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The Modeling Of Employment Decisions For Peacetime Contingency Operations

THESIS

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The Modeling Of Employment Decisions For Peacetime Contingency Operations

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

Michael Clinton Wilmer, B.S.

Captain, USA

March 1991

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Preface

The purpose of this research was to define ways in which modern decision-making tools could be used to enhance the effectiveness of operations planning. The specific type of operation used is peacetime contingency operations in low-intensity conflict. Such operations will be one of the predominant uses of military power in the future. Within these types of operations the decision that was focused on was the initial decision of how to employ the forces that have been allocated to the operational commander for the operation.

Historical research was performed to highlight the specific nuances of these types of operations and determine how they differ from mid- and high-intensity conflicts. That information was combined with current decision-making methods and a model was conceptualized that could be used to optimize the employment decision.

I would like to express my thanks to Major Morlan and Major Garrambone, my thesis committee for their invaluable assistance. They helped provide structure to what began as a rather broad topic area and kept me heading in the right direction at all times.

Above all I would like to thank my wife Fran for always understanding and for being by my side.

Michael Clinton Wilmer

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Abstract

This research provided the conceptualization of a model that can be used to aid the operations planner in choosing employment strategies for peacetime contingency operations. The model uses object-oriented design and is constructed in two levels. The top layer of the model is a decision analytic model which provides a framework within which to structure the employment decision. It enables the user to quantify the probabilities of random events and the preferences of the commander and determine how these factors influence the decision. A Game Theory model is used to determine the probabilities with which the Red commander will adopt a particular strategy. The lower level of the model is an object-oriented adaptation of SOTACA which incorporates PANTHER's methodology for evaluating popular support. This portion of the model allows the user to evaluate the results of the strategy chosen in the top layer in a more detailed combat model. This paper also identifies further research that must be performed in the modeling of non-combat activities that are an integral part of low-intensity conflicts.

The Modeling Of Employment Decisions For Peacetime Contingency Operations

I. Introduction

1.1 Background

Since the end of World War II, U.S. defense strategy has been based on the concept of deterrence. The primary focus of that strategy has been to deter the Soviet Union and Warsaw Pact from any aggressive action against the interests of the U.S., Western Europe and their allies. That strategy has been very successful as evidenced by the fact that nuclear war and large scale conventional war have been avoided. However, this success "...has been accompanied by a trend toward the ambiguous aggression of terrorism, insurgency, subversion and drug trafficking" (15:33). The decline in totalitarianism does not make the world safer but instead allows regional, racial, religious and cultural differences to surface and promote instability. This trend, coupled with the rapidly changing world geopolitical situation and public pressure to address internal problems such as drugs and the federal deficit, is changing the focus of current U.S. defense policy. As GEN Powell stated as the commander of U.S. Forces Command (FORSCOM), "The bottom line is that we can't act in the 1990s as if we had the same public consensus of the early 1980s or as if the geopolitical situation is the same" (46:14).

The country must possess the ability to respond rapidly and decisively to all threats to its national interests. As the Secretary of Defense stated in the FY 90 report to Congress, "While U.S. defense strategy is to deter threats to our interests, we must also be willing to act to ensure the credibility of our deterrent strategy and to defend our interests, should deterrence fail" (15:4).

In his national security strategy, the president has mandated that our forces, "...must be able to respond quickly and appropriately, as the application of even small amounts of power early in a crisis usually pay significant dividends" (5:104). The secretary goes on to say that, "To protect our interests at the lower end of the conflict spectrum, we must be prepared to conduct politically sensitive contingency operations of limited duration short of conventional war" (15:44).

In its capstone manual for the AIRLAND BATTLE doctrine, Field Manual (FM) 100-5, the Army defines contingency operations as, "...military actions requiring rapid deployment to perform military tasks in support of national policy" (17:169). The planning process for such operations is the cornerstone of their success. It seeks the same decisions as any other military planning process: when, where, how and with what to respond. However, the planning environment for contingency operations in low intensity-conflict (LIC) is very different from mid- and high-intensity levels of conflict.

The information required for decision-making in the LIC environment is available only in very limited quantities, and since the information is mostly in the form of raw data, it requires extensive analysis before it becomes useful intelligence. Although the general situation may have been anticipated and even practiced in training to some extent, the specifics of the conflict remain unknown until they occur. In general, today's commanders and their staffs are not well versed on all potential enemy's equipment, tactics and motivations to the extent they are with those of their traditional schoolhouse foe, the Warsaw Pact. A major constraint in contingency planning is time. Quick judgements about enemy intentions and decisions about friendly actions are needed to support operational planning.

To effectively negotiate the LIC environment requires a structured approach. Historically, the military decision-making process has used staff estimates and deliberate planning. This type system focuses on careful identification of the problem; thorough analysis of the factors involved; enumeration of possible courses of action; detailed analysis and comparison of these courses of action; and finally, the selection of the best action. This process has performed well in the past when sufficient amounts of time and preprocessed data are available, but the question is, can this methodology cope with the uncertainties of a rapidly changing situation?

As the world's geopolitical situation continues to change and as the focus of defense policy changes with it, the Defense Department must place renewed emphasis on the process of and on proficiency in contingency planning. It must do what it can to neutralize the chaos and uncertainties that can exist, to lessen the impact of time constraints and to improve the effectiveness of decision-making processes. As GEN Powell stated in an interview in April 1990, "We've always got to be ready for the contingency nobody has planned for and the crisis nobody knew was coming until it arrived" (2:24).

1.2 General Problem

Warfare is engulfed in uncertainties due to its competitive nature and the requirement to make many assumptions surrounding its conduct and outcomes. Commander's must make most combat decisions in the face of this uncertainty. They attempt to minimize it through the collection of intelligence. But Clausewitz reminds us that, "many intelligence reports in war are contradictory; even more are false, and most are uncertain" (26:117). As a result, Clausewitz states, "the objective nature of war makes it a matter of assessing probabilities" (26:85). Along with the ever present element of chance, this makes war nothing but a gamble (26:85).

This situation of uncertainty is compounded in the low-intensity conflict environment where intelligence is minimal and many different factors (political, economic, social) compete for resources and impact on the overall success of the campaign. Furthermore, when making decisions under conditions of uncertainty, risk is involved. The sensitivity of decisions made under these risk conditions is compounded by the penalty for mistakes: loss of life.

While success in warfare is traditionally measured in terms of attrition and movement, the goal in LIC is not to control terrain, but to win the support of the people. Current military planning methods still do not focus enough on this point.

Current Army planning methods do not adequately address the nuances of low-intensity conflict. They do not sufficiently consider the uncertainties involved nor do they focus on the appropriate measures of performance. Nor can current planning methods respond effectively in a time-compressed planning environment.

The planning methods currently being used at corps and division headquarters to address contingency operations do not take advantage of the state of the art in decision-making techniques. It is at this level where the critical employment decisions of how to translate the forces allocated into a tactical plan are made, yet no modern tools are used to aid that decision. At higher levels, analysis tools are used to do force structure and operational planning analysis, but none have been translated into a method useful for real time decision-making. Division and corps commanders do not even have trained analysts (FA49) on their staffs to assist them.

The staffs in these headquarters make decisions based on hueristic methods developed from conventional experiences that may not be translatable to peacetime contingency planning. No attempt is ever made to quantify the probability of occurrence of random events which effect the operation nor to update these assessments when additional intelligence is received. There are also no quantitative methods used to assess the utility or value of various outcomes. There are, however, mathematical methods available with which to address these shortcomings.

1.3 Research Problem

The purpose of this research was to analyze LIC, specifically peacetime contingency operations, and determine what makes LIC different from mid- and high-intensity conflicts. The objective was to outline the factors that influence and measure the success of those operations. This research would then allow the conceptualization of a decision aide that could be used to enhance the planning process for these types of operations.

1.4 Scope

The realm of LIC is extremely broad and as a result this research concentrated only on peacetime contingency operations (PCO). The world is moving rapidly away from U.S.-Soviet bipolarity to a more multipolar structure. This along with the proliferation of more advanced weapons may give rise to an increase in regional conflicts that will threaten U.S. interests (5:21). This circumstance elevates the importance of stability in the Third World and, therefore, the potential for and importance of peacetime contingency operations.

In any combat situation, friction and the fog of war make it impossible to determine the actual probability of the occurrence of various events. In PCO this problem is compounded by the fact that there is insufficient time and data to do in-depth analysis. Therefore, probabilities are highly subjective. Making a decision under these conditions involves a great deal of uncertainty and risk.

The research did not focus on the national command authority's (NCA) (President, Secretary of Defense, Joint Chiefs) decision to use military force, but on the operational level commander's decision of how to employ that force once it is allocated.

1.5 Research Objective

The objective of this research was to suggest the framework for a model that could be used to analyze employment decisions for peacetime contingency operations. This model would be used to analyze the effects of different decision strategies on employment decisions. The intent was to incorporate tools and methodologies that would adequately address the uncertainty and competition inherent in warfare and to also properly address the nuances of LIC. There are many areas of modeling LIC which still require additional research. Therefore, the intent of this thesis is to provide a general framework for the model in an effort to provide direction for further study. The intended user of this model is an analyst (FA49) in the plans section of a corps headquarters.

II. Literature Review

2.1 Introduction

The purpose of this review is to discuss current literature pertinent to this research. This discussion will cover the nature of low-intensity conflict, the science of decision-making and some of the techniques currently being used in modeling LIC and contingency operations. The objective was to distinguish the environment of LIC from other levels of conflict and to identify appropriate measures of performance for this type of conflict. Following that discussion some important aspects of decision-making under uncertainty are introduced and current military decision-making is reviewed. Finally, some of the current mathematical methods for modeling LIC are introduced.

2.2 Low-Intensity Conflict

2.2.1 Definition. In the 1990 Report to Congress, the Secretary of Defense quotes the President as having defined low-intensity conflict as,

> political-military confrontation between contending states or groups below conventional war but above the routine, peaceful competition among states. It involves protracted struggles of competing principles and ideologies. Low-intensity conflict ranges from subversion to the use of armed force. It is waged by a combination of means employing political, economic, informational, and military instruments. Low-intensity conflicts are often localized, generally in the Third World, but contain regional and global security implications. (15:43)

This definition has been adopted for use by the Department of Defense (DOD) and is the one found in Joint Pub 1-02, *Department of Defense Dictionary of Military and Associated Terms* and Joint Pub 3-07, *Doctrine for Joint Operations in Low-Intensity Conflict* (30:I-1).

This definition amplifies some critical concepts, but of utmost importance is the fact that low-intensity conflict is not merely a military struggle. It is waged on various fronts with political, economic and informational facets. Military operations are often constrained by complex rules of engagement (ROE) and span a wide range of activities from propaganda through subversion and terrorism to direct armed conflict against insurgents.

2.2.2 Spectrum of Conflict. The first step in understanding LIC is to understand its place in the spectrum of conflict. The spectrum of conflict (Figure 1) is a continuum which describes the various levels of confrontation that can exist between states. At the low end of the continuum is

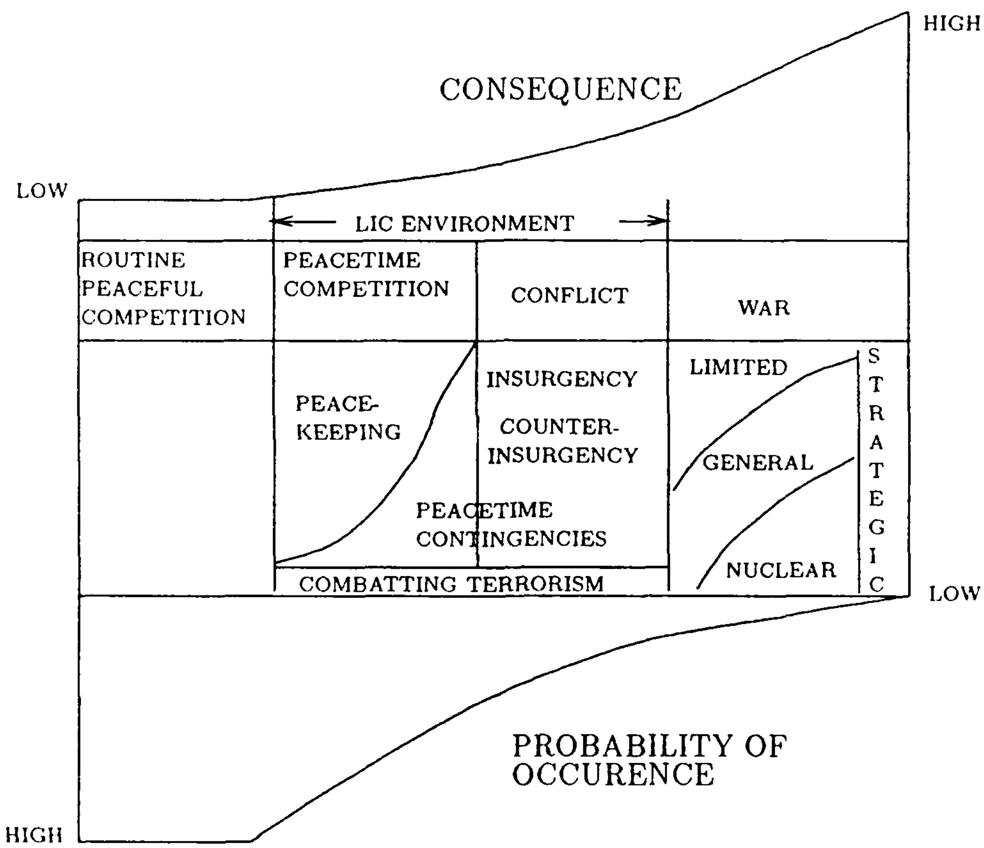

Figure 1. Spectrum of Conflict (7:3)

the desired circumstance of routine peaceful competition. "In this environment, the states of the world pursue their own interests, sometimes in harmony, but with enough commonality of interests to avoid violence" (18:vi). At the other end are the various levels of conventional war.

In between these two points is the environment of low-intensity conflict. "In LIC, the contribution of military force to the achievement of the strategic aim is indirect; that is military operations support nonmilitary actions which establish the conditions under which the strategic aim can be realized" (18:vi). These operations have relatively minor consequences to national survival but have a high probability of occurrence.

2.2.3 Peacetime Contingency Operations (PCO). There are four categories of military operations in LIC: **support for insurgency and counterinsurgency**; **combatting terrorism**; **peacekeeping operations**; and **peacetime contingency operations** (18:1-10). This research focuses on peacetime contingency operations in which general purposes forces are used. Examples of such operations are Operations Power Pack (Dominican Republic, 1965), Urgent Fury (Grenada, 1983) and most recently Just Cause (Panama, 1989).

"Peacetime contingency operations are politically sensitive military activities normally characterized by short-term, rapid projection or employment of forces in conditions short of war" (18:5-1). They are normally initiated during a crisis in which the military is required to reinforce and complement political and informational initiatives (18:5-1). The primary objective is to, "...rapidly project military forces consistent with the factors of METT-T [mission, enemy, terrain, troops available, time] in order to bring the contingency to an immediate close under conditions favorable to the United States" (18:5-2).

The nine major types of Peacetime Contingency Operations are:

- Shows of Force and Demonstrations
- Noncombatant Evacuation Operations (NEO)
- Rescue and Recovery Operations
- Strikes and Raids
- Peacemaking

- Unconventional Warfare
- Disaster Relief
- Security Assistance Surges
- Support to U.S. Civil Authority (18:5-6–5-15)

The four types of operations which this research focuses on are *shows of force, NEO, strikes and raids* and *peacemaking*. Although conventional forces support all of the major types of PCO at various levels, these four operations are most likely to involve the employment of relatively large scale conventional forces in combat operations.

Shows of force and demonstrations are ordered by the NCA in order to reinforce diplomatic promises, exhibit resolve and reassure allies. Combat is not the goal of these operations, but forces are prepared to use force should it be required.

Operation Golden Phesant is an example of a show of force operation. In 1988, Nicaraguan forces advanced into Honduran territory in pursuit of Contra rebels. U.S. forces already stationed in Honduras assisted the Honduran military in deploying to the area of the incursion. Meanwhile, elements of the 82nd Airborne Division and the 7th Infantry Division were immediately deployed to Honduras to demonstrate the U.S. commitment to protecting Honduran sovereignty. The result of this action was an immediate withdrawal of Nicaraguan forces without the need for combat action by the U.S.

Noncombatant evacuation operations (NEO) are conducted to remove civilians from potentially dangerous situations. They are characterized by, "...swift insertion of a force and temporary occupation of an objective followed by a planned rapid withdrawal" (18:5-7). They can meet with little resistance or include combat operations as in Operation Urgent Fury.

In the fall of 1983, a coup within the Cuban/Soviet supported, communist government on the island of Grenada threatened the security of the region and U.S. citizens attending school there. On 25 October, at the request of the Organization of Eastern Caribbean States, a U.S. Joint Task Force was deployed to the island to rescue U.S. citizens and return democracy to the island. The operation (although criticized by some afterwords) was swift and successful and attained its objectives with minimum casualties (45).

Strikes and raids are combat operations executed for a, "...specific purpose other than gaining or holding terrain" (18:5-9). They can be used to seize an objective, destroy threatening facilities or support counter-drug operations (18:5-9–5-10). The initial phases of Operations Urgent Fury and Just Cause are examples of these types of operations.

The initial phase of Operation Urgent Fury was a raid by special operations forces and Marines to seize and hold key airfields on the island. The success of this operation allowed follow-on forces to rapidly flow into the theater and accomplish the objectives of the campaign (45). Similarly, the opening stages of Just Cause were strikes and raids designed to seize key facilities and neutralize threatening forces. Again, the success of these missions allowed the rapid completion of the remainder of the operations with minimum casualties (8).

Peacemaking operations are conducted, "...to stop a violent conflict and to force a return to political and diplomatic methods" (18:5-11–5-12). They are often politically sensitive and require a delicate balance between the application of force to achieve the desired goals and ROE limiting the use of that force (18:5-12). U.S. intervention in the Dominican Republic in 1965 (Operation Power Pack) is an example of a peacemaking operation.

In April 1965, a coup in the Dominican Republic turned into a civil war which threatened U.S. citizens in the country. U.S. Marine and Army units were deployed, at the request of the host nation, to restore order. Combat operations were minimal compared to the non-combat (civil affairs, PSYOPs, civil-military) activities required for the success of the operation. Order was restored and a month later the mission transitioned into a multi-national peacekeeping operation (58).

2.2.4 Environment. LIC originates in an environment in which the dynamic factors of change, discontent, poverty, violence and instability are at work (18:1-3). The modernization and development of Third World nations causes rapid societal changes. These changes cause a rise in the expectations of a general populace that feels the government is not meeting their needs which in turn raises their discontent leading to violence and instability (30:1-4).

This process is part of the normal evolution of societies. It is not always detrimental to U.S. interests and in many cases is U.S. supported (30:I-4). However, when this instability is backed by groups opposing U.S. goals and national interests it becomes a threat.

Understanding the environment of LIC also requires a reorientation away from traditional concepts. It must be realized that as the name implies, unconventional warfare is "free from the normal teachings associated with the military profession" (50:5). Those teachings, which restrict our understanding of LIC, include cultural stereotypes as well as concepts about conventional military art (50:4).

Therefore, the operational parameters of low-intensity conflict must be better understood.

> Paramount in our preparation and planning for low-intensity conflict (LIC) is the requirement that we recognize LIC as not merely a scaled-down version of mid- or high-intensity conflict. Indeed, LIC is an altogether different venue of warfare, and consequently, during our planning we need to assess a number of new, more unique requirements that differentiate LIC from either mid- or high-intensity conflict. (27:19)

In low-intensity conflicts insurgents are seeking to undermine the government by amplifying its inadequacies to the society (34:22). Social and economic problems usually have created unrest. Through the effective use of propaganda, subversion and terrorism, the insurgents seek to sway popular support in their favor. This tactic cannot be countered merely by attempting to defeat the insurgents militarily.

There are four elements of national power: political, economic, informational and military (30:I-7). A successful LIC strategy must apply resources effectively in all four of these areas in order to bolster popular support for the government (34:26). A purely military action, which neglects the political, economic and social problems, is seldom successful (50:14).

The objective of LIC is the, "eradication of conditions conducive to violence and instability" (40:61). This is achieved through a, "rigorous, coherent, rational method" (40:61) of applying resources to the social, economic and political aspects of the conflict as well as the military ones. Unfortunately, soldiers are trained to think in a more conventional ground gaining fashion (34:29).

2.2.5 Imperatives for Success. The conventional goal of warfare, based on the philosophy of Clausewitz, is the defeat of the enemy's armed forces, the securing of ground and the destruction of the enemy's will to continue the fight. The measure of success in conventional warfare is the winning of the battle. In low-intensity conflict the goal is more the restructuring of the social order, not purely through military might, but also through economic, social and psychological means (36:37). This is in-keeping with the teachings of Sun Tzu. As Sun Tzu emphasized, "to subdue the enemy without fighting is the acme of skill" (23:77). This concept is still not understood by the Western military mind (36:37). Western education in the military arts is more heavily influenced by Clausewitz, a philosophy of demonstrated success in the recent two World Wars.

In order to enhance that understanding, the Joint Chiefs of Staff have outlined six **Imperatives for Success** in LIC operations: *political dominance, unity of effort, adaptability, legitimacy, perseverance and restricted use of force* (30:I-11). These imperatives are intended to bridge the gap between the traditional principles of the direct application of combat power (Principles of War, Tenants of Airland Battle) and the often indirect role of military activities in LIC (21:1–3). This is necessary because, "...in LIC superior combat power does not guarantee success, and violent action may be counter-productive in the total context of the conflict" (21:3). These imperatives for success can be considered by the analyst and planner to be measures of effectiveness for LIC operations.

Political dominance refers to the primacy of political objectives in LIC. Military operations must be planned to support those objectives (30:I-12). The political objectives dictate the rules of engagement (ROE), but should not limit military ingenuity or judgement (21:3).

Unity of effort means that military plans must be fully integrated with the political, economic and informational strategies. This requirement permeates to much lower levels of the military then in conventional war (30:I-12).

Adaptability is the ability to, "...change or modify existing structures and methods to accommodate different situations" (30:I-12). More than just being flexible enough to tailor old techniques, it includes the development of new methods (30:I-12).

Legitimacy of a state is defined by whether or not the people accept the government's right to govern and "...in the eyes of the population, the actual yardstick for legitimacy is the perception of effectiveness and whether the government has a genuine concern for public welfare" (34:26). Military operations can dramatically impact on that perception.

Perseverance reminds leaders that success in LIC is rarely achieved through a series of decisive battles culminating in a tactical victory. The other elements of power require constant, long-term attention in order to achieve the desired objectives. PCO's can be useful in seizing the initiative from the opposition but are rarely ends in themselves (30:I-13). This is most recently evident in Operation Just Cause where the U.S. is still working with Panama to improve political, economic and social conditions a year after the Noriega government was removed.

Restricted use of force refers to the fact that the excessive use of violence can adversely affect the legitimacy of the host government and the elements of national power. Rules of engagement are used to place limits on military operations. This will result in a more "...judicious, prudent and thoughtful selection and employment of forces ..." (30:I-13). The ROE must be balanced in order to preclude rapid escalation of the conflict without limiting the commander's warfighting capabilities (30:I-13).

FM 100-20, *Military Operations in Low-Intensity Conflict* outlines **principles** which are important to consider during PCO. **Coordination** reiterates the link between military operations and the other agencies of the government. There must be **balance** between the political goals of the operation and the military force required to achieve those objectives. Finally, commanders must **plan for uncertainty**. (18:5-2-5-3)

2.2.6 The Operational Level. The operational level of war is considered the link between the strategic and tactical levels. At the strategic level the NCA determines the overall objectives of the campaign, the resources that will be allocated and the limitations that will be imposed. At the tactical level, commanders employ the resources they possess within clearly defined guidelines to achieve specific objectives. It is at the operational level that the broad strategic goals are translated into specific tactical missions. In LIC, the separation of decisions and activities between these levels is often blurred (19:3).

Operational level decisions focus on where, when and how to fight. They are directed at attacking the enemy's centers of gravity or sources of strength (19:6). In LIC centers of gravity are not just military in nature (19:8). They include non-military aspects of power which affect the populations perception of legitimacy and can be attacked through means other than the direct application of combat forces.

2.2.7 Historical Perspective. In this section Operations Power Pack, Urgent Fury and Just Cause will be compared using the LIC imperatives for success.

Power Pack and Urgent Fury both had time-compressed planning sequences. In the Dominican Republic the coup began on 24 April 1965 (58:24) and the initial force of Marines landed on 28 April (58:24). For Grenada the president decided to assist on 22 October 1983 (45:53) and the assault force went in on 25 October (45:57). In each of these operations there were generic OPLANs available, but they required drastic modifications to be tailored to the actual situation.

The development of the OPLAN for Just Cause began in February 1988, however, it was under continual revision and operational security prevented widespread dissemination until the operation commenced in December (8:I-4). Both Power Pack and Urgent Fury suffered from a severe lack of intelligence (58:62-64) (3:60). In both cases, information about the composition and disposition of enemy forces, the number of groups involved and what each group's objectives were was unavailable. Similar shortfalls in intelligence, planning and coordination were also evident during Just Cause (10:III-3).

During Power Pack initial planning was done from existing evacuation plans, but as the operation continued specific plans were developed to meet each stage of the crisis as it occurred. The history of the operations planning for Urgent Fury and Just Cause is still classified. It is apparent from open sources that Urgent Fury plans were developed against a worst case scenario not a range of possibilities (45:111) (3:61). Planning for Just Cause was done over a much longer period of time and therefore was more deliberate. However, the unclassified lessons learned point to shortfalls in considering the unique aspects of LIC and recommend that, in the future, "courses of action must consider the reaction of the civilian population, refugee control and collateral damage" (10:III-3).

Each of these operations demonstrated **political dominance** of military activities. Power Pack is one of the earliest examples of political goals dictating military activities beyond the strategic to the operational and tactical levels (58:74). In fact, the commander of U.S. ground forces in the Dominican Republic, LTG Bruce Palmer, Jr., plainly stated that he was conducting stability operations which he defined as a mission to "...establish a climate of order in which political, psychological, economic, sociological and other forces can work in a peaceful environment ..." (58:73).

The primary missions of each operation clearly exhibit this political dominance. In none of these PCO was the conventional mission of closing with and destroying the enemy the primary objective. In the Dominican Republic the mission was to protect U.S. citizens, restore order and prevent the development of a second Cuba (58:86). In Grenada, the primary mission was NEO with a follow-on mission of restoring democracy through the removal of opposition forces (3:60). In Panama, the mission was to first protect U.S. lives and facilities, then capture Noriega and finally eliminate opposition to the U.S.-recognized government (8:I-5).

Legitimacy of the government was of critical importance in all of these operations. In Power Pack, almost immediately after stability was achieved in the capital city, the major mission of the ground forces became civic action, civil affairs and PSYOPs activities directed at improving conditions and restoring the image of the government (58:133-140). In Panama, civil affairs and PSYOPs missions were critical from the start and specialists in those areas were deployed with maneuver battalions (9:II-20–II-22). The Just Cause lessons learned also point out the extensive use of combat units for civil-military operations (9:II-23–II-24). Success of these operations also depended on **unity of effort** among all governmental agencies.

Perseverance was also required in all cases. U.S. forces stayed in the Dominican Republic until September 1966, 17 months after the initial deployment (58:169). Peacekeeping forces remained in Grenada for 20 months, until June 1985 (45:99). U.S. forces are still in Panama, over a year after Just Cause was completed, as part of the nation-building operation Promote Liberty (8:I-13).

In each operation U.S. forces displayed a great deal of **adaptability** in accomplishing the mission. In the Dominican Republic, innovative leap frog tactics were used to link the Marines and the 82nd Airborne Division (58:96). There are many stories of operational and tactical adaptability in Urgent Fury, including the use of travel maps to overcome topographic map shortfalls. In Panama the use of the F117 Stealth Fighter to prep a drop zone is an excellent example of adapting a new weapon system to the needs of the operation.

The **restricted use of force** was clearly evident in each operation. In Power Pack extensive

ROE were imposed in order to avoid a direct conflict between U.S. forces and the rebels (58:77). The purpose was to avoid the escalation of fighting within the capital city, to minimize collateral damage and civilian casualties (58:40). Additionally, the U.S. was attempting to play the role of a neutral peacemaking force. In both Urgent Fury and Just Cause, extensive ROE were imposed to limit collateral damage and to avoid civilian casualties (3:60) (9:II-6–II-7).

2.2.8 Conclusions. It has been shown that low-intensity conflict is a different form of warfare and that some additional factors must be considered when planning and executing these type of operations. The decision-making methods currently being used to plan these operations, specifically peacetime contingency operations, must now be reviewed.

2.3 Decision-Making

2.3.1 General. Decision-making is a mental process wherein a person evaluates the advantages and disadvantages of competing actions and, using a set of criteria, picks the action that best allows him to achieve his desired objectives. The decision that results is an irrevocable allocation of resources. Figure 2 is a diagram of the decision-making process.

The descriptive aspects of decision-making refer to how decisions are made while the prescriptive aspects deal with the theory of optimizing decision-making (24:3). "Programmed decisions are generally routine and repetitive in nature," while "...non-programmed decisions tend to be unstructured, complex, unique, and/or involve the long term commitment of major resources" (54:4). The decision-making process is effected by moral point of view, sense of duty, societal standards, personality traits and education.

2.3.2 Uncertainty and Risk. Martin Von Creveld in his book, *Command in War*, points out that,

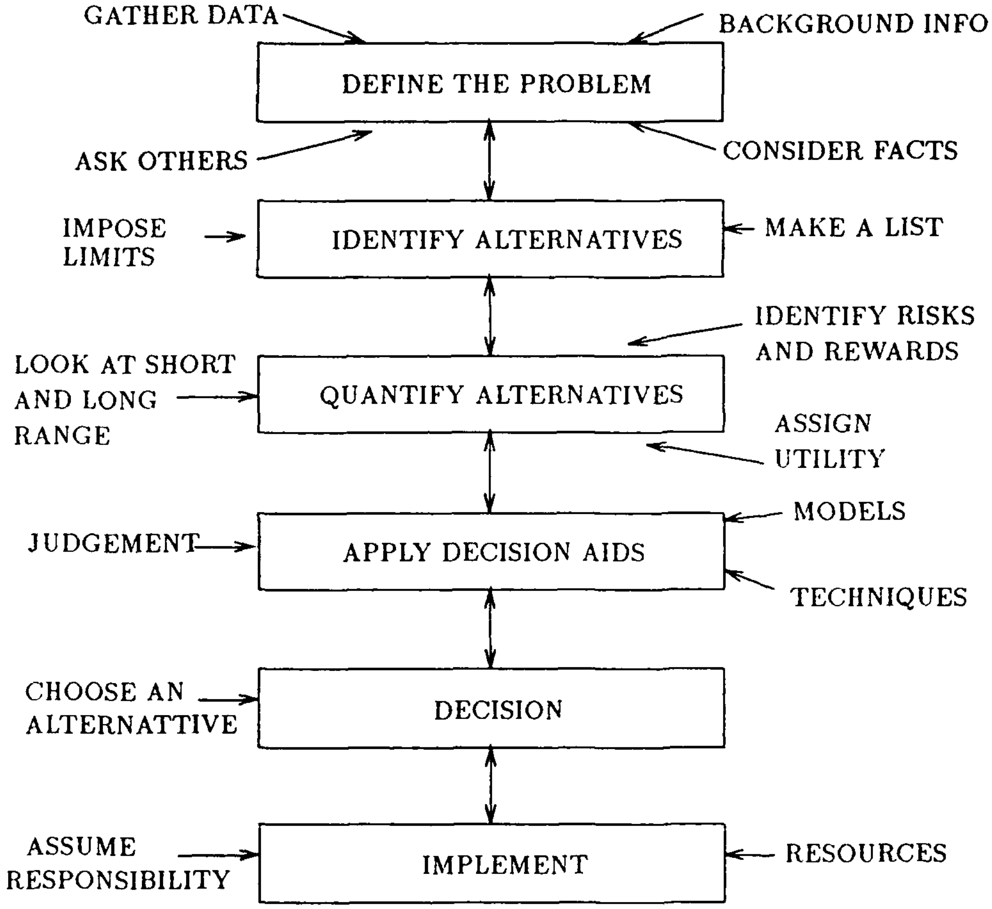

Figure 2. Decision-Making Process(24:22)

> From Plato to NATO, the history of command in war consists essentially of an endless quest for certainty — certainty about the state and intentions of the enemy's forces; certainty about the manifold factors that together constitute the environment in which the war is fought, from the weather and the terrain to radioactivity and the presence of chemical warfare agents; and, last but definitely not least, certainty about the state, intentions, and activities of one's own forces. (57:264)

Military decision makers are no closer today than they ever were of attaining certainty. War is competitive, with both sides trying to confuse, out-wit and surprise the other. It requires information. The more you need, the more time it takes to obtain and analyze it. The more data you acquire, the more difficult it becomes to separate the needed from the unneeded and the accurate from the inaccurate. (57:265-267)

Leaders are therefore faced with, "situations in which the consequences of any action . . . are not certain, because events may intervene that [one] cannot control or predict with certainty and whose outcomes will inevitably affect [the] final conditions" (48:ix). When making decisions under these conditions of uncertainty additional factors come into play. Of considerable importance are the characteristics decision makers exhibit when estimating probabilities and when required to take risks.

When estimating the probability or likelihood of an event occurring, people are subject to many heuristics and biases. Biases are, "conscious or subconscious discrepancies between the subject's responses and an accurate description of his underlying knowledge" (51:609). They can either be motivated by a person's desire to influence the decision or effected by the cognitive processes used (51:610). A displacement bias is one in which the distribution maintains its shape but the mean shifts (51:609). Variability bias is one in which the distribution changes its shape, frequently becoming centrally biased (51:609). A central bias is where, ". . . the distribution is tighter (has less spread) than is justified by the subject's actual state of information" (51:609). Figure 3 shows the effect of these various biases.

These biases are the result of the heuristic methods decision makers employ when judging the probability that a given event will cause (or result from) a set of circumstances. People depend on the extent to which the circumstances and the events are representative of each other (55:1124). They tend to disregard prior probabilities; are insensitive to the importance of the sample size; expect the characteristics of a process to be represented even over short periods; allow their predictions to be effected by the favorableness of the description of the situation; and tend to choose the result that resembles the inputs the best (55:1124-1126). Probability judgments are also biased by the availability of examples in the mind of the decision maker (55:1127).

Decision makers also tend to anchor their estimates on facts given in the formulation of the problem or based on rough calculations (55:1128). This causes an overestimation of the probability

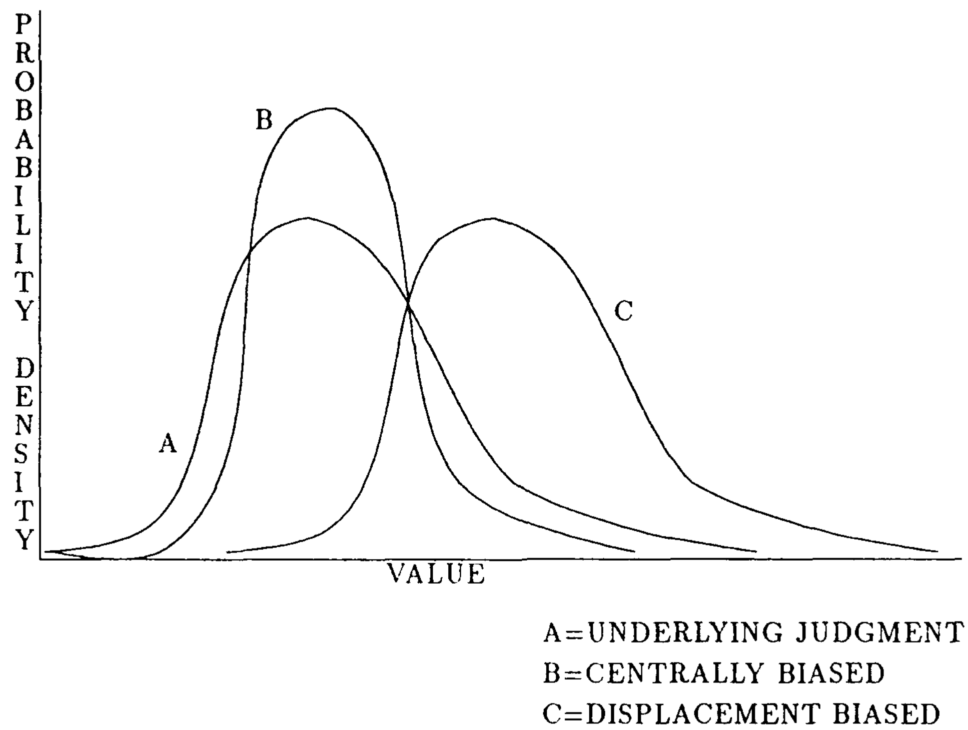

Figure 3. The effect of biases on probability distributions (51:609)

of success of a plan consisting on a number of events which individually may be very likely and an underestimation of the risks involved in a complicated plan consisting of a number of parts which individually have low risks associated with them (55:1129), (a displacement bias). Bias also cause decision makers to make the confidence intervals of subjective probability distributions narrower than is warranted (55:1129), (a central bias).

In addition to being effected by the way decision makers estimate the probability of occurrence of events in uncertain situations, the decision-making process is also affected by the decision makers attitude toward taking risks. This attitude is known as a risk preference. A decision maker can be risk neutral, risk prone or risk averse. A risk prone decision maker is willing to take greater chances to attain a more beneficial outcome, while a risk averse decision maker will settle for a less beneficial outcome in order to avoid the greater losses often associated with taking more chances.

A recent article by members of the Naval Post Graduate School (NPS), entitled "Risk Preferences in Military Decision Making: an Empirical Study", states that Army officers are risk aggressive [prone] in combat situations. This risk prone behavior is correlated to the expected number of fatalities. (20:249)

This behavior, in addition to being proliferated by promotion policies, is a by-product of doctrine and training. Officers are taught to be decisive even in the face of uncertainty. Airland battle doctrine stresses initiative and offensive operations. Clausewitz, the main influence on western military thinking, stressed the aggressive execution of combat. The famous victories of the great captains are all examples of risks which paid off. What officer is not familiar with MacArthur's gamble at Inchon or Patton's liberation of the 101st at Bastogne?

All of these things make leaders aspire to risk aggressive behavior. It is the accepted professional norm. The question remains is if it is always tactically sound behavior? Decision-making tools should take this into consideration.

The NPS study also offered some interesting comparisons to decision theory. It seemed to validate Tversky and Kahneman's theory of scalar effects which states that, "...an increase in preference for risk averse answers can be expected when the magnitude of negative effect is increased" (20:255). It also agrees with Schoemaker's hypothesis that, "...low probability events favor risk-taking attitudes" (20:255). However, it contrasts with Kogan and Wallach's findings that people become more risk averse with age (20:255).

This risk aggressive behavior was measured using tactical scenarios and probably holds for operational level decision-making as well. At these levels, decisions focus on the employment of forces already allocated. However, at the strategic level a trend toward risk averse behavior has been noted. In operations such as Urgent Fury, Just Cause and Desert Storm, senior military leaders have emphasized the use of overwhelming combat power in order to guarantee victory. In peacetime contingency operations this can have detrimental effects on the other aspects of national power. Additionally, as current budget reductions scale down force sizes the amount of combat power that can be projected to a crisis region on short-notice may also be reduced.

2.3.3 Military Decision-Making. During operations planning, the military decision-making process is used to decide how to employ combat forces. Its objective is to develop plans and orders that will achieve the final conditions necessary for victory (39:33). It is outlined for Army officers in FM 101-5, *Staff Organization and Operations*, which states, "the commander and his staff continually face situations that involve uncertainties, questionable or incomplete data, and several possible alternatives" (16:5-1). In answer to this problem, FM 101-5 presents the military decision-making process as an aide to overcoming the uncertainties of military planning. It is depicted in Figure 4. However, this process is not a strategy for making effective decisions. It is merely an outline for how the staff should interact (39:37).

The primary tool used by the staff, during this process, to evaluate possible strategies is the Estimate of the Situation. It is a structured method which begins with a clear definition of the problem. Next, facts are gathered about the problem and assumptions are made about those aspects of the problem which require initial working definitions to formulate the problem. Then courses of action are identified. The next step is to select the criteria with which these actions will be compared. Advantages and disadvantages of each action are identified and the alternatives are compared against each other using the selected criteria. Finally, the alternative that best solves the problem is chosen as the decision to be implemented. (16:5-1)

However, Klien in an article entitled, "Strategies for Decision Making" in *Military Review*, contends that this tool is too cumbersome to be effective in the time compressed environment for contingency planning (33:56). This is evident at the Combat Training Centers where, when faced with time constraints, staffs abbreviate the decision-making process by eliminating steps (22:2). Looking back at the process shown in Figure 2, the steps which usually are abbreviated or left out are those of identifying alternatives, quantifying alternatives and applying decision aids.

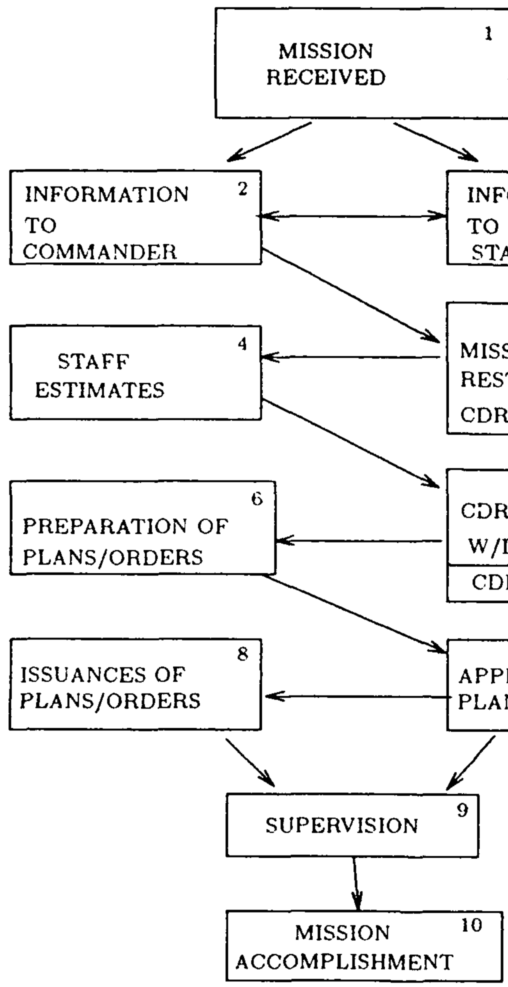

Figure 4. Military Decision-Making Process (16:5-6)

Based on personal experience, this begins when the intelligence staff and the commander subjectively choose one enemy course of action to plan against. Whether this is the most likely or the most dangerous depends on the preferences of the commander. There is rarely an attempt to plan against the random event that the enemy will choose one of several courses of action.

Normally, a more effective job is done of identifying friendly alternatives. They are generally well thought out, feasible and support the operational goals of the campaign. However, as stated above, these alternatives are rarely tested against a range of enemy strategies. The process deteriorates again when it comes to quantifying these alternatives.

The identification of risks and rewards is subjective and little attempt is made to quantify the relative magnitudes of these for different strategies and outcomes. This subjective process carries over into applying decision aids where, in a time-compressed environment, little more is ever used than a simple decision matrix of plusses, minuses and zeros.

The judgments made during this entire process are very subjective, but many would argue that this is not a problem. The premise is that training and experience enable commanders and their staffs to make effective, accurate judgments. Klein argues that in reality decision makers under pressure use recognitional decision making (33:58).

> This method is based on the observation that, proficient decision makers are able to use their experience to recognize a situation as familiar, which gives them a sense of what goals are feasible, what cues are important, what to expect next and what actions are typical in that situation. (33:58)

These decision makers use their experience to generate only plausible options, a procedure which eliminates the need to compare advantages and disadvantages. Once potential problems are ironed out, using mental wargamming, the solution can be implemented. (33:58)

However, decision-making is influenced by an individual's conditioned beliefs about cause-and-effect relationships and a need for consistency in attitudes and opinions (47:14-6). These opinions and beliefs, which are a function of training and experience, cause habitual reactions to problems and, "... habit can actually interfere with rational decision making in situations which are not routine" (47:14-2).

Most military personnel do not have a great deal of experience in low-intensity conflict. The nature of the conflict is not routine. The habits they fall back on when making decisions under stress have been formed through training and assignments that have been predominantly conventional in nature.

2.3.4 Conclusion. A tool must be developed to assist decision makers in optimizing their decisions in this non-programmed environment. It must address both the uncertainties and the competition inherent in warfare. It must consider the hueristic ways people estimate the probability of occurrence of events and the impact of their risk preferences on the decision-making process. Furthermore, it must be structured in accordance with the nuances of the LIC environment and measure performance in accordance with the measures of success outlined earlier.

In the next section, the models currently available to the operational planner will be reviewed.

2.4 Military Modeling

2.4.1 General. A model is a representation of reality. It attempts to reduce a complex set of interactions to their essential components so that the process can be further analyzed. The model is used to increase the understanding of the actual process. Assumptions and simplifications are made in accordance with the purposes of the analysis.

In the military, combat models are used to study warfare. Map exercises, wargames, simulations and analytic models, "...must in some manner represent the attendant processes of attrition, movement, and C3"(52:1). These models can represent the interactions occurring in combat at the level of the individual soldier or weapon system or can aggregate these activities together and model the conflict at the unit level.

There are numerous methods available in both high resolution and aggregated models to represent the movement and attrition of combat forces. They have been developed over many years of research and application. Although no method is perfect, each is fairly reliable and provides acceptable results within the confines of its intended purpose.

It is this author's opinion that, models to represent the command, control and communication processes are not as well developed. The mechanical aspects of communications between units; of higher headquarters issuing orders; and of subordinate units reacting to those orders are relatively straight forward. However, the subjective mental processes used by the commander in planning operations or during battlefield decision-making cannot be easily captured in mathematical representations. Compound this with the friction that makes combat an extremely random process and it is clear why little has been accomplished in C3 modeling.

The analytical outcome of most combat models in use today is primarily a result of attrition computations. These models, which are a function of force sizes and technological differences between units, decide the amount of losses sustained on each side; which unit can then advance and which must retreat; and ultimately which unit wins the engagement.

2.4.2 LIC/Contingency Models. There are very few models designed to analyze low-intensity conflict or to be used as contingency planning decision aids. Of the 347 models in J-8's *Catolog of Wargamming and Military Simulation Models*, only nine models deal with unconventional warfare, low-intensity conflict or crisis action planning (28:M-47,M-48,M-73) (See Table 1). Of these nine,

Table 1. Available Models (compiled from (28))

Type	Number	Analysis	ForceReq	Tng/ED	DecAid
Unconv	4		2	2	
Crisis	2				2
LIC	3	1		1	1

only three are decision aides. The two crisis action decision aides are primarily geared toward conventional warfare. The LIC decision aide only models the political domain. Only two of these models are three-sided and attempt to model popular support.

Conventional warfare models may adequately represent the military aspects of such a conflict, but they fail to capture the impact on the political, economic and informational aspects. The scenario construction and data requirements of most combat models make them too elaborate for use as analysis tools in a time-compressed planning sequence. There have been some recent attempts to overcome these shortfalls.

2.4.2.1 SOTACA. The State of the Art Contingency Analysis Model (SOTACA) was developed through a contract by the J-8 of the Joint Staff beginning in 1985. It is one of the two crisis action decision aide models in Table 1. It is an interactive, heterogeneous, theater level model that is intended to be used to rapidly assess and evaluate courses of action during a contingency planning scenario. The model's purpose is to quickly identify infeasible courses of action, determine force size and resource requirements and to identify strengths and weaknesses of courses of action during preliminary planning. The following information is summarized from (29, 31).

SOTACA is a two-sided, symmetric model that is aggregated at the battalion task force level. It is deterministic and utilizes a dynamic, time-step advancement. The span of the model focuses on the region where the contingency is occurring with primary emphasis on the air and land domains.

Any mix of combined, joint and component forces may be modeled. Any level of conflict can be modeled. Any combination of weapons and procedures used to accomplish a mission may be modeled.

The method used in SOTACA to structure forces and derive force ratios enables the user to analyze aspects of modern warfare that are not captured in models centered on the use of only weapon effectiveness data. Unit and weapon data is compiled in the Available Force File (AFF), the Force Planning File (FPF), the Unit Type Descriptor File (UTD), the Task Force File (TFF) and the Confronter Definition File (CDF). The relationship of these files is depicted in Figure 5. Units are defined as notional units and weapons are defined as confronters. The lowest combat element that can be represented is the battalion, tactical fighter squadron or ship. Both friendly/allied forces and threat forces must be constructed using these files. Support forces are not required, but can be included if logistical issues are of concern in the study.

The AFF lists all of the forces that are apportioned to the regional Commander-in-Chief (CINC) for contingency planning. It is derived from the Joint Strategic Capabilities Plan (JSCP) and can be created well in advance of a crisis. It represents the CINC's task organization for

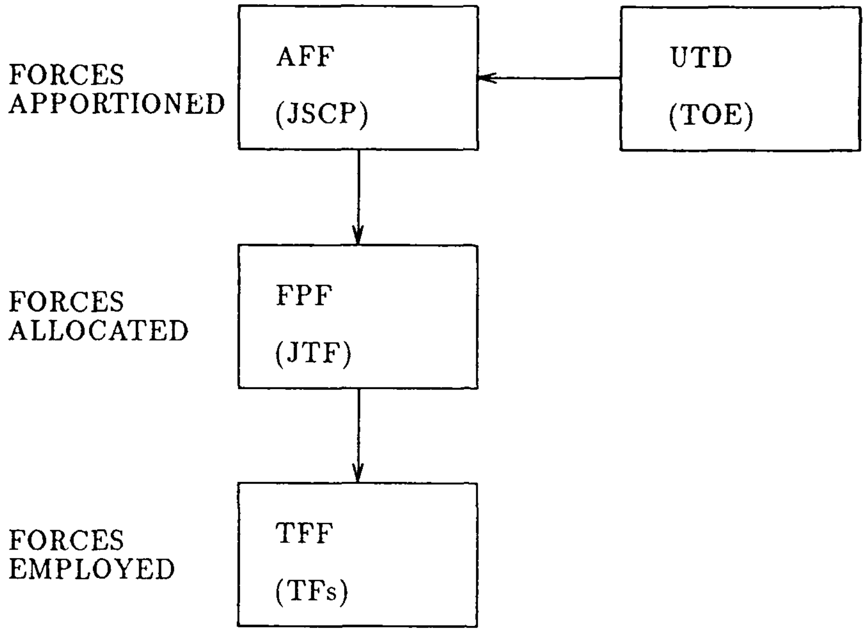

Figure 5. SOTACA Force Files

planning. It is arranged by major unit headings (usually Brigade size). Each major unit is broken down by subordinate unit headings. These subordinate units are designated as a particular type of unit.

The UTD is a subset of the AFF and is used to define the attributes of notional units. A notional unit is a surrogate of an actual organization. It contains the basic Table of Organization and Equipment (TOE) for a unit of that type. The UTD contains data on unit strengths, weapon types, basic loads, consumption rates, effectiveness definitions and the identification of weapons which describe the combat capability of the unit. SOTACA maintains a list of 39 generic weapon types. All of the names, except 1 (personnel) and 2 (support vehicles) can be modified by the user.

This system eliminates the need to input many different unit structures for similar type units based on varying levels of manning and equipment on hand. "It has been shown in models with similar attrition methods that a notional unit described in terms of a standard level of manning and organization will not greatly overestimate or underestimate the potential combat power of actual units" (29:4-6). This also allows for the creation of disparate force elements such as guerrillas, terrorist teams and special operation forces.

The FPF is constructed from the AFF and is used to separate out those units that have been allocated to the CINC for deployment as a Joint Task force (JTF). Multiple FPFs can be created from an AFF which allows the user to create different combinations of forces out of those made available. The FPF has the same size restrictions as the AFF. Units not listed in the AFF can be inserted directly into the FPF as long as a UTD exists for that type of unit.

The TFF is created from the FPF. It is used to task organize units into task forces subordinate to the JTF in order to describe the employment of those forces. Different TFFs can be developed from the same FPF to analyze varying employment scenarios. The task force is the primary entity for movement and confrontation used in SOTACA. This task force file, along with the UTDs for each of the units within the force, describe all its attributes (type, location, mission, organization, composition, logistics).

Force structure below the smallest command level is modeled using confronters, which represent different weapon/unit types. The CDF contains the data which is used to calculate the power and vulnerability of the confronters in the model. "A confronter is the smallest element of combat power in SOTACA" (29:4-19).

> Confronters contribute power to a force and are vulnerable to the power of the opposing force. A confronter may represent a weapon, an aggregated weapon type, a team, or an organization. Due to SOTACA's underlying theory, the model can represent disparate mixes of forces and elements that contribute to the total force power, but not necessarily in terms of firepower. (31:4-47)

This allows more than just technological advantages to determine force ratios. The user can designate up to 39 confronters. These confronters are defined from a listing of the 39 weapon systems in the UTD. Only those things designated as confronters are considered in the confrontation submodel.

The user then defines up to ten mission modes and up to ten categories of power that describe the power and vulnerability of the confronters in various situations. The combat power of conventional units can be compared to guerrilla forces. Mission modes refer to major missions such as attack, defend and civil affairs. Categories refer to sub-missions such as anti-tank, anti-air and construction. Confronters (rows) and categories (columns) form a matrix of power values and two matrices of vulnerability values under each mission mode.

Since SOTACA is not an aggregate model it requires calibration in order to accurately approximate the results of high resolution models. The purpose of the calibration module is to establish the force ratio values required by the confrontation model. "In SOTACA, calibration means the process of modifying data and parameters within the model to portray outcomes more realistically and to ensure that the scenario is completely defined" (31:5-1). It provides the user with the capability to establish confronter power and vulnerability values, force ratios, attrition coefficients, decision thresholds and FLOT movement rates. The calibration process is outlined in Appendix A.

This calibration process allows force ratios to be computed for various combinations of mission modes. It allows the inclusion of other aspects of combat power rather than just weapons effects data. The primary advantages of this process is the ability to compare and correlate the power of conventional and unconventional forces based on more that just technological aspects of weapons systems.

SOTACA has some limitations that have led to a lack of acceptance within the analytical community. Its first drawback is that it is very tedious and time consuming to set up the files required for a study. This is counter-productive to the needs of contingency planning and has resulted in SOTACA being shelved (43). Without more extensive usage of the model its strong points will never be fully discovered.

Furthermore, SOTACA fails to adequately address the nuances of LIC. Although, it does have the ability to include unconventional aspects of military power in the valuation of combat power it fails to measure the effects of that power on the other three aspects of national power. It does not model the civilian population, only military forces. Additionally, its measures of effectiveness (FLOT movement rates, attrition summaries, logistical consumption) are purely conventional in focus. It does not evaluate the impact of military operations on popular support.

2.4.2.2 PANTHER. The PANTHER model is a computer assisted wargame. It is the LIC training and education model in Table 1. It was initially developed by the Combined Arms Training Activity (CATA) in conjunction with the BDM corporation. The game is played on a battleboard and computer processes are used to resolve mission activities. It is being developed to fill the gap in training tactical commanders for low-intensity conflict operations. Other exercise drivers, geared more toward the conventional aspects of mid- and high-intensity conflict, do not adequately address the nuances of LIC. Counterinsurgency, peacekeeping operations and mission areas such as civil affairs, psychological operations and nation building could not be realistically played in those conventional models. The following information is summarized from (12, 13).

The model is designed to train commanders and their staffs in counterinsurgency, peacetime contingency and peacekeeping operations. Its purpose is to measure the effect of these operations on the civilian population and the extent to which the population supports the friendly government or the insurgents. It is a high resolution model. The lowest element that can be directly represented is a squad or individual weapon system, aircraft or watercraft.

The game provides flexibility to model all types of LIC forces. This includes conventional forces from squad up to brigade and unconventional forces such as special operations, police and guerrillas. It models various conventional and unconventional weapons. It has the ability to conduct operations ranging from terrorist activities up to company-on-company engagements.

PANTHER is a dynamic, time-step model. It is a stochastic model which uses a Monte Carlo process. The primary emphasis of the model is on ground combat. The domain is scaled to the regional and local levels.

PANTHER is a three-sided game. Blue represents friendly forces, both U.S. and host nation. Red represents the insurgent forces. Grey represents the civilian population. The Red and Blue forces can be symmetric or asymmetric, while the Grey side is asymmetric and nonreactive.

Panther advances the theory of low-intensity conflict models by including an algorithm which attempts to compute popular support. This algorithm combines data on the location of forces, the damages inflicted on civilians during combat operations and the success rate of PSYOP and Civil Affairs missions by using the following equation:

$$\frac{RedPresence}{BluePresence} \times \frac{BlueCollateralDamage}{RedCollateralDamage} \times \frac{RedPSYOP}{BluePSYOP} \times \frac{RedCivilAffairs}{BlueCivilAffairs} = X \qquad (1)$$

The data used as input to this equation is subjectively determined by umpires who are subject matter experts. If X is in the range 0 - .34 the population supports the red side. In the range .35 - .66 the population remains neutral. When X is between .67 - 1 they support the blue side. (44)

2.4.2.3 Lanchester in LIC. In 1916, F.W. Lanchester pioneered the use of mathematical models to analyze combat (35). He began his derivation with an analysis of ancient warfare. In these battles, combat consisted of many one-on-one duels in which the attrition rate was essentially constant due to similar weapons and tactics between opponents. Letting

1. B = The size of the Blue force
2. R = The size of the Red force
3. B_0 = The initial size of the Blue force
4. R_0 = The initial size of the Red force
5. β = The constant rate at which Blue is attrited by Red
6. ρ = The constant rate at which Red is attrited by Blue

then the change in the size of each force over time can be written as (56:28-5):

$$\frac{dB}{dt} = -\beta \tag{2}$$

$$\frac{dR}{dt} = -\rho \tag{3}$$

Lanchester then pointed out that modern weapon systems provided long-range, indirect, area firing. In this case, the rate of attrition is no longer constant, but is effected by the number of firers and the density of the troops in the target area. The rate of change of the force size can now be written as (56:28-9) (52:23):

$$\frac{dB}{dt} = -\beta RB \tag{4}$$

$$\frac{dR}{dt} = -\rho BR \tag{5}$$

Both of these sets of equations can be reduced to the same state equation, known as Lanchester's Linear Law (56:28-6) (52:24):

$$\boxed{\rho(B_0 - B) = \beta(R_0 - R)} \tag{6}$$

Lanchester then further surmised that in modern warfare when one side was able to concentrate his forces, and bring a larger force to bear on a smaller one, the attrition rate would no longer be constant but would depend on the number of attackers as well. The rate of change of the force size would then be written as (56:28-10–28-11) (52:22):

$$\frac{dB}{dt} = -\beta R \tag{7}$$

$$\frac{dR}{dt} = -\rho B \tag{8}$$

The resulting state equation is known as Lanchester's Square Law (56:28-11) (52:23):

$$\boxed{\rho(B_0^2 - B^2) = \beta(R_0^2 - R^2)} \tag{9}$$

In 1962, S.J. Deitchman pointed out that neither of these laws adequately described the nature of guerrilla warfare (14). In this type of warfare the conventional forces (Blue) undoubtly possesses overall numerical superiority over the guerrillas or insurgents (Red). However, Deitchman points out that, "...the numerically inferior guerrillas can win if they are careful to maintain local numerical superiority in any encounter with the regulars" (14:820). He then attempted to ascertain whether or not the guerrillas could win with equal or less forces by adopting the proper tactics (14:820).

He began by pointing out that the guerrillas will only engage when the tactical situation is to their advantage (56:28-28).They will most likely use ambush type tactics in which they have the advantage of terrain, cover and concealment, and surprise. In this situation, the guerrillas will have aimed fire against the regulars and the losses sustained by the blue force will be represented by Equation 7 (56:28-28). On the other hand, the conventional force will be firing at an invisible enemy and red losses will be expressed by Equation 5 (56:28-28). The resulting state equation, which is known as the Mixed Law or Deitchman's Guerrilla Warfare Model, is (56:28-29):

$$\boxed{\rho(B_0^2 - B^2) = 2\beta(R_0 - R)} \tag{10}$$

Deitchman concluded that the advantage of Red's aim fire over Blue's area fire allowed the Red force to prevail even with an inferior local force ratio. This strength could be further enhanced if Red took full advantage of the element of surprise and effectively attrited the Blue force during the opening exchange. The Blue force can counter these tactics by sending out larger forces and/or increasing the effectiveness of his area fire. The Red force could counter this strategy by increasing his force size or by spreading out his force and reducing the density of his troops within the target area. (14:822-824)

In 1966, Takasi Kisi and Tadasi Hirose used Deitchman's equations and work done by Brown (4) to derive a stochastic model for the probabilities of winning in guerrilla warfare (32). To model the breakpoint phenomena they let,

1. B^{*} = The strength at which Blue withdraws from the engagement
2. R^{*} = The strength at which Red withdraws from the engagement

They then derived that the probability that Blue wins is:

$$P(B,R) \approx \sum_{i=R-R^{*}}^{\infty} \frac{\mu^{i} e^{\mu}}{i!} \tag{11}$$

and the probability that Red wins is:

$$1 - P(B,R) \approx \sum_{i=0}^{R-R^{*}-1} \frac{\mu^{i} e^{\mu}}{i!} \tag{12}$$

where $\mu = \frac{B^2-(B^{*})^2}{2\alpha}$ (56:28-35) (32:1138). The variable α is a shape parameter based on exponentially distributed firing times, the single shot probability of kill and the area under which the fire is distributed. It is approximately equal to 500 for guerrilla warfare (56:28-35). They also pointed out that the number of Red casualties is a Poisson distributed random variable with mean μ (56:28-36) (32:1138). Therefore, if the number of casualties in a given interval is considered to be a Poisson process then, each of these intervals is independent and the rate of the casualties is a constant.

2.5 Summary

In this chapter the nature of peacetime contingency operations and the factors which influence and measure their success have been outlined. It has been pointed out that LIC is more than just a struggle between military units. It is a competition, waged using political, economic, informational and military tools, for the support of the people. The goal of the campaign is to win that support and therefore popular support is the true measure of performance, not attrition nor territory held.

Then the inadequacy of the tools currently used in planning these operations was addressed. Current military decision-making methods are based on the ability of the analyst or staff officer having adequate time to gather and decipher intelligence in order to reduce the amount of uncertainty. This time is rarely available when planning peacetime contingency operations. This problem is compounded by the limited experience of Army officers in these types of operations. Furthermore, no modern tools are used to overcome these shortfalls by structuring the problem, quantifying the uncertainty and assessing the impact (numerically) of the outcome.

Finally, some of the attempts in combat modeling to address these inadequacies were introduced. SOTACA provides a method with which to introduce unconventional aspects of military might into the calculation of combat power. PANTHER provides an algorithm to measure popular support. Deitchman has provided a deterministic model for LIC attrition and Kisi and Hirose modified that into a stochastic model.

What is needed is a model to aid decision-makers in the non-programmed process of making force employment decisions for peacetime contingency operations. There are descriptive models available that describe the decision-making process. They will be discussed in Chapter III. In Chapter IV a structure will be presented that will combine these models and the algorithms outlined in this chapter into a prescriptive model that will aid military planners in optimizing employment decisions.

III. Methodology

3.1 Introduction

In this chapter two models of decision-making will be presented. Decision Analysis is a tool used to model decisions made under conditions of uncertainty. Game Theory models decisions made amid competition. Markov processes and the world view of object-oriented programming will also be discussed. Each of these tools will be described along with a discussion of its advantages for use in the model being developed in this paper.

3.2 Decision Analysis

It has already been established that military commanders often must make decisions when the outcome of various events effecting that decision is uncertain. Since even the most experienced and trained military leader is not always consistent and rational, a method is required with which to structure the decision. "Decision analysis provides a rational methodology for decision making in the face of uncertainty" (25:828). In the model being developed by this research it will be used to structure the Blue force commander's decision about how to employ the forces that have been allocated to him.

By providing a structured, rational approach to decision-making, decision analysis is a normative approach as well as a descriptive one. It describes how a logical person should make a decision in order to attain his objectives (38:25). When used properly it can provide insight about the problem (38:23). In this thesis the use of decision analysis as a prescriptive model will be proposed. It will be used by the Blue commander as a decision-making tool to optimize the employment decision.

The aim of decision analysis is to reduce a complex problem down to its basic components (38:21). It is applied to decisions which are non-programmed and involve the allocation of significant resources. These decision problems are shrouded in uncertainty and the preferences of the decision maker can impact greatly on the outcome (38:22). It provides a logical, quantitative procedure for dealing with these uncertainties and preferences (38:25).

The procedure used (The Decision Analysis Cycle) is depicted in Figure 6.

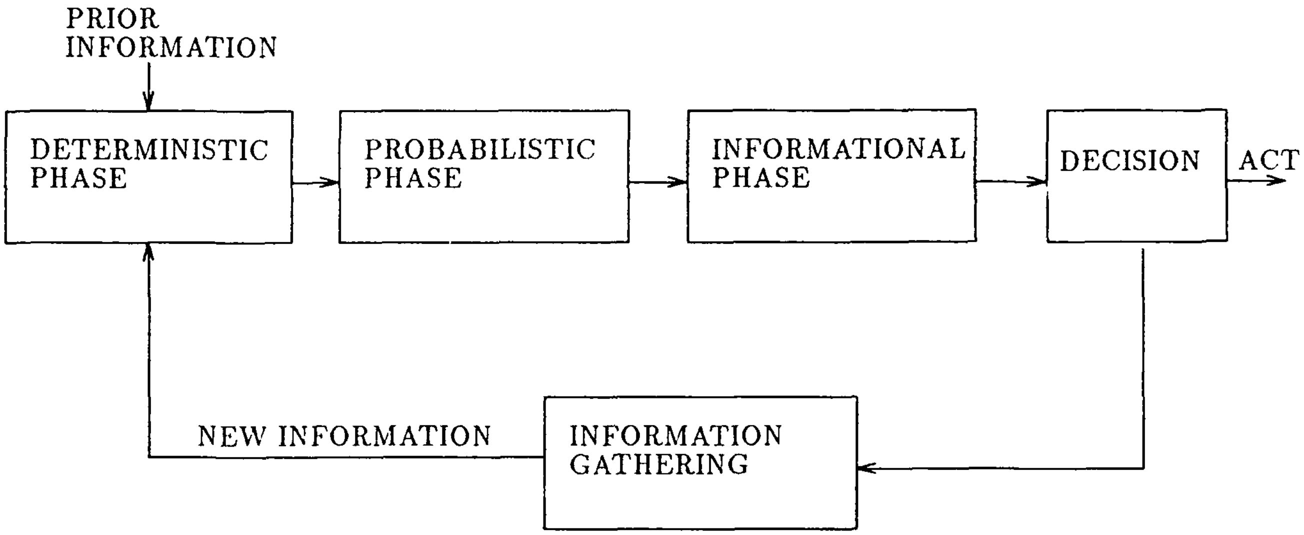

Figure 6. The Decision Analysis Cycle (38:26)

At the outset of the formulation of the problem, prior information is gathered and assembled. During the **deterministic phase** the decision is modeled. The exact decision is defined and bounded. Alternatives as well as possible outcomes are identified (38:27). Variables under the control of the decision maker (decision variables) and variables influenced by the environment (state variables) are defined along with the mathematical relationships between them (38:28). Finally, sensitivity analysis is performed on the variables to ascertain which have and which do not have an important impact on the decision (38:30).

In the **probabilistic phase** probability distributions are assigned to the uncertain variables (38:30). The value or utility that the decision maker assigns to each outcome is also determined. There are three ways to assess the decision maker's feelings about an outcome and use this information to make a decision (41).

The first method is to use an expected cost ($E(\$)$) approach. This method associates a numerical value (usually measured in dollars) to the factors that contribute to the outcome. This cost can be positive or negative. The weakness of this method is that it fails to capture the difference in how a person feels about $100 if he has no money as opposed to how he feels about $100 if he is a millionaire.

To overcome this shortcoming an expected value ($E(V(\$))$) approach might be used. This method takes into account the varying value of a dollar and models the decreasing marginal return of money as more of it is acquired. However, this method still requires indepth knowledge and certainty about the problem in order to quantify the actual dollar values of each outcome. It also lacks the ability to measure the impact of factors such as the value of human life which cannot be easily quantified.

In order to model decreasing marginal return, the uncertainty surrounding the value of some aspects of the outcomes and the inability to associate a value with other aspects of the outcomes, an expected utility ($E(U(\$))$) model can be used. This model measures the decision maker's preferences concerning the outcomes under conditions of uncertainy. These preferences are determined using a reference lottery as in the Figure 7. These lotteries measure the point at which the decision maker is indifferent between the utility of a certain outcome and a gamble between competing uncertain outcomes.

To use this lottery the analyst defines a value fro x_1 and x_3. A scale is developed such that $U(x_3) = 1$ and $U(x_1) = 0$. The analyst then proposes a value for x_2 and asks the decision maker what value of p will cause him to be indifferent between achieving x_2 for certain or taking a chance on attianing x_3. Multiple iterations are done of this process and the function

$$U(x_2) = pU(x_3) + (1 - p)U(x_1) \tag{13}$$

is used to plot the decision maker's utility curve (Figure 8). The shape of the curve demonstrates

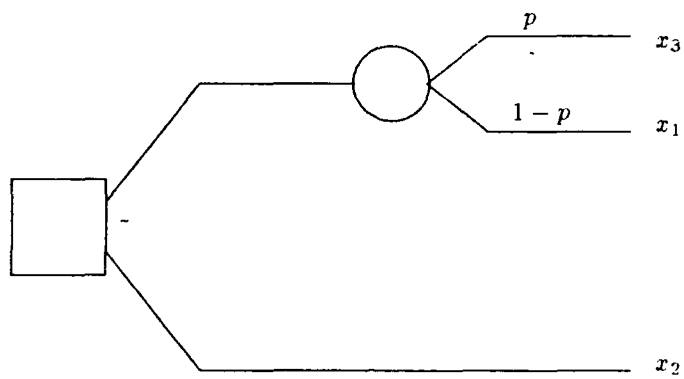

Figure 7. Reference Lottery

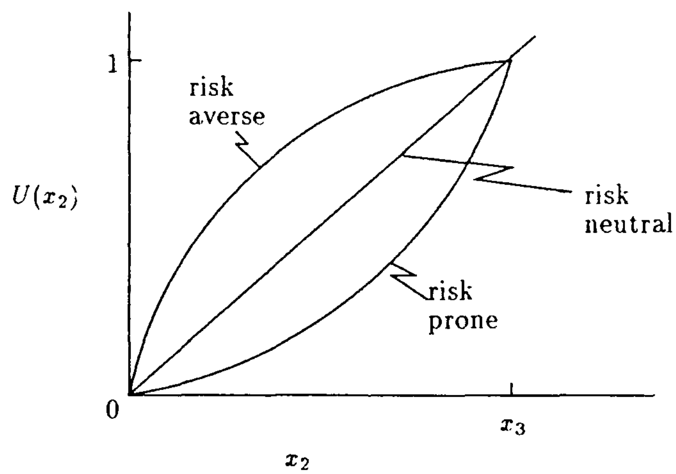

Figure 8. Utility Curve

the decision maker's risk preference. Various utility curves can be determined for different aspects of the outcome and then multiple curves combined into an overall outcome utility.

A combat example of a reference lottery might be the number of lives lost when choosing between different tactics. Tactic one would definitely result in the loss of x_2 lives while tactic two would result in x_3 lives lost with probability p or x_1 lives lost with probability $1-p$. It was stated previously in Section 2.3.2 that reference (20) indicates that Army officers are risk prone in these types of decisions.

During the analysis portion of the probabilistic phase, sensitivity analysis is performed on the variable probability distributions and on the risk preferences (38:33).

During the **informational phase** the decision maker determines the value of conducting activities to acquire new information (38:34). The objective is to ascertain whether or not the expense of conducting the activity is worth the resulting reduction in uncertainty.

Initial probability distributions are determined subjectively based on the experience and intuition of the decision maker. This is known as a prior probability, $P(A_i)$. These probabilities are used to determine the likelihood of a particular outcome given that the prior event has occurred, $P(B|A_i)$. When new information is received it can be combined with prior judgements to attain a posterior probability using Baye's Theorem:

$$P(A_i|B) = \frac{P(B|A_i)P(A_i)}{\sum_{j=1}^{n} P(B|A_j)P(A_j)} \qquad (14)$$

This provides an updated $P(A_i)$ given that event B has occurred.

One method used to structure decision problems is decision trees. The tree maps out the logical flow of the events contained in the decision. Points at which decisions are made are depicted with squares and points at which some random event is expected to occur is depicted with a circle. The estimated probability of occurrance of the random events and the utility of the outcomes are annotated on the tree. Expected Utilities can then be calculated and the appropriate decision illuminated.

The use of decision analysis in this model provides many advantages, the most important of which is being able to model quantitatively the uncertainties involved in warfare. It provides a format through which the probability of random events and the preferences of the decision maker (utilities) can be incorporated. This method also helps the decision maker to structure the problem logically which often brings added insights to the decision.

With decision analysis many facets of the problem can be examined. Sensitivity analysis can be performed to determine which random events have the greatest impact on the decision and over what range of probabilities that impact is seen. Bayes theorem provides a method to update probability assesments after additional information is received. The problem can also be structured to examine the benefits of waiting for additional information in order to reduce the amount of uncertainty in the problem.

All of these advantages make decision analysis a powerful tool not only as a descriptive model of how effective decisions can be made but also as a prescriptive model for how to optimize decision making. The structural approach helps control and reduce the impact of the biases normally associated with subjective probability assessments (See Section 2.3.2). The use of an expected utility model is an excellent format with which to quantify the preferences of the commander and examine how various risk preferences impact on the overall decision.

3.3 Game Theory

By its very nature warfare is competitive. The objectives which one side wants to attain are in direct conflict with the other side. "**Game Theory** is a mathematical theory that deals with the general features of competitive situations like these in a formal abstract way" (25:454). In the language of game theory, warfare can be modeled as a **two-person, zero-sum** game. The players in this game (for the purposes of the model being developed) are the opposing commanders. In this paper, Player I is the Blue force commander and Player II is the Red force commander.

Each commander must choose an optimal strategy from a set of strategies. A strategy is a "...a predetermined rule that specifies completely how one intends to respond to each possible circumstance at each stage of the game" (25:435). This is analogous to the commander choosing a course of action and developing the commander's concept of the operation for the operations order during the military decision-making process. In a zero-sum game each commander chooses a strategy at the same time, while guessing about the opponents choice (6:6).

The commander's order of preference for each strategy is described by a utility function (6:2). These utilities can be assembled in a table which represents the positive or negative gain that player I receives from the combination of strategies chosen (see Figure 9) where, U_{ij} = the utility of the outcome to the Blue commander if Blue uses strategy i and Red uses strategy j . The postulate

		Red Strategy		
		1	2	3
Blue Strategy	1	U_{11}	U_{12}	U_{13}
	2	U_{21}	U_{22}	U_{23}
	3	U_{31}	U_{32}	U_{33}
	4	U_{41}	U_{42}	U_{42}

Figure 9. Payoff Table

of rationality states that each player attempts to maximize the gain achieved from the selection of a strategy (6:3). However, this is a competitive situation in that a player wants to maximize his gain while preventing the opportunity for his opponent to maximize his. In game theory this is modeled using the minimax selection criteria which states that a player concentrates on minimizing his maximum losses (25:439). As a result, Player I should select the strategy which has the largest minimum payoff (maximin) while Player II chooses the strategy which provides Player I with the smallest maximum payoff (minimax) (25:439).

In wartime, commander's make strategy choices based on what they expect the enemy to do. This is a very subjective assessment and involves a great deal of uncertainty. Based on intelligence reports and experience the commander should assign a probability to each strategy choice. Looking back at Figure 9, let (25:441),

1. x_i = the probability that the Blue commander will choose strategy i (i=1,2,...,m)

2. y_j = the probability that the Red commander will choose strategy j (j=1,2,...,n)

The result is a situation in which each commander has a set of strategies to choose from while at the same time hypothesizing on a similar set of strategies that his opponent will choose from. For each combination of strategies chosen the commander will receive a particular utility. The minimax criterion states that the commander wishes to minimize the maximum expected loses (25:442).

$$\sum_{i=1}^{m}\sum_{j=1}^{n} U_{ij} x_i y_j \tag{15}$$

In order to do this the Blue (Red) commander must choose a set of x_i's (y_j's) and form a mixed strategy of the probabilities that each of the various pure strategies is chosen. The objective is to optimize the minimax criterion.

Player I's optimal mixed strategy $(x_1, x_2, \ldots, x_m)$ can be found with the following linear programming formulation (25:446):

$$\begin{array}{lrcl}
\text{Minimize:} & (-x_{m+1}) & & \\
\text{subject to:} & U_{11}x_1 + U_{21}x_2 + \cdots + U_{m1}x_m - x_{m+1} & \geq & 0 \\
 & U_{12}x_1 + U_{22}x_2 + \cdots + U_{m2}x_m - x_{m+1} & \geq & 0 \\
 & \vdots & & \\
 & U_{1n}x_1 + U_{2n}x_2 + \cdots + U_{mn}x_m - x_{m+1} & \geq & 0 \\
 & -(x_1 + x_2 + \cdots + x_m) & = & -1 \\
 & x_i \geq 0 \text{ for } i = 1, 2, \ldots, m & &
\end{array}$$

Figure 10. Game Theory Linear Programming Formulation

Player II's optimal mixed strategy can be found using a similar formulation which is dual to the formulation above.

There are many advantages to using game theory in the model being developed in this paper. It provides a format through which the competitive nature of warfare can be modeled. In this model it will be used to determine the probabilities that the Red commander will choose a particular strategy to oppose the Blue forces with. Intelligence information and historical data can be used to determine the Red commander's possible motives, preferences and plans. This information is used to develop possible strategies the Red commander may adopt and estimate, from his perspective, the probabilities of success and the utilities he associates with each strategy. Game theory can then be used to quantify the probability that the Red commander will adopt a certain strategy.

The Blue commander will then have a clearer picture of the things he may be up against. The staff can plan against this range of possibilities (using decision analysis) rather then devoting attention to only one possible Red strategy. The process of determining the strategies and the estimating utilities of the Red commander will also bring added insights to the problem.

3.4 Markov Processes

A stochastic or random process is a model used to describe the transition of some phenomena between various states over time (11:193). When a discrete (finite number of states) process is in state i there is a fixed probability P_{ij} that it will transition to state j. If such a process satisfies the Markov property, which states that the probability of transitioning to state j depends only on the present state and is independent of the past states, it is called a Markov Chain (49:135).

These processes can be represented using a state-space diagram (Figure 11). The diagram depicts all the states of the process, the possible transitions between states, and the probability of these transitions occurring. The probabilities can be arranged in a matrix **P** (49:136). The matrix for Figure 11 is shown below.

$$\mathbf{P} = \begin{bmatrix} P_{00} & P_{01} & P_{02} \\ P_{10} & P_{11} & P_{12} \\ P_{20} & P_{21} & P_{22} \end{bmatrix}$$

When multiplied by itself n times (P^n) it becomes the n-step transition matrix which represents the probability that when starting in state i it will end up in state j after n transitions

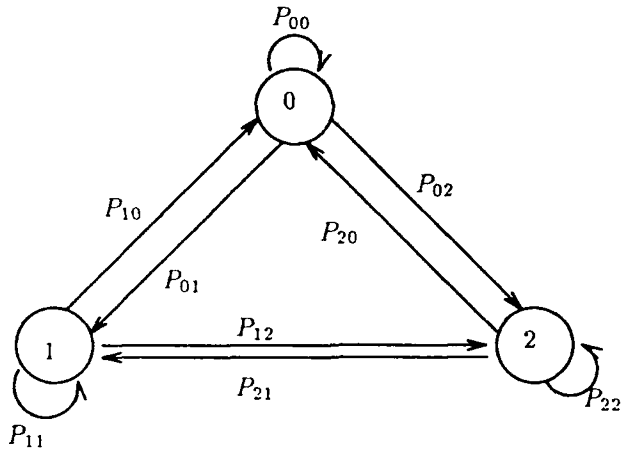

Figure 11. State Space Diagram

(49:138-9). For certain types of Markov processes the $\lim_{n \to \infty} P^n$ produces a steady state matrix of transition probabilities representing, "...the long-run portion of time that the process will be in state j" (49:152).

Combat can be modeled using the Markov chain depicted in Figure 12 (42). In this model two combat elements (aircraft, ships, units) from each side face each other and attrit each other one at a time until one side is completely attrited. The states 20, 10, 01, 02 are known as absorbing states because once the process enters these states it stays there. In a combat model these absorbing states do not have to represent a side being decimated. They can model the point as which one side elects to break contact as a percentage of initial strength remaining. This is known as the breakpoint phenomena.

Transition probabilities (P_{ij}) can be computed using probability of win equations derived from Lanchester equations as shown in Equations 11 and 12. A **P** matrix can then be developed

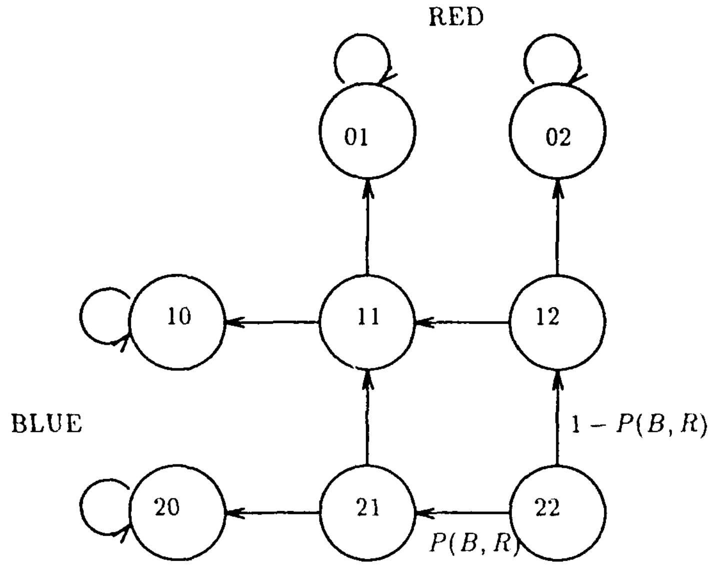

Figure 12. Markov Model of Combat

by arranging the states by classes (42).

$$\mathbf{P} = \begin{array}{c|cccccccc} & 22 & 12 & 21 & 11 & 20 & 10 & 01 & 02 \\ 22 & 0 & 1-P_{22}(B,R) & P_{22}(B,R) & 0 & 0 & 0 & 0 & 0 \\ 12 & 0 & 0 & 0 & P_{12}(B,R) & 0 & 0 & 0 & 1-P_{12}(B,R) \\ 21 & 0 & 0 & 0 & 1-P_{21}(B,R) & P_{21}(B,R) & 0 & 0 & 0 \\ 11 & 0 & 0 & 0 & 0 & 0 & P_{11}(B,R) & 1-P_{11}(B,R) & 0 \\ 20 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 10 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 01 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 02 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{array}$$

The $\lim_{n \to \infty} P^n$ produces a matrix of absorption probabilities that represent the probability of ending in one of the absorption states when starting in one of the other states.

For the model being developed in this thesis a Markov model will be used to approximate the random outcome of combat actions between opposing forces. It is a simple, aggregated model that will provide, through the use of Lanchester type transition equations, a sufficient degree of accuracy for the purposes of this model. It is pointed out that although the process of operations planning is not Markovian, the outcome of the actual battle is. The assumption of using a Markov process is considered valid since Kisi and Hirose pointed out that the number of casualties was a Poisson distributed random variable which indicates a memoryless counting process (See Section 2.4.2.3).

The computation of absorption probabilities will provide the probabilities that the battle will end in any one of the many possible ending conditions. These probabilities will then be used as the inputs for the outcome probabilities of the decision analysis and game theory models.

3.5 Object-Oriented Programming

The purpose of object-oriented programming (OOP) is to model things as they are actually seen, as clearly defined objects (53:228). The intent is to model processes as they exist. This hopefully makes the code more understandable. OOP also promotes the reuse of object code in other models (53:231).

In this methodology entities are defined at two levels: as a class and as an object. A class is an abstract representation which contains the common characteristics of an object type (37:21). It, "...represents the mold from which concrete objects are formed" (37:21). From a class, specific objects are formed through a process called instantiation which makes an object an instance of a class (37:21). An example of this hierarchy is depicted in Figure 13.

In this example classes are constructed using base Tables of Organization and Equipment (TOEs) of a Mechanized Infantry Division and its subordinate units. Specific unit objects can then be created as instances of these classes.

Three of the most important characteristics of OOP are:

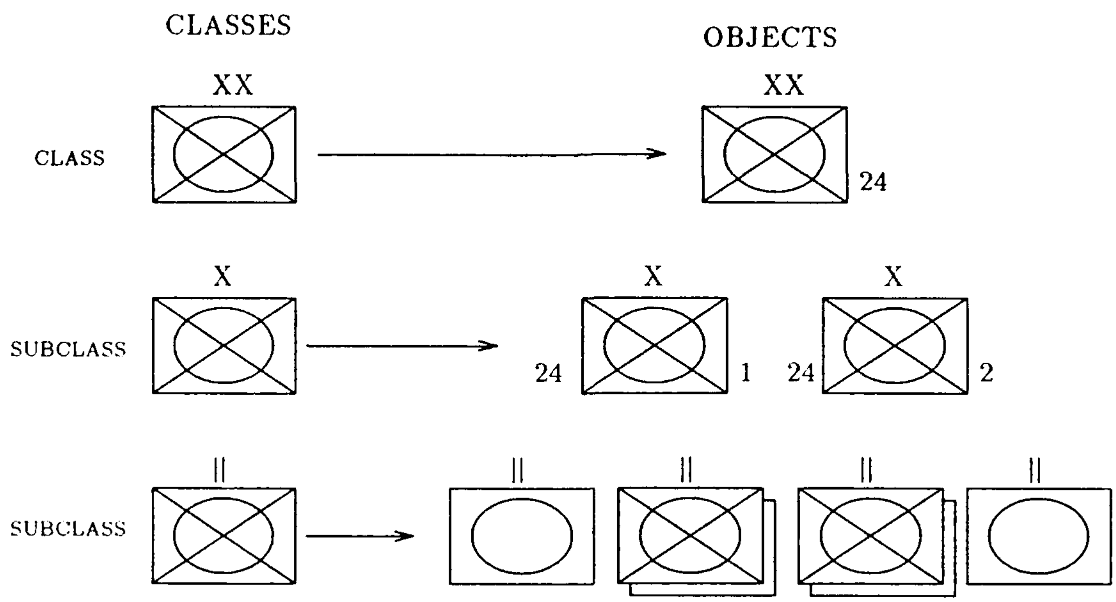

Figure 13. Class and Object Relationships

1. Encapsulation;

2. Inheritance; and

3. Polymorphism (37:20)

When creating a class or an object a state and a behavior is associated with each (53:232). The state of the object is the data which provides its structural information. For the example in Figure 13 it would include information such as number of personnel, number and types of vehicles and number and types of weapon systems. The behavior of an object is defined by methods (37:21). These methods are functions which describe how the object should manipulate the information it has stored (such as attack or defend). These methods are the only way an object's state can be changed (37:21). This structure of protecting the state of an object with methods and placing both inside the object is known as **encapsulation**.

The structure depicted in Figure 13 illustrates the next important characteristic: **inheritance**. Structural and behavioral information is passed from a higher to a lower class, from a higher to a lower object or from a class to an object which is an instance of that class (37:22). Differences between class or object levels or between different objects of the same class can be incorporated by adding or substituting data and methods as appropriate (37:22).

Objects communicate with each other through messages (37:20). These messages invoke a behavior from the receiving object (53:232). Standardizing these messages is known as **polymorphism** (37:21). In other words, the same message, attack, will invoke a slightly different response from an armor unit object then from a mechanized infantry unit object.

Object-oriented design brings many advantages to this model. Military units and their commanders exist in a definite hierarchy and share many characteristics and methods up, down and across that structure. Object-oriented design allows this to be modeled as it actually exists with classes of units and decision makers being constructed by type and level of the chain of command. They can then inherit information and processes from each other and military decision making can be modeled as it more accurately exists.

Unit classes can be constructed to contain data relating to their organization and equipment and methods describing how they perform military missions. Commander's can be modeled as an entity possessing certain knowledge about the situation and methods for using that knowledge to make decisions. Generic classes for various types of units and commanders can be developed and combined into a data base for use in any object-oriented military models. Then specific objects (modified as required) can be created based on the scenario being developed.

IV. Model Framework

4.1 Introduction

The purpose of this chapter is to present the conceptualization of a model that can be used to analyze force employment decisions for peacetime contingency operations (PCO). The intent is to describe a general framework and the major functions the model must perform in an effort to provide direction for further research. During this introduction a model taxonomy is presented followed by an example scenario. In the next section the employment decision is formulated and in the final section the model used to analyze that decision is described. The example is used to explain the application of the model.

4.1.1 Model Taxonomy. The following table outlines, based on the SIMTAX (1) format used in J-8's *Catolog of Wargamming and Simulation Models* (28), the models available to the military analyst planning a peacetime contingency operation. Column two describes the PANTHER

Table 2. Taxonomy of Available Models (compiled from (28))

Characteristic	PANTHER	SOTACA	CFAW	LIC GAMING SYS	PROPOSED
Purpose	Tng/Ed	DecAid	DecAid	DecAid	DecAid
Domain	air,land,sea	user spec	air,land,sea	abstract	user specified
Span	local	regional	theater	regional	regional
Environment	yes	network	yes	no	yes
Forces	component	any	comb,JTF	conceptual	comb,JTF
Scope	conv	conv	conv	conv,uncon	conv,uncon
Human Part	required	required	required	required	required
Time	time step	time step	time step	event step	time step
Randomness	stoch	deter	stoch	direct comp	stoch
Sidedness	3	2	2	3+	3
MOE	conv,uncon	conv	conv	pol/econ	conv,unconv
Resolution	high	aggregate	aggregate	aggregate	aggregate

model which, although it is a training model, contains some important characteristics for LIC models. Columns three through five show the three decision aides available. None of these models individually contains all of the characteristics required to capture the important aspects of LIC.

Additionally, none of these models model the decision-making process in an attempt to optimize it. Column six outlines the characteristics that a model that is to be used as a decision aid for PCO must possess.

The model being developed here is an analytic model that is to be used as an operations support tool or decision aid. It is a stochastic, static model in which human participation is required. The purpose of the model is to quickly evaluate competing courses of action during a time-compressed planning sequence for a peacetime contingency operation. The span is regional. The scope of the conflict is both conventional and unconventional and both conventional and unconventional ground forces are modeled.

The model is constructed at two levels and the domain of each is different. The top level of the model is a mathematical decision-making model whose domain is abstract. This level is highly aggregated and individual units are not specifically modeled.

The lower level of the model is an aggregated combat model whose domain is user specified based on the situation. The model is aggregated at the company level with the highest entity being modeled a division (–) task force. The model is three sided. Blue (conventional force) and Red (guerrilla or insurgent force) are both symmetric and reactive, while Grey (local population) is asymmetric and non-reactive. This level of the model is an object-oriented design of the SOTACA model with elements of PANTHER incorporated into it.

4.1.2 Scenario. The decision-making scenario which this model is intended to support is one in which a crisis has occurred in a low-intensity conflict environment. In response to this threat the National Command Authority has decided to deploy military forces to conduct operations which augment the political, economic and informational campaigns that have been under way since the insurgency began. Forces have been allocated to the regional CINC and the Task Force commander. The Task Force commander must now decide, in a time-compressed planning sequence, on an appropriate strategy to employ those forces.

Operation Urgent Fury (See Section 2.2.7) will be used as the framework for this example. The primary mission of the Task Force is to evacuate U.S. citizens living in the country. The underlying political agenda is to restore democracy to the country. Execution will begin within 72 hours. Intelligence concerning the area of operation and disposition, organization and objectives of the enemy force is limited and unreliable. Extensive rules of engagement (ROE) have been ordered to limit collateral damage and civilian casualties.

4.2 The Employment Decision

The commander's employment decision is a strategy which describes how to use the forces allocated to the Task Force to accomplish the mission of the campaign. It is constrained not only by the forces allocated, but also by the transportation and logistical assets provided as well as the ROE. Additionally, not only must the military objectives be considered, but also the political, informational and economic goals in accordance with the LIC imperatives for success outlined in Section 2.2.5.

Making this decision entails comparing alternate strategies, each consisting of a specific task organization and an associated mission breakdown. These strategies define different employment approaches as a percentage of the force assigned to each required function. Resources are constrained by logistics capabilities, transportation assets and time available, so optimizing this decision becomes a difficult problem.

This is true of any combat situation, but four other characteristics of LIC make it even more interesting during a peacetime contingency operation. First, the decision is not oriented strictly toward combat operations. As the imperatives for success remind commanders, military assets may also be applied toward and must support the political, economic and informational campaigns. This means, for example, dividing critical engineer or medical resources between combat and civil affairs missions. Infantry units may be divided between combat and civil-military missions. The ROE place limitations on the amount of force that can be applied.

Second, there is more uncertainty involved in this decision. The mission has originated from a crisis, consequently the data base of intelligence information is limited. Furthermore, there is less time to analyze the information that is available in this time-compressed environment.

Third, professionally encouraged risk prone behavior may be detrimental to the overall success of the campaign. Commander's may have to temper their urge toward aggressively pursuing the tactical defeat of the enemy based on the objectives of the political and informational campaign.

Finally, the measure of effectiveness by which the success of the decision is judged is not the traditional measure of performance of warfare. In LIC, the winner is not determined by tactical victories, by attrition or by securing key terrain. It is determined by the people and who they feel has the legitimate right to govern them. This is affected by civil affairs operations, PSYOPs, local security missions and other non-combat type military missions as well as combat missions.

In order to capture the impact of these factors on the decision, a model is required which compares competing courses of action, which deals with decision-making under conditions of uncertainty, which incorporates the commander's preferences for various outcomes and which models the effect of non-combat conflicts on popular support. Therefore, the Blue commander's employment decision will be modeled using a decision analytic framework. The tree diagram for this decision is depicted in Figure 14. The Blue commander wants to optimize the choice of strategies based on the information he currently has available.

Two random events, about which the commander possesses limited information, affect that decision. The first is the question of which strategy the Red force commander will counter with. Prior probabilities (y_j's) for this event can be determined using a game theory model. The second event is the probability of the likelihood that, given the Blue commander chooses a particular strategy and the Red commander a counterstrategy, the outcome will favor Blue or Red. States

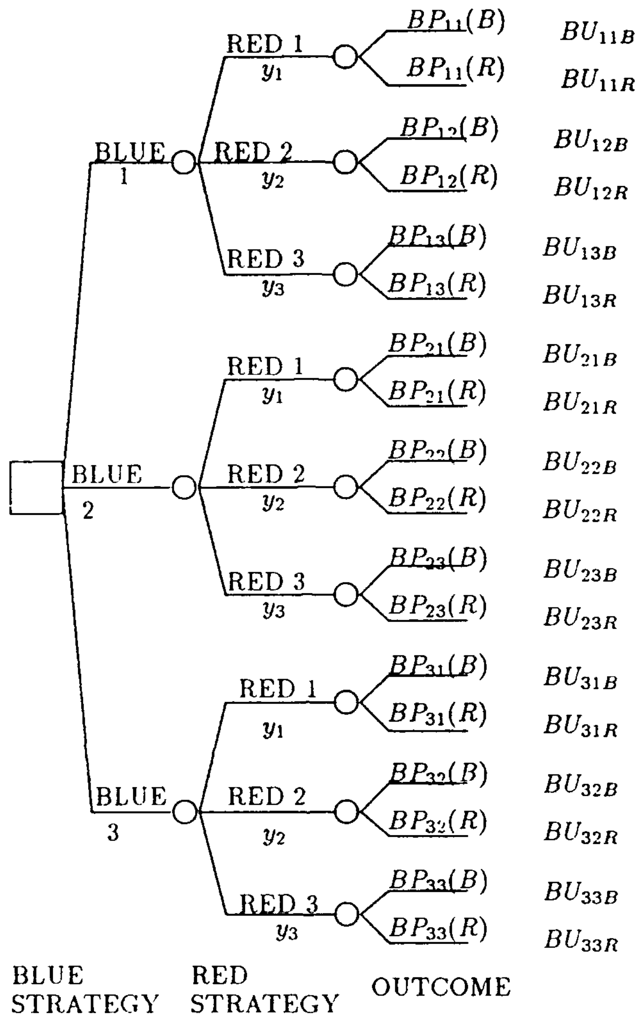

Figure 14. Blue Commander's Decision Tree

favoring Blue (Red) are those states in which Red (Blue) reaches the breakpoint before Blue (Red) does. These values will be represented by:

1. $BP_{ij}(B)$ = probability (from Blue's perspective) that Blue strategy i versus Red strategy j will end in favor of Blue

2. $BP_{ij}(R)$ = probability (from Blue's perspective) that Blue strategy i versus Red strategy j will end in favor of Red

The outcome probabilities for each strategy combination sum to one ($BP_{11}(B) + BP_{11}(R) = 1$) as do the j_j's. The combat aspect of these probabilities can be calculated using a Markov model. The Markov model will be outlined in Section 4.3.1.1.

How the Blue commander feels about these various outcomes is measured by a subjective assessment of their utility. That assessment is a function of a number of different factors including how that outcome occurred and at what cost. What is the overall impact to Blue forces? What tactics will the Red force employ in response to Blue's strategy (terrorism, hostages, propaganda)? How will these activities affect the local population and popular support? These utilities are determined by systematically querying the Blue commander about his preferences (See Section 3.2). In this model:

1. BU_{ijB} = Blue commander's utility for an outcome in favor of Blue when strategy i meets strategy j
2. BU_{ijR} = Blue commander's utility for an outcome in favor of Red when strategy i meets strategy j

This decision has a recursive nature since it is made over and over again throughout the campaign as the situation and the missions change. It is important to be aware of this in order to realize that current decisions impact on the ability to conduct future operations. The random event of the outcome of today's battle is not only a result of yesterday's decision, but it is also a precursor to the new decision that must be made tomorrow. To model this recursion in one tree would require additional data and a great deal of conjecture about future events. There are too many possible paths that could be taken for this to be reasonably attempted in a time-compressed planning sequence.

Additionally, similar decisions are made at various levels of the chain of command. Higher commanders do not dictate explicit instructions to lower commanders, they give a mission and provide their intent about what the objectives of the mission are. Each commander makes independent employment decisions although the scope of that decision narrows at lower levels of the chain of command. The decisions and the outcomes are obviously interrelated across the levels of command.

Therefore, this discussion will be isolated to the Task Force commander's initial employment decision. This will provide the structure of the basic decision and a model which can help illuminate the various facets of the decision. It is a relatively short step to expand the basic model to various levels of the chain of command and to iterate the process to analyze the repetitive nature of the decision.

4.3 Model Framework

A model is now required through which the Task Force commander's planning staff can structure the decision, define and analyze the variables involved, determine an appropriate strategy and test the implementation of that strategy. The model proposed here will utilize an object-oriented approach. The concept of encapsulation will allow decision makers to be modeled as an entity possessing certain pieces of information along with thought processes of how to manipulate that data in order to make a decision. The principle of inheritance provides a hierarchical structure through which unit task organizations can be effectively modeled. The model will be constructed in two layers (Figure 15).

The Decision Maker layer is where the decision-making process is modeled. It consists of a Blue commander object and a Red commander object. Each of these objects possess data necessary for the decision-making process and methodologies which are used to calculate values required for the Blue commander's decision model.

Below this is the Conflict layer. This is a stochastic, aggregated model developed from the strong points of the SOTACA and PANTHER models. Once an employment decision is generated

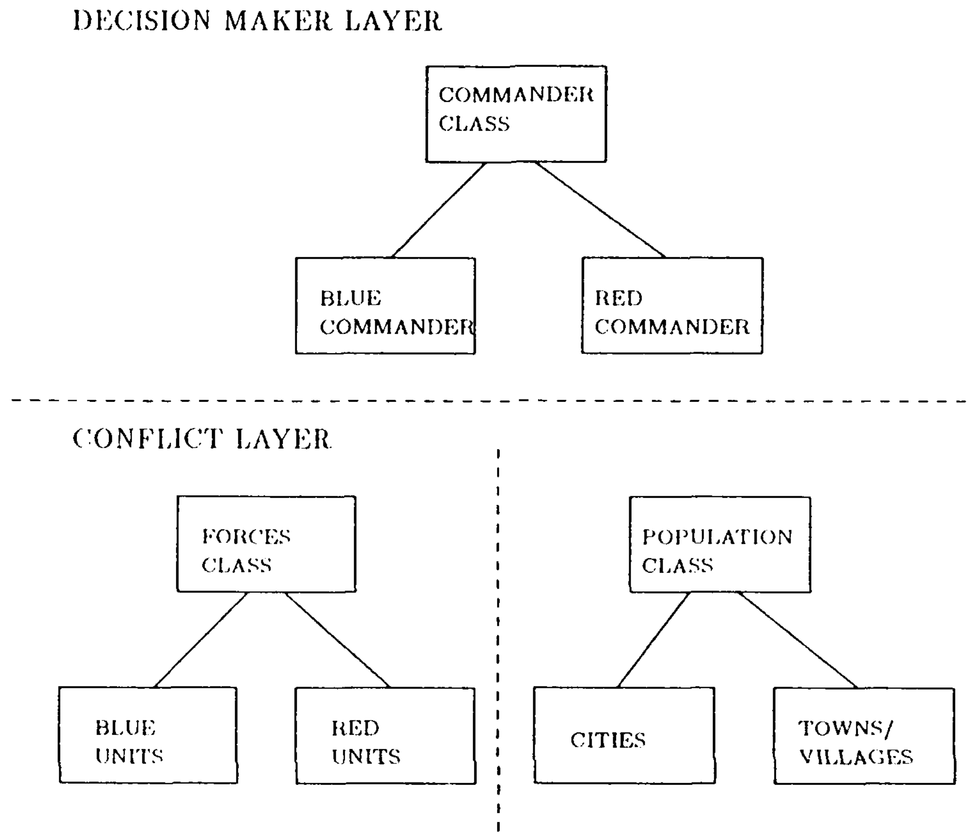

Figure 15. Basic Model Structure

in the Decision Maker layer it is passed down to the Conflict layer where it can be implemented and evaluated. Analysis of the plan can be conducted using both conventional and unconventional measures of effectiveness.

4.3.1 Decision Maker Layer. As stated previously the Decision Maker layer consists of one class of objects, the Commander (decision maker) class. This class of objects contains the data required as inputs to the decision analytic, game theoretic and Markov models and the methods which invoke these models and then pass the results of the models between other objects. The construction is shown in Figure 16.

The data base of the Commander class contains the commander's utilities for the various outcomes, the probabilities of these outcomes occurring and the Red mixed strategy. For the Red

COMMANDER CLASS	
DATA	METHODS
UTILITIES U_{ijB} U_{ijB} OUTCOME PROB $P_{ij}(B)$ $P_{ij}(R)$ RED MIXED STRATEGY y_j	*makedecision* decision analysis game theory *issueorders*

BLUE COMMANDER OBJECT	
DATA	METHODS
UTILITIES BU_{ijB} BU_{ijB} OUTCOME PROB $BP_{ij}(B)$ $BP_{ij}(R)$ RED MIXED STRATEGY y_j	*makedecision* decision analysis *issueorders*
OPTIMAL STRATEGY FORCES IN COMBAT Blue Strat i vs Red Strat j B_0, R_0, B^*, R^*	*resolvecombat*

RED COMMANDER OBJECT	
DATA	METHODS
UTILITIES RU_{ijB} RU_{ijB} OUTCOME PROB $RP_{ij}(B)$ $RP_{ij}(R)$ RED MIXED STRATEGY y_j	*makedecision* game theory *issueorders*

Figure 16. Commander Class

Commander object the utilities and probabilities are subjectively assessed by the planning staff and are input into the model. The Red mixed strategy is generated, using those inputs, by a game theory model. The Blue Commander object requires the utilities to be input into the model. The Red mixed strategy is passed to the Blue Commander object from the Red Commander object. Additionally, the Blue Commander object contains additional data about the units that will engage in combat when Blue strategy i meets Red strategy j. Each set of B_0, R_0, B^*, R^* are passed to the Markov model to compute the Blue commander's outcome probabilities. The Blue commander's utilities, outcome probabilities and Red mixed strategy are passed to a decision analytic model which uses the decision tree in Figure 14 to determine the optimal Blue strategy.

Both the Blue and Red Commander objects contain the ***makedecision*** and ***issueorders*** methods. In the Red Commander object ***makedecision*** invokes a game theory model to determine the Red mixed strategy. The results are passed to both the Blue and Red Commander objects. In the Blue Commander object ***makedecision*** invokes a decision analytic model which determines Blue's optimal strategy and returns the results to the Blue Commander object. The message ***issueorders*** tells the Blue Commander object to send the optimal strategy to the Conflict layer while telling the Red Commander object to randomly choose a y_j and pass it to the Conflict layer. The fact that the same message tells a particular object to do something different exhibits the strength of polymorphism in object-oriented design.

The Blue Commander object contains an additional method, ***resolvecombat***. This message tells the object to pass a set of Forces in Combat data to the Markov model to return a pair of outcome probabilities. This is done for each combination of Blue and Red strategies.

The entire process is depicted in Figure 17.

4.3.1.1 The Decision Cycle. The decision cycle for this model is depicted in Figure 18. The process begins with receipt of the mission, analysis of the situation and the development of Blue and Red strategies by the Blue commander and his staff. A strategy describes the assignment of units to various missions. In LIC these missions can be combat (ambush, raid, search and destroy) or non-combat (civil affairs construction, medical assistance, host nation unit training) operations. Based on mission requirements and resources available the Blue commander and his staff develop various Blue strategies ($i=1,\ldots,$m). Based on available intelligence reports competing Red strategies ($j=1,\ldots,$n) are then hypothesized. This corresponds to the first two branches of Figure 14.

The ability to generate strategies is part of the art of command. It is a predominately mental process which depends on the experience and training of the officer. In the future, however, it may be possible to develop expert systems based on historical data to assist the commander to logically

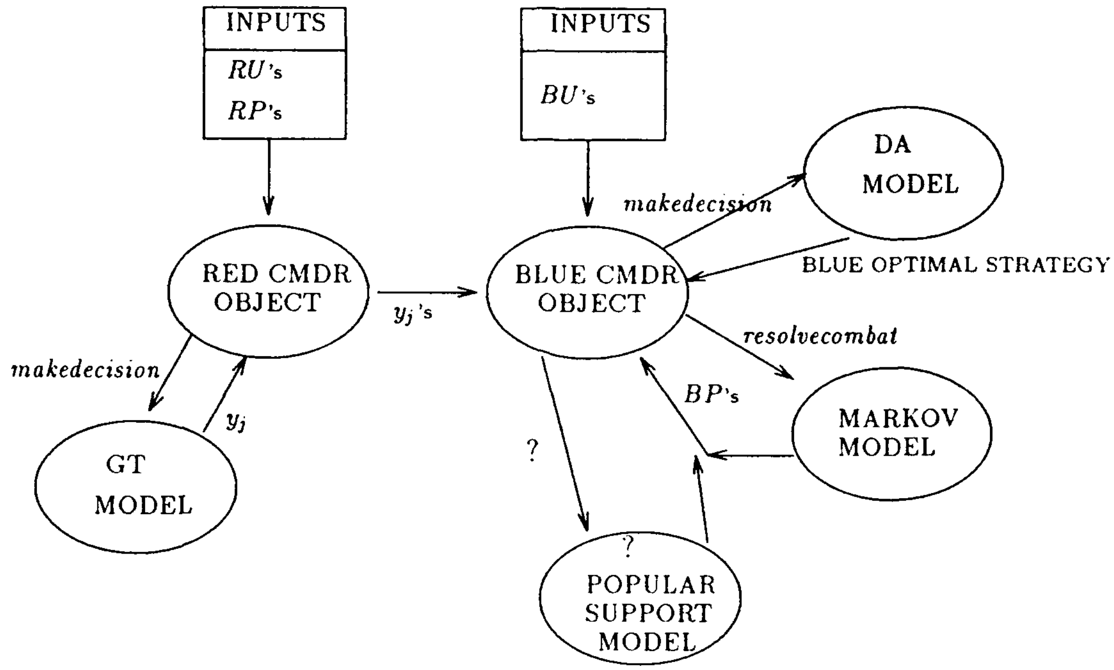

Figure 17. Decision Maker Layer Processes

and systematically consider all the factors involved when developing these strategies.

The commander must evaluate the situation in terms of METT-T (mission, enemy, terrain, troops available and time). Additionally, since this is a LIC operation the imperatives for success must be considered.

The first step is to carefully consider the mission and define all the subtasks which must be accomplished to achieve the desired objectives. The political dominance of these goals must be considered along with military necessity. In the example, the priority is to rescue U.S. civilians. Only after this is accomplished should the main effort shift to the elimination of opposition forces. This must be done in a manner which limits collateral damage. To ensure unity of effort military activities should be coordinated with embassy officials directing the efforts of other governmental agencies.

In addition to considering the disposition of enemy forces; the effect of terrain and weather;

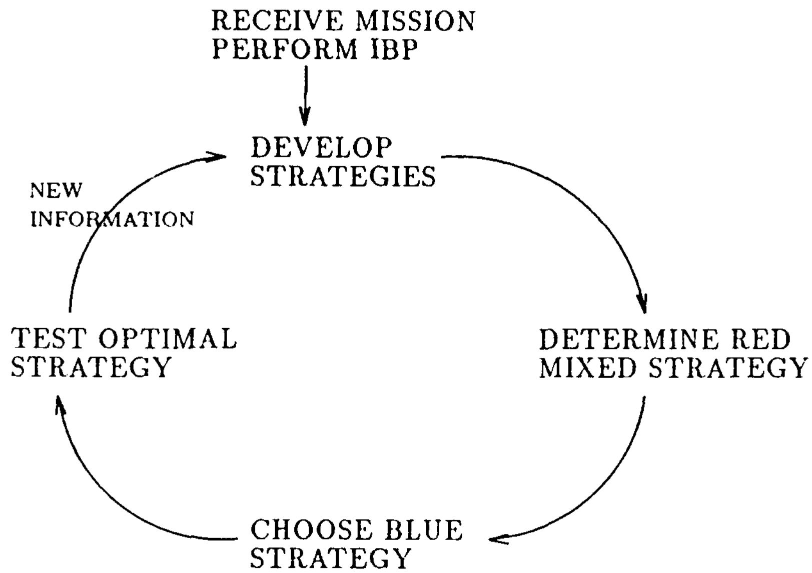

Figure 18. Model Decision Cycle

and what forces can be deployed in the time available, the commander must carefully analyze the location of civilian population centers, whether the local populace is pro or anti-U.S. and how the population pursues its economic livelihood. The commander must consider what portion of the combat force will be diverted to civil-military operations such as police duty, refugee control and medical aid to civilians. The established ROE may impact on the forces and weapon systems that can be employed. Must limits be placed on the use of artillery, mortars, tanks and air assets? What areas must be designated as no fire/restricted fire areas? All of these things and more affect the task organizations and missions in the various courses of action the commander develops.

During operation Urgent Fury the course of action (strategy) chosen for the initial employment called for the simultaneous seizure of the Port Salinas and Perlas airfields. After the operation, critics argued that the Task Force should have employed a ***coup de main*** strategy in which all objectives were attacked simultaneously (3:66). The model being developed here could have been used to compare these two strategies in order to optimize the decision.

Once the Blue commander develops two or more possible courses of action he must mentally wargame them to determine what the Red force may do in response. Again, in the future expert systems could be used to delineate the type of insurgency being faced and what tactics similar groups have used in similar situations in the past. This will help the Blue staff consider all of the possible counterstrategies they may face.

When developing possible Red strategies, the Blue commander must consider the disposition of Red's force, their objectives and their capabilities. Likely military and civilian targets should be identified.

During Urgent Fury commanders must have considered various Red strategies (the history of the planning process is still classified) but as stated in Chapter 2 planned against a worst case scenario. This model allows the commander to plan against a range of strategies, each possessing an associated probability that Red will choose that strategy. In an era in which resources are becoming tighter it is wise to optimize in this fashion rather than overcommit forces against a less likely worst case scenario. Granted this is a gamble, but the purpose of using this model and quantifying these judgements is to assist the decision maker in logically allocating resources to provide the best opportunity to optimize the outcome.

These strategies are not input into the Decision Maker layer, but are used by the commander and his staff to mentally wargame what actions will occur when Blue strategy i meets Red strategy j and what possible outcomes will result. Based on that assessment the staff determines the data required as input into the Blue and Red Commander objects.

The next step in the cycle is to determine the Red commander's mixed strategy (y_j's). The first task is for the staff to estimate, from the perspective of the Red commander, the probability that when Blue strategy i meets Red strategy j the outcome will favor Blue or will favor Red. This assessment should not be based purely on the outcome of the combat operations but should include the impact of non-combat operations as well. Once this is completed the staff must also estimate the Red commander's utility for the various outcome.

These are subjective assessments, but forcing the staff to think Red will bring insight to the problem. It is similar to functions performed during normal intelligence preparation of the battlefield procedures. It will require the staff to critically evaluate and organize intelligence information and identify essential elements of information. Additionally, it requires an analysis of how Red hopes to influence popular support and what gains the Red commander hopes to achieve as a result. In this model

1. $RP_{ij}(B)$ = probability (from Red's perspective) that Blue strategy i versus Red strategy j will end in favor of Blue
2. $RP_{ij}(R)$ = probability (from Red's perspective) that Blue strategy i versus Red strategy j will end in favor of Red
3. RU_{ijB} = Red commander's utility for an outcome in favor of Blue when strategy i meets strategy j
4. RU_{ijR} = Red commander's utility for an outcome in favor of Red when strategy i meets strategy j

These estimates are input as data to the Red commander object and the message *makedecision* calls up the game theory model. In this model the estimates are combined using the equation

$$RU_{ij} = RP_{ij}(B)RU_{ijB} + RP_{ij}(R)RU_{ijR} \tag{16}$$

and a payoff table as in Figure 19 is constructed.

The linear programming formulation outlined in Section 3.3 (Figure 10) is used to solve for the probabilities that Red will employ strategy j (y_j). These probabilities are then passed to the Blue commander object and the message *makedecision* is used to invoke the decision analytic model. This model is used to solve the decision tree depicted in Figure 14. The Red mixed strategy (y_j's)

		Red Strategy		
		1	2	3
Blue Strategy	1	RU_{11}	RU_{12}	RU_{13}
	2	RU_{21}	RU_{22}	RU_{23}
	3	RU_{31}	RU_{32}	RU_{33}
	4	RU_{41}	RU_{42}	RU_{43}

Figure 19. Red Commander Payoff Table

become the prior probabilities used in the first random event of the tree. Two additional unknowns (the likelihoods and utilities) must still be determined.

The combat engagements that occur when the two strategies meet can be resolved using a Markov model as described in Section 3.4 and Figure 20. Such a model is invoked by passing the Blue Commander object the message *resolvecombat* which creates a Markov model for each combination of opposing strategies. Blue strategy i will send units to certain areas to perform particular missions and, conversely, so will Red strategy j. Typically in a LIC environment these objective areas are isolated from each other by the terrain as they were in Urgent Fury and Just Cause. At some, but possibly not all, of these areas, Blue and Red units will confront each other and combat will result. At each location k, B_k Blue units and R_k Red units will clash. The amount of combat which occurs throughout the theater of operation depends on how the two strategies mix together. This Markov model will be used to estimate the outcome of these battles.

Aggregating together the total number of Blue ($\sum B_k = B_0$) and Red ($\sum R_k = R_0$) units involved in combat throughout the area of operations will determine the starting state (B_0,R_0). Absorption states are designated by (B^*,R) or (B,R^*) where B^*(R^*) is the point at which Blue (Red) breaks contact. Equations 11 and 12 are used as transition probabilities. Creating the **P**

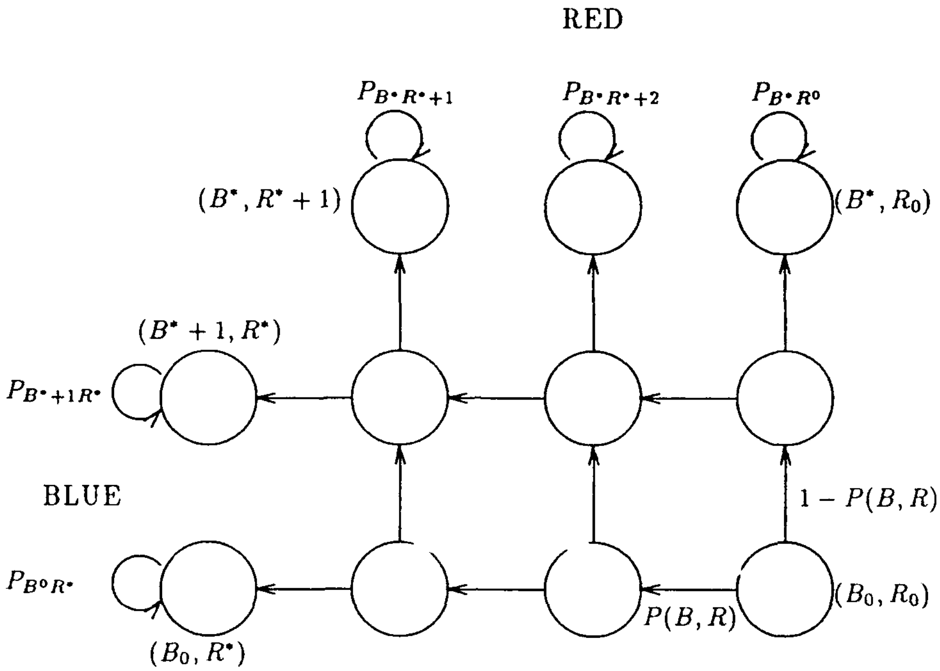

Figure 20. Markov Combat Model State Space Diagram

matrix and taking $\lim_{n\to\infty} \mathbf{P}^n$ will determine the absorption probabilities. The total probability of ending in an absorption state favorable to Blue is determined with the equation:

$$P_{ij}(B) = \sum_{B=B^*+1}^{B_0} P_{BR^*} \tag{17}$$

This summation includes all the absorption probabilities from the states where the losing side (Red) has reached the breakpoint (i.e. R^*) and the winning side (Blue) has not ($B^*+1 \to B_0$). Similarly, The total probability of ending in a state favorable to Red is calculated by:

$$P_{ij}(R) = \sum_{R=R^*+1}^{R_0} P_{B^*R} \tag{18}$$

The $P_{ij}(B)$ ($P_{ij}(R)$) are then input into the decision models as the likelihood probabilities of the outcome favoring Blue (Red) given that Blue chooses strategy i and Red strategy j.

Since this model is not addressing the recursive nature of the decision, assuming a Markov process for combat is valid. The work of Tisi and Hirose also support this assumption (see Section 3.4). Furthermore, this Markov model is only resolving the outcome of the engagement. Once the fighting begins the decisions that brought the units together are unimportant. When the combatants are under fire all that matters is the fight, not why they are there.

However, this method only determines outcome probabilities for the combat operations throughout the theater. It does not include the success or failure of non-combat struggles between Blue and Red. In LIC, these conflicts over the will and support of the people can be more important than the outcome of the battles. Vietnam demonstrated that a side can win all the battles and still lose the conflict.

Switching momentarily away from the Urgent Fury example to Operation Just Cause, civil affairs, PSYOPs and civil-military operations were being conducted simultaneously to combat operations from the outset of the conflict. Effective PSYOPs missions induced many PDF elements to give up their resistance with minimal combat required. Police and civil-security missions performed by infantry, engineer and military police units were critical to limiting collateral damage and civilian casualties. These and other such activities played an important role in the overall success of the campaign.

However, there are no methods currently available to model these non-combat struggles during operational planning and determine their impact on the success of the operation. A method of assessing the impact of civil affairs missions, PSYOPs missions, economic aid, military training and other nation-building programs on popular support is required. The only method currently being attempted is the use of Civil Affairs and PSYOPs officers as umpires in PANTHER.

This is an area of much needed research. Scientists and analysts interested in the military art have spent years working with and expanding the body of knowledge first developed by Lanchester in 1910. Similar efforts must be applied in the area of popular support to develop algorithms that model the impact on non-combat military activities on the outcome of LIC. Surveys have been conducted during past operations to attempt to measure the impact of military activities on popular support (58:135). Although, they may not be totally accurate they provide a starting point for study. An analysis of strategies and tactics employed by civil affairs and PSYOPs units should also provide valuable insights. Then, using these algorithms, one approach to implementing them in combat models may be the development of an expert system which utilizes historical knowledge and expert opinion in an effort to resolve these complex issues, similar to the way umpires are used in PANTHER.

Once such a model is developed its conclusions can be combined with the results of the Markov combat model described above, and more accurate likelihood probabilities can then be derived. These probabilities will then include all of the various impacts of military activities on a LIC campaign rather then only the results of combat. For the time being this model will have to rely on the assessment of the staff officer conducting the study for a subjective quantification of the impact of combat and non-combat activities on popular support.

The final values required by the decision model are the commander's utilities for those outcomes and how they were achieved. It again is a function of combat operations (battles won/lost) and non-combat operations (villages won/lost). It is a subjective assessment determined by querying the Blue commander about his preferences.

This is another area which requires a great deal of additional research. A function must be developed which quantifies the relationship of all the factors involved and provides a number which is the utility of that outcome. Their are many questions to be answered. What is the value of human life and what is the value of a soldier's life compared to a civilian's? Are certain military specialties worth more than others? What are various military units worth? Is it just the cost required to equip, maintain and support the unit or do different units also have other more subjective utilities that should be considered when determining the utility of winning and losing battles? How does the utility of the support of different population centers compare?

During the planning for Operation Urgent Fury the commander had to consider many factors. What was the utility for using a particular type of unit for a particular mission? How does the value of special operations forces compare to conventional forces in terms of training, readiness and cost if lost? Is it acceptable to place additional risk on soldier's lives in order to insure the safety of civilians? Is the support of the people in the capital city more or less important than the support of outlying villages? All of these considerations and more impacted on the commander's assessment of the utilities of the outcomes attained when comparing various courses of action.

It is a difficult problem to quantify all of these factors. However, attempting to do so can provide insights to the problem and help to identify the important trends of the problem. Furthermore, quantifying these questions allows the use of a model such as is being proposed here to optimize the decision-making process. For now the Blue commander's utilities are subjective assessments input directly into the model.

Once all of the values are input into the decision tree, the model calculates the expected utility of each Blue strategy. The best strategy is the one with the highest expected utility.

This strategy choice is then passed to the Conflict layer of the model along with a competing Red strategy chosen by a random number draw from the randomized game theory model (Figure 21). These strategies are run in the Conflict layer model and the results presented through the use of both traditional (attrition, logistics consumption) and unconventional (popular support) measures of effectiveness. Numerous runs can be made, choosing a different Red strategy each time with a new random number through a Monte Carlo process. Then a range of outcomes against different Red strategies can be analyzed.

The ability to produce multiple runs of the results allows the staff to perform sensitivity analysis on the variables of the problem. Since a great deal of the initial information used in the model is subjective assessments based on intelligence information, sensitivity analysis can be used

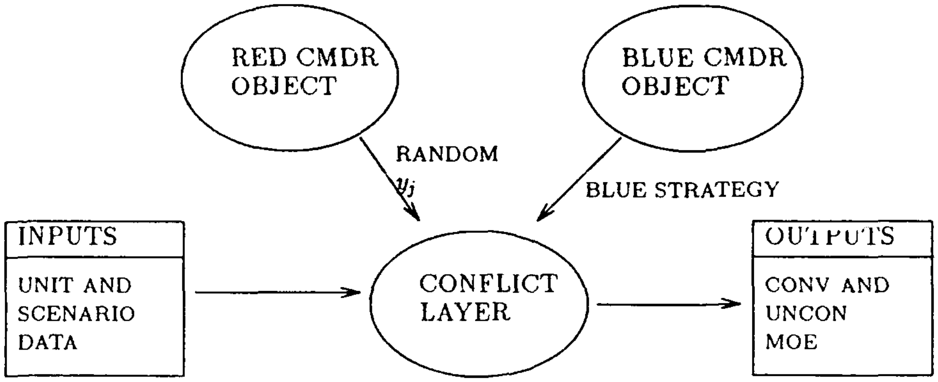

Figure 21. Conflict Layer Processes

to determine which variables have the greatest impact on the outcome and over what range of values the results can be expected. This will help to identify the important relationships which underlie the problem, creating a better understanding of the problem and therefore a more informed and hopefully effective decision. Additionally, the staff will be able to determine whether or not it is beneficial, in terms of the expected utility of the decision, to wait for additional information which will eliminate some uncertainty (randomness) from the decision.

In the Decision Maker model an extremely aggregated and simplistic Markov model of combat was used in order to estimate the outcome and make an employment decision. Once that decision is made a more advanced model is required with which to test the decision. The Conflict layer provides such a model.

4.3.2 Conflict Layer. The Conflict layer is an aggregate combat model which is used to simulate the conflict that results when Blue strategy i meets Red strategy j. A run of this model is initiated when objects in the Decision Maker layer pass Blue's optimal strategy and a Red counterstrategy to the Forces class. The purpose of the model is to predict the outcome of the conflict so that analysts can evaluate the potential success of the strategy choice using both conventional (attrition, logistics consumption) and unconventional (popular support) measures of effectiveness.

The model should be an object-oriented variation of SOTACA expanded to three sides and incorporating PANTHER popular support algorithms. The scenario being analyzed is input into the model by defining the region in which the conflict takes place, creating Blue and Red unit objects and creating population center objects. Objects are then routed through the area of operation to accomplish the missions outlined in the optimal strategy.

The Conflict layer consists of two classes, the Forces class and the Local Population class. The Forces class subdivides into a Blue Units class and a Red Units class. These classes can be further subdivided into different unit type classes. Specific unit objects are created as instances of the relevant forces subclass. The Local Population class subdivides into a Cities class and a Towns/Villages class. Specific population center objects are created as instances of these two subclasses. Using the Urgent Fury example (Figure 22), Blue unit objects would be created for each of the elements of the U.S. Task Force. Opposition forces would be modeled with Red unit objects. The local population of Grenada (including U.S. students) would be modeled using population center objects (Figure 23).

The general pattern for the Forces class is taken from the SOTACA model. The data in this class is the same data contained in the UTD and CDF of the SOTACA force files. This data includes unit designations, equipment, personnel, basic loads, consumption rates, readiness rates and location. Blue and Red unit subclasses are generated from the Forces class. As in the Decision Maker layer the Blue units contain the best data available to the staff on the status of their own units, while the Red units contain the most accurate information that intelligence reports can provide. Specific unit objects are generated from the applicable unit subclass and structured as shown in Figure 24.

The use of an object-oriented design brings many advantages to this structure. Using the concept of encapsulation units are modeled more accurately as entities possessing a certain composition (data) and a set of functions to perform (methods). Inheritance allows units up and down

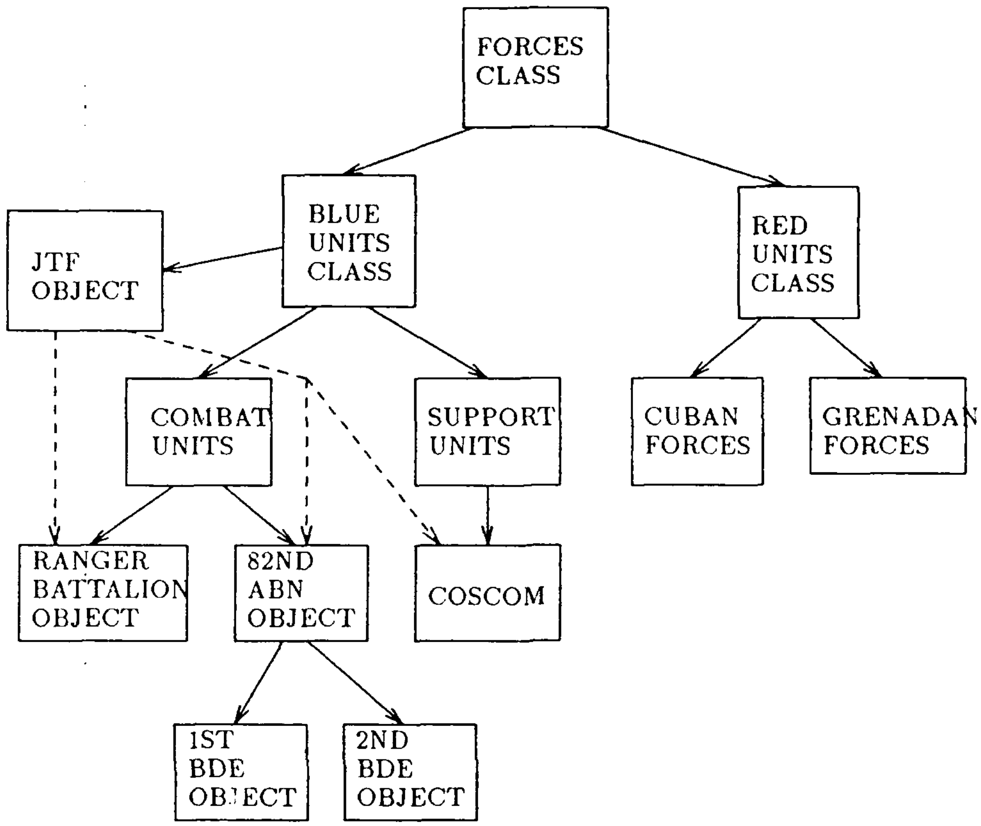

Figure 22. Example of Forces Class for Urgent Fury

the chain of command to store information about each other's status and activities. Polymorphism allows one message to initiate different functions from different units.

Each objects structure is similar, however different data entries into that structure creates different units. The JTF object, through inheritance, is able to manage the status of all its subordinate units. When JTF sends the message *issueorders* to each subordinate object the mission assumed by each will vary based on the data contained in the appropriate strategy data entry.

The methods in the Forces class resolve the interactions of the struggles that occur as a result of the clash between the Blue and Red strategies. Combat operations are resolved using algorithms from the SOTACA model. This provides the best method currently available to incorporate additional aspects of combat power, such as civil affairs, PSYOPs and civil-military functions, into the

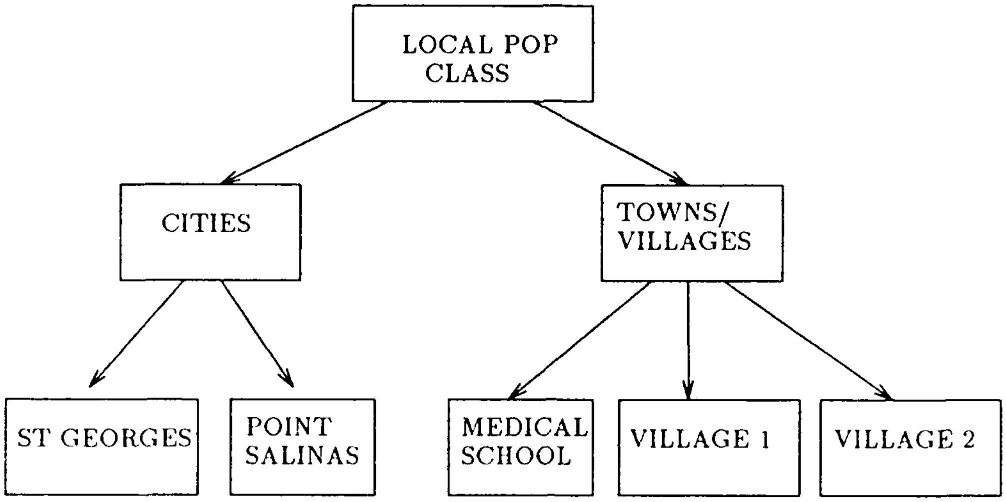

Figure 23. Example of Local Population Class for Urgent Fury

determination of relative power relationships and the associated mix of mission force ratios that are required to accurately resolve the outcome of combat between conventional and unconventional forces.

The message *issueorders* disseminates the strategy chosen to all of the subclasses and objects. This tells each unit object what mission mode it is in. Upon completion of the dissemination of the orders the SOTACA calibration procedures are initiated. (See Appendix A)

The message *pairwisecomparison* starts the SOTACA valuation procedures. This compares the units in the model as outlined in Appendix A and develops power and vulnerability relationships between Blue and Red units. These relationships depict one units ability to influence the mission of another and that units associated vulnerability to its opponents power under various mission modes. This method returns Weighted Power Values to unit objects. Designating civil affairs, PSYOPs, military police and other non-combat arms units as confronters will enhance the ability to relate non-combat capabilities to the total strength of a unit. Mission modes should also include non-combat missions.

The message *forceratios* utilizes SOTACA's algorithms (Appendix A) to determine the force

UNIT OBJECT	
DATA	METHODS
TYPE LOCATION MISSION STRATEGY 1 STRATEGY 2 STRATEGY 3 # PERSONNEL CONFRONTERS ARTILLERY SMALL ARMS MORTARS SQUADS CIVIL AFFAIRS SPECIALIST LOGISTICS BASIC LOAD CONSUMPTION RATES OVERALL EFFECTIVENESS WEIGHTED POWER VALUE FORCE RATIO MISSION MODE 1 MISSION MODE 2	*pairwisecomparison* *force ratios* *resolvecombat*

Figure 24 A Forces Class Object

ratios required between units engaged in various missions. Based on power and vulnerability values these force ratios illustrate the size force one side should posses in relation to its opponents force size in order to engage in a particular mission. For example, if Blue wants to attack a defending Red force, Blue should have (based on current military thought) a 3:1 advantage in force size to expect to be successful. These force ratios, by mission mode, are returned to the unit objects.

Upon completion of the calibration procedures the Conflict layer model executes the scenario. Blue and Red unit objects are routed through the area of operation to accomplish their assigned mission. This process is performed the same as in SOTACA. Whenever a Blue and Red unit object confront each other the *resolvecombat* method is initiated.

The message *resolvecombat* invokes the SOTACA attrition model and resolves the combat conflicts initiated by the strategies involved. SOTACA currently uses an exponential attrition model whose attrition coefficients are calculated from the power values and force ratios computed above based on the mission modes of the forces in conflict. The Mixed Law (Equation 10)should be incorporated into this model to more accurately represent guerrilla warfare. A method of alternating between these two attrition models depending on the tactical situation might further enhance the model. The outcomes of these conflicts cause the data in the unit objects to be changed as well as the data in applicable local population objects. The results are also tabulated using the same methods and MOE as in the SOTACA model.

Unfortunately, the same problem encountered in the Decision Maker layer still exists in the Conflict layer. It does not provide a means with which to evaluate the outcome of non-combat struggles between forces. As stated previously this area still requires a great deal of research. Nor does SOTACA provide a mechanism with which to evaluate the impact of both combat and non-combat struggles on the population. Ideas presented in the PANTHER model provide a direction in which development should occur.

PANTHER models the civilian population as non-reactive population centers. In the model being developed here this is done in the Local Population class. Objects are specific instances of cities, towns or villages (Figure 25). This class is broken out into city and town/village subclasses in order to model the different preferences and priorities of these portions of society. The data contained in these classes include information on how the population feels about their own security, the legitimacy of the government, their standard of living and the collateral damage being caused by the ongoing conflict. This data, along with data passed to these objects after the resolution of combat and non-combat struggles, is manipulated by the methods in this class to provide values to be used in Equation 1 to calculate the popular support. These methodologies are still not adequately defined. In PANTHER subject matter experts performing umpire duties subjectively determine these values.

There is a large enough body of historical knowledge with which to research better methods

LOCAL POPULATION OBJECT	
DATA	METHODS
TYPE LOCATION POPULATION POPULAR SUPPORT BLUE RED PRESENCE BLUE RED COLLATERAL DAMAGE BLUE RED CIVIL AFFAIRS BLUE RED PSYOPs BLUE RED	*detpopularspt*

Figure 25. A Local Population Class Object

to model this aspect of LIC. Surveys, interviews and other historical documents can be analyzed to ascertain how various combat and non-combat activities affected popular support. There are also experts available in the civil affairs and PSYOPs units within the Army with first hand experience that should be captured. These sources should provide a starting point for insights that could lead to the derivation of algorithms and models to simulate the impact of various combat and non-combat activities on popular support.

After the Conflict layer model is run, the results are analyzed. The knowledge gained from this analysis can be combined with new intelligence information. Then the Blue and Red strategies, utilities and probabilities can be modified and the entire process repeated. Depending on the planning time available, multiple iterations can be performed until the commander feels the optimal decision has been reached. This entire process will provide insights to the planning process that will in the end produce a better decision.

V. Conclusions and Recommendations

5.1 Conclusions.

This research has brought to light some important conclusions. Although operations research and decision-making sciences originated with efforts to solve military problems during World War II, the military has not kept up with the development and application of those tools. Planning for peacetime contingency operations could benefit greatly from the use of modern decision-making techniques, however, the tools and the expertise available to the commander are extremely limited.

Current military planning methods are too subjective. Planning methods fail to quantitatively assess the inherent uncertainties and competition of warfare. A more structured approach is required which forces the operations planner to assess the probability of occurrence of random events that effect the mission outcome and to incorporate the commander's preferences into the decision. When it comes to PCO, planning shortfalls are compounded by an inadequate assessment of the non-combat military activities that can so drastically effect the outcome of the conflict.

Although there are some models (SOTACA, PANTHER) and algorithms (Mixed Law) which deal with LIC and contingency planning they do not address all of the nuances of LIC (non-combat struggles, popular support), do not use the appropriate measures of effectiveness and are often too cumbersome to be effective in a time-compressed planning environment. Furthermore, the staff officers in division and corps headquarters do not have the expertise to use these models. Consequently, despite the availability and use of decision-making methods and algorithms in other areas, military decision-making is still an art which depends on the experience of the commander. The art of command can never be replaced by computers and mathematical formulas, however, the application of scientific methods can enhance the commander's ability to manage information and optimize decision-making.

This thesis has proposed the use of decision analysis as a prescriptive model with which to structure and optimize the decision of how to employ military assets in peacetime contingency operations. Decision analysis allows the staff to quantify the uncertainties and risks of such operations along with the commander's preferences about the various possible outcomes. The model provides a structure within which to perform sensitivity analysis and determine what variables have the greatest impact on the decision. It also provides a method with which to analyze the benefits associated with waiting for the outcome of a random event before the final decision is made.

Before the model suggested in this paper can be fully developed additional research must be performed. Methods are needed to quantify the impact of civil affairs, PSYOPs, military training and other non-combat applications of military power on the overall success or failure of the campaign. Models are needed to help predict the outcome of these non-combat struggles between opposing forces and their associated impact on popular support. Once completed these models can be combined with the methods presented in Chapter 2 for modeling the combat aspects of LIC. Only then will a model which gives a complete picture of all the aspects of LIC be feasible.

5.2 Recommendations.

There are also some recommendations that must be made for future enhancements to this model. The first is the development of a central data base of forces subclasses and unit objects. One of the major obstacles to the acceptance of the SOTACA model was that the amount of time it took to construct the forces required for a study. The development of a data base of classes of objects would help to eliminate this problem. Furthermore, any model which utilizes object-oriented design could draw from this data base.

Second, there are numerous places within this model where expert systems could be used. During the initial steps of the generation of the scenario and the development of strategies and expert system could be used to draw from historical data. With the known characteristics of the conflict as inputs the expert system could cross reference to conflicts that had similar qualities and tell the analyst what strategies were employed by both sides and which appeared to be successful and which did not. These historical examples could also be utilized in other expert systems to help estimate the Red commander's outcome probabilities and utilities. Another such system could also be used to help develop the Blue commander's utilities. Finally, a rule based expert system could be used to automate the pairwise comparisons needed for the SOTACA algorithms. The time it took to do these manually was another barrier to the use of SOTACA.

Appendix A. *SOTACA Calibration Process*

The theoretical foundation for the calibration process is the use of pairwise comparisons as outlined in Thomas L. Saaty's analytical hierarchy process. The advantage of this method is that it allows the inclusion of more subjective items into the calculation of combat power beyond the use of just weapons effects data. Its effectiveness is limited by the experience and credibility of the individual(s) making the comparisons.

Confronter values are determined using pairwise comparisons to fill in various power and vulnerability matrices. The first comparison is used to develop relative category power values (CPV) among confronters on a single side for each category of power under each mission mode (Figure 26). The second comparison establishes general vulnerability (GV) values for each con-

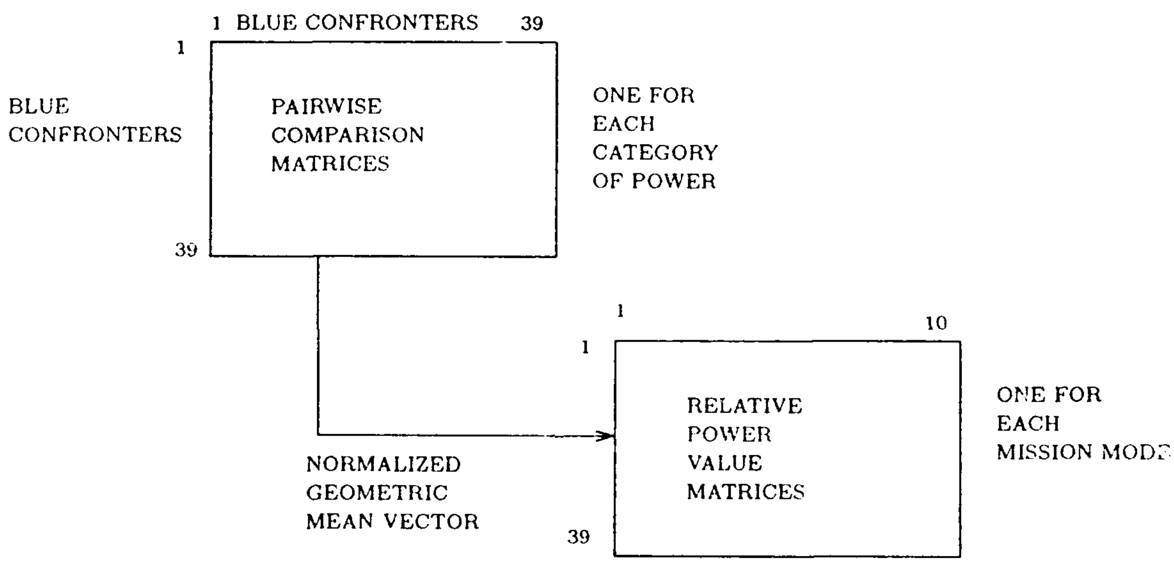

Figure 26. Relative Power Value Calculation

fronter assessed against the threats general power within each mission mode (Figure 27). The final comparison establishes relative vulnerability (RV) values for each confronter against each of the enemy's categories of power under each mission mode (Figure 28).

Comparison values are chosen from the following table:

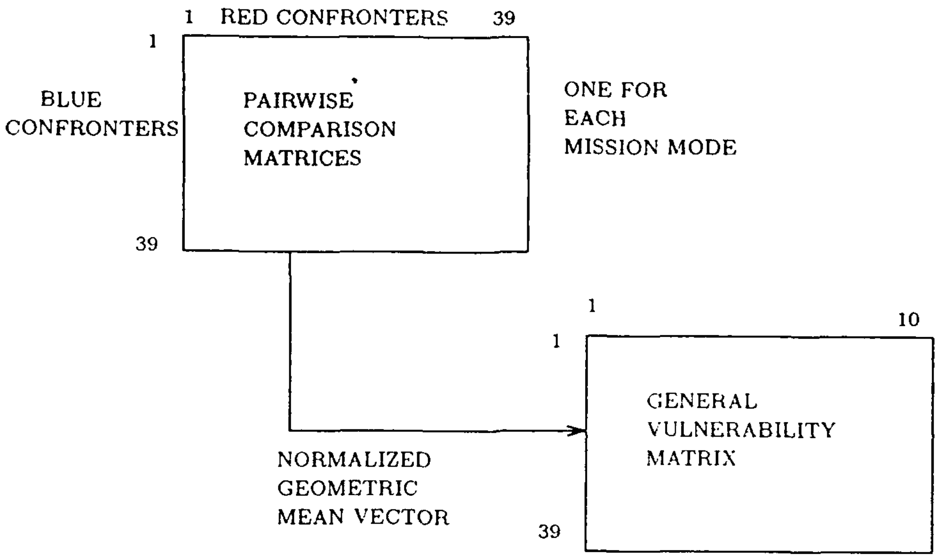

Figure 27. General Vulnerability Calculation

Table 3. Pairwise Comparison Values (reprinted from (31))

1	Equal
3	Weak importance of one over the other
5	Essential or strong importance
7	Very strong importance
9	Absolute importance

Intermediate values (2,4,6,8) can be used for compromises. Judgement consistency is also assessed based on the number of circular triads ($A > B > C > A$). The significance of this consistency versus a hypothesis that the judgements were made randomly is determined using a chi-square statistic.

Comparison values are converted to power and vulnerability values using the normalized geometric mean vector.

$$GMV_i = \prod_{j=1}^{n} A_j^{1/n} \tag{19}$$

$$GMV_n = \frac{GMV_i}{\sum_{i=1}^{n} GMV_i} \tag{20}$$

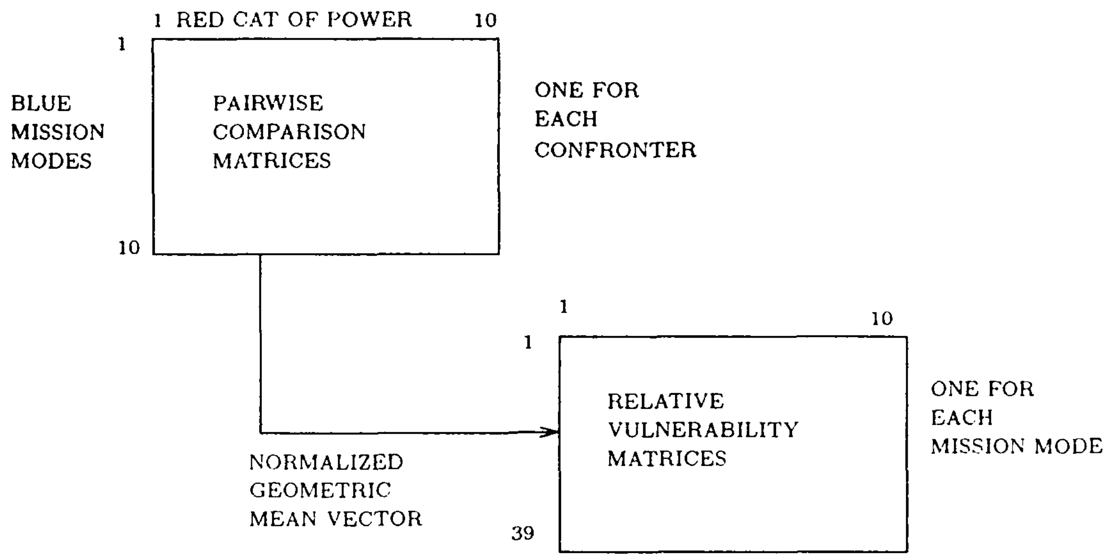

Figure 28. Relative Vulnerability Calculation

This provides a common scale for follow-on force valuations.

The confronter power value, general vulnerability of each confronter and the relative vulnerability of each confronter against specific threats can now be combined to obtain a value which represents the synergistic effects of the forces. This aggregated value is called a weighted power value (WPV). These values are then used to compute force ratios for various mission mode combinations.

The first step is to aggregate confronter category power values into a total category power value (TCPV). This is done by the following equation:

$$TCPV_i = \sum_{j=1}^{n} QBC_j \times CPV_{ij} \tag{21}$$

where,

i=categories

j=confronter type

QBC_j=quantity of confronter j

CPV_{ij}=category power value i for confronter j

Total category vulnerability values (TCV) are computed in a similar manner with the equation:

$$TCV_i = QBC_j \times GV_j \times RV_{ij} \tag{22}$$

where,

GV_j=general vulnerability of confronter j

RV_{ij}=relative vulnerability of confronter j

to opposing category of power i

The total GV value ($\sum_{j=1}^{n} QBC_j \times GV_j$) is used to normalize the total category vulnerability values ($NTCV_i$).

The total category power and vulnerability values are used to create a weighted power value under each mission mode for each side using the equation:

$$WPV = \sum_{i=1}^{n} TCPV_i \times NTCV_i \tag{23}$$

Force ratios for various combinations of mission modes can now be calculated. SOTACA provides the user with the ability to compare these ratios to historical data or the results of high resolution models that depict a similar scenario (calibration force). The ratios calculated by SOTACA can be adjusted based on this comparison and the model will back calculate new confronter relationships.

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Vita

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