSTRBOOL
L14:
AOUTPUT CLUSTERED DATA TO FILE, NEXT TWO LINES COMMENTED OUT TO PRINT
A(TIME,' ','(LPNTMP[P]),','(','XCORDTEMP[P]),','(','YCORDTEMP[P]),','
A(UNITMAT[P]),UTCNL,UTCNT)APPEND "2
P=P+1
+(P=$PMAX)/L14
'TIME'
'TIME'
'Y'
ANEXT FOUR LINES DELETES CURRENT TIME INCREMENT DATA TO PREPARE FOR NEXT
ALOOP STARTING AT L6
LPN+((COUNT(LI))L6
XCORD+((COUNT(LI))L6
YCORD+((COUNT(LI))L6
UNITMAT+((COUNT(LI),0)L6
L+L+1
+(L=$COUNT)/L6

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AGNUNTIE "2 AUNTIE NATIVE OUTPUT FILE
END:
\textbf{OCR 'MASTER'}

Z+MASTER DATA

*THE DATA MATRIX IS CALLED DATA (Rows ARE Attributes)*

*NO Standardizing Required*  

*Euclidean Distance*

Z+2 MINKOWSKI DATA A EUCLIDEAN

*CHOOSE A LINKAGE METHOD*  

*Average*

Z+CLUSTER Z

Y+Z[[i]] \oplus Y+/-1\Phi Y \rightarrow \text{END}

\text{END}:
UCR 'CLUSTER'
Z←CLUSTER X:ROW;COL:LEVEL;RED;KEEPER:I:N;IND:CC;KR;KC
A INPUT IS A RESEMBLANCE MATRIX, OUTPUT THE Z MATRIX
A ZMOD IS GLOBAL OUTPUT IN CAPT. DRYER'S FORMAT
Z←((N+1)×X),4,0 A Z IS AN EMPTY MATRIX WHOSE COLUMNS ARE:
A 1TERATION, ROW, COLUMN, LEVEL
KEEPER+Z[I;1]+11×X AKEEPER TRACKS THE TRUE OBJECTS
ZMOD+(N,N)IND+1N × I+1 A ZMOD COLLECTS ALL OBJECTS IN CLUSTERS
LIN:X+CLMETHOD X
Z[I;1+J]+(KR+KEEPER[ROW]),(KC+KEEPER[COL]),LEVEL
RED+(ρKEEPER)×1
RED[COL]×0 A RED IS THE REDUCTION VECTOR TO ELIM AN ELEMENT OF KEEPER
KEEPER+RED/KEEPER
CC+(ZMOD[I;]=KC)/IND × ZMOD[I+1N-I;CC]+KR
I+I+1 × →LIN×11×1pX
BCR 'MINKOWSKI'

Z+P MINKOWSKI X:I;J:N
a/forms the resemblance matrix using Minkowski metric (Euclidean P=2)
N=1 pX o a N is the number of columns (objects)
I+1
Z+(N,N) p0 o a Z is an empty matrix of object x object dimension
LO:J+1
LI:Z[I;J]±/(|X[I;I]-X[J;J])±P
+LIX1:N±J±J+1
+L0xN±I±I+1
Z±Z±1+P
Z±Z±@Z o Z is a resemblance matrix
OCR 'CLMETHOD'

ANS+CLMETHOD X;P;V;DD;I;J;NEWCOL;XX

A INPUT IS A RESEMBLENCE MATRIX, OUTPUT THE REDUCED RESEMBLENCE MATRIX
P+1PX o a P IS DIMENSION OF THE MATRIX
V+{(I)P}.01P o a V IS LOWER TRIANGULAR MATRIX OF ONES
DD+{I,V};.X o a DD LOWER TRIANGULAR MATRIX IN VECTOR FORM
I+{(I,V)}/IP+2 o a I IS THE INDICES MATRIX OF DD
LEVEL-l/DD o a CHOOSE SMALLEST NUMBER IN MATRIX
J+1l(DD=LEVEL)/I o a CHOOSE THE INDEX OF LEVEL
ROW+PIJ o a ROW OF UPPER MATRIX INDEX NUMBER
COL+[J+P o a COL IS THE OTHER INDEX
NEWCOL+XI;ROW]LIMPMETHOD XI;COL] o a L... COMP NEW COLUMN AND ROW
XX+{P,P]p1
XXI;COL]+XXI;COL]+0 o a XX IS A MATRIX OF 1 EXCEPT THE ELIMINATED COL
XI;ROW]+XI;ROW]+NEWCOL
ANS+{(P-1),(P-1)]p(XX)/.X o a ANS IS NOW LESS ONE ROW AND COLUMN
ANS+ANS{(P-1),(P-1)]p0,(P-1)p1 o a ENSURE ANS HAS DIAG OF 0
## APPENDIX D: Critical Point Data

<table>
<thead>
<tr>
<th>Mission</th>
<th>Time</th>
<th>XCoord</th>
<th>YCoord</th>
<th>Team</th>
<th>Momentum</th>
<th>MOE</th>
<th>MOE2</th>
<th>MOE3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA870212</td>
<td>07:44:16</td>
<td>41693</td>
<td>94185</td>
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<td>0.42</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0.00</td>
<td>0.67</td>
<td></td>
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<td>0</td>
<td>0</td>
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<tr>
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<td>0.51</td>
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<td>0</td>
<td></td>
<td>0.00</td>
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82
<table>
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<tr>
<th>Code</th>
<th>Time</th>
<th>Value1</th>
<th>Value2</th>
<th>Value3</th>
<th>Value4</th>
<th>Value5</th>
<th>Value6</th>
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<td>100650</td>
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10. Director
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    U.S. Army TRADOC Analysis Command
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    Fort Leavenworth, KS 66027-5200

12. Director
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    White Sands Missile Range, NM 88002-5502

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