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Integration of naval forces into the Early Entry Theater Level Model (EETLM)

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THESIS

INTEGRATION OF NAVAL FORCES INTO THE EARLY ENTRY THEATER LEVEL MODEL (EETLM)

by

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Thesis Advisor: S.H. Parry

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Utilizing a notional order of battle for both Blue and Red forces (ground, air and naval), multiple scenario runs were performed using three possible courses of action for both Red and Blue, and three potential entry cases for Blue: entry prior to the outbreak of hostilities, entry after the outbreak of hostilities, and entry at the time of hostilities. Employing a variety of measures of effectiveness, EETLM demonstrated that it does indeed have potential for future use in theater campaign analysis and planning once it has reached developmental maturity

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INTEGRATION OF NAVAL FORCES INTO THE
EARLY ENTRY THEATER LEVEL MODEL (EETLM)

by

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EXECUTIVE SUMMARY

Under the direction of J-8, the Conventional Forces Analysis Directorate (CFAD) of the Joint Staff, and in conjunction with the U.S. Army Training and Doctrine Command (TRADOC), professors and students at the Naval Postgraduate School (NPS) developed the Future Theater Level Model (FTLM). FTLM is a stochastic theater level combat model that utilizes Bayesian probability updates in an attempt to capture the inherent uncertainties of modern war. Users of FTLM can define levels of sensor inaccuracies, individual units proficiency levels in terms of C^3 and intelligence gathering, and can alter the ability of a commander to disseminate information to his subordinate units (or conversely, to fuse data delivered from his subordinates). Though developmentally immature, FTLM was the first step towards modeling theater combat using a non-deterministic analysis tool.

Using the FTLM architecture, several variants of the model came into being. Each of these variants focused on differing aspects of modern conflict such as peacekeeping missions, Operations Other Than War (OOTW), and small unit engagements. Additionally, it was recognized that the United States will not participate in a future conflict utilizing assets from a single military service. Joint operations, while always beneficial in the past, are now a necessity due to the extreme drawdown in the size of the Armed Services in the post-Cold War era. Accordingly, students and faculty at NPS developed a joint version of the model called the Early Entry Theater Level Model (EETLM). As the name implies, EETLM focuses on theater combat beginning with pre-hostility requirements such as projecting power via naval Carrier Battle Groups (CVBGs) and Amphibious Task Groups (ATGs), protecting and convoying U.S. Army Maritime Prepositioning Ships (MPS), and the execution of amphibious operations to effect a forced entry into the theater if needed (for this thesis, the North Korean MRC scenario was selected). Inputs regarding the characteristics of EETLM were received from a wide variety of sources such as the U.S. Naval War College, U.S. Air Force Institute of Technology, and U.S. Army TRADOC. It is of note that the Early Entry Theater Level Model has been designed from the ground up as a joint combat model, and every attempt has been made to capture the unique characteristics of the different services when designing the EETLM algorithms.

Naval forces to be used in EETLM represent the notional forces expected to be available to the United States in the near future, i.e., NIMITZ CVN's, SPRUANCE DD's, and WASP LHD's. The makeup of the Red naval forces, however, does not reflect the naval power of the North Korean Navy. Instead, two SAG's have been created so as to test EETLM's ability to counter a large Soviet style naval force and to engage a smaller missile boat threat. While not accurately depicting the threat posed by the North Korean Navy, it is believed that the Red forces involved in this scenario more vigorously test EETLM's detection and engagement algorithms. Data for all the combatants were taken from unclassified publications, and their inclusion in this thesis does not constitute an endorsement by the United States government.

Since the aim of this thesis is to determine if the time of arrival of naval forces (to include Army MPS) impacts the outcome of the overall campaign, EETLM data runs were classified based on two characteristics: the Course of Action (COA) that Red was pursuing, and the time of arrival of the naval forces. Three COAs were defined for both sides in the scenario, but only Red's COA was pre-determined. Blue forces dynamically selected their COA based on their perception of what COA Red was pursuing. For each of the three Red COAs, Blue had a corresponding COA available with which to defend the Korean Peninsula. Additionally, there were three entry options available to Blue naval forces: two days prior to the outbreak of hostilities (Case 1), two days after the outbreak of hostilities (Case 2), or arrive at the outbreak of hostilities (Case 3). The selection of entry options was pre-determined by the analyst, and is not a dynamically selected option in the current model.

In conducting the analysis of EETLM, two areas where considered. First, a graphical analysis of the COA's was conducted in order to ascertain if the variation in entry case options Blue selected would affect the ability of Red to ascertain Blue's intended COA, and conversely if Blue's entry case option would affect Blue's ability to determine Red's intended COA. This analysis concluded that Blue's entry case 1 or 3 (early or on-time arrival of naval and MPS forces) produced the most desirable situation for the Blue commander.

Second, an analysis of the effect that the time of arrival of naval forces had on the outcome of the conflict based on five Measures of Effectiveness (MOEs) that represent the survival rate of the naval and ground forces. Based on this analysis, it was determined that Blue entry case 1 was the most desirable option for the Blue theater commander. In both analyses, the decision regarding which Blue entry case to pursue was not as clear as would be intuitively expected. This lack of a clear-cut option may be a result of EETLM's immaturity as a combat model, or it may simply reflect the fact that clear cut decisions frequently do not exist in theater level combat.

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to demonstrate in principle that the Early Entry Theater Level Model (EETLM) can adequately represent the various facets of joint theater level warfare. Additionally, this thesis will demonstrate that the output of EETLM can provide the user with a set of data from which analysis can be performed and inferences regarding theater level plans can be drawn. The point will be made throughout this thesis that EETLM (an offshoot of the Future Theater Level Model (FTLM)) is in its developmental stage, and certain aspects of its modeling capability need to be refined before it is accepted as an analysis tool. Where appropriate, these aspects will be discussed and recommendations regarding corrections of these shortcomings will be offered.

B. FORMAT

This thesis consists of six chapters and five appendices with the intent of giving the reader a thorough understanding of EETLM, with particular emphasis on the changes made to the FTLM architecture in order to make EETLM a truly joint model. The development of EETLM was conducted as a joint undertaking with CPT Greg Brouillette, USA, emphasizing the modifications to the ground combat capabilities of the model. While the work presented in this thesis is original, several references to CPT Brouillette's thesis are made throughout this thesis.

Chapter II provides the reader with the rationale behind the architecture of EETLM. It discusses the changing world threats and the new emphasis on littoral warfare and Major Regional Contingencies (MRC's). It also points out the new direction that U.S. military doctrine is taking, and that all services are recognizing that the resources simply do not exist for any one service to plan on fighting a conflict without significant participation from all other services. It also gives a brief introduction to the Early Entry

Theater Level Model and provides a list of potential issues that could be investigated by EETLM

Chapter III provides an in-depth explanation of the mathematical underpinnings of EETLM's principal features. Detection algorithms are described, as are the processes EETLM uses to calculate the perceptions of both the friendly and enemy forces. The perceptions discussed include both the perceived order of battle for the forces, and the Courses of Action (COA's) each side "thinks" the other side will pursue. Estimated levels of combat power and C3 capability, and how these values are determined, are also discussed. This chapter is based on previous work done on FTLM, and the reader will be referred to the appropriate sources should more information be desired.

The modifications made to the original FTLM architecture are discussed in Chapter IV. The intent of these modifications are to make EETLM a joint model from its initial development. Many combat models purport to be "joint" in that they can make an airfield float and call it an aircraft carrier, or they model Army and Air Force operations with the underlying assumption that Naval forces are to be engaged in other theaters. These methodologies are unsatisfactory in today's war fighting environment. From the beginning of this thesis, it has been the intent of all involved to create EETLM as a truly joint model - meaning that inputs and requirements from all services would be solicited and incorporated. At the time of this writing, the evolution of EETLM has been guided by the requirements and recommendations of the following agencies:

- Conventional Forces Analysis Directorate, J8, Joint Chiefs of Staff
- Army Training and Doctrine Command, Fort Monroe Virginia
- U.S. Army Early Entry, Lethality, and Survivability Battle Lab, Fort Monroe, Virginia
- Naval War College, Newport, Rhode Island
- Naval Doctrine Command, Norfolk, Virginia

- Naval Postgraduate School, Monterey, California
- Naval Amphibious Warfare School, Little Creek, Virginia
- Air Force Institute of Technology, Wright Patterson AFB, Dayton, Ohio

It is acknowledged that no model can be all things to all agencies, but it has been a priority in the development of this model to incorporate as many of the received inputs as possible.

Where appropriate, requirements that have not yet been incorporated will be discussed. It is considered a unique feature of EETLM that it has been developed from its inception with particular attention paid to the joint aspects of warfare in which the United States will be engaging for the foreseeable future.

Chapter V contains an analysis of a North Korean MRC scenario. This analysis is conducted utilizing three replications of the scenario under various combinations of Blue naval entry times and Red courses of actions (the methodology for the analysis is discussed in more detail in Chapter V). It is important to note that due to the developmental immaturity of the model and the possible inconsistencies in its algorithms, this analysis does not represent a stringent statistical study of EETLM. Rather, it is intended to demonstrate in principle that the output provided by EETLM is amenable to statistical analysis. Graphical and comparative analysis will be performed on the models output data in an attempt to demonstrate EETLMs potential for use by a theater staff analyst.

Finally, Chapter VI details future research and development areas that need to be addressed in order to make EETLM an operational analysis tool. Many of the insights for this chapter have been gained from the inputs of the agencies listed above, and some have been draw from the aspects of theater warfare that were not able to be incorporated into the current model due to constraints of time, computer capability, etc. Also included in this chapter are the conclusions drawn from this thesis and comments regarding the applicability of EETLM to future military strategic planning.

C. ASSUMPTIONS

The design and analysis of EETLM rest upon certain key assumptions. First and foremost of these assumptions is the validity of the incorporated algorithms. While every attempt has been made to ensure that the algorithms in EETLM accurately represent the processes they purport to model, many of the algorithms can only be considered to possess face validity at this time. Comments regarding the strengths and shortcomings of EETLM's algorithms will be made throughout this thesis as appropriate.

Additionally, there have been several assumptions made regarding the North Korean MRC scenario selected for this study. Most of these are discussed in later chapters, but the key assumptions are:

- Only two aircraft carrier battle groups (CVBG's) and Amphibious Ready Groups (ARG's) will be allocated to the theater. In reality it is likely that this number will be much greater. The number of these units were limited to minimize the computational complexity required for the model runs.
- No submarine activity. The capability to model Anti-Submarine Warfare (ASW) does not yet exist in EETLM
- No mine laying operations exist. The presence of mines is a realistic expectation in a littoral warfare scenario, but the capacity to model mine warfare is not yet incorporated in the current version of EETLM. This function is planned for more mature variants of the model
- Weapons of Mass Destruction are not utilized. While this aspect of warfare definitely needs consideration in the theater planning process, inclusion in this version of EETLM has not occurred. Adding this facet of strategic warfare is recommended for future applications.

- The primary indicator of impending hostilities is the stockpiling of logistical units at the De-Militarized Zone (DMZ). Under the assumption that the North Koreans would attempt to stockpile sufficient logistical support at the DMZ for a protracted ground campaign, this rate of forward staging was chosen as the indicator of an attack. Details on the algorithm used by EETLM for determining the perceived attack time based on logistical movement rate will be discussed briefly in later chapters. Detailed description of this algorithm can be found in Reference [9].

While there are several assumptions regarding both EETLM and the North Korean scenario, the validity of the model is still considered sufficient to demonstrate in principle the ability of the model to represent joint theater level warfare. Once this proof of principle is demonstrated, more stringent validation of the model can be accomplished. Upon completion of this validation process, it is expected that EETLM could be distributed to theater staffs and utilized effectively as a tool for planning and analyzing contingency plans for future conflicts.

II. THE NEED FOR A NEW MODEL

A. A NEW WORLD ORDER

With the end of the Cold War and the subsequent decline of America's defense budget, the philosophy behind U.S. war fighting has undergone a dramatic, perhaps unprecedented, period of revision. New ways of maximizing U.S. military effectiveness and alternative ways of capitalizing on the combined force of employing elements of all services have been studied. The renewed interest in joint operations is due partly to the realization that the United States will be called upon to "do more with less", but also due in large part to the appreciation that senior commanders have for the synergistic effect produced by joint operations. The successful experiences from Operation Desert Storm are testimony to the fact that no single service can operate in a vacuum, and no realistic strategic planning can ignore the inclusion of elements from each service in combat planning.

Another fact of life in the "New World Order" is that the conflicts in which the United States will most likely engage will not be Superpower vs Superpower conflicts on a global scale, but rather regional conflicts. Examples of these types of conflicts abound; Desert Shield/Desert Storm, Somalia, and Bosnia are simply a few. North Korea is another theater where joint strategic planning has a high priority.

For these reasons, and a host of others that are beyond the scope of this thesis, there is a definitive need for a combat model that truly reflects the joint nature of future conflicts and is not restricted to the outdated idea of NATO vs Warsaw Pact global conflict.

B. ...FROM THE SEA.

To meet the new challenges of future conflicts, the Armed Services have revised their basic operational doctrine. The U.S. Navy and U.S. Marine Corps have issued a joint white paper titled "...From The Sea." [Ref. 1] that lays out the new direction the naval services are to take, placing a renewed focus on littoral warfare and the projection of power ashore. The U.S. Army has published its vision of the future in the form of FM-100-5, Operations [Ref. 2]. This manual places its emphasis on non-linear battle, speed and multi-dimensional attacks in order to confuse, demoralize, and destroy the enemy.

One of the key facets of these new doctrinal concepts is the acknowledgment that the U.S. cannot assume forces will be in the area when conflicts begin. Forced entry, early entry, and force sustainability prior to and during the commencement of hostilities must be of primary concern to strategic planners. Therefore, it is imperative that a combat model exists which combines both the uncertainty of modern conflict and the importance of early arrival and the sustained projection of power in modern military conflict.

These new doctrinal concepts, and the subsequent tactics that will be developed from them, are not adequately modeled by existing theater level models. Current models either have no significant joint modeling aspect, or are so inflexible due to their size and support requirements that they are unable to be easily modified for new doctrine or strategy changes. A need exists for a truly joint theater level model that is flexible enough to test new doctrinal concepts, yet is portable and user friendly enough to prevent it from becoming the sole domain of a single analysis agency.

C. EETLM

The Early Entry Theater Level Model (EETLM) is a theater level stochastic combat model that takes into account the issues raised in the previous sections. Detailed discussion of how EETLM operates is reserved for Chapter III of this thesis. However, with the integration of naval forces and capabilities into the existing model (which is itself in its developmental infancy), EETLM will be one of few combat models developed as a truly joint model. The combined effects of inter-service combat can therefore be modeled, joint strategies explored, and Measures of Effectiveness (MOE's) selected to statistically analyze the desirability of these new doctrines.

EETLM currently operates using a C++ operating code, and requires a 486 processor, 4 MB of RAM, and Microsoft Windows to run. Variants of EETLM may require the use of a more powerful computing platform, depending on the size and complexity of the scenario being run. The use of a Windows based PC model has the following immediate benefits:

- The model becomes more "user-friendly" since most people are either already familiar with the Windows environment or can easily learn it.
- The size of the operating model is small enough to allow wide dissemination. This allows doctrinal analysis by as many agencies as possible. Many combat models, due to their size and support requirements, are forced to be located with only a single analysis agency.

The scenarios run through EETLM are drawn from two data files, each less than one MB in size. The actual scenario, friendly/enemy course of actions (COA's) and order of battle (OOB) are contained in the scenario datafile, referred to as the *.NET file. The scheduling of carrier air strikes and Tomahawk land attack missile (TLAM) launches is temporarily accomplished through an ordnance file called the *.ORD file (this temporary scheduling of air strikes and TLAM launches are discussed in Chapter IV). The data in these files are easily modified to account for changes in friendly/enemy COA, updates in intelligence, or changes in friendly/enemy capabilities. This results in a combat model that is flexible enough to meet the demands of changing world threats as well as advancing technological developments in U.S. and enemy combat capabilities.

EETLM is stochastic based, not deterministic. This characteristic leads to a more realistic modeling of actual combat with all its uncertainties. The outputs of an EETLM scenario are data representing a range of potential outcomes suitable for statistical analysis.

The end result is a model that allows analysts and strategy planners to develop new ideas for joint operations in a given regional conflict, run many replications of the scenario to gather data on their desired MOE's, and subject the data to rigorous analysis in order to get reliable indicators of the desirability of these new concepts. Potential questions that analysts and strategic planners can address with an integrated EETLM are:

- *What is the minimum number of ground troops required in-country in order to be able to withstand a pre-emptive enemy assault?*

- *Can these in-country troops be effectively replaced with a Marine Expeditionary Unit (MEU) from a naval Amphibious Task Group (ATG) and kept offshore, diminishing the need for Host Nation Support (HNS)?*

- *What is the impact of having a Carrier Battle Group (CVBG), or multiple CVBG's, on station prior to commencement of hostilities?*

- *Does the presence of a CVBG have some type of measurable deterrent effect that can be quantified and used in determining where these assets will be deployed?*

- *How will changing technology or new employment of existing weapons affect combat effectiveness? For example, how would placing Army Multiple Launch Rocket Systems (MLRS) on Navy vessels enhance shore bombardment effectiveness?*

- *How effective is the proposed policy of embarking Marine contingency units on Aircraft Carriers, and could this policy be effectively expanded to include embarking Army units (e.g., Special Forces) on Navy units?*

Answers to these and similar questions are important to strategic planners in determining what direction U.S. force structures and deployment strategies will go. The need for a combat model to determine valid answers for these questions definitely exist. EETLM, with the integration of Naval and Marine combat capabilities, is a viable tool for addressing these complex joint issues.

III. EETLM

A. OVERVIEW

As stated in the Chapter II of this thesis, EETLM operates stochastically in an effort to capture the uncertainties inherent in modern combat. These intangibles consist of such factors as leadership of a unit's officers and NCOs, morale, spirit, and (more often than not) random luck. While it is acknowledged that these facets of warfare are not able to be precisely quantified, it is asserted that EETLM is able to approximate these random factors far better than the deterministic models currently employed.

This chapter discusses the mechanics of how EETLM stochastically represents the uncertainties inherent in joint combat. Readers who are not interested in the mathematical underpinnings of EETLM may choose to continue on to Chapter IV. Those who desire an even more detailed explanation of the mechanics of EETLM are referred to an NPS thesis by CPT Karl Schmidt, USA (OR Dept., Sept 1993) that documents the mathematical foundation of the predecessor to EETLM, the Future Theater Level Model (FTLM) [Ref. 3][1]

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[1] FTLM is the foundation upon which EETLM was built. As such, many of FTLM's algorithms and operating principles are used by EETLM. Accordingly, unless other references are specified, this entire chapter acknowledges the description of the algorithms by CPT Schmidt ([Ref. 3]).

B. NETWORK DESCRIPTION

1. Sea-Land Network

Army, Marine Corps, and Navy forces exist in a combined network that represents the geography of the theater and critical naval operating areas. This network is comprised of physical and transit nodes that define both the movement corridors available to forces in the scenario, as well as the characteristics (such as cover and concealment, trafficability, etc.) governing forces operating in the theater.

a. Physical Nodes

Movement of units in EETLM occur within networks, similar to a conventional arc-node network, that are composed of two key elements: physical and transit nodes. Each of these nodes are defined in the *.NET data file and are assigned characteristics that govern how the forces occupying these nodes behave in the various phases of the scenario. A list of the characteristics of both physical and transit nodes are included as Appendix A.

Physical nodes represent some key element of the scenario's geography. Physical nodes may correspond to fixed geographical sites such as:

- Cities
- TLAM launch baskets
- Aircraft carrier operating areas (CVOAs)
- Highway intersections
- Any other physical location deemed to be of strategic interest

The physical size of the geographical area being represented by the node (i.e., the size of the city or the area contained by the TLAM launch basket), is selected by the user in the *.NET datafile. To date, however, there is not a capability to array or partition forces within the physical node itself. As a result of this limitation, a CVBG occupying a physical node, for example, does not possess a tactical formation but instead exists as a single entity with the combined combat capability of its component ships. This results in an inability of EETLM to measure the effectiveness of AAW or ASW picket ships in a CVBG, or to model the change of a battle group's tactical formation in response to a perceived change in threat axis or threat type.

Efforts to achieve this level of fidelity are in progress. Current research is investigating a means to partition nodes into a set of "sub-nodes" that would allow for units occupying a node to position themselves within that node in response to some external cue. As an example, a physical node representing a CVOA may be partitioned into a sub-node for the carrier and its close escorts, a sub-node for outlying AAW picket ships, another sub-node for ASW screening ships, and perhaps yet another sub-node representing a rendezvous point for underway replenishment operations. If the perception of the AAW threat reached a pre-defined threshold, the AEGIS cruiser assigned to the CVBG could move from the close escort sub-node and occupy the AAW picket sub-node. Similarly, if the ASW threat reached a certain level of significance, the CVBG could appropriately change its defensive posture by stationing its destroyers in the ASW picket sub-node. As stated previously, efforts are being made to include this type of node partitioning in future versions of EETLM.

b. Transit Nodes

Transit nodes fulfill the role of arcs in the traditional arc-node network. Each transit node contains the characteristics of the terrain connecting two physical nodes. A physical node can be connected by any number of transit nodes, allowing for a very high level of resolution of the characteristics of the physical path connecting two geographic locations.

Consider a situation where a ground unit leaves city A and is proceeding to city B. The terrain between the two cities could consist of a mountain range midway between the two cities, with a known minefield between the mountains and city A, and flat open terrain between the mountains and city B. A single arc representing this terrain would have to apply some type of average of the very different effects of these three terrain types as the "cost" of the arc. In EETLM, three transit nodes can be defined to connect cities A and B, one with the characteristics of the minefield, one with those of the mountain ranges, and a third with the characteristics of open terrain. As the forces move from city A to city B, their movement rates, susceptibility to detection by enemy sensors, etc., will change as they transition from these different environments.

2. Air Network

The air network employed by EETLM consists of a grid with cell size selected by the user in the *.NET datafile. This grid is superimposed on the sea-land network and uses a linked list in the operating code to match a location in the ground network to its corresponding air network grid.

When aircraft launch for a strike mission from either an airfield or a ship, EETLM introduces the aircraft into the grid that corresponds to the location of the launch point. The aircraft then commence a transit to the target site utilizing a variant of Dijkstra's algorithm that attempts to avoid the enemy's air defense (AD) sites. As the aircraft transit through various grids, their susceptibility to attrition is calculated based on the proportion of the air grid that is within the lethality envelope of an AD site in the sea-land network. The more an air grid is within an air defense sites envelope, the greater the chance that aircraft within that grid are going to be lost to surface-to-air-missile (SAM) fire.

Assuming the aircraft reach their target and deliver their ordinance, EETLM will select an egress route for the flight. The egress route is selected to avoid the enemy's AD sites, and is typically not the same route used for target ingress. Upon successful completion of the return flight, the aircraft "land" by being transferred to the airfield or ship that is geographically correlated to the air grid at which the aircraft's flight ended.

A more detailed discussion of the air network can be found in the NPS master's thesis written by Hua-Chung Wang [Ref. 4] .

C. PERCEPTION UPDATE CYCLE

EETLM's calculations of perceived enemy actions are based on a periodic cycle in which sensor information (or information from some other source) is gathered and fused into a value that represents one side's perceptions of the composition and intended actions of the other side. This Perception Update Cycle (hereafter referred to simply as the cycle), operates independently for all sides in the scenario conflict, and the user can specify in the *.NET data file the length of these cycles.

During each of K cycles, EETLM performs the following principal functions:

- Determines if units in the scenario are detected by the opposing forces sensors.
- Computes a perception of the Order of Battle for those units detected.
- Derives an estimate of the C3 capability and combat power of detected units.
- Generates or updates perceptions regarding the detected unit's intended Course of Action.

There are obviously other functions EETLM performs during each cycle, but these are the key functions that this chapter will discuss in further detail.

D. DETECTIONS IN EETLM

Detections in EETLM are dependent upon several factors including the amount of cover and concealment available, the duration of time a unit is exposed to an opponent's sensor, and (to quite an extent) random chance. The variables used in determining detections are defined as follows:

$T_{N1,N2}$: Transit time for a unit going from node N1 to node N2.

$D_{N1,N2}$: Time to detect at least one unit going from node N1 to node N2.

$U_{N1,N2}$: Number of units transiting from node N1 to node N2.

$\mu_{N1,N2}$: Amount of surveillance effort expended by searcher on transit nodes connecting physical nodes N1 and N2. This value is obtained from the user provided *.NET file.

R: Random number drawn from an Exponential distribution with mean equal to one.

$T_{N1,N2}$ is a Normally distributed random variable with the following parameters:

$$\mu = \frac{(\text{Arc Distance})}{(\text{Unit Speed})} \tag{1}$$

$$\sigma = 0.10\mu \, . \tag{2}$$

The distance between nodes and the unit speeds are values specified in the *.NET data file.

$D_{N1,N2}$ is computed as follows [Ref. 13 : p. 1]:

$$D_{N1,N2} = [(U_{N1,N2} * \mu_{N1,N2})^{-1}]R. \tag{3}$$

Note that since $D_{N1,N2}$ is a multiplicative factor of the Exponential random variable, R, it is an Exponential random variable as well.

EETLMs detection process can be summarized by the following sequence of events:

- A unit leaves node N1 for node N2.
- $T_{N1,N2}$ is drawn from the Normal distribution as described above.
- $D_{N1,N2}$, an Exponentially distributed random variable, is calculated.
- If $D_{N1,N2}$ is less than or equal to $T_{N1,N2}$, then a detection occurs. If $D_{N1,N2}$ is greater than $T_{N1,N2}$, then the transiting unit completes its movement undetected by the searching forces.

Under this method, it is possible for a unit to evade detection even under conditions favorable to the searching force. Conversely, it is possible for a unit to travel in darkness, or through other forms of concealment, and still be detected by the searching force. This reflects the potentials faced by commanders in the field and is a realistic factor of combat

E. PERCEPTION OF UNIT ORDER OF BATTLE (OOB)

Upon detection of a unit, EETLM will begin to update its perception of the makeup of the detected unit. Prior to a detection, EETLM maintains a default prior distribution that shows all possible combinations of units on a given node to be equally likely. This initial prior distribution can be altered by the user as desired. After detection, EETLM calculates and maintains perception distributions with Bayesian updates to integrate incoming sensor data into its perceived OOB. Before discussing the mechanics of how the posterior distributions are calculated, two key definitions must be understood:

- <u>Doctrine Strength</u>: The strength of a unit as entered by the user in the

* NET data file.

- <u>Ground Truth Strength</u>: The scenario strength of a unit.

Ground truth strength is a Normal random variable with parameters α_{ij} and σij based on doctrine strength values.

$$\text{Ground Truth Strength} \sim \text{Normal}[\alpha_{ij}, \sigma_{ij}] \tag{4}$$

where $\alpha_{i,j}$ and $\sigma_{i,j}$ are the mean and standard deviation, respectively, of the **doctrine strength** of the unit as defined in the *.NET data file (i.e., the number of j equipment types attached to unit i in the scenario definition file). Note that **Ground Truth Strength** is unknown to the opposing forces.

Based on this information, and on the updated sensor observations every delta time unit, EETLM determines the mean number of j equipment types of units of type i located at node N at time t. It designates this value as $\mu_j(u_i,N,t)$, and computes a corresponding variance $v_j(u_i,N,t)$. These values do not represent the doctrinal number of assets the enemy will observe residing at node N at time t, however. They are distorted somewhat through the use of a sensor standard error factor $\tau_j(S,N,t)$, the standard deviation of sensor S while observing node N at time t. Note that this standard deviation accounts for different levels of sensor effectiveness in daytime use vice nighttime, or other times of limited visibility.

Now EETLM can calculate its perception of what forces it is encountering at node N and time t, Π_{UNIT}. Π_{UNIT} is a function of four arguments:

- u: a vector representing the combination of possible units present
- $x_j(t)$: the number of j type equipment observed at time t on a given node
- t: The scenario time
- N: A particular node in EETLM.

Recall that , Π_{UNIT} $(u,x_j(0),0,N)$, the initial prior distribution at the start of the scenario, shows all combinations of units at all nodes to be equally likely. To simplify the equation through which the posterior updates are performed, let

$$A_j = \frac{(x_j(t+1) - m_j(u,N,t))^2}{v_j^2(u,N,t) + \tau_j^2(S,N,t)} \tag{5}$$

and let

$$B_j = 2\pi(v_j^2(u,N,t) + \tau_j^2(S,N,t)) . \tag{6}$$

The Posterior distribution can now be computed by the following:

$$\Pi_{UNIT}(u, x_j(t+1), t+1, N) = C * \Pi_{UNIT}(u, x_j(t), t, N) * \prod_{j=1}^{J}[\frac{\exp(-0.5(A_j))}{\sqrt{B_j}}] \tag{7}$$

where C is a normalizing constant, x(t+1) refers to the new sensor update, and x(t) refers to the past sensor updates.

As a means of preventing implausible perceptions from being entered into the prior distribution, EETLM employs a simple checking procedure:

IF
$$\max_{u}\{|\Pi_{UNIT}(u, x(t+1), t+1, N) - \Pi_{UNIT}(u, x(t), t, N)\}| > 0.6 \tag{8}$$

THEN
Set prior distribution = $\Pi_{UNIT}(u,x(0),0,N)$
AND
Set corresponding moments to α_{ij} and σ_{ij}, respectively
AND
Recompute the posterior distribution.

The reason for including this checking mechanism is that either side may get inaccurate reports from their respective sensors which may lead them to incorrect conclusions regarding their opponents. If, however, they receive an update that is drastically different from what is expected (i.e., what is currently being carried in the prior distribution), this mechanism will force them to re-evaluate and begin the perception calculations again. This process is a fair representation of the actual process a commander or his staff may undertake when receiving battlefield reports from subordinates: if a report "makes sense" in terms of what is expected then they will accept it, if it does not, then the report may be rejected out of hand and the commander's expectations or assumptions are re-examined.

F. PERCEPTION OF COMBAT POWER AND C^3 CAPABILITIES

Once a unit is detected and a perceived OOB is calculated, EETLM begins to develop a computed perception of that unit's abilities, both in terms of combat power and Command, Control, and Communications (C^3) capability. This estimation is dependent upon two key factors: the actual combat power of the unit (D(N,t) for defending forces at node N at time t, and A(N,t) for attacking forces), and the accuracy with which a unit can estimate an opponent's capabilities ($C_B(E)$). Both of these values are provided by the analyst in the *.NET data file.

The estimated value for the defending forces level of combat power ($\hat{D}(N,t)$) is drawn from a Uniform distribution with parameters that are based on the true capabilities of the defender at node N and time t (D(N,t)),

$$\hat{D} \sim \text{Uniform}[0, C_B(E) * D(N,t))]. \tag{9}$$

The attacker's estimated level of combat capability is also Uniformly drawn, but its parameters are more complex than the defender's estimate. The level of the defender's C^3 ability at time t ($D_C(t)$) plays a crucial role in the calculation of $\hat{A}(N,t)$. The calculations involve three steps:

- First, determining the estimated value of $D_C(t)$ [Eq (10)]
- Second, calculating $h(D_C(t))$, a value (between zero and one) that provides variability for the defender's estimate of the attackers combat power [Eq (11)].
- Third, randomly drawing $\hat{A}(N,t)$ from a Uniform distribution with parameters based on $h(D_C(t))$ and A(N,t) [Eq (12)]

$$\hat{D}_C(t) \sim \text{Uniform}[(D_C(t) - e^{-S}),\ D_C(t) + e^{-S})] \tag{10}$$

where S is currently a real number between zero and one and is a measure of the attacking force's C^3 effectiveness, and

$$h(D_C(t)) = \frac{1}{1+(\mu_e D_C(t))^{\rho_e}} \quad (11)$$

where μ_e and ρ_e are analyst provided values [Ref 14 : p. 17] .

Finally,

$$\hat{A}(N,t) \sim \text{Uniform}[(A(N,t)\cdot(1-h_C(D_C(t))),(A(N,t)\cdot(1+h_C(t)))]. \quad (12)$$

G. PERCEPTION OF COURSES OF ACTIONS (COA'S)

The final major process undertaken by EETLM in the perception update cycle is the updating of the perceived COAs for each side in the scenario conflict. The Early Entry Theater Level Model focuses primarily on two-sided conflicts (i.e., Red vs Blue), but other variants of the model can expand this to any number of sides and factions desired by the user. For this thesis, however, discussion will be limited to a conflict with two opposing forces - thus for each perception update cycle there are two COA perceptions being computed independent of each other. For the purposes of this thesis, an avenue of approach (AA) is defined as one or more paths (i.e., discrete routes) between two specified physical nodes. In discussing the COA perceptions, several variables need to be defined. They are:

- $\lambda_{AA}(N)$: The detection rate for a given avenue of approach at node N. This value is drawn directly from the *.NET data file.
- $\lambda'_{AA}(N)$ The mean detection rate for a given avenue of approach at node N for the rth replication of EETLM's "mini-simulation" [Ref. 3 : p.54].

- $S_l(N,j,k)$: The lth sensor observation by sensor j over node N during the kth cycle.
- $\tau_{N,j}^2(l)$: Sensor j's variance of error on the lth observation over node N. This number is also taken from the *.NET data file.
- $b_k(N)$: Total number of sensor observations taken at node N during cycle k.
- N(AA,k): The set of all nodes that can be occupied for each avenue of approach AA in cycle k.
- L(c,k): The likelihood of COA c during cycle k.
- U(c,AA): The number of units following COA c on avenue approach AA.
- C: Total number of COA's defined in the *.NET data file.

EETLM first computes the probability that U(c,AA) units are able to transit through a specific avenue of approach **without** being detected ($p_u(k,AA,r)$). This computation is carried out through

$$p_u(k, AA, r) = [e^{-\lambda'_{AA}(k,r)}]^{U(c,AA)} . \qquad (13)$$

This probability is determined utilizing R "mini-simulations" in which the exposure time of units along an avenue of approach, their composition, and their detection by the opposition's sensors on the rth iteration of the mini-simulation is calculated [Ref. 3 : p. 53]. Obviously, the probability of a unit **being** detected while transiting the avenue of approach is one minus the value of Equation (13).

With the results from Equation (13), it is now possible to compute the likelihood that the enemy is pursuing COA c during cycle k (L(c,k)). This is accomplished through Bayesian updating of the probabilities of detections for the different avenues of approach of COA c over the update cycles k. There are three distinct situations in which L(c,k) must be computed, each requiring a slightly different equation. These situations are:

• Case one: Sensors detect units moving on all avenues of approach under COA c.

• Case two: Sensors detect units on only some of the avenues of approach under COA c.

• Case three: Sensors detect no units moving on any of the avenues of approach under COA c.

Case one is computed using

$$L(c,k) = \frac{1}{R}\sum_{r=1}^{R} \prod_{AA \in S}[1 - p_u(k,AA,r)] \tag{14}$$

where S is the set of avenues of approach where detections occurred. Case two is copmuted using

$$L(c,k) = \frac{1}{R}\sum_{r=1}^{R}\{ \prod_{AA \in Q} p_u(k,AA,r) \cdot \prod_{AA \in Q'}[1 - p_u(k,AA,r)]\} \tag{15}$$

where Q is the set of avenues of approach on which no detections occurred and Q' is the set on which detections did occur. Finally, Case 3 is computed using

$$L(c,k) = \frac{1}{R}\sum_{r=1}^{R} \prod_{AA \in P} p_u(k,AA,r) \tag{16}$$

where P is the set of avenues of approach where no detections occurred.

The outputs of Equations (14), (15), and (16) above will be used as the prior distribution for determining the perceived enemy COA (Π_{COA}) with one exception. At the initial update cycle, the prior distribution is such that all possible COA's are equally likely. This distribution can be modified by the user to reflect some pre-conflict intelligence, but for this thesis no pre-combat knowledge is assumed.

EETLM now calculates the probability that the enemy is pursuing a specific COA c during update cycle k ($\Pi_{COA}(c,k)$) for all possible COA's. These values will then become part of the prior distribution for one side's **final** perception of the opposing side's

COA for cycle k. $\Pi_{COA}(c,k+1)$ is itself a Bayesian update of all previously perceived COAs up to cycle k, and is calculated as follows:

$$\Pi_{COA}(c,k+1) = \frac{\Pi_{COA}(c,k) * L(c,k)}{\sum_{c=1}^{C}(\Pi_{COA}(c,k) * L(c,k))} . \tag{17}$$

The next step in determining the final perception of the enemy's COA is to determine the mean and variance of the number of j-type assets at node N during cycle k ($m_{N,j}(k)$ and $v_{N,j}^2(k)$, respectively) for those units that are undetected during cycle k.

$$m_{N,j}(k) = \frac{\dfrac{\sum_{l=1}^{L} S_l(N,j,k)}{\tau_{N,j}^2(l)}}{\sum_{l=1}^{L}\dfrac{1}{\tau_{N,j}^2(l)}} \tag{18}$$

$$v_{N,j}^2(k) = \frac{1}{\sum_{l=1}^{L}\dfrac{1}{\tau_{N,j}^2(l)}} . \tag{19}$$

From these two calculations, the total mean and variance of j type assets over all nodes of a given avenue of approach ($m_j(AA,k)$ and $v_j^2(AA,k)$) potentially occupied during a specific cycle can be found by summing the individual means and variances

$$m_j(AA,k) = \sum_{n \in N(AA,k)} m_{n,j}(k) \tag{20}$$

$$v_j^2(AA,k) = \sum_{n \in N(AA,k)} v_{n,j}^2(k) . \tag{21}$$

The probability of a given unit actually being on any particular avenue of approach is itself a random variable, Normally distributed with a mean specified in the *.NET data file. The standard deviation of this distribution is 10% of the mean,

$$\sigma_j(AA,k,c) = 0.1\mu_j(AA,k,c). \tag{22}$$

Having the appropriate value for L(c,k), the next step is to compute a Normal distribution utilizing a unit Normal density function and the moment values computed above:

$$\xi_j(AA,k,c) = \frac{\exp\{-\frac{1}{2}\frac{(m_j(AA,k)-\mu_j(AA,k,c))^2}{v_j^2(AA,k)+\sigma_j^2(AA,k,c)}\}}{\sqrt{2\pi(\sigma_j^2(AA,k,c)+v_j^2(AA,k,c))}}. \tag{23}$$

The final step of calculating the actual posterior distribution representing the probability that a unit will be following COA c during a given cycle k+1 ($\Pi_{COA}^{FINAL}(c,k+1)$) is given by [Ref. 15 : p. 14]:

$$\Pi_{COA}^{FINAL}(c,k+1) = \frac{\Pi_{COA}(c,k)\cdot\prod_{AA}\prod_{j}\xi_j(AA,k,c)}{\sum_{c=1}^{C}\Pi_{COA}(c,k)\cdot\prod_{AA}\prod_{j}\xi_j(AA,k,c)}. \tag{24}$$

The output from Equation (24) will serve as the **prior** distribution for subsequent updates in future cycles. This recursive relationship is representative of the fact that knowledge of enemy intentions tend to have an accumulating effect. Thus as new intelligence comes in, it is incorporated into an existing set of preconceived ideas of what the enemy is expected to do. As previously stated, it is believed that this is a reasonable approximation of the processes utilized by commanders in actual combat.

H. APPLICABILITY

The mechanisms discussed above, and the remaining EETLM functions as well, were applied only to ground combat modeling prior to this thesis. Never before had EETLM, or its predecessor FTLM, been applied to the modeling of joint combat operations such as those described in Chapter II. The reason for this is beyond the scope of this thesis, but it is believed that the EETLM architecture can model joint combat as well as pure naval operations. The next chapter will discuss the modifications made to EETLM in order to make it a truly joint model.

IV. MODIFICATION OF EETLM

A. THE PRIOR EXISTING MODEL

At the start of this thesis project, EETLM was capable of modeling ground and air combat utilizing an arc-node representation of the Korean Peninsula. The selection of Korea as the theater of action was arbitrary, and the documentation of the initial version of EETLM - at a level of detail beyond that of the previous chapter of this thesis - can be found in Reference [3]. Resolution of the model was at the brigade level for ground forces and at the flight level for air units. Naval forces were not modeled. A network of sea nodes was developed, but never used in the testing and evaluation conducted in Reference [3]. It was decided to continue the development of EETLM from the foundation of the original FTLM Korean scenario. This decision was based on the desire not to recreate work already accomplished, as well as the desire to build a model covering a theater of action that may some day prove to be of significant strategic interest.

B. ADDITION OF NAVAL FORCES

1. Blue Forces

In order to integrate Naval and Marine capabilities into EETLM, a new database was constructed containing relevant information on U.S. Navy combatants. For this thesis, two types of combatant groups were chosen: an Aircraft Carrier Battle Group (CVBG), and an Amphibious Task Group (ATG). The composition of these two groups are as listed below (detailed information on the naval combatants is provided in Appendix B).

- <u>CVBG</u>:
    - 1 NIMITZ class Nuclear Aircraft Carrier (CVN)
    - 1 TICONDEROGA class Guided Missile Cruiser (CG) (VLS variant)
    - 1 SPRUANCE class Destroyer (DD) (VLS variant)
    - 1 PERRY class Guided Missile Frigate (FFG)
- <u>ATG</u>:
    - 1 TARAWA class Amphibious Assault Ship (LHA)
    - 1 WASP class Amphibious Assault Ship (LHD)
    - 1 WHIDBEY ISLAND class Amphibious Docking Ship (LSD)
    - 1 NEWPORT class Tank Landing Ship (LST)

The composition of the CVBG was chosen based on the professional experience of the author. All ships of the CVBG are front line combatants typical of those serving today in Carrier Battle Groups throughout the world. Additionally, these ship types, due to their relatively young ages, are destined to become the backbone of the U.S. Navy Surface Fleet as the current trend of ship decommissionings continue.

The composition of the ATG was chosen based on interviews conducted with officers on staff at the Amphibious Warfare School, Little Creek, Virginia. Their input was valuable for the construction of the amphibious portion of the EETLM naval database in that it provided verification to the author that these ships were indeed typical of those used for deployed Amphibious Task Groups, and with the exception of the NEWPORT LST's , were all designated to be part of the amphibious fleet of the 21st century.

The data describing the capabilities and characteristics of these ships were gathered and entered into an EETLM database over a three month period. The format for the database is given as Reference [5]. The size of the actual *.NET and *.ORD files utilized for this scenario [Ref. 6] , while small in size relative to other combat models, is too large to be included in this thesis. The data entered in the *.NET file were gathered primarily from Jane's Fighting Ships [Ref. 7] and Guide to the Soviet Navy [Ref. 8] . A conscious effort has been made from the beginning of this research to keep the model unclassified for ease of development. It is emphasized that the capabilities of the U.S. Navy ships listed in the EETLM database, and any inferences to them elsewhere in this thesis, are not official figures and should not be construed as such. However, once the Early Entry Theater Level Model is validated and is used for actual doctrinal analysis, the information in this database file can easily be modified to reflect the true capabilities and limitations of the naval forces to be modeled.

2. Red Forces

Due to the desire to test the algorithms of EETLM to the fullest extent possible, the enemy OOB was broadened to include forces from multiple countries including heavy warships from the former Soviet Union. This enemy OOB is recognized as not being truly representative of the naval capabilities of the Democratic People's Republic of Korea (DPRK), but it is intended only as a mechanism for testing the capabilities of the naval variant of EETLM. As stated earlier, the complete and accurate OOB can be easily entered into the database as desired for real world strategic analysis. The enemy naval forces were broken into two major Surface Action Groups (SAG's) and their detailed capabilities are included as Appendix C. As a summary, they are listed below:

- Red SAG 1:
  - 1 KIROV class Nuclear Battle Cruiser (BCGN)
  - 1 KRESTA I class Guided Missile Cruiser (CG)
  - 1 MOD KASHIN class Guided Missile Destroyer (DDG)
  - 1 SOVREMENNYY class Guided Missile Destroyer (DDG)
- Red SAG 2:
  - 2 OSA II Missile Patrol Boats
  - 1 NANUCHKA III class Guided Missile Corvette

SAG 1 is intended to test EETLM's ability to model large scale naval engagements involving surface-to-surface missile (SSM) firings at over-the-horizon (OTH) ranges. SAG 2 is designed as a small, maneuverable gunboat/missile boat threat as is traditionally expected in a littoral combat environment. Again, these SAGs are not intended to portray the combat capabilities of the DPRK Navy, but instead to provide a method of testing the ability of EETLM to model naval combat in a joint environment.

C. ADDITIONAL MODIFICATIONS

1. Physical and Transit Nodes

The previously existing ground model was expanded to 35 physical nodes from the original 16 physical nodes. Transit nodes were increased from 25 nodes in the original model to 92 nodes. Original design of this version of EETLM called for significantly greater numbers of nodes, both physical and transit, but due to hardware limitations in the desktop computers utilized, this number was reduced. In the future, it may become necessary to relocate EETLM to a more powerful processing platform in order to handle larger and more detailed arc-node networks. The characteristics of these nodes were also modified to allow for the modeling of real life movement characteristics of ships at sea versus those of a ground unit moving over land. Accordingly, EETLM has the ability to take into account the following characteristics governing the movement of naval units:

- Sea state
- Depth of water constraints
- Width of channel constraints
- Presence of minefields

Characteristics such as predicted sonar ranges at a given location and the presence or absence of acoustic phenomenon such as convergence zones have not yet been incorporated. Discussion of recommendations for future modifications of EETLM will be reserved for Chapter VI of this thesis.

2. Cruise Missiles

Additional modifications to EETLM include the ability to model tactical cruise missiles, specifically the Tomahawk (both the anti-ship (TASM) and land attack (TLAM) version) and Harpoon cruise missiles. These missiles were not provided for in the original version of this model, but are now integrated in the air network of EETLM. At the time of launch, these cruise missiles appear on the air network in the air grid corresponding to the location of the launch platform. At this point, EETLM distinguishes between two types of missiles: pre-programmed "smart" missiles such as TLAM, and non-programmed "dumb" missiles such as Harpoon and TASM. TLAM employs a weighted Dijkstra'a Algorithm that allows the missile to select the most direct path to the target, while avoiding what is perceived by the firing platform to be the enemy's most effective air defenses. This is a similar process as that undertaken by Tomahawk mission planners when developing the flight profiles the missiles take to their targets.

Harpoon and TASM cruise missiles fly a direct path to their targets without regard for perceived enemy air defenses. It is acknowledged that both TASM and Harpoon have limited flight path programming capabilities, but these capabilities are not as extensive as TLAM, and for the purposes of this model are not considered.

The current model does possess a dynamic algorithm to determine when in a scenario Tomahawk and/or Harpoon attacks should occur. These decision rules are designed to allow EETLM to dynamically decide whether to engage an enemy naval combatant with cruise missiles or with strike aircraft dependent upon two factors: the range of the enemy combatant, and the availability of strike aircraft.

Range is a critical factor in the decision rule because if an enemy ship is too close to a friendly ship, the time required to schedule and launch an air sortie may be too great; thus the quicker option of a cruise missile attack is called for. As range from the enemy ship increases, the reaction time for the friendly ship also increases and an aircraft strike can be considered. Additionally, by taking the aircraft option (when available) cruise missiles are conserved, which is a serious consideration in real world naval combat.

Because the purpose of the naval forces in the littoral warfare environment is to support the ongoing ground combat, the number of aircraft available for attacking enemy surface ships is a consideration in the decision rules for naval surface strikes. The carrier based strike aircraft are assigned strike missions against shore based targets that are of either strategic interest, or are in support of tactical objectives being pursued by ground forces It is not desired to divert these aircraft from their assigned mission to support ship-to-ship engagements unless the diversion is critical to the survival of the threatened ship. Note that the scheduling of sorties for ground strikes is scripted in the *.ORD file in the current model, but will be dynamically scheduled in future versions of the model.

The pseudo-code for the scheduling algorithm is as follows:

```
IF Range > 200 NM
  AND # Strike Aircraft > 90%
  THEN Schedule Aircraft Strike
  ELSE Use Cruise Missiles.

IF 200 NM > Range > 100 NM
  AND # Strike Aircraft > 80 %
      THEN Schedule Aircraft Strike
  ELSE Use Cruise Missiles.

IF 100 NM > Range > 50 NM
  AND # Strike Aircraft > 30 %
      THEN Schedule Aircraft Strike
  ELSE Use Cruise Missiles.

IF Range < 50 NM
THEN Use Cruise Missiles
```

3. Naval Surface-to-Surface Engagements

Engagements between surface units were not previously modeled in EETLM, not even between ground units, unless the opposing units were on the same physical node. Because of this, two separate algorithms were designed: one for close range indirect fire and one for long range OTH missiles. The algorithm for the conduct of close range fire, be it from Army artillery, Multiple Launch Rocket Systems (MLRS), or Naval Gunfire Support (NGFS) from ships is documented in Reference [9].

In modeling OTH engagements between naval combatants, two problems exist: the decision to engage, and the selection of the appropriate weapon with which to engage. The engagement algorithm commences when an enemy unit is detected on a physical or transit node, and is given by the following pseudo code:

1. Calculate range to enemy
    a. IF enemy range > max range of Surface-to-Surface weapon THEN update enemy's range after next sensor update.
    b. IF enemy range ≤ max range of Surface-to-Surface weapon THEN select a weapon and engage enemy following salvo size and re-fire times as in *.NET file (Air Defense/Fire Support section).
2. Wait for next sensor update.
    a. IF enemy still detected (i.e., not destroyed), THEN repeat Step 1. ELSE end.

To select the best weapon to fire, the algorithm selects the weapon with the minimum range such that the weapons range is greater than range to the target. For example, let ranges be as follows: TASM = 100 miles, Harpoon = 50 miles, enemy = 75 miles. EETLM would select to engage with TASM since it is the only one with a range greater than the range to the enemy. Now let enemy range = 40 miles. EETLM would now choose Harpoon since it has sufficient range to strike the enemy and would not result in the unnecessary expenditure of a longer range weapon.

4. Strike Operations

Strike operations, consisting by definition of both aircraft and TLAM air-to-ground strikes, are an integral part of the Navy's support of combat ashore. Also referred to as power projection, it is intended to aid ground forces in the attainment of geographical objectives by attriting enemy forces before close ground combat is joined. EETLM has the ability to model strike operations, both air and TLAM, through the fire mission and air tasking operations (ATO) sections of an additional data file referred to as the *.ORD file ([Ref. 6]). The *.ORD file lists all information needed for EETLM to schedule, execute, and evaluate strike operations. Some of the data included in the *.ORD file are launch platform, target node, time on target (TOT), and salvo/flight size.

One characteristic of EETLM's strike operations modeling capability is its ability to prevent the conduct of strikes on target nodes that are perceived to be friendly. If, as the striking side perceives the situation, a target node is friendly, EETLM will automatically cancel the strike mission. This prevents potential blue-on-blue engagements in a manner that reasonably models true combat strike planning. A limitation of the current version of EETLM is its lack of ability to spontaneously schedule and execute strike operations. The current practice of scripting these operations through the *.ORD files is an acceptable temporary solution, but future versions of EETLM will require an ability to dynamically conduct strike operations during scenario runs.

5. Shipboard Air Operations

The prior version of EETLM allowed air operations to be conducted only on physical nodes designated as air bases. This practice was not appropriate for the modeling of naval flight operations. Ships of all classes cannot be reasonably modeled if they can only conduct flight operations at fixed geographic locations. Mobility is a key factor in naval warfare, thus any valid model must allow for flight operations at any transit or physical node. The integrated version of EETLM accomplishes this by designating each ship as a mobile airfield, thereby allowing air operations - both fixed and rotary wing - from all naval ships with embarked aircraft.

6. Embarked Marines

With the integration of naval forces, it became necessary to equate an amphibious task force into some type of ground threat in order to allow these forces to affect EETLM's perception of the ground war. This was accomplished by defining in the *.NET file an equipment type for both personnel and tanks, then assigning these types to the ships in the ATG's. By following this procedure, each time EETLM conducted a sensor sweep of the nodes containing amphibious ships, it would "see" - in addition to the ships - an appropriate number of ground troops and tanks. This allows the presence of an ATG to affect the perceptions of the enemy with regard to potential Blue COA's, in the same manner as the presence of an ATG off the Kuwaiti coast affected the thinking of Iraq during Operation Desert Storm.

In addition to modeling amphibious feints, this ability to embark ground troops makes available the option to explore new force mixes. Ground troops (be they Marines, Army, or a mixture), can easily be embarked on any type of ship and in any size desired. Modeling and evaluating the effects of embarking a Marine contingent on an aircraft carrier, or of placing an Army special forces helicopter detachment on a destroyer or frigate, is well within the abilities of the integrated version of EETLM.

7. Dynamic Scheduling of Ship Movements

Ship movement within EETLM is dynamically scheduled in response to EETLM's perception of enemy attack time (AT). AT is determined based on the perceived buildup of logistical supplies by the enemy forces prior to the commencement of hostilities (the logistics algorithm is discussed further in Chapter V, and is documented in Reference [9]). Due to the necessity of coordinating the insertion of Marine forces with the movement of Army troops, it was necessary to devise a way to ensure that amphibious forces would arrive at the designated landing zone when scheduled and that the transport of Army personnel aboard Maritime Prepositioning Ships (MPS) could be modeled.

The scheduling of arrival times for naval units are dealt with differently for CVBG units than for ATG and MPS ships. CVBG units are assigned a scenario arrival time, relative to AT, at which point they will start their transits and air strikes in accordance with the *.NET and *.ORD data files. If, after the attack time is established and the CVBG arrival time is determined, AT should change then the CVBG will arrive at the scene either early or late (dependent upon which way the AT estimate was shifted). This reflects the reality of situations where events unfold faster than the United States can get naval assets in place, or conversely when naval units arrive quickly in response to a perceived threat and find themselves waiting on station.

For ATG and MPS ships, their embarked ground units are assigned a landing time in the COA section of the *.NET file, again relative to perceived AT. EETLM then calculates back the time it will take amphibious and MPS ships to transit along the routes to the landing zone at their defined cruise speeds. The ships enter the scenario at this calculated time and transit to the assigned landing zone, disembark their personnel, then move to a patrol station for the remainder of the scenario. In the case of the amphibious ships, since their Marines have disembarked, the ships are no longer considered a potential ground threat and any further changes in the ground COA perceptions are attributed only to the units on land

8. Battle Damage Assessment

Naval battle damage assessment (BDA) is accomplished in EETLM through a temporary algorithm that performs three tasks:

- Determine if an SSM hits the intended target
- Determine if the target is destroyed or if it retains mission capability
- Determine the extent to which a damaged target loses operational capability.

The first step in this algorithm is to assign a surface-to-surface Pk for each missile i ($SSPK_i$). After the missile is fired, EETLM determines the time of flight and thus the time of impact for that particular engagement. Then EETLM draws a random number, X, from a Uniform (0,1) distribution. If $X < SSPK_i$, then the target has sustained a hit. Next, it must be determined if the target is destroyed or if it is merely damaged. This is accomplished through drawing a second Uniform (0,1) random variable, Y. If $Y >$ some previously defined threshold (for example 0.50), then target is destroyed, else it is assessed damage. Damage is assessed by selecting at random an item of equipment attached to the ship that has been damaged, thus effectively reducing its combat capability.

Due to the manner in which EETLM tracks forces moving across the sea-land network, engagements are not conducted on a ship to ship basis, rather they are done on a battle group to battle group basis. This level of resolution is realistic in terms of the engaging side (since OTH strikes are usually coordinated at the battle group level) but leaves something to be desired on the receiving end of the engagement. The result of this, however, is that the particular ship within the targeted battle group that is actually hit by the incoming missiles will be randomly selected. If it is determines a ship is destroyed, it is removed from the battle group along with its associated combat capabilities.

More realistic means for assessing BDA exist; however their use in this version of EETLM is impractical for two reasons: they require a large database of missile warhead capabilities, and they must be able to model the systems and defensive capabilities of modern combatants. Both of these requirements imply a necessity for classifying the database to an appropriate security level. Since the development of this model is at the unclassified level, and since it is desired to maintain this model on a desktop computer, it is believed that this algorithm for BDA is sufficient and reasonably valid for this thesis.

V. EETLM ANALYSIS

A. GENERAL

This chapter demonstrates the manner in which EETLM can be employed by major staffs in order to analyze theater contingency plans. The North Korean MRC scenario described previously is used as the test case for this thesis, with the issue of concern being the impact that the arrival of naval forces has on the outcome of the conflict. Data collection and analysis techniques will be discussed in order to facilitate independent replication of these procedures, as well as to illustrate the ease with which this model can be utilized as an aid to decision makers. Additionally, the results of the analysis will be discussed with graphical illustrations where appropriate. As stated in Chapter I, this thesis is intended as a demonstration of EETLMs potentia, not a statistical analysis of its output data This distinction is made in order to prevent giving the impression the EETLM is a fully functional model. As stated elsewhere in this thesis, several issues regarding EETLMs operating algorithms must be resolved before a statistical study is warranted.

There will be two distinct areas subjected to analysis: conventional MOEs such as Blue vs Red attrition rates, and an analysis of the impact the arrival of naval forces has on Red's perception of Blue's COA. The rationale and implications behind the selection of the MOEs and an explanation of why COA analysis is desirable will also be discussed in the relevant sections of this chapter.

B. PROCEDURES

1. Run Design

In order to address the specific question of how the time of arrival of naval units affect the outcome of a littoral MRC scenario, three scenario cases for the entry of naval forces were designed

- Case One: Naval forces arrive two days prior to the perceived attack time (AT-2)
- Case Two: Naval forces arrive two days after the perceived attack time (AT+2)
- Case Three: Naval forces arrive at the perceived attack time (AT)

Note that the arrival of naval forces refers also to the arrival of Army land forces via Maritime Prepositioning Ships (MPS)

In addition to the three Early Entry cases discussed above, the scenario was modified in terms of the course of action Red will pursue. For each Early Entry case, the *.NET file was modified to restrict Red to a single COA. Blue forces were still allowed to select their COA in response to what they perceived Red would do based on the perceived rate of logistical stockpiling done by Red prior to the outbreak of hostilities.

With these characteristics, each run was identified by the Early Entry case and by the Red COA selected. For example, the scenario in which Red pursued COA 1 and naval forces were to arrive at AT+2 was designated R1-E2; Red pursuing COA 2 and naval forces arriving at AT was designated R2-E3; etc. This method of designation resulted in nine different combinations to study for the North Korean MRC scenario as illustrated in Table 1

	Entry Case 1	*Entry Case 2*	*Entry Case 3*
Red COA 1	R1-E1	R1-E2	R1-E3
Red COA 2	R2-E1	R2-E2	R2-E3
Red COA 3	R3-E1	R3-E2	R3-E3

Table 1. Definition of EETLM Data Run Cases.

For each of the nine combinations, three replications of the EETLM scenario were run and data collected (data collection methods are described in the next section). Three replications were chosen in order to demonstrate that data analysis can be conducted on EETLM outputs. It is acknowledged that a sample size of three is not sufficient to achieve statistically significant results, but for this proof of principle the statistical significance of these results is irrelevant. Given that the initial characteristics of the scenario participants are not valid (which - as discussed in Chapter IV - was intentionally made so in order to avoid classification issues), the intent is to focus on demonstrating how EETLM can be utilized in strategic planning rather than to strive for a statistically significant analysis of the scenario output.

2. Data Collection

Data were collected for this analysis through automatic data output files generated by EETLM in ASCII format. The actual output data files created by EETLM for this thesis are included in Reference [12]. Portions of the output data files are given in Appendix D so that the reader may become familiar with their content and format, if desired. For each analysis run conducted, the following data files were created:

- COA data file. The COA data file contains the perception each side has regarding the intended COA that the other side is pursuing. For example, a typical entry would reveal that at time t side A believed that side B was pursuing COA 1 with probability X; COA 2 with probability Y; and COA 3 with probability Z. Data for this file are generated every sensor update cycle, which for this scenario was fixed at six hours.
- Engagement datafile: Contains the time and results of all engagements in the scenario.

• Logistics datafile. This file contains logistic movement rates and Blue's perception of Red's attack time. Additionally, this file contains the amount of float time between Blue's perception of attack time and scenario Simtime. This equates to the amount of slack time Blue has to deploy forces to the theater. If the float time is positive, Blue can deploy forces to the theater prior to the commencement of hostilities. If the float time is negative, then out-of-area forces will not be able to deploy in time to arrive in theater prior to the start of combat. Both the perceived attack time and the float time are updated and recorded in this datafile every update cycle.

• Position Datafile: records the ground truth position of each unit at each perception update cycle.

• Strength Datafile: records the strength of each unit in the scenario.

Each of the data files are named by EETLM to uniquely identify the scenario and replication to which that datafile applies. For example, given a *.NET datafile defining an EETLM scenario, the COA perceptions would output to a file called *.Cnn (where nn is an integer that identifies to which replication of the scenario the datafile applies). The engagement data file would be designated *.Enn, the logistics data file would be titled *.Lnn, etc.

The data from these files were imported into spreadsheets utilizing Lotus 1-2-3 release 4 software. From there, graphical analysis of the data was conducted. The results of the analysis are discussed in the next section of this chapter.

C. COA ANALYSIS

1. Overview of the Courses of Action (COAs)

Red has three COAs defined in the *.NET datafile for use in this scenario. Additionally, for each Red COA, there is a corresponding Blue COA that was designed as a defense against an attack by the North Koreans across the Demilitarized Zone (DMZ).

For each of the runs performed for this thesis, Red's COA was pre-selected in the *.NET datafile and a total of nine runs were made under each of the Red COAs (three for each of the three entry cases).

Blue's COA selection was performed through the perception algorithms of EETLM. As a pre-hostility maneuver, Red moved multiple logistical units to front line staging areas utilizing a logistics movement plan that is unique to each of the three Red COAs. This movement is done under the assumption that prior to an attack, Red will stockpile a substantial amount of logistic support at or near the DMZ. As detections are made of these logistic units over the physical and transit nodes, a correlation can be made by Blue as to which COA Red is intending to pursue. Once Red's intended COA is known, Blue will then select the appropriate defensive COA (Blue's COA 1 is the defensive response to Red's COA 1, etc.).

Additionally, based on the perceived rate of movement for these logistical units, Blue computes the estimated time that Red will commence their southward attack (designated as the variable AT). Once AT is calculated, EETLM will schedule the necessary movement of naval and MPS forces in order to execute the troop landings designated in the Blue COA (the dynamic scheduling of ship movement is discussed in Chapter IV). If, after AT is computed, Blue's estimation of Red's attack time changes, then Blue will attempt to re-schedule the movement of naval and MPS assets accordingly. Blue may not be able to meet the landing times dictated in the COA if their estimate of AT changes significantly. Similarly, if Blue's perception of AT is wrong, the landing of the Marines and Army troops on the MPS ships will not occur in time to execute the ground COA as planned. For a more detailed analysis of the logistics buildup algorithm and how it pertains to Blue's perception of Red's COA, see Reference [9].

As with the combat capabilities of the DPRK military, the course of actions specified in this thesis are not to be construed as an actual assessment of North Korean military plans or strategy, or as an official representation of the United States' intended response to an attack into South Korea.

a. Ground COAs

Under COA 1, Red launches a two-prong ground offensive along the eastern and western coast of the Korean peninsula. This attack is launched using 13 divisions, divided between the North Korean cities of Haeju, Pyongyang, Wonsan, P'Yonggang, and Kosong. Red's ultimate ground objectives are the South Korean cities of Kunsan, Kwangju, Pusan, Taegu, and Pohang.

COA 2 involves a two prong assault as well, but the thrusts of the ground offensive consist of one push through the center of the DMZ with an associated attack along the western coast of Korea. The initial ground forces are arrayed similar to those in COA 1, with the exception being that there are no Red forces (and thus no logistical flow) to the North Korean city of Kosong. Ultimate objectives for Red forces under COA 2 are the South Korean port of Pusan and the city of Pohang.

Red COA 3 is an all out attack by the North along both the eastern and western coasts, coupled with a frontal attack through the center of the DMZ. Attacking with 15 divisions, the North Korean Army launches their assaults from Haeju, Pyongyang, and Wonsan. No forces or logistical stockpiling are present elsewhere along the DMZ. Over half of the Red forces (7 out of 15 division), and consequently a majority of the logistics flow, are centered about the city of Pyongyang prior to the attack. The final objectives of Red COA 3 are the most ambitious of all three COAs. They are the cities of Kunsan, Taeju, Wonju, Kwangju, Taegu, Pusan, Chungju, and Pohang.

Blue COAs consist of purely defensive operations. At scenario start, there are 10 U.S. Army divisions in country, with another 8 divisions (including two U.S. Marine units) deploying into the theater after the scenario starts. Differentiating the three

Blue COAs are the positions taken by these eight follow on divisions. A detailed listing of unit positions, by COA, for both Red and Blue forces can be found in Reference [9].

b. Naval COAs

Naval forces, under the current EETLM architecture, do not have the same COA structure as ground forces. The Red naval units in this scenario travel from North Korean territorial waters at AT in search of Blue naval units to harass and interdict. Blue naval forces originate from source nodes to the east and west of the Korean peninsula and move up and down the coast as necessary in order to execute the aircraft and TLAM strikes required by the *.ORD file. When opposing naval units detect each other, engagements occur according to the algorithms described in Chapter IV, assuming hostilities have commenced (i.e., scenario time $\geq$ AT).

Movement of naval forces are controlled in the same manner as that of the ground forces (i.e., a movement corridor is defined in the *.NET file for each COA and a minimum cost Dijkstra's algorithm utilized to select the actual route taken), but due to the sparsity of the naval network, there is only one path for naval forces to take. Once EETLM transitions to a more powerful computer platform, movement of naval forces will be as diverse as the movement of ground forces.

2. Results and Analysis

The analysis given below is organized according to the entry case option chosen by the Blue forces. This organization is in keeping with this thesis' attempt to investigate the effect that the arrival of naval forces has on the outcome of a littoral conflict. For illustrative purposes, sample graphs from the twenty-seven data runs conducted with the North Korean MRC scenario using EETLM will be included in the body of the sections that follow. A complete set of graphs depicting EETLM's performance, both in terms of COA perceptions and MOE performance, is available to the reader in Reference [12].

a. Blue's perception of Red COAs

(1) Blue Entry Case 1. When Blue utilized entry case 1, a notable pattern emerged in the data. As shown in Figure 1, Blue had difficulty predicting accurately what Red's intentions were when Red was pursuing COA 3. After the time of Red's attack (Day 6.0, approximately for the three replications of case R3-E1), in only one of the three replications did Blue accurately predict that Red was indeed pursuing COA 3. In the first replication, COA 2 was considered the most likely at day 6.0, and remained the dominant COA for the remainder of the conflict. In replications two and three, Blue accurately perceived that Red was pursuing COA 3 at the time that Red launched its attack across the DMZ, but shortly thereafter other COAs became dominant. For example, in replication two Blue accurately predicted Red's intentions by day 6.0 with a perceived probability of 0.84, but by day 6.5 (approximately 12 hours after AT), COA 2 returned as the most likely Red COA (with a perceived probability of 0.76) and remained so until day 7.25. From then until day 8.0 Blue re-established that Red was pursuing COA 3. After day 8.0, Blue never considered COA 3 to be the most likely course that Red was pursuing. Thus for the last two days of the scenario (approximately half the period of active hostilities), Blue misidentified Red's intentions.

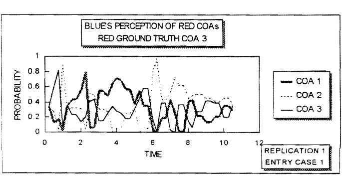


Figure 1. Blue's perception of Red COAs under case R3-E1.

This pattern did not hold when Red was pursuing other COAs. For example, when Red was pursuing COA 2 (Figure 2), Blue accurately identified COA 2 as being Red's intended course of action just prior to day 6.0. After that time, with the exception of one period of time lasting one-fourth of a day in scenario time, Blue never lost the perception that Red was indeed pursuing COA 2 until the scenario ended.

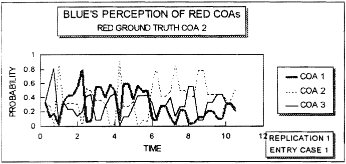


Figure 2 Blue's perception of Red's COA under case R2-E1

The fact that Blue had such a difficult time identifying and maintaining the correct perception regarding Red's COA when Red pursued COA 3 should be a high priority concern for Blue strategic planners. If the data in this scenario were the actual capabilities and COAs that applied to a Korean MRC, this pattern could indicate a potentially serious weakness in the reconnaissance and intelligence capability of the theater commander's staff.

(2) Blue Entry Case 2. Under Blue entry case 2, the same pattern emerged. When Red pursued COA3, Blue was unable to reliably determine Red's intentions. At AT (again, approximately day 6.0), Blue held all COAs to be very close in terms of likelihood. In replication three of case R3-E2 (Red COA 3, Entry Case 2), Blue correctly identified Red's COA at AT, but never held onto that perception for a substantial length of time. In replications one and two, the majority of the perceptions after AT

indicated COAs 1 or 3 were the most likely course of action for Red. Since these patterns did not hold for Blue's perception of Red COAs 1 or 2 (i.e., Blue more readily ascertained the actual COA Red was pursuing), their is an even greater reason to investigate exactly what the Red forces are doing under COA 3 that causes Blue such confusion.

(3) Blue Entry Case 3. Entry case 3 continued the perplexing pattern involving Red COA 3, as shown in Figure 3. As in the other entry cases, Red COA 3 seemed to confuse the Blue forces the most. Over the three replications of case R3-E3, the perceptions of all three COAs at AT were approximately equal (except for replication 3 in which case COA 2 and 3 were approximately equal and COA 1 was considered somewhat less likely). The results from Red COA 1 and COA 2 were similar to those experienced under the previously discussed entry cases.

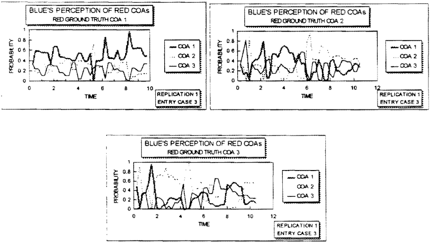


Figure 3. Blue's perception of Red COAs for cases R1-E3, R2-E3, R3-E3

(4) Comments. It is not surprising that Blue's perception of Red's COA does not vary greatly over the three entry cases. Red's actions are monitored

through sensors that are in theater at scenario start and are independent of the naval forces. The fact that naval forces arrive before, at, or after the perceived Red attack time does not affect the COA calculations of the model (refer to Chapter III for description of how EETLM computes COA perceptions).

What is significant is the pattern that was discovered regarding Red COA 3. COA 3 is similar to the other two courses of actions, perhaps enough so that Blue is confused by the observations it is taking during the scenario. Considering that COA 1 consists of an east and west coast attack and COA 2 is a dual attack down the west coast and through the center of the DMZ, it is possible that COA 3 (which combines the two COAs by utilizing a three prong attack down both coasts and through central Korea) is by its very nature, a course of action that Blue simply cannot readily identify.

b. Red's Perception of Blue COAs

(1) Blue Entry Case 1. When Blue utilized entry case 1, Red appeared to have difficulty in determining the actual COA Blue was pursuing. For example, in the case where Red was pursuing COA 3 and Blue utilized entry case 1 (replication 2 of this case is shown in Figure 4), Red correctly identified Blue as following COA 2 - which was the ground truth COA Blue selected - only between day 7.0 and 7.5 in two of the three replications performed. In replication one of case R3-E1 (Figure 5), Red never identified COA 2 as being Blue's intended course of action. For all replications, Red persistently held on to the perception that Blue was utilizing COA 3 throughout the majority of the scenario That Blue was pursuing COA 1 was never a serious consideration for Red

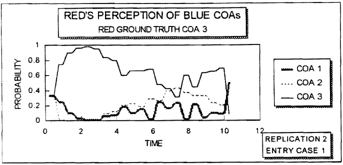


Figure 4. Red's perception of Blue COAs under replication 2 of case R3-E1.

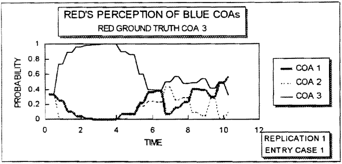


Figure 5. Red's perception of Blue COAs under replication 1 of case R3-E1.

Another interesting pattern in the perception data is that prior to AT, Red's perception of the probability that Blue is following COA 3 rises sharply to almost 1.0, then falls off between days 3.5 and 4.5 to a value closer to that of the other COA perceptions. This is interesting due to the fact that prior to AT there is very little ground movement on Blue's part from which Red can make a judgment regarding Blue's intended COA, thus it is unexpected that a single COA (particularly COA 3 with regularity) should achieve such a high probability so early in the scenario. It is not known if this is merely a result of the Bayesian updates for the COA probabilities, or if this indicates some other characteristic of the model that has been previously undiscovered.

(2) Blue Entry Case 2 With entry case 2, the same pattern of Red's perception of Blue COA 3 escalating to approximately 1.0 existed. The time at which Red first correctly identify Blue's intended COA (if it ever made that identification) fluctuated slightly over the Red COAs, but was typically at day 7.0. Note that although the initial correct identification happened at this time, the length of time in which Red held this perception was quite limited (approximately 6 hours in most cases).

Compared to entry case 1 (in which the average time until initial correct identification of Blue's COA was approximately day 7.5), this indicates that there may be a slight disadvantage to the late entry of naval forces into the theater. This observation has validity in that if Red knows that Blue has his full array of forces in theater, Red cannot rule out any force option that is within Blue's capability. For example, if Red "sees" that all of Blue's naval forces are in theater prior to AT, Red does not know if Blue will actually execute an amphibious landing, but he cannot discount the possibility (this dilemma is the defining reason for the amphibious feint). See Reference [12] for a complete set of graphs for entry case 2.

(3) Blue Entry Case 3. As with entry cases 1 and 2, Red forces seemed to be unable to accurately identify Blue's intended COA in this scenario. It would appear, however, that entry case 3 resulted in the least amount of time that Red correctly identified Blue's COA. Over nine runs of the scenario (three replications of each of the three Red COAs), Red correctly identified Blue's COA only twice. Both of these cases involved Red using COA 1 and Blue using COA 1 along with entry case 1, and both of these incidents were less than six hours in duration. Figure 6 demonstrates Red's perception of the different Blue intended actions for each of the three Red COAs.

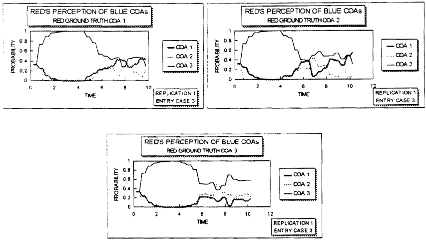


Figure 6. Red's perception of Blue COAs under cases R1-E3, R2-E3, R3-E3.

c. Overall COA conclusions

It appears that in all entry cases there is a significant level of confusion on Red's part in terms of determining which COA Blue is pursuing. While it is not clear that the entry cases are the cause of the confusion, it is a possibility. It is clear, however, that the entry of naval forces does not affect Blue's perception of Red's COA, as it should not.

Given the possibility that naval forces are successfully influencing Red's perception of Blue's COA, then it appears to be to the advantage of the theater commander to exercise entry cases 1 or 3 in order to capitalize fully on this confusion. This conclusion, in addition to being supported by the output of the EETLM runs, is reasonably valid when considering the real world flexibility of naval forces in this type of MRC environment

D. MOE ANALYSIS

1. Selection of MOEs

Five issues were identified as potential measures of effectiveness for this analysis. These MOEs were selected based on the assumption that they would be high priority issues for strategic planners when determining which contingency plan to utilize in a MRC scenario. These five MOEs are merely representative of the possible issues that could be identified as critical by future users of this model, and do not represent a complete listing of priority concerns. In addition to the graphical analysis conducted in this section, a more rigorous analysis of MOE 3 will be performed for demonstrative purposes only. As stated at the beginning of this chapter, this thesis is attemptingto demonstrate EETLMs potential for future use - not conduct a statistical analysis of its output data.

a. MOE 1

MOE 1 is the percent of surviving naval units. This MOE is broken down into five sub-MOEs according to ship type (e.g., Carriers, Cruiser/Destroyers, etc.). These types are:

- Blue Aircraft Carriers: Historically, the aircraft carrier has been considered the high value unit in a naval battle group, so it is assumed that planners will place high strategic value on the survivability of these ships.
- Blue Cruisers and Destroyers (CRUDES): With the advent of the Tomahawk cruise missile the CRUDES ships in a battle group have become strategic assets in their own right, not merely defenders of the aircraft carrier.
- Blue Amphibious Ships: Since the principle mission of the naval forces in a littoral environment is the support of the ground campaign, the safety of the amphibious assault forces should be a high priority in theater planning.

• Red SAG 1 ships: Rapid attrition of the larger CRUDES type ships of the red fleet will obviously minimize losses to Blue forces and thus may be considered as a MOE.

• Red SAG 2 ships: Similarly, it would be desirable to consider the effect of theater plans on the attrition of the smaller missile boat threats of the ships in Red SAG 2.

The values for MOE 1 are computed as follows:

$$\text{MOE1} = \frac{\text{\# of ships at end of scenario}}{\text{\# of ships at start of scenario}} \quad (25)$$

b. MOE 2

MOE 2 is the percent of surviving combat strength of the naval forces. The current policy of the United States Armed Forces is to be able to respond to two MRCs happening in different theaters nearly simultaneously. Accordingly, it may be desirable to consider the strength of the surviving naval forces at the end of one MRC so that estimates of their ability to contribute to a possible second MRC can be computed.

Due to the vast differences in what constitutes "combat strength" between the CVBG and ATG units, three types of this MOE were selected and their combat strength defined as follows:

• Blue CVBG: Combat strength is defined as the number of missile batteries remaining. An argument may be made that the combat contribution of the Mk-41 VLS launcher is far greater than that of the Mk-13 launcher system, but for purposes of this thesis they are counted as equals. The strength of the CVBG in terms of remaining aircraft is addressed later.

- Blue ATG: Due to the primary mission of the amphibious assault groups, their combat strength is defined as the number of Marine troops embarked. Once these troops are discharged via amphibious landing, they become assets of the ground component commander and the "combat potential" of the ATG is reduced (i.e., their combat potential has already been utilized). Therefore, to be considered useful to a second theater staff they must have Marines on board and ready for deployment at the end of the first MRC.
- Red units: Combat strength of Red naval forces is defined in terms of the number of missile launchers remaining.

MOE 2 is calculated as follows:

$$\text{MOE 2} = \frac{\text{\# of combat equipment at end of the scenario}}{\text{\# of combat equipment at start of scenario}} \quad (26)$$

c. *MOE 3*

MOE 3 measures the combat strength of Blue relative to Red naval forces. This strength ratio, calculated for the three categories of forces and definitions of combat strength described for MOE 2, may be of interest to the strategic planner when considering the relative amount of damage Blue is willing to incur versus the amount of attrition inflicted on Red. Destruction of all of Red's naval combat potential with a resulting loss of 50% of Blue naval combat strength may not be acceptable to a theater commander if, for example, he is concerned about public reaction to the loss of a large number of ships. The value for MOE 3 is calculated as:

$$\text{MOE 3} = \frac{\left(\dfrac{\text{Blue strength at end of scenario}}{\text{Blue strength at start of scenario}}\right)}{\left(\dfrac{\text{Red strength at end of scenario}}{\text{Red strength at start of scenario}}\right)} \quad (27)$$

d. ***MOE 4***

The percent of surviving aircraft available to the theater commander at the conclusion of combat. This measure of combat strength not only covers the combat potential of the aircraft carriers air wing, but also the strength of the ground based U.S. Air Force planes as well. Consequently, MOE 4 is measured in terms of both attack and fighter aircraft for blue naval and USAF planes as well as for Red air forces. When EETLM matures to the point that ASW and airborne C^3 assets are modeled, then this MOE may be expanded to include such aircraft as the S-3 and E-2 for blue naval forces, and the E-3 AWACS for USAF squadrons. Note that for purposes of this analysis the F/A-18 is considered to be an attack aircraft, even though it is in reality a dual fighter/attack plane. Additionally, the loss of an aircraft carrier results in the loss of its embarked airwing and is reflected in the computed value for MOE 4. MOE 4 is computed as follows:

$$\text{MOE 4} = \frac{\text{\# of aircraft at end of scenario}}{\text{\# of aircraft at start of scenario}} \tag{28}$$

e. ***MOE 5***

MOE 5 is the strength of ground forces. An analysis of the effect of naval forces on conflict outcome in a littoral warfare environment would be incomplete without some connection to the ground campaign results. Accordingly, the strength of the ground forces, measured as the percent of personnel surviving the conflict, is used as a MOE for this thesis. It is not intended to conduct a thorough analysis of EETLM's modeling of ground warfare here, but rather to quantify the effect of naval forces on ground combat. More complete analysis of the ground campaign may be found in Reference [9]. MOE 5 is computed in a similar fashion as MOEs 1 and 2:

$$\text{MOE 5} = \frac{\text{\# ground troops at end of scenario}}{\text{\# of ground troops at start of scenario}} \quad (29)$$

2. Results

The results of the data analysis performed on EETLM output are discussed in this section. As stated previously, the intent is to determine what effect (if any) the entry case utilized by the naval forces has on the outcome of the conflict as measured by the above defined MOEs. The results are discussed by MOE initially, with a combined discussion of the results and the conclusions drawn from them at the end of the section. Graphic illustrations are included as necessary to clarify the analysis, with a full set of graphs and data tables provided in Reference [12].

a. MOE 1

(1) Blue CVs. Based on the data, there was a more noticeable difference between the effects of entry case on the attrition of blue CVs than on any other blue naval asset. Specifically, the best case for carrier attrition was under entry case 1, as can be seen in Figure 7. When averaged out over the three Red COAs, entry case 1 produced the most favorable value of CV attrition.

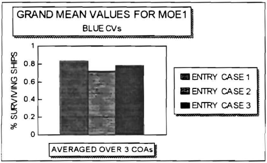


Figure 7. Survival rate for Blue CVs.

The difference between MOE values under entry case 1 and entry case 2 is small (approximately 11%), but this is due to the fact that Blue had only two carriers and never lost more than one in any given scenario run. Based on these values, Blue could consider it 83% likely that they will not suffer the loss of an aircraft carrier if they utilize entry case 1. Compared to the 77% likelihood if they pursue entry case 3 and the 72% likelihood under entry case 2, a theater commander may consider looking for more compelling indications from the other MOEs rather than decide based on CV attrition alone.

(2) Blue CRUDES. Figure 8 demonstrates that the attrition of the CRUDES ships in the Blue CVBG was not significantly different under any of the three entry cases. For all three entry cases and all three Red COAs, slightly more than half of the CRUDES ships survive the conflict.

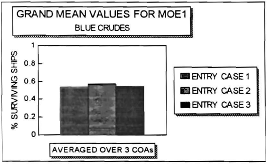


Figure 8. Survival rate for Blue CRUDES ships.

While entry case 2 yielded a slightly higher MOE value (0.56 versus 0.54 for entry cases 1 and 3), the difference is not of such a magnitude that a reliable recommendation regarding which entry case to utilize can be made.

It should be pointed out that the attrition rates for the CRUDES ships is probably unrealistically high. Given that Blue forces are not facing mine or submarine warfare, it was expected that more CRUDES ships would survive the conflict. This disproportionately high casualty rate is believed to be a result of the Battle Damage Assessment (BDA) algorithm discussed in Chapter IV. Once a more robust BDA algorithm is in place, it is believed that these attrition rates will more closely reflect reality.

(3) Blue Amphibious Ships. Blue amphibious ships showed a much higher attrition rate than did any other blue naval units (see Figure 9). This was not unexpected given the BDA algorithm discussed above and the fact that amphibious ships are armed with only the most basic self-defense weaponry. It should not be surprising that, when faced with the missile threats in this scenario, they sustained heavy losses.

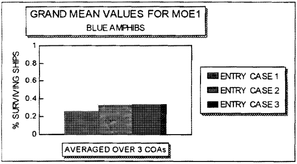


Figure 9. Survival rate for Blue Amphibious ships.

Based on the value of MOE 1 for blue amphibious ships, it appears either entry case two or three is desirable, but as with the CRUDES ships, there is insufficient difference between the three entry cases upon which to base a decision.

(4) Red SAG 1 Ships. The ships of Red SAG 1, consisting of the heavier and better armed Soviet-era warships, demonstrated the most attrition when blue forces utilized entry case three. There was only a very slight difference between the losses incurred by Red under Blue entry case 3 (77% of SAG 1 ships surviving) as compared to entry case one (83%) or case two (86%),and only a 9% difference between the best and

worst case situations. These results are shown in Figure 10. Note that since we are analyzing these data from the perspective of the Blue commander, the most desirable entry case is the one that produces the smallest MOE value for Red.

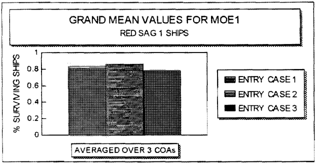


Figure 10. Survival rate for Red SAG 1 ships.

An interesting aspect of the attrition data for all ship types, but most particularly for the ships in Red SAG 1, is the variability of the levels of attrition over the different Red COAs. Since the naval forces do not follow widely different courses over the various COAs, it was not anticipated that there would be a large amount of variance over the MOE values. The fact that there is such variability in the outcomes of the scenario replications emphasizes the stochastic nature of the model. Consider Figures 11, 12, and 13, which shows SAG 1 attrition for each of the three Red COAs when averaged over three replications.

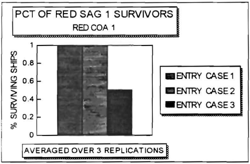


Figure 11. Survival rate of Red SAG 1 ships under Red COA 1.

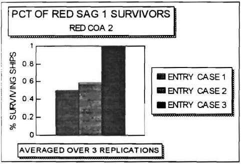


Figure 12 Survival rate of Red SAG 1 ships under Red COA 2.

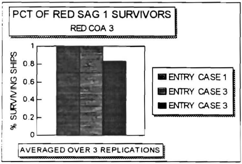


Figure 13. Survival rate of Red SAG 1 ships under Red COA 3.

Based on the data represented in Figures 11, 12, and 13, it would appear that a decisive advantage exists if Blue can ascertain Red's intended COA prior to making the decision on when to commit naval forces. For example, if Red was known to be pursuing (or could be forced into pursuing) their COA 1, then it would definitely be to Blue's advantage to commit naval forces on time under entry case 3 since Red suffers an average of 50% casualties in this situation. Alternatively if it was believed that Red would follow their COA 2, Blue's optimal move would be to commit forces to the theater early under case 1 and again cause Red to lose half of their heavier warships.

(5) Red SAG 2 Ships. Red SAG 2 ships indicated the most decisive advantage for entry case 1, with an estimated survival rate of 59% (i.e., a loss of 41% of Red's missile boat forces). This result can be seen in Figure 14. When compared to the survival rates of entry cases 2 and 3 (85% and 74%, respectively), it can be seen that a substantial advantage exists in getting naval combatants in theater early based on this MOE.

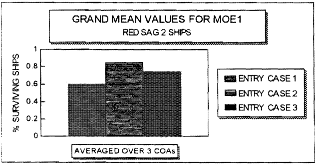


Figure 14. Survival rate of Red SAG 2 ships.

An alternative way to consider this data is to assume that the theater commander has no control over the entry case under which the naval forces will operate. The theater commander's area of responsibility may be the second MRC in the two MRC scenario, for example, and the arrival of naval and MPS assets are dependent upon the progress of the first MRC and how much force can be diverted into the theater. In this situation, a theater staff may wish to consider the expected level of damage Blue forces can inflict upon Red naval units, dependent upon the COA that Red chooses. It can be assumed that the most likely time of arrival for naval forces to the second of two MRCs is entry case 2 (late arrival of naval forces). By utilizing the data in Figures 10 and 14, the Blue staff can estimate that naval losses to Red units will be approximately 15 % (the complement of the combined survival rate of approximately 85%).

This value assumes also that Blue has no prior idea of which COA Red will pursue. If this is not true and Blue either knows what Red will do with some level of confidence, or can exert some type of pressure through other channels that will coerce Red into selecting a particular COA, then by utilizing Figures 11, 12, 13 for SAG 2 in conjunction with the data for SAG 1 found in Reference [12], more specific estimates can be offered. This type of "what-if" analysis may prove to be a valuable asset to staff analysts when faced with situations in which control over the arrival of forces can not be considered a guaranteed commodity.

(6) Overall Conclusion. Based on the MOE values from the sub-categories discussed above, no particular variant of MOE 1 provides a clear conclusion from which to make a recommendation. This should not be surprising, since there does not exist in the world an analysis tool that will decisively predict combat outcomes. There are, however, certain observations that can be made in order to aid in the strategic planning process:

• Entry case 2 offers no significant advantages for any sub-category of MOE 1.

• Entry cases 1 and 3 are equally desirable in terms of MOE 1. Entry case 1 maximizes the survival of the Blue carriers while maximizing the damage to the Red missile boat threat, while entry case 3 yields the highest survival rate for the amphibious forces while inflicting the greatest damage to Red's CRUDES forces

b. MOE 2

(1) Blue CVBGs. Aircraft carrier battle group strength was not significantly affected by changes in the entry case utilized by Blue or by the various COAs employed by Red. Over three replications for each of the entry cases and COA combinations, Blue CVBG strength varied by no more than 5%. This constant survival rate, summarized in Table 2 and shown graphically in Figure 15, indicates that Blue CVBG strength is not a useful MOE for deciding which entry case to utilize.

BLUE CVs			
	E1	*E2*	*E3*
R1	0.64	0.654	0.668
R2	0.668	0.654	0.654
R3	0.654	.687	0.654

Table 2. Remaining Combat Strength for Blue CVs per Case.

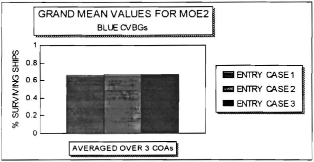


Figure 15. Average remaining combat strength for Blue CVBGs.

(2) Blue ATGs. Amphibious strength varied somewhat between entry cases and COAs in the individual scenario runs, but when averaged over the COAs, the impact of any given entry case on amphibious strength was diminished. Overall, however, entry case 2 (arrival of naval forces after the perceived attack time) demonstrated the highest utility, with entry case 3 only slightly less desirable on the average, as can be seen in Figure 16.

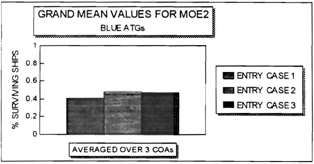


Figure 16 Average remaining combat strength for Blue ATGs.

This result supports what would be intuitively assumed about the outcome of the MOE values. It was considered likely that the arrival of forces at the perceived attack time would be equally desirable as the arrival of forces prior to attack time, since the forces would spend roughly the same amount of time engaging the enemy forces and thus would be expected to suffer similar casualty rates. It was also anticipated that the arrival of forces after attack time (entry case 2) would be considered to be more desirable than entry cases 1 or 3. Since forces under entry case 2 spend less time in a hostile environment, it was pre-supposed that their casualties would be lessened and thus the MOE values would be maximized.

(3) Red Naval Units. Red naval units' MOE values were also quite close together (approximately a 6% difference between the most and least desirable entry cases), and the pattern that the results exhibited also fit the preconceived assumptions discussed in the previous section, as is shown in Figure 17.

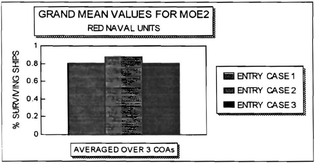


Figure 17 Average remaining combat strength for Red naval units.

As is apparent from Figure 17, there is not a large difference between the entry cases in terms of the damage inflicted upon Red's combat potential. However, this graph does show that entry case 2 is the most favorable to Red, with cases 1 and 3 being the most favorable to Blue. This result makes intuitive sense due to the fact that in entry case 2 the Blue forces are arriving after conflict begins, thus having less time in the scenario to engage and attrite Red's forces. In entry cases 1 and 3, Blue forces are in theater at the commencement of hostilities, therefore they are able to inflict damage on Red forces for the longest periods of time. This would result in the observed outcome; specifically, lower MOE 2 values for entry cases 1 and 3, and higher values for entry case 2.

(4) Overall Conclusions. Based on the data presented for MOE 2 in the sections above, the only conclusion that can be offered is that entry case 2 offers no strategic advantage in terms of the attrition of combat strength. Entry cases 1 and 3 both produce similar MOE values, and the theater commander must rely on some other influencing factor in order to decide between these two entry case options.

c. ***MOE 3***

(1) Blue CVBGs. MOE 3, defined as the ratio of Blue's strength to Red's strength and computed as in Equation (27), produced results very similar to those of MOE 2. When measured in terms of the number of ships remaining, entry cases 1 and 3 were the preferred options, with entry case 1 being the most desirable. From Table 3, it can be seen that the margin of superiority for entry case 1 was approximately 10% over 3 and 16% over entry case 2, a result that further supports the preconceived attitudes discussed in the previous section.

	BLUE CVBG		BLUE ATG	
	NO. SHIPS	EQUIP	NO.SHIPS	EQUIP
CASE 1 =	98833	.81764	.18169	.51087
CASE 2 =	.82689	.80000	.20802	.59112
CASE 3 =	.88198	.84042	.2363	.61245

Table 3. MOE 3 Values for Blue CVBGs and ATGs.

However, it is unclear if the difference between entry case 1 and 3 is significant, or if it is merely the result of random chance. In order to ascertain if entry case 1 is indeed the preferred option, a closer look is warranted. Consequently, analysis was conducted in order to determine if there is indeed any significant difference between entry case 1 and entry case 3 in terms of MOE 3. To this end, the following descriptive statistics were computed:

Statistic	Entry Case 1	Entry Case 3
Mean	0.988333	0.881969
Standard Error	0.072347	0.042565
Standard Deviation	0.21704	0.127694
Sample Variance	0.047106	0.016308

Table 4. Descriptive Statistics for MOE 3 (Blue CVBG Ships).

From Tables 4 it can be seen that, while the mean values for entry case 1 and 3 are different by a margin of 10%, the relatively large values of the standard error and sample standard deviation draw into question the significance of any difference in means between the entry cases. In fact, a 95% confidence interval for the mean values reveals that entry case 1 may actually be between 0.846537 and 1.130129. As this confidence interval envelopes the mean value of entry case 3, it is even more questionable that there is a statistically significant difference between entry cases 1 and 3. Subsequently, Student's t-test was conducted in order to establish the degree to which there is an advantage in selecting entry case 1 (for this thesis, all t-tests are two-tailed tests for the difference between means not assuming equal variances). This test revealed the following:

Observed t value	1.266924
t- Critical	2.160368
p-value	0.22741

Table 5. T-test values for MOE 3 (Blue CVBG Ships).

Thus it cannot be said that entry case 1 produces significantly more favorable results than entry case 3 when measured in terms of the ratio of Blue ships remaining relative to Red.

Similarly, when the remaining strength is measured in terms of combat equipment, the results are not conclusive. At first glance, it appears that entry case 3 is the preferred option for Blue to pursue. However, the margin of preference is merely 2.5% over entry case 1 and 4% over entry case 2. When subjected to Student's t-test, it can be determined that the difference between entry case 1 and entry case 3 is not significant to any reasonable level of confidence. Consequently, this data does not provide support for any of the entry case options under Blue's consideration.

(2) Blue ATGs. The data supported the same general results for the amphibious task groups. Entry case 3 demonstrated a fairly large margin of superiority over entry cases 1 and 2 (as can be seen in Table 3), particularly when measured in terms of combat equipment remaining. In this category, entry case 3 was 10% more favorable than entry case 1, but only slightly more than 2% more so than entry case 2. When Student's t-test was used in order to determine if the 10% difference between entry cases 1 and 3 was significant, the following results were produced:

Observed t value	-1.10795
t- Critical	2.306
p-value	0.300

Table 6. T-test values for MOE 3 (Blue ATG Equipment).

As can be seen from Table 6, there is no significant difference between the results of entry case 1 and entry case 3 in terms of this MOE.

d. MOE 4

(1) Blue USN Fighter Aircraft. The data for the aircraft attrition rates demonstrated the most variability of all the MOEs. For Blue naval aircraft, the presumption was that in entry case 1 and 3, the aircraft attrition rating would be the highest due to the fact that all scripted air strikes scheduled during hostilities would be executed. In entry case 2, some of the air strikes would be canceled by the model's algorithms since the time of arrival would have been after the scripted time of the strike - thus no strike would occur and no loss of aircraft would be experienced.

As seen in Figure 18, entry case 1 provided the most desirable MOE value for the Blue USN fighter aircraft when averaged over the three possible Red COAs. The benefit of entry case 1 was also clearly demonstrated when considered over each of the Red COAs.

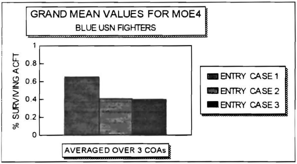
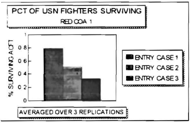


Figure 18. Average survival rate of Blue USN fighters.

It is clear from Figure 18 that entry case 1 provides the most desirable MOE values when Red pursues COA 1 or 3. When averaged over all three possible Red COAs, entry case 1 becomes the dominant option for Blue to pursue.

(2) Blue USN Attack Aircraft. The pattern of attrition demonstrated by Blue USN fighters is very closely followed by the rates of attrition of Blue USN attack aircraft. This pattern is shown in Figures 19, 20 and 21.



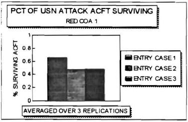


Figure 19. Comparison of survival rates for Blue USN attack and fighter aircraft under Red COA 1.

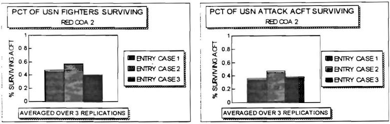


Figure 20. Comparison of survival rates for Blue USN fighter and attack aircraft under Red COA 2.

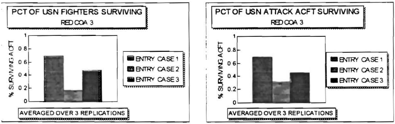


Figure 21. Comparison of survival rates for Blue USN attack and fighter aircraft under Red COA 3.

(3) Blue USAF Aircraft. Overall, the U.S. Air Force experienced the largest attrition of all the services. This observance is attributed to the simple fact that USAF aircraft presence in the theater was independent of both Red COA and Blue entry case option. Since the Air Force aircraft were in theater for the full duration of hostilities regardless of the conditions of the scenario, it is not unexpected that they show a higher average attrition rate than the U.S. Navy aircraft. The one interesting aspect of Blue USAF aircraft attrition is that it follows the same basic pattern as the Blue USN aircraft. Refer to Reference [12] for a complete set of graphs depicting Red aircraft attrition.

e. MOE 5

MOE 5 demonstrated the most clear cut measure of effectiveness of all MOEs chosen for this thesis. The interesting aspect of the data gathered from MOE 5 is the apparent symmetry between Blue ground force attrition and Red force attrition. It is apparent from this MOE that there is an advantage to Blue utilizing entry case 2 if maximizing the survival of Blue ground forces (and consequently maximizing the attrition of Red ground forces) is desired. Consider the results of the data runs for Blue and Red MOE 5 values as given by Figure 22:

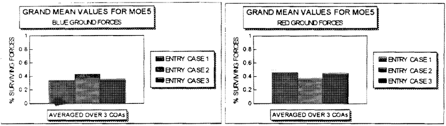


Figure 22. Average survival rates for Blue and Red ground forces.

From these graphs, it is apparent that entry case 2 is the best option for the Blue commander to take. This result, while supported by the numerical results, is counter-intuitive. It does not make sense from an operational standpoint that their would be a substantial advantage in deploying forces to a combat scene late. This is the point at which the professional judgment of the analyst would come into play. If taken at face value, the decision might be made to deploy forces late in order to maximize the value of MOE 5. While this would minimize exposure of Blue forces to hostilities and minimize casualties, it would most likely not be the best strategic decision for a theater commander to make. EETLM, like all other combat models, is an aid to decision makers - not a replacement for them.

f. Overall MOE conclusion.

As a summary to the MOE analysis, it would be helpful to consider Table 4, which summarize the most desirable entry case option as determined by the various MOEs described so far:

MOE	Preferred Entry Case
1	1
2	2
3	Undetermined
4	1
5	2

Table 7. Summary of optimal entry case option per MOE.

Note that since only MOE 3 was subjected to in depth analysis, this conclusion is not presented as a statistical study, but merely a demonstration of EETLMs capabilities. In fact, due to the premature status of EETLM as a model, it can be presumed that most of the MOEs do not indicate statistically significant preferences for the different entry cases. For demonstration purposes, however, it can be said that based on the comparison of the mean data values provided by the EETLM runs and the MOEs specified, entry cases 1 or 2 provide a similar degree of desirability. Since it is not considered realistic to assume that witholding forces to the scene of combat is a strategically sound course of action, it can be concluded that entry case 1 (arrival of naval and MPS forces prior to the start of combat) is the most desirable force entry option available to the Blue commander.

VI. RECOMMENDATIONS AND CONCLUSIONS

A. GENERAL

As stated throughout this thesis, EETLM is in its developmental infancy. It is acknowledged that due to a wide range of circumstances (including time and hardware constraints), not all of the desired aspects of theater conflict are incorporated into the EETLM architecture. It is also acknowledged that some aspects of EETLM, specifically the Battle Damage Assessment algorithm, need to be refined and improved to provide a more accurate model of combat. This chapter will discuss some of the major aspects of warfare that need to be incorporated into EETLM at future dates and will, when applicable, discuss the status of those updates that are in progress.

The source of these future incorporations are primarily:

- The Early Entry, Lethality, and Survivability Battle Lab, U.S. Army Training and Doctrine Command, FT Monroe, Virginia.
- The Naval War College Wargaming Center, specifically from the author's participation in the Global '94 Wargame Exercise.

B. FUTURE ADDITIONS TO EETLM

1. Mine Warfare

Mine warfare is becoming one of the most critical aspects of naval warfare, particularly as the Navy transitions to the littoral combat environment. It is also, unfortunately, the one area of combat that the Navy tends to disregard at much too high a cost. Within the last 10 years, three U.S. Navy warships have been severely damaged by mines (USS Samuel B. Roberts (FFG-58), USS Princeton (CG-59), and USS Tripoli (LPH-10)). The Samuel B. Roberts was nearly sunk and the Princeton and Tripoli were forced to be removed from a theater of combat as the result of enemy mine warfare. Mines are a very cheap and effective means for a less technologically powerful foe to inflict significant damage on the U.S. Navy with very little risk to themselves, and as such the area of Anti-Mine Warfare (AMiW) needs to be of prime concern to today's strategic planners.

There does not appear to be any single model that integrates the effects of mine warfare on the outcome of theater level combat. This is a deficiency that has significant impact when trying to address the issues of Strategic Sealift, delivery of Maritime Pre-Positioning Ships for the U.S. Army, and the execution of amphibious assaults. The U.S. Navy Mine Warfare Command utilizes a model called the Uncountered Mine Planning Module (UMPM) to assess the effectiveness of a minefield once laid, but this model does not interface with any other combat model, nor does it model enemy mine capabilities. Current practice is for the user to "translate" enemy mines into equivalent U.S. mines and then utilize UMPM to determine minefield effectiveness [Ref. 10] . In a wargaming or analysis situation, this result would have to be manually applied to the results of the theater combat, potentially degrading the statistical validity of the model's output.

EETLM has been designed to incorporate AMiW, although it is not currently modeled. The physical and transit nodes can be designated as having mines present, but there is no algorithm in place to date that models the effects of mine warfare. At a minimum, the following characteristics of AMiW should be modeled:

- Density of minefield
- Type of mine (i.e., acoustic, contact, etc.)
- Effects of mine sweeping operations on known minefields
- Hidden/unknown minefields.

2. Anti-Submarine Warfare

Anti-Submarine Warfare (ASW), while apparently declining as an area of concern in some circles of thinking, has not lessened in importance as the former Soviet Union fades farther into history. Many third world nations have invested in submarine technology, mostly that of the former Soviet Union. For example, it is common knowledge that Iran operates some Soviet diesel submarines, and North Korea maintains its own diesel submarine fleet. These are simply two examples of potentially hostile countries posing significant submarine threats. It should be obvious that it is not in the United State's best interest to disregard ASW as we plan for future wars. Two options exist in modeling ASW using EETLM: incorporate the modeling into the current surface network, or create a new underwater network.

The advantage of incorporating ASW into the existing surface network is a savings in computational complexity, since there would be no need for EETLM to keep track of a separate set of physical and transit nodes during each update cycle. Co-locating ASW into the surface network would require each transit and physical node to model environmental conditions relating to acoustic range predictions, presence or absence of convergence zones (CZs), and estimated background noise levels in coastal areas. This modification could be accomplished by fixed user inputs for these values into the *.NET datafile or an alternative method may be developed, perhaps through accessing a database of historical environmental data and generating predicted acoustic conditions within the operating program.

Creating a second, independent underwater network would allow for modeling the unique properties of acoustic propagation, sonar operations (both active and passive), and the intricacies of underwater detection and combat. It would also allow for modeling of naval scenarios where ASW activities is a higher threat such as the convoy of troops and supplies to the theater of action, or open water submarine vs submarine scenarios. While it is unclear the extent to which EETLM's basic structure would have to be altered in order to incorporate this third network, it does appear to be well within EETLM's capabilities to model ASW as the model develops.

3. Theater Ballistic Missile Defense

Theater Ballistic Missile Defense (TBMD) is yet another facet of theater warfare that is currently drawing significant attention from strategic planners. Highlighted during the Gulf War, TBMD is no longer limited to Patriot missile batteries defending an area target against inbound SCUD missiles. AEGIS cruisers and destroyers, equipped with an improved version of the Standard SM-2 missile and operating either independently or in conjunction with Patriot, are now being utilized as a major TBMD asset. As with mine warfare, there is no current model that incorporates this aspect of combat.

With the emergence of new technologies, it is imperative that combat models capture the advantages these technologies offer to war fighting commanders. With the addition of this aspect of theater warfare, the following issues could be explored:

- *How and where should AEGIS platforms be stationed in order to maximize TBMD effectiveness (measured in terms of area defended, area of enemy terrain from which TBM launches can be countered, etc.)? A optimization algorithm could be incorporated in this situation to provide the user with default stations if desired.*

- *How does the assignment of AEGIS platforms as TBMD assets detract from their other warfare assignments (i.e., as TLAM launchers, AAW or ASW picket ships, etc.).*

- *If there is a tactical trade-off in the assignment of AEGIS ship as a TBMD unit, can it be minimized through the use of Patriot batteries, either in conjunction with or independent of the AEGIS platform?*

- *What is the optimal mix of AEGIS ships and Patriot batteries for TBMD? This could be addressed in terms of cost effectiveness when the country is not engaged in conflict, or in terms of deployment time if hostilities have already commenced.*

Whatever the desired measure of effectiveness may be, it is apparent that there are numerous significant issues to be addressed in the field of Theater Ballistic Missile Defense. EETLM has the potential for quantitatively addressing these issues with some future modifications.

4. Weapons of Mass Destruction

With the demise of the Soviet Union, the threat of global nuclear war has diminished. Unfortunately, the threat of low level nuclear exchanges has not, as evidenced by the threat posed today by North Korea. Additionally, the threat of chemical and biological weapons being used in the next conflict is of pressing concern to today's military (the fact that chemical weapons were not used during the Gulf War surprised many military analysts). Weapons of Mass Destruction (WMD), a term encompassing nuclear, chemical, and biological weapons, are typically modeled in a separate process from traditional combat models. During the Cold War era, that approach was acceptable since the source of the chemical/nuclear threat was established (i.e., the Soviet Union and Warsaw Pact), and the method of their employment was believed to be reasonably well known. Since WMD was considered less of a variable, its contribution to the conflict was considered easier to quantify in terms of casualties and loss of combat potential. This also facilitated its transferal to special wargaming cells where higher level political and strategic issues could be resolved and the "conventional" wargamers could concentrate on fighting the war.

Present and future conflicts are shrouded in the potential use of chemical and/or nuclear weapons with little or no warning. Additionally, these weapons of mass destruction will most likely be used as a tool of terrorism or as a means of aiding a weaker military achieve some level of parity with the U.S. forces. As such, two conclusions can be reached: first, that the established paradigms regarding the use of WMD may not apply to future conflicts; second, contingency plans for WMD use by the enemy are going to have to be addressed at lower levels of the national chain of command. Given that the National Command Authority may not be able cover all contingencies in a CINC's area of responsibility, it is desirable that EETLM have the capability to model the effects WMD use will have on conflict outcomes.

5. Rules Of Engagement

The most significant decision made by a theater commander is the Rules of Engagement (ROE) he provides for his subordinate forces. The guidance provided by the ROE is what the forces in theater will use to determine the critical issues of hostile intent, hostile action, and engagement criteria in various levels of defensive/offensive postures. Review of U.S. naval activities in the Persian Gulf during the Iran-Iraq war, specifically the attack on the USS Stark (FFG- 31) by an Iraqi F-1 Mirage and the inadvertent downing of an Iranian civilian airliner by the USS Vincennes (CG-49), dramatically illustrate the effect ROE can have on all levels of U.S. operations (both tactically, strategically, and politically).

Analysis of the potential effects of ROE in different levels of hostilities and in different scenarios should be of prime concern to theater level staffs. By programming into EETLM a series of decision rules such that forces will follow a different set of ROE under differing levels of perceived/actual hostilities, analysts may be able to investigate the effectiveness of theater ROE. The obvious drawback to this aspect of modeling is that the decisions made by commanders under the rules of engagement are so very dependent on the individual commander's leadership style, his interpretation of the ROE, and his perception of the situation (among other things), that attempts to quantify this process may prove to be difficult at best.

6. Dynamic Air Tasking Order Generation

As described in Chapter IV, EETLM currently employs a scripted datafile (the *.ORD file), to trigger aircraft and TLAM strikes against land targets. There has been work done to generate a dynamic Air Tasking Order (ATO) within the structure of EETLM ([Ref. 4]), but it has not been incorporated into the model to date. As the model is transferred from a personal computer to a more powerful foundation, this capability will be installed.

7. Naval Tactical Maneuver

As mentioned in Chapter V, the current EETLM scenario does not alter the path of the naval units when they perceive a potential threat (i.e., when they come within range of enemy air, coastal artillery, etc.). By employing a weighted Dijkstra's algorithm similar to that employed by the ground forces, naval forces can, in theory, choose their paths dynamically in response to the perceived threats. This mechanism has not been tested to date due to the sparsity of the sea network and the lack of coastal defense sites in this particular scenario. With a more dense network and a more powerful platform with which to generate more complex scenarios, the application of this algorithm, once validated, will prove worthwhile.

Within the nodes themselves, it is desirable to have the naval battle groups assume tactical formations in response to the perceived level of threats from air, surface, or subsurface threats. This characteristic was discussed in Chapter III. By partitioning the physical and transit nodes, and by defining a preset formation for defending against each type of threat, the naval forces can be given a level of realism far beyond that which they currently possess. The process of partitioning the nodes in the EETLM architecture is discussed in greater detail in Reference [9].

8. Battle Damage Assessment

The Battle Damage Assessment (BDA) algorithm described in Chapter IV is acknowledged to be a very basic place holder for naval BDA. More sophisticated rules for BDA exist in other systems, but were not included in this model due to size and classification problems. It will be necessary to improve the validity of the BDA algorithm in future versions of EETLM. This may be accomplished in one of two fashions: add more sophisticated algorithms into the existing EETLM architecture or modify EETLM so that it accesses existing BDA models during scenario runs. The latter option would require significantly more effort and research to implement, but would take advantage of existing methods of determining engagement outcomes. Implementing additional algorithms into the current model will be quicker and easier to accomplish, and could be effected in the near term while future research determines a better method.

C. THESIS CONCLUSIONS

One of the priorities in the development of this model has been to incorporate as many of the joint aspects of warfare as possible, in order to reflect the changing doctrine of the United States military. The joint aspects incorporated do not just include force packages from the various services, but also the issues and requirements that different services have in terms of combat modeling. Inputs to EETLM have been received from various DOD agencies, and many of these requirements have been implemented in this thesis' version of the model, with remaining requirements scheduled for installation into future versions.

Another consideration that has been made in the development of EETLM has been to keep the model at a user-friendly level. Current versions of the model operate on a desktop personal computer, while the future versions of the model are to operate on a workstation. This upgrade in computing platforms was necessary in order to allow EETLM to model more complex scenarios and to achieve greater fidelity in the model's algorithms. But the environment in which EETLM will operate will still be a Windows style environment. This is done in order to prevent EETLM form becoming a tool that only specially trained analysts can operate, and allow for the widest dissemination of the model as possible. The utility of a model that can be used by a local theater staff, that has the flexibility to allow easy changes in scenario and combat capabilities of both sides in a conflict, and that produce outputs that are amenable to statistical analysis is considered to be quite high. That is the level of maturity EETLM is trying to achieve.

This thesis has demonstrated the utility of EETLM in aiding a theater commander in the decision making process. Utilizing the North Korean MRC scenario, data from the model were gathered and graphical analysis conducted in order to assess the impact that the arrival of naval forces had upon the outcome of a conflict. Based on the multiple MOEs selected for this analysis, the results of the model indicated that the early arrival of naval forces was the most desirable option for a commander to take, as was expected. The margin of desirability for this option, however, was not as great as it was thought it should have been, nor was it presumed to be of statistical significance. This phenomenon is attributed to the lack of maturity of some of EETLM's algorithms and the lack of technical accuracy in the DPRK Navy's combat capabilities. As the model matures and its operating algorithms validated, it is believed that future analysis will provide a much closer reflection of theater level conflict.

APPENDIX A

NODE CHARACTERISTICS

The data in this appendix defines a portion of the *.NET data file used for this thesis. A complete definition of the *.NET data file can be found in Reference [5].

1. Physical nodes.

a. Physical node name - 1 to 10 characters.

b. Node ID number - integer.

c. Latitude. Entered in degrees-minutes-seconds format with the last character indicating the direction, "N" = north and "S" = south, from the equator. Latitudes may range from 90S to 90N.

d. Longitude - 2 to 10 characters. Entered in degrees-minutes-seconds format with the last character indicating the direction, "E" = east and "W" = west, from the prime meridian. Longitudes may range from 180W to 180E.

e. In theater flag - 0 = No, 1 = Yes

f. Diameter - real in kilometers.

g. Use - 1 = air base

2 = logistics base

3 = defensive point

4 = obstacle

5 = arc crossing point

6 = carrier operations area

7 = Sea-based missile launch site

8 = NSFS line/amphibious line of departure

9 = Underway replenishment station

h. Terrain - 0 = sea

1 = open - no defenses

2 = hasty defenses

3 = deliberate defenses

4 = major obstacle

5 = urban

i. Capacity - real. Number of units that can simultaneously occupy the node.

j. Obstacles - 0 = none

1 = minefield

2 = not defined

3 = not defined

4 = chemical contamination

5 = radiological contamination

6 = Waterway constrained by width (e.g. canal)

7 = Waterway constrained by depth

8 = Waterway constrained by depth and width

k. Cover - real. Amount of cover/concealment at node (Real [0.0, 1.0]).

l. Suitable for concealed approach - 0 = No

1 = Yes

m. Suitable for defensive obstacles - 0 = No

1 = Yes

n. Sea state - integer [0,5].

o. Ammunition supply capacity - real in tons.

p. POL capacity - real in gallons.

q. Ground supply capacity - real in tons.

r. Air supply capacity - real in tons.

s. Number of sides stockpiling supplies to support an attack - integer ≥ 0.

t. Logistics buildup information. For each side enter the following:

(1) Side name - 1 to 10 characters. The name of a previously defined side

(2) Normal number of logistics packages - integer ≥ 0.

(3) Deviation of logistics packages - integer > 0

(4) Normal number of combat units - integer ≥ 0.

(5) Deviation of combat units - integer ≥ 0.

2 Transit Nodes:

a. Source node - The name of a physical node.

b. Destination node - The name of a physical node.

c. Number of transit nodes - integer ≥ 1.

d. Transit node information. For each transit node, enter the following:

(1) Transit node name - 1 to 10 characters.

(2) Distance - real in kilometers.

(3) Road type - 1 = primary

2 = secondary

3 = unpaved/trail

(4) Terrain - 0 = sea

1 = flat

2 = rolling

3 = severe

(5) Wetland/marsh - 0 = No, 1 = Yes

(6) Natural obstacle - 0 = No, 1 = Yes

(7) Manmade obstacle - 0 = No, 1 = Yes

(8) Mountain - 0 = No, 1 = Yes

(9) Urban - 0 = No, 1 = Yes

(10) Trafficability - 1 = No restriction

2 = Road movement only

3 = No heavy equipment

4 = No wheeled vehicles

5 = Foot only

(11) Capacity - real. Width in kilometers across mobility corridor.

(12) Obstacles - 0 = none

1 = minefield

2 = requires bridging

3 = requires physical clearing (non-explosive)

4 = chemical contamination

5 = radiological contamination

6 = Waterway constrained by width (e.g. canal)

7 = Waterway constrained by depth

8 = Waterway constrained by depth and width

(13) Cover - real. Amount of cover/concealment at node.

Real [0.0, 1.0].

(14) Suitable for ambush - 0 = No, 1 = Yes

(15) Suitable for obstacles - 0 = No, 1 = Yes

(16) Sea state - integer [0,5].

(17) Detection rates. For each side enter the following:

(a) Side name - 1 to 10 characters.

(b) Detect rate - real ≥ 0.

(c) Minimum detections needed to launch interdiction missions. Integer ≥ 1.

(18) Number of deep strike attrition rate entries.

(19) Deep strike attrition rates. For each entry enter the following:

(a) Side name of attacker - 1 to 10 characters.

(b) Side name of victim - 1 to 10 characters.

(c) Attrition rate - real.

APPENDIX B
BLUE NAVAL COMBATANT DATA

1. NIMITZ CVN:

(a) Radars:

Name	Range
SPS-48E	400 km
SPS-49(V)5	455 km
SPS-67	32.25 km

(b) Weapons:

Name	Range
NATO Sea Sparrow	14.6 km
Close In Weapon System (CIWS)	1.5 km

(c) Aircraft:

F-14, F/A-18, A-6E, E-2C, S-3A, EA-6B, SH-60F

2 BUNKER HILL CG:

(a) Radars:

Name	Range
SPY-1B	455 km
SPS-49(V)5	455 km
SPS-55	37 km
SPQ-9	37 km

(b) Weapons:

Name	Range
SM-2MR SAM	140 km
HARPOON	130 km
TOMAHAWK Land Attack Msl (TLAM)	1300 km
TOMAHAWK Anti Ship Msl (TASM)	460 km
5 inch Guns	23 km

(c) Aircraft.

SH-60B

3. **SPRUANCE DD:**

(a) Radars:

Name	Range
SPS-40	320 km
SPS-55	37 km
SPQ-9	37 km

(b) Weapons:

Name	Range
NATO Sea Sparrow	14.5 km
HARPOON	130 km
TOMAHAWK Land Attack Msl (TLAM)	1300 km
TOMAHAWK Anti Ship Msl (TASM)	460 km
5 inch Guns	23 km

(c) Aircraft:
SH-60B

4 **O.H. PERRY FFG:**

(a) Radars:

Name	Range
CAS/STIR	110 km
SPS-49(V)5	455 km
SPS-55	37 km

(c) Weapons:

Name	Range
SM-1 SAM	46 km
76mm Gun	16 km
HARPOON	130 km

(c) Aircraft:
SH-60B

5. **TARAWA LHA:**

(a) Radars:

Name	Range
SPS-52	439 km
SPS-40	320 km
SPS-67	37 km
SPQ-9A	37 km

(b) Weapons:

Name	Range
5/54 Gun	23 km

(c) Aircraft:
AV-8B

6. **WASP LHD:**

(a) Radars:

Name	Range
SPS-48E	400 km
SPS-49(V)5	455 km
SPS-67	37 km

(b) Weapons:

Name	Range
NATO Sea Sparrow	14.6 km

(c) Aircraft:
AV-8B

7. **WHIDBEY ISLAND LSD:**

(a) Radars:

Name	Range
SPS-49(V)5	455 km
SPS-67	37 km

(b) Weapons:
None

(c) Aircraft:
None

8. **NEWPORT LST:**

(a) Radars:

Name	Range
SPS-67	37 km

(b) Weapons:
None

(c) Aircraft:
None

APPENDIX C
RED NAVAL COMBATANT DATA

1. KIROV BCGN:

(a) Radars:

Name	Range
TOP STEER	276 km
TOP DOME	400 km

(b) Weapons:

Name	Range
SAN-6	46 km
SSN-19	400 km

(c) Aircraft:

HORMONE ASW Helicopter

2. KRESTA 1 CG:

(a) Radars:

Name	Range
HEAD NET	129 km
SCOOP PAIR	463 km

(b) Weapons:

Name	Range
SAN-1	46 km
SSN-3B	400 km

(c) Aircraft:

HORMONE ASW Helicopter

3. MOD KASHIN DDG:

(a) Radars:

Name	Range
HEAD NET	129 km
BASS TILT	220 km

(b) Weapons:

Name	Range
SAN-1	46 km
SSN-22	96 km

(c) Aircraft:

HORMONE ASW Helicopter

4. SOVREMENNYY DDG:

(a) Radars:

Name	Range
TOP STEER	276 km
BASS TILT	220 km

(b) Weapons:

Name	Range
SAN-7	46 km
SSN-22	96 km

(c) Aircraft:

HORMONE ASW Helicopter

5. OSA II PB:

(a) Radars:

Name	Range
None	

(b) Weapons:

Name	Range
SSN-2	96 km

(c) Aircraft:

None

6. NANUCHKA II CORVETTE:

(a) Radars:

Name	Range
None	

(b) Weapons:

Name	Range
SSN-9	96 km

(c) Aircraft:

None

APPENDIX D. EETLM OUTPUT FORMATS

This appendix lists portions of the output files generated from the EETLM data runs, specifically replication 1 of case R2-E1 (Red pursuing COA 2, Blue utilizing Entry Case 1). The purpose behind this appendix is to familiarize the reader with the type and format of the data produced by EETLM. The actual data from the runs conducted for this thesis are available from Dr. Sam Parry, OR Department, Naval Postgraduate School, Monterey, California 93943-5000

A. COA data file

FTLM Replication 1 Sat Jul 16 13:49:28 1994				
COURSE OF ACTION PERCEPTIONS				
A	**B**	**C**	**D**	**E**
	SEARCHING	TRACKED		
TIME	SIDE	SIDE	COA	PROB
----------	----------	----------	----------	----------
0.25	BLUE	RED	COA.1	0.333333
0.5	BLUE	RED	COA.1	0.130861
0.75	BLUE	RED	COA.1	0.180638
1	BLUE	RED	COA.1	0.020773
1.25	BLUE	RED	COA.1	0.349603
0.25	RED	BLUE	COA.3	0.333333
0.5	RED	BLUE	COA.3	0.333333
0.75	RED	BLUE	COA.3	0.736063
1	RED	BLUE	COA.3	0.736063
1.25	RED	BLUE	COA.3	0.891834

Table 8. Portion of the COA Output File for Case R2-E1, Replication 1.

Column	Purpose
A	Provides the scenario time for which the COA is applicable. The time interval corresponds to the length of the perception update cycle.
B	Designates the side generating the perceptions.
C	Designates the side that perceptions are being generated upon.
D	Indicates the Course of Action being considered.
E	The side in column B's perception of the probability that the side in column C is following the COA indicated in column D.

Example:

At time 0.5, Blue's perception is that Red is following COA 1 with a probability of 0.130861. At the same time, Red's perception is that Blue is following COA 3 with a probability of 0.33333.

B Engagement data file.

FTLM Replication 1 Sat Jul 16 13:49:28 1994
AIR STRIKES AND SURFACE-TO-SURFACE ENGAGEMENTS

A	B	C	D	E	F	G	H	I	J	K
SIDE	MISSION	START	TOT	TARGET	COMPONENT	WEAPON	ROUNDS	STRENGTH	BEFORE	AFTER
-------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------
RED	R5*	6.01827	6.03417	GROUP.2-1	EQUIPMENT	FAB-250	1	AGG	11861.00	11856
RED	R109	8.63225	8.63225	TRANSIT.68	NO_TARGET	NOT_APPLI	NOT_APPLIC	NOT_APPLIC	NOT_APPLIC	NOT_APPLI
RED	R10	6.32865	6.34675	NEWPORT	EQUIPMENT	SSN-19	4	AGG	458.00	SUNK
BLUE	B13*	6.03189	6.05000	RED.AFLD	SHELTERS	TLAM	2	NOT_APPLIC	3.00	2
BLUE	B182	8.81525	8.82275	NANUCHKA	EQUIPMENT	TASM	1	AGG	3.00	SUNK

Table 9 Portion of the Engagement Output File for Case R2-E1, Replication 1.

Column	Purpose
A	Indicates the side initiating the attack.
B	Designates the mission number. R5, for example, indicates the fifth attack initiated by Red. Those missions marked by an asterik (ex., B13*) are scripted via the *.ORD data file.
C	The time the attack was initiated.
D	Time On Target for the attack.
E	The target of the attack. Targets could be either a discrete unit, or a physical/transit node in the case of an air to ground attack.
F	The category of target being attacked.
G	Weapon used in the attack.
H	Number of rounds expended in the salvo.

I	Strength category. Each of the categories utilized in Reference [11] are reported, although they are not all shown in this appendix.
J	Strength of the target under the strength category prior to the attack.
K	Strength of the target under the strength category after the attack.

Examples:

1. Mission package R5 was a scripted mission against Group.2-1 that had a TOT of 6.03417, and thus commenced at 6.01827. The attack consisted of one FAB-250 and reduced Group.2-1's ground strength from 11861 personnel to 11856 personnel.

2. Mission package R109 was an unscripted naval engagement by Red against a target on transit node 68 (a sea node to the east of the Korean Peninsula). The attack failed due to faulty targeting by Red, thus the not applicable entries in the columns.

3. Mission package R10 was an unscripted naval engagement by Red against the USS NEWPORT. The attack consisted of four SSN-19 missiles, and sank the NEWPORT.

4. Mission package B13 was a scripted TLAM attack against a Red airfield, with a designated time on top of 6.05. One the three shelters at the airfield were destroyed by the TLAM attack.

5. Mission package B182 was an unscripted naval engagement against a Red Nanuchka missile boat. Blue utilized a single TASM for the attack and sank the Nanuchka

C. Logistics data file.

FTLM Replication 1 Sat Jul 16 13:49:28 1994

ESTIMATED LOGISTIC BUILDUP RATES AND ATTACK TIMES

A	B	C	D	E	F	G	H	I
	BUILDUP	RATES	LOG UNIT	ATTACK	TIMES	FLOAT		SELECTED
TIME	OLD	NEW	COUNT	OLD	NEW	OLD	NEW	COA
--------	----------	---------	----------	----------	----------	----------	----------	----------
0.25	0	0	0	NOT_APPLIC	NOT_APPLIC	NOT_APPLIC	NOT_APPLIC	NO_DECISION
0.5	0	6	3	NOT_APPLIC	10	NOT_APPLIC	7.10324	NO_DECISION
2.25	9	9	20	6.66667	6.66667	2.2699	2.0199	NO_DECISION
2.5	9	9.2	23	6.66667	6.52174	2.0199	1.62497	COA.2

Table 10 Portion of the Logistics Output File for Case R2-E1, Replication 1.

Column	Purpose
A	Denotes the time that the observation is applicable to. Corresponds to the time of the perception update cycle designated by the user in the *.NET data file
B	The rate of logistical buildup from the previous update.
C	The current rate of logistical buildup
D	The number of Red log units detected by Blue.
E	The perceived time for Red's attack from the previous update cycle.
F	The current perceived time of Red's attack.

G	Amount of slack time (i.e., time until the deployment of naval and MPS forces is necessary in order for these forces to arrive in theater prior to Red's attack) based on previous update cycle.
H	Current amount of slack time available.
I	Blue's intended COA based on what Blue perceives Red's ground truth COA is.

D. Position data file.

FTLM Replication 3 Sat Jul 16 13:59:29 1994
UNIT POSITIONS

A	B	C	D	E	F	G	H	I
TIME	UNIT	NODE	PERSONNEL	TANK	IFV	APC	COMBAT	LOG
---------	----------	----------	----------	--------	--------	---------	----------	----------
5.25	TF.B1	TRANSIT.70	0	0	0	0	22	0
5.25	TF.B2	TRANSIT.71	0	0	0	0	22	0
5.25	TF.B3	CVOA3	600	11	0	0	619	0
5.25	TF.B4	CVOA2	600	11	0	0	619	0
5.25	GROUP.1-1	MUNSAN	10500	436	402	0	11658	1600
5.25	GROUP.1-2	WONJU	12000	116	300	0	12760	1400
5.25	GROUP.1-3	KANGNUNG	12000	116	300	0	12760	1400
5.25	GROUP.2-1	SEOUL	11000	310	318	0	11965	1500

Table 11. Portion of the Position Output File for Case R2-E1, Replication 1.

Column	Purpose
A	Scenario time.
B	Unit. Group.1-1, Group.1-2, etc., are ground units. TF.B1, TF.B2, etc., are naval units.
C	The node that the unit in column B is occupying at the time listed in column A.
D-I	The "bean-count" of items the unit named in column B has at the time in column A.

E. Strength data file.

The strength data file is divided into two parts, one for initial strength and one for final strength. Each part of the data file consists of three distinct sections:

- Unit assets section (One for ground and one for naval units).
- Unit strength section (One for ground and one for naval units).
- Squadron strength section.

Examples provided in this appendix are for the initial strength of the naval units. When necessary, the significant differences between the naval unit format and the ground unit format will be discussed.

(1) Unit assets section

FTLM Replication 1 Sat Jul 16 13:49:28 1994

Seed = 757816775

Odd/even flag = 1

INITIAL UNIT STRENGTHS

NAVAL UNIT ASSETS

A	B	C	D	E	F	G	H	I
UNIT	SHIP	DAMAGE	PERSONNEL	TANK	MK13 LNCHR	MK 41 VLS	RED LNCHR	NAVY RADAR
-----	-----	-----	----------	---------	----------	---------	----------	----------
TF.B1	NIMITZ	U	0	0	0	0	0	2
TF.B1	C'VILLE	U	0	0	0	1	0	2
TF.B3	WASP	U	200	3	0	0	0	2
TF.B3	WHIDBEY	U	150	3	0	0	0	2

Table 11. Portion of the Strength Output File for Case R2-E1, Replication 1. Unit Asset Section.

Column	Purpose
A	Identifies the task force the unit is a member of
B	Identifies the individual unit by name.
C	Ship's status. (U= Undamaged, D= Damaged, S= Sunk).
D	The number of ground force personnel (i.e., Marines or Army troops) embarked. EETLM uses this value as a measure of how potent a ground threat a ship is.

E	The number of tanks embarked. This value is also used as a measure of the ship's ability to affect the ground campaign.
F	The number of Mk 13 missile launchers remaining.
G	The number of Mk 41 VLS launchers remaining.
H	The number of generic Red missile launchers remaining.
I	The number of generic Navy search radars remaining.

Note: The assets listed are for the naval units. Ground units list the following asset categories instead: Personnel, Tank, IFV, APC, Ground Mortars, Artillery, AD Radars, AD Launchers, Attack Helicopters, Engineering units, C^3 units, C^3 Antennae, POL, Ammunition, and MLRS launchers.

(2) Unit strength section.

A	B	C	D	E	F	G	H	I	J	K	L	M
UNIT	SHIP	AGG	AGA	AAG	AAA	CC2	CCO	CIN	CCM	LGS	LAS	LPO
----------	----------	---------	--------	----------	---------	---------	------	--------	-------	-------	-------	--------
TF.B1	NIMITZ	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TF.B1	C'VILLE	1.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TF.B1	O'BRIEN	1.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TF.B1	SPRUANCE	1.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TF.B3	WASP	203.00	2.00	0.00	0.00	0.00	0.00	200.00	0.00	0.00	0.00	0.00
TF.B3	WHIDBEY	153.00	2.00	0.00	0.00	0.00	0.00	150.00	0.00	0.00	0.00	0.00

Table 12. Portion of the Strength Output File for Case R2-E1, Replication 1. Unit Strength Section.

<u>Column</u>	<u>Purpose</u>
A	Identifies the task force the unit is a member of.

B	Identifies the individual unit by name.
C-M	Strength codes as defined in Reference [11].

(3) Squadron strength section.

SQUADRONS		
A	B	C
NAME	AIRCRAFT	AMOUNT
----------	----------	----------
VF-1	F-14	12
VF-2	F-14	12
VFA-1	F/A-18	12

Table 13. Portion of the Strength Output File for Case R2-E1, Replication 1.
Squadron Strength Section.

Column	Purpose
A	The name of the squadron.
B	The type of aircraft in the squadron.
C	The number of aircraft remaining.

APPENDIX E. EETLM OUPUT DATA

1. This appendix provides the raw data for each of the MOE's described in this thesis. For simplicity, this appendix will be organized by the scenario run case (i.e., R1-E1, R1-E2, etc.). For convenvience, the MOE's are provided below (Chapter V provides detailed descriptions of the five MOEs):

MOE 1: Number of ships surviving at the end of the scenario.

$$\text{MOE 1} = \frac{\text{\# of ships at end of scenario}}{\text{\# of ships at start of scenario}}$$

MOE 2: Percent of surviving combat strength of the naval forces.

$$\text{MOE 2} = \frac{\text{\# of combat equipment at end of scenario}}{\text{\# of combat equipment at start of scenari}}$$

MOE 3: The combat strength of Blue relative to Red.

$$\text{MOE 3} = \frac{\left(\frac{\text{Blue strength at end of scenario}}{\text{Blue strength at start of scenario}}\right)}{\left(\frac{\text{Red strength at end of scenario}}{\text{Red strength at start of scenario}}\right)}$$

MOE 4: Percent of surviving aircraft.

$$\text{MOE 4} = \frac{\text{\# of aircraft at end of scenario}}{\text{\# of aircraft at start of scenari}}$$

MOE 5: Percent of surviving ground forces.

$$\text{MOE 5} = \frac{\text{\# of ground troops at end of scenario}}{\text{\# of ground troops at start of scenari}}$$

a. R1-E1.

MOE	*CATEGORY*	*REP 1*	*REP 2*	*REP3*
1	***BLUE CVs***	1	1	1
	BLUE CRUDES	0.5	0.5	0.5
	BLUE AMPHIBS	0.25	0.25	0.25
	RED SAG 1	1.0	1.0	1.0
	RED SAG 2	0.3333	0.3333	0.3333
2	***BLUE CVBG***	0.64	0.64	0.64
	BLUE ATG	0.375	0.4167	0.4219
	RED NAVAL UNITS	0.76	0.76	0.76
3	***BLUE CVBG # SHIPS***	1.125	1.125	1.125
	BLUE CVBG EQUIP	0.8421	0.8421	0.8421
	BLUE ATG # SHIPS	0.1875	0.1875	0.1875
	BLUE ATG EQUIP	0.4934	0.5482	0.5551
4	***BLUE USN FIGHTER***	0.9167	0.625	0.8333
	BLUE USN ATTACK	0.8636	0.5	0.6136
	BLUE USAF FIGHTER	0.0833	0.0	0.0
	BLUE USAF ATTACK	0.25	0.25	0.0
	RED FIGHTER	0.4167	0.4167	0.4167
	RED ATTACK	0.0	0.0	0.0
5	***BLUE***	0.3235	0.2611	0.2611
	RED	0.2824	0.5995	0.5995

Table 14. MOE Values for Case R1-E1.

b. R1-E2.

MOE	*CATEGORY*	*REP 1*	*REP 2*	*REP3*
1	***BLUE CVs***	1.0	0.5	1.0
	BLUE CRUDES	0.5	0.6	0.6
	BLUE AMPHIBS	0.5	0.25	0.375
	RED SAG 1	1.0	1.0	1.0
	RED SAG 2	1.0	1.0	1.0
2	***BLUE CVBG***	0.64	0.682	0.64
	BLUE ATG	0.625	0.3958	0.4653
	RED NAVAL UNITS	1.0	1.0	1.0
3	***BLUE CVBG # SHIPS***	0.75	0.55	0.8
	BLUE CVBG EQUIP	0.64	0.682	0.64
	BLUE ATG # SHIPS	0.25	0.125	0.1875
	BLUE ATG EQUIP	0.625	0.3958	0.4653
4	***BLUE USN FIGHTER***	0.6667	0.1667	0.6667
	BLUE USN ATTACK	0.5455	0.3182	0.5455
	BLUE USAF FIGHTER	0.0833	0.0	0.0833
	BLUE USAF ATTACK	0.0833	0.0	0.0833
	RED FIGHTER	0.5833	0.5833	0.5833
	RED ATTACK	0.1667	0.1667	0.1667
5	***BLUE***	0.5012	0.4633	0.5012
	RED	0.2230	0.2230	0.2231

Figure 15. MOE Values for Case R1-E2.

c. R1-E3.

MOE	CATEGORY	REP 1	REP 2	REP3
1	BLUE CVs	0.5	1.0	0.5
	BLUE CRUDES	0.6	0.5	0.6
	BLUE AMPHIBS	0.625	0.25	0.625
	RED SAG 1	0.25	1.0	0.25
	RED SAG 2	1.0	1.0	1.0
2	BLUE CVBG	0.682	0.64	0.682
	BLUE ATG	0.7344	0.375	0.6875
	RED NAVAL UNITS	0.6686	1.0	0.6686
3	BLUE CVBG # SHIPS	0.88	0.75	0.88
	BLUE CVBG EQUIP	1.020	0.64	1.020
	BLUE ATG # SHIPS	0.5	0.125	0.5
	BLUE ATG EQUIP	1.098	0.375	1.028
4	BLUE USN FIGHTER	0.1667	0.6667	0.1667
	BLUE USN ATTACK	0.3182	0.8182	0.3182
	BLUE USAF FIGHTER	0.0	0.0833	0.0833
	BLUE USAF ATTACK	0.0	0.0833	0.0833
	RED FIGHTER	0.4167	0.3333	0.4167
	RED ATTACK	0.0	0.0	0.0
5	BLUE	0.2621	0.4092	0.2989
	RED	0.4771	0.4159	0.4770

Table 16. MOE Values for Case R1-E3.

d. R2-E1

MOE	*CATEGORY*	*REP 1*	*REP 2*	*REP3*
1	***BLUE CVs***	0.5	1.0	0.5
	BLUE CRUDES	0.6	0.5	0.6
	BLUE AMPHIBS	0.25	0.25	0.25
	RED SAG 1	0.25	0.25	1.0
	RED SAG 2	0.6667	1.0	0.6667
2	***BLUE CVBG***	0.682	0.64	0.682
	BLUE ATG	0.3958	0.3958	0.4167
	RED NAVAL UNITS	0.8571	0.6686	0.8586
3	***BLUE CVBG # SHIPS***	1.2	1.2	0.66
	BLUE CVBG EQUIP	0.7957	0.9573	0.7943
	BLUE ATG # SHIPS	0.2727	0.2	0.15
	BLUE ATG EQUIP	0.4618	0.5921	0.4853
4	***BLUE USN FIGHTER***	0.5	0.5	0.4167
	BLUE USN ATTACK	0.4091	0.4091	0.2727
	BLUE USAF FIGHTER	0.0	0.0	0.0
	BLUE USAF ATTACK	0.0	0.0	0.0
	RED FIGHTER	0.5	0.5	0.5833
	RED ATTACK	0.0	0.0	0.0
5	***BLUE***	0.2995	0.2994	0.4105
	RED	0.5907	0.5908	0.5294

Table 17. MOE Values for Case R2-E1.

e. R2-E2.

MOE	CATEGORY	REP 1	REP 2	REP3
1	BLUE CVs	0.5	1.0	1.0
	BLUE CRUDES	0.6	0.5	0.5
	BLUE AMPHIBS	0.25	0.5	0.25
	RED SAG 1	1.0	0.25	0.5
	RED SAG 2	0.6667	0.6667	0.6667
2	BLUE CVBG	0.682	0.64	0.64
	BLUE ATG	0.4427	0.6510	0.4427
	RED NAVAL UNITS	0.8586	0.5271	0.6071
3	BLUE CVBG # SHIPS	0.66	1.6363	1.2857
	BLUE CVBG EQUIP	0.7943	1.2141	1.0541
	BLUE ATG # SHIPS	0.15	0.5455	0.2143
	BLUE ATG EQUIP	0.5156	1.2350	0.7292
4	BLUE USN FIGHTER	0.25	0.625	0.8333
	BLUE USN ATTACK	0.3636	0.5227	0.5455
	BLUE USAF FIGHTER	0.0833	0.0833	0.0833
	BLUE USAF ATTACK	0.0833	0.0833	0.0833
	RED FIGHTER	0.6667	0.6667	0.6667
	RED ATTACK	0.25	0.25	0.25
5	BLUE	0.4369	0.3349	0.4399
	RED	0.5894	0.5893	0.5893

Table 18. MOE Values for Case R2-E2.

f. R2-E3

MOE	*CATEGORY*	*REP 1*	*REP 2*	*REP3*
1	***BLUE CVs***	0.5	1.0	1.0
	BLUE CRUDES	0.6	0.5	0.5
	BLUE AMPHIBS	0.25	0.25	0.25
	RED SAG 1	1.0	1.0	1.0
	RED SAG 2	0.6667	0.6667	0.6667
2	***BLUE CVBG***	0.682	0.64	0.64
	BLUE ATG	0.3958	0.4167	0.3958
	RED NAVAL UNITS	1.0	0.8586	0.8586
3	***BLUE CVBG # SHIPS***	0.66	0.9	0.9
	BLUE CVBG EQUIP	0.682	0.7454	0.7454
	BLUE ATG # SHIPS	0.15	0.15	0.15
	BLUE ATG EQUIP	0.3958	0.4853	0.4610
4	***BLUE USN FIGHTER***	0.25	0.2083	0.75
	BLUE USN ATTACK	0.3636	0.2045	0.5909
	BLUE USAF FIGHTER	0.0833	0.0	0.0833
	BLUE USAF ATTACK	0.0833	0.0	0.0833
	RED FIGHTER	0.5	0.5	0.5
	RED ATTACK	0.0833	0.0833	0.0833
5	***BLUE***	0.3606	0.3598	0.3607
	RED	0.5908	0.5909	0.5891

Table 19. MOE Values for Case R2-E3.

g. R3-E1.

MOE	CATEGORY	REP 1	REP 2	REP3
1	BLUE CVs	0.5	1.0	1.0
	BLUE CRUDES	0.6	0.5	0.5
	BLUE AMPHIBS	0.25	0.25	0.25
	RED SAG 1	1.0	1.0	1.0
	RED SAG 2	0.6667	0.6667	0.6667
2	BLUE CVBG	0.682	0.64	0.64
	BLUE ATG	0.4167	0.4427	0.3958
	RED NAVAL UNITS	0.8586	0.8586	0.8586
3	BLUE CVBG # SHIPS	0.66	0.9	0.9
	BLUE CVBG EQUIP	0.7943	0.7454	0.7454
	BLUE ATG # SHIPS	0.15	0.15	0.15
	BLUE ATG EQUIP	0.4853	0.5156	0.4610
4	BLUE USN FIGHTER	0.4167	0.9167	0.75
	BLUE USN ATTACK	0.4545	0.8636	0.7727
	BLUE USAF FIGHTER	0.0	0.0833	0.25
	BLUE USAF ATTACK	0.1667	0.0833	0.25
	RED FIGHTER	0.5	0.5	0.5
	RED ATTACK	0.0	0.0	0.0
5	BLUE	0.3873	0.3873	0.3874
	RED	0.2847	0.2847	0.2847

Table 20. MOE Values for Case R3-E1.

h. R3-E2.

MOE	*CATEGORY*	*REP 1*	*REP 2*	*REP3*
1	***BLUE CVs***	0.5	0.5	0.5
	BLUE CRUDES	0.6	0.6	0.6
	BLUE AMPHIBS	0.25	0.25	0.25
	RED SAG 1	1.0	1.0	1.0
	RED SAG 2	1.0	1.0	0.6667
2	***BLUE CVBG***	0.682	0.69	0.69
	BLUE ATG	0.3958	0.4427	0.4427
	RED NAVAL UNITS	1.0	1.0	0.8586
3	***BLUE CVBG # SHIPS***	0.55	0.55	0.66
	BLUE CVBG EQUIP	0.682	0.69	0.8037
	BLUE ATG # SHIPS	0.125	0.125	0.15
	BLUE ATG EQUIP	0.3958	0.4427	0.5156
4	***BLUE USN FIGHTER***	0.1667	0.1667	0.1667
	BLUE USN ATTACK	0.3182	0.3182	0.3182
	BLUE USAF FIGHTER	0.0	0.0	0.1667
	BLUE USAF ATTACK	0.0	0.0	0.1667
	RED FIGHTER	0.6667	0.6667	0.6667
	RED ATTACK	0.25	0.25	0.25
5	***BLUE***	0.3982	0.4007	0.3563
	RED	0.2849	0.2848	0.2847

Table 21. MOE Values for Case R3-E2.

i. R3-E3

MOE	*CATEGORY*	*REP 1*	*REP 2*	*REP3*
1	*BLUE CVs*	1.0	1.0	0.5
	BLUE CRUDES	0.5	0.5	0.6
	BLUE AMPHIBS	0.25	0.25	0.25
	RED SAG 1	1.0	1.0	0.5
	RED SAG 2	0.6667	0.3333	0.6667
2	*BLUE CVBG*	0.64	0.64	0.682
	BLUE ATG	0.3958	0.3958	0.4167
	RED NAVAL UNITS	0.8586	0.76	0.6071
3	*BLUE CVBG # SHIPS*	0.9	1.125	0.9429
	BLUE CVBG EQUIP	0.7454	0.8421	1.1233
	BLUE ATG # SHIPS	0.15	0.1875	0.2143
	BLUE ATG EQUIP	0.4610	0.5208	0.6863
4	*BLUE USN FIGHTER*	0.5833	0.6667	0.1667
	BLUE USN ATTACK	0.5	0.5455	0.3182
	BLUE USAF FIGHTER	0.1667	0.0	0.0833
	BLUE USAF ATTACK	0.1667	0.0	0.0833
	RED FIGHTER	0.5	0.5833	0.5
	RED ATTACK	0.0833	0.0833	0.0833
5	*BLUE*	0.3873	0.3874	0.3873
	RED	0.2847	0.2847	0.2847

Table 22. MOE Values for Case R3-E3.

LIST OF REFERENCES

1. Deparment of the Navy, "...From the Sea: Preparing the Naval Service for the 21st Century.", White Paper, 1992.

2. Department of the Army, *FM 100-5, Operations*, 1992.

3. Schmidt, Karl M., *Design Methodolgy for FTLM.*, Naval Postgraduate School, Monterey, CA., September 1993.

4. Wang, Hua-Chung, *Development and Implementation of Air Module Algorithms for the Future Theater Level Model.*, Naval Postgraduate School, Monterey, CA., March 1994.

5. Yamauchi, H., *FTLM Scenario Data Records*, Roland's and Associates, Monterey, CA., July 1994.

6. Brouillette, G., Fulkerson, M.B., *EETLM Korean Scenario Data Files*, Naval Postgraduate School, Monterey, CA., June 1994.

7. *Jane's Fighting Ships 1993*, 96th ed., Sentinel House, U.K., 1993.

8. Polmar, Norman, *Guide to the Soviet Navy*,

9. Brouillette, G., *Modeling Joint Theater Level Operations in the Early Entry Theater Level Model*, Naval Postgraduate School, Monterey. CA., September 1994.

10. Interview between LCDR Mike Jefferies, USN, Mine Warfare Command, and the author, July 1994.

11. Youngren, M.A., *FTLM Variable List (Draft)*, Unpublished, February 1993.

12. Brouillette, G., Fulkerson, M.B., *EETLM Korean Scenario Output Data Files*, Naval Postgraduate School, Monterey, CA., August 1994.

13. Gavers, D.P., Jacobs, P.A., "Sample Operational Scenarios for Stochwars Simulation", Naval Postgraduate School, Monterey, CA.

14. Gaver, D.P., Jacobs, P.A., "First Steps in Low Resolution Theater-Level Combat Modeling in the Presence of Uncertainty", Naval Postgraduate School, Monterey, CA.

15. Gaver, D.P., Jacobs, P.A., "Course-of-Action Realization and Perception in FTLM", Naval Postgraduate School, Monterey, CA.

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