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Modeling Network Centric Warfare (NCW) With the System Effectiveness Analysis Simulation (SEAS)

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MODELING NETWORK CENTRIC WARFARE

(NCW) WITH THE SYSTEM EFFECTIVENESS

ANALYSIS SIMULATION (SEAS)

THESIS

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Abstract

Significant technological advances over the past few decades have fueled the continual and rapid development of an information-based world. Network Centric Warfare (NCW) has become the buzzword of the young millennium within the Department of Defense (DoD) and is quickly becoming a popularly shared vision and rallying cry for force transformation among United States military leaders. An essential element in fully implementing this network-centric way of thinking is to develop useful measures to help gauge the effectiveness and efficiency of both our military networks and our strategic NCW doctrine. The goal of this research is first to provide a comprehensive summary of the key literary works that have forged a foundational basis for defining NCW. Second, this work will utilize a System Effectiveness Analysis Simulation (SEAS) combat model, which represents a Kosovo-like engagement (provided by the Space and Missile Center), to serve as a tool in exploring the use of NCW metrics in military worth analysis. Third and last, this effort selects measures for the physical, information, and cognitive domains of NCW and analyzes the outputs from the Kosovo scenario that are pertinent to each domain in order to assess the usefulness of each metric. In the final analysis, the average target detection distance outputs and average communication channel message loading metrics chosen for the physical and information domains yielded mixed results and levels of utility, while the highly aggregated metric of target kills served as a useful, and yet rough, final metric for the cognitive domain.

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MODELING NETWORK CENTRIC WARFARE (NCW) WITH THE SYSTEM EFFECTIVENESS ANALYSIS SIMULATION (SEAS)

I. Introduction

1.1 Background

In the current Information Age, success or failure of operations often relies heavily on the ability to gather, translate, and process large amount of data and information. Evidence of this phenomenon can clearly be seen within two distinct environments: the American business arena and the World Wide Web. In the American business arena, Wal-Mart has moved from a traditional retailer to a *precision retailer* by achieving information superiority in its domain (Alberts, Gartska, and Stein, 1999:46). The end result of Wal-Mart's highly network and information-focused approach to retail sales is that its stores reign as the nation's top retailer, having $256 billion in annual sales for 2004 (Wal-Mart, 2005:2). As for the World Wide Web, the multitude of applications for networking and sharing information on a global scale continue to be developed and applied.

> The combination of digital communications capabilities and breakthroughs in software technology in the form of Web browsers and servers has combined to enable information interactions among entities of virtually any size that can be connected to the Internet. The net result is referred to by some as the social-technological phenomenon, the "Internet Tsunami". (Alberts, Gartska, and Stein, 1999:250)

The same principles of information dominance and power which have transformed the U.S. market place and linked the world via the internet apply equally to the United States military. Information technology has significantly changed our concepts of time and distance. Distance is becoming less relevant as large amounts of information are able to be transmitted and received with increasing ease and speed. Within the battlespace, this shrinking of distance and time translates into increased combat capability and the potential for orders of magnitude increases in mission effectiveness and efficiency. The key to realizing this potential is the ability to fully utilize our systems of sensors, data processors, communication links, and decision-making methods.

A ground-breaking concept that moves the U.S. military towards the goal of achieving maximum combat success and efficiency through utilization of network technology has emerged over the last five to ten years. This revolutionary idea is called Network Centric Warfare (NCW). The defining characteristics and exact applications of NCW are continually evolving, as are its applications. NCW finds itself being explored and studied as part of a larger initiative within the DoD, that of transformation. A primary goal of transformation, and consequently of the Office of Force Transformation, is to keep the United States military at the forefront of warfare technology, tactics, and knowledge of the enemy. The concept of effects-based operations (EBO) is being employed as a theoretical means to the end of military transformation. A policy of "forward deterrence" has been adopted by the Office of Force Transformation and NCW figures to play a key role in implementing this policy.

1.2 Problem Definition

The technological advances of the Information Age have not only increased capacities of information exchange and decreased information processing time, but have also increased levels of complexity involved with sorting through data and information to find the packets that are pertinent to a certain decision or problem. The higher levels of complexity involved in vast information networks and systems make it difficult to assess the relative worth and efficiency of these networks and systems. The development of basic, definable, and measurable metrics is required in order to serve as diagnostic tools for rating the effectiveness of network performance and impact on command and control, especially within a military system or tactical engagement. These measures will be determined and chosen based on available outputs from a combat modeling scenario. Once basic metrics are established, their military worth can be measured through the utilization of various analysis methods and tools applied to output data from multiple combat simulation runs. In short, the essence of the problem for this thesis effort is to determine how to measure the effective application and worth of NCW within the context of a combat modeling simulation.

1.3 Research Objective

This research has been sponsored by the Simulation and Analysis Facility (SIMAF) at Wright-Patterson AFB, OH. This effort is focused on first defining Network Centric Warfare (NCW) from reputable research literature and doctrinal documents pertaining to the subject. This definition will be formed against the back-drop of the larger picture of force transformation currently being employed within the Department of Defense. Once defined, various modeling techniques and metrics for NCW will be addressed and established. From these proposed models and metrics, a specific modeling option will be chosen and utilized in order to measure the military worth of NCW in a well defined mission level scenario. The focus of analysis will be primarily on contrasting the performance of an NCW-enabled force in a given combat situation versus the performance of that same force acting at degraded levels of NCW capability. The outputs resulting from the baseline case and NCW degraded cases will be analyzed to provide insight into the benefits and challenges of utilizing NCW as an applied theory of conducting military operations.

1.4 Research Scope

For this effort, Modeling and Simulation (M&S) will be the primary specialty within the Operations Research tool set that will be utilized as a means of evaluating the military worth and effectiveness of an NCW-enabled force. The specific type of tool within M&S which will be utilized for this effort is agent-based modeling (ABM). The software selected for analyzing the NCW scenario is the System Effectiveness and Analysis Simulation (SEAS). The SEAS scenario will consist of generic blue and red combat forces, which will legitimately represent some NCW capabilities within the context of a mission level simulation model. As mentioned in the Research Objective section above, a baseline case of this scenario will be run and compared versus modified configurations of the scenario which removes or degrades certain NCW capabilities. Based on the output from replications of this model, various statistical analysis techniques will be employed as tools in determining the overall value of NCW within the context of this thesis research.

1.5 Thesis Overview

Following this Introduction are chapters for a Literature Review, Methodology, Analysis, and Conclusions. The Literature Review (Chapter 2) covers several definitions of NCW which have been gleaned from foundational works on the subject, as well as several fundamental definitions laid out by Joint and USAF doctrinal documents. Chapter 2 then presents a formulated definition of NCW that is uniquely crafted for this research effort and concludes with various possible approaches for modeling and measuring NCW. The Methodology chapter (Chapter 3) describes the modeling approach that will be used to represent NCW within the context of a mission-level combat model. Details and background of the SEAS Kosovo scenario will be provided here. The Analysis chapter (Chapter 4) will provide a presentation and interpretation of the results from repeated runs of the combat model NCW scenario for a baseline case versus a case that was modified in order to determine the military worth of applying NCW within scenario. The Conclusions chapter (Chapter 5) provides various bottom-line statements derived from the modeling and analysis of this NCW research. Also, recommendations for further research of NCW are offered in this chapter.

II. Literature Review

2.1 Introduction

The United States military is currently undergoing a phase of revolutionary change and transition. Paradigms are shifting from a Cold War, force-on-force philosophy of warfare to an asymmetric, network centric approach. The DoD's Office of Force Transformation has issued a new strategy for achieving this transition. Vital to this transformation effort are the concepts of Effects Based Operations (EBO) and NCW, which will be covered in more detail in section 2.2. Having thus portrayed NCW as a key enabler of EBO and as a key means of achieving U.S. military transformation, a thorough exploration of current NCW definitions and a formulated definition for this research effort will be detailed in section 2.3. Once defined, various approaches for modeling NCW will be described in section 2.4. After a brief introduction for this section, an exploration of Agent-Based Modeling (ABM) as a possible tool for modeling NCW is presented in section 2.4.2. A specific application of ABM, the System Effectiveness Analysis Simulation (SEAS), is then described as prime candidate software to model NCW in section 2.4.3. Measures of effectiveness (MOEs) for NCW are described in section 2.5, followed by a summary of this Literature Review in section 2.6.

2.2 Transformation, Effects Based Operations (EBO), and NCW

2.2.1 Transformation - The New U.S. Military Strategy

The current climate of the United States military as a whole is one of urgent and necessary change. In a speech at The Citadel in December of 2001, President Bush stated:

> The need for military transformation was clear before the conflict in Afghanistan, and before September the 11th. . . What's different today is our sense of urgency - the need to build this future force while fighting a present war. It's like overhauling an engine while you're going at 80 miles an hour. Yet we have no other choice. (Director, Office of Force Transformation, 2003:1)

The events of 9/11 exposed vulnerabilities within the Department of Defense that are no longer being ignored. As the President stated, the need for transformation of the military was present prior to the horrific terror attacks on the United States. Unfortunately, as is the case with most human endeavors, proper motivation was necessary to provide the fuel for real change, which in this case is the full implementation of military transformation.

The current vision for transformation stated by the Department of Defense is as follows:

> Military transformation will enable the U.S. Armed Forces to achieve broad and sustained competitive advantage in the 21st century. It comprises those activities that anticipate and create the future by coevolving concepts, processes, organizations, and technologies to produce new sources of military power. The transformation of our armed forces will dramatically increase our strategic and operational responsiveness, speed, reach, and effectiveness, making our forces increasingly precise, lethal, tailorable, agile, survivable, and more easily sustainable. (Director, Office of Force Transformation, 2003:4)

Essentially, transformation is the shaping and molding of our military force that seeks to fully exploit the advantages we currently possess and to protect against and minimize our vulnerabilities. Transformation is employed and accomplished through a combination of concepts, capabilities, people, and technology. The overall objective of these changes is to sustain the U.S. competitive advantage in warfare (Director, Office of Force Transformation, 2003:8).

An essential concept that drives transformation is the idea of forward deterrence, which is a stance of prevention rather than reaction. As Secretary of Defense Donald Rumsfeld said at the National Defense University in January of 2002, "We must promote a more entrepreneurial approach to developing military capabilities, one that encourages people, all people, to be proactive and not reactive…" (Director, Office of Force Transformation, 2003:29). Although current U.S. military capabilities are superior to any existing conventional threat, our supremacy will rapidly diminish over time if we do not continue to enhance our military prowess (Director, Office of Force Transformation, 2003:12). There are several key components of transformation that are geared towards achieving forward deterrence. Among these key components are EBO and NCW. These two concepts are being explored and refined in order to understand how they complement one another in meeting the needs of the new security environment (Smith, 2002:xxii).

2.2.2 EBO Fundamentals

Unlike network-centric operations, which have emerged from the technologies and thinking of the Information Age, effects-based operations are not new (Smith, 2002:xxiii). Military leaders and planners have always tried to plan and execute battle plans and create battlefield conditions favorable to the achievement of their objectives and policy goals. Rather than a new form of warfare, EBO is a way of thinking or a methodology for planning, executing, and assessing operations designed to attain specific effects that are required to achieve desired national security outcomes (Director, Office of Force Transformation, 2003:34).

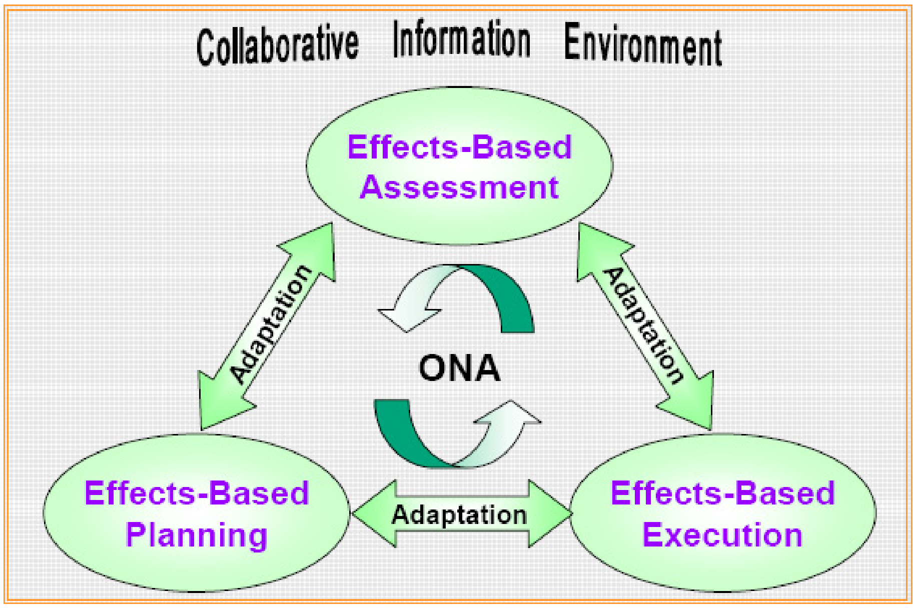

Figure 1. EBO's Major Components (Doctrine and Education Group, 2004:8)

Figure 1 shows EBO's three major components: effects-based planning, execution, and assessment (Doctrine and Education Group, 2004:8). The central, cyclic flow around "ONA" in this figure represents EBO's dependence on the continual function of something called Operational Net Assessment (ONA). ONA integrates people, processes, and tools that use multiple information sources and collaborative analysis to build a common, shared, holistic knowledge base of the operational environment (Doctrine and Education Group, 2004:9). ONA places primary focus on the operational level and prioritizes the network as the key element of effective operations.

EBO is primarily about focusing knowledge, precision, speed, and agility on the enemy decision-makers to degrade their ability to take coherent action rather than conducting combat operations on more efficient destruction of the enemy (Director, Office of Force Transformation, 2003:34). As will be detailed more fully in the next section concerning NCW, EBO is focused less on effects within the physical domain and more so on effects in the information and cognitive domain, with a special emphasis on the cognitive, or decision, arenas of warfare. The knowledge, precision, speed, and agility brought about by network-centric operations provide the necessary ingredients for entry into the realm of EBO (Director, Office of Force Transformation, 2003:34).

2.2.3 NCW - A Key Enabler of EBO

Network-centric warfare is an emerging theory of war in the Information Age. It is also a concept that, at the highest level, constitutes the military's response to the Information Age (Director, Office of Force Transformation, 2005:3). In an increasingly information-driven world, power is progressively being drawn from the sharing of information, the degree of information access, and speed of information transmission and reception. As an organizing principle, NCW accelerates our ability to know, decide, and act by linking sensors, communications systems, and weapons systems in an interconnected grid (Director, Office of Force Transformation, 2003:13). NCW involves a modern way of organizing and thinking about the application of our military forces as they relate to desired outcomes and therefore is a key element of EBO.

A basic understanding of NCW can be obtained by examining the three domains of conflict: the cognitive domain, information domain, and physical domain. There is also a fourth domain, the social domain, which has been proposed and documented by the Office of Force Transformation as of January 2005. However, for this thesis effort, the focus will be on the originally proposed three domains of NCW. The three domains provide a general framework for tracing what actually goes on in the stimulus and response process inside human minds and human organizations (Smith, 2002:161).

Physical actions often have a psychological impact, which is then translated into a decision. The physical domain spans the traditional environments of land, sea, air, and space in which conflict typically occurs. The physical domain is home to the platforms and communications networks of a given military force. Typically, measures of combat effectiveness are easiest to measure in this domain and thus it has traditionally been the focus of most analysis conducted on military warfare. However, the physical domain provides an incomplete picture in capturing the complex interactions and outcomes of real warfare. This is the primary reason for including the information and cognitive domains in the conceptual framework of NCW.

The information domain represents the realm in which information is created, manipulated, and shared. Information traces its origins to data collected from sensing events in the physical domain. Comparatively, effects in the information domain can be more difficult to measure than those in the physical domain. Often, usable measures of information are those pertaining to communication range, broadcast range, bandwidth, and the reliability of information (accuracy). This domain also encompasses all of the means of conveying the decisions, plans, and orders that translate a cognitive response into physical actions (Smith, 2002:164-165). Consequently, it is increasingly the information domain that must be protected and defended to enable a force to generate combat power in the face of offensive actions by an adversary (Director, Office of Force Transformation, 2003:33).

The cognitive domain is the locus of the functions of perceiving, making sense of a situation, assessing alternatives, and deciding on a course of action (Smith, 2002:173). This domain exists within the mind of the warfighter. This is the realm of EBO (Director, Office of Force Transformation, 2003:33). The cognitive domain holds the intangible elements of knowledge, understanding, decision-making, morale, and leadership, just to name a few. Measures for this domain are by far the most difficult to assess. Decision analysis methods and tools, plus an evaluation of artificial intelligence leadership decisions made within a combat model are possible ways of capturing behavior in this domain.

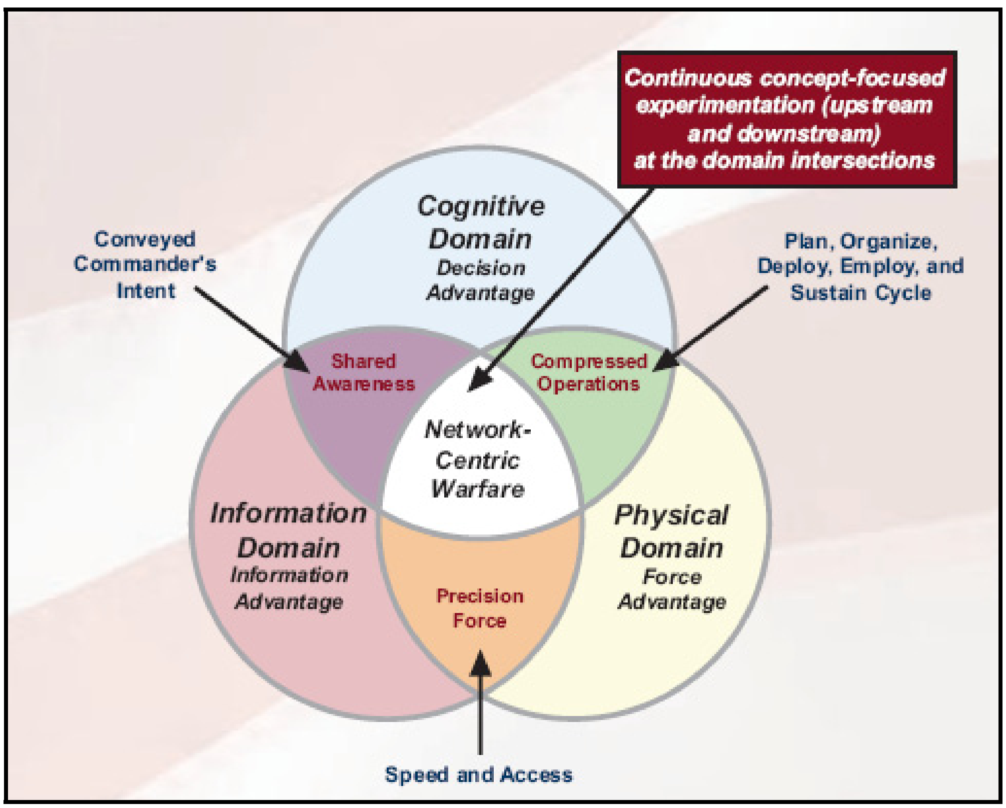

Figure 2. Domains of Conflict (Director, Office of Force Transformation, 2003:33)

Figure 2 displays more specifically how NCW relates to the three domains. The domain intersections represent important, dynamic areas within which concept-focused experimentation should be conducted (Director, Office of Force Transformation, 2003:33). The overlap area designated Conveyed Commander's Intent (the Shared Awareness region), where the information and cognitive domains intersect, is an extremely important realm when it comes to the final outcome of a given conflict because this is often the area where key decisions are made that dictate the flow of warfare. The intersection of all three domains encapsulates the realm in which NCW exists. NCW is the result of a dynamic interplay of elements from the physical, information, and cognitive domains of conflict.

2.3 Defining NCW

2.3.1 Definitions from Foundational NCW Works

Since its conception in the late 1990's, there has been a significant amount of literature published on Network Centric Warfare (NCW). Two significant documents, one by Alberts (1999) and the other by Fewell (2003), provide a baseline from which to reference fundamental definitions of NCW. The Department of Defense has embraced the term and has included the concept in its Joint Vision documents. The Air Force's Basic Doctrine also highlights basic concepts of NCW. From this plethora of sources, many various definitions and characterizations of NCW will be distilled and one comprehensive definition will be formed.

The foundational document for NCW was written by David S. Alberts, John J. Gartska, and Frederick P. Stein in 1999. In their work, *Network Centric Warfare, Developing and Leveraging Information Superiority*, Alberts *et al.* established a baseline of thinking upon which the structure of NCW has been built. Despite the excellent groundwork that has been laid, an exact and working definition of NCW is difficult to extract from this foundational text. This difficulty is largely due to the fact that NCW is still a developing idea. As Alberts said at a conference in Washington on March 28, 2005, "An idea, like a child, takes on a life of its own. It has parents, it has supporters, it has detractors -- all of which had a great influence on the development of the idea. But ultimately the idea, like the child, becomes what it becomes" (Air Force Link, 2005). In this sense, NCW is very much like a child that is still growing and developing into a future form that is largely unknown at the present time.

Despite the difficulties in finding an authoritative and accepted definition, certain key components of the current conceptions of NCW can be highlighted. The Australian Government's Defence Science and Technology Organisation (DSTO) compiled an investigative paper in 2003 that defines NCW in the following way:

> Network-centric warfare is the conduct of military operations using networked information systems to generate a flexible and agile military force that acts under a common commander's intent, independent of the geographic or organisational disposition of the individual elements, and in which the focus of the warfighter is broadened away from the individual, unit or platform concerns to give primacy to the mission and responsibilities of the team, task group or coalition. (Fewell and Hazen, 2003:39)

This same paper identifies four distinct qualities, or tenets, that are fundamental to NCW:

1) A robustly networked force improves information sharing
2) Information sharing and collaboration enhances the quality of information and shared situational awareness

3) Shared situational awareness enables collaboration and self-synchronization, and enhances sustainability and speed of command
4) These, in turn, dramatically increase mission effectiveness
(Fewell and Hazen, 2003:2)

The DSTO further cites NCW as typically being expressed in terms of ‘four rights’: the network supplies the **right information** at the **right time** in the **right form** to the **right person** (Fewell and Hazen, 2003:2). The DSTO adds a fifth ‘right’ to this list. Not only does the right information need to be available to the right person at the right time in the right form, but also it needs to be put to the **right use** (Fewell and Hazen, 2003:34).

Alberts states that NCW is about human and organizational behavior (Alberts, Gartska, and Stein, 1999:88). This is an important point because it hints at the difficulties in fully modeling NCW, given the significant human component and presence of complexity due to human decision makers and operators. Further, Alberts states that NCW is not narrowly about technology, but broadly about an emerging response to the Information Age (Alberts, Gartska, and Stein, 1999:88). In defining NCW, Alberts cautions that focusing exclusively on communications networks is a mistake and that the focus needs rather to be on warfare and operations. The communications networks are nearly a means to an end, with the end in mind being a more efficient and effective conduct of warfare.

2.3.2 Joint and USAF Guidance on NCW

The two core documents for future Joint Force operations are Joint Vision 2010 and Joint Vision 2020. Joint Vision 2010, since it was drafted in 1997 makes no mention of NCW specifically. However, this document does comment on the importance of Information Superiority, as shown by this excerpt:

> Information superiority will require both offensive and defensive information warfare (IW). Offensive information warfare will degrade or exploit an adversary's collection or use of information. It will include both traditional methods, such as a precision attack to destroy an adversary's command and control capability, as well as nontraditional methods such as electronic intrusion into an information and control network to convince, confuse, or deceive enemy military decision makers. (DoD, 1996: 16)

The last phrase about "nontraditional methods such as electronic intrusion into an information and control network" signals the early development of an idea that was to become NCW two years after the publication of Joint Vision 2010, when Alberts published his work in 1999.

Joint Vision 2020, published in 2000, makes more certain reference to the idea of network centricity. In a section on Information Superiority, Vision 2020 states:

> The evolution of information technology will increasingly permit us to integrate the traditional forms of information operations with sophisticated all-source intelligence, surveillance, and reconnaissance in a fully synchronized information campaign. The development of a concept labeled the global information grid will provide the network-centric environment required to achieve this goal. (DoD, 2000: 9)

The mention here of the Global Information Grid (GIG) points to the development of a key component of NCW. The GIG continues to be built and developed. In early 2004, Mr. Stenbit, the Assistant Secretary of Defense for Networks and Information Integration, reported that by the end of next year, DOD plans to build a base network connecting 100 locations throughout the world, involving mostly major headquarters, intelligence centers and some support organizations (Stone, 2005). Such a large-scale communications grid should serve as a sufficient hardware foundation, a vast tool upon which NCW can be fully developed, expanded, and exploited.

In defining the concept of NCW as it applies specifically to the operations of The United States Air Force, Air Force Basic Doctrine of 17 November 2003 provides key insight into what this definition might look like. While the exact term "network centric warfare" is not present in this document, there is reference to network warfare and network warfare operations, both of which fall under the main category of information operations. The following definition would seem to be the closest match to a current definition of NCW in the context of the USAF:

> Network warfare operations are the integrated planning and employment of military capabilities to achieve desired effects across the digital battlespace. Network warfare operations are conducted in the information domain, which is composed of hardware, software, data, and human components. Within this domain are the networks on which our information and information systems operate. Networks in this context are defined as any collection of systems transmitting information. This includes but is not limited to radio nets; satellite links; tactical digital information links (TADIL); telemetry; digital track files and supervisory control and data acquisition (SCADA) systems; telecommunications; and wireless communications networks and systems. The operational elements of network warfare operations are network attack, network defense, and network support. (DAF, 2003: 47)

This definition provides a solid baseline for "network warfare". However, the constantly evolving concept of NCW has come to entail much more than this USAF doctrine definition captures.

A current working definition for NCW being used by the (XPS) of Air Combat Command (ACC) at Langley AFB is as follows: "Network-centric warfare is the concept of linked sensors, communications systems, and weapons systems in an interconnected grid that allows for a seamless information flow to warfighters, policy makers, and support personnel (ACC/XPS, 2004:10). This definition captures key words that are essential to defining NCW: **linked sensors, communications systems, interconnected grids, weapons systems, seamless information,** and last but not least, **warfighters, policy makers, and support personnel -** the humans in the loop. These are the kinds of terms that characterize the essence of NCW.

2.3.3 Definition of NCW for this Effort

This research effort is primarily focused on representing an NCW scenario within a combat model, specifically within the System Effectiveness Analysis Simulation (SEAS). With this specific application and exercise of measuring NCW in mind, a somewhat customized definition of NCW must necessarily be formulated to conceptually match this application and provide a sufficient doctrinal baseline to guide this research. The following definition of NCW has been formulated for this effort:

Network Centric Warfare is the conduct of military operations through the utilization of networked information systems, which supply the warfighter with the right information at the right time in the right form to the right person being put to the right use, in order to achieve desired effects across the physical, information, and cognitive domains of warfare.

2.4 Modeling NCW

2.4.1 Introduction

As challenging as it is to formulate a current and accurate definition of NCW, it is perhaps even more challenging to take this definition and then represent NCW within the context of a combat model. There are several tools and approaches, however, which should prove very useful in modeling NCW.

Agent-Based Modeling (ABM) provides an effective representation of what Kewley and Larimer call the critical gap in military modeling capabilities, the ability to model how a combat soldier makes a tactical decision (Kewley and Larimer, 2003:10). The ability to represent agent decision making relates well to modeling NCW because the utility and overall effectiveness of a network cannot be properly evaluated without an accurate representation of the entities using the network and interacting within the network. Kewley and Larimer state that the increased capability of network-centric forces, if it really exists, is an emergent property that cannot be proven with attrition-based equations of combat. Figure 3 depicts the progression of stages that occur in the combat decision making process. ABM has the capability to effectively capture the cognition and judgment stages that occur in between the data/information levels and the final decision to act. ABM does this through a set of pre-assigned rules given to agents within the model, which allow the agents to respond accordingly to inputs and conditions.

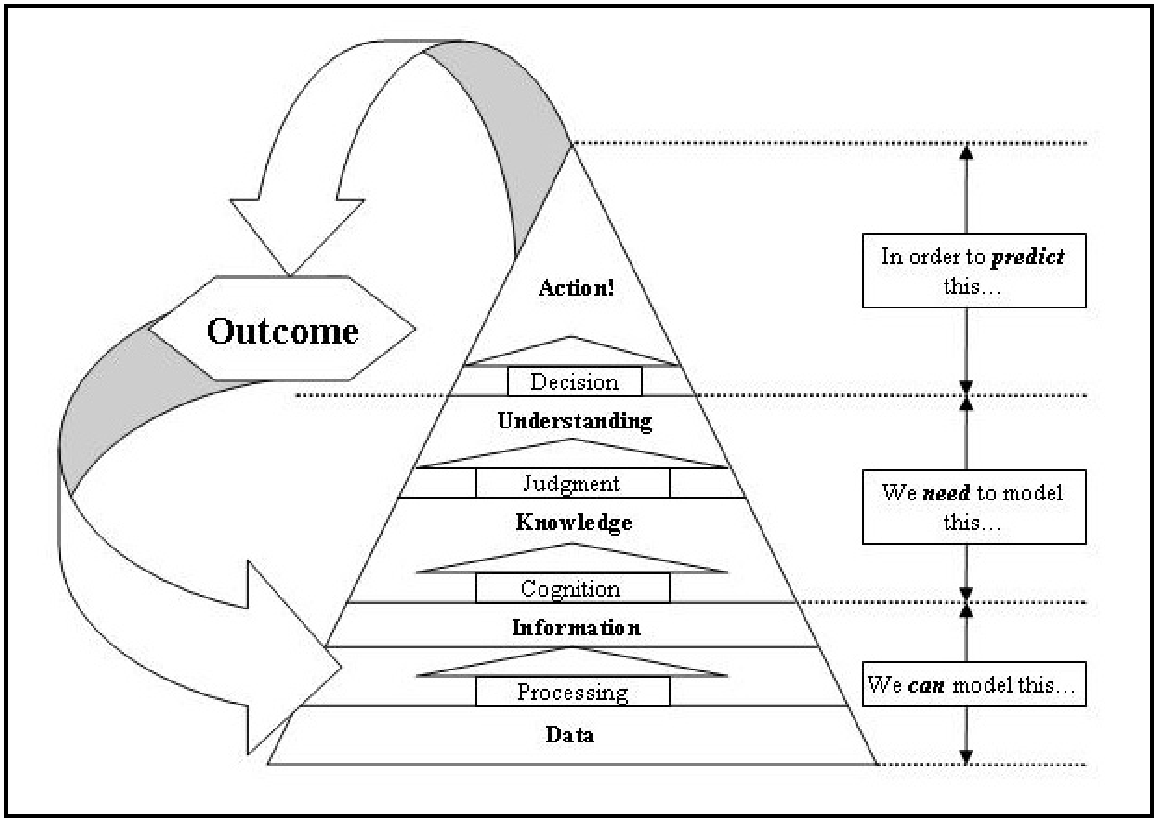

Figure 3. Combat Decision Making Pyramid (Kewley and Larimer, 2003:10)

SEAS is a particular type of agent-based model that is well suited for use as a tool in modeling NCW. SEAS is a model in the Air Force Standard Analysis Toolkit and is widely used for space mission utility studies (Walsh, Roberts, and Thompson, 2005:5-6). SEAS utilizes the fundamental principles of agent attributes and orders to model mission level combat scenarios and will serve as the primary modeling tool for this thesis research. More specific details about ABM and SEAS are presented in the following two sections.

2.4.2 Agent-Based Modeling (ABM)

Agent-based logic and programming is a relatively new approach to modeling in the military M&S community, tracing its roots to an initiative started within the U.S.

Marine Corps. In October 1995, at the direction of the Commanding General of the United States Marine Corps Combat Development Command in Quantico, two scientists embarked on what is now called *Project Albert* (Brandstein, Home, and Friman, 2000:64). Project Albert used a combination of new models and tools, multidisciplinary teams, and the scientific method to understand how agent-based modeling techniques could be correctly applied to represent a broad spectrum of military operations. In summary, Project Albert was designed to develop new tools to capture emergent behavior in synthetic environments that over time will lead to more effective maneuver warriors (Brandstein, Home, and Friman, 2000:65).

In addition to Project Albert, another significant element of the development of ABM was Irreducible Semi-Autonomous Adaptive Combat (ISAAC). Dr. Andy Ilachinski developed the complex adaptive model to simulate the interactions between small groups of marines (Tighe, 1999:33). Ilachinski determined that classical Lanchester-based models were not well suited for modeling the way in which the Marines conducted their operations. The small, independent, and well-trained marine units did not behave according to the mass attrition rates and large force-on-force representations of warfare which Lanchester equations were originally formulated to model.

Riding the momentum of Project Albert and ISAAC, ABM has since emerged as a modeling technique that is more realistic for today's combat scenarios than are the classical Lanchester-based models. Lanchester equations are deterministic differential equations. The unalterable outcome of combat adjudication is based on the starting troop strengths and their attrition rates (Tighe, 1999:28). These equations provide a very simplistic and intuitive framework for modeling warfare. However, Lanchester equations are very limited when it comes to representing the complex interactions of real-world combat because of their high degree of aggregation and constant attrition rate factors. Perhaps the greatest strength of ABM is its ability to effectively represent the random and unpredictable behavior of entities within a system, as well as the consequent outcomes resulting from interactions of such entities. The effects of random individual agent behavior and of the resulting interactions of agents are phenomenon that traditional Lanchester equation-based models simply cannot capture.

The basic idea of agent-based modeling is that autonomous agents are given a set of rules, which determine how they will respond to a set list of inputs or conditions within the model. An agent-based model is one in which the connections and interactions among the agents has significant effects, as compared to the individual actions of any particular agent (Kewley and Larimer, 2003:11). A basic summary definition of ABM from the SEAS website is as follows:

> In agent-based modeling, complex, real-world systems are modeled as collection of autonomous decision making entities, called agents. Each agent individually assesses its situation and makes decisions based upon its own set of rules. Agents may execute various behaviors appropriate for the system they represent - for example, sensing, maneuvering, or engaging. (SPARTA, Inc., 2005)

ABM results in a realistic simulation of a system because it emulates the manner in which the world really operates (Cares, 2002:935). Red and Blue forces make up a dynamic, non-linear, complex adaptive system in which the overall system behavior emerges from the aggregate interactions among individual agents (Cares, 2002:936).

2.4.3 SEAS

SEAS is a constructive, agent-interaction based simulation designed specifically for exploratory analysis of transformational, information-driven warfare across surface, air and space domains (SPARTA, Inc., 2005). It is an agent based combat model developed and maintained by SPARTA, Inc. for the Space and Missile Systems Center Directorate of Transformation and Development (SMC/TD). SEAS is one of the models in the Air Force Standard Analysis Toolkit. SEAS is quickly becoming a popularly utilized software tool in the defense M&S community, especially within the USAF.

SEAS has the ability to model the presence and interaction of a large variety of unique agents within a combat mission scenario. Some examples of the agents that can be represented in SEAS are tanks, SAM sites, UAVs, fighter jets, and satellites. A typical mission scenario which SEAS has the capability of representing is shown in Figure 4.

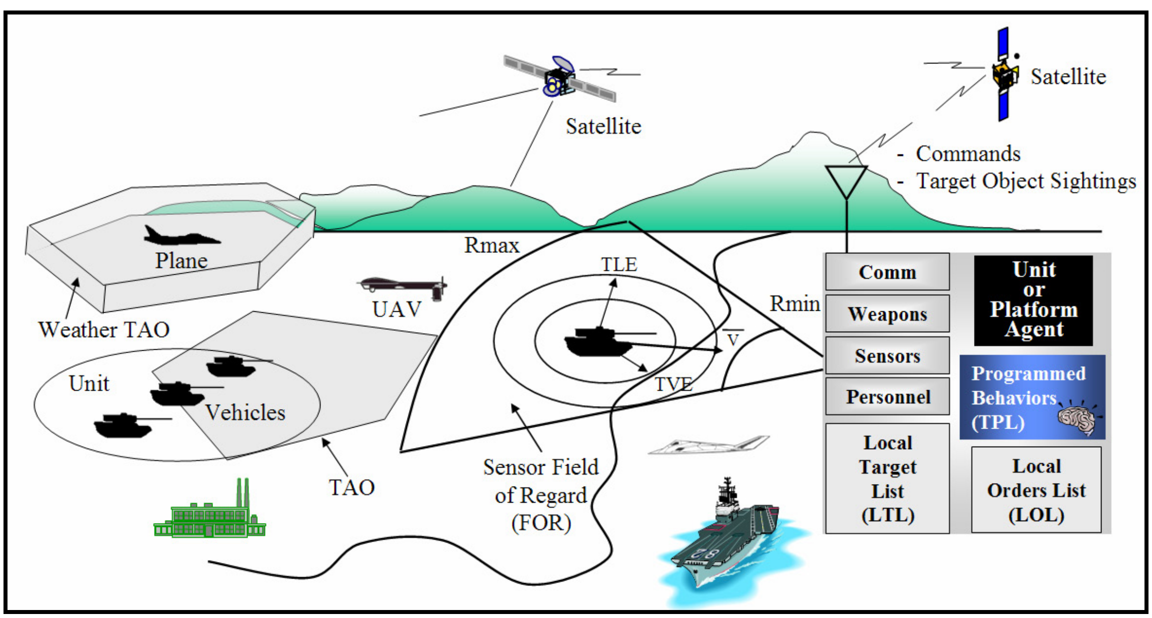

Figure 4. SEAS mission scenario representation (SPARTA, Inc., 2005:slide 2)

As illustrated in the above graphic, SEAS can not only represent various combat agents, but also their respective sensors and communication devices. SEAS is built around three simple entities: agents, devices and environments. Essentially, agents interact through the use of devices (weapons, sensors, communication) with each other and the environment. Conflict outcomes emerge from these resulting interactions. Agents are logical members acting within the combat mission scenario. They can be units, such as a brigade or multi-ship formation of planes, or subunit members such as a vehicle, individual plane, or satellite. Devices are entities such as communications devices, sensors, and weapons. The environment is the battlespace, which consists of events, locations, terrain, weather, jamming, and day/night characteristics.

A SEAS agent has the capability to move around, sense things, talk to other agents, utilize and acquire resources, and kill other agents in an environment. Agents can be assigned orders from superiors and can also be given “local programming” that will override the original orders in a given situation, if certain requirements and conditions are met. Agents can also play various roles such as an observer, killer, or even leader/controller of other agents. Each agent with sensing capability keeps a list of targets to be prepared to carry out an order either to 1) do nothing, 2) move toward them, 3) move away from them, 4) tell others about them, or 5) kill them or perform some combination of the above (SPARTA, Inc., 2005:slide 5). Agents and their respective interactions follow four key concepts: the local target list (LTL), local orders list (LOL), target interactions range (TIR), and broadcast interval (BI). All four of these key concepts interact with each specific type of agent and the scenario environment to produce conflict outcomes within SEAS.

2.5 Measures of NCW

There are several difficulties faced when trying to form a clear definition of NCW and formulate an appropriate model to represent it. The task of determining appropriate and measurable metrics for NCW also poses a difficult and unique challenge. There are a wealth of measures that have been formulated to date and recorded in various documents and references. For example, Fewell and Hazen provide a comprehensive list in the form of several tables which describe a large number of possible NCW metrics. Alberts laid a basic guideline for metrics, as shown by Figure 5.

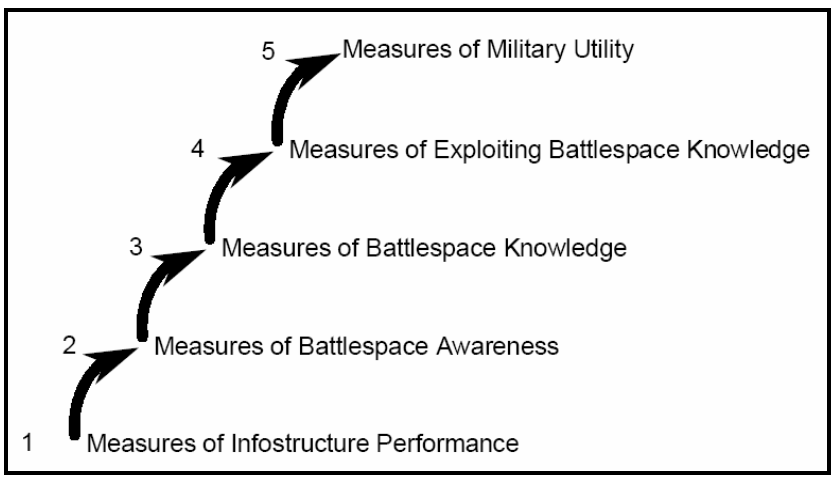

Figure 5. Alberts Baseline Metrics (Alberts, Gartska, and Stein, 1999:219)

Infostructure Performance, Battlespace Awareness, Battlespace Knowledge, Exploiting Battlespace Knowledge, and Military Utility are general categories under which more exactly defined metrics for NCW fall. Fewell and Hazen describe metrics for the characteristic 'speed of command', force agility and the ability to amass effects, the ‘degree of autonomy’ aspect of self-synchronization, the level of shared situational awareness, the conduct of effects-based operations, reachback operations, information superiority, the degree of interoperability, and mutual trust. All total, thirty-three different metrics falling under these main headings are described in their document. However, as Fewell and Hazen point out, none of these metrics serve as an indicator of the level of network centricity even though they do describe characteristics of net-centric systems (Fewell and Hazen, 2003:37). Further, they propose that the key characteristic of network centricity is the broadening of warfighter focus away from the individual, unit or platform concerns to give primacy to the mission and responsibilities of the team, task group or coalition. Quantifying this ‘broadening of focus’ is a difficult problem, especially when one tries to do so in a sense that is independent of a specific scenario.

Ling, Moon, and Kruzins (2005) propose more quantifiable metrics for measuring network centric warfare in the form of connectivity, reach, richness, and characteristic tempos. Figure 6 shows interactions between the OODA loop and these various metrics.

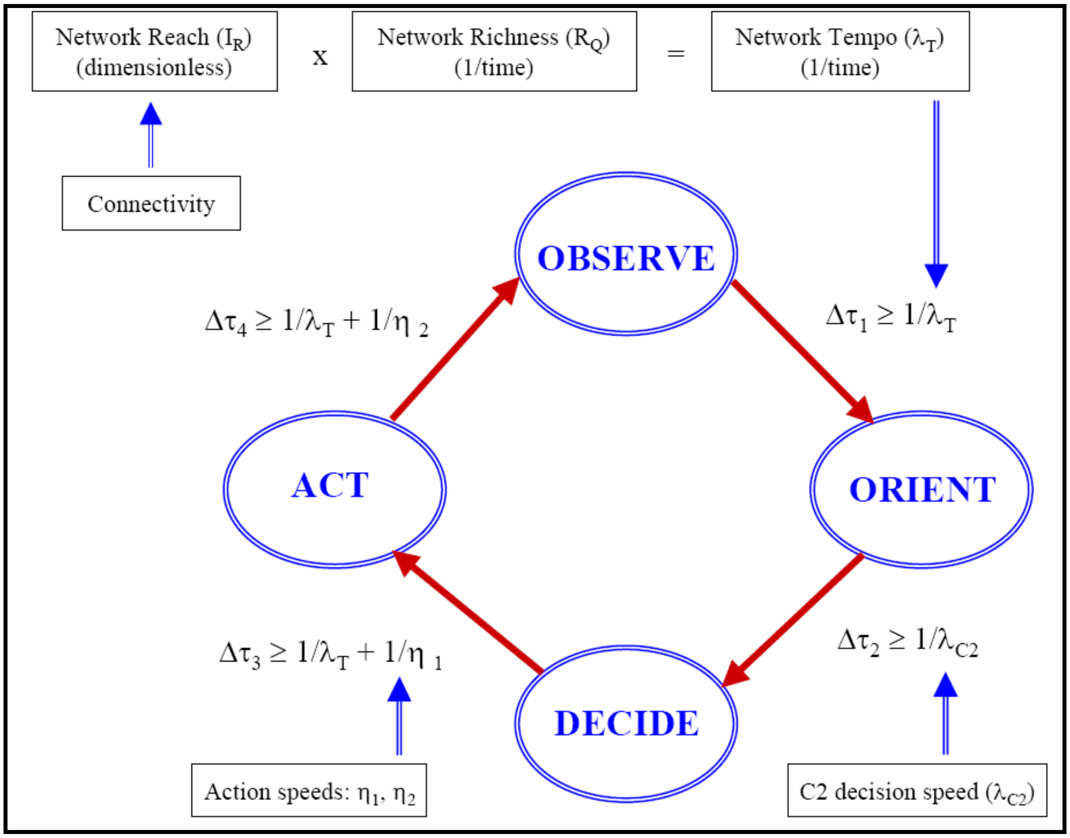

Figure 6. OODA Cycle with Proposed Metrics (Ling, Moon, and Kruzins, 2005:10)

Perhaps the simplest and most straight-forward place to start in quantifying and measuring a force's degree of NCW capability is to focus on network transmission delay time and the corresponding time required to make a decision to act. This second metric, decision time, may be more difficult to track and measure than network delay time. SPARTA proposes the use of NETE and SEAS as a way to measure network delay time, stating that one way to use these tools together is to use measures of performance (MOPs) from NETE to represent network delay times in the SEAS model where the overall campaign is simulated (Walsh, Roberts, and Thompson, 2005:6).

2.6 Summary

The push for military transformation received significant motivational energy when terrorists invaded our homeland with a domestic aerial invasion on September 11th, 2001. The stark realization that our nation was not supremely safe and secure elevated the cause of military transformation and modernization from an identified need to an urgent and absolute necessity. The concept of EBO has been employed, with NCW being recruited as a key enabler of EBO, to meet this new demand for maximized situational awareness and decision-making supremacy. Having established NCW as a critical area of military exploration and application, the natural follow-on activity of clearly defining NCW has presented a unique and continually morphing challenge. Several key documents and resources, including David S. Albert's foundational work on NCW and the Joint Vision documents, were utilized in the formulation of a fundamental definition of NCW for this research effort. Following this conceptual framework for NCW, options for modeling NCW were discussed. In particular, agent-based modeling was described and proposed as a legitimate way to represent the interactions and concepts of NCW. A specific application of ABM, the simulation software SEAS, was selected as the chosen tool for constructing a scenario for use in analyzing the military worth of NCW. Finally, several options for measures of effectiveness were described and a few key measures were chosen for the purposes of representation and analysis in SEAS.

III. Methodology

3.1 Overview

A SEAS scenario possessing a relatively high degree of complexity is required to adequately characterize the key elements of conducting NCW, namely the operation and coordination of sensors, communication devices, weapons systems and decision-making entities. An appropriate scenario which meets these criteria had already been created prior to this thesis effort and was utilized by DeStefano and Zinn for their collaborative thesis efforts in 2004. The scenario was written in SEAS to represent a mission scenario typical of the Kosovo conflict during 1999.

The following sections provide a description of the Kosovo scenario background, warfile, verification and validation (V&V), and NCW features. Then, the selected measures that will be extracted from the Kosovo scenario and analyzed for their military worth within the context of NCW are described. Next, the analysis approach describing the specific procedure and statistical tools are covered. Finally, this Methodology chapter concludes with a brief summary of all the topics covered and important points to keep in mind before proceeding to the next chapter, Analysis.

3.2 SEAS Kosovo Scenario

3.2.1 Background

The Space and Missile Center Transformation Directorate (SMC/TD) has created a warfile in SEAS to represent a typical mission in the Kosovo war (DeStefano, 2004:3-3). The SEAS warfile was created for the Air Force by the MITRE Corporation in

Hampton, VA (DeStefano, 2004:3-1). The scenario consists of a Blue United States Air Forces in Europe (USAFE) force, a Red Serbian force, and a Brown Kosovar force of militia and civilians, all programmed to operate and interact within the context of typical operations in the Kosovo conflict during 1999. It essentially models Red forces conducting "ethnic cleansing" operations against the Brown civilians (Zinn, 2004:48). Blue force's objective is to stop the Red force from killing the Brown force. Blue achieves this objective by attacking the Red force and by attempting to contain their military operations and movements.

DeStefano utilized the Kosovo scenario as an architectural data product to represent the Time Critical Targeting (TCT) activities of the Air Operations Center (AOC) (DeStefano, 2004:iv). DeStefano made needed additions and adjustments to the original Kosovo scenario delivered by SMC/TD to fit his research and analysis needs as he sought to demonstrate the significance of Time Critical Targeting (TCT) activities of the AOC. The version used by DeStefano and Zinn for their thesis efforts is the same version of the Kosovo scenario that will be utilized in modeling NCW for this research effort.

3.2.2 Kosovo Scenario Warfile

The programming code used within the SEAS interface is called Tactical Programming Language (TPL). Multiple lines of TPL compose a file designated as the "warfile", which contains all the necessary information concerning locations, agents, their sensors, weapons, and communication capabilities, as well as the orders followed by each agent. Figure 7 shows an example of SEAS TPL from the Kosovo warfile which gives agent attributes and order for the Blue *SOF_ReconSqdEast* unit.

```
      Unit  "SOF_ReconSqdEast"
          ICON                  "icons\beyesico"
          Speed                 4
          Interval              2
          Bodies                9          !! Each unit is a nine person team
          Mass                  1000
          Altitude              0
          Dig_Start             1
          Dig_Done              5
          Dig_Pd                0.01
          Dig_Pk                0.5
          Deploy_Delay          0
          Promote_Limit         4
          Fusion_Type           0
          Broadcast_Interval    1
          Max_Target_Range      100
          Comm                  "Sat_TacR"          !! These are all comm devices used by unit
          Comm                  "ElintSAT_TacR"
          Comm                  "SOF_Ord"
          Comm                  "SOF_Sat_Ph_R"
          Comm                  "JSTARS_TacR"
          Comm                  "Gunship_TacR"
          Sensor                "Distress_Detector"
          Vehicle               "SOF_ReconSqd_Mem"   9
          Orders
             Declare Global ReconLocs[5], SOFSqloc[5], Gshiponmission[5],
             Declare Global SOF_SAM_tgts[6], SOF_Armor_tgts[2], SOF_Kos_allies[2]
             Declare Local ms = 0, ls, mt = 0, lt, km = 0, kos
             Declare Local lastExcursion, scoutPoint
             Declare Local i = 0, MySpeed, InitTotalMass, UnitFireThreshold=10
             SOF_SAM_tgts[0] = "RedSA3RadarVan"          !!  These arrays set target priorities
             SOF_SAM_tgts[1] = "RedSA61RadarVan"
             SOF_SAM_tgts[2] = "RedSA62RadarVan"
             SOF_SAM_tgts[3] = "SA3Tel"
             SOF_SAM_tgts[4] = "SA61Tel"
             SOF_SAM_tgts[5] = "SA62Tel"
             SOF_Armor_tgts[0] = "T80"
             SOF_Armor_tgts[1] = "SUV"
             SOF_Kos_allies[0] = "KosVillage1_unit"
             SOF_Kos_allies[1] = "KosVillage2_unit"
```

Figure 7. Example of TPL Code from the Kosovo Warfile

Each line of code is numbered on the far left margin. All of the unit attributes for *SOF_ReconSqdEast* are listed in this block of TPL. Below the attributes is a list of the various communication devices utilized by the SOF agents. Also shown in Figure 7 are orders which each agent will follow as they interact in the scenario. In this case, the SOF agents are assigned a priority list for target sighting reporting purposes. Comments in TPL are preceded by two exclamation marks and given a light blue color in the warfile.

A typical SEAS warfile is structured in sequential blocks that designate the timing, location, and force composition of the scenario. The Kosovo scenario warfile follows this same general format. The first lines of TPL state that the scenario takes place well in the future, on August 2nd, 2016. The scenario date is, for all practical purposes, arbitrary. It simply provides a timeline reference from which to track the flow of combat activities. This TPL for event timing in the Kosovo warfile allows for a possible 20-day scenario that will end on August 22nd, 2016. However, as noted by DeStefano and confirmed by runs for this thesis effort, no significant activity occurred after 6000 minutes (100 hours or 4.17 days) of simulation time, and no event based criteria to stop the simulation was uncovered (e.g. all Serbian forces are killed or withdrew) (DeStefano, 2004:4-2).

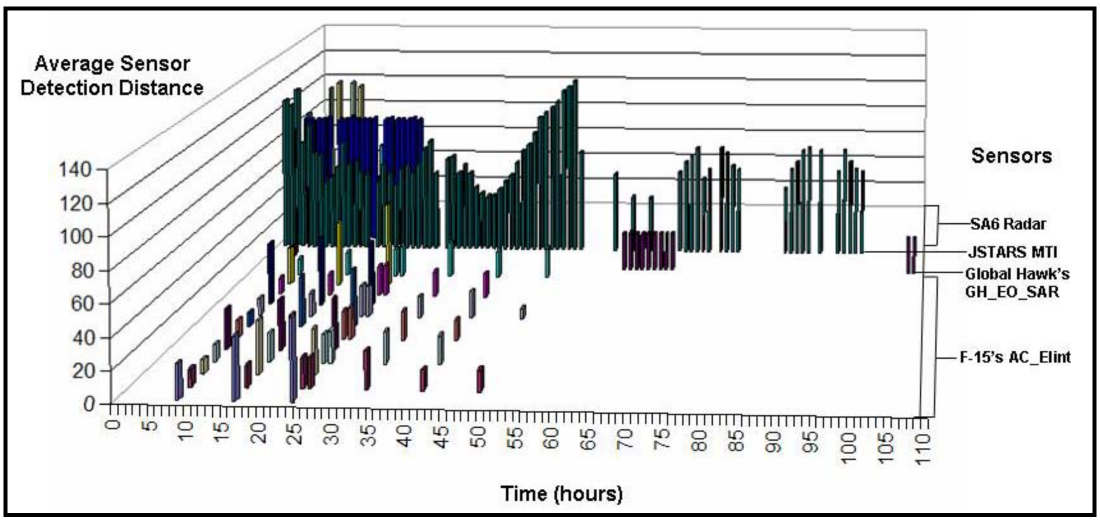

Figure 8. Sensor Detection Activity for Key Kosovo Scenario Agents

Figure 8 confirms the drop-off in activity as measured by activity of sensors for several key agents after 100 hours. Although the Global Hawk exhibits a few detections for hours 108 and 109, all activity has essentially ceased for all other major players after

100 hours and therefore this run time will also be used as the run time for multiple simulation replications.

Location information follows the event timing block of the warfile. A graphical depiction showing several of the key locations for the scenario is illustrated in Figure 9. These location lines of code specify key locations for the Kosovo scenario, all of which are assigned a name (e.g. the point for Aviano AFB in the figure's upper left-hand corner) and are coded in the warfile according to their coordinates of latitude and longitude.

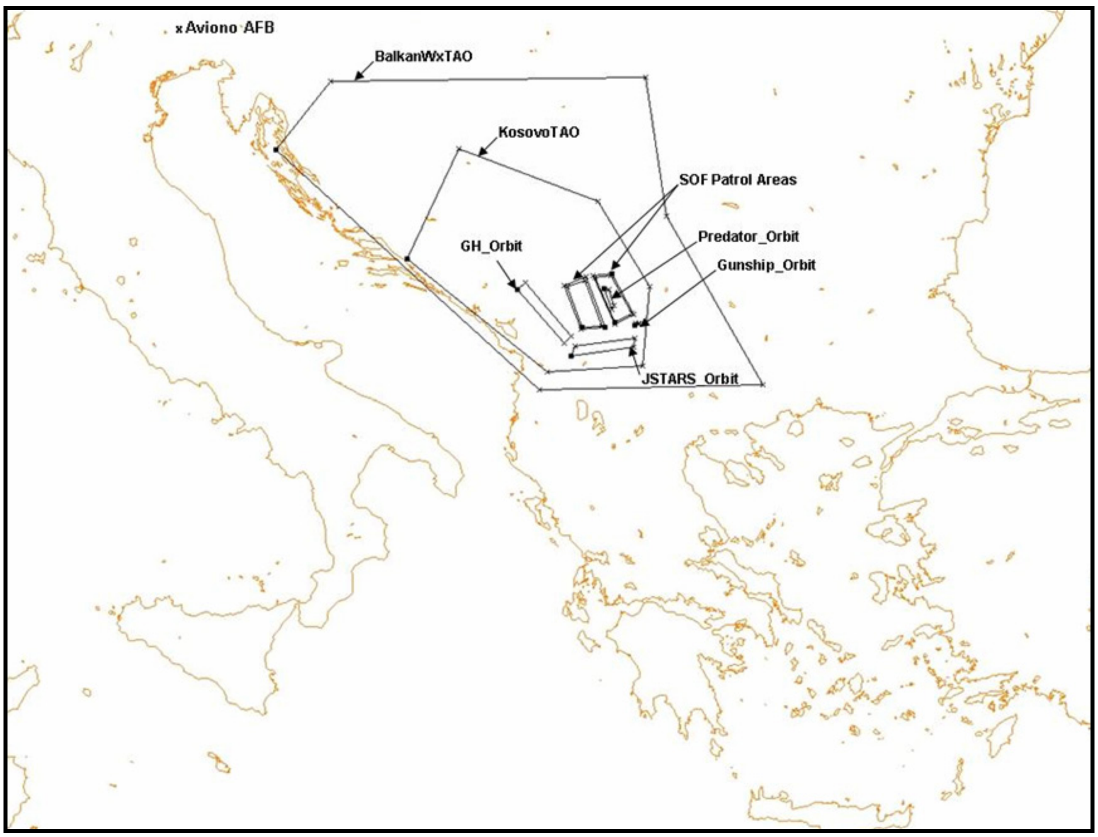

Figure 9. Kosovo Scenario Locations

This figure shows several Tactical Area of Operations (TAO) areas, all of which are shown as irregular shapes bounded with black lines. The largest TAO, *BalkanWxTAO*, represents a region of weather whose attributes, primarily altitude range and intensity factor, degrade communication signals' transmission/reception and sensor performance occurring in the areas bounded by the TAO. Another significant TAO, *KosovoTAO*, lies within the *BalkanWxTAO*. Also shown in this figure are the *GH_Orbit*, *Predator_Orbit*, *Gunship_Orbit*, *JSTARS_Orbit*, and *SOF Patrol* TAOs which specify aircraft orbits and troop patrol areas, respectively.

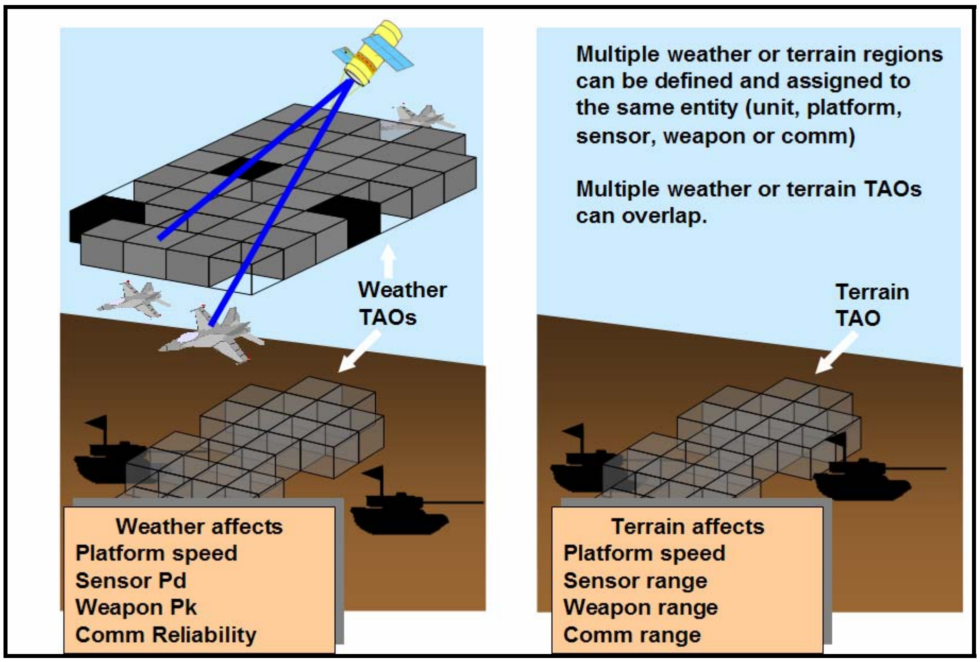

Figure 10. Weather and Terrain Effects in SEAS (SEAS Training CD Slides, 2005: slide 274)

Figure 10 illustrates the specific attributes within SEAS that are affected by weather and terrain TAO areas. Weather is listed as affecting platform speed, sensor probability of detection, weapon probability of kill, and communications reliability. Terrain is listed as affecting platform speed, sensor range, weapon range, and communications range. It is important to keep in mind that the degradation effects implemented in the Kosovo scenario are being utilized as generic ways to degrade network performance on a large-scale (*BalkanWxTAO*) and more local scale (*KosovoTAO*), both of which affect unique aspects of performance. The *KosovoTAO* draws the boundary for a terrain region whose degradation factor degrades the ability of the Blue Force's UAV to see targets and therefore makes the simulation of the UAV patrolling the area more realistic. In other words, agents will occasionally be hidden from the UAV's view because the terrain factor (which ranges from 0 to 1 in SEAS and is set at 0.8 for the *KosovoTAO*) is applied to all sensing operations within that TAO and will only allow a percentage of line of sight detections to occur. For instance, within the *KosovoTAO*, only eighty percent of the target sightings in that region will be officially recorded as a clean detection.

```
!!********************** WEATHER DATABASES ****************************
   Weather  "WxFront"
      Region "BalkanWxTAO"
            Factor     0
            Color      200 200 200
            Visible    1
            Floor      10
            Ceiling    15
            Begin_Time 0
            End_Time   10000
            Start_Time 0
            Stop_Time  1440
      End
   End
!!
!!
!!
!!********************** TERRAIN DATABASES ****************************
   Terrain  "SatAltitude"
      Region "KosovoTAO"
            Factor         0.8
            Visible        1
            Begin_Time     0
            End_Time       10000
            Start_Time     0
            Stop_Time      1440
      End
   End
```

Figure 11. Kosovo Scenario Weather and Terrain Blocks TPL

Figure 11 shows the TPL for the Balkan weather block and Kosovo terrain block. The *KosovoTAO* terrain factor of 0.8 can be seen here, as well as the *BalkanWxTAO* attributes of altitude range (10 to 15 kilometers) and degradation factor of zero. The zero degradation factor for *BalkanWxTAO* means that no communication or image detection can be accomplished if it has to pass through this region. For instance, if one of the satellites in the scenario searches for targets in the *BalkanWxTAO*, it will not detect anything and also will not be able to broadcast any information into that region.

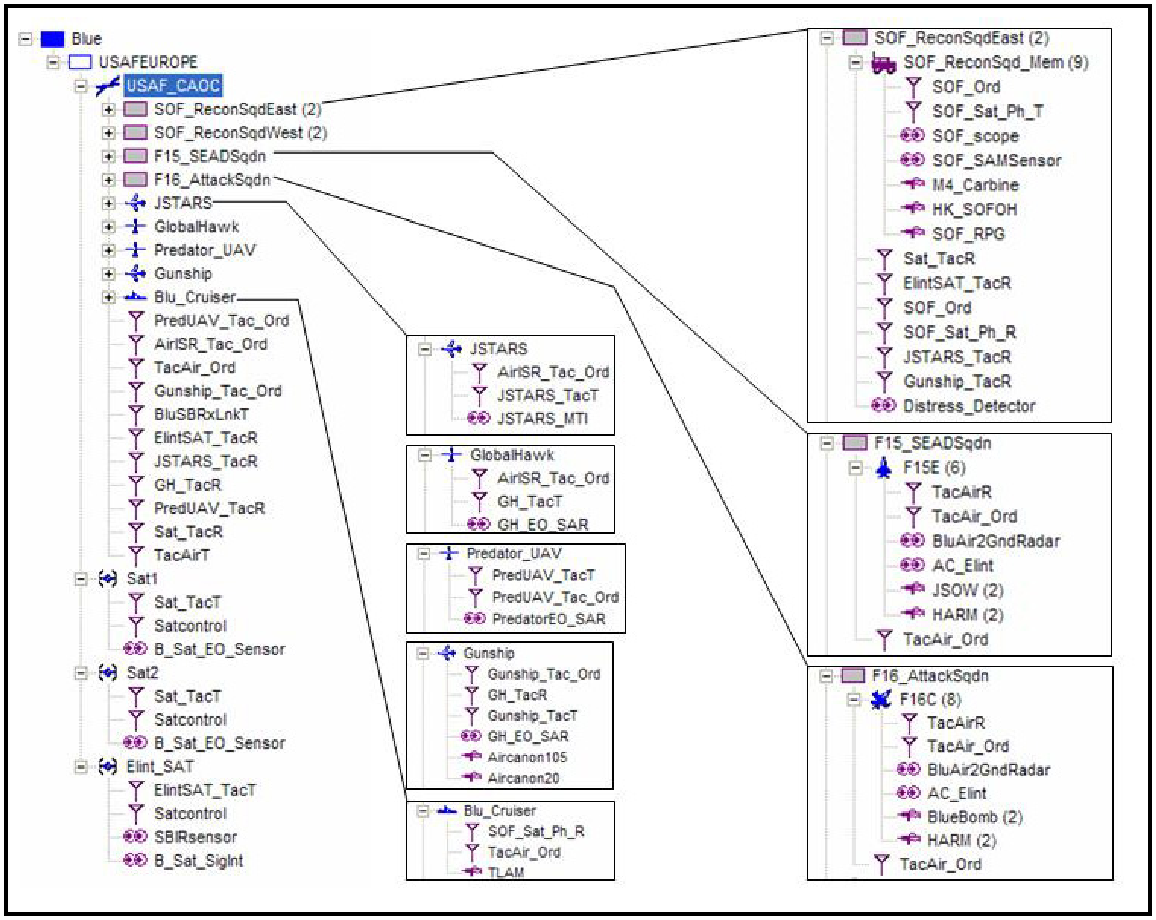

Figure 12. Blue Force Structure

Now that the timing, location, TAO, weather, and terrain blocks have been covered, the TPL sections for the forces, units, and vehicle hierarchy of the scenario must be described. As has been previously mentioned, there are three forces in the Kosovo scenario: a USAFE force, Serbian force, and Kosovar force. Figure 12 gives a graphical depiction and breakdown of the Blue USAFE force.

As can be seen from this figure, the Blue force has a considerable number of units and vehicles, especially in relation to the Red and Brown forces, which are depicted in Figures 13 and 14. All units for the Blue force fall under and are owned by the USAF Combined Aerospace Operations Center (CAOC), which is referred to as the "parent unit" for the Blue force. The significance of the parent unit is that a parent's orders take precedence over any orders that each individual "child unit" (units that are subordinate to the parent) may have within their own code block. The Blue Force Structure illustration depicts the typical force breakdown within SEAS, in which units are composed of vehicles (e.g. the *F15_SEADSqdn* is composed of multiple F-15s), each having the potential of owning sensors, communication devices, and weapons. For example, the Special Operations Forces (SOF) units of East and West (West unit breakdown is not shown in Figure 12 since its composition is identical to the East unit) both own the communication device *SOF_Ord*, the sensor *SOF_scope*, and the weapon *M4_Carbine*. The numbers in parenthesis following any name in the hierarchy indicates the quantity of a particular unit or vehicle within the Kosovo scenario. For instance, the Blue Force has two *SOF_ReconSqnEast* units, nine *SOF_ReconSqd_Mem* vehicles, and the F-15s each have two *JSOW* and two *HARM* weapons. While the Blue force is quite capable on the ground with the SOF units, the major emphasis of the force is on air assets and the application of air power.

The Red Serbian force, shown in Figure 13, is much simpler in comparison to the Blue force. The Serbian force is not centralized as is the blue force possessing the CAOC unit agent, which owns all other blue agents. The Red force consists solely of ground assets of the Serbian Army. Serbian unit agents include air defenses, ground targets, and three army divisions (DeStefano, 2004:3-5).

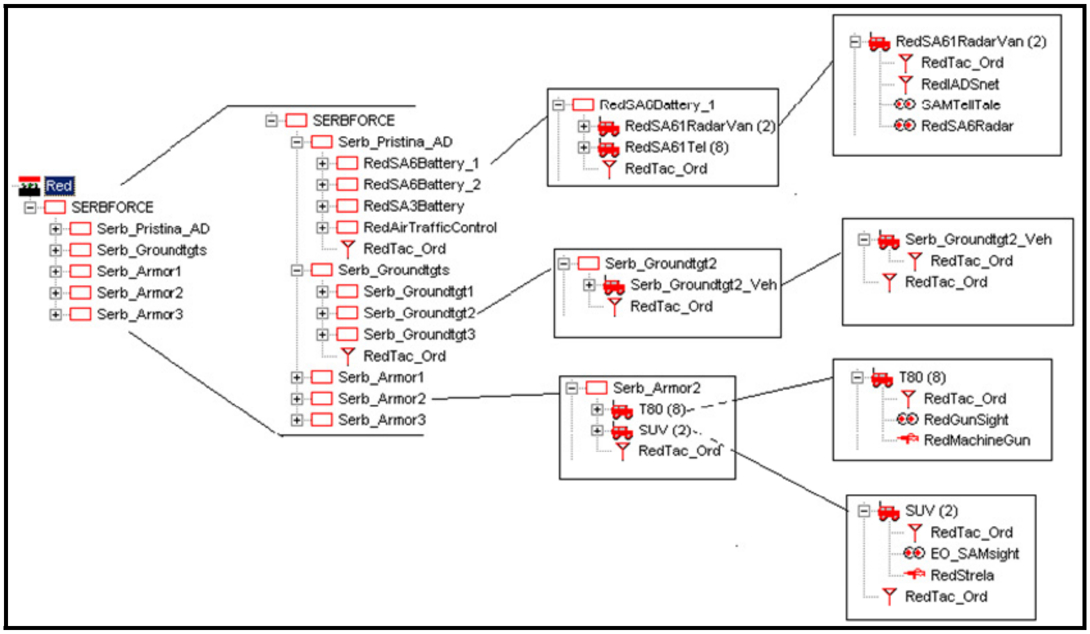

Figure 13. Serbian Force Structure (DeStefano, 2004:3-6)

The Serbian surface-to-air missile capabilities present the greatest threat to the Blue force in terms of attrition, based on initial experimental runs of the scenario. However, since the goal of the Blue force in the scenario is to minimize the impact of Serbian Army operations on the Kosovars, ultimately the three Serbian armor units are the most threatening members of the Red force in terms of Blue achieving its objective. Orders are passed from the five main Serbian unit agents to their subordinate agents, but there is not the degree of coordination of the Blue force since these five units essentially act autonomously. This is a fairly obvious, and yet true to life, weakness for the Serbian force. The Serbian force behaves according to a realistic concept of operations. For instance, the surface to air radar vans are given orders to hide when information is passed that an F-15 is near, or to hide and move after firing a missile (DeStefano, 2004:3-5).

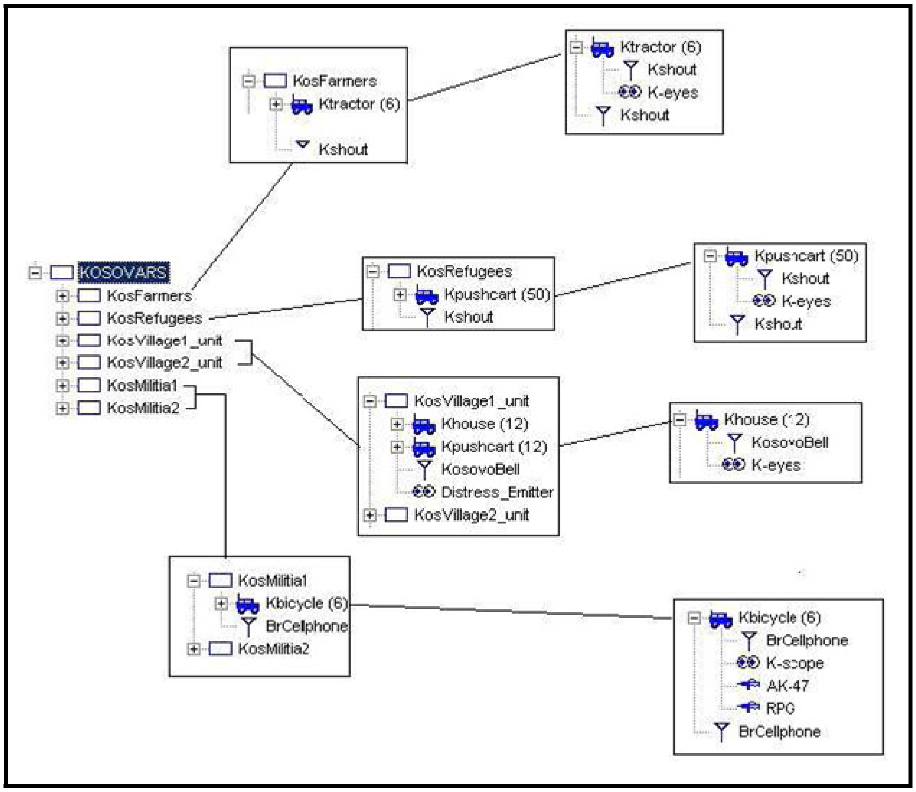

Figure 14. Kosovar Force Structure (DeStefano, 2004:3-7)

The Brown Kosovar force is similar to the Red Serbian force in the sense that there is no centralized command structure, as seen in Figure 14. The Kosovars force consists of farmers, refugees, villagers, or militia members. The militia members are the only armed agents of the Brown force and they are enemies with the Serbian force, but are neutral in relation to the Blue force. The Kosovar agents have extremely rudimentary sensing and transmitting capabilities such as unaided human eyes, cell phones, and even bells, all of which are coded in the warfile as devices whose attributes have been assigned to match the low strength and low range of these types of sensors and communication devices.

Instead of the Kosovars being placed in aggregated masses at certain locations they can be modeled as agents who can pass along information to the U.S. forces and hide from the enemy (DeStefano, 2004:3-5). In this sense, the Kosovars can be viewed as allies to the Blue force. However, since they are only able to offer limited combat support, they would more accurately be labeled as a neutral force in this scenario.

3.2.3 Warfile Verification and Validation

DeStefano describes various verification and validation (V&V) activities applied to the Kosovo scenario warfile in his thesis effort. He states that some of the standard methods employed in the V&V process for his effort were a structured walk-through of the code, consultation with experts, viewing the animation, and looking for reasonable output (DeStefano, 2004:3-24). Every time agent orders changed, DeStefano performed a structured walk-through of the warfile code and utilized the SEAS details and debug window to ensure that global and local variables were appropriately updated so that agent orders were correct and current. Further, DeStefano consulted with experts at SMC (a primary user of SEAS), Sparta Inc. (model managers), and RAND (analysts) throughout his use and modification of the warfile (DeStefano, 2004:3-24). SEAS animation proved to play a key role in DeStefano's V&V process. For instance, movement of the global hawk away from its TAO to investigate a potential target was confirmed by viewing SEAS animation of the Kosovo warfile.

A few additional investigations were performed during this thesis research to further verify and validate the Kosovo SEAS model. For instance, through initial exploratory checks of the Kosovo scenario TPL and SEAS animation, it was observed that one of the scenario's three satellites, *Elint_SAT*, held an extremely high altitude orbit. The orbit was so high relative to the other two satellites that it seemed at first to be a programming error. Figure 15 shows a screen capture of this satellite's location, as well as the location of the other two USAFE satellites.

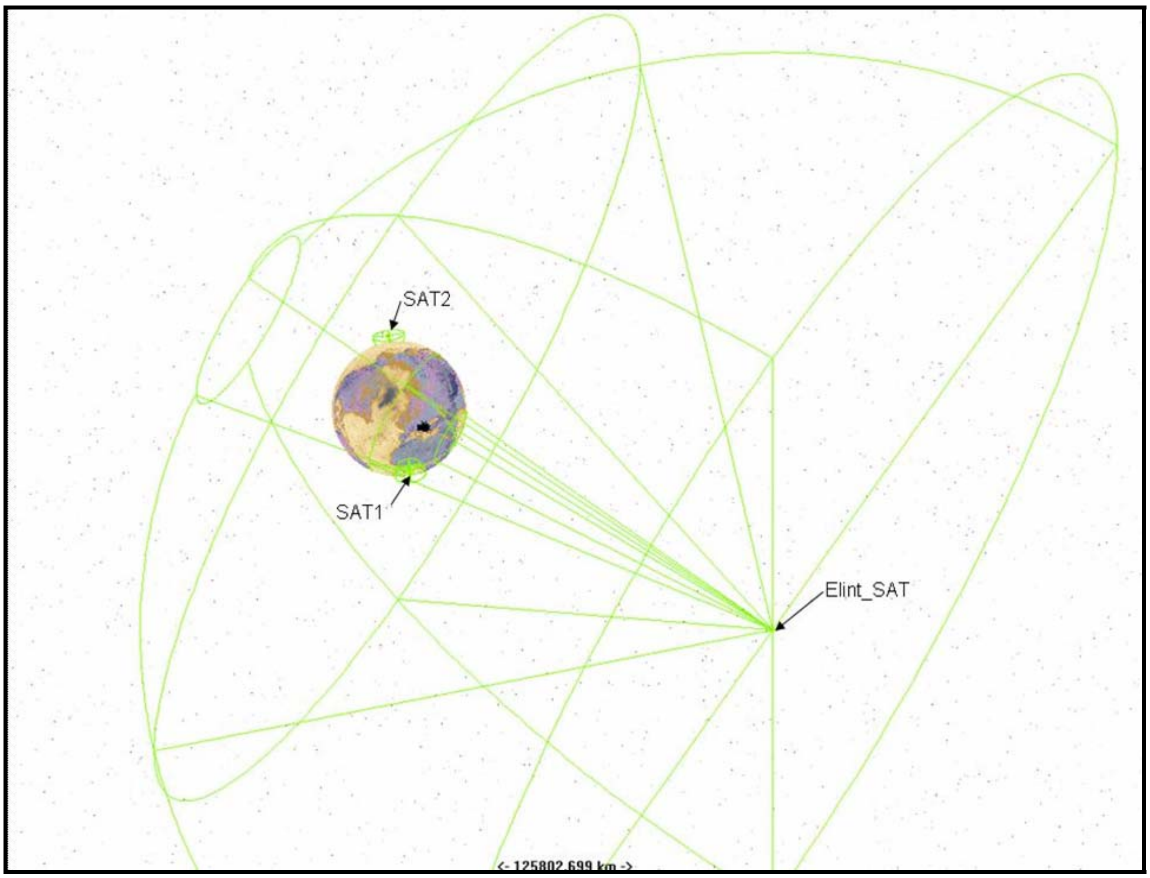

Figure 15. Kosovo Scenario Satellite Picture

The lines and circles emanating from each satellite show the sensor field of regard for each respective satellite relative to the earth. Upon further investigation of the warfile orbit information (which is contained in a *.sat file that is called out within the Kosovo scenario warfile), it was discovered that the *Elint_SAT* is a geosynchronous satellite. For a satellite's orbit period to be one sidereal day (the time it takes the Earth to rotate 360 degrees, which is equal to 23 hours, 56 minutes and 4 seconds), it must be approximately 35,786 kilometers (19,323 nautical miles or 22,241 statute miles) above the earth's surface (NASA Liftoff Home, 1995). Through utilization of the kilometer scale for screen width given by SEAS in its graphics display (shown to be 125,802.699 kilometers in Figure 15, which is not to scale for this illustration due to image cropping), it was concluded that *Elint_SAT* is indeed approximately 35,786 kilometers above the earth's surface. Therefore, the *Elint_SAT* altitude in the scenario matches the real-world altitude of a geosynchronous satellite. Also, *SAT1* and *SAT2* occupy orbits that allow them to sweep the Kosovo area once every 12 hours. This verification confirms that the satellite orbits are realistic and contributes to an increased confidence level that the Kosovo scenario as a whole is written and composed correctly. Similar checks for scenario accuracy were performed for various other platforms and agents throughout the Kosovo warfile in order to verify that that the scenario was properly coded.

Validation of results from SEAS was performed primarily as face validation throughout the analysis process. This face validation consisted of common sense checks of the output values for detection distances, times of detections, communication channel activity, and kill numbers.

3.2.4 Kosovo Scenario NCW Features

There are several key elements of the Kosovo scenario that allow it to be used as a scenario which legitimately represents and applies the concepts of NCW. Drawing from the various NCW definitions covered in the Literature Review, the concept of linked sensors was highlighted in the definition of NCW used by Air Combat Command's Future Plans (ACC/XPS) division. A count of sensors in the Kosovo warfile shows that 20 total sensors are used in the scenario: 13 sensors belong to the Blue USAFE force, four sensors belong to the Red Serbian force, and three sensors belong to the Brown Kosovar force. Some of these sensors are shared, such as the *BluAir2GndRadar* and *AC_Elint* used by both the F-15s and F-16s. ACC/XPS also highlighted linked communications as another key component of NCW. The Kosovo scenario holds 23 total communication channels: 17 channels belong to the Blue USAFE force, three channels belong to the Red Serbian force, and three channels belong to the Brown Kosovar force. Many of these communication channels, especially on the Blue force side, are shared between several different units and vehicles. The linked sensors and communications aspects of NCW are definitely captured in the Kosovo scenario. This interconnected grid of sensing and communication devices allows for the operation of linked weapons systems and creates shared situational awareness in the scenario, especially among the Blue USAFE force units and vehicles.

3.3 Selected Measures

Based on the outputs available from SEAS and the analysis options provided by the SEAS Post Processor (an Excel-based analysis tool), the focus for selected measures in this research has been placed primarily on the physical and information domains of NCW. For the physical domain, the most appropriate measure seems to be sensor detection distance. The SEAS Post Processor provides extensive capability for the filtering, graphing, and raw data analysis of detection distances for each sensor active in the scenario. The average detection distances for key platforms will be analyzed for trends in performance over the four cases of the Kosovo scenario. Also, the average number of detections per replication will be looked at for these same key platforms.

For the information domain, the load on the communications network for various key channels in the Kosovo scenario will be measured. The SEAS Post Processor will also be employed for this analysis, as well as use of Excel to directly manipulate and filter the raw data of communication outputs from SEAS. SEAS keeps track of three communications metrics: the number of messages added, the number of messages currently on, and the number of messages removed for each communications channel over each one-minute time step of the simulation. The data that tracks this running tally of communications channel loading will be utilized to analyze performance of the Blue Force's communications channels in order to determine the effects of applying various degradation levels in the Kosovo region.

Even though no direct measure for the cognitive domain will be extracted from the Kosovo scenario for this effort, an indirect measure of the cognitive domain will be analyzed. The chosen measure to gauge the quality and success of decisions made by agents in the scenario is the killer and victim data tracked by SEAS as a standard output. The Killer Victim Scoreboard (KVS) is a useful tool within the SEAS Post Processor for filtering, analyzing, and presenting information pertaining to the number of kills throughout the scenario, as well as the identity of the killer and victim and the timing during which the kill occurs. KVS information will be compared for the four cases in order to determine the ultimate effect of degrading the performance of sensors and communications equipment. The analysis will focus on comparing the number of Red Force Serbian agents killed by Blue Force USAFE agents, the number of Blue killed by Red, and the number of Brown Force Kosovars killed.

3.4 Analysis Approach

Multiple replications of the Kosovo scenario will be run in a configuration that is free of weather and terrain effects. The measures described in Section 3.3 will be collected from these multiple runs of the scenario and analyzed to find the mean and standard deviation values and confidence intervals will be constructed for these outputs. Next, the scenario will be run multiple times in a configuration where weather and terrain TAO effects are applied separately to degrade the sensing and communication operations, respectively. The resulting average sensor distances for all sensors detecting enemies in the scenario will be analyzed for both cases. Then, multiple runs applying both weather and terrain effects will be performed. The resulting average detection distances from the full weather and terrain effects scenario will then be analyzed in the same manner as the cases applying weather effects only and terrain effects only. The resulting average detection distances for all sensing agents will be compared to base case outputs. Output analysis in the form of a two-sided t-test will be performed to determine whether the differences between the three configurations' outputs and the base case outputs are statistically significant. From this comparison and analysis, various insights and conclusions will be drawn concerning the results and performance of all three forces in the Kosovo scenario, all determined and presented in light of NCW principles.

3.5 Summary

This section has described the background, warfile, verification and validation, and NCW features of the Kosovo scenario SEAS warfile. The warfile was originally written by SMC/TD and used by DeStefano and Zinn for their theses. Essentially, the Kosovo scenario depicts an ethnic cleansing operation in which the role of the Blue USAFE force is to stop the Red Serbian force from killing the Brown Kosovar force. Warfile TPL code analysis, expert consultation, simulation animation checks, and scenario output analysis were used in the V&V process for the Kosovo warfile. These V&V activities were conducted both by DeStefano for his thesis effort and for this current effort to model NCW. Key features of NCW were cited as being present in the Kosovo scenario. These NCW features primarily relate to the high degree of linked sensors, communication, and weapons systems contained in the scenario. SEAS measures for the physical and information domain were chosen. For the physical domain, target detection distance is the selected measure to be extracted from multiple simulation runs. The average detection distances for all sensing vehicles and agents in the scenario will be analyzed using the SEAS Post Processor. For the information domain, communications channels loading and activity will be analyzed. Both the number of messages and timing of these messages throughout the scenario will be analyzed and comparisons made between the four scenario cases. These selected measures will be the focus for analysis of outputs taken from multiple simulation runs. The analysis will determine the average output values from the base case scenario, as well as for three cases in which weather only, terrain only, and a combination of weather and terrain effects will be added into the scenario. The next chapter, Analysis, presents the outputs and statistical analysis resulting from the accomplishment of multiple simulation replications.

IV. Analysis

4.1 Overview

This chapter provides statistical analysis and results as well as a description of the process involved in determining what Kosovo scenario platforms and outputs are worth focusing on for the sake of measuring NCW. The chapter begins by laying out preliminary analysis conducted to determine an appropriate number of simulation runs. Next, there is a section about detection distance analysis pertaining to the physical domain of NCW, followed by an investigation and analysis of communication channel loading for the information domain. The chapter then concludes with a section covering the analysis of kill numbers, which serve as a final measure of agent decision output for the cognitive domain, followed by a brief chapter summary.

4.2 Selecting the Number of Simulation Replications

A preliminary task of simulation analysis is to select the number of replications to run in SEAS in order to obtain output data sets which have desirable statistical properties. Tentatively, 100 runs were chosen as the target number of replications. However, due to the extensive time required to run the Kosovo scenario 100 times (one hour per 100 runs, times four for each case) and the considerable file size of output data from initial checks of running the scenario ten, twenty, and thirty times (sensor output data files for thirty runs were in the 350-450 MB range), it was discovered that working with 100 runs was not a practical approach. To strike a balance between obtaining a sufficient amount of data to ensure the ability to make legitimate statistical inferences, while at the same time keeping the time required to perform the simulation replications and output file sizes within reasonable limits, thirty simulation replications was chosen as the new target.

A check for normality was performed for outputs of average detection data for different sensors at the levels of ten, twenty, and thirty replications. Output data from the *JSTARS* was selected as the focus for this normality check because preliminary analysis of model outputs showed that the *JSTARS* agent provided the highest number of detection samples over each replication and therefore data from this platform seemed to provide a fair representation of the overall distribution of data for platforms in the scenario as a whole.

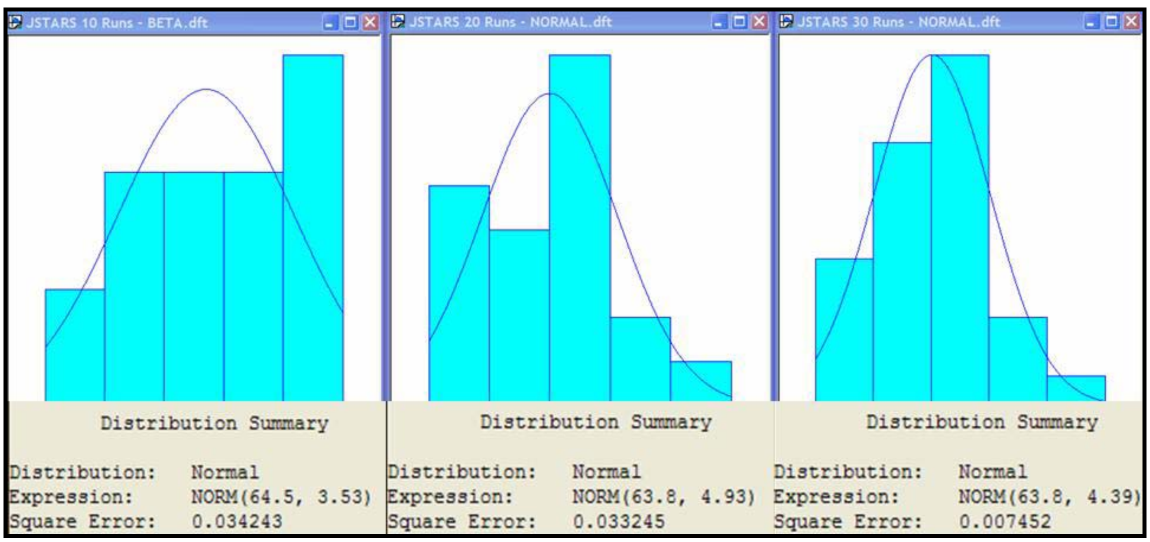

Figure 16. Check for Normality - Plots from Arena Input Analyzer

Figure 16 shows the increasing progression of data normality from analysis of the average detection distance output for the *JSTARS* resulting from ten, twenty, and thirty replications. The square error for a normal distribution fit decreases from 0.03 to 0.007 as the number of replications is increased from ten to thirty. These statistical distribution plots offer support for the assumption that thirty simulation runs is a sufficient number to obtain approximately normally distributed output data from multiple runs of the Kosovo scenario.

4.3 Physical Domain Analysis

4.3.1 Single Run Analysis - Targets and Sensors of Interest

Preliminary analysis of sensor detection distances for the physical domain of NCW began with determining which sensors were programmed in the Kosovo warfile as being affected by the degradation effects. The illustration in Figure 17 was used as a guide throughout the detection distance analysis. The figure helped to track which sensors were influenced by which TAO degradation effects. The figure illustrates that *Sat1*, *Sat2*, the *GlobalHawk*, and the *Predator_UAV* were all coded in the Kosovo warfile as being effected by both weather and terrain effects, while the *Elint_SAT* was affected only by the weather TAO and the *JSTARS* was affected only by the terrain TAO. As mentioned in Chapter 3, the weather and terrain effects influence specific performance attributes. Weather affects platform speed, sensor probability of detection, weapon probability of kill, and communications reliability. Terrain affects platform speed, sensor range, weapon range, and communications range. The degradation effects are implemented to degrade network performance in the two distinct TAO regions according to their respective influence on performance attributes.

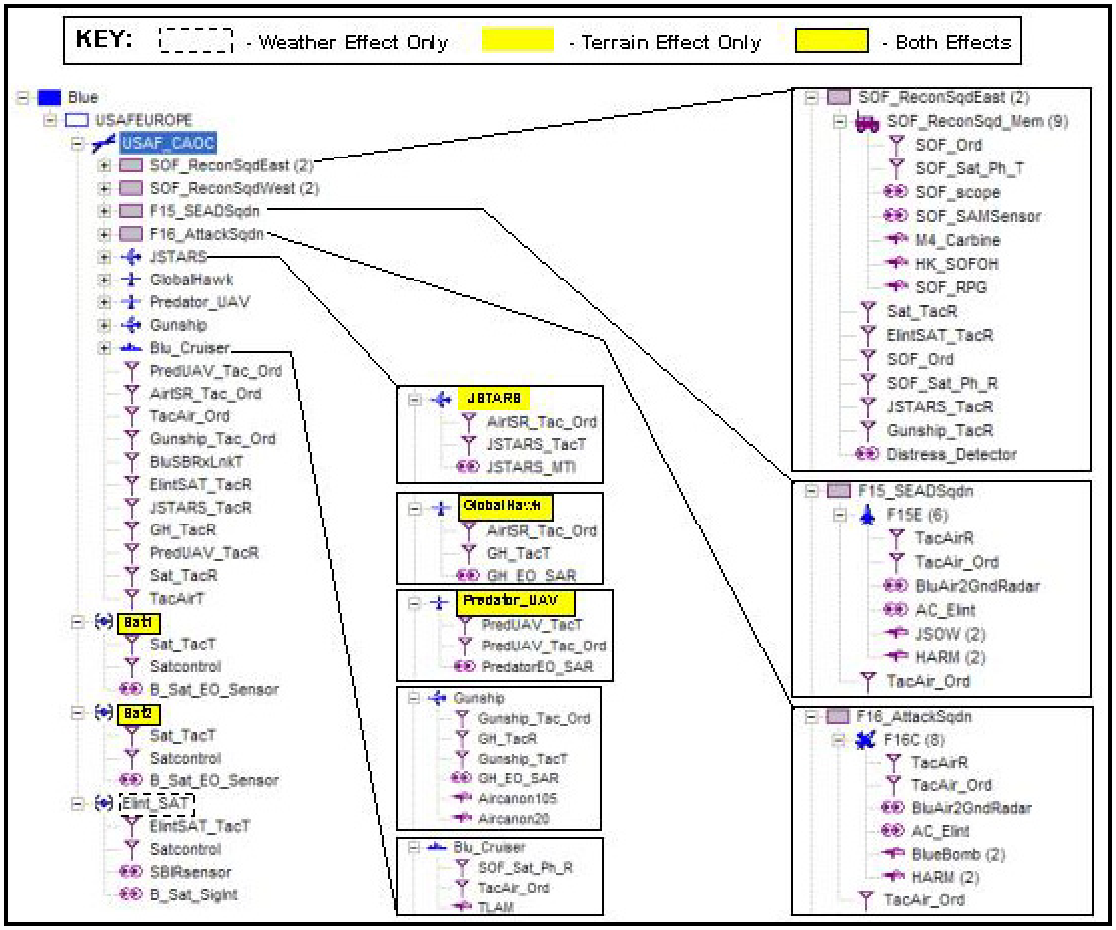

Figure 17. Blue Force Sensors Affected by Network Degradation Effects

Graphical trends seen in average detection distance plots for a single run of the Kosovo scenario helped to focus the subsequent analysis of data gained from thirty replications. Figure 18 is a SEAS Post Processor plot of average detection distance data from one run of the full effects case. The agents listed on the “Sensors” and “Targets” axes are not all inclusive for the sake of space and clarity of reading in the figure. Therefore, the hash marks on the “Sensors” axis listing *F15E#1*, *F15E#3*, and *F15E#6*, for example, represent the whole group of F-15E agents. Similarly, the specific listings on the “Targets” axis for individual members of the *RedSA6*, *Serb_Armor*, and *Ktractor* units are not representative of those types of agents for that region of the axis. Since there is only one *JSTARS* in the scenario, its hash mark on the "Sensors" axis correctly lines up with the *JSTARS* row of average detection distances versus various type of target.

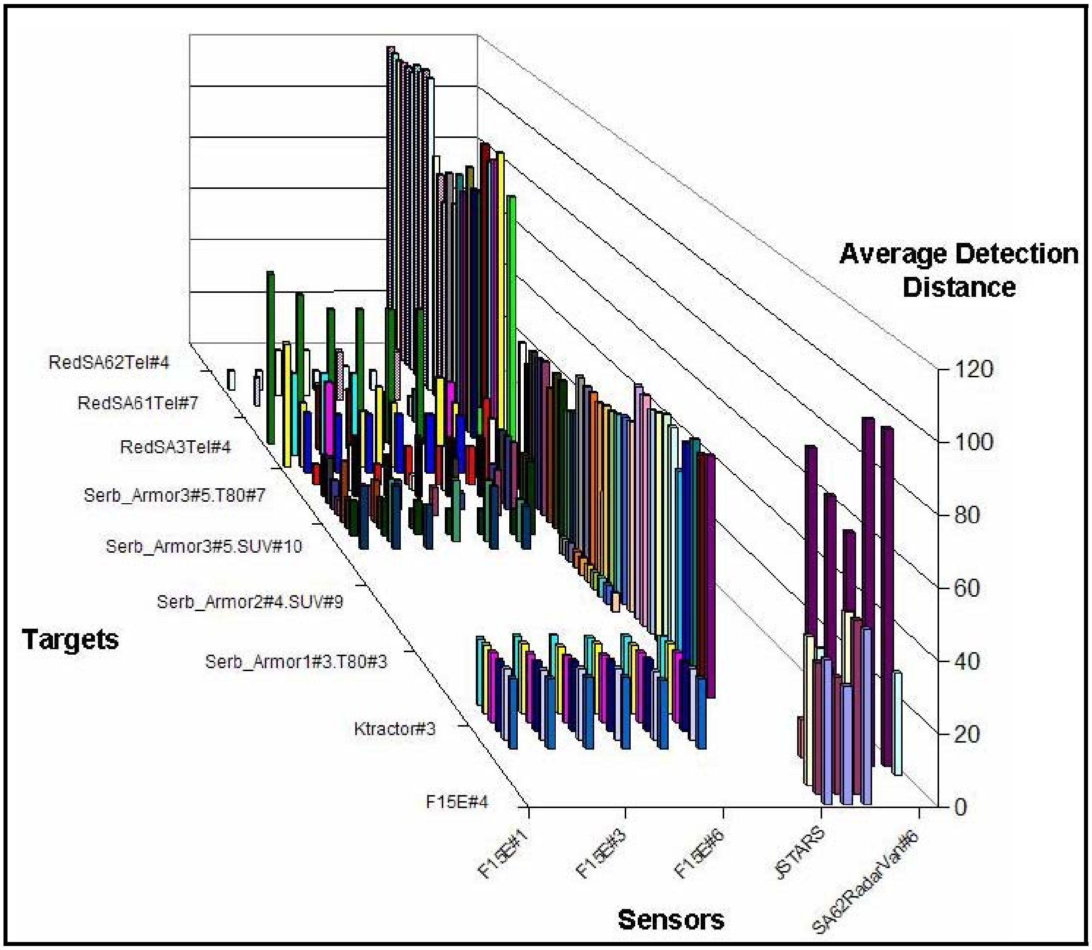

Figure 18. Average Detection Distance Versus Various Targets and Sensors

Several trends and points of interest can be gleaned concerning the behavior of agents within the Kosovo scenario from this plot. First of all, the *JSTARS* is the most active and effective Blue force sensor, clearly seeing the most Red targets and at the farthest average ranges, anywhere from 20 to 120 kilometers. Also, the F-15's are fairly effective at detecting Red armor and surface-to-air threats, but not nearly to the range of the *JSTARS*. Last, the Red radar vans are detecting the F-15's fairly consistently and from distances of 20 to 100 kilometers, which is much farther away than the F-15's are seeing their targets, although the F-15's can be cued by other Blue ISR assets.

Seeing these detection trends from single run output data was very helpful in better approaching the thirty runs analysis. From this single run analysis, it was learned which sensor platforms would be most worth focusing comparative performance analysis on for the three degraded scenario cases versus the baseline case. Also, knowing which targets were being detected by which sensors helped to provide a fuller understanding of what types of detections the more aggregated data for thirty runs was truly representing.

4.3.2 Thirty Runs Analysis - Four Cases Output Comparison

The second phase of analysis conducted for detection distances of the Kosovo scenario was to compare average detection distance outputs from thirty runs of the baseline case, which has no weather or terrain effects, versus average detection distance outputs from thirty runs of the three states of network degradation (represented as the application of weather only, terrain only, and weather and terrain effects combined). The goal of this analysis is to determine whether the difference between case outputs is statistically significant. A paired-*t* confidence interval approach is selected as the statistical tool to test for this difference, with the key indicator of statistical difference being whether or not zero is included in the confidence interval for difference in outputs. If zero is included in the confidence interval, then there cannot be a conclusion of statistical difference between the two model outputs being compared.

The procedure of the paired-*t* confidence interval approach involves first defining the variable Z_j as

$$Z_j = X_j - Y_j , \tag{1}$$

where X_j is the random variable average output from the baseline model. For the analysis of Kosovo scenario outputs, X_j represents average output for the baseline case, where no terrain and weather effects are present. Y_j is the random variable output from the model against which the baseline is being compared. In the context of the Kosovo scenario, Y_j represents the three degraded cases of terrain effects only, weather only, and combination of weather and terrain. The expected value of the Z_j's is

$$\overline{Z}(n) = \frac{\sum_{j=1}^{n} Z_j}{n} . \tag{2}$$

The approximate 100(1-α) percent confidence interval is defined by

$$\overline{Z}(n) \pm t_{n-1,1-\alpha/2} \sqrt{\frac{\widehat{Var}[\overline{Z}(n)]}{n}} , \tag{3}$$

where $t_{n-1,1-\alpha/2}$ is the test statistic and $\widehat{Var}[\overline{Z}(n)]$ is defined as

$$\widehat{Var}[\overline{Z}(n)] = \frac{\sum_{j=1}^{n} [z_j - \overline{Z}(n)]^2}{(n-1)} . \tag{4}$$

Table 1. Satellites Paired-*t* Test Detection Distance Analysis

Satellite #1				
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	178.30	(166.38,190.23)	**Yes**	**-13.75**
Terrain Only	174.57	(165.88, 183.26)	**Yes**	**-13.46**
Weather Only	15.91	(3.18, 28.63)	**Yes**	**-1.23**
Satellite #2				
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	176.66	(164.02, 189.30)	**Yes**	**-13.80**
Terrain Only	164.00	(154.65, 173.35)	**Yes**	**-12.81**
Weather Only	18.05	(0.36, 35.75)	**Yes**	**-1.41**

Table 1 shows $\overline{Z}(n)$ and the 95% confidence interval (α = 0.05) for *Sat1*. The full paired-*t* test results and analysis are listed in Appendix A. The table lists whether or not statistically significant differences exist between each degraded case and the baseline model case for average detection distance outputs and also the percentage change in the average detection distance from the baseline case. Table 1 illustrates that both satellites' average detection distance ranges are clearly reduced, especially in the full effects and terrain only cases. It is a bit surprising that the weather case did not hinder the average detection distance more severely for both satellites. This could be due to the fact that both satellites are detecting targets less frequently in the weather case, as the weather factor of zero in the TPL eliminates line of sight target viewing for each satellite. Detections are still possible for the satellites on the edges of the weather TAO, but a smaller number of detections may be limiting observance of the true degradation affect in the weather only case.

Table 2. F-15 Squadron Paired-*t* Test Detection Distance Analysis

F-15E#1				
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	-0.44	(-6.19, 5.31)	**No**	**1.05**
Terrain Only	-6.56	(-11.71, -1.41)	**Yes**	**15.78**
Weather Only	1.56	(-4.75, 7.87)	**No**	**-3.75**
F-15E#4				
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	0.38	(-8.22, 8.97)	**No**	**-0.92**
Terrain Only	-2.15	(-8.45, 4.16)	**No**	**5.20**
Weather Only	3.07	(-2.83, 8.97)	**No**	**-7.42**
All 6 F-15's Together				
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	0.49	(-3.39, 4.37)	**No**	**-1.18**
Terrain Only	-3.07	(-7.05, 0.91)	**No**	**7.38**
Weather Only	0.62	(-2.99, 4.23)	**No**	**-1.49**

Table 2 shows $\overline{Z}(n)$, the 95% confidence intervals, and percentage changes in average detection distances versus the baseline case for *F-15E#1*, *F-15E#4*, and the F-15 squadron as a whole. This table illustrates that, except for the *F-15#1* comparison of the baseline with the terrain only effect, there is no statistical difference between the average F-15 squadron detection distances for all of the three case comparison variations versus the base case. This is essentially the expected result since the F-15's are not coded in the Kosovo warfile as being affected by the weather or terrain TAO. However, the improvement in *F-15#1*'s average detection distance in the case where only terrain effects are applied is not clearly understood. Perhaps this improvement in average detection distance is due to the fact that the satellites' detection distances are severely hampered and therefore *F-15#1* is not able to rely on cueing information from the satellites, but rather must more actively seek out targets on its own. *F-15#1* is the first F-

15 to deploy from the Blue base and it is able to relay this information on to the rest of the squadron, which rely on both the satellites' and *F-15#1*'s detection information to guide them to targets. This may be why *F-15#1*'s average detection distance undergoes this change for the terrain only case while *F-15#1*'s average detection distance, as well as that of the squadron as a whole, are not significantly different. In summary of the data analysis presented in Tables 1 and 2, terrain and weather effects are seen to significantly affect the NCW physical domain metric of detection distance for the satellites in the Kosovo scenario, but not for the F-15's. Due to their respective coding in the warfile as to how the terrain and weather affects each platform, this is the expected outcome.

Table 3. JSTARS and Global Hawk Paired-*t* Test Detection Distance Analysis

JSTARS				
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	0.21	(-2.09, 2.51)	**No**	**-0.33**
Terrain Only	0.28	(-2.48, 3.05)	**No**	**-0.44**
Weather Only	-0.63	(-3.05, 1.79)	**No**	**0.98**
Global Hawk				
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	-0.06	(-0.18, 0.05)	**No**	**0.24**
Terrain Only	-0.06	(-0.12, 0.00)	**No**	**0.24**
Weather Only	0.13	(0.03, 0.23)	**Yes**	**-0.53**

Similar paired-*t* confidence interval analysis was also performed for the *JSTARS* and *GlobalHawk* agents. Table 3 summarizes the results of this analysis. The results in Table 3 show that in five case comparisons out of six for the *JSTARS* and *GlobalHawk*, there were no statistically significant differences in the average detection distances for each platform. In the comparison for the *GlobalHawk* in the case of baseline versus weather only effects, even though this change was statistically significant according to the paired-*t* confidence interval, the percentage decrease in average detection distance of 0.53 percent is arguably not practically significant. The lack of statistically significant differences across the case comparisons for the average detection distances of the *JSTARS* and *GlobalHawk* is an unexpected result. Both platforms exhibit higher degrees of sensing activity in all scenarios over all four cases than any other platform.

The *JSTARS* is coded as being affected by the terrain TAO only, so the lack of difference in performance for the weather effects only case is understandable. However, it would stand to reason that an observable difference in sensor detection distance range would be seen for the full effects and terrain only cases. It is not clear why the expected differences in output are not observed. The same holds true for the *GlobalHawk*, especially in light of the fact that this platform is coded as being affected by both the terrain and the weather TAO. And yet, there is no statistical decrease of sensor distance range for any of the three case comparisons for this platform, except for the weather only case whose increase in range, while very unexpected, is not of a magnitude to be considered practically significant.

One possible conclusion that can be drawn from this lack of statistically significant difference for the *JSTARS* and *GlobalHawk* is that average detection distance may not be a reliable metric within SEAS by which to measure the physical domain for sensing platforms other than satellites. Apparently, the degradation effects of the weather and terrain TAO are having significant affects for the long-range sensing activities of the satellites but not for the relatively closer range detections of the *JSTARS* and *GlobalHawk*.

4.4 Information Domain Analysis

4.4.1 Preliminary Multiple Run Analysis

The metric selected for the information domain in the Kosovo scenario was a performance measurement of the networks' communication channels. Specifically, the number of messages handled by each channel was analyzed for key platforms of the Blue Force. The focus was on determining the affect of regional TAO degradation on each channels' ability to handle and transfer messages pertaining to target detections, agent orders, and a few variable types of messages. All three types of messages are tracked in SEAS for each channel specified in the TPL and designated in the communications output file as the channel name followed by _*Sit*_, for situation report (i.e. target sighting), _*Var*_, for broadcast variables (which can be various message types such as target priority arrays), and _*Ord*_, for orders and command messages.

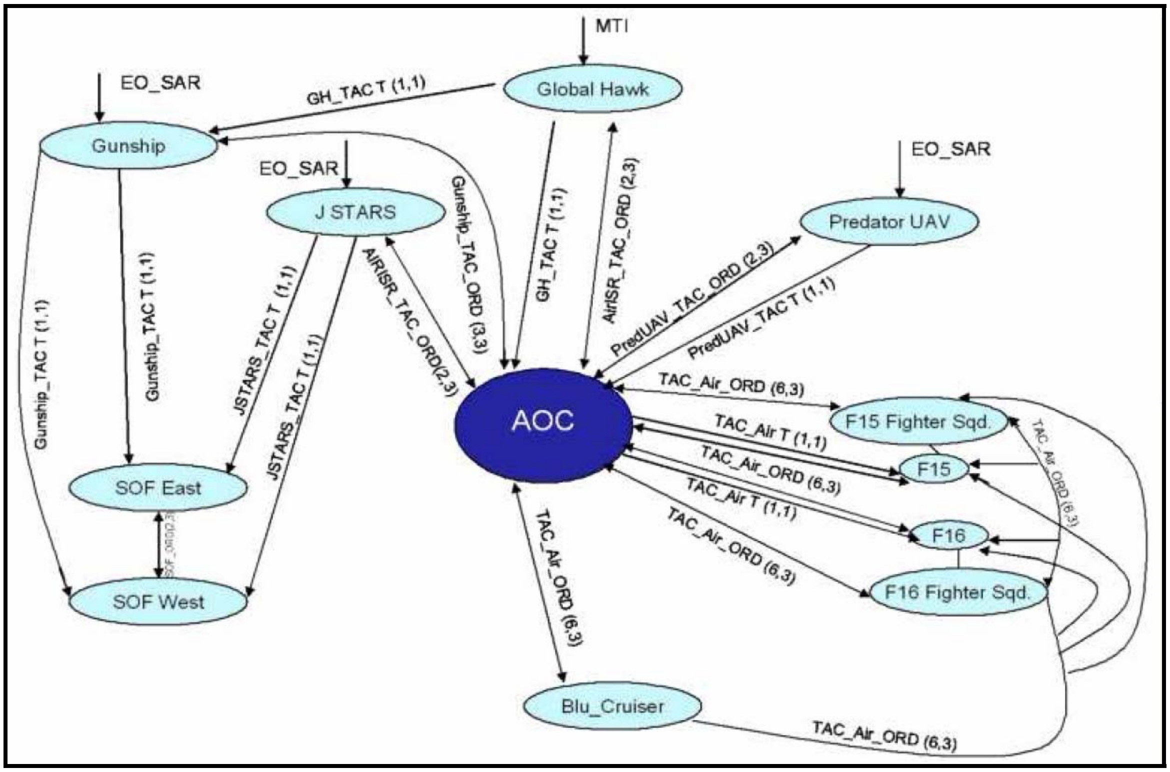

Figure 19. AOC Communication with Group & Air Assets (DeStefano, 2004:3-10)

Figure 19 is a graphic illustration of the Blue Force communications network from DeStefano's work. The figure shows that the *TAC_Air_ORD(6,3)* and *TAC_Air_Ord(1,1)* communications lines provide a critical link between the AOC and several key Blue platforms, including the F-15 squadron, F-16 squadron, and *Blu_Cruiser*, which is a Navy carrier agent that launches the TOMAHAWK Land Attack Missile (TLAM). Analysis of message loading and activity across all channels conducted for this thesis effort confirms that the *TAC_Air* communication device's primarily used channel, *TacAirQ_Sit*, is one of the most highly active channels in the scenario. It relays target sightings to the aforementioned platforms.

As a first look in trying to appropriately measure the communications output data for individual channel loading, one run of the scenario was analyzed to look at both the one-run total number of messages and the average number of messages handled by each channel per one minute time-step. Table 4 shows the results of this preliminary analysis.

Only the data for number of messages removed from each respective channel is listed in the table since this value is most indicative of the activity on the channel and the message loading for each channel. It is identical to the output data for the number of messages added to each channel. The number of messages currently on a channel is tracked by SEAS, but this metric is not used because the amount of time that each channel broadcasts a batch of messages varies according to its delay time attribute. Therefore, channels having a longer programmed delay time would show higher average total message counts and average messages per time-step counts than agents with shorter broadcast times and unequal channel performance comparisons would be made. Using the number of messages removed from each channel levels the playing field and works to normalize the data for each channel.

Table 4. All Active Communication Channels Analysis

COMPARISON OF ALL ACTIVE CHANNELS' TOTAL MESSAGE COUNT AND AVERAGE MESSAGE COUNT PER MINUTE TIME-STEP FOR ONE RUN

	BASELINE - No Effects		*Full Effects*		*BASELINE minus Full Effects*	
Channel	**Count**	**Average**	**Count**	**Average**	**Count Diff**	**Average Diff**
JSTARSQ_Sit_Rem	2262.00	0.51	3728.00	0.61	(1466.00)	(0.10)
GShipQ_Sit_Rem	1985.00	0.43	424.00	0.10	1561.00	0.33
GHQ_Sit_Rem	3362.00	0.68	833.00	0.15	2529.00	0.53
SBRQ_Sit_Rem	22302.00	4.90	18781.00	3.23	3521.00	1.67
TacAirQ_Sit_Rem	22302.00	4.90	18781.00	3.23	3521.00	1.67
GShip_OrdQ_Ord_Rem	1.00	0.00	1.00	0.00	0.00	0.00
Air_OrdQ_Ord_Rem	3.00	0.00	3.00	0.00	0.00	0.00
ImSatQ_Sit_Rem	64.00	0.01	14.00	0.00	50.00	0.01
ElintSATQ_Sit_Rem	233.00	0.06	216.00	0.06	17.00	0.00
SOF_OrdQ_Ord_Rem	342.00	0.21	207.00	0.13	135.00	0.09
SOF_Sat_PhQ_Sit_Rem	336.00	0.05	311.00	0.06	25.00	(0.01)
RTac_OrdQ_Var_Rem	11342.00	2.14	11342.00	2.12	0.00	0.03
RTac_OrdQ_Ord_Rem	11198.00	1.93	11578.00	1.99	(380.00)	(0.06)
RIADSQ_Sit_Rem	827.00	0.18	1205.00	0.25	(378.00)	(0.06)
RSRTQ3_Sit_Rem	371.00	0.20	353.00	0.20	18.00	0.00
KSHQ_Sit_Rem	218.00	0.04	237.00	0.04	(19.00)	0.00
KSHQ_Ord_Rem	283.00	0.05	249.00	0.05	34.00	0.00
KBellQ_Sit_Rem	3652.00	0.45	6742.00	0.78	(3090.00)	(0.33)
KBellQ_Ord_Rem	24.00	0.00	24.00	0.00	0.00	0.00

	Terrain Only		*BASELINE minus Terrain Only*	
	Count	**Average**	**Count Diff**	**Average Diff**
JSTARSQ_Sit_Rem	2260.00	0.46	2.00	0.05
GShipQ_Sit_Rem	1800.00	0.34	185.00	0.09
GHQ_Sit_Rem	3197.00	0.56	165.00	0.12
SBRQ_Sit_Rem	21321.00	4.11	981.00	0.79
TacAirQ_Sit_Rem	21321.00	4.11	981.00	0.79
GShip_OrdQ_Ord_Rem	1.00	0.00	0.00	0.00
Air_OrdQ_Ord_Rem	3.00	0.00	0.00	0.00
ImSatQ_Sit_Rem	21.00	0.01	43.00	0.01
ElintSATQ_Sit_Rem	205.00	0.04	28.00	0.02
SOF_OrdQ_Ord_Rem	567.00	0.13	(225.00)	0.08
SOF_Sat_PhQ_Sit_Rem	131.00	0.04	205.00	0.01
RTac_OrdQ_Var_Rem	13448.00	2.26	(2106.00)	(0.12)
RTac_OrdQ_Ord_Rem	7138.00	1.73	4060.00	0.20
RIADSQ_Sit_Rem	1250.00	0.20	(423.00)	(0.01)
RSRTQ3_Sit_Rem	367.00	0.09	4.00	0.10
KSHQ_Sit_Rem	303.00	0.04	(85.00)	0.00
KSHQ_Ord_Rem	310.00	0.05	(27.00)	0.00
KBellQ_Sit_Rem	3635.00	0.42	17.00	0.03
KBellQ_Ord_Rem	24.00	0.00	0.00	0.00

	Weather Only		*BASELINE minus Weather Only*	
	Count	**Average**	**Count Diff**	**Average Diff**
JSTARSQ_Sit_Rem	1077.00	0.48	1185.00	0.04
GShipQ_Sit_Rem	131.00	0.09	1854.00	0.33
GHQ_Sit_Rem	180.00	0.16	3182.00	0.53
SBRQ_Sit_Rem	5328.00	2.65	16974.00	2.26
TacAirQ_Sit_Rem	5328.00	2.65	16974.00	2.26
GShip_OrdQ_Ord_Rem	1.00	0.00	0.00	0.00
Air_OrdQ_Ord_Rem	3.00	0.00	0.00	0.00
ImSatQ_Sit_Rem	27.00	0.01	37.00	0.01
ElintSATQ_Sit_Rem	172.00	0.04	61.00	0.01
SOF_OrdQ_Ord_Rem	189.00	0.08	153.00	0.13
SOF_Sat_PhQ_Sit_Rem	512.00	0.05	(176.00)	0.00
RTac_OrdQ_Var_Rem	13367.00	2.19	(2025.00)	(0.05)
RTac_OrdQ_Ord_Rem	7118.00	1.86	4080.00	0.07
RIADSQ_Sit_Rem	765.00	0.18	62.00	0.00
RSRTQ3_Sit_Rem	369.00	0.11	2.00	0.09
KSHQ_Sit_Rem	264.00	0.04	(46.00)	0.00
KSHQ_Ord_Rem	256.00	0.05	27.00	0.00
KBellQ_Sit_Rem	9828.00	0.62	(6176.00)	(0.17)
KBellQ_Ord_Rem	24.00	0.00	0.00	0.00

Table 4 gives a good indicator of not only which channels are handling the highest message loads, but also provides a good illustration of which channels are most affected by the degradation effects. Values which are bold and listed in parenthesis represent negative values and therefore, these are the cases and channels which yielded higher levels of either total message count and/or average message count per one minute time-step and therefore actually saw higher activity for that respective degraded case and channel combination relative to the baseline case performance.

Channels of interest which saw this increase in activity for both total message count and average message count for at least one case versus the baseline are shaded since these channels exhibit unexpected behavior for the degraded cases. These six channels of interest are *JSTARSQ_Sit*, *RTac_OrdQ_Ord*, *RIADSQ_Sit*, *RSRTQ3_Sit*, *KSHQ_Ord*, and *KBellQ_Sit*. *JSTARSQ_Sit* is a channel that relays target sighting information from the *JSTARS* agent. *RTac_OrdQ_Ord* carries orders for the Red Force. *RIADSQ_Sit* is a channel used by the *RedIADSnet* device, which is held by the *RedSA61Tel*, *RedSA62Tel*, *RedSA61RadarVan*, and *RedSA62RadarVan* vehicles. *KSHQ_Ord* and *KBellQ_Sit* are used by the Brown Kosovar agents as distress emitting "channels" on which to shout commands to each other and ring bells to signal attack by the Red Serbian Force. Of these six channels of interest based on their communications data improvements in the degraded cases, only *JSTARSQ_Sit* is of particular interest since this is a highly active channel of the Blue Force and since it is used by a vehicle, the *JSTARS*, that is affected by the terrain TAO, whereas the Red and Brown forces are not affected by either the terrain or the weather TAO. Thus, of these six channels, only *JSTARSQ_Sit* warrants further analysis.

4.4.2 Average Message Loading of Active Channels

The problem with the foregoing analysis method for the communications data is that the zero values for time-steps when no messages are removed from a channel tend to distort the calculated averages. The legitimacy of this analysis technique is also weakened by the fact that the output data stream from a single run is not independent. A closer look and more intensive analysis approach is required in order to determine the values for a more appropriate measure, which would be the average message load handled by each channel only during the times when that channel is holding a batch of messages. Once again, the number of messages removed field from the standard SEAS communication output file will be utilized. The preliminary analysis conducted over all time-steps for one replication was used as a guide for determining the communication channels to focus on for analysis of average channel load only when that channel is active. Only the baseline case and full effects case were analyzed for the sake of comparison due to the considerable amount of time required to extract the desired information from the SEAS raw data communication output files. Table 5 presents average active channel usage data for the top five most active channels in the Kosovo model.

Table 5. Average Active Channel Usage for One Simulation Run

BASELINE - NO EFFECTS CASE					
Channel	*JSTARSQ_Sit*	*SBRQ_Sit*	*TacAirQ_Sit*	*RTac_OrdQ_Var*	*RTac_OrdQ_Ord*
Number of Active Minute Time-Steps	196.00	324.00	179.00	513.00	1132.00
Average Message per Active Time-Step	7.18	64.82	117.34	27.16	14.77
FULL EFFECTS CASE					
Channel	*JSTARSQ_Sit*	*SBRQ_Sit*	*TacAirQ_Sit*	*RTac_OrdQ_Var*	*RTac_OrdQ_Ord*
Number of Active Minute Time-Steps	352.00	293.00	187.00	525.00	882.00
Average Message per Active Time-Step	10.43	58.02	90.91	23.60	14.88

This table shows mixed results as far as the usefulness of the average active time-step measure. The *JSTARSQ_Sit* channel has already been discussed. The *SBRQ_Sit* is one of the primary channels used by the CAOC to relay target sighting information. The *TacAirQ_Sit* has also been previously discussed. *RTac_OrdQ_Var* and *RTac_OrdQ_Ord* are command channels used by the Red Force to relay various types of orders information to the Red units and vehicles.

There seems to be no clear or consistent pattern of either decrease or increase for the average number of active time-steps across these channels and cases. The average number of messages per active time-step measure seems to be more indicative of a real trend, in that three out of five channels show a drop in average active usage from the baseline case to the full effects case. A decrease in message load for the full effects case is the expected result, especially for the Blue Force channels of *JSTARSQ_Sit*, *SBRQ_Sit*, and *TacAirQ_Sit*. *JSTARSQ_Sit* activity should decrease due to a reduced number of target sightings because of the terrain effect that the JSTARS agent is coded as being affected by. However, this is not the case, as the activity on *JSTARSQ_Sit* actually increases for the full effects case. The message load per time-step of *SBRQ_Sit* and

TacAirQ_Sit decreases for the full effects case, as would be expected since the CAOC should have less target sighting messages to relay, especially from the satellites since their target detection frequency and range was significantly affected by the weather and terrain effects. *RTac_OrdQ_Var* sees a decrease, from 27.16 to 23.60, in average message load per active time-step, as might be expected since the Red Force behaves largely in a reactive way to Blue Force's activities. The presence of full degradation effects tends to reduce the overall activity of Blue and consequently tends to reduce the reactionary activity of Red. *RTac_OrdQ_Ord* carries a slightly higher number of average messages per active time-step for the full effects case, but the increase is less than one percent (from 14.77 to 14.88, a 0.74% increase) and therefore arguably not practically significant.

4.4.3 Average Message Loading Over Time

A final approach taken to determine an appropriate and usable information domain metric which can be gleaned from the SEAS communication output data involves plotting the overall average message load for the top four active channels over ten ten-hour segments of one simulation run. The resulting plots are illustrated in Figure 20 and 21. The average number of messages per ten-hour time block is calculated over all 60 minute time-steps for the baseline and full effects cases using the same starting random number seed. There was no adjustment made to filter out time-steps when the channels are broadcasting zero messages. Four out of five of the communications channels selected for the previous phase of analysis are presented in these plots. *SBRQ_Sit* was excluded on these plots because this channel's average message activity per ten-hour time segment is exactly the same as the *TacAirQ_Sit* channel's average number of messages and this holds true for both the baseline case and full effects case.

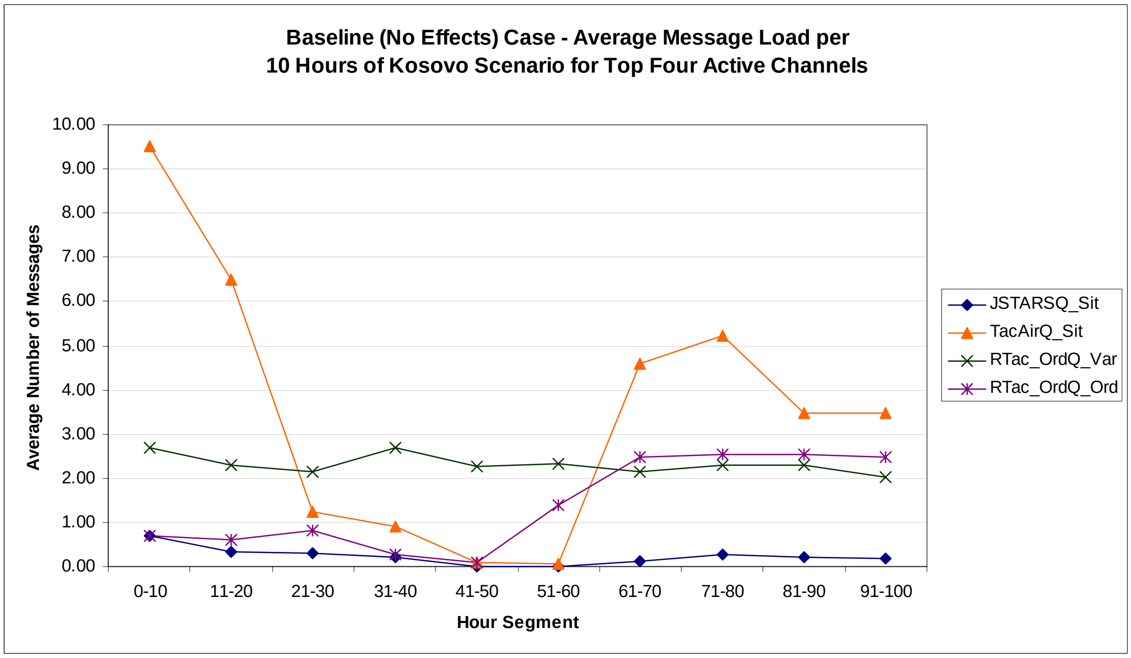

Figure 20. Baseline Case Average Message Load per 10-hour Segment

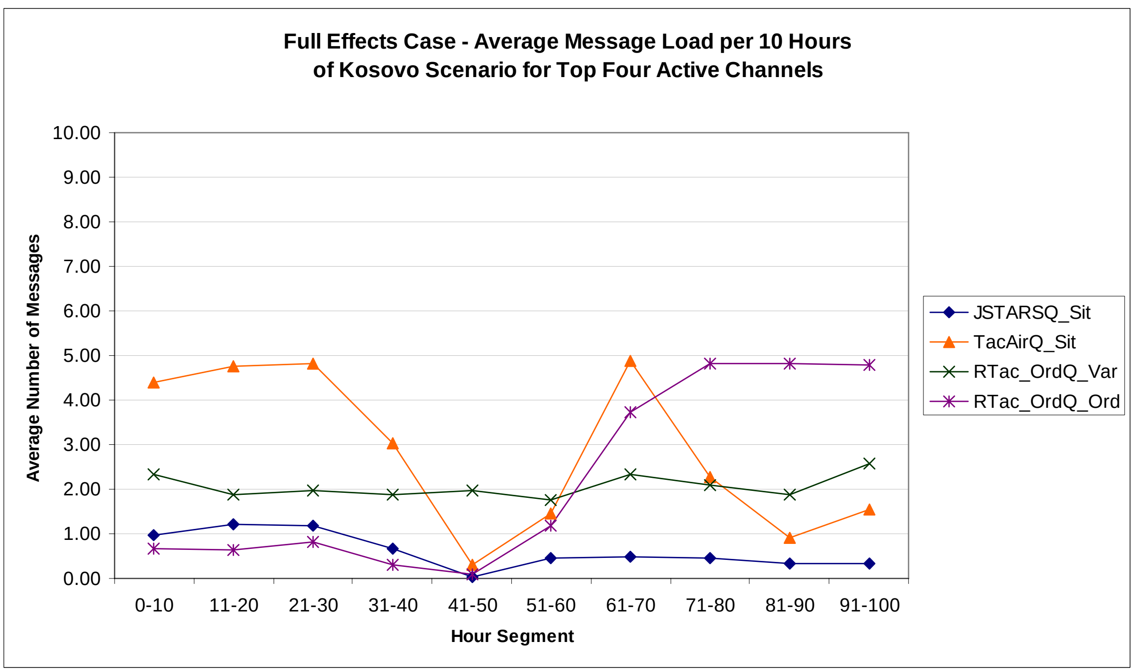

Figure 21. Full Effects Case Average Message Load per 10-hour Segment

A few trends can be seen in the average communication loading for these top four active channels. A pattern of relatively high message activity on *TacAirQ_Sit* for approximately the first 20 hours, then decrease up until approximately 50 hours, followed by a rise until about the 70 hour mark and fall after that, holds true for both cases. These two distinct phases of communication activity match up closely with DeStefano's findings concerning phases of war for the Kosovo scenario. Figure 22 illustrates these two phases in terms of number of kills.

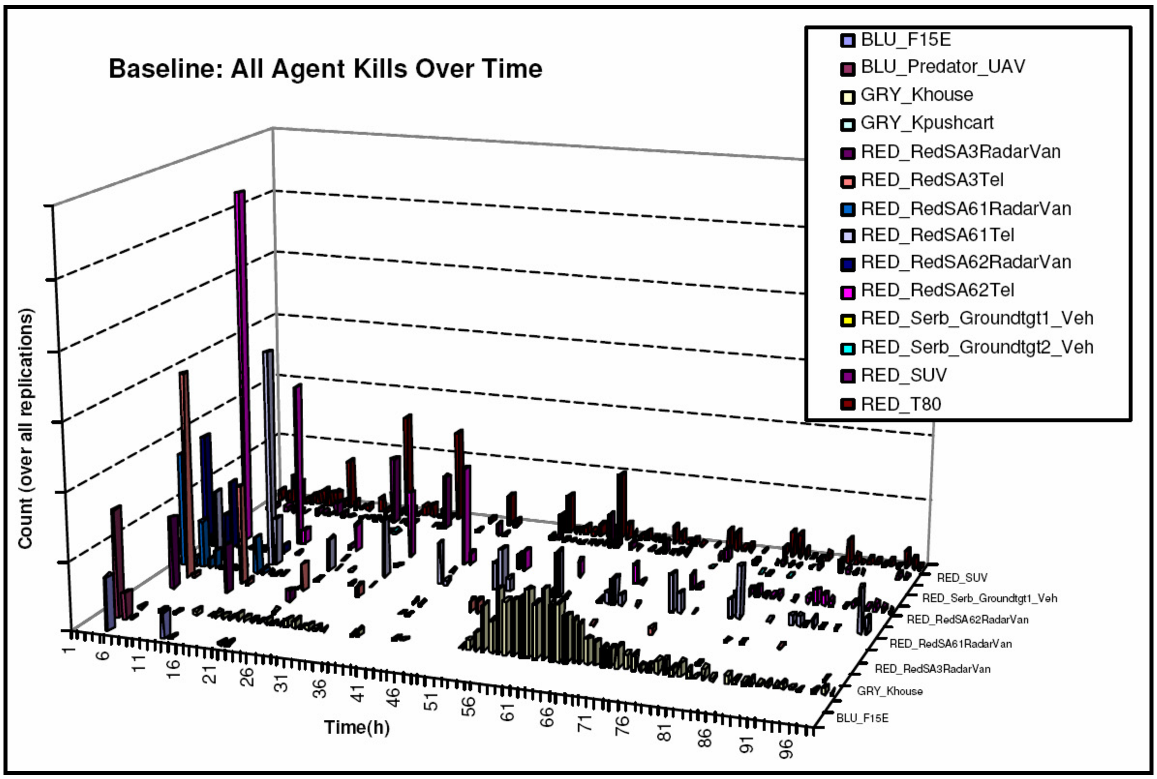

Figure 22. Two Phases of the Kosovo War Based on Kill Data (DeStefano, 2004:4-3)

Phase I, origin of the war to approximately 48 hours, is considered a SEAD phase. Phase II, from approximately 48 hours on, is considered as intervention of killing on the ground. This phase is highlighted by a large distribution of Kosovar kills as opposed to other activities occurring during this time (DeStefano, 2004:4-2). The plots for both cases portraying the average number of messages per ten-hour segment match up nicely with these two phases of war and the generally lower number of messages on *TacAirQ_Sit* for the full effects case matches the expected outcome for this degraded case.

The trends are not quite as easy to observe for data on the Red channels, *RTac_OrdQ_Var* and *RTac_OrdQ_Ord*. *RTac_OrdQ_Var* follows a similar nearly flat-line pattern in both cases and generally holds a slightly lower number of average messages per ten-hour segment (ranges from 0.18 to 0.83 for ten-hour segments where the no effects average is greater than the full effects average). *RTac_OrdQ_Ord* follows essentially the same exact progression of values for each case over the first approximately 50 hours, but after that the average number of messages on this channel for the full effects case shoots up to nearly twice the amount as seen in the no effects baseline. The general trend of *RTac_OrdQ_Ord*'s message activity for both cases seems to match the two-phase pattern seen by DeStefano's kill data analysis and by the message activity line plotted in each case for *TacAirQ_Sit*.

Activity for *JSTARSQ_Sit* for both cases also roughly matches the two-phases of war trend. However, the average message load on *JSTARSQ_Sit* again appears to increase for the full effects case, which again is an unexpected given that the *JSTARS* is coded as being affected by the terrain TAO. Terrain effects should result in a drop of the communications reliability and hence a lower number of average messages being relayed, but this is not what the output data is showing. Just as was the case in the detection distance analysis for the *JSTARS*, it is unclear as to why this platform is performing better in the degraded cases.

4.5 Cognitive Domain Analysis

The chosen measure for the cognitive domain of NCW is the somewhat indirect metric of number of kills (and, consequently, number of victim deaths) per platform. Kill data is representative of decision-making behavior because the recording of a kill in the scenario is conclusive evidence of the outcome resulting from a decision made to attack. The kill numbers measure the "act" part of the OODA (Observe, Orient, Decide, Act) loop. Unlike the physical and information domain metrics, the outputs for kill numbers used to measure the cognitive domain of NCW are relatively clear and definitive. This section illustrates that, in general, the no degradation effects (baseline) case is the best case scenario for the Blue USAFE Force both in terms of higher number of Red killed and lower number of Brown killed.

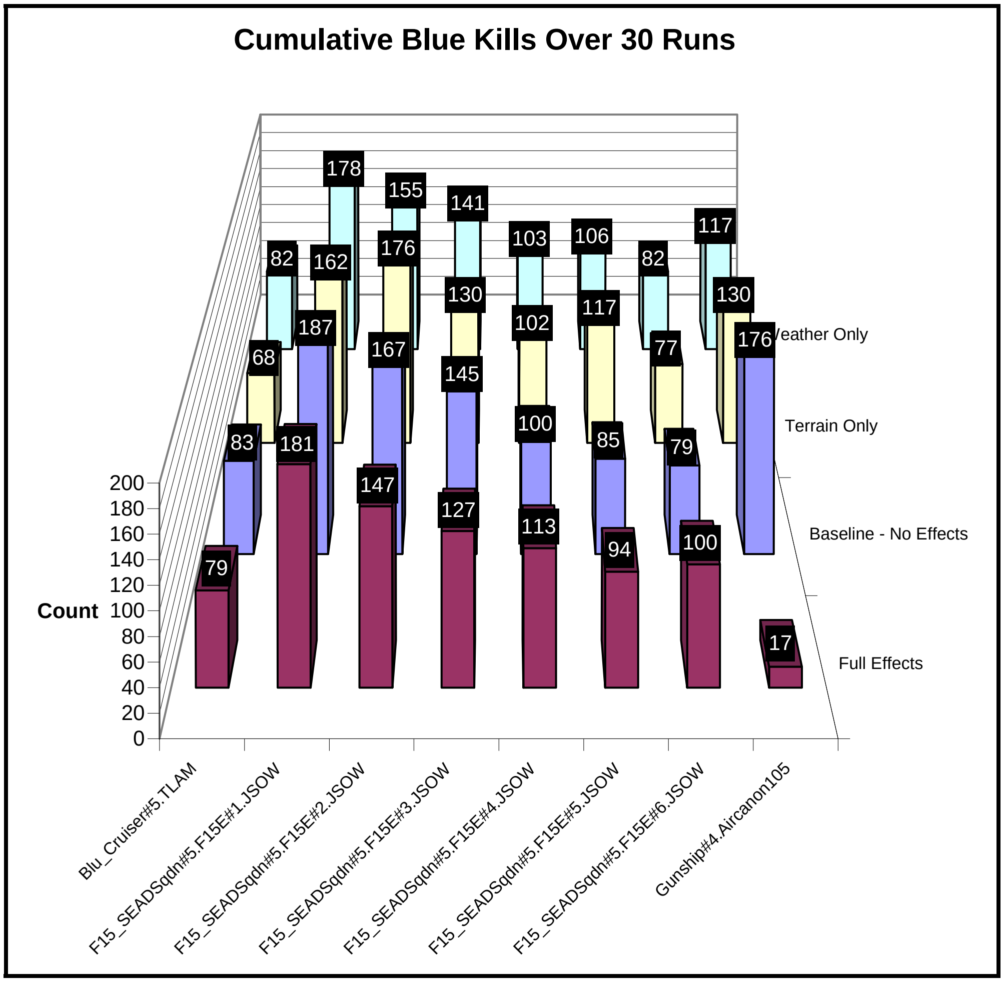

Figure 23. Kill Counts for Blue's Most Active Weapons for All Four Cases

Figure 23 shows the cumulative number of kills over thirty runs for Blue's most active weapons. The numbers for the *Gunship#4.Aircanon105* weapon exhibit a considerable effect of the degradation states on the final outcome of this agent's mission success in terms of enemy agents killed. The *Blu_Cruiser#5.TLAM* weapon also exhibits the trend of higher kills for the baseline case versus the three degraded cases. The cumulative kill numbers for the F-15s' *JSOW* weapons, however, in general do not show the same clear trends.

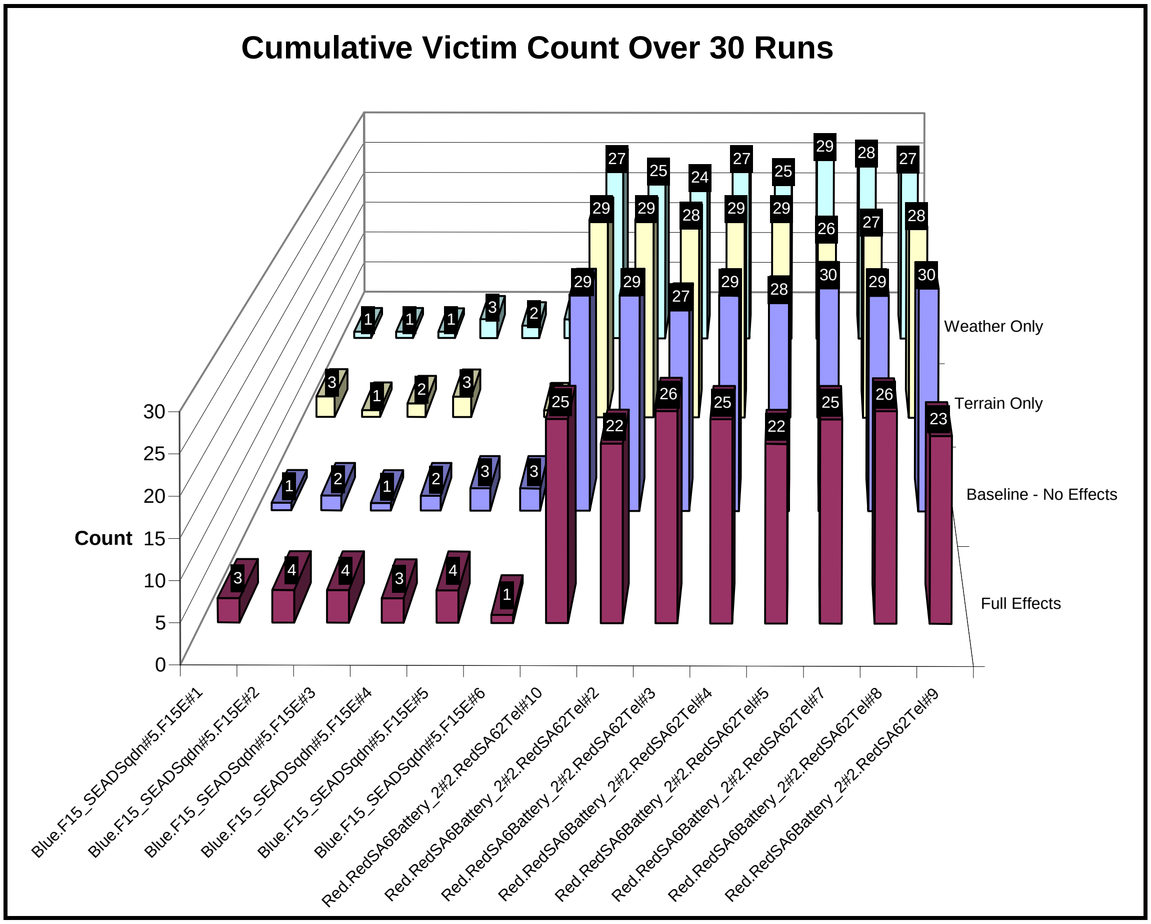

Figure 24. Blue F-15 and Red Tel Victim Counts for All Four Cases

Figure 24 shows the cumulative victim count over thirty runs of each case for the Blue F-15's and Red SA6 Tels. Similar positive trends for the Blue Force are seen in this victims plot as were seen in Figure 23. Generally less Blue agents are killed in the no effects baseline case as compared to the full effects case (except for in the case of *F15_SEADSqdn#5.F15E#6*). The results for F-15 losses are mixed when comparing the baseline case with the terrain only and weather only cases. Red, meanwhile, has higher losses across all Red SA6 Tels in the no effects case versus the baseline case. Similar to the F-15 losses, the results for Red SA6 Tel losses are mixed when comparing the baseline case with the terrain only and weather only cases.

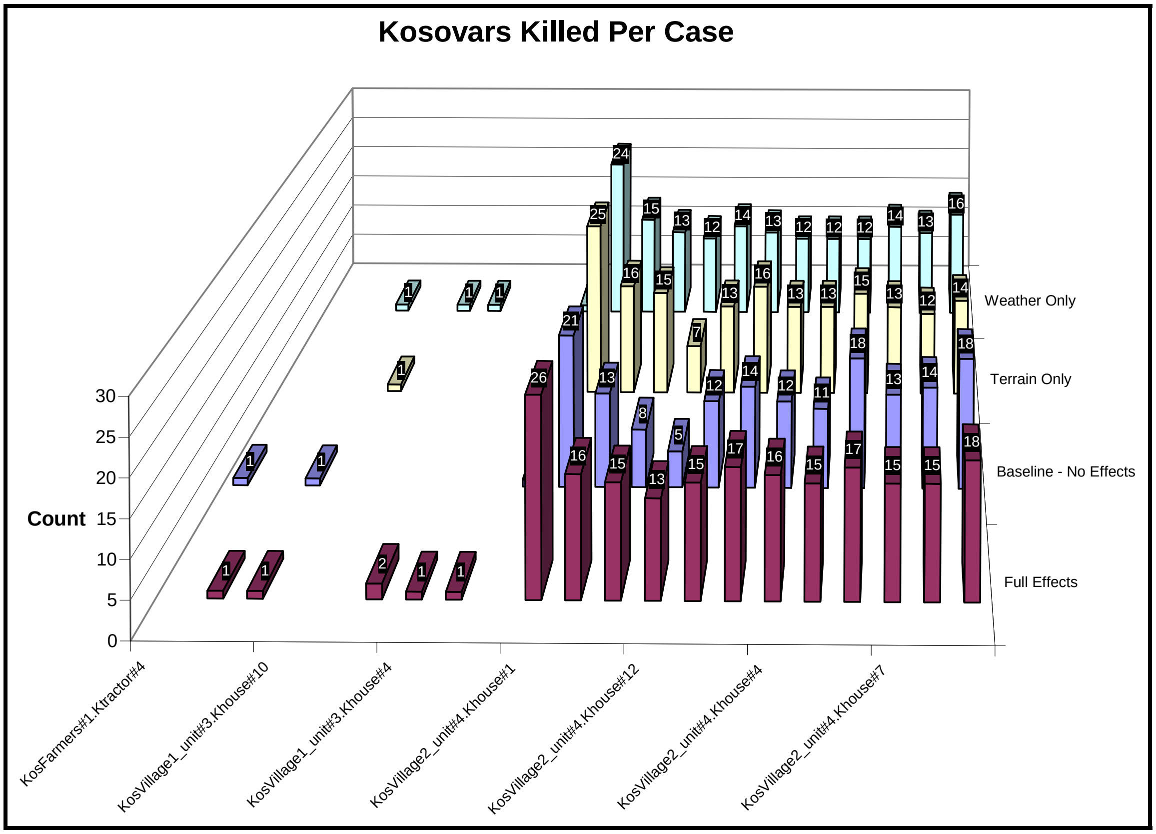

Figure 25. Number of Kosovars Killed in All Four Cases

The number of Kosovars killed over the various effects cases is shown in Figure 25. This plot also shows positive trends for the Blue USAFE Force, whose mission is to protect the Brown Kosovar Force agents and minimize the number of Kosovars killed. It can be clearly seen from the various kill labels that, in general, less Kosovar agents are dying in the no effects baseline case as opposed to the three degrading effects cases.

Cumulative kill counts over 30 runs offer rough insight into behavior and performance within the Kosovo scenario over the four degraded cases. However, to gain deeper insight into the true behavior, a paired-*t* confidence interval approach will once again be utilized. The procedure used here is similar to the one used for average detection distance analysis, but this time X_j represents total kills per platform for the baseline case and Y_j represents total kills per platform for the degraded cases. Results of the paired-*t* confidence interval analysis are presented in Table 6. The full paired-*t* test results and analysis are listed in Appendix A. On average over thirty runs, Blue kills more Red SA Tels and Radar Vans in the degraded cases, but a statistically significant difference is not found at a 95% confidence level. Each degraded case resulted in higher losses for the number of Kosovar houses destroyed by Red. While no statistically significant difference is seen for the terrain and weather only comparisons, the difference was statistically significant at a 95% confidence level for the full effects versus baseline comparison. This result leads to the conclusion that Blue is more successful at achieving its mission of saving Kosovars when its network capability of sensing and communicating is not fully degraded.

Table 6. Paired-*t* Test Results for Red and Brown Victim Counts Over Thirty Runs

Blue Kills of Red SA Tels and Radar Vans			
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?
Full Effects	1.37	(-0.32, 3.05)	**No**
Terrain Only	0.13	(-1.22, 1.48)	**No**
Weather Only	0.83	(-0.88, 2.54)	**No**
Kosovar Houses Destroyed by Red			
Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?
Full Effects	-2.20	(-4.33, -0.07)	**Yes**
Terrain Only	-0.40	(-1.50, 0.70)	**No**
Weather Only	-0.43	(-1.75, 0.88)	**No**

4.6 Summary

The analysis presented in this chapter demonstrates that the task of developing appropriate measures for NCW within the context of a SEAS model can be quite challenging. This analysis also illustrates that determining whether a particular metric is fundamental enough to serve as a useful measure for the degree, or performance, of NCW is not a very clear-cut proposition. Average sensor detection distance seemed to be a fitting and effective measure of performance in the physical domain for the satellites in the Kosovo scenario, but didn't seem as applicable for measuring the performance of other agents, such as the *JSTARS* and *GlobalHawk*. Analysis of the information domain provided different approaches and ways of looking at the average number of messages being handled by the network for various communication channels. The metric of average channel message load seemed to be a suitable measure for some channels, such as for *TacAirQ_Sit*, but not as suitable a measure of performance for other channels, such as *JSTARSQ_Sit*. Utilization of Killer Victim Scoreboard (KVS) information for measuring outcomes pertaining to the cognitive domain seemed to be the most consistent and reliable measure, as compared with the measures for the physical and information domains. Positive trends for the Blue Force were seen in comparing the case of no degradation effects to those three cases employing effects that would degrade performance of the sensors and communication devices. In the no effects case as compared with the three cases of varying degradation, Blue killed more Red and spared more Brown agents. An increase of Kosovar houses killed in the full effects degradation case was found to be statistically significant.

V. Conclusions

5.1 Overview

This research utilized a SEAS scenario representative of the Kosovo conflict during 1999 to simulate the performance of an NCW enabled force and to provide an investigative framework from which to identify appropriate measures of NCW that are available from the SEAS software. The methodology for determining appropriate NCW measures was conducted by means of implementing effects within the Kosovo scenario which degraded the sensing and communications ability of the Blue Force. This chapter presents a summary of the conclusions drawn from statistical output analysis conducted for measures of the three domains of NCW for a baseline case of the Kosovo scenario with no degradation effects versus three cases possessing varying levels of degradation effects. Following a description of conclusions drawn from analysis, recommendations for improvement of SEAS software and the SEAS Post Processor are addressed. This chapter concludes with several suggestions for future research.

5.2 Analysis Conclusions and Limitations

In general, the physical domain measure of average detection distance was found to be an appropriate measure for the Blue Force satellites in the Kosovo scenario, but not for other agents affected by the degradation effects, namely the *JSTARS* and *GlobalHawk*. The analysis was somewhat limited by the fact that determining the number of detections for various platforms was very challenging and intensive, especially when dealing with the considerably large sensor detection output files from 30 runs of the scenario.

For the information domain, measuring various averages of communication channel loading for single run as well as for multiple runs provided some insight into the affect of degradation on the active communications channels in the Kosovo scenario. Message count data for all channels in the Kosovo scenario was analyzed from three different perspectives: total count and average message load numbers for eleven runs of the scenario, total count and average active message load for all channels handling messages in the scenario (some channels saw no activity), and average message loading for the top four active channels plotted according to ten ten-hour segments of one simulation run. Encouraging trends were observed from analysis of the average message loading measure, such as a reduction in the average message activity for Blue's primary channel, *TacAirQ_Sit*, from the baseline no degradation effects case to the full degradation effects. Also, message loads for the top four active channels in the scenario were seen to approximately match the two phases of war pattern, phases which were initially discovered by Destefano in his analysis of kill data for one run of the Kosovo scenario. Analysis of the *JSTARS* target sighting channel showed an unexpected increase in average message load for the degraded case, which slightly undermined the legitimacy of the chosen technique for measuring communication channel performance. However, this unexpected result may be unique to the *JSTARS* platform in this scenario and does not necessarily totally invalidate the technique.

The most compelling results were seen in analysis of kill data for the cognitive domain. Both number of kills and number of victims for the Blue, Red, and Brown forces were analyzed in order to determine what affect the various degradation states would have on the attrition numbers. Clear trends were seen portraying fewer kills for Blue and higher losses for Brown in the degraded cases versus the baseline case, all of which were compelling because these are the results that one would logically expect to observe given the primary role played by sensors and communications devices in the scenario. These killer and victim outcomes give a fair representation of Blue's reliance on the network and show how Blue's performance suffers when the network capability is reduced.

5.3 Recommendations for SEAS Improvement

The Excel-based SEAS Post Processor is a very useful tool for processing, filtering, and graphically representing various types of output data created by a typical SEAS scenario. However, several problems and limitations were encountered over the course of analysis for this effort, especially when analyzing output data for the various communications channels in the Kosovo scenario. The standard plots for output data for the various communications channels that were available from the SEAS Post Processor ultimately proved to be more confusing than they were useful. There is considerable room for improvement as far as the options available for filtering and setting up plots for communications data. Also, the lack of ability to quickly filter and process large data files was a major hindrance in using SEAS Post Processor throughout the analysis process. This was especially true for the communications data analysis. One communications data output file from 30 runs of the Kosovo scenario of moderate file size relative to the sensor data output files (typically 70 MB for the communications files versus 375 MB for the sensor files) required one hour just to load within Post Processor.

5.4 Future Research

There are several follow-on activities that could be pursued in order to enhance and build upon the findings of this research. The utilization of write statements is a SEAS coding technique which offers great promise and potential in its ability to extract specific pieces of data. Employing write statements, either in the Kosovo scenario or in another SEAS scenario which adequately represents NCW, could potentially provide a powerful aid in helping to filter and isolate appropriate NCW measures, especially in the information and cognitive domains. A few measures which write statements may be able to capture include tracking the overall cycle time required to detect and neutralize a target and tracking the number of target sighting messages from a specific key sensor that are being relayed to a certain weapons platform.

Another research methodology that could prove to be a useful approach in finding appropriate measures for NCW is an analysis of the outcomes resulting from changing the degree of information sharing by varying the message cueing attribute for key agents in a scenario. Measures of performance could be analyzed relative to the extent to which agents in the scenario are sharing information.

Network Centric Warfare is a continually evolving concept. Research and analysis of appropriate measures is likely to be an ongoing activity for as long as the DoD includes NCW as part of its military doctrine and strategy. Continued pursuit of understanding NCW and how to appropriately measure it through use of combat models, simulations, case studies, and lessons learned from practical experience will definitely continue to benefit our forces and improve their current and future efficiency of operations in the brave new network-centric environment.

Appendix A. Paired-*t* Tests Data

Average Detection Distances for All Four Cases

Blue.USAFEUROPE.Sat1#1.B_Sat_EO_Sensor

Run #	No Effects	Full Effects	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	1280.99	1142.02	138.97	178.30	1546.99	**34.10**
2.00	1292.78	1082.57	210.21		1018.32	
3.00	1273.93	1079.37	194.56		264.39	
4.00	1267.11	1079.11	188.01		94.21	
5.00	1279.05	1100.92	178.13		0.03	
6.00	1251.16	1081.55	169.60		75.65	
7.00	1287.16	1079.83	207.33		842.70	
8.00	1301.90	1081.38	220.52		1782.26	
9.00	1280.85	1127.17	153.68		606.04	
10.00	1263.23	1060.65	202.58		589.34	
11.00	1279.33	1096.14	183.18		23.83	
12.00	1259.03	1058.44	200.59		496.92	
13.00	1258.70	1193.13	65.57		12708.24	
14.00	1272.67	1100.41	172.26		36.52	
15.00	1283.93	1063.20	220.73		1800.48	
16.00	1283.66	1089.07	194.58		265.10	
17.00	1293.64	1084.06	209.59		978.68	
18.00	1306.99	1100.33	206.66		804.24	
19.00	1240.94	1078.05	162.89		237.57	
20.00	1271.79	1094.98	176.80		2.25	
21.00	1256.79	1074.53	182.26		15.68	
22.00	1239.56	1116.96	122.60		3102.49	
23.00	1269.47	1089.76	179.71		2.00	
24.00	1242.06	1079.51	162.54		248.32	
25.00	1248.26	1072.57	175.69		6.81	
26.00	1234.35	1094.47	139.88		1476.12	
27.00	1257.66	1082.29	175.37		8.60	
28.00	1279.42	1095.58	183.84		30.67	
29.00	1287.80	1086.57	201.23		525.73	
30.00	1245.50	1076.04	169.46		78.20	
Averages:	**1269.66**	**1091.35**		SUM=	**29668.35**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**166.38**	**190.23**

Blue.USAFEUROPE.Sat1#1.B_Sat_EO_Sensor

Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	1280.99	1091.97	189.02	174.57	208.84	**18.10**
2.00	1292.78	1099.63	193.15		345.37	
3.00	1273.93	1088.26	185.67		123.31	
4.00	1267.11	1084.00	183.12		73.11	
5.00	1279.05	1089.57	189.48		222.22	
6.00	1251.16	1084.54	166.62		63.25	
7.00	1287.16	1096.40	190.75		261.93	
8.00	1301.90	1104.75	197.15		510.06	
9.00	1280.85	1064.16	216.69		1774.24	
10.00	1263.23	1104.90	158.33		263.59	
11.00	1279.33	1129.70	149.63		622.01	
12.00	1259.03	1081.26	177.77		10.23	
13.00	1258.70	1099.59	159.11		238.96	
14.00	1272.67	1084.30	188.37		190.54	
15.00	1283.93	1084.59	199.34		613.62	
16.00	1283.66	1153.34	130.32		1958.17	
17.00	1293.64	1105.61	188.03		181.17	
18.00	1306.99	1101.26	205.73		971.22	
19.00	1240.94	1105.64	135.30		1542.18	
20.00	1271.79	1081.27	190.52		254.42	
21.00	1256.79	1080.51	176.27		2.91	
22.00	1239.56	1076.77	162.79		138.64	
23.00	1269.47	1072.20	197.27		515.19	
24.00	1242.06	1091.44	150.61		573.84	
25.00	1248.26	1118.63	129.63		2019.49	
26.00	1234.35	1083.18	151.16		547.74	
27.00	1257.66	1096.35	161.31		175.91	
28.00	1279.42	1089.36	190.06		239.84	
29.00	1287.80	1106.07	181.73		51.34	
30.00	1245.50	1103.37	142.12		1052.82	
Averages:	**1269.66**	**1095.09**		SUM=	**15746.15**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**165.88**	**183.26**

Blue.USAFEUROPE.Sat1#1.B_Sat_EO_Sensor						
Run #	**No Effects**	**Weather Only**	**Z**	**Z bar**	**(Z-Z bar)^2**	**Var(Z bar)**
1.00	1290.71	1252.02	38.69	26.04	160.08	**34.22**
2.00	1259.56	1264.03	-4.47		930.46	
3.00	1274.63	1240.71	33.92		62.18	
4.00	1265.26	1281.97	-16.71		1827.56	
5.00	1283.17	1275.78	7.39		347.56	
6.00	1289.71	1280.87	8.84		295.54	
7.00	1307.49	1269.97	37.51		131.71	
8.00	1236.81	1204.33	32.48		41.51	
9.00	1289.30	1290.37	-1.07		734.82	
10.00	1248.63	1293.53	-44.91		5033.03	
11.00	1285.04	1212.83	72.21		2131.69	
12.00	1262.96	1245.39	17.57		71.67	
13.00	1295.55	1305.71	-10.15		1309.78	
14.00	1294.60	1231.13	63.47		1401.65	
15.00	1290.07	1238.28	51.79		663.42	
16.00	1285.23	1233.14	52.10		679.08	
17.00	1248.79	1253.39	-4.60		938.28	
18.00	1307.33	1229.46	77.88		2687.30	
19.00	1261.66	1259.42	2.24		566.23	
20.00	1284.45	1264.55	19.90		37.63	
21.00	1302.29	1247.59	54.70		821.55	
22.00	1284.47	1253.73	30.75		22.19	
23.00	1266.88	1273.06	-6.18		1037.72	
24.00	1297.42	1209.93	87.49		3776.14	
25.00	1278.43	1242.08	36.35		106.44	
26.00	1250.15	1185.01	65.15		1529.54	
27.00	1302.10	1242.26	59.84		1142.77	
28.00	1272.96	1258.05	14.91		123.87	
29.00	1304.11	1300.17	3.94		488.31	
30.00	1273.82	1273.76	0.06		674.85	
Averages:	**1279.79**	**1253.75**		SUM=	**29774.55**	

95% Test Stat: 2.04

		Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =		**14.09**	**37.98**

Average Detection Distances for All Four Cases

Blue.USAFEUROPE.Sat1#2.B_Sat_EO_Sensor						
Run #	**No Effects**	**Full Effects**	**Z**	**Z bar**	**(Z-Z bar)^2**	**Var(Z bar)**
1.00	1290.71	1123.98	166.73	176.66	98.65	**38.32**
2.00	1259.56	1098.34	161.22		238.32	
3.00	1274.63	1098.70	175.93		0.53	
4.00	1265.26	1093.18	172.08		21.01	
5.00	1283.17	1157.54	125.63		2603.62	
6.00	1289.71	1098.62	191.09		208.29	
7.00	1307.49	1062.81	244.68		4626.72	
8.00	1236.81	1073.21	163.60		170.58	
9.00	1289.30	1150.40	138.90		1425.72	
10.00	1248.63	1084.07	164.55		146.54	
11.00	1285.04	1082.16	202.88		687.35	
12.00	1262.96	1095.78	167.18		89.86	
13.00	1295.55	1092.53	203.03		695.28	
14.00	1294.60	1059.00	235.60		3473.76	
15.00	1290.07	1148.79	141.28		1251.83	
16.00	1285.23	1122.49	162.74		193.62	
17.00	1248.79	1118.79	130.01		2176.36	
18.00	1307.33	1076.14	231.19		2973.66	
19.00	1261.66	1089.62	172.04		21.32	
20.00	1284.45	1147.29	137.16		1560.14	
21.00	1302.29	1114.84	187.45		116.44	
22.00	1284.47	1121.36	163.11		183.55	
23.00	1266.88	1103.40	163.48		173.71	
24.00	1297.42	1056.31	241.11		4153.54	
25.00	1278.43	1130.26	148.18		811.20	
26.00	1250.15	1114.63	135.52		1692.16	
27.00	1302.10	1099.39	202.71		678.78	
28.00	1272.96	1086.69	186.27		92.31	
29.00	1304.11	1078.06	226.05		2439.85	
30.00	1273.82	1115.44	158.37		334.31	
Averages:	**1279.79**	**1103.13**		SUM=	**33339.02**	

95% Test Stat: 2.04

		Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =		**164.02**	**189.30**

Blue.USAFEUROPE.Sat1#2.B_Sat_EO_Sensor						
Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	1290.71	1098.29	192.42	164.00	807.62	**20.96**
2.00	1259.56	1108.86	150.71		176.69	
3.00	1274.63	1110.91	163.73		0.07	
4.00	1265.26	1078.71	186.55		508.36	
5.00	1283.17	1111.50	171.67		58.91	
6.00	1289.71	1122.67	167.04		9.27	
7.00	1307.49	1125.85	181.63		311.04	
8.00	1236.81	1116.70	120.11		1925.89	
9.00	1289.30	1110.70	178.60		213.28	
10.00	1248.63	1129.70	118.92		2031.76	
11.00	1285.04	1131.82	153.22		116.13	
12.00	1262.96	1128.44	134.52		869.20	
13.00	1295.55	1113.66	181.89		320.01	
14.00	1294.60	1135.69	158.92		25.84	
15.00	1290.07	1122.06	168.01		16.12	
16.00	1285.23	1179.46	105.77		3390.04	
17.00	1248.79	1110.12	138.67		641.39	
18.00	1307.33	1130.70	176.63		159.65	
19.00	1261.66	1100.54	161.11		8.32	
20.00	1284.45	1111.35	173.10		82.86	
21.00	1302.29	1100.54	201.75		1425.27	
22.00	1284.47	1103.09	181.38		302.24	
23.00	1266.88	1120.88	146.01		323.73	
24.00	1297.42	1118.46	178.96		223.77	
25.00	1278.43	1108.97	169.46		29.84	
26.00	1250.15	1119.14	131.01		1088.16	
27.00	1302.10	1092.02	210.08		2123.52	
28.00	1272.96	1093.85	179.11		228.44	
29.00	1304.11	1115.12	188.99		624.62	
30.00	1273.82	1123.86	149.96		196.97	
Averages:	**1279.79**	**1115.79**		SUM=	**18239.01**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**154.65**	**173.35**

Blue.USAFEUROPE.Sat1#2.B_Sat_EO_Sensor						
Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	1290.71	1229.25	61.46	18.05	1883.83	**75.10**
2.00	1259.56	1225.54	34.02		254.95	
3.00	1274.63	1259.52	15.11		8.64	
4.00	1265.26	1360.17	-94.92		12762.03	
5.00	1283.17	1286.88	-3.71		473.83	
6.00	1289.71	1309.83	-20.11		1456.68	
7.00	1307.49	1311.32	-3.84		479.14	
8.00	1236.81	1260.68	-23.87		1757.63	
9.00	1289.30	1280.22	9.08		80.57	
10.00	1248.63	1238.52	10.10		63.24	
11.00	1285.04	1178.53	106.51		7824.85	
12.00	1262.96	1210.43	52.53		1188.77	
13.00	1295.55	1311.74	-16.19		1172.57	
14.00	1294.60	1285.56	9.04		81.25	
15.00	1290.07	1345.33	-55.26		5374.35	
16.00	1285.23	1248.59	36.65		345.65	
17.00	1248.79	1202.18	46.62		815.80	
18.00	1307.33	1174.49	132.85		13177.17	
19.00	1261.66	1305.18	-43.53		3792.04	
20.00	1284.45	1270.24	14.21		14.77	
21.00	1302.29	1278.56	23.73		32.26	
22.00	1284.47	1262.97	21.50		11.89	
23.00	1266.88	1238.10	28.78		115.09	
24.00	1297.42	1187.21	110.20		8491.51	
25.00	1278.43	1254.24	24.19		37.69	
26.00	1250.15	1285.82	-35.67		2886.22	
27.00	1302.10	1273.19	28.92		118.03	
28.00	1272.96	1231.72	41.24		537.64	
29.00	1304.11	1281.47	22.64		21.01	
30.00	1273.82	1264.50	9.32		76.28	
Averages:	**1279.79**	**1261.73**		SUM=	**65335.36**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**0.36**	**35.75**

Average Detection Distances for All Four Cases

Blue.USAFEUROPE.USAF_CAOC#1.F15_SEADSqdn#5.F15E#1.AC_Elint						
Run #	**No Effects**	**Full Effects**	**Z**	**Z bar**	**(Z-Z bar)^2**	**Var(Z bar)**
1.00	46.77	30.96	15.80	-0.44	263.83	**7.93**
2.00	64.10	59.04	5.07		30.34	
3.00	40.17	43.65	-3.48		9.25	
4.00	41.88	49.72	-7.84		54.85	
5.00	34.35	32.81	1.54		3.91	
6.00	36.58	34.35	2.23		7.12	
7.00	35.49	44.31	-8.81		70.11	
8.00	50.00	21.63	28.37		830.04	
9.00	28.67	47.14	-18.47		325.14	
10.00	43.63	58.36	-14.73		204.33	
11.00	39.27	27.22	12.05		156.05	
12.00	40.56	39.81	0.75		1.41	
13.00	45.97	43.56	2.41		8.13	
14.00	41.97	29.41	12.56		168.88	
15.00	46.12	68.89	-22.77		498.63	
16.00	39.86	39.95	-0.09		0.12	
17.00	54.71	28.01	26.70		736.41	
18.00	40.55	33.72	6.83		52.88	
19.00	45.78	54.68	-8.90		71.66	
20.00	23.86	37.78	-13.92		181.83	
21.00	38.13	31.01	7.12		57.08	
22.00	48.78	45.49	3.30		13.95	
23.00	29.91	50.52	-20.61		406.82	
24.00	29.68	33.89	-4.21		14.25	
25.00	56.07	59.44	-3.37		8.58	
26.00	42.59	61.54	-18.95		342.62	
27.00	38.98	36.16	2.82		10.62	
28.00	47.54	27.48	20.06		420.28	
29.00	41.54		41.54		1762.21	
30.00	33.70	47.83	-14.13		187.57	
Averages:	**41.57**	**42.01**		SUM=	**6898.88**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-6.19**	**5.31**

Blue.USAFEUROPE.USAF_CAOC#1.F15_SEADSqdn#5.F15E#1.AC_Elint						
Run #	**No Effects**	**Terrain Only**	**Z**	**Z bar**	**(Z-Z bar)^2**	**Var(Z bar)**
1.00	46.77	47.42	-0.66	-6.56	34.89	**6.35**
2.00	64.10	58.42	5.69		150.04	
3.00	40.17	41.94	-1.76		23.04	
4.00	41.88	47.01	-5.13		2.05	
5.00	34.35	43.57	-9.22		7.08	
6.00	36.58	37.75	-1.17		29.09	
7.00	35.49	46.20	-10.70		17.14	
8.00	50.00	42.06	7.94		210.18	
9.00	28.67	45.67	-17.00		108.96	
10.00	43.63	55.00	-11.38		23.17	
11.00	39.27	57.92	-18.65		146.05	
12.00	40.56	58.65	-18.09		132.96	
13.00	45.97	38.56	7.41		195.32	
14.00	41.97	44.31	-2.33		17.87	
15.00	46.12	43.12	3.01		91.58	
16.00	39.86	46.87	-7.01		0.20	
17.00	54.71	59.75	-5.04		2.31	
18.00	40.55	43.28	-2.73		14.66	
19.00	45.78	24.10	21.68		797.62	
20.00	23.86	50.53	-26.67		404.15	
21.00	38.13	60.20	-22.08		240.66	
22.00	48.78	29.40	19.38		673.02	
23.00	29.91	48.65	-18.75		148.48	
24.00	29.68	64.77	-35.09		814.10	
25.00	56.07	34.43	21.64		795.37	
26.00	42.59	59.56	-16.96		108.21	
27.00	38.98	54.10	-15.12		73.30	
28.00	47.54	60.41	-12.87		39.79	
29.00	41.54	45.40	-3.86		7.31	
30.00	33.70	55.03	-21.33		218.17	
Averages:	**41.57**	**48.14**		SUM=	**5526.77**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-11.71**	**-1.41**

Blue.USAFEUROPE.USAF_CAOC#1.F15_SEADSqdn#5.F15E#1.AC_Elint

Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	46.77	54.74	-7.97	1.56	90.91	**9.55**
2.00	64.10	31.13	32.98		987.14	
3.00	40.17	34.85	5.33		14.17	
4.00	41.88	29.52	12.36		116.54	
5.00	34.35	36.39	-2.04		12.94	
6.00	36.58	44.68	-8.09		93.17	
7.00	35.49	28.55	6.94		28.94	
8.00	50.00	54.81	-4.81		40.56	
9.00	28.67	58.93	-30.27		1013.00	
10.00	43.63		43.63		1769.75	
11.00	39.27	58.70	-19.43		440.49	
12.00	40.56	34.65	5.91		18.92	
13.00	45.97	33.69	12.28		114.99	
14.00	41.97	40.11	1.86		0.09	
15.00	46.12	42.60	3.52		3.85	
16.00	39.86	32.44	7.42		34.33	
17.00	54.71	49.73	4.98		11.68	
18.00	40.55	31.88	8.67		50.55	
19.00	45.78	32.63	13.14		134.11	
20.00	23.86	32.04	-8.18		94.87	
21.00	38.13		38.13		1337.15	
22.00	48.78	23.71	25.07		552.85	
23.00	29.91	37.02	-7.12		75.30	
24.00	29.68	32.37	-2.70		18.12	
25.00	56.07	43.99	12.08		110.57	
26.00	42.59	42.65	-0.06		2.61	
27.00	38.98	55.51	-16.53		327.34	
28.00	47.54	24.46	23.08		463.16	
29.00	41.54	52.30	-10.76		151.90	
30.00	33.70	46.28	-12.58		200.09	
Averages:	**41.57**	**40.01**		SUM=	**8310.10**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-4.75**	**7.87**

Average Detection Distances for All Four Cases
Blue.USAFEUROPE.USAF_CAOC#1.F15_SEADSqdn#5.F15E#4.AC_Elint

Run #	No Effects	Full Effects	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	46.23	22.42	23.81	0.38	549.35	**17.72**
2.00	65.23		65.23		4206.54	
3.00	34.06	42.73	-8.67		81.86	
4.00	42.41	45.56	-3.15		12.40	
5.00	62.20	31.56	30.64		915.90	
6.00	32.40	45.16	-12.77		172.70	
7.00	37.54	44.63	-7.10		55.85	
8.00	36.39	22.04	14.35		195.21	
9.00		51.28	-51.28		2668.03	
10.00	36.39	56.06	-19.68		402.09	
11.00	39.41	36.67	2.74		5.58	
12.00	41.40	50.33	-8.93		86.55	
13.00	38.46	42.07	-3.61		15.87	
14.00	34.35	34.82	-0.47		0.72	
15.00	38.95	47.50	-8.56		79.80	
16.00	28.42	35.99	-7.57		63.12	
17.00	38.77	28.08	10.69		106.43	
18.00	41.57	42.12	-0.55		0.86	
19.00	40.44	52.84	-12.40		163.16	
20.00	26.38	39.72	-13.34		188.06	
21.00	54.48	31.24	23.25		523.17	
22.00	37.36	47.13	-9.78		103.07	
23.00	45.03	47.13	-2.10		6.11	
24.00	30.52	35.83	-5.31		32.31	
25.00	48.08	53.02	-4.94		28.21	
26.00	42.39	49.30	-6.91		53.12	
27.00	46.39		46.39		2117.17	
28.00	51.39	33.65	17.73		301.27	
29.00	48.07		48.07		2275.08	
30.00	34.84	37.79	-2.95		11.06	
Averages:	**41.36**	**40.99**		SUM=	**15420.66**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-8.22**	**8.97**

Blue.USAFEUROPE.USAF_CAOC#1.F15_SEADSqdn#5.F15E#4.AC_Elint

Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	46.23	50.32	-4.09	-2.15	3.79	**9.53**
2.00	65.23	32.08	33.15		1246.02	
3.00	34.06	40.60	-6.54		19.35	
4.00	42.41	50.68	-8.27		37.47	
5.00	62.20	25.27	36.92		1526.46	
6.00	32.40	34.43	-2.03		0.01	
7.00	37.54	46.48	-8.95		46.24	
8.00	36.39	36.61	-0.23		3.69	
9.00		39.43	-39.43		1389.93	
10.00	36.39	45.36	-8.97		46.64	
11.00	39.41	46.73	-7.32		26.77	
12.00	41.40	42.05	-0.65		2.25	
13.00	38.46	37.90	0.56		7.32	
14.00	34.35	35.65	-1.30		0.71	
15.00	38.95	22.97	15.98		328.45	
16.00	28.42	62.44	-34.01		1015.64	
17.00	38.77	53.61	-14.84		161.09	
18.00	41.57	49.38	-7.81		32.08	
19.00	40.44	42.96	-2.52		0.14	
20.00	26.38	50.90	-24.52		500.73	
21.00	54.48	64.66	-10.17		64.46	
22.00	37.36	25.87	11.49		185.93	
23.00	45.03	46.42	-1.38		0.58	
24.00	30.52	64.25	-33.73		997.49	
25.00	48.08	34.43	13.65		249.54	
26.00	42.39	40.03	2.36		20.30	
27.00	46.39	31.44	14.95		292.18	
28.00	51.39	61.31	-9.92		60.42	
29.00	48.07	49.16	-1.09		1.12	
30.00	34.84	41.86	-7.02		23.76	
Averages:	**41.36**	**43.51**		SUM=	**8290.56**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-8.45**	**4.16**

Blue.USAFEUROPE.USAF_CAOC#1.F15_SEADSqdn#5.F15E#4.AC_Elint

Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	46.23	34.60	11.63	3.07	73.29	**8.35**
2.00	65.23	25.63	39.61		1335.09	
3.00	34.06	45.47	-11.41		209.51	
4.00	42.41	39.61	2.81		0.07	
5.00	62.20	32.21	29.99		724.54	
6.00	32.40	42.39	-9.99		170.57	
7.00	37.54	36.92	0.62		6.00	
8.00	36.39	50.14	-13.76		283.17	
9.00		26.06	-26.06		848.60	
10.00	36.39	19.27	17.12		197.35	
11.00	39.41	51.61	-12.20		233.00	
12.00	41.40	43.33	-1.93		24.96	
13.00	38.46	21.89	16.57		182.43	
14.00	34.35	48.10	-13.75		282.94	
15.00	38.95	40.86	-1.92		24.87	
16.00	28.42	16.35	12.07		81.04	
17.00	38.77	51.08	-12.31		236.35	
18.00	41.57	28.27	13.30		104.63	
19.00	40.44	33.93	6.52		11.89	
20.00	26.38	39.12	-12.73		249.72	
21.00	54.48	36.86	17.62		211.77	
22.00	37.36	19.70	17.66		212.88	
23.00	45.03	61.53	-16.50		382.73	
24.00	30.52	38.13	-7.61		113.98	
25.00	48.08	43.18	4.90		3.37	
26.00	42.39	37.12	5.27		4.85	
27.00	46.39	55.81	-9.42		156.04	
28.00	51.39	25.43	25.95		523.74	
29.00	48.07	58.84	-10.76		191.33	
30.00	34.84	45.44	-10.60		186.87	
Averages:	**41.36**	**38.30**		SUM=	**7267.57**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-2.83**	**8.97**

Average Detection Distances for All Four Cases

Average Detection Distance Comparisons for All 6 F-15 AC_Elint Sensors

Run #	No Effects	Full Effects	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	43.53	22.10	21.43	0.49	438.52	**3.61**
2.00	63.81	59.08	4.73		17.94	
3.00	41.06	43.33	-2.27		7.64	
4.00	39.42	47.31	-7.90		70.43	
5.00	46.21	29.97	16.24		247.96	
6.00	44.24	34.32	9.92		88.86	
7.00	31.87	46.45	-14.57		226.98	
8.00	44.49	30.45	14.04		183.45	
9.00	32.29	41.10	-8.82		86.66	
10.00	44.65	57.24	-12.59		171.13	
11.00	42.24	38.77	3.47		8.86	
12.00	34.41	37.65	-3.24		13.95	
13.00	46.36	40.86	5.49		24.99	
14.00	36.34	35.20	1.15		0.43	
15.00	41.15	51.65	-10.50		120.85	
16.00	36.34	37.51	-1.17		2.76	
17.00	42.72	27.93	14.79		204.45	
18.00	39.41	38.44	0.97		0.23	
19.00	41.99	48.09	-6.10		43.52	
20.00	33.66	36.21	-2.56		9.32	
21.00	40.04	34.24	5.80		28.17	
22.00	36.55	43.54	-6.99		56.00	
23.00	42.88	45.46	-2.58		9.43	
24.00	33.02	29.42	3.60		9.63	
25.00	50.11	42.90	7.21		45.08	
26.00	45.27	53.95	-8.68		84.16	
27.00	46.76	43.97	2.79		5.28	
28.00	49.53	28.34	21.18		428.02	
29.00	43.87	62.21	-18.35		354.98	
30.00	33.35	45.05	-11.70		148.63	
Averages:	**41.58**	**41.09**		SUM=	**3138.30**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-3.39**	**4.37**

Average Detection Distance Comparisons for All 6 F-15 AC_Elint Sensors

Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	43.53	42.10	1.43	-3.07	20.24	**3.80**
2.00	63.81	44.42	19.40		504.82	
3.00	41.06	41.08	-0.02		9.33	
4.00	39.42	46.14	-6.73		13.38	
5.00	46.21	35.40	10.80		192.46	
6.00	44.24	41.23	3.01		37.00	
7.00	31.87	45.87	-14.00		119.45	
8.00	44.49	37.67	6.82		97.78	
9.00	32.29	47.27	-14.98		141.89	
10.00	44.65	47.15	-2.50		0.33	
11.00	42.24	42.81	-0.56		6.28	
12.00	34.41	46.91	-12.50		89.00	
13.00	46.36	38.38	7.98		122.11	
14.00	36.34	42.05	-5.71		6.98	
15.00	41.15	40.93	0.22		10.83	
16.00	36.34	48.32	-11.98		79.30	
17.00	42.72	53.66	-10.94		61.95	
18.00	39.41	45.91	-6.50		11.75	
19.00	41.99	34.44	7.55		112.80	
20.00	33.66	51.87	-18.21		229.29	
21.00	40.04	50.13	-10.09		49.23	
22.00	36.55	28.03	8.51		134.18	
23.00	42.88	48.82	-5.94		8.24	
24.00	33.02	59.99	-26.98		571.61	
25.00	50.11	37.32	12.79		251.43	
26.00	45.27	47.18	-1.91		1.34	
27.00	46.76	36.96	9.80		165.68	
28.00	49.53	61.48	-11.96		78.99	
29.00	43.87	46.28	-2.41		0.44	
30.00	33.35	49.85	-16.50		180.37	
Averages:	**41.58**	**44.66**		SUM=	**3308.47**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-7.05**	**0.91**

Average Detection Distance Comparisons for All 6 F-15 AC_Elint Sensors

Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	43.53	41.42	2.11	0.62	2.21	**3.13**
2.00	63.81	37.87	25.95		641.35	
3.00	41.06	39.02	2.04		2.00	
4.00	39.42	37.25	2.17		2.39	
5.00	46.21	40.05	6.16		30.65	
6.00	44.24	45.92	-1.68		5.33	
7.00	31.87	35.69	-3.82		19.75	
8.00	44.49	49.57	-5.08		32.53	
9.00	32.29	45.19	-12.90		182.97	
10.00	44.65	43.00	1.65		1.05	
11.00	42.24	54.51	-12.27		166.15	
12.00	34.41	43.71	-9.31		98.61	
13.00	46.36	24.64	21.71		444.73	
14.00	36.34	42.07	-5.73		40.34	
15.00	41.15	45.37	-4.23		23.52	
16.00	36.34	33.28	3.07		5.97	
17.00	42.72	48.20	-5.48		37.31	
18.00	39.41	30.76	8.65		64.38	
19.00	41.99	37.19	4.80		17.42	
20.00	33.66	37.30	-3.64		18.22	
21.00	40.04	46.07	-6.03		44.25	
22.00	36.55	29.06	7.49		47.11	
23.00	42.88	48.66	-5.78		40.96	
24.00	33.02	36.97	-3.95		20.93	
25.00	50.11	41.94	8.17		56.95	
26.00	45.27	43.21	2.06		2.05	
27.00	46.76	53.64	-6.88		56.29	
28.00	49.53	26.87	22.66		485.50	
29.00	43.87	46.97	-3.10		13.86	
30.00	33.35	43.43	-10.08		114.53	
Averages:	**41.58**	**40.96**		SUM=	**2719.30**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-2.99**	**4.23**

Average Detection Distances for All Four Cases
Blue.USAFEUROPE.USAF_CAOC#1.JSTARS#1.JSTARS_MTI

Run #	No Effects	Full Effects	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	71.95	63.47	8.47	0.21	68.30	**1.26**
2.00	59.44	65.78	-6.35		42.98	
3.00	61.11	67.75	-6.64		46.89	
4.00	68.71	69.91	-1.20		1.99	
5.00	65.08	58.96	6.12		34.91	
6.00	57.99	68.72	-10.73		119.68	
7.00	59.36	60.55	-1.19		1.96	
8.00	60.93	60.40	0.53		0.10	
9.00	62.85	65.42	-2.57		7.73	
10.00	59.76	63.81	-4.05		18.16	
11.00	68.20	59.07	9.14		79.67	
12.00	59.18	55.62	3.56		11.25	
13.00	66.24	64.53	1.71		2.26	
14.00	66.01	60.74	5.27		25.65	
15.00	68.69	58.69	10.01		95.97	
16.00	70.86	68.06	2.80		6.72	
17.00	62.49	76.11	-13.63		191.39	
18.00	59.36	64.91	-5.56		33.28	
19.00	70.36	56.48	13.88		186.86	
20.00	67.95	66.57	1.38		1.38	
21.00	66.59	61.42	5.17		24.62	
22.00	62.84	65.41	-2.57		7.72	
23.00	59.04	66.62	-7.58		60.60	
24.00	64.08	65.43	-1.34		2.41	
25.00	65.82	62.02	3.79		12.83	
26.00	70.29	70.15	0.14		0.00	
27.00	66.36	64.64	1.72		2.29	
28.00	60.89	63.77	-2.89		9.58	
29.00	61.04	60.72	0.32		0.01	
30.00	58.02	59.47	-1.46		2.78	
Averages:	**64.05**	**63.84**		SUM=	**1099.98**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-2.09**	**2.51**

Blue.USAFEUROPE.USAF_CAOC#1.JSTARS#1.JSTARS_MTI

Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	71.95	59.78	12.17	0.28	141.18	**1.83**
2.00	59.44	68.11	-8.67		80.17	
3.00	61.11	64.68	-3.57		14.87	
4.00	68.71	63.60	5.11		23.28	
5.00	65.08	69.10	-4.02		18.54	
6.00	57.99	72.78	-14.80		227.45	
7.00	59.36	62.09	-2.74		9.12	
8.00	60.93	73.28	-12.36		159.74	
9.00	62.85	52.48	10.37		101.66	
10.00	59.76	68.18	-8.42		75.72	
11.00	68.20	66.29	1.91		2.65	
12.00	59.18	57.64	1.54		1.58	
13.00	66.24	61.96	4.29		16.03	
14.00	66.01	55.42	10.59		106.30	
15.00	68.69	61.88	6.82		42.67	
16.00	70.86	58.69	12.17		141.29	
17.00	62.49	59.51	2.98		7.26	
18.00	59.36	60.88	-1.52		3.26	
19.00	70.36	67.00	3.36		9.49	
20.00	67.95	63.25	4.70		19.47	
21.00	66.59	65.69	0.90		0.38	
22.00	62.84	57.95	4.89		21.22	
23.00	59.04	66.87	-7.83		65.82	
24.00	64.08	66.53	-2.44		7.43	
25.00	65.82	61.46	4.36		16.57	
26.00	70.29	61.85	8.44		66.48	
27.00	66.36	68.70	-2.34		6.88	
28.00	60.89	74.46	-13.57		191.92	
29.00	61.04	64.54	-3.49		14.27	
30.00	58.02	58.32	-0.30		0.34	
Averages:	**64.05**	**63.77**		SUM=	**1593.04**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-2.48**	**3.05**

Blue.USAFEUROPE.USAF_CAOC#1.JSTARS#1.JSTARS_MTI

Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	71.95	59.63	12.31	-0.63	167.52	**1.41**
2.00	59.44	56.90	2.53		10.02	
3.00	61.11	60.79	0.32		0.90	
4.00	68.71	70.36	-1.65		1.03	
5.00	65.08	60.69	4.38		25.16	
6.00	57.99	54.20	3.79		19.51	
7.00	59.36	77.92	-18.56		321.58	
8.00	60.93	63.71	-2.78		4.62	
9.00	62.85	60.51	2.34		8.84	
10.00	59.76	64.74	-4.98		18.94	
11.00	68.20	74.00	-5.79		26.66	
12.00	59.18	56.62	2.56		10.17	
13.00	66.24	64.49	1.75		5.68	
14.00	66.01	67.42	-1.40		0.60	
15.00	68.69	69.98	-1.28		0.43	
16.00	70.86	59.89	10.97		134.58	
17.00	62.49	67.41	-4.92		18.39	
18.00	59.36	70.41	-11.06		108.74	
19.00	70.36	72.20	-1.84		1.45	
20.00	67.95	57.87	10.08		114.75	
21.00	66.59	67.80	-1.21		0.34	
22.00	62.84	59.19	3.64		18.29	
23.00	59.04	63.21	-4.17		12.50	
24.00	64.08	67.66	-3.58		8.69	
25.00	65.82	78.69	-12.88		149.92	
26.00	70.29	72.32	-2.03		1.95	
27.00	66.36	65.68	0.69		1.73	
28.00	60.89	63.37	-2.48		3.41	
29.00	61.04	57.89	3.15		14.29	
30.00	58.02	54.86	3.16		14.36	
Averages:	**64.05**	**64.68**		SUM=	**1225.04**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-3.05**	**1.79**

Average Detection Distances for All Four Cases

Blue.USAFEUROPE.USAF_CAOC#1.GlobalHawk#2.GH_EO_SAR

Run #	No Effects	Full Effects	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	24.70	24.67	0.03	-0.06	0.01	**0.00**
2.00	24.93	25.02	-0.09		0.00	
3.00	24.98	25.01	-0.03		0.00	
4.00	24.55	24.47	0.08		0.02	
5.00	24.67	24.58	0.08		0.02	
6.00	24.80	25.12	-0.31		0.06	
7.00	24.79	24.93	-0.14		0.01	
8.00	24.67	24.95	-0.28		0.05	
9.00	24.78	25.10	-0.32		0.06	
10.00	24.62	24.74	-0.12		0.00	
11.00	24.90	24.21	0.69		0.56	
12.00	24.80	24.61	0.19		0.06	
13.00	24.69	24.43	0.26		0.10	
14.00	24.72	24.96	-0.24		0.03	
15.00	24.98	24.92	0.05		0.01	
16.00	24.69	24.90	-0.21		0.02	
17.00	24.63	24.65	-0.02		0.00	
18.00	24.89	24.74	0.15		0.04	
19.00	24.57	25.15	-0.58		0.26	
20.00	24.61	25.01	-0.40		0.11	
21.00	24.96	24.96	0.00		0.00	
22.00	24.62	25.03	-0.41		0.12	
23.00	24.59	25.09	-0.50		0.19	
24.00	24.79	24.67	0.12		0.03	
25.00	24.78	24.73	0.06		0.01	
26.00	24.79	24.93	-0.14		0.01	
27.00	24.66	25.02	-0.36		0.09	
28.00	24.81	24.34	0.47		0.29	
29.00	24.96	24.50	0.46		0.27	
30.00	24.79	25.20	-0.41		0.12	
Averages:	**24.76**	**24.82**		SUM=	**2.59**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-0.18**	**0.05**

Blue.USAFEUROPE.USAF_CAOC#1.GlobalHawk#2.GH_EO_SAR

Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	24.70	24.83	-0.13	-0.06	0.01	**0.00**
2.00	24.93	24.77	0.15		0.05	
3.00	24.98	24.94	0.04		0.01	
4.00	24.55	24.84	-0.29		0.05	
5.00	24.67	24.87	-0.20		0.02	
6.00	24.80	24.80	0.00		0.00	
7.00	24.79	24.89	-0.09		0.00	
8.00	24.67	24.77	-0.10		0.00	
9.00	24.78	24.88	-0.10		0.00	
10.00	24.62	24.64	-0.02		0.00	
11.00	24.90	24.78	0.12		0.03	
12.00	24.80	24.83	-0.03		0.00	
13.00	24.69	24.71	-0.03		0.00	
14.00	24.72	24.80	-0.07		0.00	
15.00	24.98	24.77	0.21		0.07	
16.00	24.69	24.75	-0.06		0.00	
17.00	24.63	24.85	-0.22		0.03	
18.00	24.89	24.63	0.26		0.10	
19.00	24.57	24.90	-0.33		0.07	
20.00	24.61	25.08	-0.47		0.17	
21.00	24.96	24.95	0.02		0.01	
22.00	24.62	24.65	-0.03		0.00	
23.00	24.59	24.79	-0.20		0.02	
24.00	24.79	24.64	0.15		0.04	
25.00	24.78	24.74	0.05		0.01	
26.00	24.79	24.85	-0.06		0.00	
27.00	24.66	25.04	-0.37		0.10	
28.00	24.81	24.77	0.04		0.01	
29.00	24.96	24.83	0.13		0.04	
30.00	24.79	24.91	-0.11		0.00	
Averages:	**24.76**	**24.82**		SUM=	**0.85**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-0.12**	**0.00**

Blue.USAFEUROPE.USAF_CAOC#1.GlobalHawk#2.GH_EO_SAR

Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	24.70	24.55	0.15	0.13	0.00	**0.00**
2.00	24.93	24.34	0.58		0.20	
3.00	24.98	24.60	0.38		0.06	
4.00	24.55	24.70	-0.15		0.08	
5.00	24.67	24.64	0.02		0.01	
6.00	24.80	24.44	0.36		0.05	
7.00	24.79	24.20	0.59		0.21	
8.00	24.67	25.05	-0.38		0.26	
9.00	24.78	24.57	0.21		0.01	
10.00	24.62	24.94	-0.32		0.20	
11.00	24.90	25.18	-0.28		0.17	
12.00	24.80	24.47	0.33		0.04	
13.00	24.69	24.37	0.31		0.03	
14.00	24.72	24.49	0.23		0.01	
15.00	24.98	24.76	0.21		0.01	
16.00	24.69	24.70	-0.01		0.02	
17.00	24.63	24.70	-0.07		0.04	
18.00	24.89	24.95	-0.06		0.04	
19.00	24.57	25.08	-0.50		0.40	
20.00	24.61	24.76	-0.16		0.08	
21.00	24.96	24.33	0.63		0.25	
22.00	24.62	24.72	-0.10		0.05	
23.00	24.59	24.39	0.21		0.01	
24.00	24.79	24.91	-0.12		0.06	
25.00	24.78	24.40	0.38		0.06	
26.00	24.79	24.27	0.52		0.15	
27.00	24.66	24.39	0.27		0.02	
28.00	24.81	24.36	0.45		0.10	
29.00	24.96	24.51	0.45		0.10	
30.00	24.79	25.00	-0.21		0.12	
Averages:	**24.76**	**24.63**		SUM=	**2.86**	

95% Test Stat: 1.70

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**0.03**	**0.23**

Kill and Victim Data Analysis

Red SA and Radar Vans Victim Counts - TOTAL per run

Run #	No Effects	Full Effects	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	21	13	8.00	1.37	64.00	**0.68**
2.00	24	24	0.00		0.00	
3.00	13	24	-11.00		121.00	
4.00	24	21	3.00		9.00	
5.00	24	23	1.00		1.00	
6.00	24	16	8.00		64.00	
7.00	24	24	0.00		0.00	
8.00	22	24	-2.00		4.00	
9.00	22	23	-1.00		1.00	
10.00	24	21	3.00		9.00	
11.00	24	22	2.00		4.00	
12.00	23	17	6.00		36.00	
13.00	22	23	-1.00		1.00	
14.00	24	20	4.00		16.00	
15.00	19	19	0.00		0.00	
16.00	24	23	1.00		1.00	
17.00	24	22	2.00		4.00	
18.00	22	20	2.00		4.00	
19.00	20	24	-4.00		16.00	
20.00	24	23	1.00		1.00	
21.00	22	23	-1.00		1.00	
22.00	24	22	2.00		4.00	
23.00	22	13	9.00		81.00	
24.00	24	24	0.00		0.00	
25.00	23	16	7.00		49.00	
26.00	21	13	8.00		64.00	
27.00	21	21	0.00		0.00	
28.00	24	24	0.00		0.00	
29.00	16	22	-6.00		36.00	
30.00	24	24	0.00		0.00	
Averages:	**22.30**	**20.93**		SUM=	**591.00**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-0.32**	**3.05**

Red SA and Radar Vans Victim Counts - TOTAL per run

Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	21	19	2.00	0.13	4.24	**0.44**
2.00	24	18	6.00		36.71	
3.00	13	24	-11.00		119.70	
4.00	24	24	0.00		0.00	
5.00	24	22	2.00		4.24	
6.00	24	24	0.00		0.00	
7.00	24	24	0.00		0.00	
8.00	22	22	0.00		0.00	
9.00	22	21	1.00		1.12	
10.00	24	24	0.00		0.00	
11.00	24	24	0.00		0.00	
12.00	23	23	0.00		0.00	
13.00	22	23	-1.00		0.89	
14.00	24	17	7.00		49.83	
15.00	19	24	-5.00		24.41	
16.00	24	18	6.00		36.71	
17.00	24	24	0.00		0.00	
18.00	22	24	-2.00		3.77	
19.00	20	20	0.00		0.00	
20.00	24	21	3.00		9.36	
21.00	22	22	0.00		0.00	
22.00	24	22	2.00		4.24	
23.00	22	23	-1.00		0.89	
24.00	24	23	1.00		1.12	
25.00	23	22	1.00		1.12	
26.00	21	21	0.00		0.00	
27.00	21	24	-3.00		8.65	
28.00	24	21	3.00		9.36	
29.00	16	24	-8.00		63.06	
30.00	24	23	1.00		1.12	
Averages:	**22.30**	**22.17**		SUM=	**380.58**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-1.22**	**1.48**

Red SA and Radar Vans Victim Counts - TOTAL per run

Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	21	20	1.00	0.83	1.00	**0.70**
2.00	24	24	0.00		0.00	
3.00	13	24	-11.00		121.00	
4.00	24	19	5.00		25.00	
5.00	24	24	0.00		0.00	
6.00	24	16	8.00		64.00	
7.00	24	24	0.00		0.00	
8.00	22	21	1.00		1.00	
9.00	22	24	-2.00		4.00	
10.00	24	19	5.00		25.00	
11.00	24	24	0.00		0.00	
12.00	23	21	2.00		4.00	
13.00	22	19	3.00		9.00	
14.00	24	16	8.00		64.00	
15.00	19	20	-1.00		1.00	
16.00	24	23	1.00		1.00	
17.00	24	23	1.00		1.00	
18.00	22	24	-2.00		4.00	
19.00	20	24	-4.00		16.00	
20.00	24	18	6.00		36.00	
21.00	22	24	-2.00		4.00	
22.00	24	22	2.00		4.00	
23.00	22	21	1.00		1.00	
24.00	24	11	13.00		169.00	
25.00	23	24	-1.00		1.00	
26.00	21	24	-3.00		9.00	
27.00	21	23	-2.00		4.00	
28.00	24	22	2.00		4.00	
29.00	16	22	-6.00		36.00	
30.00	24	24	0.00		0.00	
Averages:	**22.30**	**21.47**		SUM=	**609.00**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-0.88**	**2.54**

Kill and Victim Data Analysis

Brown Houses Victim Counts - TOTAL per run

Run #	No Effects	Full Effects	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	8	5	3.00	-2.20	9.00	**1.08**
2.00	10	9	1.00		1.00	
3.00	6	11	-5.00		25.00	
4.00	2	8	-6.00		36.00	
5.00	7	9	-2.00		4.00	
6.00	7	4	3.00		9.00	
7.00	6	7	-1.00		1.00	
8.00	8	8	0.00		0.00	
9.00	7	4	3.00		9.00	
10.00	6	8	-2.00		4.00	
11.00	8	7	1.00		1.00	
12.00	10	7	3.00		9.00	
13.00	8	7	1.00		1.00	
14.00	4	7	-3.00		9.00	
15.00	2	8	-6.00		36.00	
16.00	7	6	1.00		1.00	
17.00	1	3	-2.00		4.00	
18.00	9	7	2.00		4.00	
19.00	4	6	-2.00		4.00	
20.00	7	8	-1.00		1.00	
21.00	8	10	-2.00		4.00	
22.00	7	7	0.00		0.00	
23.00	7	8	-1.00		1.00	
24.00	6	7	-1.00		1.00	
25.00	6	5	1.00		1.00	
26.00	0.00	6	-6.00		36.00	
27.00	0.00	9	-9.00		81.00	
28.00	0.00	5	-5.00		25.00	
29.00	0.00	7	-7.00		49.00	
30.00	0.00	24	-24.00		576.00	
Averages:	**5.37**	**7.57**		SUM=	**942.00**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-4.33**	**-0.07**

Brown Houses Victim Counts - TOTAL per run

Run #	No Effects	Terrain Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	8	5	3.00	-0.40	9.36	**0.29**
2.00	10	7	3.00		9.36	
3.00	6	7	-1.00		0.89	
4.00	2	10	-8.00		63.06	
5.00	7	4	3.00		9.36	
6.00	7	7	0.00		0.00	
7.00	6	6	0.00		0.00	
8.00	8	8	0.00		0.00	
9.00	7	7	0.00		0.00	
10.00	6	7	-1.00		0.89	
11.00	8	5	3.00		9.36	
12.00	10	6	4.00		16.48	
13.00	8	9	-1.00		0.89	
14.00	4	7	-3.00		8.65	
15.00	2	5	-3.00		8.65	
16.00	7	7	0.00		0.00	
17.00	1	5	-4.00		15.53	
18.00	9	11	-2.00		3.77	
19.00	4	8	-4.00		15.53	
20.00	7	7	0.00		0.00	
21.00	8	5	3.00		9.36	
22.00	7	3	4.00		16.48	
23.00	7	5	2.00		4.24	
24.00	6	5	1.00		1.12	
25.00	6	6	0.00		0.00	
26.00	0.00	3	-3.00		8.65	
27.00	0.00	2	-2.00		3.77	
28.00	0.00	6	-6.00		35.30	
29.00	0.00	0	0.00		0.00	
30.00	0.00	0	0.00		0.00	
Averages:	**5.37**	**5.77**		SUM=	**250.69**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-1.50**	**0.70**

Brown Houses Victim Counts - TOTAL per run

Run #	No Effects	Weather Only	Z	Z bar	(Z-Z bar)^2	Var(Z bar)
1.00	8	5	3.00	-0.43	9.00	**0.41**
2.00	10	8	2.00		4.00	
3.00	6	6	0.00		0.00	
4.00	2	8	-6.00		36.00	
5.00	7	9	-2.00		4.00	
6.00	7	4	3.00		9.00	
7.00	6	7	-1.00		1.00	
8.00	8	3	5.00		25.00	
9.00	7	7	0.00		0.00	
10.00	6	6	0.00		0.00	
11.00	8	8	0.00		0.00	
12.00	10	6	4.00		16.00	
13.00	8	8	0.00		0.00	
14.00	4	6	-2.00		4.00	
15.00	2	7	-5.00		25.00	
16.00	7	11	-4.00		16.00	
17.00	1	9	-8.00		64.00	
18.00	9	7	2.00		4.00	
19.00	4	7	-3.00		9.00	
20.00	7	6	1.00		1.00	
21.00	8	1	7.00		49.00	
22.00	7	5	2.00		4.00	
23.00	7	5	2.00		4.00	
24.00	6	6	0.00		0.00	
25.00	6	7	-1.00		1.00	
26.00	0.00	5	-5.00		25.00	
27.00	0.00	7	-7.00		49.00	
28.00	0.00	0	0.00		0.00	
29.00	0.00	0	0.00		0.00	
30.00	0.00	0	0.00		0.00	
Averages:	**5.37**	**5.80**		SUM=	**359.00**	

95% Test Stat: 2.04

	Lower Limit	Upper Limit
Confidence Interval: W bar +/- Test Stat*SQRT(Var(W Bar)) =	**-1.75**	**0.88**

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14. ABSTRACT

Significant technological advances over the past few decades have fueled the continual and rapid development of an information-based world. Network Centric Warfare (NCW) has become the buzzword of the young millennium within the Department of Defense (DoD) and is quickly becoming a popularly shared vision and rallying cry for force transformation among United States military leaders. An essential element in fully implementing this network-centric way of thinking is to develop useful measures to help gauge the effectiveness and efficiency of both our military networks and our strategic NCW doctrine. The goal of this research is first to provide a comprehensive summary of the key literary works that have forged a foundational basis for defining NCW. Second, this work will utilize a System Effectiveness Analysis Simulation (SEAS) combat model, which represents a Kosovo-like engagement (provided by the Space and Missile Center), to serve as a tool in exploring the use of NCW metrics in military worth analysis. Third and last, this effort selects measures for the physical, information, and cognitive domains of NCW and analyzes the outputs from the Kosovo scenario that are pertinent to each domain in order to assess the usefulness of each metric. In the final analysis, the average target detection distance outputs and average communication channel message loading metrics chosen for the physical and information domains yielded mixed results and levels of utility, while the highly aggregated metric of target kills served as a useful, and yet rough, final metric for the cognitive domain.

15. SUBJECT TERMS

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