Re-Architecting the Battalion Tactical Operations Center: Transitioning to Network Centric Operations

by

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Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the
Massachusetts Institute of Technology
February 2007

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ABSTRACT

As the Army conducts transformation in the midst of an ongoing information driven Revolution in Military Affairs (RMA) and the War on Terror, it has realized the need to develop leaner, more agile, versatile and deployable forces. As part of its latest transformation to Brigade "Units of Action," the Army realized the need to improve the "tooth to tail" ratio of its forces and transferred from a Cold War "Divisional" force structure to one focused around more deployable and sustainable Brigade Units of Action. Ironically, this transformation to what is suppose to become a more lean and deployable force structure has produced larger and more heavily staffed battalion, brigade and division command posts. Despite introduction of the Army Battle Command System (ABCS), a system of digital systems that are intended to help speed up the Army's ability to transfer information, improve situational awareness, make decisions, and out "OODA" (Observe-Orient-Decide-Act) its opponents, in many aspects the Army has actually taken a step backwards.

The end result is that these larger command posts are becoming more hierarchical and bureaucratic, and are reducing the Army's ability to get ahead of the enemy's decision cycle. Platoon Leaders and Company Commanders in Iraq and Afghanistan constantly lament that "if they only had the information they needed 48 hours earlier," they could have captured the target. This study examines one small aspect of this tremendous problem, the architecture of the Battalion Tactical Operations Center (TOC). It analyzes the current information revolution, the contemporary operating environment, network centric warfare, other emerging Revolution in Military Affairs (RMA) concepts, and the current Battalion TOC configuration and doctrine. It then applies System Dynamics techniques and develops a set of heuristics to address the problem. The ultimate goal of this study is to develop a practical concept for an improved organization, structure and function of the command post.

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BIOGRAPHICAL NOTE

Nathan Minami is an active duty Army Captain currently working on a Masters of Science Degree in Engineering and Management as a prerequisite for subsequent assignment as an Instructor in the Systems Engineering Department at the United States Military Academy at West Point. He is a combat veteran who served as an infantry officer in multiple command and staff assignments around the world including Macedonia, Kosovo, Iraq and Germany.

Captain Minami most recently served as Commander, Bravo Company, 1st Battalion, 14th Infantry Regiment in Iraq and at Schofield Barracks, Hawaii. Previously, he served as the Assistant Operations Officer for the 2nd Brigade Combat Team, 25th Infantry Division, and as the Assistant Chief of Training and Assistant Chief of Exercises, G3, 25th Infantry Division, Hawaii. Other assignments include Rifle Platoon Leader, Company Executive Officer, Scout Platoon Leader, and Battalion Assistant Operations Officer in the 1st Battalion, 26th Infantry Regiment, in Schweinfurt Germany.

Captain Minami is a graduate of the Infantry Captain Career Course, the Combined Arms and Services Staff School, the Scout Platoon Leader Course, the Bradley Leader's Course and the Infantry Officer Basic Course. His awards and decorations include the Bronze Star Medal for service in Iraq, Meritorious Service Medal, Army Commendation Medal, the Army Achievement Medal, the Airborne Badge, the Air Assault Badge, the Ranger Tab, the Expert Infantryman's Badge, and the Combat Infantryman's Badge.

Captain Minami graduated in 1997 from the United States Military Academy with a Bachelor of Science Degree in Arabic and French Language. He also holds a Masters degree in National Security Studies with a Middle East Concentration from the American Military University and this work completes the requirements for his Masters of Science in Engineering and Management from the Systems Design and Management Program at the Massachusetts Institute of Technology.

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ACKNOWLEDGEMENTS

Boston, Massachusetts Nathan A. Minami

January 10, 2007

First, I would like to thank Dr. Donna Rhodes, my supervisor, for her patience, insight, and constant guidance during this research. She is a superb mentor.

SDM '05 alumni Kevin Brown helped me immeasurably by providing initial guidance and directing me to key sources that have proven invaluable in this study. I relied heavily on his thesis as a blueprint or architecture for my own. SDM Director Pat Hale has also provided great mentorship throughout this process that has helped me to focus my studies.

I would also like to thank Major Dan McCarthy, Phd Student at MIT and Assistant Professor at the United States Military Academy. His hours of patient mentorship in teaching me the complexities of System Dynamics and assisting me with my model were invaluable, and contributed greatly to my learning. Additionally, Lieutenant Colonel Michael Kwinn, Associate Professor at the United States Military Academy, proof read my draft products and provided critical analysis of my work. I am grateful for his continued support and mentorship throughout this process. Also, I would be remiss if I did not recognize and thank my long time mentor, Lieutenant Colonel (Ret) Thomas Moore, Professor of Physics at Rollins University, for his continued friendship, mentorship, and critical analysis of my concepts, models and work.

Finally, and clearly most important, I am grateful for the continuous love and support of my family; my beautiful wife Melissa, and my wonderful children Selina and David. They are my inspiration.

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PART I - Background / Literature Review

Chapter 1: Introduction

> "There is a rank due to the United States among Nations, which will be withheld, if not absolutely lost, by the reputation of weakness. If we desire to avoid insult, we must be able to repel it; if we desire to secure peace, one of the most powerful instruments of our rising prosperity; it must be known that we are at all times ready for war."[1]
>
> - President George Washington (December 3, 1793)

America's founding fathers stood for the principals of peace, individual liberty, freedom, and the pursuit of happiness. Yet, having fought in the brutal Seven Years War and the American Revolution, President Washington realized that ironically America could not become the "beacon on a hill" for the world and reject the war prone politics of Continental Europe without maintaining a strong military. Unfortunately, over the last 200 years few American leaders demonstrated the remarkable foresight of its first president. Instead, most American presidents allowed the military to languish between wars, for which Soldiers consistently paid a high price at war's onset. Indeed, other than the 1991 Persian Gulf War, it is hard to think of a single war in American history for which the U.S. was well prepared. This is a result of many factors, including Americans' inherent hatred for war, an idealistic nature and belief that Americans are "above" war, as well as the military's over reliance on past success and inability or lack of initiative to evolve and prepare for the "next" war. The motivation for this paper is based on the desire to help change this historical trend.

Section 1.1 - Define Concern/Question

As the current wars in Iraq and Afghanistan clearly demonstrate, the United States and the remainder of the world are undergoing a complete and total change in "how" wars are fought. The U.S. victory in the Cold War, the lack of a peer competitor, the information age and the unrivaled superiority of U.S. conventional forces produced a remarkable change in the primary threats and threat tactics, techniques and procedures that will be employed against the United

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[1] President George Washington's Fifth Annual message to Congress, Philadelphia, December 3, 1793: ***George Washington Writings***, edited by John Rhodehamel, (New York: The Library of America, 1997), page 848.

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States in the future. The military as a whole, and the Army in particular, has undertaken great efforts to study this new threat and the impact of the information age on war, and to transform into a more modular and deployable organization. Nevertheless, as this study will show, more analysis and improvements are needed. Adding technologies and making minor changes to existing organizations and command and control networks is not enough. A deeper analysis of the current information revolution shows that the impact of information age technologies is so significant that it is likely to have as great an impact in how to optimally organize and equip units for war as the Gunpowder Revolution had over 500 years ago. Social, economic and political changes are also responsible for these changes in the art and science of war, all of which will be addressed in this study. More importantly, this study will show that not only are changes in organization and equipment needed, but rather a completely new framework for command and control and the management of information is needed if the Army is to reap exponential benefits from the power of the information revolution. This means unshackling itself from the current stove-piped hierarchy, increasing the experience level of leaders at lower levels, "flattening out" current command and control architectures, leaning tactical command posts, and much more.

Section 1.2 - Define Scope/Goal

The primary goal of this paper is to provide heuristics that will guide the development of an improved architectural concept for the Battalion Tactical Operations Center (TOC) and an enhanced command and control system for the overall Brigade Combat Team (BCT). See Figure 1-1 for a simplified BCT Command and Control (C2) Architecture showing the interactions between the BCT TOC, the Battalion (BN) TOC, and the Company Command Post (CP). A secondary goal is to initiate wider discussion on reform in the United States Army as it applies to the tactical level of war, at the level of the BCT and below, and focused around the BN TOC. Specifically, it will address the question of why the Army is not leaning its staff organizations concurrent with leaning of combat and support forces and will clearly articulate the need to reverse this trend. In the end, this study is meant to provide helpful recommendations to Army leadership that will help improve policy making in the field of Command and Control.

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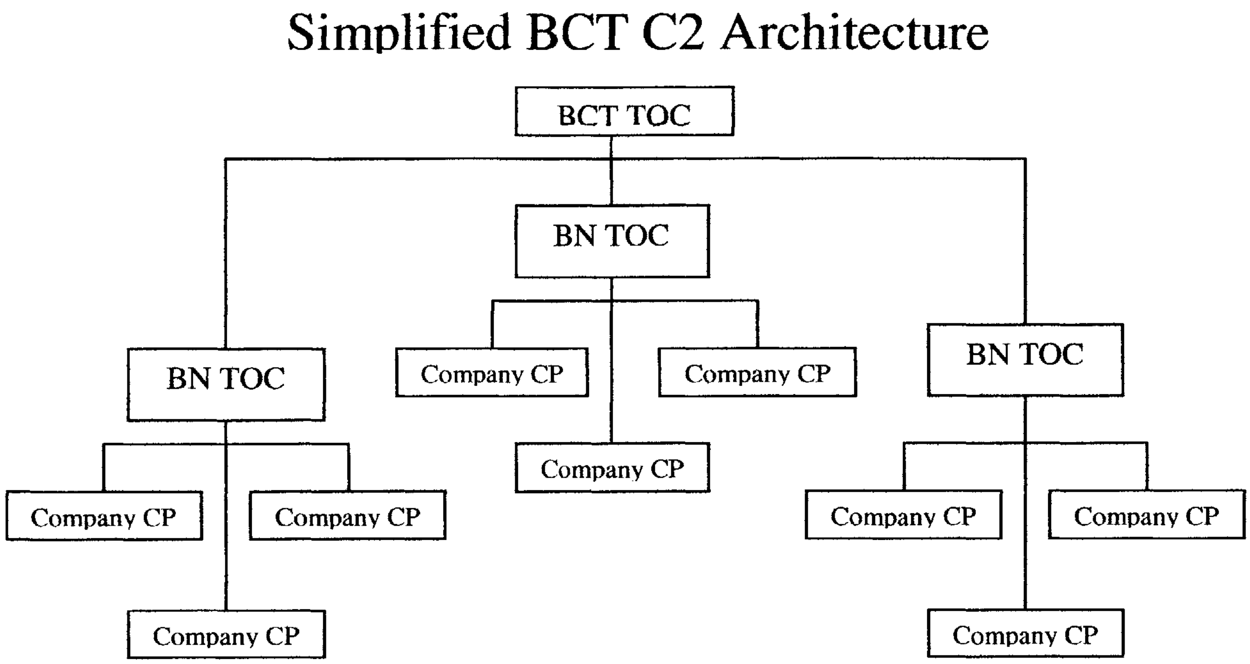

Figure 1-1 Simplified BCT Hierarchical C2 Architecture

Consequently, the scope of this study is to focus primarily at the Battalion level, while also addressing aspects of Platoon, Company and Brigade organization as their interactions with the Battalion level are paramount to its success. This paper will produce heuristics for two new architectures. The first is for the internal architecture of the BN TOC focusing on improved information flow, with a second "external" architecture showing how the BN TOC can better communicate (transfer and use information) with both its platoons and companies and its "higher" Brigade headquarters. Therefore, an implied objective of this study is to also propose a concept that will lead to an improved BCT command and control architecture.

Section 1.3- Project Description/Method

This study will integrate a number of emerging theories and methods. First, the literature review will examine the Contemporary Operating Environment (COE), which is the still relatively new term used for the emerging theory or "template" of current and future threats. Both COE theoretical concepts and actual events exhibited on the battlefield as part of the War on Terror and conflicts of the 1990s will be

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examined. After addressing the COE, the literature review will examine what constitutes a Revolution in Military Affairs (RMA) by assessing the implications of historical RMAs on the art and science of war. Next, it will address extensively the emerging theories of Network Centric Warfare (NCW) and Effects Based Operations (EBO) which stem directly from observations of the impact of the current information revolution in the civilian sector. Finally, it will review the impact of current Army transformation and the current command and control architecture and organization of the Battalion TOC. Once this extensive literature review is complete a detailed definition of the problem will be postulated.

Next, System Dynamics theory and techniques will be used to examine the impact of current Army policies on the application of command and control at the tactical level of war, and to derive an optimal set of policies or heuristics that the Army might consider for use in optimizing its command and control networks. Ultimately, it is expected that this combination of theories and methods applied to the problem of command and control will show that not only is a new architecture needed, but cultural change is also quintessential to organizational and technical change.

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Chapter 2– The Contemporary Operating Environment

> "Know the enemy and know yourself; in a hundred battles you will never be in peril"[2]

This classical quote by one of the greatest military philosophers of all time, Sun Tzu, clearly highlights the importance of detailed analysis of enemy, friendly, and environmental situations prior to undertaking military operations. Consequently, this study begins with a detailed review of the current threat context, asymmetric warfare, an assessment of U.S. strengths and weaknesses, and a review of threat developments during the last 15 years of warfare.

Section 2.1 – Threat Context

First, it is important to understand what constitutes a threat. What are the driving factors behind world turmoil? What is the "traditional" American view in understanding and preparing for "the threat?" After answering these questions, it is also critical to understand the diverse nature of historical threats in warfare.

Section 2.1.1 – World Instability

> "During the next twenty years, U.S. joint forces will operate in a geostrategic environment of considerable instability, driven by significant demographic, geopolitical, economic, and technological dynamics...This will create a geostrategic environment of friction as cultures, religions, governments, economics and people collide in a highly competitive global market."[3]

Indeed, the world is becoming increasingly unstable and less orderly each day. Some of the key sources of global instability arise from demographic indicators such as an exponentially increasing world population that will reach 8.2 Billion by 2030, a growing wealth distribution chasm where the richest 5% of the world have incomes that are 114 times greater than the poorest 5%, and a growing elderly population that will exceed 2 Billion people over age 60 by

[2] Griffith, p. 84. Sun Tzu clarifies in his classic work ***The Art of War*** that the superior general carefully analyzes the situation with regards to both friendly and enemy forces before deciding to undertake battle. Sun Tzu clarifies which military actions (primarily to defend, withdraw or attack) will be most successful in a variety of different relative situations between friendly and enemy forces.
[3] USJFCOM, p. 8.

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2030.[4] Exacerbating this problem is the fact that a majority of the world community still lacks basic health care. This coupled with rampant outbreaks of both new and old infectious diseases such as tuberculosis, malaria, hepatitis and AIDS is creating an alarming health crisis in the developing world. All of this is increasing the perceived chasm between the West and developing states. In addition, growing international crime syndicates and ideological and ethnic strife are also producing increased turmoil in the world. Samuel Huntington in his highly acclaimed 1996 best seller *The Clash of Civilizations* supports this idea by showing that the majority of the world views Western culture as materialistic, corrupt, decadent and immoral. According to Huntington, they also see the West as arrogant, materialistic, repressive, and brutal; and that this view is not held only by fundamentalist imams but also by citizens of many countries that the U.S. considers "close allies."[5] All of these factors, as well as a decrease in the availability of natural resources are likely to increase world conflict in the 21st Century.

Section 2.1.2 – The "Traditional" Threat

The "traditional threat" is what America prepared to fight against over the past 225 years. This "traditional" or symmetric threat for which the U.S. historically organized, equipped, and trained its military is based on the traditional European style of war, and envisions an enemy with a Navy, Air Force, and Army that will organize, equip, train, and employ itself in terms of doctrine, tactics, and strategy in a manner that mirrors the U.S. This trend originated immediately following the American Revolution as a result of U.S. fear of European domination and involvement in the Western Hemisphere and a desire to detach itself from European power politics. In the 20th Century this trend continued as a result of American involvement in the First and Second World Wars as well as the Cold War. But, as will be seen, this historical approach towards preparing for war was often faulty. In addition, the evidence discounts the idea that if the United States organizes and trains for the traditional threat, she can easily fight and win other types of wars.

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[4] USJFCOM, p. 9-14.

[5] Huntington. Read Samuel Huntington's book ***The Clash of Civilizations*** for a detailed explanation of how global forces are at work that are increasing the chasm between the West and the rest of the world. Huntington's work supports the theory that the world is becoming more fragmented and regional in nature. This counters other contemporary theories proposing that the world is becoming more uni-polar as a result of globalization.

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Section 2.1.3– Historical Threats

Throughout its history America consistently prepared for the "traditional" threat, yet on more occasions than not, actually fought against an enemy that was very different. Indeed, America faced a number of diverse threats over the last 225 years. First, America engaged in a number of symmetric wars. These include the American Revolution (although the colonists used both a combination of symmetric and asymmetric methods to win), the Mexican-American War, the Civil War, the Spanish-American War, the First and Second World Wars, the Korean War, and the Cold War. All of these conflicts can be viewed as largely symmetric struggles against an enemy that organized, equipped, trained, and employed itself in a manner similar to the American Army. However, there were many more wars and conflicts in American history that took a more asymmetric form. These included conflicts with the Barbary Pirates in the early 19th Century as well as conflicts with America's own rebelling citizens over taxes in the late 18th Century and early 19th Century. Also included is an exhaustive list of Indian Wars from the time well prior to the American Revolution until the late 1800s. In addition, American military action against the Boxer Rebellion and the Pilipino insurrection at the turn of the Century, as well as American involvement in Costa Rica, Panama, and a number of other Central and South American countries in the 1930s were all asymmetric conflicts. Asymmetric conflicts during the second half of the 20th Century include the Vietnam War, the 1989 invasion of Panama and the 1992-1993 conflict in Somalia. Naturally, the War on Terror should also be included. All of these conflicts can be summarized as asymmetric struggles against an enemy that organized, equipped, trained, and employed itself in a manner that was very different from the U.S. military.

Section 2.2 – Asymmetric Warfare (The Enemy Situation)

> "Future Threats will not confront us head on, but will attack us asymmetrically avoiding our strengths-firepower, maneuver, technology-and come at us and our partners the way the insurgents do in Iraq and Afghanistan."[6]

[6] Petraeus, p. 2. In his article ***Learning Counterinsurgency: Observations from Soldiering In Iraq***, Army Lieutenant General Petraeus asserts that future threats to the United States and its Coalition partners will mimic the current insurgency in Iraq and Afghanistan. Petraeus then articulates the "14 observations" or heuristics he believes are most important for fighting and winning in this "new" battlefield environment.

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Historically, while America's failure to prepare sufficiently for asymmetric threats often led to difficulties early on in a conflict; in most cases America was able to win the struggle by superior military forces and a dominant ideological position. Indeed, Vietnam and Somalia are the only two examples of asymmetric conflicts where America was not successful. However, the advent of the information age is producing a proliferation of new technologies that gives asymmetric threats an exponentially improved list of capabilities that can potentially cause catastrophic consequences for the United States. Therefore, the following review of the asymmetric threats that exist today, and particularly understanding which threats the Brigade Combat Team and the battalion TOC will most likely face, is vital to this study.

Section 2.2.1 – Driving Factors

Asymmetric warfare methods are used when a weaker state or actor is not capable of matching its enemy in a symmetric or traditional manner. Asymmetries arise from a number of factors, but may include differences of interest, will, values, strategies, tactics, technologies, capabilities, organization and time.[7] For example, a comparison between Al Qaeda and the United States shows a clear asymmetrical relationship between the two actors in all of these areas. In contrast, in the future potential peer competitors might also employ asymmetrical means against America despite symmetric conventional military strategies, tactics, technologies, capabilities and organization. The reason why a future war with an emerging peer competitor might take asymmetrical form is a direct result of potential differences in the realms of ideology, interests, will and values.

Section 2.2.2 – Types of Asymmetric Threats

There are three primary types, or categories, of asymmetric threats. The Brigade Combat Team and the Battalion TOC will likely play an important role in operating against all three of these categories of threats, and many of their sub-types, in the 21st Century. Specifically, the BCT will play a dominant role in future irregular warfare scenarios and most likely a supporting role

[7] Potts, 247-251. Potts asserts that the primary "types" of asymmetry are of interest, of will, of values, of strategies and tactics, in technologies and capabilities, in organization, and of time.

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to Special Operations Forces (SOF) and other governmental agencies (OGAs) when the U.S. is faced with Catastrophic and Disruptive Threats. These three asymmetric threat types include:

a) Irregular Warfare: Irregular warfare has been around since the beginning of times. Subtypes of Irregular Warfare include terrorism, guerilla warfare and insurgency. The goal of irregular warfare is to erode a larger or stronger actor's ability, power, and desire to maintain the struggle over a long period of time. Larger objectives of irregular warfare normally include regime change, expulsion of an occupying power, or obtainment of another political objective that the weaker actor can not obtain through normal political channels or "traditional" warfare techniques. Examples of Irregular Warfare in history include the Jewish Zealots' rebellion against the occupying Roman Army in the 1st Century B.C.; the French Revolution against Louis XVI and the *Ancien Regime* in the late 18th Century, Spanish guerilla warfare against Napoleon's occupying troops in the early 19th Century, the Pilipino insurgency against the American Army at the turn of the century, underground actions taken against the Nazis in France, Yugoslavia, Poland and many other countries during World War II; the Algerian insurgency against French Occupation in the 1950s and early 1960s; and the Viet Cong's struggle against Japanese, French and American occupation during the 1940s through the early 1970s. As evidenced by the above examples, irregular warfare is not a new concept, yet it has been alarmingly difficult for the United States military to break away from the "traditional" approach so popular during the 20th Century and better prepare for irregular warfare.

b. Catastrophic: Catastrophic warfare techniques are relatively new as it was not until the 20th Century that technology allowed mass production of militarized weapons of mass destruction (WMD) as well as the proliferation of terrorism and "rogue" states. The closest historical example of catastrophic warfare techniques include burning of fields and other necessities in order to inhibit an opposing army's ability to operate or to starve a local population into submission. Coupled with this was the historical use of dead humans and animals to contaminate an enemy's water supply or to cause plague among a besieged population.

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c. Disruptive: Like irregular and catastrophic warfare types, disruptive warfare is not a completely new concept, however, the means of conducting disruptive warfare are now becoming more prolific as a direct result of the information revolution. Weak actors employ disruptive warfare techniques, usually derived from superior niche technology or a dominant position in a certain category relative to the stronger power, in order to obtain a relative advantage and ultimately to obtain a key political objective. Disruptive warfare techniques include biological warfare to intimidate a population, cyber warfare attacks against vital economic, political and military infrastructure, space war against satellites, ultra-miniaturization, directed-energy weapons, diplomatic blackmail, and cultural and/or economic war.[8]

Section 2.2.3 – Asymmetric Tactics, Techniques & Procedures (TTPs)

> "The enemy's plan is simple and effective: lure American forces into terrain where information age knowledge, speed and precision give way to the more traditional Warfighting advantages of mass, will, patience, and the willingness to die."[9]

Based off the analysis above, the following is a derivation of the most likely threat asymmetric tactics, techniques and procedures that will be employed against the BCT and the Battalion TOC in the foreseeable future.

a) Create mass casualties: The threat realizes that America's greatest weakness is its aversion to casualties. Thus, the enemy will seek to exploit this by causing mass casualties integrated with media opportunities that capture large numbers of American Soldiers dying on the battlefield.

b) Conduct Sophisticated Ambushes: As evidenced in Iraq and Afghanistan, the threat realizes that sophisticated ambushes conducted in an urban or highly populated area are the best technique for causing mass U.S. casualties while also maximizing the probability that they will be able to escape unscathed in the process. Sophisticated ambushes include use of multiple Improvised Explosive Devises (IEDs) and/or mines, and use of direct and

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[8] Henry, p. 13. In Henry's assessment of the 2005 DoD Quadrennial Defense Review, he shows that the "Historical Transformation Pattern" has now transferred from a traditional threat approach during the 20th Century to a new set of threats. He asserts that this will require "new strategic thinking" in the 21st Century. Henry claims that the "four dimensions" of the future threat are Irregular, Traditional, Catastrophic, and Disruptive.

[9] Scales, ***Urban Warfare: A Soldier's View***, p. 9.

indirect fire weapons such as assault rifles, machine-guns, rocket propelled grenades (RPGs), shoulder fired missiles, assault guns, mortars, artillery, and others. The threat may also integrate use of limited chemical and biological weapons in these attacks

c) Suicide Attacks: The threat will use suicide attacks in an attempt to inflict mass U.S. casualties. These attacks will include man carried suicide vests, vehicles laden with explosives, and aircraft rigged with massive quantities of explosives and fuel. It is also probable that suicide attacks will soon include delivery of weapons of mass destruction (WMD) such as dirty bombs, chemical and biological agents, and small nuclear devices.

d) Avoid defending fixed sites: The threat realizes that the BCT's superior organization, equipment, training and stand-off capability give it a tremendous ability to attack and seize both terrain and facilities. Therefore, the threat will not be terrain oriented, but will remain elusive and integrated with the civilian population in every aspect. Their safe-haven will be both everywhere and nowhere. The only time the threat will mass is when it thinks it can succeed in a major attack against a small unit of U.S. forces.

e) Use urban areas and other complex terrain to nullify U.S. standoff capability and technological superiority: The threat will use complex terrain and urban areas as cover and concealment to maximize their ability to surprise U.S. forces, maximize their possibility of escaping by melting back into the civilian population after the engagement, and to maximize the possibility of U.S. forces killing innocent civilians during the engagement.

f) Employ air and missile defense technology: While this has limited direct implications for the BCT and the BN TOC, it does mean that U.S. air superiority by bomber, fighter, attack aviation and unmanned aerial vehicle (UAV) platforms may not always be possible. The BCT and BN TOC currently rely on all of these; on fighters/bombers for close air support (CAS), on Army aviation for close combat attacks, deep attacks and for air-assault operations. The BCT also currently relies on aviation for logistics and reconnaissance operations and on UAVs for reconnaissance and surveillance. Because the threat will attempt to negate U.S. air superiority, the BCT and BN TOC must be prepared to operate in environments without air support.

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g) Cause U.S. Soldiers to over-react & kill civilians: The threat occasionally exploited this tactic to some success in Iraq and Afghanistan. Threat success in using sophisticated ambushes and suicide attacks is very frustrating for U.S. Soldiers and Marines, who often watch their comrades die in ambushes but rarely have the opportunity to close with and kill the enemy. This situation creates the propensity for the U.S. Soldier to "fire at something" in retaliation during an ambush, and too often this includes the well intentioned Soldier or Marine firing at innocent civilians. This has a tremendously negative impact on the affections of the local population towards U.S. forces. Thus, the more frustrated BCT Soldiers become, the more likely the threat will be able to exploit this tactic.

h) Media Operations: The Threat will use video cameras and surveillance to watch U.S. forces. This will include videotaping their own ambushes and attacks against U.S. forces, and monitoring U.S. patrols to see their interaction with the local population. Any footage that appears to show Americans in a negative manner, or that can be manipulated to do so, will be shown to the world community, Americans, and the local population as appropriate in an effort to turn popular support away from the U.S.

Section 2.2.4 – Battlefield Contiguity

> "The future threat will attempt to find and attack critical links, nodes, seams, and vulnerabilities in U.S. systems that offer the best opportunity to level the playing field."[10]

Unlike most "traditional" battlefields, the future battlefield where asymmetric enemies will be fought will be exceedingly distributed in nature. For example, the insurgency in Iraq is being fought across the entire country, but normally is focused in several non-connected areas. For example, in fall 2004 the insurgency was focused in the areas of Baghdad, Samara and Falluja. This changed in 2005, when the insurgency "moved" and focused more in areas south of Baghdad, in the west in Al Anbar province, and in the North around Mosul and Tal Afar. In the larger picture, Al Qaeda is being fought not only in Afghanistan and Iraq, but also in Saudi Arabia, Jordan, Europe, the U.S., the

[10] USJFCOM, p. 49.

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Philippines, and many other countries. The implications for the Brigade Combat Team and the BN TOC is that they will need to be more mobile, and conduct increasingly distributed operations that will require a robust Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) infrastructure. This may also require the BCT and the BN TOC to reassess traditional command and control relationships and institutional norms.

Section 2.2.5 – Threat Center of Gravity

Because the threat can not seize and hold terrain for a prolonged period of time, their safe havens will be ubiquitous and opaque. This means they will rely on the local civilian population to harbor them, which requires that their ideology or cause be accepted or at least make the population sympathetic or at worst neutral to them. Therefore, the threat center of gravity revolves around their ability to maintain their safe havens, which requires that the population remain unsympathetic to U.S., coalition and host nation forces. This is the threat's primary vulnerability, against which the BCT and BN TOC must focus their efforts.

Section 2.3– Understanding the Friendly Situation

After assessing the threat, it is now critical to examine the friendly situation in order to understand the relative relationships between the two entities upon which future decisions regarding force structure, organization, and manning might be made. This will also make it possible to draw some conclusions that will help design the best command and control architecture that will optimize information flow for the Brigade Combat Team and the Battalion TOC.

Section 2.3.1 – Full Spectrum Operations

The BCT will operate in an environment that increasingly requires them to conduct simultaneous full spectrum operations. Indeed, in Iraq and Afghanistan it is not uncommon for the BCT to simultaneously conduct defensive operations in one area, while conducting offensive operations in another, stability operations in a third area, and support operations in a fourth. Historically, the U.S. Army did not train its Brigades and subordinate units to do this. In the past, tactical units were usually able to focus on one operation at a time in a linear manner. For example, in

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World War II the 26th Regimental Combat Team (a predecessor to the modern BCT) conducted defensive operations during the Battle of the Bulge in December 1944, offensive operations into the heart of Germany from January until April of 1945, and then conducted stability followed by support operations after V - E Day. In contrast, future wars against increasingly asymmetrical threats will require the BCT's subordinate organizations to show increasing flexibility in an environment where they might conduct a humanitarian mission in the morning (support), a static security mission at the local governor's building in the afternoon (defense), and then raid an insurgent safe house in the evening (offense).

Section 2.3.2 – Joint, Combined & Interagency Operations

Asymmetrical threats, globalization and improvements in collaborative information sharing tools will require increasingly joint, combined and interagency operations. For example, in the war on terror, the majority of operations include integration of all four services (Army, Marines, Navy and the Air Force) as well as military forces from approximately sixty different countries. This Joint/Combined approach to operations is not necessarily new, but what is perhaps unique is the increasing level of integration. Historically, there was little integration between Army, Marines, Navy and the Air Force at the lower tactical levels of war. In Iraq, however, Air Force tactical air controllers operate with Army platoons, companies and Special Forces teams. It is also not uncommon to see Brigade Combat Teams that are task organized with both Army and Marine forces. Ironically, there is also increasing integration between land and sea forces. For example, Navy Seals and construction engineers are increasingly integrated with both conventional and unconventional Army units.

In addition, other governmental organizations (OGAs) will also integrate more into military operations. This is largely because the threat will often take on attributes of both an irregular, catastrophic and disruptive nature simultaneously. Al Qaeda and other terrorist organizations are an excellent example, and the boundaries between these attributes are also blurred. Therefore, other governmental organizations such as the CIA, NSA and many others, which bring expertise specifically in human intelligence collection where catastrophic and disruptive attributes of the enemy are present, are presenting an opportunity for enhanced collaboration between the military

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and OGAs. Consequently, the BCT and the BN TOC must be capable of operating in a joint and combined environment where seamless integration with OGAs is necessary.

Section 2.3.3 – Self Imposed Constraints and Limitations

> "We cannot assume that our enemies will abide by our own moral codes, indeed we should assume the contrary and expect them to ruthlessly exploit our own constraints and sensibilities."[11]

It is important to consider that Western society has imposed a number of critical constraints and limitations on itself as a result of societal changes over the past two centuries. American aversion to violence is a natural subsidiary of its traditional idealistic view of itself as a "beacon of democracy" for the world. Future enemies will take advantage of this "soft" nature and will operate outside "our own legal and moral constraints."[12] In addition, future threats will seek to exploit America's fear of collateral damage, fear of losing American Soldiers, and increasing resistance to the idea of killing the enemy. Consequently, the BCT will need to protect itself against this vulnerability and understand that the enemy will target this, specifically where "legal and moral constraints are involved."

Section 2.3.4 – Western Center of Gravity

Finally, it is important to understand what constitutes the West's center of gravity. One idea is that "America's vulnerable center of gravity is dead American Soldiers."[13] In Vietnam, however, it was not only dead American Soldiers that turned Americans' opinion against the war but also a lack of faith and trust in their military and a dwindling belief that the country was fighting a "just fight." Images of napalm being dropped on a twelve year old girl and the My Lai Massacre destroyed American confidence, faith and belief in its military. Consequently, the American population forced the politicians to end the war, thus forcing the U.S. military to pull out of Vietnam. Therefore, despite their inability to win a single major battle against U.S. military forces between 1964 and 1972, the North Vietnamese Army and the Viet Cong earned their victory by defeating the American people at home. Thus, America's center of gravity, against

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[11] Potts, p. 14.
[12] Potts, p. 13.
[13] Scales, ***Urban Warfare: A Soldier's View***, p. 9.

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which asymmetric threats will focus their efforts in the future, lies in the realm of first creating massive American casualties in as graphic a manner as possible then eroding America's confidence in its military's ability to fight and win a just war while "doing the right thing." Consequently, victory on the battlefield will not guarantee success for the BCT in the future, but rather, it must win its victories with as little bloodshed as possible, while protecting the force, and conducting itself in a manner that is unblemished despite detailed public scrutiny.

Section 2.4– Proof of Concept

> "Opponents will attempt to outpace the American response to their capabilities and present the US with a strategic fait accompli. Moreover, by threatening a war of attrition or the use of WMD to avenge battlefield successes by the Armed Forces, enemies will seek to eliminate [U.S.] political resolve."[14]

The following examples support the ideas asserted above, specifically that America will face an increasingly asymmetrical threat in the future. This does not mean that the "traditional" threat will no longer exist, but that the asymmetric threat will increase in terms of both its frequency and ability to inflict increasing damage against the BCT and the United States of America.

Section 2.4.1 – The 1990s

The fall of the Soviet Union and elimination of a clear "traditional" monolithic threat against the United States ushered in a new era. Since then, America's:

> "enemies have sought to evoke global criticism and weaken coalition resolve by exploiting American sensitivity about casualties and international aversion to collateral damage. Failing that, enemies have sought to reduce the vulnerability to coalition action through air defense, camouflage, concealment, deception, dispersal, mobility and hardened facilities."[15]

Numerous examples during the 1990s exist of this changing enemy threat. U.S. action against Somali warlords in 1993 is a clear case that shows a number of asymmetrical tactics used successfully against the United States in order to obtain the desired political goal, which was the withdrawal of American forces from Somalia. Somali war lords killed 17 Army Rangers and others in one day of fighting, and achieved this by using primitive but effective air defense

[14] MacGregor, p. 26.
[15] Bowie, p. 130.

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measures to shoot down two U.S. helicopters, exploited camouflage, concealment, deception and dispersal capabilities by operating amongst the civilian population and firing their weapons from behind innocent women and children. They exploited their ability to maneuver freely by not carrying weapons in order to appear as civilians to allow them to move freely, then picking up cached weapons at a new location which they used to engage U.S. forces. They also exploited mobility by using civilian "technical" trucks with 12.7 mm machine guns. Other examples of asymmetric tactics used against U.S. forces include drive-by shootings, sniper, and "rocket-man" attacks against U.S. forces in Kosovo, the ambush and capture of three U.S. Soldiers by Serbian Special Forces in Macedonia in early 1999, and multiple suicide bombings of U.S. embassies around the world.

Section 2.4.2 – The War on Terror

> "Afghanistan and Iraq show that the enemy understands and accepts our superiority at sea, air and space, and thus has chosen to challenge us at the tactical level...[and the] surest way to negate big-war technology is in complex terrain such as jungles, mountains and cities where junior combat leaders are forced to make decisions and take actions normally expected of much senior military officers.[16]

The current War on Terror is a clear example that supports the idea that the threat will increasingly employ asymmetric tactics against the U.S. A number of examples supporting this have already been discussed. Even if the U.S. proves successful in both Iraq and Afghanistan it is likely that the War on Terror will continue for some time to come. There are dozens of other terrorist organizations in addition to Al Qaeda against which the U.S. and the West will continue to battle. These organizations lacking a conventional military capability will have no choice but to use asymmetric tactics. In addition, there are a number of potential state actors that are likely to challenge the West in the near future, these include members of the "Axis of Evil" such as North Korea and Iran, but many others are possible.[17] These states will also be forced to use asymmetric

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[16] Scales, ***The Second Learning Revolution***, p. 37.

[17] Bush, p.3. In President George Bush's 2002 State of the Union Addressed, he suggested that Iraq, Iran and North Korea pose a national security threat to the United States and labeled them as the "Axis of Evil."

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tactics against the U.S. as their conventional military capabilities, even combined, are clearly incapable of standing toe to toe with the U.S. military.

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Chapter 3 The Information Revolution and the RMA

After a review of both friendly and enemy forces, it is critical to understand the impact that developing technology is having on warfare. In order to understand the impact of the current revolution in military affairs (RMA), a historical review and an examination of the impact that the information revolution is having on the civilian sector is important. Next, a review of the current military literature and new emerging theories deriving from this RMA is also critical. This will include a review of both Network Centric Warfare (NCW) and Effects Based Operations (EBO) theories, and will also include a quick review of the Army's current transformation plan and progress made to date.

Section 3.1 – Historical Context

Since the birth of civilization, man undertook organized warfare as a means of achieving political goals and solving disputes. Like man, war evolved considerably during the past 4000 years, changing in its form as a result of social, political, economic and technological advances, but never changing in nature. Indeed, these human advances caused a number of what many historians call Revolutions in Military Affairs (RMAs).

Arguably, there have been eight major RMAs throughout recorded history with the first two occurring in antiquity. First, the introduction of bronze metal working made possible the Greek Phalanx and the subsequent use of combined arms tactics by Alexander the Great. Greek domination during the Greco-Persian wars culminated in the Battles of Salamis and Plataea during the Persian invasion of Greece in 479 B.C. and Alexander's defeat of Darius at Gaugamela (Arbela) in 331 B.C.[18] Second, advances in iron working shortly thereafter led to the Iron Age and ultimately to the domination of the Roman Legion in war from roughly 202 B.C. until the fifth Century A.D. Third, the major RMA of the Medieval Ages derived from invention of the stirrup, allowing cavalry to dominate infantry for the first time. Thus, the medieval knight and castles dominated warfare until the gunpowder revolution ushered in the 4th RMA during the 15th Century. In 1494, Charles VIII used gunpowder enabled weapons such as the cannon and the arquebus to conquer Italy in less than a year. His trained arquebusiers forced the Italian

[18] Addington, p. 12-23.

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condottieri to fight from behind walls and castles, which Charles VIII's mobile cannon then easily demolished.[19] In doing so, Charles VIII showed that vertically constructed castles were no match for the power of the modern cannon ball, nor were mounted knights a match for the musket ball.

The gunpowder revolution led to wide scale unrestrained warfare as it no longer took tens of years to train a warrior, as the new weapons of the gunpowder era (mainly muskets and cannon) required relatively less individual training than the medieval knight or archer. This era ended at the end of the barbarous Thirty Years War which killed nearly 1/3 of the population of Germany alone, leading the members of the Treaty of Westphalia in 1648 to agree to future restrictions on war. This led to the fifth major RMA, instituted by social change, which led to the age of limited or dynastic war. The kings of Europe agreed not to attack each other's populations, but rather to attack armies only. They also agreed that in order to maintain the status quo (i.e. their collective thrones), future wars should be limited in nature. Thus, the period from the Treaty of Westphalia in 1648 to the French Revolution in 1789 was marked by few large battles, and primarily consisted of siege warfare. Thus, the art of fortifications in war advanced, most notably by Louis XIV's chief engineer, Sebastien Le Prestre Vauban.

The French Revolution in 1789 led to the rise of nationalism and allowed a state to harness the "passion of the people" for the first time.[20] Napoleon's creation of the *Levee en Masse* led to the first mass conscription army in history, and forced him to design a new level of organization and form of operational maneuver: the Corps system. As Napoleon's Armies were too large to move in one mass, he generally moved his Army in five to seven Corps sized elements on multiple axes, allowing his Army to live off the land (costing much less and allowing it to move faster) but to mass for battle when needed. This system was based on the heuristic of "march to the sound of the guns," which allowed Corps and Division commanders to synchronize their actions

[19] Addington, p. 74-75.
[20] Clausewitz, p. 89. Clausewitz noted that warfare is composed of a "paradoxical trinity-composed of primordial violence, hatred and enmity" which were controlled by the people, the commander and his army, and the government.

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without detailed prior coordination.[21] Advent of the rifle, followed by the machine gun and breech loading rifled cannon led to the seventh RMA, attrition warfare, which dominated from the American Civil War through the First World War. The eighth RMA occurred at the end of World War I, where the advent of mechanization, the tank, and the airplane led to the dominance of maneuver warfare which reigned throughout World War II and up until Operation Desert Storm in 1991. This led to the advent of the ninth RMA, that which we are currently experiencing, which is a direct result of the current information revolution. The focus of this current RMA is on new information age technologies such as the computer, GPS and the Internet. This is causing improvements in command and control and the availability and use of accurate, timely and relevant information in war. At the same time, however, it is also creating many new challenges such as information overload, bandwidth management challenges, and others.

Although the functions of command, control and information are the focus of the ninth RMA, all three of these functions were critical to success and failure in war since its inception. At the battle of Plataea in 479 B.C., the Persian Commander Mardonius had a poor view of the battlefield and was unable to exert command or control over his troops, resulting in a lack of maneuver space between his bowmen and his Asiatic troops that "rendered the bow-front rigid" and resulted in a "crucial blunder, which was to cost him the battle and his life."[22] Likewise, the Roman Army was able to defeat the Carthaginian Commander Hannibal during the Second Punic War because of superior information ability. After 10 years of ravaging the Italian Peninsula, Hannibal needed reinforcements. His brother Hasdrubal marched with roughly 10,000 men from Spain, over the Alps and into Italy like his brother had done 10 years earlier. However, the Roman Army intercepted a message regarding this advance, enabling the Romans to daringly split their forces, leaving a small covering force to watch Hannibal while a large portion of their Army went to defeat Hasdrubal at the battle of Mataurus in 207 B.C. Armed with this superior information ability regarding both friendly and enemy forces, Rome was able to defeat

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[21] Alberts, ***Understanding Information Age Warfare***, p. 28-29.
[22] Fuller, p. 49. Despite a three-fold superiority in numbers, the vaunted Persian Army was unable to defeat the inferior Greeks largely because Mardonius was not in a position where he could view the entire battlefield, nor was he in a position where he could control the marshalling of his troops.

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Hasdrubal's force to the man, making Hannibal's long term occupation of the Italian Peninsula untenable, and crushing his hopes of some day sacking Rome.

In the 20th Century command, control and information remained critical in warfare. Germany's ability to exploit all three components at the tactical level resulted in the creation of *auftragstaktik* (mission orders) during the First World War. This decentralized style of command and control subsequently allowed them to break the stalemate on the western front by developing infiltration tactics during World War I, and then developing mechanized Blitzkrieg tactics that allowed them to conquer all of Europe during the Second World War. However, Allied capture of the enigma machine from a German u-boat during the Second World War gave them a superior information position over the Germans, this coupled with superior mechanization and mass industrialization allowed the Allies to emerge victorious in 1945 despite superior German tactical skill derived from command and control.

Consequently, the great military philosophers throughout history have also touted the importance of command, control and information in war. In Sun Tzu's "Art of War" written over 2500 years ago, he clearly exerts the importance of these factors. He stated that "to control many is the same as to control few...This is a matter of formations and signals."[23] Sun Tzu realized that the ability to exert commander's influence by controlling the actions of combat formations, and to visualize the battlefield through superior information of both friendly and enemy forces was tantamount to success in war.

The renowned military philosopher Carl von Clausewitz also highlighted the importance of these concepts 200 years ago. In his *On War*, Clausewitz uses the concepts of *Fog* and *Friction* in war to demonstrate the importance of command, control and information in warfare. By *Fog*, Clausewitz referred directly to the lack of information in war, specifically, the commander's inability to visualize the battlefield in terms of the terrain, enemy and his own forces, particularly once battle is underway. By *Friction*, Clausewitz states that "Everything in war is simple, but

[23] Griffith, p. 84-91. Sun Tzu highlights the importance of command, control and information in war in his chapters on "Offensive Strategy" and "Energy."

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the simplest thing is difficult. The difficulties accumulate and end by producing a kind of friction that is inconceivable unless one has experienced war."[24] Clausewitz believed that Fog and Friction were the factors that inhibited a commanders' ability to exert command influence, control his combat formations, and manage information flow between units. Clausewitz believed that Fog and Friction were overcome by what he coined "military genius," and he weaved these concepts throughout his classical work *On War.*[25]

So, if command, control, and information have been critical components to success or failure in warfare since the beginning of man, then why has it taken 9 major RMAs and well over 2500 years for it to revolutionize the battlefield? Examples of past innovations that greatly enhanced command and control are the advent of couriers on horseback, signal flags, encryption and code breaking, telegraph, wireless radio, aerial reconnaissance and photography, radar, electronic warfare, satellites, and advances in navigation such as the magnetic compass and global positioning system.[26] While a few of these past technologies are still critical to the ninth RMA, none of them alone were able to produce a truly revolutionary change in command and control because one critical ingredient was missing: ***the network.***

Section 3.2– The Information Revolution

> "...technology is bridging the distances and providing the capability for individuals to be able to interact with each other in increasingly sophisticated ways, making it easier for individuals and organizations to share information, to collaborate on tasks, and to synchronize actions or effects."[27]

The information revolution is already well under way as evidenced by prolific changes that recently took place in the civilian sector over the past ten years. Although military innovation has not always followed civilian innovation in the past, the ninth RMA is being fueled almost entirely by innovation in the civilian sector. The following outlines the most significant aspects of the information revolution and the key implications for the Battalion TOC and the Brigade Combat Team.

[24] Clausewitz, p. 119.
[25] Clausewitz, p. 100-112.
[26] Office of Force Transformation, p. 23.
[27] Alberts, ***Understanding Information Age Warfare***, p. 45.

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The Information Age is significantly different from the Agricultural and Industrial Ages that preceded it. In the Agricultural Age, value was created by physical labor, first by man working the fields and then assisted by beasts of burden that turned mills, plowed fields, and provided transportation. The Industrial Age produced exponential increases in production of goods and led to a massive expansion of services as fewer humans were required to produce or manufacture basic needs such as food, clothes, and shelter. The focus of the Industrial Age was on optimization, but the new Information Age is clearly focused on innovation. Thus, its chief characteristics are new ways of creating wealth, a change in the nature and distribution of power, the increasing importance and compression of time which increases the tempo of human life, globalization, and exponentially increased complexity.[28]

The advent of the information age compressed times and distances to measures previously thought impossible by creation of a powerful "network." Data and information can now be shared instantaneously at an unlimited number of points around the globe at virtually little to no cost. This was made possible by a paradigm shift from platform centric computing to network centric computing. This concept of network computing is regulated by Metcalfe's Law which proposes that the "power" of a network is proportional to the square of the number of nodes in the network. Consequently, the power or payoff of "network-centric computing comes from information-intensive interactions between very large numbers of heterogeneous computational nodes in the network."[29] The following charts demonstrate the exponential benefits of network computing derived from Metcalfe's Law.

[28] Alberts, ***Network Centric Warfare***, p. 15.
[29] Cebrowski, p. 3.

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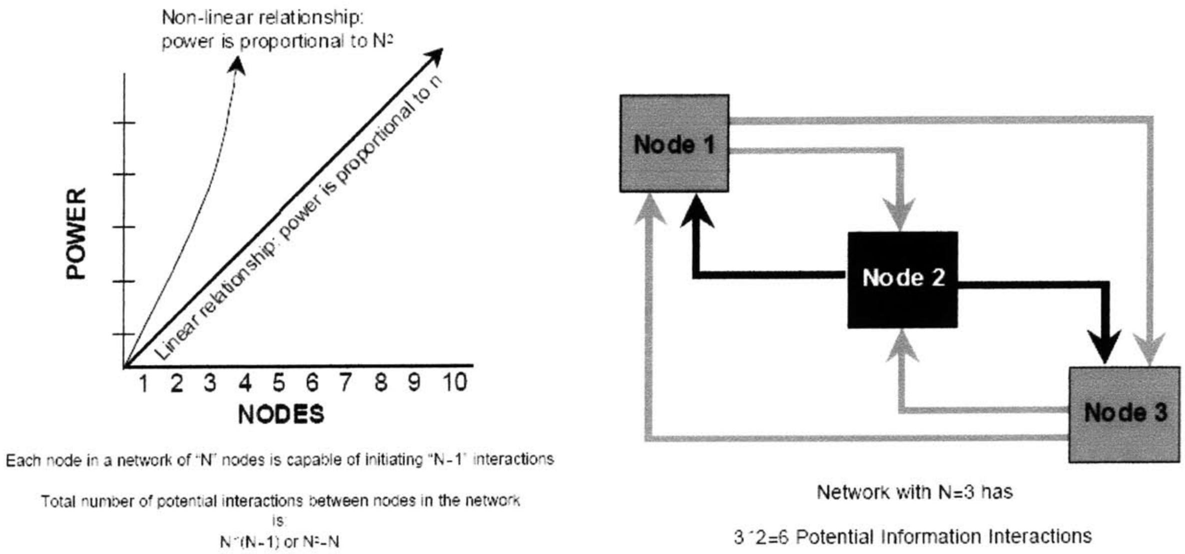

Figure 3-1 Metcalfe's Law[30]

Information Age enterprises that can harness the power of the network are able to achieve information superiority over their competitors and obtain competitive advantage. This is because network power allows for improved situational or shared awareness, superior collaboration capability without having to travel great distances, and "increased richness" by allowing "multi-source information to be shared, correlated, fused and accessed.[31]

Consequently, the power of the network allows for value creation in ways previously unimaginable. There is a tremendous amount of value created by the transfer of timely data and information over the network. A large amount of this is derived not just from the improved content and superior quality of information, but more importantly by the timeliness of information. Value increases exponentially as information reaches 100% relevancy, 100% accuracy, and without any measurable time delay. This produces information superiority.[32] The following chart describes how value is created in the Information Age.

[30] Alberts, ***Network Centric Warfare, p.33***.
[31] Alberts, ***Understanding Information Age Warfare***, p. 62.
[32] Cebrowski, p. 4.

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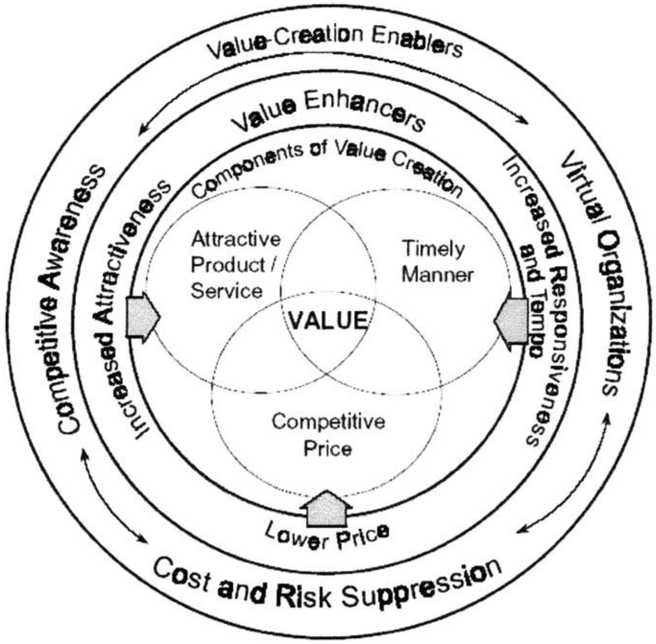

Figure 3-2 Value Creation Process[33]

A number of companies in several sectors have recently seen exponential growth as a result of their ability to harness the power of the network and create value. The following chart demonstrates how network centric enterprises harness the power of the network to achieve information superiority over their competitors to obtain competitive advantage.

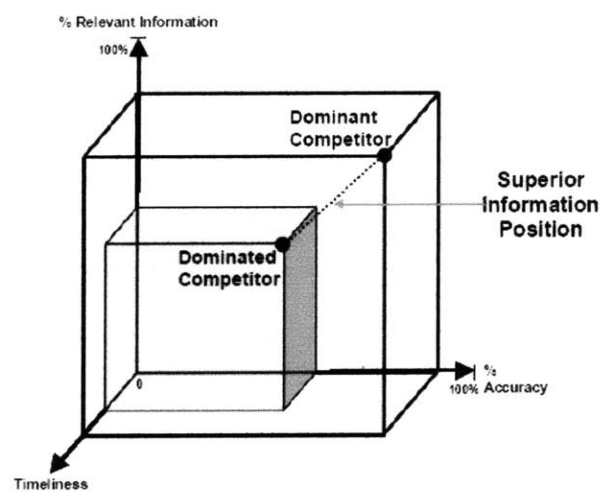

Figure 3-3 Superior Information Position[34]

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[33] Alberts, ***Network Centric Warfare***, p. 31.
[34] Alberts, ***Network Centric Warfare***, p.34. Chart is taken from page 34.

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The ability of companies to achieve a superior information position relative to their competitors allows them to achieve higher profitability not only through increased market share, but also by lowering costs. Indeed, network centric enterprises are able to shrink the size of their corporate headquarters, eliminate top heavy management, increase organizational flexibility, and improve their ability to downsize, reengineer, outsource and decentralize production, distribution and operations.[35] Walmart and Deutsche Morgan Grenfell are examples of two firms that have made the change to network centric operations and gained tremendous competitive advantages by "co-evolving their organizations and processes to exploit information technology."[36] Other examples include IBM who improved their ability to test software across time zones, Sun Microsystems who improved their 24-7 customer support worldwide, Boeing who was able to reduce the amount of scrap produced when building large aircraft such as the 777, and Dell which has been able to dominate computer sales by improving their process manufacturing.[37]

This review of the success in the commercial sector derived from the implementation of network centric operations suggests a number of important lessons that are relevant to the revolution in military affairs and the Brigade Combat Team. First is the idea that in the information age dominant firms can achieve product "lock-in" by being the first to produce a dominant design and obtain a superior information position in the market. Examples are the QWERTY key board, VHS over Beta Max, and WINTEL over Apple.[38] This suggests that the first military to achieve a dominant design standard for network centric operations might be able to achieve "lock-in" over rival militaries. Another key attribute seen in the commercial sector that will prove highly relevant for the RMA is the increased timeliness, richness and relevance of information that is derived from the network which ultimately allows for improved situational awareness and enhanced agility and flexibility. In addition, the empirical evidence suggests that network centric operations (NCO) will allow for the flattening of organizations and "the creation of virtual organizations that redefine the relationships within an organization," creating "edge organizations" that are characterized "by the widespread sharing of information and the

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35 MacGregor, p.26.
36 Cebrowski, p. 4.
37 Alberts, ***Network Centric Warfare***, p. 41.
38 Cebrowski, p. 3.

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predominance of peer-to-peer relationships" where those at the edge of an organization are empowered.[39]

Section 3.3 - Network Centric Warfare

"Network Centric Warfare is to warfare what e-business is to business."[40]

Network Centric Warfare (NCW) is comparable to the new economic model that will inevitably bring increasing returns on investment to the Department of Defense and the United States Army. By integrating the concepts and technologies dominating the current information revolution into a new theory and doctrine of warfare, the U.S. will be able to "lock out" asymmetrical and traditional enemy strategies while "locking in" success. NCW will accomplish this primarily by introducing revolutionary changes in the realm of command and control, predominantly by increasing the speed of command and allowing self-synchronization.[41]

Section 3.3.1 - Tenets & Principles

The theory of network centric warfare is maturing rapidly for two reasons. First, NCW is at the forefront of a number of books, articles and conferences about command and control and information warfare, allowing scholars to debate various concepts and allowing the theory to mature. Second, and more importantly, the War on Terror and rapid acquisition of mature technologies allowed a number of essential NCW critical technologies and concepts to be tested in a combat environment. Over the last five years, the following tenets of network centric warfare emerged and are largely accepted by most theorists:

- A robustly networked force improves information sharing
- Information sharing enhances the quality of information and shared situational awareness
- Shared situational awareness enables collaboration and self-synchronization, and enhances sustainability and speed of command
- These in turn, dramatically increase mission effectiveness.[42]

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[39] Alberts, ***Power to the Edge***, p. 176.
[40] DOD Report to Congress, p. iii.
[41] Cebrowski, p. 4.
[42] Office of Force Transformation, p. 7.

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In addition, several "governing principles" have also been accepted by the majority of NCW proponents (these do not replace the traditional Principles of War- Maneuver, Mass, Objective, Offensive, Economy of Force, Unity of Command, Simplicity, Surprise, and Security):

- Fight first for information superiority: Just as information superiority has become the prerequisite for competitive advantage in the civilian sector, the same will apply for NCW.

- Access to information- shared awareness: Situational awareness where everyone can see the friendly and enemy picture is critical to NCW success.

- Speed of command and decision making: Enabled by the network, this is a requirement for "getting inside of" the enemy's decision-making cycle and maintaining the initiative on the battlefield.

- Self-synchronization: Diffusing "power to the edge," gives subordinates both the information required and command flexibility needed to take initiative, creating a self-synchronizing force with optimal agility.

- Dispersed forces: non-contiguous operations. Forces will be able to communicate and operate across distances previously impossible.

- Demassification: Mass effects against the enemy, not forces.

- Deep Sensor Reach: Increases the engagement envelope and allows more decision making time.

- Alter initial conditions at higher rates of change: The ability for fragmentary order planning is increased so that the plan can be changed at any time without slowing the tempo of operations.

- Compressed operations and levels of war:[43] The continually evolving COE demonstrates that the shades are increasingly blurred between tactical, operational and strategic realms of war. NCW allows the networked force to integrate these levels in a translucent manner.

Ultimately, the combination of these tenets and principles provides NCW users (i.e. The Blue Force) with a superior information position vis-à-vis a non-NCW capable adversary (i.e. Red

[43] Office of Force Transformation, p. 8.

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Force). The chart below demonstrates how improved relevance, accuracy, and timeliness of information make this possible.

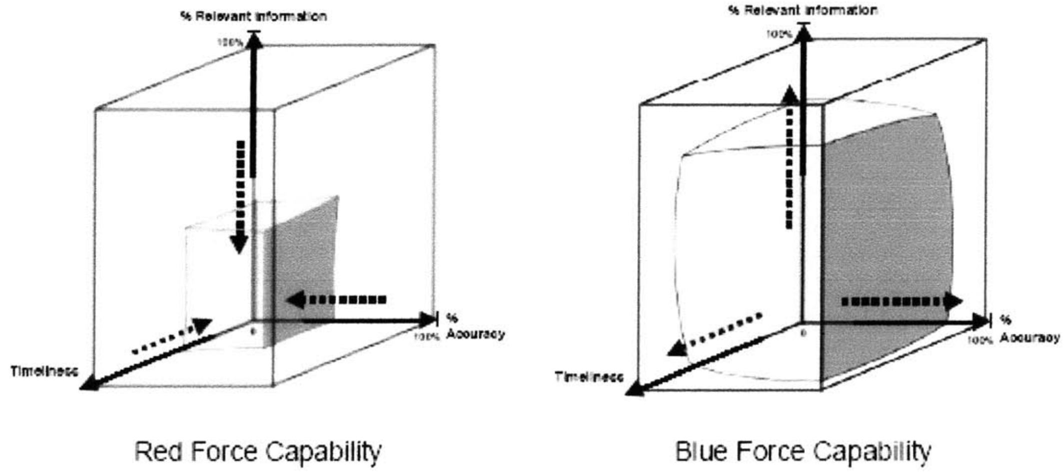

Figure 3-4 Superior Information Position Vis-à-vis an Adversary[44]

Section 3.3.2 – Key Technologies

A number of critical technologies are emerging from the information revolution making NCW theory possible. These include technologies such as network architectures, satellites, radio bandwidth, un-manned aerial vehicles (UAVs), un-manned vehicles (UVs), computer processor ships, nanotechnology, the global positioning system (GPS) and software. The most important technologies, however, are arguably internet, extranet, and intranet technologies that make networks possible, coupled with ever increasingly powerful computer chips. Moore's Law explains this phenomenon. It states that every 18 months computer chips become four times as functional.[45] This not only makes computers more powerful, but increases the ability of multiple computers operating on a network to collaborate by processing data into information in a timely manner.

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[44] Alberts, ***Network Centric Warfare***, p. 56.
[45] Wilson, p. 3-6.

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Section 3.3.3 – Domains of War

NCW theory argues that the power of the network lies in its ability to seamlessly integrate activities that occur in the physical, information, and cognitive domains, which produces a "New Mental Model" for understanding "information superiority" and "information advantage." The integration of these three domains allows for enhanced situational and shared awareness and self-synchronization, which allows the networked force to lock-out the enemy and use its information (decision) and execution advantages to obtain competitive advantage relative to the enemy.[46]

Traditionally, the command and control or decision process in military affairs has been thought of in terms of the OODA loop, also known as the "Boyd Cycle."[47] The OODA loop was initially drawn from aerial combat during the Korean War, but eventually it was realized that it applied to most other decision making situations outside of dog fights. The Boyd Cycle consisted of four steps: observe, orient, decide and act. The integration of these four steps into the three domains of NCW is shown in the chart below.

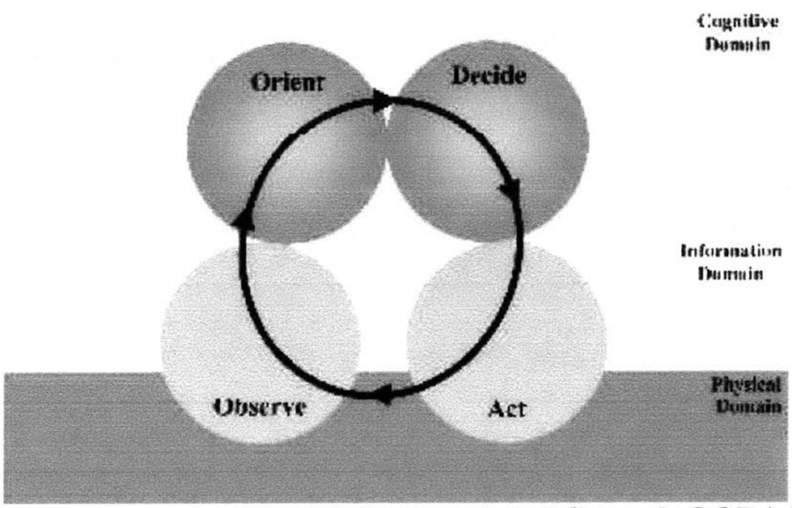

Figure 3-5 Traditional View of Command and Control: OODA Loop[48]

NCW theorists argue, however, that the Boyd Cycle is no longer the best model for thinking about decision making. They propose that the following model is more accurate as it better explains the decision making process in terms of the actual C4ISR process. In the past, most of

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46 Alberts, ***Understanding Information Age Warfare***, p. 72-76.

47 Hooker, p. 9. For more information on OODA concept, read Part I of Maneuver Warfare: An Anthology.

48 Alberts, ***Understanding Information Age Warfare***, p. 132.

the integration in the C4ISR process occurred solely in the information domain, where command and control centers such as Battalion and Brigade TOCs used information systems such as telephones and radios to transfer data between "battle space monitoring" and "battle space management." Today, new systems such as Blue Force Tracker (BFT) are allowing for increased information sharing in both the information and physical domains. The following two charts show this evolution.

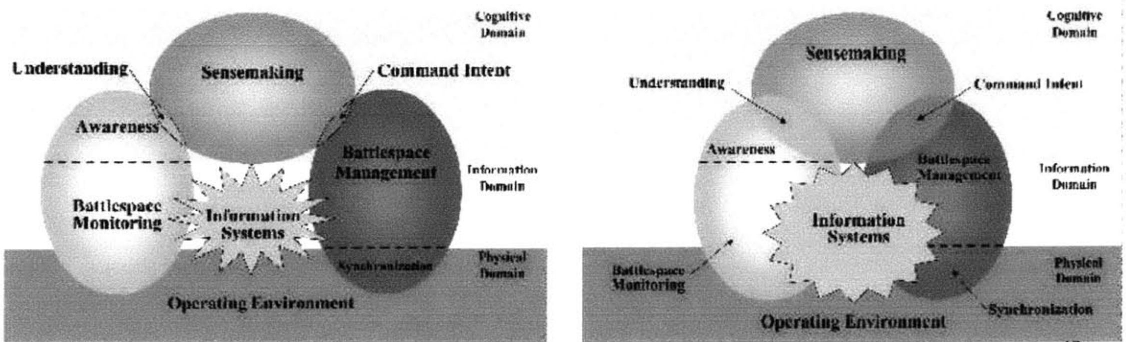

Figure 3-6 OLD C4ISR Process vs. Today's C4ISR Process[49]

NCW proponents argue, however, that the improvement of network centric warfare technologies and concepts will allow for the total integration of the C4ISR process, therefore decreasing the time it takes to make decisions by orders of magnitude and almost eliminating the decision making process. Ultimately, this explains how NCW improves speed of command and allows for self-synchronization. The following chart demonstrates this concept.

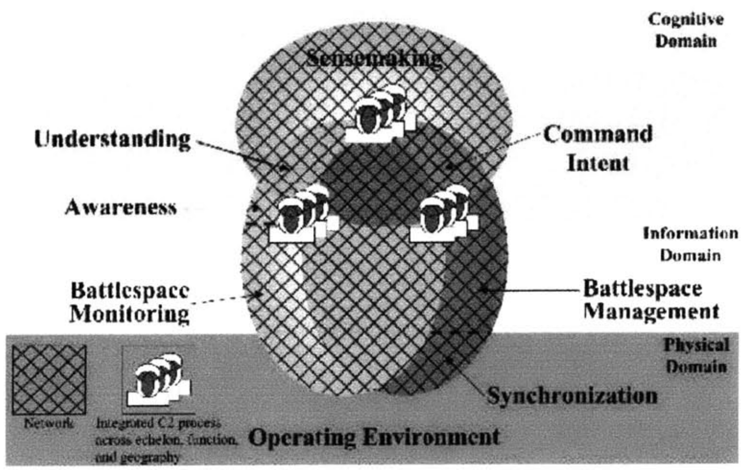

Figure 3-7 NCW Enabled C4ISR[50]

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[49] Ibid.

[50] Alberts, ***Understanding Information Age Warfare***, p. 158.

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Section 3.3.4 – Key Concepts of NCW

> "The command function is not absent in self-synchronized forces; however, it does depend on achieving congruent command intent, shared situation awareness, authoritative resource allocation, and appropriate rules of engagement, as well as similar measures that guide but do not dictate details to subordinates."[51]

The concept of self-synchronization is fundamental to network centric warfare. In order for self synchronization to become practical, the following assumptions are necessary: [52]

- Clear and consistent understanding of command intent
- High quality information and shared situational awareness
- Competence at all levels of the force
- Trust in the information, subordinates, superiors, peers, and equipment.

These assumptions require an extremely professional force of well trained and educated Soldiers, non-commissioned officers (NCOs), and officers. An additional concept central to NCW theory is the idea that massed effects are more important than mass of troops, which can be accomplished by a geographically dispersed force. This requires an improvement not only in information sharing capability but an improvement in weapons systems and sensors.

One of the most important concepts to NCW theory is an understanding of the roles of battlespace entities, which are comprised of sensors, actors and decision makers.[53] Traditionally, decision makers controlled a number of actors, and actors controlled a number of sensors. In this system, a sensor owned by a particular actor reported to that actor and that actor only, and an actor owned by a particular decision maker reported to that decision maker only. This reflected the stove-piped hierarchical system that was discussed earlier. NCW changes these relationships in a number of ways. First, it allows for the transfer of intelligence from any one sensor in the network to all of the actors and all of the decision makers in the network. This eliminates the need for stove-pipe sensor-weapon pairings, and disassociates the sensors and actors from the platforms that deliver them to the battlefield today. Consequently, NCW theorists propose that invention and development of a new array of sensors and actors are needed to take advantage of

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[51] Alberts, ***Power to the Edge***, p. 27.
[52] Ibid.
[53] Alberts, ***Network Centric Warfare***, p. 116.

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these new network enabled capabilities.[54] It is important to note that NCW theory does not "imply a free for all on the battlefield, but rather that all assets be employed more flexibly" allowing for a more agile force.[55]

The following charts demonstrate the differing roles and relationships between battlespace entities as contrasted between the late 20th Century and what will be made possible by 21st Century technologies.

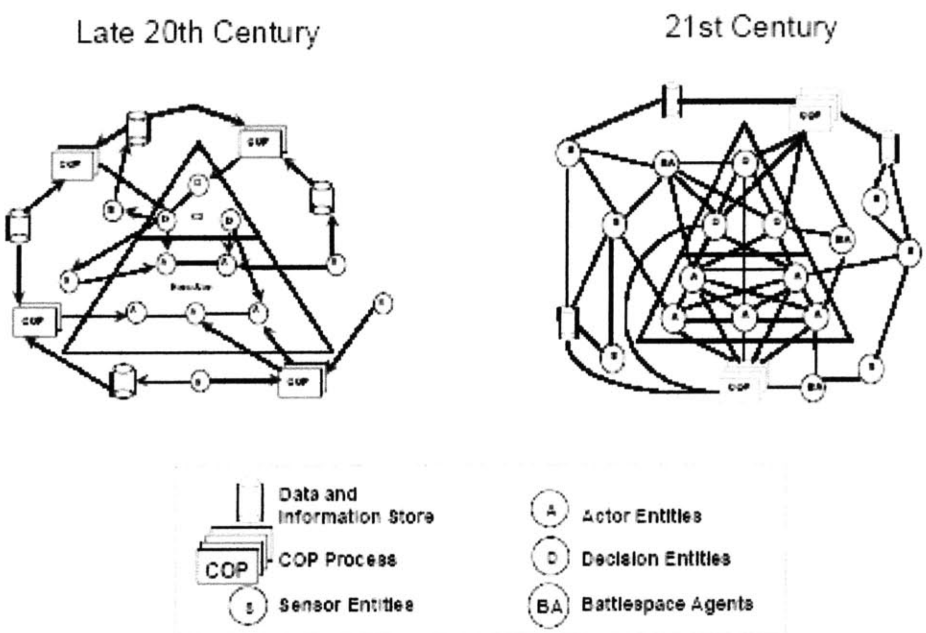

Figure 3-8 Roles of Battlespace Entities[56]

Further depicting the relationship between sensors, actors and decision entities, the following chart demonstrates the process interaction between sensors, shooters and decision makers in the network as envisioned by NCW theory.

[54] Alberts, ***Network Centric Warfare***, p. 65.
[55] Alberts, ***Network Centric Warfare***, p. 121.
[56] Alberts, ***Network Centric Warfare***, p. 125.

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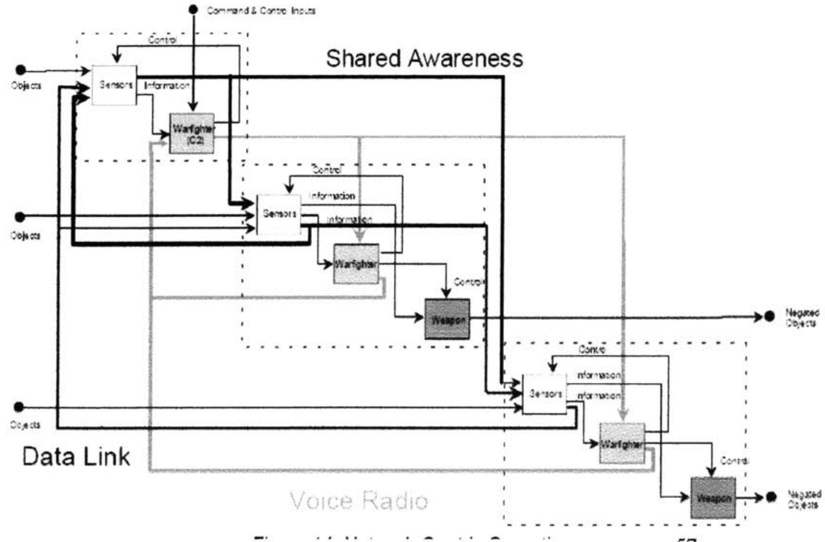

Figure 3-9 Network Centric Operations[57]

A final concept that is central to network centric warfare theory is the idea of how "value" is created from the network via self synchronization and improved decision making speed and effectiveness. Ultimately, value is added in terms of combat power by improving the engagement envelope collectively among weapon systems in the force. The traditional sensor-weapons system envelope is described on the diagram below.

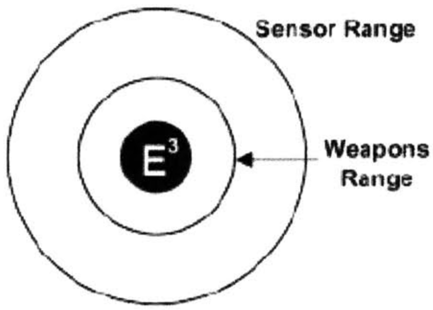

Figure 3-10 Platform Centric Engagement Envelope[58]

However, NCW theorists argue that when sensors and weapons are integrated together within a network, it produces an order of magnitude improvement in terms of engagement capability by pushing the engagement envelop out and geometrically increasing the "value-added combat

[57] Alberts, ***Network Centric Warfare***, p. 101.
[58] Alberts, ***Network Centric Warfare***, p. 97.

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power associated with a network-centric operation."[59] The following charts demonstrate this concept.

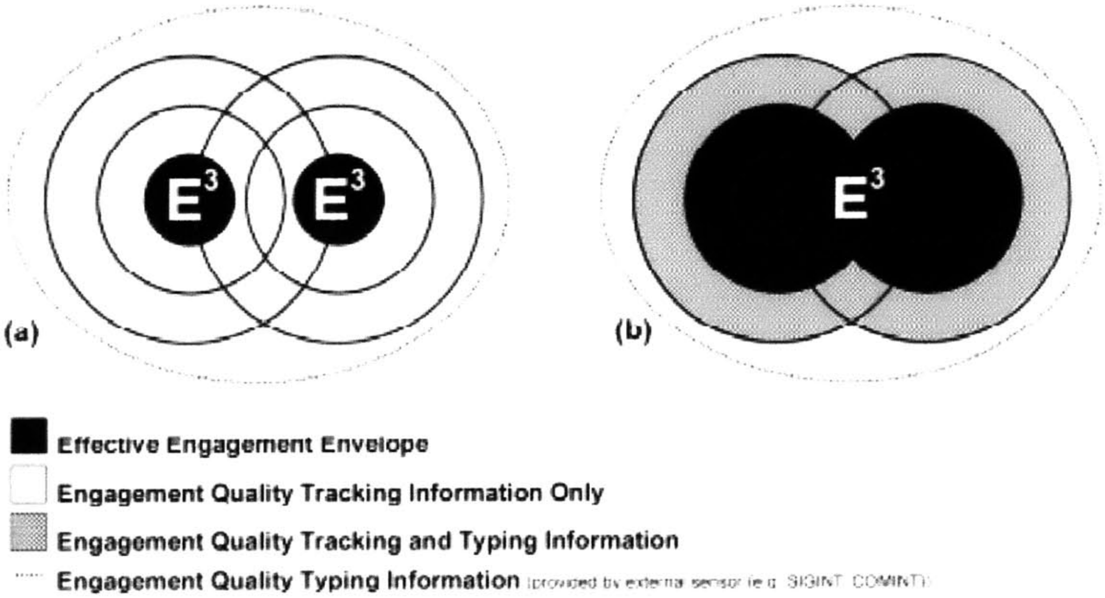

Figure 3-11 NCW Enabled Combat Power[60]

Section 3.3.5 – Other Emerging Concepts

Two other emerging theories that are not associated with the main stream collection of network centric warfare literature, but seem to support it are the Recognition-Primed Decision Making Model (RPDM) and Persistent Surveillance. The first addresses how to improve the current Military Making Decision Process (MDMP) and the second examines how to improve U.S. intelligence collection capabilities.[61] Both of these concepts are critical to network centric warfare because "Centralized planning is antithetical to agility because it is relatively slow to recognize and respond to changes in the situation, results in ill-informed participants, and places many constraints on behavior."[62] NCW theorists also acknowledge the need to improve integration between planning and execution into "one seamless process."[63]

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[59] Alberts, ***Network Centric Warfare***, p. 103.
[60] Alberts, ***Network Centric Warfare***, p. 102.
[61] Alberts, ***Power to the Edge***, p.63.
[62] Ibid
[63] Alberts, ***Network Centric Warfare***, p. 74.

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The RPDM is likely to provide a tool to help this. The traditional MDMP is a lengthy process, during which the staff goes through a long planning process that usually includes eight lengthy steps in which two or three courses of actions are developed, analyzed, and compared. The RPDM, however, relies on commander experience to recognize the situation and what course of action will be most effective. Then, based on early commander guidance, only one course of action is developed and analyzed. The focus of the staff is on maximizing the coordination and synchronization of elements within one course of action, thus decreasing planning time significantly. During testing at Fort Leavenworth, a staff using both procedures found that the RPDM is 30% faster than the MDMP.[64]

The concept of persistent surveillance is also being developed and it appears to hold a lot of promise in its ability to complement NCW theory. The concept of persistent surveillance is being driven by the War on Terror, during which existing intelligence collection systems, most of which were designed for "traditional" warfare, proved ineffective. Current systems allow for acquisition and tracking of a target for a period of time, but the target is usually lost as it maneuvers on the battlefield. This is particularly the case when tracking terrorists who wear civilian clothes and do not openly carry weapons, especially making it difficult to capture the financers and bomb makers who make terrorist and insurgent attacks possible. Naturally, persistent surveillance is much easier when tracking enemy aircraft, tanks, and ships. Therefore, persistent surveillance theorists are focusing hard on "how to" integrate "the human component and various technologies and processes across formerly stove-piped domains" in order to make "the targeted entity...unable to move, hide, disperse, deceive, or otherwise break contact with the focused intelligence system."[65]

Section 3.3.6 – Proof Of Concept

> "The direction of the current RMA points to a system of systems that encircles the earth. It will be critical for ground forces to integrate seamlessly into the global strike capabilities system...to exploit its potential and to guarantee the safety of those forces."[66]

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[64] Ross, p. 1.
[65] Pendall, 41.
[66] MacGregor, p. 27.

There have already been a number of "successful" tests that support NCW concepts. The following chart lists the tests/ studies of operations for which detailed "Network Centric Operations Case Studies" have already been conducted, initiated or planned by the Office of Force Transformation.

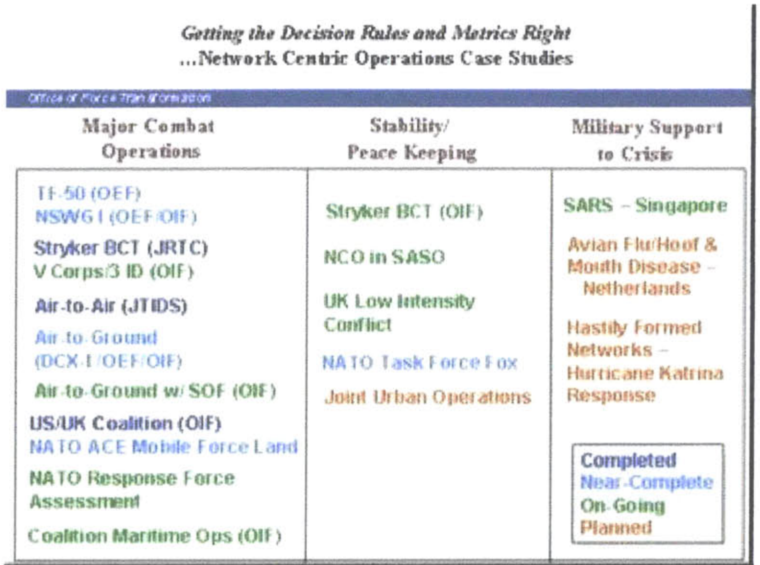

Figure 3-12 NCO Case Studies[67]

In addition, after action reviews from on going operations in Iraq and Afghanistan clearly demonstrate the successfulness of new technologies that are being fielded and tested. Of particular note are the FBCB2 and Blue Force Tracker (BFT) systems as well as the Command Post of the Future (CPOF) initiative, all of which allow for improved networking capability and therefore enhanced situational awareness.[68]

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[67] http://www.oft.osd.mil/initiatives/ncw/studies.cfm
[68] Tomlinson, p. 1-2. Tomlinson's article addresses the successful fielding and use of the first CPOF system in combat with the First Cavalry (CAV) Division in Iraq in 2004. The CPOF appears to have been highly acclaimed by all leaders in the 1st CAV.

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Section 3.3.7 – Potential NCW Pitfalls

It is important to note that some scholars have addressed concerns with current NCW theory. Two of these theorists include retired U.S. Army General William Wallace and Australian defense scholar Aldo Borgan. First, among General Wallace's concerns are the following: [69]

1) The amount of information envisioned in NCW may overwhelm the commander and staff;

2) The most critical and urgent information may be difficult to distinguish from trivial data;

3) NCW may encourage attempts to micromanage subordinate actions;

4) NCW concentrates too much on the science of control while neglecting the art of command;

5) NCW ignores the role of the commander.

Complementing General Wallace, Aldo Borgan asserts the following concerns:

1) Challenges with physical vulnerability of the infostructure required to support NCW & bandwidth.[70]

2) The challenge of distinguishing between the theory behind NCW and how it will actually and eventually be applied in practice.[71]

3) The challenge in applying the NCW concept to the ground is that "the land environment is far more demanding and complicated than the air and the sea and it is comprised of complex terrain such as cities, buildings, mountains, and jungles...Nothing NCW may promise will eliminate the probability of close combat between individuals remaining a fundamental factor in future warfare."[72]

A final concern is one that was raised in a CRS report for Congress, which recognized the possible use of technology to launch asymmetric attacks against NCW systems. These concerns included the use of directed energy devices to jam satellite signals and burn out computer circuits at a distance, as well as malicious computer code to subvert controls for complex weapons.[73] An

[69] Wallace, p. 3.
[70] Borgan, p.1.
[71] Borgan, p. 2.
[72] Borgan, p. 8.
[73] Wilson, p. 13.

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additional concern that was not directly addressed but should be included in this category is the potential use of electric magnetic pulse (EMP) weapons to destroy or temporarily disable all electrical systems on the battlefield.

Section 3.3.8 – Implementing NCW

There are also several "costs" involved with implementing NCW. First, NCW is deeply rooted in operational art, it is not possible to simply apply new technologies to the current platforms, organizations and doctrine; therefore organizational change is a prerequisite to network centric warfare. It also requires an infostructure that will allow for all actors to be on the network, and containing enough bandwidth for instantaneous, or near instantaneous sharing of information. Finally, it will require new systems that are NCW capable; this means a new fleet of ships, array of ground force systems and new aircraft with network centric systems in lieu of current platform centric systems. Consequently, it is clear that implementation of NCW as envisioned will cost money and take time.

Section 3.4 – Effects Based Operations

> "EBO enables us to apply the power of NCW not just to traditional combat, as many are inclined to do, but to go beyond kinetic means to consider means in the information and cognitive domains to create effects in the cognitive domain across the full mission spectrum in peacetime and crisis response operations as well as in combat."

The concept of effects based operations is strongly supported by NCW theory. Indeed, many Army leaders are already applying its concepts to ongoing combat operations in Iraq and Afghanistan. The following synopsis discusses the rise of EBO theory, its major concepts, and addresses some of its current applications in the War on Terror.

Section 3.4.1 – The Rise of EBO Theory

Although the Cold War and Operation Desert Storm validated the concept of traditional Air-Land battle, subsequent military operations in the 1990s demonstrated that this concept while successful for fighting a major theater war, did not provide the flexibility and depth desired for waging war against increasingly asymmetrical threats. Consequently, military planners in the

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mid-1990s expanded the Powel Doctrine and developed the concept of EBO. Planners realized that Clausewitz's traditional Trinitarian model where political aims are achieved by first defeating the Army, then occupying the capital to control the government, who would then force the population to submit no longer worked. Rather, with advent of nationalism wars are now won by controlling the population, who then tells the government to cease hostilities, and subsequently the government tells the military to stop fighting.[74]

Therefore, planners realized that war is more about eliminating the enemy's means and will to resist rather than defeating an opposing army in the field. This is not really a new concept; even America's great attrition wars (Civil War, WWI & WWII) were ultimately won by eliminating its opponents' desire and physical capacity to continue the war.[75] Consequently, American war theorists looked to the cognitive domain as the focus for a new war doctrine.

Section 3.4.2 – EBO Concepts

Official military doctrine defines effects based operations as "a set of actions planned, executed, and assessed with a systems perspective that considers the effects needed to achieve policy aims via the integrated applications of various instruments of power."[76] Another definition states that "Effects-based operations are coordinated sets of actions directed at shaping the behavior of friends, foes, and neutrals in peace, crisis, and war."[77] Regardless of which definition one prefers, EBO represents a clear paradigm shift from traditional thought. In attrition based warfare, symmetry of means and will existed between two opponents. In asymmetrical warfare, a state with great means is now at war with a state or actor with little means, and the state with little means usually has greater will than the state with great means. Consequently, the following formula is critical to EBO theorists:[78]

$$\text{The Probability of Success} = \text{Means} \times \text{Will}^2$$

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[74] Emery, 11-12.
[75] Smith, 20-24.
[76] Meilinger, p. 116.
[77] Smith, p. xiv.
[78] Smith, p. 30-39.

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Therefore, the "will" to fight is clearly more important in EBO than the "means." The following chart highlights some additional differences between attrition and effects based doctrines.

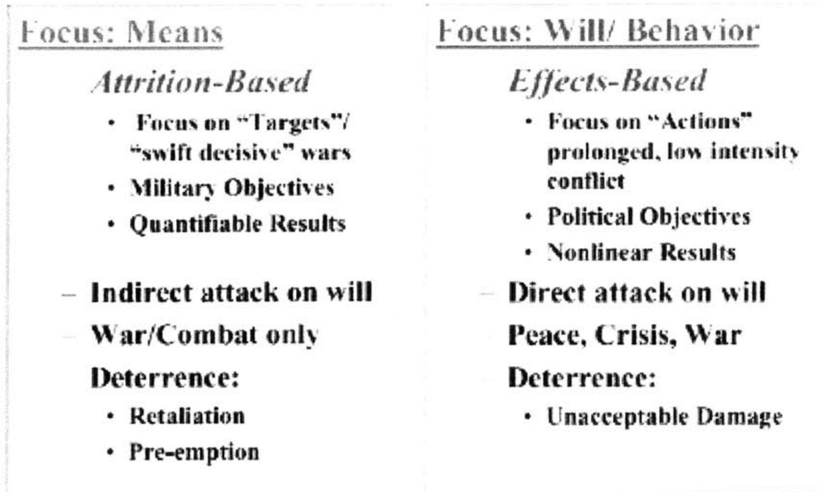

Figure 3-13 Attrition vs. Effects Based Operations[79]

Several other ideas are central to EBO theory, among them are:

a) Effects based operations include not only the military component of war, but also includes the full range of political, economic and military tools a state might use to gain the desired political advantage.

b) Effects based operations can be used against both state and non-state enemies.

c) Physical destruction of the enemy is still important in EBO theory, however, it is no longer the central goal, but rather the focus in EBO is the creation of psychological or cognitive effects against the enemy in order to destroy his will to continue the struggle.[80]

d) The traditional attrition based metric of Pk (probability of kill) is now replaced with Po, which is the probability of an effect producing a "useful option" for a specific situation.[81]

e) Effects based operations deal with the human dimension of conflict and involves itself in the realm of interactions between human decision makers, actors, and organizations.

[79] Smith, p. 43.
[80] Meilinger, p. 128-129.
[81] Smith, xix.

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In addition, EBO proposes six "rules' to the game: [82]

a) Actions create effects
b) Effects are cumulative
c) Any action-reaction cycle will have both active and passive participants
d) Action-reaction cycles occur simultaneously in multiple dimensions
e) All actions and effects at each level and in each arena are interrelated
f) Effects are both physical and psychological

Finally, the "effects" themselves fall into two different areas, "those that are predominantly physical in nature, and those that are primarily psychological."

Physical	Psychological (Reason/Belief)
Destruction	Chaos/Entropy
Physical Attrition	Foreclosure • Passive • Active
Chaos/Entropy	Shock
	Psychological Attrition

Figure 3-14 Kinds of Effects[83]

Section 3.4.3 – EBO in Action

> "Without the people, we have no information...They hide us, protect us, feed us and tend our wounded."[84]
> - General Vo Nguyen Giap

This quote demonstrates that the North Vietnamese clearly understood that the inhabitant population is critical to achieving the desired effects in war. The U.S. Army and Marines are re-learning this lesson today in Iraq. At the end of major combat operations in May 2003, the war in Iraq became a lot tougher. The Iraqi Army simply melted away, put on civilian clothes, went home, and temporarily buried their weapons. Then in the fall as the U.S. proved incapable of maintaining a safe and secure environment, failed to provide the basic necessities such as electricity, food and water, and appeared to many Iraqis to be acting more as an occupying power than a liberator, the insurgency kicked off.

[82] Smith, p. 210-222.
[83] Smith, p. 257.
[84] Emery, p. 13.

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This created a situation where U.S. commanders on the ground were forced to engage in simultaneous full spectrum operations as discussed earlier, a situation where air-land battle offered little help. Consequently, many commanders looked to EBO as a template for planning operations. Commanders realized that:

> "Success requires comprehending the intricacies of the Iraqi psyche-the tribal loyalties, the stubborn sense of national pride, the painfully learned distrust of America's promises, and the 'power of fear'...[and that] The US must convince Iraqis that the temporary US presence in Iraq is necessary to rebuild the country for the benefit of the Iraqi people."[85]

Tantamount in this process is convincing the local population that each time they support or even ignore the enemy there will be a direct and negative effect on their future, and the future of their children. One formula that helped some leaders to understand this and measure their progress is the following model called the "Insurgency Payoff Function."[86]

$$(EV_i - EC_i) >/< (EV_r - EC_r)$$

<u>Where</u>:
E = expectation
V_i = the value of joining the insurgency
C_i = the cost of joining the insurgency
V_r = the value of joining the regime
C_r = the cost of joining the regime

In Iraq, a neutral population means passive support for the insurgency, a situation that arises when Iraqis feel that the state and/or U.S. forces can not protect them. Terrorist and insurgent assassinations of key governmental leaders (usually an execution style bullet to the head or a video-tapped beheading) helps to strengthen their advantage. In addition, the majority of the population refuses to support U.S. forces as they see the U.S. as occupiers who will depart soon, or as occupiers who do not care for their best interests. Unfortunately, Iraqis also regularly fail to support their own Soldiers and policemen as they do not believe they are capable of protecting them from the better trained, equipped, financed, and better organized terrorists and insurgents. In addition, insurgents regularly bribe or coerce the population, even Iraqi Security Forces (ISF),

[85] Ibid.
[86] Smith, p. 12.

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into remaining silent, providing refuge, and spying on coalition forces, and even taking part in direct action.

Section 3.5 - Army Transformation

Not wanting to get behind in the RMA, the Army has already looked to the civilian sector for lessons learned and made a number of progressive steps towards improving its force structure. Thus, a review of the current Army transformation process, moving from a "legacy" force structure to the "future" force is in order.

Section 3.5.1 – The "Legacy" Force

The "Legacy Force" was designed during the Cold War to defeat the Soviet Union in Europe. It was Division centric, meaning that it was difficult for elements lower than Division level to operate independently as certain key logistical and combat support assets were organic at Division level. This included air defense, aviation, artillery, quartermaster, transportation, construction and combat engineers, and many other "combat multipliers." In essence, this made the Division a functional organization, where units were generally organized within a functional hierarchy all reporting to the Division Commander. In practice, the Division would "task organize" into cross-functional organizations when it went to the field to train and in event of war, operating in theoretically cross functional Brigade Combat Teams (roughly 3100 Soldiers) and Battalion Task Forces (roughly 800 Soldiers).

There were two types of "Legacy Force" divisions, Heavy and Light. A Heavy Division was comprised of heavily armored mechanized combat vehicles centered on M2 Bradley Fighting Vehicles and M1 Abrams Tanks. These maneuver platforms were supported by other heavily armored mechanized vehicles, such as the M113 Armored Personnel Carrier and the M109 Paladin Self-Propelled Artillery Cannon. These divisions were designed specifically for the Cold War, required a tremendous amount of logistical support and took a long time to deploy around the world, but were very effective in combat. In 2003 there were six of these Heavy Divisions in the U.S. Army. There were also four Light Divisions in the Army in 2003, one of which was airborne capable and the other air-assault capable. These light divisions were centered on the dismounted infantry Soldier, with nine 700 man infantry battalions in the

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Division. They were supported principally by unarmored light trucks (1.25 tons) and medium trucks (5 ton trucks) that carried supplies, mounted anti-armor weapons, and served as command and control vehicles. The Light Division was easy to deploy around the world and sustain almost indefinitely, but carried little staying power against a well equipped and trained mechanized threat.

Section 3.5.2 – The "Interim" Force

The Army created the Interim Force concept in the late 1990s as a stop gap between the "Legacy Force" and the "Future Force." Realizing that they could not wait until the Future Combat Systems was developed, Army leaders went ahead and created a new Stryker Brigade Combat Team organization that would be readily deployable like a light infantry division but would have the staying power similar to that of a mechanized organization. Also critical to this concept was creating an organization that required much less logistic support than the traditional mechanized division. Thus, the Army searched for a wheeled vehicle platform that would be light enough to deploy on a C-130 aircraft but would still carry significant combat power. The Stryker vehicle was chosen, and a new combat formation created: the medium brigade which was quickly named the Stryker Brigade Combat Team (SBCT). The first SBCT deployed to Iraq in the fall of 2003 and most after action reviews applauded the success of this new organization. The following chart shows the vehicles and systems that are critical to the SBCT.

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The Stryker Infantry Battalion

- The Stryker Infantry Battalion's strength is based on its 36 infantry squads. To complement this, the Stryker IN Battalion is augmented with 10 variants of the Stryker vehicle, each of which brings new capabilities to the Infantry Battalion:
  - Infantry Carrier Vehicle
  - Mobile Gun System
  - Reconnaissance Vehicle
  - Mortar Carrier
  - Command Vehicle
  - Fire Support Vehicle
  - Engineer Support Vehicle
  - Medical Evacuation Vehicle
  - Anti-Tank Guided Missile Vehicle
  - NBC Reconnaissance Vehicle

Figure 3-15 SBCT Infantry Battalion

Army leaders also integrated the new Army Battle Command System (ABCS) into the new SBCT and into the Legacy Divisions as part of the Interim Force. By 2003, most Divisions in the U.S. Army had a suite of digital systems, one for each key functional area (maneuver, intelligence, fires, air-defense, etc). Theoretically, these systems were suppose to create a cross functional Common Operating Picture (COP) that would integrate with sister services' systems creating a Joint COP. So far the integration piece has proved problematic, but the majority of the systems work well as stand alone systems within a specific functional area giving the commander and subordinate units a clearer picture of the battlefield. The following diagram depicts how all of the ABCS systems "should" operate conceptually.

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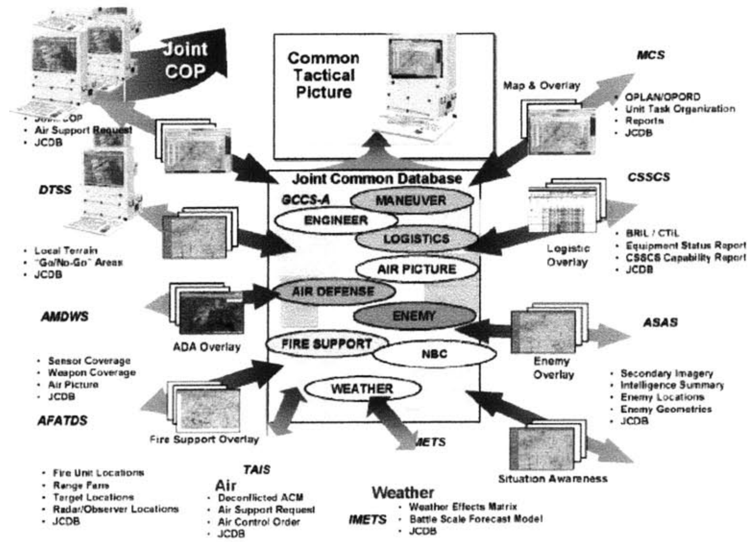
Figure 4.7
ABCS Components



RAND MG257 4.7

Figure 3-16 ABCS Systems[87]

The Army also decided not to wait for the Future Combat System (FCS) to change from a functional Division centric system to a cross functional Brigade centric system. In 2004, the Army began to transform all of its Legacy Divisions into 3 or 4 Brigade size Units of Action (UAs). In doing so, it created cross functional Brigade Combat Teams that now make it more feasible for a Brigade Combat Team to deploy anywhere around the world and operate as a stand alone organization, not relying any longer on Division support. The first of these Brigade Units of Action, also called Brigade Combat Teams, deployed to Iraq in 2005.

Section 3.5.3 – The "Future" Force

The Army has not released a lot of information to date concerning the Future Combat Systems (FCS). What is known is that it will be centered on cross functional brigade size units of action, and at the core consists of 18 manned and unmanned systems, with a robust network that allows all systems to function as a single integrate system of systems. Conceptually, the FCS will provide a lethal and agile force capable of conducting simultaneous full spectrum operations

[87] RAND, p. 54.

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within the contemporary operating environment. The following chart shows the key concept for the FCS.

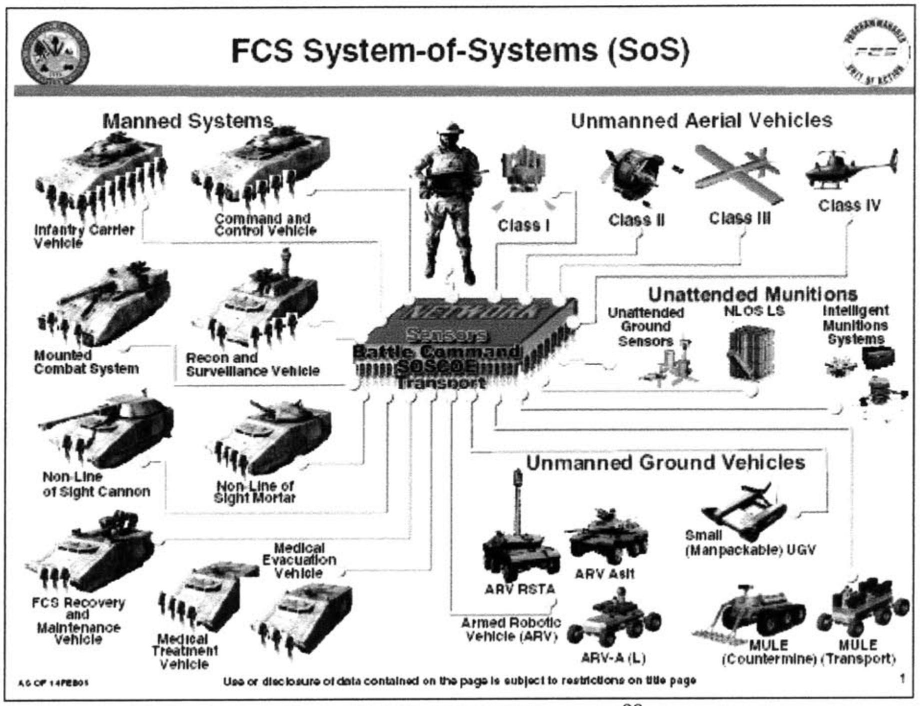

Figure 3-17 FCS Concept[88]

Section 3.5.4 – Transformation Challenges and Concerns

A number of retired military officers, policy makers, scholars and private citizens have raised concerns with the current Army transformation plan. They include the following:

a) In order for the FCS to be lighter than the current mechanized force and deliver the same staying power, it will have to see and hit the enemy first in order to survive. The problem is developing the technologies that allow massive amounts of intelligence to be collected and shared and for all individual systems to be "linked in" with a true cross-functional COP.[89]

b) Current Digital systems only create a real time and accurate picture of friendly forces. The problem of identifying the enemy and creating an accurate and real time enemy picture has yet to be solved even for a "traditional" fight. The problem primarily lies in how to "sense" the enemy, but also involves how to input sensor information into a common enemy digital database. Creating a real time, accurate enemy picture in an insurgency or other asymmetric scenario is a problem that is even an order of magnitude larger than this.

[88] GAO, p. 5.
[89] GAO, p. 1.

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c) Transformation is really about organizational change. Modular, cross-functional transformation will not achieve its stated objectives unless command echelons are also flattened out providing more "usable combat power for operational deployments."[90]

d) Transformation is also about leadership change. This means training leaders to be more flexible and adaptable in nature, as required on the asymmetric battlefield. Current Army transformation policies do not appear to adequately address changes to leader training or leader manning. Indeed, it appears that the new transformation model and the COE require increased leader experience at the edge of the organization, not at the center.

e) Despite paring down the interim Division organization into three or four cross-functional brigade units of action, the Division headquarters has increased nearly two fold in size. This policy does not appear to support modularity.

[90] Melton, p. 58.

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Chapter 4– Current Battalion TOC & C4ISR Architecture

A quick review of the current BN TOC and Brigade C4ISR architecture is critical. The BN TOC is a dynamic and versatile organization. While generally universal in terms of function, most BN TOCs differs in form because each BN TOC is normally tailored to meet the needs of each individual unit's specific mission set as well as its commander's own individual needs. Therefore, it is important to understand the differences and similarities in both its form and function.

Section 4.1– TOC Characteristics

There are currently three primary types of maneuver BN TOCs in the Army. These are the Light Infantry BN TOC, the Heavy BN TOC (armor or mechanized infantry) and the Stryker Infantry BN TOC. The primary differences are size deriving from number and size of vehicles attached to the TOC as well as personnel manning. Despite these differences in form, they are generally the same in function. For the purpose of this study, a generic TOC structure will be used that closely resembles all three types of TOCs. Also, it is important to note that BN TOCs also differ in form due to commander style preferences.

Both the C2 architecture between units and the physical architecture of the battalion TOC have a critical impact on how effectively units communicate on the battlefield. The layout of the internal TOC architecture directly impacts how effectively different staff sections working inside the TOC collaborate and share critical information. For example, the Battalion engineer might be tracking that a critical bridge was just recently destroyed or that the bridge only supports up to 25 tons. If he is not communicating with the operations section, however, the Battalion Operations Officer might direct a platoon of tanks to cross over that bridge. This failure to communicate could result in a waste in combat power which would certainly inhibit the Battalion's ability to accomplish its mission and might quite possibly risk Soldiers' lives. It is important to note that there is no doctrinally approved technique for TOC configuration, but rather TOC architectures generally vary depending on each commander's unique preferences, the type of mission, and equipment available. Because different missions might require different

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configurations, function is usually a much more important factor than form when architecting the TOC.

Likewise, how units outside the BN TOC communicate and share information is critical to the Battalion and ultimately the Brigade's overall success. For example, when the Battalion Commander prefers to control operations centrally, the TOC can easily become overloaded with information. But when the Commander encourages his subordinate company commanders to communicate and coordinate operations horizontally within the organization, using his intent as general guidance but demonstrating their own initiative within that framework, the Battalion TOC generally does not become overloaded.

Section 4.2– Battalion TOC Manning

The following is a review of the different staff sections associated with the BN TOC. Also included is a review of the typical number of Soldiers and their function for each section inside the TOC. Note that these numbers often vary in practice.

a) **Command Section:** The command section consists of the Battalion Commander, the Executive Officer, and the Battalion Command Sergeant Major. At any given time, usually one of them is present inside the TOC.

b) **S2 Section (Intelligence):** The intelligence section consists of the Intel Officer, his Assistant, three intelligence Non-Commissioned Officers (NCOs), and four junior enlisted intelligence analysts. At any given time, there are normally four personnel working in the intelligence section inside the TOC.

c) **S3 Section (Operations):** The S3 section is normally comprised of the Battalion Operations Officer, the Operations Sergeant Major, four Assistant Operations Officers, 5 NCOs, and 6 Soldiers. At any given time, two officers, two non-commissioned officers, and 2 soldiers are normally working inside the TOC.

d) **S5 Section (Civil Affairs):** The S5 at the Battalion level normally consists of a single officer who sometimes has an NCO as an assistant. On occasion, the Battalion will have an actual three man Civil Affairs Team attached. On average, one Civil Affairs personnel work inside the TOC at any given time.

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e) **S6 (Communications):** The S6 section is relatively large and normally consists of one officer, 4 NCOs, and 5 Soldiers. At any given time, normally 2 of them are working inside the TOC. The majority are normally out working on broken equipment within the Battalion.

f) **FSE (Fire Support Element):** The FSE normally consists of one officer, 2 NCOs, and 2 Soldiers. At any given time, normally two FSE personnel are working inside the TOC.

g) **Air Defense Artillery (ADA):** The Air Defense cell normally consists of one officer, 2 NCOs, and 2 Soldiers. At any given time, normally two ADA Soldiers are working inside the TOC.

h) **NBC (Nuclear, Biological & Chemical) Section:** The NBC section consists of one officer and one NCO. Usually one of them is on duty inside the TOC at any given time.

i) **ALO (Tactical Air Controller):** At Battalion level, the ALO team normally consists of two Soldiers, one of which is on duty at any given time inside the TOC.

It is important to note that the Battalion S1 (Personnel Section) and S4 (Logistics Section) are doctrinally located in a separate command post called the Combat Trains Command Post (CTCP). The CTCP serves as the central node for coordinating and synchronizing all logistics operations to include re-supply and maintenance, and serves as the alternate TOC (Main Command Post) in the event the TOC is destroyed or incapable of command and control.

Section 4.3– Battalion TOC Architecture

Like TOC manning, the internal BN TOC architecture varies greatly between different TOCs, reflecting varying types of units (light, heavy & Stryker), commander preference, and whether the unit is using tents or a "hard stand" (i.e. a host nation building) as the structure. Despite these differences, the actual arrangement of where various personnel are placed inside the TOC has a tremendous impact on how well information flow passes between staff sections and ultimately on the overall productivity of the TOC.

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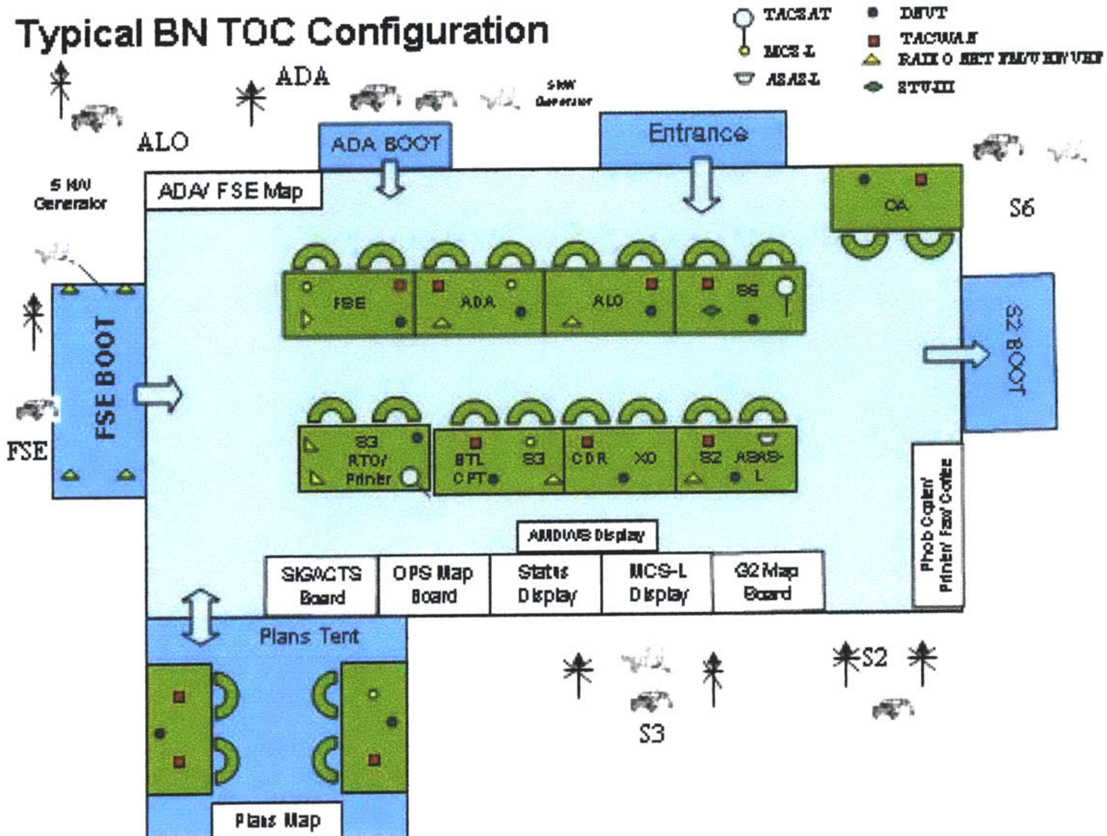

Figure 4-1 TOC Internal Configuration

Section 4.4– Brigade C4ISR Architecture

Unlike TOC manning and internal architecture, the external Brigade C2 Architecture is very consistent within the Army. For this study, a simplified model of a typical light or heavy brigade organization is used. Only the major units within the BCT are shown, the Brigade headquarters, the three subordinate battalion headquarters, then each battalion's three maneuver companies. The following diagram shows what this existing architecture looks like using both a decompositional view and a structural view. In addition, the structural view is broken down to show what the battlefield typical looks like when the BCT is employed against a "Traditional" threat or an asymmetric threat on a non-contiguous battlefield.

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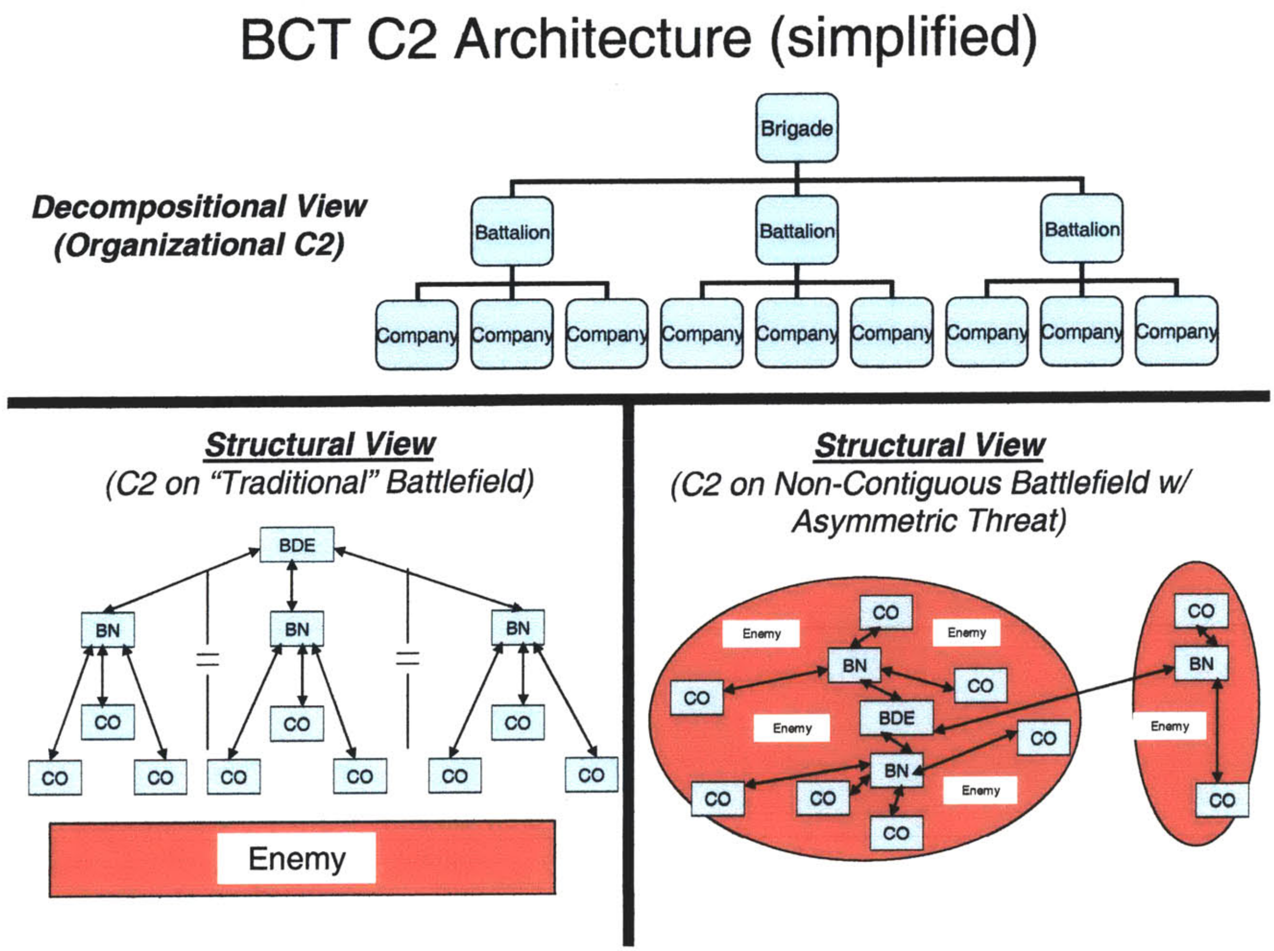

Figure 4-2 BCT C2 Architecture

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PART II Analysis of Current Battalion TOC

Chapter 5– System Dynamics Introduction

System Dynamics was created during the 1950s by MIT Professor Jay Forrester as a method for modeling large real world systems. While System Dynamics is grounded in the rigorous mathematical disciplines of control theory and nonlinear dynamics, it was created with the intention of becoming "a practical tool that policy makers can use to help them solve the pressing problems they confront in their organizations."[91] Thus, it recognizes that other fields such as psychology, decision making and organizational behavior are as important as mathematics, as these fields allow the modeler to take into account factors such as ambiguity, time pressure, personalities and politics.[92] A number of different software applications exist for creating and running System Dynamics models. This study uses Vensim® software. The following sections explain the basic principles of System Dynamics.

Section 5.1 Causal Loops and System Behavior

Causal loops are important because they help to clarify the feedback within systems. In complex systems, normally complex feedback interdependencies and relationships exist that make the system complex, rather than variables themselves being complex. The following examples are taken from Chapter 1 of John Sterman's ***Business Dynamics***.[93]

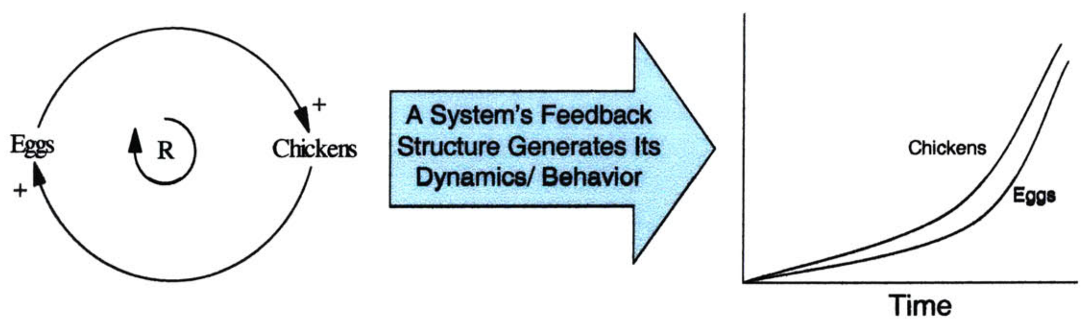

Figure 5-1 Positive Feedback Loops

[91] Sterman, p. ix.
[92] Sterman, p. x. The concepts of causal loops, stocks and flows, delays, and non-linearities are the main concepts behind the theory of System Dynamics. Read Sterman's Business Dynamics, Chapters 1, 5, 6, 11 & 14 for a full review of all of these concepts.
[93] Sterman, p. 12-14.

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An example of a positive feedback loop is shown in Figure 6-1. The causal loop shows that as the number of eggs increases, more chickens are hatched and therefore you increase the number of chickens increases. The more chickens, then naturally the more eggs will be laid. This is called a positive feedback loop. Positive feedback loops produce exponential behavior, in this case, in the number of chickens and eggs over time. It is also important to note that positive feedback loops can also cause exponential decreases, not just exponential increases as shown in Figure 6-1. For example, the same logic follows for Figure 6-1 that if the number of chickens in the populations decreases, then they will lay fewer eggs, which will lead to fewer chickens, and so forth.

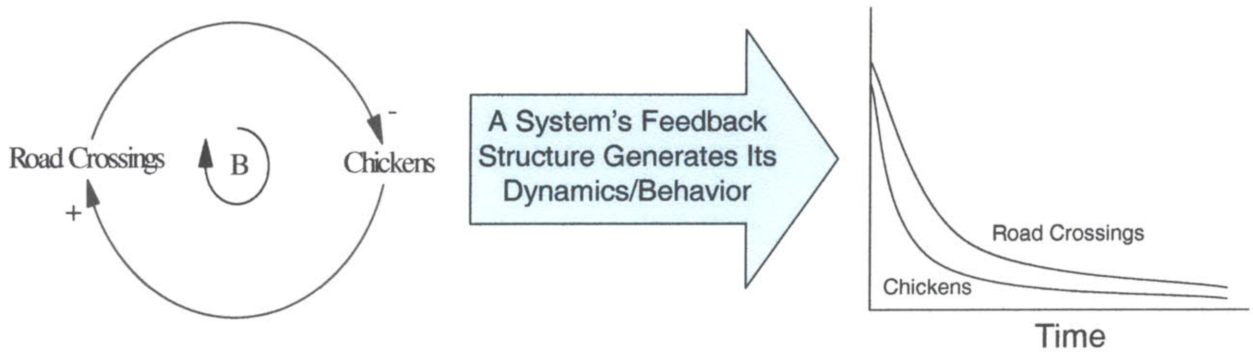

Figure 5-2 Negative Feedback Loops

An example of a negative feedback loop is shown in Figure 6-2. This causal loop shows that as the number of chickens in the population increases, then the number of chickens that die in road crossings also increases. Consequently, as the number of chickens that die in road crossings increases, the number of chickens in the general population decreases. This is called a balancing loop. Balancing loops normally cause goal-seeking behavior, in this case the number of both road crossings and chickens will decrease over time until they reach equilibrium and balance out at some point.

Figure 6-3 shows a new causal loop model where both reinforcing and balancing loops are combined. In models that have both reinforcing and balancing loops, system behavior often takes on an S-shape with goal seeking behavior.

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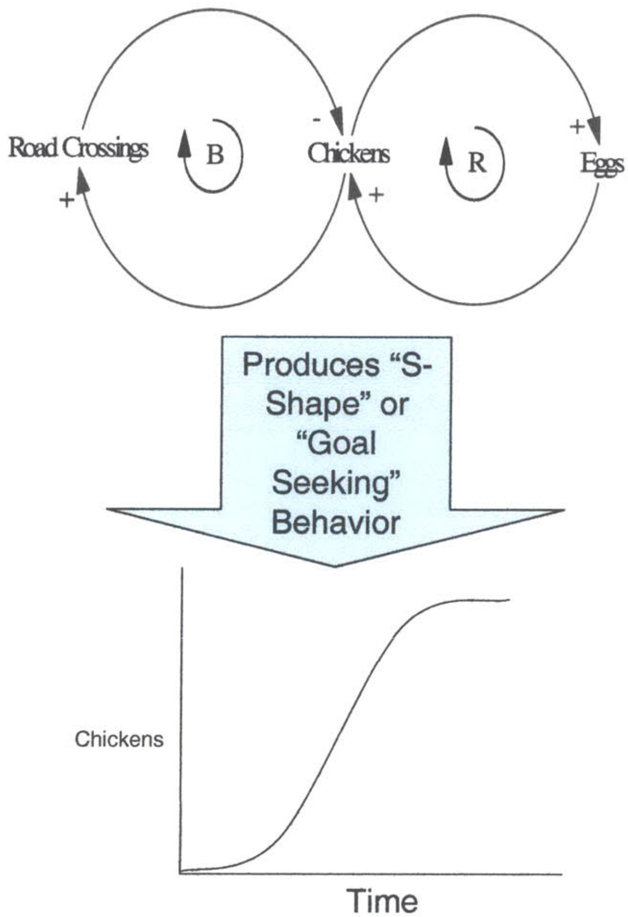

Figure 5-3 Combining Reinforcing and Balancing Loops

Section 5.2 Stocks and Flows

While causal loops are helpful in understanding interdependencies and feedback within systems, they do not allow for a complete modeling process because they do not capture stocks and flows. Stocks are accumulations that allow the modeler to characterize a system as they provide a system with inertia and memory. Below is a simple Stock and Flow model.[94] In this case, inventory manufactured "widgets" are accumulated inside the inventory box below.

[94] Sterman, 191-194. Read Sterman's ***Business Dynamics***, Chapter 6, for more background information on Stocks and Flows.

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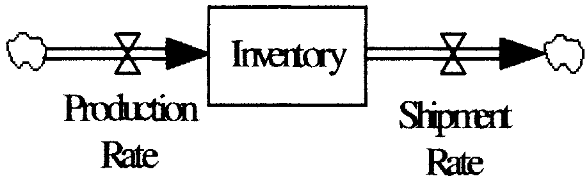

Figure 5-4 Stocks and Flows

The Production Rate Valve shows how many widgets are manufactured/unit of time and the Shipment Rate valve shows how many widgets are shipped to distributors and wholesalers/ unit of time. Therefore, if production rate is greater than shipment rate, the inventory of widgets will increase. If the shipment rate is greater than the production rate, then the inventory will decrease until no more are left, which would create a backlog of orders for widgets.

Section 5.3 Applications

Many different real world systems have been modeled using System Dynamics. Indeed, System Dynamics apply to just about every scholastic discipline imaginable, to the realms of business, mathematics, science, public health, and many more. To date, however, there are few examples of studies where System Dynamics has been used to model military problems, specifically problems dealing with Army operations. The following brief model will help to explain System Dynamics in more detail and will show in simple terms the applicability of System Dynamics to the domain of military operations.

Figure 6-5 shows the Stock of Iraqi Insurgents. It is regulated by the inflow of New Insurgents and the outflow of Killed or Captured Insurgents and those that Leave the Insurgency. In order for the Coalition to win in Iraq, it must drain the Iraqi Insurgents Stock to some value close to zero.

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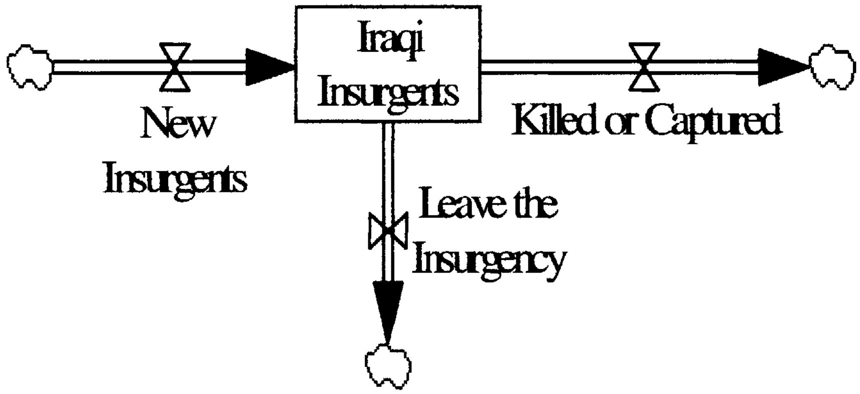

Figure 5-5 The Basic Iraqi Insurgency Stock and Flow Structure

Figure 6-6 develops this further by adding three causal (or feedback) loops. It also shows the Coalition policy of "Direct Action." This is represented by balancing loop B1, which signifies that as the stock of insurgents grows the Coalition will undertake more combat operations aimed at killing or capturing insurgents. This will cause more insurgents to be killed or captured, and therefore drain more of the Iraqi insurgents out of the existing stock. While this causal loop seems to support U.S. policy goals, it does not take into account the adverse effects of these actions. Loop R2 shows the effects of an alienated population. The local Iraqi population becomes alienated during combat operations as it often destroys their homes, results in innocent civilians being killed, and in general disrupts their daily lives. Therefore causal loop R2 shows that as the number of Iraq insurgents grows, the coalition will undertake more combat operations, which will cause the local population to become more alienated, and therefore increase the rate of new insurgents joining the insurgency, which will cause the stock of Iraqi insurgents to increase. When combined with the causal loop R1, where the insurgency spreads by word of mouth, this creates a situation where the insurgency rises exponentially over time.

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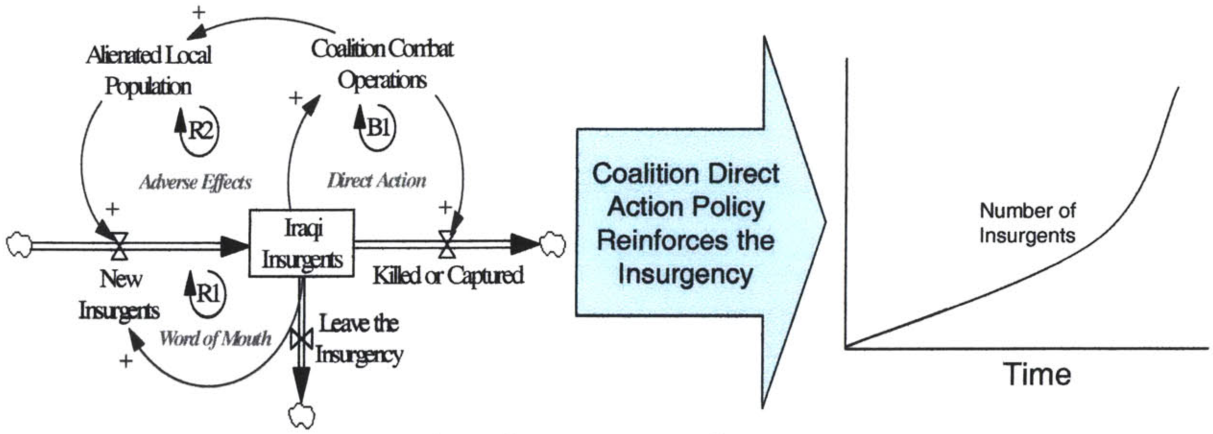

Figure 5-6 The Consequences of Direct Action

Figure 6-7 shows the effects of another U.S. policy, namely that of conducting information operations and rebuilding in lieu of direct combat operations as a means of winning the hearts and minds. This model shows that two balancing loops are created as information operations and rebuilding helps to gain informants that leads to the capture of insurgents and also convinces some insurgents to change sides or at least to take a neutral position towards the Coalition. This produces an exponential decrease over time.

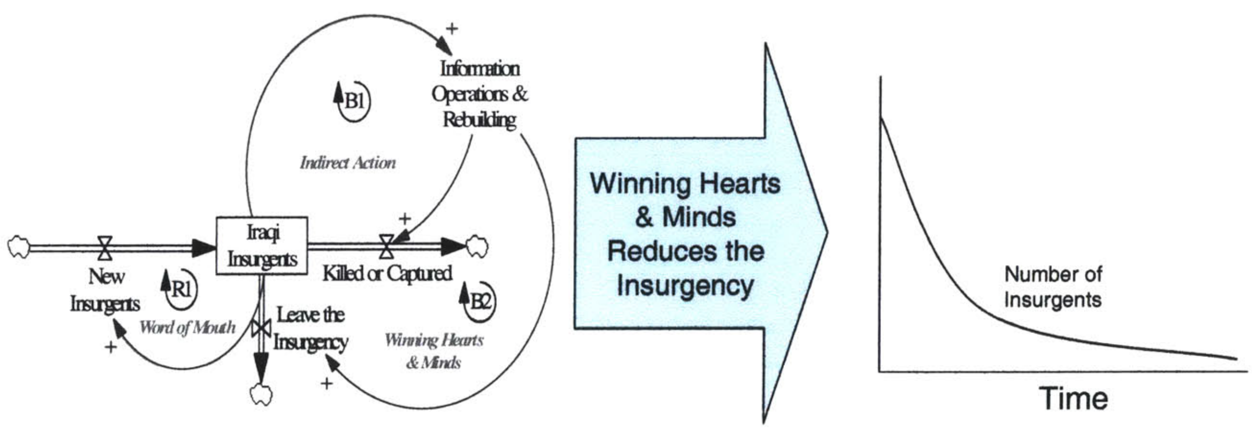

Figure 5-7 The Benefits of Indirect Action

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Chapter 6– Description of System Dynamics Model

The following system dynamics model is primarily composed of two sections. The first section deals with aspects that affect the internal information flow, or the information flow inside the tactical command post. The second section addresses aspects that affect the external information flow, or the information flow between tactical command posts. See appendix B for a full 8.5" x 11" version of the model. Also, appendix C shows detailed definitions and explanations of what each variable represents and the formula used for calculating variable values. The following diagram is part of the model, and is used to show the overall NET value of information flow, as determined by various causal relationships within the system.

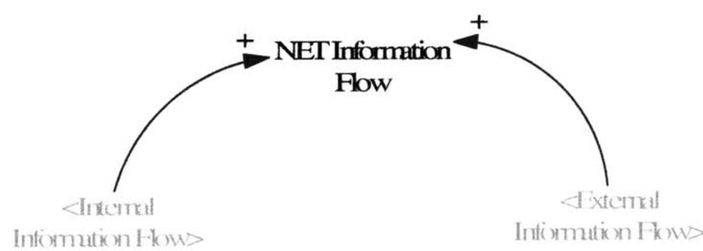

Figure 6-1 System Dynamics Model (NET Information Flow)

Section 6.1 Internal Information Flow

The following diagram shows the portion of the model that represents internal information flow.

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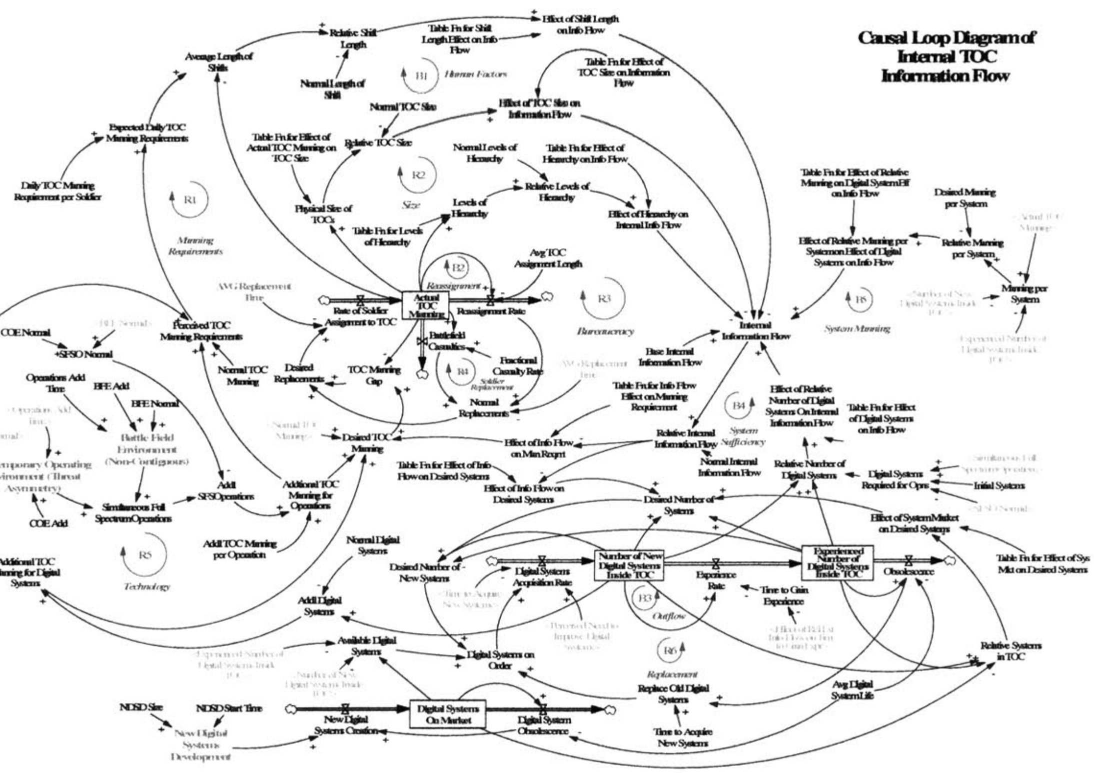

Figure 6-2 System Dynamics Model (Internal Information Flow)

The Internal Information Flow portion of the model is comprised of four important stocks, which are Actual TOC Manning, Digital Systems On Market, Number of New Digital Systems Inside TOC, and Experienced Number of Digital Systems Inside TOC. Critical exogenous variables are Battle Field Environment, Contemporary Operating Environment and New Digital Systems Development. The analysis section will focus on how changes in these three critical extraneous variables affect the stocks in the system as well as the critical variable "Internal Information Flow." Note that because information flow is difficult to measure, the model is based on a relative/normal value of 5. Therefore, a value of 10 for Internal Information Flow would mean that information flow is twice as good as normal, or a value of 2.5 would mean it is half as good as normal.

There are many complete feedback or causal loops in this model (not all are depicted explicitly in the model), eight of which are most important to understanding the dynamics involved in this study. These eight "critical" loops are labeled B1 (Human Factors), R2 (Size), R3 (Bureaucracy), B4 (System Sufficiency), R5 (Technology), R1 (Manning Requirements), R6 (Replacement) and

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B5 (System Manning). A thorough understanding of each of these loops is critical to understanding the dynamics involved in the model as values for the exogenous variables are changed.

<u>Loop B1 (Human Factors) is a balancing loop</u>. It shows that as the Internal Information Flow is increased, the Relative Internal Information Flow increases, which produces a decrease in the Effect of Information Flow on Manning Requirements. This decrease produces a decrease in the Desired TOC Manning which produces a decrease in the TOC Manning Gap and a decrease in the Desired Replacements and a decrease in the Rate of Solider Assignment to the TOC. Decreasing the Rate of Solider Assignment to the TOC produces a decrease in Actual TOC Manning, which increases the Average Length of Shifts, increases the Relative Shift Length, increases the Effect of Shift Lengths on Information Flow, and therefore decreases the Internal Information Flow.

<u>Loop R2 (Size) is a reinforcing Loop</u>. It shows that as the Internal Information Flow is increased, the Relative Internal Information Flow increases, which produces a decrease in the Effect of Information Flow on Manning Requirements. This decrease produces a decrease in the Desired TOC Manning which produces a decrease in the TOC Manning Gap and a decrease in the Desired Replacements and a decrease in the Rate of Solider Assignment to the TOC. Decreasing the Rate of Solider Assignment to the TOC produces a decrease in Actual TOC Manning, which produces a decrease in the Physical Size of TOCs and an increase in the Relative TOC Size and Effect of TOC Size on Information Flow which ultimately produces an increase in Internal Information Flow.

<u>Loop R3 (Bureaucracy) is a reinforcing Loop</u>. It shows that as the Internal Information Flow is increased, the Relative Internal Information Flow increases, which produces a decrease in the Effect of Information Flow on Manning Requirements. This decrease produces a decrease in the Desired TOC Manning which produces a decrease in the TOC Manning Gap and a decrease in the Desired Replacements and a decrease in the Rate of Solider Assignment to the TOC. Decreasing the Rate of Solider Assignment to the TOC produces a decrease in Actual TOC

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Manning, which produces a decrease in the Levels of Hierarchy. A decrease in the Levels of Hierarchy produces a decrease in Relative Levels of Hierarchy and a decrease in Effect of Hierarchy on Internal Information Flow and ultimately an increase in Internal Information Flow.

Loop B5 (System Manning) is a balancing loop. It shows that as the Internal Information Flow is increased, the Relative Internal Information Flow increases, which produces a decrease in the Effect of Information Flow on Manning Requirements. This decrease produces a decrease in the Desired TOC Manning which produces a decrease in the TOC Manning Gap and a decrease in the Desired Replacements and a decrease in the Rate of Solider Assignment to the TOC. Decreasing the Rate of Solider Assignment to the TOC produces a decrease in Actual TOC Manning, which produces a decrease in the Manning per System. This produces a decrease in the Relative Manning per System and a decrease in the Effect of Relative Manning per System on Information Flow and therefore a decrease in Internal Information Flow.

Loop R6 (Replacement) is a reinforcing loop. It shows that as the Digital Systems Acquisition Rate increases the Number of New Digital Systems Inside the TOC will also increase, which will produce an increase in the Experience Rate. As the Experience Rate increases, the Experienced Number of Digital Systems Inside the TOC will also increase, which will increase the Obsolescence Rate. As the Obsolescence Rate increases, the need to Replace Old Digital Systems will also increase, which will increase the Digital Systems on Order and therefore increase the Digital Systems Acquisition Rate.

Loop B4 (System Sufficiency) is a balancing loop. It shows that as Internal Information Flow increases the Relative Internal Information Flow will also increase, therefore decreasing the Effect of Information Flow on Desired Systems and decreasing the Desired Number of Systems. As the Desired Number of Systems decreases the Desired Number of New Systems will also decrease as will the number of Digital Systems on Order. As the number of Digital Systems on Order decrease the Digital Systems Acquisition Rate will also decrease, decreasing the Number of New Digital Systems Inside the TOC which will decrease the Experience Rate and the Experienced Number of Digital Systems Inside the TOC. As the Experienced Number of Digital

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Systems Inside the TOC decreases, the Relative Number of Digital Systems will decrease, decreasing the Effect of Relative Number of Digital Systems On Internal Information Flow and therefore decreasing Internal Information Flow.

Loop R5 (Technology) is a reinforcing loop. It shows that as Internal Information Flow increases the Relative Internal Information Flow will also increase, therefore decreasing the Effect of Information Flow on Desired Systems and decreasing the Desired Number of Systems. As the Desired Number of Systems Decreases the Desired Number of New Systems will also decrease as will the number of Digital Systems on Order. As the number of Digital Systems on Order decrease the Digital Systems Acquisition Rate will also decrease, decreasing the Number of New Digital Systems Inside the TOC. This will produce a decrease in the Additional Digital Systems and Additional TOC Manning for Digital Systems, which will produce a decrease in Desired TOC Manning, a decrease in the TOC Manning Gap and a decrease in the Desired Replacements. A decrease in the Desired Replacements will produce a decrease in the Rate of Soldier Assignment to the TOC, a decrease in Actual TOC Manning and Levels of Hierarchy. A decrease in Levels of Hierarchy will produce a decrease in Relative Levels of Hierarchy and a decrease in Effect of Hierarchy on Internal Information Flow which will produce an increase in Internal Information Flow.

Loop R1 (Manning Requirements) is a reinforcing loop. It shows that as Internal Information Flow increases the Relative Internal Information Flow will also increase, therefore decreasing the Effect of Information Flow on Desired Systems and decreasing the Desired Number of Systems. As the Desired Number of Systems Decreases the Desired Number of New Systems will also decrease as will the number of Digital Systems on Order. As the number of Digital Systems on Order decrease the Digital Systems Acquisition Rate will also decrease, decreasing the Number of New Digital Systems Inside the TOC. This will produce a decrease in the Additional Digital Systems and Additional TOC Manning for Digital Systems, and a decrease in the Perceived TOC Manning Requirements. A decrease in the Perceived TOC Manning Requirements produces a decrease in the Expected Daily TOC Manning Requirements and a decrease in the Average Length of Shifts, which produces a decrease in the Relative Shift Length, a decrease in the Effect of Shift Length on Information Flow, and therefore an increase in Internal Information Flow.

Section 6.2 External Information Flow

The following diagram shows the portion of the model that represents external information flow (See Annex B for a full 8.5" x 11" version of this model).

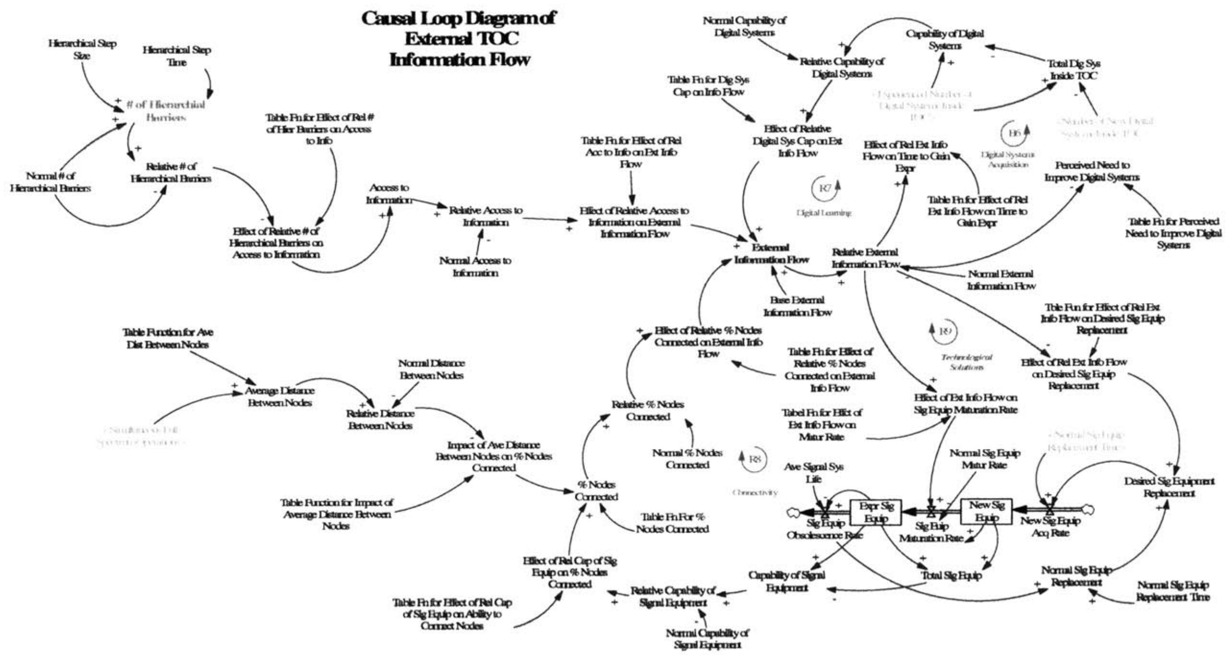

Figure 6-3 System Dynamics Model (External Information Flow)

This portion of the model is comprised of two important stocks, which are New Signal Equipment and Experienced Signal Equipment. It is linked to the Internal Information Flow portion of the model by the variables Simultaneous Full Spectrum Operations, Normal Signal Equipment Replacement Time, Effect of Relative External Information Flow on Time to Gain Experience, Perceived Need to Improve Digital Systems, Experienced Number of Digital Systems Inside TOC, and Number of New Digital Systems Inside TOC. The critical extraneous variable is Number of Hierarchical Barriers. The analysis section will focus on how changes in this critical extraneous variable affects the stocks in the system as well as the critical variable "External Information Flow." Note that like Internal Information Flow, because External Information Flow is difficult to measure, the model is based on a relative/normal value of 5.

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Therefore, a value of 10 for External Information Flow would mean that information flow is twice as good as normal, or a value of 2.5 would mean it is half as good as normal.

There are many complete feedback or causal loops in this portion of the model (not all are depicted explicitly in the model), four of which are most important to understanding the dynamics involved in this study. These four "critical" loops are labeled R7 (Digital Learning), B6 (Digital Systems Acquisition), R8 (Connectivity), and R9 (Technological Solutions). A thorough understanding of each of these loops is critical to understanding the dynamics involved in the model as values for the exogenous variables are manipulated.

Loop R7 (Digital Learning) is a reinforcing loop. It shows that as External Information Flow increases the Relative External Information Flow will increase, which will increase the Effect of Relative External Information Flow on Time to Gain Experience, and decrease the Time to Gain Experience. Decreasing the Time to Gain Experience will increase the Experience Rate and therefore increase the Experienced Number of Digital Systems Inside the TOC. Increasing the Experienced Number of Digital Systems Inside the TOC will increase the Capability of Digital Systems. Increasing the Capability of Digital Systems will increase the Relative Capability of Digital Systems and the Effect of Relative Digital Systems Capability on External Information Flow which will therefore increase the External Information Flow.

Loop B6 (Digital Systems Acquisition) is a balancing loop. Increasing the External Information Flow will increase the Relative External Information Flow, which will decrease the Perceived Need to Improve Digital Systems, decrease the Digital Systems Acquisition Rate and therefore decrease the Number of New Digital Systems Inside the TOC. Decreasing the Number of New Digital Systems Inside the TOC will increase the Total Digital Systems Inside the TOC and therefore decrease the Capability of Digital Systems. As the Capability of Digital Systems decreases, the Relative Capability of Digital Systems decreases and the Effect of Relative Digital Systems Capability on External Information Flow decreases, which will decrease the External Information Flow.

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Loop R8 (Connectivity) is a reinforcing loop. This loop shows that increasing the External Information Flow increases the Relative External Information Flow, which increases the Effect of External Information Flow on Signal Equipment Maturation Rate and increases the Signal Equipment Maturation Rate. Increasing the Signal Equipment Maturation Rate increases the stock of Experienced Signal Equipment, which increases the Capability of Signal Equipment and increases the Relative Capability of Signal Equipment. Increasing the Relative Capability of Signal Equipment increases the Effect of Relative Capability of Signal Equipment on the Percentage of Nodes Connected and increases the Percentage of Nodes Connected. Increasing the Percentage of Nodes Connected increases the Relative Percentage of Nodes Connected and increases the Effect of Relative Percentage of Nodes Connected on External Information Flow, which therefore increases External Information Flow.

Loop R9 (Technological Solutions) is a reinforcing loop. This loop demonstrates that as the External Information Flow increases, the Relative External Information Flow increases, which causes a decrease in the Effect of External Information Flow on Desired Signal Equipment Replacement and a decrease in the Desired Signal Equipment Replacement and in the New Signal Equipment Acquisition Rate. A decrease in the New Signal Equipment Acquisition Rate causes a decrease in the stock of New Signal Equipment, a decrease in Total Signal Equipment, and an increase in the Capability of Signal Equipment. Increasing the Capability of Signal Equipment increases the Relative Capability of Signal Equipment. Increasing the Relative Capability of Signal Equipment increases the Effect of Relative Capability of Signal Equipment on the Percentage of Nodes Connected and increases the Percentage of Nodes Connected. Increasing the Percentage of Nodes Connected increases the Relative Percentage of Nodes Connected and increases the Effect of Relative Percentage of Nodes Connected on External Information Flow, which therefore increases External Information Flow.

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Chapter 7– Analysis of System Dynamics Model (Simulation)

This study will use two different approaches to simulation. First, it will include a one-variable-at-a-time approach where only one exogenous variable will be changed at a time to determine the full range of implications that change will have on different internal variables in the model. Once this is complete, an array approach will be used where multiple exogenous variables are changed simultaneously so that the effects of a more dynamic scenario can be studied. A total of 17 separate deterministic simulations are used in this part of the study. The three key exogenous variables that will be manipulated are Simultaneous Full Spectrum Operations (a variable that combines "Battle Field Environment" and "Contemporary Operating Environment"), New Digital System Development, and Number of Hierarchical Barriers. The five key internal variables that will be studied are Actual TOC Manning, Number of Digital Systems Inside the TOC, Internal Information Flow, External Information Flow, and NET Information Flow.

Section 7.1 Simultaneous Full Spectrum Operations

The first four experiments were conducted by manipulating the exogenous variables "Battle Field Environment" and "Contemporary Operating Environment." These two variables when summed produce a value for "Simultaneous Full Spectrum Operations" where: "Battle Field Environment" + "Contemporary Operating Environment" = Simultaneous Full Spectrum Operations (SFSO). A full definition of each of these variables is found in Appendix C. In short, these variables represent the additional functional areas that are needed inside the TOC as mission sets become more diverse (i.e. when Army units are expected to conduct multiple operations simultaneously such as Defense, Offense, Security and Support operations). The model considers a value of four additional functional areas to be normal (represented by SFSO). Experimental trials were conducted by raising the value of SFSO by 2 at a time for a total value of six, eight, and ten. Increasing these values represents the need to add new functions to the TOC, such as Civil Affairs, Information Operations Officers, Police Liaison Officers, Reconstruction Teams, etc. The following graph shows how the exogenous variables were changed for each of the four experimental trials. The exogenous variable was changed at time =

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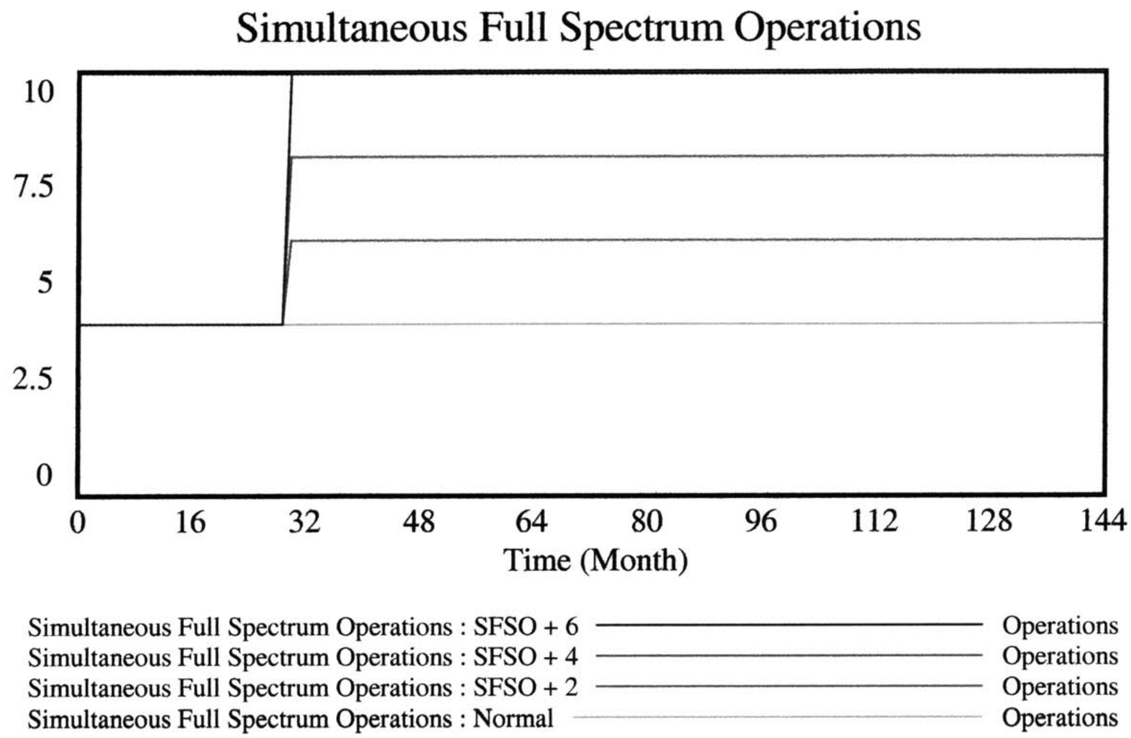
30 months or t = 30. The following chart demonstrates how changes in the exogenous variable Simultaneous Full Spectrum Operations was manipulated during each experiment.[95]



The following five charts show the impact that increasing Simultaneous Full Spectrum Operations has on the system. As the graphs show, increased SFSO produces a strong increase in Actual TOC Manning and a minor increase in Number of Digital Systems Inside the TOC. It also produces a significant decrease in Internal Information Flow and NET Information Flow, but only a very moderate decrease in External Information Flow. Comparing the charts titled Actual TOC Manning and Internal Information Flow also suggests a correlation between the number of Soldiers working inside the TOC and Internal Information Flow. Specifically, it suggests that as Actual TOC Manning increases, Internal Information Flow decreases.

[95] For a color version of these graphs, please see the LFM-SDM website at https://lfmsdm.mit.edu./VCSS/jsp/internship.jsp?tab=2&nav=10 or send an e-mail to the author at below or minamin@sloan.mit.edu.

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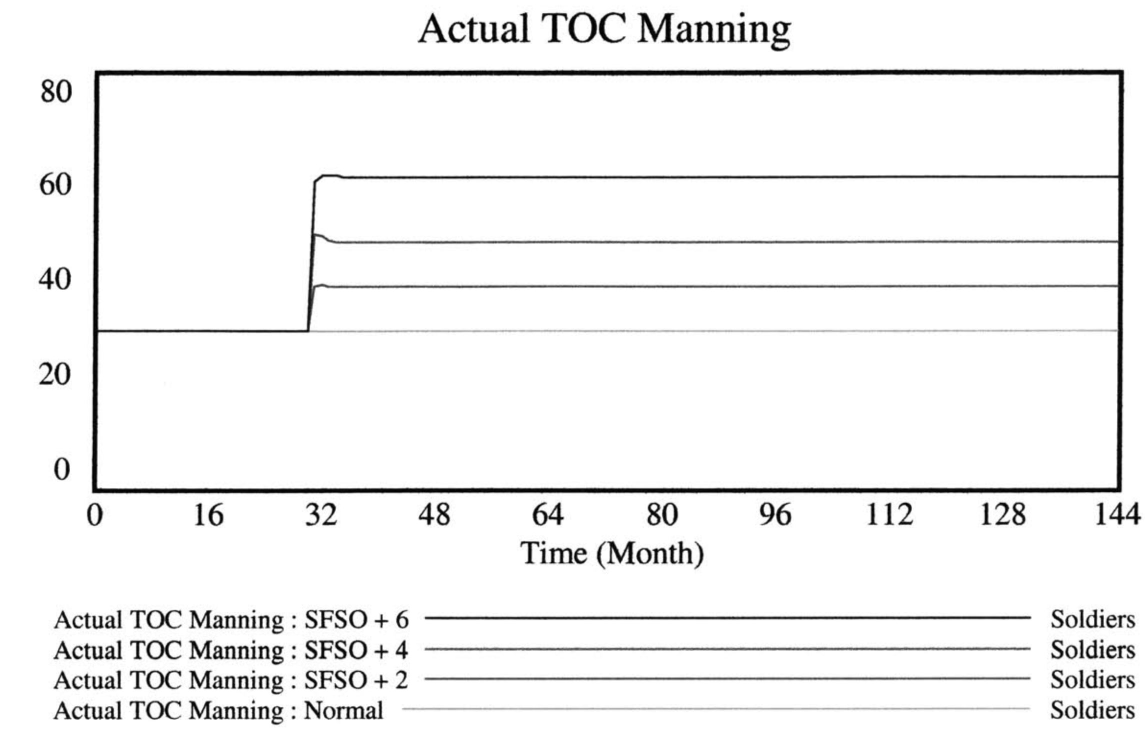

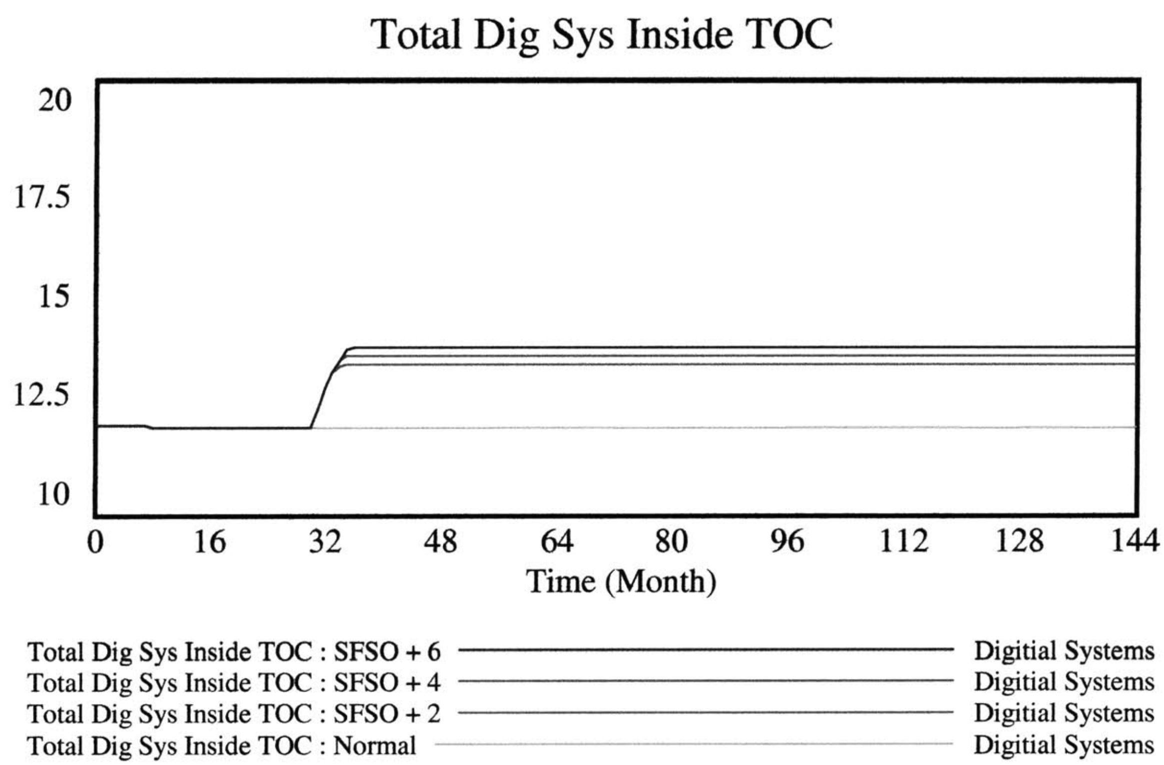

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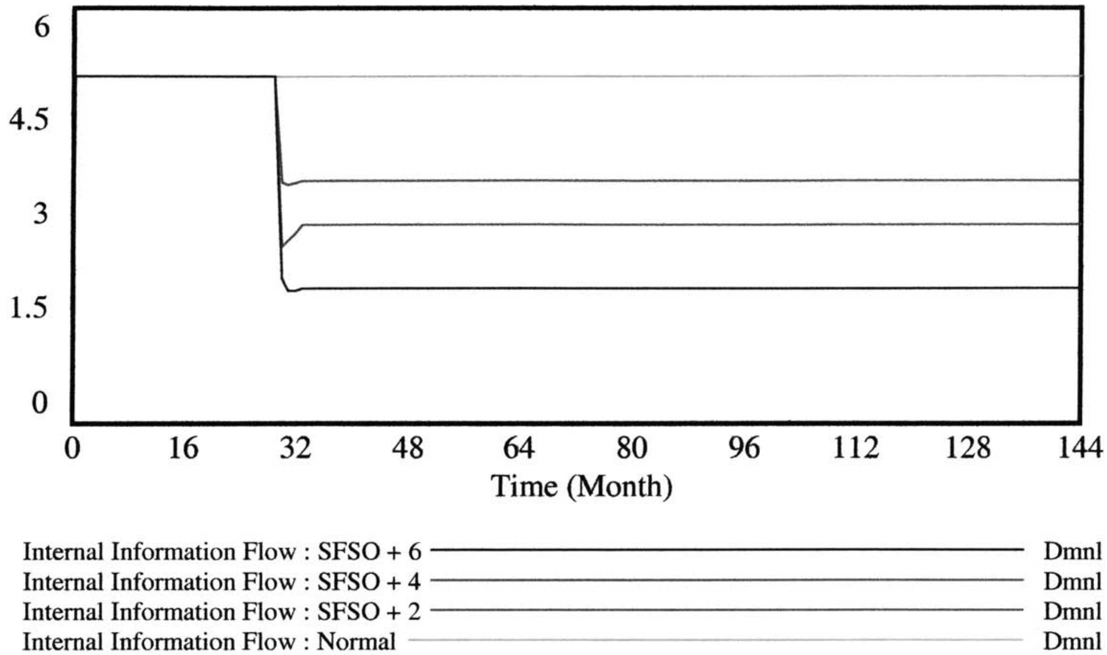
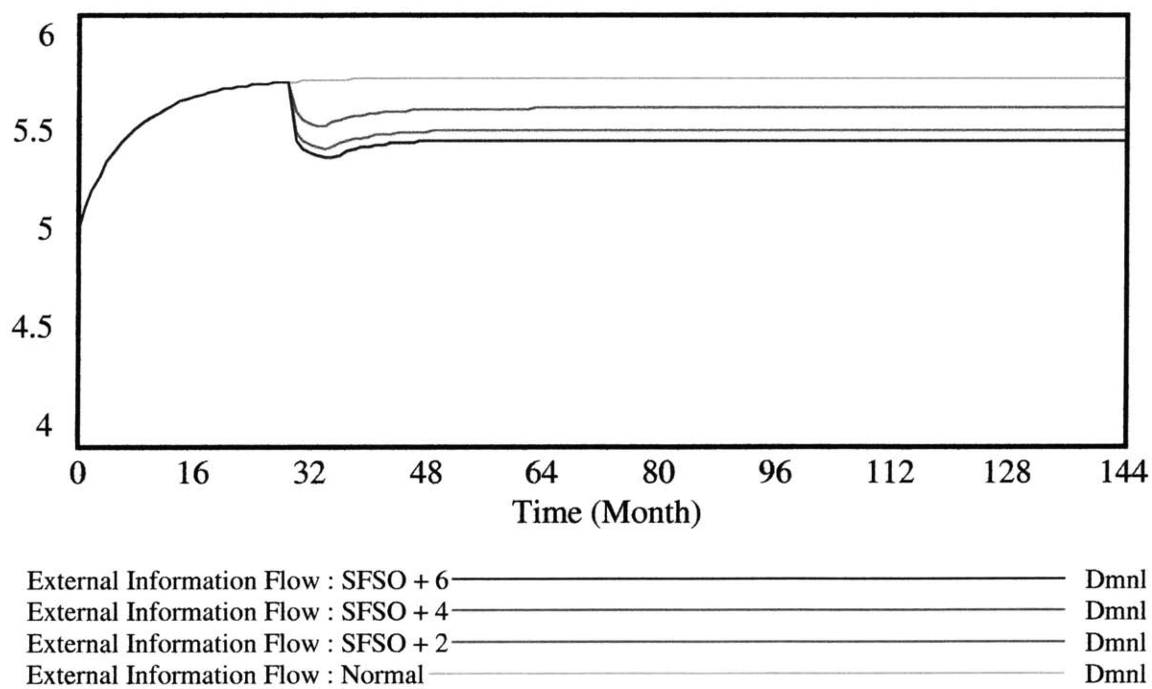
Internal Information Flow



External Information Flow



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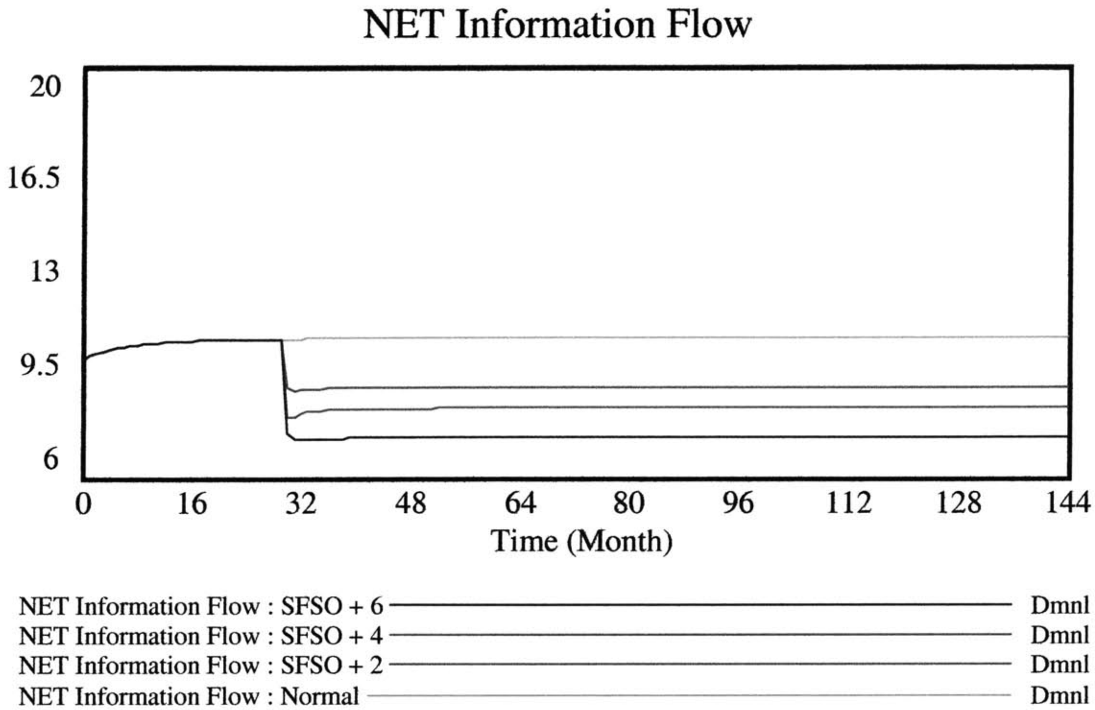

Section 7.2 New Digital Systems Development

The next four experiments were conducted by manipulating the exogenous variable "New Digital System Development." As the System Dynamics model shows, increasing the "New Digital System Development" increases the "Creation of New Digital Systems" which increases the "Digital Systems on the Market." A full definition of each of these variables is found in Appendix C. In short, these variables represent the creation of new digital systems produced by both private and government industries. The model considers a value of zero to be normal, therefore representing the situation prior to 1995 when digitalization of Battalion TOCs began to increase significantly (note: the time horizon for the simulation is 12 years, thus simulating the time period from 1995 to 2007). Experimental trials were conducted by raising the value of New Digital System Development from zero, to one new system every six months, then to one new system every two months, and finally to one new system per month. The exogenous variable was changed at time = 30 months or t = 30. The following chart demonstrates how changes in the exogenous variable New Digital Systems Development was manipulated during each experiment.

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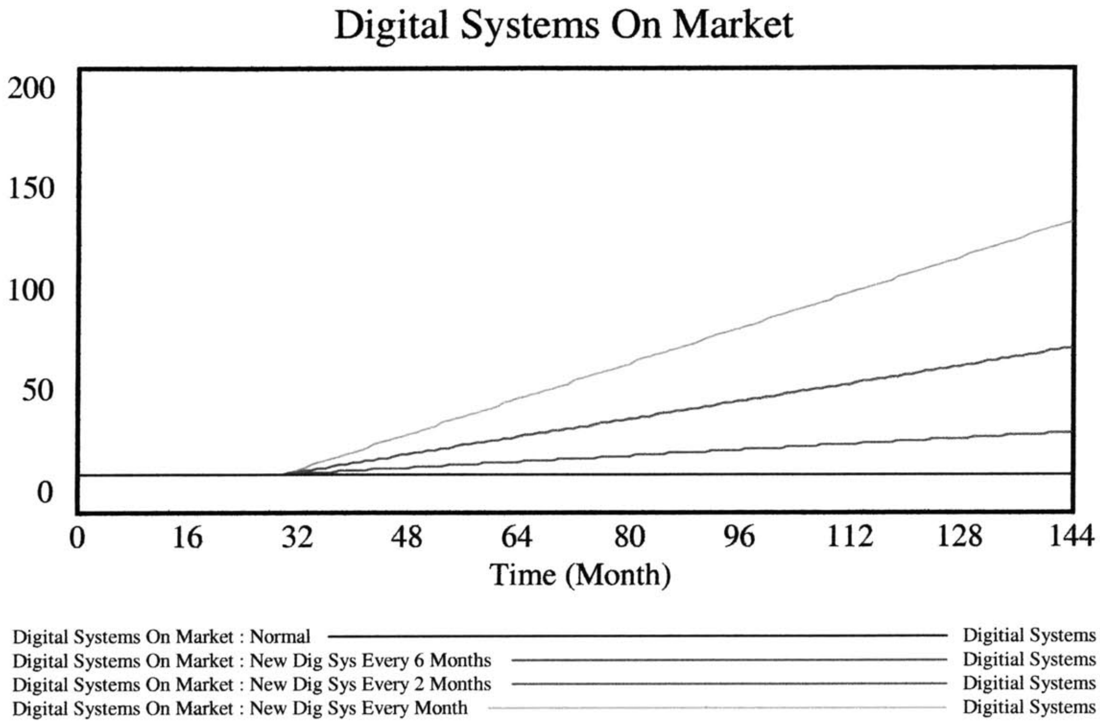

The following five charts show the impact that increasing Digital Systems on the Market has on the system. As the graphs show, increased Digital Systems on the Market produces a moderate increase in Actual TOC Manning and a significant increase in Total Digital Systems Inside the TOC. It also produces a significant decrease in Internal Information Flow, a moderate decrease in NET Information Flow, but only a very modest decrease in External Information Flow. The data also suggests a correlation between Actual TOC Manning and Internal Information Flow as well as Total Digital Systems Inside TOC and Internal Information Flow. Specifically, it suggests that as Actual TOC Manning and Total Digital Systems Inside TOC increase, Internal Information Flow decreases.

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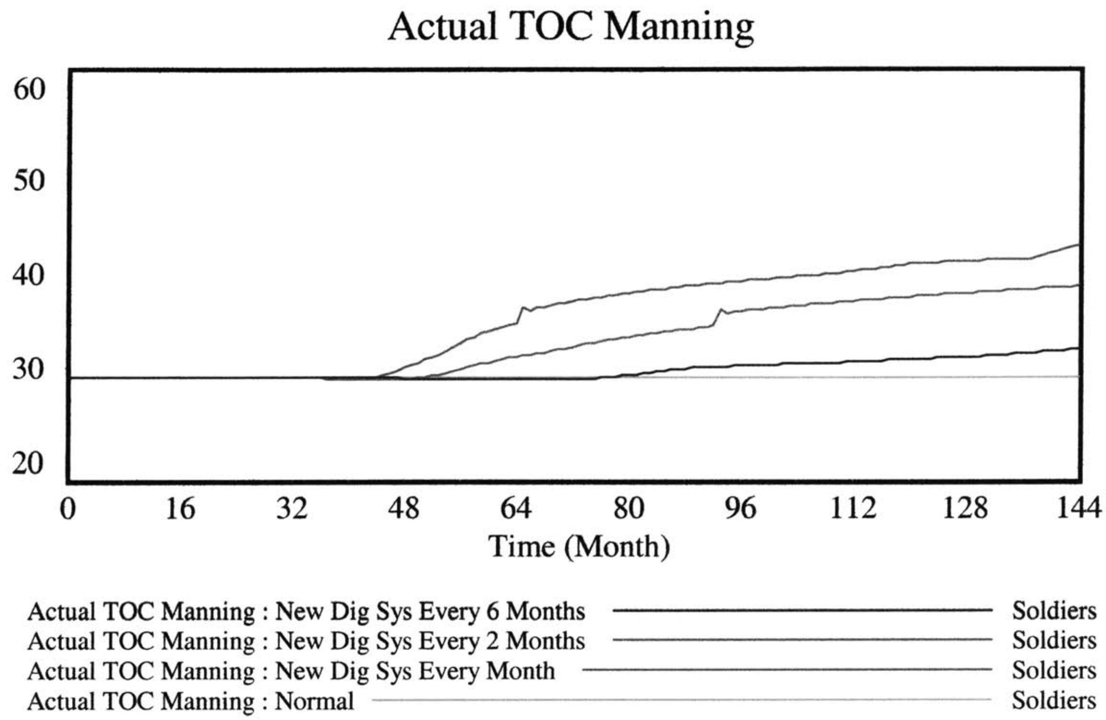

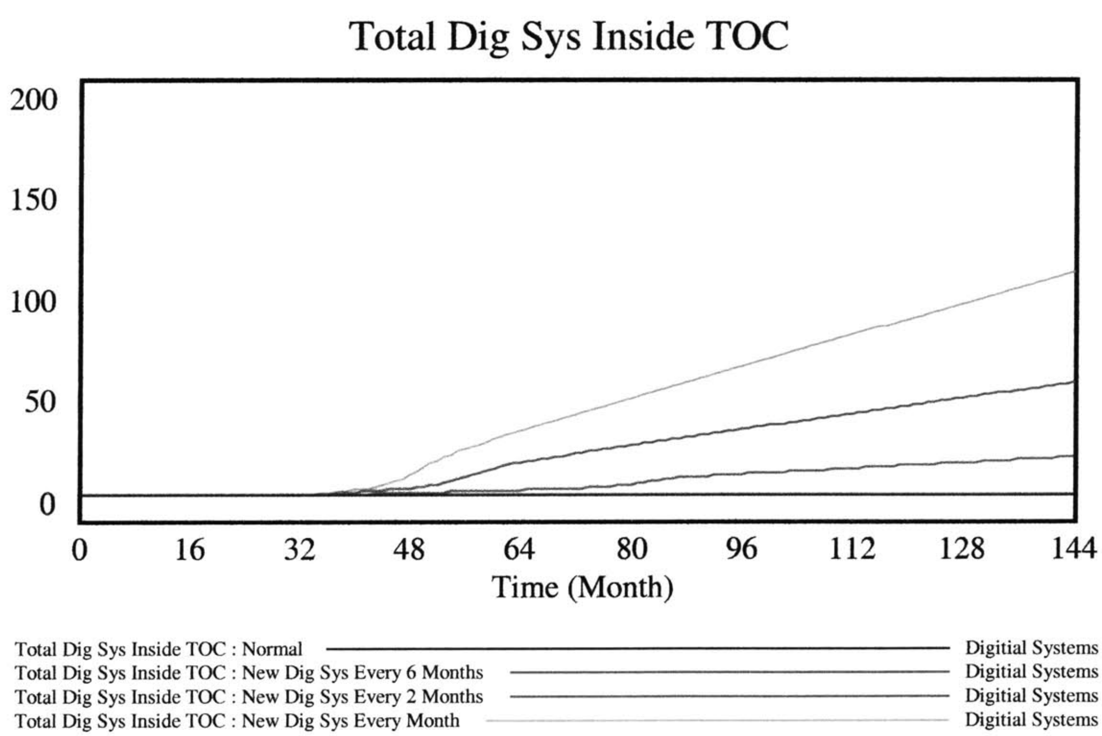

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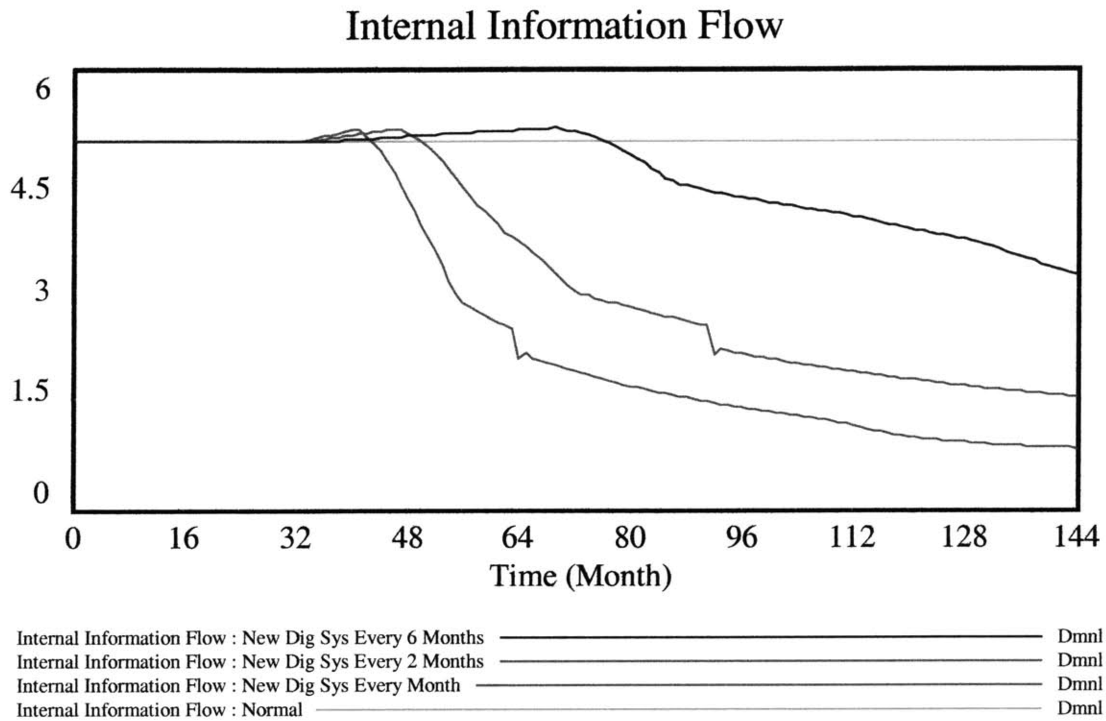

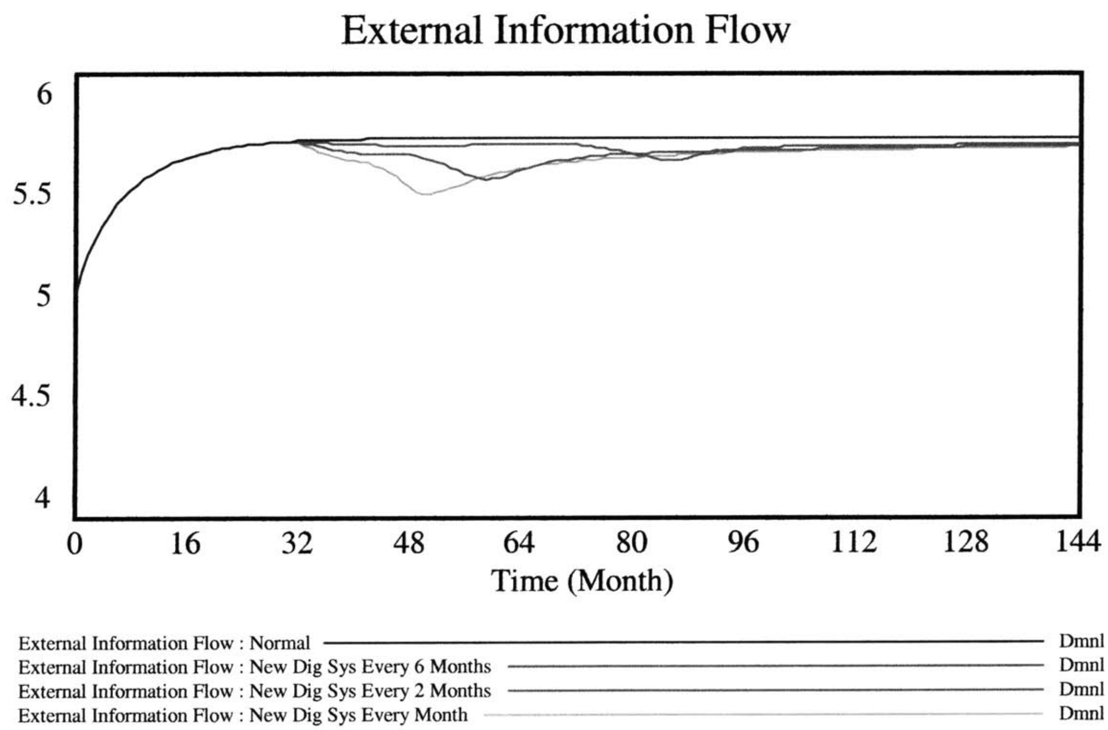

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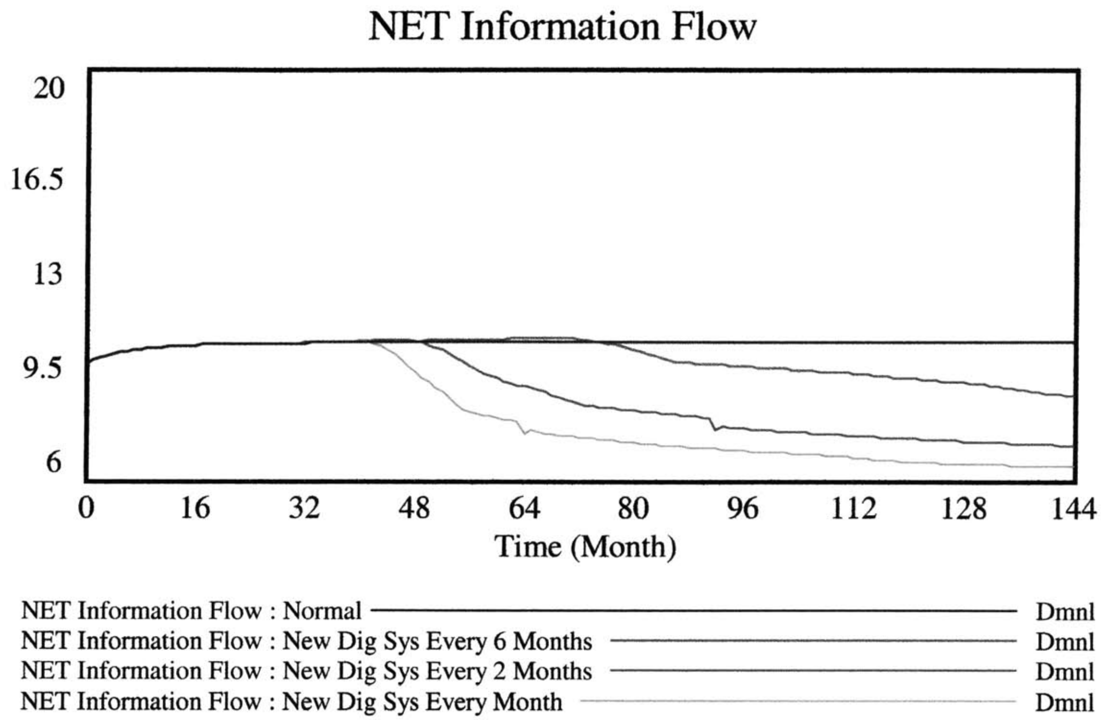

Section 7.3 Number of Hierarchical Barriers

The next four experiments were conducted by manipulating the exogenous variable "Number of Hierarchical Barriers." A full definition of this variable and those closely associated with it are found in Appendix C. In short, this variable measures the number of Hierarchical Barriers involved with transmittal of information between TOCs or between command and control nodes. For example, it is not normal practice for Army units to share information laterally (unless they have the same parent nodes, for example two companies in the same battalion, but even this is almost always limited). The model considers a value of four hierarchical barriers normal. At the tactical level where Platoons are the primary units of maneuver, these barriers are at Company, Battalion, Brigade and Division levels. Experimental trials were conducted by decreasing the value of Hierarchical Barriers from 4 to 3, then to 2 and 1. What this represents is moving from a stove-piped hierarchical reporting system to where information is shared laterally throughout the network of command and control nodes. The following graphs show the impact of changing the Number of Hierarchical Barriers on the system. The exogenous variable was changed at time

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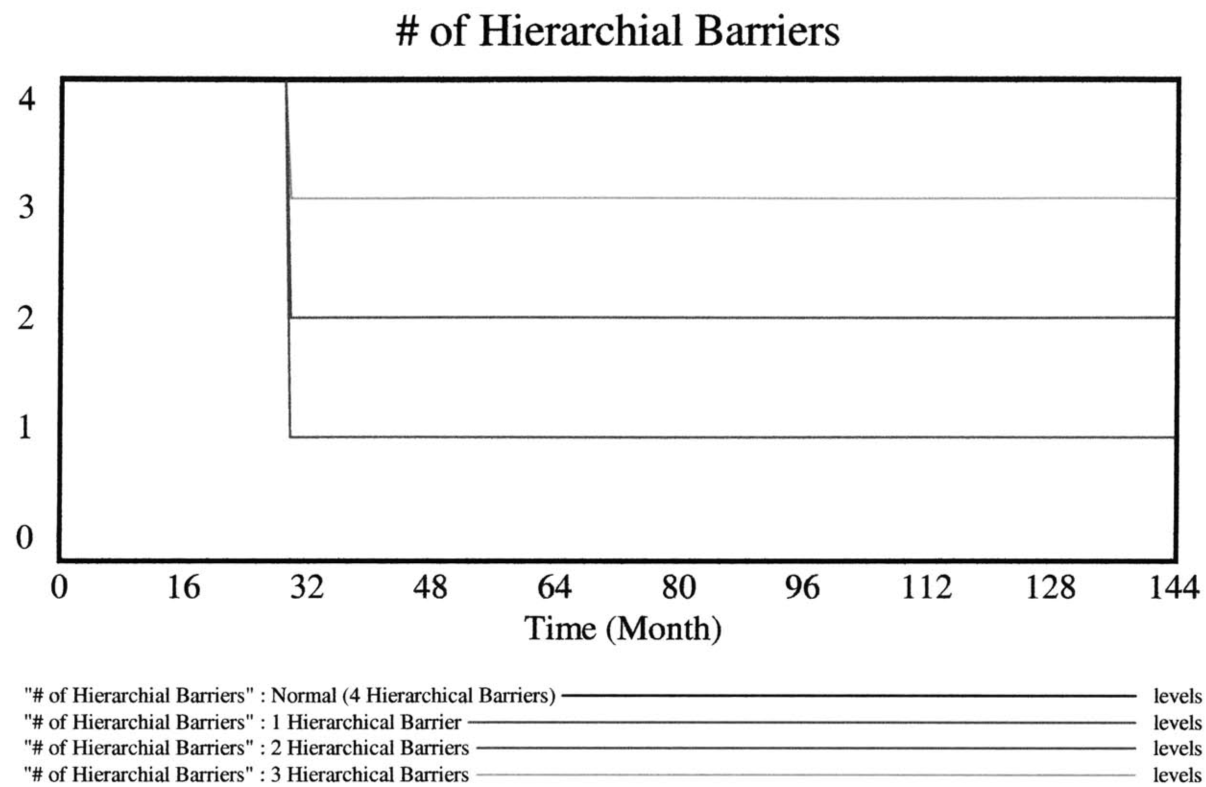
= 30 months or t = 30. The following chart demonstrates how changes in the exogenous variable Number of Hierarchical Barriers was manipulated during each experiment.



The following five charts show the impact that decreasing the Number of Hierarchical Barriers has on the system. As the graphs show, decreased Hierarchical Barriers has an almost insignificant impact on both Actual TOC Manning and Total Digital Systems Inside the TOC. Consequently, it also shows that decreasing the Number of Hierarchical Barriers has an insignificant impact on Internal Information Flow. This confirms the previous correlation between Total Digital Systems Inside TOC and Internal Information Flow and Actual TOC Manning and Internal Information Flow. Most importantly, however, these four simulations

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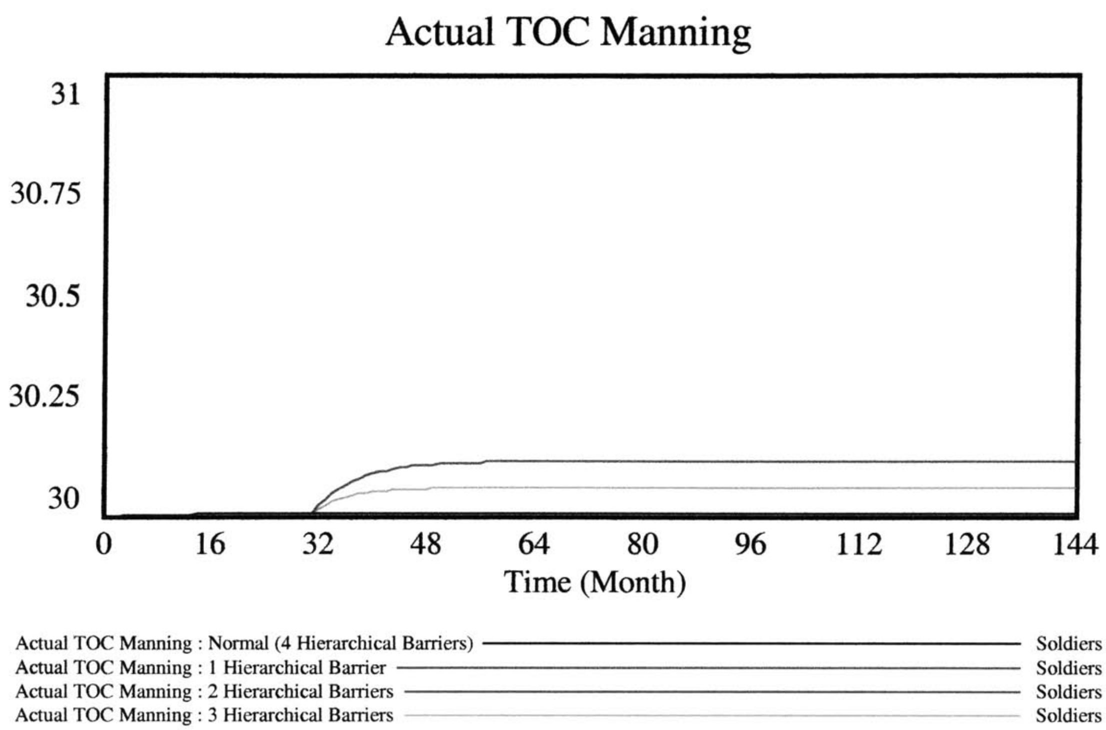
show that as the Number of Hierarchical Barriers is decreased, External Information Flow and NET Information Flow increases exponentially.



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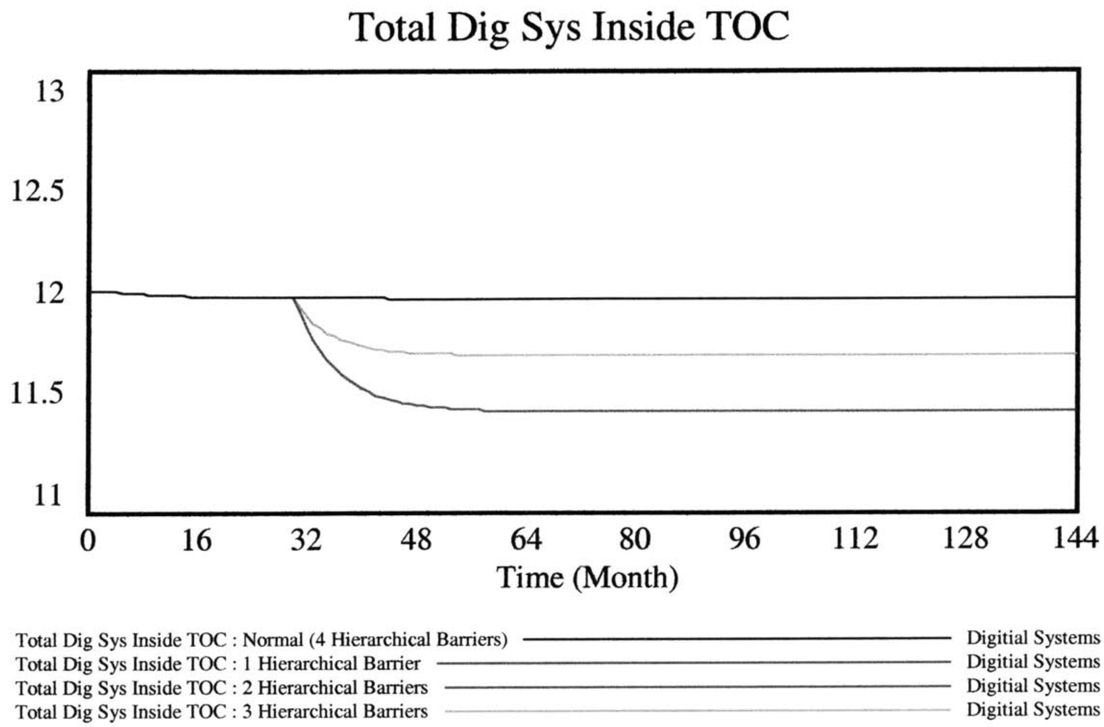

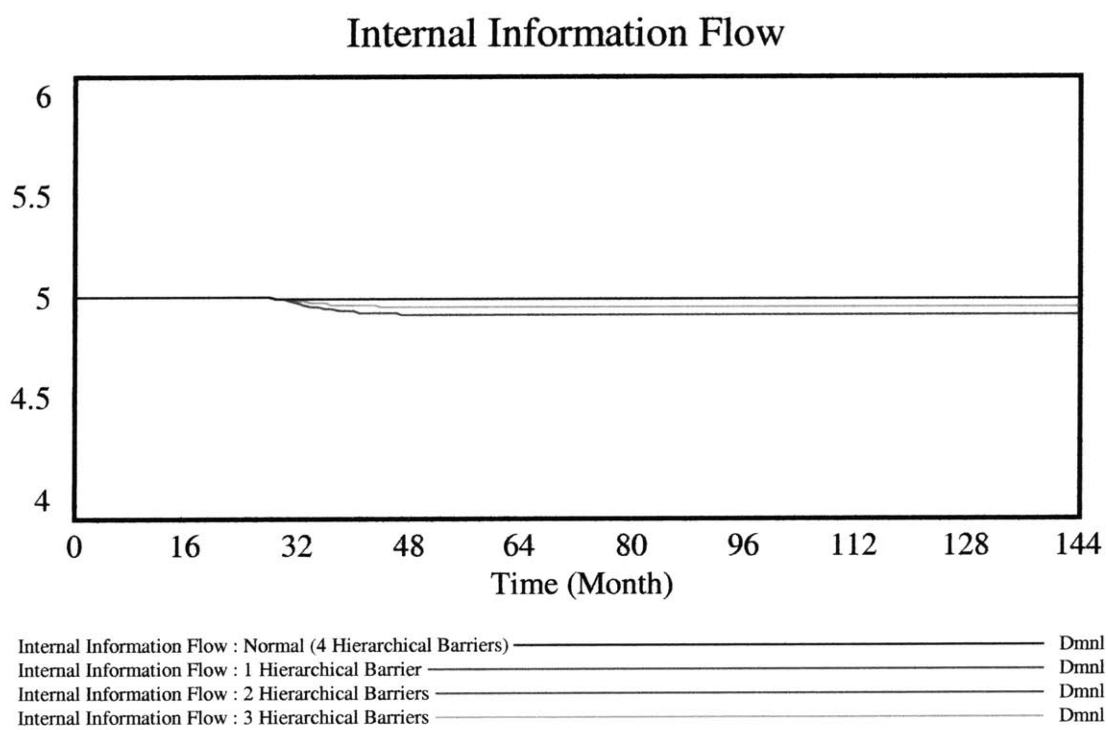

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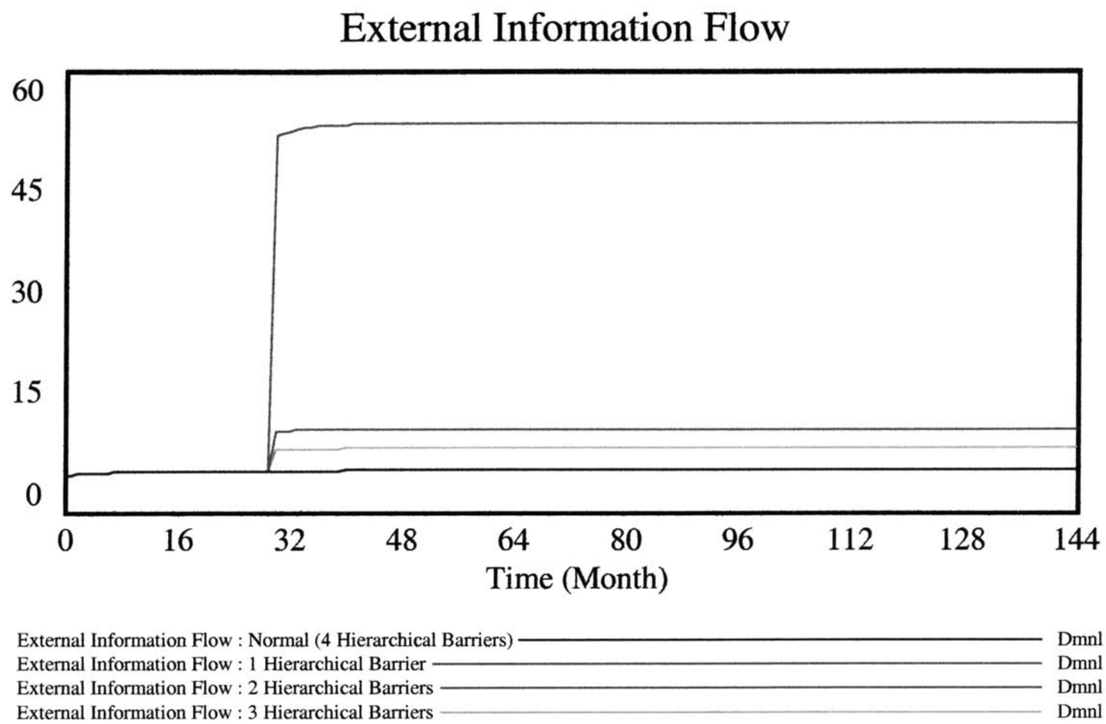

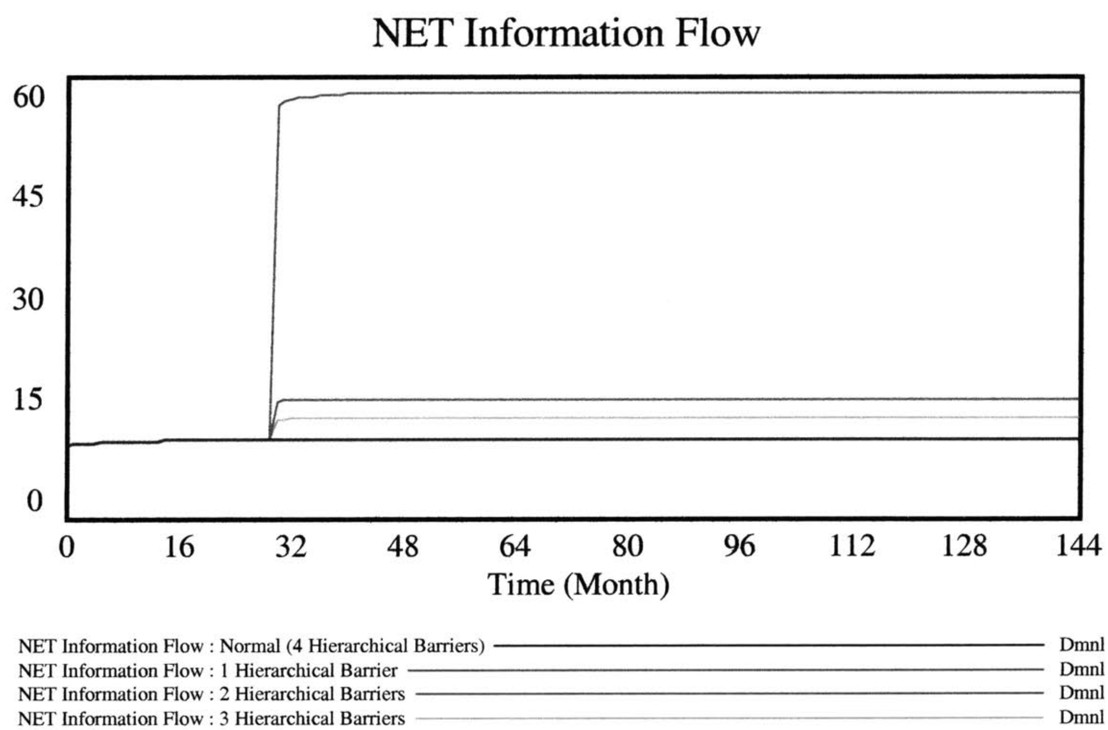

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Section 7.4 Simulation Using Arrays

After using the one-at-a-time method for manipulating the exogenous variables, an array method was used to determine any additional insights and confirm the previous findings in more realistic scenarios. Five distinct arrays or scenarios were developed and tested. During each test 2 or 3 exogenous variables were manipulated. The times when each variable was changed varied so that the effects that each variable was having on the system could still be measured with some degree of independence. All changes for Simultaneous Full Spectrum Operations (SFSO) occurred at time thirty (t = 30), all changes for New Digital Systems Development (NDSD) occurred at time sixty (t = 60), and all changes for Number of Hierarchical Barriers (NHB) changed at time ninety (t = 90). The following table shows what values the exogenous variables were set at for each simulation.

Simulation Number	SFSO	NDSD	NHB
1	4	0	4
2	7	2 months	4
3	10	1 month	4
4	10	1 month	3
5	10	1 month	1

The following graphs show the impact that each array of variables had on the system for each impact. The first three graphs, specifically, show how the exogenous variables changed for each simulation iteration.

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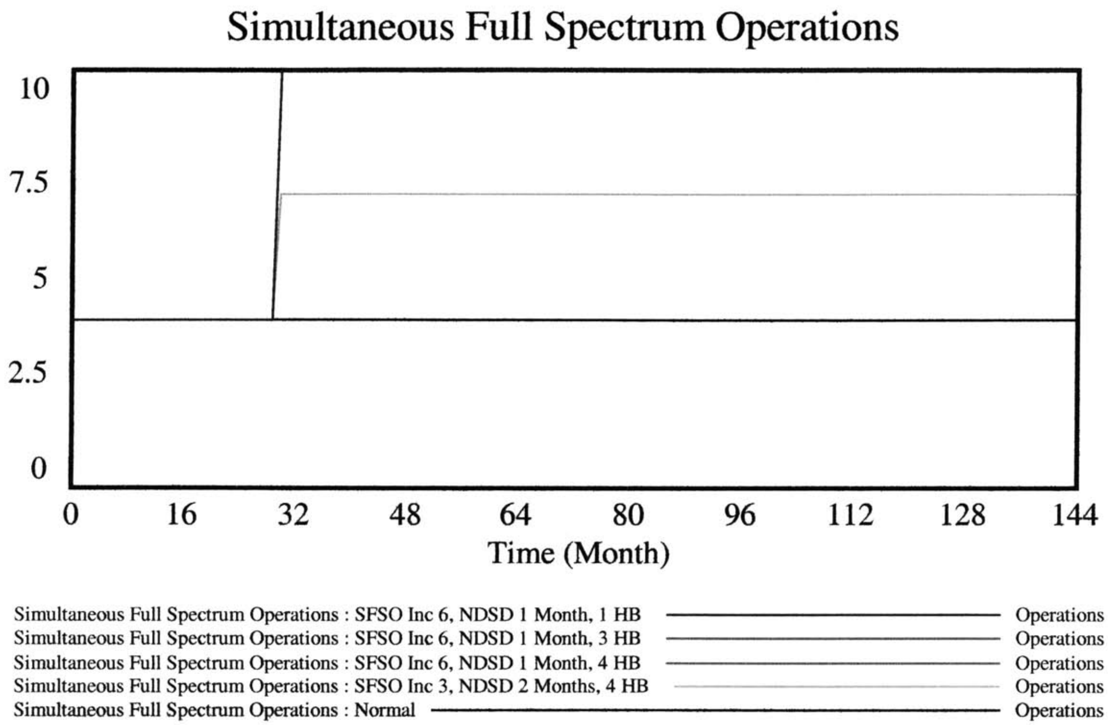

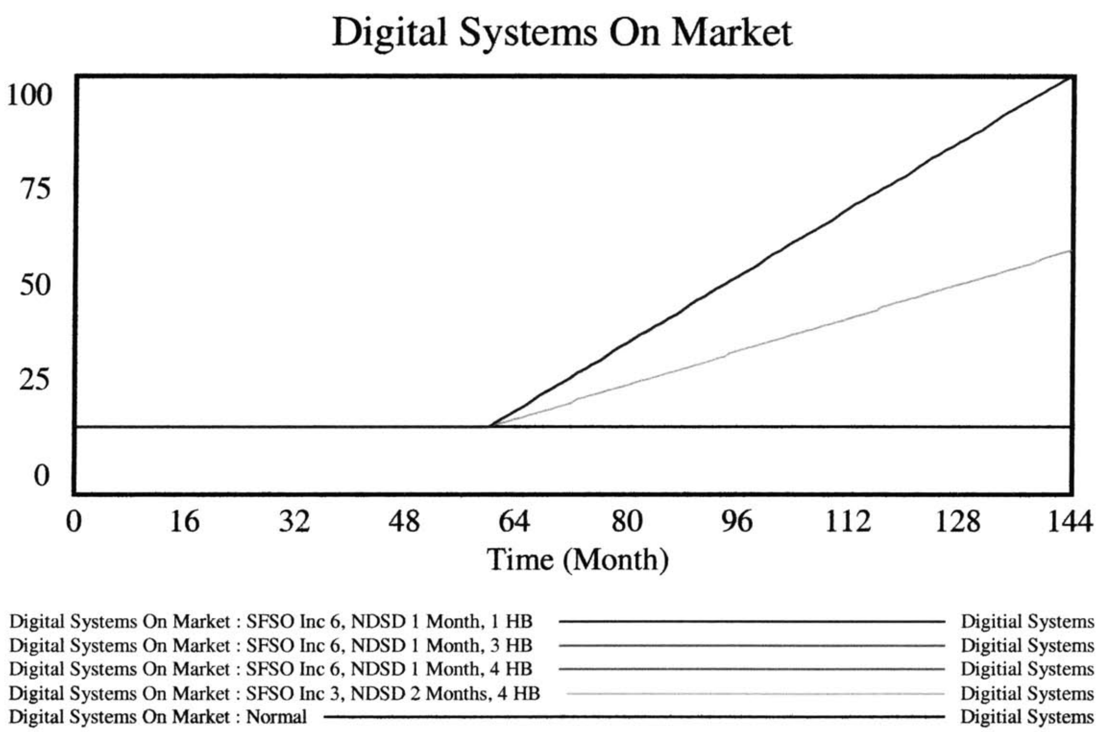

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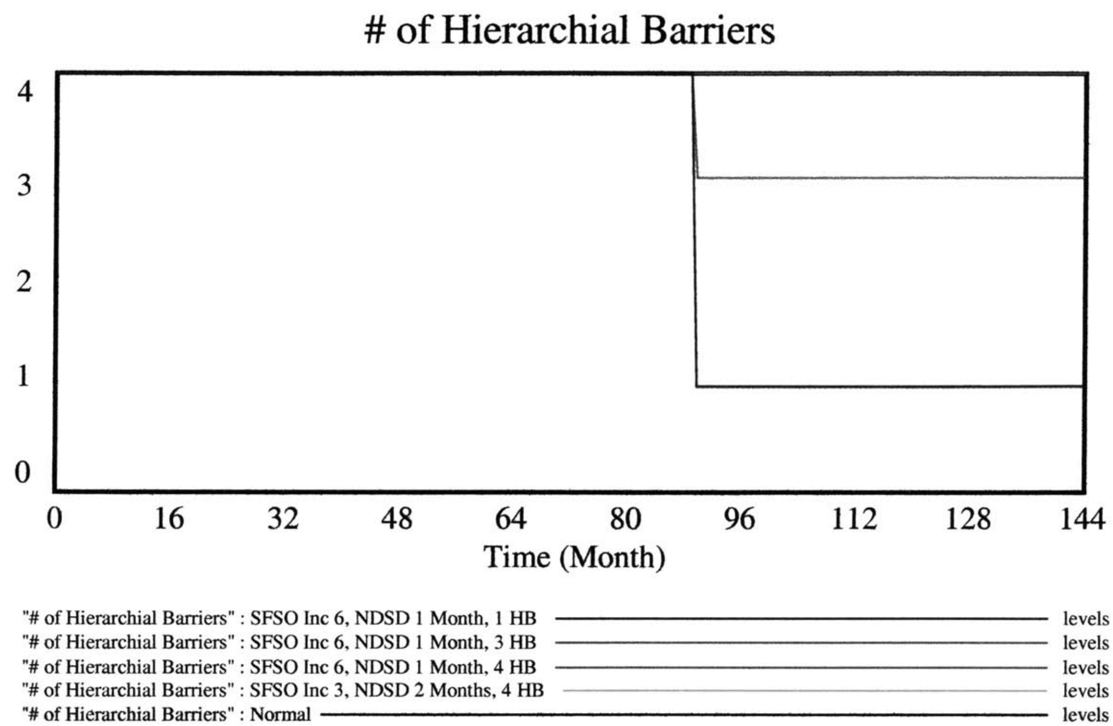

The next five graphs show how these changes in the exogenous variables produced changes in the system. For actual TOC Manning, the graph clearly shows that most of the changes occurred at time 30 when the level of Simultaneous Full Spectrum Operations was increased. Increasing New Digital System Development at time 60 had a delayed, but moderate impact, and decreasing the number of hierarchical barriers at time ninety at a very low impact. The graph for Total Digital Systems Inside the TOC shows that increases in the level of Simultaneous Full Spectrum Operations at time 30 had a negligible impact on this variable, while increasing New Digital System Development at time 60 had a significant affect, and decreasing the Number of Hierarchical Barriers at time 90 had an insignificant impact.

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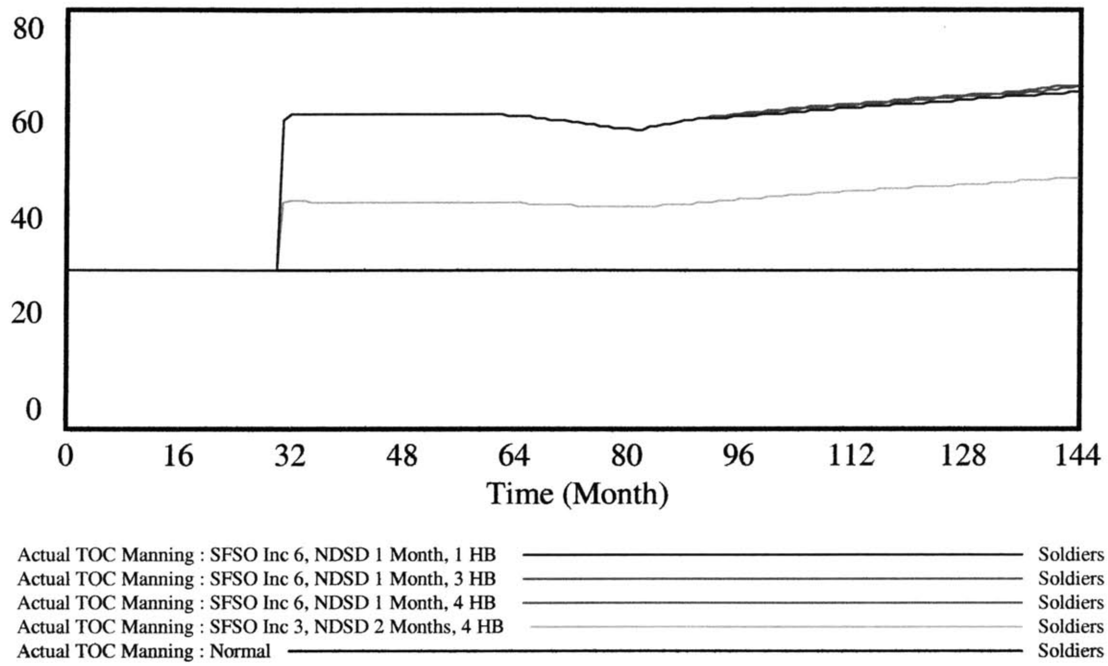
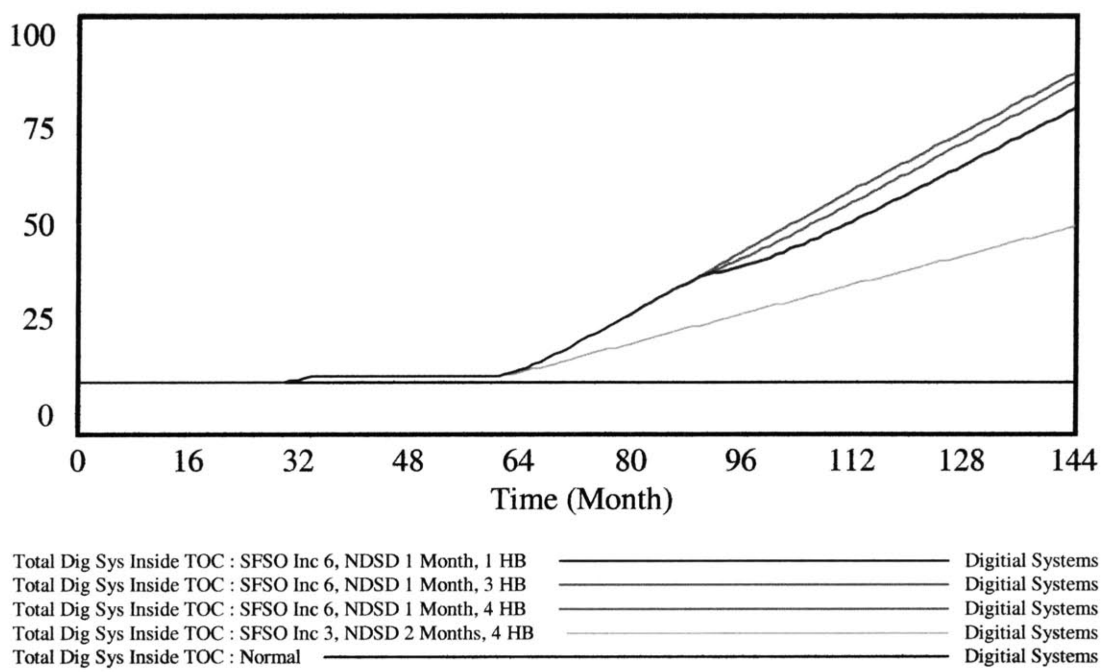
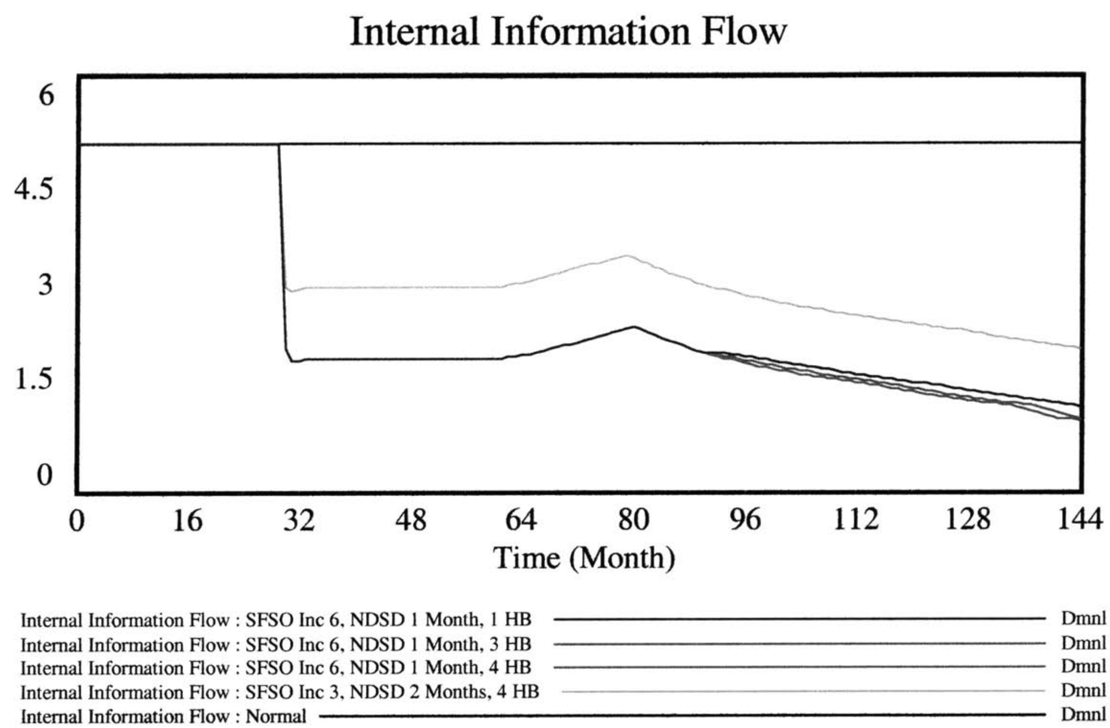
Actual TOC Manning



Total Dig Sys Inside TOC



The following three graphs show how each of the arrays impacted Internal, External, and NET Information Flow. As the Internal Information Flow graph shows, increases in Simultaneous Full Spectrum Operations at time 30 had a very significant and negative impact on Internal Information Flow, while an increase in New Digital Systems Development at time 60 at first had a slightly positive impact but then at time 80 produced a negative impact. This means that initially at time 60 New Digital Systems Development was improving Internal Information Flow but that this improvement was not sustainable and it collapsed at time 80. Therefore, New Digital Systems Development had an overall low but negative impact on Internal Information Flow. The chart also clearly demonstrates that decreasing the Number of Hierarchical Barriers at time 90 had an insignificant impact on Internal Information Flow.



The graph of External Information Flow shows that both increases in Simultaneous Full Spectrum Operations at time 30 and increases in New Digital Systems Development at time 60 had an insignificant impact on External Information Flow. However, it shows that a reduction in the Number of Hierarchical Barriers at time 90 has a significant and positive impact on External Information Flow. Also, it is important to mention that the chart shows that decreasing the

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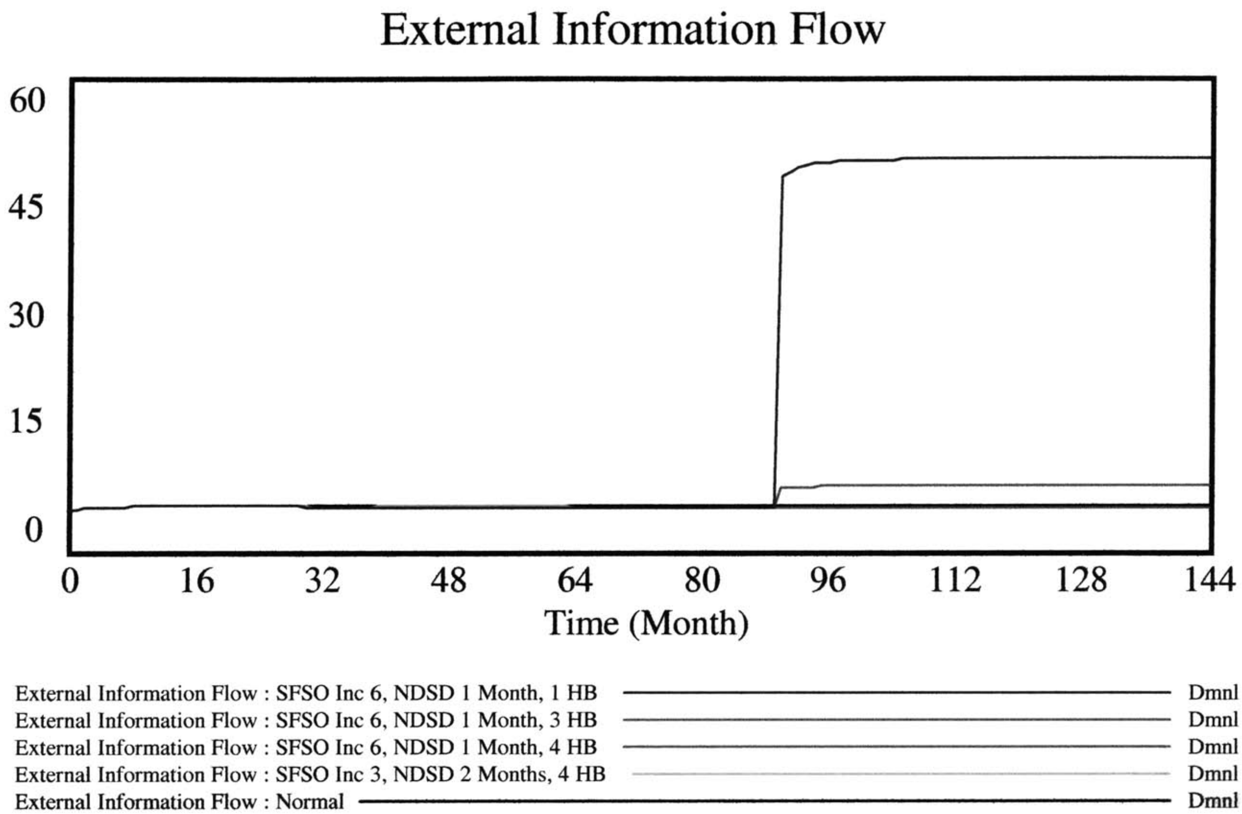
Number of Hierarchical Barriers clearly increases the External Information flow exponentially by several orders of magnitude. This suggests that decreasing the Humber of Hierarchical Barriers might have a revolutionary impact on External Information Flow.



Finally, the chart below shows that increasing Actual TOC Manning at time 30 has a moderate and negative impact on NET Information Flow, increasing New Digital System Development at time 60 has a minor and almost insignificant impact on NET Information Flow, and decreasing the Number of Hierarchical Barriers at time 90 has a significant and positive affect on NET Information Flow.

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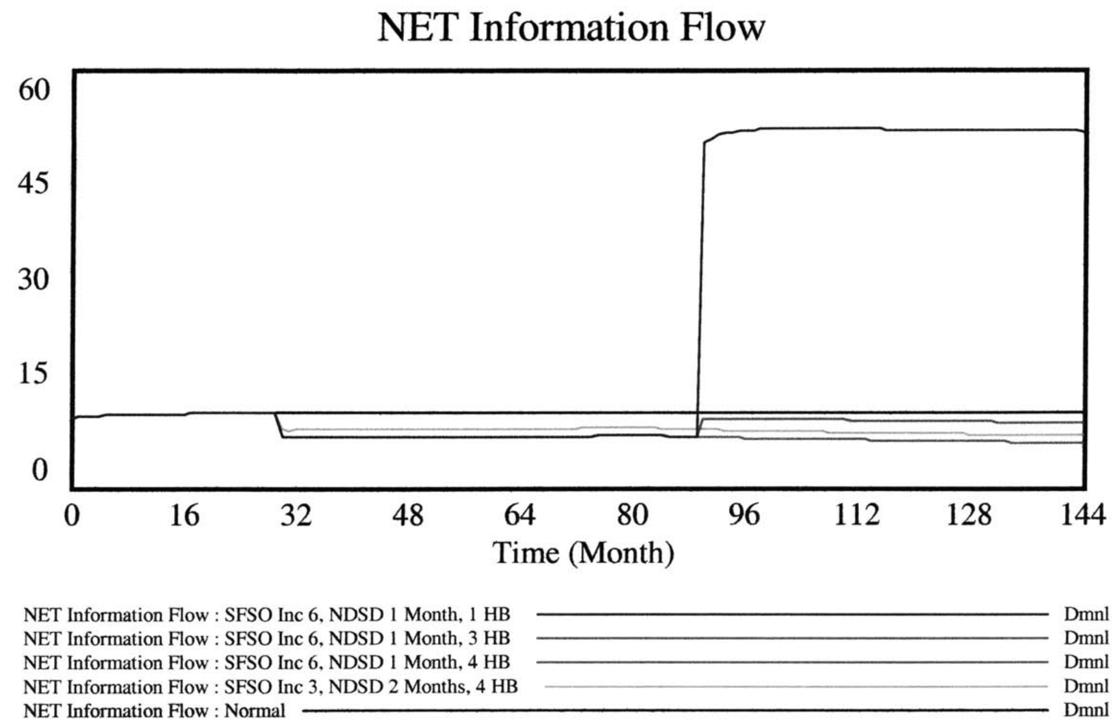

Section 7.5 Summary of Simulation Key Insights

There were several key findings that emerged during conduct of the 17 simulations, all of which have important implications for the Battalion TOC as well as the Brigade Combat Team Command and Control Architecture. These findings are summarized as follows:

1. Contrary to normal intuition, increasing the number of personnel working inside the Tactical Operations Center has a negative and very significant impact on Internal Information Flow. The simulations also suggest that this loss is not made up for by improved External Information Flow or NET Information Flow. Therefore, the findings from this study suggest that while it may be important to add new functional areas to the TOC, these functions should be covered by as few people as possible in order to minimize the number of bureaucratic hierarchical layers as well as the size of the TOC, both of which produce a decrease in overall TOC Information Flow.

2. Increasing the number of digital systems inside the TOC has a negative impact on Internal Information Flow. While the additional digital systems do produce a minor improvement in

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External Information Flow, this improvement does not make up for the loss in Internal Information Flow as evidenced by its insignificant impact on NET Information Flow. The model suggests that the problem with adding digital systems to the TOC is actually that more people are added to the TOC to man the new systems, therefore increasing the number of personnel working in the TOC. Thus, increasing the bureaucratic hierarchy and the physical size of the TOC, and therefore decreasing Internal Information Flow. These findings suggest that while new digital systems may be necessary, they should replace existing systems when possible or ways should be found to integrate the new systems into the TOC without adding more Soldiers to man them.

3. Decreasing the Number of Hierarchical Barriers increases External Information Flow by orders of magnitude. This is a very exciting finding. It supports much of the Network Centric Warfare literature discussed in the literature review and suggests that Metcalfe's Law applies to tactical command and control of Army units.

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PART III – Concept for a Re-Architected Battalion TOC & Recommendations

Chapter 8 – Conclusions and Recommendations

The following set of five heuristics are a result of the synthesis of material discussed in both the literature review and analysis sections of this study. These five heuristics are all considered to be equally critical, and are intended to provide a concept for future design improvements of the BCT C2 Architecture and the BN TOC.

1) ***A flatter C2 Architecture will produce enhanced self-synchronization, speed of command, and improve the timeliness, relevance and richness of information flow.*** This requires elimination of the stove-piped command and control structure, focusing on lateral reporting and transmittal of intelligence across the organization in lieu of stove-piped vertical reporting. As discussed in the Network Centric Warfare review, this heuristic is supported by Metcalfe's Law and is depicted on the following two diagrams.

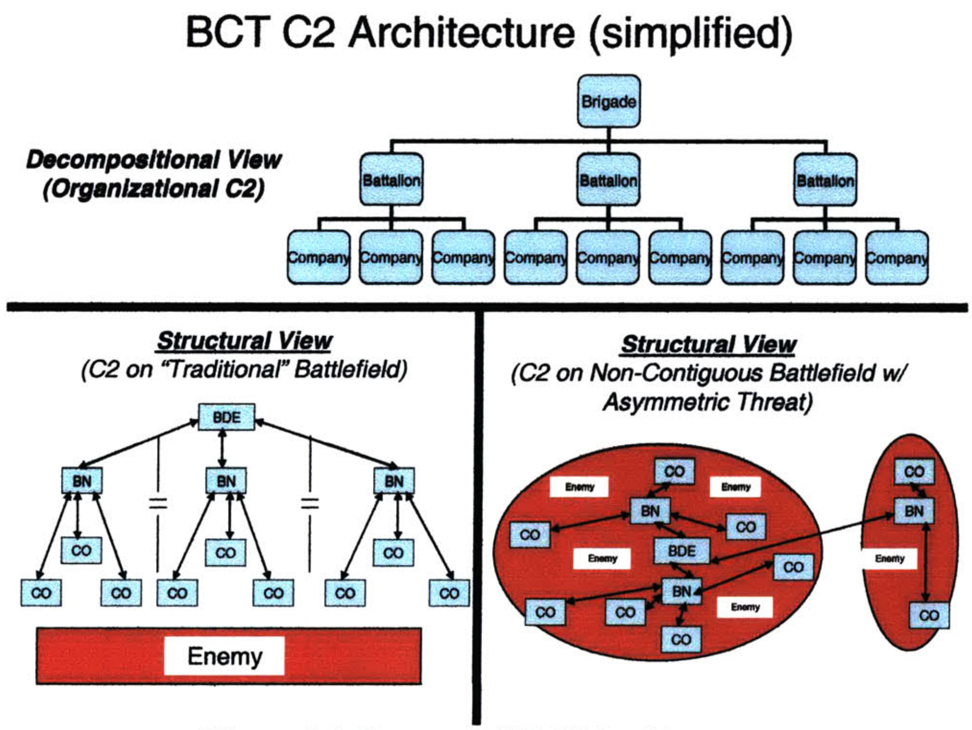

Figure 8-1 Current BCT C2 Architecture

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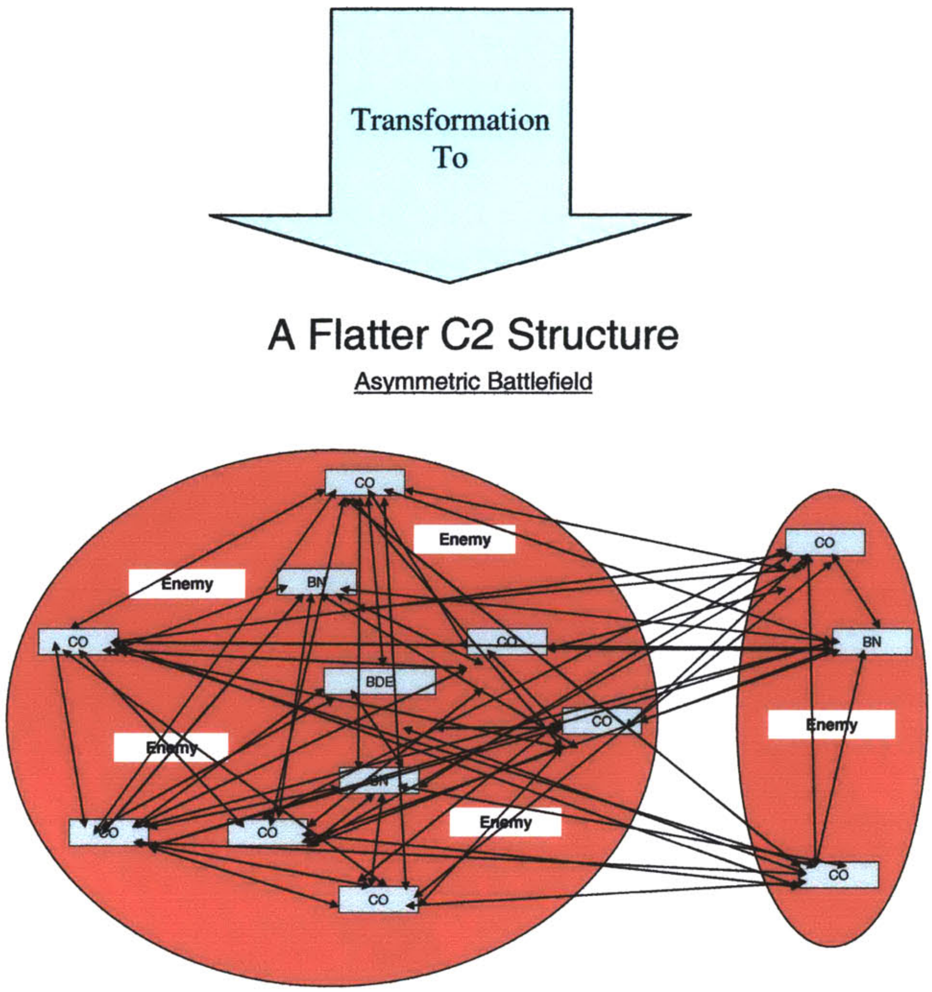

Figure 8-2 A Flatter C2 Structure

2) ***Switching the locus of power control by "powering down" or moving "power to the edge" will enable self-synchronization, exponentially accelerated flexibility and agility, increased speed of command, and improved timeliness, relevance and richness of information.*** Modern wars are fought by platoons and companies and Information Age systems give platoons and companies an unprecedented real time view of the battlefield and therefore an improved ability to make decisions while understanding the larger context. In order to power down, however, cultural change is required. Currently, the Army's least experienced people (Lieutenants with no experience and Captains with normally less than seven years experience command these "edge" organizations). In order to power down effectively, the Army should consider placing more

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experienced people in these positions (i.e. senior Lieutenants and junior Captains with three to six years experience as platoon leaders and senior Captains or junior Majors with eight to twelve years experience as company commanders). This would require changes to the entire Army personnel manning system and therefore much study would be needed to determine how to best implement this system. But in the context of the contemporary operating environment and the information revolution, it no longer appears optimal to have the most experienced people staffing brigade headquarters and above and the least experienced people at the edge of the organization.

3) ***Leaning out the BN TOC will improve the flexibility and agility of the organization, improve the speed of command, and enhance the timeliness, relevance and richness of information flow.*** The System Dynamics model for this study clearly articulates this point, as does the literature review section. In order to accomplish this, special attention should be paid to how many digital systems are needed in the TOC, and eliminating those that do not create value for the organization. In addition, it is critical to minimize the manning of these digital systems so as to avoid creating an excessive hierarchy and bureaucracy inside the TOC. Also, as the contemporary operating environment and non-contiguity of the battlefield require more functions to be accomplished within the TOC, it is important to minimize the number of people who are added to the TOC to accomplish these functions by asking: Can one person accomplish two or more functions instead of one? Can a particular function be accomplished by one or two people in lieu of five or six?

4) ***Switching from deliberate to more expedited decision making techniques and procedures will increase the speed of command and improve the flexibility and agility of the organization.*** As previously mentioned, the current MDMP is a very long and laborious process that is symptomatic of the current focus on objective specific, problem solving style of command and control (see Figure 8-3). Switching to a command focused system such as the mission specific philosophy of command and control that is either control free or exercises selective control supports network centric warfare theory and will improve the flow of information and the speed of command within the BCT and the BN TOC. Also, switching from the lengthy MDMP to an expedited process such as the RPDM should also be considered.

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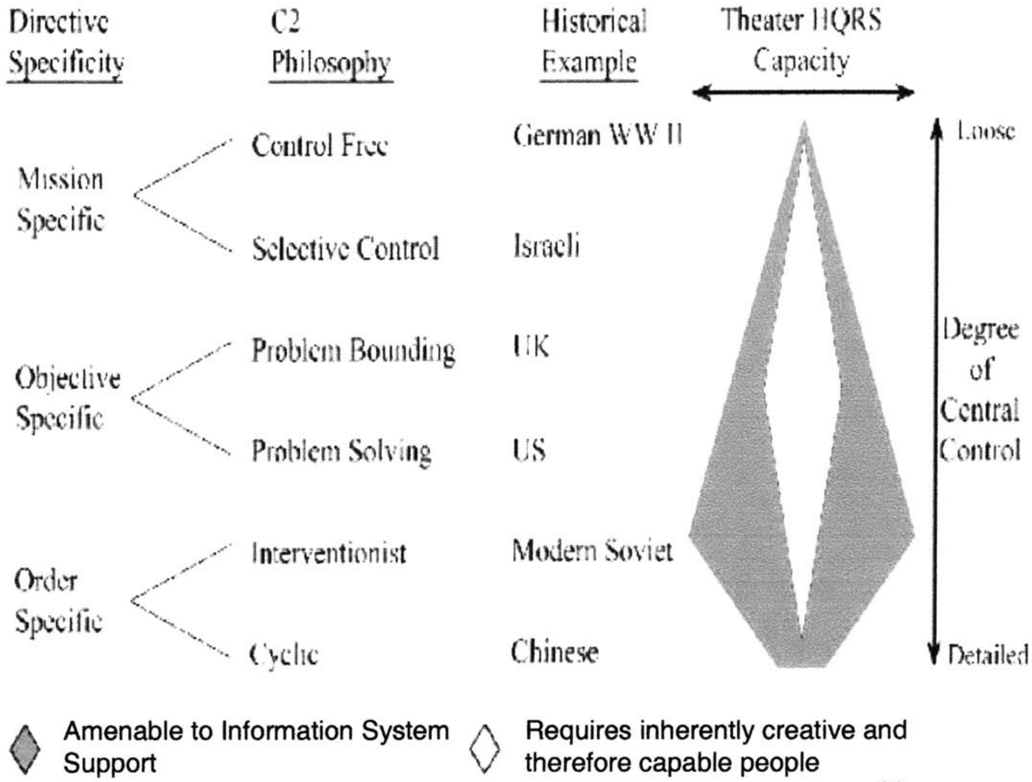

Figure 8-3 Historical Choices Among C2 Philosophies[96]

5) ***Improved Intelligence, Surveillance and Reconnaissance capability within the BCT, and a switch from push to pull intelligence will improve self-synchronization, exponentially increase flexibility and agility, enhance the speed of command, and drastically improve the timeliness, relevance and richness of information.*** As previously mentioned, the current stove-piped hierarchy focuses on reporting vertically within the organization. This translates to critical intelligence being stored and processed for lengthy periods of times at the highest levels of the organization (usually at levels above the BCT such as Division and Corps). By creating a database where "edge" or "lead" users, the consumers of intelligence, can pull the intelligence they need from higher organizations, actors will be enabled to action target packages much faster than they have in the past. This will improve the BCT's ability to out OODA its adversaries, and achieve unprecedented dominance on the battlefield.

[96] Alberts, Understanding Information Age Warfare, p. 170.

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In conclusion, this study provides a set of heuristics that can be used by the Army to help guide future architectural enhancements to both the BCT C2 Architecture and to organization of the BN TOC. Further study is needed to determine "HOW TO" best implement each of these five heuristics, and to determine to what extent each of them should be implemented. In addition, this study also demonstrates the ability of System Dynamics to be used as a tool to help analyze and provide helpful insights to military problems.

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Appendix A: Acronyms

ABCS	Army Battle Command System
ADA	Air Defense Artillery
AFATDS	Advanced Field Artillery Tactical Data System
ALO	Air Liaison Officer
AMDWS	Air and Missile Defense Work Stations
ASAS	All Source Analysis System
BCT	Brigade Combat Team
BFT	Blue Force Tracker
BN	Battalion
BOOT	The connection between the main tent and a connected vehicle.
C2	Command and Control
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CA	Civil Affairs
CAS	Close Air Support
CDR	Commander
CIA	Central Intelligence Agency
CO	Company
COE	Contemporary Operating Environment
COP	Common Operational Picture
CP	Command Post
CSSCS	Combat Service Support Computer System

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CPOF	Command Post of the Future
CTCP	Combat Trains Command Post
DNVT	Digital Non-Secure Voice Terminal
EBO	Effects Based Operations
EMP	Electro-Magnetic Pulse
FBCB2	Force XXI Battle Command, Brigade-and-Below
FSE	Fire Support Element
FCS	Future Combat Systems
IED	Improvised Explosive Device
ISF	Iraqi Security Forces
G2	Designates the Intelligence Section of the General Staff.
GPS	Global Positioning System
MCS	Maneuver Control Station
MCS-L	Maneuver Control Station- Light
MDMP	Military Decision Making Process
NBC	Nuclear, Biological and Chemical
NCO	Network Centric Operations
NCW	Network Centric Warfare
NSA	National Security Agency
OGAs	Other Governmental Agencies
OODA	Observe-Orient-Decide-Act (AKA Boyd Cycle)
OPS	Operations

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RMA	Revolution in Military Affairs
RPDM	Recognition Primed Decision Making
RPG	Rocket Propelled Grenade
RTO	Radio Telephone Operator
S1	Personnel Officer/ Section (S denotes BN or BCT Staff, G denotes General Officer Staff (Division and Above))
S2	Intelligence Officer/Section
S3	Operations Officer/Section
S4	Logistics Officer/Section
S6	Signal Officer/Section
SBCT	Stryker Brigade Combat Team
SIGACTS	Significant Activities
STU-III	Secure Telephone Unit- Third Generation
TACSAT	Satellite Radio
TOC	Tactical Operations Center
UA	Unit of Action
UAV	Un-manned Aerial Vehicle
UV	Un-manned Vehicle
WMD	Weapons of Mass Destruction
XO	Executive Office (2nd in Command)

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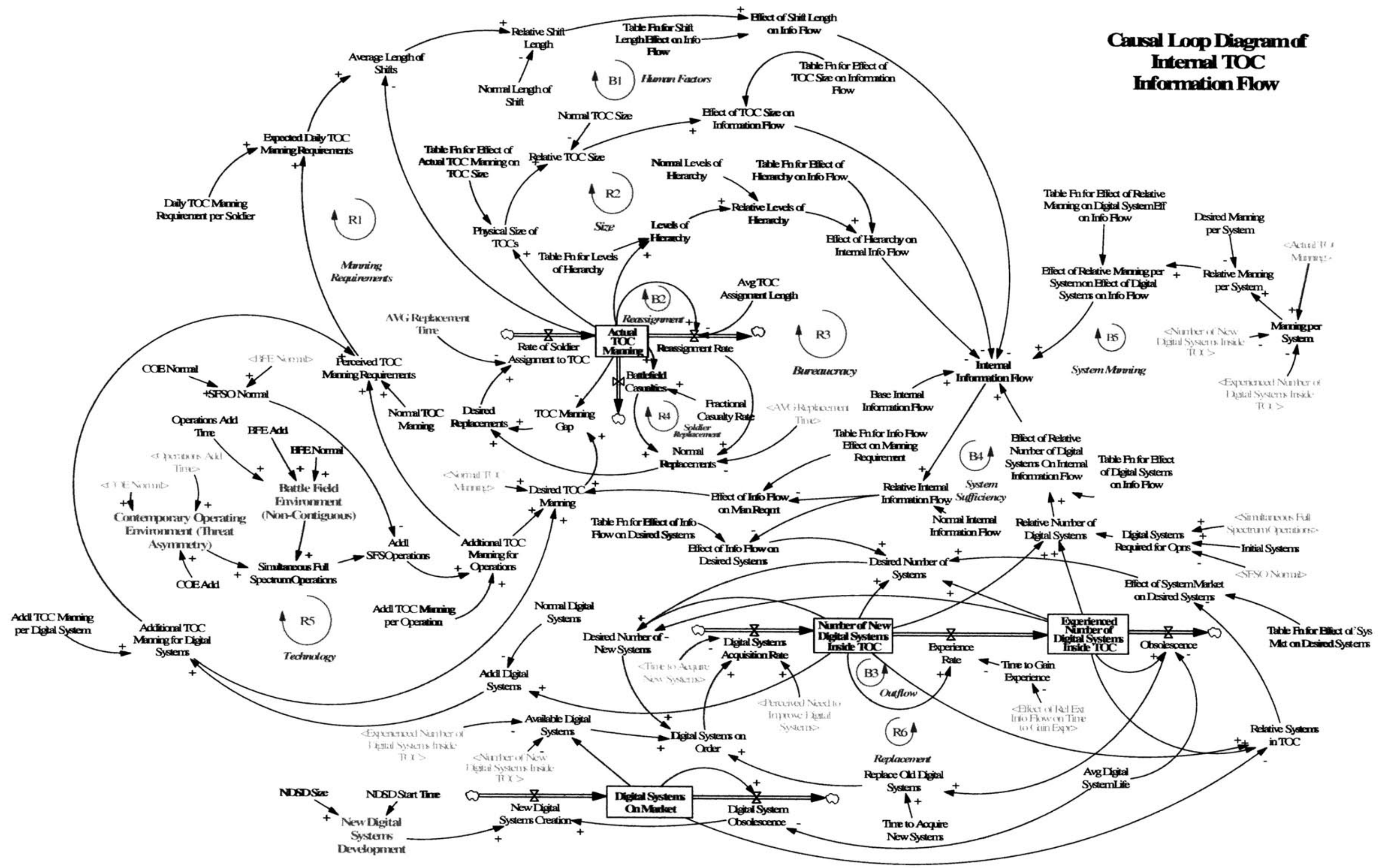
Appendix B: System Dynamics Model



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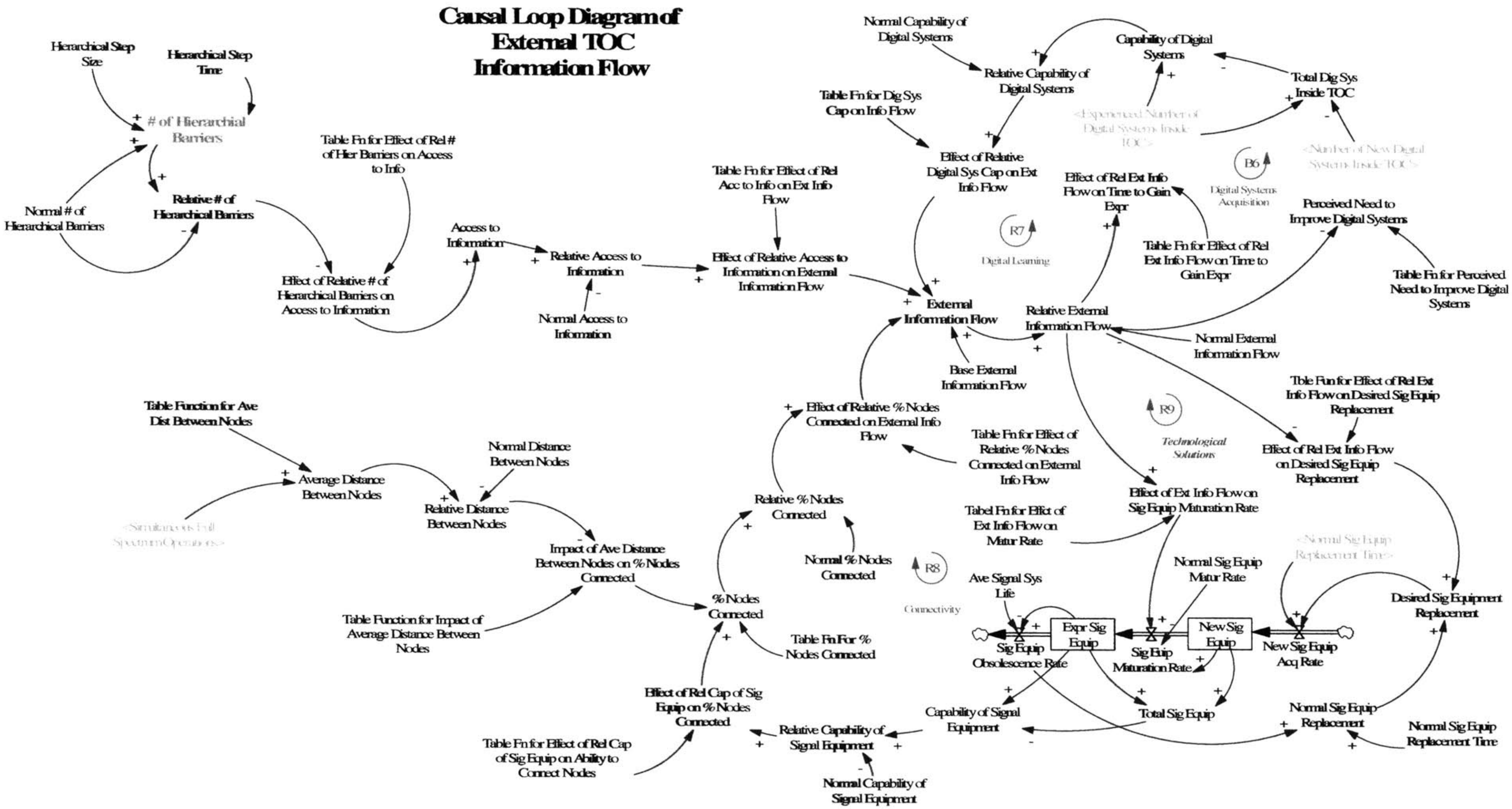

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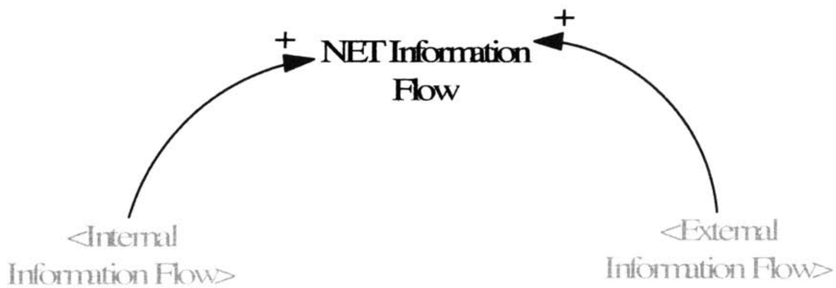

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Appendix C: System Dynamics Variables and Formulas

of Hierarchical Barriers=Normal # of Hierarchical Barriers"+STEP(Hierarchical Step Size, Hierarchical Step Time)
Units: levels
There are currently 4 levels of hierarchical barriers regarding external information flow. This means that information must travel up the hierarchy before it can be sent back down the hierarchy, these 4 levels are the battalion, brigade, division, and corps headquarters. In reality, there is some lateral sharing of information, but this is not deemed as the normal means of reporting or sharing information and the level of cross level sharing varies between units.

% Nodes Connected=
"Table Fn For % Nodes Connected"(("Effect of Rel Cap of Sig Equip on % Nodes Connected"+"Impact of Ave Distance Between Nodes on % Nodes Connected")/2)
Units: nodes
The percentage of nodes (or TOCs) connected in the network

Access to Information=
"Effect of Relative # of Hierarchical Barriers on Access to Information"
Units: Dmnl
Calculates the ability of a unit to access information given a number of hierarchical barriers in existence

Actual TOC Manning= INTEG (Rate of Soldier Assignment to TOC-Battlefield Casualties-Reassignment Rate,30)
Units: Soldiers
The initial value of 30 accounts for the "normal TOC Manning" then takes into account the inflow of Soldiers minus the two outflows of "reassignment" and "battlefield casualties."

Additional TOC Manning for Digital Systems=
MAX(Addl Digital Systems*Addl TOC Manning per Digital System, 0)
Units: Soldiers
Takes into account the number of digital systems inside the TOC and the number of Soldiers needed to operate each system, producing the TOTAL number of Soldiers needed to operate all of the digital systems.

Addl Digital Systems=
Number of New Digital Systems Inside TOC-Normal Digital Systems
Units: Systems
The number of new digital systems added to the TOC to account for an increased need in systems.

Addl SFSOperations=Simultaneous Full Spectrum Operations-SFSO Normal
Units: Operations

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This variable accounts for the number of "new" operations needed above the normal amount to support full spectrum operations.

Addl TOC Manning per Digital System=2
Units: Soldiers/System
In almost every case, one additional Soldier is needed to operate each new system, assuming 3 shifts in an ideal world each day, this means 3 additional Soldiers/ new system.

Addl TOC Manning per Operation=3
Units: Soldiers/Operation
This variable accounts for the average of 3 soldiers per additional staff function in the TOC. i.e. the Civil Affairs Cell usually has 3 Soldiers working 8 hour shifts in the TOC, which is the norm for most functional groups.

Additional TOC Manning for Operations=Addl SFSOperations*Addl TOC Manning per Operation
Units: Soldiers
This variable accounts for the total number of "extra" personal assigned to the TOC as a result of the need to conduct simultaneous full spectrum operations.

Available Digital Systems=MAX(0,Digital Systems On Market-Number of New Digital Systems Inside TOC-Experienced Number of Digital Systems Inside TOC)
Units: Systems
The number of digital systems on the market minus the number of digital systems already inside the TOC.

Ave Signal Sys Life=72
Units: Months
The average signal system lasts 6 years before it needs to be replaced or becomes obsolete

Average Distance Between Nodes=Table Function for Ave Dist Between Nodes(Simultaneous Full Spectrum Operations)
Units: Kilometers
Provides a value for the average distance between nodes as derived from the lookup table and simultaneous full spectrum operations.

Average Length of Shifts=
Expected Daily TOC Manning Requirements/Actual TOC Manning
Units: Hours/Soldier
The average shift length is the total number of Soldier-Hours required to accomplish all required TOC functions over the length of a day divided by the total number of Soldiers assigned to the TOC (Actual TOC Manning).

Avg Digital System Life=72
Units: Month

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The Army currently considers 72 months as average product life time for most digital systems, especially ones that are based on a lap top computer, thus the Army replaces MOST of its digital systems/ computer hardware every 72 months, so this value will be used as the constant variable for average digital system life

AVG Replacement Time=1
Units: Month
One month is assumed as the normal time it takes from when a manning requirement is identified until the time it is filled

Avg TOC Assignment Length=12
Units: Month
Although it is not Army doctrine, almost all commanders and command sergeant majors consider 12 months to be the right amount of time to keep a Soldier in the TOC, any less and he/she never really becomes proficient, and anymore and they can really start to get unmotivated. NOTE: Assignment to the TOC for most Military Occupational Specialties is a "special duty" that a Soldier might perform for a period of time outside from their "normal" specialty. This is often not the case for intel analysts, but for infantrymen, artillerymen, tankers, air defenders and most others it is certainly the case.

Base External Information Flow=5
Units: Dmnl
A qualitative measure for the starting value, equal to the normal value, of the quality of external information flow. Any values greater than this for external information flow signifies an improvement in overall external information flow. Any values below this signify a decrease in the quality of external information flow.

Base Internal Information Flow=5
Units: Dmnl
For the purpose of this model, a value of 10 implies perfect information flow. Information flow is currently measured on a scale of 0-10, with 0 being the absolute worst and 10 the absolute best.

"Battle Field Environment (Non-Contiguous)"=BFE Normal+STEP(1,Operations Add Time)*BFE Add
Units: Operations
This constant variable takes into account the increased number of staff functions that are needed inside the TOC when operating on a non-contiguous battlefield. Normally these additional functions are an aviation liaison section, Air Force close air support controller, a robust signal/communications section, and an engineer section.

Battlefield Casualties=Actual TOC Manning*Fractional Casualty Rate
Units: Soldiers/Month
Accounts for the outflow of Soldiers due to battlefield casualties each month, which is the product of "actual TOC manning" and the "fractional casualty rate."

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BFE Add=0
Units: Operations
The additional number of battle field environment functions
needed as operations become more complex.

BFE Normal=2
Units: Operations
Two battlefield environment functions is considered normal for operations.

Capability of Digital Systems=Experienced Number of Digital Systems Inside TOC/Total Dig Sys Inside TOC
Units: Dmnl
Provides a measure for determining the capability of digital systems inside the TOC by dividing the number of experienced digital systems by the total number of digital systems

Capability of Signal Equipment=Expr Sig Equip/Total Sig Equip
Units: Signal Equipment
The capability of signal equipment is defined as the ratio of the number of experienced signal equipment over the total number of signal systems.

COE Add=0
Units: Operations
Additional functions needed in the TOC as a result of a more complex operating environment.

COE Normal=2
Units: Operations
The normal number of contemporary operating environment functions needed to support operations.

"Contemporary Operating Environment (Threat Asymmetry)"=COE Normal+STEP(1, Operations Add Time)*COE Add
Units: Operations
This constant variable takes into account the average number of additional staff functions that are needed inside the TOC while conducting operations against an asymmetric enemy. Normally these include information operations, civil affairs, psychological operations, civil police liaison cell, host nation national guard/army coordination cell, and a contracting cell (project team).

Daily TOC Manning Requirement per Soldier=12
Units: Hours/Soldier
The average Soldier is expected to work 12 hours in the TOC.

Desired Manning per System=2
Units: Soldiers/System

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The desired manning per system is 2 persons, since average shift length is 12 hours. This allows each system to be fully manned by 1 Soldier 24 hours per day.

Desired Number of New Systems=Desired Number of Systems-Number of New Digital Systems Inside TOC-Experienced Number of Digital Systems Inside TOC
Units: Systems
The desired number of new digital systems as derived by subtracting the total number of systems currently inside the TOC from the total number of desired systems.

Desired Number of Systems=(Number of New Digital Systems Inside TOC+Experienced Number of Digital Systems Inside TOC)*Effect of Info Flow on Desired Systems*Effect of System Market on Desired Systems
Units: Systems
Calculates the desired number of digital systems based on the current status of information flow, the number of systems available on the market, and a consideration of the number of new and experienced systems already inside the TOC.

Desired Replacements=Normal Replacements+TOC Manning Gap
Units: Soldier
This variable takes into account the total number of desired replacements as determined by reassignment and battlefield losses and changes in the TOC Manning Gap.

Desired Sig Equipment Replacement=
Normal Sig Equip Replacement*Effect of Rel Ext Info Flow on Desired Sig Equip Replacement
Units: Sig Equip

Desired TOC Manning=(Normal TOC Manning+Additional TOC Manning for Digital Systems+Additional TOC Manning for Operations)*Effect of Info Flow on Man Reqmt
Units: Soldiers
This variable accounts for the Total Desired TOC manning based on need for normal operations, additional digital systems being fielded/added to TOC, and the impact of Simultaneous Full Spectrum Operations.

Digital System Obsolescence=Digital Systems On Market/Avg Digital System Life
Units: Systems/Month
The rate at which new digital systems on the market become obsolete.

Digital Systems Acquisition Rate=
(Digital Systems on Order/Time to Acquire New Systems)*Perceived Need to Improve Digital Systems
Units: Systems/Month
The average number of new digital systems added to the TOC each month, assuming the Army will buy one fifth of those available New Digital Systems on Market/Time to Acquire New Systems

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Digital Systems On Market= INTEG (+New Digital Systems Creation-Digital System Obsolescence,16)
Units: Digital Systems
The number of new digital systems on the market

Digital Systems on Order=MAX(0,Min(Available Digital Systems,Replace Old Digital Systems+Desired Number of New Systems))
Units: Systems
The total number of digital systems on order

Digital Systems Required for Opns=Simultaneous Full Spectrum Operations*(Initial Systems/SFSO Normal)
Units: Systems
Takes into account the total number of digital systems required for operations

Effect of Ext Info Flow on Sig Equip Maturation Rate=Table Fn for Effct of Ext Info Flow on Matur Rate(Relative External Information Flow)
Units: lessons/Month
Provides a relative and proportional value for measuring the effect of relative external information flow on the signal equipment maturation rate, or the time it takes new signal equipment to become fully integrated and maximized within the signal system and therefore become "experienced."

Effect of Hierarchy on Internal Info Flow=Table Fn for Effect of Hierarchy on Info Flow(Relative Levels of Hierarchy)
Units: Dmnl
Accounts for the impact of hierarchy on TOC information flow

Effect of Info Flow on Desired Systems=Table Fn for Effect of Info Flow on Desired Systems(Relative Internal Information Flow)
Units: Dmnl
Provides the value of the effect of internal information flow on the desired number of digital systems

Effect of Info Flow on Man Reqmt=Table Fn for Info Flow Effect on Manning Requirement(Relative Internal Information Flow)
Units: Dmnl
Provides a ratio for how much TOC manning should change based on status of information flow.

"Effect of Rel Cap of Sig Equip on % Nodes Connected"=Table Fn for Effect of Rel Cap of Sig Equip on Ability to Connect Nodes(Relative Capability of Signal Equipment)
Units: Dmnl
Provides a relative and proportional value for the effect of relative capability of signal equipment on the percentage of nodes connected.

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Effect of Rel Ext Info Flow on Desired Sig Equip Replacement=Tble Fun for Effect of Rel Ext Info Flow on Desired Sig Equip Replacement(Relative External Information Flow)
Units: sig systems/Month
Provides a relative and proportional value for determining the effect of relative external information flow on desired signal equipment replacement

Effect of Rel Ext Info Flow on Time to Gain Expr=Table Fn for Effect of Rel Ext Info Flow on Time to Gain Expr(Relative External Information Flow)
Units: lessons
Provides a value for the effect of relative external information flow on the time to gain experience. This idea states that the more effective external information flow is, the faster digital systems will gain experience.

"Effect of Relative # of Hierarchical Barriers on Access to Information"="Table Fn for Effect of Rel # of Hier Barriers on Access to Info"("Relative # of Hierarchical Barriers")
Units: Dmnl
Provides a value for the effect of relative number of hierarchical barriers on the access to information

"Effect of Relative % Nodes Connected on External Info Flow"="Table Fn for Effect of Relative % Nodes Connected on External Info Flow"("Relative % Nodes Connected")
Units: Dmnl
Provides a relative and proportional value for the effect of the percentage of nodes connected on external information flow

Effect of Relative Access to Information on External Information Flow=Table Fn for Effect of Rel Acc to Info on Ext Info Flow(Relative Access to Information)
Units: Dmnl
Provides a relative and proportional value for the effect of a unit's ability to access information on overall external information flow

Effect of Relative Digital Sys Cap on Ext Info Flow=Table Fn for Dig Sys Cap on Info Flow(Relative Capability of Digital Systems)
Units: Dmnl
Provides a relative and proportional value for determining the effect of relative digital systems capability on external information flow

Effect of Relative Manning per System on Effect of Digital Systems on Info Flow=Table Fn for Effect of Relative Manning on Digital System Eff on Info Flow(Relative Manning per System)
Units: Dmnl
This variable provides the relative and proportional impact that manning per system has on internal information flow.

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Effect of Relative Number of Digital Systems On Internal Information Flow=Table Fn for Effect of Digital Systems on Info Flow(Relative Number of Digital Systems)
Units: Dmnl
Provides a lookup for determining the effect of digital systems on information flow

Effect of Shift Length on Info Flow=Table Fn for Shift Length Effect on Info Flow(Relative Shift Length)
Units: Dmnl
Provides the effect of Soldier errors on TOC information flow. It is set up so that the effect on information flow is inversely proportional to the number of Soldier errors. For example, when the average number of Soldier errors/hour reaches 10 (for 24 hour shifts) the proportional and relative effect it has on information flow produces a value of 0, which will nullify the information flow in the TOC as it relates to Soldier errors. On the contrary, a value of 0 errors/hour (impossible in this model) would theoretically give a value of 1 for "Effect of Soldiers Errors on Info Flow" which would produce perfect information flow as it relates to Soldier Errors (Other factors such as bureaucracy and TOC size could still mitigate the overall information flow).

Effect of System Market on Desired Systems=Table Fn for Effect of Sys Mkt on Desired Systems(Relative Systems in TOC)
Units: Dmnl
Provides a value for the effect of the digital systems market on the desired number of systems for the TOC.

Effect of TOC Size on Information Flow=Table Fn for Effect of TOC Size on Information Flow(Relative TOC Size)
Units: Dmnl
This variable provides the relative and proportional impact that TOC size has on Information flow, derived from the Table Function "Effect of TOC Size on Information Flow)

Expected Daily TOC Manning Requirements=
    Perceived TOC Manning Requirements*Daily TOC Manning Requirement per Soldier
Units: Hours
This is the total daily expected number of Soldier Hours required in the TOC. First, the assumptions for this model state that an average of 3 Soldiers are needed at any time for Operations, 3 for Fires, and 4 for Intelligence. In addition, this model assumes you need at least 1 person on shift at any time for each of the additional functions (6 and 4 respectively) required under "Contemporary Operating Environment" and "Battlefield Environment." Therefore, you need (3+3+4+10) = 20 personnel working in the TOC at any given time, multiplied by 24 hours in a day gives 480 Soldier-Hours each day.

Experience Rate=Number of New Digital Systems Inside TOC/Time to Gain Experience
Units: Systems/Month
The number of systems that a Battalion TOC eliminates from the TOC each month

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Experienced Number of Digital Systems Inside TOC= INTEG (+Experience Rate-Obsolescence, Initial Systems/2)
Units: **undefined**
The number of experienced or fully integrated and trained systems inside the TOC. For the purpose of this model, it is assumed that half of the total systems inside the TOC begin as experienced systems.

Expr Sig Equip= INTEG (Sig Equip Maturation Rate-Sig Equip Obsolesce Rate,5)
Units: Sig Equip
The number of signal systems allocated to the battalion TOC

External Information Flow=Base External Information Flow*"Effect of Relative % Nodes Connected on External Info Flow"*Effect of Relative Access to Information on External Information Flow*Effect of Relative Digital Sys Cap on Ext Info Flow
Units: Dmnl
The measure of quality of external information flow is operationalized as the product of the base external information flow and the effect that the % of connected nodes, the effect of access to information and the effect of digital systems capability on external information flow.

FINAL TIME = 144
Units: Month
The final time for the simulation.

Fractional Casualty Rate=0.01
Units: 1/Month
A low rate is assumed and this is difficult to measure. In Iraq or Afghanistan, a small TOC casualty rate is largely uncommon, rather a TOC will often have a very HIGH casualty rate (in unusual circumstances where it is unfortunate to be hit directly by a rocket or suicide bomber, thus suffering devastating casualties), or a very low to almost non existent casualty rate. For the purpose of this model I will assume a very low casualty rate of 1 percent each month

Hierarchical Step Size=0
Units: levels
Accounts for an increase in the number of hierarchical barriers

Hierarchical Step Time=90
Units: Months
The time at which the increase in hierarchical barriers step size is added to the model

"Impact of Ave Distance Between Nodes on % Nodes Connected"=Table Function for Impact of Average Distance Between Nodes(Relative Distance Between Nodes)
Units: Dmnl
Provides a relative and proportional value for the impact of average distance between nodes on the percentage of nodes connected

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Initial Systems=12
Units: Systems
The number of digital systems required to support normal TOC operations
INITIAL TIME = 0
Units: Month
The initial time for the simulation.

Internal Information Flow=Base Internal Information Flow*Effect of Hierarchy on Internal Info Flow*Effect of Relative Manning per System on Effect of Digital Systems on Info Flow *Effect of Relative Number of Digital Systems On Internal Information Flow* Effect of Shift Length on Info Flow*Effect of TOC Size on Information Flow
Units: Dmnl
The measure of quality of information flow is operationalized as the product of the base internal information flow and the degrading or improving effect that multiple levels of hierarchy, Soldier errors, TOC Size and other factors have.

Levels of Hierarchy=Table Fn for Levels of Hierarchy(Actual TOC Manning)
Units: Dmnl
Levels of hierarchy or bureaucracy in the TOC.

Manning per System=Actual TOC Manning/(Number of New Digital Systems Inside TOC+Experienced Number of Digital Systems Inside TOC)
Units: Soldiers/System
The number of Soldiers available in the TOC to work on each system

NDSD Size=0
Units: Systems/Month
An input for an increase step function for the number of new digital systems developed.

NDSD Start Time=60
Units: Month
The model's start time for adding new digital systems development.

NET Information Flow=External Information Flow+Internal Information Flow
Units: Dmnl
The total NET information flow. A value of 10 is normal, and therefore anything above this denotes a positive improvement in overall information flow capability, and a value of anything less than 10 denotes a decrease in overall information flow.

New Digital Systems Creation=Digital System Obsolescence+New Digital Systems Development
Units: Systems/Month
The rate at which new digital systems are designed and produced.

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New Digital Systems Development=STEP(NDSD Size,NDSD Start Time)
Units: Systems/Month
The number of new digital system ideas that are developed

New Sig Equip= INTEG (+New Sig Equip Acq Rate-Sig Equip Maturation Rate,5)
Units: Sig Equip
The amount of new signal equipment assigned to the Battalion TOC

New Sig Equip Acq Rate=
Desired Sig Equipment Replacement/Normal Sig Equip Replacement Time
Units: sig systems/ Month
The rate at which new signal equipment is acquired for the battalion TOC

"Normal # of Hierarchical Barriers"=4
Units: levels
The normal # of hierarchical barriers to achieving lateral information sharing between "edge organizations" is the battalion, brigade, division, and corps headquarters.

"Normal % Nodes Connected"=0.25
Units: Dmnl
Normally, 25% of all nodes in theater are fully connected and able to transfer information at any given time.

Normal Access to Information=3
Units: Dmnl
The normal ability to access information

Normal Capability of Digital Systems=0.5
Units: Dmnl
Provides a value for the normal capability of digital systems

Normal Capability of Signal Equipment=0.5
Units: Dmnl
Since half of the signal systems start out as new signal equipment and half as experienced, the normal capability of signal equipment is equal to .5.

Normal Digital Systems=12
Units: Systems
The normal number of digital systems that are required for normal operations

Normal Distance Between Nodes=28
Units: Kilometers
Since simultaneous full spectrum operations normally requires 4 functions, the average distance between TOCs (nodes) is 28 kilometers.

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Normal External Information Flow=5
Units: Dmnl
The normal quality of external information flow

Normal Internal Information Flow=5
Units: Dmnl
Normal Information flow is the information flow (measured 0-10) expected under normal conditions. As a "normal" TOC has 4 levels of hierarchy (4 people the information must go through to get to the decision maker (radio operator==> battle NCO ==>battle Captain==> Commander)), the normal information flow has a constant value of 10/4 or 2.5

Normal Length of Shift=12
Units: Hours/Soldier
The normal TOC shift length is assumed to be 12 hours. In practice this is usually the case, but often this variable can be as low as 8 hours or as high as 20 hours.

Normal Levels of Hierarchy=4
Units: Dmnl
A TOC with 30 personnel has 4 levels of hierarchy (operator, battle NCO, battle CPT and operations officer or executive officer), this level of hierarchy is considered normal for this model.

Normal Replacements=(Reassignment Rate+Battlefiled Casualties)*AVG Replacement Time
Units: Soldiers
Takes into account the normal number of replacements needed for the TOC to cover reassignment and battlefield casualty losses

Normal Sig Equip Matur Rate=12
Units: Month
It normally takes 12 months for personnel to become fully trained on new signal equipment and for it to be fully integrated into the existing system

Normal Sig Equip Replacement=Sig Equip Obsolesce Rate*Normal Sig Equip Replacement Time
Units: Months
The normal amount of signal equipment replaced for the TOC based on the signal equipment obsolesce rate and the normal signal equipment replacement time

Normal Sig Equip Replacement Time=12
Units: Months
It normally takes 12 months to replace signal equipment

Normal TOC Manning=30
Units: Soldiers

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This constant variable accounts for the "normal" number of Soldiers assigned to the BN TOC according to Army doctrine. This will be assumed as the average, some commanders choose to add more, some less. The 3 baseline TOC functions are Operations, Intelligence, and Fires. Usually OPS and Fires have 3 Soldiers per shift, and Intelligence at least 4 (often more) but we will assume 4 as the baseline for this model.

Normal TOC Size=4
Units: Tents
The normal TOC size for this study is assumed to be 4 tents. In reality, different units use different types and size of tents so this variable may differ from place to place.

Number of New Digital Systems Inside TOC= INTEG (Digital Systems Acquisition Rate-Experience Rate,Initial Systems/2)
Units: Systems
The number of digital systems normally inside the TOC (absolute minimum required to function), specifically at time Zero for this model. The seven systems needed for normal baseline TOC operations are, FBCB2, BLUEFOR Tracker, ASAS-L, RWS, AFATADS, AMDWWS & CPOF. In addition to these systems, the following laptops are needed, Intel x 2, OPS x 2, fires x 1 = 5 laptops. This is what you would find in a "normal" battalion today as a baseline minimum, many TOCs actually have more as they can be reconfigured by the Battalion Operations Officer and Commander to suit their needs.

Obsolescence=Experienced Number of Digital Systems Inside TOC/Avg Digital System Life
Units: Systems/Month
The rate at which systems become obsolete

Operations Add Time=30
Units: Month
The model's add time for stepping up the number of functions needed.

Perceived Need to Improve Digital Systems=Table Fn for Perceived Need to Improve Digital Systems(Relative External Information Flow)
Units: Dmnl
Provides a value for the perceived need to improve digital systems and is based on the current quality of external information flow

Perceived TOC Manning Requirements=Normal TOC Manning+Addtional TOC Manning for Operations+Additional TOC Manning for Digital Systems
Units: Soldiers
The total perceived TOC Manning requirements as a result of normal TOC manning and changes in requirements due to additional digital systems that need manning and additional manning needed for increased operations requiring more functions.

Physical Size of TOCs=

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Table Fn for Effect of Actual TOC Manning on TOC Size(Actual TOC Manning)
Units: Tents
Physical size of TOC is measured as the number of tents needed for working space and sleeping area (obviously this would correspond to a square footage layout, but for the purpose of this model it is irrelevant). What is perhaps more relevant, and what this model measures more accurately, is the dynamic effect that increasing the number of tents has on compartmentalization, and its corresponding effect on information flow. Thus, what is called physical size of TOC could also be called compartmentalization, ultimately, it measures both.

Rate of Soldier Assignment to TOC=MAX(0,Desired Replacements/AVG Replacement Time)
Units: Soldiers/Month
This variable calculates the rate at which the TOC will be filled with new Soldiers (inflow), it also includes a constraint that this value can never be negative, in that we will not decrease the number of Soldiers in the TOC thru the rate of assignment, but rather through normal attrition by "reassignment rate" and "battlefield casualties."

Reassignment Rate=Actual TOC Manning/Avg TOC Assignment Length
Units: Soldiers/Month
This is the rate at which Soldiers are reassigned from the TOC to new jobs (primary outflow), this is simply the number of Soldiers assigned to the TOC divided by the average TOC Assignment length.

"Relative # of Hierarchical Barriers"="# of Hierarchical Barriers"/"Normal # of Hierarchical Barriers"
Units: Dmnl
Calculates the relative number of hierarchical barriers by dividing the current number of barriers by the normal number.

"Relative % Nodes Connected"=% Nodes Connected"/"Normal % Nodes Connected"
Units: Dmnl
The relative percentage of nodes connected

Relative Access to Information=Access to Information/Normal Access to Information
Units: Dmnl
Provides a relative value for access to information by dividing the current status of access to information by the normal access to information

Relative Capability of Digital Systems=Capability of Digital Systems/Normal Capability of Digital Systems
Units: Dmnl
Provides a value for the relative capability of digital systems

Relative Capability of Signal Equipment=Capability of Signal Equipment/Normal Capability of Signal Equipment
Units: Dmnl

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Provides a relative value for the capability of signal equipment

Relative Distance Between Nodes=Average Distance Between Nodes/Normal Distance Between Nodes
Units: Kilometers
Provides a value for the relative distance between nodes

Relative External Information Flow=External Information Flow/Normal External Information Flow
Units: Dmnl
Provides a relative value for measuring the quality of external information flow.

Relative Internal Information Flow=Internal Information Flow/Normal Internal Information Flow
Units: Dmnl
The current value of information flow divided by the "normal" or expected information flow.

Relative Levels of Hierarchy=Levels of Hierarchy/Normal Levels of Hierarchy
Units: Dmnl
Computes the relative levels of hierarchy so that the effect of hierarchy on internal information flow can be calculated.

Relative Manning per System=Manning per System/Desired Manning per System
Units: Dmnl
Calculates the relative manning per system so that the effect of system manning capability can be accurately measured and its effect on internal information flow calculated.

Relative Number of Digital Systems=(Number of New Digital Systems Inside TOC+Experienced Number of Digital Systems Inside TOC)/Digital Systems Required for Opns
Units: Dmnl
Accounts for system sufficiency, whether or not there are enough digital systems in the TOC to account for increased functions needed due to simultaneous full spectrum operations.

Relative Shift Length=Average Length of Shifts/Normal Length of Shift
Units: Dmnl
This variable puts average shift length into relative terms so that its effect on information flow can be quantified accurately.

Relative Systems in TOC=(Number of New Digital Systems Inside TOC+Experienced Number of Digital Systems Inside TOC)/Digital Systems On Market
Units: Dmnl
Calculates the number of systems inside the battalion TOC relative to the total number of systems available on the market.

Relative TOC Size=Physical Size of TOCs/Normal TOC Size
Units: Dmnl

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Replace Old Digital Systems=Obsolescence*Time to Acquire New Systems
Units: Systems
The total number of digital systems that need to be replaced in the TOC

SAVEPER = TIME STEP
Units: Month [0,?]
The frequency with which output is stored.

SFSO Normal=BFE Normal+COE Normal
Units: Operations
The total number of normal functions needed to support the battlefield environment and contemporary operating environmental needs.

Sig Equip Obsolesce Rate=Expr Sig Equip/Ave Signal Sys Life
Units: sig systems/Month
The rate at which signal equipment becomes obsolete and must be replaced

Sig Equip Maturation Rate=(New Sig Equip/(Normal Sig Equip Matur Rate))*Effect of Ext Info Flow on Sig Equip Maturation Rate
Units: sig systems/Month
The rate at which new signal equipment becomes experienced signal equipment

Simultaneous Full Spectrum Operations="Battle Field Environment (Non-Contiguous)"+"Contemporary Operating Environment (Threat Asymmetry)"
Units: Operations
This variable accounts for the total number of additional functions needed in the TOC as a result of the Contemporary Operating Environment and Non-contiguous battlefield, which require simultaneous full spectrum operations.

Table Fn for Effct of Ext Info Flow on Matur Rate([(0,0)-(2,2)],(0,0),(0.5,0.8),(1,1),(1.5,1.2),(2,2))
Units: Dmnl
Provides a lookup table for determining the effect of external information flow on the signal equipment maturation rate.

"Table Fn For % Nodes Connected"([(0,0)-(5,1)],(0,0.15),(1,0.25),(2,0.5),(3,0.75),(4,0.9),(5,1))
Units: Dmnl
Provides a lookup table for determining the percentage of nodes connected as derived from the distance between TOCs and the capability of signal equipment.

Table Fn for Dig Sys Cap on Info Flow([(0,0.5)-(2,1.5)],(0,0.5),(0.5,0.85),(1,1),(1.5,1.05),(2,1.1))
Units: Dmnl
Provides a lookup table for determining the effect of relative digital systems capability on the external information flow

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Table Fn for Effect of Actual TOC Manning on TOC Size([(0,0)-(200,20)],(0,1),(8,1),(9,2),(16,2),(17,3),(24,3),(25,4),(32,4),(33,5),(40,5),(41,6),(48,6),(49,7),(56,7),(57,8),(64,8),(65,9),(72,9),(73,10),(80,10),(81,11),(88,11),(89,12),(96,12),(97,13),(104,13),(105,14),(112,14))
Units: Tents
The average TOC tent holds eight Soldiers (this was true with the old SICCUPS, but with new BASEX and other models the actual number varies. This is a step function that accounts for the fact that you can not have a fraction of a tent, so if you have 1 Soldier or 8 Soldiers, you still need one tent. Consequently, if you have 81 or 88 Soldiers you still need 11 tents, but if you have 80 Soldiers you only need 10 tents and for 89 Soldiers you need 12 tents\!\!\!

Table Fn for Effect of Digital Systems on Info Flow([(0,0)-(2,1.25)],(0,0.6),(1,1),(2,1.2))
Units: Dmnl
Provides a lookup value for determining the effect of relative number of digital systems on internal information flow

Table Fn for Effect of Hierarchy on Info Flow([(0,0)-(2,2)],(0.25,1.25),(0.5,1.1),(0.75,1.05),(1,1),(1.25,0.85),(1.5,0.7),(1.75,0.4))
Units: Dmnl
Provides value for effect of hierarchy on information flow, allowing for up to 7 layers of hierarchy within the TOC. 4 layers is assumed as normal.

Table Fn for Effect of Info Flow on Desired Systems([(0,0),(2,2)],(0,2),(0.25,1.9),(0.5,1.75),(0.75,1.5), (1,1),(1.12538,0.75),(1.5,0.55),(2,0.5))
Units: Dmnl
Provides a lookup table for calculating the effect of relative internal information flow on desired number of systems.

"Table Fn for Effect of Rel # of Hier Barriers on Access to Info"([(0,0)-(2,81)],(0.25,81),(0.5,27),(0.75,9),(1,3),(1.25,1),(1.5,0.33),(1.75,0.11),(2,0.04))
Units: Dmnl
Provides a lookup up table for calculating the effect of the level of hierarchical barriers on access to information. Naturally, as the level of hierarchical barriers goes up, the access to information goes down.

Table Fn for Effect of Rel Acc to Info on Ext Info Flow([(0,0)-(27,10)],(0.01,0.5),(0.5,0.8),(1,1),(3,1.5),(10,2),(20,4),(27,9))
Units: Dmnl
Provides a lookup table for determining the impact of access to information on external information flow. The better access to information is, then the better external information flow is.

Table Fn for Effect of Rel Cap of Sig Equip on Ability to Connect Nodes([(0,0)-(2,2)],(0,0),(0.5,0.25),(1,1),(1.5,1.1),(2,1.25))

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Units: Dmnl
Provides a lookup table for determining the effect of relative capability of signal equipment on the percentage of nodes connected

Table Fn for Effect of Rel Ext Info Flow on Time to Gain Expr([(0,0)-(2,2)],(0,0),(0.5,0.8),(1,1),(1.5,1.2),(2,2))
Units: Dmnl
Provides a lookup table for determining the effect of relative external information flow on the time to gain experience

"Table Fn for Effect of Relative % Nodes Connected on External Info Flow"([(0,0)-(2,1.5)],(0,0.5),(0.5,0.7),(1,1),(1.5,1.3),(2,1.5))
Units: Dmnl
Provides a lookup table for determining the effect of relative percentage of nodes connected on external information flow.

Table Fn for Effect of Relative Manning on Digital System Eff on Info Flow([(0,0)-(2,1.2)],(0,0),(1,1),(2,1))
Units: Dmnl
Provides a lookup table for calculating the effect of relative manning of digital systems on internal information flow. Note that above a relative level of 1, there is no additional positive effect on internal information flow. This means that having more than 1 person available to work on a system at any given time is not value added.

Table Fn for Effect of Sys Mkt on Desired Systems([(0,0)-(1,2)],(0,2),(0.75,1),(1,0))
Units: Dmnl
Provides a look-up table for determining the number of systems needed for the TOC based on the relative number of digital systems already inside the TOC (relative to the number of systems on the market.

Table Fn for Effect of TOC Size on Information Flow([(0,0)-(5,2)],(0,1.25),(0.25,1.25),(0.5,1.2),(0.75,1.1),(1,1),(1.51376,0.77193),(2.44648,0.535088),(4,0.5),(5,0.5))
Units: Dmnl
The effect on information flow is inversely proportional to the TOC's size (i.e. number of tents). So if everyone is working in one tent (1-8 Soldiers) then the effect on information flow is 1 since it is a small group of people, everyone is in one tent, and it is easy to pass information to each other. For this model, once the BN TOC reaches a value of 21 tents (normally a BN TOC never has more than 10 as an absolute max) then the effect on information flow is zero.

Table Fn for Info Flow Effect on Manning Requirement(
[(0,0)-(2,2)],(0,1.5),(0.6,1.1),(1,1),(1.4,0.9),(2,0.5))
Units: Dmnl
Accounts for S shaped impact of relative Information Flow on Manning Requirements. Assumes 1/2 is the most you will ever want to adjust TOC manning by. So if information flow is a perfect10,

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then relative information flow is 4, and the lookup table will give you a value of .67 for effect on info flow on manning requirements. Conversely, poor info flow, say zero, gives you a lookup value of 1.33, or the max you would ever want to adjust TOC manning by. The expected value for relative information flow of 1 (2.5/2.5) gives you a lookup value of 1, so this value will have no affect on TOC manning.\!\!\!

Table Fn for Levels of Hierarchy([(0,0)-(150,8)],(0,1),(5,1),(5,2),(10,2),(10,3),(20,3),(20,4),(35,4),(35,5),(50,5),(50,6),(100,6),(100,7),(150,7))
Units: Dmnl
Simply provides lookup values correlating the number of Soldiers who are working in the TOC to the number of layers of hierarchy in the TOC. Obviously, the more Soldiers you add then the more leaders or "people in charge" that are added, thus there are more people that information must go through to get to the decision maker, and the more people competing for his/her finite amount of time. I believe this follows a step ladder pattern, which the lookup accounts for. 4 layers is considered normal and thus correlates to the "normal" TOC manning of 30 Soldiers.

Table Fn for Perceived Need to Improve Digital Systems([(0,0)-(2,2)],(0,2),(0.5,1.15),(1,1),(1.5,0.8),(2,0.5))
Units: Dmnl
Provides a table lookup for determining the perceived need to improve digital systems

Table Fn for Shift Length Effect on Info Flow([(0,0)-(2,2)],(0,1.25),(0.25,1.25),(0.5,1.2),(0.75,1.1),(1,1),(1.25,0.75),(1.5,0.55),(1.9,0.5),(2,0.5))
Units: Dmnl
Provides value for effect of shift length on Soldier Error rate. This is an exponential error rate. Initially, there is an error rate in the first two hours when a Soldier comes on shift as they try to familiarize themselves with what happened while they were off shift, but then their performance levels out. After about 8 hours they start to get tired, and after the 12th hour things start to get tough (remember, this means they are working 12 hours EVERY DAY, 7 days a week, 365 days a year, in the same cramped quarters, with the same people, doing the same repetitive actions---this is a lot tougher than it sounds). Therefore, if Soldiers are working up in the range of 18-24 hours each day, their bodies will start to shut down and the number of errors they make each hour will become astronomical. Assumes 3 errors first hour, 1 error hours 2-8, 3 errors hour 9 & 10, 6 errors hours 11 & 12, 8 errors hours 13 & 14, 10 errors hours 15 & 16, 13 errors hours 17 & 18, 20 errors hours 19 & 20, 25 errors hours 21 & 22, 30 errors hours 23 & 24.\!\!\!

Table Function for Ave Dist Between Nodes([(0,0)-(20,60)],(0,8),(2,18),(4,28),(7,40),(10,45),(15,50))
Units: Dmnl
Provides a lookup table for determining the average distance between nodes based on the increased complexity of simultaneous full spectrum operations (SFSO). As SFSO increases, the average distance between nodes increases.

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Table Function for Impact of Average Distance Between Nodes([(0,0)-(6,3)],(0.01,3),(0.25,1.5),(0.5,1.2),(1,1),(2,0.7),(3,0.15),(4,0.1),(5,0.05))
Units: Dmnl
Provides a table lookup for determining the impact of the relative distance between nodes on the percentage of nodes connected in the network

Tble Fun for Effect of Rel Ext Info Flow on Desired Sig Equip Replacement(
[(0,0)-(2,2)],(0,2),(0.5,1.3),(1,1),(1.5,0.8),(2,0))
Units: Dmnl
Provides a table lookup for determining the effect of relative external information flow on desired signal equipment replacement

TIME STEP = 1
Units: Month [0,?]
The time step for the simulation.

Time to Acquire New Systems=6
Units: Month
On average, it take the Army 6 months to acquire a new digital system

Time to Gain Experience=6/Effect of Rel Ext Info Flow on Time to Gain Expr
Units: Month
It normally takes 6 months enough people to become trained on a system and to understand how to best integrate it into the TOC so that it becomes a mature system.

TOC Manning Gap=Desired TOC Manning-Actual TOC Manning
Units: Soldiers
This variable accounts for the difference between the desired TOC manning adjusted for information flow and the actual or current TOC manning level.

Total Dig Sys Inside TOC=Experienced Number of Digital Systems Inside TOC+Number of New Digital Systems Inside TOC
Units: Digital Systems
Provides a value for the total number of digital systems inside the TOC

Total Sig Equip=Expr Sig Equip+New Sig Equip
Units: Sig Equip
The total number of signal systems allocated to the BN TOC

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