SEARCHING FOR ORDER WITHIN CHAOS: COMPLEXITY THEORY'S IMPLICATIONS TO INTELLIGENCE SUPPORT DURING JOINT OPERATIONAL PLANNING

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Clausewitz uses the analogy of an object balanced between three magnets to describe the balance of war between the dominant tendencies within the paradoxical trinity. In effect, Clausewitz's trinity describes war as a nonlinear phenomenon. Thus, one is able to consider warfare as a dynamical system with the implication it is unpredictable. As a dynamical system that exhibits emergence, adaptability, and self-organization; warfare is well suited to be analyzed as a complex adaptive system. In the effort to understand complex systems, Chaos and Complexity Theories have been developed. As Complexity Theory subsumes Chaos Theory, Complexity Theory techniques have been evaluated to identify potential utilization during joint intelligence analysis. Although joint intelligence analysis describes analyzing systems from a holistic systems perspective, most analytic techniques are reductionist in nature. Complexity Theory engenders a holistic view with the consideration that the sum of a complex adaptive system is greater than the sum of the parts. With this in mind, Complexity Theory has been analyzed to identify concepts and techniques that would benefit the joint intelligence analyst during joint operational planning.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

SEARCHING FOR ORDER WITHIN CHAOS: COMPLEXITY THEORY'S IMPLICATIONS TO INTELLIGENCE SUPPORT DURING JOINT OPERATIONAL PLANNING, by Major Ricardo S. Flores, 80 pages.

Clausewitz uses the analogy of an object balanced between three magnets to describe the balance of war between the dominant tendencies within the paradoxical trinity. In effect, Clausewitz's trinity describes war as a nonlinear phenomenon. Thus, one is able to consider warfare as a dynamical system with the implication it is unpredictable. As a dynamical system that exhibits emergence, adaptability, and self-organization; warfare is well suited to be analyzed as a complex adaptive system. In the effort to understand complex systems, Chaos and Complexity Theories have been developed. As Complexity Theory subsumes Chaos Theory, Complexity Theory techniques have been evaluated to identify potential utilization during joint intelligence analysis. Although joint intelligence analysis describes analyzing systems from a holistic systems perspective, most analytic techniques are reductionist in nature. Complexity Theory engenders a holistic view with the consideration that the sum of a complex adaptive system is greater than the sum of the parts. With this in mind, Complexity Theory has been analyzed to identify concepts and techniques that would benefit the joint intelligence analyst during joint operational planning.

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complexity in action. You three mean the world to me and your hard work in school inspires me more than you know. Moreover, to my parents, Gunnery Sergeant Ricardo Flores Sr. U.S. Marine Corps, Retired and Jacqueline Flores, thank you for life, encouragement, and your self-sacrifice. The care you continue to show our family goes beyond words and imagination. No matter where we are in the world, we always know who to call for support.

TABLE OF CONTENTS

ACRONYMS

ATP	Army Techniques Publication
AWFC	Army Warfighting Challenges
CATFOREM	Combined Arms and Support Task Force Evaluation Model
COA	Course of Action
CoE	Center of Excellence
COG	Center of Gravity
EINSTein	Enhanced ISAAC Neural Simulation Tooklkit
FCC	Functional Combatant Command
GCC	Geographic Combatant Command
IPB	Intelligence Preparation of the Battlefield/Battlespace
JCATS	Joint Conflict and Tactical Simulations
JFC	Joint Force Commander
JIPOE	Joint Intelligence Preparation of the Operating Environment
JP	Joint Publication
JTF	Joint Task Force
MAGTF	Marine Air-Ground Task Force
MCRP	Marine Corps Reference Publication
MCTP	Marine Corps Tactics Publication
MEF	Marine Expeditionary Force
OneSAF	One Semi-Automated Forces
PMESII	Political, Military, Economic, Social, Infrastructure, and Information

ILLUSTRATIONS

TABLES

CHAPTER 1

INTRODUCTION

> Our task therefore is to develop a theory [of war] that maintains the balance between these three tendencies, like an object suspended between three magnets.
>
> — Carl von Clausewitz, *On War*

Overview

Clausewitz uses the analogy of an object balanced between three magnets to describe the balance of war between the dominant tendencies within the paradoxical trinity (Clausewitz 1984, 89). In effect, Clausewitz's paradoxical trinity describes war as a nonlinear and chaotic phenomenon. Thus, one is able to consider war as a chaotic system with the implication it is unpredictable since it is sensitive to initial conditions the span of which can never be fully understood or measured (Waldrop 1993, 142). Considering war as a chaotic system, however, does little to facilitate wartime operational planning.

Although seemingly chaotic, war and its outcomes can be analyzed as the interactions of dynamically complex systems. Within complexity theory, uncertainty is again inherent because of the self-organization and emergence characteristics associated with complex systems (Mitchell 2009, 13). However, complexity theory may provide a better framework to understand and analyze the interactions of complex systems.

To aid in the commander's decision making, the commander employs his staff—particularly the intelligence warfighting function—to evaluate the effects of the adversary, terrain, and weather. In this role, intelligence's primary objective "is to support decisionmaking [sic] by reducing uncertainty" (Department of the Navy 1997b, 5). Considering that warfare is unpredictable, seemingly chaotic and complex, how can military intelligence reduce uncertainty to support wartime planning? What insights from complexity theory can aid intelligence's analysis of the operating environment? These are a few of the questions analyzed in this thesis.

Primary Research Question

From a traditional intelligence analysis perspective, the military intelligence analyst uses an analytic framework described in phases of analysis, synthesis, and estimation (Department of the Navy 2016, 1-4). Within the analysis phase of the analytic framework, the military intelligence analyst identifies key elements with the battlespace to formulate hypotheses regarding the enemy and the environment to ultimately identify relevant conclusions regarding the effects of terrain, weather and enemy action against friendly force operations. The method of formulating and testing hypotheses is referred to as deductive reasoning and is a logical analytic methodology for an intelligence analyst to use to satisfy intelligence requirements. However, it is unclear whether this framework is the most effective methodology to analyze all systems.

Clausewitz's three-magnet analogy for a proposed theory of war would today be viewed as an analogy of a chaotic system. This does not, however, imply that the techniques currently used by military intelligence analysts are not applicable for analysis of a chaotic or complex system. Nor does it imply that unawareness of chaos or complexity theories leads to a poor analysis of a problem. Therefore, to further understand the problem the researcher will answer the primary research question, "Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?" It should be noted that joint intelligence analysis is directed to analyze the operating environment from a systems perspective using the subsystems of Political, Military, Economic, Social, Infrastructure, and Information (PMESII) during the Joint Intelligence Preparation of the Operational Environment (JIPOE) process (Department of Defense 2014, III-33). Although the JIPOE process acknowledges the use of a systems perspective to analyze the operating environment, there is no discussion of how the dynamic relationships and interactions within the systems can alter both the analysis and potential outcomes. This thesis examines if complexity theory techniques allow an intelligence analyst to describe the operating environment and the interactions between systems more effectively.

Secondary Research Questions

To answer my primary research question, "Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?" the answers to secondary questions must be analyzed. Analyzing these secondary research questions will be conducted in a logical progression of inquiry from the roots of complexity theory, to the techniques derived from complexity theory, current U.S. military intelligence analysis techniques, and finally to advantages or disadvantages of the application of complexity theory techniques during intelligence analysis.

The secondary research questions answered in this thesis are:

1. What is complexity theory and how does it view systems?
2. What are the complexity theory techniques used to analyze complex systems?

3. What doctrinal techniques are used by military intelligence analysts to analyze systems?
4. What complexity theory techniques can be used during joint intelligence analysis?

The secondary research questions provide a systematic approach to analyze and answer the primary research question. The findings of the secondary research questions, when aggregated, ultimately lead to the answering of the primary research question, the development of conclusions, and the proposal of recommendations for both commanders and for future researchers.

First, it must be determined what complexity theory is. To understand how complexity theory techniques may potentially be adapted for use in intelligence analysis, an understanding of the theory itself is required. This is critical, as the implementation of any change without the understanding of the basis for the change would be irresponsible. If the techniques derived from complexity theory are used in intelligence analysis, the analyst should know why.

Next, the researcher will analyze the complexity theory techniques used to analyze complex systems. Before an examination of how the techniques derived from complexity theory can be utilized in intelligence analysis can be conducted, an examination of the techniques must first be identified. Like many theories, complexity theory is likely to have multiple approaches. Further, there will likely be different problem-solving techniques used on different types of systems—ecological, mechanical, or otherwise. After understanding the various complexity theory techniques used to analyze complex systems study of their use in solving military problems will be completed.

As previously identified, the JIPOE process directs intelligence analysts to describe the operating environment in terms of a systems perspective. It is possible that the pertinent complexity theory techniques are already integrated into the JIPOE process and no changes will be needed to the methods in which intelligence analysis is currently conducted. Therefore, once the researcher examines various complexity theory techniques, an examination of the techniques currently used in military doctrine will be conducted. The goal of this examination is to identify the current methods and techniques used within military intelligence doctrine. Further, an examination of how they may be similar or different from complexity theory techniques is necessary.

After the examination of complexity theory and current military intelligence doctrine techniques, the researcher will conduct an analysis of the use of complexity theory techniques during military intelligence analysis. The pursuit of integrating new and interesting theoretical models should not be for the sake of change. Instead, there should be a benefit associated with any additional tasks or changes. Additionally, the researcher will analyze potential risks and benefits of executing complexity theory techniques. If complexity theory techniques are useful during intelligence analysis of the operational environment but are difficult to employ than it may not be practical to implement a change to current doctrine. Likewise, it would also prove impractical to recommend a change to current intelligence doctrine if complexity theory techniques and current intelligence doctrine techniques resulted in the same, or similar, analysis of a military problem.

Assumptions

There are a few assumptions that will be discussed in order to provide the proper framework as it applies to the primary research questions. These assumptions provide the context for my primary research question to be answered. Further, these assumptions provide a focus that will allow the research question to be answered within that context. The assumptions, however, may serve as additional areas for future research that will be discussed in chapter 5.

First, this thesis assumes that complexity theory and the complexity theory techniques used to analyze complex systems are not already integrated and used within current U.S. military intelligence doctrine and practice. Currently, U.S. joint intelligence and planning doctrine direct intelligence and operational planners to analyze operational environments using a systems perspective (Department of Defense 2011, III-10). It is assumed that although a systems perspective is used in Joint doctrine it does not necessarily imply a direct relationship to systems theory or any other nonlinear theory. It is unclear if a nonlinear theory serves as the basis for the systems perspective usage in joint doctrine. It appears that it is an analytical reductionist technique—although it espouses to be a holistic analytic technique— to analyze nodes and links within a proposed system. Systems theory and other nonlinear theories refuse a reductionist view and emphasize a holistic analysis must be conducted to identify new and emergent behavior within the system (Bertalanffy 1993, 55). Regardless, this assumption will be further explored in chapter 2 as the nature of analytical modeling in U.S. intelligence doctrine will be further examined.

The second assumption is that intelligence analysis of the operational environment is a critical necessity to facilitate staff understanding during joint operational planning. JIPOE is the principal product provided by the intelligence warfighting function to the joint force staff (Department of Defense 2014, I-1). Below the operational level, the U.S. Army and U.S. Marine Corps provide Intelligence Preparation of the Battlefield (IPB) products to support tactical planning (Department of the Army 2015, 2-2). If the outcome of the operational planning process—whether at the operational or tactical level—is independent of the intelligence products provided, then the analytic methods in which the intelligence is produced is trivial.

Lastly, it is assumed that military planning processes are capable of solving dynamically complex problems. If military planning processes are not capable of solving complex problems, then insight provided by intelligence regarding the operational environment is inconsequential to the outcome of the operation. For the purpose of this thesis, it will be assumed that military planning processes are capable of solving complex problems. Further, it is accepted that a principle purpose of intelligence to reduce uncertainty and support the commander's decision making in the effort to achieve the commander's desired end state—results. Therefore, the methods in which intelligence describe the operational environment—complex systems—are intrinsically tied to resulting outcomes.

Definitions and Terms

Complex Adaptive System: "a system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolutions" (Mitchell 2009, 13).

Complex Systems Theory: "the study of the behavior of [complex adaptive] systems" (Ilachinski 2004, 4). For the purpose of this thesis there is no distinct difference between complex systems theory and complexity theory; see definition below.

Complexity Theory: The study of complex systems, "the study of how critically interacting components self-organize to organize potentially evolving structures exhibiting a hierarchy of emergent systems properties" (Couture 2007, 19).

Dynamical system: "The word dynamic means changing, and dynamical systems are systems that change over time in some way" (Mitchell 2009, 15).

Linear dynamical system: a system in which "any external disturbance induces a change in the system that is proportional to the magnitude of the disturbance. In other words, small changes to the input result in correspondingly small changes to the output" (Ilachinski 2004, 2).

Nonlinear dynamical system: a system for which the "proportionality between input and output does not necessarily hold. In nonlinear systems, therefore, arbitrarily small inputs may lead to arbitrarily large output" (Ilachinski 2004, 2).

Limitations and Delimitations

Although the research conducted in preparation for this thesis has been comprehensive, a key limitation to this thesis is the time constraints imposed in which this thesis will be completed. The time constraint has focused the research on the analysis of secondary sources. Additionally, there is limited literature regarding the application of complexity theory concepts during military planning—specifically limited in literature that links the direct use of complexity theory to military operational success. There are, however, a number of scholarly articles that describe the potential connection and application of complexity theory concepts to military planning.

As the title suggests, the focus of this thesis will be on the U.S. Joint Force operational planning by a U.S. Joint Force Command (JFC) headquarters. Within the JFC the thesis will specifically focus on the intelligence actions executed by the J2 Intelligence Directorate in support of joint operational planning—JIPOE. Hence, the thesis will be focused on actions by the J2 within Geographic Combatant Commands (GCC), Subordinate Unified (Sub-Unified) Commands, and Joint Task Forces (JTF).

Functional Combatant Commands (FCC) are not explicitly included in the thesis as the focus of the thesis is the effect of complexity theory techniques on joint operational planning against an adversary. Although FCCs conduct joint operational planning, their operations—in the context of ground combat—are assumed to serve in a supporting role to the GCC, Sub-Unified Command, or JTF. Additionally, although a number of varying formations may serve as the nucleus for a JTF, this thesis will focus on joint operational planning for ground combat operations. Therefore, the JTF options will be limited to the preferred U.S. Army Corps or U.S. Marine Corps Marine Expeditionary Force (MEF).

For the purposes of this thesis doctrinal intelligence publications will be limited to Joint Publication (JP) 2-01.3 *Joint Intelligence Preparation of the Operational Environment*, Army Techniques Publication (ATP) 2-01.3 *Intelligence Preparation of the Battlefield*—which is a dual service publication and also known as Marine Corps Reference Publication (MCRP) 2-3A *Intelligence Preparation of the Battlespace*—ATP 2-33.4 *Intelligence Analysis*, and Marine Corps Tactics Publication (MCTP) 2-10B

MAGTF Intelligence Production and Analysis. Although there may be additional references used by intelligence analysts within the Joint Force, the above-listed publications serve as the core doctrinal references for intelligence analysis within the U.S. Army and U.S. Marine Corps. As the core references, they are the foundation intelligence training curriculum throughout both services. Although additional references, material, or techniques may be utilized by an intelligence analyst working within the Joint Force, those items would be in addition to the core references.

Army Warfighting Challenges

Army Warfighting Challenges (AWFCs) are, "Enduring first-order problems, the solutions to which improve the combat effectiveness of the current and future force" (Department of the Army 2017, 1). The AWFCs are mechanisms for various elements throughout the U.S. Army and Joint Force to contribute to a core challenge within the current and future operating environment. Further, the AWFCs and the contributions to solving them ensure that the largest net possible is cast to identify relevant views and bottom-up feedback. Although any branch can contribute solutions to the AWFCs, each AWFC is maintained by a lead warfighting Center of Excellence (CoE).

This results of this thesis will provide input to the solution for AWFC #1: Develop Situational Understanding. AWFC #1 is described as, "How to develop and sustain a high degree of situational understanding while operating in complex environments against determined, adaptive enemy organizations" (Department of the Army 2017, 1). The lead U.S. Army agency for AWFC #1 is the Intelligence CoE. This thesis acknowledges that current and future operating environments are and will remain complex and that intelligence support is a necessity for success in complex environments.

As such, this thesis intends to identify if alternative intelligence analysis techniques, specifically techniques developed from complexity theory, would provide improved situational understanding in support of operations.

Chapter Conclusion

The next chapter, chapter 2, will provide the background information to inform the analysis of the secondary research questions:

1. What is complexity theory and how does it view systems?
2. What are the complexity theory techniques used to analyze complex systems?
3. What doctrinal techniques are used by military intelligence analysts to analyze systems?
4. What complexity theory techniques can be used during joint intelligence analysis?

Exploration and answering the secondary research questions and evaluating the results will support and inform the answer to the primary research question, "Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?"

CHAPTER 2

LITERATURE REVIEW

> Complex-systems scientists, when asked, "What's a complex system?" usually reply: "Look out the window!" Clouds, mountains, rivers, the whole jumbled and surprising landscape of our world, are expressions of what results from unpredictable interactions.
>
> — Joshua Cooper Ramo, *The Age of the Unthinkable*

Chapter Introduction

A literature review is the initial step to answering the primary research question, "Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?" The purpose of the literature review is to set the foundation to explore and analyze the secondary research questions. Subsequently, the analysis conducted during the literature review will support answering the secondary research questions within chapter 4. Additionally, the secondary research questions will be analyzed against evaluation criteria which ultimately supports answering the primary research question.

This literature review will follow a thematic outline which will directly support answering the secondary research questions. To begin, the literature review will explore complexity theory and how this theory views complex systems. Without a foundational understanding of complexity theory, it will be difficult to make a judgment as to the applicability of the theory to other disciplines. Next, the literature review will explore the techniques utilized within complexity theory. Understanding the complexity theory techniques and how they are used to analyze complex systems will be necessary to assess the applicability of the techniques to varying problem sets and systems.

Once complexity theory and its techniques have been explored, the literature review will study current doctrinal joint intelligence techniques used to analyze operational problems. As previously mentioned in chapter 1, a systems perspective analysis is already integrated within JIPOE. It is, however, critical to understand if and how the current joint intelligence techniques differ from complexity theory techniques.

From Chaos to Complexity

A linear system is one in which the system is simply the sum of its parts while a nonlinear system is one in which the system is "different from the sum of the parts" (Mitchell 2009, 22). Understanding the type of system being evaluated is a critical first step. The techniques used to evaluate a linear system will likely not work on a nonlinear system. This is because the evaluation of a linear system attempts to determine cause-and-effect where the evaluation of a nonlinear system should attempt to determine "cascading effects" (Williams 2004, 40). Therefore, one must first consider the type of system being evaluated before applying techniques to analyze it.

Warfare is not a linear phenomenon. The military theorist, Carl von Clausewitz, describes the phenomenon by saying, "[war] is not the action of a living force upon a lifeless mass (total nonresistance would be no war at all) but always the collision of two living forces" (Clausewitz 1984, 77). Similarly, Clausewitz's description of the paradoxical trinity and his analysis of "friction" and "chance" further describes the interactive nature of warfare (Beyerchen 1993, 72). Through these metaphors, Clausewitz illustrates warfare as the dynamic interactions within a complex system (Leonard 2001, 14). Thus, warfare should be analyzed as a nonlinear phenomenon making accurate predictions of warfare's outcomes difficult, if not impossible.

During the exploration and study of nonlinear systems, chaos theory was developed. Clausewitz may not have anticipated what is now termed chaos theory; nevertheless, his explanation of "competing and interactive factors" describe warfare as a nonlinear system which would require a theory beyond what was available to Clausewitz in the 1800s (Beyerchen 1993, 70). Within chaos theory, a defining concept is that even minor errors in the measurement of the system will result in large deviations in long-term prediction; this is known as "sensitive dependence on initial conditions" (Mitchell 2009, 20). Again, warfare is dominated—either in metaphor or in theory—by the almost obvious idea that it is unpredictable. This realization, however, does little to support analysis of war or to facilitate the evaluation of its outcomes.

To assist in the understanding and analysis of chaotic systems, complexity theory was developed. As stated by Dale Lichtblau et al., "Complexity theory is the attempt to organize and guide the study of complex interactions and the emergent properties they engender. Complexity theory subsumes chaos theory (i.e., all chaotic systems are complex, but not vice versa)" (Lichtblau et al. 2006, 18). Therefore, complexity theory may provide insight into the chaotic system of war and aid in the identification of possible long-term outcomes.

In the evaluation of complex systems, Peter Senge proposes two different types of complexities: detail complexity and dynamic complexity (Senge 2006, 71). Detail complexity applies to systems where there are many variables but the interactions between the variables have limited to no freedom of action outside of their pre-set actions. As a result of this limited freedom, analysis of the individual components within a detail complex system can provide a greater understanding of the whole system—detail complex systems can be analyzed using conventional analytic models. Dynamic complexity applies to systems where the interactions between components are not restricted which allows for emergent structure and behavior (Waldrop 1992, 148-149). In dynamically complex systems, a holistic analysis of the system must be utilized as conventional analytic methods are inadequate (Williams 2004, 52).

Complexity Theory Analysis Techniques

Many systems are complex in that they have many components interacting within them. Two basic types of complexity have already been discussed within this chapter, detail complexity and dynamic complexity. A commercial jet is an example of a detail complex system. Although it has many moving components, the components within the aircraft have been engineered to have limited freedom of action, thus the components interact a certain way each time or else a failure in the system occurs. In the commercial jet system, the individual components can be separated from the system and individually analyzed to determine how they will perform within the system. Thus, conventional analytic techniques of observing individual components and their relationship to other components within the system allow an engineer to determine and model the performance of the resulting aircraft. The same technique, however, of observing individual components may not have the same effectiveness in analyzing dynamically complex systems.

In an analysis of complex systems, dynamically complex systems are sometimes referred to as complex adaptive systems. Complex adaptive systems "are dynamic systems able to adapt and change within, or as part of, a changing environment" (Moffat 2003, 50). Ilachinski notes that land—ground—combat is a complex adaptive system stating, "land combat is essentially a nonlinear dynamical system composed of many interacting semi-autonomous and hierarchically organized agents continuously adapting to a changing environment" (Ilachinski 1996b, 2). Table 1 lists the key features of complex systems and their related land combat description as described by Ilachinski.

Two computer simulation techniques have been proposed to facilitate analysis of complex adaptive systems that may provide insight to ground combat: combat simulations using cellular automata modeling and agent-based modeling (Ilachinski 1996b, 97-98). Both cellular automata and agent-based modeling are forms of experimental mathematics used to describe dynamic behavior (Moffat 2003, 16). Although these techniques may provide insight into potential outcomes in warfare it has already been noted within this chapter that long-term predictions are difficult, if not impossible.

Table 1. Land Combat as a Complex Adaptive System	
General Property of Complex Systems	Description of Relevance to Land Combat
Nonlinear Interaction	Combat forces composed of a large number of nonlinearly interacting parts; sources include feedback loops in C2 hierarchy, interpretation of (and adaption to), enemy actions, decision making process and elements of chance.
Networks of Agents	Military organizations consist of many agents and meta agents, including individual combatants, squad leaders, company commanders, . . ., joint forces, etc.
Non-reductionist	The overall "fighting ability" of a combat force is not a simple aggregate function of the fighting ability of individual combatants.
Bounded Rationality	Individual combatants have neither infinite resources nor operate in an environment with infinite information; they are constrained to choose their actions quickly, locally and use bounded information.
Emergent Behavior	The global patterns of behavior on the combat battlefield unfold, or emerge, out of nested sequences of local interaction rules and doctrine.
Hierarchical structure	Combat forces organized in a command and control hierarchy.
Decentralized Control	There is no master "oracle" dictating the actions of individual combatants; the course of battle is ultimately dictated by the aggregate of local decisions.
Self-organization	Combat, which often appears "chaotic" locally, displays long-range order.
Nonequilibrium Order	Military conflicts, by their nature, proceed far from equilibrium; understanding how combat unfolds is more important than knowing the "end state."
Adaptation	In order to survive, combat forces must continually adapt to a changing environment.
Micro:Macro Feedback Loops Autopoiesis	There is a continual feedback between the behavior of (low-level) combatants and the (high-level) command structure While the identity of squads, fire-teams, and the entire echelon of authority constantly changes over time, a structured fighting force and C2 structure remains intact; self-organized, autopoietic structures constantly arise in firefights and skirmishes on the battlefield.

Source: Andrew Ilachinski, *Artificial War: Multiagent-Based Simulation of Combat* (River Edge, NJ: World Scientific, 2004), 13.

Cellular Automata Modeling

Cellular automata models are simple models created using a "large number of identical, simple, locally interacting components" (Ilachinski 1997a, 74). Each cellular automata model is created to fit the specific system requirements for the model it intends to represent. Each cellular automata is a "form of a machine with rules from getting from an initial to a final state" (Dockery and Woodcock 1993, 234). Regarding cellular automata in combat simulation Ilachinski observes,

> If one abstracts the essentials of what happens on a battlefield, ignoring the myriad layers of detail that are, of course, required for a complete description, one sees that much of the activity appears to involve the same kind of simple nearest-neighbor interactions that define cellular automata. . . highly elaborate patterns of military force-like behavior can be generated with a small set of cellular automaton-like rules. (Ilachinski 1997b, 97)

Cellular automata, however, are created with the idea of limiting the number of variables to the greatest extent possible. Thus, the simple cellular automata models created lack sufficient detail to accurately predict every divergent outcome that would arise from a model that included increased options. Significantly, cellular automata models can be used to identify potential patterns—potential outcomes—from previous conflicts that may assist the intelligence analyst in identifying indicators of adversary action.

Cellular automata modeling has been able to replicate some aspects of small-scale combat (Dockery and Woodcock 1993, 234). For example, cellular automata modeling was able to accurately simulate combat with six sets of mathematical rules or conditions that included: (1) situation assessment rules, (2) movement rules, (3) combat assessment rules, (4) hierarchical control rules, (5) substrate rules and (6) the cellular automata battlefield (Dockery and Woodcock 1993, 237-243, 273-274). An example of these rules is provided in figure 1. Applying these rules and conditions, researchers are able to replicate historic military battles with limited variables and conditions on the terrain which limited actions. Further, researchers are able to apply changes within the rules to simulate changes in tactics and rerun the simulation to observe changes in outcomes based on new inputs.

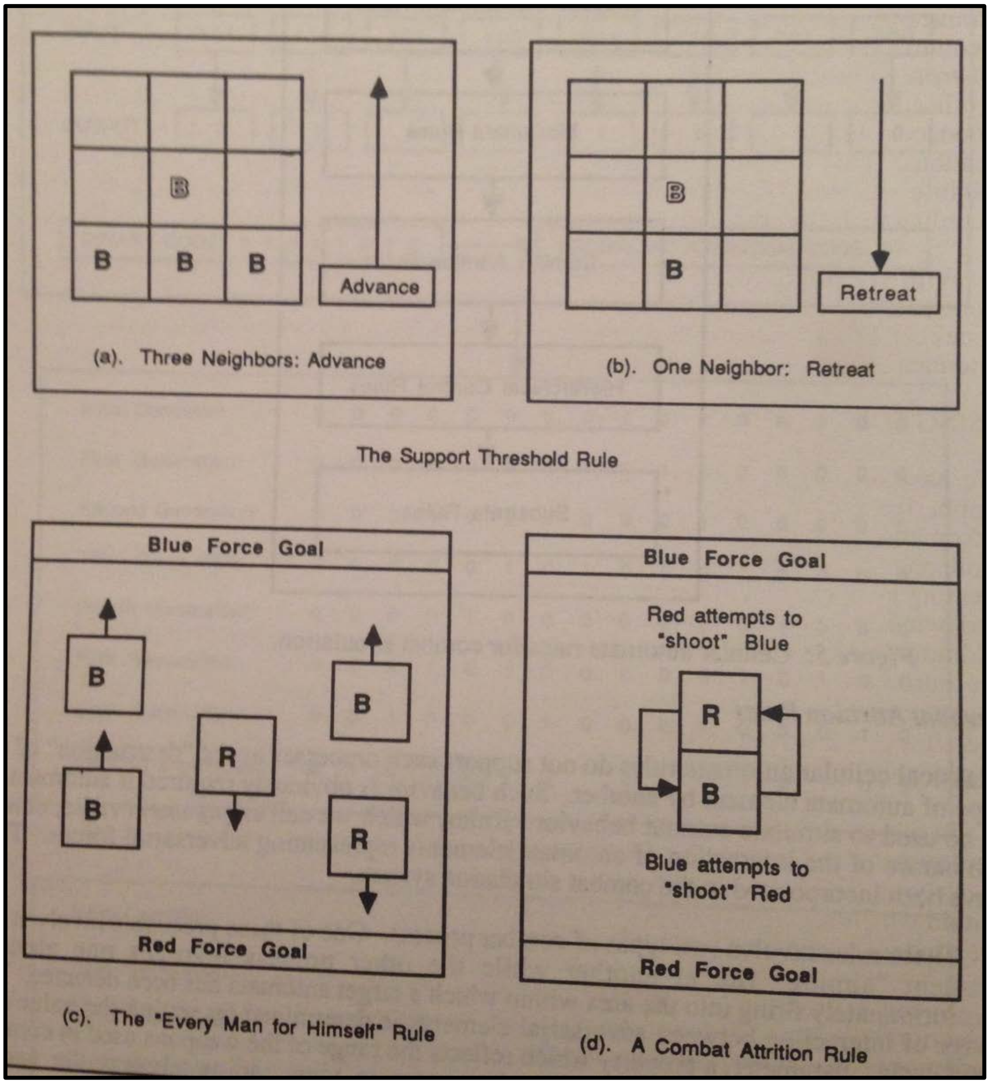

Figure 1. An Example of Cellular Automata Rules.

Source: John T. Dockery and A. E. R. Woodcock, *The Military Landscape: Mathematical Models of Combat* (Cambridge: Woodhead Publishing 1993), 240.

Agent-Based Modeling

Similar to cellular automata modeling, agent-based modeling—sometimes referred to as agent-based simulation or multiagent-based simulation—attempts to simulate real-life behavior by following specific rules depending on their individual perspectives. Unlike cellular automata modeling where cells react according to their immediate neighbors, agents within an agent-based model act in accordance with their internal rules in relation to the simulation's other entities and environmental properties (Lichtblau et al. 2006, 13). In regard to combat modeling and simulation, Ilachinski explains,

> . . .agent-based simulations represent a fundamental shift from focusing on simple force-on-force attrition calculations to considering how complex, high-level properties and behaviors of combat emerge out of (sometimes evolving) low-level rules of behaviors and interactions. In general, the conceptual focus of agent-based models is on finding a set of low-level rules defining the local behavior of individual agents; the collective action of these agents determines the dynamics of the whole system. (Ilachinski 2004, 48)

In essence, the use of agent-based models has potential to exhibit emergent behavior with the use of low-level rules and defining of local behavior.

Similar to cellular automata, agents within an agent-based model take action within the environment and receive feedback as shown in figure 2. The basis for any agent-based model is the agent's action-selection logic. In general, the action taken by the agent must coincide and be the best solution to achieve the agent's objective. The most important distinction between cellular automata modeling and agent-based modeling is that agents interact not only with the conditions within the environment but with the other agents themselves. The ability to interact provides the agents the opportunity to work together to achieve shared goals.

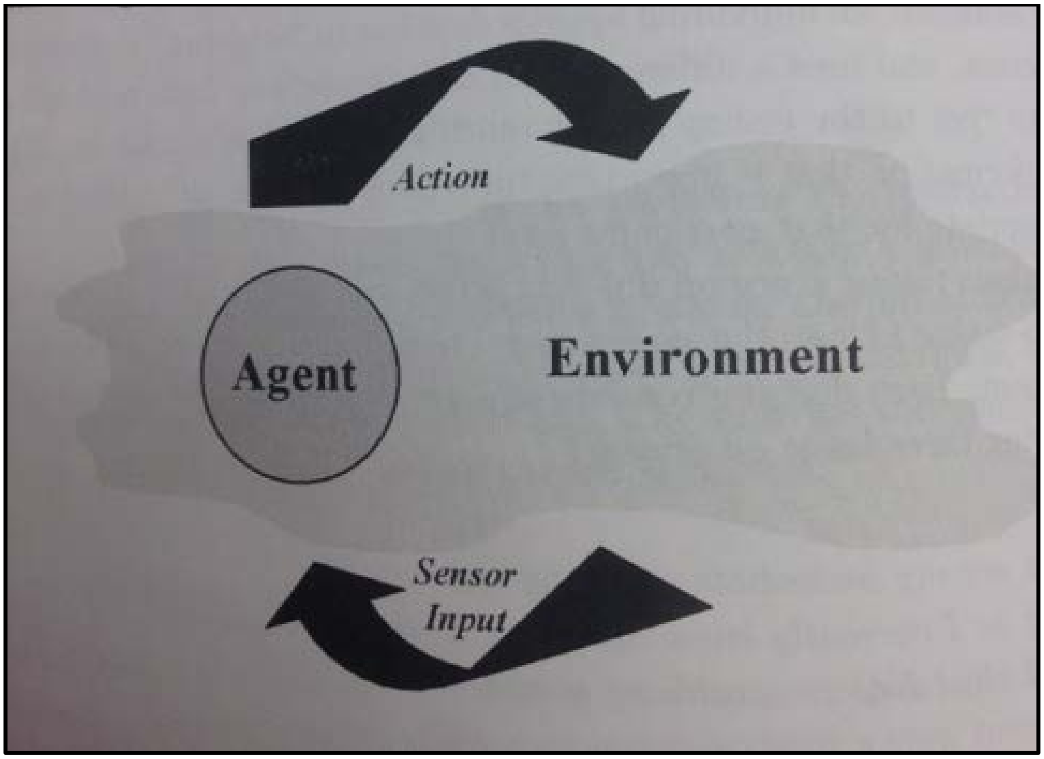

Figure 2. Basic Elements of an Agent-Based Model

Source: Andrew Ilachinski, *Artificial War: Multiagent-Based Simulation of Combat* (River Edge, NJ: World Scientific, 2004), 224.

Although entities within the agent-based model have a more life-like interaction with the environment and other entities when compared to the individual cells within a cellular automata model, the agents are still bound by specific rules and lack the ability to choose alternatives other than the goals already scripted. Although seemingly deterministic, Fredlake and Wang identify that "multiagent-based models, based on the mathematics of cellular automata, offer a novel approach to combat problems that analysts should not ignore" (Fredlake and Wang 2008, 53). Therefore, an agent-based model is likely to more closely represent the interactions of individuals within a complex system than cellular automata modeling alone.

Current Doctrinal Intelligence Techniques

In support of joint planning, intelligence analysts conduct JIPOE which is a four-step process that includes:

1. Define the operational environment
2. Describe the impact of the operational environment
3. Evaluate the adversary and other relevant actors
4. Determine the course of action (COA) for adversary and other relevant actors, particularly the most likely COA and the COA most dangerous to friendly forces and mission accomplishment (Department of Defense 2014, I-1).

As described, JIPOE is conducted to identify the adversary's intent and most like COA. The JIPOE publication acknowledges a holistic view of the operating environment is required to understand the operating environment. As illustrated in figure 3, the JIPOE publication specifies that the holistic view of the operational environment is comprised of (1) Physical Areas and Factors, (2) the Information Environment, and (3) Systems.

Because of the complexity of the operational environment, a holistic view is required to identify the various conditions within the operational environment that may affect Joint Force operations and mission accomplishment. In the analysis of the adversary, as an element of the military subsystem of PMESII, the JIPOE publication recommends the use of a systems perspective that identifies nodes and links through the use of an association matrix to create a link diagram (Department of Defense 2014, III-48, IV-5). Further, it is identified that the use of the systems perspective can provide insight into the adversary's center of gravity (COG) by conducting analysis of the critical factors within the link diagram to identify the "relationship between a COG's critical capabilities, requirements, and vulnerabilities" (Department of Defense 2014, IV-14). Following the methods prescribed in the JIPOE publication, the analyst is able to begin analysis of the adversary as a system.

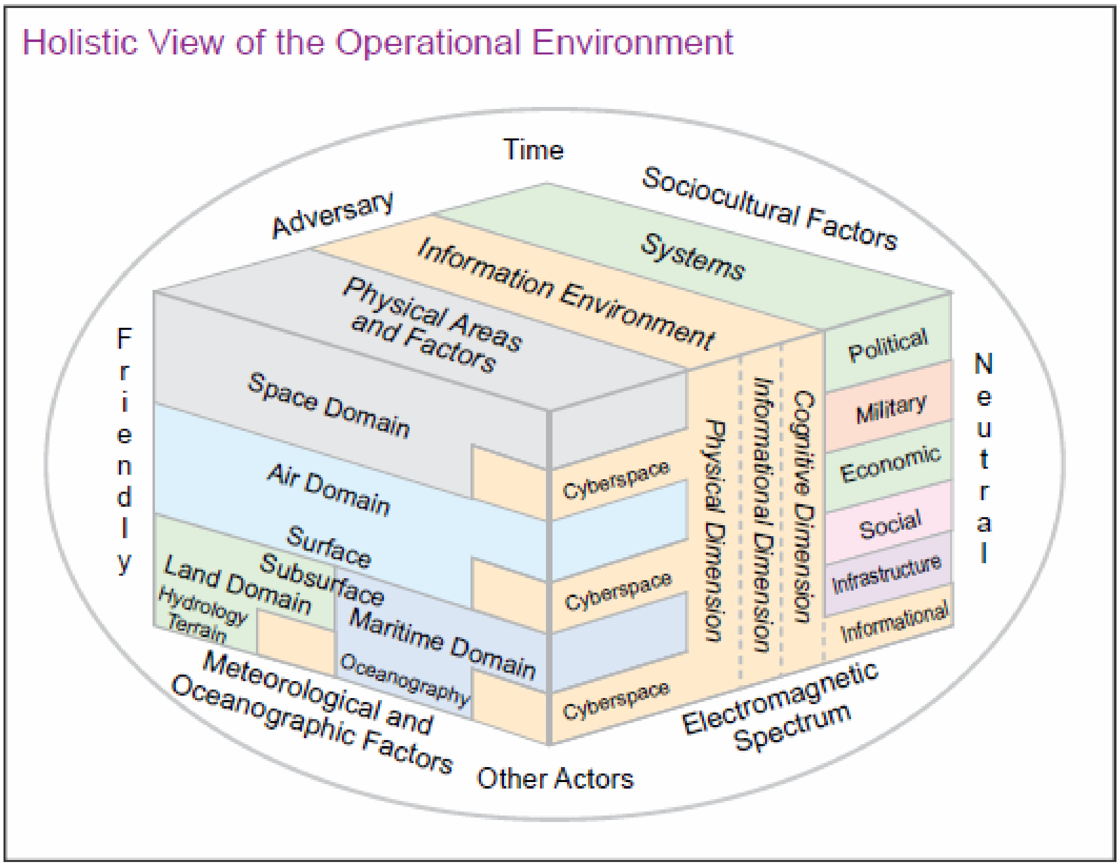

Figure 3. Holistic View of the Operational Environment

Source: Department of Defense, Joint Publication 2-01.3, *Joint Intelligence Preparation of the Operational Environment* (Washington, DC: Joint Staff, 2014), I-3.

Below the Joint Force level, both the U.S. Army and the U.S. Marine Corps use the IPB process to evaluate the effects of weather, terrain, and the adversary against friendly courses of action. As a result of the IPB process, the intelligence analysts are able to provide the following products necessary to support planning (Department of the Army 2015, I-4):

1. Enemy situation overlays with associated course of action statements and high-value target lists.
2. Event templates and associated event matrices.
3. Modified combined obstacle overlays, terrain effects matrices, and terrain assessments.
4. Weather forecast charts, weather effects matrices, light and illumination tables, and weather estimates.
5. Civil considerations overlays and assessments.

The development of these products can be supported by automated systems but are often done with limited computer tools or analytic software. The above products, as well as other items produced during IPB and the decision-making process, support the time intensive steps of course of action analysis and orders development. The emphasis on thorough JIPOE and IPB as a requirement for effective staff planning and mission accomplishment cannot be understated.

Chapter Conclusion

The literature review provides the foundation for exploring and answering the secondary research questions. During the literature review, the researcher was able to identify a larger amount of literature regarding both chaos and complexity theories and their application during the analysis of complex systems. There has been, however, limited literature available regarding the use of complexity theory during the conduct of intelligence analysis. Therefore, it will be incumbent on the researcher to evaluate potential uses of complexity theory techniques within current intelligence analytic methodologies. In total, this preliminary research will facilitate the evaluation of the secondary research questions which will be presented during chapter 4 and ultimately lead to answering the primary research question. The next chapter, chapter 3, will provide the outline for the research methodology that will be utilized within this thesis to answer the primary research question.

CHAPTER 3

RESEARCH METHODOLOGY

> Accordingly, whenever we attempt to do work or take action inside a [closed] system—a concept and its match-up with reality—we should anticipate an increase in entropy, hence an increase in confusion and disorder.
>
> — John R. Boyd, *Destruction and Creation*

Chapter Introduction

To complete this thesis a systematic step-wise approach will be utilized to answer the primary research question, “Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?” The methods within the systematic approach include a review of the literature and an application of evaluation criteria. Answering the primary research question will be facilitated through the evaluation of the answers to the secondary questions.

This chapter will describe, in detail, the process in which the primary research question will be answered. Specific evaluation criteria will be defined and the research method will be justified to support why the selected evaluation criteria are correct in order to make recommendations for commanders and future researchers. The secondary research questions will be analyzed and evaluated using a set of evaluation criteria developed to determine the answer to the primary research question. Once the secondary questions have been analyzed and evaluated, an answer to the primary research question will be determined with any potential caveats. Lastly, based on the results of the research and the conditional answer to the primary research question, conclusions and future research recommendations will be provided.

Evaluation Criteria

The primary research question is preceded by the word “should.” As such, the answer to the primary research question will be conditional. Although this thesis has been delimited to include only intelligence analysts on a joint staff during ground combat operations, the number of variables and conditions that could apply to joint ground combat operations are too great to list. Therefore, the evaluation criteria will be used not only to facilitate answering the primary research question but to also provide insight to any conditional factors associated with the answer.

The primary research question’s use of the word “should” indicates there may be a number of alternatives other than the use of complexity theory techniques to conduct intelligence analysis in support of joint operational planning. Within that perspective, this thesis and the primary research question seeks to examine if complexity theory techniques are applicable to intelligence analysis during joint operational planning. The degree to which complexity theory techniques may or may not be applicable will be determined by examination of the secondary research questions against evaluation criteria.

The degree of applicability of complexity theory techniques to intelligence analysis during joint operational planning will be determined through the application of the evaluation criteria. Table 2 depicts the selected criteria that will be used to determine if the use of complexity theory techniques have “low applicability,” have “moderate applicability,” or have “high applicability.” First, each secondary research question will be evaluated individually with the results presented in chapter 4. The applicability level of complexity theory techniques to intelligence analysis during joint operational planning and the conditions of that applicability will be discussed in chapter 5.

Table 2. Response Evaluation Criteria

Secondary Research Question	Low Applicability (1 point)	Moderate Applicability (2 points)	High Applicability (3 points)
1) What is complexity theory and how does it view systems?			
2) What are the complexity theory techniques used to analyze complex systems?			
3) What doctrinal techniques are used by military intelligence analysts to analyze systems?			
4) What complexity theory techniques can be used during joint intelligence analysis?			

Source: Developed by author.

For complexity theory technique use during intelligence analysis, applicability will be measured against three important factors. First, the results of the techniques should provide increased understanding of the operational environment to support staff planning answering information requirements. Second, the technique results should be repeatable each time the technique is used while analyzing a specific problem. Third, the technique should be simple enough to be conducted without the need for additional software or hardware.

Any element that challenges the first or second factors—regardless of the result of the third factor—will be considered to have "low applicability." Regardless of the ease of use of an analytic technique, if the results do not support an increased understanding of the operational environment then the technique can be considered of little use. If the results from the use of the technique provide inconsistent results or produce results that cannot be replicated, the use of the technique may provide limited support to enhance the understanding of the operational environment. Any element that challenges only the third factor will be considered to have "moderate applicability." If the element demonstrates that it provides an increased understanding of the operational environment with consistent results but would require additional software or hardware for its effective use, then it could be estimated that in the future, the use of the technique might be practical. Lastly, should an element not challenge any of the three key factors it will be considered to have "high applicability." If all key factors are satisfactorily met, then it would demonstrate to be effective, consistent, and usable without the need for additional computing resources.

As discussed in chapter 1, the secondary research questions will be used as criteria during a systematic methodology for answering the primary research question. For that reason, answering the secondary research will provide insight into the conditional nature of the answer to the primary research question. Understanding the conditions associated with the primary research question is important as the primary research question supposes that there is a potentially superior alternative than current practices. During chapter 4, each criterion will be evaluated and provided justification for its placement on a tri-range scale: low applicability (one point), moderate applicability (two points), and high applicability (three points). Once each criterion has been evaluated, the scores will be aggregated and the highest score will identify the applicability based on evaluation criteria. Additionally, in chapter 4 the conditional nature of the applicability of complexity theory techniques during intelligence analysis during joint operational planning will be further discussed as it pertains to answering the primary research question.

Research Methodology

The following is the step-wise approach that will be used to answer the primary research question:

Step 1: The first step in the research design will be to conduct a review of the literature to establish a foundation to explore and analyze the secondary research questions in the following steps. This literature review will be in chapter 2.

Step 2: The second step in the research design will be to analyze the first secondary research question against the evaluation criteria. The results of this analysis will be presented in chapter 4.

Step 3: The third step in the research design will be to analyze the second secondary research question against the evaluation criteria. The results of this analysis will be presented in chapter 4.

Step 4: The fourth step in the research design will be to analyze the third secondary research question against the evaluation criteria. The results of this analysis will be presented in chapter 4.

Step 5: The fifth step in the research design will be to analyze the fourth secondary research question against the evaluation criteria. The results of this analysis will be presented in chapter 4.

Step 6: The sixth step in the research design will be to aggregate the analysis from steps two through five. The results of the aggregation will be applied to answer the primary research question. The answer to the primary research question and any conditions will be presented in chapter 4.

Step 7: Finally, the last step in the research design will be to provide the conclusions and recommendations for both commanders and future research in chapter 5.

Threats to Validity and Biases

As with all research projects, there are threats to validity that must be identified and mitigated to ensure the conclusions presented are without logical errors which would "undermine the meaningfulness of research" (Garson 2016). One such threat against the validity is the test of internal validity known as the Hawthorn effect. The Hawthorn effect undermines the conclusions due to the researcher's actions contaminating the outcomes (Garson 2016). This will be mitigated in this thesis by purposefully searching for literature with varying perspectives and conclusions. Further, no conclusions will be drawn until all the data has been aggregated and analyzed fully.

Another threat to validity is the test of contextual external validity where the data presented is questioned to be used out of context or forced into a rigid context where it could apply in a broader sense (Garson 2016). This will be mitigated by analyzing the outcomes in the broadest sense possible and explicitly identifying within the research where additional contexts are present. Additionally, when alternative explanations for the results are possible, they will be explicitly acknowledged.

The nucleus of this thesis is centered on the actions of intelligence analysts supporting the operational planning for ground combat operations. As a U.S. Marine Corps Intelligence Officer, the researcher may have both cultural and personal bias which may influence a specific outcome for this research. The threat of a cultural or personal bias undermining the conclusions from this thesis will be mitigated by using peer reviews of the conclusions by non-U.S. Marine and non-intelligence personnel to provide assistance in validating the logic of the conclusions. Although threats to validity and bias can never be completed removed, identifying the threats to validity and biases early in the research process and establishing a plan to mitigate them will assist in preventing them from undermining the end result.

Chapter Conclusion

Utilization of the step-wise approach for research methodology will facilitate answering the primary research question through the aggregation of analysis from the secondary research questions. Further, previous identification of limitations and delimitations from chapter 1 and the threats to validity and biases identified within this chapter provide the environmental frame in which the research is to be conducted. Finally, the review of the literature and application of the evaluation criteria against the secondary research questions will provide the data necessary to answering the primary research question, "Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?"

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

> Unfortunately, most systems analyses focus on detail complexity not dynamic complexity.
>
> — Peter M. Senge, *The Fifth Discipline*

Chapter Introduction

This chapter will provide the presentation of the analysis conducted in order to answer the primary research question, "Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?" Through the course of this study, the literature review and research methodology allow for the analysis of the secondary research questions and ultimately the primary research question. As described in the step-wise methodology in chapter 3, the remainder of this chapter will provide the presentation and analysis of the research's findings.

As described in chapter 3, the applicability of complexity theory within intelligence analysis will be analyzed and evaluated along three important factors. First, the results of the techniques should provide increased understanding of the operational environment to support staff planning answering information requirements. Second, the technique results should be repeatable each time the technique is used while analyzing a specific problem. Third, the technique should be simple enough to be conducted without the need for additional software or hardware.

Any element that challenges the first or second factors—regardless of the result of the third factor—will be considered to have “low applicability.” Regardless of the ease of use of an analytic technique, if the results do not support an increased understanding of the operational environment than it is of little use. Further, if the results from the use of the technique provide inconsistent results or produce results that cannot be replicated, they are of limited use in facilitating an enhanced understanding of the operational environment. Any element that challenges only the third factor will be considered to have “moderate applicability.” If the element demonstrates that it provides an increased understanding of the operational environment with consistent results but would require additional software or hardware for its effective use, then it could be estimated that in the future the use of the technique might be practical. Lastly, should an element not challenge any of the three key factors it will be considered to have “high applicability.” If all key factors are satisfactorily met, then it would demonstrate to be effective, consistent, and usable without the need for additional computing resources.

Step 1: Summary of the Literature Review

As presented in chapter 2, a literature review was conducted to establish a foundation based on the current body of knowledge from which to explore and analyze the secondary research questions. The literature review was presented thematically to allow the researcher to conduct an in-depth analysis of the secondary research questions, which will ultimately lead to answering the primary research question. As part of the step-wise methodology, the following steps in this chapter will use the insights from the literature review to analyze and answer the secondary research questions.

<u>Step 2: Analysis of the First Secondary Research Question</u>

To answer the primary research question, it is first necessary to determine what complexity theory is and how it view systems. Therefore, the first secondary research question is “What is complexity theory and how does it view systems?” To evaluate how complexity theory techniques may be applied to intelligence analysis, the theory must be understood and analyzed to identify potential application within intelligence analysis.

Complexity Theory

Complexity science is “the attempt to organize and guide the study of complex interactions and the emergent properties they engender” (Lichtblau et al. 2006, 18). The identification of the emergent properties—emergence—within a complex system is an important aspect of complexity theory. As identified by Ilachinski, “emergence refers to properties of the whole that are not possessed by, nor are directly derivable from, any of the system’s part” (Ilachinski 2004, 108). Within the study of complex systems, the central focus is on the identification of its emergent properties rather than on a system’s organization or solely on the properties of the individual elements within the system. The identification of the behavior of the individual parts and their relationship within the system may, however, provide insight into the emergent properties of the system (Bertalanffy 1993, 55). In the context of analyzing an adversary, the identification of interactions and emergent behavior assist the analysis in evaluating potential adversary courses of action.

Not all complex systems demonstrate emergence as a property or system behavior. This is because not all complex systems provide freedom of movement or action of the individual elements within the system that would allow emergent behavior.

A complex system that prescribes the behaviors of its individual elements may have a large number of elements and may still not demonstrate emergent behavior. Therefore, complexity theory seeks to analyze dynamically complex systems where the interactions between elements are not restricted and where analysis of emergent behavior is more important than the analysis of the structure within the system.

Complex Adaptive Systems

Warfare, as described by Clausewitz, contains elements—factors—that are both competing and interacting with one another. The interaction of the different elements within warfare lends warfare to be analyzed as a dynamically complex system, specifically a complex adaptive system. Because of the emergence property, dynamically complex systems have the ability to adapt and change in relation to the feedback it receives from the environment (Moffat 2003, 50). The adaptive properties of dynamically complex systems allow them to be recognized as complex adaptive systems. Since warfare can be described as a complex adaptive system it is possible that it can be analyzed using the same methodologies used to analyze other complex adaptive systems such as ecology (Ilachinski 1996b, 2-3). Therefore, complexity theory techniques may be well suited to analyze potential outcomes during war.

Evaluation

Secondary research question 1: What is complexity theory and how does it view systems? Complexity theory—or more accurately in the view of land warfare, complex systems theory—attempts to analyze and understand dynamical systems that change over time. Specifically, complex systems theory is used to understand and describe complex adaptive systems. Intelligence analysis may benefit from analyzing the operating environment and potential adversaries as complex adaptive systems. This is possible because, like theorized complex adaptive systems, belligerents within land warfare demonstrate the general properties of complex systems to include emergent behavior, self-organization, and adaptation (Ilachinski 2004, 13). Moreover, it should be expected that in a competitive environment where national interests and lives are at stake, an adversary will adapt to provide himself the best opportunity of success during conflict.

In the evaluation of the first secondary research question, a high applicability can be established as categorized in table 3. Many analytic techniques attempt to analyze systems through reductionist means to focus on detail complexity. Unfortunately, however, due to the emergence property of dynamical systems, reductionist thinking is inadequate (Checkland 1981, 65). To understand a complex adaptive system, such as a terrorist organization or insurgent group, is a problem that requires analytic techniques focused on dynamic complexity (Senge 2006, 72). Consequently, the analytic techniques used to evaluate a complex adaptive system must acknowledge the unpredictability resident in complex adaptive system and the limitations of analysis.

Additionally, understanding the relationship between nodes within a system and how they are organized is important during analysis of the system. Identifying a dynamical system's structure—whether it is hierarchical and centralized, or non-hierarchical and decentralized—can provide insight into the adaptability of the system (Bousquet 2009, 182). Understanding a system's ability—or lack thereof—to adapt may lead an analyst to identify vulnerabilities or areas of focus for intelligence collection.

Table 3. Response Evaluation Criteria – Complexity Theory Systems			
Secondary Research Question	Low Applicability (1 point)	Moderate Applicability (2 points)	High Applicability (3 points)
1) What is complexity theory and how does it view systems?			X

Source: Developed by author.

Step 3: Analysis of the Second Secondary Research Question

To answer the primary research question, it is also necessary to determine what techniques are used to analyze complex systems. Therefore, the second secondary research question is "What are the complexity theory techniques used to analyze complex systems?" To evaluate how complexity theory techniques may be applied to intelligence analysis, the complexity theory techniques applicable to the analysis of complex adaptive systems must be analyzed to identify their potential application.

Modeling Combat as a Complex Adaptive System

To improve the understanding of chaotic systems, computer numerical modeling and simulation have provided chaotic system researchers with increased understanding of physical chaotic systems (Nichols and Tagarev 1994, 53). During the literature review, it was identified that two types of complexity theory computer modeling techniques have been developed to study land combat as a complex adaptive system, cellular automata and agent-based modeling. Cellular automata have demonstrated the ability to mimic military force-like behavior with relatively few behavioral rules. Like cellular automata models, agent-based models use relatively simple rules to produce simulated behavior.

Agent-based models, however, provide a richer simulation of the systems being analyzed as the agents interact with other agents and with the information received from the environment.

In a comparison of the two techniques, agent-based modeling more closely represents a complex adaptive system because of the agents' interactions with the environment and other agents to collectively determine the agents' actions. This closely fits how a complex adaptive system would perform. As described by Murray Gell-Mann, "A complex adaptive system acquires information about its environment and its own interaction with that environment, identifying regularities in that information, condensing those regularities into a kind of 'schema' or model, and acting in the real world on the basis of the schema" (Gell-Mann 1994, 17). Furthermore, during effective modeling, understanding a system's goals or objectives will become critical to understanding how the system might interact in a given environment based on its schema.

Both techniques, however, are reliant on nonlinear mathematics which can only be effectively explored using the processing power of a computer (Bousquet 2009, 169). Although the use of computers is necessary to run the simulations, the use of computers allows an analyst to run multiple iterations of a simulation with the ability to analyze the results looking for changes within the system. Further, running multiple iterations with different rules has the potential to uncover emergent behavior within the system (Waldrop 1993, 241-243). However, although an analyst may be able to run multiple simulations and receive interesting results, it should be noted the data produced is only as good as the equations and variables used during the simulations.

The mathematician, F. W. Lanchester, developed the first equations to analyze opposing forces in battle in 1916 (Schmieman 1967, 1). Because of the mathematics at the time, Lanchester's equations were deterministic using few and simple variables and assumed homogenous forces meaning that the opposing forces fought as a singular unit. The use of simple models may have been sufficiently accurate prior to the 20th century because, as Neil Johnson describes:

> Wars used to be simple—or rather, it used to be relatively simple to understand the mechanics of how wars were fought. . . . First, there were typically only two opposing forces. . . . Second, the weapons which each side had available were similar. . . . Third, the sizes of the two armies were usually fairly small. For these reasons, each side would be willing and ready to fight in a similar way to each other. This lead to a very conventional warfare. (Johnson 2007, 160-161)

Accordingly, although the use of Lanchester-type equations has been useful for modeling the results of historic battles and force-on-force attrition rates (Fredlake and Wang 2008, 17), a successful model for a complex adaptive system will likely require mathematical models that are not deterministic—stochastic—allowing for feedback among the individual agents.

Although the discovery of emergent behavior is a goal within combat modeling, most combat models in the U.S. Department of Defense are derivations of the Lanchester-type equations and are deterministic (Fredlake and Wang 2008, 58), meaning that the models will always produce the same output from a given starting condition. A deterministic model does not provide for randomness which would not be indicative of a model that involved human behavior.

Some models have already been developed for the U.S. military to simulate ground combat which include the Combined Arms and Support Task Force Evaluation Model (CATFOREM), the Joint Conflict and Tactical Simulations (JCATS), and One

Semi-Automated Forces (OneSAF) (Fredlake and Wang 2008, 8-11). Unfortunately, these three models have been built on Lanchester-type equations—the limitations of which have previously been discussed. There is, however, a model that stands apart from the Lanchester-type equation based model, the Enhanced ISAAC Neural Simulation Toolkit (EINSTein). EINSTein differs from other combat models because it derives its mathematical framework from complexity theory (Fredlake and Wang 2008, 21). Because EINSTein uses a framework based on a nonlinear theory, it is possible that it can more effectively analyze the interactions within and between complex systems.

Evaluation

Secondary research question 2: What are the complexity theory techniques used to analyze complex systems? Complexity theory has produced nonlinear mathematics to describe both complex systems and complex adaptive systems. Further, the use of nonlinear mathematics has been used to simulate combat using both cellular automata simulation and agent-based model simulations. Although the results from these simulations can appear real, it should be remembered that in order to create the combat models, many assumptions were used to simplify the model (Fredlake and Wang 2008, 58). Therefore, the intelligence analyst should identify the assumptions used within the model and collect against them to identify when those assumptions become false.

In the evaluation of the second secondary research question, a moderate applicability can be established as categorized in table 4. Even if using a complex systems model that is based on a deterministic mathematical formula—either linear or square as in the case of Lanchester-type equations—a computer is necessary. Further, even with the use of a computer, a model must be built that can effectively describe the combat forces involved which would require an analyst who can program such a model or new software that can be manipulated to represent the combat forces involved. Lastly, even with a model derived from complexity theory such as EINSTein, the results of the model are only as good as the inputs. Specifically, complex systems are sensitive to initial conditions (Mitchell 2009, 21), meaning that how the analyst approximates the combat forces, directly relates to the outcomes and behavior of the model.

Although approximation errors or incomplete modeling will limit the accuracy of a model's output, the use of an agent-based model such as EINSTein can support intelligence analysis. Even though a modeling tool may be used, critical analysis about the combat forces involved will not be diminished in the analyst's research regarding the potential adversary and friendly forces. Additionally, thorough JIPOE is still required in order to populate the data fields within the model. It will, however, require the analyst to learn and use a new software suite which challenges the third factor in the evaluation of the secondary research question which results in a moderate applicability.

Table 4. Response Evaluation Criteria – Complexity Theory Techniques

Secondary Research Question	Low Applicability (1 point)	Moderate Applicability (2 points)	High Applicability (3 points)
2) What are the complexity theory techniques used to analyze complex systems?		X	

Source: Developed by author.

Step 4: Analysis of the Third Secondary Research Question

The next step in answering the primary research question is to evaluate the current joint intelligence techniques used to analyze systems. The third secondary research question is, "What doctrinal techniques are used by military intelligence analysts to analyze systems?" To evaluate how complexity theory techniques may be applied to intelligence analysis, the current intelligence techniques must be evaluated to identify potential areas for application of complexity theory techniques.

Doctrinal Joint Intelligence Systems Analysis Techniques

As described in chapter 2, during joint planning intelligence analysts provide intelligence support by conducting the four steps of JIPOE:

1. Define the operational environment
2. Describe the impact of the operational environment
3. Evaluate the adversary and other relevant actors
4. Determine the course of action (COA) for adversary and other relevant actors, particularly the most likely COA and the COA most dangerous to friendly forces and mission accomplishment (Department of Defense 2014, I-1).

The goal of the JIPOE process is to provide a holistic analysis of the operational environment in order to support commander decision making and staff planning.

An important distinction between JIPOE and IPB is the emphasis on the use of a systems perspective (Department of Defense 2014, I-5). According to the JIPOE publication, "a systems perspective is developed through the analysis of relevant sociocultural factors and system nodes and links" (Department of Defense 2014, III-1). Further, the JIPOE publication asserts that understanding the relationship of the operational environment’s systems can assist the joint force in visualizing and describing the actions of the different systems (Department of Defense 2014, III-33).

To analyze the relationships and interdependencies within a system, the JIPOE publication recommends analysis of the node-link relationship using association matrices and network analysis diagrams to identify key nodes within the network. (Department of Defense 2014, III-44-45). Figure 4 illustrates an example network analysis diagram. The emphasis on a systems perspective emphasizes the relationship between the individual nodes within the system. The holistic understanding of the interaction between the different nodes provides value to the analyst to move onto the proceeding steps of the JIPOE process to evaluate the adversary’s capabilities and potential COAs.

Once the adversary, and other systems, have been analyzed, JIPOE progresses to the third step which requires the intelligence analyst to develop models of the adversary and other identified relevant actors. From these models, the analyst is required to determine the current situation, centers of gravity, and capabilities and vulnerabilities (Department of Defense 2014, IV-1). In the final step of the JIPOE process, the analyst is required to identify the adversary and relevant actors’ likely objectives and desired end states. With the deduction of the objectives and end state, the analyst can then use the previous analysis from the first three steps of the JIPOE process to estimate actors’ COAs (Department of Defense 2014, V-1).

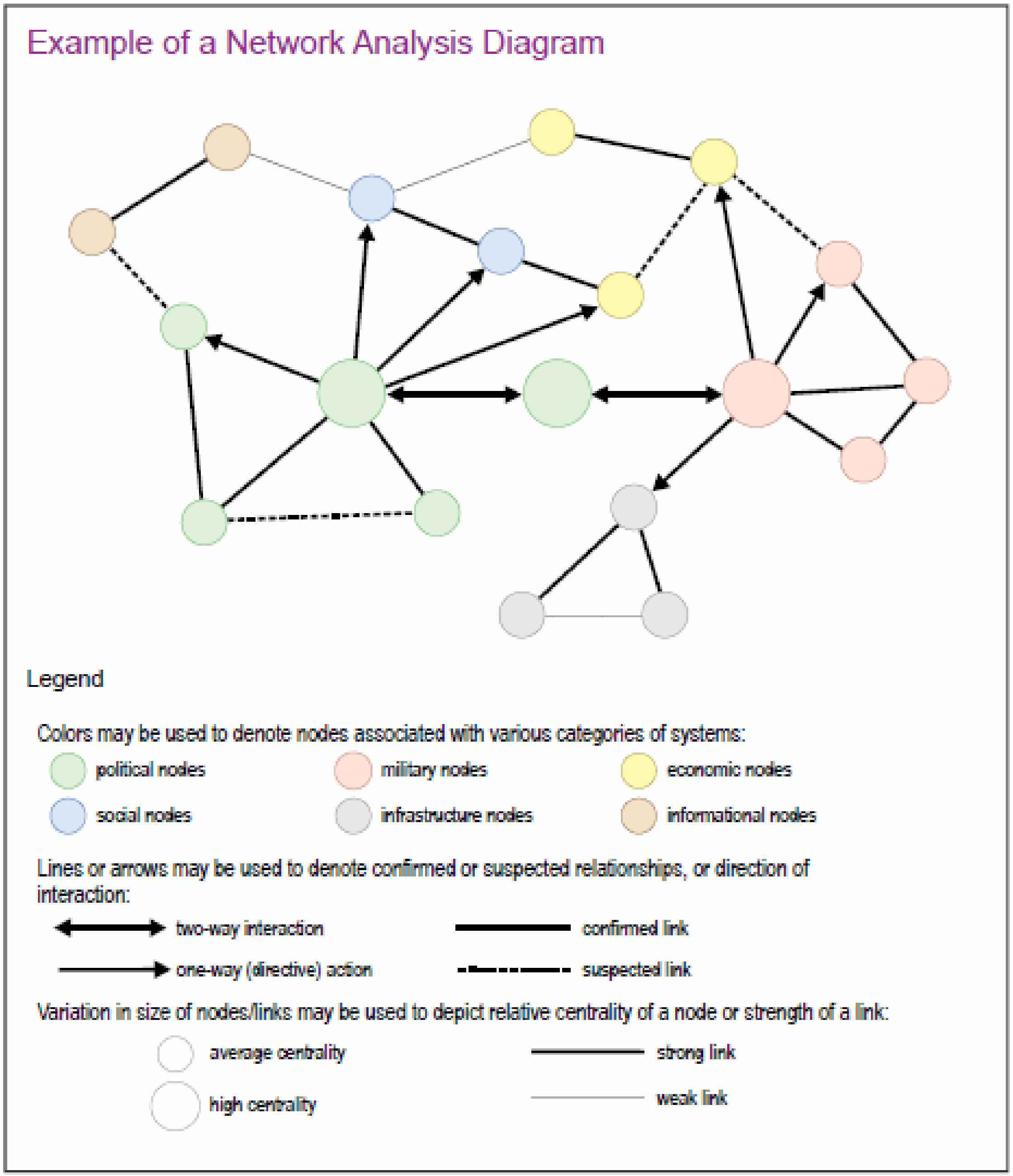

Figure 4. Example of a Network Analysis Diagram

Source: Department of Defense, Joint Publication 2-01.3, *Joint Intelligence Preparation of the Operational Environment* (Washington, DC: Joint Staff, 2014), III-45.

Evaluation

Secondary research question 3: What doctrinal techniques are used by military intelligence analysts to analyze systems? Within the U.S. Joint Force, intelligence analysts use the JIPOE process which requires the use of a systems perspective. The current JIPOE methods recommend evaluating systems through the analysis of the relationships and interdependencies of nodes and links within the system. In this way, the analysis conducted within JIPOE can directly support analysis of the systems as complex adaptive systems.

To evolve the current systems perspective recommended in the JIPOE process, additional elements from a complexity theory perspective are required. During analysis of the nodes and links within the system, the nodes can be viewed as individual agents within the system, where agents are described among four qualities: diversity, connection, interdependence, and ability to adapt (Page 2011, 6). Understanding the nodes along these qualities would provide a richer description of the individual agents for further analysis of the system as it is more important to understand how agents within a system interact than it is to identify all the individual parts (Hendricks 2003, 7). Additionally, systems analysis within JIPOE is static, providing a view of the system as a snapshot in time. While this may be required to initially understand, visualize, and describe the system being analyzed, it does not provide insight into the potential behavior of the system. Therefore, an analysis of how the system will adapt over time is required.

In the evaluation of the third secondary research question, a high applicability can be established as categorized in table 5. The current systems perspectives techniques recommended in the JIPOE publication set the stage for analysis of the systems as complex adaptive systems. Further, analysis of complex adaptive systems without the use of the JIPOE process is likely impossible. The four-step JIPOE process provides the basic data required to analyze an adversary as a complex adaptive system: structure, relationships, and objectives. From these factors, an analyst is able to analyze complex adaptive systems for potential emergent behavior, self-organization, and adaptation in relation to time and changes within the operating environment created by other systems which may include joint force actions.

Table 5. Response Evaluation Criteria – Current Doctrinal Techniques

Secondary Research Question	Low Applicability (1 point)	Moderate Applicability (2 points)	High Applicability (3 points)
3) What doctrinal techniques are used by military intelligence analysts to analyze systems			X

Source: Developed by author.

Step 5: Analysis of the Fourth Secondary Research Question

To answer the primary research question, it is next necessary to determine what techniques are applicable within joint intelligence analysis. The fourth secondary research question is "What complexity theory techniques can be used during joint intelligence analysis?" To evaluate how complexity theory techniques may be applied to intelligence analysis, complexity theory techniques must be analyzed and a determination of if and where the theory's techniques can be integrated must be established.

Uncovering the Limits of Predictive Analysis

Within the joint force, it is expected that the joint intelligence analyst is capable of providing predictive analysis. JP 2-0 *Joint Intelligence* states, "predictive analysis goes beyond the identification of capabilities by forecasting enemy intentions and future COAs. . . . The analyst who successfully performs predictive analysis and accurately assesses enemy intentions in advance of events performs an invaluable service to the commander and staff" (Department of Defense 2013a, II-10). As previously discussed, however, warfare—due to the interaction of numerous agents and feedback—is a complex adaptive system, is unpredictable and has the potential for uncontrollable behavior (Depart of the Navy 1996, 44). Although warfare may be unpredictable, this does not alleviate the need for the intelligence analyst to forecast possible adversary actions.

Further limiting a joint intelligence analyst's ability to provide accurate predictive analysis is the dynamic nature of the enemy. Marine Corps Doctrinal Publication 2 *Intelligence* describes this dilemma well:

> [T]he problems facing intelligence are further complicated by the irony that good intelligence may actually invalidate itself. Consider the following instance. Intelligence estimates that the enemy is preparing to launch an attack in a certain sector. Acting quickly on this intelligence, the commander strengthens that sector. The enemy, however, detects our enhanced defensive preparations, which causes him to cancel the attack. As a result, the intelligence estimate which predicted the attack in the first place appears wrong—but only because it was initially correct. Intelligence is thus a highly imprecise activity at best, and its effects are extremely difficult, if not impossible, to isolate. (Department of the Navy 1997b, 16)

The challenge addressed above is further discussed within *Joint Intelligence* and is described as "The Paradox of Warning" (Department of Defense 2103, I-28-29, II-10).

Although it is challenging, and potentially paradoxical, estimating the future is still a requirement for the joint intelligence analyst.

Using Complexity to Advance Joint Intelligence Analysis

It is not enough to admit that predictive analysis is difficult, or even impossible; therefore, advancements must be made to improve joint intelligence analysis. The JIPOE process provides the analyst with a thorough framework to describe the operational environment, effects against operations, the adversary's capabilities, and the adversary's potential COAs. The results from JIPOE can directly support the analysis of the systems within the operational environment as complex adaptive systems through the analysis of the system's diversity, connection, interdependence, and adaptability (Brown 2013, 4). The goal of the additional perspectives is not to simply add additional items for the joint intelligence analyst to fill-in; rather, the intent is for the analyst to take the results from JIPOE to analyze the adversary as a dynamic system.

Diversity

The identification of the adversary's system within a diversity perspective is a logical expansion of the adversary's order of battle analysis that was conducted in step three of JIPOE. According to Page, diversity within a system can be described in terms of diversity of type, or variation, and diversity of composition (Page 2011, 20). Describing an adversary's system through diversity of type would provide insight into the types of weapons systems the adversary can employ. An infantry battalion has far less variation of equipment than a tank division. The diversity of composition describes how different agents within the system are arranged. Following the previous example, the infantry battalion and tank divisions composition would be described from the order of battle analysis. Composition for a conventional adversary would be interesting when it differs from what is expected; for example, the infantry battalion reinforced with attachments or the tank division minus air defense assets.

Understanding the level of diversity within a system can facilitate the analysis of capabilities and limitations within the system. For instance, although the infantry battalion is less capable than a tank division, it may be more effective and efficient from a command and control perspective. Another type of diversity that can be seen within systems in war may include diversity from differing family, tribes, religions, countries, or other metrics. The behavior of a multi-national force is different from that of a unilateral force (Department of Defense 2013b, II-8) with potential vulnerabilities that can be exploited. Similarly, the composition of an insurgent group may have similar diversity characteristics that can make it more or less effective or vulnerable.

Connection

The connections within a narcotics network can be described using the techniques within JIPOE; association matrix, activities matrix, and link diagrams (Department of Defense 2014, E-6-11). From this analysis, JIPOE identifies functions within the system—logistics, operations, finance, etc.—and evaluates the connections between the agent functions with other agents within the system. The same techniques can be used during the analysis of a conventional adversary. In consideration of an infantry battalion, the standard hierarchical link diagram provides the foundation for the connections within the battalion. To improve this, the functions that the infantry battalion conducts should be identified; resupply, fire support, command and control, etc. The connections between the agents within the system are required for the system to achieve a certain goal or objective. With the system's objective in mind, analysis of the connections can provide insight into critical linkages within the system.

Interdependence

The interdependence of the system refers to the degree of reliance between the agents within the system. Analysis of the diversity and connections within the system provide insight into the functions within the system and the interdependency of the agents. Greater amounts of interdependence between agents within the system reduce the amount of diversity possible within the system thereby limiting possible adaptation (Page 2011, 138). This is easily described with command and control philosophies within the military. A centralized command and control organization is unable to adapt effectively if elements are unable to make decisions without approval from a higher commander; as the subordinate elements are highly interdependent on direction from higher echelons. Alternatively, a decentralized command and control organization may be able to adapt quicker to changing situations or unforeseen battlefield conditions.

Adaptation

The individual agents within a system adapt, leading to system-level adaptation (Page 2011, 25). As previously discussed, the potential paradox of warning is a challenge in providing predictive analysis of the adversary because the adversary is able to adapt. As has been described in the analysis of a system's diversity, connection, and interdependence, the JIPOE process provides the basic information regarding an adversary system to facilitate further analysis of the adversary as a complex adaptive system. The most critical element from JIPOE in identifying an adversary's potential adaptations is the identification of the adversary's objective. In identifying the adversary's objective, the joint intelligence analyst can begin to visualize how the adversary will react within the operational environment while constrained by the limits of the adversary's diversity, connections, and interdependence.

An intangible element yet to be discussed is the identification of the agents' motivations within the system. Particularly, does the organizational interest outweigh the self-interest of the agent? As noted by Page, "individual self-interest harms collective performance [and is] the classic example of the disconnect between individual adaptation and community failure" (Page 2011, 25). If the individual agent's motivations within the system are incongruent to the objective of the system, then there is a greater potential for the system to adapt in ways that do not achieve the system's objectives. A conscript, underequipped and poorly trained army may not adapt well when used to attack a near-peer neighbor for resources that will serve the state. That same army, however, may adapt particularly well when defending against an invasion of their own land and homes. The desires of the agents and the connect between the agents' desires to the system's objective matter.

Modeling and Simulation

To describe dynamical systems, the identification of diversity, connection, interdependence, and adaptation is important to estimating how a system being analyzed will evolve and interact within an environment. Beyond providing different perspectives in which to analyze a dynamical system, complexity theory researchers have also experimented with the use of modeling and simulation software. In particular, two simulation methods have been utilized specifically for the analysis of land combat: cellular automata and agent-based modeling.

Although there is potential to glean insight into a complex adaptive system through the use of simulation, the tools used are still too difficult for the majority of analysts to utilize. James Rosenau notes the limits of computer simulations, “Few of us have the skills or resources to undertake sophisticated computer simulations” (Rosenau 1997, 41). The use of computer simulations may provide insight into how a complex adaptive system may act; however, the results of the simulation are only as good as the inputs provided by the analyst. It should be remembered that within a complex adaptive system, the “slightest change in initial conditions can lead to very different outcomes” (Rosenau 1997, 38). The bulk of understanding required to set the initial conditions to even make a simulation possible is provide through the JIPOE process and analysis of the system as a complex adaptive system.

Computer simulation is not a shortcut for the time and research intensive work for the joint intelligence analyst. Lichtblau, and others, discuss the value of agent-based modeling stating:

> Ultimately a computer-based simulation is the exercise of a computer program, elements of which may or may not be mappable to the physical world. The dots running around on the screen (or lattice cells changing color) are ultimately just that: dots running around on the screen. It is the structure that determines that “running around” behavior that may be the same structure that determines some real world behavior in which we’re vitally interested [sic]. (Lichtblau, et al. 2006, 68)

In essence, the value of simulations is the ability to experiment with the hypothesis of how the complex adaptive system you are attempting to analyze will actual act. This cannot be completed, however, without first developing an understanding of the adversary system through a comprehensive process such as JIPOE.

Evaluation

Secondary research question 4: What complexity theory techniques can be used during joint intelligence analysis. In the analysis of dynamical systems, researchers have described different methods to evaluate complex adaptive systems. Clearly, none of the techniques can be used effectively without understanding the system being analyzed in great detail. Thus, the analysis of an adversary as a complex adaptive system is a natural progression of JIPOE's system-perspective analysis.

In the evaluation of the fourth secondary research question, a moderate applicability can be established as categorized in table 6. Analyzing complex adaptive systems along the qualities of diversity, connection, interdependence, and adaptation facilitates a deeper understanding of the adversary. However, the use of simulations challenges the third evaluation factor as it would require additional software and potentially new hardware to run the simulations. Although the use of computer simulations may not be ideal for use in intelligence analysis, the use of complex adaptive systems qualities may have the potential to enhance the JIPOE process.

Analysis of the adversary as a complex adaptive system requires a thorough understanding of the adversary through JIPOE. Techniques derived from complexity theory, however, can facilitate improved predictive analysis because unlike JIPOE, which analyzes the adversary as a snapshot in time, complexity theory techniques attempt to identify how the adversary system will adapt over time. As previously described, an important factor to identify is the adversary's objective. Once the adversary's objective is evaluated, analysis of how the adversary will react within the environment becomes possible. Consequently, without an understanding of the adversary's objectives, complexity theory techniques will likely be unable to facilitate thorough analysis.

To understand complex systems, Dettmer suggests that the analyst, "must *probe* by experimentation—thoughtful trial and error—*sense* whether their experiments seem to be succeeding or not, then *respond* based on those observations" (Dettmer 2011, 20). In this construct, results of the predictive analysis the joint intelligence analyst provides become the basis for the hypothesis for how the adversary will behave in the operational environment. Probing the adversary is conducted by intelligence, reconnaissance, and surveillance assets as part of the intelligence collection plan or through combat operations. Where to probe is dependent on the hypothesis of how the adversary will behave. Sensing is conducted by the JTF staff when new information is received from collection or combat operations as the staff attempts to analyze the patterns or potential patterns observed in probing. The responses are the decisions and actions the JTF takes in reaction to the adversary's actions and in accordance with the JTF's objectives. The goal of the response is to destabilize the actions the adversary is taking that are undesirable and to set conditions within the environment for desirable adversary actions to emerge (Kurtz and Snowden 2003, 469). Successful probing of the complex adaptive system is enhanced if the joint intelligence analyst understands the agents and relationships within the system and can estimate how the system will behave in response to changing factors in the operational environment to include the JTF actions.

Complexity theory thinking can enhance joint intelligence analysis. Computer-based simulations, however, are not likely as useful to the joint intelligence analyst.

Simulations are currently too burdensome for use during JIPOE. Additionally, although there may be many similarities between future adversaries the United States may face, there are likely just as many differences. It is unlikely that any one cellular automata or agent-based model will provide enough simulation fidelity to be applied broadly to all future challenge the joint force will face. Although computer simulations have been successful at modeling complex patterns and behavior for ecological systems, "the contextual differences between human organizations and those of ant colonies . . . make it more difficult to simulate [human organizations] using computer models" (Kurtz and Snowden 2003, 464-465).

Further, the complex and interactive nature of numerous agents in the operational environment would take even today's supercomputer years to calculate (Van Riper 2009, 83). Even if advances in computers allowed for the calculations to occur with relative speed and efficiency, the results of the simulation would only be as good as the inputs. Hence, even with a computer simulation, thorough JIPOE and analysis of the adversary as a complex system is required. Without a substantial breakthrough in computer technology and the ability to forecast the future of a dynamical system, computer simulations will likely be limited to force-on-force analysis where adaptations can be limited and variables approximated.

Table 6. Response Evaluation Criteria – Complexity Theory in Joint Analysis			
Secondary Research Question	Low Applicability (1 point)	Moderate Applicability (2 points)	High Applicability (3 points)
4) What complexity theory techniques can be used during joint intelligence analysis?		X	

Source: Developed by author.

Step 6: Answer the Primary Research Question

After having applied the evaluation criteria against the four secondary research question, the sixth step of the research design is to aggregate and present the findings of this research. This aggregation of the evaluation criterion and the aggregate scores are presented below in table 7.

Table 7. Response Evaluation Criteria – Aggregate			
Secondary Research Question	Low Applicability (1 point)	Moderate Applicability (2 points)	High Applicability (3 points)
1) What is complexity theory and how does it view systems?			X
2) What are the complexity theory techniques used to analyze complex systems?		X	
3) What doctrinal techniques are used by military intelligence analysts to analyze systems?			X
4) What complexity theory techniques can be used during joint intelligence analysis?		X	
Total	0	4	6

Source: Developed by author.

The application of the evaluation criteria establishes that the use of complexity theory techniques in joint intelligence analysis has moderate to high applicability. As presented in the evaluation of the second and fourth secondary research questions, the complexity theory techniques that involve the use of computer simulations are evaluated at having a moderate applicability to joint intelligence analysis. Although potentially useful for analysis of attrition during force-on-force combat scenarios, computer simulations have yet to be shown as capable of accurately representing complex adaptive systems that involve humans. As presented in the first and third secondary research questions, the methods in which complexity theory views and describes complex systems is evaluated as having high applicability to joint intelligence analysis. Analysis of the adversary as a complex adaptive system is a logical progression from JIPOE analysis.

Step 7: Conclusions and Recommendations

The final step in the research design is to draw conclusions and to provide recommendations for decision makers and for future research. The thesis conclusions and recommendations are found in chapter 5.

Chapter Conclusion

Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning? Simply put, the answer to the primary research question is yes. A review of the literature identifies that warfare is complex and that adversaries within war act as complex adaptive systems. As complexity theory provides concepts and methods to analyze complex adaptive systems, the use of complexity theory techniques can support and enhance joint intelligence analysis. Although this answers the primary research question, additional conclusions as well as recommendations for both the decision maker and for future research found in chapter 5.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Chapter Introduction

As the analysis from chapter 4 presented, the answer to the primary research question, "Should military intelligence analysts utilize techniques derived from complexity theory to analyze military problems and increase joint staff understanding of the operational environment during joint operational planning?" is yes with caveats. This result is not because complexity theory provides an easier technique for analyzing dynamical systems. The answer to the primary research question is yes because complexity theory focuses on identifying adaptation within a system over time in relation to its environment and objective. In this way, the preparation for joint operations requires focused attention against the adversary to gain a deep understanding of his character. Marine Corps Doctrinal Publication 1 *Warfighting* describes this well:

> We should try to understand the unique characteristics that make the enemy system function so that we can penetrate the system, tear it apart, and if necessary, destroy the isolated components. . . . This means focusing outward on the particular characteristics of the enemy rather than inward on the mechanical execution of predetermined procedures. (Department of the Navy 1997a, 77)

Therefore, an outward analysis of the adversary system and its characteristics is more important than focusing on the rigid procedures of planning and execution. Said simply, concentrating on detailed planning without first understanding the adversary is hopeless.

Conclusion

Complexity theory techniques can assist the joint intelligence analyst during joint operations. As a logical progression of the systems perspective analysis conducted during

JIPOE, considerations of how the adversary's system will change over time is beneficial to the joint intelligence analyst and can be used to support predictive analysis. There is, however, a caveat to the use of complexity theory techniques, specifically regarding the use of computer simulations during analysis.

Although cellular automata and agent-based models have been successful in modeling emergent behavior of complex adaptive systems in ecology, systems that involve human behavior are highly unpredictable because "humans are not limited to one identity. . . are not limited to acting in accordance with predetermined rules. . . and are not limited to acting on local patterns" (Kurtz and Snowden 2003, 464-465). Because of the lack of constraints on human behavior and decision making, the use of a computer simulation might lead an analyst to draw incorrect conclusions about how the adversary will act.

Although computer simulations may mimic emergent behavior observed in the physical world, the simulations are merely analogs of actual behavior. Agents in the real world react to the environment, but more importantly, they learn (Ramo 2009, 178). Learning is not something that can currently be replicated in a simulation. The use of computer simulation may, however, be applicable for wargaming specific scenarios after identifying the adversary's potential COAs or in reaction to friendly COAs. Again, however, the results of the computer simulation should be viewed as potential "what if" scenarios and not as a prediction of actual adversary actions.

Still, with computer simulation aside, the techniques required to analyze a complex adaptive system are what make complexity theory techniques valuable during joint intelligence analysis. Even if some day quantum computing and advanced mathematics were able to produce true artificially intelligent agents that could learn within the simulation, the basis for how agents interact within the simulation would have to be based on JIPOE and analysis of the adversary as a complex adaptive system.

The results of this thesis assist in answering AWFC#1, "How to develop and sustain a high degree of situational understanding while operating in complex environments against determined enemy organizations." The use of complexity theory techniques during JIPOE or IPB can provide a greater understanding of the adversary and how it may adapt over time to achieve its objectives. With this understanding, the intelligence analyst is able to develop a hypothesis for how the adversary will behave to achieve his objectives which are provided in the form of adversary COAs. From there, the intelligence analyst creates the intelligence collection plan to identify which COA the adversary has chosen.

The use, of complexity theory techniques, supports collection by identifying key agents or relationships within the system where collection resources can be focused. Further, because the adversary is assumed to be adaptive and learning, each action taken by the friendly force should be paired with corresponding collection requirements to identify changing adversary behavior in relations to changes in the environment induced by the friendly force. By providing additional means to analyze adversary COAs and identify areas to focus collection, complexity theory supports the enhanced development of situational understanding.

Recommendations

Recommendations for Decision Makers

Complexity theory concepts and techniques should be included within joint intelligence doctrine and specifically within the JIPOE publication. Unconventional warfare, insurgencies, transnational crime, and conventional forces operating under maneuver warfare are a few examples of "kinds of systems [that] would qualify as truly complex, and adaptive" (Dettmer 2011, 13). As such, the joint intelligence analyst requires techniques to analyze these types of systems. The current JIPOE methods are inadequate. The addition of complexity theory techniques would support the analysis of the adversary and his potential to adapt and behave over time.

Although the primary recommendation is for the inclusion of complexity theory techniques into doctrine, this would have direct impacts to the domains of training, leadership, and education. Training will be impacted because doctrine serves as the basis for curricula within the military. Any updates or changes to doctrine will require an update and change within training. Leadership and education would be impacted because JIPOE, or IPB, is taught within the officer professional military education system and specifically within intermediate level school as part of learning area 2 during joint professional military education phase I (Department of Defense 2015, E-D-2). Therefore, adding complexity theory techniques into intelligence doctrine will initiate a potential change across the officer training continuum.

Within this thesis, four qualities of complex adaptive systems have been discussed for inclusion during analysis: diversity, connection, interdependence, and adaptation. There may, at some point, be an idea that a crosshatch with the above four qualities and

PMESII be created as the method for analyzing complex adaptive systems across the sub-systems of PMESII. This is not recommended as it would be using a technique to analyze one system to analyze multiple systems at once. While a holistic view is required to understand an individual system, attempting to identify all the relationships from a PMESII perspective across a joint operational area may be impossible, or worse yet, a waste of time. If system thinking is required for a large area, a design methodology is likely to yield better results, particularly systemic operational design as described by John Schmitt (Schmitt 2004, 23).

Recommendations for Future Researchers

For a future researcher interested in a similar topic, a deeper analysis of computer simulations may provide interesting results and additional implications to intelligence analysis. Although this thesis does not recommend computer simulations to support the analysis of complex adaptive systems, this conclusion is based on the current limitations of cellular automata and agent-based models. It may be insightful for a researcher to identify what elements would need to be improved for a computer simulation to be effective in evaluating an adversary. Additionally, an evaluation of the level of personnel, expertise, and training that would be required to run an effective simulation would also be helpful as that knowledge may provide insight into which echelon of command it would be feasible to introduce such enablers and systems.

Final Thoughts

Warfare is unpredictable; however, this does not obviate the joint intelligence analyst’s requirement to provide predictive analysis to support joint operational planning.

Analyzing an adversary as a complex adaptive system acknowledges the nonlinear nature of the adversary and his ability to adapt and learn. Complexity theory provides concepts and techniques to assist the joint intelligence analyst to analyze the adversary as a complex adaptive system. There are, however, no shortcuts and JIPOE remains the foundation for insightful intelligence estimates. Computers simulations may be able to mimic emergent behavior in some complex adaptive systems; however, complex adaptive system models have yet to accurately model the complexity introduced by human behavior. Human tendency and the desire for control may lead some to estimate that computer simulation and analysis will ultimately reduce uncertainty and friction in war. Unfortunately, it is human ability to quickly adapt and learn that cannot be replicated in 1s and 0s. The best that can be done is to learn when the adversary may adapt and adapt faster than he will.

> It would be nice to have better ways of monitoring what we're up to so that we could recognize change while it is occurring. . . . Maybe computers can be used to help this, although I rather doubt it.
>
> — Lewis Thomas, *The Life of a Cell: Notes of a Biology Watcher*

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