12-5-2007

Modeling and Analysis of Resolve and Morale for the `Long War'

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MODELING AND ANALYSIS OF RESOLVE AND MORALE

FOR THE 'LONG WAR'

DISSERTATION

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AFIT / DS / ENS / 07-02

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AFIT/DS/ENS/07-02

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DISSERTATION

Presented to the Faculty

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

in Partial Fulfillment of the Requirements for the

Degree of Doctor of Philosophy

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December 2007

AFIT/DS/ENS/07-02

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Abstract

In *The Art of War*, Sun Tzu begins by stating: “War is a matter of vital importance to the State; the province of life or death; the road to survival or ruin. It is mandatory that it be thoroughly studied” (c500BC/1963, p. 63). Sun Tzu follows this opening by stating five fundamental factors a commander must master to be successful in combat (Tzu, c500BC/1963, p. 65). The first of these factors is moral influence which Sun Tzu defines as “that which causes the people to be in harmony with their leaders, so they will accompany them in life and death without fear of mortal peril” (Tzu, c500BC/1963, p. 64). In the face of the instant communication provided by satellites, 24 hour news media coverage, and other technological advances, this factor is even more relevant today.

This research provides an analytic framework, based on the principles of fourth generation operations, capturing the effects of will and resolve of the combatant and population. The strategic level model investigates the long term impacts of asymmetric conflict. These results are primarily measured in the socio-political arena rather than the military battlefield. The model developed in this dissertation remains a model of conflict and combat. However, some of the impacts from the political, economic, and informational instruments of power are represented in the model through the dynamic adaptation of public resolve and combat spirit. To paraphrase Sun Tzu, war is vitally important and must be studied (Tzu, c500BC/1963, p. 63). Therefore, this dissertation puts forth a means to model key aspects of conflict in the ‘long war.’

Acknowledgments

I would like to thank my advisor and committee for insuring the research was a contribution. I thank my high school calculus teacher for telling me I can not do math with a pen. By ignoring her I learned to think carefully before I write. I thank my AFJROTC instructor for suggesting I go to the ‘company school’. I am thankful for my Dad who taught me to always use a building block approach. I thank my Mom for teaching me persistence. I thank my daughter for always being on the lookout for pirates. I finally thank my wife for always being my cheerleader.

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MODELING AND ANALYSIS OF RESOLVE AND MORALE FOR THE 'LONG WAR'

I. Introduction

Background

In *The Art of War*, Sun Tzu states:

> *War is a matter of vital importance to the State; the province of life or death; the road to survival or ruin. It is mandatory that it be thoroughly studied.* (c500BC/1963, p. 63)

Sun Tzu follows this opening by stating five fundamental factors a commander must master to be successful in combat (Tzu, c500BC/1963, p. 65). The first of these factors is moral influence which Sun Tzu defines as "that which causes the people to be in harmony with their leaders, so they will accompany them in life and death without fear of mortal peril" (Tzu, c500BC/1963, p. 64). In the face of the instant communication provided by satellites, 24 hour news media coverage, and other technological advances, this factor is even more relevant today.

Current combat models were developed in a time of strategic parity. They generally focused on impacting the military and infrastructure. Such an approach was acceptable when all combat models correlated to national survival of the combatants; i.e. force on force attrition. Today, the US is the sole superpower and the conflicts it faces are often asymmetrical. Combatants may not be nation-states and national survival may not be perceived as being directly threatened. When national survival is attacked through conventional means, the military, as an instrument of power, is one of the most critical elements of national power. Therefore, modeling a near peer as force on force was sufficient for generating courses of action and comparative analyses of weapon systems. The other instruments, diplomatic, informational, and economic, if considered in models at all, were analysis functions. The exception to this practice could be found, in part, in some models of military operations other than war (MOOTW).

Today's conflicts involve a foe who is directly attacking our population's and our coalition partners' will and support as their principle strategy. To paraphrase Sun Tzu, war is vitally important and must be studied (Tzu, c500BC/1963, p. 63). Therefore, this dissertation develops a framework to model key aspects of conflict in the "long war" (QDR 2006, p. v).

Problem Statement

Clausewitz reminds the reader that war is a political tool and the political goals must always be considered when developing military goals and objectives:

> *We see, therefore, that war is not merely an act of policy but a true political instrument, a continuation of political intercourse, carried on with other means…The political objective is the goal, war is the means of reaching it, and means can never be considered in isolation from their purpose.* (Clausewitz, 1832/1984, p. 87)

Additionally, the political goal is the true objective and must be achieved regardless of the status of the military goals. To help assure the Department of Defense is achieving the political goals, every four years the Quadrennial Defense Review is performed. The 2006 *Quadrennial Defense Review Report* stated 35 shifts in emphasis that the

Department of Defense must pursue to meet the new strategic environment. This dissertation directly addresses five of these shifts. These five are:

- *From nation-state threats – to decentralized network threats from non-state enemies* (p. vi)
- *From conducting war against nations – to conducting war in countries we are not at war with (safe havens)* (p. vi)
- *From major conventional combat operations – to multiple irregular, asymmetric operations* (p. vii)
- *From static post-operations analysis – to dynamic diagnostics and real-time lessons learned* (p. vii)
- *From "one size fits all" deterrence – to tailored deterrence for rogue powers, terrorist networks and near-peer competitors* (p. vi)

The likelihood of interstate conflict in the near future has decreased. This evolution of paradigm is evident in the first three above shifts of emphasis suggested by the *Quadrennial Defense Review Report*. Therefore, a refinement of the definition of conflict is required to better understand the world the US military and its coalition partners are facing. This dissertation offers a definition of fourth generation operations and proposes that fourth generation operations represent an environment which is decentralized, irregular, and asymmetric. The combatants may be from a nation-state (with or without the government's or population's support) or from one of several transnational groups.

The fourth shift in emphasis suggests that the models must be dynamic, capable of updates based on current events and situations. While methods have been developed to incorporate the impacts of resolution and combatant's spirit within combat models, these models do not update the parameters based on the actions within the model. These traditional models present a static representation of key aspects of conflict.

The fifth shift in DoD emphasis suggests that courses of action tested within a combat model may significantly differ from case to case, context to context, or environment to environment. It follows, then, that the tools available to the combatant commander can not be limited to classical attrition based warfare.

This research creates a conflict model which incorporates the effects of public resolution, combat spirit, will-to-fight and morale. Current combat models are generally limited to modeling a single battle. This focus, while adequate for a major, traditional armed engagement, does not fully address many of the key aspects of conflict which face the nation and its coalition partners at the start of the 21st century. With transnational terrorists fomenting insurgencies throughout the world, the victors of future conflict may not be decided by the decisive battle of conventional troops. The proposed model does not replace current combat models, since it would be foolish to assume that traditional warfare will not exist in the future. Additionally, these campaign level models may still be useful in analyzing the courses of action in a traditional battle and aiding in the proper equipping and resourcing of battles and campaigns.

The proposed strategic level model investigates the longer term impacts of asymmetric conflict on public resolve and soldier morale. Additionally, this strategic level model captures the impacts of multiple engagements. As such, the proposed strategic level model must incorporate the effects of the combat spirit of the troops, and the morale of the population. The proposed model is still a model of conflict and combat. However, some of the impacts from the political, economic, and informational instruments of power are represented in the model through the dynamic adaptation of public resolve and combat spirit.

General Assumptions and Scope

The proposed model is focused on the strategic level of war, implying that the impacts are measured in terms of weeks, months and years. Individual duels and battles are not modeled. It is assumed a higher fidelity operational or tactical model is able to provide inputs to this lower fidelity model.

The focus of this research is the resolve and spirit of the people within a combatant group and the supporting population, not the terrain. The current location of the forward line of troops is not modeled nor is the percentage or location of land held by either friend or foe. Specific movement of troops, other than how they affect a combatants' will-to-fight, are not accounted for or modeled.

The proposed strategic level model of fourth generation operations is initially developed as a deterministic model. Hartman states a model is deterministic if it "contains no probabilities or random effects" (Hartman, 2005, p. 1-3). He further defines stochastic models as "those models that incorporate uncertain outcomes using probability distributions over the sample space of possible outcomes" (Hartman, 2005, p. 1-3). As a first step in modeling national resolution; modeling the environment deterministically provides insights that can assist in developing future efforts.

Deterministic models are used throughout combat modeling. Hartman states that deterministic combat models are typically used for highly aggregated combat (Hartman, 2005, p. 2-2). Higher resolution models of combat tend to be stochastic, while lower resolution deterministic models “resolve the complex phenomenon of large scale combat into a collection of single shots” (Hartman, 2005, p. 2-2). Such models can reduce the complexity of the combat scenario to something better understood.

The definition of fourth generation operations is based on the literature of fourth generation warfare. This dissertation assumes fourth generation operations is an extension or outgrowth of the concept of fourth generation warfare.

Finally, this research assumes that the will-to-fight of the combatants and public resolve of the population are critical to modeling conflict and combat. Specifically, the importance is increased when viewing irregular asymmetric conflict. The principles of fourth generation operations rely on the principles of legitimacy and perseverance. It is assumed these principles reinforce the importance of public resolve and combat spirit. It is further assumed legitimacy is represented within the views of the indigenous population and perseverance represents the combatants and combatants’ support structure.

Research Contributions

The overall objective and contribution of this research is to:

> Provide an analytic framework of elements of fourth generation operations, capturing the effects of will of the population and combatant.

To obtain the objective, four principal objectives must be achieved and combined. These principal objectives are:

1) Develop and model a theory of fourth generation operations based on the framework of US Joint doctrine

2) Develop the supporting principles of fourth generation operations

3) Construct a theoretical modeling framework to dynamically portray public resolve, will-to-fight, morale and combat spirit within a combat model

4) Provide a capability to model and evaluate the impacts of public resolve, will-to-fight, morale, and combat spirit of combatants and population on the outcome of the conflict

The objectives of this research provide six specific contributions to the field of operations research and specifically combat and conflict modeling. These are discussed in greater detail in Chapters 3 through 7 and summarized in Chapter 8.

1) Developed a theory of fourth generation operations based on the framework of US joint doctrine

2) Developed the supporting principles of fourth generation operations
   - Introduced principle of Population Perception

3) Constructed a theoretical modeling framework to dynamically portray fatigue within a combat model
   - System dynamic model with events
   - Implemented the Lanchester Laws within a system dynamics model

4) Constructed a theoretical modeling framework of public resolve
   - Founded on empirical evidence of four key factors
   - Provided a capability to model and evaluate impacts of conflict on public resolve

5) Constructed a theoretical modeling framework that dynamically portrays soldier morale
   - Provided a capability to model and evaluate impacts of soldier morale on outcome of conflict

6) Constructed an analytic framework of fourth generation operations which captures the will of the population and combatants

Document Overview

This dissertation is divided into multiple chapters. The first chapter introduces the problem, provides a summary of assumptions, and lists the research contributions.

The second chapter presents the relevant literature. This chapter begins by describing fourth generation warfare. This is followed by an introduction to discrete event simulations and system dynamics. This is followed by an introduction to generalized linear models focusing on logistic regression. The next section of the literature review focuses on the tools used to model combat. The Lanchester Laws are introduced and illustrated with some examples and explanations. The next area discussed is the research previously accomplished to model the impacts of the will-to-fight, morale and combat spirit. The literature review concludes with a discussion of control theory.

Chapters 3 though 7 build upon the literature review to construct an analytic framework of fourth generation operations. Figure I-1 provides a framework of the research depicting the four steps, used in this research, to develop a fourth generation operations model. Each input is divided into a separate chapter to develop the required contributions. The results from each individual chapter are combined together, producing an analytic framework of fourth generation operations which captures the will of the population and combatants.

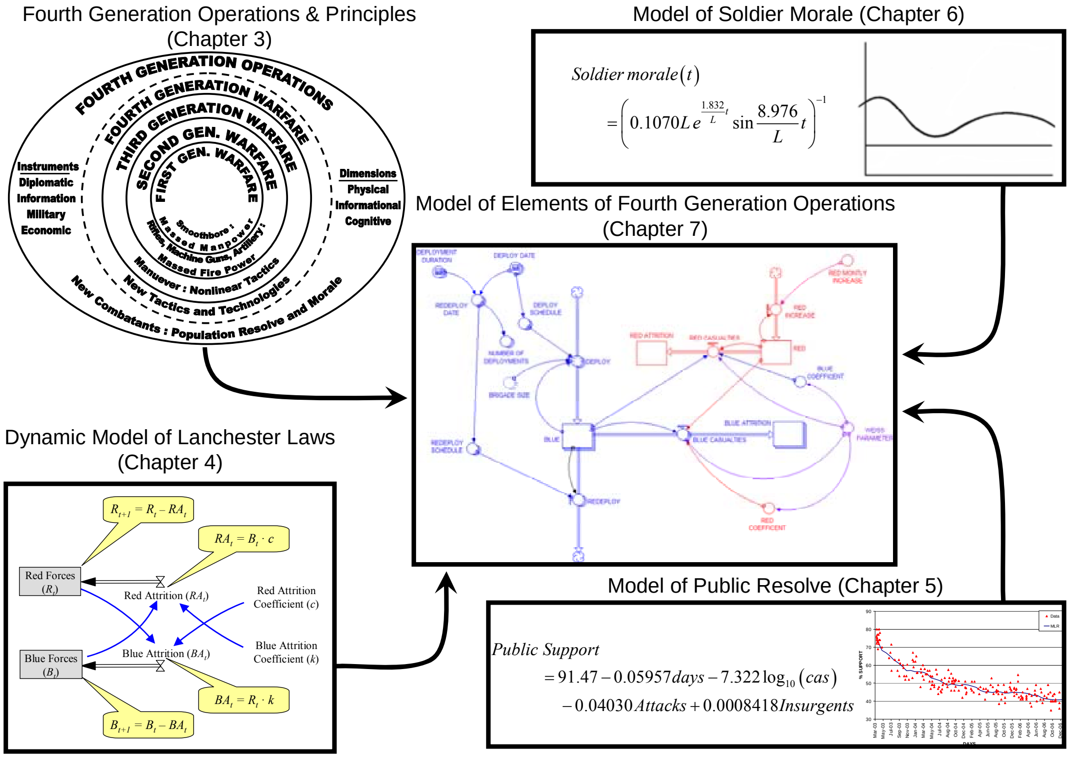


Figure I-1: Framework of Research

Specifically, the third chapter introduces the concept of fourth generation operations. Assuming that fourth generation operations is an outgrowth of fourth generation warfare, the dissertation next develops and identifies the principles required for this type of conflict. Thus, the principles of fourth generation operations are formed and examined. These principles are based on the current principles of war and principles of joint operations, along with discussions of the principles of counterinsurgency warfare. This chapter addresses the first two principal objectives.

Chapter 4 develops a framework using the Lanchester Laws in a system dynamics model with events. Two models of the Lanchester Laws are compared. The first is a traditional discrete event simulation and the other is a system dynamics model. Comparisons of the modeling techniques are presented through the implementation of an excursion where the forces are fatigued.

The fifth chapter presents a format to understand the perception of the ongoing operations in both Afghanistan and Iraq. Specifically, the public resolve for the conflict is analyzed. Models for the public resolve are created and evaluated based on linear and non-linear modeling techniques. The objective was to construct a theoretical modeling framework of public resolve. The framework was founded on empirical evidence of key factors influencing the public resolve. This chapter contributes to the public resolve portion of the third principle objective.

Chapter 6 presents a theoretical modeling framework of combat spirit. Several factors which impact the framework are discussed. The chapter includes an application of the modeling framework. The notional morale of each brigade and battalion that have deployed into Iraq is presented and combined to produce the notional morale for the United States Army and the United States Marine Corps (USMC). An excursion based on the impact of multiple deployments was also presented. This chapter completes the third principle objective of the research.

The seventh chapter combines the previous chapters to build a notional model of elements of fourth generation operations which evaluates the public resolve of the conflict and the morale of the troops. This model is represented within a system dynamics framework. The model is then verified and validated to build confidence in the model. Two demonstrations of the model's utility conclude the chapter. This completes the fourth and final principle objective of the research.

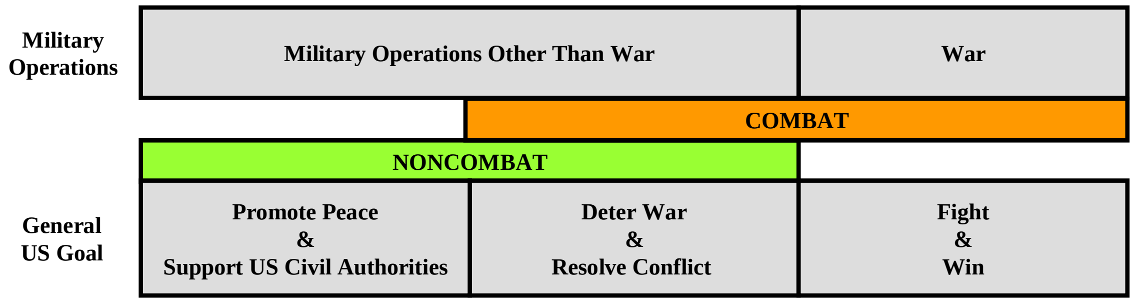
The final chapter provides a summary of the objectives and contributions to the field, and suggestions for future research.

II. Literature Review

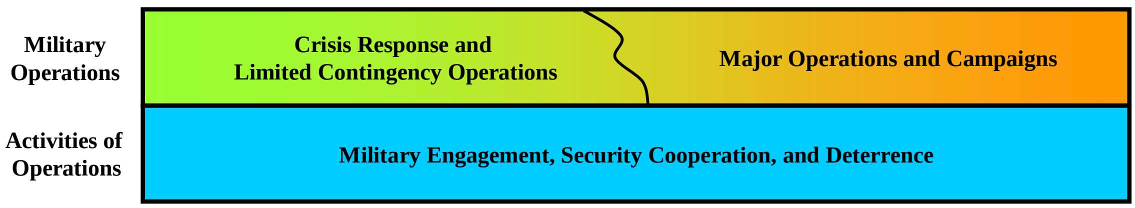
This chapter presents a summary of the literature that underpins this research. The first section describes fourth generation warfare. The review next identifies the principles used within current conflicts. The concept of a strategic level model is then introduced. The areas of discrete event simulation and system dynamics are introduced along with some examples of how these tools have been applied to national security problems. The Lanchester Laws are also discussed and illustrated with some examples and explanations. This review is followed by a discussion on the research previously accomplished to model the impacts of the will-to-fight, morale and combat spirit. Next, a discussion on data fitting is provided; specifically logistic regression and overdispersion are introduced. Control theory is the final area introduced in the literature review.

Fourth Generation Warfare

Joint Warfare of the Armed Forces of the United States: JP 1 defines military operations other than war (MOOTW) as "situations short of war that require the use of US military forces" (JP 1, 2001, p. III-8). In September 2006, *Doctrine for Joint Operations: JP 3-0*, dated September 2001 was reissued as *Joint Operations: JP 3-0*. Several changes were made in the document including the deletion of the term MOOTW. By removing this phrase from joint vocabulary, several modifications were made to JP 3-0. To begin, the range of military operations lost the dichotomy of war and MOOTW. The old and new paradigm is illustrated in Figure II-1.



Range of Military Operations from JP 3-0, 10 Sep 01



Range of Military Operations from JP 3-0, 17 Sep 06

Figure II-1: Range of Military Operations (adapted from JP 3-0, 2001 & 2006)

Figure II-1 demonstrates how doctrine had previously defined the range of military operations as discontinuous. The US goals were associated to the methodological approach of conflict. The new paradigm is a continuation from limited crisis response to full-scale major campaigns. Additionally, the new perspective states that all operations require military engagement, security operations, and deterrence.

An additional change to joint operations is the phasing of these operations. JP 3-0, dated September 2001 defined four phases of a joint campaign. The first phase was to deter and engage the enemy while the crisis is developing (JP 3-0, 2001, p. III-19). The second phase was to seize the initiative. Both combatant and noncombatant operations can be utilized to achieve the access to the region of operations required by subsequent phases (JP 3-0, 2001, p. III-20). The third phase of operations was to decisively defeat the enemy (JP 3-0, 2001, p. III-21). This was also known as the conflict or combat phase of operations. The final phase of operations was the transition to a selfsustaining peace (JP 3-0, 2001, p. III-21). This phase was additionally referred to as post-hostilities. The phases and typical associated goals are portrayed in the top portion of Figure II-2.

No clear break existed between phase three (decisive operations) and phase four (transition) within JP 3-0 dated September 2001. For example, when there was no official cessation of hostilities, or the complete defeat and destruction of the enemy, the operations existed between phases three and four. It has been suggested that conflict in OPERATION ENDURING FREEDOM and OPERATION IRAQ FREEDOM may be judged to be in the 'between' phase or 'phase 3.5.'

JP 3-0 dated September 2006 expanded the phases of joint operations to six phases. A new phase was added prior to the crisis being defined and deterred. This new phase, phase 0, shapes the operational environment through appropriate prevention and preparation. Additionally, a new phase was added in the gap previously described between phases three and four. This is now referred to as the stabilization phase of JP 3-0 dated September 2006. The final phase remains a transition of power to the civil authorities and redeployment of the military. The phases and typical associated goals are portrayed in Figure II-2.

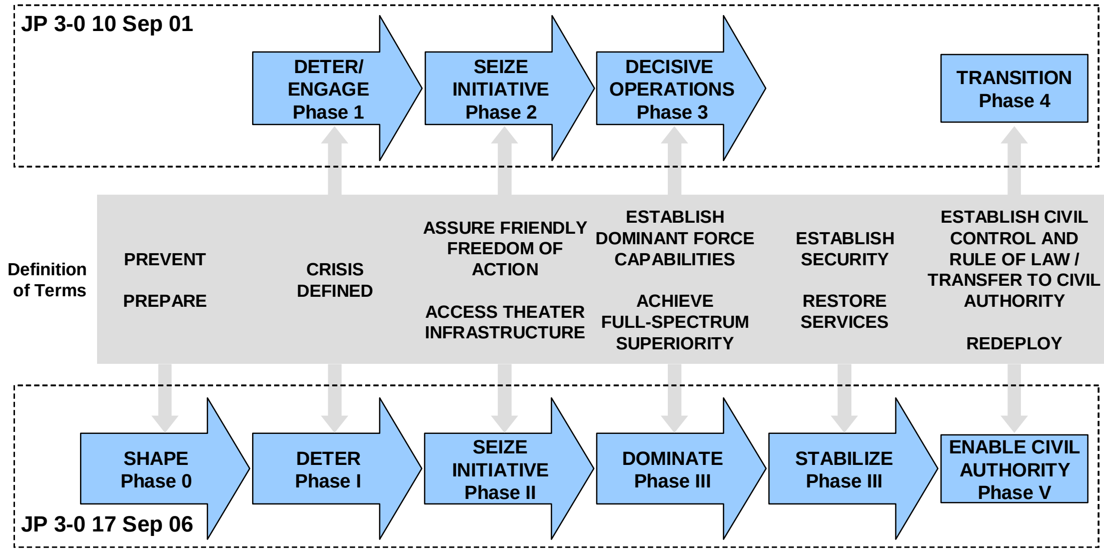


Figure II-2: Phases of Joint Operations (adapted from JP 3-0, 2001 & 2006)

In 2003, the United Kingdom's Ministry of Defence (UK/MOD) Joint Doctrine and Concept Centre released the study, *Strategic Trends*, which is a view of what the world may look like for the next 30 years. The study looked at seven different dimensions: Physical, Social, Science and Technology, Economic, Legal, Political and Military (*Strategic Trends*, 2003, para. 2). The military dimension stated three types of armed conflict which currently exist and will continue to exist. *Interstate conflict* is conflict between nations. *Intrastate conflict* is conflict within a nation to include domestic terrorism, insurgencies and civil war. The final type of conflict is *international terrorism*, which is defined as "between non-state actors and foreign states" (*Strategic Trends*, 2003, para. 7.2). These three types of conflict are used here to establish a common set of terms for this dissertation.

The following is a review of each of these three types of conflict and discussion regarding the likelihood that the United States of America will be involved in each type of conflict in the first part of the 21st century. This discussion is followed by an introduction to fourth generation warfare.

The National Intelligence Council (NIC), which is responsible for the strategic thinking of the United States Intelligence Community, commissioned the 2020 project to take a broad and long term view of future threats. An outcome of this project is the 2004 document entitled, *Mapping the Global Future: Report of the National Intelligence Council's 2020 Project*. This document follows in the footsteps of the NIC's 2015 project which resulted in the publication *Global Trends 2015: A Dialogue about the Future with Nongovernment Experts*. These two documents present the NIC's vision of the global environment. They include proposed alternate futures which are used for debate and discussion of both current and expected trends. The documents also include a discussion of significant discontinuities which describe the outlier events that could change the overall trends. The NIC discounts the claim that interstate conflict will occur.

> *The likelihood of great power conflict escalating into total war in the next 15 years is lower than at any time in the past century, unlike during previous centuries when local conflicts sparked world wars.* (*Mapping the Global Future*, 2004, p. 14)

The UK/MOD agrees that the future is unlikely to hold much interstate conflict for three reasons (*Strategic Trends*, 2003, para. 7.4). First, it is unlikely that a new superpower will emerge as in the Cold War, thus the United States will keep its current hegemony for the near term. Secondly, this superiority of the United States will discourage attacks by foreign countries; this includes attacking the allies and interests of the United States. Finally, the risks and penalties of interstate warfare are continually increasing. Simply put, countries can not afford to directly wage warfare against the United States (*Strategic Trends*, 2003, para. 7.4).

Nye, in *The Paradox of American Power*, appears to agree with the UK/MOD. "The closest thing to an equal that the United States faces at the beginning of the twenty first century is the European Union" (2002, p. 29). Nye justifies this remark by showing the economy of the European Union is roughly equal to the United States economy. Further, the European Union has a larger population and larger share of the world exportation of goods than the United States. Additionally, the European Union has already begun to challenge the United States economically with the Euro and by countering United States sanctions against Cuba and Iran (Nye, 2002, p. 30).

In considering any near to mid-term peer, the threat from China must be acknowledged. "The United States is much more likely to go to war with China than it is with any other major power"; however, "it is hardly inevitable that China will be a threat to American interests" (Betts, 2000, p. 17). The United States economy is twice that of China; only with strong growth will China's economy be equal by 2020 (Nye: 19). Nye therefore suggests the most likely conflict with China would occur over Taiwan and not from China challenging the United States to be the dominant power in East Asia (2002, p. 22). While it is a possibility that war could erupt with China over Taiwan (or perhaps North Korea), both sides would suffer greatly.

In 2003, Barnett wrote an article in *Esquire* magazine entitled "The Pentagon's New Map." This article was expanded in Barnett's 2004 book by the same name. Barnett reinforces the contention that state-on-state wars are a condition of the past (Barnett, 2004, p. 85). He claims "when wars occur now, they are almost exclusively internal wars, where some subsection of a state wishes to break off from the whole or where social violence between groups within a state erupts into full-blown civil war" (Barnett, 2004, p. 85). This views lead to the discussion of intrastate conflict.

The UK/MOD compiled data from the Peace Science Society's Correlates of War Project dataset. Figure II-3, presents the number of interstate and intrastate conflicts from 1946-1995 complied by UK/MOD.

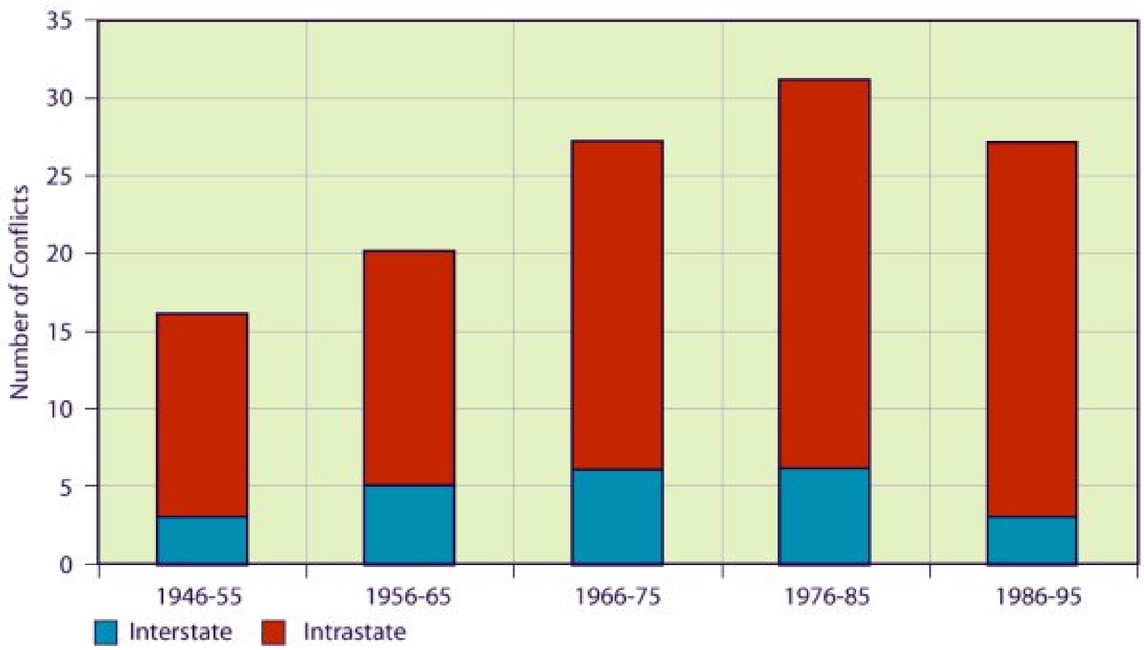


Figure II-3: Number of conflicts from 1946-1995 (*Strategic Trends,* 2003, Chart A)

This data shows how interstate conflict remains low and constant for each ten year period; however, the number of intrastate conflicts has been increasing. *Strategic Trends* claims the increase in intrastate conflict results from "independence movements, separatist nationalism, and surrogate superpower conflict" (*Strategic Trends*, 2003, para. 7.3).

The United States involvement in the number of conflicts from 1946-1995 was found by analyzing the Correlates of War Projects dataset version 3.0. These data include the United States in the following three interstate conflicts: Korea-1950, Vietnam-1965, and the Gulf War-1991 (Sarkees, 2000, p. 134). The United States was involved in five intrastate conflicts during that time period: Lebanon-1958, Vietnam-1961, Laos-1964, Cambodia-1970, and Somolia-1992 (Sarkees, 2000, p. 139). The UK/MOD sees the likelihood of intrastate warfare increasing as globalization impacts the culture of non-globalized countries (*Strategic Trends*, 2003, para. 7.6). The pre 9/11 trend was that the United States was involved in such intrastate conflicts at a rate of one per decade. There is no reason to expect this trend will do anything but increase with the current Global War on Terrorism.

Barnett states that during the mid-1990's the Pentagon was developing war plans for combat against a mythical asymmetric near-peer scenario (Barnett, 2004, p. 93). Barnett claims this asymmetrical threat comes from transnational terrorists, not from any nation or state whose people or assets can be directly attacked. This leads the discussion to the final type of conflict expected by the UK/MOD, international terrorism.

The United States is currently involved in the Global War on Terrorism, the 'Long War'. As such, the first part of the 21st century must include the United States combating international terrorism. However, many definitions for terrorism exist (Wentz & Wagenhals, 2004, p. 6). The UK/MOD's *Strategic Trends* defines terrorism as armed conflict between "non-state actors and foreign states" (*Strategic Trends*, 2003, para. 7.2). The types of non-state actors were categorized and presented in Table II-1.

Table II-1: Potential Non-state Adversaries (*Strategic Trends*, 2003, Table C)

Sectarian	Obsessionalists	Militarists	Profiteers	Proliferators
Tribalists Religious denominators Nationalists Insurgents Revolutionists Warloads Dissidents Militants Gangs	Vigilantes Single movement issues Cults Sects Radicals Mentally unstable individuals Anarchists Dissidents Militants Instigators	Mercenaries Extreme right paramilitaries Private military companies	Cartels Criminals Opportunists Pirates	Of Information Of Technology Of Weapons

The UK/MOD provides a very broad definition of terrorism which includes five different factions: religious, fixated, militaristic, exploiters for profit, and proliferators. These categorizations include areas which are excluded in the definitions of terrorism used by the United Nations and the United States. Wentz and Wagenhals state the United Nations defines terrorism as (2004, p. 6):

> *A unique form of crime. Terrorist acts often contain elements of warfare, politics and propaganda. For security reasons and due to the lack of popular support, terrorist organizations are usually small, making detection and infiltration difficult. Although the goals of terrorism are sometimes shared by wider constituencies, their methods are generally abhorred.* (2004, p. 6)

The United Nations and UK/MOD both have different definitions than the United States definition of terrorism. The *National Security Strategy* defines terrorism as

> *Premeditated, politically motivated violence perpetrated against innocents.* (2002, p. 5)

The *National Security Strategy* definition is the basis of the following definitions from the Department of Defense, Department of State and Department of Homeland Security.

> **U.S. Department of Defense:** *The calculated use of unlawful violence or threat of unlawful violence to inculcate fear; intended to coerce or to intimidate governments or societies in the pursuit of goals that are generally political, religious, or ideological* (JP 3-07.2, 1998, p. I-1).
>
> **U.S. Department of State:** *the premeditated, politically motivated violence perpetrated against noncombatant targets by subnational groups or clandestine agents, usually intended to influence an audience* (Title 22 of the U.S. Code, Chapter 38, Section 2656f(d)).
>
> **U.S. Department of Homeland Security:** *Any premeditated, unlawful act dangerous to human life or public welfare that is intended to intimidate or coerce civilian populations or governments* (*National Strategy for Homeland Security*, 2002, p. 2)

The common theme is that terrorism is a premeditated form of violence used to insight fear to attain a goal, objective, or program. No matter the specific definition, terrorism will be a focus for the Department of Defense, Department of State, and Department of Homeland Security for the first part of the 21st century. However, even with the multiple definitions, the specifics of terrorism are nebulous.

These nebulous definitions of terrorism are subsumed in the term violent non-state actors (VNSA) used by Thomas, Kiser, and Casebeer in their several technical reports and their book, *Warlords Rising: Confronting Violent Non-State Actors*. The VNSA does not abide by Clausewitz's concept of Trinitarian war (Thomas & Kiser, 2002, p. 74). The concept of Trinitarian war assumes the major three elements of war are political leadership, the army and the population (Thomas & Kiser, 2002, p. 74). VNSAs do not follow this paradigm and instead reflect pre-nation state politics. Additionally, VNSAs employ tactics which are "asymmetric, including violent crimes, guerrilla operations, terrorism, and in some rare cases, cyber warfare" (Thomas & Kiser, 2002,

p. 75). These tactics are not typical of the modern army. This concept of a VNSA may be a better means to understand the enemy faced in current and future conflicts.

In October 1989, Lind, Nightengale, Schmitt, Sutton and Wilson authored "The Changing Face of War: Into the Fourth Generation." Their article, which was simultaneously published in both *Marine Corps Gazette*, and *Military Review*, coined the term *Fourth Generation Warfare*.

Lind *et al.*, maintain that there have been three generations of modern warfare. The first generation began with the employment of the smoothbore musket. This technology required the tactics to be changed to create a more effective army. Specifically, armies lined up to produce a high rate of fire (Lind *et al.*, 1989, p. 2).

The second generation of modern warfare also began as a response to technological changes: the invention of the "rifled musket, breechloaders, barber wire, machine gun, and indirect fire" (Lind *et al.*, 1989, p. 3). These new weapons defeated the lines and columns tactics of first generation warfare. In second generation war, artillery and massed firepower were used to overcome infantry and massed manpower. Both the first and second generations of warfare were overall linear in nature (Lind *et al.*, 1989, p. 3).

The third generation of modern war is embodied in the idea of blitzkrieg or maneuver warfare. Although the technology continued to increase, the shift of tactics came from a change in ideas of warfare (Lind *et al.*, 1989, p. 4). The difference of tactics enabled the Germans to better command and control their troops through the effective and efficient implementation of technologies (radio and tanks) readily available to all the allies. The attacker planned to bypass and cut-off the defender, causing the defender to collapse due to a lack of access to command and logistics.

The mechanism for transition for each of the previous three generations of warfare was improvements in technology or ideas (Lind *et al.*, 1989, p. 4). Similarly, a change in technology or ideas results in the fourth generation of warfare. Several elements of the previous three generations are expected to be present and improved upon in the fourth generation. First, the independence of the individual combatant has increased with each generation. The expectation of the commander's intent may directly translate into the mission order (Lind *et al.*, 1989, p. 4). Second, decreasing the reliance on the logistic train, forces the combatants to increase their reliance on the enemy's resources and territory (Lind *et al.*, 1989, p. 4). Third, maneuver warfare continues to be exploited (Lind *et al.*, 1989, p. 4). Finally, the ability to cut-off the enemy may be improved such that the enemy is attacked internally. Lind *et al.* assert that "targets will include such things as the population's support for the war and the enemy's culture" (1989, p. 5).

Changes of technology creating fourth generation warfare was felt to lead to improved weapons which may cause the individual combatant to have the military strength and value an order of magnitude greater than seen in previous generations. Unfortunately, in 1989, the authors claim, "the current American research, development, and procurement process may simply not be able to make the transition to a military effective fourth generation of weapons" (p. 8). Currently, the technology grows significantly faster than the DOD acquisition process can maintain. This is evident by Moore's Law which states that the number of transistors on a chip will double every two years; however, the DOD acquisition process takes significantly longer (Moore, 1965, p. 2). For example, the F-22 took over twenty years from concept to an operational capability.

A change of ideas creating the fourth generation of warfare may also be a possibility (Lind *et al.*, 1989, p. 8). Lind *et al.*, state “the genesis of an idea-based fourth generation maybe visible in terrorism” (1989, p. 8). This does not imply that terrorism is the fourth generation of warfare; just some of the elements of terrorism may be present in the fourth generation of warfare. Some of these elements include how terrorism attacks the enemy internally to cause the enemy to collapse. In addition, terrorists use the strength of a free society’s freedom and openness as a weapon (Lind *et al.*, 1989, p. 8-9). Terrorists can wage their warfare while being protected by the very laws of their enemy. This enables the terrorist to be hidden within the society until the moment of attack. Terrorist actions are able to bring the combat to the population directly, bypassing standing armies. An additional element is that the terrorists are able to live off the land, perhaps in the land of his enemy, until an attack. A final element of terrorism which may translate into the fourth generation of warfare is that the material of conflict can be far cheaper than in previous generations of war. As an example, Lind *et al.* note a third generation stealth bomber costs multiple millions of dollars, whereas a terrorist stealth bomber is an average looking car, possibly stolen, filled with explosives (1989, p. 10).

Münkler, in his article entitled “The Wars of the 21st Century,” agrees that the next generation of warfare may include a demilitarization of war.

> *21st century wars will be fought only partially by soldiers and not against traditional military objectives. Thus a future objective will be the will or morale of the population and not just the standing army.* (2003, p. 18)

Münkler continues by stating the wars of the 21st century will not “be a linear extension of the trends of the twentieth century” (2003, p. 9). Münkler statement suggests that fourth generation warfare may not simply be the next step in evolution of war, but a shift to a new paradigm of warfare.

In a 1994 article entitled “The Evolution of War: The Fourth Generation,” Hammes provides five tactical traits inherent in fourth generation warfare (p. 44):

- *Be fought in a complex arena of low-intensity conflict*
- *Include tactics/techniques from earlier generations*
- *Be fought across the spectrum of political, social, economic, and military networks.*
- *Be fought worldwide through these networks*
- *Involve a mix of national, international, transnational, and subnational actors* (p. 44).

These traits can be seen in the conflicts occurring within Iraq and Afghanistan.

In 2004, Lind revisited the four generations of war in light of the post 9/11 environment and the military actions in Afghanistan and Iraq. Lind states that in the fourth generation of warfare the “state has lost its monopoly on war” (2004, p. 13). Fourth generation war has also returned to a warfare of cultures and is no longer solely a warfare of states. The tactics of the evolving fourth generation warfare are not new. A number of the tactics are standard guerrilla tactics. Additional tactics are “classic Arab light cavalry warfare carried out with modern technology” (Lind, 2004, p. 16). Lind reiterates, the warfare in Iraq is not yet fourth generation warfare.

Hammes disagrees with Lind stating the "Fourth generation warfare, which is now playing out in Iraq and Afghanistan, is a modern form of insurgency" (2005, p. 1). Hammes continues by explaining this type of warfare is the only kind that the United States has lost and the enemy knows this. Hammes suggests the United States has lost such conflicts three times: in Vietnam, Lebanon, and Somalia (2005, p. 2).

This idea of insurgency is not new; Münkler suggests Mao Tse-tung used a deceleration of the course of events successfully by means of guerilla warfare (2003, p. 7). The insurgency method of decelerating events is used against an enemy which is superior in technology and organization. A technologically and organizationally superior adversary accelerates the warfare to obtain the decisive battle. However, the decisive battle of the Napoleonic era is meaningless in the fourth generation of war (Hammes, 2005, p. 2). Guerilla warfare makes the enemy pay the price of attempting acceleration until it becomes unaffordable (Münkler, 2003, p. 8).

> *The dramatic superiority the US military apparatus has achieved over all potential enemies in the last two decades is largely due to its capacity to exploit the various opportunities for accelerating the pace at the different combat levels* (Münkler, 2003, p. 8)

This asymmetry forces an enemy to evolve to an asymmetric insurgency approach.

Fadok, in a School of Advanced Aerospace Studies Thesis, wrote about controlling the pace of the battle. He explains that Mao Tse-tung used a protracted war to defeat the Imperial Japanese (Fadok, 1995, p. 19). Fadok illustrated the point that controlling the pace of the conflict wins the war with a basketball analogy. In his example, a team which is known for the 'fast break' style of play is playing a team which is not suited for that style of game; perhaps better at a 'run and gun' style. Fadok states that typically the fast break team continues to increase the pace of the game until it paralyzes the other team. However, the ‘run and gun’ team may be able to slow down the pace of the game. When this occurs, the players and fans of the ‘fast break’ team gets restless which allows the ‘run and gun’ team the possibility to win. Fadok continues by stating the “analogy seems to apply even better when, as in war, we remove the time clock” (1995, p. 18). It is apparent that insurgency tactics are very capable of protracting the war against the fast paced United States forces operating in a conventional warfare mode.

Those countries oriented towards preserving life, “will ultimately be defeated by those who are ready to sacrifice themselves” (Münkler, 2003, p. 19). The first three generations of warfare attempted to preserve life of one’s own army while attritting or annihilating the enemy. The concepts of the potential fourth generation of warfare, such as sacrificing troops which is used as a key tactic, is often difficult for Western Nations to understand and thus is difficult to prepare successful defenses against.

Manwaring presents five fundamental concepts in “The New Master of Wizard’s Chess: The Real Hugo Chavez and Asymmetric Warfare”, which are required to prepare and defeat the fourth generation combatants. The five “educational and organizational imperatives” are summarized below (Manwaring, 2005, p. 48):

1. Military and civilian leaders at all levels of combat must understand how the fourth generation tactics achieve political ends

2. Civilian and military personnel must learn to work well with the media and coalitions

3. Leaders must grow the intelligence capabilities well beyond their current abilities

4. Since traditional peacekeeping operations will continually become hazardous, the peacekeepers must become effective warfighters

5. All civilian and military instruments of power must be working together to achieve the same end state (Manwaring, 2005, p. 48)

Manwaring warns that unless the five imperatives are incorporated into the United States strategies and doctrine, conflicts will end with unfavorable outcomes (2005, p. 48).

With fourth generation warfare reviewed, the next section discusses the principles of warfare.

Principles of Fourth Generation Warfare

> *To advance against the enemy's main force (objective), with the intention of destroying it (offensive), with the greatest numbers possible (mass and economy of force), with the least friction (co-operation), and in the shortest possible time (movement), so that we may take him unawares (surprise), without undue risks to ourselves (security)* – J. F. C. Fuller (Fuller, 1916, p. 5)

The current principles of war, while evolving from the dawn of conflict, are based on the eight principles suggested by Fuller in 1916. The eight strategical principles suggested by Fuller were; Objective, Offensive, Mass, Economy of Force, Movement, Surprise, Security, and Cooperation (1916, p. 3). (Strategic is now the modern term for strategical.) These are nearly identical to the principles of war found in today's US Joint doctrine. The principle of Simplicity was not included by Fuller. Additionally, the principles of Movement and Cooperation have been reworded to Maneuver and Unity of Command.

The strategical principles of war proposed by Fuller are immediately followed by nine considerations which must be acknowledged regarding the principles of war. These conditions are time, space, ground, weather, numbers, moral, communication, supply and armament (Fuller, 1916, p. 3). After a discussion of the eight principles and nine considerations, Fuller introduces the tactical principles of war. His three tactical principles of war are demoralization, endurance, and shock (Fuller, 1916, p. 18). These three principles are required to develop the four stages of attack; approach, demoralization, decision, and annihilation (Fuller: 20).

The principles of war and MOOTW from Joint Publication 1 (2000), are discussed to assist in developing the principles of fourth generation operations. Table II-2 summarizes the principles of war from JP 1. Table II-3 presents the principles of MOOTW from JP 1.

Table II-2: Principles of War (JP 1, 2000, Appendix B)

Principle	**Definition**
Objective	Direct every military operation toward a clearly defined, decisive, and attainable objective
Offensive	Seize, retain, and exploit the initiative
Mass	Concentrate the effects of combat power at the place and time to achieve decisive results
Economy of Force	Allocate minimum essential combat power to secondary efforts
Maneuver	Place the enemy in a position of disadvantage through the flexible application of combat power
Unity of Command	Ensure unity of effort under one responsible commander for every objective
Security	Never permit the enemy to acquire unexpected advantage
Surprise	Strike the enemy at a time or place or in a manner for which it is unprepared
Simplicity	Prepare clear, uncomplicated plans and concise orders to ensure thorough understanding

Table II-3: Principles of MOOTW (JP 1, 2000, Appendix C)

Principle	Definition
Objective	Direct every military operation toward a clearly defined, decisive, and attainable objective
Unity of Effort	Seek unity of effort in every operation
Security	Prevent hostile factions from acquiring a military, political, or informational advantage
Restraint	Apply appropriate military capability prudently
Perseverance	Prepare for the measured, protracted application of military capability in support of strategic aims
Legitimacy	Committed forces must sustain the legitimacy of the operation and of the host government, where applicable

Both the principles of war and MOOTW share the concepts of Objective, Security, and Unity of Command. The principles of MOOTW refer to Unity of Command as Unity of Effort since it must include civil, military and other agencies.

The 2006 update to JP 3-0, changed the principles of war by creating the term principles of joint operations, this change has also been reflected in the 2007 update to JP-1 entitled, *Doctrine for the Armed Forces of the United States*. These principles are a merger of the principles of war and MOOTW. All nine of the original principles of war are included with only minor changes. Additionally, the three unique principles of MOOTW were added. The new JP 3-0 redefines the principle Restraint to "limit collateral damage and prevent the unnecessary use of force" (JP 3-0, 2006, p. A-3). The definition of Perseverance has been changed to "ensure the commitment necessary to attain the national strategic end state" (JP 3-0, 2006, p. A-4). Whereas, the definition of Legitimacy is to "develop and maintain the will necessary to attain the national strategic end state" (JP 3-0, 2006, p. A-4). The principle of Perseverance includes the concepts that all instruments of power (political, military, informational and economic) may be required through the duration of a long conflict. While the principle of Legitimacy may include influences from foreign nations, indigenous government, indigenous civilian population, and the participating forces. Figure II-4 illustrates the relationship of the principles of joint operations.

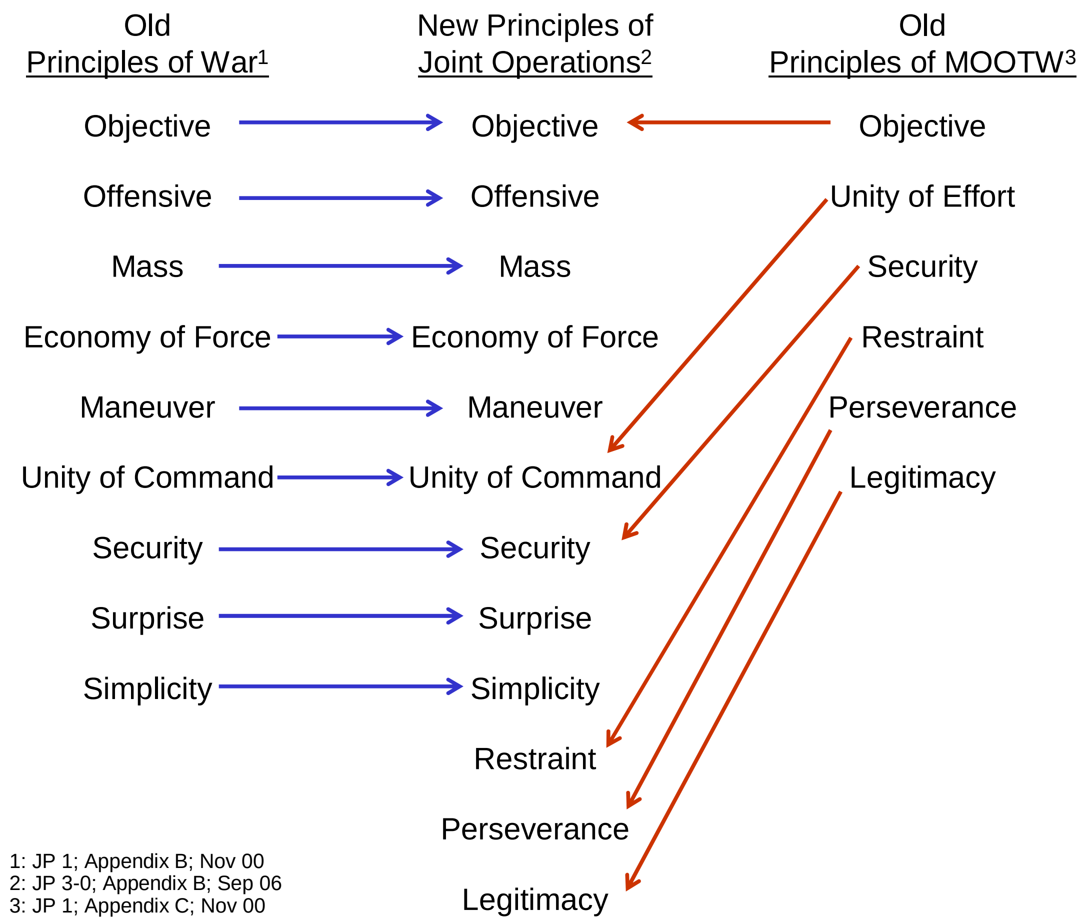


Figure II-4: Principles of Joint Operations

The concept of fighting a counterinsurgency is related to what has been occurring in both Iraq and Afghanistan. For this reason, it is important to insure the principles, laws, and deductions, of counterinsurgency are encapsulated within the principles of joint operations and specifically fourth generation operations. Galula considered the requirements to fight a counterinsurgency in his text, *Counterinsurgency Warfare: Theory and Practice*. He proposed six principles of waging a counterinsurgency.

First, initiative is required (Galula, 1964, p. 82). He defines this as an offensive strategy which tracts as Offensive from the principles of joint operations.

The second principle suggested by Galula, is “full utilization of the counterinsurgent’s assets” (1964, p. 83). Galula explains that all assets must be applied to include propaganda (informational), economic, military and administrative (political). All the national instruments of power or Diplomatic, Information, Military and Economic (DIME) must be employed. Therefore, this is equivalent to the Mass principle, only in the proper scale. Galula realizes that *all* instruments of power available to a nation-state must be utilized to defeat an insurgency.

Galula’s third principle is Economy of Force (1964, p. 81). Economy of Force is one of the Joint doctrine’s principles of war.

Irreversibility is the fourth principle suggested by Galula (1964, p. 82). The example and definition provided by Galula suggests this is similar to the Perseverance principle of joint operations. The example Galula provides is when the counterinsurgent’s military gains the confidence and support of the population, the insurgent’s power will be difficult to rebuild (1964, p. 82). Additionally, once leaders within the population emerge and support the counterinsurgency, they can be trusted because the leaders have too much to lose if the insurgency returns.

Galula’s fifth principle is “To Command is to Control” (1964, p. 85). This is the principle of Unity of Command.

Galula's final principle is Simplicity, which is again a direct classic principle of war (1964, p. 84). Figure II-5 relates the principles of war and principles of MOOTW to the principles of counterinsurgency suggested by Galula.

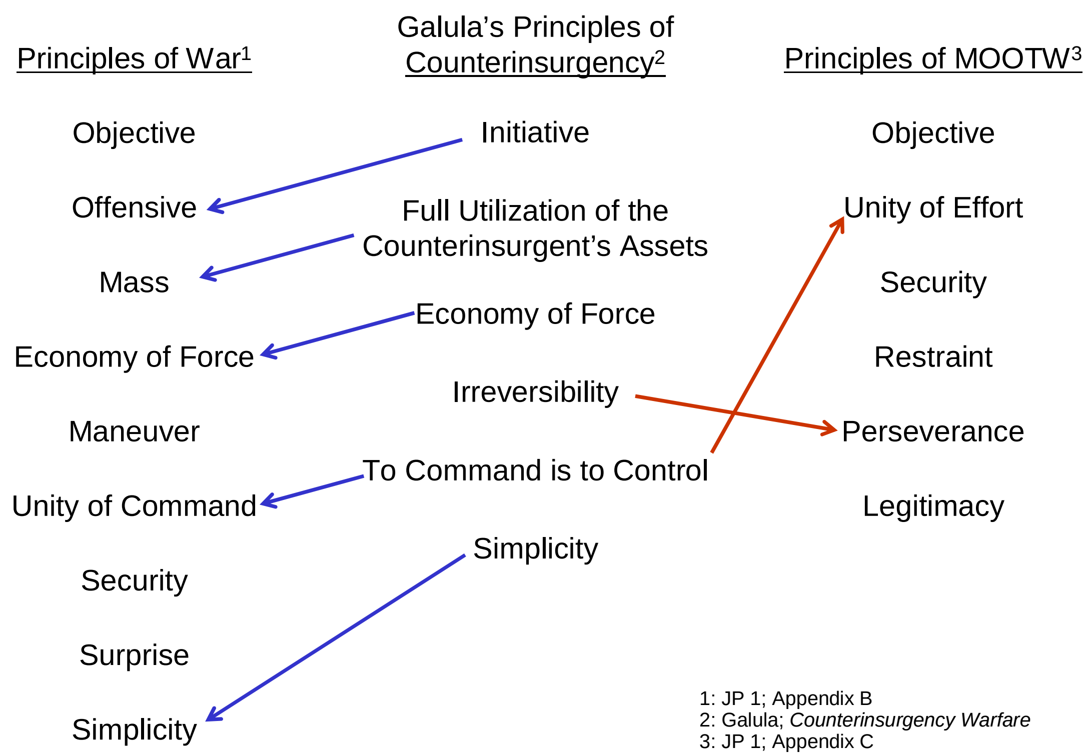


Figure II-5: Galula's Principles of Counterinsurgency

Galula also presents four laws which must be followed to win a war against insurgents:

> *The first law: The support of the population is as necessary for the counterinsurgency as for the insurgent* (Galula, 1964, p. 74)
>
> *The second law: The support is gained through an active minority* (Galula, 1964, p. 75)
>
> *The third law: Support from the population is conditional* (Galula, 1964, p. 78)
>
> *The fourth law: Intensity of efforts and vastness are essential* (Galula, 1964, p. 79)

The first three laws Galula proposes encompass the idea that the population's perception of the conflict is extremely important to the success of the operation. These laws support the joint operations principle of Legitimacy as well as recognizing the importance of public opinion. Galula proposes persuading a minority to gain the support of the entire population. Additionally, the population's support is always conditional. The fourth law differs in that it involves the principles of Mass and Economy of Force. In addition to the four laws, the third law has four important deductions.

1) *Effective political action on the population must be preceded by military and police operations against the insurgent political organizations*

2) *Political, social, economic, and other reforms, however much they ought to be wanted and popular, are inoperative while the insurgent still controls the population*

3) *The counterinsurgency needs a convincing success as early as possible in order to demonstrate that he has the will, the means, and the ability to win*

4) *The counterinsurgency cannot safely enter into negotiations except from a position of strength, or his political supporters will flock to the insurgent side* (Galula, 1964, p. 78-79)

The first two deductions support the principle of Legitimacy. The third deduction requires both the principles of Mass and Objective. The third deduction again suggests that the population's perception is significantly important. The final deduction involves the principles of Perseverance and Irreversibility. Traditionally, counterinsurgency tactics have involved limiting the opposition's area of operations and undermining the insurgents' support within a nation. Containment and denial is problematic for today's transnational insurgency. The insurgencies may have cells throughout the world, which, enhanced by modern communication, can communicate in ways previously unimagined.

Hoffman and Taw, in their RAND publication *A Strategic Framework for Countering Terrorism and Insurgency*, give four elements critical to a successful counterinsurgency:

1. *An effective overall command and control structure*

2. *"Legitimizing" measures, taken by the government to build public trust and support, combined with antiterrorist legislation sensitive to public sentiments*

3. *Coordination within and between intelligence services*

4. *Collaboration among governments and security forces of different countries* (Hoffman & Taw, 1992, p. 3)

The first and fourth elements relate to the principles of Unity of Command. The second element is the MOOTW principle of Legitimacy. The third element is a combination of both the principles of Security and Unity of Command. This reinforces the requirement of these principles within proposed principles of fourth generation operations.

Dupuy suggests thirteen "Timeless Verities of Combat" in his book, *Understanding War* (Dupuy, 1987 p. 1). These are overarching principles that apply to all types of combat as oppose to the more limited scope of fourth generation operations, MOOTWs, or other specific combat variants. Dupuy's Verities of Combat are presented in Table II-4. A discussion on how the verity of combat is related to the principles of war and MOOTW is also included in Table II-4.

The verities of combat all have relations to the principles of war and the principles of MOOTW. As shown in Table II-5, all the principles of war and MOOTW are present within the verities of combat except for the MOOTW principle of Legitimacy.

The Joint Forces Staff College provides a collection of several countries' principles of war in *JFSC Pub-1: Joint Staff Officer's Guide*. Table II-6 is a summary provided by the Joint Forces Staff College.

Table II-4: Dupuy's Timeless Verities of Combat and Discussion

Verities of Combat	Discussion
1. *Offensive action is essential to positive combat results* (p. 1)	Similar to the principle of Offensive. If the combatant does not seize the initiative, the battle's objectives will not be obtained.
2. *Defensive strength is greater than offensive strength* (p. 2)	The defender maintains both the principles of Restraint and Mass
3. *Defensive posture is necessary when successful offense is impossible* (p. 2)	When the forces cannot be offensive, employing the principle of Economy of Force in a defensive nature is the only alternative.
4. *Flank or rear attack is more likely to succeed than frontal attack* (p. 3)	The principle of Maneuver insures the combatant attacks the enemy at the weakest position.
5. *Initiative permits application of preponderant combat power* (p. 3)	Galula's principles of counterinsurgency address the importance of initiative. This is contained within the principle of Offensive.
6. *Defenders' chances of success are directly proportional to fortification strength* (p. 4)	The ability of the defender to delay the attacker provides an opportunity to Mass and retain the principle of Security.
7. *An attacker willing to pay the price can always penetrate the strongest defenses* (p. 5)	With the proper leadership provided by the principle of Unity of Command, the associated Objective can be achieved with Perseverance.
8. *Successful defense requires depth and reserves* (p. 5)	The proper application of the reserves can shift the tide of the battle. This requires an understanding of the principle of Economy of Force
9. *Superior Combat Power Always Wins* (p. 6)	An outnumbered force can win the battle if the principles of Mass and Maneuver are combined to obtain superior combat power.
10. *Surprise substantially enhances combat power* (p. 6)	The principle of Surprise "has been proven to be the greatest of all combat multipliers" (p. 6).
11. *Firepower kills, disrupts, suppresses, and causes dispersion* (p. 7)	The nature of warfare causes significant friction. This friction is best countered by a strong command. Therefore, the principle of Unity of Command is required.
12. *Combat activities are always slower, less productive, and less efficient than anticipated* (p. 7)	"In war more than anywhere else things do not turn out as we expect . . . Perseverance in the chosen course is the essential counterweight" (Clausewitz, 1832/1964, p. 193).
13. *Combat is too complex to be described in a single, simple aphorism* (p. 7)	Since the nature of war is extremely complex, the principle of Simplicity attempts to bring the nature of the battle to the most simplistic form

Table II-5: Collection of the Various Principles of Warfare

	Principles of MOOTW	Principles of War	Fuller's Principles of War	Galula's Principles of Counter-insurgency	Hoffman & Taw's Principles	Dupuy's Verities of Combat	Principles of Joint Operations
Objective	X	X	X			1 & 7	X
Offensive		X	X	Initiative		1 & 5	X
Mass		X	X	Utilization of Assets		2, 6 & 9	X
Economy of Force	Restraint	X	X	X		2, 3, 6 & 8	X
Maneuver		X	Movement			4 & 9	X
Unity of Command	Unity of Effort	X	Cooperation	Command is Control	Command & Control: Collaboration	7 & 11	X
Security	X	X	X		X	6	X
Surprise		X	X			6	X
Perseverance	X			Irreversibility		7 & 12	X
Simplicity		X		X		13	X
Legitimacy	X				X		X

Table II-6: Mulinational Principles of War (JFSC Pub 1, 2000, Figure D-1)

United States	Great Britain Australia	Former Soviet Union "Principles of Military Art"	France	People's Republic of China
Objective	Selection & Maintenance of Aim			Selection & Maintenance of Aim
Offensive	Offensive Action			Offensive Action
Mass	Concentration of Force	Massing and Correlation of Forces	Concentration of Effort	Concentration of Force
Economy of Force	Economy of Force	Economy, Sufficiency of Force		
Maneuver	Flexibility	Initiative		Initiative and Flexibility
Unity of Command	Cooperation			Coordination
Security	Security			Security
Surprise	Surprise	Surprise	Surprise	Surprise
Simplicity				
	Maintenance of Morale	Mobility & Tempo, Simultaneous Attack on All Levels, Preservation of Combat Effectiveness, Interworking & Coordination	Liberty of Action	Morale, Mobility, Political Mobilization, Freedom of Action

Adapted from JP 1, FM 100-1, AFM 1-1, and FMFM 6-4, Military Review, May 1955, and Soviet Battlefield Development Plan

Strategic Level Modeling

In the first part of the 21st century we can anticipate the nation and its coalition partners will be involved in intrastate conflicts, often focused on combating international terrorism. As discussed earlier, an interstate war involving the US is highly unlikely in the early part of the century. Next, this research addresses how the principles of Joint Operations can be modeled to provide insight to current and future decision makers. This type of analysis is expected to be most effective at the campaign or the strategic level. Unfortunately, campaign models of the projected fourth generation warfare primarily exist as attrition based models of interstate conflict (Lanchester Law based models.)

Taylor and Lane state, "A campaign model can be defined as one that captures the full scope of a military campaign" (Taylor & Lane, 2004, p. 333). Additionally, Hughes, in his book *Military Modeling for Decision Making*, provides a definition of campaign models though an example:

> *…the defense of shipping in the Atlantic over an extended campaign, air-ground combat in a Major Regional Contingency, or the joint air campaign of missile and bomber attacks against Iraq in preparation for the ground campaign.* (1997, p. 6)

Compare this to the examples provided for single engagement models and battle or multiple-unit engagement models:

> *Single engagement models, such as submarine versus submarine, fighter versus bomber, or tank versus tank.*
>
> *Battle or multiple-unit engagement models, such as a naval task force versus combined air and submarine attackers, or an army divisional assault on a defending brigade, or a formation of air interceptors vectored by a fighter direction system to attack fighter-bombers who are conducting a strike.* (Hughes, 1997, p. 6)

Dupuy, in *Understanding War*, defines a hierarchy of combat. He defined the frequently used terms of war, campaign, battle, engagement, action, and duel. These terms are presented in the hierarchy given in Table II-7. This table summarizes the specifics on the duration, type or unit, and goal for each level of combat.

Table II-7: Hierarchy of Combat (Dupuy, 1987, Table 7-1 Page 67)

Level of Combat	Duration	Units Involved	Common Tread
War	Months – Years	National Forces	National Goals
Campaign	Weeks – Months	Army Groups or Field Armies	Strategic Goals
Battle	Days – Weeks	Field Armies or Army Corps	Operational Mission
Engagement	1 – 5 Days	Divisions – Companies	Tactical Mission
Action	1 – 24 Hours	Battalions – Squads	Local Objective
Duel	Minutes	Two Individuals, People or Mobile Fighting Machines	Local Objective

Dupuy states that the first level in the hierarchy is war, and war is conflict between nations or states (1987, p. 65). This statement must be expanded to include transnational terrorist organizations to capture fourth generation operations. Dupuy continues by stating that a war is fought for political or economic reasons. The next level in the hierarchy is a campaign, which is the first subdivision of a war. This is followed by a battle which is the clash of major forces with an operational objective. Engagement is the next level of warfare. An action is a specific event within an engagement. The final level of combat is the duel; which is the interaction between two entities of combat. This can be, for instance, between two tanks, two riflemen, or two aircraft. A man with a rocket propelled grenade (RPG) might dual a tank. Technically speaking, however, the rules of the duel (in the classic sense) are two equivalently armed combatants.

Dupuy further described the levels of combat by relating them to tactics, operations, and strategy. Figure II-6 presents a diagram relating how these concepts relate to the levels of combat. Additionally, the commanders for each level are presented.

	are a matter of	and are carried out by	under the command of
Single engagements	tactics	the smallest unit up to divisions and army corps	line officers
Battles	operations	army corps and armies	sub-commanders
Campaigns	strategy	armies, army groups, or entire branches of the service	the commander in chief
Military War		the entire armed forces: army, navy and air force	

Figure II-6: Relationship of Tactics, Operations, and Strategy (Dupuy, 1987, Figure 7-1 Page 69)

Air Force Instruction 16-1003 (AFI 16-1003), categorizes analytical models as one of four areas: campaign, mission, engagement and other. The definitions provided for each category follow, though no definition for 'other' existed in the AFI.

> *Campaign Model—A model that attempts to capture all important aspects of aerospace power over the duration of a conflict across an entire theater or theaters of operation in a force vs. force campaign length scenario.*
> (AFI 16-1003, 2006, p. 7).

Mission Model—A model that captures one or more interacting aspects of aerospace power during the course of representing an aerospace mission or missions by evaluating mission effectiveness against enemy forces in a few-on-few or many-on-many combat scenario. (AFI 16-1003, 2006, p. 8).

Engagement Model—A model that provides measures of effectiveness at the system level of representation by evaluating system effectiveness against enemy systems in a one-on-one or few-on-few combat scenario. (AFI 16-1003, 2006, p. 7).

Hill, Miller and McIntyre present the levels of combat and the models included in the Air Force Standard Analysis Toolkit at each level in their article "Applications of Discrete Event Simulation Modeling to Military Problems" (Hill, Miller & McIntyre, 2001, p. 782). This listing of types of models is commonly portrayed in a pyramid of models as shown in Figure II-7.

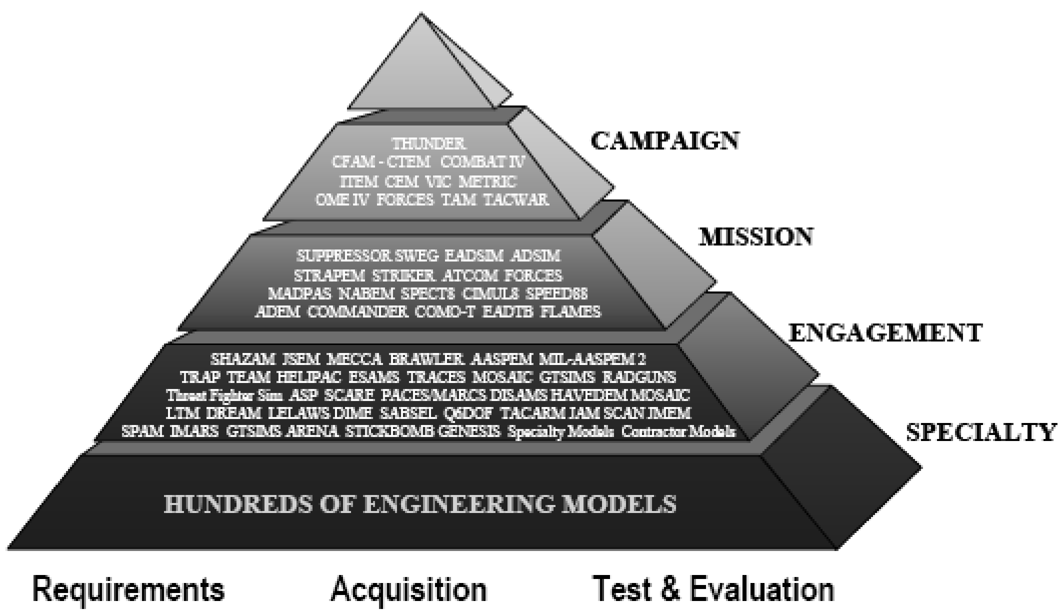


Figure II-7: Hierarchy of Models (Hill, Miller & McIntyre, 2001, Figure 1 Page 782)

It is a proposition of this research that the hierarchy of military modeling can be appropriately classified by how the model represents time. Engineering or system level models focus on instantaneous events. The instantaneous event needs only seconds to capture the impact and effect. An example is molecules flowing over a wing (resulting in lift) or the moments and forces on an aircraft during a weapon's release. This could also encompass Dupuy's duel.

An engagement model looks at time as a short series of events or actions. Such models account for time in minutes. Examples of engagement models include: the engagement of two aircraft in a basic fighter maneuver (i.e. dogfight) or a tank locating and shooting at an enemy's position. This covers both Dupuy's action and duel levels of combat.

A mission model is focused on the aggregation required to model in terms of hours of activities. Therefore, a mission model can capture the events of take-off, aircraft refueling, ingress towards the target, attacking the target, and finally returning to base. The mission model also includes the activities of the enemy's forces. These actions may include the surface-to-air lay down, air-to-air defenses, and target movement. A mission model is capable of modeling Dupuy's engagement and a single battle. This can be further seen as modeling multiple actions.

Campaign models continue this trend; time is represented as multiple days of missions and engagements. Therefore, the campaign model is aggregated to allow for multiple missions in a day over several days or months. This provides the ability to analyze the impacts of logistics and attrition over an extended time. A campaign model can capture the effects of larger battles and Dupuy's campaign.

A strategic model captures the impacts of battles and campaigns over months or years. This proposed definition of campaign and strategic models facilitates the ability to view the impacts of intrastate warfare, international terrorism, fourth generation warfare, or the 'long war.' Figure II-8 presents this hierarchy, along with the appropriate time measure. Figure II-9 relates Dupuy's levels of combat and the proposed hierarchy of combat models.

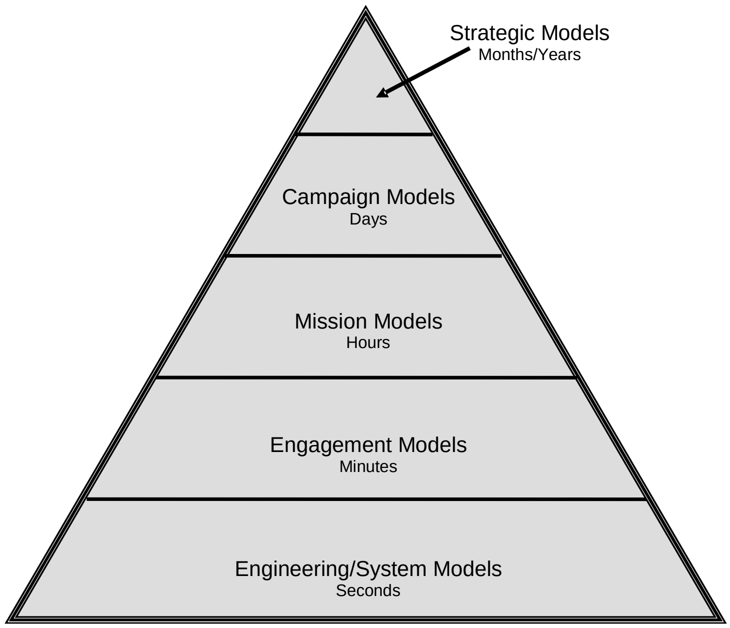


Figure II-8: Hierarchy of Combat Models

Dupuy's Level of Combat	Hierarchy of Combat Models	Old Paradigm: Fidelity of Forces	New Paradigm: Measure of Time
War	Strategy	Army on Army	Months/Years
Campaign			
Battle	Campaign	Force on Force	Days
Engagement	Mission	Many on Many or Few on Few	Hours
Action	Engagement	Few on Few or One on One	Minutes
Duel	Engineering	Components	Seconds

Figure II-9: Relationship of Level of Combat and Hierarchy of Combat Models

The traditional definitions of the hierarchy of models consider the level of detail and aggregation of entities as the defining attribute. This can be seen as the fidelity of forces within the model. The weakness of the traditional paradigm is that models which incorporate details of an adversary's decision process and the impacts of our actions over time is considered an engineering level model because of the detail required to model the influences of the adversary. Models of an adversary's decision making process obviously provide insight and support to the campaign and strategic plans and, as such, should be considered campaign/ strategic models. The descriptions of the hierarchy of combat models do not contradict the current hierarchy; however, they add the engineering and strategic level models and focus on the primary measurement of the event instead of the level of aggregation and the size/ type of entities. Therefore, both paradigms can and do exist simultaneously to describe combat models.

Discrete Event Simulation

Law and Kelton define discrete event simulation as "the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time" (2000, p. 6). Many of today's combat models can be characterized as discrete event simulations. These include THUNDER, STORM, CEM, TACWAR and JWARS, among others. (THUNDER and STORM are the leading campaign models used by the US Air Force. CEM is used by the US Army Center for Army Analysis. TACWAR is the official campaign model of the Joint Staff. JWARS is a next generation campaign model under development by Joint Forces Command).

Kelton, Sadowski and Sadowski suggest nine elements of discrete event simulations: Entities, Attributes, Resources, Queues, (Global) Variables, Statistical Accumulators, Events, Simulation Clock, and Starting and Stopping (2002, p. 24-28). An entity is the first common piece of a discrete event simulation. The entity is created by the user or the model. The entity has specific attributes which gives the entity individual characteristics. As the entity moves through the system, resources are expended. The waiting for, and consumption of, these resources creates queues within the system. Additionally, variables are globally changed within the system.

Statistical accumulators are used to measure the status of the attributes, variables, and queues. Events are the time that a change to variables, entities, and attributes occurs within the simulation. The time of the event is tracked by the simulation clock. This is not a continuous clock but a time sequential list of events. Finally, the simulation must have starting and stopping conditions.

Banks lists thirteen advantages of discrete event simulations (1998, p. 10-12). Ten of these thirteen advantages are inherit in modeling a system, regardless of the tool being used. However, three of Banks' advantages are more directly related to discrete event simulation as opposed to some other methodologies. First, discrete event simulations can compress and expand time. The time clock within a simulation can be altered to investigate specific events in great detail or increased so the impact over days/weeks/months/years can be investigated.

Next, discrete event simulations can be used to identify constraints. Simulations can reveal the bottlenecks within complex systems. This can assist in revealing the causes of delays. Discrete event simulation modeling and data collection of queues is specifically significant.

Finally, discrete event simulation can help visualize the interactions within the analysis. Most modern simulations have animation features which allow the users to visualize the events but generally require smaller time slices. The focus of a discrete event simulation, however, is generally the actions at the event instead of the entirety of the system.

As suggested earlier, most combat models have traditionally been implemented as discrete event simulations. The advantages and flexibility of discrete event simulations have allowed an array of applications of combat to be modeled by this approach, from the high fidelity engineering-level models to the lower-fidelity campaign-level models.

System Dynamics

Forrester defines a system as a "grouping of parts that operate together for a common purpose" (1968, p. 1-1). This grouping can include the parts, people, and/or resources required of the system. A system of combat might include the equipment, troops, leaders, and supplies of both sides of the battle. Sweetser states that "dynamics refers to change over time. System dynamics is, therefore, a methodology used to understand how systems change over time" (1999, p. 2). The system dynamics society defines system dynamics as the "methodology for studying and managing complex feedback systems" (SDS, 2006, p. 1).

Forrester discusses two types of systems, 'open' and 'feedback' (1968, p. 1-5). An open system takes inputs and produces an output that does not influence future inputs.

A feedback system, or closed system, uses the outputs of one cycle to affect inputs for future cycles of decisions. The feedback can be seen as positive feedback (where an action produces more actions) or negative feedback (where the system seeks a goal). Thus, a system with feedback is preferred when decisions are made by decision makers which rely on the past performance or can affect functions integral to future decisions. This is clearly a trait of combat. The modern commander is aware of the current position of troops, material, force strengths, and outcomes which are feedback from the previous time period of combat. Additionally, the current decision impacts future locations of troops and material and therefore future options and decisions.

A system dynamics model changes in a transient nature rather than at an event. This implies that the system is continuous in both states and variables. Thus, the rate of effectiveness is continuously changing over time rather than held at a constant until the next event which changes the rate occurs. A final attribute of system dynamics models is their non-linear nature; the model can capture effects which are more than additive.

The concepts of levels and rates drive system dynamics models. When a system is at rest, the levels are the amount of materials and supplies that are present (Forrester, 1961, p. 68). This might be viewed in a combat model as the number of troops, equipment, or material present at any point during the model. The rates are the instantaneous flows of materials and items rather than time stepped increments in discrete event simulations (Forrester, 1961, p. 69). The rates of flow can depend upon levels determined within the model. Additionally, information about the levels must be communicated to adjust the "valve" which controls the rate of flows within the model.

Figure II-10 is a representation of a system dynamics model of saving money with positive feedback presented by Kirkwood (2005, p. 10).

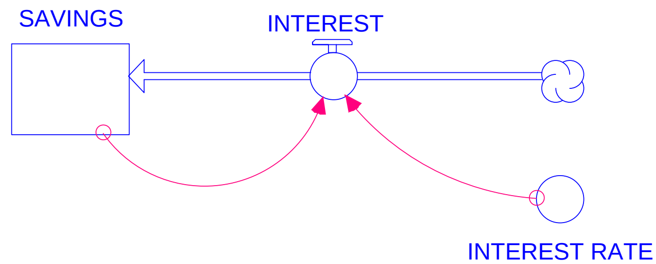


Figure II-10: System Dynamics Model of Savings

The Savings is a level and is indicated by a square container. Interest is a decision function that is represented by a valve. The valve controls the rate of flow into Savings from Interest which is represented as the double arrow. Finally, the Interest is dependent upon the current level of Savings and the Interest Rate. This dependency is identified by the single arrows. The Interest causes a rate to change the amount of the Savings. Assuming an initial Savings level of $100 and an Interest Rate of 5% per year, the positive feedback and growth of the system can be observed.

System dynamics models can easily be adjusted by the decision maker to test new and different scenarios (Sweetser, 1999, p. 1). This includes adding new linkages and feedback loops to the system. Additionally, system dynamics models are designed to model continuous processes rather than discrete events (Sweetser, 1999, p. 2). The flow of battle can certainly be seen as a continuous event.

System dynamics models are able to represent "softer" qualitative aspects, such as behavior. These aspects can be difficult to model in a discrete event simulation. Coyle states, "system dynamics, however and rightly, is strategic in orientation and it is often seen as necessary to introduce 'soft' variables" (2000, p. 227). Examples of these softer variables include: consumer satisfaction, chaos, suffering, and other human activities (Aracil, 1999, p. 5). For further information regarding the use of system dynamics to model the qualitative effects and the softer aspects see Aracil (1999), Coyle (2000), and Forrester (1994), among others. The application of qualitative aspects is pertinent to combat since such drivers as morale, training, and leadership are all qualitative concepts which historically have been difficult to model.

Another feature of system dynamics models, similar to complex adaptive systems, is these models are focused on the internal dynamics of the individual system. The evolution of the system is more important than the specific event that precipitated the solution (Sweetser, 1999, p. 3). This concept is also valued in combat modeling, as the solution or victory may be less important than the path to achieve the victory in a modeling analysis.

A final advantage of system dynamics models is the choice of time step does not impact the results. This allows the modeler to focus on the interactions within the model and not the size of the time step to get the required level of detail.

Regression Models

This section provides an introduction to simple linear regression models, multiple linear regression models and logistic regression models.

Least Square Linear Regression Models

Least square regression models fit a relationship of one or more independent factors to a dependent factor. In this dissertation, simple linear regression models

(Equation II-1) and multiple linear regression (Equation II-2) analyses are applied. The regression coefficients are β_i and the independent variables are x_i.

$$\mathrm{y}=\beta_0+\beta_1 \cdot x_1+\varepsilon \tag{II-1}$$

$$\mathrm{y}=x' \cdot \beta+\varepsilon=\beta_0+\beta_1 \cdot x_1+\cdots+\beta_\mathrm{n} \cdot x_n+\varepsilon \tag{II-2}$$

The errors (ε) are assumed to have a mean of zero, all have the same (but unknown) variance, and be uncorrelated (Montgomery, Peck, & Vining:, 2001, p. 13).

Least squares estimates can be used to estimate the regression coefficients (β_i) (Montgomery, Peck, & Vining:, 2001, p. 71). The regression analysis results used throughout this dissertation are presented in an Analysis of Variance (ANOVA) table. Some of the definitions, assumptions and interpretations are discussed next.

The coefficient of determination, or R^2, measures the amount of variation present in the response after the accounting for the independent variables (Hughes & Grawoig, 1971, p. 344). As more factors are added to the model, an adjusted R^2 is preferred since it accounts for the degrees of freedom of the associated model. When the R^2 and adjusted R^2 are close to one, this implies most of the variability of the response is explained by the regression model (Montgomery, Peck, & Vining:, 2001, p. 40). The standard error of the model, or Root Mean Square Error (RMSE) is the square root of the mean squared error.

Since the models in this dissertation are used to predict the public support for a conflict, the Prediction Error Sum of Squares (PRESS) statistic and $R^2_{\text{Prediction}}$ are included in the ANOVA tables. The PRESS statistic is a measure of the prediction quality of the model. It is defined as $\sum_{i=1}^{n}\left[y_i-\hat{y}_{(i)}\right]^2$ where $\hat{y}_{(i)}$ is the i^{th} predicted response when the regression is performed without the i^{th} respective data points

(Montgomery, Peck, & Vining: 2001, p. 152). The $R^2_{Prediction}$ is defined as $1 - PRESS/SS_{Total}$, where SS_{Total} is the total sum of squares from the ANOVA table. $R^2_{Prediction}$ 'explains' the percent of variability in predicting new observations (Montgomery, Peck, & Vining: 2001, p. 153). Similar to R^2, a $R^2_{Prediction}$ close to one is highly desired.

The null hypothesis for the *F*-test is that all of the coefficients are equal to zero (H_0: $\beta_i = 0 \;\forall\, i$; H_a: $\beta_i \neq 0$ some at least one *i*). If the observed *F*-test statistic is larger than the appropriate reference value from the *F*-distribution, then the null hypothesis is rejected (indicating at least one regression coefficient is significant).

The null hypothesis used in the analysis for each variable was that the regression coefficient equaled zero (H_0: $\beta_i = 0$; H_a: $\beta_i \neq 0$). The magnitude of the *t*-test statistic was compared to the appropriate reference value from the two-sided *t*-distribution with $\alpha = 0.05$. The null hypothesis was rejected if the magnitude is greater than the critical value (implying a coefficient other than zero), or failed to reject (implying there was insufficient evidence to support the coefficient is not zero).

For further details on linear regression analyses see Hughes & Grawoig (1971), Neter *et al.* (1996), or Montgomery, Peck, & Vining (2001) among others.

Logistic Regression Models

Montgomery, Peck, and Vining provide some benefits of using generalized linear models (GLMs). First, GLMs unify both linear and non-linear techniques. Second, the assumptions and requirements that the data are normal and have constant variance are no longer required. Finally, the responses only need to be a member of the exponential family. This broader category includes all exponential, gamma, normal, Poisson, and binomial distributions (Montgomery, Peck, & Vining, 2001, p. 443). Specifically, multivariate logistic regression is used in this study to model public support. The logistic regression model was chosen after exploring the Poisson distribution, because the survey data used in the study are binary. Equation II-3 is the basic multivariate logistic regression model.

$$E(y) = \frac{e^{x'\beta}}{1 + e^{x'\beta}} = \frac{1}{1 + e^{-x'\beta}} \tag{II-3}$$

The method of maximum likelihood is used to estimate the parameters. The expected responses for each observation are therefore $E(y_i) = p_i$. A link function is used to transform the basic model to a linear model. This link for the binomial model is known as the *logit* function and presented in Equation II-4.

$$g(x) = \ln\left(\frac{p}{1-p}\right) = x'\beta \tag{II-4}$$

Deviance is used to measure the goodness of fit. Equation II-5 is presented by Collett to evaluate the deviance of a binary logistic model (2003, p. 67). The deviance measures the difference of log of the likelihood function of the saturated model and the fitted model.

$$Dev = -2\sum_{i=1}^{n} y_i \log \frac{\hat{p}_i}{1-\hat{p}_i} + \log\left(1-\hat{p}_i\right) \tag{II-5}$$

The goodness of fit is evaluated by comparing the deviance of the model to a χ^2 with (n - p) degrees of freedom. If Dev > $\chi^2_{(n-p)}$ then the model is not adequate. There are two possible reasons for this inadequacy (Collett, 2003, p. 195). The first explanation is that the model requires additional factors to be included or the factors which are included, need to be transformed to better represent the data. The second reason the deviance is high could be that the data is overdispersed or has extra binomial variation.

Overdispersion is present when the actual variance is greater than the expected variance. Since a binomial was used for the data analyzed in this study, the variance is based directly on the mean. This direct connection between mean and variance is not the best representation of the data.

Lambert and Roeder developed a simple diagnostic for indicating a logistic regression model with overdispersion. Their test plotted the binomial probability (p) to the convexity of the binomial plot represented by $C(p) = n^{-1}\sum_{i=1}^{n}\left(\frac{p}{\hat{p}_i}\right)^{y_i}\left(\frac{1-p}{1-\hat{p}_i}\right)^{m_i-y_i}$ (Lambert & Roeder, 1995, p. 1226). If the resulting curve is convex, then the model has overdispersion.

Williams provided the following procedure to evaluate the overdispersion factor, ϕ (Williams, 1982, p. 146):

1) Let overdispersion factor ϕ=0 and all weights w_i=1, evaluate the Pearson deviance (χ^2) of the saturated model (all possible factors), where $\textit{Pearson Deviance} = \chi^2 = \sum_{i=1}^{n}\frac{w_i\left(y_i - n_i\hat{p}_i\right)^2}{n_i\hat{p}_i\left(1-\hat{p}_i\right)}$.
2) Compare χ^2 with $\chi^2_{(n-p)}$ where n is the number of binomial observations and p is the number of parameters of the fitted model. If χ^2 is unacceptably large, conclude ϕ>0 and estimate $\hat{\phi} = X^2 - \frac{\sum_{i=1}^{n} w_i\left(1-w_i v_i d_i\right)}{\sum_{i=1}^{n} w_i\left(n_i-1\right)\left(1-w_i v_i d_i\right)}$, where $v_i = n_i p_i\left(1-p_i\right)$ and d_i is the i^{th} diagonal element of the variance-covariance matrix.

3) Let the new weights be, $w_i = \left(1 + \left(n_i - 1\right)\hat{\phi}\right)^{-1}$ and estimate $\boldsymbol{\beta}$ and recalculate χ^2.

4) If χ^2 is close to the degrees of freedom (n - p) quit, else recalculate $\hat{\phi}$ and return to step 3.

After correcting a model for dispersion, the deviance can no longer be used to check overall adequacy of the model. This is because the deviance has been adjusted to be close to the degrees of freedom within of the model.

This section provided an introduction to generalized linear models and overdispersion. For more detailed please see Montgomery, Peck, and Vining (2001) or Collett (2003).

Lanchester Laws

This section is divided into three subsections. The first provides a background to the Lanchester Laws. The second is a discussion of the direct and area fire applications of the Lanchester Laws. The final subsection demonstrates how the Lanchester Laws have been applied to insurgency warfare.

Lanchester's Work

Beginning on September 4, 1914, Lanchester published a series of sixteen weekly articles entitled "Aircraft in Warfare: The Dawn of the Fourth Arm." The fifth and sixth articles, printed on October 2nd and 9th are the foundations of the Lanchester Laws. A brief summary is provided in this section. MacKay provides an excellent mathematical summary of the Lanchester Laws (MacKay, 2006, p. 17).

Lanchester begins by proposing that the ancient battle was comprised of several individual duels. Lanchester states that in an ancient battle there is "little or no importance" between a battle of 1000 Blue forces versus 1000 Red forces and 500 Blue forces versus 500 Red forces (1914, p. 422). These two battles result in the same victorious side depending only on the individual fighting value and not numerical strength of the forces. Although the equations were never directly listed, Taylor and others suggest that Lanchester could mathematically represent his statements of the linear ancient battle as Equation II-6 (Taylor, 1983a, p. 54).

$$\frac{dR}{dB} = E = \frac{c}{k} \tag{II-6}$$

where, *B* and *R* are the number of Blue and Red forces engaged, *c* and *k* are the individual fighting values for the Red and Blue forces (better known as the Red / Blue attrition coefficients), and *E* is the exchange ratio. Equation II-6 can be integrated and rewritten as the Lanchester Linear Law, Equation II-7 (Taylor, 1983a, p. 54)..

$$k[R_0 - R(t)] = c[B_0 - B(t)] \tag{II-7}$$

Equation II-7 assumes R_0 and B_0 are the initial sizes of the Red and Blue forces, and $B(t)$ and $R(t)$ are the number of loses for Blue and Red forces, respectively, at time t.

The Linear Law can also be demonstrated as the Area Fire Equation (Equation II-8):

$$\begin{aligned} \frac{dB}{dt} &= -R \times B \times c \\ \frac{dR}{dt} &= -R \times B \times k \end{aligned} \tag{II-8}$$

The Area Fire Equations have been used to describe the effectiveness of attritting an enemy's army by shooting into any area as opposed to directly targeting an individual.

This characterizes both the impacts of artillery and shooting in the direction of a non-tracked target.

Taylor provides the following example as an application of the Lanchester Linear Law. For this example, let there initially be one hundred Red forces (R_0 = 100), and let $k = c$, thus the exchange ratio is one (E=1). Additionally, let the initial number of Blue forces (B_0) increase from 100 to 300 in increments of 50. Solving for the size of Blue's forces surviving ($B_f = B_0 - B(t)$) when all Red forces are annihilated ($R(t) = 100$) provides the results given in Table II-8.

Table II-8: Ancient Warfare Example (Taylor, 1983a, p. 56)

B_0	100	150	200	250	300
B_f	0	50	100	150	200
Blue losses	100	100	100	100	100

* Fighting continues until $R_f = 0$

Lanchester provides a description of ancient battle to introduce the idea that modern battle is a result of a concentration of resources as opposed to a series of duels. The concentration of forces allows for a single target to be attacked from multiple sources and thus is no longer a simple duel. However, when it is assumed that the forces have equal individual fighting values, "the number of men knocked out per unit time will be directly proportional to the numerical strength of the opposing force" (Lanchester, 1914, p. 422). Lanchester provides the following two equations as mathematical representations of the preceding statement (Equation II-9); when integrated, these are now referred to as the Lanchester Square Laws (Equation II-10) (Taylor, 1983a, p. 61).

$$\frac{dB}{dt} = -R \times c$$
$$\frac{dR}{dt} = -B \times k \qquad \text{(II-9)}$$

$$k[R_0^2 - R^2(t)] = c[B_0^2 - B^2(t)] \qquad \text{(II-10)}$$

Using the same assumptions from Taylor's Lanchester Linear Law example, Table II-9 presents the impact of concentration of forces determined by solving the Lanchester Square Law.

Table II-9: Modern Warfare Example (Taylor, 1983a, p. 62)

B_0	100	150	200	250	300
B_f	0	112	173	229	283
Blue losses	100	38	27	21	17

* Fighting continues until $R_f = 0$

Taylor explains the Lanchester Laws can be used to answer the following seven questions for previous generations of warfare:

1. *Who will "win"? Be annihilated?*
2. *What force ratio is required to guarantee victory?*
3. *How many survivors will the winner have?*
4. *How long will be battle last*?
5. *How do the force levels change over time*?
6. *How do the parameters [i.e. initial force levels, b_0 and r_0, and the attrition-rate coefficients, c and k] affect the outcome of battle*?
7. *Is concentration of forces a good tactic*? (Taylor, 1983a, p. 65-66)

These are broad questions whose answers are applicable to a battle where political objective is achieved by attritting or annihilating the enemy's forces. The equations for the solutions of each of these questions are found directly from the Lanchester Linear and Square Laws.

It is important to note that the Lanchester Laws were also developed independently by Osipov in 1915 (Helmbold, 1993 p. 279). The work by Osipov begins with a comparison of the casualties of 38 battles spanning from 1805 until 1905 (Osipov, 1915/1995, p. 296). Osipov states that a mathematical model of the casualties can be made by inversely relating the remaining strengths to the initial strengths. He provides Equation II-11, where A and B are the initial strengths of each side and A' and B' are the remains strength of forces at a specific time (Osipov, 1915/1995, p. 299).

$$A'^2 - B'^2 = A^2 - B^2 \tag{II-11}$$

Osipov adds that the effectiveness of each side impacts the outcome of the battle. Osipov includes two factors α and β, which "are the hits caused by riflemen on sides A and B in one unit of time" (1915/1995, p. 302). Osipov includes these factors into Equation II-11 yielding the new expression for casualties, Equation II-12.

$$\alpha(A^2 - A'^2) = \beta(B^2 - B'^2) \tag{II-12}$$

Equation II-12, with variable and parameter substitutions, is equivalent to the Lanchester Square Law in Equation II-10. Osipov continues by providing a method to include the impacts of machine guns and artillery. This enables the work to move from a homogenous to a heterogeneous study of combat. Osipov showed Equation II-13 determines the number of riflemen casualties given A riflemen and M cannons for one side, and B riflemen and N cannons for the other side, with α being the rate of kill of the riflemen and β being the rate of kill of the cannons (1915/1995, p. 303).

$$\left(A+\frac{\beta}{\alpha}M\right)^2-\left(A'+\frac{\beta}{\alpha}M\right)^2=\left(B+\frac{\beta}{\alpha}N\right)^2-\left(B'+\frac{\beta}{\alpha}N\right)^2 \qquad \text{(II-13)}$$

If $a = A - A'$ and $b = B - B'$, then Equation II-13 can be reduced to a more familiar Lanchester representation, Equation II-14, which is the Lanchester Law for multiple weapons (Osipov, 1915/1995, p. 303).

$$(A^2 - A'^2) = (B^2 - B'^2) - 2\frac{\beta}{\alpha}(aM - bN) \qquad \text{(II-14)}$$

Modeling Area and Direct Fire

The Lanchester Laws, originally representing ancient and more modern warfare, evolved into representing area and direct fire weapons. Fortunately, the analyst may not have to choose between the two laws but instead can use a combination. Helmbold expanded the Lanchester Laws by representing both the Linear and Square Laws in one general form given in Equation II-15 (1965, p. 858).

$$\begin{aligned}\frac{dB}{dt} &= c\left(\frac{B}{R}\right)^{1-w} R \\ \frac{dR}{dt} &= k\left(\frac{R}{B}\right)^{1-w} B\end{aligned} \qquad \text{(II-15)}$$

When the Weiss parameter (w) equals 1, the Lanchester Square Law results. Similarly, when $w = 1/2$, the result is a form of the Lanchester Linear Law. Additionally, when $w = 0$ the expression in Equation II-15 describes the Lanchester Logarithmic Laws. The Lanchester Logarithmic Laws are typically used to describe the number of casualties of non-fighting participants, such as the doctors, chaplains, and headquarters staff (Helmbold, 1965, p. 858).

Bracken introduced a tactical parameter to the Lanchester Laws in "Lanchester Models of the Ardennes Campaign." This parameter has been used by authors, since its introduction, to better fit the Lanchester Laws to historical battles (See Chen and Chu (2001), Lucas and Turkes (2004), and Hung *et al.* (2005)).

Starting from the general form of the Lanchester Laws (Equation II-15), Bracken added a tactical parameter, d, and rewrote w in terms of p and q, where $p + q = 1$, to result in Equation II-16 (Bracken, 1995, p. 419).

$$\begin{aligned} \frac{dB}{dt} &= c(d \; or \; 1/d) R^p B^q \\ \frac{dR}{dt} &= k(1/d \; or \; d) B^p R^q \end{aligned} \qquad \text{(II-16)}$$

The Red and Blue exponent parameters (p and q) are able to model the linear laws, square laws and the continuous range between. When $p = q = 0.5$ the linear laws result, and when $p = 1$ and $q = 0$ the square laws result.

Bracken's tactical parameter was used as a constant d for the defending force and $1/d$ for the attacking force. The parameter switched when the attacking force changed during the battle. When $d < 1$ the defender receives less casualties and when $d > 1$ the defender receives more casualties. Bracken (1995), Chen and Chu (2001), Lucas and Turkes (2004), and Hung *et al.* (2005) all showed the data of the Ardennes Campaign (Battle of the Bulge) and the Battle of Kursk could be better fit using Bracken's Tactical Parameter, d. During both of these battles, the attacking force changed.

Regardless of the source, Bracken's parameter suggests a means to capture the impacts of will-to-fight of the troops when they are attacking or defending. This approach to incorporate the will and morale of the troops works effectively only for true attrition based battles found in interstate conflicts and some intrastate conflicts. For example, this method works for a Korean conflict but was not a good fit for historical data from Bosnia or Somalia. The alliance battles in Bosnia and Somalia did not involve large force on force engagements; therefore, a turning point as required by Bracken's Tactical Parameter did not exist. While not applicable to all conflicts, the methodology of incorporating a morale/will factor, as well as the attrition coefficient is valid.

Modeling Insurgencies

Deitchman published an early article applying the Lanchester Laws to insurgent warfare (Taylor, 1983b, p. 446). This article, entitled "A Lanchester Model of Guerrilla Warfare," focused on the force ratios and size of the guerrilla bands versus the conventional/regular army. Deitchman suggests that an ambush set by the guerrillas is best described by the guerrillas attacking by direct fire, while the conventional army returns fire into an area or using indirect fire. Equation II-17 describes this engagement, where x_1 is the number of guerrillas, x_2 is the number of conventional forces, $\dot{x}_1$ and $\dot{x}_2$ are the rate of change of force size over time, $A = r_2 A_{e2}/ A_1$ (where r_2 is the rate of fire of the conventional army, A_{e2} is the conventional army's single round area effectiveness, and A_1 is the area that the guerrillas are hiding) and $b = r_1 p_{12}$ (where r_1 is the rate of fire of the guerrilla's weapons, and p_{12} is the single shot probability of kill of the guerrilla's weapons) (Deitchman, 1962, p. 821).

$$\begin{aligned} \dot{x}_1 &= -Ax_2x_1 \\ \dot{x}_2 &= -bx_1 \end{aligned} \qquad \text{(II-17)}$$

Equation II-18 is the condition for equality given these circumstances (Deitchman, 1962, p. 821).

$$x_{1_0} = \left(\frac{A}{2b}\right) x_{2_0}^2 \qquad \text{(II-18)}$$

Deitchman continues his analysis of guerrilla warfare by demonstrating that Equation II-18 implies that the regular forces must have a significantly favorable force ratio to be able to win against the guerrillas. Unfortunately, the area fire weapons may only slightly improve the capabilities of the regular forces, since the rate of fire is reduced (Deitchman, 1962, p. 824).

Deitchman justifies his results with historical data arguing that the lower the force ratio, the more likely it is that the guerrillas win the conflict. Figure II-11 illustrates the outcome of guerrilla warfare since World War II up to the publication of Deitchman's work in 1962 correlated to the force ratio of regular forces versus guerrilla forces.

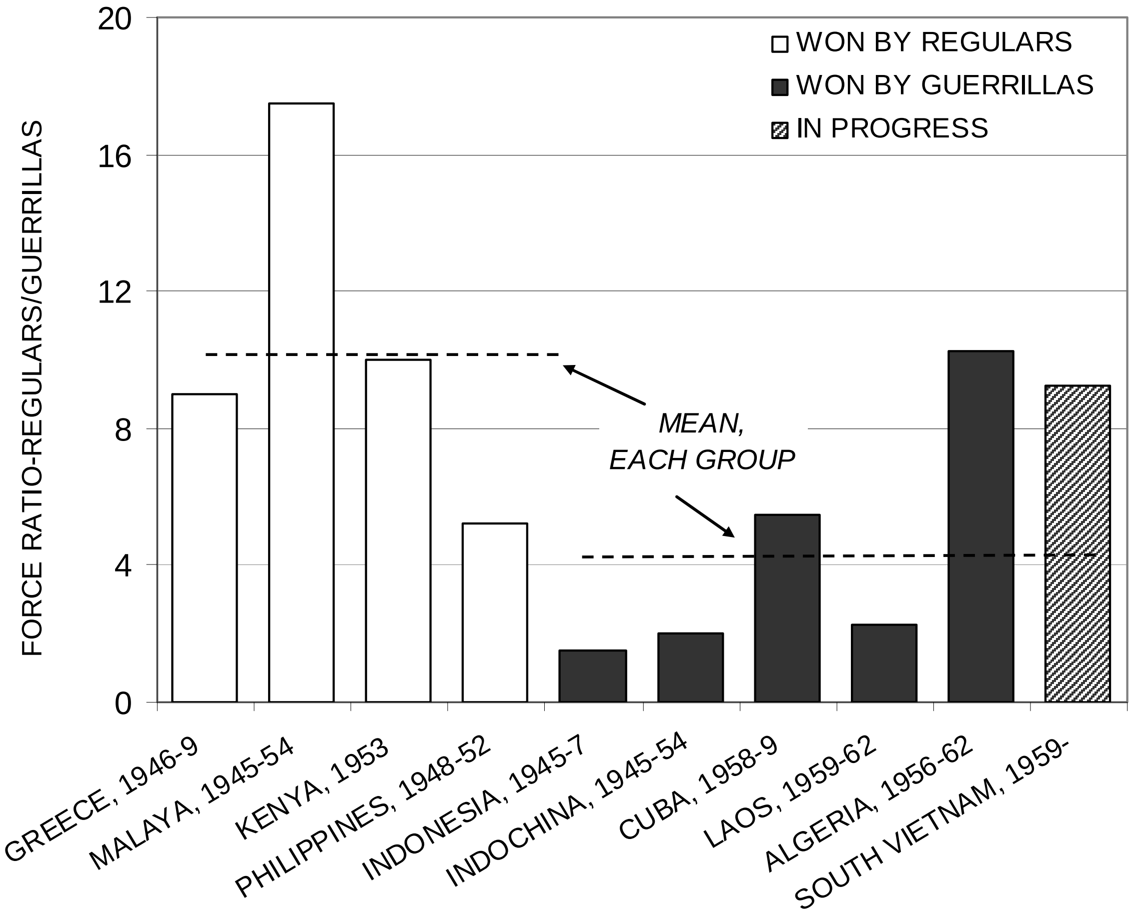


Figure II-11: Estimated Force Ratios in Guerrilla Wars (Deitchman, 1962, Figure 2 Page 821)

Deitchman indicates significant limitations to his methodology at the beginning of the article:

> *This analysis neglects many important factors in guerrilla-counterguerrilla operations, particularly the effect of the attitude and support of the local population, for which the two sides must contend by political, economic, and psychological as well as military means.* (Deitchman, 1962, p. 819)

This dissertation directly improves upon these limitations.

Schaffer, in his RAND research paper entitled *Lanchester Models of Guerrilla Engagements,* continued Deitchman's research. He specifically modeled three categories of guerrilla warfare; skirmishes, ambushes, and sieges. Schaffer begins with a general form of the Lanchester Laws for the number of casualties, *c*, of each side *m* and *n* (1967, p. 5).

Equation II-19 presents this formulation, where $k_n (t,m)n = k_n mn$ when the linear law is appropriate and $k_n (t,m)n = k_n n$ when the square law is appropriate. The term $\sum^{i} E_i(t,m)W_i(t)$ represents the use of supporting fire within the Lanchester Laws.

$$\begin{aligned} \left(\frac{dm}{dt}\right)_c &= -k_n(t,m)n - \sum^{i} E_i(t,m)W_i(t) \\ \left(\frac{dn}{dt}\right)_c &= -k_m(t,n)m - \sum^{j} E_j(t,n)W_j(t) \end{aligned} \qquad \text{(II-19)}$$

Schaffer continues with two assumptions about the rate of surrender and desertion with the model (1967, p. 6). First, the expected values for the rates can be developed in a similar manner and thus they can be added together. Second, the rate of surrender and desertion is based on the rate of casualties and the difference between the force ratio and one. Schaffer postulates the rates can be represented as the power series (Equation II-20), where a_m, a_n, b_m, b_n, c_m and c_n are all coefficients representing the discipline and morale of the troops (1967, p. 6).

$$\begin{aligned} \left(\frac{dm}{dt}\right)_{s+d} &= a_m - \left[b_{m_1}\left(\frac{dm}{dt}\right)_c + b_{m_2}\left(\frac{dm}{dt}\right)_c^2 + \dots\right] - \left[c_{m_1}\left(\frac{n}{m}-1\right) + c_{m_2}\left(\frac{n}{m}-1\right)^2 + \dots\right] \\ \left(\frac{dn}{dt}\right)_{s+d} &= a_n - \left[b_{n_1}\left(\frac{dn}{dt}\right)_c + b_{n_2}\left(\frac{dn}{dt}\right)_c^2 + \dots\right] - \left[c_{n_1}\left(\frac{m}{n}-1\right) + c_{n_2}\left(\frac{m}{n}-1\right)^2 + \dots\right] \end{aligned} \qquad \text{(II-20)}$$

Equation II-20 assumes the rates $\left(\frac{dm}{dt}\right)_{s+d}$ and $\left(\frac{dn}{dt}\right)_{s+d}$ must be less than zero, a_m and a_n also must be less than or equal to zero, and if the force ratio *m/n* is greater than one, then $c_{m_i} = 0$ (similarly if *n/m* > 1, then $c_{n_i} = 0$).

Schaffer then combines the casualty, surrender, and desertion rates to reduce the power series to only first and second order terms to get the generalized attrition equations, Equation II-21.

$$\begin{aligned}\frac{dm}{dt} &= -\left(1-b_m\right)k_n(t,m)n - c_{m_1}\left(\frac{n}{m}-1\right) - c_{m_2}\left(\frac{n}{m}-1\right)^2 - \left(1-b_m\right)\sum^{i} E_i(t,m)W_i(t) \\ \frac{dn}{dt} &= -\left(1-b_n\right)k_m(t,n)m - c_{n_1}\left(\frac{m}{n}-1\right) - c_{n_2}\left(\frac{m}{n}-1\right)^2 - \left(1-b_n\right)\sum^{j} E_j(t,n)W_j(t)\end{aligned} \qquad \text{(II-21)}$$

Equation II-21 still requires $\frac{dm}{dt}$ and $\frac{dn}{dt} < 0$, b_m and $b_n \le 0$, and if $\frac{m}{n} > 1$, then $c_m = 0$ (similarly $\frac{n}{m} > 1$, $c_n = 0$).

Schaffer first investigates skirmishes. He defines skirmishes as where the riflemen on each side are engaged in aimed fire (Schaffer, 1967, p. 9). Since aimed fire is considered on both sides, Equation II-21 reduces to Equation II-22.

$$\begin{aligned}\frac{dm}{dt} &= -\left(1-b_m\right)k_n n - c_{m_1}\left(\frac{n}{m}-1\right) - c_{m_2}\left(\frac{n}{m}-1\right)^2 - \left(1-b_m\right)\sum^{i} E_i(t,m)W_i(t) \\ \frac{dn}{dt} &= -\left(1-b_n\right)k_m m - c_{n_1}\left(\frac{m}{n}-1\right) - c_{n_2}\left(\frac{m}{n}-1\right)^2 - \left(1-b_n\right)\sum^{j} E_j(t,n)W_j(t)\end{aligned} \qquad \text{(II-22)}$$

Assuming there are more *m* forces than *n* forces and no supporting fire, Equation II-22 further reduces to Equation II-23 (Schaffer, 1967, p. 13).

$$\begin{aligned}\frac{dm}{dt} &= -\left(1-b_m\right)k_n n \\ \frac{dn}{dt} &= -\left(1-b_n\right)k_m m - c_n\left(\frac{m}{n}-1\right)^2\end{aligned} \qquad \text{(II-23)}$$

Schaffer next models the ambush. Similar to Deitchman, Schaffer assumed the ambushee initially engages in area fire. However, as the battle continues, the ambushee transfers to aimed fire (Schaffer, 1967, p. 24). The ambushers use aimed fire during the entire engagement. Schaffer assumes that at the start of the engagement the ambusher has little motivation to desert or surrender and that at a predetermined time, t_c, they typically begin removing their forces from the battle to prevent undue attrition. Equation II-24 represents Schaffer's formulation of this exchange, where H represents a unit step function, indicating the combat strength of the ambushers remaining in the fight at time t (Schaffer, 1967, p. 25):

$$c_n(t) = |c_n| H\left(t - t_c\right) H\left(\frac{m}{n} - 1\right) \tag{II-24}$$

The generalized attrition equations for the rate of attrition of the ambushed (m) and the ambusher (n) are presented as Equation II-25 (Schaffer, 1976, p. 25):

$$\begin{aligned} \frac{dm}{dt} &= -\left(1 - b_m\right) k_n(t) n - c_m \left(\frac{n}{m} - 1\right)^2 - \left(1 - b_m\right) \sum^{i} E_i(t, m) W_i(t) \\ \frac{dn}{dt} &= -k_m(n, t) m - c_n(t) \left(\frac{m}{n} - 1\right)^2 - \sum^{j} E_j(t, n) W_j(t) \end{aligned} \tag{II-25}$$

The final category of guerrilla warfare modeled by Schaffer is the siege. The siege takes place in two stages (Schaffer, 1967, p. 39). The first stage employs the support weapons when the riflemen are out of range. This is used to prepare the battlefield. Unfortunately it does compromise the element of surprise. The second stage is the engagement of riflemen. Sieges can either involve both stages or only one stage. For the first stage of the siege, the generalized attrition equation, Equation II-21, can be reduced to Equation II-26 (Schaffer, 1967, p. 40).

$$\frac{dm}{dt} = -\left(1-b_m\right)\sum^{i} E_i(m)W_i$$
$$\frac{dn}{dt} = -\left(1-b_n\right)\sum^{j} E_j(n)W_j \qquad \text{(II-26)}$$

The second stage of a siege can be represented as Equation II-27 where P_{K_n} is the probability of kill of the weapon used by side *n*, $\frac{\gamma_n A_m}{m}$ is the average time for a troop to acquire a target and t_{f_m} is the time to fire on a target (Schaffer, 1967, p. 45).

$$\frac{dm}{dt} = -\left(1-b_m\right)P_{K_n}\frac{nm}{\gamma_n A_m}$$
$$\frac{dn}{dt} = -\left(1-b_n\right)P_{K_m}\frac{m}{t_{f_m}} \qquad \text{(II-27)}$$

Schaffer's work is continued in the 1969 RAND research paper, *Application of Lanchester Theory to Insurgency Problems*. This paper includes applications, data and conclusions about skirmishes and ambushes from the Vietnam conflict.

Over the last one hundred years a great deal of development of the Lanchester Laws has occurred. This discussion was limited to the development of the initial theory and the progression of that theory as applied to guerrilla and insurgency warfare. It is important to note that in most of the work presented the attrition coefficients are assumed to be static and not dependent upon the current conditions within the model. Therefore, it has been assumed that the parameters do not change within the battle. The Bracken tactical parameter was the one of the few occurrences in the literature where the attrition coefficients were adjusted based on current conditions within the conflict. Additionally, it could be concluded that since only one battle/ campaign is modeled that this must be the decisive battle of the war. No dynamic impacts of the previous battles, or future influences from the modeled battle, are directly accounted for within the reviewed Lanchester Laws.

Modeling Will-to-Fight, Morale, and Combat Spirit

While much has been written about how warfare is changing; a resilient aspect is the permanence that warfare directly attacks the will-to-fight. This was known in Sun Tzu's time and can be seen in the emphasis of information operations and recent creation of Air Force Cyber Command. This section discusses the will-to-fight and morale of the combatant as related to combat effectiveness. The discussion thus far has included some means to incorporate the will-to-fight, morale and combat spirit into combat models. Bracken added a tactical parameter to the Lanchester Laws. This parameter gave an advantage to the attacker during a battle. When correlating the Lanchester model to historical data, Bracken's parameter was used as a free variable to best fit the casualties of the battle. His parameter was not determined dynamically by the model. Additionally, the value and impact was predetermined only for the time the parameter (or its inverse) was applied.

Schaffer introduced the coefficients of a_m, a_n, b_m, b_n, c_m and c_n which all representing the discipline and morale of the troops (1967, p. 25). Schaffer also introduces the parameter, t_c, which indicated the time that the ambushers begin withdrawing their troops from battle (1967, p. 6). All of Schaffer's parameters were determined prior to the model being run and were static during the model's application.

Neither Bracken nor Schaffer related the values of their parameters to the actions and events within the model. This is acceptable for a single, short battle but is not applicable in the longer durations required for campaign and strategic level models.

The impacts of combat degradation and unit deterioration are discussed in the first subsection. The conclusions of Marshall are presented and discussed. This subsection on degradation and deterioration includes the impacts of ineffective combatants, the differences between training versus active combat, and how the factors can be implemented in the Lanchester Laws. Next, Perry's civil stability index accounts for the impacts of the population will within a combat model. The civil stability index subsection is followed by a discussion of how morale has been incorporated within the modern campaign models, specifically the Joint Warfare System (JWARS). The final subsection discuss how morale has been previously modeled. This discussion begins by presenting the individual components of combat spirit, and concludes with a discussion on how morale of the troops changes while they are deployed.

Combat Degradation

The ideas of morale and combat spirit have refined over the years. During World War One, 'shell shock' was considered a physical injury as opposed to a mental restriction, since men did not suffer from mental deficiencies. "At first, doctors in the UK proposed an organic explanation: either a microscopic cerebral hemorrhage caused by the concussive or toxic effects of an exploding shell" (Jones & Wessely, 2007, p. 167).

Marshall investigated the psychological aspects of war in his book: *Man Against Fire*. He interviewed World War Two and later Korean combatants immediately after battle and reported remarkable trends about the willingness of combatants to actually engage the enemy. Marshall found that a number of combatants did not fire at the enemy.

> *…not more than one quarter of his men will ever strike a real blow unless they are compelled by almost overpowering circumstance or unless all junior leaders consistently "ride heard" on troops with the specific mission of increasing their fire.*
>
> *The 25 per cent stands even for the well trained and campaign-seasoned troops. I mean that 75 per cent will not fire or will not persist in firing against the enemy and his works. These men may face the danger but they will not fight.* (Marshall, 1947, p. 50)

Marshall's results indicate that the 25% that actually fought against the enemy varies based on the type of equipment the combatant carried.

> *…we found that on an average not more than 15 per cent of the men had actually fired at the enemy positions of personnel with rifles, carbines, grenades, bazookas, BARs, or machine guns during the course of an entire engagement. Even allowing for the dead and wounded, and assuming that in their number there would be the same proportion of active firers as among the living, the figure did not rise above 20 to 25 per cent of the total for any action. The best showing that could be made by the most spirited and aggressive companies was that one man in four had made at least some use of his firepower.* (Marshall, 1947, p. 54)

The assumption that the dead fired their weapons at the same rate as the surviving may be questioned. Those that actively attacked/defended their position may have become targets because of their aggressiveness, and thus were killed. Additionally, it could be argued the statistics quoted by Marshall included all the troops within the theater; it is not expected combat service support personnel regularly engage in combat operations. Marshall counters this latter argument stating:

> *Most of the actions had taken place under conditions of ground and maneuver where it would have been possible for at least 80 per cent of the men to fire, and where nearly all hands, at one time or another, were operating within satisfactory firing distance of enemy works.* (Marshall, 1947, p. 54)

It can therefore be seen that the percentage does include some number of supporting troops; however, all troops were within direct contact with the enemy, and capable of engaging the enemy.

Chambers attempted to discredit Marshall's claims in his article "S.L.A. Marshall's *Men Against Fire*: New Evidence Regarding Fire Ratios." Through an interview with Frank J Brennan, Chambers concludes that Marshall may not have been very scientific in his data collection process. Brennan was an escort officer for Marshall during some of Marshall's post-battle interviews with troops during the Korean War (Chambers, 2003, p. 115). When questioned whether Marshall asked the troops specifically about the firing their weapons, Brannan responded:

> *I remember he brought up the question but that he did not push it in regard to the amount of firing. That came up incidentally rather than as a result of a specific question from him. He asked mostly open-ended questions to elicit information about what really occurred* (Chambers, 2003, p. 117).

Continuing the interview, Brennan said he discussed the conclusion in the book *Men Against Fire* with Marshall. Brennan states:

> *I asked him specifically whether those percentages of his 25 or 30 per cent of the men firing their weapons – were supportable. He assured me that they were supportable talking to the soldiers of the time* (Chambers, 2003, p. 117).

By supportable, Brennan meant, "any attempt to quantify the percentage that he presented in his book" (Chambers, 2003, p. 117). From the interview with Brannan, Chambers concludes that:

> *Marshall was unscientific in his methodology and that his figures about the percentage of troops firing their weapons were either sloppy, fabricated or simply guesswork.* (Chambers, 2003, p. 119)

While the methods used by Marshall may be contested, the original book, *Men Against Fire*, did cause many within the US Army to recognize that not all armed and able warfighters were engaging the enemy. Additionally, the data used by Marshall was based originally on World War Two data and expanded to the Korean War. Both of these conflicts involved a significant number of draftees as opposed to volunteer forces. This factor was not included in Marshall's analysis.

Rowland's paper "The Use of Historical Data in the Assessment of Combat Degradation" compared actual combat results to trials performed in training. The results suggest an amount of force degradation that is experienced in battle (Rowland, 1987, p. 149). Rowland used data from the US Civil War through the infantry battle of the Falklands in 1982.

Rowland began by quantifying the effects of force ratio to the battle's casualties. The horizontal axis of Figure II-12 indicates the force ratio of attacking to defending infantrymen. The vertical axis is the effect of the rate of fire in terms of attacker casualties per defender. Notice that both axes are logarithmic scale. Rowland points out that at a 4:1 force ratio, the number of casualties is double the number when the force ratio is even (1:1) (Rowland, 1987, p. 150).

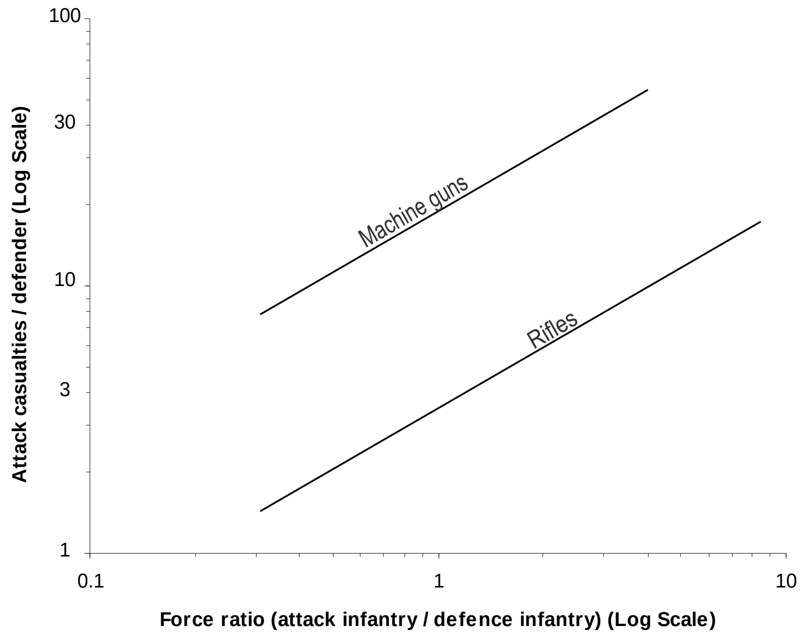


Figure II-12: Variation of Attack Casualties /Defense (Rowland, 1987, Figure 1 Page 151)

Rowland then compared the rifle data from actual combat to the rifle data from the training trials. The rifle data from the Boer Wars, US Civil War, and specific battles from World War I (Landrecies, Mons, and Neuve Chappelle) was used to create Figure II-13 (Rowland, 1987, p. 152).

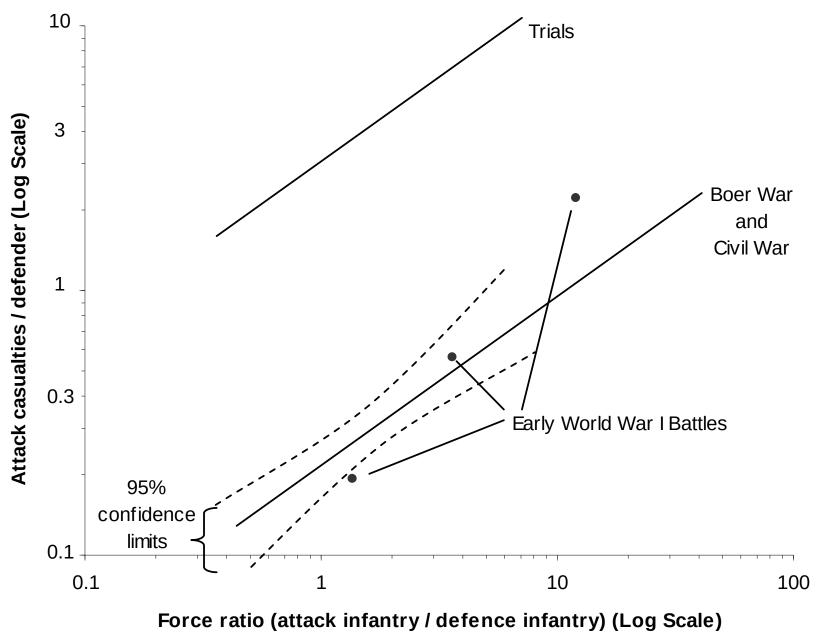


Figure II-13: Comparison of Rifle Data (Rowland, 1987, Figure 3 Page 152)

Rowland notes the trends in the slopes between the trials and actual combat are similar; however, the specific data from over 47 battles is quite different than the trials. The actual battles indicate the number of attacker casualties per defender range from one tenth to one eighth of the trial data. The data produced by Rowland does indicate support to S. L. A. Marshall's claim that on average 15% of riflemen engage in combat (Rowland, 1987, p. 153).

Rowland continued the analysis by looking at machine-gun and artillery fire. These results again indicated degradation in the effectiveness of the actual battles when compared to the training trials. Rowland's paper concluded with Equation II-28, which was the defender's casualties caused from small arms fire, where *D* is a factor for prepared/hasty positions, *G* is a constant for weapon type, N_a is the number of attackers, N_d is the number of defenders, *d* is the preparatory bombardment density (lb/yd^2), *t* is the duration of the preparatory bombardment, t_a is the number of attacking armored fighting vehicles, and N_s is the number of defending machine guns and anti-tank guns (Rowland, 1987, p. 161).

$$D \cdot G\left(N_a / N_d\right)^{0.68}\left[1-\exp\left(-5.75d / t^{0.5}\right)\right]\left[1-\exp\left(-1.1t_a / N_s\right)\right] \qquad \text{(II-28)}$$

Civil Stability Index

Perry created a tool useful in capturing the population's morale. In his thesis entitled, *Modeling Operations Other Than War: Non-Combatants in Combat Modeling*, Perry developed the Civil Stability Index (CSI). This index is defined such that the lower values imply anarchy/instability. Table II-10 provides subjective examples of the CSI number for observable conditions. Perry used this CSI within a model of MOOTW representing the influence of the population within his model.

Table II-10: Sample CSI Value Representations (Perry, 1994, Table 1 Page 21)

CSI Number	Conditions
0.15	Rwanda, April 1994
0.25	LA Riots, 1992
0.40	South Africa, March 1994
0.50	Washington, D.C. Urban housing, after dark
0.75	Average day in any European city
0.85	Average day in a U.S. small town in the Midwest

Perry proposed that specific thresholds of the CSI cause the model to alter its activities. Table II-11 lists the CSI thresholds and associated activities his model performs. The CSI is directly tied to the success of the conflict, effectiveness of weapons, and the number of guerrillas and potential guerrillas.

Table II-11: Activity on Model Caused by CSI Thresholds (Perry, 1994, Table 2 Page 22)

CSI Threshold	Resulting Model Activities
> 0.15	U.S. must cease offensive action
> 0.20	Perform random draw each day against 10% chance that outside force required U.S. to withdraw from theater
> 0.30	U.S. player prohibited from using area fire weapons
> 0.40	Transfer 2% of unarmed civilian unit personnel to armed personnel for each day CSI is below 0.40
< 0.60	Civilians prohibited from supporting rebels with log/intel
< 0.65	Transfer 2% of armed personnel per civilian unit to unarmed personnel

The CSI was updated based on the actions within the model. This created a feedback loop common to system dynamics. These updates were presented in the form of the rates found in Table II-12.

Table II-12: CSI Activities (Perry, 1994, Table 3 Page 22)

CSI Change	Impacts on CSI by Model Activities
+0.01	Per delivery of logistical support to civilian unit
+0.01	Per day without a starvation death
+0.01	Per day without a combat death
-0.00007	Per death due to starvation
-0.0003	Per death due to direct combat
-0.0001	Per death due to collateral damage
-0.1	Per incident of terror attack
-0.05	Per day of rioting, pro-rated % of day

The interactions of the CSI can be seen in Figure II-14. Logistical support can only improve the CSI, while terror attacks and rioting only decreases the CSI value. The absence of deaths increase the value of the CSI; however, each death due to starvation, direct combat, and collateral damage negatively affect the CSI. All values in Tables II-10 through II-12 were determined subjectively or as estimates to demonstrate the model (Perry, 1994, p. 21).

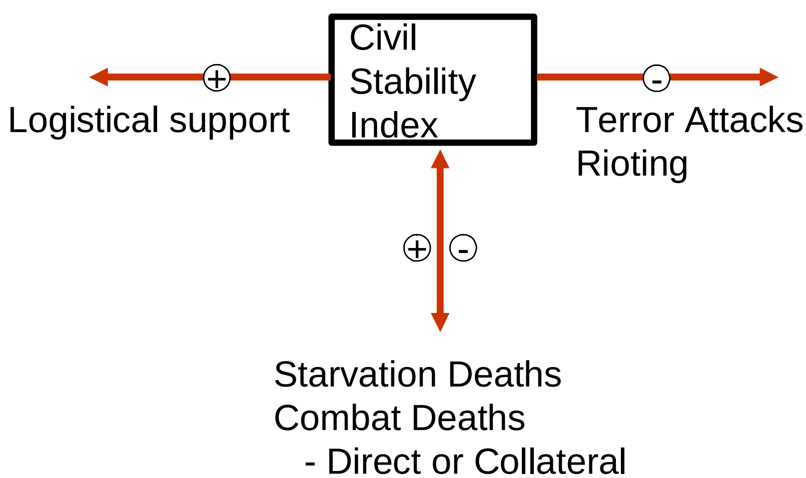


Figure II-14: Schematic of Impacts to CSI

Table II-13 is an example provided by Perry indicating how the CSI was calculated at the beginning of each simulation day (Perry, 1994, p. 57). In this example, combat had not begun; therefore, only the deaths due to starvation were included in the calculation.

Table II-13: Changes to CSI Due to Starvation (Perry, 1994, Table 12 Page 58)

Node	Units	Casualties	Old CSI	Modifiers	New CSI
N1	R1 / W1	2 / 8	0.45	-0.00007 * 10	0.4493
N2	R2	3	0.45	-0.00007 * 3	0.4498
N3	B1 / B2	0 / 0	0.45	0	0.4500
N6	W2	8	0.40	-0.00007 * 8	0.3998

Using the CSI within a combat model provides the analyst an ability to connect the actions of the combatants to the public resolve for the conflict. This provides justification for other events to occur within the model.

Campaign Model Implementation (JWARS)

Bross, in a technical report titled, *Measuring the "Will to Fight" in Simulation*, used the definitions of the National Ground Intelligence Center (NGIC) to incorporate morale and leadership into the campaign model JWARS. JWARS was used in conjunction with the Synthetic Environment for Analysis and Simulation (SEAS) model to adjust to actions with the models. JWARS is a campaign level model which "has the capability to adjust the ability of the respective combatant forces by a variety of behavioral factors such as leadership, training, *etc*" (Bross, 2005, p. 2). These factors are referred to by the JWARS community as 'soft factors.' SEAS "is an agent-based simulation that concentrates on the non-military aspects of social interaction" (Bross, 2005, p. 2). These models were used together during the war-game Unified Vision 04 (UV04). The goal of the experiment was to link the 'will-to-fight' attributes of SEAS to the JWARS morale and unit cohesion values.

Bross' claim that JWARS is capable of adjusting the ability of combatants based on leadership and training does not imply a direct value within JWARS linking training to the combatant's effectiveness. The soft factors within JWARS are able to adjust five behaviors of troops used within JWARS. These behaviors are:

- *Unit Rate of Direct Fire*
- *Unit Speed of Maneuver*
- *Unit Suppression of the Rate of Direct Fire*
- *Unit Suppression of the Speed of Maneuver*
- *Unit Breakpoints* (Bross, 2005, p. 4)

The five behaviors are impacted by factors associated to the country, unit function, and unit ranking. The country factor is determined by a vector of sixteen country attributes defined by NGIC. These attributes are presented in Table II-14.

Table II-14: NGIC Country Attributes (Bross, 2005, Table 1 Page 5)

Ability to Assimilate	Joint and Combined Operations
Air Defense	Leadership
Battle Command	Maneuver
Combat Experience	Mobility and Survivability
Combat Service Support	Morale and Cohesion
Combined Arms Operations	Power Projection
Fire Support	Readiness
Intelligence	Training

Bross only investigated the impact of the morale and cohesion attributes; however, when one attribute within JWARS is activated, they are all active. The number used for the morale and cohesion attribute within JWARS is based on the score developed by NGIC. This score is based on the evaluation of the sub-elements of morale and cohesion. Table II-15 represents the sub-elements and score for an arbitrary adversary.

Table II-15: NGIC Morale and Cohesion Sub-elements (Bross, 2005, Table 2 Page 6)

Level	Service Officers & soldiers	Pride	Risk Soldiers & leaders	Discipline	Tension	Ldr-Sub Loyalty	Soldier Loyalty	Unit Morale	National Support
10	Serve in regiment or cohort	All units have pride	Share risk assumption	All units highly disciplined	Tension within units almost non-existent	High degree	High degree	Very high	Very high degree
9	Serve in same units	90% + units have pride	Share risk assumption	90%+ units highly disciplined	Tension within units almost non-existent	Reasonable degree	High degree	High in most units	Moderately high degree
8	Serve in same units	Many units have pride	Share risk assumption	Many units highly disciplined	Tension within units almost non-existent	Reasonable degree	Reasonable degree	Fairly good in most units	High degree
7	Usually serve in same unit	Many units have pride	Sometimes share risk assumption	Many units highly disciplined	Tension within units minimal	Some degree	Reasonable degree	Good in elite units; others fair	Mostly supports
6	Sometimes serve in same units	Some units have pride	Sometimes share risk assumption	Units generally disciplined	Tension within units minimal	Some degree	Some degree	Fair in most units	Mostly supports; some dissidents do not
5	Sometimes serve in same units	Some units have pride	Sometimes share risk assumption	Units generally disciplined	Some tension within units	Little degree	Some degree	Low in some units	Nation supports; many dissidents do not
4	Sometimes serve in same units	Few units have pride	Sometimes share risk assumption	Units generally disciplined	Some tension within units	Little degree	Little degree	Low in most units	Nation tends to support; large minority does not
3	Sometimes serve in same units	Few units have pride	Risk assumption between soldiers & leaders unusual	Units frequently lack discipline	Some tension within units	Little to no degree	Little degree	Low in all units	Nation divided
2	Seldom serve in same units	Few units have pride	Risk assumption between soldiers & leaders unusual	Units frequently lack discipline	Frequent tension within units	Little to no degree	Little to no degree	Low in most units; low desertion rate	Nation does not support; some groups do
1	Seldom serve in same units	Virtually all lack pride	Risk assumption between soldiers & leaders almost non-existent	Absence of discipline	Frequent tension within units	Little to no degree	Little to no degree	Low in most units; high desertion rate	Nation has no respect for military
Score	8	6	3	7	5	7	6	7	9
Average	NGIC Factor = 6.4								

Bross states that the columns associated with service officers and soldiers, pride, discipline, leader-sub loyalty, soldiers loyalty, and unit morale do not change during a short (20 day) conflict (2005, p. 7). This implies that the columns associated with risk soldiers and leaders, tension, and national support are the only characteristics that could change during a short conflict.

The unit function factor of JWARS divides the unit into one of three categories; combat, combat support, and combat service support. A setting for each category is fixed globally (Bross, 2005, p. 7). Since this is a global variable, it impacts all combatants equally. Generally, the combat units have a factor of one. The value of the combat support unit is less that the combat unit, and the value of the combat service support unit is less than the combat support unit.

The unit ranking factor is the final contribution to the soft factors. Again, each unit is considered to be in one of three categories. It is assumed the unit is an elite, standard or militia unit. The value for each follows a similar relation as the unit function factor and is again considered a global factor. Thus, the value for elite unit is greater than the standard unit which is greater than the militia unit. This greatly limits the capabilities of the model when comparing asymmetrical forces since the factors involving a conventional force being ambushed are not properly modeled.

Bross states Equation II-29 for the impact for each behavior where *N* is the county factor, *R* is the unit ranking factor and *F* is the unit function, the % subscript indicates the amount of influence of the factor on the total behavior (2005, p. 8).

$$SF_{Behavior} = \left(1-\left(N_{\%}\cdot\left(1-N\right)\right)\right)\cdot\left(1-\left(R_{\%}\cdot\left(1-R\right)\right)\right)\cdot\left(1-\left(F_{\%}\cdot\left(1-F\right)\right)\right) \qquad \text{(II-29)}$$

Bross next restricted the investigation to only elite combat troops and so reduced Equation II-29 to Equation II-30 (2005, p. 8).

$$SF_{Behavior} = \left(1 - \left(N_{\%} \cdot \left(1 - N\right)\right)\right) \tag{II-30}$$

Bross concludes with an experimental design which changed the country attributes to impact the behaviors of the JWARS model. Figure II-15 represents the Red and Blue troop losses as the Red soft factors are varied from ineffective to effective (Bross, 2005, p. 12). The area indicated by the ripple on the chart suggests the possibility of an area Dewar *et al.* refers to as non-monotonic behavior. If so, the results are chaotic in nature.

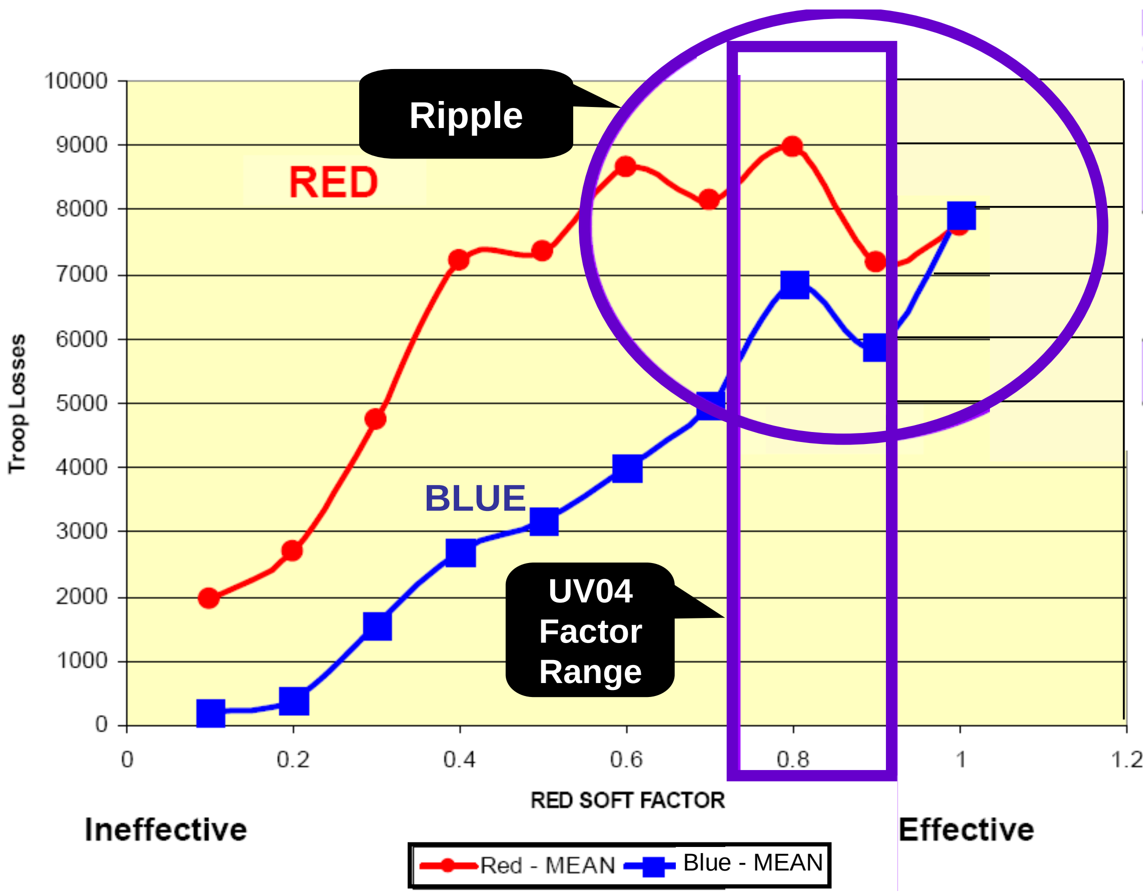


Figure II-15: Troop loses by Red Soft Factor (Bross, 2005, Figure 6 Page 12)

Bross concludes that the impact of the will-to-fight on combat outcomes within JWARS with the following statement:

> *Combat outcomes vary significantly, both statistically and military, as the will to fight takes on different values. Even more important for the analyst is the fact that these effects are strongly non-linear and evidenced primarily as interactions. This means that tracing cause-and-effects will be extremely difficult in the battles produced by the model, just as it is in real historical and operational analysis. The search for answers will be more time consuming rather than quick due to this level of complexity.* (Bross, 2005, p. 19)

As indicted in Bross's conclusions, an impact to the model is evident as factors relating to will-to-fight are changed. However, this test did not dynamically change these factors, but rather merely established that the model does depend on the factors. Additionally, these factors were not traced to specific events or actions conducted by friend or foe. Finally, the complexity of JWARS has limited the conclusions and direct connections of will-to-fight to the results of the battle.

Efforts to Model Morale

The effectiveness of the troops as presented by Marshall and Rowland is dependent upon the combat spirit or morale of the troops. There are many definitions and descriptions of morale. An analysis by Richardson decomposed morale into three divisions (Richardson, 1978, p. 171).

The first division is the personal or individual morale. This division includes physical and mental factors. The physical factors are aspects such as health, food, rest and sleep. The mental factors included understanding the cause, self-confidence in abilities, religious beliefs and moral principles, and the perception of the quality of leadership.

Williams wrote of morale that mail and food were the "two areas of largest complaint" (Williams, 1992, p. 21). This indicated two major aspects of both the physical and mental factors. Lt. Thornton stated "In garrison and in the field, officers must fight continually to secure prompt deliverance of mail. No other factor in a soldier's existence is so important as the prompt receipt of news from home" (Thornton, 1943, p. 1). This factor, evolving to internet connectivity and e-mail, appears to be as important in the network centric, inter-connected world.

The second division suggested by Richardson is the morale of the small group; also known as unit cohesion (1978, p. 171). Richardson describes three facets of unit cohesion. First, the soldier is a member of the unit with confidence in leadership. Second, the soldier has the confidence and respect of comrades. Finally, the soldier is determined to not let friends down (both leaders and comrades in arms). During World War II Spiegel observed unit cohesion during the Tunisian campaign. He states:

> *They expressed little hate for the enemy and they had little desire to kill. Rather, their aggressive action was motivated by a positive force – love more than hate – manifested by 1) a regard for their comrades who shared the same dangers, 2) a respect for their platoon leader or company commander who led then wisely, and backed them with everything at his command, 3) a concern for their reputation with their commander and leaders, and 4) an urge to contribute to the task and success of their group and unit. They were fighting for themselves and for their unit, and in that way for their country and their cause.* (Spiegel, 1944, p. 310)

The third division presented by Richardson is the unit morale. This is the *Esprit de Corps* of the unit as a whole. This division represents the importance of being in the Army, Corps, or division. General Anthony Zinni stated, "Service rivalry leads to service pride, which is good for building morale and *esprit*" (Zinni, 2001, p. 3). Morale influences the decision to join the specific services and further drives the individual to strive for being a Ranger, Special Force Operator, or a member of other elite organizations. It also leads members of selected units to believe their unit *is* special.

The review of morale and combat spirit thus far has been static in nature. The research that follows is based in part on the results of a World War II study which suggested a dynamic model for morale dependent upon the number of sorties flown by Royal Air Force (RAF) Bomber crews. Stafford-Clark, a flight surgeon, interviewed and flew with the bomber aircrew members for over four years (Stafford-Clark, 1949, p. 14). The RAF Bomber Command's policy was the airman's tour of duty was complete after thirty successful bomber missions.

> *The average rate of loss over this period was officially assessed at 5 percent on each operation, but this referred in fact only to aircraft which were missing. It did not include crashes in the United Kingdom, either on takeoff or return, whether due to the normal hazards of flying or to enemy action. In practice the chances of any particular individual surviving his 30 trips alive, unwounded and without having been taken prisoner, or having been forced down over enemy territory were generally accepted by the air crew themselves as being just about one in five.* (Stafford-Clark, 1949, p. 13)

Over the duration of the 30 missions, the morale of each aircrew varied. The opportunity to accomplish the mission and the novelty of flying drove the aircrews to a high morale for the first two or three operational missions. By the fifth to eighth mission, the aircrew had most likely seen aircraft shot down and the novelty of operational flying was gone (Stafford-Clark, 1949, p. 19). This decrease in morale appeared to continue subconsciously until about the twelfth to fifteenth mission when the morale was at the lowest point. The morale increased as the aircrew only looked toward the success and surviving the next mission. From the mid-point in missions to be flown, aircrew's morale increased (Stafford-Clark, 1949, p. 20). The peak occurred near the twenty-fifth mission.

At this point the cumulative stress and fatigue were apparent. The commanding officer could suspend the tour-of-duty for the aircrew at this point; however, “by far the majority of aircrew who survive a tour complete their full quota of thirty operational sorties” (Stafford-Clark, 1949, p. 20).

Stafford-Clark presented Figure II-16, as a graphical illustration of the change to morale for each mission. He offered no mathematical derivation for his illustration.

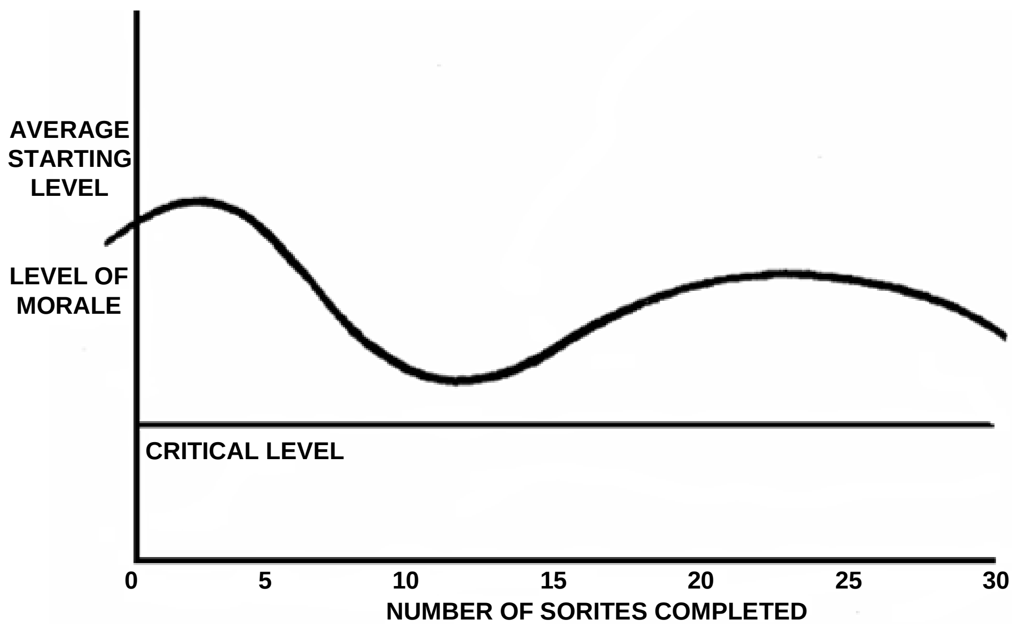


Figure II-16: Stafford-Clark Model of Morale (Stafford-Clark, 1949, Figure 1 Page 21)

Several cases were analyzed by Stafford-Clark to show different implications of the curve. Group A were aircrew that entered the service with a low morale. These aircrew members did not complete the 30 missions (Stafford-Clark, 1949, p. 27). Group B suffered from an impact of environment and low outlook for their future . It could be suggested that these aircrew suffered from a lack of unit cohesion. The group B aircrew had extremely low morale before their morale improved (Stafford-Clark, 1949, p. 29). The majority of these aircrew members did return to duty. Group C aircrew reported very low morale due to the cumulative stress of the operations. These aircrew members also continued to fly; however, they were at critical levels for their morale (Stafford-Clark, 1949, p. 31). Figure II-17 presents the number of aircrew in each group, and the prognosis of each case is also indicated. The cases that encountered exceptional stress all had bad prognoses. Figure II-18 demonstrates the impact to the generic morale curve from each of the groups.

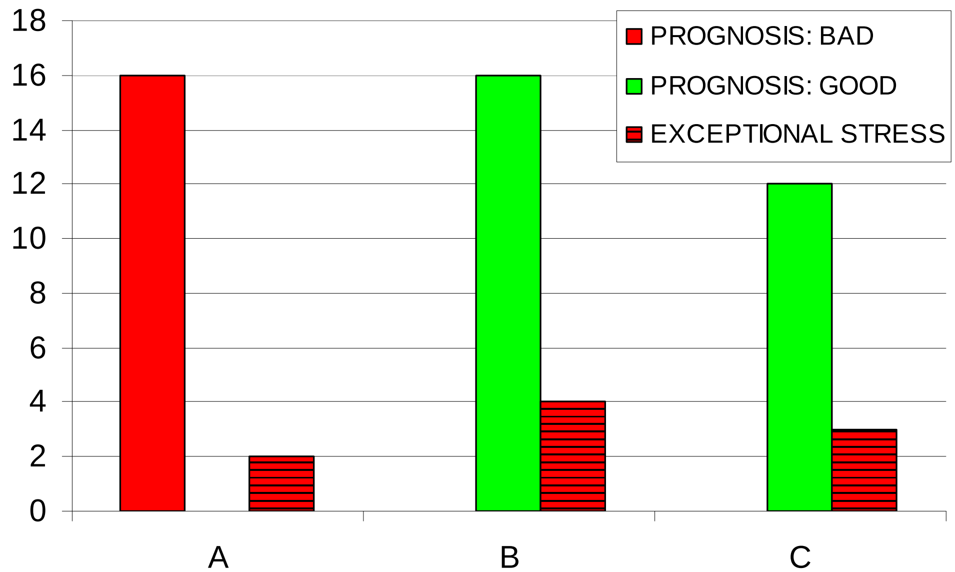


Figure II-17: Number of Aircrew in each Group
(Stafford-Clark, 1949, Table 2 Page 24)

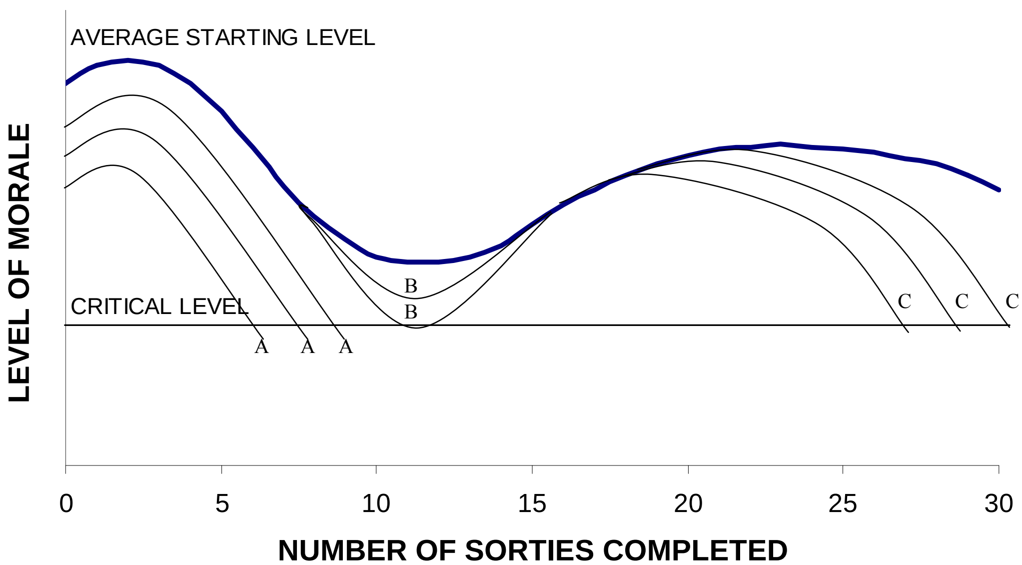


Figure II-18: Impact to Morale Model from each Group
(Stafford-Clark, 1949, Figures 2-4 Pages 36-37)

Menninger appears to have built upon the work of Stafford-Clark by applying the morale curve to the duration of time of a Peace Corps member's tour of duty. Additionally, four periods of crisis are identified and the universality and scalability of the morale curve was introduced.

Menninger used the results of nearly 1,000 questionnaires of Peace Corps members to build the morale curve presented in Figure II-19 (Menninger, 1988, p. 200). There were four critical periods of psychological adjustment that were identified: arrival, engagement, acceptance, and reentry.

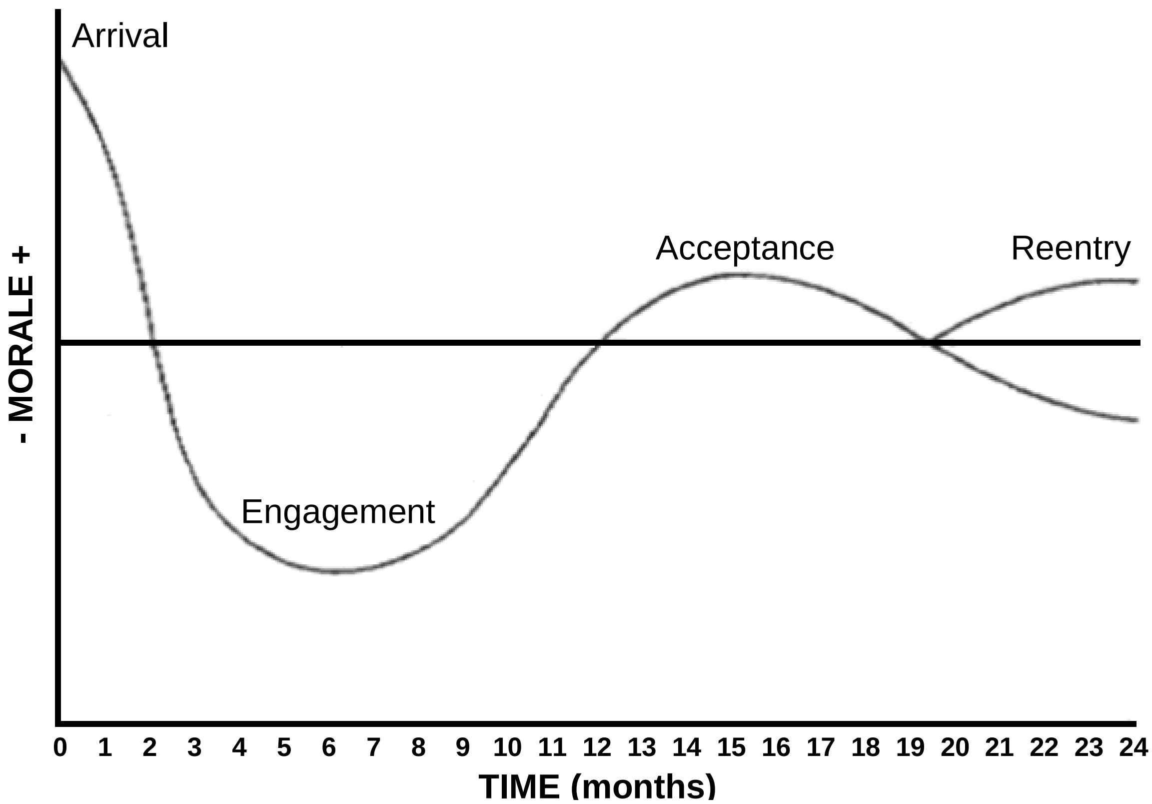


Figure II-19: Morale Curve for the Peace Corps (Menninger, 1988, Figure 1 Page 201)

A direct benefit of Menninger's Morale Curve is how it varies on time versus number of missions. Additionally, Menninger provides support that this model is both universal and scalable. Menninger suggests that the morale curve is accurate (scalable) for a twenty-four month Peace Corps commitment as well as a five day education seminar, nine month academic year, or a four year college education (Menninger, 1975, p. 110). For example, during a six week camp, the first week is the point of high morale associated with arrival. The crisis of engagement occurs during the end of the second week. The crisis of acceptance occurs during week four. Finally, reentry occurs during the final week (Menninger, 1988, p. 202-203). Similarly, the four year degree program demonstrates “freshman anxiety, the sophomore slump, junior activism, and the senior disorientation” (Menninger, 1975, p. 110).

Menninger also provides information on how to employ the morale curve when there is no expected end to the state of affairs:

> *When the new situation has no clear end point, there is no obvious fourth crisis (reentry); rather, as a general rule, the process evolves over a 2-year period as the individual develops a new sense of self.* (Menninger, 1988, p. 204)

This provides an ability to model the morale of an individual that is in a conflict with no clear deployment/redeployment schedule or fighting for one’s own survival.

Figure II-20 presents Swank and Marchand’s schematic representation of the impact of combat efficiency of the first sixty days of combat during the D-day invasion. As seen previously by both Stafford-Clark and Menninger, the morale and effectiveness is high or quickly increases when the soldier first enters combat. Stafford-Clark’s model defends the lack of efficiency after the second month by the description of Group A aircrew. Figure II-20 is restricted to a continuous period of extreme conflict. This occurred during the engagement phase suggested by Menninger. It is not clear whether the morale and effectiveness are recoverable and thus increase to a phase of acceptance.

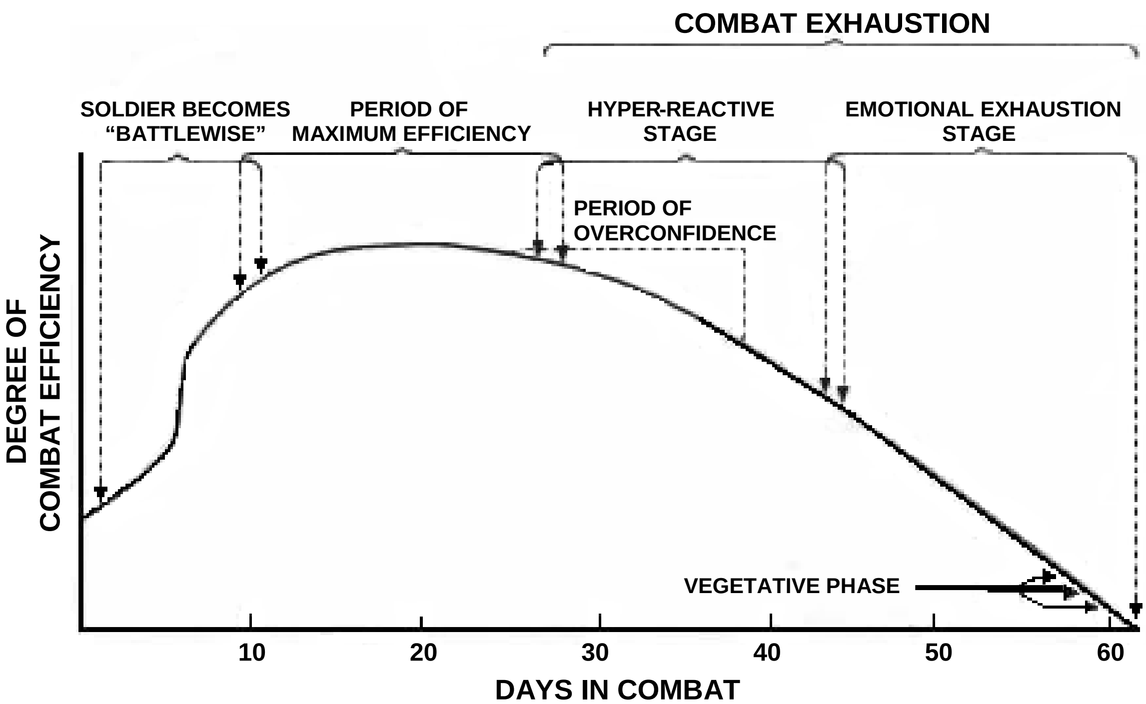


Figure II-20: Effects of Continuous Combat (Swank & Marchand, 1946, Figure 1 Page 238)

This section provided a review of how morale has been modeled. The review included three models of morale: RAF bomber crews during World War II, deployments of the Peace Corps, and the sixty days following invasion at Normandy. These three models demonstrate how morale has changed with time during a conflict.

Control Theory

Control theory provides the capability to analyze the response to systems over time (Ogata, 1997, p. 63). A brief overview of how a system at equilibrium responds to an impulse is provided. The discussion is limited to the second order transient response to a unit-impulse of an underdamped system. Basically, this is how a system establishes equilibrium over time, following an impulse or significant event, based on a damping ratio (ζ) for the period (T). The transient response is based on the undamped (or resonant) natural frequency (ω_n), which is defined as $\omega_n = \dfrac{\omega_d}{\sqrt{1-\zeta^2}}$, where $\omega_d = \dfrac{2\pi}{T}$. ω_d is referred to as the damped natural frequency. With ζ and ω_n defined, the transient response $c(t)$ is represented by Equation II-31 (Ogata, 1997, p. 159):

$$c(t) = {\omega_n}\Big/{\sqrt{1-\zeta^2}}\, e^{\zeta\omega_n t} \sin \omega_n \sqrt{1-\zeta^2}\, t \text{, where } 0 \le \zeta < 1 \text{ and } t \ge 0 \qquad \text{(II-31)}$$

The response over time can be seen for varying ζ's in Figure II-21.

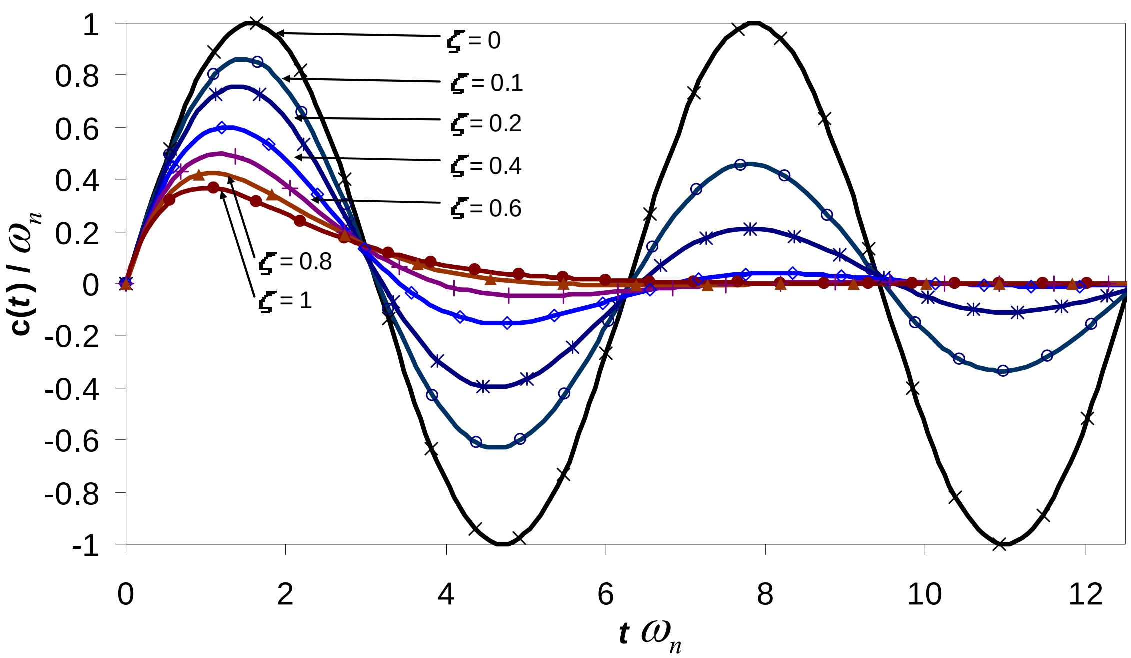


Figure II-21: Response over Time as ζ Varies

When $\zeta = 0$ the system is undamped and continues to respond to the impulse at full magnitude indefinitely. When $\zeta = 1$ the system is critically damped and returns to equilibrium with out undershooting the status quo. While $0 < \zeta < 1$, the system is underdamped and the settling time increases as ζ decreases.

If ζ and ω_n are known, the system is easily defined. However, if any two peaks are known, the function can be fit using the log decrement method. The log decrement method solves $\zeta = \delta \Big/ \sqrt{\delta^2 + 4\pi^2}$ where $\delta = \frac{1}{m}\ln\left(\frac{x_n}{x_{n+m}}\right)$ (Macioce, 2003, p. 12). The height of the first peak is x_n, and x_{n+1} is the height of the next peak. The valley between the peaks can be used, where $x_{n+0.5}$ is the distance from equilibrium. Using a control theory approach may prove useful in fitting the morale curve.

Summary

This chapter introduced and discussed fourth generation warfare. The principles for such a conflict were also presented. Next, the concept of a strategic level model was introduced. The section is followed by a brief overview of system dynamics. This field is focused on the use of continuous event models which contain feedback within the system. The Lanchester Laws were then described. Due to the similarity of fourth generation warfare and guerrilla warfare, the application of Lanchester Laws in this specific field was thoroughly discussed. Unfortunately, none of the research in this area involves dynamic models, and thus does not capture all of the key aspects of fourth generation warfare.

The section on modeling the will-to-fight provides several descriptions, models, and trends in modeling morale and public resolve. This was followed by a brief introduction to control theory's second order response to an impulse.

Attributes of each of these methods are used within the next chapters to create a theory and modeling framework of fourth generation operations.

III. Fourth Generation Operations and Principles

Chapter Overview

This chapter develops the concepts of fourth generation operations and associated principles. Additionally, the first two contributions of the dissertation are achieved in this chapter. They develop a concept of fourth generation operations based on the framework of US Joint doctrine and develop the supporting principles of fourth generation operations. This contribution requires the introduction of the principle of Population Perception.

Fourth Generation Operations

An element of Lind *et al.*'s fourth generation warfare is the attrition of the will and morale of the enemy (Lind *et al.*, 1989, p. 5). This attrition compels the enemy to capitulate to the goals and objectives of their foe. This chapter asserts that fourth generation warfare, particularly the aspects of will and resolve, is the backbone of fourth generation operations. Joint doctrine presents conflict bridging the spectrum from peace to war and back to peace (JP 3-0, 2006, p. IV-26). It is critical in today's arena that military operations and responsibilities span *across* this spectrum, thus *operations* is substituted for warfare.

Fourth generation operations are defined in this study as conflict which combines elements of guerrilla tactics, insurgency, terrorism, traditional warfare, and the ability to exploit and skip generations of technology to conduct operations, particularly to target the will and morale of the enemy's support structure, in order to achieve political victory.

In this definition, the support structure refers to both the population and the combatants. This definition does not focus on nation-states, and therefore includes cases where transnational groups are the instigator or target of the conflict. Additionally, the specific methods applied in the conflict are not specified; therefore, fourth generation operations may use any military, diplomatic, economic or informational instrument of power to influence their enemy's will and morale. Just as US military doctrine has expanded the concept of information warfare to the broader and more inclusive concept of information operations, fourth generation warfare must be expanded to fourth generation operations.

In this paradigm, operations occur not only during actual conflict, but also across the spectrum from peace to combat and back to peace. Transnational asymmetric conflict does not require a conventional declaration of war to be initiated. While 9/11 may be an easily identified starting point for the 'long war,' our foes started their operations well before that date. Since the population may be specifically targeted by the combatants within fourth generation operations, fourth generation operations require a change in technology, tactics, doctrine, combatants, and definition of conflict from those for third generation warfare.

Fourth generation operations, while not currently defined in US doctrine, addresses a gap previously identified within the doctrine used by the US military. This gap has been filled by continuous transitions from non-war operations to full-scale campaigns with the additional phases of joint operations (specifically stabilization) and back to a sustainable peace (JP 3-0, 2006, p. IV-26).

The concept of fourth generation operations does not precisely fit any of the definitions of combating terrorism, supporting counterinsurgency, or supporting insurgency provided by joint doctrine. It clearly bridges the gap in the range of operations between war and MOOTW. This is evident by the current operations in both Iraq and Afghanistan where the major traditional war operations ended with a resounding victory by the coalition forces; yet, the transition to 'supporting' the indigenous forces in their suppression of counterinsurgents and terrorists has been difficult to achieve. The US and coalition forces are currently still overseeing the majority of counterinsurgency and peacekeeping operations in a number of areas. Obviously, the military is not in a supporting role. While this is an intermediate goal in both Iraq and Afghanistan, this goal has not yet been fully achieved. Environments within Iraq and Afghanistan can be cited as two occurrences of fourth generation operations, as can elements of the worldwide global war on terrorism.

Figure III-1 depicts the relationships of the first four generations of war and fourth generation operations. The transition from fourth generation warfare to fourth generation operations is represented by dotted lines as opposed to the previous generations. The solid lines represent the evolution of generations. Additionally, the recognition of the four instruments of power (diplomatic, information, military, and economic) are listed to emphasize how *all* the instruments of power are now required. Defeating the enemy's standing army does not immediately result in political victory, particularly when the enemy may not have a standing army in the classic sense. Finally, three dimensions of the operational environment are listed. These three dimensions interact within fourth generation operations to accomplish the objectives.

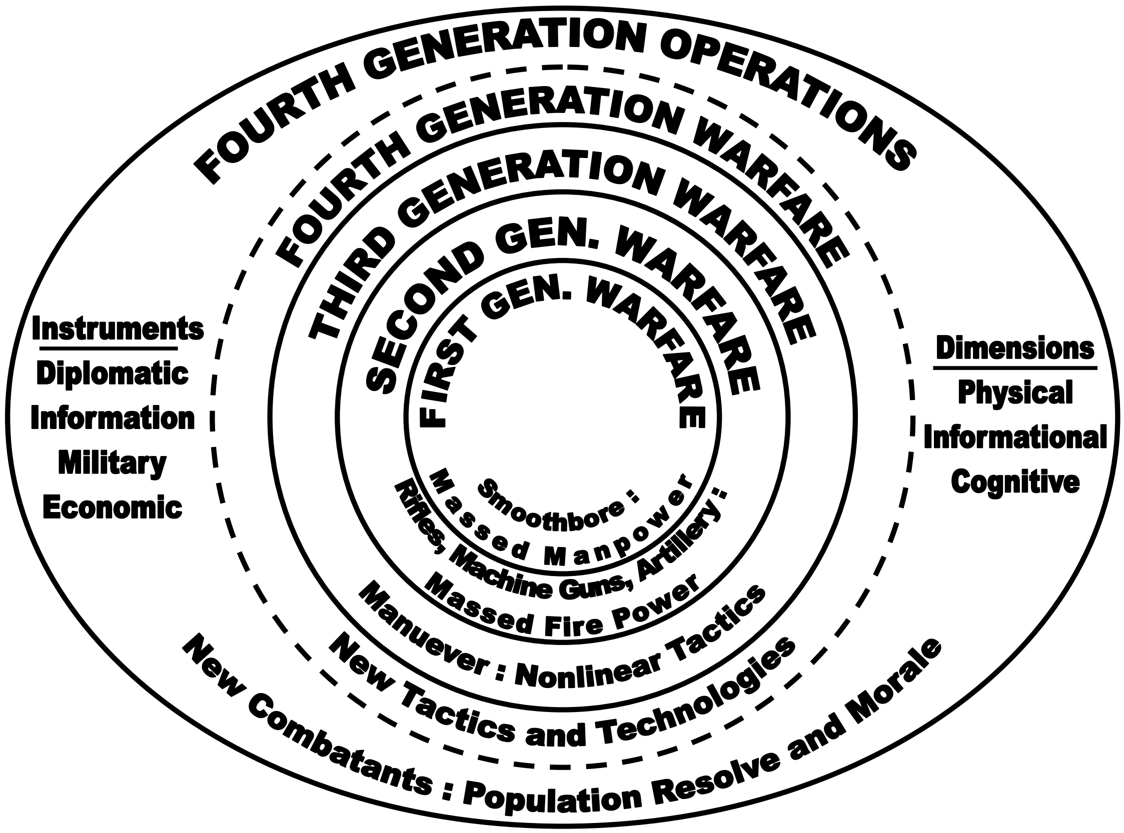


Figure III-1: Fourth Generation Operations

With the fourth generation operations defined, the principles of fourth generation operations are next introduced.

Principles of Fourth Generation Operations

While the principles of joint operations may be sufficient in covering aspects of fighting a counterinsurgency, they are not necessarily sufficient for fourth generation operations. This section proposes the addition of one more principle for fourth generation operations to those introduced in Chapter 2 (Objective, Offensive, Mass, Economy of Force, Maneuver, Unity of Command, Security, Surprise, Simplicity, Restraint, Perseverance, and Legitimacy). The new principle is Population Perception. The principle of Population Perception focuses on the indigenous population.

Population Perception can be viewed as the combatant's attention and response to the effects of the operations within the appropriate population. The other principles which exist mainly in the cognitive operational environment include Perseverance and Legitimacy. Perseverance, Legitimacy, and Population Perception all interrelate.

This research redefines Perseverance as ensuring the commitment *of both the American population and military*, necessary to attain the national strategic end state. This definition is based on US military doctrine with the italics area added. The principle of Perseverance is how our military and supporting population perceives the ongoing operations. The supporting population of our forces (US population) is distinctly different than the supported population (indigenous Iraqi population). This is best presented by the response to the question: *Can we achieve our objectives if we continue operations?*

Legitimacy is redefined as developing and maintaining the will *of both the government and military*, necessary to attain the national strategic end state. Legitimacy is the perception of both the US military and indigenous government by the enemy and the indigenous (supported) population. Legitimacy is understood by the response to the question: *Are we doing the right thing?*

Finally, Population Perception is defined as *attending and responding to the operation's effects within the appropriate population*. Population Perception is how the government and military are perceived by the appropriate population. Population Perception is represented by the question: *Do they think we can achieve our objectives and are doing the right thing?*

Population Perception is not to be confused with perception management, which is defined as:

> ***Perception Management*** *— Actions to convey and/or deny selected information and indicators to foreign audiences to influence their emotions, motives, and objective reasoning as well as to intelligence systems and leaders at all levels to influence official estimates, ultimately resulting in foreign behaviors and official actions favorable to the originator's objectives. In various ways, perception management combines truth projection, operations security, cover and deception, and psychological operations.* (JP 1-02, 2006, p. 407)

Perception Management may be used to shape Population Perception.

This study proposes thirteen principles of fourth generation operations. These principles begin with the twelve principles of joint operations and include the principle of Population Perspective. These thirteen principles are defined in Table III-1. Changes to the principles of joint operations (JP 3-0, 2006, Appendix A) are indicated by italics.

Summary

This chapter introduced the concept of fourth generation operations. Fourth generations operations are the evolution and extension of third and fourth generation warfare based on a change of tactics, technology, and combatants. These operations are currently ongoing in Afghanistan and Iraq, and with the Global War on Terrorism.

The principles of joint operations were used as a building block for the principles of fourth generation operations. The principles of fourth generation operations include all the principles of joint operations. The chapter redefined the principles of Legitimacy and Perseverance and added the principle of Population Perspective to create the principles of fourth generation operations.

Table III-1: Principles of Fourth Generation Operations

Principle	**Definition***
Objective	Direct every military operation toward a clearly defined, decisive, and achievable goal
Offensive	Seize, retain, and exploit the initiative
Mass	Concentrate the effects of combat power at the most advantageous place and time to produce decisive results
Economy of Force	Allocating minimum essential combat power to secondary efforts
Maneuver	Place the enemy in a position of disadvantage through the flexible application of combat power
Unity of Command	Ensure unity of effort under one responsible commander for every objective*, including military, coalition, American government and civilian organizations*
Security	Never permit the enemy to acquire unexpected advantage
Surprise	Strike at a time or place or in a manner for which the enemy is unprepared
Simplicity	Prepare clear, uncomplicated plans and concise orders to ensure thorough understanding
Restraint	Limit collateral damage and prevent the unnecessary use of force
Perseverance	Ensure the commitment, *of both the American population and military*, necessary to attain the national strategic end state
Legitimacy	Develop and maintain the will, *of both the government and military*, necessary to attain the national strategic end state
Population Perception	*Attend and respond to the operation's effects within the appropriate population*

* Changes to definitions found in JP 3-0, 2006 are indicated by italics. JP 3-0 provides updated definitions of principles found in JP 1, 2000 (see Table II-2 and Table II-3).

IV. Lanchester Laws in a System Dynamics Framework

Chapter Overview

System dynamics models are able to represent qualitative aspects of combat that may be difficult to capture in a discrete event simulation. Additionally, the system dynamics construct allows for the modeling of continuous events and incorporating system feedback. This chapter develops a systems dynamics framework of the Lanchester Laws with events. Two models of the Lanchester Laws are presented. The first is a traditional discrete event simulation which is offered as a baseline for comparison; the other is a system dynamics implementation of the Lanchester Laws. Results from the discrete event simulation and the system dynamics model are analyzed, compared and contrasted.

The chapter provides examples of how the Lanchester Laws can be modeled using both discrete event simulation and system dynamics. Comparisons of the modeling techniques are presented through the implementation of an excursion (compared to a baseline) where reserve forces are implemented. The suitability of the system dynamics framework in some settings is further demonstrated with an excursion where the forces are fatigued. The chapter concludes with a summary of results.

Discrete Event Simulation versus Systems Dynamics

This section compares and contrasts modeling the Lanchester Square Law in both a discrete event simulation and system dynamics model. A simple case is used in this section to demonstrate how to apply the discussed framework. These illustrations can be solved analytically; however as the complexity of interactions and dimension of the state-space increase in an actual operational scenario, the analytic solution becomes prohibitive to solve. This is evident by the number of complex combat scenarios which require simulation to model the initial interactions and are therefore never reduced to analytic equations.

The Lanchester equations are implemented in discrete event simulations by solving the equations at discrete time intervals. When the analytic solution to the Lanchester Equations can not be found because of the complexity of the example, a discrete event simulation is not able to solve the equations to predict the *exact* time future events occurred. Therefore, the exact future event times are not generated. A discrete event simulation evaluates events at predetermined time intervals. This is referred to by Bratley, Fox, and Schrage as a synchronous discrete event simulation (1987, p. 17).

In general, synchronous discrete event simulation has several potential drawbacks. One drawback is non-simultaneous events must be treated as simultaneous if they fall within the same time period. This requires all possible interaction combinations to be anticipated, modeled and planned. Additionally, when the step size is decreased, the accuracy of results increases; however, the speed of the simulation decreases (Bratley, Fox, & Schrage, 1987, p. 17). To increase the speed of the simulation, it is possible to skip intervals if enough information about the system can be obtained. Skipping intervals must be based on expected conditions and the required fidelity of the solution, both further complicating the simulation (Bratley, Fox, & Schrage, 1987, p. 17).

A discrete event simulation must approximate the values of attributes and variables between events. This can be resolved by reducing event times, but it may force the model to take substantially more time to complete. A system dynamics model does not approximate to achieve the level between events. A benefit of system dynamics models, when required by the analysis, is their ability to smoothly transition the levels of the attributes and variables. This does not imply that the levels can not be adjusted in step increments as demonstrated later in this chapter with the implementation of reserve troops.

In some modeling scenarios the arrival of a regiment, army, or additional fighters can be adequately and appropriately modeled as a discrete event, perhaps as the average time. In other settings, the actual flow of troops into the fight may be critical, suggesting the use of system dynamics. An example might be the arrival of Marschall Blücher's forces at Waterloo. While the main body had not totally arrived, the appearance of the forward elements on the battlefield was instrumental in turning the tide of battle.

Basic Discrete Event Simulation and System Dynamics Models

There are numerous methods to model the Lanchester Laws. This study implemented the basic Lanchester Laws in a simple discrete event simulation. The entities generated within the discrete event simulation, for this study, do not have any attributes, nor require any resources. As real world aspects (like ammunition, equipment and supplies) are added to the model, they would be modeled as attributes or resources. Figure IV-1 is the pictorial representation of a basic implementation of the Lanchester Square Law developed in Arena 10.0.

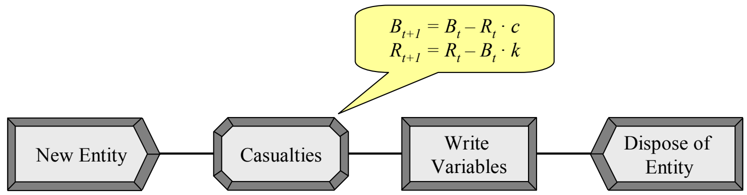


Figure IV-1: Discrete Event Simulation of the Lanchester Square Law

The furthest left container created a new entity at each time interval. The entity flowed to the Casualties container where the global variables representing the number of Blue and Red forces at time $t + 1$ (B_{t+1} and R_{t+1}) were calculated based on the attrition coefficients (c and k) and the current size of the forces (B_t and R_t). After the global variables were adjusted, the simulation proceeded to output the status of the variables and then the entity was disposed. The balloons on the figure display the equation within each container.

The system dynamics representation of the Lanchester Square Law focused on the level of Blue and Red Forces (B_t and R_t), where the forces were the number of personnel or the total combat value. Blue and Red forces levels were changed by the rate of Blue or Red Attrition. Figure IV-2 is the depiction of the system dynamics representation of the basic illustration. Red Attrition through time (RA_t) was the total number of Red Forces killed (or otherwise removed from battle) by the surviving Blue Forces during each time interval, and vice versa for Blue Attrition (BA_t). The Blue Attrition Coefficient (k) represented the number of force of Red that could be killed per unit of Blue force.

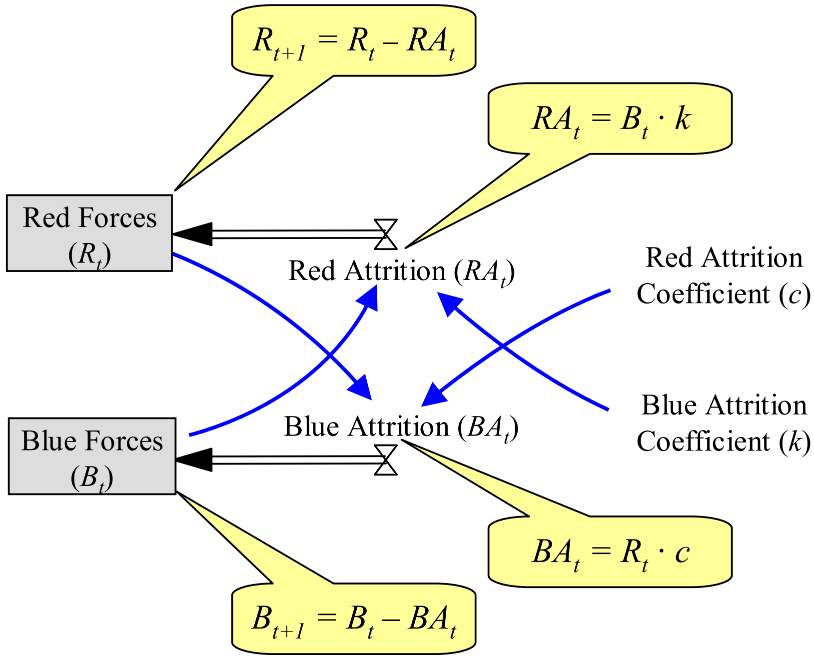


Figure IV-2: System Dynamics Model of the Lanchester Square Law

Discrete Event Simulation and System Dynamics Models with Reserves

This subsection demonstrates that a system dynamics model performs the same as a discrete event simulation for a more complicated model. The basic discrete event simulation and system dynamics models were modified to represent Dewar, Gillogly, and Juncosa's (1996) combat model presented in Table IV-1 . Dewar, Gillogly, and Juncosa simulated a two sided conflict with troop replacements using a discrete event simulation with a time-step of one-half hour. Their model used the Lanchester Square Laws with a Red Attrition Coefficient (c) of 1/2048 and the Blue Attrition Coefficient (k) that equaled 1/512. The initial Red (R_0) and Blue (B_0) Troop sizes are also presented in Table IV-1. When specific thresholds based on a force ratio or percent of surviving forces were breached, reinforcements were requested. The reinforcement block size was 300 troops. Each side had five reinforcement blocks and the reinforcements arrived 70 time steps (or

35 hours) after the reinforcement threshold were breached. Withdrawal (or defeat) of the forces was declared once additional predetermined thresholds for either combat ratio or percent of surviving forces was crossed. Victory was declared based on a specific combat ratio (i.e. forces were substantially outnumbered), or a force strength dropping below a predetermined level (i.e. the battle was too costly to continue) based on the thresholds in Table IV-1.

Table IV-1: Combat Model (Dewar, Gillogly & Juncosa, 1996: Table 1, Page 39)

Parameter	Blue	Red
Initial troop strength	$B_0 = 839$	$R_0 = 1{,}500$
Combat attrition calculation	$B_{t+1} = B_t - R_t/2048$	$R_{t+1} = R_t - B_t/512$
Reinforcement threshold	$R_t/Bt \geq 4$ or $B_t < 0.8\ B_0$	$R_t/B_t \leq 2.5$ or $R_t < 0.8\ R_0$
Withdrawal threshold	$R_t/B_t \geq 10$ or $B_t < 0.7\ \mathrm{B}_0$	$R_t/B_t \leq 1.5$ or $R_t < 0.7\ R_0$

Figure IV-3 depicts the discrete event simulation which represents Dewar, Gillogly, and Juncosa's combat model. The Casualties were computed as described for Figure IV-1. Next, the model checked to see if the conditions required to declare the winner were met. This is represented in Figure IV-3 as the diamond labeled 'winner.' If there was a winner, the global variable indicating a combat force had won was changed. If there was not a winner, the model checked to see if the Blue side was currently waiting for reserves. If the Blue side was not waiting for reserves, the model checked the Blue reinforcement thresholds to see if Blue Reinforcements were necessary. If reserves were required, the global variable for Blue Waiting for Reserves was triggered, and the model scheduled the event to add reinforcements in 70 time steps. The model reset the Blue Waiting for Reserves variable after 70 time steps and disposed of the entity. If the system was waiting on Blue Reserves or did not need Blue Reserves, similar checks were made regarding Red Reserves. This implementation did not allow for both Red and Blue forces to add Reserves at the same time period. This was possible to implement but would add an additional layer of condition checks and directives to the model. As discussed earlier, a drawback of synchronous discrete event simulations is all possible material critical state-spaces and conditions must be anticipated and those paths and conditions must be tested and implemented within the model.

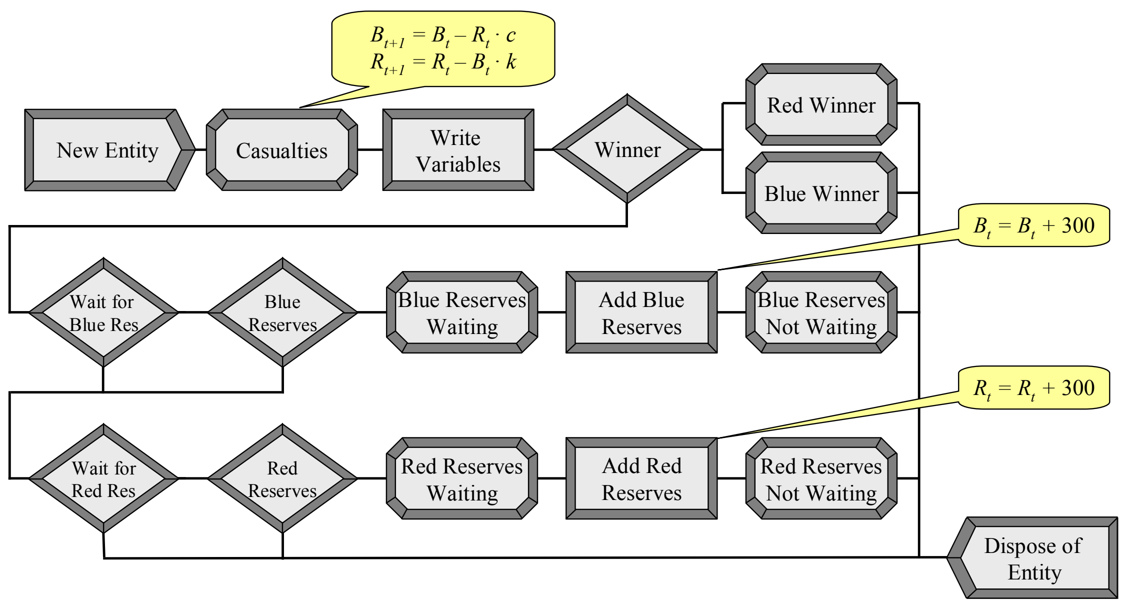


Figure IV-3: Discrete Event Simulation of the Combat Model

The results of the discrete event simulation are presented in Figure IV-4. This figure presents the number of forces surviving at each time period. The discontinuous points were due to the arrival of the 300 reinforcements. The Red Forces required all of their reserves, while the Blue Force won after only adding three reserve blocks.

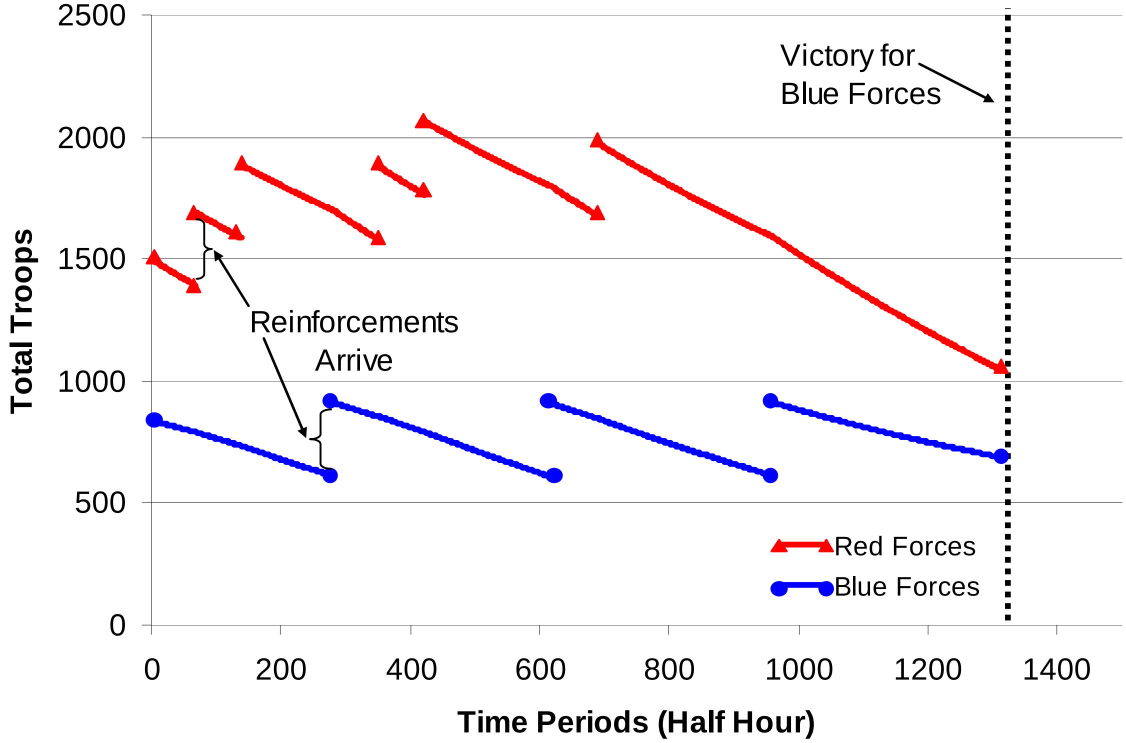


Figure IV-4: Results of the Combat Model

The basic system dynamics model was modified to represent Dewar, Gillogly, and Juncosa's combat model by first creating the levels of Blue/Red Force Strength and Combat Ratio. The Blue/Red Force Strength was the percent of forces still alive at the current interval of the battle. The Combat Ratio was the Red Forces divided by the Blue Forces. The Combat Ratio and Blue/Red Force Strength levels were required to determine the requirement of Red and Blue Reserves. If the reserve force thresholds were achieved, the system checked to see if it was waiting on reserves and if there were reserve blocks available. If all conditions were met to add the new reserves, the value labeled Add Red Reserves (RR_t) and/or Add Blue Reserves (BR_t) was changed to 300 and the rate flowed to the Red and Blue Forces respectively.

The system dynamics representation of the simple combat model was presented in Figure IV-5. As opposed to the discrete event simulation, the system dynamics model allowed both Red and Blue Forces to be added at the same time, since the addition of troops does not require all possible interaction combinations to be anticipated for each time interval. Additionally, the time the reserves were requested could be identified at the exact moment the thresholds were reached. The timing could be more precisely identified within the discrete event simulation by reducing the time step, but the time step was already small relative to the scenario.

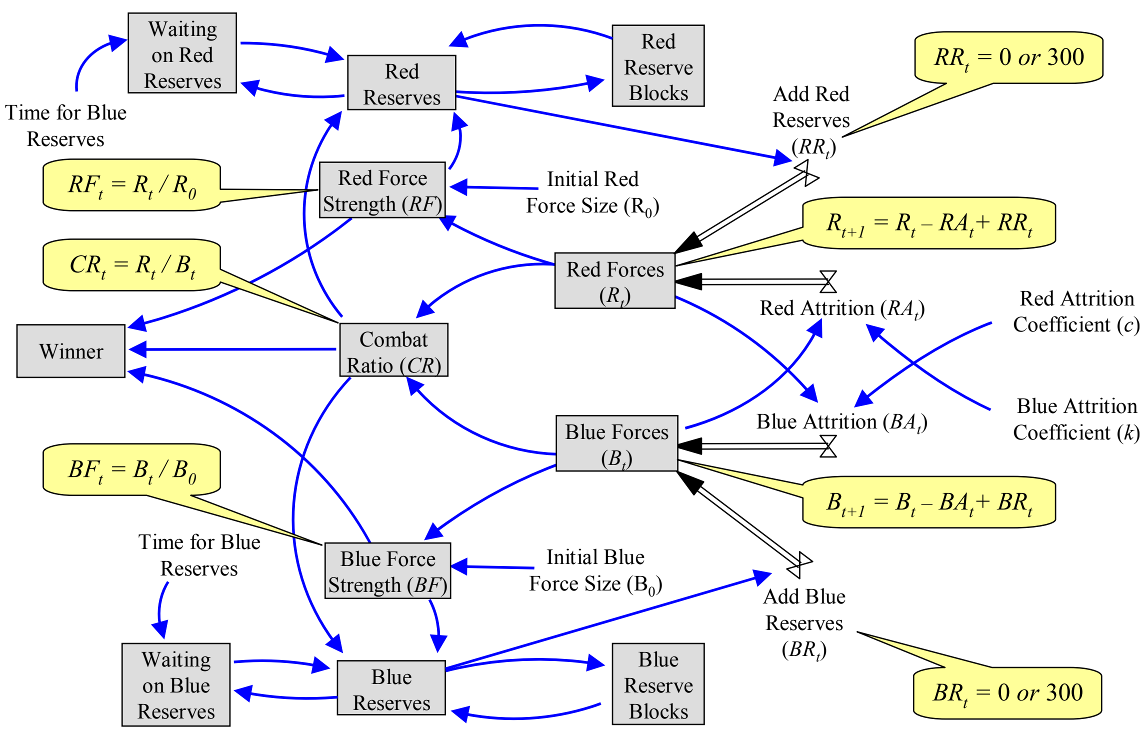


Figure IV-5: System Dynamics Model of the Combat Model

The discrete event simulation and system dynamic models produce equivalent results. In both representations, the reserves arrived on the same day and the battle concluded on the same day. There were only minor variations in the force size throughout the run of the model. The largest difference between the sizes of forces reported by each model for the 1,310 time intervals was 0.0013 or 0.00011% of the response. Figure IV-4 can be used to represent the results from both the discrete event simulation and the system dynamics models. The correlation of Blue force at the end of each time interval of the discrete event simulation with results from the system dynamics model was 1 – 1.29E-12. Red correlation was 1 – 1.11E-12. Both represent a correlation of results which is approximately one. This exercise demonstrates that system dynamics models can effectively model the Lanchester Laws which have been historically modeled as a discrete event simulation; in addition if a continuous flow more accurately models the environment, a system dynamics model may be preferred.

The system dynamics model of these events and rates can be easily adjusted based on the current environment. For example, if the reserves were located near the engaged troops, the time of arrival of the reserves could be less than when the front line of troops were at a distance. Additionally, the system dynamics models could 'flow' the reserves into the engaged forces as logistics allowed rather than assuming all the reserves arrived at the same time (as typically expected within a discrete event simulation). A system dynamics based model can easily incorporate this change by connecting the 'level' indicating the troop's location to the 'level' indicating time to wait for reserves. The time to wait on the reserves is no longer a constant and can depend on the location of troops and the rate of their arrival. In addition, the rate of arrival of troops to the front can be controlled, if desired.

The discrete event simulation and system dynamics examples focused on the engagement, or battle, level of warfare. As the Lanchester Laws have been applied to all levels of warfare (engagement, mission, campaign and strategic), both approaches can be used to as a modeling framework for all levels of warfare. This is not meant to suggest current discrete event simulations are inadequate or inappropriate. Rather as combat and conflict become more affected by continuous, dynamic interacting elements, especially at the campaign or theater level and the data to model such events becomes more available, system dynamics may offer a different level of insight to decision makers. Historically, system dynamics has been applied to a vast array of levels in planning from the factory floor to world models (see Forrester, 1961, 1969 and 1971, among others). This suggests that it can be applied from skirmishes through strategic levels, given proper inputs. System dynamics models are particularly appropriate when not accounting for the continuation of time, leads to issues of accuracy. Its consideration provides another modeling option. As with all modeling, the analyst should select the appropriate technique for the fidelity required by the decision environment.

Implementation of Fatigue

Thus far the values of the attrition coefficients have been static. While in real combat the troops would become more or less effective as the battle continues and fatigue, among other attributes, change. As a demonstration of potential options, the dynamic attributes of the system dynamics model was expanded by incorporating a 'fatigue' coefficient into the Dewar, Gillogly, and Juncosa's combat model. To model this, fatigue was represented as the effective combat power for a force. A force having no fatigue retains 100% of its combat power. Over time while in combat, fatigue increases, effectively reducing combat power. The new attrition coefficient now equaled the original coefficient multiplied by one minus the fatigue factor. It was first assumed that the initial forces have no fatigue. It was further assumed that the reserves entered the conflict with no fatigue. When the reserves entered, the percentage of fatigue was reset to reflect the addition of fresh troops.

In this excursion it was assumed that when the reserves entered, the new fatigue was a weighted average of the fatigue from the reserves and the existing forces. For example, when 1000 troops were fatigued at 30% and 500 fresh reserves entered combat, the new fatigue value was two thirds (1000/1500) of it previous value or 20% based on this illustrative fatigue aggregation formula (any appropriately vetted factor may be used). This implementation implied that the reserves were mixed throughout the current combatants when the reserves entered combat (of course, a damping function or morale boost could be included).

Fatigue is modeled in the discrete event simulation by the creation of four new global variables. These could be referred to as the Blue/ Red Attrition Coefficients (*c* / *k*) and Blue/ Red Fatigue (*BF* / *RF*). Additionally, new decision nodes are required to decide how, why and when to change these new global variables. The alterations are possible, but not insignificant.

The system dynamics model added two new levels (identified as Red and Blue Fatigue). The system dynamics model with the fatigue factor is presented as Figure IV-6. Red and Blue Fatigue were a function of the rate reserves entered the system and the current level of forces. The attrition coefficients (*c* and *k*) were now a function of fatigue.

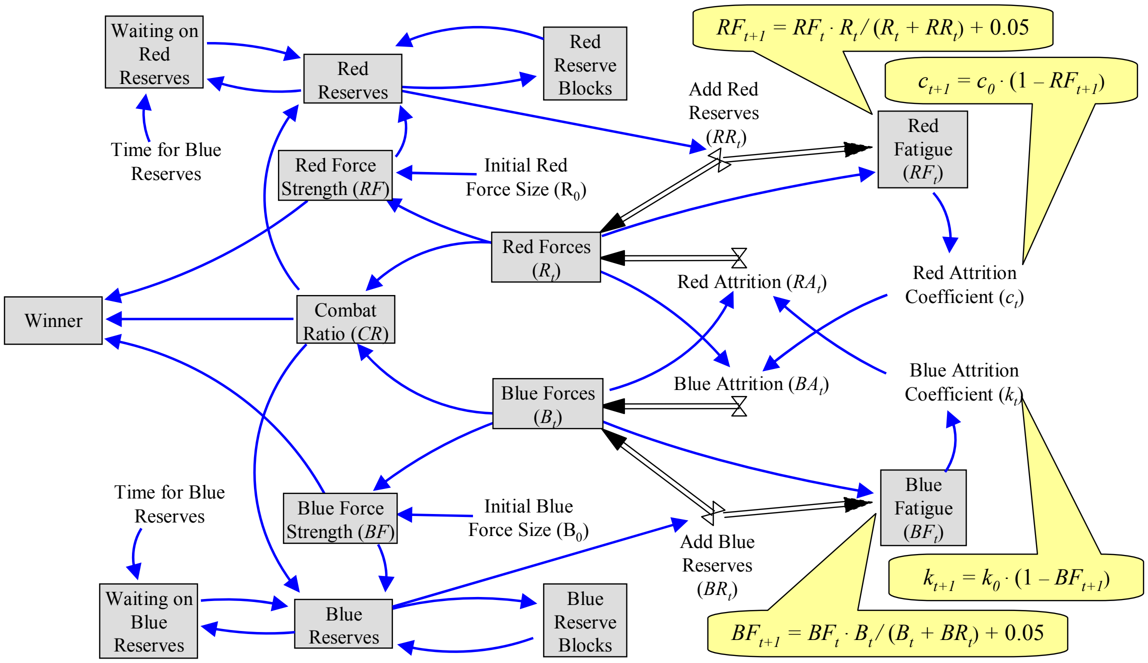


Figure IV-6: System Dynamics Model with Fatigue

The systems dynamics based modeling approach did not require the effect be modeled as a new fatigue level; however, by directly representing this new term, the model emphasized the new factor. The concept of fatigue could have been directly represented within the attrition coefficient value with the arrows from ‘Red Forces’ and ‘Add Red Reserves’ being connected to the appropriate ‘Attrition Coefficient.’ Figure IV-7 presents the fatigue of each force over time.

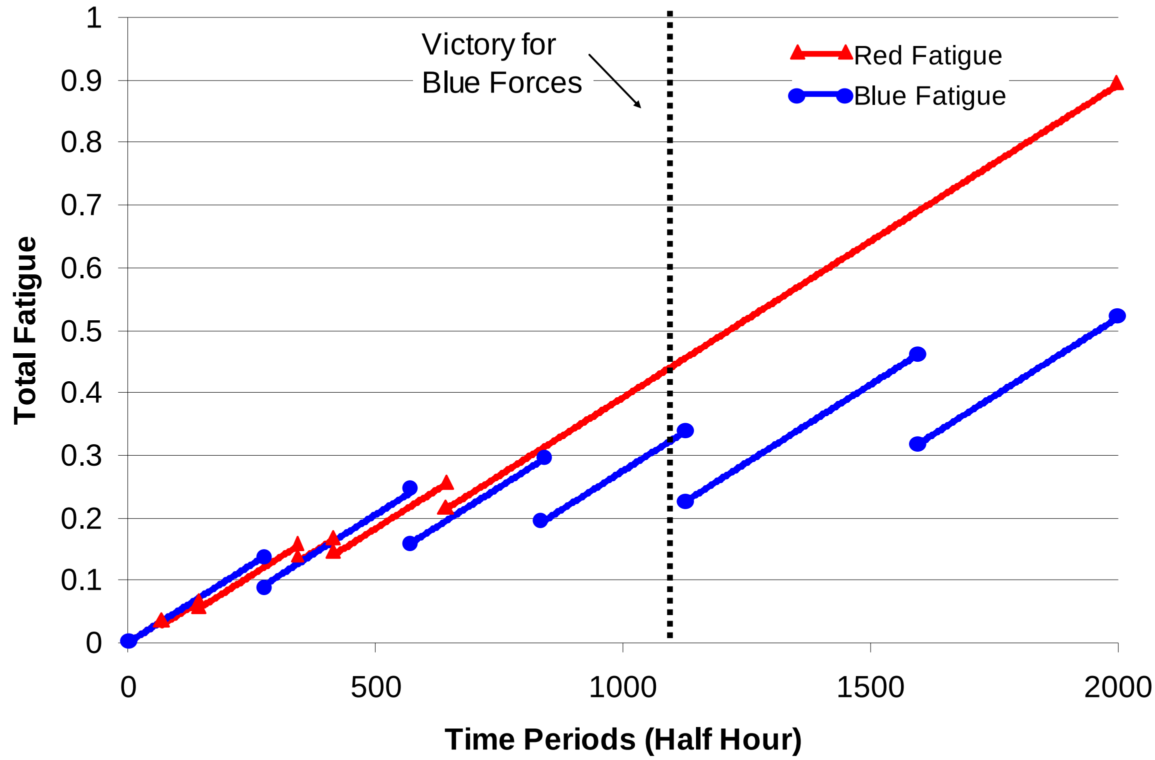


Figure IV-7: Fatigue of Red and Blue Forces

The arrival of Red reserves through 300 hours of conflict had the effect of reducing overall Red fatigue. Once all the reserves were committed, Red fatigue impacted Red's overall effectiveness since relief was not available later in the battle. This was opposed to the Blue forces which maintained less battlefield fatigue. The model was run beyond the Blue victory termination point to demonstrate this point.

Figure IV-8 compares the force levels of both the Red and Blue forces with and without the effects of fatigue. Not only did both sides suffer more losses, the battle ended significantly sooner due to the impacts of fatigue. While fatigue was added in this sample example, any number of factors can be incorporated as appropriate. System dynamics offers an additional option to the modelers when the scenario and fidelity of the analysis requires this level of detail.

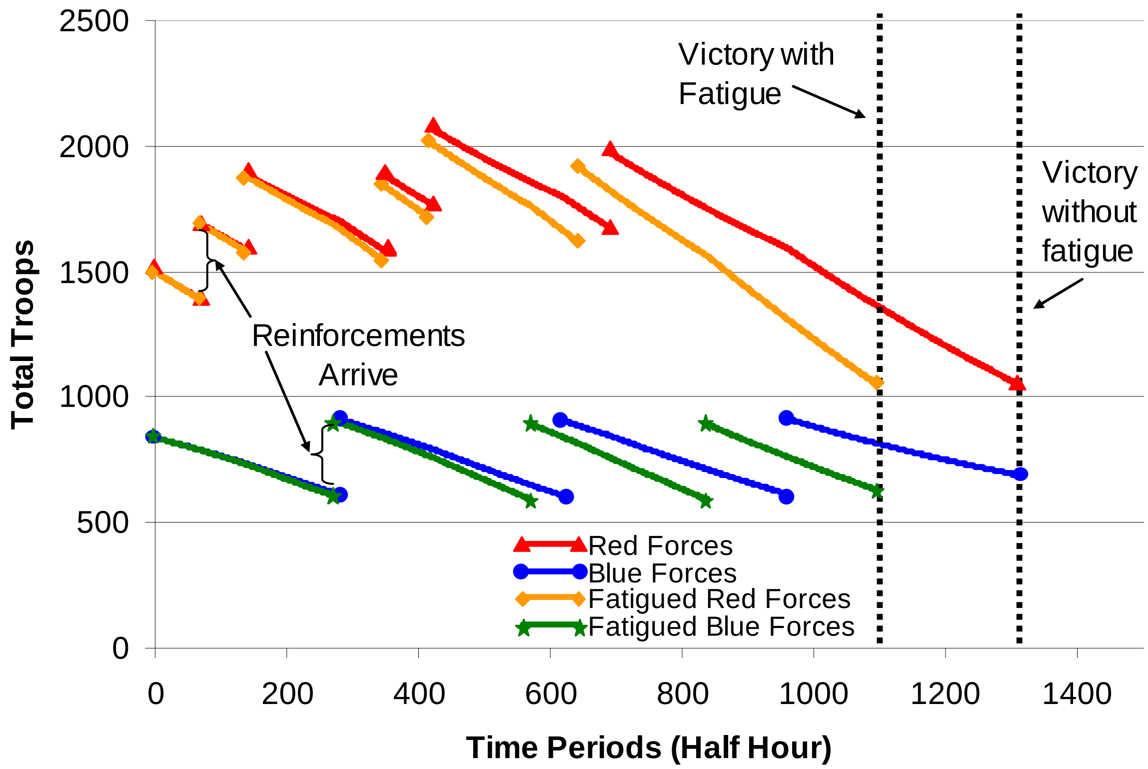


Figure IV-8: Comparison of Results

This example demonstrated how to dynamically represent the Lanchester Laws within a dynamic conflict model and shows the inclusion of a softer factor. By including fatigue, a qualitative aspect has been directly incorporated into the combat effectiveness coefficient. The rate of attrition is now altered by the change of fatigue. Therefore, there is now a change of rates being included in the combat model. The combat ratio and attrition is still used by the system dynamics model; however, the values of the combat effectiveness coefficients are no longer static. The coefficients are now dynamic and continuous. This changes the paradigm generally used in discrete event simulation which focuses on the events in the model. System dynamics highlights the rates of change. While Lanchester Laws requires 'breakpoints' to declare victory, the focus is on the rate of attrition. System dynamics provides an ability to change the rates based on other, possibly softer, aspects. This indicates a strength provided by dynamically representing the Lanchester Laws if appropriate to the analysis.

This simple example illustrates how feedback loops can be used is a system dynamics simulation. While 'softer' factors were used, the approach can be applied to any factor where rates of continuous flow are to be modeled.

Summary

Discrete event simulation and system dynamics models have been used to approximate first, second, and third generation warfare. However, in some operational settings it may be insufficient to model only military attrition. This can be particularly true in insurgency warfare or the broader fourth generation operations. All instruments of power (diplomatic, informational, military, and economic) must be represented. System dynamics provides an ability to include the impacts of the softer aspects of diplomacy, information, economics, as well as military actions, when continuous flows might provide improved insight over discrete event simulation. Feedback loops and changing the rate of rates can be useful in capturing the broader non-attrition and non-maneuver aspects of conflict.

This chapter compared the use of discrete event simulation and system dynamics to model first and second generation (example on Lanchester Laws) to establish the viability of the approach. The chapter then provided a simple system dynamics model which fatigued the forces. The fatigued forces provided an example of how other aspects required when modeling fourth generation operations could be implemented into combat models.

A systems dynamics presentation was developed to model a two sided conflict subject to continuous, non-linear, transient behaviors with feedback. The system dynamics presentation of the model provides the decision maker with a clearer representation of a continuous system than a discrete event simulation. The specific interactions are represented as levels, rates, and decision functions. The system dynamics format can be more straightforward than the sometimes 'black box' appearing presentation of a discrete event simulation.

System dynamics models can be quickly adjusted to represent new assumptions. Additionally, as discussed in the introduction to system dynamics, system dynamics model are able to represent 'fuzzy' concepts that are traditionally not approached by discrete event modelers. Furthermore, system dynamics models smoothly transition the values within the levels, as opposed to approximating the values as required by a discrete event simulation.

While some discrete event simulations are able to represent continuous variables, this does not imply the simulation represents completely dynamic models. When incorrect conclusions could occur due to not accounting for continuous time, a model developed to implement a system dynamics framework should be used. However, if a mix of discrete and continuous variables is advantageous in a modeling effort, systems which incorporate both can be developed and utilized. Care in selecting time steps must be taken to assure accuracy sufficient for the analysis.

The implementation of Lancaster Laws within a system dynamics model adds a significant amount of flexibility to how combat models are able to incorporate the dynamics of battle. This added flexibility provides a means to model the impacts of the population's resolve and combatants' spirit. Additionally, this may allow combat models to capture many other aspects of the conflict such as the political, economic, and informational; rather than exclusively the military impacts.

This chapter accomplished the third contribution of the dissertation, the construction of a theoretical modeling framework to dynamically portray fatigue and other behavioral factors within a combat model. This chapter also demonstrated the utility of using a system dynamics modeling framework to represent the Lanchester Laws as opposed to the traditional discrete event simulation framework.

V. Public Resolve

Chapter Overview

In October of 2006, the Chairman of the Joint Chiefs of Staff, General Peter Pace, stated:

> *Baghdad is the center of gravity in Iraq, and the American people are the center of gravity for our enemies. And what the American people believe and the American people's ability to sustain -- what they must sustain to defeat this enemy is what our enemies are trying to influence.* (p. 1)

General Pace highlights the importance of public opinion in the war in Iraq and subsequently the global war on terrorism - the 'Long War.' This chapter presents an analysis that incorporates, into a model, the impacts of the continuous actions of our forces on the resolve of the United States population. The utility and effectiveness of historical methods is statistically tested against the suggested model. Multiple linear regression models, as well as generalized linear models are used. The chapter discusses new key factors that influence the public's opinion. In this chapter public resolve refers to the percent of the US population which supports an on going conflict.

It is apparent that our adversaries are directly targeting the public resolve of the US population. Results from this chapter provide commanders, decision makers and analysts models to aid in gauging the adversaries impact on the US's resolve. Additionally, these models are included in the final combat model presented in Chapter 7.

This chapter investigates the American public's perception of the ongoing operations in both Afghanistan and Iraq. Models of public resolve are constructed and statistically evaluated based on linear and non-linear modeling techniques, with the intent to develop a modeling framework of public resolve. The framework was founded on empirical evidence of key factors influencing the public resolve.

The importance of the public support and resolve is highlighted. Public resolve from Korea, Vietnam, Afghanistan, and Iraq are then reviewed. Two simple least squares linear regression models of public resolve are presented. The first model uses the number of days into the conflict as an independent variable, while the second model uses the logarithm of casualties as the independent variable. This latter model was first introduced by Mueller (1973, p. 60). In both cases the dependent variable was public support for the war as given by polling data.

The third section of the study presents a multiple linear regression model expanding on the findings of the two previous models and also evaluates ten additional independent variables specific to Iraq. A model of public support based on four statistically significant variables is provided. These variables reflect actions taken by both the insurgents and the US military.

A factor analysis of the identified key variables is also performed. The subsection applies the technique to minimize the impacts of the correlation between the statistically significant variables revealed in the multiple linear regression analysis.

The next section provides an alternate model of public support based on logistic regression. The benefits of this technique are then discussed. This section also applies the William's procedure for fitting a model with overdispersion (extra binomial variation).

The fifth section provides some insights to the impact of negative and positive media reporting of the event ongoing in theater. The percent of positive media reports is used as a new independent variable in the model. Unfortunately the data available only spanned a small portion of the conflict; therefore, the analysis was performed with a limited data set compared to the other analyses in the chapter.

The chapter concludes with a check of the model by comparing the model's results with recent polling data. Additionally, the key relations that have been revealed are reviewed. Finally, the implications of the research and possible paths for future research are suggested.

Simple Least Squares Linear Models

Recognizing that the tactics of fourth generation operations include attacking the public resolve of the adversary, this effort quantifies the effect of the continuous actions employed by the enemy. The study gauges the national resolve in a clash of wills using polling data as a proxy for public resolve and support of recent and current wars. The specific questions used by the various polling data sources are detailed in Appendix A. A simple linear regression for several factors was performed on data from Korea, Vietnam, Afghanistan, and Iraq. The response collected represented the percent of the United States population which supported the current conflict.

Duration of Conflict

When the data on public support, based on the number of days into the conflict was fit for the Vietnam, Afghanistan, and Iraq with time as the independent variable, a decrease in public support was identified. The start of conflict for Korea (25 June 1950), Afghanistan (7 October 2001) and Iraq (20 March 2003) was used as the start of hostilities. For the purpose of this analysis, the Gulf of Tonkin resolution (7 August

1964) was used as the start of hostilities for the Vietnam conflict since this authorization approved the escalation of forces in the theater (Snow, 1994, p. 210).

Tables V-1 though V-4 present the fitted public resolve models for Korea, Vietnam, Afghanistan, and Iraq respectively. For this analysis, the magnitude of the *t*-test statistic (*t Stat*) was compared to the appropriate reference value from the two-sided *t*-distribution with α = 0.05. If any coefficient or model was determined to be statistically insignificant, the equation indicated this in bold markings.

Table V-1: Public Support for Korea per Time

Regression Statistics	
R^2	**0.15**
Adjusted R^2	**0.05**
Standard Error	8.34
PRESS	1128.23
$R^2_{Prediction}$	**-0.54**
Observations	11

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	106.93	106.93	**1.54**	**0.25**
Residual	9	625.79	69.53		
Total	10	732.73			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	48.56	4.76	10.20	3.03E-06
Days into Conflict	-0.0109	0.0088	**-1.24**	**0.25**

Table V-2: Public Support for Vietnam (1965-1973) per Time

Regression Statistics	
R^2	0.85
Adjusted R^2	0.85
Standard Error	3.64
PRESS	387.39
$R^2_{Prediction}$	0.80
Observations	23

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1612.23	1612.23	121.47	3.44E-10
Residual	21	278.73	13.27		
Total	22	1890.96			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	60.13	1.82	33.12	1.3E-19
Days into Conflict	-0.0126	0.0011	-11.02	3.44E-10

Table V-3: Public Support for Afghanistan per Time

Regression Statistics					
R^2	0.95				
Adjusted R^2	0.94				
Standard Error	347.57				
PRESS	0.93				
$R^2_{Prediction}$	4.03				
Observations	18				
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4717.69	4717.69	291.09	1.09E-11
Residual	16	259.31	16.21		
Total	17	4977.00			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	90.33	1.25	72.29	1.48E-21	
Days into Conflict	-0.01949	0.0011	-17.06	1.09E-11	

Table V-4: Public Support for Iraq per Time

Regression Statistics					
R^2	0.71				
Adjusted R^2	0.70				
Standard Error	5.43				
PRESS	5722.94				
$R^2_{Prediction}$	0.70				
Observations	191				
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	13402.02	13402.02	454.17	3.77E-52
Residual	189	5577.21	29.51		
Total	190	18979.23			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	64.96	0.76	85.53	4.8E-153	
Days into Conflict	-0.0204	0.0010	-21.31	3.77E-52	

Table V-1 indicates that there is *not* a significant linear trend for public support of the Korean War, based on days of conflict. The R^2 in Table V-1 suggests the model does not explain much of the variation in the observed data and the coefficient for days of conflict. Additionally, the magnitude of the *t*-test statistic for the days coefficient (-1.24) is less than the critical value from the *t*-distribution ($t_{\alpha=0.05,44}$=2.32). Therefore, the null hypothesis fails to be rejected and there is insufficient evidence that the coefficient is not zero. Additionally, the PRESS statistic and $R^2_{Prediction}$ indicate this model should not be used to predict the public resolve.

It should be noted that combat in the Korean War lasted just over three years before the cease fire was signed. The Korean War followed on a global war that generally had national support. It appears that the limited duration of the conflict and proximity to World War Two may have influenced the Korean War data that is based on duration of the conflict.

The R^2 for each of the other conflicts suggests a stronger connection between time and public support. Additionally, the magnitudes of the *t*-test statistic for all the coefficients in Tables V-2 through V-4 are greater than the critical value; therefore, the null hypotheses can be rejected, indicating strong evidence that the coefficients are not zero (with $\alpha = 0.05$). Finally, the *F*-test statistics are greater than the *F*-test critical values further indicating the coefficients are statistically significant.

The Prediction Error Sum of Square (PRESS) statistic was used to determine the $R^2_{Prediction}$. The $R^2_{Prediction}$ for Vietnam (Table V-2) and Afghanistan (Table V-3) both indicated the model accounted for over 80% of the variability of the residuals for the predicted values. The model of Iraq (Table V-4) only accounted for 70% of the variance when predicting.

The fitted decline of support for Vietnam, Afghanistan, and Iraq varies from 0.0127% to 0.0204% per day. The data used for Vietnam spans nine years of the conflict. The first five years on the conflict was also analyzed for comparison to the conflict in Iraq and Afghanistan using similar timeframes. When the first five years of data for the Vietnam conflict were used in the analysis (see Table V-5), the R^2 for the Vietnam model rose to 0.89 with a slope of 0.0185% per day. Additionally, the range of slopes for Afghanistan, Iraq and Vietnam (prior to 1970) only varied from 0.0185% to 0.0204% loss of support per day.

Table V-5: Public Support for Vietnam (1965-1969) per Time

Regression Statistics	
R^2	0.89
Adjusted R^2	0.88
Standard Error	2.70
PRESS	142.89
$R^2_{Prediction}$	0.86
Observations	17

	df	***SS***	***MS***	***F***	***Significance F***
Regression	1	876.92	876.92	120.46	1.45E-08
Residual	15	109.20	7.28		
Total	16	986.12			

	Coefficients	***Standard Error***	***t Stat***	***P-value***
Intercept	66.26	1.99	33.23	1.83E-15
Days into Conflict	-0.0185	0.0017	-10.98	1.45E-08

Figure V-1 presents the available polling data for the Vietnam conflict along with two linear regression lines. The solid line depicts the result of fitting all of the available data, while the dashed line includes only the data prior to 1970.

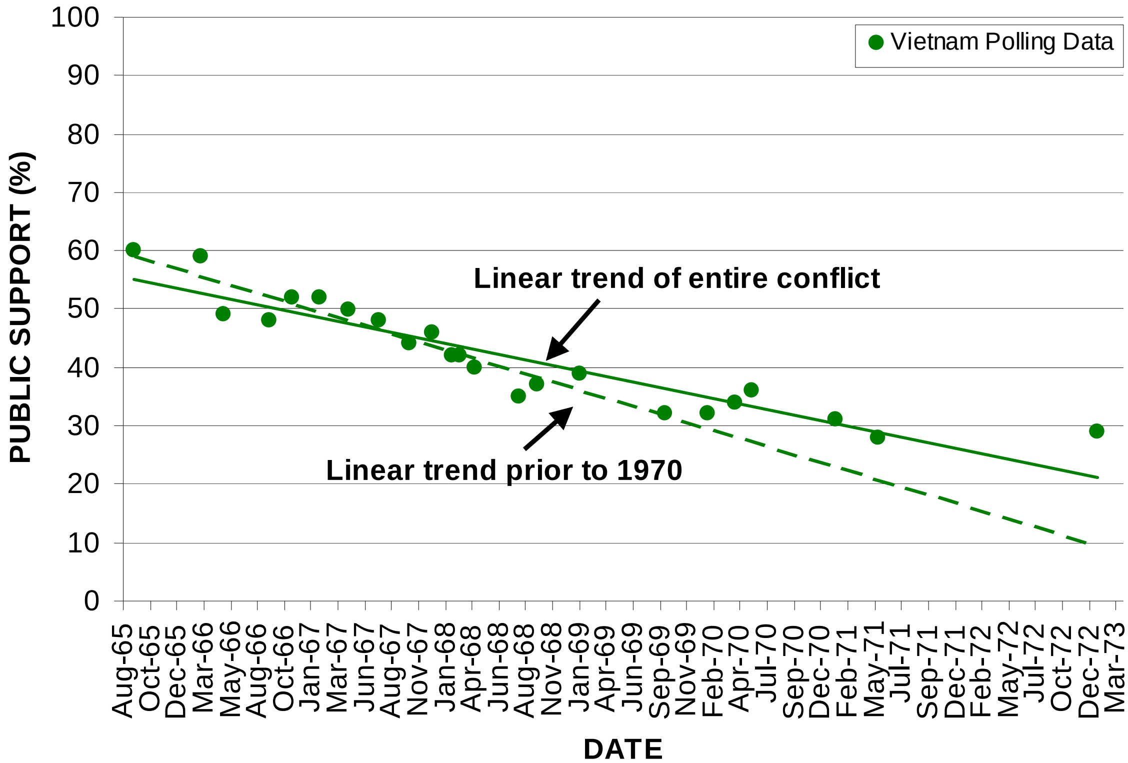


Figure V-1: Public Support of the Vietnamese War with Linear Trends

When only the first five years of Vietnam were included in the regression, the R^2 increased from 0.85 (Table V-2) to 0.89 (Table V-5), and standard error of the model (RMSE) decreased from 3.64 to 2.70. Figure V-2 presents the decline of support for the wars in Vietnam, Afghanistan, and Iraq over time. The linear trend of all data points for each conflict is also presented. The slopes of the fitted models for Vietnam (prior to 1970), Afghanistan, and Iraq are approximately parallel suggesting public opinion in modern wars decline at a fixed rate over time. For the available data, this rate of decline is between 0.018% to 0.021% per day or roughly 0.6% per month.

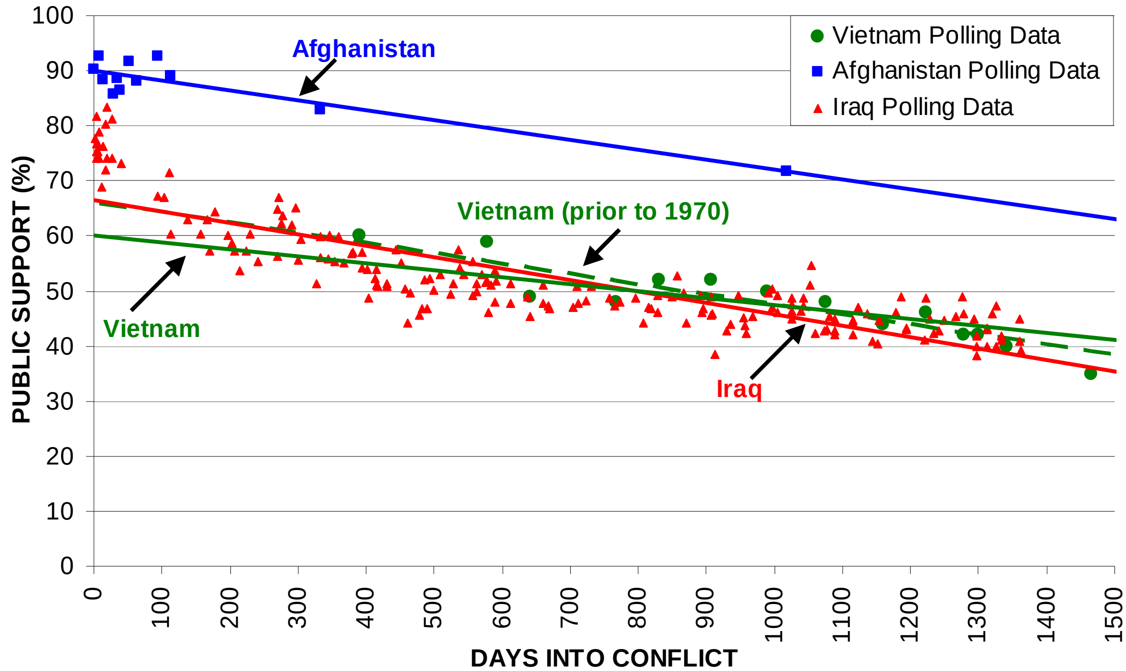


Figure V-2: Decline of Public Support over Duration of Conflict

The confidence interval for a regression coefficient (β_i) in a linear model with n data points and p variables is given by, $\beta_i \pm t_{\alpha/2,n-p} SE_{\beta_i}$. The 95% confidence intervals for the slopes (β_1) of the fitted models Afghanistan, Iraq and Vietnam are presented in Figure V-3. The confidence interval for the coefficient for time all overlap at 0.02. This suggests a hypothesis that public opinion declines at approximately the same rate over time for similar conflicts. Based on these three data sets, the hypothesis that public opinion declines at 0.02% per day cannot be statistically rejected. This suggests that for each month roughly 0.6% of the total public support is lost.

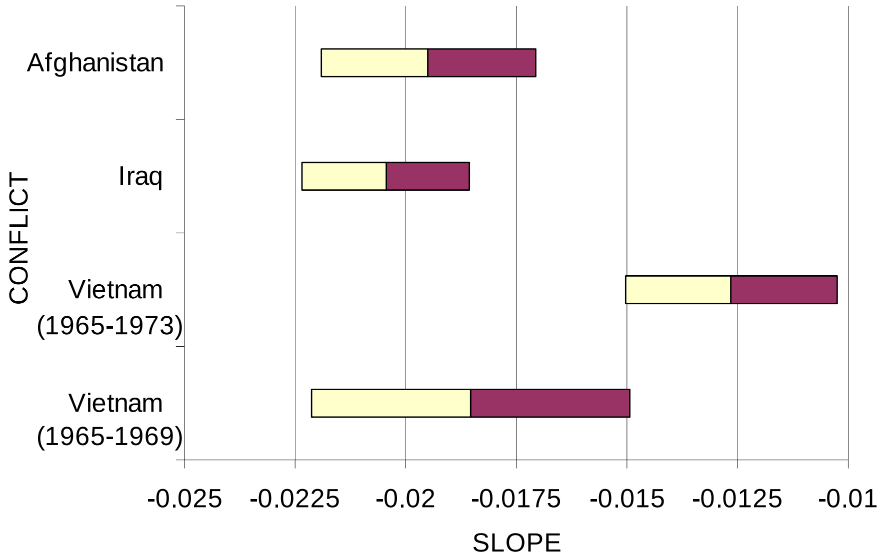


Figure V-3: Confidence Interval of Slope (Duration of Conflict)

The confidence intervals on the public support at the start of the conflict are presented in Figure V-4. The Y-intercept (β_0) is interpreted to be the initial support for the conflict. Clearly, public support varied widely at the start of these conflicts. However, note that the 95% confidence intervals for the first four years of Iraq and the first five years of Vietnam overlap at 65%. Based on these two data sets, the hypothesis that public opinion began at 65% cannot be statistically rejected.

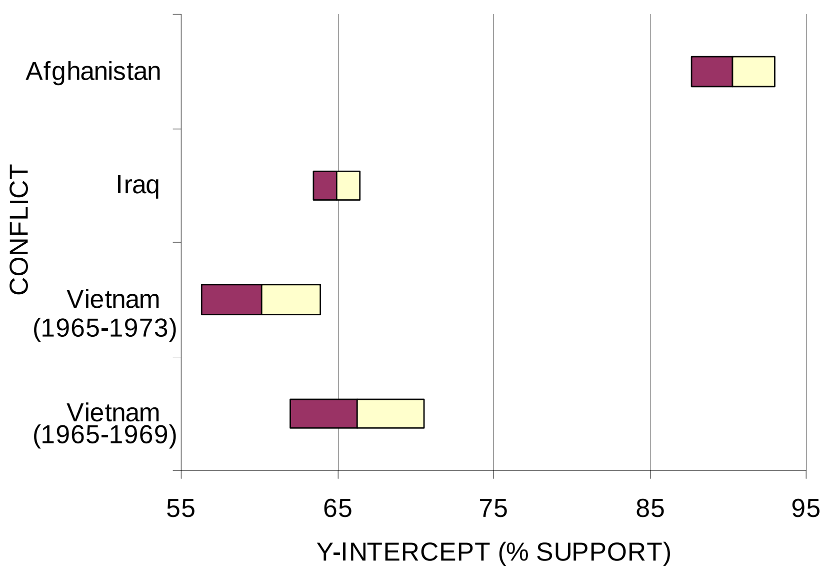


Figure V-4: Confidence Interval of Y-Intercept (Duration of Conflict)

Equation V-1 presents a composite model for public support based on both Vietnam and Iraq data. This implies that a model of the public support for Iraq is statistically indistinguishable from the model of the first five years of Vietnam.

$$Public\ Support = 65 - 0.02 days \tag{V-1}$$

The residual plots did not indicate trends within the residuals which would require further analysis for Vietnam (Figure V-5) or Afghanistan (Figure V-6). The residuals for Korea are not included since the model has been determined to not be statistically significant.

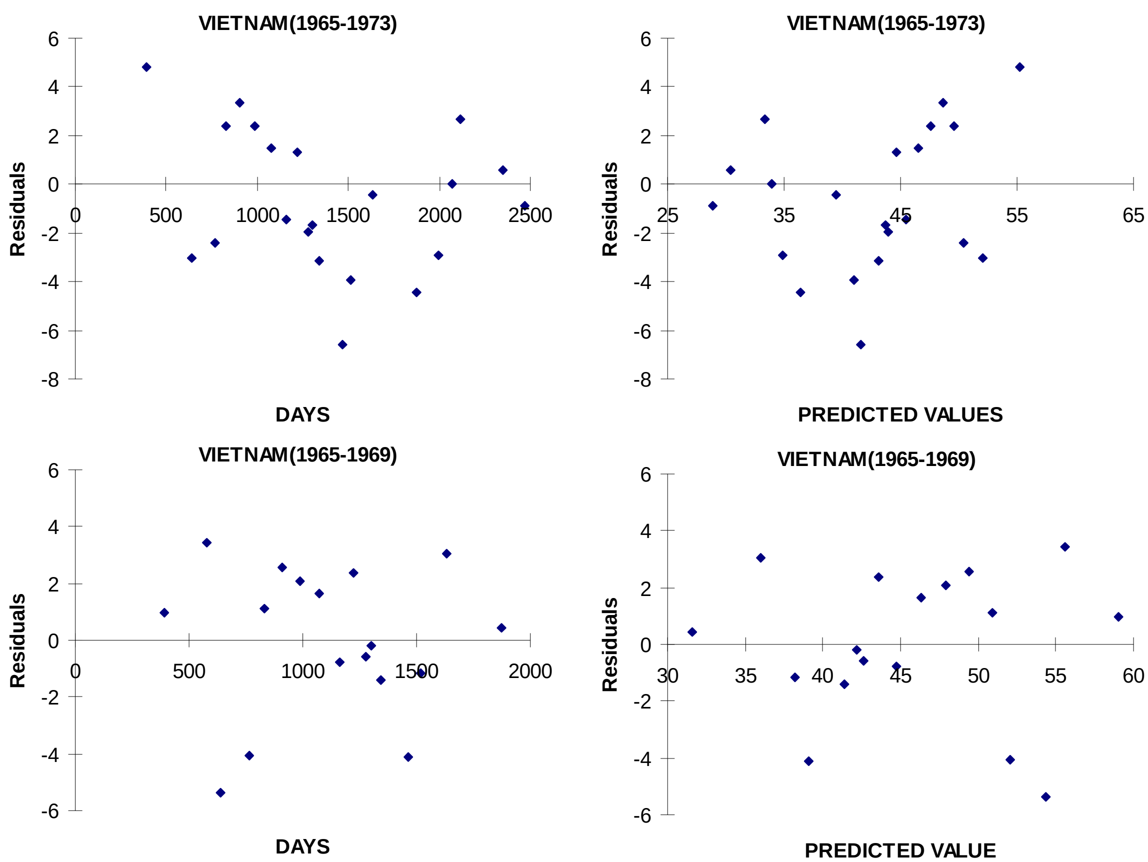


Figure V-5: Residuals for Vietnam Model (Days into Conflict)

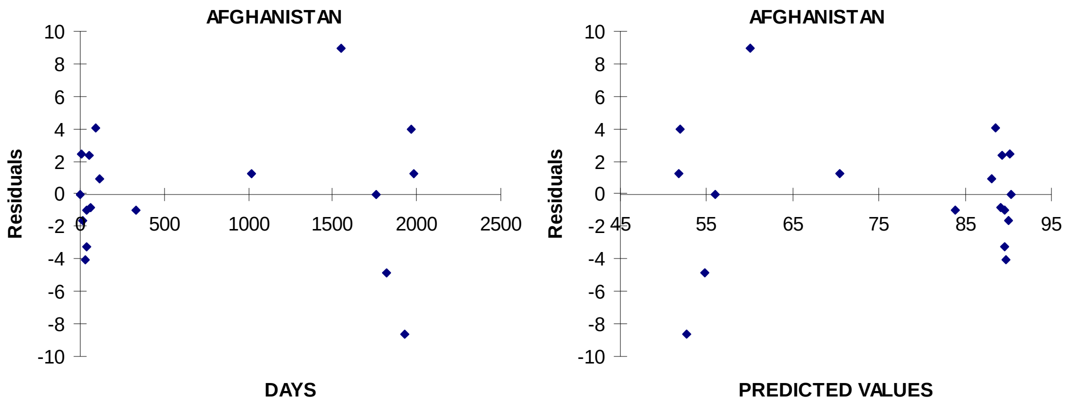


Figure V-6: Residuals for Afghanistan Model (Days into Conflict)

The residuals for the model of Iraq indicate that the number of days into the conflict has a non-linear impact on the response (top of Figure V-7). Therefore, the model was regressed with number of days into the conflict squared ($Days^2$) as an additionally variable. The results of this regression are in Table V-6. The residuals for the analysis are included in the bottom of Figure V-7. The inclusion of the squared number of days into the conflict improves the predictability ($R^2_{Prediction}$ improves from 0.70 to 0.83) and the residuals indicate no trends.

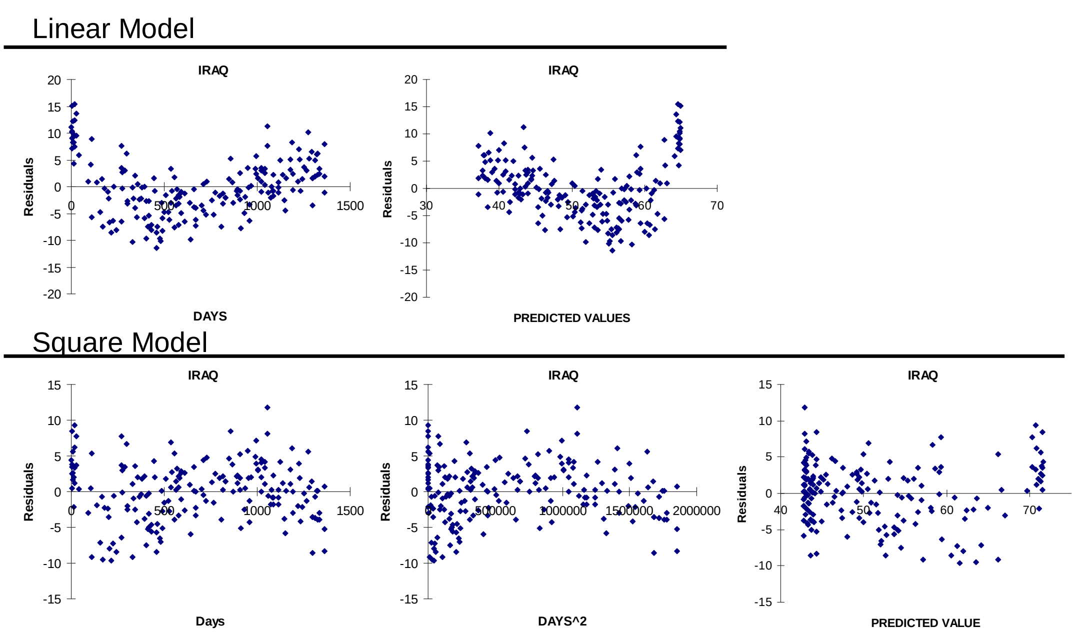


Figure V-7: Residuals for Iraq Model (Days into Conflict)

Table V-6: Public Support for Iraq per Time Squared

Regression Statistics	
R^2	0.83
Adjusted R^2	0.83
Standard Error	4.11
PRESS	3285.97
$R^2_{Prediction}$	0.83
Observations	191

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	15801.87	7900.94	467.49	1.09E-73
Residual	188	3177.36	16.90		
Total	190	18979.23			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	71.71	0.81	88.85	1.7E-155
Days into Conflict	-0.0522	0.0028	-18.91	2.36E-45
Days into Conflict^2	2.35E-05	1.97E-06	11.92	9.45E-25

Logarithm of Casualties

While simple linear models for the public support using the number of days into the conflict provided a good fit for Vietnam, Afghanistan and Iraq (the model of Iraq improved when using the variable squared); the variable did not adequately fit the Korean conflict. Mueller suggests an alternative to the number of days in the conflict. He related the number of casualties in both the Korean and Vietnam wars to the public opinion polls of the day. He found that the support for the war dropped by 15 percentage points each time the order of magnitude of number of casualties increased (Mueller, 1973, p. 60). As we are modeling US resolve and support, casualties were defined as total number of US military killed and wounded during the conflict. Additionally, Mueller suggested that the Korean and Vietnamese conflicts even begin with essentially the same level of support (1973, p. 60).

Using the data provided in Mueller's book, Figure V-8 was created. In Figure V-8 , the percentage of the US population which supported the wars in Korea and

Vietnam was correlated with the base ten logarithm of the total number of casualties.

Figure V-9 presents the same data plotted relative to time.

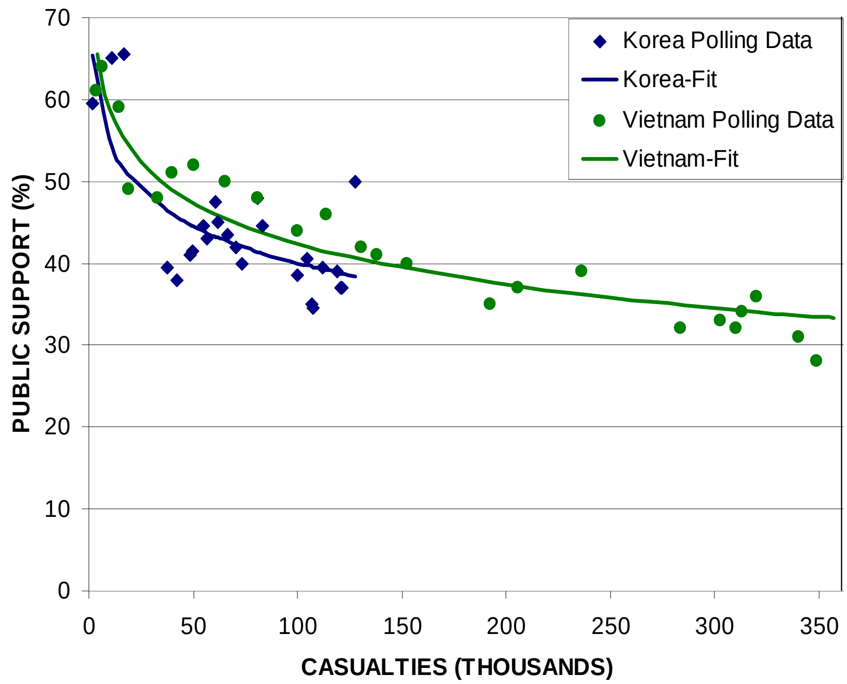


Figure V-8: Casualties versus Public Support (Mueller's Model)

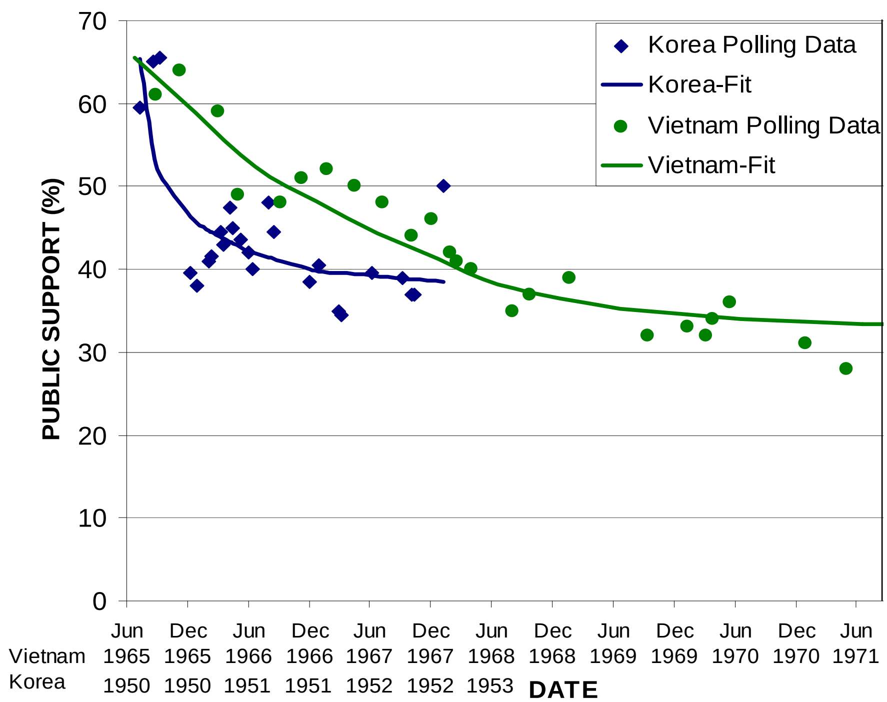


Figure V-9: Mueller's Model with Date Indicated

Using the same methodology presented by Mueller, the public support for the war in Iraq is given in Figure V-10. Figure V-11 presents the data relative to the date of the war.

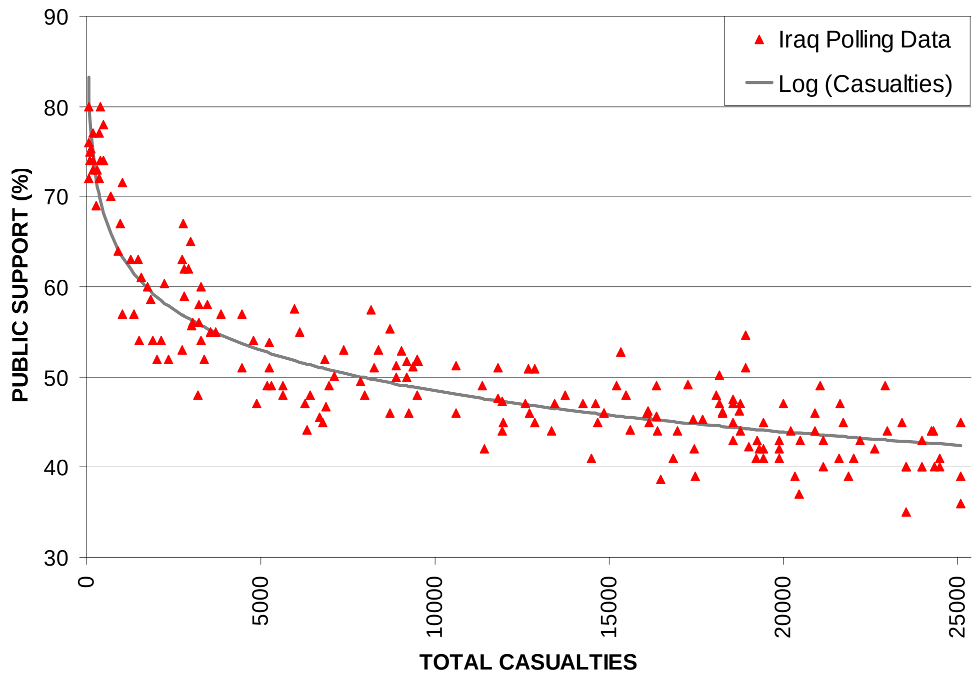


Figure V-10: Casualties versus Public Support (Iraq)

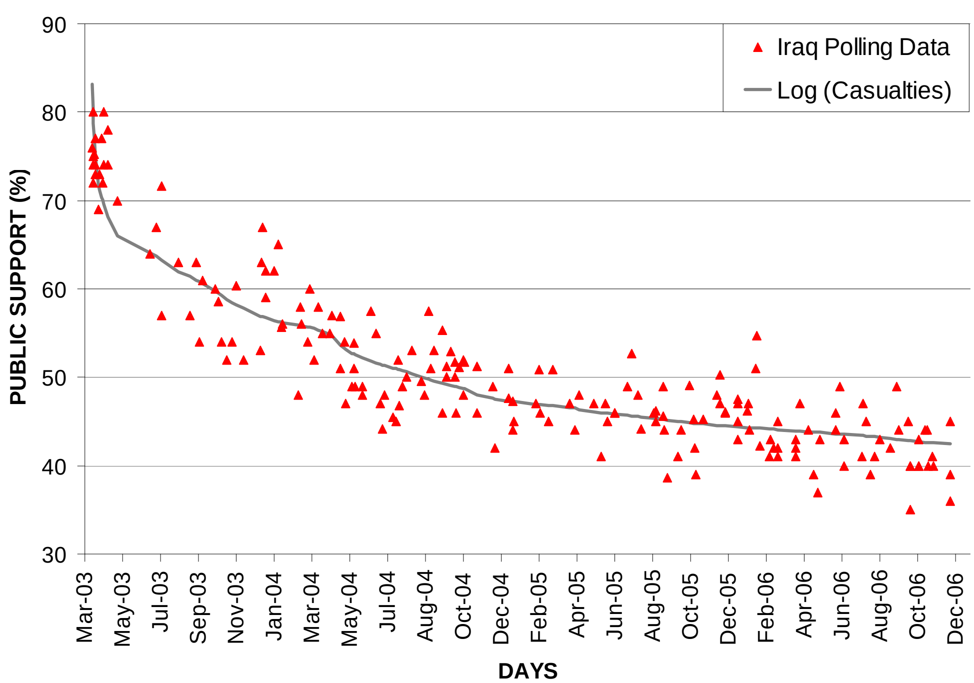


Figure V-11: Date versus Public Support (Iraq)

When the data of public support were fit for Korea, Vietnam, and Iraq with an analysis based on Mueller's work, a decrease in public support relative to casualties was identified ($\log_{10}$(cas)). Tables V-7 though V-9 present the data for models based on the log of casualties for Korea (Table V-7), Vietnam (Table V-8) and Iraq (Table V-9). The tables present the model results as described earlier. All the models were significant.

Table V-7: Public Support for Korea per Casualty (Based on data from Mueller, 1973, p. 61)

Regression Statistics	
R^2	0.83
Adjusted R^2	0.82
Standard Error	5.21
PRESS	1138.25
$R^2_{Prediction}$	0.74
Observations	25

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3610.9	3610.9	112.3	2.53213E-10
Residual	23	739.6	32.2		
Total	24	4350.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	114.46	13.82	8.28	2.34E-08
$\log_{10}$(cas)	-14.89	2.39	-6.23	2.34E-06

Table V-8: Public Support for Vietnam per Casualty (Based on data from Mueller, 1973, p. 61)

Regression Statistics	
R^2	0.90
Adjusted R^2	0.89
Standard Error	3.20
PRESS	316.8
$R^2_{Prediction}$	0.86
Observations	24

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2041.3	2041.3	186.57	3.18E-12
Residual	22	240.7	10.9		
Total	23	2282.0			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	124.98	6.04	20.68	2.34E-16
$\log_{10}$(cas)	-16.51	1.16	-14.23	6.85E-12

Table V-9: Public Support for Iraq per Casualty

Regression Statistics	
R^2	0.85
Adjusted R^2	0.85
Standard Error	3.84
PRESS	2869.21
$R^2_{Prediction}$	0.85
Observations	191

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	16185.85	16185.85	1095.14	1.44E-80
Residual	189	2793.37	14.78		
Total	190	18979.23			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	108.52	1.76	61.77	2.9E-127
Log_{10}(cas)	-15.02	0.45	-33.09	1.44E-80

The *t*-test statistics indicate the coefficients for the models for public support based on logarithm of casualties are all statistically significant. Additionally, the R^2 and adjusted R^2 values above 0.80 signify the models appropriately represent the variance within the data.

Figure V-12 provides the residuals for Korea, Vietnam and Iraq. No significant trends occur in the data. The residuals versus the log of casualties, predicted value and time have been included in the figure.

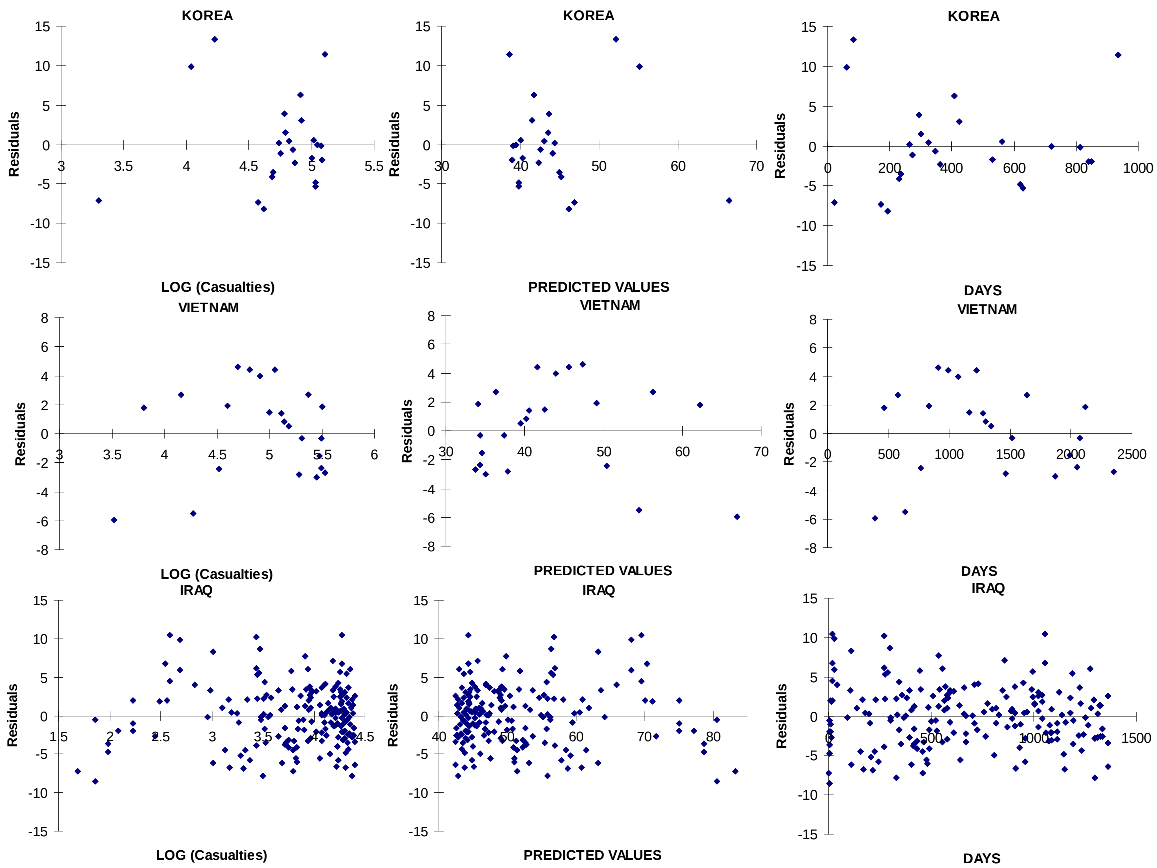


Figure V-12: Residuals for Korea, Vietnam, and Iraq (Log_{10}(Casualties))

Figure V-13 presents the 95% confidence intervals of the coefficient for $\log_{10}$(cas) for each of the three wars and indicates that Mueller's rule of thumb (as casualties increased by an order of magnitude: the support for the war dropped by about 15 percentage points) is supported by the data from Iraq. It should be noted that casualties can only increase with time; therefore, a correlation between these factors is expected (the rate, however, may vary). Additionally, the 95% confidence intervals for the start of the war (Y-Intercept) for Korea, Vietnam and Iraq overlap at 113% of public support as seen in Figure V-14. Based on these three data sets, the hypothesis that public opinion theoretically began at 113% cannot be statistically rejected.

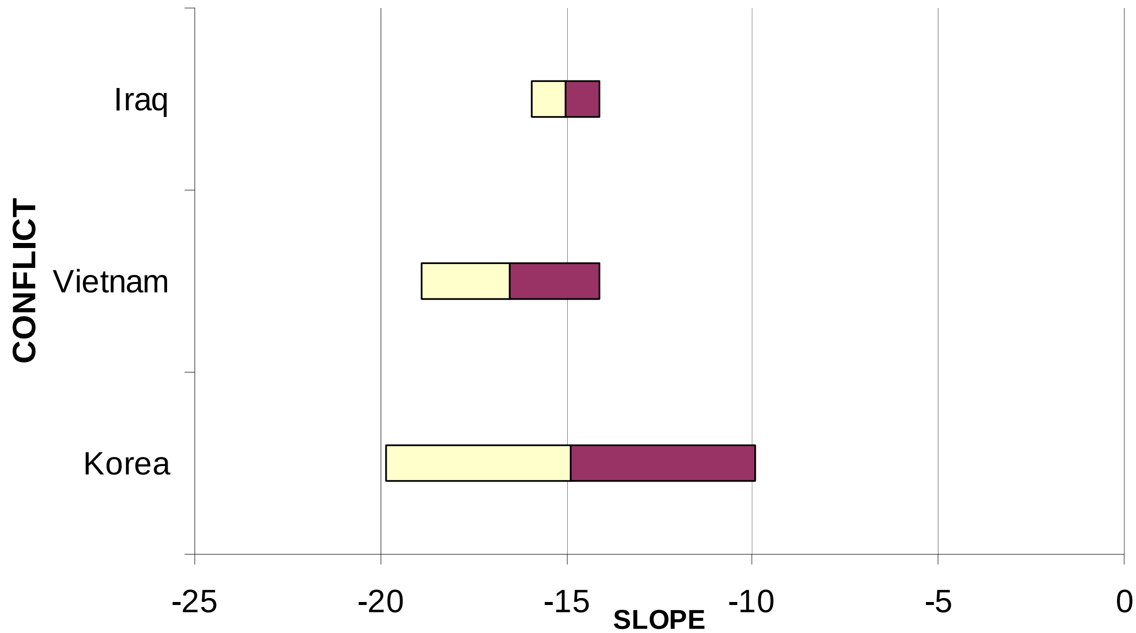


Figure V-13: Confidence Intervals of Slope (Log_{10}(Casualties))

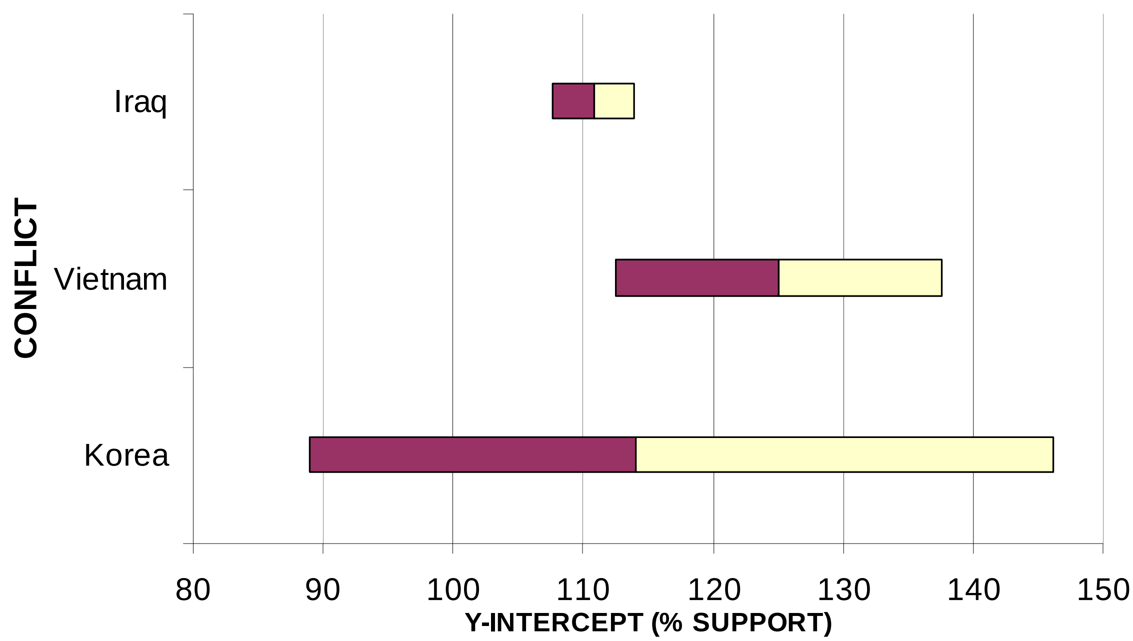


Figure V-14: Confidence Intervals of Y-Intercept (Log_{10}(Casualties))

Based on the confidence intervals, Equation V-2 provides a generic model of public support as the logarithm of total casualties in Iraq.

$$Public\ Support = 113 - 15\log_{10}(casualties) \quad \text{(V-2)}$$

The model does not fit well in early stages of the conflict when the casualties are low or zero. However, this only occurs when there are less than ten casualties. Further addressing this issue Mueller states:

> *The intercept figure is a backward extrapolation to an imaginary starting point percentage ... at the point when casualties would have been zero. To avoid this absurdity a transformation of the dependent variable could have been undertaken, but this would have complicated the analysis without adding any important new information.* (Mueller, 1973, p.60)

Least Squares Multiple Linear Regression

Basic Model

In the previous section, two single variable models for the three conflicts were presented. This section considers a model combining both previous variables along with additional variables into a single model. Using data provided by The Brooking Institute within the *Iraq Index*, ten variables were included in a least squares multiple linear regression (MLR) model (O'Hanlon & Kamp, 2006):

Number of US troops present
Daily attacks by insurgents
Iraqi Security Forces (ISF)
Insurgents captured or killed
Foreign nationals taken prisoner
Total insurgents
Total foreign insurgents
British fatalities
Iraqi civilian fatalities
Iraqi military fatalities

The original variables ($\log_{10}$(cas) and number of days) were also included in the MLR. A stepwise linear regression analysis was performed and eight of the new variables were rejected at an $\alpha = 0.05$ level, for modeling public support. For this data, the α must be relaxed to 0.17 before the next variable (British Fatalities) would be included in the MLR model. Table V-10 provides the results and appropriate p-value from the analysis.

Table V-10: Results from Stepwise Procedure

Variable	*Estimate*	*P-value*
Intercept	91.47	4.42E-41
Log_{10}(cas)	-7.322	0.00161
Insurgents (Captured/Killed)	0.0008418	0.00228
Days	-0.05957	0.00240
Daily Attacks	-0.0403	0.00813
British Fatalities	0	0.1684
Iraq Military Fatalities	0	0.2166
Total Insurgents	0	0.3020
Iraqi Security Forces	0	0.3999
Iraq Civilian Fatalities	0	0.4515
Foreign Insurgents	0	0.4947
Foreigners Kidnapped	0	0.6334
US Troops	0	0.9565

The remaining four variables were statistically significant at an $\alpha = 0.05$ level: logarithm of number of casualties ($\log_{10}$(cas)), number of insurgents captured (insurgents), days into the conflict (days), and daily number of attacks by insurgents (attacks) (see Appendix B). Table V-11 is the complete MLR model. The model and coefficients are significant, as shown in the table. Log_{10}(cas), days, and daily attacks have a negative impact on public support, while insurgents captured or killed has a small, but positive effect on public support. Figure V-15 plots the data along with the fitted data curve from the MLR model. The 'MLR results' line of Figure V-15 used the historical values of each independent variable for the month indicated along the horizontal axis.

Table V-11: Public Support for Iraq (MLR Model)

Regression Statistics					
R^2	0.87				
Adjusted R^2	0.86				
Standard Error	3.72				
PRESS	2728.43				
$R^2_{Prediction}$	0.86				
Observations	191				
	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	16400.2	4100.0	295.69	1.98E-79
Residual	186	2579.1	13.9		
Total	190	18979.2			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	91.47	5.24	17.47	4.42E-41	
Log_{10}(cas)	-7.322	2.287	-3.20	0.00161	
Insurgents Killed	0.0008418	0.000272	3.09	0.00228	
Days	-0.05957	0.01935	-3.08	0.00240	
Attacks	-0.04030	0.01506	-2.68	0.00813	

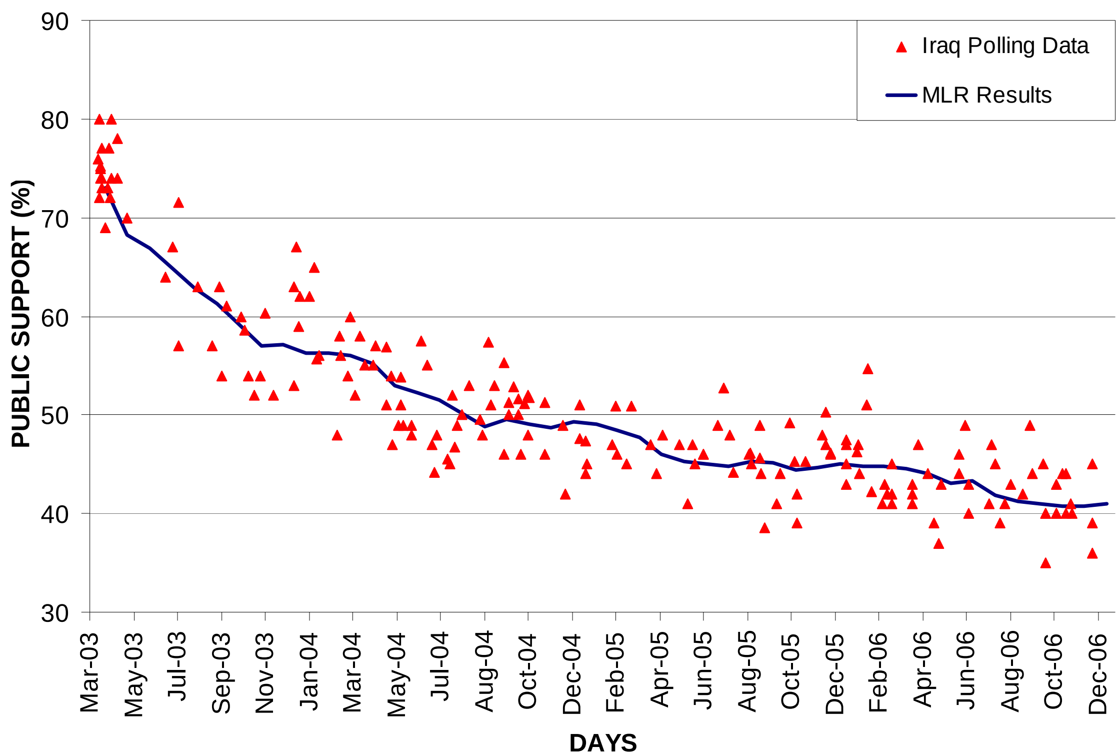


Figure V-15: Public Support of Iraq (MLR Results)

Table V-12 is the correlation matrix of the significant variables. As suggested earlier, the $\log_{10}$(cas) was correlated with the number of days into the conflict. Similarly, the number of insurgents capture or killed was correlated with the number of days into the conflict. This correlation suggests redundancy in the significant variables and violates the independence assumption discussed in Chapter 2. Multicollinearity may cause the variable's standard error to increase or the *t*-test statistic to decrease, among other problems. These consequences would cause concerns about the suitability of the model. Factor analysis may be applied to produce rotated factors which are uncorrelated and therefore do not have the consequences associated with multicollinearity.

Table V-12: Correlation of Variables for MLR

	Log_{10}(cas)	***Insurgents***	***Days***	***Attacks***
Log_{10}(cas)	**1**	**0.84**	**0.88**	**0.76**
Insurgents	**~**	**1**	**0.99**	**0.91**
Days	**~**	**~**	**1**	**0.90**
Attacks	**~**	~	**~**	1

The residuals plots for each variable from the MLR are presented in Figure V-16.

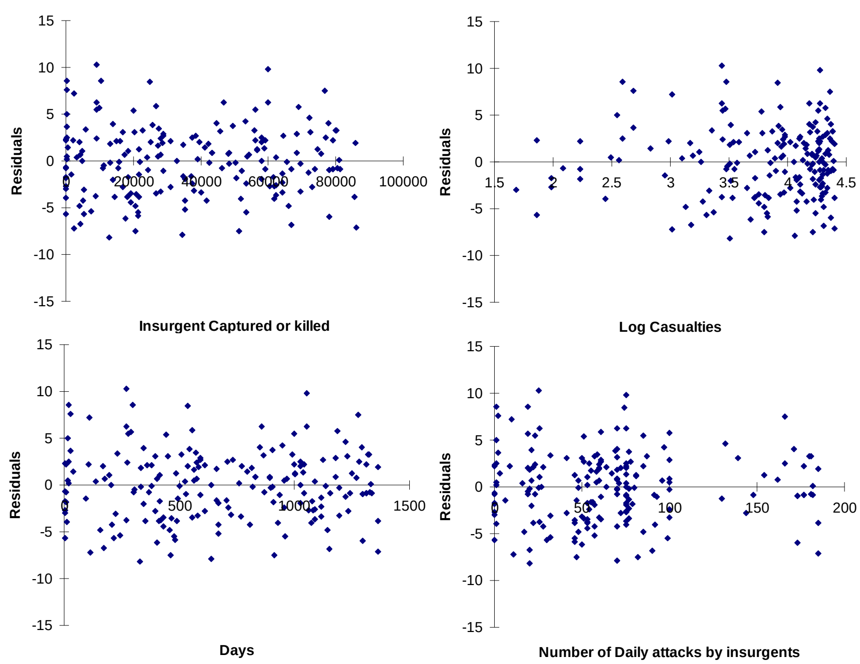


Figure V-16: Residual Plot for Each Variable in MLR Model

The three linear regression models presented in this section are compared in Figure V-17. Table V-13 compares the R^2, F-test statistics, and standard errors (RMSE) for the three models. The data curves relied on the historical data of each independent variable at the month indicated.

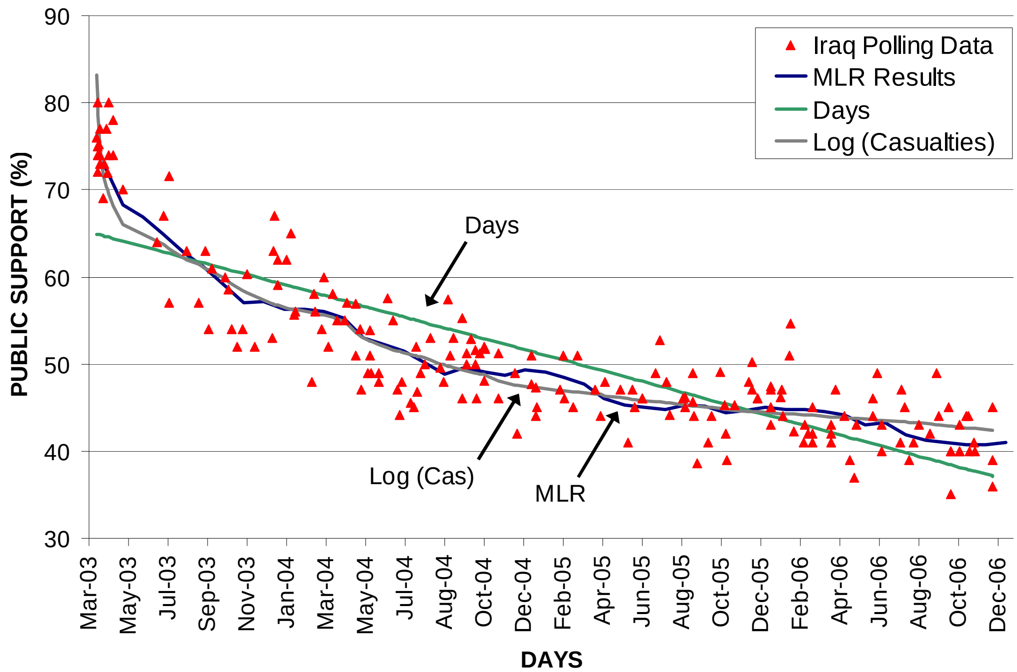


Figure V-17: Comparison of Linear Models of Public Support

Table V-13: Comparison of Linear Models

	Iraq (Days)	Iraq (Log_{10}(cas))	Iraq (MLR)
R^2	0.71	0.85	0.87
Adjusted R^2	0.70	0.85	0.86
$R^2_{Prediction}$	0.70	0.85	0.86
F-Test	454.16	1095.13	295.69
Standard Error (RMSE)	5.43	3.84	3.72

The MLR analysis indicates that the actions taken by the insurgents and by the US military shape the public opinion of the conflict. The number of US casualties and number of insurgent captured are influenced by the actions and decisions of both sides, while the insurgents alone are able to directly have an effect on the number of daily attacks. Therefore, the MLR model is able to quantify, for the variables used, the impacts to public opinion from actions taken by both the insurgents and the military.

Factor Analysis

The fitted model provides a precise estimate of the coefficient and the coefficient is the influence of the variable. Multicollinearity makes the direct influence of a variable potentially difficult to precisely obtain. One method to address multicollinearity is to apply an orthogonal factor analysis. This section provides a basic overview to factor analysis and applies the technique to the data used to fit the multiple linear regression. Fruchter (1954), Harman (1976), and Montgomery, Peck and Vining (2001), among others, all provide more details.

Factor analysis is a method to analyze data which reveals significant, unobserved factors within observed variables or factors. If orthogonal factors are extracted the factors may be used to avoid the multicollinearity of the underlying variables. This does, however, require interpretation of the factors.

The technique is very similar to principle component analysis. However, factor analysis is generally preferred when the goal is to determine an underlying structure, while principle component analysis is typically applied for data reduction (Harmon, 1976, p. 14). Additionally, Dillon and Goldstein state that principle component analysis is variance oriented, and factor analysis is focused of the covariance (Dillon & Goldstein, 1984, p. 71). If an orthogonal rotation is used, these orthogonal representations are uncorrelated by design to satisfy the multiple linear regression assumption of independence. Oblique rotations may also be used to identify other factors. This research uses regression analysis of the uncorrelated factors to build a model of public resolve.

An orthogonal, varimax factor analysis was originally performed on the data with all twelve variables; however, the results did not provide any additional analytic insight. Therefore, the remainder of the section only refers to the factor analysis performed on the four significant variables found in the multiple linear regression analysis. Table V-14 presents the resulting eigenvalues and percent variability accounted for by their factors. A factor analysis of four variables yields four eigenvalues each associated with a factor. The percent variability is the contribution of the factor to the variance of all the variables (Harmon, 1976, p. 18).

Table V-14: Factor Analysis

	Factor 1	***Factor 2***	***Factor 3***	***Factor 4***
Eigenvalue	***3.6554***	***0.2496***	***0.0943***	***0.0006***
Percent Variability	***91.39***	***6.24***	***2.36***	***0.02***
Cum Percent	***91.39***	***97.63***	***99.98***	***100***

Franklin *et al.* (1995) and Horn *et al.* (1979) both indicate the number of factors selected in the factor analysis is a highly debated issue. Some methods, such as Kaiser's rule, retain all components with eigenvalues greater than one (Franklin *et al.*, 1995, p.

101). Some tests such as Bartlett's Chi-Square test use the latent roots of the residual matrix (Horn *et al.*, 1979, p. 288). Other tests rely on graphical interpretations. Cattell's scree test looks for the knee of the curve when plotting the eigenvalue of each factor in the analysis. Cattell suggests using the number of factors after the trend in the plot no longer changes rapidly; therefore, the 'knee in the curve' is counted when determining the number of factors.

Criticism for each method exists. Kaiser's rule can over extract components and thus not include factors which may help provide understanding of the data (Franklin *et al.*, 1995, p. 103). Bartlett's Chi-Square test is highly dependent upon sample size and Cattell's scree test may overestimate the number of factors (Franklin *et al.*, 1995, p. 103). Applying Cattell's scree test, Figure V-18 suggests the use of two factors.

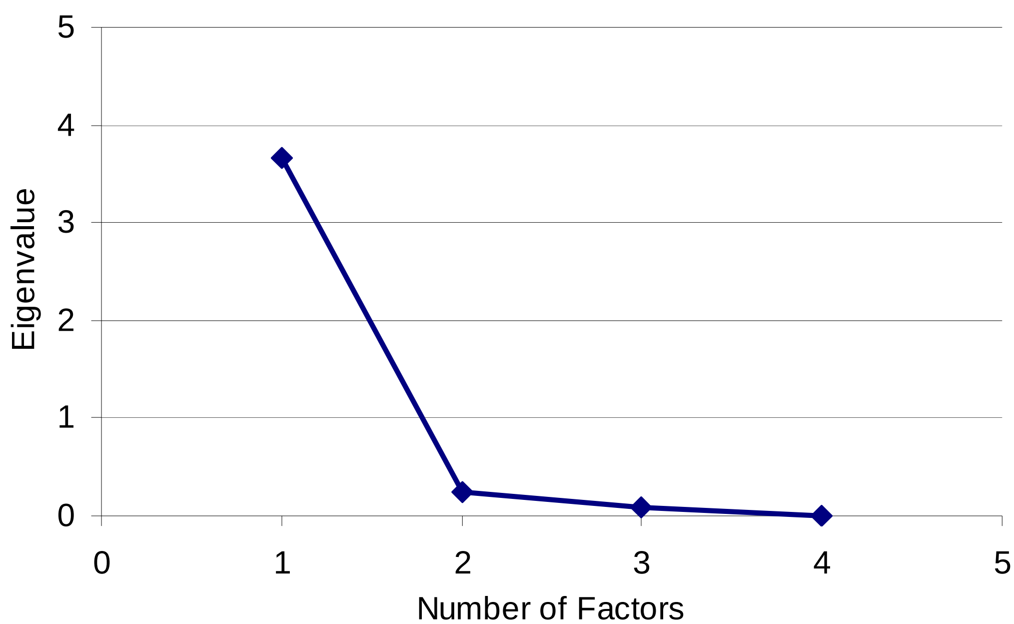


Figure V-18: Scree Plot for Factors of Public Resolve

An orthogonal rotation was performed using the varimax method (see Harman, 1976, p. 290-299). Table V-15 is the factor loading matrix for the key factors of public resolve. As observed during the scree test, two factors were obtained from the factor loading matrix. A pattern exists in the matrix where the first factor has influences from the days into the conflict, number of daily attacks and total insurgents captured or killed. This was defined as the *time driven component*. The second factor is primarily influenced by the $\log_{10}$ of US casualties. This factor was defined as the *casualty driven component*. Table V-16 provides the rotation matrix.

Table V-15: Factor Loading Matrix of Public Support Key Factors

Variable	Factor 1 Time Driven Component	Factor 2 Casualty Driven Component
$Log_{10}(cas)$	0.48	0.85
Insurgents (Captured/Killed)	0.86	0.49
Days	0.81	0.57
Daily Attacks	0.82	0.43

Table V-16: Rotation Matrix of Public Support

Variable	Factor 1 Time Driven Component	Factor 2 Casualty Driven Component
Intercept	-1.18	-2.22
$Log_{10}(cas)$	0.593	-0.375
Insurgents (Captured/Killed)	0.000303	-0.000380
Days	-0.0176	0.0253
Daily Attacks	-0.00288	0.00511

Applying the rotation to the initial data with four variables yields a new set of data with two factors. A multiple linear regression of public resolve and these two factors yields the ANOVA table presented in Table V-17.

Table V-17: Public Support for Iraq (Two-Factor Analysis Model using MLR)

Regression Statistics	
R^2	0.85
Adjusted R^2	0.85
Standard Error	3.85
PRESS	2874.18
$R^2_{Prediction}$	0.85
Observations	191

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	16197.76	8098.88	547.40	4.01E-79
Residual	188	2781.47	14.80		
Total	190	18979.23			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	51.11	0.28	183.64	4.8E-214
Time Factor	-4.77	0.28	-17.26	1.23E-40
Casualty Factor	-7.91	0.28	-28.69	1.35E-70

The standard error (RMSE) of the model remains very close to the error of the other linear models as presented in Table V-13; however, the model does not possess the multicollinearity of the previous models.

Figure V-19 depicts the results of the factor analysis model and provides the multiple linear regression model results (Table V-11) for comparison. The 'MLR results' and 'Factor Analysis' lines of the figure used the historical values of each independent variable/ factor for the month indicated along the horizontal axis.

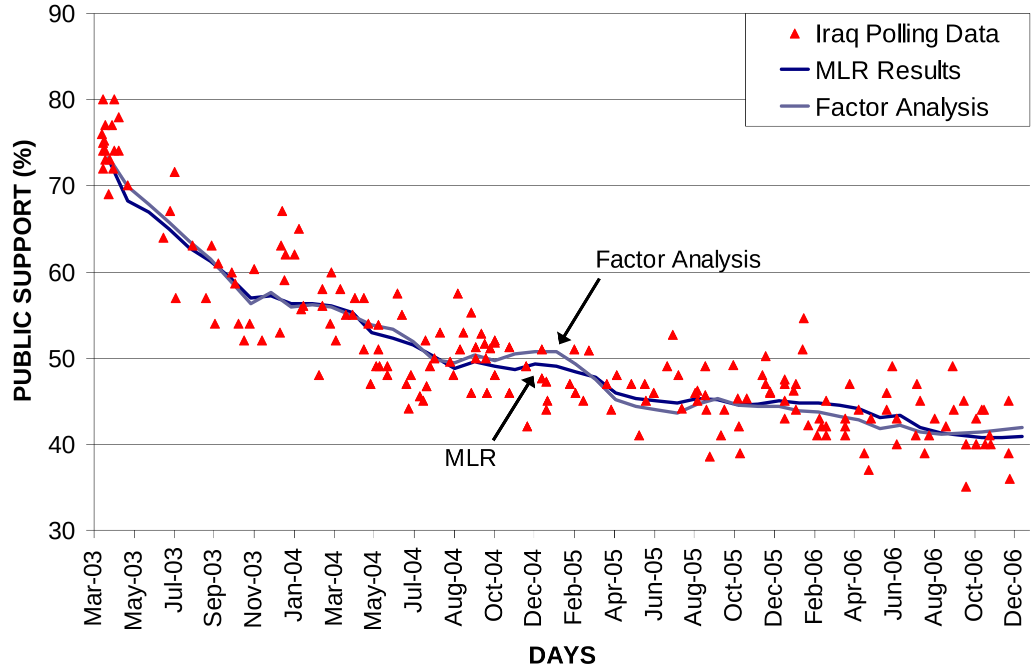


Figure V-19: Comparison of Public Support from MLR Model and Factor Analysis Model

Several of the residuals from the factor analysis are presented in Figure V-20. No significant trends were observed in the data.

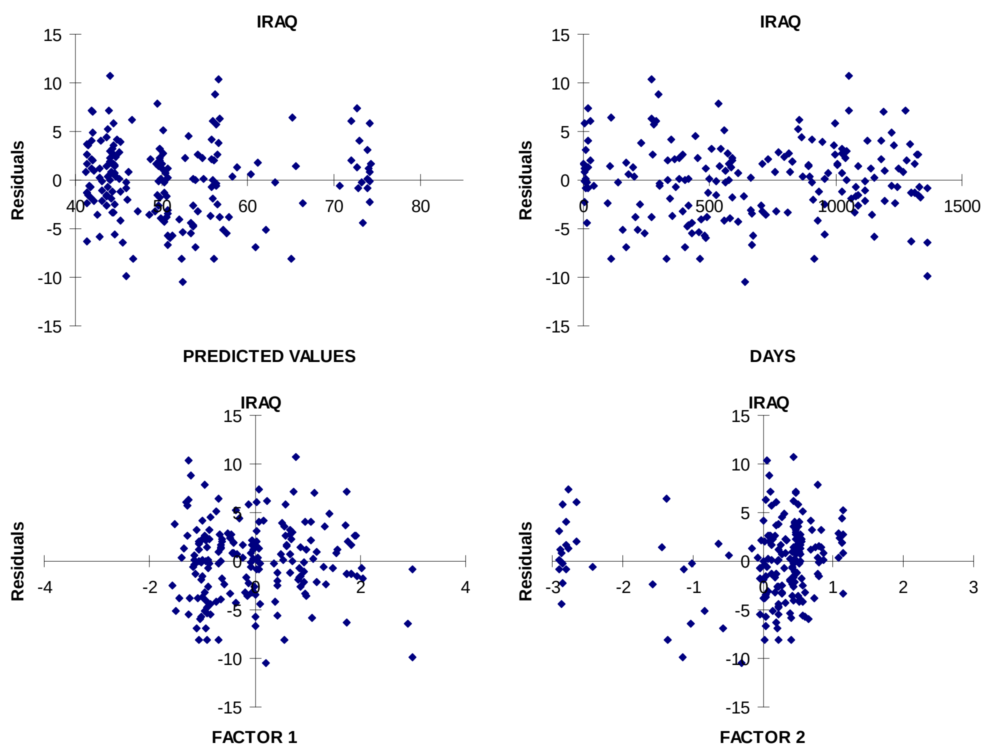


Figure V-20: Residuals from Factor Analysis (Two Factors)

As with any factor analysis, the ideal number of factors to be used can be contested. The scree test indicates that two variables should be included. It should be noted, since the second eigenvalue is much less than one, justification can also be made for one factor. Table V-18 are the results when only one factor was used and regressed to the public opinion response.

Table V-18: Public Support for Iraq (One-Factor Analysis Model using MLR)

Regression Statistics	
R^2	**0.21**
Adjusted R^2	**0.21**
Standard Error	8.90
PRESS	15161.97
$R^2_{Prediction}$	**0.20**
Observations	191

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4020.50	4020.50	50.80	2.1E-11
Residual	189	14958.73	79.15		
Total	190	18979.23			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	51.11	0.64	79.40	4.2E-147
Factor 1	-4.55	0.64	-7.13	2.1E-11

The results in Table V-18 indicate the use of one factor results in a weaker model. Additionally, the residuals in Figure V-21 suggest a trend in the data.

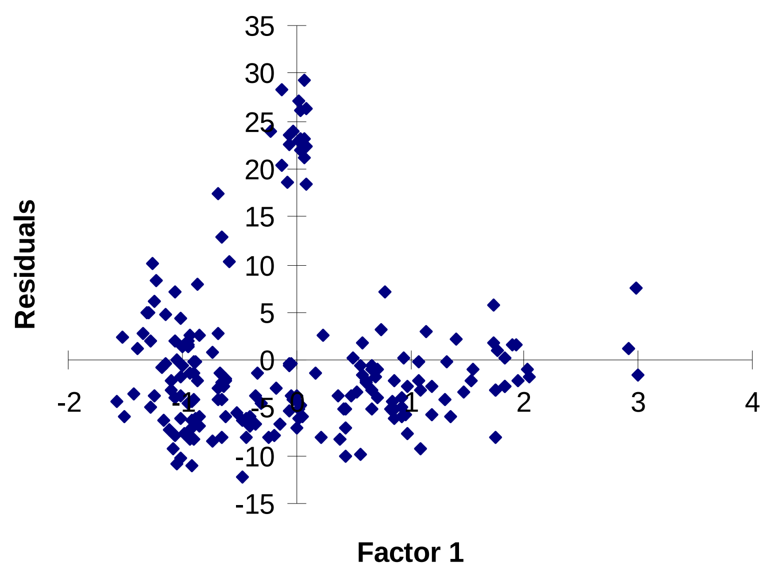


Figure V-21: Residuals from Factor Analysis (One Factor)

One limitation of least squares linear regression models is they should not be used, if not supported, for extrapolation beyond the range of the variables used in building the model. For methods to approximate the response beyond the known data ranges see Bratley, Fox, and Schrage (1987), among others. Because of this limitation, the results of the analyses should be viewed cautiously when projected outside the range supported by the data.

An approach to avoid exceeding the bounds for public resolve is to build a multivariate logistic regression model. A benefit of logistic regression is the expectation function is constrained between zero and one. Since the data for public resolve represents the percent of the population which supports the conflict using logistic regression limits the fitted model to feasible responses. This approach is presented in the next section.

Generalized Linear Model

The public support for the conflict in Iraq was fit to a logistic regression model using the twelve independent variables identified in the previous section on MLR. Since the number of people questioned for each survey was known, it was possible to use a binomial model. Each survey (p_i or observation) questioned n_i people, with m_i people supporting the conflict.

The survey data referenced within Appendix A and the data for the factors from the *Iraq Index* was used to fit a logistic regression model (Appendix B). Five variables were determined to be significant; the same four variables used in the MLR and the independent variable indicating the number of Iraqi Security Forces (ISF). The model is presented in Table V-19. The summary of the regression coefficients and standard error is presented for each of the factors.

Table V-19: Public Support for Iraq (Logistic Regression Model)

Goodness of Fit Factor	
Deviance	**809.7**
Pearson Deviance	**802.7**

	-LogLikelihood	χ^2	*df*	*Prob* > χ
Difference	2824.02	5648.04	5	0.0E-200
Full	133229.03			
Reduced	136053.05			

	Coefficients	*Standard Error*	χ^2	*Prob* > χ
Intercept	2.42	0.12	461.2	2.70E-102
Days	-0.0009919	0.0004	6.4	0.011
Log_{10}(cas)	-0.552	0.048	134.1	5.27E-31
Attacks	-0.00129	0.00026	24.2	8.80E-07
Insurgents Killed	1.77E-05	5.30E-06	11.1	0.00086
Iraq Security Force	-5.88E-07	2.26E-07	6.8	0.0093

As discussed in Chapter 2, deviance was used to measure overall adequacy of the logistic regression model. The deviance for this model was 809.7, which was greater than the critical value, $\chi^2_{\alpha=0.05,\ 185} = 225$. Since deviance > 225, it was concluded this initial model was not adequate.

The model was evaluated for additional independent variables and the residuals were investigated for trends indicating if additional transformations of factors were required. No additional variables were found and the residuals did not indicate any required transformations. Figure V-22 presents the normalized predicted responses compared to the deviance residuals.

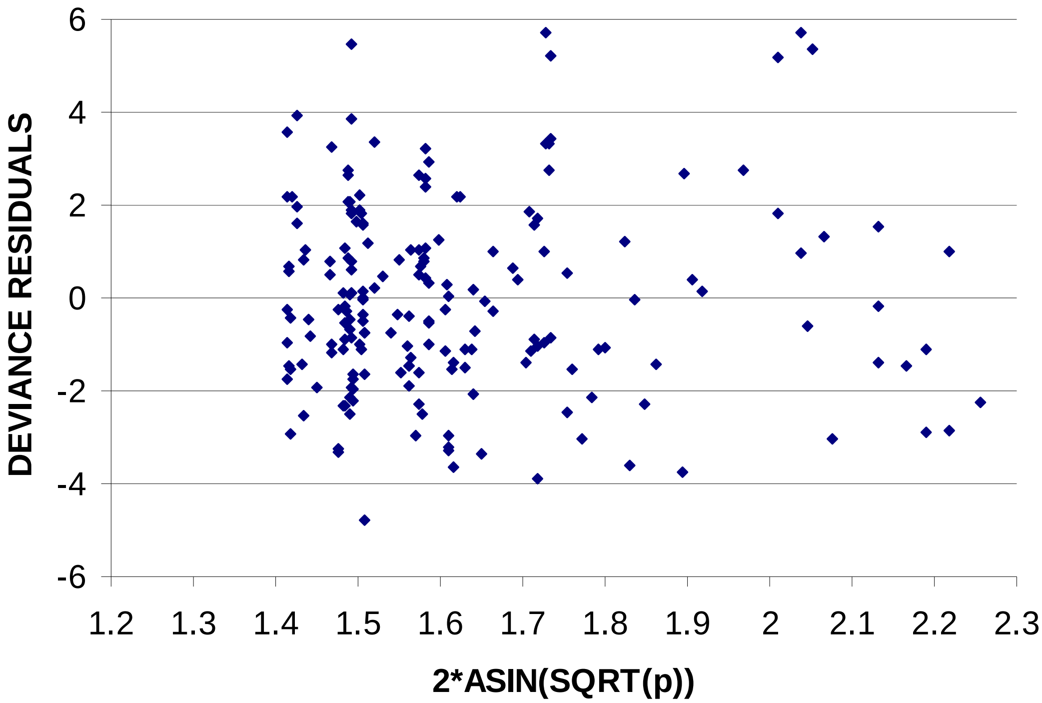


Figure V-22: Residuals from Public Support (Logistic Regression Results)

Since no other variables could be added to account for the variability within the results and no specific trends were discovered in the residual analysis, the data was assumed to be overdispersed or exhibit extra binomial variation.

The Lambert and Roeder test of convexity was used for the model of public support represented in Table V-19. The resulting graph (Figure V-23) was clearly convex, indicating the presence of overdispersion. Overdispersion indicates the actual variance is greater than the expected variance. Since a binomial was used for the data, the variance is based directly on the mean. This direct connection between mean and variance was not the best representation of the data. The overdispersion factor, ϕ, accounts for this disconnect.

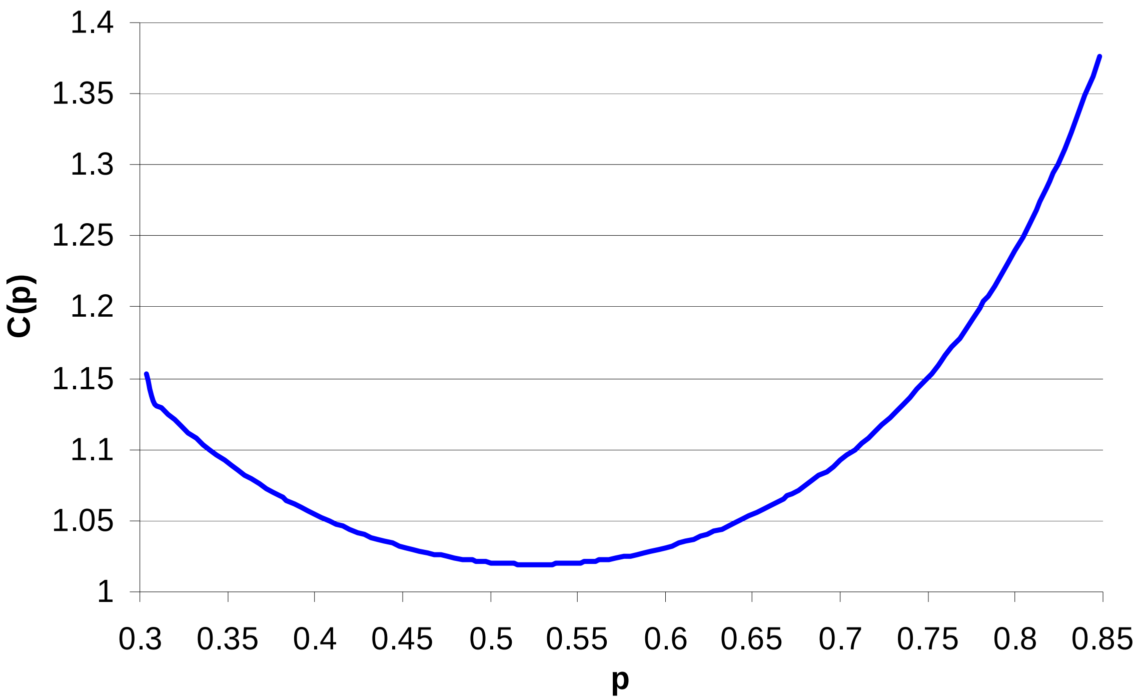


Figure V-23: Convexity Plot of Logistic Regession Model of Public Support

Using William's procedure, $\hat{\phi}$ was determined to equal 0.003627 when all twelve factors of the model were included. The weights for each observation were calculated and the model was refit. The model adjusted for overdispersion had the same four significant factors as the MLR. Table V-20 is the final logistic regression model of public support. The equation displays the regression coefficients, standard error, and χ^2 for each factor. Figure V-24 presents the logistic regression model and the original survey data. The 'Logistic Regression results' line of the figure used the historical values of each independent variable for the month indicated along the horizontal axis.

Table V-20: Public Support for Iraq (Logistic Regression Model Corrected for Overdispersion)

Goodness of Fit Factor	
Deviance	188.0
Pearson Deviance	186.0
William's Weight	0.003627

	-LogLikelihood	χ^2	*df*	*Prob* > χ
Difference	705.30	1410.61	4	3.46E-304
Full	27446.21			
Reduced	28151.51			

	Coefficients	*Standard Error*	χ^2	*Prob* > χ
Intercept	2.16	0.22	98.82	2.77E-23
Days	-0.00204	0.00077	6.96	0.0083
Log_{10}(cas)	-0.436	0.094	21.55	3.45E-06
Attacks	-0.00162	0.00056	8.42	0.0037
Insurgents Killed	3.04E-05	1.08E-05	7.89	0.0050

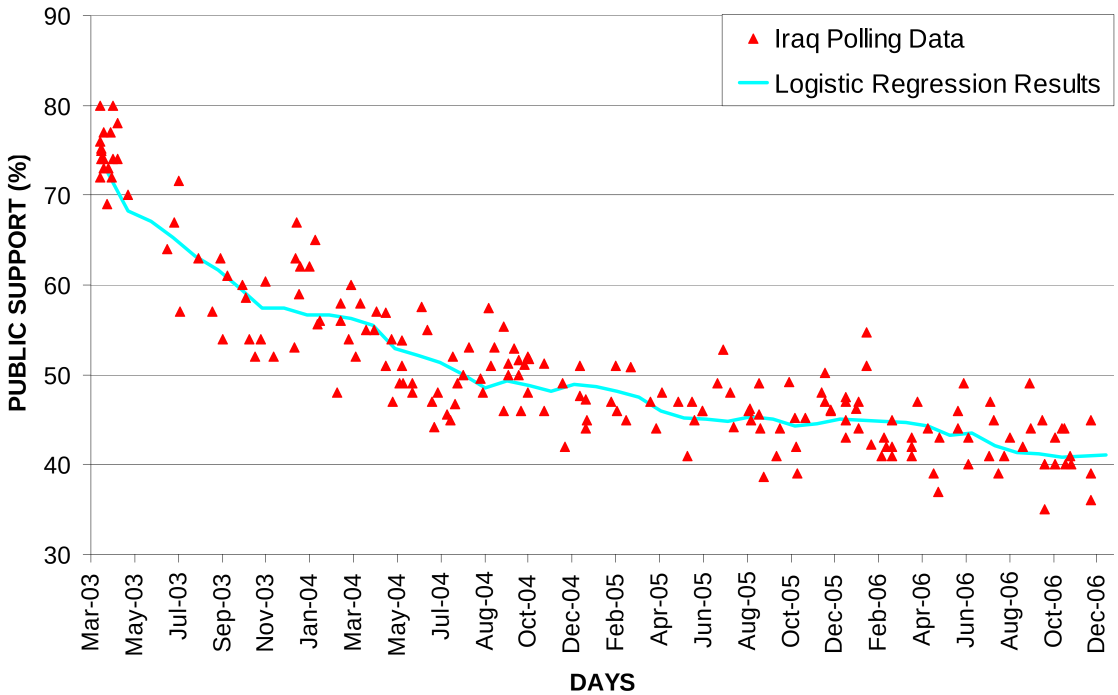


Figure V-24: Public Support of Iraq (Logistic Regression Results)

Unfortunately, deviance of the model was no longer a valid check of the overall adequacy of the model, due to William's procedure which adjusts the deviance to the degrees of freedom within of the model. No conclusion about the statistical significance of the model can be made; therefore, the logistic regression model was not used later in the development of the model of fourth generation operation in Chapter 7.

As with the MLR model, the same correlations were observed (see Table V-12). As applied in the MLR section, factor analysis was used to address the observed multicollinearity. The time and casualty components were used from the factor analysis performed in the previous section. These factors were regressed using logistic regression. Table V-21 provides the results from the logistic regression. The deviance of the model was significantly higher than the critical value from the χ^2 distribution, implying the model was again inadequate. As observed earlier in this section, the lack of fit may result from a lack of independent variables or overdispersion.

Table V-21: Public Support for Iraq (Factor Analysis Model using Logistic Regression)

Goodness of Fit Factor				
Deviance	**974.4**			
Pearson Deviance	**966.8**			
	-LogLikelihood	χ^2	***df***	***Prob > χ***
Difference	2741.65	5483.30	2	0
Full	133311.40			
Reduced	136053.05			
	Coefficients	***Standard Error***	χ^2	***Prob > χ***
Intercept	0.103	0.0047	491.3	7.54E-109
Time Factor	-0.191	0.0045	1831.6	0
Casualty Factor	-0.334	0.0057	3757.5	0

While logistic regression offers several potential benefits, including a response which is constrained between zero and one, this research did not use the technique or models in later chapters of the dissertation.

Impact of Media Reporting

This research suggested one additional important variable; the percent of positive stories about the war in Iraq. This area of research required data provided by two studies conducted by The Media Research Center. The first study investigated the major network evening news coverage (ABC, CBS, and NBC) of the war in Iraq from January through September 2005 (Noyes, 2005, p. 1). The second study analyzed news reports of the cable television channels (CNN, MSNBC, and Fox News Channel) for ten weeks from May 15th through July 21st 2006 (McCormack *et al.*, 2006, p. 2).

The Media Research Center classified each of the news stories of the war as positive, negative, or neutral.

> *To be classified as "positive," the optimistic news had to exceed the pessimistic by at least a three-to-two margin; to be counted as a "negative" story, the story had to be similarly dominated by bad news. Stories that could not be assigned to either group were counted as balanced or neutral.* (Noyes, 2005, p. 2)

It should be noted that the classification of what is *positive*, *neutral*, and *negative* may be open to interpretation. Be that as it may, the Media Research Center's data was taken as accurate for this analysis. Clearly, the analysis should be repeated if this assumption proves to be inaccurate.

The percent of stories which were reported to be positive regarding the war in Iraq was never greater than 28% in the Media Research Center's analysis. While the percent of negative stories reached a high of 83% at the end of May 2006. On average, for the period reported by the Media Research Center, 58% of the stories were negative, 30% were neutral and only 12% were positive.

Using least squares simple linear regression, the percent of positive and negative stories were both regressed to public support. The analysis used the public opinion data from the two timeframes the Media Research Center provided data. This limited the analysis to only thirty-five points of data. Table V-22 provides the resulting model based on the number of positive stories, and Table V-23 provides the model based on percent of negative stories. The same hypothesis tests were used as discussed in Chapter 2.

Table V-22: Public Support for Iraq based on Percent of Positive Stories

Regression Statistics	
R^2	**0.34**
Adjusted R^2	**0.32**
Standard Error	2.44
PRESS	221.37
$R^2_{Prediction}$	0.26
Observations	35

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	100.99	100.99	16.98	0.000239
Residual	33	196.30	5.95		
Total	34	297.29			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	43.12	0.97	44.25	5.8E-31
Percent Positive	30.16	7.32	4.12	0.000239

Table V-23: Public Support for Iraq based on Percent of Negative Stories

Regression Statistics	
R^2	**0.031**
Adjusted R^2	**0.002**
Standard Error	2.95
PRESS	328.71
$R^2_{Prediction}$	**-0.11**
Observations	35

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9.24	9.24	**1.06**	**0.310934**
Residual	33	288.05	8.73		
Total	34	297.29			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	49.24	2.47	19.96	5.45E-20
Percent Negative	-4.06	3.95	**-1.03**	**0.311**

Table V-22 shows there was a correlation between the percent of positive stories and the increase in public support for the conflict. The R^2 indicated that this factor alone did not fully explain the variance of the data. However, the factor was statistically significant. Conversely, Table V-23 indicated the percent of negative stories was not statistically significant. The magnitude of the *t*-test statistic (-1.03) was less than the critical value from the *t*-distribution (2.03). Additionally, as expected based on the *t*-test, the *F*-test statistic indicated the model was not statistically significant.

A multiple linear regression analysis was also performed using the twelve previous independent variables and the percent of positive and negative news reports. The completed analysis created a model which included the logarithm base ten of the total US casualties and the percent of positive media reports. The other variables were not considered to be statistically significant at an $\alpha = 0.05$ level. The decrease in significant factors (from the previous MLR model) was anticipated given the smaller sample size. Table V-24 provides the model for the limited timeframe.

Table V-24: Public Support for Iraq (MLR with Percent of Positive Media Reports)

Regression Statistics	
R^2	0.997
Adjusted R^2	0.967
Standard Error	2.61
PRESS	253.35
$R^2_{Prediction}$	0.997
Observations	35

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	76578.22	38289.11	5636.74	1.7E-41
Residual	33	224.16	6.79		
Total	35	76802.38			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Log_{10}(cas)	38.70	7.64	5.06	1.53E-05
Percent Positive	10.01	0.24	41.36	5.19E-30

As the R^2 and F-tests indicate, the model provides significant insight into the factors impacting the public resolve for the time period. Figure V-25 illustrates the original data for public resolve (Iraq Polling Data), and the model's response at each data point given the independent variables historical value for the date on the horizontal axis (MLR results). The figure also presents the percent of positive media reports (Positive Reports). The connection between the changes in the public resolve and the number of positive reports is clear. Positive reports appear to have a mitigating effect, improving public support for the war.

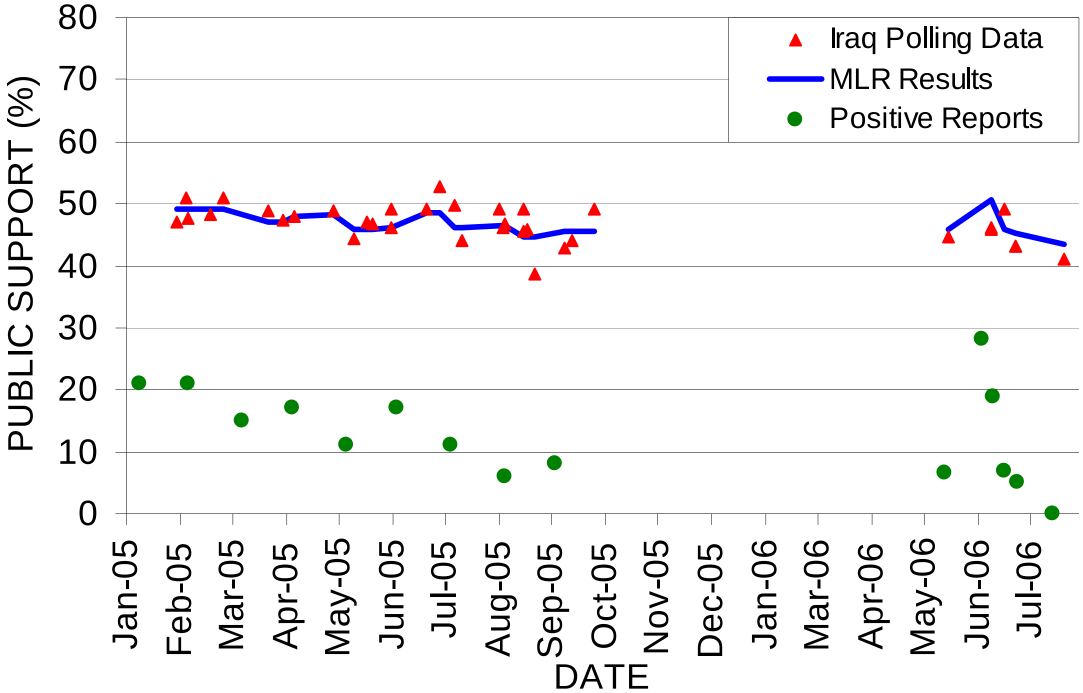


Figure V-25: Public Support and Percent of Positive Media Reports

Further analysis of the final data point on Figure V-25 provides an illustration of how this impact may be evaluated. Given there were no positive reports that week, there was no positive impact; however, if the percent of positive reports increased to 10%, the model suggested that the notional support of the war would increase to 47% from 43%. Similarly, if the percent of media reports were at levels seen in early 2005 (21%), the model implied that support for the war might have been as high as 52%. Additionally, if the percent of positive media reports was at the reported high of 28%, the public support may have been as high as 54% (a full 10% increase in total public support).

Unfortunately, the data covered less than a year of the conflict in Iraq. Therefore, percent of positive media stories was not included in the final model of public resolve used later in this dissertation. While not included in the model for the dissertation, the independent variable and related importance did require a discussion. Further research and analysis of media reporting, as well as other scores of positive, neutral and negative stories from varied raters, would allow this variable to be included within a model of public resolve.

Recent Polling Data and Summary

Recent Polling Data

The models presented in this chapter were created using data ending in 2006. These were compared to activities which occurred in July 2007. The opinion survey from 6-8 July shows only 36% support (Gallop); July 18th-21st, 36% (ABC); and finally, July 20th-22nd, 42% (CBS). This gives a simple average of 38.0% of the US population is supporting the current conflict in Iraq. The standard deviation is 3.5%.

The least squares simple linear regression model based only on days into the conflict (Table V-4) suggests the public support should be 33.1%. The model based on the logarithm of the number of casualties (Table V-9) suggests the public support should be 41.2%. The MLR model (Table V-11) reports 37.9% in July 2007, GLM (Table V-20) reports 38.8%, and the factor analysis model (Table V-17) reports 35.0%. The values were based on reported data for each factor for mid-July 2007 (O'Hanlon & Campbell, 2007). All the models, except the least squares simple linear regression model based on days, provided predictions very close to the observed values and were within one standard deviation of the data. Based on the data available, it can be supported statistically that public resolve decreases over time and is related to the casualties sustained.

The least squares multiple linear regression model of public resolve provides insights to the implications of current policy and military doctrine. The number of US casualties and duration of the conflict which has already occurred can not be reduced; therefore, their contribution to public resolve cannot be reversed. However, if the total number of insurgents captured (or killed) increased and the number of daily attacks decreases, the model suggests that public support for the conflict may increase. The research also suggests (based on a limited sample) that positive media reports have a positive effect on public support.

The Brookings Institute's *Iraq Index* suggest that at the end of 2006 there were roughly 25,000 insurgents (O'Hanlon & Campbell, 2007, p. 26) and approximately 175 daily attacks made by insurgents (O'Hanlon & Campbell, 2007, p. 7). Theoretically, if all of these estimated insurgents could be removed (additionally causing the daily attacks to reduce to zero) without creating new insurgents, the percent of population supporting the conflict based on the statistical model could increase by 28.1%, suggesting over 71% of the US population might support the conflict. If only a quarter of this objective was completed, the model suggested the public resolve could potentially increase to over 50%. Unfortunately, data from Korea, Vietnam, or Afghanistan provide no empirical evidence that the downward trend of public resolve has been reversed.

Summary

This chapter presented multiple models of US support for conflicts, with particular attention to Iraq. The data for building these models included recent public opinion data along with historical data from Korea, Vietnam and Afghanistan. The first model, a simple least squares linear regression with time as the covariate, showed a similar trend in slope for Vietnam, Afghanistan and Iraq, suggesting that public opinion declines at ~0.6% per month or ~2% per quarter. Additionally, public support for the first four years of Iraq and the first five years of Vietnam (1965-1969) can be represented with the same model (Equation V-1). This conclusion indicates that the decline of public support for Vietnam and Iraq over time are statistically the same.

Mueller proposed that as the number of casualties increase by an order of magnitude, the public support for a war decreases by 15%. This was based on data from Vietnam and Korea. This research concludes Mueller's proposed model is still valid for the conflict in Iraq.

When looking for other variables which influence public opinion, a multiple linear regression analysis and logistic regression analysis both identify the same four variables. The key variables were the logarithm of the number of US casualties, days into the conflict, number of daily attacks made by insurgents, and number of insurgents captured or killed. Only the number of insurgents captured or killed had a positive impact on public opinion.

Factor analysis was applied to the key variables found during the linear and logistic regressions. This analysis was able to eliminate the correlation within the factors used in the models. Finally, the impact of the percent of positive media reports regarding the war in Iraq was analyzed. The factor was determined to have significant influence on the public resolve for the conflict; however, there was insufficient data spanning the duration of the conflict to support including the factor in the following chapters.

As seen in this chapter, both the multiple linear regression model (Table V-11) and the logistic regression model (Table V-20) can be used to estimate the public resolve for the conflict. As they are both members of generalized linear models (GLM), GLM has been demonstrated as a valid and powerful technique to estimate the US public resolve during a conflict.

The chapter constructed a modeling framework of public resolve. The framework was founded on empirical evidence of key factors influencing the public resolve. The proposed model within this study demonstrates how actions made by both the insurgents and the US military impact public opinion. The $R^2_{Prediction}$ values for several of the models indicate the prediction of the variance within the model is greater than 80%.

Further research incorporating perturbations, such as elections and troop surges, to the public resolve should be pursued. These impacts may significantly change the regression coefficients. These models for public resolve can be used within current combat models to gauge the public support of various courses of action. Additionally, the impact of public resolve can be connected to the combat effectiveness of our troops.

This chapter presented the fourth contribution of the dissertation. The chapter constructed a modeling framework of public resolve. The framework was founded on empirical evidence of key factors influencing the public resolve. The proposed model within this study demonstrates how actions taken by both the insurgents and the US military impact public opinion.

VI. Modeling Morale

Chapter Overview

Warfare has always included aspects of fighting spirit and morale. This can be seen by the effects of drums, the Spartan's red cloaks, the sighting of a single Iroquois Confederation scout, Lord Haw-Haw's or Hanoi Hannah's broadcasts, or today's asymmetric conflicts with the employment of improvised explosive devises (IEDs). These aspects can be seen currently in the many facets of information operations and information warfare. However, as the services expand their information operation efforts, this ability to directly influence the hearts and minds of the population and soldiers will be more commonplace.

This chapter develops a theoretical modeling framework of combat spirit. Several factors which impact the framework are discussed. The chapter concludes with an application of the modeling framework. The example models the morale of notional brigades and battalions that have deployed into Iraq based, in part, on the actual histories. An excursion based on the impact of multiple deployments is also presented.

Supposition of Soldier Morale

This section develops an equation representing the model of morale provided by Stafford-Clark and Menninger. The morale curves were introduced in Chapter 2. This equation, which is based on control theory, enables other influences to be modeled impacting the morale of deployed soldiers.

Applying the log decrement method from control theory, both the Stafford-Clark model and Menninger model were represented as a second order response to an impulse. The heights at arrival, engagement, and acceptance were used to derive ζ, and the distance between peak times of engagement and acceptance was used to calculate the period of the function. The coefficients from the log decrement method are presented in Table VI-1, arbitrarily assuming the system's steady-state is zero and the height at arrival is 0.5.

Table VI-1: Coefficients for Response to an Impulse

	Stafford-Clark	Menninger	Model of Soldier Morale
ζ	0.18	0.21	0.2
Period, T (% of deployment)	0.77	0.71	0.7

Equation VI-1 presents the model of soldier morale based on the length of deployment (L) and time in theater (t).

$$\text{\textit{Soldier morale}}(t) = \left(0.1070 L\, e^{\frac{1.832}{L} t} \sin \frac{8.976}{L} t \right)^{-1} \qquad \text{(VI-1)}$$

Using the data from Table VI-1, the transient response to an impulse was overlaid on the original morale curves provided by Stafford-Clark and Menninger (Figure VI-1 and Figure VI-2). Unfortunately, a statistical fit of the relation can not be conducted since the original graphs were only hand drawn and not mathematically derived.

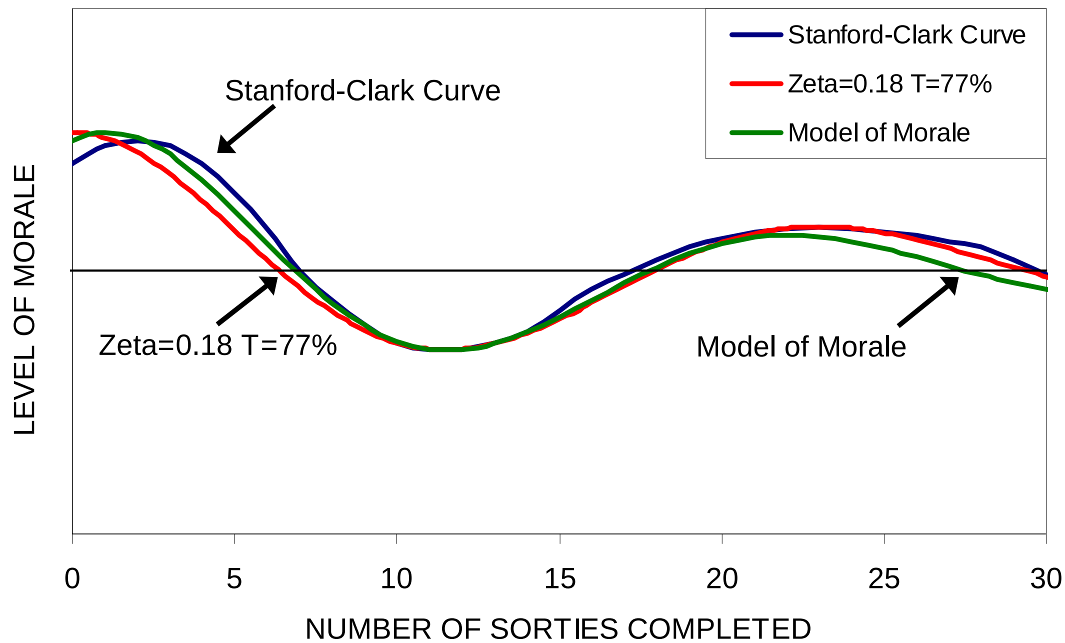


Figure VI-1: Comparing the Stafford-Clark Curve and a Response to an Impluse

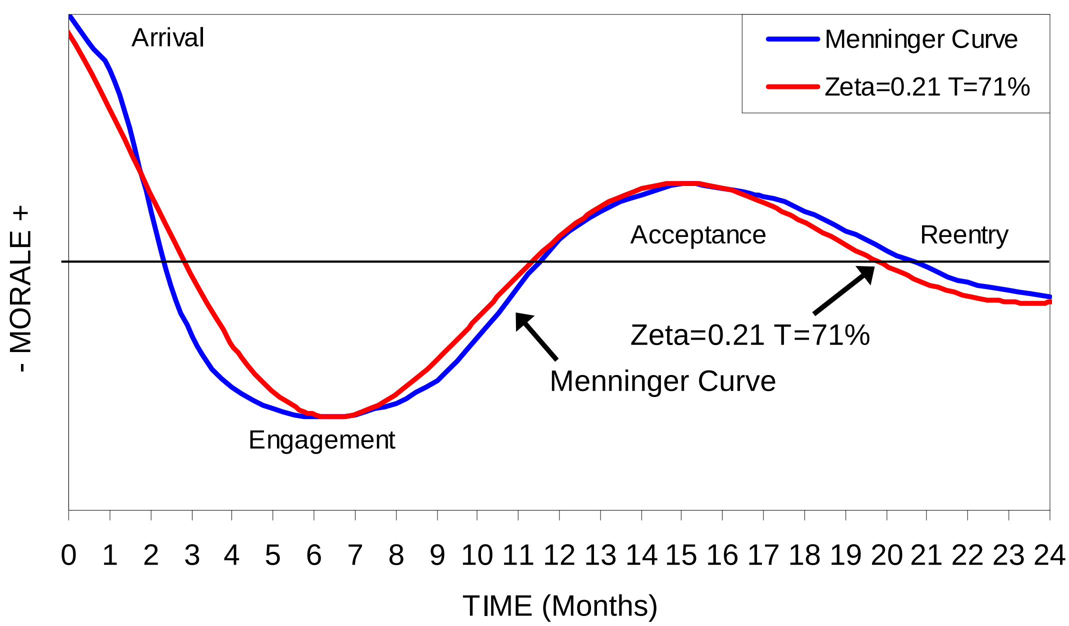


Figure VI-2: Comparing the Menninger Curve and a Response to an Impluse

Figure VI-1 and Figure VI-2 indicate that the model of soldier morale from Equation VI-1 provides similar results as the hand drawings provided by Stafford-Clark and Menninger. From these observations a general supposition of soldier morale is proposed:

Supposition of Soldier Morale: The Morale of an individual or unit engaged in a classical combat situation can be modeled as a second order system represented as the transient response to an impulse. Specifically, the period is 70% of the length of deployment and $\zeta = 0.2$.

While individual elements will always affect a specific unit's morale, the supposition can be used in combat models. The coefficients of the proposed relation are presented in Table VI-1. Figure VI-1 also compares this proposed relation with the Stafford-Clark morale curve and the fitted impulse. The proposed relation is not illustrated in Figure VI-2, since the data are obscured by the fitted impulse. The system is well represented by an impulse, since the unit is at an average level of morale while in garrison waiting to be deployed. The deployment order is the impulse to the system. The morale curves suggested within this study do not start at zero. This represents the time required to transit to theater and engage the enemy.

Assuming a deployment of twelve months, with peak morale occurring prior to deployment and the minimum morale occurring one-third of the way through the deployment, the morale curve for a typical brigade is estimated by Figure VI-3.

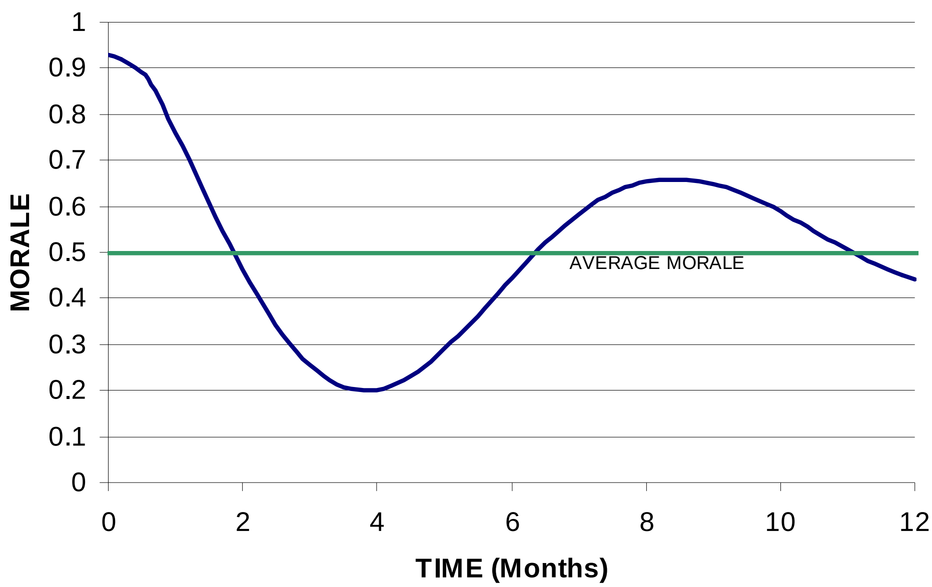


Figure VI-3: Morale Curve of a Twelve Month Deployment

The supposition is supported by research on OPERATION IRAQI FREEDOM conducted by Smith and Hagman (2006). They researched the morale and cohesion of members of the 172nd Stryker Brigade, immediately preceding their deployment to Iraq and also six months into their deployment (mid-deployment). They categorized the results of their surveys based on horizontal changes, vertical changes and organizational changes. This represented how the members associated with their comrades (horizontal), the unit cohesion with their commanders (vertical) and of the overall brigade (organizational). The results (as seen in Figure VI-4) demonstrate the soldiers lost unit cohesion with their leadership (vertical) both directly and organizationally. The cohesion between comrades did not change (horizontal). The trend of loss of morale from pre-deployment to mid-deployment further supports the supposition of soldier morale presented in this section. Comparing the initial morale with the morale at month six, in Figure VI-3, tracks with the decrease suggested by Smith and Hagman.

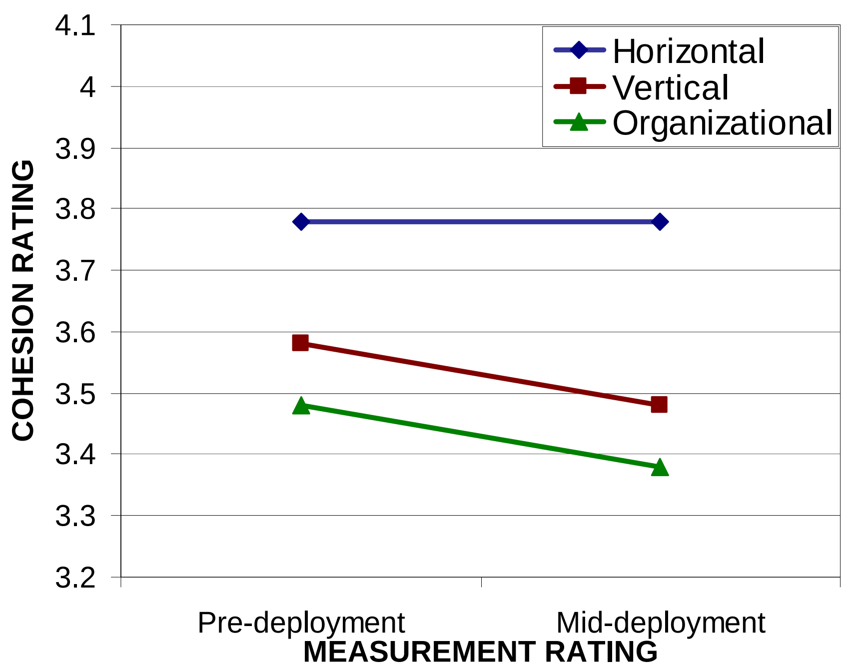


Figure VI-4: Platoon Member Ratings of Cohesion (Smith & Hagman, 2006, Figure 2 Page 8)

The control theory based soldier morale model introduced and developed in the section, supported by historical and empirical evidence, is next adapted by introducing several factors which may impact the shape and attributes of the morale curve.

Influencing Factors

The basic morale curve may be adjusted to represent several key factors. These factors differ between each conflict due to military policies and environment. This section highlights and develops several of these factors with support for their importance and methods to integrate the factors into the morale curve.

Unit Cohesion

As opposed to World War II, soldier could leave combat before the conflict ended in the Vietnam War. "The realization that one did not have to get killed or wounded to return stateside, as was the expectation in World War II, raised hopes and individual morale" (Helmus & Glenn, 2005, p. 18). On the other hand, individual rotations within Vietnam caused lower unit cohesion (Helmus & Glenn, 2005, p. 18). The enlisted soldiers generally rotated out of theater after 12 months, while the officers might only spend six months in theater (Helmus & Glenn, 2005, p. 17). The experience of the commander directly impacted the morale and effectiveness of the soldier.

> *Over half the battalion commanders in Vietnam were routinely relieved without cause prior to the end of their sixth month in command in country: over half the company commanders were similarly relieved before they completed four months in command.* (Thayer, 1975, p. 225)

The vertical unit cohesion was difficult to build and maintain when commanders were rotated more often than the troops. Additionally, combat effectiveness was directly impacted. The average number of KIAs per month for a battalion commander with less than six months experience was 4.98 soldiers in 1965 and 1966. A battalion commander with over six months experience averaged 4.25 KIA per month (Thayer, 1975, p. 225). The impact is more significant when reporting the number of soldiers lost in sizable skirmishes (five or more deaths in a company in one day). The battalion commander with less than six month in command lost 2.46 soldiers per month, while the commander with more than six months experience lost 1.62 soldiers per month in sizable skirmishes (Thayer, 1975, p. 225). Therefore, it was good for effectiveness to be assigned in a unit with an experienced commander; however, since these commanders were routinely reassigned, it was difficult to assure these benefits.

The current policy of the US Army is that soldiers train and deploy together so that can meet operational requirements (AR 600-35, 2006, p. 3). The policy is designed to increase both morale and combat effectiveness. Unit cohesion is stronger since the unit trains and deploys together. Further, extended training and operational time with the same commanders improve unit combat effectiveness.

Veteran Status

Rotation policy also relates directly to the next factor: combat veteran status. A soldier who is a combat veteran performs differently than the soldier on their first deployment. Quester *et al.* provide some insight into how morale changes over multiple deployments. Quester *et al.* suggest that more deployments lower the soldier's morale and therefore lower the reenlistment rates (2006, p. 9). Figure VI-5 shows that the reenlistment rate decreases for first time USMC reenlistments as the number of deployments increase. A first term reenlistment is a young Marine facing their first reenlistment decision (Quester *et al.*, 2006, p. 1). Fifty-three percent of the Marines making reenlistment decisions have no dependents and thus are single without children (Quester *et al.*, 2006, p. 7).

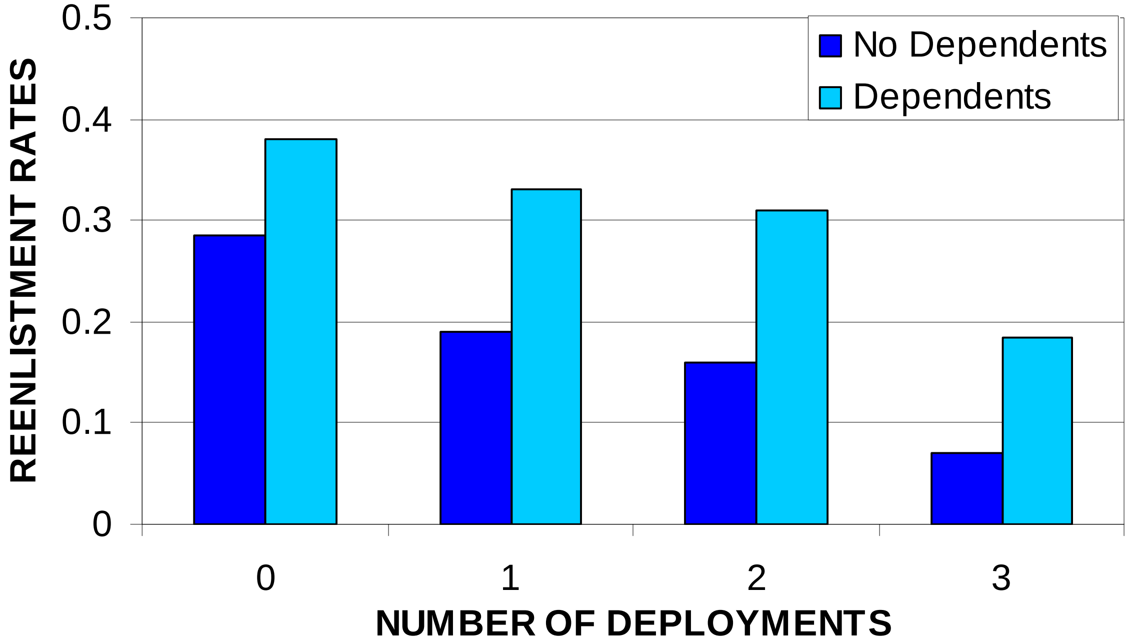


Figure VI-5: FY05 Reenlistment Rates for First Term Marines (Quester *et al.*, 2006, Figure 4 Page 9)

More information on the morale of veterans can be found in the Mental Health Advisory Team's (MHAT) Reports. The third report dated May 2006 provided information on the soldier's morale deployed during OPERATION IRAQI FREEDOM 04-06. One of the insights from the MHAT's Report was the personal morale between first time and multiple deployers did not vary significantly. Specifically, 55% of first time deployers and 57% of multiple deployers ranked their morale as medium, high or very high (MHAT-III, 2006, p. 18). On the other hand, individual views of how these individuals viewed their unit morale did significantly differ; only 45% of the multiple-time deployers ranked morale as medium, high or very high, compared to 59% for first timers (MHAT-III, 2006, p. 18). This difference was shown to be statistically significant (z-value = -2.48, p <0.05) (MHAT-III, 2006, p. 18). These results imply that the combat veteran's perception of unit cohesion decreases, by 14%, when each unit redeploys to theater. The same trend was observed in the MHAT-IV report.

Multiple deployers are also more susceptible to mental health problems. The MHAT-IV report indicates acute stress, depression, and anxiety were all statistically higher among multiple deployers when compared to first time deployers. Figure VI-6 provides the percent of soldiers who screened positive for each mental health problem.

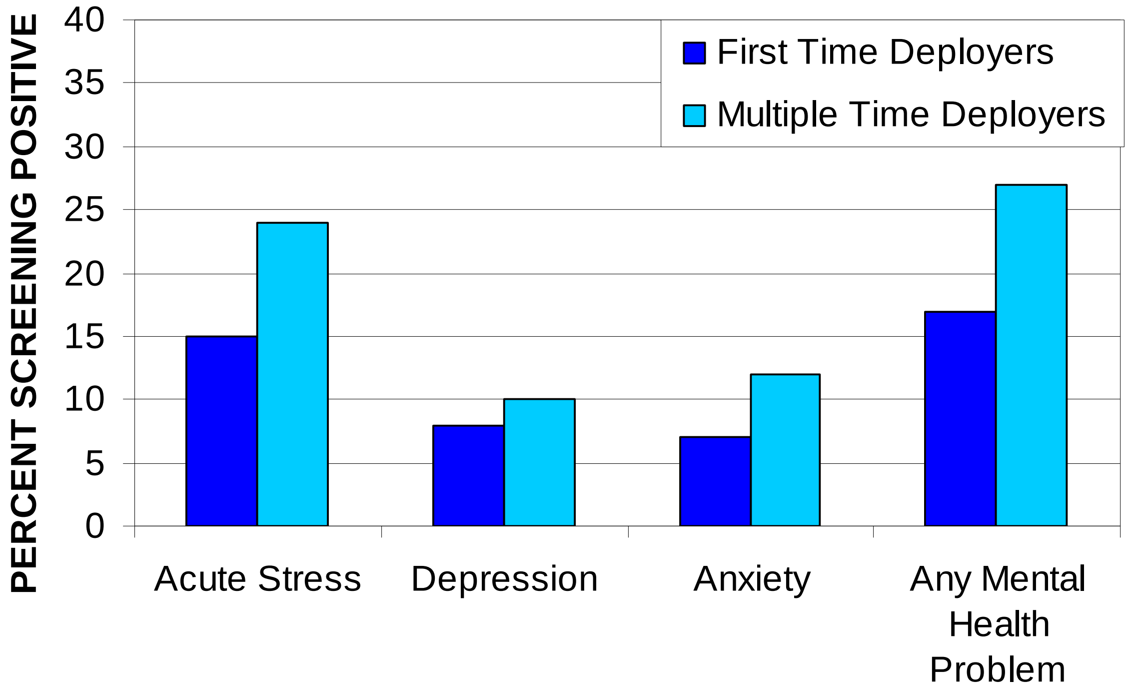


Figure VI-6: Mental Health Problems of First and Multiple Time Deployers (MHAT-IV, 2006, Figure 8 Page 23)

As seen with unit morale, the multiple time deployers on average exhibit lower morale and potentially lower combat effectiveness. Their effectiveness is potentially lower since they are more susceptible to mental health problems.

Deployment Duration

Another factor which may impact the morale of the forces is the actual deployment duration as opposed to the DEROS (date of expected return from overseas.) Hosek, Kavanagh, and Miller provide a model which predicts the probability of retention based on time away as opposed to expected time away. Table VI-2 provides the results of their model and suggests how the intention to stay (thus implying morale) decreases as the actual time in theater extends beyond the expected DEROS.

Table VI-2: Probability of Intension to Stay
(Hosek, Kavanagh & Miller, 2006, Table 4.8 Page 78)

	Army	Navy	USMC	Air Force
Enlisted				
Much Less	0.34	0.34	0.28	0.44
Less	0.39	0.33	0.27	.04
Neither	0.36	0.33	0.29	.041
More	0.36	0.27	0.27	0.38
Much More	0.31	0.17	0.27	0.24
Officer				
Much Less	0.6	0.5	0.54	0.59
Less	0.57	0.58	0.54	0.59
Neither	0.62	0.53	0.55	0.58
More	0.58	0.54	0.53	0.49
Much More	0.48	0.38	0.46	0.44

The rows indicate the probability of intension to stay in the military based on the actual duration of deployment versus the expected DEROS. For example the 'Much Less' column indicates the when an enlisted sailor was actually deployed much less time than expected, the rate of retention was predicted to be 34%. On the other hand, when an enlisted sailor spent much more time deployed than expected, the probability the sailor stayed in the Navy was only 17%. The percent of expected reenlistments dramatically decreased from those whom returned from theater when expected (indicated as the Neither row in Table VI-2) and those whom returned much later than expected. Navy enlisted were nearly one half the original rate, while the Air Force enlisted saw a decrease of 17%.

We can model the impact of deployment changes by adjusting the morale curve based on the timing of the announcement to extend a unit or return the unit sooner than expected. If a unit is extended for a few months soon after arriving to the theater of operations, the morale curve may simply be stretched to adjust to the longer duration. However, if the extension is announced just prior to returning stateside, the morale curve, which is already on the down slope from acceptance to reentry, continues to decrease perhaps at a higher rate.

Leadership

The leadership of a unit is also very important to the soldier's morale. Examples of how leaders were able to manifest victory from their troops can be found throughout the pages of history. Several examples occurred during the Civil War battle of Manassas in 1861. Brigadier General Barnard Bee rallied his brigade stating:

> *There is Jackson standing like a stone wall. Let us determine to die here, and we will conquer. Follow me.* (Freeman, 1950, p. 82)

The result was:

> *His men obeyed the call; and, at the head of the column, the very moment when the battle was turning in our favor he fell, mortally wounded.* (Freeman 1950, p. 82)

Brigadier General Thomas Jackson was henceforth referred to as 'Stonewall.' Later during the same battle, addressing the 2nd and 4th Virginia Infantry, Stonewall Jackson stated, “Reserve your fire till they come within fifty yards, then fire and give them the bayonet; and when you charge, yell like furies!” (Henderson, 1906, p. 151). This was considered the first use of the Rebel Yell, further demoralizing the forces of the Union. McPherson states:

> *Startled by this screaming counterattack the discouraged and exhausted Yankee soldiers, their three-month term almost up, suddenly decided they had fought enough. They began to fall back, slowly and with scatted resistance at first, but with increasing panic as their officers lost control, men became separated from their companies, and the lest shred of discipline disappeared. The retreat became a rout as men threw away guns, packs, and anything else that might slow them down in the wild scramble for the crossings of Bull Run.* (1988, p.344)

The image of ‘Stonewall’ Jackson standing before the troops as a ‘stone wall’ and his directive to use the Rebel Yell provided the leadership required to break the morale of the Union forces. This loss of morale allowed the Confederate States of America to win the battle that day.

This section provided an overview of how specific factors can impact the model of soldier morale. The next section provides an example of how the model can provide insight to the conflict in Iraq.

Application (Notional Morale in Iraq)

In this section, the model of soldier morale is applied to illustrate a notional estimate of the morale based on the US troops in Iraq. The morale of each land brigade and amphibious battalion is approximated using the model of soldier’s morale. By combining the morale for each unit, an overall morale of land and amphibious units is estimated. This estimate offers insight the morale within theater, providing commanders the ability plan operations when morale is at high levels.

The date each US Army Brigade and USMC Battalion entered and left theater was used to model the notional morale. Korb *et al.* published the dates of the US Army Combat Brigade's deployments in their report titled, *Beyond the Call of Duty* (2007). The Center for Naval Analysis's Marine Corps Deployed Unit Database (2007) was used to obtain the dates of USMC Battalion deployments. While the actual dates are used, other parameters are notional; thus the illustration, while based on existing units, is notional. The following analysis should not be assumed to actually represent any particular unit's morale. The notional estimated morale for each brigade/ battalion was represented by the model of soldier morale. The morale curve was scaled to the length of the deployment and the system, prior to the impulse, was set at 0.5 (average morale on a scale from zero to one). Additionally, the lowest morale of an average unit was assumed to occur at one third of the deployment duration. Again, individual factors will certainly affect specific unit morale.

The estimated morale of a single unit deployed for twelve months can be seen in Figure VI-3. Figure VI-7 presents an overall notional estimate of hypothetical amphibious troop morale for four years of conflict. The overall estimated morale was determined by using the weighted average of the each battalion. The weight was based on the number of amphibious troops in each battalion. Figure VI-7 also provides the estimated morale for two ground force battalions. The time the battalion arrived in theater and duration can be observed.

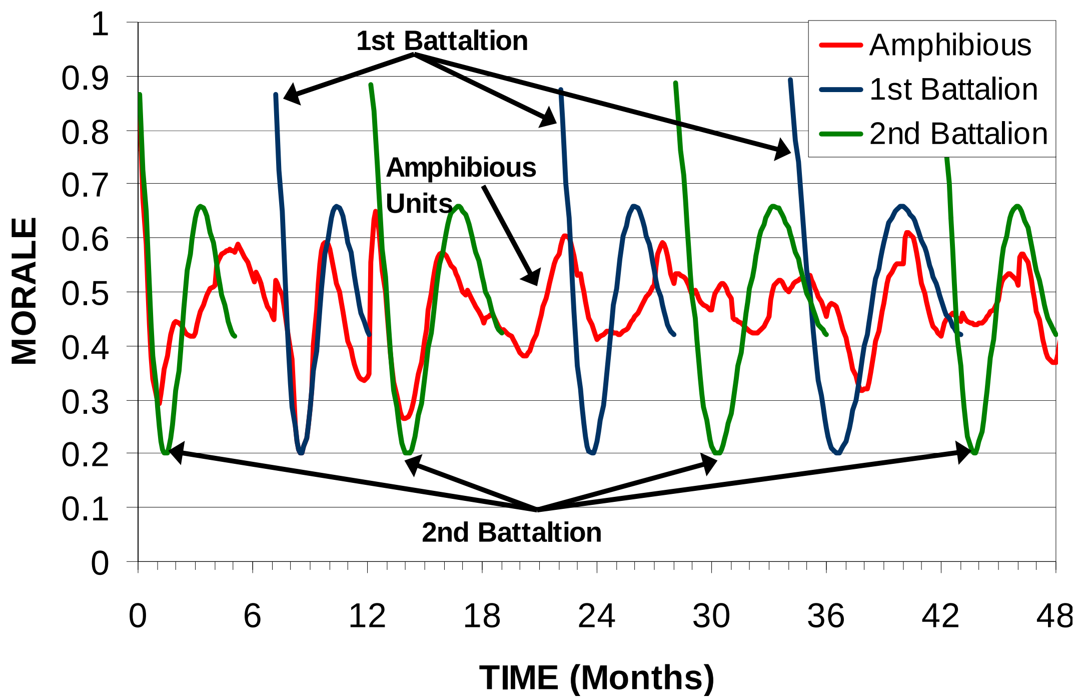


Figure VI-7: Hypothesized Morale of Amphibious Units and two Battalions

Figure VI-8 presents the notional estimate for all land and amphibious units for four years. The hypothesized land unit's morale and overall morale were both calculated using weighted averages, as discussed previously.

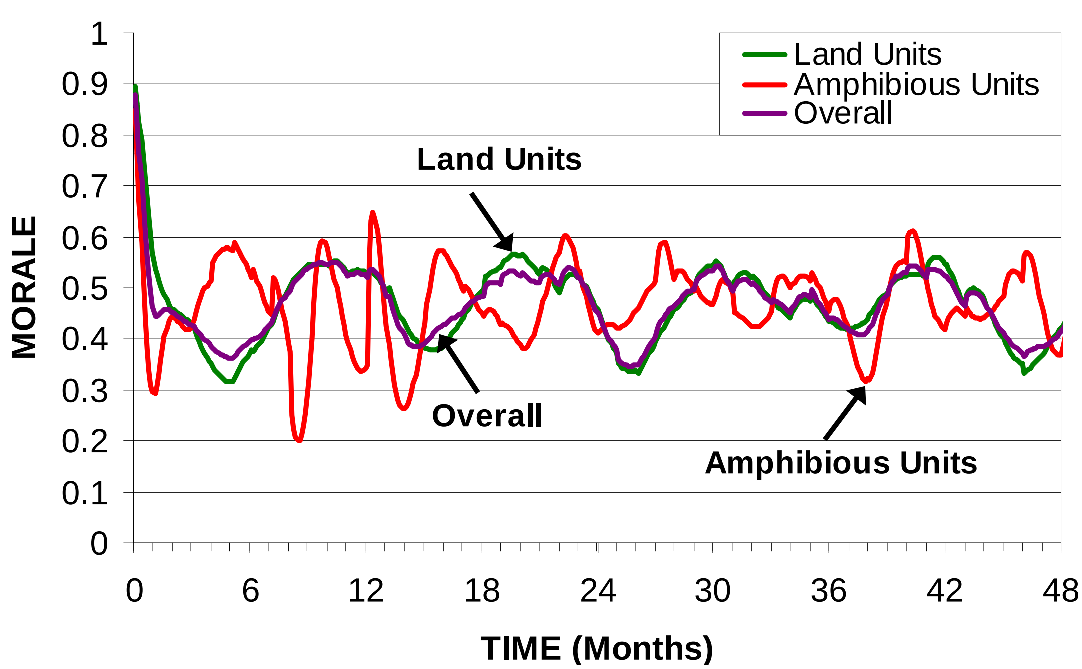


Figure VI-8: Overall Hypothetical Morale

Excursions can be tested by applying the insights from the influencing factors previously discussed. For example, the morale curve can be adjusted to reflect the impact of veteran units returning to theater. Quester *et al.*'s data about retention rates implies that morale deceases at least 6% each time an individual returns to theater (Quester *et al.*, 2006, p. 9). In this scenario it was assumed that 50% of the troops previously deployed with unit; therefore, the overall morale of the unit decreased 3% each time the unit returned to theater. With more data it would be possible to take a weighted average of the number of veterans in a unit. Figure VI-9 illustrates the hypothesized impact to amphibious units' morale after implementing such a notional loss of morale for veterans.

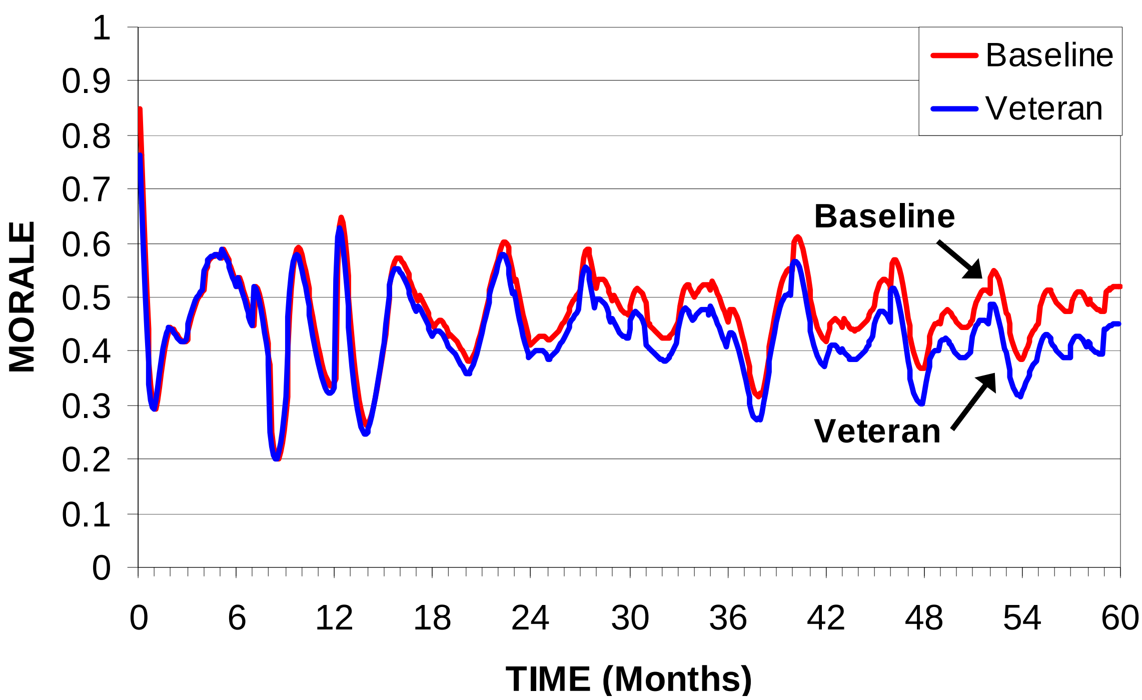


Figure VI-9: Hypothetical Amphibious Unit's Morale as Impacted by Combat Veteran Status

Figure VI-9 projects the morale to the fifth year of the conflict based on the deployment schedule. After five years of the conflict, the baseline assumption of morale projects morale at roughly 0.5. However, as more veterans return to theater the overall amphibious unit's morale is decreased by as much as 0.085. While actual unit morale is affected by unit cohesion, experience, training, and leadership, this model can be used to *estimate* the optimal deployment schedule to maximize the morale within theater. For example if all the troops enter the theater simultaneously, the morale will fall to its low when all the troops enter the engagement phase at the same time. On the other hand, if the forces were appropriately staggered, some troops will be at the engagement phase while others troops will have higher morale since they were at the arrival or acceptance phase. Figure VI-10 demonstrates the morale for two different deployment schedules. The first assumes twelve month deployments begin in the spring and six month deployments begin in both the spring and fall. The second scenario had the forces evenly deployed (or staggered) every month. The higher variance of the morale when the forces deploy in large groups is evident, when compared to the steady morale in theater when the deployments are evenly spread among all the months.

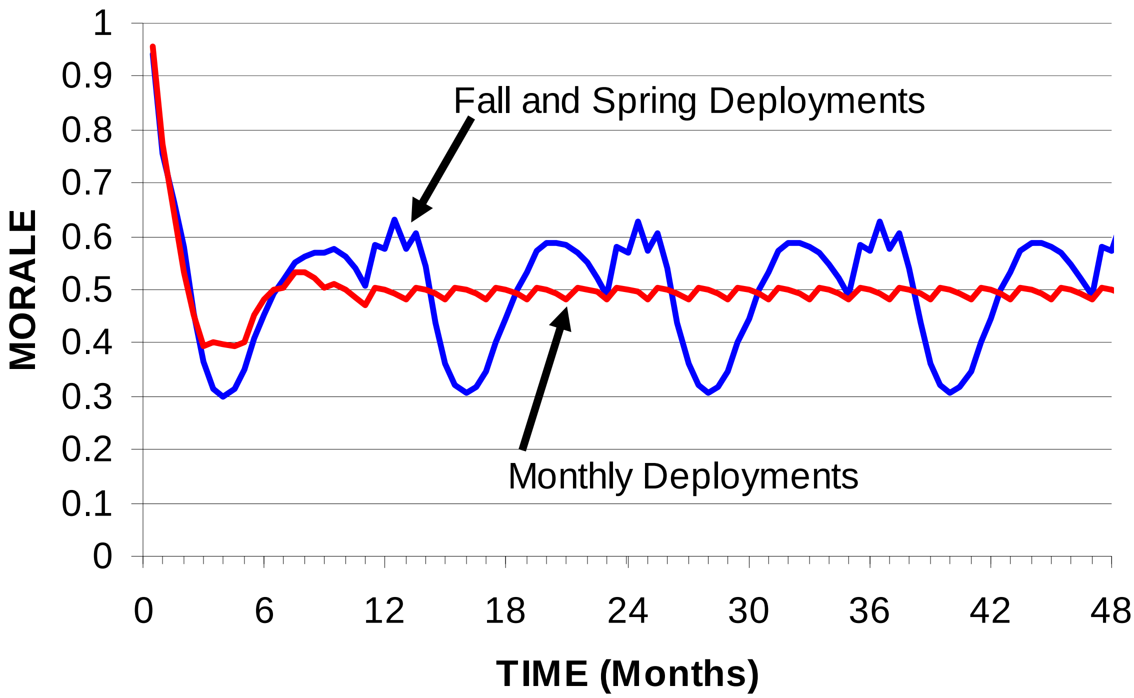


Figure VI-10: Hypothetical Morale of Various Deployment Schedules

The model can also be used in other, more complex simulations and war-games to estimate combatant morale. Of course, actual morale is a fusion of individual unit cohesion, training, leadership, and experience.

Although the application presented within this study focuses on the friendly operations, the theoretical modeling framework might be extended to an insurgency as well. Hypothetically, the insurgent is recruited when a significant event creates an impulse to their morale which sends their support for the insurgency above the recruit's specific threshold. Since the insurgent has no expected duration of the conflict, the duration of the impact of the impulse is two years unless another significant event occurs. This duration is based on the time to create a new sense of self as described by Menninger (Menninger, 1988 p. 204). The individual morale for each insurgent must be modeled since they are not among a deployed unit. However, it may be possible to group the insurgents based on the months they were recruited and adjusted by the operations they participate in. Any hypothesized results would have to factor in the effects of religious fervor and a suicide bomber mentality.

Since the model of soldier morale is based on control theory, there are at least two means to improve the results. First, regression analysis techniques can be applied to obtain statistically significant regressors for the control factors. As the number of data points are provided, the regression and fit of the control theory improves.

The performance parameters of control theory can also be optimized. The parameters can be optimized to impact the level of morale. It is possible to adjust parameters of the combatant's morale so that a planned major operation can be conducted while the morale and effectiveness of the engaged combatants is expected to be high. For more information on the methods and procedures used to optimize the performance of control theory by adjusting the parameters, see Ogata (1997) among others.

While developed to model the soldier's morale, this framework can also be used in other situations where morale is important. Obviously, this model provides a mathematical framework which can be used to model the deployments of Peace Corps members; however, as Menninger suggests his non-mathematical model can be applied universally, this control theory based framework may be applied universally. The model can be applied to model the morale and effectiveness of a new employee, when developing a lesson plan to teach students, or to anticipate the performance of a project team. Providing a new employee the encouragement or needed support during the initial slump may produce a more effective employee. Whereas developing a lesson plan which integrates the morale curve may produce a more effective learning environment and therefore more effective students. Given the morale cycle, work effort and effectiveness might be estimated in project planning. Additionally, this model may be applied to model the morale of a firm after a merger, the start-up of a new company, or a team built for a specific task.

Summary

The fighting spirit and morale of the troops is a target in fourth generation operations. This chapter provided a model which could be implemented to minimize the impact to the morale of our troops. By investigating the troop's morale and combat spirit, the impact to their combat effectiveness can be better understood.

A theoretical modeling framework of combat spirit was developed. Several factors which impact the framework are discussed. The chapter concluded with an illustration of the modeling framework. The notional morale of each brigade and battalion that have deployed into Iraq was presented and combined to produce the hypothetical morale for land and amphibious units. An excursion based on the impact of multiple deployments was also presented.

The model of soldier morale based on a systems response to an impulse can be used as a measure of effectiveness during courses of action analyses. The morale factor can be used within a combat model to insure the combatants are effective and efficient during the combat maneuvers. With the proposed model, the effects of average morale can be incorporated into larger modeling efforts.

This chapter presented the fifth contribution of the dissertation. This contribution constructed a theoretical modeling framework that dynamically models soldier morale. This provides a capability to model and evaluate the aggregate impact of soldier morale due to various courses of action the commander may take or from other external factors.

This chapter also completes the third objective of this research. This objective was to construct a theoretical modeling framework to dynamically portray public resolve, will-to-fight, morale and combat spirit within a combat model. The public resolve portion of the objective was completed in Chapter 5, and the morale and combat spirit is presented in this chapter. These elements will next be combined into an overall model of elements of fourth generation operations.

VII. Modeling Elements of Fourth Generation Operations

Chapter Overview

This chapter provides an analytic framework for modeling elements of fourth generation operations. This framework captures the morale of a deploying force and public resolve in support of their forces. The model remains a model of conflict and combat; however, the impacts from the political, economic, and informational instruments of power are represented in the model through the dynamic adaptation of public resolve and soldier morale.

This chapter combines the results of the previous four chapters creating a model of some elements of modern conflict. The methodology to build the model is presented along with the submodels. Additionally, the data for a scenario based on OPERATION IRAQI FREEDOM is populated during the discussion of model development. Once the complete model is developed, the next section provides a discussion on the verification and validation of the model. The verification and validation process is based on a multiple step procedure which is intended to provide confidence in the model.

The final section provides two demonstrations of the potential applications of the model. The first demonstration varies five key factors, providing a potential decision maker with insight to the importance of each factor. The second demonstration emphasizes the versatility and importance of feedback loops and highlighting the framework's ability to include softer aspects of combat.

Analytic Framework of Elements of Fourth Generation Operations

The analytic framework of the model of elements of fourth generation operations is presented in this section. This model expands on the system dynamics representation of the Lanchester Laws presented in Chapter 4. A scenario based on the US forces (Blue) and insurgents (Red) in Iraq, from March 2003 through December 2006, was used to populate the model with data. The deployment and redeployment schedules determined the number of Blue forces in theater (troops participating in the conflict). The scenario's implementation predetermined the Blue deployment schedules; however, it is possible to alter the implementation creating other options to deploy the Blue forces. The number of Red forces was determined by the rate Red accumulated new forces which depended on the recruiting and training of insurgents.

Figure VII-1 is the system dynamics representation of a top-level model of elements of fourth generation operations. Using the symbology presented in Chapter 2, the square containers indicate levels, valves indicate rates, the double arrows show flow created by the rates, and single arrows indicate dependencies between various model components.

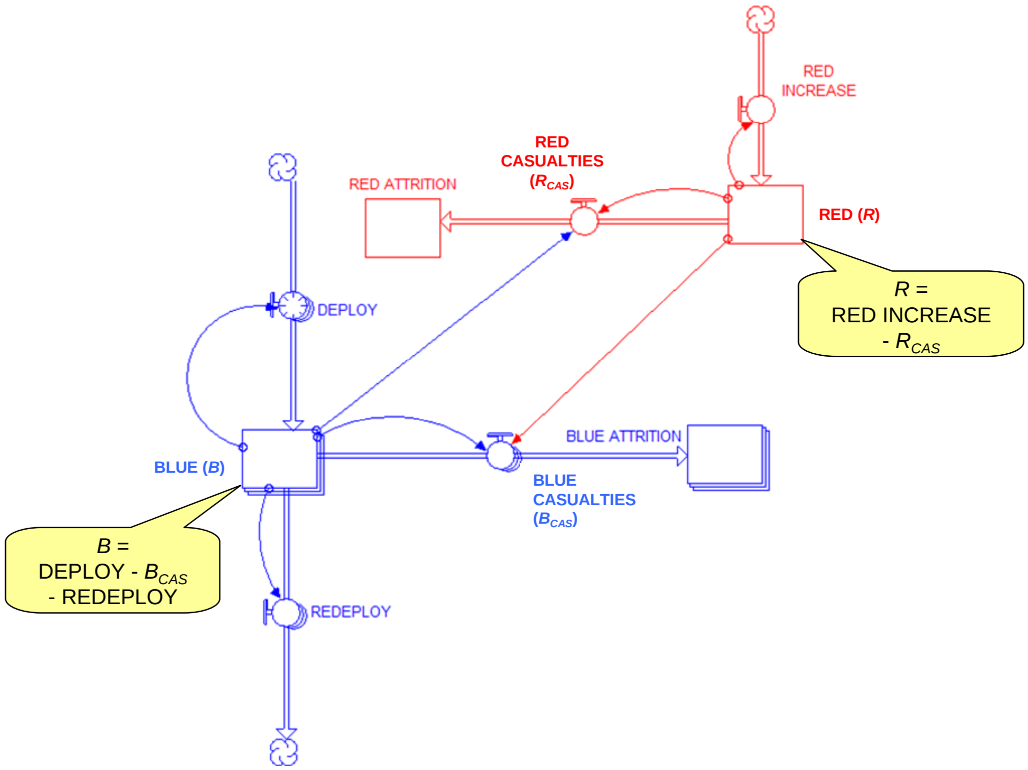


Figure VII-1: Simple Model of Combat

The system dynamics representation of the Lanchester Laws is focused on the level of Blue and Red forces, where the forces are the number of personnel as represented by Helmbold's general form of the Lanchester Laws (Equation II-15). Blue and Red force levels are changed by the rate of Blue and Red Casualties. Red Attrition is the total number of Red forces killed (or otherwise removed from battle) by the surviving Blue forces, and vice versa for Blue Attrition. The Red and Blue Casualty rates depend upon the number of forces and their respective attrition coefficients. The Blue forces increase as units Deploy into theater and decrease as the units redeploy to home station. The Red force increase is determined by the number of new forces which enter on their side.

In the broader analytic framework, either Red or Blue may increase by way of either deployments or simple increases. In the scenario, Blue deploys and Red flows as a rate of recruitment. The deployment of Blue forces requires a Deploy Date and

Deployment Duration for each unit. The Deploy Date is used to create a Deploy Schedule of when all troops enter the theater. This schedule, along with the Brigade Size, provides the information required for the rate of Deploy. Similarly, the Deployment Duration and Deploy Date determine the Redeploy Date. The Redeploy Date is used to create the Redeploy Schedule and count the Number of Deployments each unit has completed. The Redeploy Schedule is used by the Deploy rate to remove all surviving troops from the theater of operations. These interactions can be seen in the left side of Figure VII-2. It should be noted that the system dynamics framework allows for more complex representations, including feedback loops, if the situation and the data support such models.

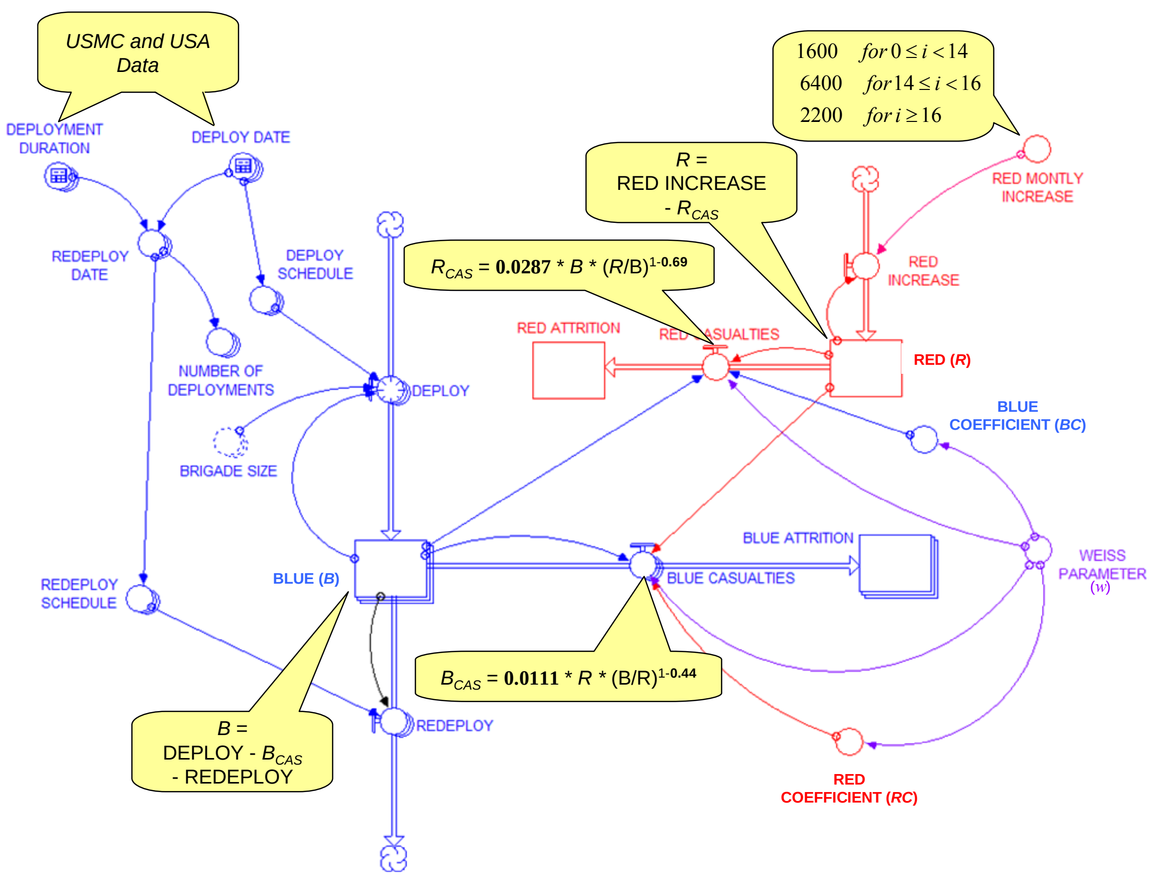


Figure VII-2: Model of Fourth Generation Operations

The actual date each US Army Brigade and USMC Battalion entered and left theater was used in this example model. Korb *et al.* published the dates of the US Army Combat Brigade's deployments in their report titled, *Beyond the Call of Duty* (2007). The Center for Naval Analysis's Marine Corps Deployed Unit Database, was used to obtain the dates of USMC Battalion deployments. While the actual dates are used, other parameters are notional; thus the illustration, while populated with existing units, is notional.

Unlike Blue forces deploying into and redeploying out of theater, the Red forces in the model enter and accumulate. Red Monthly Increase changes the rate of increase of insurgents. This was established by the number of insurgents in theater and number of insurgents captured or killed as reported by the *Iraq Index*. In this example scenario, it was assumed the rate of increase equaled the monthly change in total insurgents plus the number of insurgents captured or killed.

Analysis of the data provided by O'Hanlon and Kamp identified three distinct rates of insurgent increase. The average of the increase in insurgents for the first thirteen months of the conflict was 1,596 (O'Hanlon & Kamp, 2006, p. 16, 17). For simplicity, 1,600 insurgents were added to the model each month for the first thirteen months. This was followed by a steep increase in insurgents for three months. The average month increase was 6,405 (O'Hanlon & Kamp, 2006, p. 16, 17). Therefore, the rate of new insurgents was 6,400 for this three month period. Since this steep increase, the average number of new insurgents per month has been 2,196 (O'Hanlon & Kamp, 2006, p. 16, 17). The scenario thus assumed a rate of 2,200 insurgents per month. Equation

VII-1 summarizes these rates of insurgent increase, where *i* is the number of months transpired in the scenario.

$$\begin{aligned} Rate\ of\ increase\ of\ insurgents(i) = &\ 1{,}600 \quad for\ 0 \le i < 14 \\ &\ 6{,}400 \quad for\ 14 \le i < 16 \\ &\ 2{,}200 \quad for\ i \ge 16 \end{aligned} \qquad \text{(VII-1)}$$

This is a very simplified model to add new insurgents to the model. If a more detailed insurgent model is required, see Allan and Stahel (1983), Coyle (1985), Hetherington (2005), and Anderson (2006). Models to capture these works can be added to the basic model as required. A continuous flow into and out of theater can be modeled.

It was initially assumed that the Lanchester Square Law could be used to represent the attrition of the conflict. Equation VII-2 represents the appropriate coefficients and equations resulting from applying the method of least squares to fit the data from the *Iraq Index*, created by the Brookings Institute. The *t*-test statistic was used to as the test criteria for evaluating the fit of the data. When comparing the difference between the original data and the results from the Lanchester Laws, the data suggests symmetry about zero. Figure VII-3 provides a histogram of the errors for the Blue attrition and Figure VII-4 provides the results for the Red attrition. Therefore, the assumptions discussed in Chapter 2 regarding the *t*-test appear to be satisfied and the *t*-test may be used to test the significance of the attrition coefficients. Bracken (1995) and Chen and Chu (2001), among others, have also used the same technique for determining the attrition coefficients for the Lanchester Laws. As sever skewness does not appear, the *t*-test was used. Of course, other tests are possible and should be used when appropriate.

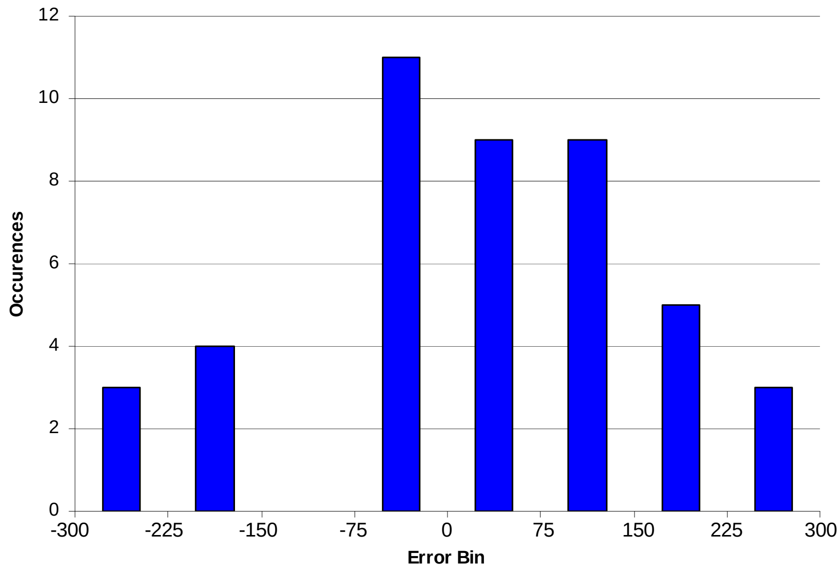


Figure VII-3: Histogram of Blue Attrition Error

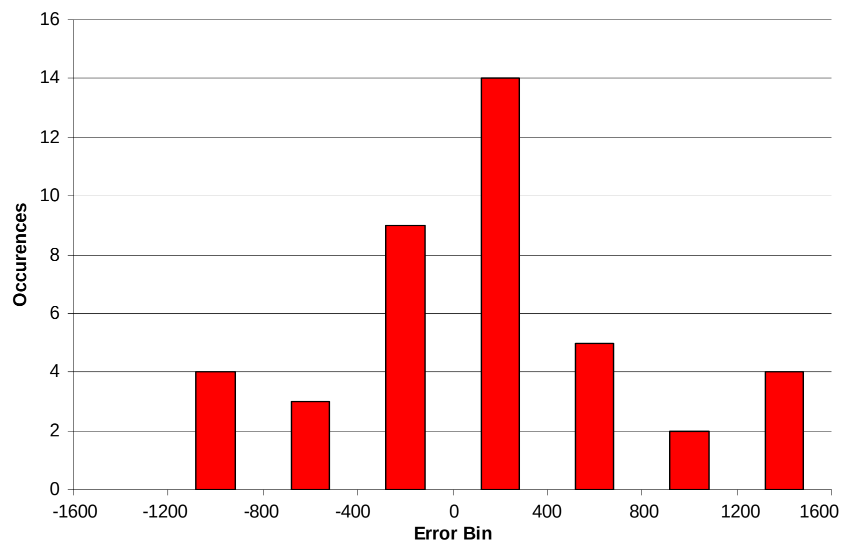


Figure VII-4: Histogram of Red Attrition Error

Unfortunately, the *t*-test for the model indicates that one of the coefficients is not statistically significant at the $\alpha = 0.05$ level for a two sided null hypothesis test for $\beta = 0$. Therefore, the model of attrition based on the Lanchester Square Law was rejected.

$$\begin{aligned} \frac{dB}{dt} &= 0.03425R \qquad t = \mathbf{1.24} < t_{\alpha=0.05,44} = 2.32 \\ \frac{dR}{dt} &= 0.01379B \qquad t = 17.96 > t_{\alpha=0.05,44} = 2.32 \end{aligned} \tag{VII-2}$$

Since the Lanchester Square Law was not appropriate to model the attrition, Helmbold's general form of the Lanchester Laws was applied (Equation II-15). Helmbold's general form allows for a mixing of the square, linear, and logarithm laws; therefore, modeling direct fire, area fire, and attacks on non-combatants. Data from the *Iraq Index* was used to empirically determine the values of the Red and Blue Coefficients and the Weiss Parameter (see Appendix B). The data was initially regressed requiring the same Weiss parameter (w) for both the Red and Blue attrition. This model was not rejected at the $\alpha = 0.05$ level and it is presented in Equation VII-3. Based on Schaffer's research, the Weiss parameter at w = 0.664 can be interpreted as indicating the Red and Blue forces are both using a mix of area and direct fire (Schaffer, 1967, p. 24).

$$\begin{aligned} \frac{dB}{dt} &= 0.01763\left(\frac{B}{R}\right)^{1-0.664} R \qquad t = 15.27 > t_{\alpha=0.05,44} = 2.32 \\ \frac{dR}{dt} &= 0.02970\left(\frac{R}{B}\right)^{1-0.664} B \qquad t = 20.51 > t_{\alpha=0.05,44} = 2.32 \end{aligned} \qquad \text{(VII-3)}$$

While the model is not inappropriate, it assumes the proportion of area and direct fire used by the Red and Blue forces was the same. To better match the tactics employed, the research next focused on finding an individual Weiss parameter for each side of the conflict. Equation VII-4 includes the coefficients derived from the method of least squares regression of the Red and Blue forces with different Weiss parameters.

$$\begin{aligned} \frac{dB}{dt} &= 0.01111\left(\frac{B}{R}\right)^{1-0.44} R \qquad t = 14.97 > t_{\alpha=0.05,44} = 2.32 \\ \frac{dR}{dt} &= 0.02869\left(\frac{R}{B}\right)^{1-0.69} B \qquad t = 20.51 > t_{\alpha=0.05,44} = 2.32 \end{aligned} \qquad \text{(VII-4)}$$

A Red Weiss Parameter of *w* = 0.44 can be interpreted to imply that the Red forces are concentrating on area fire. However, Red's techniques occasionally involve killing noncombatants. This can be seen in the tactics of the Improvised Explosive Device (IED). The Blue Weiss Parameter of *w* = 0.69 implies that the Blue tactics are a mix of both area and direct fire. Schaffer suggested that in an ambush, the ambushee's initial response is area fire but the combatant transitions to direct fire as the ambusher is acquired (Schaffer, 1967, p. 24). Shaffer's theory is empirically supported by this research, and Equation VII-4 was implemented in the model of elements of fourth generation operations.

The model of soldier morale based on Equation VI-1 and Figure VI-3 was implemented as a submodel of the model of elements of fourth generation operations. This implementation for each unit can be seen in Figure VII-5.

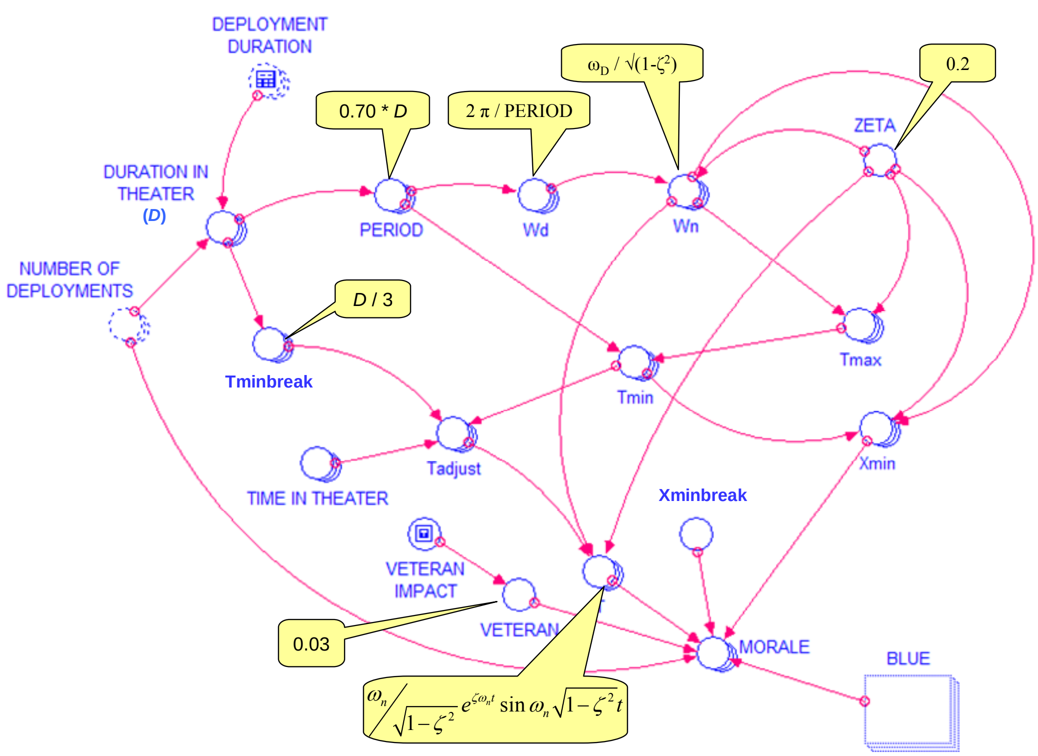


Figure VII-5: Submodel of Soldier Morale

The Deployment Duration and Number of Deployments are calculated previously in the model, hence they are represented in the figure as dotted lines as opposed to solid outlines (see Figure VII-2). These parameters are used to calculate the actual number of months each unit is in theater (*D*). This deployment duration is used to calculate the Period (*T*), Damped Natural Frequency (ω_d), Natural Frequency (ω_n), and Time of Minimum Morale ($T_{minbreak}$). T_{min}, T_{max}, T_{adjust}, X_{min}, and $X_{minbreak}$ are all used to adjust the phase of the unit's morale curve so the first period of low morale occurs at one third of the deployment duration.

Quester *et al.*'s data about retention rates implies that morale deceases at least 6% each time an individual returns to theater. In the illustrative scenario it was assumed that 50% of the troops previously deployed with unit; therefore, the overall morale of the unit decreased 3% each time the unit returned to theater. Thus, the Veteran Impact was set at 0.03. This decrease was applied for each subsequent return to combat. The value could also be a weighted average of experienced troops in a unit if such information were available.

The final submodel estimates the United States Public Opinion for an ongoing conflict. The implementation of the factors from Table V-11 can be seen in Figure VII-6. The number of days in the conflict (*days*), Blue Casualties, and Red Casualties are all levels from the model. The number of Daily Attacks was not directly available but was estimated from other available data. A multiple linear regression was performed using the known factors/levels the model produced against the number of daily attacks reported by the *Iraq Index.* Table VII-1 summaries the result of that regression.

The model of daily attacks suggests that the number of daily attacks can be estimated by the square of the cumulative Blue Casualties (B_{CAS}) and size of Red forces (R).

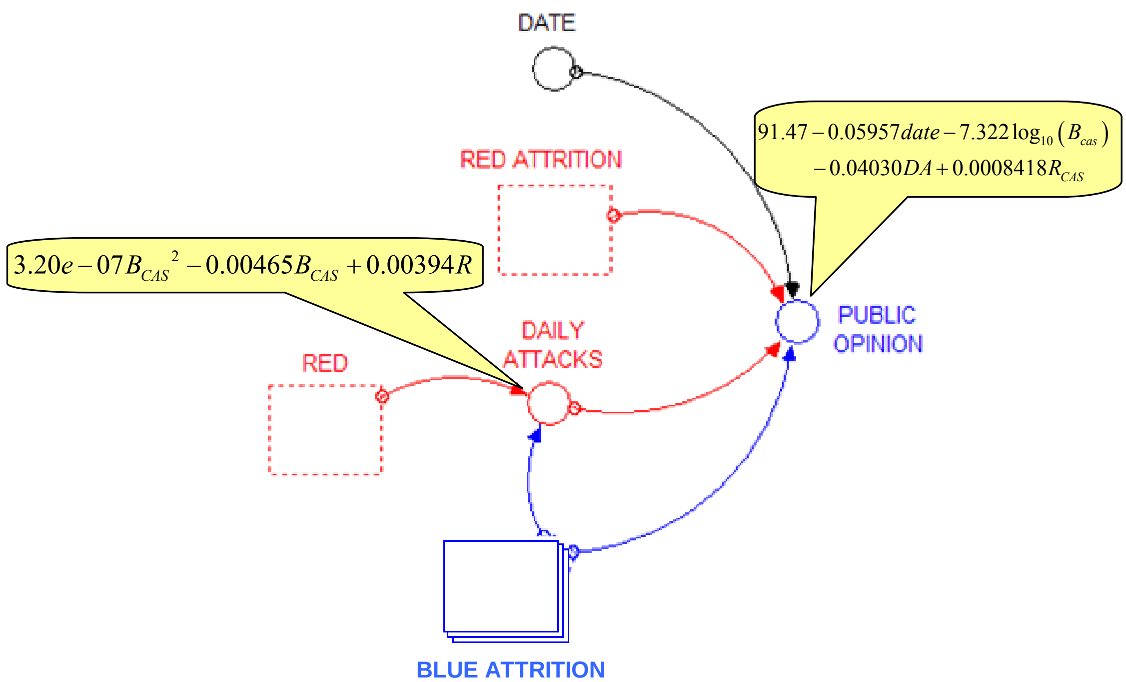


Figure VII-6: Submodel of Public Resolve

Table VII-1: Model of Daily Attacks

Regression Statistics					
R^2	0.96				
Adjusted R^2	0.94				
Standard Error	16.60				
PRESS	12846.36				
$R^2_{Prediction}$	0.96				
Observations	44				
	df	***SS***	***MS***	***F***	***Significance F***
Regression	3	305766.88	101922.29	370.06	3.38E-29
Residual	41	11292.12	275.42		
Total	44	317059.00			
	Coefficients	***Standard Error***	***t Stat***	***P-value***	
B_{CAS}	-0.00465	0.0017	-2.67	0.0109	
B_{CAS}^2	3.20E-07	5.6E-08	5.71	1.1E-06	
R	0.00394	0.00071	5.52	2.09E-06	

Figure VII-7 illustrates the original data for the number of daily attacks and compares this to the estimates produced by the model of daily attacks given the data from the *Iraq Index* (O'Hanlon & Kamp, 2006, p. 22). The data produced by the simulation are also presented in the figure. The simulation data is discussed in the section on verification and validation.

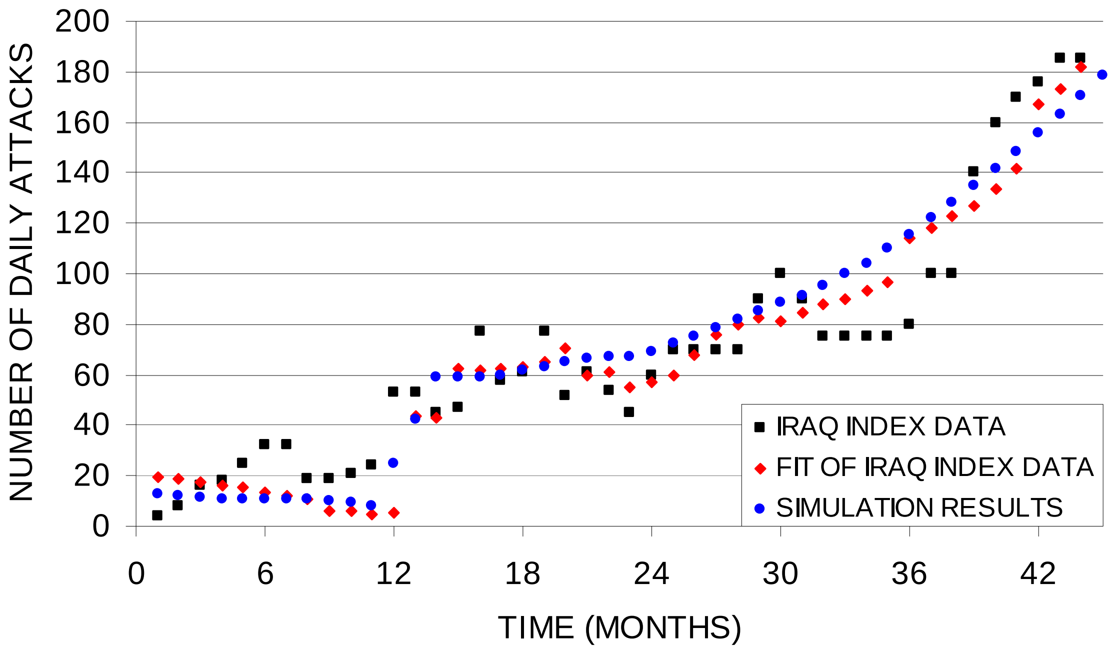


Figure VII-7: Number of Daily Attacks

While both the multiple linear regression model (Table V-11) and the logistic regression model (Table V-20) can be used to estimate the public resolve for the conflict, the MLR model was used when constructing the model of elements of fourth generation operations demonstration. As discussed in Chapter 5 a benefit of logistic regression is the expectation function is constrained between zero and one. The logistic regression model can be implemented by changing the equation for Public Opinion indicated in Figure VII-6.

This section introduced an analytic framework of elements of fourth generation operations via a notional scenario. This model is empirically supported by data from the current conflict in Iraq. This framework is not limited to the Iraq conflict as presented in this study, but may be extended to other conflicts. The next section provides the verification and validation of the analytic framework.

Verification and Validation

The Department of Defense provides the following definitions for verification, validation and accreditation with respect to the modeling and simulation process.

> Verification. *The process of determining that a model implementation and its associated data accurately represents the developer's conceptual description and specifications* (DODI 5000.61, 2003, p. 15)
>
> Validation. *The process of determining the degree to which a model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model* (DODI 5000.61, 2003, p. 15)
>
> Accreditation. *The official certification that a model, simulation, or federation of models and simulations and its associated data are acceptable for use for a specific purpose* (DODI 5000.61, 2003, p. 10)

These definitions can be summarized as: verification ensures the model is built correctly, validation ensures the model performs correctly, and accreditation accepts the model for the proper use. This study is only able to perform tests which support verifying and validating the model. Accrediting the model requires a user to perform additional tests with a specific purpose and accept the model as able to perform the specific purpose.

Forrester and Senge discussed the requirements to verify and validate system dynamics models. They stated:

> *There is no single test which serves to 'validate' a system dynamics model. Rather, confidence in a system dynamics model accumulates gradually as the model passes more tests and as new point of correspondence between the model and empirical reality are identified* (Forrester & Senge, 1980, p. 209).

Sterman summarizes the frustration of validating system dynamics models:

1. *There can be no absolute test of validity,*

2. *There can be no objective tests of validity,*
3. *There can be no single test of validity.* (Sterman, 1984, p. 51)

Forrester and Senge suggest a three phase process to build validation. The phases validate the model structure, model behavior, and policy implications. Each phase is discussed in greater detail in the following sections with the results from the verification and validation of the model of elements of fourth generation operations. Figure VII-8 provides an overview of the tests suggested by Forrester and Senge. The core tests (which are shaded in Figure VII-8) are considered by Forrester and Senge as being the most important (1980, p. 226).

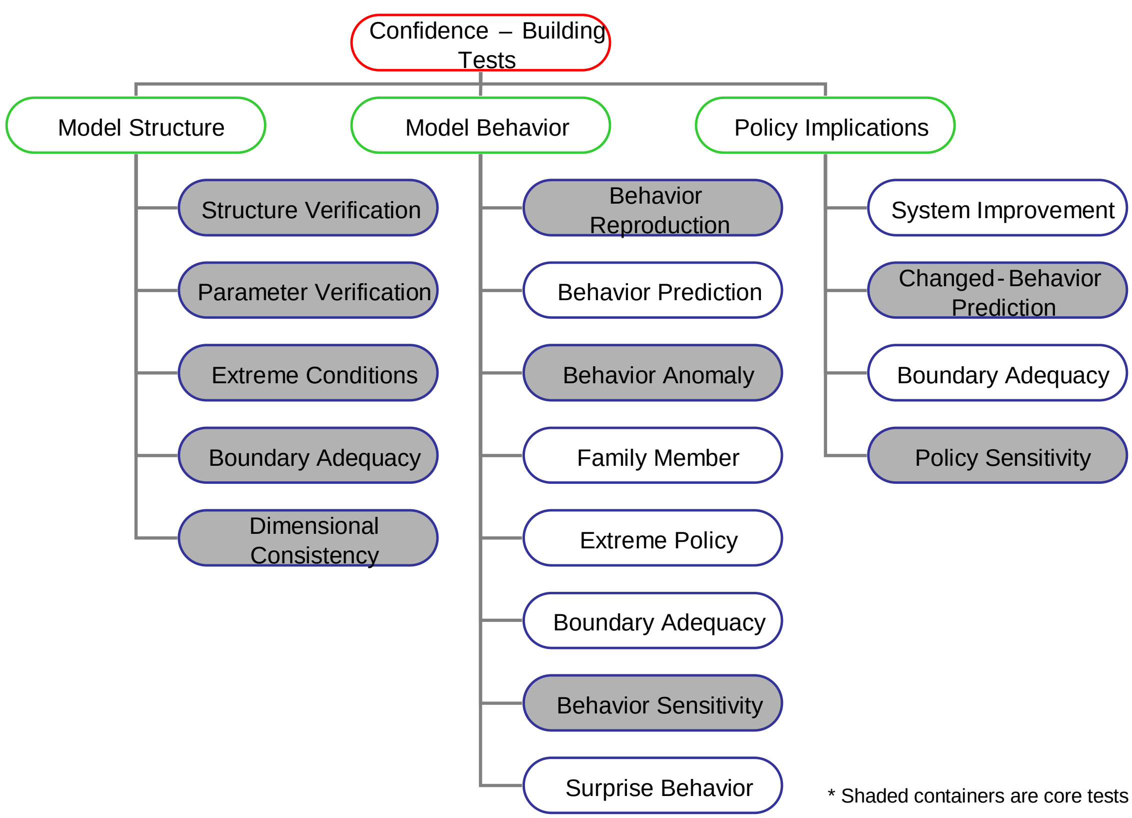


Figure VII-8: Confidence-Building Tests (Forrester & Senge, 1980, Table 1 Page 227)

Building on Forrester and Senge, Khazanchi (1996), Coyle and Exelby (2000) and Martis (2006) provide applications, clarifications and insights for some of the tests.

Model Structure

Validation of the model structure was divided into multiple tests. Each test is focused on how the model is built. These tests closely align with the DoD definition of verification. The first test is the *structure verification*.

> *Verifying structure means comparing structure of a model with structure of the real system that the model represents. To pass the structure-verification test the, the model structure must not contradict knowledge about the structure of the real system* (Forrester & Senge, 1980, p. 212)

The structure verification also questions if all the relevant structures have been modeled. The justification of the basic structure of the model, as seen in Figure VII-1, is based on the research of the Lanchester Laws, discussed in Chapter 2. This structure is expanded to the combat model presented in Figure VII-2, Figure VII-5 and Figure VII-6 providing the necessary factors for the model of conflict. Both the Red and Blue forces and their movement (at a strategic level) are modeled. The attrition of those forces is available along with the notional soldier morale. Additionally, the Blue's Public Opinion of the conflict is represented. The model exhibits the proper structure for modeling elements of fourth generation operations.

The next test is the *parameter verification*. This test addresses whether the parameters are consistent with numerical values and are recognizable to the real world. The basic parameters within the model are the individual soldier and time, accounted for in terms of months. The public opinion and soldier morale parameters are scaled from zero to one, representing the respective percent of public support and level of morale. All parameters are based on numerical values fitted to the real world values, except the morale parameter. This parameter assumes the notional morale of a soldier is bounded and averages 0.5. Consequently, all parameters have a recognizable meaning in the real world.

The third test is the *extreme condition* test. The test focuses on running the model at the parameter's boundaries and comparing the data to the real system's behavior in the same conditions. Forrester and Senge state:

> *The extreme-conditions test is effective for two reasons. First, it is a powerful test for discovering flaws in model structure. Many proposed formulations look plausible until considered under extreme conditions.*
>
> *The second reason for utilizing the extreme-conditions test is to enhance usefulness of a model for analyzing policies that may force a system to operate outside historical regions of behavior.* (1980, p. 214)

Unfortunately, as is the difficulty in verifying any combat model, it is not possible to replicate the conditions of combat solely for the purpose of model verification and validation. Therefore, this test can not be accurately performed for the example. The model can only be compared to how the real world is expected to perform. The equations that underlay the system dynamics model produce reasonable results for conditions ranging in number of units deployed, size of units deployed, number of insurgents, and number of casualties for each side. In the demonstration section of this chapter, five factors are varied to notional extreme conditions and produced reasonable responses. The demonstration did not reveal any flaws in the model structure.

The next test of structure validation is *boundary adequacy* of the structure. This focuses on the level of aggregation of the model (Forrester & Senge, 1980, p. 215). The test evaluates if the necessary parameters for the decision are all internal to the model. The submodels and parameter settings are statistically significant at the $\alpha = 0.05$ level. The insights into the number of forces, casualties, public opinion, and soldier morale are the focus of the model. The model is able to estimate each of these parameters with its current structure with only one external input: the deployment schedule of the Blue forces. This allows for the Blue deployment schedule to be varied, providing insights to policy changes. As a result, all other decisions are endogenous to the model.

The final test of the structure is *dimensional consistency*. This investigates if all the equations are using the proper units within the model. As briefly discussed earlier, the units within the model account for the number of individual soldiers and time is tracked by months. These dimensions are consistent with the specific purpose of the notional scenario. All equations in the model use these two parameters except for the model of public opinion. The input for this submodel is the number of days into the conflict; therefore, the time scale is converted to days when used in the equation.

The model conforms to all the model structure tests. Accordingly, the confidence that the structure can represent the selected elements of fourth generation operations is strong. The next set of tests suggested by Forrester and Senge focus on the models behavior and results.

Model Behavior

Once the tests of model structure have been performed, the tests of model behavior are conducted. These tests focus on the results, responses or behaviors of the model. The first test is *behavior reproduction*. The focus of this test is a qualitative comparison of the model results with historical data. Sterman suggests that when the model data can be statistically compared to the real system, a test of *statistical character* is used (1984, p. 52). The behaviors of the real world data and the simulation results are presented for the number of soldiers, casualties, daily attacks and public opinion. The figures test the behavior reproduction when viewing the historical fit. Additionally, a paired *t*-test was performed at monthly increments to validate the statistical character. The null hypothesis was that there was no difference (δ) between the simulation results and the real world data, and the alternative hypothesis was that they were different (H_0: $\delta = 0$; H_a: $\delta \neq 0$).

Figure VII-9 illustrates the results from the model and historical data. Similar trends and cycles of the historical and model data can be seen in the plot of the data. Additionally, the paired *t*-test indicates there was no statistical difference. The paired *t*-test statistic equaled $t=|0.65|$, which was less than the critical value from the *t*-distribution, $t_{\alpha=0.05,31}=2.36$. Consequently, the null hypothesis cannot be rejected; we cannot assume there is a difference between the real and simulated results.

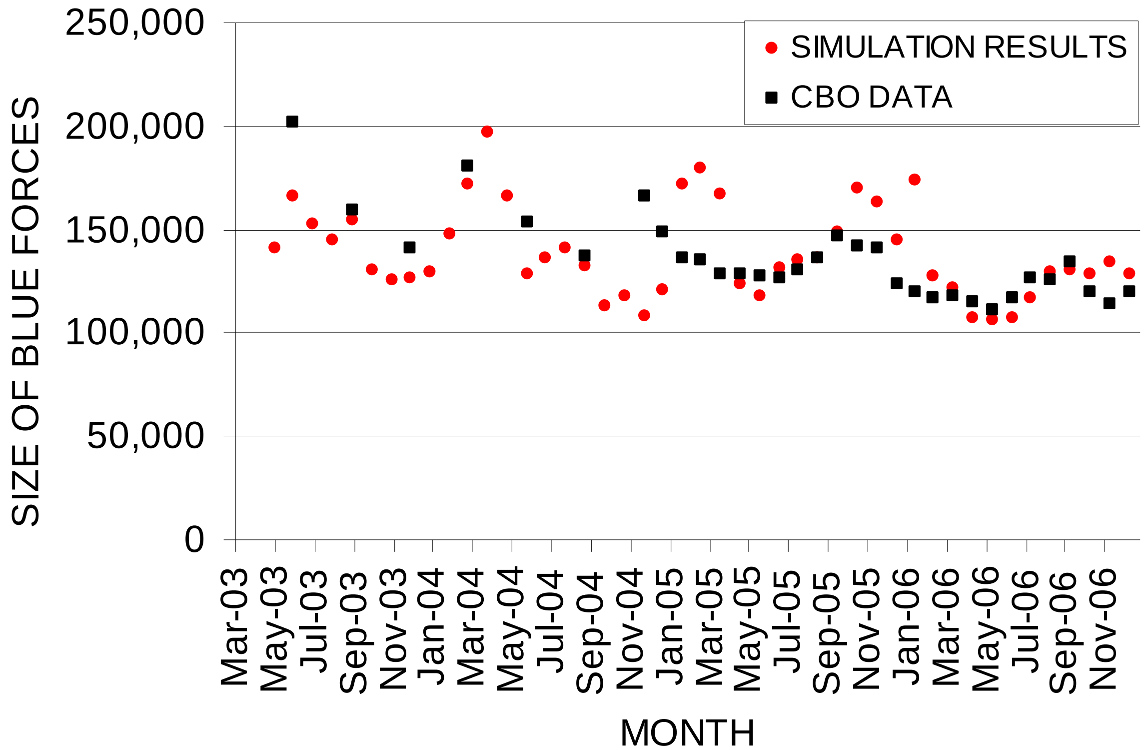


Figure VII-9: Simulation Results of Size of Blue Forces

The size of the Red forces is based on the number of insurgents captured or killed (Equation VII-4) and the number of new insurgents (Equation VII-1). Figure VII-10 compares the actual number of insurgents from the *Iraq Index* and the simulation results. As with the Blue forces, the historical and model data reflect similar trends. The paired t-test results are $t=|1.39| < t_{\alpha=0.05,45}=2.32$. We fail to reject the null hypothesis that the average of the differences is zero. As a result it can not be shown that there is a statistical difference between the model and the true data.

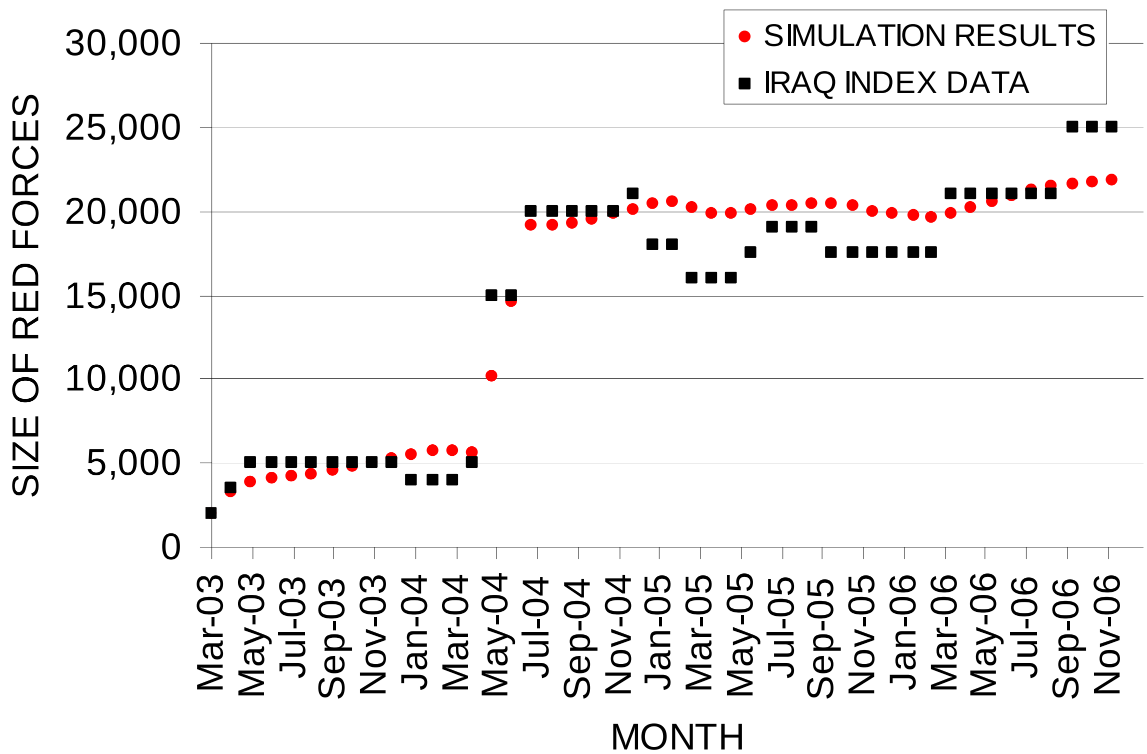


Figure VII-10: Simulation Results of Size of Red Forces

Next, Figure VII-11 demonstrates the monthly number of Blue Casualties. Although the real data had a higher variance, the simulation did reflect the trends of the data. Statistically, $t=|-0.142| < t_{\alpha=0.05,45}=2.32$, consequently the null hypothesis cannot be rejected and again, there was no statistical difference suggested. The cumulative impact was that at the end of December 2006 the model estimates 25,388 Blue Casualties while the *Iraq Index* reports approximately 25,631 US troops wounded or dead (O'Hanlon & Campbell, 2007, p. 11, 13). This was a difference of less than 300, with a cumulative error of less than 1%.

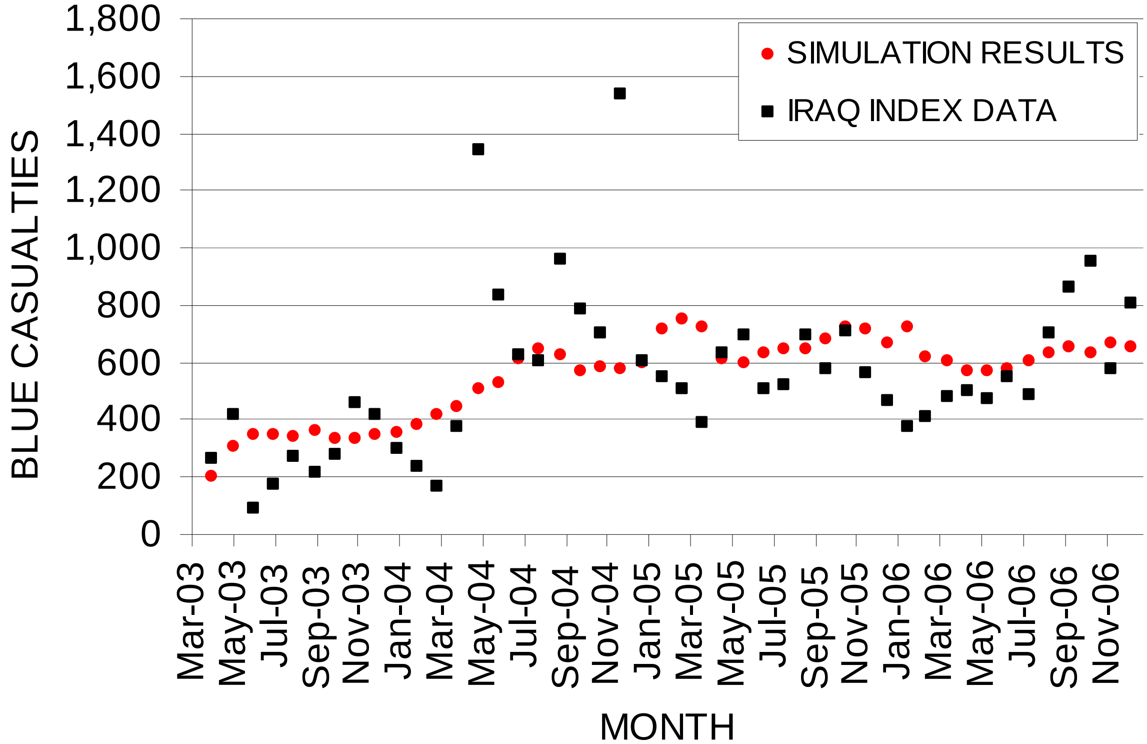


Figure VII-11: Simulation Results of Blue Casualties

Figure VII-12 contrasts the simulation estimates of Red Casualties and the *Iraq Index* data at each month. Once again, the paired *t*-test suggested no statistical difference (t=|-0.523| < $t_{\alpha=0.05,44}$=2.32). The cumulative impact was that by the end of November 2006 the model estimated 82,949 Red casualties while the *Iraq Index* reported approximately 82,470 insurgents captured or killed (O'Hanlon & Kamp, 2006, p. 16). This was a difference of less than 500 insurgents and a cumulative error of less than 0.6%.

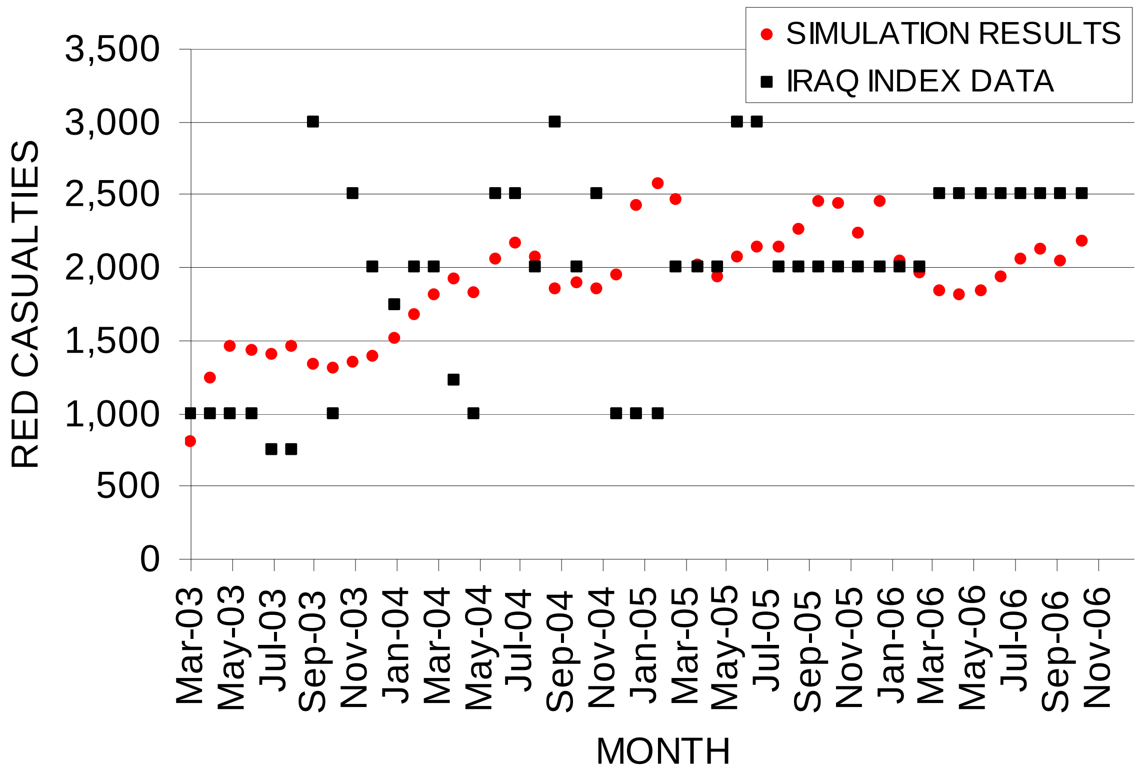


Figure VII-12: Simulation Results of Red Casualties

The simulation results of the number of daily attacks using Table VII-1 was included previously in Figure VII-7. The paired *t*-test indicated no statistical difference between the *Iraq Index* data and the simulation results (t=|-0.25| < $t_{\alpha=0.05,44}$=2.32).

The final historical comparison was the Multiple Linear Regression (MLR) estimate of Public Opinion. The model results are plotted in Figure VII-13. The historical estimate and model results display no statistical difference based on the paired *t*-test, t=|0.50| < $t_{\alpha=0.05,45}$=2.32. As a result, we are unable to reject the null hypothesis of $\delta = 0$ for any of the major comparisons with historical data and simulation data. Therefore, it is assumed the model satisfied the behavior reproduction and statistical character tests for the elements tested.

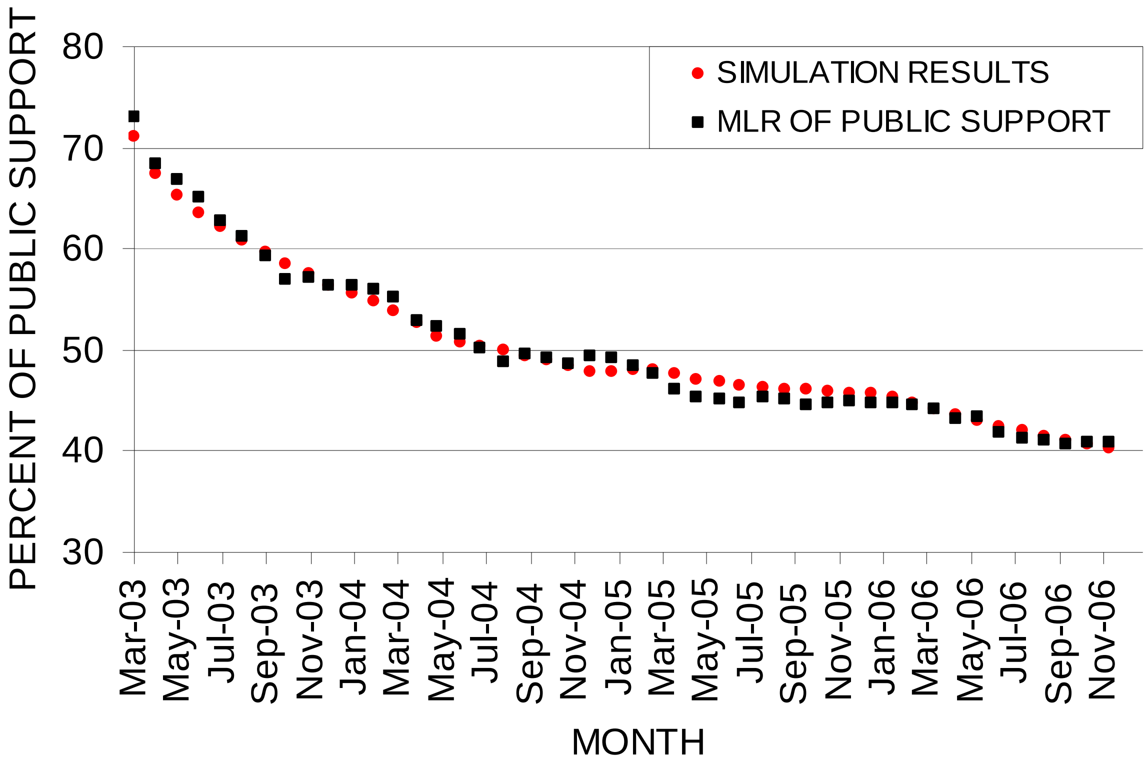


Figure VII-13: Simulation Results of Public Support

As the behavior reproduction test focuses on reproducing historical data, *behavior prediction* tests focuses on future behavior. System dynamics "models do not strive for prediction of future values of system variables…However, system dynamic models should tell certain things about the behavior in the future" (Forrester & Senge, 1980, p. 219).

Using the data from July 2007, the model behavior was evaluated based on how it could project the future behavior. The percent of public support for the war in July 2007 was 38.0% (see Chapter 5). The model shows the public support would be 36.6%. The difference falls with the standard error of the polling data. Additionally, the model estimates there would be 29,797 Blue casualties. The *Iraq Index* reported there were 30,612 Blue casualties (O'Hanlon & Campbell, 2007, p. 17, 19). As seen in Figure

VII-11 there were a few months that the Blue forces suffered an intense number of casualties. The actual number of Blue casualties that occurred in June and July 2007 similarly spiked causing the model to underestimate the actual values. While these estimates are not exact, the behaviors do match expectations.

The next test is *behavior anomaly*, which investigates if the model responds to assumptions and parameters being removed from the system. This test also provides insight to the assumptions since "one can often defend particular model assumptions by showing how implausible behavior arises if the assumption is altered" (Forrester & Senge, 1980, p. 220). Since the model was empirically built, all factors are statistically significant. If any factor was removed, the model may no longer produce defendable or understandable results. The demonstration section provides an example of how parameters of five factors are changed. This analysis provides further justification of the inclusion of the factors, since each factor screened shows impact on the responses.

The *family member* test was then considered. This test was focused on whether the model can be applied to other examples of systems within the same class. This insures the model has broad applications as opposed to being specifically designed for only one purpose. Sterman asked, "can an urban model generate the behavior of New York, Dallas, Carson City, and Calcutta when parameterized for each?" (1984, p. 52). The basic structure of the Lanchester laws has been applied to a number of battles and conflicts. Taylor (1983) provided specific applications of the Lanchester Laws. The submodel of public opinion evolved from data from the wars in Korea, Vietnam, Afghanistan, and Iraq. Additionally, the submodel of soldier morale was based on research from World War Two and Peace Corps deployments. Even though the framework, in its entirety, has not been applied to a different 'family member,' each individual model has been applied to its setting.

Forrester and Senge also suggest the *extreme policy* test. They ask "does the model behave as we might expect for the real system under the same extreme policies circumstances?" (1980, p. 221-222). All of the equations of the model produce logical outputs as the parameters are moved to the extremes. The only exceptions may be in the submodel of public opinion. This model is capable of producing negative public opinion. Negative public opinion can happen due to two circumstances: when there are too many Blue casualties; and when the conflict lasted a long time. This does not invalidate the model. This outcome implies caution should be used when applying the relations outside the range of the data used to develop them. This model, however, is still able to produce findings which can be used for comparison of policies or courses of action. In addition, a nation could possibly turn against a war.

As with the tests of model structure, the model behavior has a test of *boundary adequacy*. Again, this test investigates if all the structure is valid at the boundary of the relations. The rationale for the model structure test on boundary adequacy is still valid since the parameters within the model are all empirically justified through statistical tests, all at an $\alpha = 0.05$ level.

The final behavior validation tests explore the *behavior sensitivity* of the model to plausible variations and *surprise behaviors*. Behavior sensitivity asks, does the model still pass the previous behavior tests when the parameters are varied? Surprise behaviors are behaviors which are unexpected but offer insight to how the system operates. By changing the size of each brigade and battalion in the model, the size of Blue forces can be changed. By changing the force size by plus or minus 20% and 10%, Figure VII-14 and Figure VII-15 were created. Figure VII-14 shows the size of Red forces decreasing as the size of Blue forces increases. As expected, as the Blue Forces are reduced, the size of Red Forces increased. Similarly, when Blue forces increased the number of Red forces decreased. As these results are consistent with expectation, the behavior sensitivity test is considered satisfied.

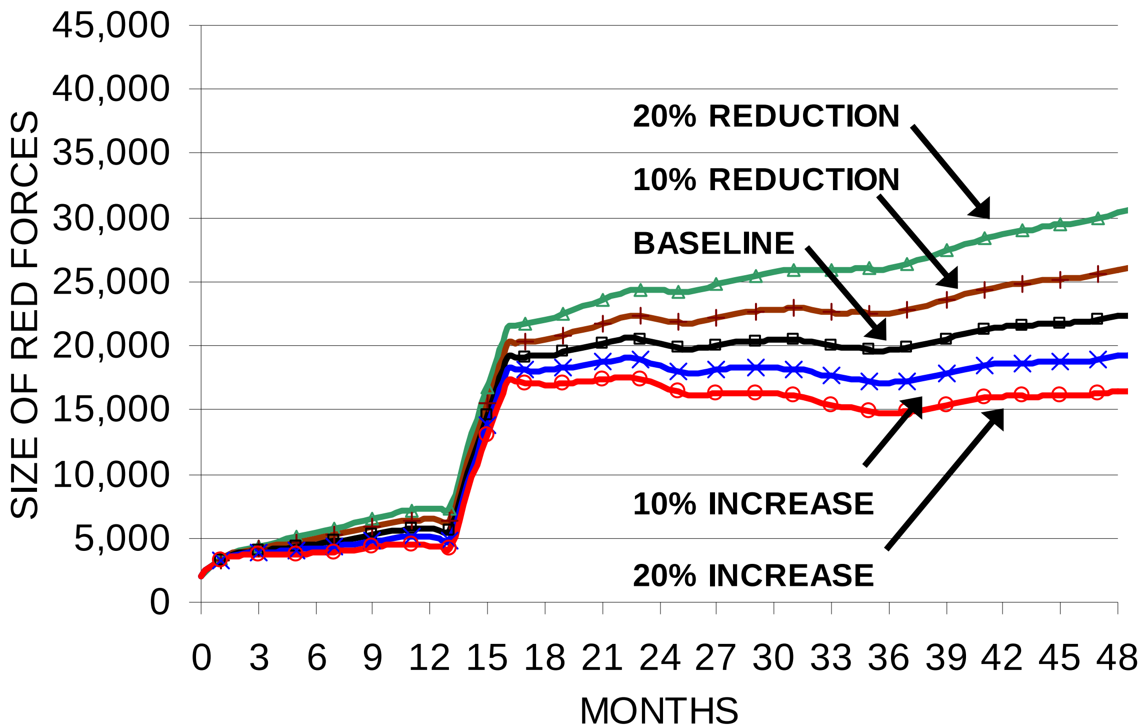


Figure VII-14: Behavior of Red Forces as Total Blue Forces Varies

Figure VII-15 shows that by increasing the number of Blue forces, there are initially more Blue Casualties. While this might be seen as a surprise behavior, more troops in theater provide more targets. As more troops enter, there are initially more casualties; however, after 36 months, the number of Blue casualties for the larger force is less than the other courses of action. This switch in casualty rates does not occur earlier in the model due to the rapid increase of Red forces at the 13th month. The demonstration section of this chapter sets five factors at different settings simultaneously in a full factorial design of experiments. The response of that analysis additionally justifies the behavior sensitivity and surprise behavior tests. In conclusion, the model passes both of these tests.

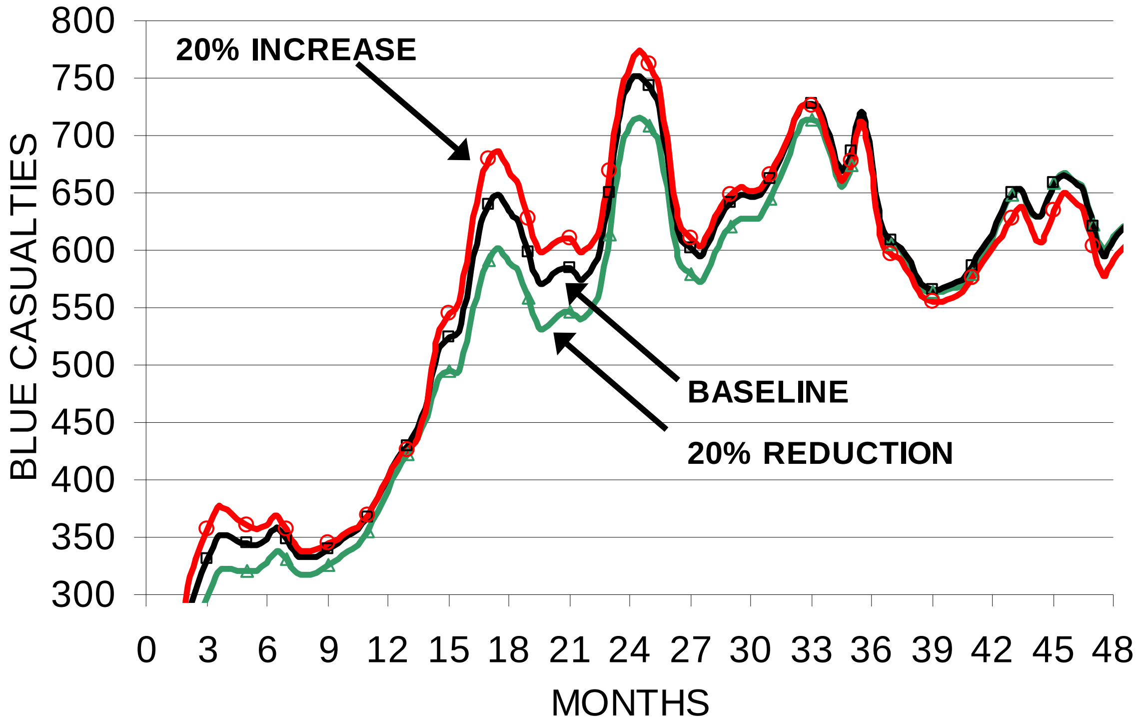


Figure VII-15: Behavior of Blue Casualties as Total Blue Forces Varies

The final phase to validate a system dynamics model suggested by Forrester and Senge is validating the policy implications. The "tests of policy implication differ from the other tests in their explicit focus on comparing policy changes in a model and in the corresponding reality" (Forrester & Senge, 1980, p. 224). Since these tests all require the implementation of the policy evaluated in the system dynamics model and then compared to the policy implemented in reality, such tests are beyond the scope of this research. Such an analysis is left for future research.

Many of the validation tests of model structure and behavior were able to be applied to the model of elements of fourth generation operations. As the model is applied in more situations and the results observed, the confidence in the model is expected to increase. Forrester and Senge suggest all five tests of the model structure, and specifically three model behavior tests (reproduction, anomaly, and sensitivity), are core tests. The model presented in this dissertation was able to satisfy all eight of these core tests.

Demonstrations

This section provides demonstrations of the potential applications of the model of elements of fourth generation operations. First, five of the factors within the model were varied to provide a possible decision maker insight into the importance of each factor and their interactions. These five factors were: (1) size of Blue forces deployed, (2) rate of new Red Forces, (3) Red fighting effectiveness, (4) percent impact of morale on Blue fighting effectiveness, and (5) implementation of veteran status. The responses considered for review were the estimated public support for the war, number of Red forces and the Blue/Red combat ratio which provides insight where the higher the ratio, the higher the likelihood of success for Blue forces.

The second demonstration focuses on the functionality of the modeling framework. The rules of engagement within the model are adjusted based on the public's support for the conflict. The interactions within the model and feedback loops are identified.

This section is divided into three subsections. The first defines the setting used in the demonstration. The second subsection is the results of the screening experiment. The third subsection provides the second demonstration.

Settings of First Demonstration

A five factor full factorial design of experiments was chosen for the first demonstration. The demonstration is therefore a screening experiment capable of providing insights about the factors, the related responses and also the factor interactions. Since this is a deterministic model, only one replication was performed at each setting for a total of 32 experiments.

The first factor changed the size of Blue deployed battalions and brigades. The size of each brigade/ battalion was changed by 25%, depending on the high or low setting. As discussed earlier, this changes the total number of Blue force in theater. Initially, the unit strength of the battalions/ brigades was 2,600/ 6,300 respectively.

The second factor alters the rate that Red forces increase their recruitment. Equation VII-1 suggests that after sixteen months, 2,200 new Red forces are added each month. The factor changes this rate by 10%. Thus, it assumed the rate of new Red forces may be as low as 1,980 or as high as 2,420. This provided the decision maker insight on how efforts to stop the recruiting of new Red forces impact the battle. Again, if some other vetted relationship were available, it could be represented.

The third factor directly adjusted the fighting effectiveness. The Red Coefficient was set 20% lower at the low setting and 20% higher at the high setting from the base setting. This replicates actions taken by the Blue forces which directly impact Red's capability to wage war. This may occur by interdicting the Red's weapons, for example. This may also happen if Blue reduces their vulnerability to Red's weapons or tactics by improving armor or techniques.

The fourth factor adjusted the level of impact of Morale on the Blue Coefficient (*BC*). Similar to how Bracken implemented the Bracken Tactical Parameter, the Blue Coefficient was adjusted where Morale was substituted for Bracken's Tactical Parameter (see Equation II-16). The morale impact factor (M) varied from 0 to 1 to adjust the significance of Morale to the changes of the Blue Coefficient. When $M = 0$ there was no impact and the original Blue Coefficient was used. However, when $M = 1$, twice the Morale was used as a multiplier of the Blue Coefficient. Since pre-deployment morale was 0.5, twice the morale was used, so when morale was greater than average, the troops were more efficient (morale factor greater than one). Similarly, there was a decrease in capabilities when the morale was less than one. The equation $(2Morale{*}M + 1 - M)\ BC$ was used to account for transient values of M. If some other known or fitted relationship existed, it could be used in the model. Since this factor was not implemented in the previous section on verification and validation, the 'baseline' case assumes the level to be at the lower or no impact value.

Based on historical evidence, each time a unit is returned to theater, their overall morale is decreased by 3% (see Figure VII-5) (Quester *et al.*, 2006, p. 9). This final factor was adjusted if this impact to overall morale was implemented or not.

Table VII-2 provides a summary of the settings used in the screening experiment. The levels used in the screening experiment were set at -1 for the low setting and 1 for the high setting; therefore, normalizing the factors for analysis.

Table VII-2: Screening Experiment High and Low Factors

	Setting	*Baseline* (0)	*Low* (-1)	*High* (1)
Size of Blue Forces (B) Battalion / Brigade	±25%	2,600/6,300	1,950/4,725	3,250/7,875
Rate of Red Increase (RRI)	±10%	2,200	1,980	2,420
Change of Red Coefficient (C)	±20%	0.0111	0.00889	0.0133
Morale Impact (M)	0 to 1	0	0	1
Veteran Impact (V)	On/Off	0	0	0.03

Screening Experiment Results

Thirty two experiments were run completing the full factorial design of experiments for five factors. Three responses were observed: Blue/Red combat ratio, public support for the war, and the number of Red forces.

Figure VII-16 provides the main effect plots and Figure VII-17 provides the interaction plots for the Blue/Red combat ratio. The numbers on the x-axis indicate the settings for the factors indicated in each column for both figures. For the interaction plots, the numbers on the plots provide the settings for the factor of each row. When the slope of the line is horizontal, the factor indicated by the row has limited influence on the results. The influence of the factor identified in the column is observed by the separation of the two lines. The difference in slope of the two lines within a plot implies an influence of the interaction of the two factors.

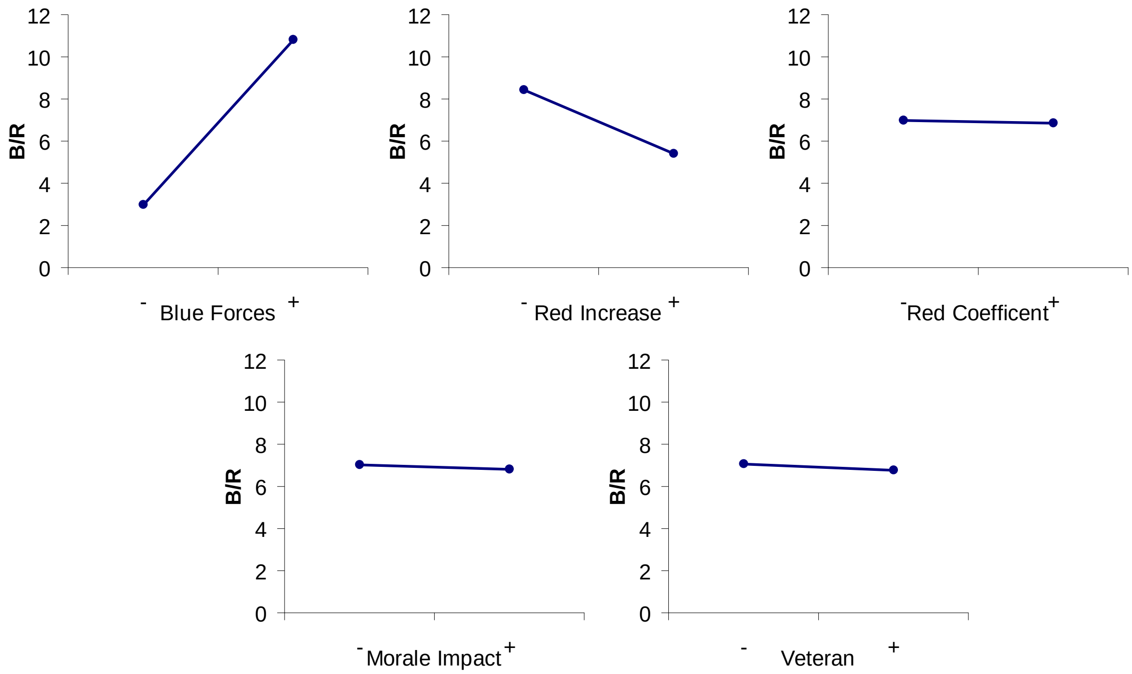


Figure VII-16: Main Effect Plots for Blue/Red Combat Ratio

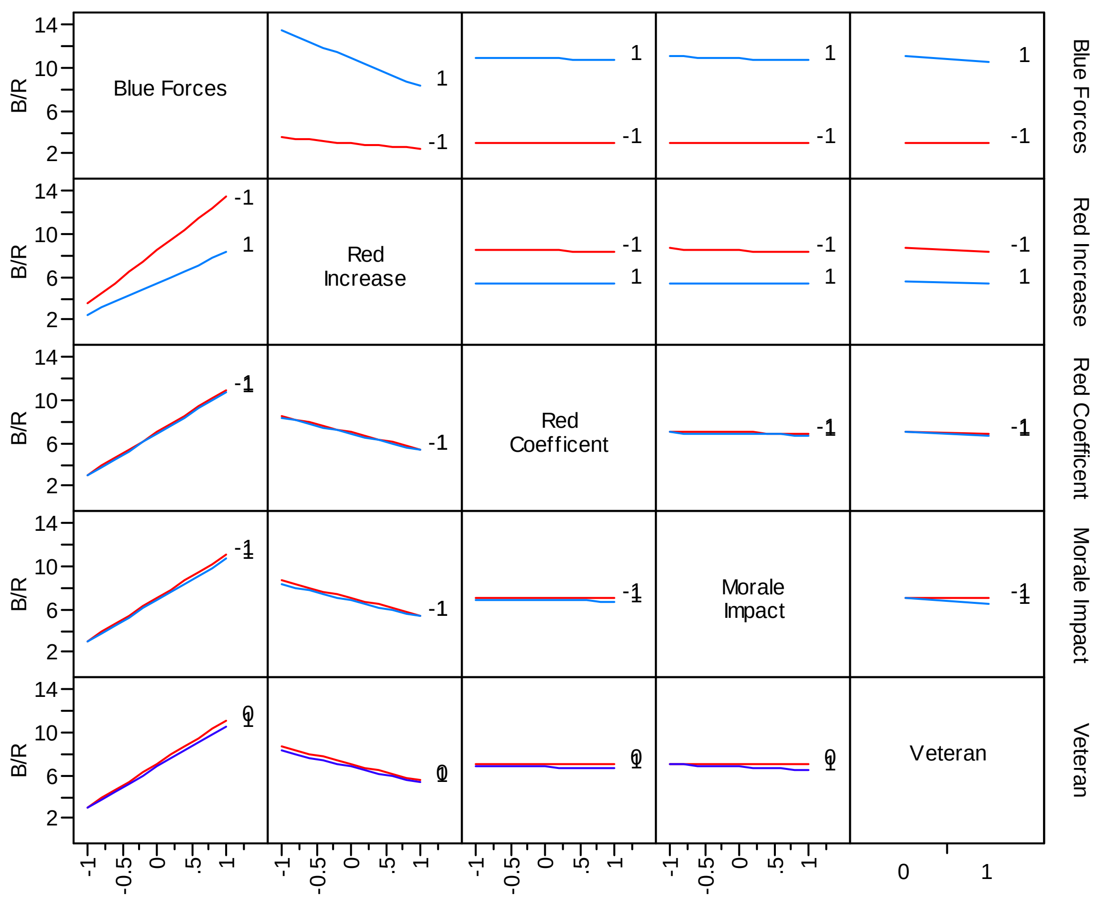


Figure VII-17: Interaction Plots for Blue/Red Combat Ratio

The plot in the first row and third column indicates the Combat Ratio was approximately ten when the Size of Blue Forces was at the high setting. This plot additionally indicates the influence from the Red Coefficient was minimal. On the other hand, the plot in the first row and second column indicates an influence from the change in Size of Blue Forces, the Rate or Red Increase and their interaction term.

As described by Deitchman, and portrayed in Figure II-11, when the insurgent forces achieved victory the average combat ratio was four regular soldiers per insurgent (1962, p. 821). On the other hand, when the regular forces achieved victory the average combat ratio was approximately ten regular soldiers per insurgent (Deitchman, 1962, p. 821). This analysis suggests that lowering the number of Blue forces in theater by 25% may lead to defeat no matter the setting or any of the other factors.

Figure VII-16 illustrates that when the Size of Blue Forces was decreased by 25%, the combat ratio was less than four to one. Conversely Figure VII-17 indicates, increasing the number of Blue forces by 25% and lowering the Red's recruiting by 10% lead to a combat ratio greater than ten to one. Only by increasing the number of Blue forces could the combat ratio be improved to a winning outcome.

The factor with the most influence on the combat ratio was the Size of Blue Forces. When the Blue forces increased in size there was a positive influence on the Blue/Red combat ratio. The second most influential factor was the Rate of Red Increase, indicating as the red recruited more forces there was a negative impact on the combat ratio. The third most influential factor was the interaction of the Size of Blue Forces and the Rate of Red Increase. All the other settings and conditions appear indeterminate.

Table VII-3: Estimated Effect on Red/Blue Combat Ratio

Term	***Estimated Effect***
Intercept	6.91
Size of Blue Forces (B)	7.82
Rate of Red Increase (RRI)	-3.04
Change of Red Coefficient (C)	-0.136
Morale Impact (M)	-0.24
Veteran Impact (V)	-0.3
B * RRI	-2.12
B*C	-0.05
RRI*C	0.03
B*M	-0.144
RRI*M	0.096
C*M	0.014
B * V	-0.22
RRI*V	0.094
C*V	-0.0022
M * V	-0.3

Keeping a larger number of forces may be the course of action required to win this notional conflict. To do this, public support must also remain high. Figure VII-18 provides the main effect plots and Figure VII-19 provides the interaction plots for the public support. Figure VII-19 shows that if there are an increased number of Blue forces and the Red fighting effectiveness is decreased, then the public support for the war is approximately 50%. The Red fighting effectiveness can be reduced by technology or other tools available in fourth generation operations. Technologies may be able to reduce the weapon effectiveness by increasing armor strength, preventing IEDs, or decreasing the total number of weapons available to the Red forces. The Red Coefficient may also be impacted through political, economic or informational methods. For example, the Blue forces may have a more effective media campaign, creating a less efficient Red force. Figure VII-19 also indicates the significance of the interaction of the Morale and Veteran impact.

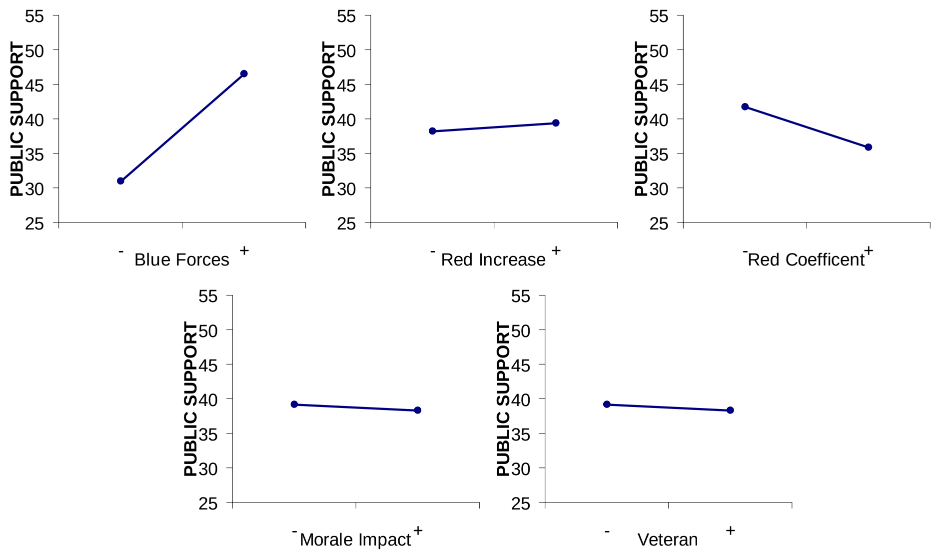


Figure VII-18: Main Effect Plots for Public Opinion

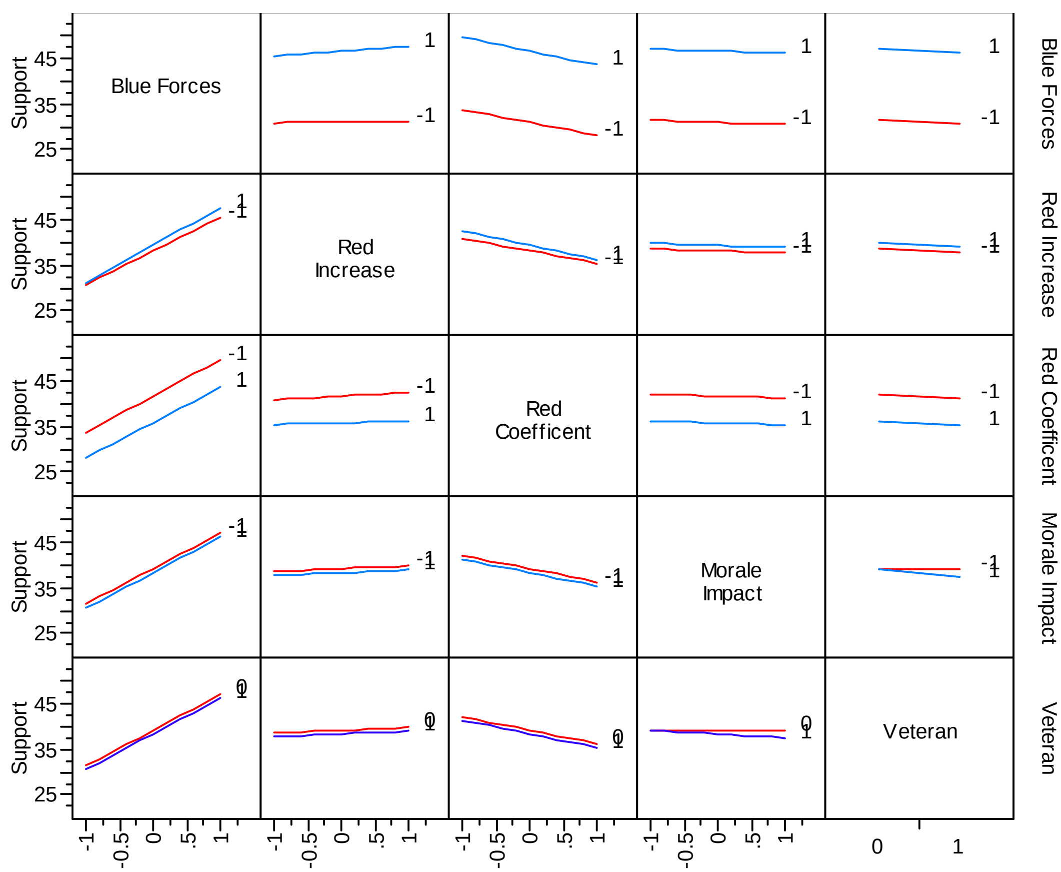


Figure VII-19: Interaction Plots for Public Opinion

Table VII-4 provides a summary of the influence of the factors on US public support. As seen in Figure VII-18 the most influential factor on US public support was the Size of Blue Forces, followed by the Change in Red Coefficient.

Table VII-4: Estimated Effect on Public Support

Term	*Estimated Effect*
Intercept	38.74
Size of Blue Forces (B)	15.58
Rate of Red Increase (RRI)	1.2
Change of Red Coefficient (C)	-5.88
Morale Impact (M)	-0.88
Veteran Impact (V)	-0.8
*B * RRI*	1
*B*C*	-0.24
*RRI*C*	-0.44
*B*M*	0.08
*RRI*M*	-0.054
*C*M*	-0.068
*B * V*	0.002
*RRI*V*	-0.056
*C*V*	-0.036
*M * V*	-0.8

It may seem counterintuitive that as Blue forces increase, the public support also increases. This change occurs in the simple scenario because more Red forces are captured which directly impacts public opinion. Additionally, with a larger Blue force there are less Blue casualties and less daily attacks by the Red forces in the notional scenario.

The size of Red forces in theater directly impacts the Blue/Red combat ratio and indirectly impacts the public support. Not surprisingly, by reducing the number of Red forces the ratio favors a victorious Blue force. The results when investigating the factors impacting the size of Red force, as seen in Figure VII-20, Figure VII-21 and Table VII-5, were very similar to the results of the Blue/Red Combat Ratio.

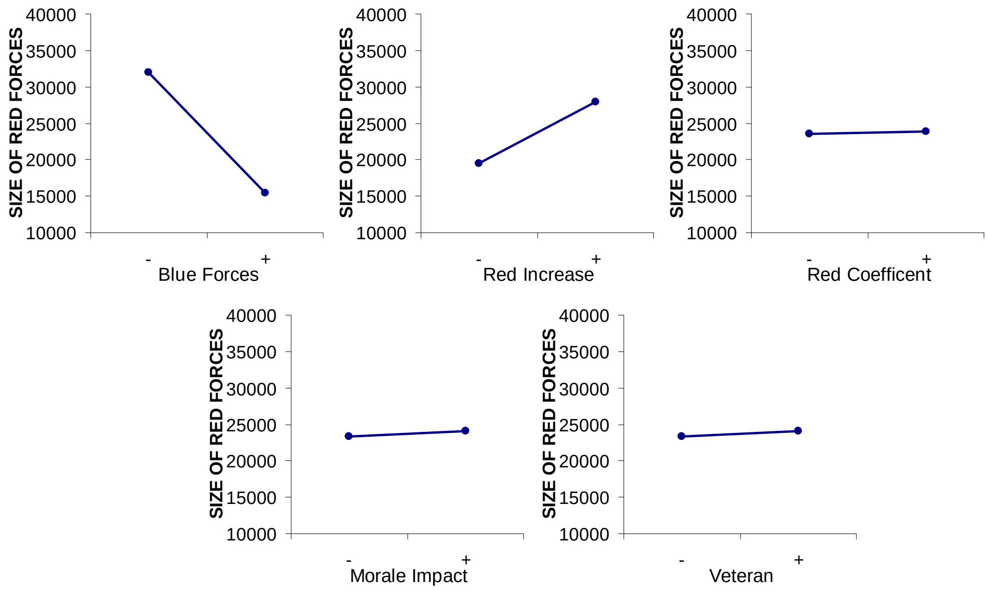


Figure VII-20: Main Effect Plots for Size of Red Forces

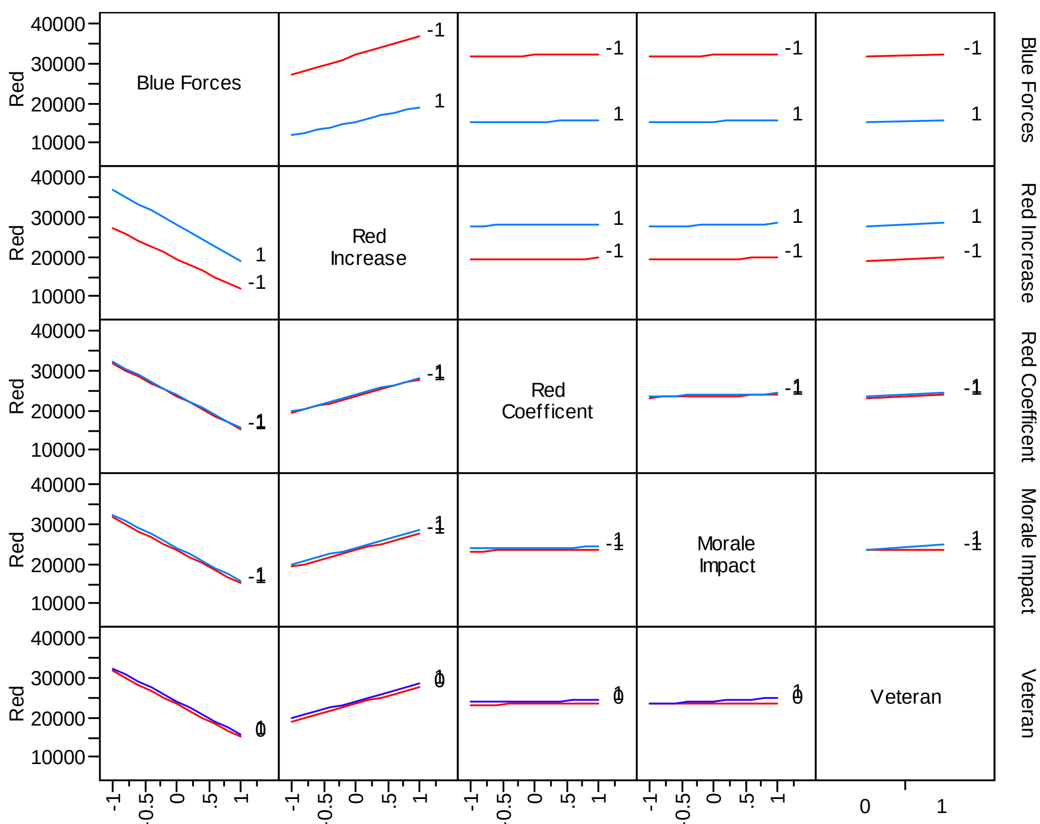


Figure VII-21: Interaction Plots for Size of Red Forces

Table VII-5: Estimated Effect on Size of Red Forces

Term	*Estimated Effect*
Intercept	23723
Size of Blue Forces (B)	-16531
Rate of Red Increase (RRI)	8507
Change of Red Coefficient (C)	331
Morale Impact (M)	688
Veteran Impact (V)	733
B * RRI	-1268
B*C	-133
RRI*C	45
B*M	-142
RRI*M	50
C*M	-3
B * V	-28
RRI*V	56
C*V	11
M * V	733

This screening experiment produced insights indicating the most significant factors impacting the combat ratio, public support for the war, and number of Red forces for the notional example. To obtain a historically effective combat ratio, the number of Blue forces must be increased and the recruiting of Red force must be reduced. To positively impact public support, enough troops must be employed to gain victories and the effectiveness of the adversary must be reduced. The public support must remain high to ensure the troops stay in theater. To reduce the number of adversaries in the theater, again more troops must be sent and training and recruiting of Red forces must be reduced. Additionally, this analysis suggests that in the notional scenario, the outcome of the current course of action is undetermined, while reducing the number of forces may lead to defeat.

Second Demonstration

This subsection demonstrates a second application of the model. This example is notional and is intended to highlight some of the features the framework provides. The intent of the demonstration is to present the functionality of the modeling framework illustrated with of elements of fourth generation operations. Specifically, the demonstration provides insight to how the framework can be applied to model the transition of rules of engagement (ROE) affected by US public support of the conflict, demonstrating feedback loops and dynamic rates of flow. Figure VII-22 illustrates the model of elements of fourth generation operations including public resolve. This model of public resolve was empirically developed in Chapter 5.

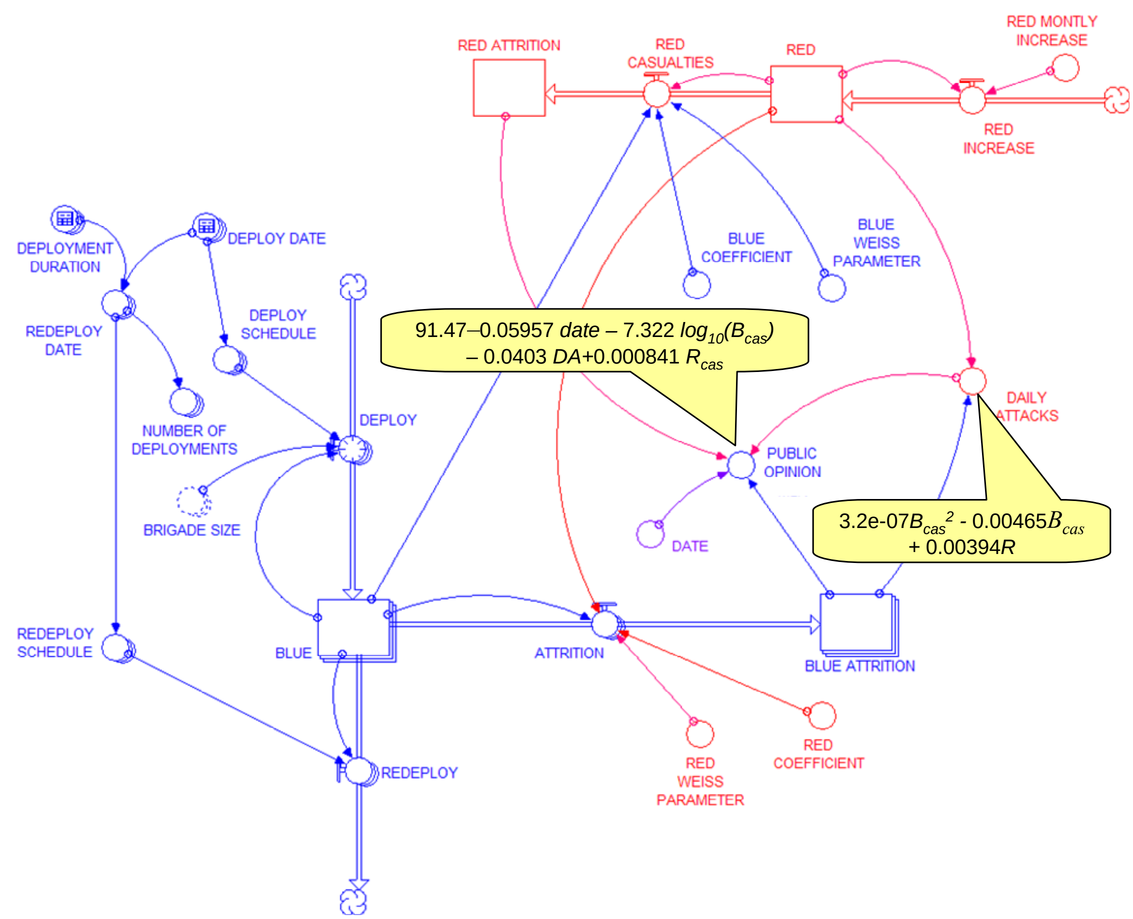


Figure VII-22: Model of Elements of 4GO with Public Resolve

The model represented by Figure VII-22 can change to include the influence that Public Support has on the ROE. The ROE dictate Blue's response when attacked. The response was the fighting behavior of the Blue Forces. As indicated in Equation VII-4, the attrition of Red forces was represented as a mix of direct and area fire. As public support for the conflict decreased, the rules of engagement are adjusted to reflect more of an emphasis on direct fire; therefore, limiting the possibility of collateral damage. For this demonstration, when public support was greater than 75% Equation VII-4 was used to represent Blue's attrition of Red's Forces. When public support was below 25% the Blue forces can only employ direct fire attacks ($w = 1$), thus Equation VII-2 was applied or the Lanchester Square Laws.

When public support was between 25% and 75%, a linear transition for the Blue Weiss Parameter and Blue Coefficient was used. This excursion is represented in Figure VII-23. Since the model is dynamic, the value of the Weiss Parameter may continuously vary between these extremes to appropriately model the engagements at a campaign level.

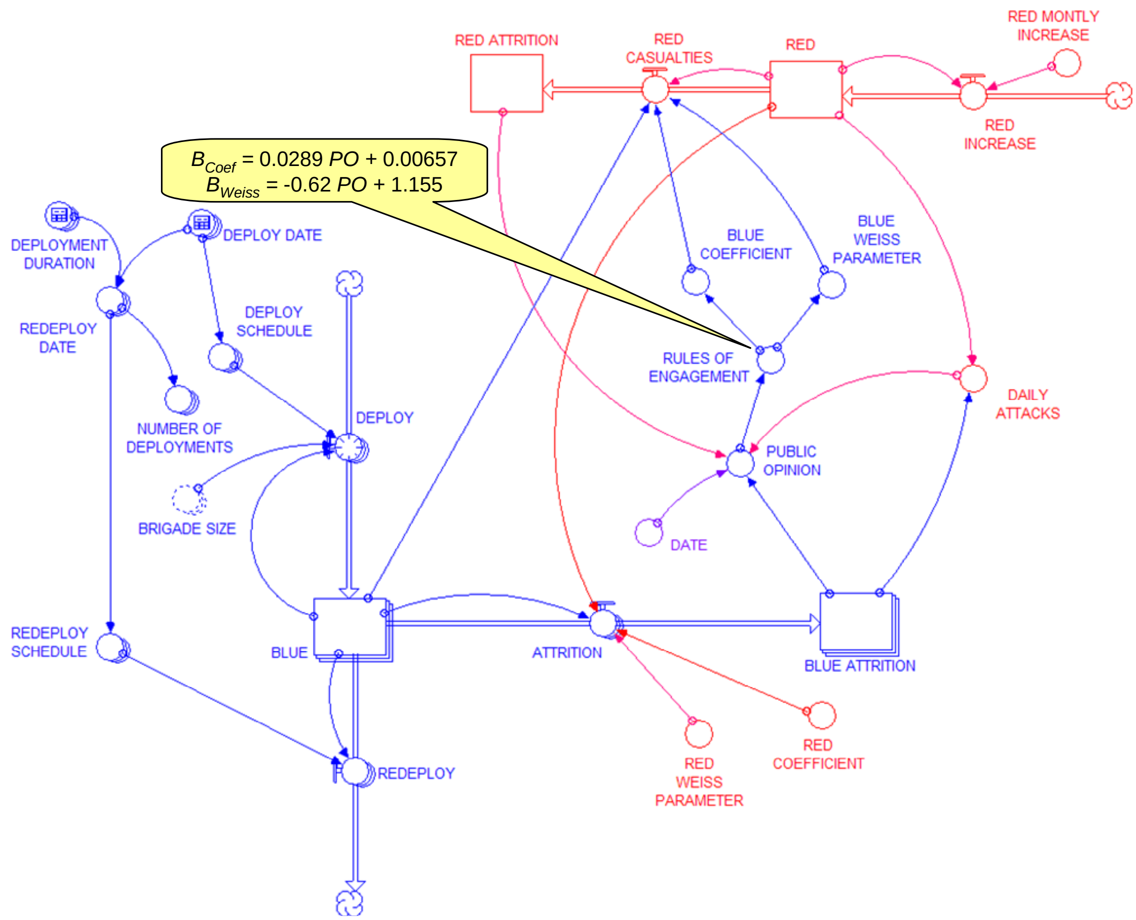


Figure VII-23: Rules of Engagement Demonstration

The model results without implementing the impacts of public support on the ROE were used as a baseline case. This was compared to the results with the dynamic ROE in Figure VII-24.

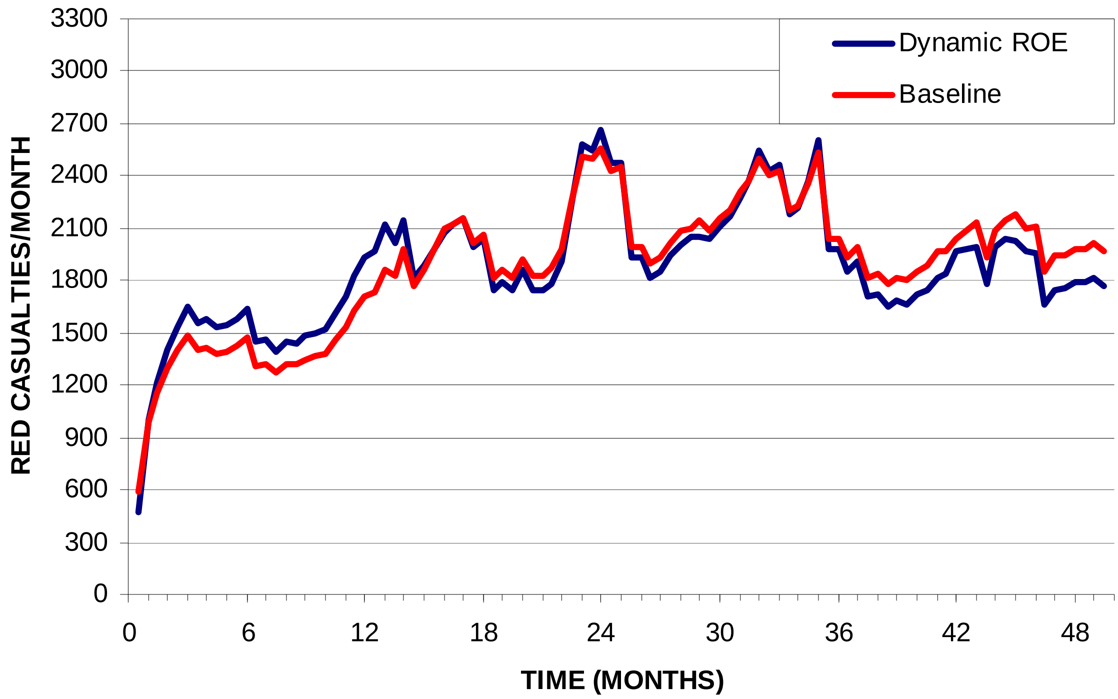


Figure VII-24: Number of Red Casualties per Month with Dynamic Rules of Engagement

The dynamic ROE excursion captured or killed more Red forces early in the conflict when the public support was high. As the conflict continued, the baseline case demonstrated a higher effectiveness against Red forces, since the Blue forces applied a direct fire approach requiring more time and accuracy to attack the target.

The impacts of feedback are observed in two areas of this demonstration. The first feedback loop is from Red Attrition to Public Opinion to Rules of Engagement. This feedback loop continues to both the Blue Coefficient and Blue Weiss Parameter, completing at Red Casualties and Red Attrition. This loop is a positive influence where higher attrition causes, higher public support and thus more Red Casualties.

The second feedback loop was from Red forces to Blue Attrition to Public Opinion. The loop continues to Rules of Engagement, and the Blue Coefficient and Blue Weiss Parameter, which impacted the Red Casualties reducing the number of Red forces. This feedback loop had a negative influence on the US public opinion.

This demonstration presents an example of how the analytic framework of elements of fourth generation operations can be applied and altered to provide insights for a decision maker. The dynamic relationships require additional data and support; however, this is an initial framework which may be applied to provide additional information. The modeling framework provides a basis to develop a number of approaches as relations are developed and verified.

Summary

The objective of this chapter was to present an analytic framework for elements of fourth generation operations, demonstrating how some elements may be included. The framework is a strategic level dynamic model of modern conflict. The model is empirically based on Helmbold's general form of the Lanchester Laws. The components of the formulation suggest that the insurgents' tactics use area fire techniques causing havoc, while the regular forces may initially respond by area fire but transition to a more effective direct fire approach.

The framework was introduced and information on the verification and validation of the framework was presented. The structure and behaviors of the base model passed several validation tests. The model however, was not tested against policy implementations since these tests involve "comparing policy changes in a model and in the corresponding reality" (Forrester & Senge, 1980, p. 224). The policy implementation test would likely occur during an accreditation process.

Examples of the framework's utility were provided through two demonstrations. The first demonstration was a full factorial screening experiment of five factors. Three responses were analyzed, providing insight to the notional results of several scenarios. The number of Blue forces in theater positively impacted both the public support for the war and the combat ratio. These responses are critical to the success of the conflict. Each factor included in the analysis was shown to influence the results and were considered significant. This further provides validation and verification of the model and its implementation. The second demonstration emphasized the importance of feedback loops and the framework's ability to represent softer aspects of combat

The system dynamics framework provides a mechanism to incorporate elements of fourth generation operations. It can be used either directly or in concert with other modeling approaches to aid in analyzing courses of action, effects, and plans in asymmetrical or irregular warfare.

This chapter completed the sixth contribution of the research by constructing an analytic framework of elements of fourth generation operations which captures the public resolve and the combatant's morale.

VIII. Conclusions

The objective and contribution of this research was to provide an analytic framework of elements of fourth generation operations, capturing the effects of will of the combatant and population. This objective required four principle objectives to be completed, building upon each other to obtain the overarching objective. This format resulted in six specific contributions to the field of operations research and particularly combat modeling.

Contributions

The first contribution developed a theory of fourth generation operations based on the framework of US Joint doctrine. This contribution defined fourth generation operations as conflict which combines elements of guerrilla tactics, terrorism, traditional warfare, and the ability to exploit and skip generations of technology to conduct operations, particularly to target the will and morale of the enemy's support structure, in order to achieve political victory. This contribution was accomplished in the third chapter of the dissertation. This achieved the first half (development) of the first principle objective which was to develop and model a theory of fourth generation operations based on the framework of US Joint doctrine.

The second contribution developed the supporting principles of fourth generation operations. This was also completed in Chapter 3. The principles required to achieve victory in fourth generation operations are detailed in Table III-1. The significant segment of the contribution was adding the principle of Population Perception and clarifying the principles of Legitimacy and Perseverance. This contribution also completed the second objective of the research.

The third contribution of the dissertation was the construction of a theoretical modeling framework to dynamically portray fatigue within a combat model, which was accomplished in the fourth chapter. This demonstrated the utility of using a system dynamics modeling framework to represent the Lanchester Laws as opposed to the traditional discrete event simulation framework. The framework that was built is a hybrid of system dynamics since it demonstrated an ability to model discrete events (addition of reserve forces), while dynamically portraying the impacts of fatigue on the combatant's effectiveness.

The fourth contribution was the construction of a theoretical modeling framework of public resolve. The model was founded on empirical evidence of four key factors. These key factors were: the number of days into the conflict, the logarithm base ten of the number of casualties, the number of daily attacks made by the adversary, and the number of adversary captured or killed. This framework provides a capability to model and evaluate impacts of conflict on public resolve.

The fifth contribution developed a theoretical modeling framework that dynamically portrays soldier morale. By using the second order response to an impulse, the morale of a soldier, or unit, can be estimated in a combat model based on the expected deployment duration and the number of days deployed. This provides a capability to model and evaluate impact of soldier morale due to various courses of action or from other external factors. This contribution allows campaign and strategic level models to include a morale factor during future analyses.

The sixth chapter also completes the third objective of this research. This objective constructed a theoretical modeling framework to dynamically portray public resolve, will-to-fight, morale and combat spirit within a combat model. The public resolve portion of the objective was completed in Chapter 5, and the morale and combat spirit was presented in Chapter 6.

The seventh chapter combines all the contributions to create a complete model of fourth generation operations. This synergy provides the sixth contribution: construct an analytic framework of elements of fourth generation operations which captures the will of the population and combatants. The final contribution provides new measures created to evaluate the impacts of public resolve and combat spirit. This additionally completes the final principle objective of the research, which was to provide a capability to model and evaluate the impacts of public resolve, will-to-fight, morale, and combat spirit of combatants and population on the outcome of the conflict.

Future Research

This research builds on well established Lanchester laws and theory. The dynamic framework of these laws presented within this dissertation allows for the impact of an array of factors and influences. The expansion of these factors and influences can be both internal and external to the model, allowing the analyst to perform a wide array of analyses. Examples of how this framework can be expanded include, but are not limited to: sub-dividing Blue forces, adding stochastic features, and adding other justified relations. The subdivision of Blue forces to each country of the coalition, and also the indigenous police and military would provide additional insight to the effectiveness of each type of unit. It would also provide observation into how the force structure could be altered. The model could also expand from a deterministic model to a stochastic model. This would allow the analyst to use probabilistic models when the data is uncertain. Finally, as discussed throughout this dissertation, the framework can be easily expanded to represent other important factors and relations as they become evident.

Further research can model the impact of significant events, such as elections and troop surges, to the public resolve. These models for public resolve can be used within current combat models to gauge the public support of various courses of action. Additionally, the impact of public resolve can be connected to the combat effectiveness of our troops.

Chapter 5 demonstrated the positive impact that the percent of positive stories had on the public resolve for a limited data set. Expanding the sample size to include data from the entire conflict would provide additional information on the public's response to positive and negative news reporting. Additionally, the technique used to measure the number of positive, neutral and negative stories may provide significant results. Modeling the 'attrition' of public morale would also be an interesting excursion. Similarly, future research may also apply the Lanchester Laws to the soldier's morale and combat spirit; therefore, directly attritting the morale of the combatant.

One other area of future research could be to apply the framework of elements of fourth generation operations to other scenarios and conflicts. Specifically, the Vietnam War would be an excellent candidate for further investigation to help validate the modeling framework.

As data is built-up, the framework should be useful in many areas. The framework can be used by analysts to provide insights aiding decision making. The framework can also be used to investigate various scenarios of interest to the decision maker. Finally, the framework could be used to develop and evaluate a multitude of courses of action. The proposed fourth generation operations model provides a foundation to incorporate elements of counterinsurgency and asymmetric warfare in an increasing interconnected world.

Appendix A: Sources and Data for Public Resolve

Table A-1 presents the public resolve data used in this study. The table indicates the date the poll was taken, the results of the poll, and the source used to compile the responses. If the source is indicated as being ABC, CBS, PEW or Gallop Poll, the data implies the actual question and response was reviewed and placed in the table. The Pulse of Democracy: The War in Iraq (Gallop, 2006) and American Public Opinion on Iraq: Five Conclusions (Newport, 2006) are reports developed by the Gallop Association and include the specific data indicated. The questions did differ slightly between conflicts and sources; therefore, the original questions asked are presented in Table A-2.

Table A-1: Polling Data of Public Resolve

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Iraq							
2007 July 20-22	51	42	7			889	5
2007 July 18-21	63	36	1			1125	4
2007 July 6-8	62	36	2			1014	1
2006 Dec 7-11	61	36		2		1005	4
2006 Dec 8-10	55	39		6		922	5
2006 Dec 6-10	51	42		7		1489	6
2006 Dec 8-10	53	45	2			505	2
2006 Nov 12-13	56	40		4		721	5
2006 Nov 9-12	51	41		8		1479	6
2006 Nov 2-5	55	40	5			1516	2
2006 Nov 1-4	53	44		2		1205	4
2006 Oct 27-31	51	44		5		932	5
2006 Oct 19-22	57	40		2		1200	4
2006 Oct 17-22	47	43		10		1552	6
2006 Oct 20-22	58	40	2			1002	2
2006 Oct 5-8	63	35		2		1204	4
2006 Oct 5-8	55	40		5		983	5
2006 Oct 6-8	56	40	4			1007	2

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Iraq (continued)							
2006 Sep 21 - Oct 4	47	45		8		1804	6
2006 Sep 15-19	51	44		5		1131	5
2006 Sep 15-17	49	49	2			1003	2
2006 Sep 5-7	56	42		2		1003	4
2006 Aug 17-21	53	43		4		1206	5
2006 Aug 11-13	53	41		6		974	5
2006 Aug 3-6	59	39		1		1002	4
2006 Jul 28-30	54	45	2				2
2006 Jul 21-25	48	47		5		1127	5
2006 Jul 21-23	56	41	2			1005	2
2006 Jun 22-25	58	40		2		1000	4
2006 Jun 23-25	55	43	1			1000	2
2006 Jun 14-19	44	49		7		1501	6
2006 Jun 10-11	51	44		5		659	5
2006 Jun 9-11	51	46	2			1002	2
2006 May 16-17	53	43		4		636	5
2006 May 11-15	62	37		1		1103	4
2006 May 4-8	56	39		5		1241	5
2006 Apr 28-30	51	44		5		719	5
2006 Apr 7-16	46	47		7		1501	6
2006 Apr 6-09	58	41		1		1000	4
2006 Apr 6-9	53	43		4		899	5
2006 Apr 7-9	57	42	1			1004	2
2006 Mar 9-12	54	41		5		1136	5
2006 Mar 8-12	49	45		6		1405	6
2006 Mar 10-12	57	42	1			1001	2
2006 Mar 2-5	57	42		1		1000	4
2006 Feb 28-Mar 1	55	43	2			1020	2
2006 Feb 22-26	54	41		5		1018	5
2006 Feb 9-12	55.02	42.2		2.42	0.32	500	1
2005 Feb 4-6	44.76	54.68		0.44	0.13	1011	1
2006 Feb 1-5	44	51		5		1502	6
2006 Jan 23-26	55	44		1		1002	4
2006 Jan 20-25	50	47		3		1229	5
2006 Jan 20-22	50.84	46.23		2.49	0.44	1007	1
2006 Jan 5-8	55	43		2		1001	4
2006 Jan 5-8	49	47		4		1151	5
2006 Jan 4-8	47	45		8		1503	6

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Iraq (continued)							
2006 Jan 6-8	50.02	47.47		1.91	0.61	504	1
2005 Dec 15-18	52	46		1		1003	4
2005 Dec 16-18	52.15	46.1		1.49	0.27	1003	1
2005 Dec 7-11	48	47		5		1502	6
2005 Dec 9-11	48.23	50.24		1.4	0.14	1003	1
2005 Dec 2-6	48	48		4		1155	5
2005 Nov 11-13	54.01	45.25		0.33	0.41	481	1
2005 Oct 30 - Nov 02	60	39		1		1202	4
2005 Oct 30 - Nov 01	50	42		8		936	5
2005 Oct 28-30	53.51	45.24		1.18	0.06	801	1
2005 Oct 21-23	49.05	49.13		1.27	0.55	1008	1
2005 Oct 6-10	50	44		6		1500	6
2005 Oct 3-5	55	41		4		808	5
2005 Sep 16-18	59.56	38.59		1.8	0.05	812	1
2005 Sep 9-13	50	44		6		1167	5
2005 Sep 8-11	44	49		7		1523	6
2005 Sep 8-11	53.16	45.64		0.86	0.34	1005	1
2005 Aug 29-31	49	45		6		~1000	5
2005 Aug 28-30	53.14	46.17		0.48	0.21	1007	1
2005 Aug 25-28	53	46		1		1006	4
2005 Aug 5-7	53.94	44.16		1.65	0.25	485	1
2005 Jul 29 - Aug 2	46	48		6		1222	5
2005 Jul 22-24	45.96	52.73		1.31	0	1006	1
2005 Jul 13-17	44	49		7		1502	6
2005 Jun 23-26	53	46		1		1004	4
2005 Jun 24-26	53	46	1				2
2005 Jun 10-15	51	45		4		1110	5
2005 Jun 8-12	45	47		8		1464	6
2005 Jun 2-5	58	41		1		1002	4
2005 May 20-24	49	47		4		1150	5
2005 Apr 29-May 1	49.27	47.97		2.29	0.46	485	1
2005 Apr 21-24	54	44		2		1007	4
2005 Apr 13-16	48	47		5			5
2005 Mar 18-20	46.02	50.92		2.7	0.37	441	1
2005 Mar 10-13	53	45		2		1001	4
2005 Feb 24-28	50	46		4		1111	5
2005 Feb 25-27	47.31	50.93		1.26	0.51	1008	1
2005 Feb 16-21	47	47		6		1502	6

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Iraq (continued)							
2005 Jan 14-18	49	45		6		1118	5
2005 Jan 12-16	55	44		1		1007	4
2005 Jan 14-16	51.68	47.3		0.78	0.24	1007	1
2005 Jan 5-9	44	51		5		1503	6
2005 Jan 7-9	50.21	47.63		1.54	0.61	1008	1
2004 Dec 16-19	56	42		2		1000	4
2004 Dec 1-16	44	49		7			6
2004 Nov 18-21	48	46		6		885	5
2004 Nov 19-21	47.36	51.23		1.23	0.17	502	1
2004 Oct 29-31	44.49	51.74		2.33	1.44	1036	1
2004 Oct 28-30	44	52		4		1345	5
2004 Oct 27-30	41	48		11		2804	6
2004 Oct 22-24	47.15	51.16		1.48	0.21	1537	1
2004 Oct 15-19	42	46		12		803	6
2004 Oct 14-17	46	50		4		1048	5
2004 Oct 14-16	46.82	51.66		1.28	0.24	1013	1
2004 Oct 9-10	45.83	52.87		0.96	0.34	547	1
2004 Oct 1-3	39	50		11		1233	6
2004 Oct 1-3	47.49	51.22		1.29	0	1017	1
2004 Sep 23-26	51	46		3		1204	4
2004 Sep 24-26	41.86	55.31		2.29	0.55	1006	1
2004 Sep 8-13	39	53		8		2494	6
2004 Sep 6-8	45	51		4		1202	4
2004 Sep 3-5	37.71	57.42		3.87	1	542	1
2004 Aug 26-29	50	48		2		1000	4
2004 Aug 23-25	48.2	49.52		2.11	0.17	471	1
2004 Aug 5-10	41	53		6		1512	6
2004 Jul 30-Aug 1	47.75	50.02		1.66	0.57	1011	1
2004 Jul 22-25	48	49		3		1202	4
2004 Jul 19-21	49.7	46.75		3.3	0.25	1005	1
2004 Jul 8-18	43	52		5		2009	6
2004 Jul 11-15	51	45		4		955	5
2004 Jul 8-11	53.55	45.53		0.72	0.2	524	1
2004 Jun 23-27	46	48		6		1053	5
2004 Jun 21-23	53.85	44.16		1.55	0.44	512	1
2004 Jun 17-20	52	47		2		1201	4
2004 Jun 3-13	38	55		7		1806	6
2004 Jun 3-6	41.36	57.53		0.71	0.4	496	1

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Iraq (continued)							
2004 May 20-23	50	48		1		1005	4
2004 May 20-23	46	49		5		1113	5
2004 May 11	45	49		6		448	5
2004 May 3-9	42	51		7		1800	6
2004 May 7-9	43.91	53.83		2.25	0	497	1
2004 May 5-6	47	49		5		802	4
2004 Apr 23-27	46	47		7		1042	5
2004 Apr 21-25	37	54		9		1000	6
2004 Apr 15-18	47	51		2		1201	4
2004 Apr 16-18	41.69	56.92		1.23	0.16	512	1
2004 Apr 1-4	35	57		8		790	6
2004 Mar 30 - Apr 1	39	55		6		1024	5
2004 Mar 17-21	39	55		6		1703	6
2004 Mar 10-14	37	58		5		~1000	5
2004 Mar 4-7	44	52		3		1202	4
2004 Feb 24-29	32	60		8		715	6
2004 Feb 24-27	39	54		7		~1000	5
2004 Feb 11-16	39	56		5		1500	6
2004 Feb 12-15	37	58		5		1221	5
2004 Feb 10-11	50	48		2		1003	4
2004 Jan 15-18	41	56		3		1036	4
2004 Jan 12-15	41.94	55.68		1.76	0.63	509	1
2004 Jan 6-11	30	65		5		1503	6
2003 Dec 19 - 2004 Jan 4	28	62		10		1506	6
2003 Dec 21-22	34	62		4		799	5
2003 Dec 18-21	39	59		2		1001	4
2003 Dec 15-17	26	67		7		815	6
2003 Dec 14-15	31	63		6		635	5
2003 Dec 14	42	53		5		506	4
2003 Nov 12-16	44	52		4		1023	4
2003 Nov 3-5	39.01	60.33		0.66	0	518	1
2003 Oct 26-29	44	54		2		1207	4
2003 Oct 20-21	42	52		6		571	5
2003 Oct 9-13	44	54		2		1000	4
2003 Oct 6-8	40.61	58.61		0.41	0.37	522	1
2003 Oct 03	33	60		7			6
2003 Sep 10-13	37	61		2		1104	4
2003 Sep 4-7	42	54		4		1004	4

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Iraq (continued)							
2003 Sep 03	31	63		6			6
2003 Aug 20-24	37	57		5		1024	4
2003 Jul 14 – Aug 5	30	63		7		2528	6
2003 Jul 9-10	40	57		3		1006	4
2003 Jul 7-9	27.13	71.59		1.28	0	508	1
2003 Jun 20 - Jul 2	24	67		9		1201	6
2003 Jun 18-22	33	64		3		1024	4
2003 Apr 27-30	27	70		4		1003	4
2003 Apr 10-16	19	74		7		924	6
2003 Apr 8-9	19	74		7		809	6
2003 Apr 2-7	20	72		8		912	6
2003 Mar 28 - Apr 1	25	69		6		674	6
2003 Mar 25-27	21	74		5		539	6
2003 Mar 24-25	23.03	75.25		1.72	0	492	1
2003 Mar 23-24	21	74		5		592	6
2003 Mar 20-22	22	71		7		903	6
Afghanistan							
2007 Mar 11	41	53		6		1027	7
2007 Feb 25	41	56		3		1082	4
2007 Jan 21	52	44		4		1008	7
2006 Oct 2	48	50		2			7
2006 Aug 3	41	56		3			7
2004 Jul 19-21	25.56	71.77		2.59	0.08	1005	1
2002 Sep 2-4	13.13	82.83		3.56	0.47	1002	1
2002 Jan 25-27	8.54	89.06		1.82	0.58	1012	1
2002 Jan 7-9	6.23	92.52		1.25	0	498	1
2001 Dec 6-9	8.89	88.24		2.26	0.62	1003	1
2001 Nov 26-27	6.62	91.73	1.65			1025	1
2001 Nov 9-15	10.55	86.35	3.1			2418	1
2001 Nov 2-4	11.1	85.72	3.18			1012	1
2001 Nov 8-11	8.69	88.67		2.23	0.41	523	1
2001 Oct 19-21	9.53	88.4	2.07			1006	1
2001 Oct 11-14	6.73	92.63		0.32	0.32	534	1
2001 Oct 7	5.21	90.32	4.47			670	1

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Vietnam War							
1973 Jan 12-15	60	29	11				3
1971 May 14-17	61	28	11				3
1971 Jan 8-11	60	31	9				3
1970 May 21-26	56	36	8				3
1970 Apr 2-7	51	34	15				3
1970 Jan 15-20	57	32	11				3
1969 Sep 17-22	58	32	10				3
1969 Jan 23-28	52	39	9				3
1968 Sep 26-Oct 1	54	37	9				3
1968 Aug 7-12	53	35	12				3
1968 Apr 4-9	48	40	12				3
1968 Feb 22-27	49	42	9				3
1968 Feb 1-6	46	42	12				3
1967 Dec 7-12	45	46	9				3
1967 Oct 6-11	47	44	9				3
1967 Jul 13-18	41	48	11				3
1967 Apr 19-24	37	50	13				3
1967 Jan 26-31	32	52	16				3
1966 Nov 10-15	31	52	17				3
1966 Sep 8-13	35	48	17				3
1966 May 5-10	36	49	15				3
1966 Mar 3-8	26	59	15				3
1965 Aug 27-Sep 1	24	60	16				3

	Yes, a mistake	No, not a Mistake	No opinion	Don't Know / Refused To Answer		Number polled	Source
Korean War							
1953 Jan 11-16	36	50	14				3
1952 Oct 17-22	43	37	19				3
1952 Oct 9-14	43	37	20				3
1952 Feb 28-Mar 5	51	35	14				3
1951 Aug 3-8	42	48	11				3
1951 Jun 16-21	43	40	17				3
1951 Apr 16-21	37	45	18				3
1951 Mar 26-31	45	43	12				3
1951 Feb 4-9	49	41	9				3
1951 Jan 1-5	49	38	13				3
1950 Aug 20-25	20	65	15				3

1: Data from Gallop Poll of date indicated
2: Data from Gallop's *Pulse of Democracy: The War in Iraq* (Gallop, 2006)
3: Data from *American Public Opinion on Iraq: Five Conclusions* (Newport, 2006)
4: Data from ABC of date indicated
5: Data from CBS of date indicated
6: Data from PEW of date indicated
7. Data from CNN of date indicated

Table A-2: Questions Asked During Polling

Conflict	Timeframe of Question	Question
Afghanistan	2001 - 2002 *	Do you approve or disapprove of the current U.S. military action in Afghanistan?
Afghanistan	2004 *	Do you think the United States made a mistake in sending military forces to Afghanistan, or not?
Iraq-ABC	2003-2006	All in all, considering the costs to the United States versus the benefits to the United States, do you think the war with Iraq was worth fighting, or not?
Iraq-CBS	2003-2006	Looking back, do you think the United States did the right thing in taking military action against Iraq, or should the U.S. have stayed out?
Iraq-Gallop	2003 - 2006 * & **	In view of the developments since we first sent our troops to Iraq, do you think the United States made a mistake in sending troops to Iraq, or not?
Iraq-PEW	2003-2006	Do you think the U.S. made the right decision or the wrong decision in using military force against Iraq?
Korea	Feb. 1951 - Jan. 1953 ***	Do you think the United States made a mistake in going into the war in Korea, or not?
Korea	Aug. 1950 - Jan. 1951 ***	In view of the developments since we entered the fighting in Korea, do you think the United States made a mistake in deciding to defend Korea, or not?
Vietnam	1965 - 1973 ***	In view of the developments since we entered the fighting in Vietnam, do you think the U.S. made a mistake sending troops to fight in Vietnam?

* Question from Gallop Poll of dates indicated
** Question from Gallop's Pulse of Democracy: The War in Iraq (Gallop, 2006)
*** Question from American Public Opinion on Iraq: Five Conclusions (Newport, 2006)

Appendix B: Monthly Data for Operations in Iraq

The data in Table B-1 is complied from data within the *Iraq Index* (O'Hanlon & Kamp, 2006). The value in the table is the estimated data at the end of the month. Blue casualties include the cumulative number of wounded and killed. The number of insurgents, Red forces captured and killed, and daily attacks are the estimates as reported.

Table B-1: Complied Data from *Iraq Index* (O'Hanlon & Kamp, 2006)

Date	Days into Conflict	Blue Casualties	Number of Insurgents	Red Captured & Dead	Daily Attacks
March-03	11	267	0	0	0
April-03	41	681	2500	0	0
May-03	72	772	5000	1000	0
June-03	102	949	5000	2000	8
July-03	133	1222	5000	3000	16
August-03	164	1439	5000	4000	18
September-03	194	1717	5000	4750	25
October-03	225	2174	5000	5500	32
November-03	255	2593	5000	8500	32
December-03	286	2894	5000	9500	19
January-04	317	3128	4000	12000	19
February-04	346	3295	4000	14000	21
March-04	377	3668	4000	15750	24
April-04	407	5012	5000	17750	53
May-04	438	5847	15000	19750	53
June-04	468	6473	15000	20970	45
July-04	499	7079	20000	21970	47
August-04	530	8035	20000	24470	77
September-04	560	8818	20000	26970	58
October-04	591	9522	20000	28970	61
November-04	621	11056	20000	31970	77
December-04	652	11659	21000	33970	52
January-05	683	12205	18000	36470	61
February-05	711	12711	18000	37470	54
March-05	742	13099	16000	38470	45
April-05	772	13728	16000	39470	60
May-05	803	14420	16000	41470	70

Date	Days into Conflict	Blue Casualties	Number of Insurgents	Red Captured & Dead	Daily Attacks
June-05	833	14930	17500	43470	70
July-05	864	15449	19000	45470	70
August-05	895	16147	19000	48470	70
September-05	925	16722	19000	51470	90
October-05	956	17433	17500	53470	100
November-05	986	17995	17500	55470	90
December-05	1017	18464	17500	57470	75
January-06	1048	18841	17500	59470	75
February-06	1076	19250	17500	61470	75
March-06	1107	19727	17500	63470	75
April-06	1137	20230	21000	65470	80
May-06	1168	20701	21000	67470	100
June-06	1198	21251	21000	69970	100
July-06	1229	21735	21000	72470	140
August-06	1260	22439	21000	74970	160
September-06	1290	23301	21000	77470	170
October-06	1321	24251	25000	79970	180
November-06	1351	24828	25000	82470	175
December-06	1382	25631	25000	84970	175

Appendix C: Equations Created in Public Resolve Chapter

The regressions performed in this dissertation are implemented as equations within the model of elements of fourth generation operations. This appendix provides the equations developed in the earlier chapters. The name of the equations reflects the name of the table used when developed previously.

The first line in each equation of the simple and multiple linear regression models provide the coefficients and the associated R^2 of the model. The second line provided the standard error for each coefficient along with the root mean square error, or standard error of the model in the last column. The third line shows the *t*-test statistic for each coefficient, with the null hypothesis that the coefficient equaled zero (H_0: $\beta_i = 0$; H_a: $\beta_i \neq 0$). The magnitude of the *t*-test statistic was compared to the appropriate reference value from the two-sided *t*-distribution with $\alpha = 0.05$ (located in the final column) and the null hypothesis was rejected if the magnitude is greater than the critical value (indicating strong evidence of a non-zero coefficient), or failed to reject (implying there is little or no evidence suggesting that the coefficient is not zero). The *F*-test for the model is included in the second to last line of each equation. (While redundant for models with a single independent variable, it is provided for completeness.) The null hypothesis for the *F*-test is that all of the coefficients are equal to zero (H_0: $\beta_i = 0 \;\forall\, i$; H_a: $\beta_i \neq 0$ some at least one *i*). If the observed *F*-test statistic is larger than the appropriate reference value from the *F*-distribution, then the null hypothesis is rejected (indicating at least one coefficient is significant). The final line provides the number of data points available for that conflict. If any coefficient or model was determined to be statistically insignificant the equation indicated this in bold markings. As multicollinearity is present in several of the MLR models, care should be taken in reviewing the results.

For the logistic regression equations, the summary of the regression coefficients and standard error is presented in the first two lines for each of the factors. The third line provides the χ^2 term for each coefficient, which is a measure of goodness of fit where the larger the number implies the better the fit. If any coefficient or model was determined to be statistically insignificant, the equation indicated this in bold markings.

Equation C-1 represents Table V-1: Public Support for Korea per Time. (Not significant)

$$\begin{array}{lll} \textit{Public Support} = 48.56 - 0.0109 \textit{days} & & R^2 = \mathbf{0.15} \\ \quad (4.76) \quad (0.0088) & & SE = 8.34 \\ \quad 10.20 \quad \mathbf{-1.24} & & t_{\alpha=0.05} = 2.23 \\ & F = \mathbf{1.54} < F_{\alpha=0.05} = 4.96 & \\ & & N = 11 \end{array} \tag{C-1}$$

Equation C-2 represents Table V-2: Public Support for Vietnam (1965-1973) per Time.

$$\begin{array}{lll} \textit{Public Support} = 60.13 - 0.0126 \textit{days} & & R^2 = 0.85 \\ \quad (1.82) \quad (0.0011) & & SE = 3.64 \\ \quad 33.12 \quad -11.02 & & t_{\alpha=0.05} = 2.07 \\ & F = 121.47 > F_{\alpha=0.05} = 4.30 & \\ & & N = 23 \end{array} \tag{C-2}$$

Equation C-3 represents Table V-3: Public Support for Afghanistan per Time

$$\begin{array}{lll} \textit{Public Support} = 90.33 - 0.01949 \textit{days} & & R^2 = 0.95 \\ \quad (1.25) \quad (0.0011) & & SE = 4.02 \\ \quad 72.29 \quad -17.06 & & t_{\alpha=0.05} = 2.12 \\ & F = 291.09 > F_{\alpha=0.05} = 4.49 & \\ & & N = 18 \end{array} \tag{C-3}$$

Equation C-4 represents Table V-4: Public Support for Iraq per Time

$$\begin{aligned} &Public\ Support = 64.96 - 0.0204 days && R^2 = 0.71 \\ &\qquad (0.76) \quad (0.0010) && SE = 5.43 \\ &\qquad 85.53 \quad -21.31 && t_{\alpha=0.05} = 2.26 \\ & && F = 454.17 > F_{\alpha=0.05} = 5.10 \\ & && N = 191 \end{aligned} \tag{C-4}$$

Equation C-5 represents Table V-5: Public Support for Vietnam (1965-1969) per Time

$$\begin{aligned} &Public\ Support = 66.26 - 0.0185 days && R^2 = 0.89 \\ &\qquad (1.99) \quad (0.0017) && SE = 2.70 \\ &\qquad 33.23 \quad -10.98 && t_{\alpha=0.05} = 2.12 \\ & && F = 120.46 > F_{\alpha=0.05} = 4.49 \\ & && N = 17 \end{aligned} \tag{C-5}$$

Equation C-6 represents Table V-7: Public Support for Korea per Casualty

$$\begin{aligned} &Public\ Support = 114.46 - 14.89 Log_{10}(Cas) && R^2 = 0.83 \\ &\qquad (13.82) \quad (2.39) && SE = 5.21 \\ &\qquad 8.51 \quad -5.35 && t_{\alpha=0.05} = 2.07 \\ & && F = 28.62 > F_{\alpha=0.05} = 4.26 \\ & && N = 25 \end{aligned} \tag{C-6}$$

Equation C-7 represents Table V-8: Public Support for Vietnam per Casualty

$$\begin{aligned} &Public\ Support = 124.98 - 16.51 Log_{10}(Cas) && R^2 = 0.90 \\ &\qquad (6.04) \quad (1.16) && SE = 3.20 \\ &\qquad 20.69 \quad -13.66 && t_{\alpha=0.05} = 2.07 \\ & && F = 186.57 > F_{\alpha=0.05} = 4.28 \\ & && N = 24 \end{aligned} \tag{C-7}$$

Equation C-8 represents Table V-9: Public Support for Iraq per Casualty

$$\begin{aligned} &Public\ Support = 108.51 - 15.02 Log_{10}(Cas) && R^2 = 0.85 \\ &\qquad (1.76) \quad (0.45) && SE = 3.84 \\ &\qquad 61.77 \quad -33.09 && t_{\alpha=0.05} = 2.26 \\ & && F = 1095.14 > F_{\alpha=0.05} = 5.10 \\ & && N = 191 \end{aligned} \tag{C-8}$$

Equation C-9 represents Table V-11: Public Support for Iraq (MLR Model)

$$\begin{aligned}
&\textit{Public Support} \\
&= 91.47 - 0.05957\,days - 7.322\log_{10}(cas) - 0.04030\,Attacks + 0.0008418\,Insurgents \qquad R^2 = 0.87 \\
&\quad (5.24)\quad (0.01935)\quad (2.287)\quad (0.01506)\quad (0.000272) \qquad SE = 3.72 \\
&\quad 17.47\quad -3.08\quad -3.20\quad -2.68\quad 3.09 \qquad t_{\alpha=0.05} = 1.97 \\
&\qquad F = 295.69 > F_{\alpha=0.05} = 3.89 \\
&\qquad N = 191
\end{aligned} \tag{C-9}$$

Equation C-10 represents Table V-17: Public Support for Iraq (Two-Factor Analysis Model using MLR)

$$\begin{aligned}
&\textit{Public Support} = 51.11 - 4.77\,time - 7.91\,casualty \qquad R^2 = 0.85 \\
&\quad (0.28)\quad (0.28)\quad (0.28) \qquad SE = 3.85 \\
&\quad 183.64\quad -17.26\quad -28.69 \qquad t_{\alpha=0.05} = 2.07 \\
&\qquad F = 547.4 > F_{\alpha=0.05} = 3.89 \\
&\qquad N = 191
\end{aligned} \tag{C-10}$$

Equation C-11 represents Table V-19: Public Support for Iraq (Logistic Regression Model) (Not significant)

$$\begin{aligned}
&\textit{Public Support} \\
&= \left(1 + e^{-2.42 + 0.00099\,days + 0.552\,Log_{10}(cas) + 0.00129\,Attacks - 1.77e-05\,Insurgents + 5.87e-07\,ISF}\right)^{-1} \\
&\quad (0.12)\quad (0.0003)\quad (0.048)\quad (0.00026)\quad (5.30e-06)\quad (2.26e-07) \\
&\quad 461.2\quad 6.4\quad 134.1\quad 24.2\quad 11.1\quad 6.8 \\
&\qquad Dev = \mathbf{809.6} > 219 = \chi^2_{\alpha=0.05,186} \\
&\qquad N = 191
\end{aligned} \tag{C-11}$$

Equation C-12 represents Table V-20: Public Support for Iraq (Logistic Regression Model Corrected for Overdispersion)

$$\begin{aligned}
&\textit{Public Support} \\
&= \left(1 + e^{-2.15 + 0.00204\,days + 0.436\,Log_{10}(cas) + 0.00162\,Attacks - 3.030e-05\,Insurgents}\right)^{-1} \\
&\quad (0.22)\quad (0.00077)\quad (0.094)\quad (0.00056)\quad (1.08e-05) \\
&\quad 98.81\quad 6.96\quad 21.55\quad 8.41\quad 7.89 \\
&\qquad Dev = 188 \le 219 = \chi^2_{\alpha=0.05,186} \\
&\qquad N = 191
\end{aligned} \tag{C-12}$$

Equation C-13 represents Table V-21: Public Support for Iraq (Factor Analysis Model using Logistic Regression) (Not significant)

$$Public\ Support = \left(1 + e^{-0.103+0.191time+0.334casualty}\right)^{-1}$$

$$\begin{array}{ccc} (0.0047) & (0.0045) & (0.0056) \\ 491.3 & 1831.6 & 3757.5 \end{array} \qquad \text{(C-13)}$$

$$Dev = \mathbf{974.4} > 221 = \chi^2_{\alpha=0.05,188}$$

$$N = 191$$

Equation C-14 represents Table V-22: Public Support for Iraq based on Percent of Positive Stories

$$\begin{array}{lr} Public\ Support & \\ = 43.12 + 30.16 PositiveStories & R^2 = 0.340 \\ \quad (0.97) \quad (7.32) & SE = 2.44 \\ \quad 44.25 \quad\ \ 4.12 & t_{\alpha=0.05} = 2.03 \\ & F = 16.97 > F_{\alpha=0.05} = 3.28 \\ & N = 35 \end{array} \qquad \text{(C-14)}$$

Equation C-15 represents Table V-23: Public Support for Iraq based on Percent of Negative Stories (Not significant)

$$\begin{array}{lr} Public\ Support & \\ = 49.24 - 4.06 NegativeStories & \mathbf{R^2 = 0.031} \\ \quad (2.47) \quad (3.95) & SE = 2.95 \\ \quad 19.96 \quad \mathbf{-1.03} & t_{\alpha=0.05} = 2.03 \\ & \mathbf{F = 1.05} \le F_{\alpha=0.05} = 3.28 \\ & N = 35 \end{array} \qquad \text{(C-15)}$$

Equation C-16 represents Table V-24: Public Support for Iraq (MLR with Percent of Positive Media Reports)

$$\begin{array}{lr} Public\ Support & \\ = 10.01 \log_{10}(cas) + 38.70 PositiveStories & R^2 = 0.997 \\ \quad (0.24) \qquad\qquad (7.64) & SE = 2.60 \\ \quad 41.36 \qquad\qquad 5.06 & t_{\alpha=0.05} = 2.03 \\ & F = 5636.7 > F_{\alpha=0.05} = 3.28 \\ & N = 35 \end{array} \qquad \text{(C-16)}$$

Equation C-17 represents Table VII-1: Model of Daily Attacks

$$\begin{aligned}
&\textit{Daily Attacks} = 3.20e-07 B_{CAS}{}^{2} - 0.00465 B_{CAS} + 0.00394 R && R^2 = 0.96 \\
&\qquad (5.6e-08) \qquad (0.0017) \qquad (0.00071) && SE = 16.6 \\
&\qquad (5.71) \qquad (-2.67) \qquad (5.52) && t_{\alpha=0.05} = 1.71 \quad \text{(C-17)} \\
& && F = 370.06 > F_{\alpha=0.05} = 4.07 \\
& && N = 44
\end{aligned}$$

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
11-16-2007	Doctoral Dissertation	Sep 2004 – Dec 2007

4. TITLE AND SUBTITLE Modeling and Analysis of Resolve and Morale for the 'Long War'	**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Artelli, Michael, J., Major, USAF	**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way WPAFB OH 45433-7765	**8. PERFORMING ORGANIZATION REPORT NUMBER** AFIT / DS / ENS / 07-02
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Edwin J.Offutt, Lt Col, USAF USCENTCOM J8-ARB 7115 South Boundary Blvd MacDill AFB, FL 33621-510	**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
In *The Art of War*, Sun Tzu begins by stating: "War is a matter of vital importance to the State; the province of life or death; the road to survival or ruin. It is mandatory that it be thoroughly studied." Sun Tzu follow's this opening by stating five fundamental factors a commander must master to be successful in combat. The first of these factors is moral influence which Sun Tzu defines as "that which causes the people to be in harmony with their leaders, so they will accompany them in life and death without fear of mortal peril." In the face of the instant communication provided by satellites, 24 hour news media coverage, and other technological advances, this factor is even more relevant today.
This research provides an analytic framework, based on the principles of fourth generation operations, capturing the effects of will and resolve of the combatant and population. The strategic level model investigates the long term impacts of asymmetric conflict. These results are primarily measured in the socio-political arena rather than the military battlefield. The model developed in this dissertation remains a model of conflict and combat. However, some of the impacts from the political, economic, and informational instruments of power are represented in the model through the dynamic adaptation of public resolve and combat spirit. To paraphrase Sun Tzu, war is vitally important and must be studied. Therefore, this dissertation puts forth a means to model key aspects of conflict in the 'long war'.

15. SUBJECT TERMS
fourth generation warfare, system dynamics, public opinion, morale, global war on terrorism

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Richard F. Deckro, DBA, (ENS)
REPORT	**ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
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Standard Form 298 (Rev: 8-98)
Prescribed by ANSI Std. Z39-18