

# NAVAL POSTGRADUATE SCHOOL Monterey, California



## THESIS

**LITERATURE SURVEY ON NETWORK CONCEPTS AND  
MEASURES TO SUPPORT RESEARCH IN NETWORK-  
CENTRIC OPERATIONS**

by

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June 2003

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**LITERATURE SURVEY ON NETWORK CONCEPTS AND MEASURES TO  
SUPPORT RESEARCH IN NETWORK-CENTRIC OPERATIONS**

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## **ABSTRACT**

The United States Navy and its joint partners continually seek to maintain a responsive, agile, and effective fighting force well suited to combat present-day threats to national security. As a result, U.S. forces are currently undergoing force transformation to adopt an organizational structure capable of supporting this mission. This new organizational structure is known as Network-Centric Warfare.

The purpose of this research is to analyze any performance metrics, measures of effectiveness, or analytical methods used by existing organizations engaged in network-centric operations that would assist the Navy and joint forces along with their transformation process. This research will be done in the form of a literature review, examining existing material written on communication, economic/business, and social/organizational networks. In addition to identifying quantitative and qualitative metrics, an emphasis will be placed on the methodologies used for network assessment. Final sections relate findings from each resource to Network-Centric Warfare and address matters relevant to the future of force transformation.

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## EXECUTIVE SUMMARY

The United States Navy and its joint partners continually seek to maintain a responsive, agile, and effective fighting force well suited to combat present-day threats to national security. As a result, U.S. forces are currently undergoing force transformation to adopt an organizational structure capable of supporting this mission. This new organizational structure is known as Network-Centric Warfare.

The purpose of this research is to analyze any performance metrics, measures of effectiveness, or analytical methods used by existing organizations engaged in network-centric operations that would assist the Navy and joint forces along with their transformation process. This research will be done in the form of a literature review, examining existing material written on communication, economic/business, and social/organizational networks. In addition to identifying quantitative and qualitative metrics, an emphasis will be placed on the methodologies used for network assessment.

Traditionally, the Navy operates as a platform-centric force, meaning that warfare operations center around the capabilities of individual platforms. In order to fully exploit the technological advantage established by American forces, the Navy currently seeks to transform its long-standing “platform-centric” organization to a “network-centric” organization. Looking within the American society, evolution in information technology, economics, and organizations continue to guide and inspire the Navy along its transformation process. Admiral Cebrowski, currently head of the Pentagon’s Office of Force Transformation, links the following netcentric themes to the Navy:

- The shift in focus from the platform to the network
- The shift from viewing actors as independent to viewing them as part of a continuously adapting ecosystem
- The importance of making strategic choices to adapt or even survive in such changing ecosystems. (Cebrowski, 1998)

This literature review in this research gives insight to support the tenets above.

The findings of this literature review are intended to inform inquiring parties of some currently available methods of assessing organizational performance and to promote future research in the area of gauging netcentric performance. Communication

and information networks provide the technological background necessary for netcentric operations. Business and economic networks present working examples of organizations linked within a networked environment for purposes of benefiting from their collective strength. Lastly, organizational and social models address how personnel and training should be handled in a netcentric organization.

Communication and information networks also provide the operational backbone for any network-centric organization. For this reason, the understanding of communication networks provides a valuable foundation for netcentric basics. Since the transformation process occurs at every level, the sources reviewed in the communications chapter provide network analysis techniques for low, mid, and high-level networks.

The network-centric revolution not only impacts the communication industry, but the business and economic industry as well. Through information sharing technology, businesses continue to expand their influence around the globe. The business world presents an excellent model of how success and competitive advantage results from a network-centric design. Concepts in netcentric business allude to how information systems and netcentric architecture affect decision strategies, company alliances, and operating procedures. These concepts are transparent to the Navy.

In order for the Navy to continue its transition to a netcentric fighting force, a significant amount of time and effort must apply to properly educating and training the personnel responsible for performing network-centric duties. The powerful changes brought on by information technology certainly require the restructuring of the management and people that support it. With some familiarity with communications and business networking, it is important to discuss the inner aspects within organizations, such as organizational structuring, leadership, management, and personnel factors.

As Naval and joint forces continue their transition to Network-Centric Warfare, members of the government, Naval leadership, and of the operational force should take the proper steps to ensure an optimal process. Tenets found in this thesis: 1) suggest various approaches to assessing the progress and performance of network-centric organizations, and 2) highlight contributing factors that affect the performance of these

organizations. Netcentricity remains a relatively new concept and demands future research in order to fully understand the implications that it carries.

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# I. INTRODUCTION

## A. BACKGROUND

In recent years, the acceleration of technological growth has propelled many advances in both civilian and military sectors. We now live in an information age where communications and data processing continue to rise at an increasing rate. Technological boosts continue to enable many organizations to increase their operational capacity by several factors. With enhanced computing and information systems, organizations are able to operate at increased speeds and thus seize a time-critical advantage, one of the most critical factors for successful organizations. While technology largely contributes to an increase in operational capability, reforms in organizational structures and architectures have played a major role as well.

Recent success by several civilian organizations supports revolutionary ideas in organizational restructuring. From market economies to the communication industry, various organizations have transitioned from a traditional organization to a network-based or “network-centric” architecture in order to fully exploit the full potential of information power. As more and more companies continue to shift their organizational structure, it is critical for management to monitor the performance of the organization. To effectively monitor organizational performance, a series of different methodologies have emerged from research, deriving performance metrics that accurately assess both long and short-term performance. Witnessing the power of a network-centric design, the military seeks to monitor civilian organizations and any related performance analysis methods in hopes to transform its own organization to engage in network-centric operations, or “Network-Centric Warfare”.

Boosted by advances in information technology, the Navy has already initiated a transition to Network-Centric Warfare. During Operation Iraqi Freedom, the U.S. Navy, along with joint and coalition forces, demonstrated identifiable success of networked forces on the battlefield. While many civilian industries continue to benefit from their network-centric transition, the military seeks to learn from their example in hopes to build on its transition.

The focus of this research is to analyze any performance metrics, measures of effectiveness, or analytical methods used by existing organizations engaged in network-centric operations. This research will be done in the form of a literature review, examining existing material written on communication, economic/business, and social/organizational networks. In addition to identifying quantitative and qualitative metrics, an emphasis will be placed on the methodologies used for network assessment. Closing comments will relate all findings and address matters relevant to the future of force transformation.

## **B. NETWORK-CENTRIC WARFARE**

### **1. General**

Throughout history, technological growth has propelled the evolution of warfare. For several centuries, the majority of advancement in warfare directly reflected the improvement of weapon technology and speed of travel. Innovations in propulsion enabled forces to increase their operational tempo. Although the same remains true today, communications and information superiority now drive the operational tempo which yields battlefield advantage. Since the advent of accelerated communication devices, information superiority has become the new focus of the military. Time remains one of the most critical elements to optimize for battlefield success. In hopes of increasing the operational tempo, the U.S. Navy seeks to achieve a rapid rate of information sharing, and so current research focuses on transitioning the current military organization to an information-intensive organization.

Traditionally, the Navy operates as a platform-centric force, meaning that warfare operations center around the capabilities of individual platforms. These platforms could only sense and engage contacts within a specified range. At most, platforms could only share information with other platforms within close vicinity. In order to fully exploit the technological advantage established by American forces, the Navy currently seeks to transform its long-standing “platform-centric” organization to a “network-centric” organization. Then Vice Admiral Arthur K. Cebrowski, currently retired from the Navy and head of the Pentagon’s Office of Force Transformation, and Mr. John Gartska

referred to this transition with the following statement, “We are in the midst of a revolution in military affairs (RMA) unlike any seen since the Napoleonic Age, when France transformed warfare with the concept of *levée en masse*. (Cebrowski and Garstka, 1998)

In 1998, Vice Admiral Cebrowski, and Mr. John J. Garstka wrote an article titled, “Network-Centric Warfare: Its Origin and Future” that addresses the Navy’s recognition of the network-centric concept, its current successful practice in the civilian sector, and the Navy’s continual desire for force transformation to a network-centric organization. (Cebrowski and Garstka, 1998) To begin this article, the authors highlight individual accounts of successful civilian organizations, particularly in the economic and technological arenas. Next, the network-centric architecture is mapped to a conceptual model used to draft the desired organizational structure of the Navy. Lastly, a discussion addresses the challenges the Navy faces while undergoing organizational transformation. In this chapter, discussion will only focus on the military aspect of the article.

## **2. Force Integration**

The new network-centric warfare design centers on asset integration. Previously, platforms coordinated more in terms of area of operation and strike sequence. Aside from preplanned missions, platforms traditionally relied on their own sensors and weapons to engage hostiles encountered outside planned operations. Network-Centric Warfare calls for all platforms and units to combine human sight, radar, sonar, satellite imagery, and all other forms of detection to join and create a sensor grid. Concurrently, units would combine firepower and strike assets to create an engagement grid. Most importantly, an information grid then integrates these other two grids, creating a synchronized force far more powerful and capable than the previous collection of platforms. At the root of the information grid resides command and control, or C2, which maintains responsibility for the smooth planning, directing, coordinating, and controlling of forces and operations in the accomplishment of the mission. (DoD Dictionary of Military and Associated Terms, 2003) Below is a diagram that graphically illustrates the integration of the sensors, fires, and information with the command and control process:

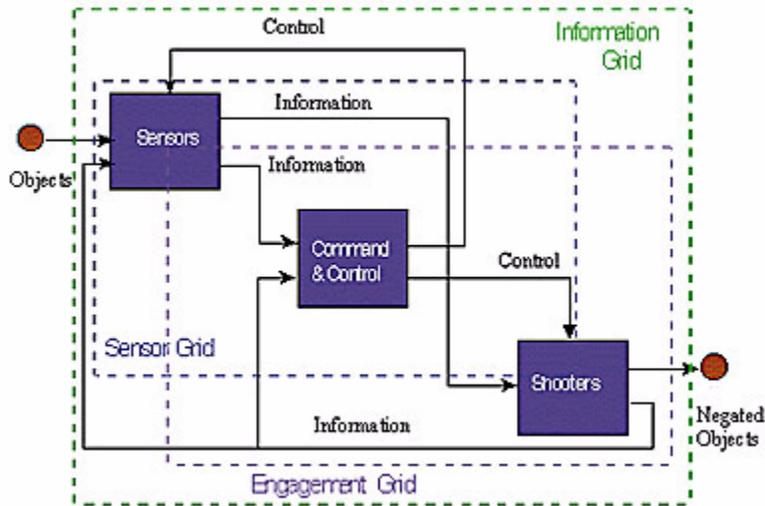


Figure 1. Logical Model for Network-Centric Warfare (From: Cebrowski and Garstka, 1998)

With Network-Centric Warfare, platforms become less restricted by detection and engagement range limitations. Instead of operating as individuals, platforms will now serve as nodes within a large network. As platforms become nodes within a network, their sensing and strike capabilities are pooled together to form a conglomerate force more capable than the sum of the individual platforms. Network-Centric Warfare also scales to all levels of warfare: strategic, operational, and tactical. This means that networks can virtually take on any size. According to Cebrowski and Garstka, this integration of assets generates a competitive advantage by enabling the following:

- Network-centric warfare allows our forces to develop speed of command.
- Network-centric warfare enables forces to organize from the bottom up – or to self-synchronize – to meet the commander’s intent. (Cebrowski and Garstka, 1998; pg. 5)

Speed of command is defined as the increased tempo of decision making via information superiority. Speed of command subdivides into the following areas: 1) improved battlefield awareness via comprehensive information superiority rather than raw data, 2) massing effects via the rapid movement of forces 3) rapid foreclosure via fast decision making enabled by decision support systems. Speed of command is essential to all combat scenarios; a swift operational tempo can render enough damage to an enemy to decisively influence a conflict outcome. Cebrowski and Garstka assert the importance of

the operational tempo advantage with the following statement, “One of the strengths of network-centric warfare is its potential, within limits, to offset a disadvantage in numbers, technology, or position.” (Cebrowski and Garstka, 1998; pg. 6)

Establishing a network-centric architecture continues to be the focus of the transformation to Network-Centric Warfare. In efforts to integrate the sensors and weapons of various platforms, an emphasis should be placed on the interoperability of organizations and systems. The Joint Technical Architecture and the Defense Information Infrastructure currently offer the best solutions to do this. Below is a diagram showing various information systems and their relationships with respect to information plane timeliness and accuracy:

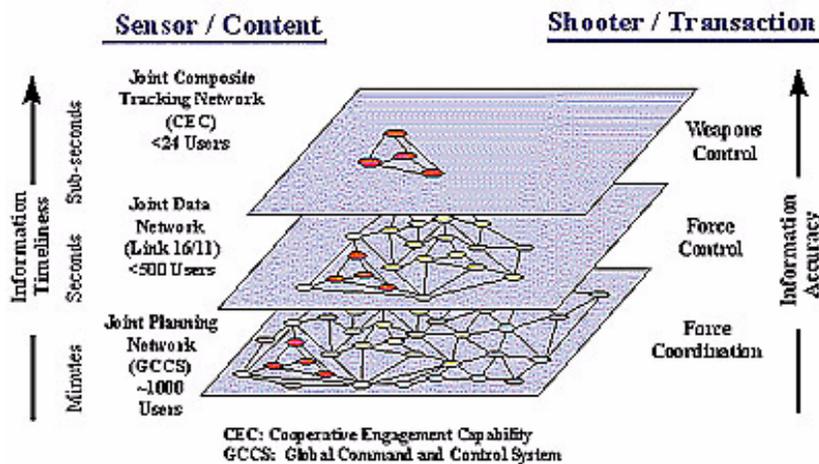


Figure 2. Emerging Architecture for Network-Centric Warfare (From: Cebrowski and Garstka, 1998)

Not only does the information grid provide a medium for communication, but it also processes threat information into a readable form that improves the decision-making process (through a decision support system). Cebrowski and Garstka identify the cooperative engagement capability (CEC) as an example of system that is responsible for coordination and handling of the network information.

Cebrowski and Garstka first illustrate the network-centric concept through a hypothetical scenario where U.S. forces are tasked with the suppression of enemy air defense units. They describe how, under the current platform-centric organization, enemy missile sites can only be acquired via the sensors and weapons of individual aircraft

passing through the area. With network-centric warfare, additional platforms would improve battlefield awareness by forwarding their sensor input to an information network and combat potential would improve with the availability of the weapons of the various platforms in theater. Such platform coordination provides a time advantage that would accelerate the destruction of enemy anti-aircraft missile sites and thus yield air superiority. This rapid and effective deployment of friendly forces also inhibits the enemy forces' ability to coordinate their units.

The Network-Centric Warfare concept also discusses the formation process of such an organization. In forming a military organization, leaders traditionally form their units using a top-down approach, which historically does not provide for optimal force synchronization. Under the pretenses of network-centric warfare, unit organization would be constructed from a bottom-up approach, which provides for a self-synchronous, cohesive unit. A self-synchronous unit derives its power from highly coordinated operations made possible by battlefield awareness. This contrasting formation process in turn affects the command and control process, a continual concern for military operations. Cebrowski and Garstka cite the details of the U.S. Navy's response to the China-Taiwan crisis as an example of the successful execution of command and control from a bottom-up organization. (Cebrowski and Garstka, 1998)

A general understanding of Network-Centric Warfare provides an overarching perspective for the content of this thesis. The military continually seeks to learn from the civilian sector, studying the systems and methods used by private organizations. Cebrowski and Garstka comment on the challenges of force transformation with the following, "We are some distance from a detailed understanding of the new operations – there is as yet no equivalent to Carl von Clausewitz's *On War* for this second revolution—but we can gain some insight through the general observation that nations make war the same way they make wealth." (Cebrowski, 1998; pg. 2)

### **3. A Glance at the Transformation Process**

Currently, sensor and weapon capabilities are improving at a constant rate, and the Navy knows how to incorporate these improvements. The transformation challenge

lies in the inherent complexity in the information sharing process and coordination of units. Cebrowski and Garstka include a section in their article regarding guidelines to be followed in order for the Navy to successfully transform its current organizational structure to a network-centric structure. Looking within the American society, evolution in economics, information technology, and business processes in organizations continue to guide and inspire the Navy in the transformation process. Cebrowski and Garstka link these areas with the following themes:

- The shift in focus from the platform to the network
- The shift from viewing actors as independent to viewing them as part of a continuously adapting ecosystem
- The importance of making strategic choices to adapt or even survive in such changing ecosystems. (Cebrowski and Garstka, 1998)

The literature review in this thesis gives insight to support the tenets above. Although the U.S. Navy has already begun the transformation process, further research will certainly be necessary.

### **C. NETCENTRICITY BASICS**

Traditionally, larger organizations typically operate in some type of hierarchical configuration. For management purposes, a hierarchical configuration enables information to be passed between different levels within the organization for proper filtering and dissemination. This design requires humans in the different tiers of management to simplify or filter the pertinent information in order for higher levels to process the information. With the advances made in information processing and communications, organizations can now reduce the number of levels required to properly process and interpret the information. In addition, speed of information processing is critical to success. Current technology enables businesses to transmit enormous amounts of processed information at record speeds.

Compared to the tiers of a hierarchical organization, a network-centric organization is configured with a central control position and multiple nodes. All nodes in the system are interconnected and thus enable information sharing to occur quickly. Interconnecting all nodes also enhances the robustness of the network as well. Not only

can networking occur within a particular organization, but also networking can occur externally with other organizations with relevant utility. A network-centric design in the commercial world improves a business's success by optimizing the delivery of a product to the customer. In the past few years, the military has recognized the advantages of a network-centric design and now looks to implement the network-centric concept to warfighting.

### **1. A Review of: "Harnessing the Power of Netcentricity"**

In December of 1999, the Defense Advanced Research Projects Agency (DARPA) teamed up with the Robert H. Smith School of Business at the University of Maryland College Park to produce an extensive and comprehensive document addressing the economic and organizational impact of the "network-centric" or "netcentricity" concept in various areas (Blue Ribbon Panel, 1999). The authors of this document, forming the Blue Ribbon Panel, along with many contributors, to include members from the Space and Naval Warfare Systems Command, made certain that the contents of their research presented relevant insight to the Navy during its transformation process to Network-Centric Warfare. Sections within this document seek to map the impacts of netcentricity in the following arenas:

- Organizational structures and cultures
- Business models
- Alliances across businesses
- Customer relationships and e-consumer behavior
- Individual's information and cognitive processes.
- Military

Although, this research does not address communication networks individually, the document integrates information network concepts with each of the above sections. This resource distinguishes itself from the other sources with its in-depth discussions of the internal and human aspects of operating a network-centric business. In the sponsorship and purpose section of this research, the goals of the authors are listed as follows:

- Collect and summarize existing knowledge related to netcentricity.
- Organize and conduct field studies to observe netcentricity in action.
- Create and deploy an expert Blue Ribbon Panel of government, military, academic, and industry thought leaders to review analyses of netcentric organizations, and converge on the key dimensions of netcentric business and organizational models.
- Identify the primary questions that warrant future in-depth investigation, and suggest research structures to address these questions as part of a national research agenda. (Blue Ribbon Panel, 1999; pg. iii)

In regards to assessing network performance and drafting measures of effectiveness, this document primarily emphasizes the qualitative aspects of performance or the impact of adopting a network-centric architecture. Discussion of performance also exists on a comparative basis, contrasting the new and revolutionary ways of network-centric organizations to previous or traditional organizations. In addition, the authors conclude their work by identifying factors and issues that require attention in the future. This document further distinguishes itself from other studies by focusing on the juncture between information technology (IT) and the businesses and organizations as well as the aggregate impacts of IT and netcentric architectures. Tenets of “Harnessing the Power of Netcentricity” will be discussed in further detail in the business/economic chapter and the social/organizational chapter.

#### **D. OVERVIEW OF CHAPTERS**

The network-centric concept asserts its usefulness in various organizational arenas. Consequently the chapters in this document have been divided by the respective disciplines. The chapters are divided as following:

- Measurement and measures of netcentricity
- Communication networks
- Business/economic networks
- Social/organizational networks
- Conclusion.

The measurement and measures of netcentricity chapter begins by outlining a basic framework used by the military when analyzing performance metrics or

determining measures of effectiveness. Next, a brief discussion characterizes the metrics and methodologies used by sources in the literature review and then compares them to the methods used by the military. Finally, measures of effectiveness are then subdivided into basic categories in order to differentiate the approaches to performance measurement.

This literature review begins with the communication industry, since it was amongst the first to engage in network-centric operations. Additionally, communication systems provide the information background that is critical for any organization engaged in network-centric operations. This chapter will outline some methodologies and approaches to network performance assessment as well as touching upon how some companies in the communication industry manage and assess the communication services that they provide to their costumers.

With a baseline understanding of how communication and information handing performance assessment is conducted, the following chapter illustrates how the corporate industry implements information technology into their organization and what types of metrics exist to assess economic performance of a company. Other sources in the business and economic chapter discuss qualitative metrics or impacts brought on by netcentricity.

The next chapter talks about the social and organization aspect of network-centric organizations. When analyzing a company, performance metrics are difficult to define when examining human factors. Usually, the performance of the humans transpires to the performance of the company as a whole. Instead, this chapter will discuss in brief the implications associated with organizations engaged in network-centric operations.

The final chapter recaps the findings of the literature review in the context of force transformation and discusses the implications for the Navy to consider when analyzing the performance of its own network. Additionally, the last chapter addresses recent information on the Navy's performance in Operation Iraqi Freedom and what plans the Navy may have in the future.

## II. MEASUREMENT AND MEASURES OF NETCENTRICITY

Without a doubt, the Navy faces a notable challenge in transforming its long-standing “platform-centric” way of fighting to the new and complex “network-centric” approach. The Navy is just beginning operations under the proposed network-centric configuration. However, several civilian and private organizations have successfully made the transition for some time now. The military, along with other organizations, often allocate analysis teams to assess organizational performance and assert quality control. These groups work to define various metrics and measures of effectiveness that determine the direction of an organization’s growth, strengths, weaknesses, and the roots that effect performance. One set of standards, or measures of effectiveness currently utilized by the military to define levels of performance is given below:

- Measure of Force effectiveness (MOFE) – This describes the aggregate level measurement that describes the net performance of an organization
- Measure of effectiveness (MOF) – measured against some standard
- Measure of performance (MOP) – some physical parameter

Ideally, when reviewing literature on existing methods of network/organizational assessment and trying to develop a framework for the military to assess their own performance during organizational transformation, the mapping of the above levels to this domain would be convenient. Since netcentricity remains relatively a new concept, material written on performance assessment is limited and thus the mapping of performance metrics becomes challenging. Ideally, this thesis would provide a literature review that would indicate how different network permutations would affect organizational performance along with how to monitor ongoing performance. However, review of over 50 sources only provided relatively abstract ideas that require significant filtering and interpretation. Therefore, the methodology or approach used in this thesis varies according to each particular source. The section below discusses how performance metrics in this thesis were categorized.

### **1. Quantitative Measures**

Quantitative measures refer to discrete, measurable data. Examples of low-level metrics include: throughput, error probability, arrival times, volume of production, personnel, and cost. Combined higher-level quantitative metrics include cost-performance benefits, efficiency, and return-on-investment. Quantitative metrics are most applicable to communication networks and often applicable to business and economic networks.

### **2. Qualitative Measures**

Qualitative measures refer to nonnumeric assessments. They are usually subjective in nature and often only carry validity with expert opinions. In this research, qualitative measures are more common than quantitative measures since opinions and quality assessments are easily formulated about any facet that contributes to performance. Qualitative measures usually present results in terms of the impact.

### **3. Comparative Measures**

Comparative measures are qualitative in nature and are used to assess organizational performance against another organization of identical purpose. This type of assessment method is useful when no official standards are available for stand-alone assessments. In a comparative analysis, the results could report on how two companies contrast on the same attribute or how one company gains advantage via a particular means.

In addition to decomposing their performance metrics, most of the sources discussed in this thesis provide aggregate metrics for their respective network. The Navy is particularly interested in aggregate information, especially during the acquisition process. Many sources express their concepts, theories, and methodologies through the use of models. Models present a cost-effective solution to demonstrate measurement concepts. The Navy consistently requires modeling and analysis before commencing any sort of large project.

### **III. COMMUNICATION AND INFORMATION NETWORKS**

#### **A. GENERAL**

Communications, through history, prevails as one of the most important aspects of military operations. In particular, the Navy spreads its assets over great distances and continually seeks to improve its communication capability. Before the advent of radio transmission, naval communication was limited to eyesight and physical signals. Today, communications exist on the greater portion of the E-M spectrum, from ground waves to extremely high frequency, in various formats, analog and digital, and through different mediums, from under the sea to outer space. An effective communication system enables necessary information sharing to take place.

A strong communication system is critical to the success of any organization, especially those engaged in network-centric operations. For this reason, communication networks will be discussed first. Unlike the other disciplinary areas, performance metrics for communication systems are well defined. They are technical and usually mathematical in nature. Human factors play a smaller role in how a communication system performs, but they determine the performance specifications to be met, e.g., desired throughput and quality. Performance measures for communication systems ultimately simplify to three factors: latency, accuracy and reliability. For the most part, the measures of effectiveness for data and time make up the fundamental components of communication MOEs. Formatting, information accuracy and encryption are but a few other factors critical to communications.

The majority of the literature reviewed on communications uses models to facilitate concepts and theories on how to best monitor or assess network performance. The Department of Defense (DoD) usually requires modeling before committing to any new large project or transforming current systems. The materials reviewed primarily discuss the methodology of how to assess network performance rather than how different network arrangements or topologies would perform. Additionally, the impact of communication technology will be discussed.

**B. A REVIEW OF THE INFORMATION TECHNOLOGY AND COMMUNICATIONS SECTION OF: “NETWORK-CENTRIC WARFARE: ITS ORIGINS AND FUTURE”**

In this section of Cebrowski and Garstka’s article, they do not specify any particular performance metrics for communication networks, rather they identify the explosive growth in information technology as the central theme to network-centric organizations and why it is important to further monitor its development. Not only have the performance capabilities of information systems improved, but the organization and management has improved as well.

Similar to the ideas outlined in Network-Centric Warfare, a fundamental shift in platform-centric computing to network-centric computing has occurred in the IT realm as well. For example, the focus of technology has shifted from improving the capabilities of isolated platforms such as the personal computer to improving the enabling technology of computer networks, such as the Internet, intranets, and telecommunications. Advancements in hardware technology also enable an increase in information and high-speed data transfer. In business applications, improved information processing continues to enhance management awareness and thus improve business decision-making and performance. Cebrowski and Garstka cite Sun Microsystems and IBM as two computer giants that have transitioned to network-centric computing to maintain a competitive strategy in the market.

Cebrowski and Garstka identify one performance metric associated with computing power, Metcalfe’s Law. Using Metcalfe’s Law, the power of network-centric computing can be assessed to be proportional to the square of the number of nodes in the network. This means that a network becomes more effective as the number of nodes increase, and the power increases much faster than the size of the network; a bigger network is much more powerful. Cebrowski and Garstka express the following, “The ‘power’ or ‘payoff’ of network-centric computing comes from information-intensive interactions between very large numbers of heterogeneous computational nodes in the network.” (Cebrowski and Garstka, 1998; pg. 3) The tenets expressed in Cebrowski and Garstka’s model have already led the Navy to improve upon its information and

communication assets. Furthermore, current research sponsored by the Navy focuses on examining assessment techniques used in the civilian sector.

### **C. A REVIEW OF: “MULTILEVEL MODELING AND ANALYSIS”**

In early 1999, S. Hariri, H. Xu, and A. Balamash performed research in the ATM HPDC Lab at the University of Arizona in Tucson under the Department of Electrical Engineering and Computer Science. (Hariri, Xu, Balamash, 1999;p. 169) Their research seeks to move beyond queueing network models concerning standard data/communication networks and seeks to address the design, analysis, and development of parallel and distributed applications on high performance Network-Centric Systems (NCS). In doing so, they present a fundamental bottoms-up methodology consisting of a three-level hierarchy modeling approach for analyzing end-to-end performance of a NCS. (Hariri, Xu, Balamash, 1999;p. 169) Supplementing the outline of their methodology, the authors provide a case study of a video-on-demand system that illustrates how the methodology would be used.

In general, the authors identify three approaches to network modeling. They include: measurement techniques (system monitoring), analytical techniques, and simulation techniques. Their research focuses on the analytical techniques, that through the use of mathematics (such as the use of Markov chains and stochastic Petri nets), provide for an end-to-end multilevel analysis of a networked communication system. This modeling process then decomposes into three hierarchical levels: the application level, protocol level, and the network level. Each of these generic levels is explained in the following sections.

#### **1. Methodology: A Hierarchical Modeling Approach**

This multilevel process uses an identical approach/methodology to analyze each level within the system. Beginning with the lowest layer, analysts isolate the layer of concern from the influences of the upper levels, facilitating a focused and concentrated analysis. During the analysis at each level, queueing networks are used to generate the functions that simulate system behavior. Once the analysis is complete at a particular

level, the results are simplified and represented by a Norton equivalence or equivalent queueing models. A Norton equivalence model is a representation of a selected portion or subsection of the entire network and is used for analysis simplification. This enables quick analysis of different network and protocol configurations as well as improving efficiency and accuracy of the overall analysis.

To begin an end-to-end analysis for a communication line, performance metrics are first determined at the lowest level, the network level. Once the network is completed and represented by a Norton equivalency node, analysis at the protocol level can begin. Lastly, after the results from the protocol level are complete, the network-centric application level analysis can provide an overall aggregate assessment of the network-centric system. The sections below discuss the measures of performance associated with each level as well as the functions and issues that directly influence performance.

## **2. Network Analysis**

In this study, network analysis is conducted at the most fundamental level of the hierarchy. Since network analysis has been around for some time, performance metrics are well defined and easily monitored. Some parameters include: average packet transfer time, network utilization, and what-if analysis scenarios. Each of these parameters can be further decomposed, in particular packet transfer time, which divides into four subcategories: transmission delay, propagation delay, switch delay, and queueing delay. Network utilization describes the capacity and cost-performance considerations of the network. What-if scenarios are created by generating equivalent network queueing models. These equivalent models are represented by nodes that can be used in different configurations in what-if scenarios. Networks can vary greatly in size and performance. Some examples include: Ethernet, ATM, and FDDI. Each of these types of network possesses different performance qualities that would be aggregated into a simplified node. In these models, mathematical functions are used to determine the different transfer rates of different types of networks.

### **3. Protocol Analysis**

The protocol level is one step above the network level and is responsible for connecting various networks together. Examples of standard protocol include TCP/IP, IP/ATM, or synthesized protocols. Measures of performance that exist at this layer include: throughput, protocol processing overhead and latency, reliability, flow and error control. These parameters will fluctuate according to how the protocol functions are managed.

The authors of this research used a general set of protocol functions to develop their model. These functions include: connection management, flow control, error control, and acknowledgements. Although some of these functions do not directly correspond to some sort of metric or measure of performance, they all must be considered and monitored since they do have an effect. Each of these protocol functions affects the overall performance of the protocol level.

### **4. Application Analysis**

The depth of applications can vary significantly. In this case of this study, only network-centric applications or grouped applications were analyzed. The authors of this research used analytical models to simulate the network-centric applications. The analysis at the application level focuses on end-to-end performance metrics. Some of these metrics include application response time, application utilization on each computing platform involved in its execution, and application execution cost. (Hariri, Xu, Balamash, 1999) Considerations at the application level include: processor scheduling, parallel or distributed processing, storage strategy, type of stage technology (disk or tape), type of data distribution on disks (striping and duplicating), and use of caches.

### **5. Conclusions**

The multilevel methodology used by Hariri, Xu, and Balamash to analyze the effectiveness of a communication network closely reflects the multilevel methodology used by the military to analyze the effectiveness of their weapon systems. This research uses a model-based approach that well suits an organization currently in a

transformational period, such as the Navy. The Navy constantly attempts to assess and manage its communication systems. This research presents a practical model for lower to mid-level layers within a communication system. The application of this research most applies during the designing processes of network rather than monitoring a network that already exists.

#### **D. A REVIEW OF: “FRAMEWORK-BASED APPROACH TO NETWORK-AWARE APPLICATIONS”**

In mid 1998, Jürg Bolliger and Thomas Gross, both members of IEEE, performed research within the Department of Computer Science at the Swiss Federal Institute of Technology in Zürich, Switzerland. (Bolliger and Gross, 1998) Their research seeks to link the gap between network and application Quality of Service (QoS) models through the use of a framework-based approach with models. The authors assert the following: “The framework provides the skeleton to address two fundamental challenges for the construction of network-aware applications: 1) how to find out about dynamic changes in network service quality and 2) how to map application-centric quality measures (e.g., predictability) to network-centric quality measures (e.g., QoS models that focus on bandwidth or latency).” (Bolliger and Gross, 1998; p. 376) The overall goal of this study focuses on determining the predictability of application behavior that results from variations in network performance. The proposed framework uses a feedback loop as the primary mechanism for network monitoring and system adjustments. (Bolliger and Gross, 1998)

##### **1. Network Models**

The authors acknowledge recent shifts from best-effort service models (those using low-level network parameters such as bandwidth, latency, and jitter), to more comprehensive network QoS models. The aggregate Quality of Service measurement is the user-perceived quality, determined by the amount of data, in many cases accuracy, and the time required to receive that data. Balancing data volume and accuracy with a timely delivery provide the essentials when managing network performance. In addition

to network-specific characteristics, the authors discuss briefly the systems within the nodes that make up the network since their performance can influence the overall performance of the network.

Nodes within the network must also undergo system analysis, or become system aware. Node performance can sometimes bottleneck other components and must be carefully monitored. Some system performance metrics include response time, disk Input/Output latency, bus bandwidth, and processor speed. Once the systems within the nodes perform within specifications, focus can shift to the monitoring performance or service quality of the network.

The authors discuss network service quality awareness on a unicast request-response exchange between clients and servers. Typically, a user sends a request to a server for a file, such as text, images, videos, etc., and based on the size of the file, QoS restrictions, and server capabilities, a certain response can be given by the server, thus governing performance. The authors describe the server performance in the following manner: “A server accepts and acts upon request messages containing a list of objects to be retrieved (or computed) and some QoS-restrictions characterize the minimum quality that is beneficial to the user, and a limit  $T$  on the time allowed for processing the request and transmitting the response.” (Bolliger and Gross, 1998; p. 378)

At any given time, a server receives a certain number of requests and must negotiate its capacity amongst these requests. In order to optimize network performance, the application determines a quality metric of the files or objects requested by its users. Then the application defines a quality metric to a particular request and assigns a weight for purposes of determining file importance and precedence. Once the foundation of the network can be monitored, a careful analysis of application models must follow.

## **2. Application Models**

Application models seek to address user-to-user issues, where measures of effectiveness include response time, predictability, and budgets (i.e., transmission costs). Network-aware applications demonstrate their responsiveness by balancing the volume of data to be transmitted with the time required to transmit it. With this balance, the

application is able to respond accordingly by rearranging the location of network demands. A network-aware application escapes the need for mode distinction. Mode distinction, e.g., a particular format of certain resolution, places a given requirement on the network and thus limits any sort of flexibility. Flexibility is key to network negotiation. The delivery of higher-resolution data increases the overall delivery time, which becomes problematic during periods of congestion. A network-aware application's behavior is governed by network availability. In turn, monitoring network availability becomes critical. Application demands can be negotiated via alternate delivery methods, like compression. Once a methodology for determining both network and application performance is established, a framework provides guidance to coordinate the behavior between a network and an application.

### **3. Framework**

The authors propose to use frameworks (an abstract method) as an approach that encapsulates (and integrates solutions to) the problems of adapting an application's behavior to the availability of network resources. (Bolliger and Gross, 1998) In a request-response communication system, a software feedback control loop serves as the backbone in monitoring network metrics. Through the use of software, a closed-loop control system primarily coordinates the available bandwidth in bursty applications (non-continuous such as streaming video). The authors discuss a feedback control system with three independently working phases: 1) a monitor and react phase, 2) a preparation phase, and 3) a transmit phase. To remain within the scope of this literature review, focus will remain on the monitor and react phase.

The monitor and react phase mainly acquires feedback on available bandwidth within the network and determines whether to increase or decrease the amount of data to be transmitted, or the amount of system adaptation required. (Bolliger and Gross, 1998) (p. 378) Bandwidth, one of an application's most critical parameters, is measured in two different ways: bottleneck bandwidth and available bandwidth. The available bandwidth indicates the best-case operating capacity of the network while bottleneck bandwidth, a more important consideration, indicates the speed that an application should transmit in

order to maintain network stability. Both types of bandwidth are important when an application manages fluctuations within the network.

#### **4. Multilevel Approach**

Similar to the methodology used by Hariri, Xu, and Balamash, Bolliger and Gross identify a multilevel method to network analysis as well. To obtain feedback in an end-to-end network path, they identify three approaches that span across different layers in the ISO/OSI-protocol hierarchy. These approaches include: 1) application-level QoS monitoring, 2) end-to-end transport-level congestion control, and 3) network-level traffic management. The lower the layer in the hierarchy, the more accurate and frequent the feedback. However, the lower layers require more protocol cooperation from network protocols on each side.

The application-level QoS monitoring approach uses a “black box” analysis perspective for the sender and receiver network quality parameters, especially the QoS-state between peers. Some of these parameters include packet interarrival times and bandwidth. With this black box type analysis, it is difficult to differentiate between weakness in the network or in the application.

In the end-to-end transport-level congestion control, bottlenecked or under-utilized bandwidth is monitored through another set of metrics, to include: packets lost or measurements of delay variations and interarrival times of packet-pairs. Bolliger and Gross cite the following advantages, “Several benefits can be gained from making such transport-level feedback information transparent to network-aware applications: the feedback-loop is shortened and queueing unnecessary data for transmission can be avoided in times of congestion.” (Bolliger and Gross, 1998; p. 379) Proper monitoring and management of network bandwidth can lead to a more efficient operation of a network-centric system.

Lastly, network-level traffic management allows for the effective monitoring of network traffic through hardware devices, particularly routers. Routers provide precise feedback about end-systems and can isolate misbehaving senders. In attempting to

support network-aware applications, one must keep in mind that the mechanisms used by each approach yield different perceptions on network performance.

## **5. Conclusions**

While using a similar multilevel approach to that used by Hariri, Xu, and Balamash, the work performed by Bolliger and Gross primarily focuses on integration of an application and its corresponding network. A prototype network system was developed in order to illustrate the applicability of their research. These authors seek to extend their findings to more accurately predict bandwidth as well as the reliability of that prediction. The analysis of application performance across a network addresses a critical interest in the Navy's transition to a network-centric organization. This source best serves as a tool for mid-level network analysis.

## **E. A REVIEW OF: "MEASUREMENT-BASED NETWORK MONITORING AND INFERENCE: SCALABILITY AND MISSING INFORMATION"**

### **1. General**

In May of 2002, Chuanyi Ji and Anwar Elwalid released an article in IEEE that addresses how network monitors can be used to infer network conditions and thus assess the performance of a network-centric communication system. (Ji and Elwalid, 2002) This study provides a precise and quantitative method on how to employ and manage network sensors for purposes of monitoring network performance, particularly when a network increases in size. This method identifies the required resources and time necessary to properly monitor a network-centric system. The nature of this monitoring, or management of a scalable network, primarily focuses on the quality of information transfer, specifically detecting lost information, e.g. packets. This study is divided into the following sections: 1) discussion of the problem of network monitoring in a specific context of inference; 2) missing data formulation; 3) density estimation and scalability definition; and the 4) investigation of scalability analytically and numerically. (Ji and Elwalid, 2002)

When establishing a network monitoring system, the primary concern is to determine how to distribute enough sensors to properly assess the network. An emphasis centers on scalability, or the number of sensors and their location. Ji and Elwalid define the scalability of measurement-based network monitoring as, “The growth rate of the number of measurements required for accurate network monitoring/interference with respect to the size of a network.” The authors construct a framework that incorporates the scalability of a network-sensing system. When considering network size, the probability density of network states is used to mathematically determine network monitoring/interference. (Ji and Elwalid, 2002; pg. 714) In this type of network analysis, node locations become essential for system performance measurement. However, a network-centric approach requires an analysis of the state of the entire network rather than monitoring individual nodes in isolation. The authors also apply their concept of scalability when addressing missing information; unobservable nodes are responsible for unaccounted for or missing information and thus the increase in the number of required measurements grows linearly with the size of the network. Similarly, scalability is determined from competing growth rates, particularly the growth rate of the network size and observed versus missed information. Scalability was identified as difficult to determine when losses became large and thus encourages the need for scaling. (Ji and Elwalid, 2002)

To avoid the complexity of large IP networks, the authors conducted their study on a multicast network. Within this multicast network, analysts determine the density estimation or the joint probability of network states, and based on the accuracy of this estimation, the performance of the network can be determined. (Ji and Elwalid, 2002; pg. 715) The sample complexity is derived from the number of samples or measurements. Subsequently, sample complexity is then used to help determine network performance. When considering what to measure, packet loss presents a fundamental metric that is used to measure network performance. The authors determine the growth rate using the missing data framework. Missing data corresponds to states of internal nodes without monitors.” (Ji and Elwalid, 2002; p.g715) In order to further explain details, the authors begin discussion of network monitoring by further defining the problem.

## 2. Problem

To facilitate their discussion, the authors elect a multicast tree network as their test bed. The information disseminated through this network is simplified to basic information packets and these packets are passed down from the central location through each parenting node. Each node with a monitor is observable, and for calculation purposes, observable data is assigned a value of “1” while unobservable nodes register no measurement. Below is a diagram of a multicast network:

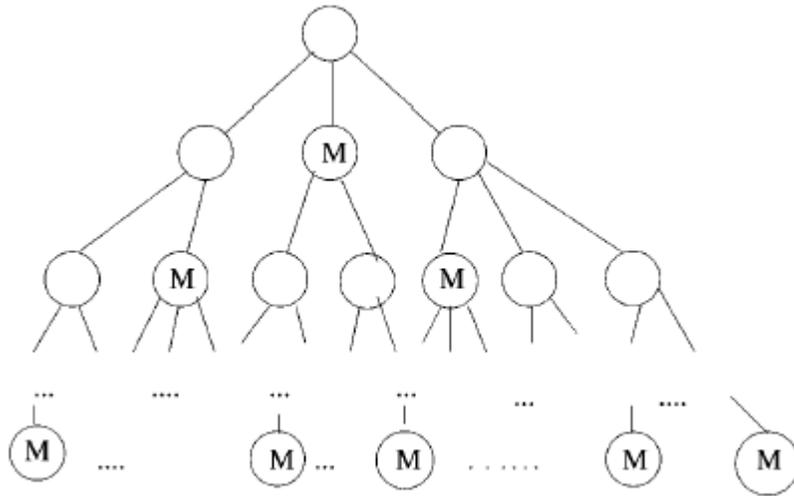


Figure 3. A Multicast Tree From (From: Ji and Elwalid, 2002; pg. 716)

A series of mathematical expressions that represent probabilities of observation accompany this diagram as well. Follow-on procedures call for a survey of each node in the network, determining whether a node is readable or not. This process is known as missing data formulation.

## 3. Missing Data Formulation

In this section, the authors distinguish between observable variables and missing random variables. Observable variables correspond to the states of observable nodes while missing random variables correspond to the states of unobservable nodes. In attempt to properly monitor a network, the missing data formulation aspect requires two steps: 1) developing a complete likelihood model, and 2) estimating the unknown parameters of the model. The likelihood model establishes a representation of different

network states. Mathematically, a modified multinomial probability belonging to a general class of the exponential family is used along with Bernoulli probabilities to determine network states. (Ji and Elwalid, 2002)

Necessary for proper network monitoring, the authors discuss how to mathematically estimate missing state parameters. They propose an EM (expectation and maximization) algorithm, a two-step process. The expectation step requires an evaluation of expected log complete likelihood while the maximization step maximizes the expected log likelihood. These two numerical methods alternate until a convergence is achieved. Once the likelihood model is complete and the unknown parameters of the model are estimated, density estimation and scalability are then considered.

#### **4. Density Estimation and Scalability**

This section discusses into more depth on density estimation and scalability. Density refers to the complete likelihood of information detection. Estimation refers to unknown parameters within the density. Ji and Elwalid define the following regarding density estimation: “The missing data formulation shows that the network monitoring can be considered as density estimation and the performance of density estimation can be measured by a distance between the estimated and the true density.” (Ji and Elwalid, 2002; pg. 717) The authors define scalability as the increase of measurements with respect to the size of a multicast network,” (Ji and Elwalid, 2002). A mathematical definition was also provided. Using true parameters as random variables (via Bayesian principles), the square error can be used as a performance measure while monitoring a network. Once these measurements are collected, network analysis can begin.

#### **5. Analysis**

Ji and Elwalid discuss the analysis aspect of network monitoring in seven topics: 1) missing information and estimation error; 2) missing information and convergence rate; 3) bounds; 4) evaluation of convergence rate; 5) best case of edge monitors – small losses; 6) worst case for edge monitors – large losses; 7) benign case of edge monitors – local losses. Missing information and the estimation error serve as the fundamental

metric necessary for network analysis. These metrics are determined by unobservable nodes and underlying losses. The convergence rate is defined as how fast discrepancies between known and unknown information can be fixed. This rate proves necessary for assessing the computation time of the previously mentioned EM algorithms and consequently accessing the scalability. Bounds refer to the evaluation of the number of measurements needed and the convergence rate using the information and speed matrices. (Ji and Elwalid, 2002) Topics 4) through 7) are discussed below.

In the next section, analytical methods are provided for calculating the convergence rate, tailored towards the proposed multicast tree network. In the best and worse cases of the edge monitors, equations and corollaries are provided that capture the network state given particularly small or large amounts of missing information. Lastly, the benign case of edge monitors addresses more realistic cases of how local losses or congestion can cause a degradation of network performance, i.e., bottlenecks. At the conclusion of the analysis section, a better understanding is provided as to how to approach the analytical aspect of network monitoring, especially at various network states.

## **6. Simulation**

The authors of this study developed a computer model simulation in order to demonstrate their concepts. They specifically investigate the following areas: 1) at what packet loss probabilities is the inference technique non-scalable? and 2) given the underlying packet loss probabilities, how would the size of the network affect scalability? (Ji and Elwalid, 2002; pg. 720) The outputs of the simulation are presented in the form of graphics and performance related data. The plots display information on the number of network probes and the convergence rate of the computational iterations required to determine scalability. The specific results suggest edge monitors are in fact effective for monitoring networks with small nodal losses (a few percent). A nodal loss probability greater than 0.15 indicates a need for rapid growth in monitoring resources. At the conclusion of the analysis, scalability was exemplified a single value,  $np$ , or the average number of probe packets received at the edge monitors. (Ji and Elwalid, 2002; pg. 723)

Additionally, caution is advised when inferring on overloaded or congested networks (not necessary large networks). Results also indicated that network with local issues should increase the number of sensing probes as well.

## **7. Alternate Monitors**

The authors explore the possibility of internal monitoring systems when edge monitoring becomes nonscalable. An investigation of passive monitors at the interior of the multicast tree took place. It was revealed that internal passive monitoring only improved the computation time for the probability algorithms and that the number of probes needed and scaling, remained unknown. Active internal monitors were also considered. The active monitors discussed had two functions: 1) recording the reception of probes from a source, and 2) acting as a source for sending probes to the nodes down the multicast tree. However, the authors only speculate the potential of the active internal monitor and mention future research of such monitor.

## **8. Conclusions**

Unlike the previous reports, this source focuses on a practical means of assessing networks on a large scale and especially as they grow. Ji and Elwalid provide a fundamental framework that addresses the scalability of measurement-based network monitoring. This framework is derived from missing data formulation and density estimation. Ji and Elwalid limit their findings to scalable monitoring situations, that is, when underlying losses are relatively small in comparison to the size of the network.

The Navy, along with joint forces, seeks to expand networked systems currently in use. With a focus of force transformation, network nodes are expected to grow in number, and the findings of this research give insight as to an effective method of monitoring and managing network performance. Although most applicable to communication systems, the methodology used in this research could be applied to the sensory network proposed in the Network-Centric Warfare concept.

## **F. CONCLUSIONS TO COMMUNICATION NETWORKS**

Communication and information networks lay the foundation for any network-centric organization. The power of information sharing enables many organizations, the military in particular, to become more aware of their environment, the state of the enemy, and the state of their own forces. Information power also yields a competitive advantage through an increased operational tempo. With this in mind, investment and protection of communication and information systems proves critical to any organization interested in performing netcentric operations.

The sources reviewed in this chapter provide network analysis techniques for low, mid, and high-level networks. Several of the sources use models to facilitate the presentation of their concepts, which is a highly preferred method when considering costs. Other sources provide practical techniques to monitor network performance real-time. Cebrowski and Garstka discuss communication systems on the highest level: how they play an integral part of other organizations.

Fortunately, the military maintains an aggressive attitude towards improving their communication assets and communication usage. A keen awareness is kept with commercial technologies in order to maintain a competitive edge. More and more, the military leans more toward contacting through the competitive civilian industry for communication support rather than exhausting internal resources attempting to match the same operational capability maintained by civilians. Cebrowski and Garstka link the importance of information and communication systems to other networks with the following statement, “The Internet and other information networks are simply the core operating tools to facilitate rapid information exchange as part of the overarching Netcentric business model.” (Netcentric World, 2)

## **IV. BUSINESS AND ECONOMIC NETWORKS**

### **A. BACKGROUND**

The network-centric revolution not only impacts the communication industry, but the business and economic industry as well. More and more business organizations are realizing the benefits of a network-centric architecture and seek transition. Combined with information and communication technologies, netcentricity in the corporate arena relies heavily on the integration of management and resources, whether internal or external, or at high levels or low levels.

Corporate networks become very complex as they develop and expand both their internal and external network clout. Internal networking focuses on how franchises manage their own organizational structure, assets, and the information that threads them together. Emphasis on external networking proves equally important. External associations in the form of business alliances yield advantages to all relevant parties through the coupled strength of specialized companies. Alliances may be composed of marketers, suppliers, support teams, and in some cases, competitors.

Through information sharing technology, businesses continue to expand the influence around the globe. With the explosive growth of the Internet, companies can reach customers anywhere in the world. Businesses present excellent specimens for organizational studies for the military – they both face similar challenges. Like the military, business organizations seek to route out competition by yielding a product or service superior to that of rival businesses.

Many of the sources discussed in this chapter focus on qualitative measures of effectiveness while fewer discuss quantitative measures. Usually, sources that focus on qualitative evaluation discuss measures in terms of “impacts” on a network-centric design rather than any other form. Additionally, “compare and contrast” analyses between netcentric and traditional businesses easily show the improved effectiveness generated by network-centric organizations. Some sources focused on concrete descriptions of business networks while other sought more abstract approaches.

**B. A REVIEW OF THE BUSINESS AND ECONOMIC SECTION OF:  
“NETWORK-CENTRIC WARFARE: ITS ORIGINS AND FUTURE”**

**1. General**

Vice Admiral Arthur Cebrowski and Mr. John Garstka draw strength for their Network-Centric Warfare concept from the business and economic arena. The business world presents an excellent model of how success and competitive advantage results from a network-centric design. Global markets best demonstrate this concept. The examination of corporate dynamics is important to the military for two reasons. First of all, corporate America requires a wide variety of organizations to seek innovative and competitive strategies in order to survive. These companies serve as organizational models that educate the Navy ahead of time on the successes and failures experienced by these organizations during their transformation process. Secondly, the military invests interest in the civilian market because it relies heavily on contractors for system procurement.

Although the tenets of this article do not provide specific quantitative measures of effectiveness that assess performance, noteworthy qualitative metrics are provided in order to assess the impact of a network-centric architecture. The article addresses economics and business in different sections, where economic relevance pertains to competitive effectiveness and the business relevance pertains to organizational effectiveness.

An economy derives its effectiveness from competition within and between ecosystems, where the effectiveness is defined as return on investment per unit time. The authors credit information technology as the main propellant for success in modern economics. Since the advent of IT systems, the economy has split into two different forms. The first economy discussed relates economic effectiveness to economies based on producing a competitive product amongst rival companies. An example would be a product based on competing standards, such as personal computers or communication devices. The second type of economy highlights the shift made by corporations to support interoperability. In this case, products compete for interoperability – the ability for items from different vendors to communicate. Windows and Intel products, or WINTEL,

remains the most popular example. This type of economy seeks to lock-in customers via the need to maintain product interoperability. This lock-in is achieved through internal and external networking.

In recognition of the interoperability-based economy, discussion leads to the businesses aspect of netcentricity and methods used by companies to boost their performance. The authors identify a dynamic shift within the corporate ecosystem where companies seek to collaborate and create partnerships rather than focusing on competing standards. In these corporate networks, information sharing provides for increased awareness and increased operational tempo that augments the effectiveness of this corporate networking. Information processing and accuracy are important components to managing information power, particularly in transaction intensive organizations. Internally, businesses have improved their network by restructuring their organizations to support network-centric operations.

Cebrowski and Garstka draw a parallel between the Network-Centric Warfare and the network-centric concept in Corporate America. Similar to the three grids used in war fighting, Cebrowski and Garstka identify three grids that comprise the netcentric business architecture: a sensor grid, a transaction grid, and a high-powered information grid that integrates the previous two. The interaction of these business grids closely resembles the interaction of the warfare grids. Like the battlespace, corporate competition and consumers establish the operational environment. Cebrowski and Garstka contribute the following summarizing tenets to economics, business, and the network-centric concept:

- The shift from platform to network is what enables the more flexible and more dynamic (and profitable) network-centric operation. Therefore, the construction of high-quality networks is their top priority.
- The shift from viewing partners as independent to viewing partners as part of a continuously adapting ecosystem increases speed and profitability in both sales and production. Therefore, they have developed high-speed sensor grids and automated command-and-control systems closely coupled with their transaction grids.
- The key to market dominance lies in making strategic choices appropriate to changing ecosystems. Simply pursuing operational effectiveness while adhering to an obsolete strategy is a formula for failure. (Cebrowski and Garstka, 1998; pg. 4)

## **2. Example: Wal-Mart and Network-Centric Retailing**

Cebrowski and Garstka assert confidence in the netcentric concept through business examples. These concepts mentioned above are well illustrated in a case study of Wal-Mart. As early as 1996, Wal-Mart began utilizing information superiority to conduct network-centric retailing. Wal-Mart gained its competitive edge by reducing the cost of sales under the industry average by a few percentage points. This was achieved by synchronizing the supply and demand information from the top down. The process begins with the sensor grid, when merchandise is purchased at local retailers. This information is then processed through the information grid that connects all of the retailers, or nodes, together. With this high-speed transfer of information, the transaction grid is engaged when suppliers become notified of a request for item replacement. This process occurs in near real-time. With this system, production, distribution, and supply lines become optimized. With this information, measures of effectiveness are easily determined with trend data and performance statistics. Ultimately, this information makes top-level management and decision-making easier.

## **3. Example: Network-Centric Trading of Securities**

A second example in Cebrowski and Garstka's article addresses network-centric securities trading. This example discusses how IT systems now facilitate nearly all trading of securities in present day. Through information power, customer awareness increases while the time required to complete a transaction decreases significantly. The next section will discuss in further detail the measures of effectiveness used to describe the performance of the market place operating with network technology.

**C. A REVIEW OF: “EFFICIENCY METRICS FOR E-MARKETS: THE IMPACT OF THE NEW YORK STOCK EXCHANGE’S IT INVESTMENTS”**

**1. General**

In January 2001, Henry Lucas, Wonseok Oh, Gary Simon, and Bruce Weber released the results of a study that identifies measures of effectiveness that assess the impact of information technology (IT) in the electronic commerce arena, particularly over the past 20 years. This document seeks to define a methodology consisting mainly of quantitative measures that assess the performance of systems responsible for electronic transactions between buyers and sellers, specifically at the New York Stock Exchange (NYSE). The authors quote their purpose with the following statement, “While size and value of transactions is one measure of a market, we propose a set of metrics for evaluating the impact of market technology, including productivity, capacity, cycle time, quality, efficiency, market share and turnover.” (Lucas, Wonseok, Simon, and Weber, 2001; pg. 1) Increasing demands for trade capacity and productivity as well as constraints on physical space necessitated a transition to IT based trading systems. In addition to these performance metrics, identification of variables within each measure increases the understanding of how the measures are influenced. At the end of this study, the authors conclude with the overall impact of the advent of information technology.

Since this research primarily focuses on the NYSE, discussed principles mainly reflect the top-level impact of netcentric trading on the larger economy and little is mentioned on how large trading networks impact individual businesses. This research provides an excellent understanding of the power of information superiority (effective trade through high-speed transmission) in a pure form.

**2. Measurement Framework**

The authors of this study acknowledge the general difficulty of defining metrics with the following statement, “Identifying the economic contribution of electronic commerce to an organization is a specific example of the general problem of evaluating

the value of information technology.” (Lucas, Wonseok, Simon, and Weber, 2001; pg. 3) In order to generate their background theory, the authors divided their research subjects into two categories: multiple organizations and single firms. This division allowed analysis to focus on different aspects of an organization. With multiple organization analysis, generic performance measures are distinguishable among organizations that perform or produce similar work. Single firm analysis allowed for measurements of productivity and other non-financial aspects that cannot be evaluated against other firms.

Multiple firm analysis techniques yielded high-level, discriminating metrics between competing firms such as return on investment (ROI), return on sales, revenue growth, sales by assets, sales by employee, and market to book value. The impact of information technology becomes evident through quantitative data sets generated by companies in the same industry. The authors compiled most of the necessary data from numerous published financial reports. A few of the industries under analysis include banking, insurance agencies, the healthcare industry, and the airlines. In addition to multiple firms, single organization studies contribute an internal perspective of IT value. In this type of analysis, difficulties regarding firm idiosyncrasies and generalizations are identified and recognized by the authors. Some of single-firm metrics performance indicators include: changes in workflow, employment, organization structure, user interfaces and technology. Analysts also considered the cost of the IT system and the perceived outcome.

The authors examined several electronic/computerized systems designed to perform market transactions and provide floor support. The systems discussed include: the Common Message Switch (CMS, 1977), the Designated Order Turnaround system (DOT, 1977), Display Book (1983), SuperDOT (1984), and Broker Booth Support System (1993). A brief discussion within this document outlines the system architecture and the flow of information necessary for transactions to be complete. Additionally, the systems mentioned above assisted in providing data necessary to establish some fundamental variables that will be used to discuss market metrics.

### 3. Variables

Within each measure, analysis must be conducted on the variables. The authors debate the relevance of the volume of shares traded versus the number of transactions. Ultimately, they argue the number of trades is more relevant since the transactions typically bear the weight on the information exchange process and not so much the share value that is represented by one piece of data. The NYSE FactBook and the previously mentioned floor support systems provided significant portions of the data used in this research particularly data relevant to the transfer handling productivity and not market surveillance. The table below outlines the variables, provides a brief explanation of the variable, and identifies the source which the data came from:

<b>Variable</b>	<b>Definition</b>	<b>Source</b>
Volume	Share volume	NYSE Factbook
Log (Transactions)	Total trade transactions per year	NYSE Factbook
IT investment	Yearly NYSE investment in IT at the Exchange and through SIAC, adjusted for inflation	NYSE & SIAC
IT head count	Number of IT staff at the NYSE and SIAC each year	NYSE & SIAC
Number of floor employees	Number of people employed by the NYSE on the floor of the Exchange (note specialists and traders are not NYSE employees)	NYSE
Price continuity	The size of the price variation, if any, from one trade to the next in the same stock=% of all transactions that occurred with no change or minimum of 1/8 <sup>th</sup> point change	NYSE FactBook
Quotation spread	% of the quotation spread of 1/4 point or less	NYSE FactBook
Market Depth	% of the average stock in 3000 shares that showed no price change or 1/8 <sup>th</sup> point change	NYSE FactBook
Market share	Percentage of trades on the NYSE	NYSE FactBook NASDAQ Web site

Table 1. Variables in the Study (From: Lucas, Wonseok, Simon, and Weber, 2001; pg. 21)

The authors considered inflation and its effects while interpreting the data. As well, a table with explanations to why they selected these particular variables was provided.

#### 4. Metrics for Measuring Market (NYSE) Effectiveness

With the previously mentioned variables in mind, Lucas, Wonseok, Simon, and Weber generated a list of common measures of effectiveness applicable to different industries. Although applicable to most businesses, the authors applied their performance metrics to the New York Stock Exchange. Below is a table of measures:

1. Productivity	The amount of work done per unit of time
2. Capacity	The maximum amount of work possible per unit time
3. Cycle time	The time from the beginning until the end of a process
4. Quality	Achieving goals, freedom from defects
5. Efficiency	Outputs divided by inputs
6. Market Share	The firm's percentage of volume in a market
7. Turnover Ratio	The "velocity" of the assets traded in a market

Table 2. NYSE Metrics. (From: Lucas, Wonseok, Simon, and Weber, 2001; pg. 5)

The sections to follow explain into better detail each of these measures of effectiveness.

##### *a. Productivity*

The productivity metric is used to identify the total amount of work completed per unit time. Through data provided by systems like SuperDOT, Broker Booth Support System, and Display Book, productivity is determined by the number of listed stocks, transaction volume, and transactions per number of floor employees. With

enclosed data in their study, the authors conclude with certainty that the investment in information technology has boosted productivity in the NYSE. The two graphs below illustrate the trend set by information technology. The trends relate time, the number of listed stocks, and transactions.

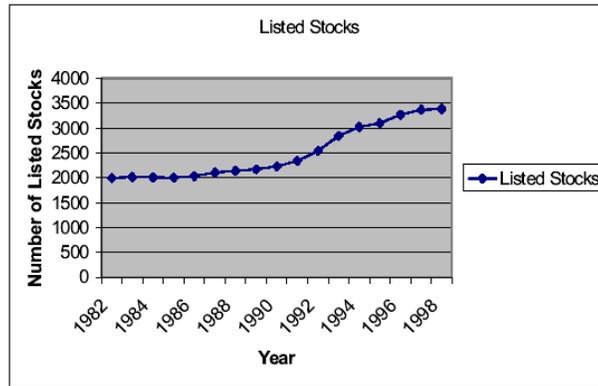


Figure 4. Listed Stocks (From: Lucas, Wonseok, Simon, and Weber, 2001; pg. 22)

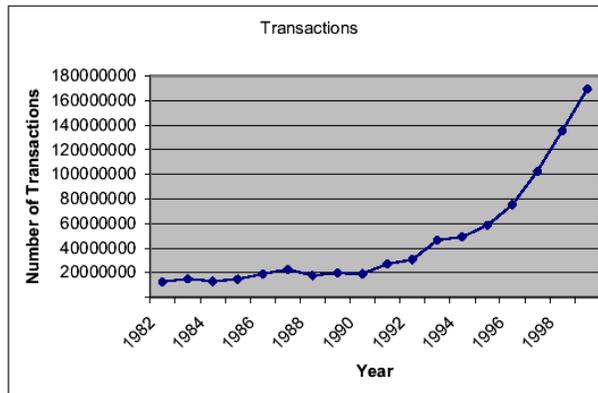


Figure 5. Transactions (From: Lucas, Wonseok, Simon, and Weber, 2001; pg. 23)

**b. Capacity**

In this report, capacity exists more as a standard set by policy rather than a fluctuating quality to be measured. To demonstrate the impact of IT on the wide-scale market, a review of the Exchange’s policy was conducted and the following was indicated about the capacity: “Interviews with NYSE senior management indicated the Exchange’s policy is to have: 1) Capacity for twice the highest 5 minute peak in messages per second. 2) Capacity for 2.5 times the average high peak over a 10 day period. 3) Capacity to process 5 times the average daily volume.” (Lucas, Wonseok, Simon, and Weber, 2001; pg. 11) Capacity works well to define a network’s potential.

*c. Cycle Time*

Cycle time indicates the time required in order to complete a sales transaction. In the past, this transaction required a person-to-person interaction, whereas now, the entire process is done electronically and many times online and thus cycle time prevails as the most influenced metric by information technology. The high-speed of information transfer serves as the root for short cycle times.

*d. Quality*

Quality, a non-quantitative measure, addresses the precision and accuracy of trade operations, particularly the avoidance of buy-sell discrepancies. In addition, quality incorporates price continuity, quotation spread, and market depth. These indications reveal that IT investments yield smooth trading, speedy execution, fewer price fluctuations, and narrower spreads. (Lucas, Wonseok, Simon, and Weber, 2001; pg. 13) The authors specify how these factors improve market liquidity and capacity.

*e. Efficiency*

Efficiency defines the ratio of production (volume of trade), to the corresponding work effort (number of working employees). A comparison was made between the number of floor employees and the number of IT employees involved with the NYSE. Data over the past 15 years showed a drastic decrease in floor employees while the number of IT employees remained relatively low. In conjunction with the increase in trade volume, the trend of employees indicates the impact of information technology. Below are graphs that compare time, employees, and transactions.

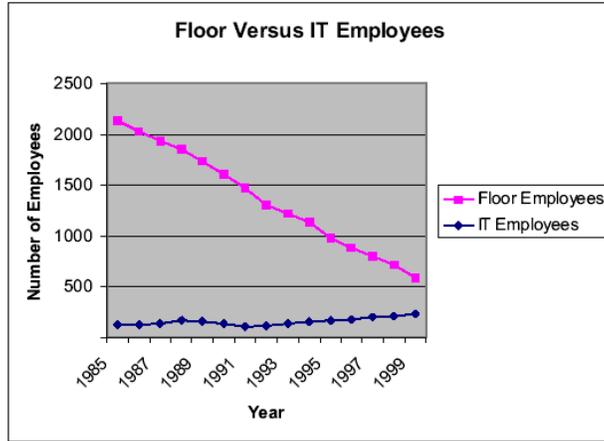


Figure 6. Floor Versus IT Employees (From: Lucas, Wonseok, Simon, and Weber, 2001; pg. 26)

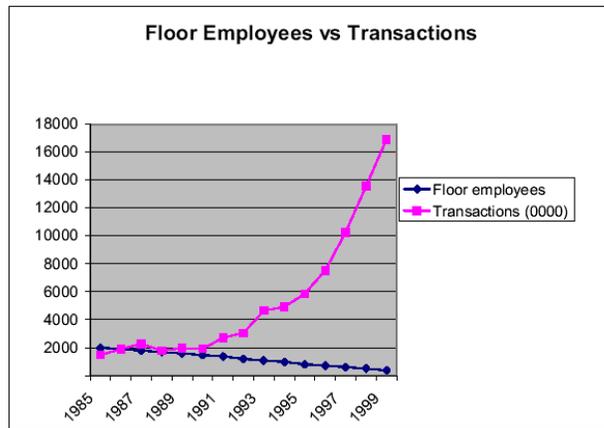


Figure 7. Floor Employees vs Transactions (From :Lucas, Wonseok, Simon, and Weber, 2001; pg. 24)

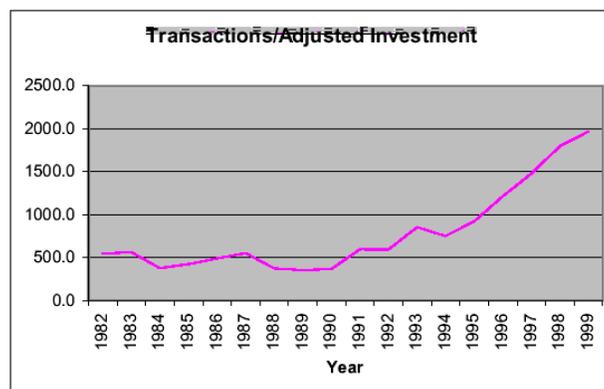


Figure 8. Transactions/Adjustment Investment (From: Lucas, Wonseok, Simon, and Weber, 2001; pg. 28)

*f. Market Share*

Market share indicates the percentage of overall shares traded per year or trading activity. Data shows that the NYSE has experienced a steady loss in market share over the past two decades. Although this data presents a negative case, the authors state this decline was minimized by investments in IT. Conversely, the authors speculate that some foreign markets not investing in IT systems face a high uncertainty in the future.

*g. Turnover Ratio*

Turnover ratio is determined by dividing the total number of shares traded by the total numbers of shares listed. The table below illustrates an increase in turnover ratio of the past decade:

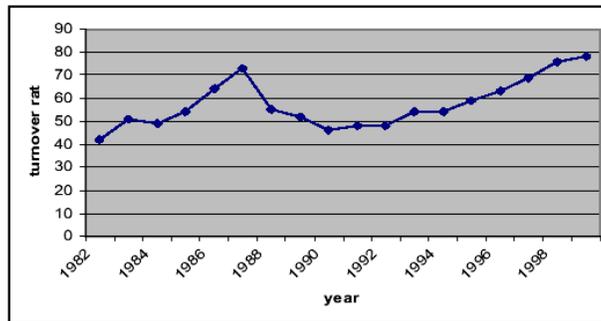


Figure 9. Time vs. Turnover Ratio (From: Lucas, Wonseok, Simon, and Weber, 2001; pg. 30)

This increase is accredited to the investment in IT. Following the explanation of these various metrics, the impact and implications of these findings are put into perspective.

**5. Implications**

At the conclusion of the study, the authors debate whether IT investments influence the volume of transactions or whether the volume of transactions influences the investment in IT. Through the use of mathematical methods, they propose that both are true. The data in their research strongly supports their argument. The authors stress the aggregation of all the previously mentioned measures of performance as they conclude

their study with the following: “Our examination of the New York Stock Exchange’s performance on all seven metrics provides evidence that IT has a positive effect on the Exchange. The data strongly suggests that the NYSE has achieved greater productivity, higher capacity, reduced cycle times, higher quality, and greater efficiency from its investments in information technology.” (Lucas, Wonseok, Simon, and Weber, 2001; pg. 15) In addition to the NYSE, the metrics discussed in this study are also applicable to the e-market and online exchanges.

## **6. Conclusions**

This study illustrates the criticality of information technology in the economic realm. The findings of this research may not necessarily assist the Navy in understanding the mechanisms of network-centric businesses but this resource does support the Navy in understanding the impact of information technology at the top-level. This research provides critical metrics and measures of performance that help. The measures of effectiveness discussed in this study are generic in nature and may be applied to any business organization.

## **D. A REVIEW OF THE BUSINESS AND ECONOMIC SECTION OF: “HARNESSING THE POWER OF NETCENTRICITY”**

### **1. General**

The Blue Ribbon Panel looks to the business example for guidance and insight on how to properly manage a network-centric organization. In bridging information technology to business and corporate success, the authors refer to methods used by existing companies currently improving their performance through the exploitation of information technology. Groups reaping the benefits of netcentricity come from all sectors of the economy. Examples include: manufactures, logistics, supply companies, retailers, banks, financial trading companies, travel agencies, education providers, government agencies, customers, and the military. (Blue Ribbon Panel, 1999) For most of these groups, the Internet and other information networks serve as the overarching mechanism that maintains their networks.

Throughout their research, the authors identify performance metrics and illustrate their concepts with examples from present-day companies in action. For instance, the first example they used to explain a business engaged in network-centric operations was the Compaq computer company. They briefly explained how Compaq uses an online ordering system that checks inventory, schedules the assembly, and notifies the customer in three seconds that his/her order is processed. This remarkable timeliness illustrates one quantitative metric that describes company performance while the positive impact noted by customer satisfaction describes a qualitative measure. Other examples go beyond the corporate arena and cite similar findings for medical applications, political movements, and computer security for the military. All of the tenets in this section may not yield performance metrics, however, many important aspects related to netcentric businesses are highlighted so companies undergoing transition may know what to expect and what to look for.

The authors separated the netcentric principles applicable to business networks into the following three sections: business models, netcentric alliances, and customer relationships. The business model section mainly explains how distinctive business principles apply to netcentric companies. The network alliance section explains the basis for business partnerships and the associated protocol. Lastly, customer relationships refer to marketing strategies employed by netcentric companies.

## **2. Business Models**

The authors primarily address measures of effectiveness in their business model section on a comparison basis, that is, between pre-network and network-centric businesses. In addition to these comparisons, some qualitative and quantitative metrics are mentioned. To divide the organizational structures and cultures section of “Harnessing the Power of Netcentricity”, the impacts of netcentricity were mapped to the following areas:

- Launch strategy
- Planning and execution
- Cycle time

- Growth trends
- Pricing model
- Product or service design
- Target markets
- Costs of entry
- Cost-cutting
- Store front
- Distribution
- Marketing channels
- Resource management
- Valuation
- Barriers to entry

“Launch strategy” describes the ability of a netcentric business to quickly scale up many components of its business, most importantly, the number of customers that it can serve. This benefit is characterized as the “first mover” advantage and proves significant over traditional businesses. (Blue Ribbon Panel, 1999) Most importantly, this ramping up occurs with small incremental investments. Binding to the “launch strategy” allows flexibility of planning and execution. “Planning and execution” describes a qualitative advantage characteristic to network-centric business. Netcentric businesses enjoy flexibility to varyng market strategies with the benefit of instantaneous results. This permits for experimentation in the marketplace and thus “strategic optioning” replaces planning. (Blue Ribbon Panel, 1999) The authors cite General Motors as a company that utilizes flexible planning and execution. The outcome of rapid planning and execution results from shorter cycle times.

“Cycle time” refers to a long-established performance metric that indicates the amount of time required to design, produce, process, and deliver a product. Via superior information sharing, network-centric businesses drastically reduce this time. Synchronous operation amongst network components and partners remains critical for the reduction in cycle time to occur. “Growth” trends represent a traditional performance metric not very relevant to netcentric businesses. Since netcentric businesses operate with fast cycle

times, their performance trend becomes volatile and unpredictable. This characteristic is not negative since dramatic up-spikes commonly compensate for periods of lower performance.

The “pricing model” refers to a qualitative feature utilized by netcentric businesses that provides real-time fixed and dynamic pricing online. The purpose of this type of pricing is to respond to the supply and demand relationship and thus optimize sales. Travel industries using electronic ticketing constantly use the pricing model during their vending process. Similarly, “product or service design” refers to the strategy of linking the consumer requirements with the design process. This is made possible with high-speed communications, usually through the Internet. The authors cite an example using Volkswagen automobiles and how customers can go online, select the model along with desired trim and features, and within a few hours are notified of the delivery date. The Internet continues to enhance netcentric business performance in yet another way. “Target markets” describe quantitatively the increase of market reach through electronic mediums, such as Internet. A lack of government, legal, and logistical restrictions further augments market reach, allowing businesses to expand their market.

“Costs of entry” refer to the initial required costs to start, support and supply an infrastructure. Comparatively, costs of entry are consistently lower for netcentric businesses and therefore facilitate the ease of starting a company. Continuing with costs of entry, “cost-cutting” refers to a quantitative measure that indicates the money saved through efficiency. Network-centric businesses improve their efficiency through the synchronous transfer of information, by outsourcing non-core activities via networked partners, and by slashing their inventories by ordering by demand only. Reduced “storefront” adds to cost-cutting by lowering the amount of physical assets required by an organization to conduct business. In lieu of the larger facilities used by traditional companies, netcentric marketing is expanded through online shopping. While customers shop from the comfort of their own home, reducing manning and store operations will lower costs and overhead for netcentric organizations. “Distribution” addresses the effectiveness of delivering products or services. A netcentric organization benefits by delivering through multiple channels within its network. As mentioned above, direct marketing channels, such as the Internet, enable improved distribution.

Besides the Internet, netcentric businesses improve their performance through other mediums. “Marketing channels” refers to intermediary parties or network partners who contribute to the sales or transaction process. A few examples include retailers, financial brokers, or music distributors. Although not categorized as a performance metric, marketing channels provide essential advantages for netcentric business. Netcentric business also maintain channels not related to marketing. “Resource management” describes a qualitative feature that addresses how businesses acquire their required supplies and resources. Rather than seeking ownership, netcentric businesses focus on supply company alliances and partnerships. Emphasis is placed on a “just in time” philosophy for purposes of supply optimization.

“Valuation”, an abstract characteristic, addresses how a business makes money. Valuation states that assets, production, and output do not necessarily indicate company performance. The authors cite America On Line (AOL) as an example where a company’s worth is not apparent in its assets. The bulk of the company’s worth comes from revenue generated by customer subscriptions to their service rather than accumulation of physical assets. The authors recognize the difficulty when trying to determine the valuation of a netcentric business and highlight this topic for further research.

Along with all of the benefits of netcentricity, there exist some disadvantages. “Barriers to entry” qualitatively discuss the impedance encountered by netcentric businesses as they operate. These barriers refer to complications associated with a business consisting of many networked partners. Some examples include intellectual property laws, access rules, international contract and liability laws, and privacy rules. (Blue Ribbon Panel, 1999)

*a. The Federal Express Example*

The authors of this research cite a case study of Federal Express and how its transition to a network-centric organization boosted its effectiveness. As a result, the impact of this transition yields both quantitative and qualitative benefits. Quantitatively, Federal Express experiences faster transactions, reduced costs, and therefore more

business and profit. Qualitatively, Federal Express: 1) maintains improved customer service via global connectivity; 2) possesses improved information control available to employees, customers, and between customers; and 3) provides advanced business solutions via supply chains and business. The seamless operations performed by Federal Express is attributed their transition to a network-centric organization.

### **3. Netcentric Alliances**

This section of “Harnessing the Power of Netcentricity” does not specifically address measure of effectiveness or performance metrics. Instead, this section focuses beyond the internal boundaries of a company and discusses the impact of business alliances on network-centric organizations. The strength and performance of a netcentric business relies heavily on networking with other companies, especially those who specialize in a specific area. With today’s increased competition, many customers seek product specialization when the desired quality is high. The netcentric alliances section of “Harnessing the Power of Netcentricity” maps the impact of netcentricity to the following areas:

- Business partnerships
- Supply chain
- Alliance constraints
- System interoperability

Netcentricity constantly promotes alliances among networks of companies. Business partnerships often consist of complimentary companies, i.e., supplier-buyer, and sometimes competing companies. The authors cite partnership examples such as General Motors and Sun Microsystems, who are teaming together to produce a Web car capable of accessing the Internet. Other examples include partnerships between competing companies such as Apple and Microsoft. Netcentric partnerships also remain flexible, permitting for changes within a short notice.

Netcentric or not, the supply chain continues its importance among all companies. Alliances with supply companies promote a smooth, coordinated, and synchronous operation. A secure link with a supply company yields reduced cycle times, reduced

intermediaries, and optimizes inventory. If merchandise is under or oversold, miscalculations in product stock can become quite costly for venders. Ensuring a good relationship between venders and suppliers necessitates good communication. Effective communication requires vender-supplier alliances to maintain extensive and intimate information sharing. Associated with proper information sharing are cooperation, collaboration, and criticality. Cooperation calls for firms to exchange essential information where collaboration calls for firms to become interdependent on each other. Criticality means that firms view each other as “critical” for success.

Alliance constraints refer to the limitations inherent in a network and necessary compromises that network members must make. For example, a vender company needs to possess the ability to reconfigure itself to suit the needs of netcentric supply-chain partners. Traditional businesses more commonly experience alliance constraints than netcentric businesses. Especially through Internet-based companies, startup costs reduce significantly by utilizing existing digital networks, since digital assets are easily moved without geographic factors. Netcentric organizations enjoy fewer alliance constraints, however, system interoperability becomes an important factor.

System interoperability, not product interoperability, addresses a company’s ability to interact with other companies by standardizing communication and operating protocols. As network size increases and becomes more complex, system interoperability ensures a smooth relationship between network partners and protects both human and intangible assets.

#### **4. Customer Relationships**

The customer relationship section addresses how technology and corporate networking have impacted sales performance over the past few years. Although no quantitative metrics are discussed in this section, discussions are relevant in understanding how this topic affects business performance. This section of “Harnessing the Power of Netcentricity” maps the impact of netcentricity to the following areas:

- Interface with customers
- Relationship management, customer information, and intermediaries
- Buying behavior
- Customer experience

Interface with customers refers the additional interface channels acquired through business networking. Not only can more customers receive service at the same time, but continual customer service ensures customer satisfaction and repeat business. With the Internet, a vast amount of information remains accessible to the customer at all times via self-service features.

Relationship management, customer information, and intermediaries add another dimension to network-centric businesses. Information superiority is exploited when customers can go online and influence design, production, and service processes. The authors cite that netcentric businesses preserve relationships with customers with trust, loyalty, and “lock-in”. This occurs when customers knowingly and unknowingly surrender private information. (Blue Ribbon Panel, 1999)

Buying behavior becomes an important issue to consider when attempting to maintain customer business. With the Internet, customer buying power and negotiation position increases with the large amounts of online product information. Marketplace dynamics are greatly affected by these factors and must be closely considered for business success. Buying behavior can be enhanced with a positive customer experience.

The customer experience describes how the Internet medium provides “hybrid realities” that blend physical and virtual dimensions. (Blue Ribbon Panel, 1999) An example shows how previewing an MP3 song before making a purchase or taking a virtual tour of the interior and exterior of an automobile enhances the customer’s attitude towards making a purchase. At the conclusion of this section, the authors illustrate their points with a discussion of Amazon.com, an online vender of books, music, and toys. This Internet-based company provides unprecedented customer service with the ability to purchase nearly any book, music CD, and toy in the market. The customer experience is enhanced with extensive product information and availability.

## **5. Conclusions**

In the research conducted by the Blue Ribbon Panel, their sections on the business model, network alliances, and customer relationships provide either specific measures of effectiveness or else factors that largely contribute to organizational performance. Within each section, the authors precisely map the impacts of netcentricity to important business aspects. The business model highlights fundamental changes to business planning and operations necessary for a netcentric companies to optimize its performance. The netcentric alliances section explains networking concepts that govern business partnerships between companies. Lastly, the customer relationships section describes some marketing practices used in netcentric retailing.

In the quest to understand network-centric organizations as a whole, “Harnessing the Power of Netcentricity” contributes the most relevant concepts and theories through corporate examples. The purpose of this research was specifically to look at the commercial industry and learn why some companies are experiencing explosive success. The tenets within this research relate well to aspects within the Navy. The business model suggests how the Navy would run its infrastructure in conjunction with information systems. The principle of alliances would apply to the Navy’s relationships with the other services in the joint arena and civilian contractors in the systems development field. The authors express throughout their document intentions of continual research of network-centric concepts.

### **E. A REVIEW OF THE BUSINESS AND ECONOMIC SECTION OF: “LINKED: THE NEW SCIENCE OF NETWORKS”**

#### **1. General**

In 2002, Albert-László Barabási published a book titled, “Linked: The New Science of Networks”, that brilliantly relates network theory to many real-world phenomena. In addition to everyday subject matters such as social coincidences, trends, and fads, Barabási relates network concepts to multiple aspects of present-day businesses. Although the author certainly recognizes the importance of information technology, he

focuses more on the criticality of nodal links and the interdependency inherent within a networked economy. The economy chapter in this book is divided into the following sections: large company mergers, organizational concepts and strategies in netcentric businesses, political networking in businesses, strategic alliances and links, large-scale economic interdependency, outsourcing, and market propagation through network dispersion.

Although Barabási does not directly address performance metrics, he makes fascinating connections between network concepts and business/economics that indicate factors that influence performance. Furthermore, rather than focusing his arguments on a particular business, discussions target networks, aggregate groups, and nodal clusters; the impacts of netcentricity map to entire networks rather than mapping to single businesses.

## **2. Company Mergers**

In continuation to the business alliance concepts articulated by the Blue Ribbon Panel, Barabási introduces business mergers. Mergers discussed in this section result via two different ways. The first highlighted how two strongly complementing companies recognize the potential of the other and seek permanent union. The author referred to Time Warner and America Online (AOL), for example. Time Warner possessed the entertainment content and America Online possessed the means for dissemination. In recognition of this perfect match, the two corporate giants merged in 2000. As a result, AOL Time Warner multiplied their worth many times. Reasons for the second type of merger consisted of identical or like companies, in many cases competitors. Instead of competing, companies networked themselves together to collect a combined profit. Examples included Exxon and Mobil, Amoco and British Petroleum, Bell Atlantic GTE, SBC Communications and Ameritech, Bank of America and Nations Bank, Citicorp and Travelers Group.

## **3. Organizational Concepts and Strategies in Netcentric Businesses**

Ideas expressed in this section closely resemble those from Cebrowski and Garstka's work and "Harnessing the Power of Netcentricity". Tenets from this section

compare traditional companies to netcentric companies by focusing on the concepts of organizational restructuring and “fundamental rethinking” of business strategies. (Barabási, 2002) In order to survive in the competitive environment of present-day, organization structures need to shift from rigid hierarchical trees to internally and externally flexible networks. Organizational focus needs to shift from the principle of mass production to the value of ideas and information. Traditional businesses achieved mass production through optimization. Optimization, however, inhibits flexibility, a necessity for netcentric organizations. Barabási quotes the following regarding optimization, “Optimization leads to what some call Byzantine monoliths, organizations so overorganized that they are completely inflexible, unable to respond to changes in the business environment.” (Barabási, 2002; pg. 201) Both internal and external flexibility are critical for network-centric businesses. The ideas mentioned above carry many implications of management restructuring, personnel competencies, and business practices.

#### **4. Political Networking in Businesses**

This section elaborates on the political networking that occurs within top-level decision makers of large companies. Arguments are based on the board members responsible for running the Fortune 1000 corporate world. Barabási explains in earlier chapters of his book how people are connected through a series of personal links. This concept happens to translate to executives running large companies. As a result, personal networks at the upper circles of the economy consequently affect the performance of many companies. Vernon Jordan is highlighted as the chief example where blending social networks and business networks becomes significant. Jordan happens to reside on the board of over 10 different large companies. The author cleverly illustrates how companies are affected by this concept but does not indicate how a netcentric business can influence this factor other than encouraging company leadership to branch out and become active in the political arena.

## **5. Strategic Alliances and Links**

In network terms, nodes join each other through links. In business terms, businesses join each other through alliances. Similar to the points expressed by the Blue Ribbon Panel, Barabási explains the importance of netcentric companies extending themselves to other businesses. Forming alliances becomes especially critical for newer or smaller businesses that may not possess the infrastructure or the capital to support operations that produce a competitive product or service. Barabási cites the following quote from Walter W. Powell: “in markets the standard strategy is to drive the hardest possible bargain on the immediate exchange. In networks, the preferred option is often creating indebtedness and reliance over the long haul.” (Barabási, 2002; pg. 209) The author cites small biotech companies as examples of organizations that rely heavily on strategic partnerships in order to maintain their businesses. Alliances provide a scale-free mechanism for company growth. Barabási briefly describes the scalability with a power law that essentially states a network with more links increases its strength.

## **6. Outsourcing**

Outsourcing presents one of the most critical links to a network-centric organization. Nearly all netcentric businesses maintain alliances with supply companies in order to reduce requirements on their own infrastructure. Typically, vender companies arrange for a “just in time” product in order to optimize inventory. Outsourcing is an effective strategy when executed well. In order for “just in time” supplying to be effective, venders and suppliers need to consider network effects by keeping their operations well synchronized. Barabási highlights two cases where poor outsourcing proved disastrous. Compaq designed a popular Pocket PC that received extremely high demands. Unfortunately, orders outpaced supply by twenty-five times, leaving many unfulfilled orders. (Barabási, 2002) The opposite phenomenon is equally damaging. Cisco Systems experienced a situation where supply exceeded demand and upper-management neglected to cease shipments – they acquired vast amounts of merchandise

that they could not sell. Twelve other major companies experienced similar failures between March 2000 and March 2001. (Barabási, 2002) The performance of a company notably relies on proper outsourcing.

## **7. Economic Interdependency**

Interdependency is the most emphasized concept in Barabási's economic section. Witnessing the detriment of poor outsourcing, we realize company performance is dependent on others. Conceptually, the author discounts traditional economics by asserting that the consequences of one company can greatly affect another company. He continues by equating economies to networks and businesses to nodes within the network. According to Barabási, the concept of dependency scales all the way up to the economies of entire nations and even on the global scale, where economies between nations become interdependent on each other. For example, the author traces a disaster in Thailand back in 1997 that in turn affected the economies of Asian countries and later the economy of the United States. This cascaded failure can only be understood by examining both micro and macroeconomics. The importance of economic interdependency scales down to the lower levels as well. Companies must value all transactions across their networks and consider their partners when making large business decisions. Selfish decisions by one company could adversely affect another company and could result in a disbandment of a partnership. Even within company boundaries, many systems and departments depend on each other.

## **8. Market Propagation Through Network Dispersion**

Barabási concludes his economic networking section with the story of Hotmail's explosive success. Hotmail, possessing nearly a quarter of all email accounts, achieved its remarkable success through networked marketing. The originators propagated their popular email service via the most popular market medium – the Internet. As a free service, users of hotmail would send emails that included advertisements of the free service. Imagine how quickly that spread. Along with an easy service to use, Hotmail became very attractive. In a one-year period, the value of Hotmail rose from \$400 million

to \$6 billion dollars. Although an exceptional case, Hotmail illustrates the explosive power of networked marketing.

## **9. Conclusions**

Although several of Barabási's tenets echo those of previous literature reviews, his research certainly adds perspective. The author asserts the importance of companies combining their strength with partners of similar or complementary nature. He explains how the consequences of certain external network behavior can either enhance or inhibit business performance. He also identifies internal changes necessary for an organization to adapt to its netcentric environment. Finally the author articulates the essentials of combined matters with the following statement, "As valuable resources shift from physical assets to bits and information, operations move from vertical to virtual integration, the reach of businesses increasingly expands from domestic to global, the lifetime of inventories decreases from months to hours, business strategies changes from top-down to bottom-up, and workers transform into employees or free agents." (Barabási, 2002; pg. 202)

The Navy can certainly learn from the conceptual principles presented in this book. As the concepts of operations, organization, and politics apply to businesses, they can also be applied to military forces. "Linked: The New Science of Networks" provides less concrete guidance to an organization in the transformation process, however, it does provide abstract guidance that is conclusive and summative.

## **F. CONCLUSIONS TO ECONOMIC AND BUSINESS NETWORKS**

The combination of business literature reviewed in this chapter seeks to provide insight to the Naval Service during its transformation processes. Beginning with Cebrowski and Garstka, their ideas on the business world certainly set the pace for this chapter. In this work, Cebrowski and Garstka integrate the use of information technology and a network-centric architecture. They assert their confidence in the Navy's ability to continue its transformation process using the guidance provided by various business models.

Henry Lucas, Wonseok Oh, Gary Simon, and Bruce Weber provide valuable research serving two purposes – to assert the significance of information technology on large-scale economic trading systems while providing basic efficiency metrics that delineates the impact of the implemented IT systems. Their findings were evident, conclusive, and appropriate for laying the foundation for literature review to follow.

The Blue Ribbon Panel provides the most relevant literature for this chapter. Their research in business was divided into three sections: the business model, netcentric alliances, and customer relationships. Within each segment, the impacts of netcentricity are mapped to important business principles. The authors include many real world instances where netcentric behavior takes place.

Lastly, Albert-László Barabási presents a more abstract view of netcentricity and its application to economies. He covers important concepts on large company mergers, organizational concepts and strategies in netcentric businesses, political networking in businesses, strategic alliances and links, large-scale economic interdependency, outsourcing, and market propagation through network dispersion. This section of literature culminates multiple theories and leaves the reader with the proper mindset of netcentricity.

The Navy as an organization does not have the same purpose as Compaq, Federal Express, or Amazon – the Navy does not seek to engage the marketplace and sell any goods. Instead the Navy is tasked with providing national defense at sea. Although given a different purpose, many lessons can be learned from commercial organizations. Principles of organizational structure, leadership, management, communications, and the use of high-speed information systems apply to both businesses and the military.

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## **VI. ORGANIZATIONAL AND SOCIAL NETWORKS**

### **A. GENERAL**

With some familiarity with communications and business networking, it is important to discuss the inner aspects of organizations, such as organizational structuring, leadership, management, and personnel factors. Rather than specifically identifying performance metrics inherent in the organizational and social aspect, the literature most relevant to this subject focuses more on contributing factors to performance, to include various individual and workgroup aspects. Considering the new and still revolutionary state of network-centric organizations, the most pronounced discussion on organizational and social aspects mainly consists of challenges encountered by netcentric businesses, particularly when transitioning to a network-centric organization.

The powerful changes brought on by information technology certainly require the restructuring of the management and people that support it. The authors of “Harnessing the Power of Netcentricity” quote the following, “There is no doubt that netcentricity enables (and requires) radical changes in the way organizations are structured, led, and managed, as well as the way they establish and retain relationships with employees.” (Blue Ribbon Panel, 1999; pg. 23) Unfortunately, the literature reviewed on this subject presenting relevance to the social aspect of network-centric organizations was very limited. All of the findings in this chapter came from the work performed at the Robert Smith Business School, found in “Harnessing the Power of Netcentricity.”

### **B. A REVIEW OF THE ORGANIZATIONAL AND SOCIAL SECTION OF: “HARNESSING THE POWER OF NETCENTRICITY”**

“Harnessing the Power of Netcentricity” contains two sections that address issues relevant to organizational and social networking. The authors of this research target the focus of this thesis by mapping the impacts of netcentricity to the following: 1) organizational structures and cultures; and 2) the individuals’ information and cognitive process. Each section is decomposed into smaller elements in order to provide for better understanding.

## 1. Organizational Structures and Cultures

When trying to assess the performance of an organization, analysis tends to focus on the economic inputs and outputs to an organization. However, a lot of credit is due to the management and personnel that run and support the company. In order to successfully run a network-centric organization, the authors identify the need for reengineering of entire organizational structures and subsequently decompose the organizational components that require attention. (Blue Ribbon Panel, 1999; pg. 23) The organizational structures and cultures section of “Harnessing the Power of Netcentricity” takes a closer look into the requirements of the management structure and what human factors affect organizational performance. The list below identifies the areas where the impact of netcentricity are mapped to organizational structures:

- Leadership
- Management processes
- Knowledge ownership
- Organizational size
- Organizational change
- Organizational form
- Employee attraction and retention
- Employee-employer contract

The leadership required to direct a netcentric organization is considerably different. Rather than charismatic or transformational leadership, a more transactional type of leadership is desired. A leader’s effectiveness would be based more on an exchange basis than a change basis. Closely related to this type of leadership is the management process. Management within a netcentric organization is shown to be more effective with the enabling of information flow rather than the close exercising of control and authority. The authors quote, “Control and authority reside with those who possess and deploy knowledge and information.” (Blue Ribbon Panel, 1999; pg. 4) Knowledge ownership refers to an asset embedded into the network and in the knowledge of the network workers. Here the manager-worker delineation becomes less defined as organizations strengthen their networks. Contrary to traditional organizational structures,

especially the military, the knowledge ownership in network-centric groups promotes the free flow of information to all internal and external partners as well as up and down the chain. (Blue Ribbon Panel, 1999; pg. 4)

Network-centric organizations tend to be smaller than traditional organizations. This research does not specifically address how size affects company performance, however, it does mention that a company of smaller size enables greater speed, agility, spontaneity, and direct connectivity. All these factors improve company performance. The smaller company size is possible since many aspects required by the business are “networked” out. Organizational changes allowed to occur within netcentric organizations promotes flexibility and thus enables better performance. Changes in company agenda are designed to shorten cycle times and occur without planning. This translates to real-time experimentation. With a short cycle time, the negative results of a non-lucrative experiment would arrive quickly and with minimal damage. At this point, another marketing plan can be implemented and tested. Additionally, this ability for change allows netcentric companies to change or disband groups with great fluidity. In this way, the organizational form of netcentric companies differs greatly from that of traditional companies. The authors state, “Instead of hierarchies, netcentric organizations are structured as fluid knowledge teams, which are formed and disbanded around real-time business needs.” (Blue Ribbon Panel, 1999; pg. 4)

The authors of this research also found it necessary to discuss the employee aspects of netcentric companies. Ensuring quality workers has always been necessary for any business. The first area discussed is employee attraction and retention. Workers who seek more autonomy and less structure would enjoy the information openness of netcentric work groups. Since the proper management and handling of company information (the paramount asset of these types of companies), is the first order of business, employees gain a genuine sense of ownership of this asset, which helps worker retention. Employee-employer contract refers to conditions in which workers are connected to their jobs. Additionally, netcentric businesses typically permit more flexible employment, allowing for temporary and geographically distributed employment. However, at the same time, these aspects may detract other workers who generally seek more job security.

## **2. Individuals' Information and Cognitive Process**

Following the discussion on organizational factors, the authors decompose their concepts of the employee factor down to the individual level. With a better understanding of human performance within a netcentric workgroup, companies can tailor their organization to better suit individual effectiveness. The individuals' information and cognitive process section of "Harnessing the Power of Netcentricity" mapped the following impacts of netcentricity to the individual:

- Separation between work and personal lives
- Information volume/accessibility and knowledge obsolescence
- Knowledge acquisition
- Information presentation

The first aspect the authors address is the separation between work and personal lives. Information technology brings a mixed blessing to the individuals employed under its network. Through multimedia, workers can perform tasks from anywhere at anytime. On one hand, this enables work flexibility, where employees can enjoy the freedom to work in various places along with a flexible schedule. On the other hand, this same information capability enables management to utilize workers for extended working hours and thus lessening the distinction between work and personal lives. If this relatively unlimited access to employees is not carefully monitored, workers may become fatigued and thus decrease productivity and company performance.

Information volume/accessibility and knowledge obsolescence refers to large amounts of information that employees in netcentric organizations are responsible for. This implies netcentric employees require a high level of competency and the ability to multitask. This concept follows into knowledge acquisition, which explains how employees must not only hire on with a certain skill level, but that they must also be competent learners. In netcentric organizations, distant education and training can occur through several mediums, to include the Internet and local intranets.

Lastly, information presentation refers to the importance of information processing within a network-centric organization. With the dissemination of high amounts of information across a wide variety of sources, effective information processing

will reduce the turnaround time required to make use of the information. The authors discuss briefly future possibilities of a seamless process through a hybrid reality that merges physical and virtual perceptions of information.

### **3. Conclusions**

The organizational and social concepts discussed in this document address important human-related issues for network-centric organizations. First, human factors are addressed on a large scale – at the organizational level. The main components include company leadership, management, and organizational fit. Secondly, human factors are addressed on a small scale – at the individual level. Here, aspects of personnel competencies and personal issues are addressed.

Similar to the business sections of “Harnessing the Power of Netcentricity”, the tenets within this research correlate well to concerns within the Navy. Discussion on organizational form suggests how the Navy would run its infrastructure in conjunction with the continually evolving information systems. Takeaways include aspects of force structure, senior and junior leadership, and supervision considerations. Discussion of the individual suggests recommendations for technical training for personnel as well as worker moral and welfare.

#### **C. CONCLUSIONS TO ORGANIZATIONAL AND SOCIAL NETWORKS**

Upon reviewing the organizational and social tenets addressed by the authors of this research, it is evident that many human-related factors influence an organization’s performance. There currently exists ample material written on social and organizational theory, human performance, and management that identify performance metrics in a traditional sense, however, very little information presently exists that analyzes the impacts of these factors on current network-centric businesses.

In order for the Navy to continue its transition to a netcentric fighting force, a significant amount of time and effort must be applied to properly educating and training the personnel responsible for performing network-centric duties. Regardless of trade

specialties, it will become important for all warfighters to become knowledgeable and competent users of the information technology issued to them. To keep within ideal operational performance, the Naval administration and leadership need to consider both the organizational and social tenets mentioned in this chapter.

## VII. CONCLUSION

The U.S. Navy stands as an organization older than the country it is assigned to defend. It has performed its duty for 227 years through a long-standing hierarchical organization and via proven processes. As a keen and responsive organization, the Navy constantly seeks to improve and outperform its competitors by a considerable margin. In the quest to outperform its opponents, the Navy is quite a privileged organization, given its extraordinary relationships with the most technologically advanced developers in existence. American forces continue to maintain technological superiority over other nations, however, with the threats the United States faces today, overwhelming force and technology may not provide for the best defense.

Back in 1998, Vice Admiral Arthur Cebrowski and Mr. John Garstka asserted in their article both their confidence and doubt regarding the Navy's future with the following statement, "No one operates better than the U.S. Navy. Our forward presence force is the finest such force in the world. But operational effectiveness in the wrong competitive space may lead to mission success. More fundamentally, has the underlying rule set changed so that we are now in a different competitive space? How will we revalue the attributes in our organization?" (Cebrowski and Garstka, 1998) Consequently, the Navy and its joint partners sought to harness their technological advantage into a more suitable fighting force for combating asymmetrical threats. This fighting force needed to be responsive, agile, and effective. These demands were answered with the concept of Network-Centric Warfare. Although present-day operations adhere to some of the principles of Network-Centric Warfare, many aspects within the Navy and joint forces need continual reworking. In order for the Navy to successfully continue its transition to a network-centric organization, Cebrowski and Garstka emphasized that a definite shift would have to occur within the upper-levels of administration. While continual changes in force structure, training, and resource allocation remain necessary for the transformation process, Cebrowski and Garstka identified the continual need for resources in three other fundamental areas: 1) intellectual capital; 2) financial capital; 3) and process.

Intellectual capital targets information-based processes in both commercial and military arenas. Further discussion targets the personnel within military organizations, especially between members with operational experience and those with technical expertise. Traditionally, military leaders and operators concentrated on gaining operational experience, which historically promotes individuals quicker through the ranks. In order to embrace an information-intensive way of fighting, a much larger emphasis needs to be placed on technical expertise. Financial capital discusses the financial commitment necessary for the Navy's successful transition to Network-Centric Warfare. Information Technology for the 21<sup>st</sup> Century (IT-21) is mentioned as the primary enabler for the acquisition and procurement of necessary IT systems. Starting in 1997, budget allocations began supporting IT programs. Mentions of the Future Years Defense Program and Joint Vision 2010 also support the acquisition needs for a network-centric force. Process, referring to the transformation process, addresses the challenge of implementing IT systems into service and joint doctrine. The co-evolution of organization, technology, and doctrine proves necessary to overcome cultural and systemic problems. Specific top-down experimentation presents a reasonable and cost-effective approach to test the transitional process. The Navy's Fleet Battle Experiment Program is equipped for just this.

Fortunately, the U.S. Navy and joint forces have already begun to transform their organizational structures to a network-centric design. Although Network-Centric Warfare has already been initiated, the transformation is predicted to last for years to come. The findings of this literature review are intended to inform inquiring parties of some currently available methods of assessing organizational performance and to promote future research in the area of gauging netcentric performance. Communication and information networks provide the technological background necessary for netcentric operations. Regardless of the type of network, information sharing enables nodes within a network to maintain connectivity and thus carry out their mission. Business and economic networks present working examples of organizations linked within a networked environment for purposes of benefiting from their collective strength. Lastly, organizational and social models address how personnel and training should be handled in a netcentric organization.

In the May 26<sup>th</sup>, 2003, issue of the Navy Times, Amy Svitak's article, titled "Cebrowski: Networking paid off in Iraq," highlighted the networked operations performed in Operation Iraqi Freedom. Svitak conveys Cebrowski's confidence in the current state of force transformation and the success of network-centric warfare with the outcome of coalition operations in Iraq.

The success of the joint and coalition forces was credited to the responsive and versatile operations enabled by integrated communications and better sensing capabilities. Improved sensing was made possible by shared awareness in intelligence, surveillance, and reconnaissance. The coalition's responsiveness was characterized by the speed and power demonstrated by operating units. Svitak captures Cebrowski's thoughts of force responsiveness and adaptability with the following quote, "When you have people say this didn't come out the way we thought, that it doesn't seem to be the way of American warfare that we thought ... that's exactly what you want." (Svitak, 2003; pg. 32) Even within friendly forces, Cebrowski delineates the performance between networked units and non-networked units. The non-networked forces were identified as points of concern for the transformation process and whether or not those forces should be eliminated in the future. Credit was given to well coordinated land-air operations while intelligence analysis and access to space for communications left room for improvement. Lastly, Cebrowski identifies the concern that several administrative bodies only focus on simply sustaining current force capabilities instead of emphasizing growth to better address global threats.

As Naval and joint forces continue their transition to Network-Centric Warfare, members of the government, Naval administration, and of the operational force should take the proper steps to ensure an optimal process. Tenets found in this thesis: 1) suggest various approaches to assessing the progress and performance of network-centric organizations, and 2) highlight contributing factors that affect the performance of these organizations. Netcentricity remains a relatively new concept and demands future research in order to fully understand the implications that it carries.

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