The Complexity Systems Management Method: A Next Generation Decision Support Tool for the Management of Complex Challenges at Institutions of Higher Education

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Abstract of Dissertation

The Complexity Systems Management Method: A Next Generation Decision Support Tool for the Management of Complex Challenges at Institutions of Higher Education

This research study is based on the hypothesis that new knowledge has arisen from scientific breakthroughs in our understanding of naturally occurring complex systems that can increase the human understanding of complex systems and improve the management of complex events and situations. This includes the complex interdependent systems that characterize modern institutions of higher education. Based on the review and study of the scholarly literature, the different frames of reference used to conceive, understand, and explain the positivist and post-positivist epistemologies of science are triangulated. The frames of reference for the two epistemologies are then compared and contrasted with four scientific theories that have lead to breakthroughs in our understanding of complex naturally occurring systems. The results of this analysis are used to identify those frames of reference arising from the study of the scientific theories that are not reflected in either the positivist or post-positivist epistemologies. The study of the scholarly literature shows that there is a disparity between the frames of reference used to conceive, understand, and explain the scientific theories and the positivist and post-positivist epistemologies. Based on this disparity, the research study suggests that there is new knowledge arising from scientific breakthroughs in our understanding of naturally occurring complex systems that is not reflected in either the positivist or post-positivist epistemologies of science. The study concludes that this new knowledge has led to the emergence of a more advanced epistemology known as *a priori optionality* that can improve the human management of complex events and situations. A new process, based on the tenets of *a priori optionality*, known as the complexity systems management method, to enhance human learning and decision making in the management of complex events and situations is described. The research study concludes with a description of the application of the complexity systems management method as a way to more effectively integrate strategic plans with operational budget outcomes at institutions of higher education.

Dedication

This research study is dedicated to my wife Melinda. Without her love, understanding and encouragement this project would not have been possible. I also want to dedicate this research study to my beloved father who passed away in October 2002. My father was a man of great wisdom and deep intellectual curiosity. I will never forget him, his unconditional love for me and the encouragement he gave to me during the early phases of this project.

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Chapter 1. Introduction

Overview of the Research Study

This research study is based on the hypothesis that new knowledge has arisen from scientific breakthroughs in our understanding of naturally occurring complex systems that can be applied to increase the human understanding of complex systems and improve the management of complex events and situations. This includes the complex interdependent systems that characterize modern institutions of higher education. Based on the review and study of the scholarly literature, the different frames of reference used to conceive, understand, and explain the positivist and post-positivist epistemologies of science are triangulated. The frames of reference for the two epistemologies are then compared and contrasted with four scientific theories that have lead to breakthroughs in our understanding of complex naturally occurring systems. The results of this analysis are used to identify those frames of reference arising from the study of the scientific theories that are not reflected in either the positivist or post-positivist epistemologies. The study of the scholarly literature shows that there is a disparity between the frames of reference used to conceive, understand, and explain the scientific theories and the positivist and post-positivist epistemologies. Based on this disparity, the research study suggests that there is new knowledge arising from scientific breakthroughs in our understanding of naturally occurring complex systems that is not reflected in either the positivist or post-positivist epistemologies of science. The study concludes that this new knowledge has led to the emergence of a more advanced epistemology of science known as *a priori optionality* that can improve the human understanding of complex systems and the human management of complex events and situations. This includes the more effective management of complex events and situations at institutions of higher education. A new process, based on the tenets of *a priori optionality*, known as the complexity systems management method, to enhance human learning and decision making in the management of complex events and situations is described. The research study concludes with a description of a contemporary application of the complexity systems management method to more effectively integrate strategic plans with operational budget outcomes at institutions of higher education.

Statement of the Problem

Naturally occurring systems can reach levels of complexity that defy human understanding (Gleick, 1987; Gould, 1991; Kauffman, 1995; Perrow, 1982; Prigogine & Gregoire 1998). Much of today's research that attempts to bridge the gap between new scientific knowledge of complex naturally occurring systems and complex human social systems is based on metaphorical fancy rather than analogical rigor (Kerbel, 2005; Rosenhead 1998). This research study attempts to bring a higher level of analogical rigor to the examination of new knowledge arising from scientific breakthroughs in our understanding of complex naturally occurring systems and the potential application of this new knowledge to increase the understanding of complex systems and improve the human management of complex events and situations. This includes the more effective management of complex events and situations at institutions of higher education.

A review of the scholarly literature suggests that today's two reigning epistemological constructs, i.e., positivism and post-positivism, use frames of reference that may not reflect new knowledge arising from scientific breakthroughs in our understanding of complex naturally occurring systems (Cassidy 1992; Heisenberg, 1999; Jeans, 1981; Miller 2000; Perrow, 1982; Prigogine & Gregoire 1998; Runes, 1942; Trochim, 2004). A review of the scholarly literature also suggests that there is no widely accepted body of theory or methodology that integrates qualitative sociological and quantitative technology factors in the context of complex interdependent systems (Alberts & Czerwinski, 1999; Gell-Mann, 1999; Joslyn & Rocha, 2000; Miller, 2000; Perrow, 1982; Rosenhead, 1998; Ruso-Toderean, 1992). This includes the highly complex interdependent systems that characterize institutions of higher education (Balderston, 1995; Birnbaum, 2000; Commission on National Investment in Higher Education, 1997; Duderstadt, 1997 & 1998; Johnstone, 1988 & 1998; Layzell, 1998; Schmidtlein, 1981; Schmuck & Runkel, 1994; Shulcok & Harrison, 1998).

Purpose and Research Questions

The purpose of this dissertation is to determine if there is new knowledge arising from scientific breakthroughs in our understanding of complex naturally occurring systems that is not reflected by the positivist and post-positivist epistemologies of science and if this new knowledge can be applied to create a new learning and decision making tool that can increase the human understanding of complex systems and improve the human management of complex events and situations. This includes the more effective integration of strategic plans with operational outcomes at institutions of higher education.

In order to determine if there is new knowledge arising from scientific breakthroughs that can be applied to increase the human understanding of complex systems and improve the human management of complex events and situations, this research study addresses the following eight principal research questions:

1. What are the predominant conceptual frames of reference used to structure the positivist epistemology?
2. What are the predominant conceptual frames of reference used to structure the post-positivist epistemology?
3. What are the predominant conceptual frames of reference used to structure four theories of science which have contributed to our understanding of complex naturally occurring systems, i.e., relativity theory, the indeterminacy principle, dissipative structure theory and complexity theory?
4. What conceptual frames of reference for the two epistemologies and the four selected scientific theories are the same? What conceptual frames of reference are different?
5. What, if any, are the new frames of reference not used to structure the positivist or the post-positivist epistemologies?
6. Does a new combination of frames of reference arise from the comparison and contrast of the two existing epistemologies and the scientific theories?
7. If a new combination of frames of reference does arise, how does it help human beings better understand complex systems and manage complex events and situations?
8. How can this new knowledge be applied in a practical way to enhance human learning and improve decision making in order to more effectively manage highly complex events and situations? This includes the more effective integration of

quantitative factors and qualitative considerations to improve decision making in organizations including institutions of higher education.

Statement of Potential Significance

The positivist and post-positivist epistemologies are insufficient to explain the behaviors of complex naturally occurring systems. A deeper understanding of complex naturally occurring systems holds the promise of providing new insights regarding the natural world. This includes the behavior of complex human social systems to subsume institutions of higher education. It is possible that the positivist and post-positivist epistemologies may not reflect the different conceptual frames of reference that have emerged as a result of new scientific understandings of complex naturally occurring systems. The study of the scholarly literature indicates that much of the previous research that attempts to bridge gap between new scientific understandings of complex naturally occurring systems and complex human social systems is based on metaphorical fancy rather than analogical rigor (Kerbel, 2005; Rosenhead, 1998). The application of analogical rigor to a comparison of the positivist and post-positivist epistemological constructs with scientific theories that have advanced our understanding of nature may provide new insights regarding the possible strengths or shortcomings of these epistemologies as they relate to our understanding of complex naturally occurring systems. This includes complex human social systems to subsume institutions of higher education.

The results of this research study can make an important contribution to the scholarly body of knowledge as it pertains to our understanding complex naturally occurring systems, including human social systems and institutions to subsume institutions of higher education. By applying analogical rigor, we can begin to bridge the gap between new knowledge of complex naturally occurring systems and complex human social systems and institutions in a systematic and structured way (Kerbel, 2005; Rosenhead, 1998). By examining the limitations of the positivist and post-positivist epistemologies in the context of new scientific knowledge, we may be in the position to enhance existing epistemological constructs or create a totally new epistemology of science that increases the human understanding of complex systems. With this new knowledge, we may be able to create a new generation of decision support tools that will enhance human learning and improve decision making in the management of complex events and situations at institutions critical to the functioning of our society, including institutions of higher education.

As noted above, a review of the scholarly literature suggests that there is no widely accepted body of theory or methodology that integrates qualitative social and quantitative scientific factors in the context of complex interdependent systems (Alberts & Czerwinski, 1999; Gell-Mann, 1999; Joslyn & Rocha, 2000; Miller, 2000; Perrow, 1982; Rosenhead, 1998; Ruso-Toderean, 1992). This includes the highly complex interdependent systems that characterize institutions of higher education (Balderston, 1995; Birnbaum, 2000; Commission on National Investment in Higher Education, 1997; Duderstadt, 1997 & 1998; Johnstone, 1988 & 1998; Layzell, 1998; Schmidtlein, 1981; Schmuck & Runkel, 1994; Shulcok & Harrison, 1998). The results of this research study can make an important contribution to the scholarly body of knowledge by providing a new decision support tool that more effectively integrates quantitative science with qualitative social factors in the context of complex interdependent systems at institutions critical to the functioning of our society, including institutions of higher education.

The potential and significant results of this research study include:

1. If any of the frames of reference used to conceive and understand the scientific theories under study are not reflected in the positivist or post-positivist epistemologies, this may reveal inherent limitations of the epistemologies as constructs for conceiving, understanding and explaining the behaviors of complex naturally occurring systems, including complex human social systems.
2. The triangulation of the scholarly literature suggests that distinct differences between the frames of reference used to conceive and understand the scientific theories selected for study and the positivist and post-positivist epistemologies do, in fact, exist.
3. By examining the limitations of the positivist and post-positivist epistemologies in the context of new scientific knowledge, we may be in the position to enhance existing epistemological constructs or create a totally new epistemology of science that increases our understanding of complex systems and improves the human management of complex events and situations by applying these new frames of reference. This includes the more effective management of complex events and situations at institutions of higher education.
4. Applying these new frames of reference to advance the human understanding of complex systems, can form the basis for a new generation of decision support tools that can be used to enhance human learning, more effectively integrate quantitative technology with qualitative social factors in the context of complex

interdependent systems and improve human decision making in the management of complex events and situations. This includes the more effective integration of strategic plans and operational outcomes at institutions of higher education.

Theoretical Foundation and Conceptual Framework

This research study explores the possible limitations of the positivist and post-positivist epistemologies in the context of new scientific knowledge that may increase our understanding of complex systems and improve the human management of complex events and situations by applying new frames of reference in the process of problem solving and decision making. Understanding the limitations of the positivist and post-positivist epistemologies may lead to an alternative epistemology of science that will enhance our understanding of complex naturally occurring systems. This includes complex human social systems and institutions, including institutions of higher education. The possibility of a new epistemology arises from the study and triangulation of the scholarly literature relating to the positivist and post-positivist epistemologies and four scientific theories. These scientific theories are special and general relativity, probability, dissipative structure, and complexity theory. The positivist and post-positivist epistemologies and the four scientific theories are compared and contrasted using ten conceptual frames of reference. These conceptual frames of reference are linearity and nonlinearity, reductionism and holism, certainty and uncertainty (of measurement), reversibility and irreversibility (of systems), and induction and deduction. Pattern sets that reflect the "acceptance" or "rejection" of these ten conceptual frames of reference (based on collective prevalence, i.e., predominance) for each of the positivist and post-positivist epistemologies and four scientific theories under study are identified based on the triangulation of the scholarly literature. The epistemological pattern sets are compared and contrasted with the scientific theory pattern sets to determine whether any of the pattern sets match. Then the pattern sets for each of the four scientific theories are compared and contrasted with one another to identify matches. If there are resulting scientific theory pattern sets that do not match any epistemological pattern set they are grouped to form a unique epistemological structure. The resulting epistemological structure is unique because it reflects a new combination of the ten conceptual frames of reference not found in the positivist or post-positivist epistemologies. After isolating the new epistemological structure the research study examines how it can be applied to increase human understanding of complex systems. A practical method for applying the new epistemology to enhance human learning, more effectively integrate quantitative technology with qualitative social process factors in the context of complex interdependent systems, and improve decision making in the human management of complex events and situations is described. How the new method can be applied to more effectively integrate strategic plans with operational budget outcomes at institutions of higher education is described in detail.

Summary of the Methodology

To identify and isolate this new knowledge for study, a review of the scholarly literature as it pertains to the positivist and post-positivist epistemologies and the four scientific theories selected for examination, i.e., relativity theory, the indeterminacy principle, dissipative structure theory, and complexity theory is undertaken. Seven specific criteria were used to scope the selection of the scholarly literature examined as part of this research study.

1. The integration of the philosophy of science with scientific theory in ways that were responsive to the eight research questions identified for examination.
2. The connection among science, theory and practical outcomes.
3. Concise definitions, clarity and descriptions of terms.
4. The integration of philosophy with scientific outcomes was more important than “pure science”, i.e., how you got there versus the breakthrough itself.
5. Contrast between analogy and metaphor.
6. Selective use of contemporary articles for explanation, breadth and to enhance understanding.
7. Linking strategic plans with operational outcomes in the modern university.

This research study compares and contrasts the positivist and post-positivist epistemologies with Einstein's special and general relativity theory, Heisenberg's principle of indeterminacy, Prigogine's dissipative structure theory and complexity theory. Ten conceptual frames of reference triangulated from the study of the scholarly literature are used to guide the analysis. These conceptual frames of reference are linearity and nonlinearity, reductionism and holism, certainty and uncertainty (of measurement), reversibility and irreversibility (of systems) and induction and deduction.

A logic block that compares and contrasts the positivist and post-positivist epistemologies and the four theories against the ten conceptual frames of reference of linearity and nonlinearity, reductionism and holism, certainty and uncertainty (of measurement), reversibility and irreversibility, and induction and deduction is developed. Based on the triangulation of the scholarly literature and analysis, the logic block indicates whether the ten conceptual frames of reference of linearity and nonlinearity, reductionism and holism, certainty and uncertainty (of measurement), reversibility and irreversibility and induction and deduction predominate in the two epistemologies and four scientific theories under study.

Through the process of comparison and contrast, unique patterns based on the predominance of the key concepts of linearity and nonlinearity, reductionism and holism, certainty and uncertainty (of measurement), reversibility and irreversibility (of systems) and induction and deduction emerge. These pattern sets or groupings of pattern sets illustrate how the ten conceptual frames of reference have been integrated or combined to form a variety of conceptual frameworks for understanding the natural world. The purpose of the logic block is to isolate a new pattern set or grouping of pattern sets that form a unique framework, i.e., epistemological construct, for understanding complex naturally occurring systems. This includes complex human social systems and institutions. If a unique framework emerges based on the study and triangulation of the scholarly literature a new epistemological construct may also emerge, one that is based on the application of analogical rigor versus metaphorical fancy (Rosenhead, 1998). This new epistemological structure may provide significant insights in better understanding the behaviors of complex systems that can be applied to enhance human learning, more effectively integrate quantitative scientific with qualitative social factors in the context of complex interdependent systems, and improve decision making in the human management of complex events and situations. A review of the scholarly literature as it pertains to institutions of higher education as representing complex interdependent systems that involve the integration of quantitative factors and qualitative social considerations is undertaken. This includes the integration of strategic plans with operational budget outcomes at institutions of higher education.

In summary, the methodology used to conduct this study consists of eight specific steps.

1. Establish criteria to guide the selection of the scholarly literature to be studied.
2. Review selected examples of the scholarly literature as it pertains to the positivist and post positivist epistemologies and four scientific theories.
3. Attempt to triangulate a set of frames of reference from these sources of the scholarly literature.
4. Compare and contrast the prevalence, i.e., predominance, of frames of reference among two epistemologies and four scientific theories.
5. Develop a logic block.
6. Deduce the tenets of an advanced epistemology of science, i.e., *a priori optionality*, based on the scholarly literature.
7. Connect the tenets of *a priori optionality* with actual practice, i.e., the complexity systems management method.
8. Describe a practical application of the complexity systems management method using the modern university as one of many potential examples.

Limitations of the Research Study

This research study examines only a sampling of the scholarly literature as it pertains to many different epistemologies and a multitude of scientific theories that have increased human understanding of complex naturally occurring systems. Thus, there exist huge volumes of scholarly literature that were not the subject of analysis as part of this research study. To partially address this limitation, the following seven specific criteria to scope the selection of the scholarly literature examined as part of this research study were used.

1. The integration of the philosophy of science with scientific theory in ways that were responsive to the eight research questions identified for examination.
2. The connection among science, theory and practical outcomes.
3. Concise definitions, clarity and descriptions of terms.
4. The integration of philosophy with scientific outcomes was more important than "pure science", i.e., how you got there versus the breakthrough itself.
5. Contrast between analogy and metaphor.
6. Selective use of contemporary articles for explanation, breadth and to enhance understanding.
7. Linking strategic plans with operational outcomes using the modern university as one of many potential examples.

This research study compares and contrasts only the positivist and post-positivist epistemologies, ten conceptual frames of reference and a limited number of scientific theories that have increased human understanding of complex naturally occurring systems. Other epistemologies, frames of conceptual reference and additional scientific theories exist. Thus, another potential criticism of the research study may be the limited number of epistemologies, conceptual frames of reference and scientific theories selected for study. But, the research methodology has been specifically designed for expansion using different epistemological constructs, conceptual frames of reference and additional scientific theories to serve as the basis for future research.

Critics may also argue that the methodology used for this study incorrectly characterizes the human cognitive process as both static and linear in nature. These critics may assert that the human cognitive process is dynamic and non-linear. For example, let us consider the conceptual frame of induction. The opposing conceptual frame is deduction. Some critics may contend that individuals move back and forth from the conceptual frame of induction to deduction many times and to varying degrees as they engage in the cognitive process of problem solving (Trochim, 2004). In another example, let us consider the conceptual frame of certainty. This conceptual frame accepts Newtonian mechanics with its notion of certainty of measurement (Miller, 2000; Trochim, 2004). The opposing conceptual frame is indeterminacy or the uncertainty of exact measurement as represented by Heisenburg in the principle of indeterminacy (Cassidy, 1992; Heisenberg, 1999; Miller, 2000). Some critics may contend that individuals move back and forth from the conceptual frame of certainty to indeterminacy many times and to varying degrees as they engage in the cognitive process of problem solving. To complicate matters further, critics may argue that individuals also move back and forth from conceptual frame or combination of frames to other conceptual frames or combinations of frames many times and to varying degrees as they engage in the cognitive process of problem solving (Trochim, 2004). But, determining how and when and in what combinations the ten different conceptual frames are applied by human beings as they engage in the cognitive process of problem solving is beyond the scope of this research study. Rather, the methodology used in this research study only seeks out the collective or predominate prevalence of a given conceptual frame of reference based on the study of the scholarly literature.

This study provides a description of only one application of how the resulting research can be applied to achieve practical results. The specific application described involves the use of an advanced decision support tool known as the complexity systems management method to more effectively manage complex systems of fiscal management at institutions of higher education. As discussed later in the research study, the complexity systems management method has far reaching applications that go well beyond the improved administration of institutions of higher education. To partially address this limitation, Chapter 5 of the research study is divided into two portions. The first portion of Chapter 5 provides a generic description of the complexity management system method that can be tailored for different applications across a broad range of complex systems challenges. Detailed descriptions of a range of other applications of the complexity systems management method are included as an appendix to this research study. The second portion of Chapter 5 is exclusively devoted to a description of institutions of higher education as complex adaptive interdependent systems of systems and how the complexity systems management method can be applied to the specific challenge of more effectively administering complex systems of fiscal management.

Another potential criticism of this research study is that the complexity management system is only notional and remains untested in the real world. To address this potential criticism of the research study, Chapter 5 includes a description of a course developed and taught at National Defense University during academic year 2000-2001. In developing and conducting the course, the critical aspects of the complexity systems management decision support tool were successfully tested and shown to be highly effective in linking strategic plans with operational outcomes in the management of highly complex events and situations (Eisler, 2000; Hnatio, 2000). A copy of the course syllabus is included as an appendix to this dissertation.

Definitions of Key Terms (Epistemologies, Theories, and Conceptual Frames of Reference)

The scholarly literature is used as the basis for defining the key concepts and terms used in this research study. For purposes of this research study, the positivist and post-positivist epistemologies, the four scientific theories selected for study and the ten conceptual frames of reference are described below. Sources from the scholarly literature upon which the definitions for each term of reference are based are identified.

1. Positivism

The positivist epistemology denies the validity of metaphysical speculations and the anthropomorphic perception of an all-knowing god. Positivists believe that there exists an objective reality independent of the observer and that the experience of the five human senses is the only thing that defines the reality of existence (Runes, 1942; Trochim, 2004). Newtonian mechanics are perceived as a ruling principle and the certainty of measurement applies (Feiser & Dowden, 2005; Miller, 2000; Trochim, 2004). The positivist epistemology focuses on the study of facts and experimentation as the way to perfect human knowledge (Ess, 2002; Trochim, 2004). Abstractions or general theories or ideas are nothing more than collective judgments. Judgments are the mere colligation of facts. Rationality is articulated using inductive methods. To the positivist, all human knowledge can be reduced to sense experience and empirical analysis, i.e., quantitative analysis (Ess, 2002; Trochim, 2004). A significant outgrowth of the positivist epistemology is logical positivism. Logical positivism asserts that only statements about empirical observations have any meaning thus assuring that all metaphysical statements are meaningless, i.e., "nonsense." Logical positivists believe that there exists an objective reality independent of the observer (Trochim, 2004). Newtonian mechanics are perceived as a ruling principle and the certainty of measurement applies. The logical positivist epistemology asserts that the meaning of a statement is its verification. In other words, you can understand a statement only if you know what kind of observations can verify it. This is known as the "verification principle" (Feister & Dowden, 2005). Logical positivism assumes that all science rests on a foundation of facts. Once enough facts are collected and analyzed generalizations can be extracted enabling the scientist to predict, given some set of circumstances at T_1, some fact that will still hold true at T_2. If the prediction is true then the hypothesis, principle or theory must also be true (Feister & Dowden, 2005; Miller, 2000; Shalizi, 2002; Trochim, 2004).

2. Post-positivism

The post-positivist epistemology asserts that there is a reality independent of our ability to empirically prove it that depends on the observer (Feister & Dowden, 2005). Post-positivists assert that all observations are fallible and all theory is subject to revision. They contend that all that is observed is affected by observation. In this sense, Newtonian mechanics with their certainty of measurement do not apply (Cassidy, 1992; Heisenberg, 1999). Thus, multiple measures and observations are core to the advancement of knowledge, i.e., triangulation (Feister & Dowden, 2005; Runes, 1942; Trochim, 2004). Post-positivists believe that constant scrutiny of research leads to the evolutionary creation of the "best" knowledge. Under this construct, only the best theories survive leading to the natural selection theory of knowledge. In this context, quantitative analysis and empirical proofs do not prove or disprove hypotheses, principles or theories – they only temporarily validate the usefulness of a given hypothesis, principle or theory. Thus, hypotheses, principles and theories are only temporary (Feister & Dowden, 2005; Runes, 1942; Trochim, 2004).

3. Relativity Theory

In special relativity theory Einstein posits the ruling principle that distance and time are not absolute and depend on the motion of the observer (Jeans, 1981; Miller, 2000). In general relativity theory Einstein posits the ruling principle that gravity pulling in one direction is equivalent to acceleration in the opposite direction. This is known as the equivalence principle. Einstein, like Newton before him, believed in a reality independent of the observer. He also believed like Schrodinger that universal principles exist to explain nature (Cassidy, 1992; Miller, 2000). In special relativity theory, Einstein used bold intuition and deduction to perceive time and space as a single inseparable continuum. Einstein's perception required the use of non-Euclidean geometry for expression. When combined, the special and general theories of relativity paint a picture of reality, i.e., Einsteinian four-dimensional space, which is outside the bounds of the five human senses – a reality that can only be imagined and understood by the human imagination and intellect (Epstein 2000; Hawking, 1998; Miller, 2000).

4. Indeterminacy Principle

Heisenberg's indeterminacy principle postulates that precise measurements of sub atomic particles are impossible because of the interference (disturbances to the environments in which they are moving, i.e., effects on momentum) created by the methods used to measure them (Cassidy, 1992; Heisenberg, 1999). Heisenberg asserts that the path of an electron can only be determined within specified bounds using stochastic statistical methods. Heisenburg abandons the precept of Newtonian mechanics by postulating that the certainty of measurement does not exist at the sub-atomic level. He goes one step further to proclaim that there is no reality independent of the observer and that nothing can be precisely measured because the act of observation itself affects the entity we are attempting to measure (Cassidy 1992; Heisenberg, 1999). This notion, according to Heisenberg, is expressed at the subatomic level by the belief that the event path of an electron does not come into existence until after it is observed by a human being (Cassidy 1992; Heisenberg, 1999).

5. Dissipative Structure Theory

In 1977, Ilya Prigogine won the Nobel Prize for developing the theory of dissipative structures. Prigogine postulated that complex thermodynamic systems absorb energy to self organize at higher equilibrium states or lose energy to move to lower equilibrium states or disintegrate. Prigogine asserts that naturally occurring systems are capable of organizing and reorganizing themselves in an infinite number of ways to form new and more complex systems (Prigogine & Gregoire, 1998). This gives rise to Prigogine's belief that naturally occurring systems are irreversible, i.e., they can never be exactly replicated, and raises questions about the utility of reductionism and reversibility as conceptual frames for the understanding of complex systems (Prigogine & Gregoire, 1998).

6. Complexity Theory

Complexity theory asserts that naturally occurring systems reach levels of complex interaction where the normal rules of linearity no longer apply. Complexity theory posits that even simply formulated systems with few variables can display highly complex behaviors that are unpredictable and unforeseeable. Slight differences in one variable can have profound effects on the outcome of a whole system. This is referred to as sensitive dependence on initial conditions (Gell-Man, 1999; Gleick, 1987; Kauffman, 1995; Prigogine & Gregoire, 1998).

7. Linear causality and Non-linearity

The notion of linear causality assumes that, with sufficient study, direct cause and effect relationships can be discerned to explain all phenomena. From this, universal principles to explain all natural phenomena can be determined. Systems are seen as reversible and linear (Gell-Mann, 1999; Gleick, 1987; Miller, 2000; Prigogine & Gregoire, 1998). The opposing conceptual frame is nonlinearity. Nonlinearity posits that direct cause and effect relationships may not exist. From this conceptual frame, systems are perceived as irreversible (Cassidy, 1992; Gell-Mann, 1999; Gleick, 1987; Heisenberg, 1999; Kauffman, 1995; Prigogine & Gregoire, 1998).

8. Reductionism and Holism.

Reductionism asserts that, with sufficient study, the individual parts of any system can be isolated and analyzed to determine their relationship(s) with other parts of the system (or systems). Systems can be dissected and reassembled to produce identical systems. Systems are seen as linear and reversible (Miller, 2000). The opposing conceptual frame is holism. Holism asserts that complex systems can be best-understood using deduction to identify patterns or simplicities. These patterns or simplicities provide important insights about the functioning of a complex system (Alberts & Czerwinski, 1999; Gleick, 1987; Prigogine & Gregoire, 1998; Kauffman, 1995; Resnick, 1999).

9. Certainty and Indeterminacy

Certainty (of measurement) asserts the validity of Newtonian mechanics and the notion that if you are aware of an object's momentum and speed and all of the forces acting on the object you can precisely determine its location (Miller, 2000). The opposing conceptual frame is indeterminacy. Indeterminacy asserts that no universal principle exists to predict any exact future state at the subatomic level (movement of electrons around the nucleus of an atom) because exact measurements cannot be obtained (Heisenberg, 1999). All future states are subject to the rules of probability. Probabilities can only be determined by the application of statistical methods (Cassidy, 1992; Gleick, 1987; Heisenberg, 1999; Miller, 2000).

10. Reversibility and Irreversibility

Reversibility asserts that the parts of any system in the same state space will reassemble exactly the same way as they disassembled to produce the identical system (Miller, 2000). The opposing conceptual frame is irreversibility. Irreversibility asserts that all natural systems are capable of organizing and reorganizing themselves in an infinite variety of ways. The sum of the parts of any system that reassembles itself will never be exactly equal to the system from which it evolved (Alberts & Czerwinski 1999; Gell-Mann, 1999; Gleick, 1987; Prigogine & Gregoire, 1998; Resnick, 1999).

11. Induction and Deduction

Induction asserts that understanding systems at the micro levels of existence can reveal certain principles that guide systems behaviors at the macro level (Trochim, 2004). The conceptual frame of induction gives rise to the notions of linearity and reductionism as the best way to understand complex systems. The opposing conceptual frame is deduction. Deduction asserts that the best way to understand a complex system is to consider it in a holistic fashion to identify patterns or simplicities that can reveal principles that explain system behaviors (Alberts & Czerwinski, 1999; Cassidy, 1992; Resnick, 1999; Trochim, 2004).

Chapter 2. Literature Review

Topics of the Literature Review

There are four principal topics of relevance to this research study. The first topic involves the epistemological constructs being studied. These are the positivist and the post-positivist epistemologies. The second topic involves the four scientific theories selected for study. These scientific theories are special and general relativity, probability, dissipative structure and complexity theory. The third topic involves how the ten conceptual frames of reference that, in different combinations, undergird both the positivist and post-positivist epistemologies and the four scientific theories under study. These ten conceptual frames of reference are linearity and nonlinearity, reductionism and holism, certainty and uncertainty (of measurement), reversibility and irreversibility (of systems), and induction and deduction. The fourth topic involves the integration of quantitative scientific with qualitative social factors in the context of complex interdependent systems. This includes human social systems and institutions.

Purposes of the Literature Review

The study and triangulation of the scholarly literature is used to indicate whether or not the conceptual frames of reference predominate in the positivist and post-positivist epistemological constructs and the four scientific theories under study. There are four principal purposes for this literature review. The first purpose of the literature review is to examine the scholarly body of knowledge pertaining to the positivist and post-positivist epistemologies. The second purpose of the literature review is to examine a sample the scholarly body of knowledge pertaining to four scientific theories that have increased our understanding of the natural world and complex naturally occurring systems. These scientific theories are relativity, dissipative structure, complexity theory and the indeterminacy principle. The third purpose of the literature review is to identify the frames of reference used to conceive and structure the positivist and post-positivist epistemological constructs and the four scientific theories being studied. The fourth purpose of the literature review is to examine the scholarly body of knowledge as it pertains to the integration of quantitative scientific with qualitative social factors in the context of complex interdependent systems. This includes human social systems and institutions. Two areas of specific interest involve institutions of higher education as complex adaptive interdependent systems of systems and the integration of strategic plans and operational budget outcomes at institutions of higher education.

Methods of the Literature Review

The literature review seeks out significant scholarly works that describe the positivist and post-positivist epistemologies and each of the four scientific theories selected for study. These scientific theories are special and general relativity, probability, dissipative structure and complexity theory. In addition, the literature review seeks out significant scholarly works as they pertain to the integration of quantitative scientific with qualitative social process factors in the context of complex interdependent systems. The literature review also seeks out scholarly books and articles pertaining to institutions of higher education as complex adaptive interdependent systems of systems and the integration of strategic plans and operational outcomes at institutions of higher education. A particular focus of the literature review involves operational budget outcomes. The method used to identify pertinent literature for in-depth study and analysis begins with a broad library and web-based search for books, journal articles and other information of significance. Titles of scholarly works, authors, and currency of information are considered in making selections of the most pertinent literature for in-depth study and analysis. Seven specific criteria are used to scope the selection of the scholarly literature examined as part of this research study.

1. The integration of the philosophy of science with scientific theory in ways that were responsive to the eight research questions identified for examination.
2. The connection among science, theory and practical outcomes.
3. Concise definitions, clarity and descriptions of terms.
4. The integration of philosophy with scientific outcomes was more important than "pure science", i.e., how you got there versus the breakthrough itself.
5. Contrast between analogy and metaphor.
6. Selective use of contemporary articles for explanation, breadth and to enhance understanding.
7. Linking strategic plans with operational outcomes using the modern university as one of many potential examples.

The Core Scholarly Literature

The review of the scholarly literature emphasizes a core collection of scholarly books, research papers and studies relating to the philosophy of science and the scientific theories under study, institutions of higher education as complex adaptive interdependent systems of systems and the integration of strategic planning with operational budget outcomes at institutions of higher education. The core collection of the scholarly literature emphasized as part of this research study consists of:

Alberts, D., Garstka J. & Stein, F. (ed.). (1999, August). Network centric warfare: Developing and leveraging information superiority, (2cnd ed). Washington, DC: Center for Advanced Concepts and Technology, Department of Defense.

Alberts, D. & Czerwinski T. (eds.) (1999, January). Complexity, global politics, and national security. Washington, DC: Institute for National Strategic Studies, National Defense University.

Balderston, F.E. (1995). Managing today's university: Strategies for viability, change, and excellence (2cnd ed). San Francisco, CA: Jossey-Bass Publishers.

Barbour, J. (1999). The end of time: The next revolution in physics. New York, NY: Oxford University Press.

Birnbaum, R. (2000). Management fads in higher education. CA: Jossey-Bass Publishers.

Cassidy, D.C. (1992). Uncertainty: The life and science of Werner Heisenberg. New York, NY: W.H. Freeman.

Chaffee, E. (1981). *The link between planning and budgeting.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 405-14.

Commission on National Investment in Higher Education, Council on Aid to Education (1997). *Breaking the social contract: The fiscal crisis in higher education*. Retrieved from the World Wide Web on March 10, 2001: http: www.rand.org/publications/CAE/CAE100/

Comte, A. (1907). *A general view of positivism*, Internet modern history sourcebook. New York, NY: Fordham University. Retrieved from the World Wide Web on February 26, 2005: http://www.fordham.edu/halsall/mod/comte-positivism.html

Duderstadt, J. (1997, August). *The future of the university in an age of knowledge.* University of Michigan. Retrieved from the World Wide Web on March 10, 2001: http:// www.aln.org/alnweb/journal/issue2/ duderstadt.htm

Duderstadt, J. (1998, February 23). *The 21st century university: A tale of two futures*, The millennium project papers. University of Michigan. Retrieved from the World Wide Web on March 10, 2001: http://www.milproj.ummu.umich.edu/ mill2k/ presentations/ CFO/index.html

Duderstadt, J. (undated). *The cost, price and value of a college education*, The millennium project papers. University of Michigan. Retrieved from the World Wide Web on March 10, 2001: http://www.milproj.ummu.umich.edu/ mill2k/presentations/value/ index.html

Epstein, L. C. (2000). Relativity visualized. San Francisco, CA: Insight Press.

Feiser, J. & Dowden, B. (gen. eds.) (2005). *"Logical positivism," and "Time,"* The internet encyclopedia of philosophy. Martin, TN: University of Tennessee. Retrieved from the World Wide Web on February 26, 2005: http://www.utm.edu/research/iep/l/logpos.htm and http://www.utm.edu/research/iep/t/time.htm

Friedman, S. M. (2006). *Albert Einstein online*. Independent website containing Einstein's major scientific and philosophical writings. Retrieved from the World Wide Web on May 28, 2006. Internet available at: http://www.westegg.com/einstein/

Gell-Mann, M. (1999). *The simple and the complex,* Complexity, global politics and national security. Washington, DC: National Defense University, pp. 3-28.

Gibbs, P. (1998). *Is faster than light travel or communication possible?* Riverside, CA: University of California, Department of Mathematics. Retrieved from the World Wide Web on August 21, 2005. Internet available at: http://math.ucr.edu/home/baez/physics/Relativity/SpeedOfLight/FTL.html

Gleick, James (1987). Chaos: Making a new science. New York, NY: Penguin Books.

Hawking, S. (1998). A brief history of time. New York, NY: Bantam Books.

Heisenberg, Werner (1999). Physics and philosophy: The revolution in modern science. Amherst, NY: Prometheus Books.

Helm, Terry (2001). *Cerro Grande fire decision-making: Analysis of the decision drivers.* Los Alamos, NM: Los Alamos National Laboratory, Accident investigation team report on the Cerro Grande fire. Retrieved from the World Wide Web on August 25, 2001: http://www.lanl.gov/diateam/cerrogrande/index.htm\

Jacobs, T.O. (2004). Strategic leadership: The competitive edge. Washington, DC: Industrial College of the Armed Forces, National Defense University.

Janis, I. (1982) Groupthink (2nd edition). Boston, MA: Houghton Mifflin.

Jeans, James (1981). Physics and philosophy. New York, NY: Dover Publications.

Johnstone D. (1999). *Financing higher education: Who should pay?* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 3-16.

Johnstone D. (1988). *Patterns of finance: Revolution, evolution, or more of the same.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 17-24.

Layzell D. (1998). *Linking performance to funding outcomes for public institutions of higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 199-206.

Michelson B., McGee M. & Hawley L. (1994). Consensus team decisionmaking for strategic leaders. Washington, DC: Industrial College of the Armed Forces, National Defense University.

Miller, Arthur I. (2000). Insights of genius: Imagery and creativity in science and art. Cambridge, MA: MIT Press.

Perrow, C. (1982). Normal accidents. Princeton, NJ: Princeton University Press.

Prigogine, I. and Gregoire N. (1998). Exploring complexity: An introduction. New York, NY: W. H. Freeman & Co.

Resnick, M. (1999). Turtles, termites and traffic jams: Explorations in massively parallel microworlds. Boston, MA: MIT Press.

Rosenhead, J. (1998). *Complexity theory and management practice*. Retrieved from the World Wide Web on August 20, 2001: http://www.human-nature.com/science-as-culture/rosenhead.html

Runes, D. (ed.) (1942). Dictionary of philosophy. New York, NY: Philosophical Library. Retrieved from the World Wide Web on February 11, 2006: http://www.ditext.com/runes/

Sanders, I. (1998). Strategic thinking and the new science: Planning in the midst of chaos, complexity, and change. New York, NY: The Free Press.

Schmuck R. & Runkel P. (1994). The handbook of organization development in schools and colleges. Prospect Heights, IL: Waveland Press, Inc.

Schmidtlein, F. (1981). *Why linking budgets to plans has proven difficult in higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 415-24.

Schulock, N. & Harrison M. (1998). *Integrating, planning, assessment, and resource allocation.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 437-44.

Trochim, William M. (2004). The research methods knowledgebase (2nd edition). Retrieved from the World Wide Web on February 22, 2005: http://trochim.human.cornell.edu/kb/index.htm

U.S. General Accounting Office (GAO) (2000). *Fire management: Lessons learned from the Cerro Grande (Los Alamos) fire.* Washington, DC: US Government Printing Office (GAO/T-RCED-00-257, August 14, 2000). Retrieved from the World Wide Web on July 15, 2005: http://www.gao.gov

Waggaman J. (2000). *Strategies and consequences: Managing costs in higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, 301-15.

Waldrop, M. (1992). Complexity: The emerging science at the edge of order and chaos. New York, NY: Simon and Schuster.

Wheatley, M. (1999). Leadership and the new science: Discovering order in a chaotic world. San Francisco, CA: Berrett-Koehler Publishers.

Wilson, E.O. (1998). Consilience: The unity of knowledge. New York, NY: Random House.

Description and Critique of the Scholarly Literature

According to the positivist (and logical positivist) epistemology the experience of the senses is the only thing that defines the reality of existence. It assumes that all science rests on a foundation of facts and that once enough facts are collected and analyzed generalizations can be extracted enabling a scientist to predict given some set of circumstances at T_1 some fact that will still hold true at T_2. If the prediction is true then the hypothesis (or theory) must also be true (Feiser & Dowden, 2005; Runes, 1942; Trochim, 2004). As such, positivism applies inductive reasoning to solve problems and embraces a Newtonian "clockworks" view of reality where the rules of linearity, reductionism, certainty of measurement and reversibility apply (Feiser & Dowden 2005; Miller, 2000). The positivist tradition is characterized by the underpinning Newtonian belief that behaviors in the natural environment, including social behaviors, are guided by established rules of cause and effect — a causal linear perception of the natural order where the whole is necessarily equal to the sum of its parts (Feiser & Dowden, 2005; Miller, 2000; Runes, 1942). According to this reductionist view, the challenge for scientists is to achieve enough understanding of the natural environment at the micro levels of existence to discern the fundamental rules that result in specified cause and effect outcomes, i.e., extrapolate behaviors at the macro level (Miller 2000; Wilson, 1998). This linear perception of the natural world gives rise to the belief that understanding the physical aspects of systems in enough detail at the micro level holds the key to determining the behavior of complex systems at the macro level, i.e., inductive reasoning (Trochim 2004; Wilson, 1998). This reductionist view of complex systems also gives rise to the notion of reversibility. Reversibility in complex systems is akin to a watchmaker taking apart and putting back together the pieces of an expensive watch. All of the pieces of a particular watch taken apart and put back together in the same way will produce exactly the same watch — the sum of the individual parts is always equal to the whole (Miller, 2000). According to this view, complex systems can be understood and managed to identify the possible causes of systems failures by in-depth process-engineering that identifies all of the "pieces" of a system and considers in a linear deterministic fashion the potential cause and effect relationships that can occur in the system or interactions between and among systems, i.e., interdependent systems (Miller, 2000; Perrow, 1982; Runes, 1942). The post-positivist epistemology rejects the positivist assertion that there is no reality beyond our ability to empirically prove it through sense experience. Post-positivists believe that a reality exists beyond our ability to empirically prove it and that reality is dependent on the human observer (Feiser & Dowden, 2005; Runes, 1942; Trochim, 2004). The most common form of post-positivism is called critical realism. Unlike positivists, critical realists believe that all observation is fallible and all theory is subject to revision. For this reason, they contend that multiple measures and observations, i.e., triangulation, are core to the advancement of knowledge (Trochim, 2004). Thus, the collection and analysis of large amounts of information and continuing scrutiny of research results leads to the evolutionary creation of the "best" knowledge (Feiser & Dowden 2005; Trochim, 2004). In this sense, only the "most correct" ideas or theories survive. This concept has come to be known as the natural selection theory of knowledge (Trochim, 2004). So, according to the positivist view, the certainty of any measurement is subject to continuous improvement because the act of human observation itself is limited by lack of knowledge, affected by bias or the effects that the act of observation itself has on what is being observed. The fact remains, however, that positivists and post-positivists are both still realists that continue to rely on induction and a Newtonian clockwork perception of existence that embraces the notions of linear causality, reductionism and reversibility. It is also highly significant that these frames of reference guide and legitimate scientific method in the fields in which these frames dominate. Consequently, they determine the nature of new knowledge these fields of science can obtain and the extent to which new theory can be developed. That is, their established methods preclude some domains of inquiry, and thus new understandings that might result from inquiry in these domains. Thus, these fields are self-limiting by virtue of the methods prescribed for investigation. As discussed below, these notions may no longer be sufficient to explain the behavior of complex systems and the need to integrate quantitative and qualitative factors.

In 1827, Scottish botanist Robert Brown noticed that pollen grains suspended in water moved randomly about under the lens of the microscope. Brown believed that the movement of the pollen grains was the result of the movement of water molecules in which the pollen grains were suspended. The inability to accurately predict the movements of the pollen grains puzzled scientists. This phenomenon became known as Brownian motion (Miller, 2000). In 1905, Albert Einstein published a paper postulating that particles of dust suspended in water move about because moving water molecules are constantly bombarding them. In his famous paper on Brownian motion, Einstein found that while he could not predict the exact path of a particle of dust suspended in water he could predict its average path. But he continued to believe that a more complete understanding of all of the forces acting on the water molecules and dust particles could lead to exact prediction (Friedman, 2006; Miller, 2000). Like Newton, Einstein believed that nature could be fully understood in the context of causal relationships and reductionism where systems are reversible and measurements are certain (Friedman, 2006; Miller 2000). That same year, Einstein published his theory of special relativity. In 1915, he published his theory on general relativity. In special relativity theory Einstein posits a ruling principle that distance and time are not absolute and depend on the motion of the observer. Einstein, like Newton before him, believed that reality exists independent of the observer (Cassidy, 1992; Friedman, 2006; Miller, 2000). In general relativity theory Einstein posits the ruling principle that gravity pulling in one direction is equivalent to acceleration in the opposite direction. This is known as the equivalence principle. Relying on the deductive proposition that distance and time are not absolute and depend on the motion of an observer and the ruling principle that gravity pulling in one direction is equivalent to acceleration in the opposite direction, Einstein was able to paint a whole new picture of reality, i.e., non-Euclidean four-dimensional space, outside the bounds of the five human senses – a reality that can only be visualized and understood by imagination and intellect (Epstein, 2000; Friedman, 2006; Miller 2000).

In 1927, Werner Heisenberg postulated that precise measurements of sub atomic particles are impossible because of the interference (disturbances to the environments in which they are moving, i.e., effects on momentum) created by the methods used to measure them (Heisenberg, 1999). In his book, Uncertainty: The Life and Science of Werner Heisenberg, Cassidy (1992) observes,

> Heisenberg took this one step further: he challenged the notion of simple causality in nature, that every determinate cause in nature is followed by the resulting effect. Translated into "classical physics," this had meant that the future motion of a particle could be exactly predicted, or "determined," from knowledge of its present position and momentum and all of the forces acting upon it. The uncertainty principle denies this, Heisenberg declared, because one cannot know the precise position and momentum of a particle at a given instant, so its future cannot be determined. One cannot calculate the precise future motion of a particle, but only a range of possibilities for the future motion of the particle...one should note that Heisenberg's uncertainty principle does not say, "everything is uncertain." Rather, it tells us very exactly where the limits of uncertainty lie when we make measurements of sub-atomic events. Heisenberg's uncertainty principle constituted an essential component of the broader interpretation of quantum mechanics known as the Copenhagen Interpretation.[1]

Based on this thinking Heisenberg went even further to conclude, "The 'path' [of a sub atomic particle] comes into existence only when we observe it" (Cassidy, 1992;

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[1] Cassidy, D.C. (1992). Uncertainty: The life and science of Werner Heisenberg, NY: W.H. Freeman, p. 8. Internet available on the World Wide Web at: http://www.aip.org/history/heisenberg/p08c.htm

Heisenberg, 1999). But, as Cassidy observes, not everyone agreed with Heisenberg's bold new interpretation of reality,

> Einstein and Schrödinger were among the most notable dissenters. Until the ends of their lives they never fully accepted the Copenhagen doctrine, i.e., the basic tenet of quantum mechanics. Einstein was dissatisfied with the reliance upon probabilities. But even more fundamentally, he believed (like Newton before him) that nature exists independently of the experimenter, and the motions of particles are precisely determined. It is the job of the physicist to uncover the laws of nature that govern these motions, which, in the end, will not require statistical theories. The fact that quantum mechanics did seem consistent only with statistical results and could not fully describe every motion was for Einstein an indication that quantum mechanics was still incomplete.[2]

In 1977, Ilya Prigogine won the Nobel Prize for developing the theory of dissipative structures. Prigogine postulated that complex thermodynamic systems absorb energy to self organize at higher equilibrium states or lose energy to move to lower equilibrium states or disintegrate (Prigogine & Gregoire, 1998). Prigogine's insights are significant because they indicate that systems are capable of organizing and reorganizing themselves to form new and more complex systems. Prigogine's work gives rise to the notion of irreversibility. In the physical world we know that complex systems broken apart into their separate "pieces" self-organize themselves in an infinite combination of ways to produce new systems with different characteristics. In other words, the sum of the parts never exactly equals the original whole (Prigogine & Gregoire, 1998). Irreversibility means that no matter how deeply we process-engineer them, it is not possible to identify all of the potential ways complex systems can

[2] Ibid. Internet available at: http://www.aip.org/history/heisenberg/p08c.htm

reorganize themselves. The irreversibility of complex systems brings into question the positivist and post-positivist reliance on linear causality, reductionism and induction as the correct methods for understanding complex systems (Gell-Mann, 1999; Gleick, 1987; Prigogine & Gregoire, 1998; Resnick, 1999).

The work of Prigogine and other theorists in the 1970's and 1980's brought other new ideas about the behavior of naturally occurring complex systems. To complexity theorists, the notions of initial conditions and randomness that drive the propagation of evolving complex systems raise the possibility of unexpected and dramatically different end states (Gell-Mann, 1999; Gleick, 1987). The notions of initial conditions and randomness that drive the propagation of system behaviors, when combined with random interactions of different systems with each other represent the holy grail of complexity theory (Alberts & Czerwinski 1999; Gell-Mann, 1999; Gleick, 1987; Prigogine & Gregoire, 1998; Resnick 1999).

In 1996, National Defense University in cooperation with the RAND Corporation sponsored a symposium on the topic of "Complexity, Global Politics and National Security." Gregory Treverton of RAND opened the session by describing the confusing and seemingly chaotic nature of the world in which we live. Referring to a comment made by Winston Churchill following an unexciting meal that, "The pudding lacked a theme," Treverton asked how, without a theme, do we apprehend; how do we understand the world around us? In the Foreword to the symposium's proceedings, Air Force Lieutenant General Ervin J. Rokke, then President of National Defense University, observed,

> In trying to answer that [Treverton's] question, I think it is fair to say that the intellectual response to the end of the Cold War…is driven by advances in technology, primarily information technology. However, to my taste, what emerges is a "pudding without a theme". We have given less attention to what our colleagues in the arenas of physics, biology and other New Sciences have to say. They suggest that neither technology nor the Newtonian principles of linearity are sufficient to deal with the increasingly complex world in which we find ourselves. Complexity theory contends that there are underlying simplicities, or patterns, if we but look for them. These provide us with insights, if not predictions or solutions. Such an effort, if successful, promises to help us find the theme in the pudding.[3]

So then, how is it that human beings seem to "muddle through" to find solutions to complex problems that they cannot possibly fully comprehend? General Rokke's observation that the underlying simplicities and patterns that characterize complex events and situations can provide human beings with key insights necessary to solve complex problems may be an important part of the answer to this question. As Sowell (1987) observes in his studies of the qualitative social process aspects of complex political struggles:

> The ever-changing kaleidoscope of raw reality would defeat the human mind by its complexity, except for the mind's ability to abstract, to pick out parts and think of them as the whole. This is nowhere more necessary than in social visions and social theory, dealing with the complex and often subconscious interactions of millions of human beings.[4]

Complexity theorists maintain that a holistic perception of a system (or interacting systems of systems) beginning with deduction can lead to the observation of simplicities or patterns that can provide insights about the behavior of complex systems or systems

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[3] Alberts, D. & Czerwinski, T. (eds.) (1999). Complexity, global politics, and national security. Washington, DC: National Defense University, p. xi, xii .

[4] Sowell, T. (1987). A conflict of visions: Ideological origins of political struggles. New York: NY: William Morrow, p. 15.

of systems (Alberts & Czerwinski, 1999; Gleick, 1987; Resnick, 1999, Miller, 2000). Resnick's research at the Massachusetts Institute of Technology supports the thesis that the behavior of complex interdependent systems can be understood by identifying the underlying rule sets that define their patterns of behavior (1999). For example, he posits that all traffic jams can be explained, at their most fundamental level, in terms of three simple rules. First, the driver of an automobile by applying foot pressure on the accelerator can choose to speed up a vehicle. Second, the driver of an automobile by relieving foot pressure on the accelerator can choose to slow down a vehicle. Third, the driver by applying foot pressure on the brake can slow down or completely stop a vehicle (Resnick, 1999). Of course, variations in initial conditions, e.g., volume of traffic, number of lanes, weather conditions, the aggressiveness of individual drivers, enforcement of speed limits and many other factors can influence in what combinations individual drivers exercise these three basic rules and how the effects of their individual behaviors multiply. Thus, the right combination of driving conditions and how this influences the exercise of Resnick's basic rules by drivers can either cause or prevent traffic jams (Gell-Mann, 1999; Gleick, 1987; Resnick, 1999). But, of course, the wild card in all of this is the assumption that drivers will act rationally and respond in a consistent fashion to initial and a subsequent change in driving conditions. All of us know too well that human beings do not always act rationally — some drink while driving, pass in violation of double yellow solid lane markings, engage in acts of road rage, enter into high speed chases with the police and otherwise behave in ways that defy rational explanation — at least in quantitative analytical terms. In complex systems we are also confronted with the notion of randomness as a fundamental characteristic of nature. To complexity theorists this means that even minor deviations in initial conditions due to random deviation can produce unimaginably different end states (Gell-Mann, 1999; Gleick, 1987; Resnick, 1999). The notion of randomness raises serious questions about the positivist reliance on linear cause and effect, certainty of measurement, the reversibility of systems, reductionism and induction as the best way to understand the behaviors of complex systems.

In an article appearing in the New Scientist, Graham Lawton (2001) describes his research into what is known as the "rogue wave" phenomenon. Rogue waves are huge walls of water sometimes reaching 30 meters in height, i.e., the height of a 10-story building, that appear without warning in otherwise benign conditions in the oceans of the world. Lawton tells us that freakish waves have been part of marine folklore for centuries but until recent times reports of rogue waves have been dismissed as mariner's tales. He reports that over the past 30 years hundreds of ships have sunk under mysterious circumstances and that new scientific findings are causing naval architects to conclude that a large number of these vessels were sunk by rogue waves. Recently, oceanographers have begun to question the age-old assumption that waves are simply the result of a straightforward linear process. This old view postulates that all of the big waves in the ocean are simply the result of constructive interference- small waves joining forces and adding up. But rogue waves appear too frequently to be explained by the simple linear process of constructive interference. According to Lawton,

> Interference effects ought to produce a bell-shaped distribution of wave heights with the vast majority close to the average height, some taller, some shorter. Outliers can occur, but they are rare. Freaks [rogue waves] more than twice the

> average height would only crop up once in a lifetime. But this bears no resemblance to reality. What oceanographers are seeing suggests that the majority of waves are smaller than the mean and that the true giants rise up more frequently than anyone imagined. Orthodox oceanography has been holed below the waterline.[5]

Then, of course, there are the qualitative human social aspects of decision making and policy formulation that add an entirely new dimension to the notion of complexity and the challenge of effective problem solving (Jacobs, 2004; Janis, 1982; Perrow, 1982; Sarkesian, 1995). In today's complex world it is becoming increasingly difficult to fully comprehend the underlying causal factors that promote poor decision-making. This is particularly true when highly skilled and objective decision-makers fail to comprehend the consequences of seemingly "routine" judgment calls that can erupt in unexpected ways to produce drastic consequences (Helm, 2001; Jacobs, 2004; Perrow 1982). Moreover, our culture demands that an individual(s) be blamed when a disastrous situation occurs even in those cases where thoughtful analysis discloses that flawed strategic plans and policies rather than the actions of an individual(s) were the major contributing factors (Helm, 2001; Perrow, 1982). But, there is an emerging body of knowledge suggesting that major systems failures are more frequently the result of flawed planning and policies rather than human operational error. Some theorists postulate that flawed plans and policies may actually shape the environment to cause reasonable people acting in reasonable ways to err catastrophically. They believe that individual human operators cannot be expected to comprehend the unanticipated

[5] Lawton, G. *Monsters of the deep*. New Scientist. London, UK: Reed Business Information, Ltd., June 2001, p. 31.

consequences of their actions in highly complex systems and possibly be expected to keep pace with the non-linear systems behaviors that emerge as a result of systems of systems interactions (Helm, 2001; Perrow, 1982; Sagan, 2004).

The 1970's and 1980's brought a new understanding of complex naturally occurring systems to the fore with the work of scientists like Illya Prigogine who won the Nobel Prize in 1977 for his theory of dissipative structures and Charles Perrow who wrote the book, Normal Accidents (Perrow, 1982; Prigogine & Gregoire, 1998). In Normal Accidents Perrow asserts that when operating systems reach a certain threshold of complexity accidents become inevitable because of the inability of human operators to comprehend the unanticipated consequences of their actions and then keep pace with the non-linear systems behaviors that emerge as a result of systems of systems interactions, i.e., closely coupled systems. Perrow further postulates that social process factors are major contributors to breakdowns of complex safety systems. He theorizes that accidents are inevitable as systems become more complex because of the difficulty inherent in effectively integrating the human qualitative aspects of complex systems, e.g., policies, processes, and procedures, with the non-human quantitative aspects of complex systems, e.g., technical safety system design, technical specifications of operating equipment, etc. (1982). Janis in Groupthink supports the view that qualitative human social process factors can seriously affect the quality of decision making in groups (1982).

As Rosenhead recounts in his analysis of complexity and management theory, social scientists like Peter Senge, R.D. Stacey, Margaret Wheatley, M. D. McMaster, Ulrich Merry and many others have attempted to bridge the gap between the quantitative world of empirical science and the qualitative world of social process and organizations in ways that try to address Perrow's conundrum (1998). These researchers maintain that there are bases in natural science that can be used to rationalize the unstructured aspects of human decision-making and human behavior. They believe that the better we understand the complexity of nature the better we can extrapolate to the human condition and learn how to more effectively manage society's organizations and institutions. These policy and management theorists contend that Newton's clockwork view of the universe is no longer adequate to explain the growing complexity of society's organizations and institutions. They believe that nature shows us that we may never be able to predict, "extended order effects" in simple linear terms (Sanders, 1998; Wheatley, 1999). Instead, people and organizations must learn in real time and be able to adapt quickly and continuously by adjusting to and taking advantage of changes in their environments (Rosenhead, 1998; Sanders, 1998; Senge, 1990; Wheatley, 1999). For example, in his writings Rosenhead describes research on organizations and the two types of management patterns required to sustain competitive advantage in an organization. "Ordinary" management worries about things like today and tomorrow's short-term operations, the efficiency of the organization, the bottom line and people. "Extraordinary" management serves as an early detection and warning system that looks at the environment as uncertain and unpredictable — an environment that requires one to quickly adapt or die (Rosenhead 1998). Thus, the notion of the learning organization emerges (Senge, 1990). But Rosenhead aptly points out, the work of these management theorists is based largely on metaphorical fancy rather than analogical rigor (1998).

Rosenhead in his writings on complexity theory and management tells us that metaphor is a figure of speech that we transfer to something that is not directly applicable in order to illuminate by highlighting or providing a unique interpretation. For example, we often hear politicians and economists say things such as "we need to put the brakes on inflation" or "we need to step on the accelerator to speed up the economy" (1998). But, as Rosenhead reminds us, while metaphors help to illuminate, politicians and economists do not really mean that we should design a macroeconomic policy or system based on the parts of a car. Rosenhead goes on to say that analogy is different because it asserts some level of direct similarity or difference between the elements of two or more different domains and the causal relationships driving them. Analogies are usually used to connect one well-understood domain to one less well understood by extrapolating similarities. Using analogy to extrapolate between domains one can then devise empirical tests to prove or disprove similarities or differences as one moves from one well-understood domain to another less understood domain (1998). For example, Rosenhead reminds us that Huygens extrapolated the wave theory of light based on the better-understood and empirically tested notions of sound waves. Similarly, he tells us that Fourier's theory of heat conduction was based on better-known laws associated with the flows of liquids (Rosenhead, 1998).

So then, the central question becomes, how can we apply analogical thinking to help us bridge the gap between new scientific understandings of complex naturally occurring systems, including complex human social systems, and the improved human management of complex events and situations? Perrow in Normal Accidents (1982) tells us that the purpose of post-accident investigations is to determine the root cause(s) resulting in the event and to assign accountability. By assigning accountability we attempt to do two things. First, to assure that corrective measures are taken in order to prevent a recurrence of the event in the instant case. Second, for deterrence — to send an unambiguous signal to those in positions of responsibility in organizations that negligence or failure to follow established safety policy or procedures can impact their individual job security. Thus, the principal focus of investigations is usually on whether or not human operators followed established policy and procedures (Helm, 2001; Perrow, 1982; Sagan, 2001). Sometimes, however, too little attention is paid to the inability of single human operators to comprehend the unanticipated consequences, i.e., extended order effects, of their own actions as they operate to manage a complex system and then keep pace with the non-linear systems behaviors that emerge from highly complex systems of systems interactions (Helm, 2001; Perrow, 1982; Sagan, 2001). Frequently, the fault of major systems failure may also rest with the validity of policy itself and the effectiveness of the procedures that flow from it (Helm, 2001; Perrow, 1982). For example, Terry Helm at Los Alamos National Laboratory undertook a study of the events surrounding the Cerro Grande fire that consumed thousands of acres of woodlands and threatened to consume the city of Los Alamos in New Mexico (2001). The fire was intentionally set as part of a government program of "controlled burns". The study concludes that individuals, i.e., human operators, were held accountable for malfeasance when the fire burned out of control even though they followed established policy and procedures. The Los Alamos analysis disclosed that the government policies and procedures that fire personnel were required to follow were inherently flawed (Helm, 2001). A Government Accounting Office report supports the Los Alamos findings that government polices were inherently flawed (GAO, 2000). Later, the fire personnel who started the “controlled burn” were publicly exonerated of personal wrongdoing in the blaze (Sanchez, 2001).

The results of the Los Alamos and GAO studies are significant for four important reasons. First, the Cerro Grande fire and other major disasters show that when systems reach a certain threshold of complexity accidents can become inevitable if we fail to recognize the inability of individual human operators to comprehend the unanticipated consequences of their actions as they operate in complex systems and try to keep pace with non-linear systems behaviors that emerge as a result of complex systems of systems interactions (Helm, 2001; Perrow, 1982; Sagan 2001). Second, both studies demonstrate the danger of assuming that a policy and the procedures that flow from it are effective. As the Cerro Grande fire and other disasters show, too frequently policies and procedures go untested for validity until during or after a calamity occurs (GAO, 2000; Helm, 2001; Perrow, 1982). Third, the Los Alamos National Laboratory study supports the conclusions of Perrow by demonstrating the propensity toward holding individuals versus the organizations they work for accountable and assigning blame based on qualitative social factors versus unbiased quantitative analysis (GAO, 2000; Helm, 2001; Perrow, 1982). Fourth, both the Los Alamos National Laboratory and GAO studies raise significant questions about how policy is derived within and between large organizations and whether the process itself is valid. In the case of the Cerro Grande fire, the failure of different government organizations to effectively coordinate efforts to contain the fire because of conflicting policies was identified as a contributing causal factor (GAO, 2000; Helm, 2001). In the case of other government agencies for example, how do the decision-makers who formulate the policy validate the process used to formulate it? In other words, do they decide the best way to decide before they decide? Or is policy formulation a disjunctive consensus activity across limited subject matter expert domains with no quality control and tests of merit before it is implemented? If the extended order effects of policies and procedures that individual human operators are required to follow during emergencies do not consider the extended order effects of their implementation and the unanticipated, i.e., nonlinear, systems of systems interactions that may emerge, then how effective can the policy or procedure itself be?

Oftentimes, the formulation of strategic plans and decisions to make long-term policy decisions and resource investments can be an amalgam of highly complex political and bureaucratic systems that involve both qualitative social considerations and scientific or technical quantitative factors (Allison & Zelikow, 1999; Janis, 1982; Sarkesian, 1995). Frequently, strategic plans and investment decisions may be driven by qualitative social factors and social process, e.g., political and other human considerations, with little regard for quantitative factors or technical aspects (Allison & Zelikow, 1999; Balderston, 1995; Birnbaum, 2000; Janis, 1982; Reynolds, 2001; Sarkesian, 1995). For example, the decision to build and the failure to identify serious design flaws until after the production and delivery to the Air Force of the B-1 bomber is an example where qualitative sociological and quantitative technology factors were not appropriately integrated to produce a sound, forward-looking national security investment decision (Reynolds, 2001). This is consistent with a large body of scholarly literature that suggests there is no widely accepted body of theory or methodology that integrates qualitative social considerations with quantitative scientific and technical factors in the context of complex interdependent systems (Alberts & Czerwinski, 1999; Balderston, 1995; Birnbaum 2000; Gell-Mann, 1999; Miller, 2000; Perrow, 1982; Rosenhead, 1998; Ruso-Toderean, 1992).

The positivist tradition is characterized by the underpinning Newtonian belief that behaviors in the natural environment, including human behaviors, are guided by established rules of cause and effect — a linear deterministic perception of reality and the natural order where the whole is necessarily equal to the sum of its parts (Miller 2000; Ruso-Toderean, 1992; Trochim, 2004). According to this reductionist view, the challenge for scientists is to achieve enough understanding of the natural environment at the micro levels of existence to discern the fundamental rules or principles that result in specified cause and effect outcomes, i.e., extrapolate behaviors at the macro level (Feiser & Dowden, 2005; Miller 2000, Trochim, 2004; Wilson 1998). But in the natural world we know that complex systems broken apart into their separate "pieces" may self-organize themselves in any one of an infinite combination of ways to produce new systems with different characteristics. In other words, the sum of the parts never exactly equals the original whole (Gell-Mann, 1999; Prigogine & Gregoire, 1998).

In the study of complex systems this gives rise to the concept of irreversibility. Irreversibility means that no matter how deeply we process-engineer complex systems, it is not possible to identify all of the potential ways they can reorganize themselves (Barbour, 1999; Bolton, Durant, et. al., 2000; Prigogine & Gregoire, 1998). In the context of major safety systems failures like the near meltdown of the Three Mile Island commercial nuclear power reactor, the Chernobyl reactor meltdown, and the Challenger space shuttle accident this means that the behaviors of complex systems can never be fully understood making it impossible to process-engineer, in a predictive manner, all possible systems redundancies necessary to prevent catastrophic systems failures (Helm, 2001; Perrow, 1982; Sagan, 2001). As noted earlier, this problem is only exacerbated when we consider the unstructured aspects of human decision-making. Perrow in Normal Accidents posits that catastrophic failures are inevitable, as systems grow more complex. Perrow states that this is because the redundancies or combination of redundancies introduced by humans to prevent system failures only serve to create additional complexity (1982). Perrow's thinking is supported by Sagan (2004). According to this view, more complexity begets more opportunity for accidents. The work of Sagan suggesting the inherent limitations of redundant backup systems in preventing safety failures supports Perrow's view (2001). As discussed earlier, the results of work conducted by scientists at Los Alamos National Laboratory in their analysis of both the qualitative social process and technical factors contributing to catastrophic systems failures also support this view (Helm, 2001).

Other research supports the significance of an integrated approach that considers both quantitative technical and qualitative social factors to increase our understanding of complex interdependent systems. In his book, Consilience: The Unity of Knowledge, Wilson posits that our increased understanding of science at the bio-molecular level is leading to new revelations about the nature of complex systems including human thought and consciousness. Wilson contends that this new knowledge may be leading to the convergence of the hard and the soft sciences to produce what he believes is an emerging "unity of knowledge" (1998). This means that universal principles or, at the least, common denominators that explain natural behaviors that cross the boundaries between life and the lifeless universe from which it arose, must exist. In his work, Wilson concludes that scientific advances are leading to break-through discoveries that are yielding new knowledge about the “soft sciences” of human behavior and the human decision process itself. He contends that the soft and hard sciences are moving toward an inexorable convergence as our scientific understanding of life and the interactions of chemical and biological systems at the bio-molecular level increase (Wilson, 1998). Thus, Wilson’s work supports the notion that understanding existence at the micro-level can allow you to extrapolate behaviors of complex systems at the macro-level (1998). This reflects a linear view of existence, albeit complex, but with discernible cause and effect outcomes. It also supports a significant body of scholarly literature suggesting that a practical methodology to effectively integrate qualitative social considerations quantitative scientific and technical factors in the context of complex interdependent systems currently does not exist (Alberts & Czerwinski, 1999; Gell-Mann, 1999; Miller, 2000; Perrow, 1982; Reynolds, 2001; Rosenhead, 1998; Ruso-Toderean, 1992). This includes the highly complex interdependent systems that characterize institutions of higher education (Balderston, 1995; Birnbaum, 2000; Commission on National Investment in Higher Education, 1997; Duderstadt, 1997 & 1998; Johnstone, 1988 & 1998; Layzell, 1998; Schmidtlein, 1981; Schmuck & Runkel, 1994; Shulcok & Harrison, 1998).

Resnick’s work at the Massachusetts Institute of Technology using object-oriented supercomputing as an educational tool for understanding complex event phenomenology focuses on patterns and discerning the core attributes of systems behaviors and their propagation to create complex systems and understand systemic behavior patterns (1999).[6] Resnick's work supports the notion that systems can best be understood in a holistic fashion based on patterns of complex systems behavior. As a large body of existing scientific literature on complexity theory shows, initial conditions can drive systems to behave in ways that it is impossible to determine linear cause and effect relationships (Gell-Mann, 1990, Gleick, 1987; Prigogine & Gregoire, 1998; Waldrop, 1992).

Prigogine's work on dissipative structure theory may also provide insights upon which the qualitative social aspects of the human condition and the quantitative rules of natural science can be integrated[7] (Prigogine & Gregoire, 1998). Collectively, the research of Gleick (1987), Gould (1991), Prigogine (1998), Gell-Mann (1999), Resnick (1999), Perrow (1999), Barbour (1999), Sagan (2004), and others, may signal the emergence of a new epistemology of science that will allow us to integrate qualitative social considerations with quantitative science and technology factors in ways that will help us to more deeply understand and better manage complex interdependent systems. The acceptance and application of this kind of integrated systems factors analysis to the strategic decision process holds great potential to improve our ability to manage complex events and situations. This includes the complex interdependent systems that characterize today's institutions of higher education.

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[6] (See: http://www.media.mit.edu/starlogo/home.htm)
[7] (See: http://order.ph. utexas.edu/)

Chapter 3. Methods

Overview of Methodology

Based on the review and study of the scholarly literature, the different conceptual frames of reference used to conceive and structure the positivist and post-positivist epistemological constructs and the four scientific theories selected for study are triangulated. The frames of reference for the two epistemological constructs are compared and contrasted with the frames of reference used to conceive and understand each of the four scientific theories selected for study. The resulting analysis is used to identify those frames of reference used to conceive and structure each of the scientific theories, if any, that are not reflected in the positivist and the post-positivist epistemologies in order to highlight possible limitations of the positivist and post-positivist epistemologies as constructs for understanding the behaviors of complex naturally occurring systems. As further described below, with the emergence of complexity theory as a new construct for understanding complex systems, all of the positivist frames of reference become subordinate to a new predominate set of cognitive frames of reference, namely, non-linearity, holism, uncertainty (of measurement), irreversibility (of systems) and deduction. These new frames of reference are used to describe a new epistemology of science known as *a priori optionality* that can increase the human understanding of complex systems and systems of systems interactions. This includes the complex interdependent systems that characterize today's institutions of higher education. The tenets of *a priori optionality* are then used to structure a process known as the complexity systems method that can be applied to: 1) enhance human learning; 2) more effectively integrate quantitative science and technical factors with qualitative human social considerations in the context of complex interdependent systems, and; 3) improve human decision making in the management of complex events and situations. Improved decision making is a significant factor to the more effective integration of strategic plans with operational outcomes in complex human systems and organizations, including institutions of higher education.

The methodology used to conduct this research study involves the comparison and contrast of the two reigning epistemological constructs of positivism and post-positivism with Einstein's special and general relativity theory (Cassidy, 1992; Friedman, 2006; Hawking, 1998; Miller, 2000), Heisenberg's principle of indeterminacy (Cassidy, 1992; Heisenberg, 1999; Miller 2000), Prigogine's dissipative structure theory (Prigogine & Gregoire, 1998), and complexity theory (Gleick, 1987; Gell-Mann, 1999; Kauffman, 1995). Based on the study of the scholarly literature, ten predominate frames of reference have been triangulated that are used to conceive and structure the positivist and post-positivist epistemological constructs and the scientific theories selected for study. The ten conceptual frames of reference triangulated from the study of the scholarly literature are linear causality and non-linearity, reductionism and holism, certainty and uncertainty (of measurement), reversibility and irreversibility (of systems), and induction and deduction.

The research methodology includes the development of a logic block to compare and contrast the positivist and post-positivist epistemologies and the scientific theories against the ten conceptual frames of reference identified as a result of the triangulation of the scholarly literature. The logic block is used to indicate whether the associated epistemology or scientific theory "accepts" or "rejects" (based on collective prevalence, i.e., predominance) each of the ten conceptual frames of reference. Through the process of comparison and contrast, unique patterns based on the predominance of the ten conceptual frames of reference emerge. These pattern sets or groupings of pattern sets show how the ten conceptual frames of reference have been integrated or combined in different ways to conceive and structure the positivist and post-positivist epistemological constructs and the four scientific theories under study. The purpose of the logic block is to determine if a new pattern set or grouping of pattern sets emerges that forms a unique framework for understanding complex naturally occurring systems, i.e., a new epistemological construct.

Based on the review and triangulation of the scholarly literature, a logic block that compares and contrasts the positivist and post-positivist epistemological constructs and the four scientific theories selected for study against the ten conceptual frames of reference of linear causality and non-linearity, reductionism and holism, certainty (of measurement) and indeterminacy, reversibility and irreversibility (of naturally occurring systems) and induction and deduction was developed. The logic block appears as Figure 1. The logic block indicates the "acceptance" or "rejection" of each of the ten conceptual frames of reference for the positivist and post-positivist epistemologies and relativity theory, the indeterminacy principle, dissipative structure and complexity theory based on the triangulation of the scholarly literature as described in Chapter 2. Through the process of comparison and contrast, unique patterns based on the predominance of the ten conceptual frames of reference emerge. These pattern sets or groupings of pattern sets illustrate how the frames of reference have been integrated or combined to form a variety of conceptual frameworks for conceiving and understanding complex naturally occurring systems.

Table 1: Epistemological Logic Block

	Linearity / Non-linearity	Reductionism / Holism	Certainty / Uncertainty	Reversibility / Irreversibility	Induction / Deduction
Positivism	Linearity	Reductionism	Certainty	Reversibility	Induction
Post-positivism	Linearity	Reductionism	Uncertainty	Reversibility	Induction
Relativity Theory	Linearity	Reductionism	Certainty	Reversibility	Deduction
Indeterminacy Principle	Non-linearity*	Reductionism	Uncertainty*	Irreversibility*	Induction
Dissipative Structure Theory	Non-linearity	Holism	Uncertainty	Irreversibility	Induction
Complexity Theory	Non-linearity	Holism	Uncertainty	Irreversibility	Deduction

* Within defined bounds at the subatomic level

Table 1., illustrates, based on the triangulation of the scholarly literature a unique set of five cognitive frames of reference that predominate in the positivist epistemology, namely, linearity, reductionism, certainty (of measurement), reversibility (of systems),

and induction. With only one deviation, the frame of uncertainty (of measurement), all of the remaining positivist frames predominate in the post-positivist epistemology, i.e., linearity, reductionism, reversibility (of systems) and induction. With the single exception of deduction, the positivist frames of reference of linearity, reductionism, certainty (of measurement) and the reversibility (of systems) apply to relativity theory. With the three exceptions of non-linearity, uncertainty (of measurement), and irreversibility (of systems) the positivist frames of reference of reductionism and induction still predominate with respect to the indeterminacy principle. With the four exceptions of non-linearity, holism, uncertainty (of measurement), and irreversibility (of systems), the single positivist frame of induction still predominates in dissipative structure theory. Only with the emergence of complexity theory as a new construct for understanding complex systems are all of the positivist frames of reference subordinate to a new predominate set of cognitive frames of reference, namely, non-linearity, holism, uncertainty (of measurement), irreversibility (of systems) and deduction. This finding is of significance because it shows that our increased scientific understanding of the nature of complex naturally occurring systems may have rendered the positivist and the post-positivist epistemologies of science obsolete. The positivist epistemology has played the predominant role in the furtherance of quantitative science during the last half of the twentieth century and, even today, the positivist epistemology is the predominant guiding force for determining appropriate quantitative methods of scientific inquiry and the validity of scientific research results. As the review of the scholarly literature in Chapter 2 suggests, the post-positivist epistemology appears to have gained some ground as a legitimate research methodology based on the scientific legacy of

Heisenberg's indeterminacy principle and his contention that the act of observation itself affects what is being observed. But as the scholarly literature also suggests, it appears that both positivists and post-positivists are still realists who rely on linearity, reductionism, reversibility (of systems) and induction as their predominant frames of cognitive reference to conceive, understand and explain complex events and situations.

In Chapter 4, the unique pattern of frames of reference that emerge with the advent of complexity theory are used to describe a new epistemology of science known as *a priori optionality* that can increase the human understanding of complex systems and systems of systems interdependencies. This includes the highly complex interdependent systems that characterize institutions of higher education (Balderston, 1995; Birnbaum, 2000; Commission on National Investment in Higher Education, 1997; Duderstadt, 1997 & 1998; Johnstone, 1988 & 1998; Layzell, 1998; Schmidtlein, 1981; Schmuck & Runkel, 1994; Shulcok & Harrison, 1998). The tenets of *a priori optionality* are used to structure a process known as the complexity systems method that can be applied to enhance human learning, more effectively integrate quantitative scientific and technical factors with human qualitative social considerations in the context of complex interdependent systems, and to improve human decision making in the management of complex events and situations. This includes the improved management of complex events and situations by administrators at institutions of higher education.

In summary, the methodology used to conduct this study consists of the following eight specific steps.

1. Establish criteria to guide the selection of the scholarly literature to be studied.

2. Review selected examples of the scholarly literature as it pertains to the positivist and post positivist epistemologies and four scientific theories.
3. Attempt to triangulate a set of frames of reference from these sources of the scholarly literature.
4. Compare and contrast the prevalence, i.e., predominance, of frames of reference among two epistemologies and four scientific theories.
5. Develop a logic block.
6. Deduce the tenets of an advanced epistemology of science, i.e., *a priori optionality*, based on the scholarly literature.
7. Connect the tenets of *a priori optionality* with practice, i.e., the complexity systems management method.
8. Describe a practical application of the complexity systems management method involving the modern university.

Foreshadowed Conjectures and Exploratory Questions

The triangulation of the scholarly literature, indicates that complex naturally occurring systems have the following five predominant characteristics: 1) at certain thresholds of complexity their behaviors cannot be explained in terms of linear cause and effect relationships (Friedman, 2006; Gell-Mann, 1999; Gleick, 1987; Heisenberg, 1999, Perrow, 1999); 2) they cannot be fully understood using reductionist methods (Gell-Mann, 1999; Heisenberg, 1999; Lawton, 2001; Miller, 2000; Prigogine & Gregoire, 1998); 3) they are characterized by the random nature of (systems of systems) interactions (Gell-Mann, 1999; Gleick, 1987) where there is no absolute certainty of measurement 4) they are irreversible (Prigogine & Gregoire, 1998), and;

5) they physically exhibit patterns of behavior that can be recognized using deduction and subsequently validated using induction and empirical methods (Resnick, 1999).

The study and triangulation of the scholarly literature also shows us that complex systems can behave in nonlinear ways that defy human understanding in linear Newtonian terms (Cassidy, 1992; Heisenberg, 1999; Perrow, 1982). Moreover, the scholarly literature tells us that there is no absolute certainty of measurement in complex systems and that the evolution of complex systems cannot be reversed with precision (Prigogine & Gregoire, 1998). This means that events never occur exactly the same way as they occurred at some previous moment in time (Barbour, 1998). The introduction of randomness in nature means that the confluence of these factors can result in compounding nonlinear effects that are unexpected and may be accompanied by very significant unanticipated consequences (Gell-Mann, 1999; Gleick, 1986). This is well represented in mathematics by Feigenbaum numbers (Gleick, 1986).

So then, if complex systems behave in nonlinear ways that defy human understanding where events can neither be precisely measured nor ever occur exactly the same way as they did previously, are human beings in control of their own destiny? With the introduction of randomness in nature and compounding nonlinear effects that can result in significant unanticipated consequences, how can human beings ever hope to manage complex events and situations? Under these conditions, what are the implications for conceiving, understanding and managing complex situations and events? Is Perrow correct when he asserts that catastrophes involving complex systems are inevitable (1999)? Is Sagan correct when he posits that the introduction of redundant safety back-up systems just makes complex systems more complex begetting still greater opportunity for catastrophe (2001)? Are there are more effective ways to manage complex systems based on changing the frames of reference we use to conceive and understand their behaviors? If the behavior of a complex system cannot be predicted with certainty, would it be more effective to consider and prepare for a range of possible outcomes? Perhaps, the Newtonian notion that there is a single correct answer to a given problem based on linear mechanics must give way to the possibility of a range of "right" answers between "bounds" that are continuously evolving based on systems of systems interactions. If no event ever exactly repeats itself, perhaps the notion of predicting the future behavior of a complex system based on past behavior may lead us to make decisions that can trigger nonlinear excursions where unexpected events occur resulting in wildly unanticipated consequences.

Chapter 4.

Improving the Human Conception, Understanding and Explanation of Complex Systems

Overview

This chapter describes how the five predominant frames of reference of non-linearity, holism, uncertainty (of measurement), irreversibility (of systems), and deduction form a new epistemological construct that can improve the human conception, understanding and management of complex systems. The new epistemological construct is called *a priori optionality*.

The scholarly literature tells us that complex systems reach levels of complexity where the normal rules of Newtonian linearity in which *a* causes *b* which, in turn, causes *c* to happen, no longer apply (Gell-Mann, 1999; Gleick, 1986; Heisenberg, 1999; Lawton, 2001; Prigogine & Gregoire, 1999). In Chapter 2, we discussed the work of Heisenburg and the indeterminacy principle showing that at the subatomic level, linear causality does not effectively explain the behaviors of electrons moving around the nucleus of an atom (Cassidy, 1992; Heisenberg, 1999). In Chapter 2, we also discussed the implications of nonlinear systems behaviors on the understanding and management of complex situations and events such as large traffic systems and the occurrence of traffic jams (Resnick 1999), the management of complex forest eco-systems and the occurrence of the Cerro Grande fire (Helm, 2001) and the unexplained occurrence of massive ocean waves that are not the result of the simple linear process of constructive interference (Lawton, 2001). The study of the scholarly literature also shows that when systems reach these thresholds of complexity the notion of Newtonian certainty of measurement no longer applies (Gleick, 1986; Heisenberg, 1999). At these thresholds of complexity, we are no longer able to precisely measure complex systems behaviors (Cassidy, 1999; Heisenberg, 1999; Lawton, 2001). From the work of Gleick (1986), Prigogine and Gregoire (1998) and Gell-Mann (1999), we know that at these thresholds of systems complexity, randomness, sensitivity of systems to initial condition sets, and our inability to precisely measure systems behaviors make exact prediction of future events in complex systems impossible. Thus, *a priori optionality* posits that since we cannot, with precision, predict future behaviors of complex systems we must, instead, look for potential ranges of behavior between the inexact and continuously changing bounds of observed patterns in complex systems.

The work of Gleick (1986) and scholars including Waldrop (1992) and Gell-Mann, (1999) also shows that complex systems are highly sensitive to initial conditions and affected by systems of systems interactions that can result in non-linear excursions and wildly unanticipated behavior. This is because of the potential for an increasing number of systems of systems interactions that compound to produce non-linear excursions (Gell-Mann, 1999; Gleick, 1986; Prigogine & Gregoire, 1998). The application of linear deterministic methods and imprecise mathematical constructs used to measure and understand complex systems also contributes to our inability to understand how certain behaviors exhibited by complex systems propagate. For example, as Lawton illustrates in his description of the rogue wave phenomenon, exponential increases in certain behaviors exhibited by complex systems are not the result of the conventional mathematical construct of constructive interference, i.e., linear increases in wave energy to produce bigger and bigger waves (2001). Thus, *a priori optionality* posits that the application of linear deterministic methods, when coupled with the imprecise mathematical constructs we use to measure complex systems, contribute to our inability to predict with precision the future behavior of a complex system.

The scholarly literature tells us that complex systems, when perceived from a holistic frame of reference, can lead us to consider them in the context of the patterns of behavior they exhibit (Alberts & Czerwinski, 1999; Gell-Mann, 1999, Gleick 1986, Prigogine & Gregoire, 1998; Resnick, 1999). By studying these patterns of behavior to deduce the fundamental rules sets that create and bound them, we can gain important quantitative insights into how complex nonlinear systems may behave (Resnick, 1999). For example, Resnick treats the idea of "traffic" as a holistic system of complex interweaving subsystems that represents a complex and adaptive whole. To understand the "traffic system" he applies the holistic frame of reference to identify a specific pattern of behavior exhibited within the larger system that can be analyzed. In the case of a traffic system, the pattern observed by Resnick is a traffic jam appearing within a larger traffic system (1999). Resnick is careful to discriminate between the initial conditions, e.g. rain, traffic accidents, number of cars, etc., and the randomness inherent in complex systems, as he deduces a set of fundamental rule sets that are responsible for propagating the specific pattern, i.e., the traffic jam, that we physically observe. In the case of traffic systems, Resnick logically deduces that there are only three fundamental rules that bound the pattern of systems behavior we observe as a traffic jam. Again, from our discussion in Chapter 2, we recall Resnick's identification of the three fundamental rules that create all traffic jams: 1) push your foot down on the accelerator to speed up the car; 2) take your foot off the accelerator to slow down the car, and; 3) put your foot on the brakes to stop the car (Resnick, 1999). This rule set is then validated by simulating the propagation of traffic jams using object oriented supercomputing (Resnick, 1999, 2004). Thus, *a priori optionality* posits that while exact prediction of the future behavior of complex systems is not possible, the potential future behaviors of a complex system can be projected, albeit imprecisely. This is accomplished by applying the holistic frame of reference to the larger system and observing (or imagining) a pattern of behavior within the larger system at t_1. The pattern of behavior being studied is then analyzed to deduce the fundamental rule set that bounds the behavior being observed (or imagined). A system behavior is then simulated at t_2 to validate the rule set by recreating at t_2, via computer simulation, the same or similar patterns observed at t_1. Different systems behaviors can then be induced using the validated rule sets to propagate, based on different initial conditions, a range of simulated potential future systems behaviors. This is akin to the work of Resnick using Star Logo™ (2004).

The work of Heisenberg shows that the path of an electron at the sub-atomic level is uncertain within statistically derived bounds (1999). As Cassidy reminds us, Heisenberg's principle does not state that everything is uncertain (1992). Instead, Heisenberg relies on probability theory and the use of statistical methods to establish absolute, i.e., fixed and unchanging, bounds within which the exact location of subatomic particles remains illusory. Unlike the indeterminacy principal where the bounds of certainty are absolute based on probability theory and statistical methods, *a priori optionality* posits that the bounds within which patterns of behavior occur within complex systems are not absolute. *A priori optionality* posits that these bounds can only be understood and imprecisely quantified because of systems of systems interactions, the randomness of nature and the limitations of the mathematical constructs we use to measure a system's behavior. A basic tenet of *a priori optionality* is that there exist no absolute bounds of certainty in any complex system within which different behaviors may occur. This is because these bounds change based on the evolving adaptation of the system itself resulting from continuous systems of systems interactions with the environment in which it exists. Thus, *a priori optionality* is based on the principle that no system ever stands alone or remains unaffected by the state space, i.e., environment, in which it exists. In such environments, nothing is ever exactly predictable because nothing ever stays exactly the same.

For example, the entire basis of Einstein's relativity theory rests squarely on the assumption that the maximum velocity of light in a perfect vacuum free of other potential interference is now and will forever be 299,792,458 meters per second and as such represents a universal and never changing constant. While there are many mathematically and empirically derived proofs of the maximum velocity of light, we also know that the speed of light varies depending on the medium through which it is passing. The velocity of light moving through glass is slower than the velocity of light passing through air. We also know from relativity theory that the path of light is measurably affected by intense gravitational fields (Cassidy, 1992; Epstein, 2000; Friedman, 2006; Hawking, 1998; Heisenberg, 1999; Maddox, 1998; Miller, 2000). Thus, in the complex system of the universe, if you do not understand all of the forces acting on light from the time of its original emission from its source, say a far distant star, until it reaches the eye of an observer on earth, you are unable to predict with exact certainty the time it took the light to travel from the distant star to the eye of the observer. Likewise, there exists no empirical proof that the current measured maximum velocity of light, i.e., 299,792,458 meters per second, will remain the same for eternity as the universe evolves and changes in the time and space continuum occur because of systems of systems interactions. After all, as human beings, we occupy only an infinitesimally small portion of the eternal total evolutionary time of the universe. Moreover, as human beings we only see a microcosm of an infinitely larger macrocosm of a universe where the phenomenon we experience locally may or may not represent universal constants (Jacobson & Parentani, 2005).

From the work of complexity theorists we also know that complex systems are irreversible (Prigogine & Gregoire, 1998). This means that complex systems or events can never be exactly replicated or repeated, respectively (Gell-Mann, 1999; Gleick, 1986; Prigogine & Gregoire, 1998). Or, in other words no set of systems interactions, i.e., an event, will ever exactly repeat itself the way it did in the past or the way it may occur at some future time. This notion is also supported by the work of Barbour (1999). Thus, *a priori optionality* states that because of systems of systems interactions and randomness, nothing that has happened in the past will ever occur again exactly as it occurred initially. *A priori optionality* posits that that only by thinking about a range of potential events that may occur within the bounds of the patterns of behavior that we observe in complex systems can we ever hope to conceive, albeit in inexact terms, the possible future behavior of any complex system. But this requires that we continuously reassess the validity of the assumptions upon which we explain the behavior of a complex system and revalidate the fundamental rule sets defining the patterns we observe in complex systems. This is significant because it forces us to discriminate among causal linear assumptions, initial conditions and randomness that affect the behaviors of complex systems. Thus, identifying potential rule sets that define patterns of systems behavior and validating them using simulation and empirical testing is one of the significant principles that can be used to improve our ability to understand, monitor and manage complex systems. Resnick's work using Star Logo™ is an important example of how this process can be supported using object oriented supercomputing to simulate real or imagined patterns of systems behaviors (Resnick, 1999 & 2004) and empirically validate the rules sets that define, in the context of different combinations of initial conditions, the patterns of systems behavior we observe.

From the study of the scholarly literature, we know that modern science still relies heavily on the tenets of logical positivism (Miller, 2000, Trochim, 2004). The predominant belief among scientists today is that once enough facts are collected and analyzed generalizations can be extracted enabling the scientist to predict, given some set of circumstances at T_1, some fact that will still hold true at T_2. If the prediction is true then the hypothesis, principle or theory must also be true (Trochim, 2004). In its pure form, the process is predominantly inductive moving in the upward direction from observed fact or assumption to validate or support broad generalizations. The deductive frame of reference, on the other hand, does not necessarily draw hard conclusions based on the study of prior fact or assumption. Instead, the process in its pure form is predominantly deductive moving in the downward direction from broad generalization or assumption to the identification of supporting sets of facts or assumptions that can then be empirically tested for validity (Miller, 2000; Schneider, 2002; Shalizi, 2002; Trochim, 2004).

Deducing the rule sets that define patterns of behavior in complex systems is akin, in some important ways, to Ernst Mach's use of *gedankenexperiment*, i.e., thought experiment, where complex systems are viewed holistically in an attempt to understand them at realms of existence that can only be imagined by the mind because the behaviors being studied fall outside the ability to understand them based on the five human senses and Newtonian causal relationships. Relativity theory with its highly imaginative notion of a space time continuum and the existence of four dimensional space may represent the premiere example in science of an initial predominant application of the deductive frame of reference (within the framework of the positivist tradition) to conceive, understand and explain the behavior of a complex system. *Gedankenexperiment* was a tool of choice used by Einstein to describe relativity theory (Epstein 1999; Friedman, 2006; Miller 2000). Using *Gedankenexperiment* a complex problem can be initially imagined in the mind in a deductive manner with mathematical and inductive proofs applied to empirically test the accuracy of the imagined behavior. Even then, the mathematical and inductive proofs we require to prove the validity of a theory often create a conundrum by conflicting with existing scientific principles and more frequently than not, move beyond our immediate scientific ability to empirically prove them. The result is that we are constantly playing "catch up" trying to develop the physical means to empirically prove or disprove what we can only imagine might or might not be true. For example, the use of virtual particles that by definition must exceed the maximum velocity of light to explain quantum theory (Gibbs, 1998) may be a good representation of this conundrum. Recent research on the Hawking's effect and paired photon separation at the event horizon of a black hole may be another good example. Parentani and Jacobson suggest that the propagation of light may involve more than just a photo electromagnetic phenomenon that, unlike sound, requires no supporting environmental conditions to propagate (2005). In fact, they posit that Einstein's notion of a continuous space and time continuum may have to give way to the possibility that space-time may be granular, i.e., "atoms of space-time", if we are to reconcile general relativity with quantum mechanics (2005). But, how many physicists would be willing to completely abandon Einstein's notion that the maximum velocity of light is 299,792,458 meters per second and, as such, represents a universal and never changing constant? How many physicists would be willing to abandon Einstein's field concept, i.e., continuous structures? To do so would shake the cornerstones of a huge body of scholarly knowledge upon which most of today's modern physics still rests.

Summary of the Six Tenets of *A Priori Optionality*

In summary, *a priori optionality* is guided by the application of six tenets.

1. The application of linear deterministic methods, when coupled with the imprecise mathematical constructs we use to measure complex systems, contributes to our inability to predict with precision the future behavior of a complex system.
2. Because of the irreversibility of systems, systems of systems interactions and randomness, there can be no single exact prediction of the future behavior of a complex system or systems of systems.

3. There exist no absolute bounds of certainty in a complex system within which different behaviors may occur. This is because the bounds within which different behaviors may occur change based on the evolving adaptation of the system itself resulting from continuous systems of systems interactions with the environment in which it exists. Thus, no system ever stands alone or remains unaffected by the space, i.e., environment, in which it exists. In such environments, nothing is ever exactly predictable because nothing ever stays exactly the same.
4. The irreversibility of systems, systems of systems interactions and randomness show us that nothing that has happened in the past will ever occur again exactly as it occurred initially. Only by thinking about a range of potential events that may occur within the bounds of the patterns of behavior we observe in complex systems can we project, albeit in inexact terms, the possible future behavior of any complex system.
5. Because of the compounding effects of systems of systems interactions and randomness, the validity of the assumptions upon which we explain the behavior of complex systems must be continuously assessed to revalidate the fundamental rule sets that define the patterns of behavior we observe in complex systems.
6. While the exact prediction of the future behavior of complex systems is not possible, the potential future behaviors of a complex system can be imprecisely projected. This can be accomplished by identifying the fundamental rule sets that bound the patterns of systems behavior we observe and propagating future

behaviors based on changing initial conditions which affect the manner in which fundamental rule sets are exercised to propagate different patterns of systems behaviors. In complex systems, fundamental rules sets bound how initial conditions propagate to produce different systems behaviors. Because of systems of systems interactions, we must continuously revalidate the fundamental rule sets we use to define the bounds of a system’s behavior.

Chapter 5.

The Complexity Management System: A Next Generation Decision Support Tool to More Effectively Integrate Strategic Planning with Operational Outcomes at Institutions of Higher Education

The Complexity Systems Management Method

This chapter describes a process methodology known as the complexity systems management method. As discussed in Chapter 1, the complexity systems management method has far reaching applications that go well beyond the improved administration of institutions of higher education. For this reason, Chapter 5 of the research study is divided into two portions. The first portion of Chapter 5 provides a generic description of the complexity management system method that can be tailored for different applications across a broad range of complex systems challenges. Detailed descriptions of a range of other applications of the complexity systems management method are included as an appendix to this research study. The second portion of Chapter 5 is devoted to a description of institutions of higher education as complex adaptive interdependent systems of systems and how the complexity systems management method can be applied to the specific challenge of more effectively administering complex systems of fiscal management at institutions of higher education.

The complexity systems management method is different from other processes used to conceive understand and manage complex systems and their behaviors because it relies on a pattern or grouping of frames of reference not found in either the positivist or post-positivist epistemologies. As discussed in Chapter 2, this unique grouping of frames of reference has been analogously derived by studying and triangulating the scholarly literature to form a new epistemology of science known as *a priori optionality*. The complexity systems management method is different from other processes used to conceive, understand, and manage complex systems and their behaviors because it systematically integrates the quantitative scientific and technical factors of complex interdependent systems behaviors with the qualitative social considerations that affect learning and decision making as humans manage complex events and situations. The complexity systems management method is based on the six tenets of *a priori optionality* described in Chapter 4. The more effective integration of strategic plans and operational outcomes at institutions of higher education is only one of many possible applications of the complexity systems method. Potential applications are far reaching to include a very broad array of both risk and benefit applications ranging from more effective financial management, enhanced prevention and response to emergencies, counter-terrorism, and many others. As noted above, detailed descriptions of other applications of the complexity systems management method are included as an appendix to this research study.

The complexity systems management method is comprised of three distinct process phases as further described below: 1) quantifying complex systems behaviors; 2) integrating quantitative reality with qualitative human social process, and; 3) focused organizational interventions.

<u>Phase 1: Quantifying Complex Systems Behaviors</u>

The purpose of phase 1 of the complexity systems method is to quantitatively examine the behavior of a complex system. During phase 1 multidisciplinary subject matter experts are brought together to quantify and reverse engineer selected patterns of complex systems behavior. During phase 1 these multidisciplinary groups of experts examine, from the holistic frame of reference, real (or imagined) systems to identify patterns of interest, i.e., behaviors, exhibited by a complex system or systems of systems at t_1. Fundamental rule sets that bound the observed or imagined patterns of behavior are deduced using analogous scientific methods. Care is taken to discriminate between initial conditions and the fundamental rule sets. In complex systems, fundamental rules sets bound the manner in which initial conditions propagate to produce different systems behaviors. The use of multidisciplinary expertise assures that a variety of perspectives and knowledge are brought to bear in deducing fundamental rule sets that define the behavior versus the initial conditions sets that can affect how the observed behavior may propagate in a complex system. This includes recognition of significant qualitative social process factors that can affect the manner in which human beings exercise the fundamental rule sets defining and bounding the propagation of patterns of complex systems behavior that are addressed as part of phase 2 of the process. Based on the fundamental rule sets defining the behavior being observed at t_1, the *critical nodes* of system operation are determined. The *critical nodes* of a complex system are those core interrelationships within the system itself that are particularly sensitive to changes in initial conditions. The *critical nodes* of a complex system, if significantly affected, would upset the equilibrium of a system and result in its evolution or devolution. This is akin to Prigogine's notion of the stability of a turbulent gaseous system as a function of energy gain or loss as described in dissipative structure theory (Prigogine & Gregoire, 1998). It is also akin to Resnick's deduction of rule sets that discriminate between initial conditions and fundamental rule sets as exemplified by his work with traffic systems and the occurrence of traffic jams (1999). Since the application of linear deterministic methods, when coupled with the imprecise mathematical constructs we use to measure complex systems contribute to our inability to precisely predict the future behavior of a complex system, a range of potential scenarios of potential future systems behaviors are developed. Using fundamental rule sets to define and bound potential systems behaviors, a range of possible scenarios using different combinations of initial conditions that affect the *critical nodes* of the system at t_1 are derived. These scenarios reflect the different ways in which human beings can exercise fundamental rule sets to propagate an array of potential outcomes. Each potential scenario (within bounds) that could affect a *critical node* of system operation is reverse engineered. During the process of reverse engineering each *critical node* of system operation, the potential initial conditions that affect the *critical node* of system operation are identified. The specific series or sequence of events for each scenario that would have to occur to significantly affect each *critical node* of operation is identified. This is done using real or imaginary combinations of initial conditions and assessing their relative impact on the manner in which fundamental rules sets are exercised to propagate a pattern of behavior. As scenarios are reverse engineered by subject matter experts, great care is taken to identify and structure the precise events and the sequence in which they must occur for a given scenario to take place in the real world. For risk applications, subject matter experts are asked to structure scenarios along a time continuum that begins with earliest possible detection of an adverse event moving sequentially through deterrence, prevention, response, immediate mitigation of consequences, and long term recovery. Subject matter experts are asked to identify and provide structured responses to the following two questions as they reflect on each hypothetical risk scenario: 1) What information had it been known before the adverse situation happened could have been used to have prevented it from happening in the first place? 2) And, what information had it been known before the adverse situation occurred could have used to mitigate its consequences? These become the *warnings* of impending adverse events and the focus of highly focused intelligence collection strategies designed to interrupt event sequences as early as possible to prevent adverse outcomes. For benefit applications, subject matter experts are asked to structure scenarios along a time continuum that begins with earliest possible recognition of an opportunity moving sequentially through strategy development to take advantage of the opportunity, specific actions to capture the opportunity and short and long-term sustainment of beneficial outcomes. Subject matter experts are asked to identify and provide structured responses to the following two questions as they reflect on each hypothetical benefit scenario: 1) What information had it been known before the opportunity was first recognized could have been used to recognize and act on it sooner? 2) And, what information had it been known beforehand could have been used to sustain the benefits of the opportunity longer? These become the *indicators* of impending opportunities and the subject of highly focused intelligence collection strategies designed to identify opportunities as early as possible and sustain optimum event sequences, i.e., those of greatest benefit, in both the short and long term. Quantitative, i.e., science-based, models are used to scientifically extrapolate the extended order effects of the outcomes of possible decisions that could be made to manage each scenario. Computer supported collaborative tools such as *Group Systems* and *Meeting Works*® are used to guide and consistently structure knowledge generation and capture. Consistent with the tenets of *a priori optionality* we recognize that the relative impacts of initial conditions expressed as mathematical values are imprecise because of the irreversibility of systems, continuous systems of systems interactions and the imprecision of the mathematical constructs we use to measure complex systems. Specific sequences of events and different combinations of initial conditions (in a real or imagined system) are considered in terms of a range of potential outcomes as bounded by fundamental rule sets. Consistent with the tenets of *a priori optionality* we recognize that the bounds within which patterns of systems behavior arise are inexact and ever-changing because of systems of systems interactions that affect fundamental rule sets. The fundamental rule sets, initial conditions, sequence of events and the potential outcomes for each scenario involving a *critical node* of operation, the warnings of adverse situations and the indicators of opportunity situations are structured, catalogued and archived in a supporting computer knowledgebase. Utilizing the same rule sets deduced at t_1, an array of future system behaviors can then be simulated at t_2, t_3, t_4, t_5 and so on, by adjusting the relative values of initial conditions affecting the manner and degree to which fundamental rule sets are exercised to propagate system behaviors that can, in turn, affect *critical nodes* of systems operation. The assumptions upon which fundamental rule sets deduced at t_1, however, must be continually reassessed at t_2, t_3, t_4, t_5 and so on based on system of system of system interactions. For example, significant step advances in technology development can change the fundamental rule sets upon which complex systems behave. In the case of Resnick's traffic system analogy imagine a future time, say 150 years from today, when personal vehicles operate on the principle of magnetic levitation via centrally controlled computer secure automated data acquisition (SCADA) networks in order to optimize safe, efficient and very large volume traffic flows in highly complex traffic systems. While the observed behavior of speeding up, slowing down and stopping a vehicle remains the same, the fundamental rule sets defining and bounding the behavior of the traffic system would have significantly changed. In such a different traffic system, the notion of a driver putting their foot on the brakes to stop the vehicle would no longer represent a fundamental rule of the behavior of the traffic system. This is because human intervention to exert foot pressure on a brake pedal would be replaced by a SCADA network that automatically increases or decreases the amount of power provided to a personal vehicle being supported by a magnetic field as it moves along an electrified rail. In such a system of the future, humans would no longer have to put their foot on an accelerator to speed up a car. Since no human controlled accelerator pedal exists in the magnetically levitated vehicle of the future, the notion of taking your foot off the accelerator to slow down a vehicle no longer applies. In similar fashion, since reducing to zero the flow of electrical power necessary to levitate the vehicle would stop it, the notion of a human controlled brake pedal would be rendered obsolete. In such an imaginary traffic system of the future, the fundamental rule sets defining and bounding how initial conditions affecting today's traffic systems would change dramatically.

Subject matter experts conclude phase 1 of the complexity systems method by developing storyboards for the production of split screen multimedia simulations that portray a projected range of systems behavior based on interactions among *critical nodes* using the information previously developed and archived in the supporting knowledgebase. These simulations are designed to reflect complex interdependencies among different *critical nodes* and their effects on outcomes. As depicted in Figures 2. and 3., below, for risk applications, storyboards follow an event continuum from earliest possible detection of an adverse event through deterrence, prevention, response, short term mitigation of consequences to long-term recovery. Subject matter experts are asked to pay special attention to the relationships between and among deterrence, detection, prevention, response, mitigation and recovery. For example, actions taken to respond to a given event can have a major effect on mitigating the consequences of an event. Mitigating the consequences of an adverse event can positively affect long term recovery.

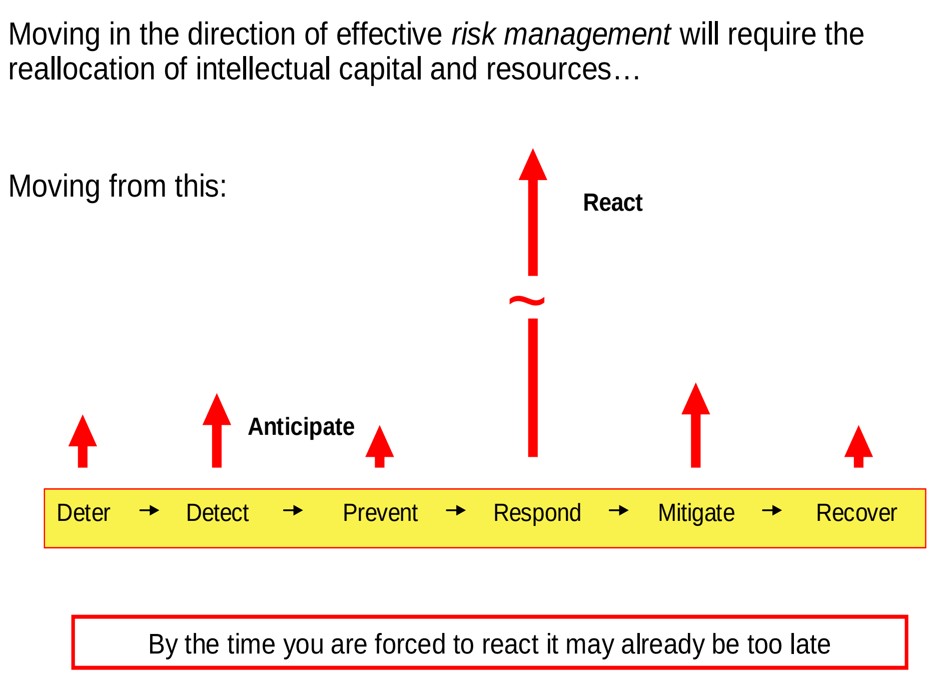

Figure 1: The Current Center of Gravity for Risk Management

is a Function of Reaction and Response

Figure 1 illustrates that the current center of gravity for risk management rests on reaction with principal attention focused on *ex post facto* response to events. If organizations fail to prevent adverse events that can quickly escalate from contingencies to disasters to catastrophes, they lose competitive advantage (Perrow, 1982, Smith H., 1999; Jacobs, 2004).

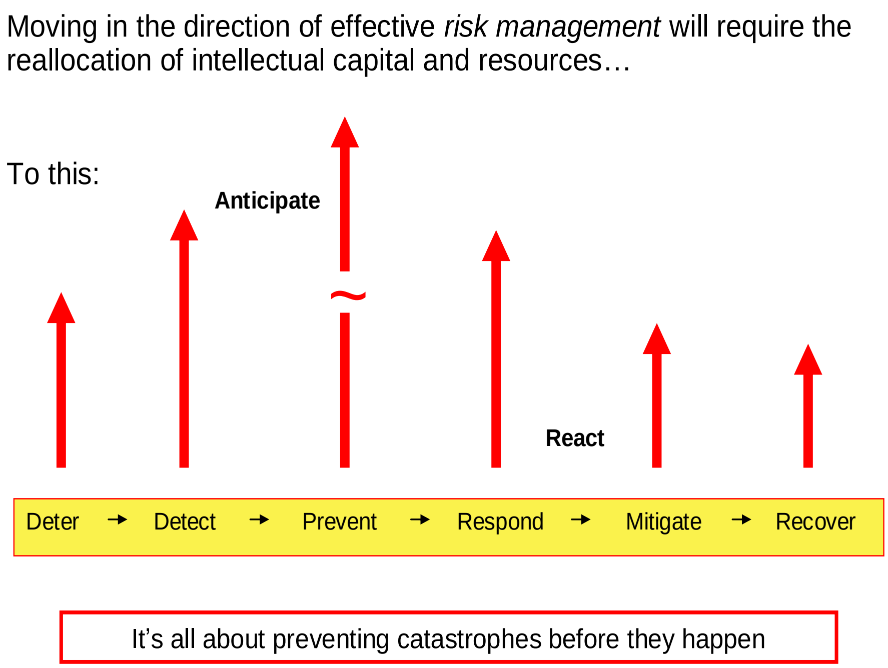

Figure 2: Under the Complexity Systems Management Method the New Center of Gravity for Risk Management is a Function of Anticipation and Prevention

Figures 2 illustrates the shift in the center of gravity from react and respond to the anticipation and prevention of adverse events under the complexity systems management method. If organizations can prevent adverse events before they happen or more effectively mitigate their consequences they can gain competitive advantage (Jacobs, 2004; Rosenhead, 1998; Smith H., 1999).

As depicted in Figures 3 and 4, below, for benefit applications, storyboards follow an event continuum from the earliest possible recognition of opportunity, through the development of a strategy to exploit the opportunity, the implementation of a strategy to capture the opportunity, the short-term sustainment of the opportunity to the long-term sustainment of the opportunity. Subject matter experts are asked to pay special attention to the relationships between and among opportunity recognition, strategy development, opportunity capture and short and long-term sustainment. For example, strategies used to capture an opportunity may affect both short and long-term sustainment.

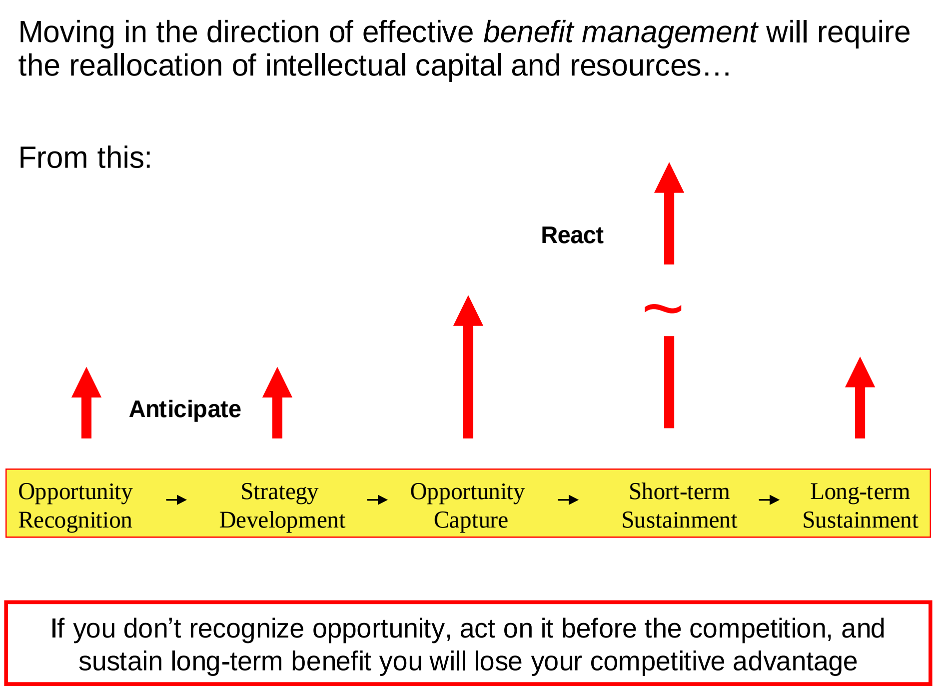

Figure 3: The Current Center of Gravity for Benefit Management as a Function of Reaction and Short-term Sustainment

Figure 3 illustrates that the current center of gravity for benefit management rests on reaction with principal attention focused on short-term sustainment of opportunity. If organizations do not recognize opportunity and act to capture and sustain it for the long-term, they can lose their competitive advantage (Jacobs, 2004; Rosenhead; 1998; Smith H., 1999).

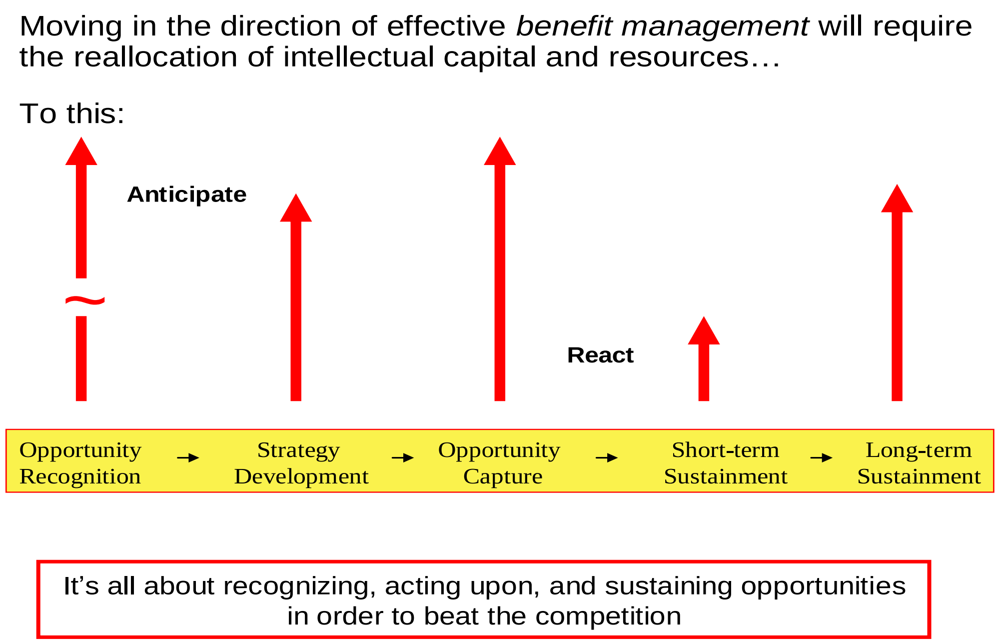

Figure 4: Under the Complexity Systems Management Method the new Center of Gravity for Benefit Management is a Function of Anticipation and Long-term Sustainment of Benefit

Figure 4 illustrates the shift in the center of gravity from react and short term sustainment to the earliest possible anticipation of opportunity, capture, and long-term sustainment of the benefits of the opportunity. In this way, the organizations of the future will achieve and maintain competitive advantage (Jacobs, 2004; Rosenhead, 1998; Smith H., 1999).

Subject matter experts then identify those critical points within a simulation where decisions must be made to exploit the evolution or avoid the uncontrolled devolution of a system. These are called *critical decision points*. Multidisciplinary subject matter experts reverse engineer each *critical decision point* in a simulation carefully considering the risk and/or benefit continuum and the outcomes and extended order effects of different decision options. Out of the range of possible decisions, the optimum decision sets in a simulation that lead to the most desirable outcome(s) are identified. The supporting rationale for selected decisions, in both quantitative and qualitative terms is structured, digitized and indexed using consistent methods to assure repeatability, i.e., re-use of the information at t_2, t_3, t_4 and so on, and archived in the supporting knowledgebase. Subject matter experts are asked to structure and catalogue the consequences of decisions and the warnings and indicators of risk or benefit applications, respectively. Computer supported collaborative tools such as *Group Systems* and *Meeting Works®* are used to guide and consistently structure knowledge generation and capture during this process. These computer supported collaboration tools also help to assure the repeatability of information by organizing both structured and unstructured information and knowledge for input to a supporting knowledgebase in ways that the information can be readily understood by subsequent users. Computer graphic representations of *critical nodes* of operation, models visualizing systems and systems behaviors, decision outcomes and the extended order effects of decisions to include decision maps, decision fault trees, and other computer visualization techniques are developed in preparation for phase 2 of the complexity systems method.

Phase 1 Process Steps

1. Multidisciplinary experts examine a complex system from the holistic frame of reference to deduce the fundamental rule sets that define and bound the propagation of a real (or imaginary) system's behavior being observed at t_1. For example, in the case of Resnick's research on a traffic system, the fundamental rule sets that result in a traffic jam would be deduced using analogous scientific methods (1999). The initial conditions and the fundamental rules sets that bound how initial conditions propagate to produce different systems behaviors are isolated. For example in Resnick's traffic system analogy the rule sets bounding the system's behavior to produce a traffic jam, i.e., press your foot down on the accelerator, take your foot off the accelerator and put your foot on the brakes are discriminated from the initial conditions that affect the traffic system, e.g., weather conditions, drunken drivers, road rage, road construction, broken down cars, etc.
2. The complex system is viewed holistically to determine the *critical nodes* of a system's operation, i.e., those core interrelationships or activities unique to a given system that are particularly sensitive to changes in initial conditions. For example, in the case of Resnick's traffic system we could view a geospatial image of a specified geographic area and look for major population centers, the convergence of major roadways where large amounts of traffic must flow and other factors. In a traffic system, such areas would be especially sensitive to the types of initial conditions described in Step 2 because people would be more likely to exercise in a different

combination the three fundamental rule sets identified by Resnick that can produce traffic jams (1999). In this case, more people would be taking their foot off the accelerator, applying the brakes and accelerating less frequently and to a lesser degree thus producing a traffic jam.

3. Using fundamental rule sets to define and bound potential systems behaviors, a range of possible scenarios using different combinations of initial conditions that affect the *critical nodes* of the system at t_1 are derived. For example, in a large traffic system we might consider a severe rainstorm that floods major roadways, a dramatic increase within a specified time period of incidents of road rage, a major accident involving a gasoline fuel truck or other initial conditions that may occur either singly or in combination involving a *critical node(s)* of a traffic system.
4. Scenarios (within bounds) are developed which identify and structure the precise events and their sequence that must occur for a given scenario to occur in the real world. For example, in our traffic system example, what initial conditions would have to occur and in what sequence to result in the long term closure of a major interstate?
5. For risk applications scenarios are structured along a time continuum that begins with earliest possible detection of an adverse event moving sequentially through deterrence, prevention, response, immediate mitigation of consequences, and long term recovery. Subject matter experts are asked to identify and provide structured responses to the following two questions as they reflect on each hypothetical risk scenario: a) What information had it been known before the adverse situation happened could have been used to have prevented it from happening in the first

place? b) And, what information had it been known before the adverse situation occurred could have used to mitigate its consequences? These become the *warnings* of impending adverse events and the attention of highly focused intelligence collection strategies designed to interrupt event sequences as early as possible to prevent adverse situations.

6. For benefit applications, subject matter experts are asked to structure scenarios along a time continuum that begins with earliest possible recognition of an opportunity moving sequentially through strategy development to take advantage of the opportunity, specific actions to capture the opportunity and short and long-term sustainment of benefit. Subject matter experts are asked to identify and provide structured responses to the following two questions as they reflect on each hypothetical benefit scenario: a) What information had it been known before the opportunity was first recognized could have been used to recognize and act on it sooner? b) And, what information had it been known beforehand could have been used to increase and sustain the benefits of the opportunity longer? These become the *indicators* of impending opportunities and sustainment and the subject of highly focused intelligence collection strategies designed to identify opportunities as early as possible and sustain optimum event sequences, i.e., those of greatest benefit in the short and long term.

7. Each scenario is reverse engineered to isolate how potential initial conditions would affect the manner in which people exercise the fundamental rule sets that in combination serve to propagate system's behaviors that, in turn, affect the *critical nodes* of a system's operation. For example, using Resnick's traffic system analogy,

how might a snowstorm leading to the jack-knifing of gasoline tanker on a major interstate at mile marker 7 during rush hour affect the manner in which people would exercise Resnick's three fundamental rule sets that result in traffic jams (1999)? Values representing the relative effect of one or a combination of initial conditions on the manner in which fundamental rule sets are exercised to propagate a systems behavior observed at t_1 are derived and considered in terms of their potential outcomes. For example, suppose the snowstorm alluded to above was only minor relative to normal snowfalls during a storm and average seasonal weather conditions for the area. But the jack-knifing of the gasoline fuel tanker resulted in a rupture of the tank requiring road closure and the dispatch of special environmental response teams for clean up. And, suppose that an intersection with another feeder interstate roadway known for its very heavy traffic volumes during rush hour was located at mile marker 7 and the tanker jack-knifed at the height of rush hour. What would be the relative importance and sequence of these initial conditions in affecting how people would exercise Resnick's three rules bounding the occurrence of a traffic jam (1999)? Clearly, conditions such as these would affect the manner in which people exercise Resnick's fundamental rule sets leading to traffic jams (1999). More time spent with your foot on the brake instead of on the accelerator. The immediate effect would be a traffic jam. Extended order effects could include delays in clean up because of weather conditions, blockage of emergency shoulder response routes because of the confluence of multiple first responders such as police, fire, and hazardous materials team (HAZMAT) responders, ambulances and other first responders trying to access the scene using the limited capacity of the shoulders of the roadway, etc.

8. Subject matter experts based on the results of reverse engineering scenarios involving *critical nodes* of systems operation assist in the development of storyboards that are used to produce split-screen multimedia simulations of risk or benefit situations that can affect the system. These simulations are designed to reflect complex interdependencies among different *critical nodes* and their effects on outcomes. They identify the *critical decision points* within each hypothetical simulation, i.e., those points where decisions must be made to avoid the uncontrolled evolution or devolution of a system. For example, using our traffic system analogy suppose our fuel tanker spill at mile marker 7 has resulted in a complete closure of all four lanes of traffic and a traffic backup along the highway is building at a rate of approximately one mile every two minutes (stopping approximately 1450 cars and trucks per mile). The previous exit off of the interstate is at mile marker three. The next previous exit is 22 miles farther back up the interstate. Based on a quantitative analysis of the situation, a *critical decision point* in an accompanying simulation would occur four minutes from the time the interstate was closed at mile marker 7. If a decision is not made to detour traffic at the mile marker 3 exit within four minutes, traffic could continue to back up for at least another 22 miles potentially placing up to 32,000 cars in gridlock.

9. Multidisciplinary subject matter experts reverse engineer each *critical decision point* in a simulation carefully considering the risk and/or benefit continuum, the outcomes and extended order effects of different decision options, and the identification of

warnings and/or indicators of risk and benefit situations. Out of the range of possible decisions, the optimum decision sets in a simulation that lead to the most desirable outcome(s) are identified. In our example above, the optimum decision could be to immediately close the roadway at mile maker 3 and detour traffic off the interstate to secondary roadways in order for traffic to bypass the accident at mile marker 7.

10. The fundamental rule sets, associated initial conditions, the sequence of events associated with different scenarios, arrays of potential outcomes for each scenario involving a *critical node* of operation and the warnings and/or indicators or risk or benefit situations for t_1 are structured, catalogued and archived in a supporting knowledgebase.

11. The process is repeated for hypothetical scenarios involving different *critical nodes* at t_2, t_3, t_4 and so on by adjusting the combinations and values assigned to initial conditions to create an array of potential outcomes for each or the *critical nodes* of system operation that are bounded by the fundamental rule sets deduced during Step 1 of the process. Outcomes are derived for each scenario based on the relative affect of one or a combination of initial conditions and the manner in which associated fundamental rule sets are exercised to propagate a systems behavior observed at t_2, t_3, t_4, and so on.

12. The fundamental rule sets, associated initial conditions, the sequence of events associated with different scenarios, arrays of potential outcomes for each scenario involving a *critical node* of operation and the warnings and/or indicators of risk or benefit situations for t_2, t_3, t_4, t_5 and so on are structured for repeatability, catalogued and archived in a supporting knowledgebase.

Phase 2: Integrating Quantitative Reality with Qualitative Human Social Process

The purpose of phase 2 of the complexity systems method is to address the current lack of a widely accepted body of theory or methodology that analogously integrates qualitative social process and quantitative technology factors in the context of complex interdependent systems (Alberts & Czerwinski, 1999; Gell-Mann, 1999; Miller, 2000; Perrow, 1982; Rosenhead, 1998; Ruso-Toderean, 1992). Phase 2 of the complexity systems method focuses on the systematic integration of the quantitative reality of complex interdependent systems as developed during phase 1 with the qualitative social processes that affect the human management of complex events and situations. Phase 2 of the process uses what are called *immersions* to bring select groups of decision makers and technical personnel who would be involved in managing an event in the real world together to manage hypothetical simulations of complex events developed based on the scenarios developed and reverse engineered during phase 1 in accordance with the six tenets of *a priori optionality*. Phase 2 *immersions* allow policy makers and technical experts to consider complex situations before they happen in the real world. They are provided with the opportunity to systematically consider and plan in advance for complex contingencies and create risk and benefit decision support templates that can be used to guide decision making when similar analogous events happen in the real world. During phase 2 of the complexity systems management method, subject matter experts and decision makers, cut across both the horizontal and vertical boundaries of organizations, are brought together in an *immersion*. This is done to encourage shared situational awareness from the policy to the operational level. Analogously derived science-based simulations of hypothetical events and situations involving systems relationships among *critical nodes* of operation of a complex system are used during *immersions*. As noted previously, these simulations reflect the earlier thinking of the multidisciplinary experts who developed and reverse engineered scenarios for the *critical nodes* of systems operations during phase 1. During phase 2 *immersions*, decision makers and technical personnel who would be involved in managing an event in the real world are brought together to manage hypothetical simulations of complex events developed based on the scenarios developed and reverse engineered during phase 1. They are asked to identify the decisions they would make, identify the outcomes and the extended-order effects of their decisions as they work through simulations involving the behavior of complex systems and their associated *critical nodes* of systems operation. The decisions made by participants and the outcomes and extended order effects of their decisions are compared and contrasted against the results of the phase 1 structured data already archived in the supporting computer knowledgebase. This data includes the *critical decision points*, i.e., those points in a simulated event where decisions must be made in order to avoid catastrophic system failure or to take advantage of significant opportunity. The notions of opportunity advantage and catastrophic system failure are akin to Prigogine's description in the theory of dissipative structures of the evolution or devolution of systems based on energy gain or loss, respectively (1998). A special consensus team decision tool is used during phase 2 *immersions* to help achieve consensus among the participants on the "best" decision options to pursue as they manage their way, as a team, through hypothetical simulations of situations involving the *critical nodes* of a systems operation based on the scenarios developed in phase 1. Michelson, McGee and Hawley describe consensus as a term that connotes something more than simple agreement (1994). Consensus means that participants in a group develop “best” decision options based on a structured process of “give and take” that takes into account the different knowledge and perspectives of other multidisciplinary members of the team (Michelson, McGee & Hawley, 1994). Using the process of compare and contrast with phase 1 data, participants in an *immersion* are provided an opportunity to see and experience the outcomes and extended order effects of both good and bad decisions. During *immersions*, decisions are structured using group collaborative tools such as *Group Systems* or *Meeting Works®* in a way that combines the thinking of all *immersion* participants to produce an analogously derived optimum solution. The result is called a *best decision option. Best decision options* reflect the “best” combined elements of the ideas of the *immersion* team to produce a solution with the most desirable outcomes and extended order effects. *Best decision options,* outcomes and extended order effects are visually mapped for simulations considered by *immersion* participants and archived in the supporting knowledgebase. The process allows participants to achieve consensus on *best decision options* in a way that the lessons learned from the experience can be captured in a computer knowledgebase to build a body of repeatable knowledge that establishes reference points for further simulations and the creation of risk and benefit situation decision support systems that can be used to assist in the management of analogous events as they occur in the real world. Figure 5, below, depicts in visual form the structure of a phase 2 complexity systems management *immersion* environment.

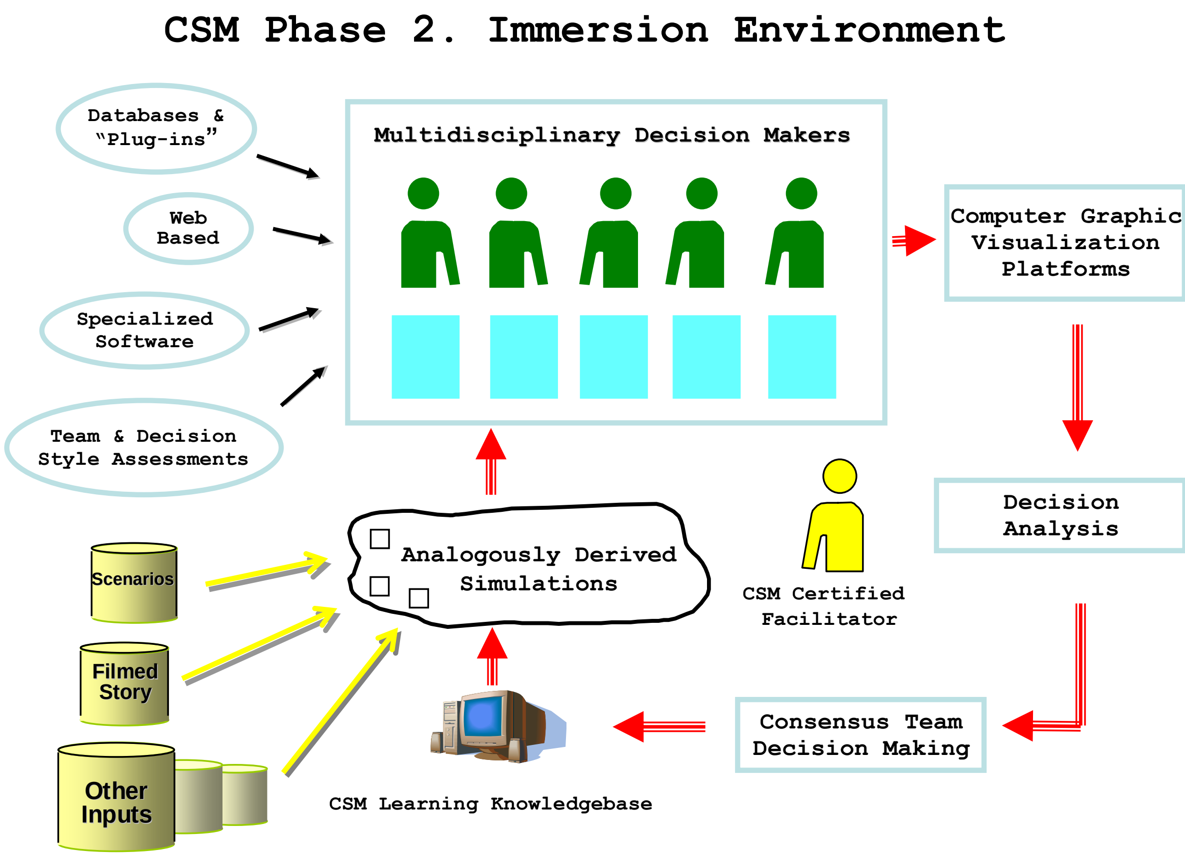

Figure 5: Diagram of a Complexity Systems Management Method
Phase 2 *Immersion* Environment

Phase 2 of the complexity system management process begins with the development of analogously derived, i.e., science-based, simulations. Before an *immersion* takes place, inputs are sought from the entire system both vertically and horizontally to gather subject matter knowledge of experts at every level. The *critical nodes* of systems operation for the complex systems behavior under examination are identified and reverse engineered. For risk applications, the precursor warning signals that can lead to disasters or cause disasters to escalate to become catastrophes are identified. For benefit applications, the precursor indicators of opportunity that can be exploited to increase the competitive advantage of the organization are identified. Depending on the nature of the application, the *critical decision points* to prevent and/or respond to simulated disasters or to exploit impending opportunities are identified. The *immersion* process examines the range of possible decisions that could be made and their extended order effects. Science-based models that show participants the extended order effects of decisions are used. Based on this extensive preliminary work, a select combination of decision makers, operational responders and multidisciplinary subject matter experts who would be responsible for managing similar events in the real world are brought together to manage risk and/or benefit simulations. A number of tools and techniques are used to help the group reverse engineer critical decisions and decide on *best decision options* under a given set of circumstances. A team decision process is used for participants to achieve consensus on the best decisions to make (Michelson et. al., 1994). This team decision process is designed to address the concerns raised by Janis in Groupthink (1982). Decision templates based on these inputs that have been structured for repeatability are archived in a supporting computer knowledgebase that gets "smarter and smarter" as successive groups run through the simulation. The resulting knowledgebase can be used for educational, strategic and tactical operational uses as a planning and response tool to manage analogous events that confront decision makers in the real world.

Phase 2 Process Steps

1. Multimedia simulations, i.e., split screen movies, of hypothetical events and situations based on the phase 1 analysis of the behavior of a complex system are developed. These simulations of different situations reflect the interrelationships among the *critical nodes* of a complex system and the fundamental rule sets,

associated initial conditions, the sequence of events and means and methods associated with different scenarios and arrays of potential outcomes for each scenario involving a *critical node* of systems operation as developed during phase 1. These multimedia simulations are digitized and archived in a supporting knowledgebase.

2. Special red teams of knowledge domain experts identify the *critical decision points* in each simulation that could lead to catastrophic systems failure or represent significant opportunity advantage. Red teams reverse engineer each *critical decision point* to analogously determine the outcomes of the different decisions that could be made within the bounds of the fundamental rule sets established for each *critical node* of systems operation. The same red teams determine the outcomes and extended order effects of a range of different decisions for each of the *critical nodes* of operation identified during phase 1. Care is taken to assure that the range of possible decisions reflect the fundamental rule sets bounding the behavior of the system. This information is visually structured as decision fault trees showing related outcomes and associated extended order effects. Scientific models are developed to assist *immersion* participants visualize the extended order effects of their decisions. This information is digitized and archived in a supporting computer knowledgebase.

3. *Immersion* participants are selected to cut across both the horizontal and vertical boundaries of organizations. They are intentionally selected to horizontally cut across "stovepipes" of organizations and to vertically cut from the operational to the senior decision making levels. Included within the group of *immersion* participants are subject matter experts familiar with the type of system and systems behavior under

study. The total number of *immersion* participants can vary from 12 to 16 participants.

4. Phase 2 of the complexity systems method pays special attention to the human social process aspects of individual preferences and group behavior. Each participant in an *immersion* is requested to take a battery of personality preference, cognitive and team interaction assessments. The results of these tests can provide significant insights on how individuals think, learn, and behave differently in a group or as a member of a team (Jacobs, 2004). The results of human assessments are provided in strict confidence to each participant. Human assessment feedback results are used to:
   a. Learn how different *immersion* participants think, learn and behave, especially in group settings. This allows the information presented during *immersions* to be tailored based on how participants think and learn. This type of human social process knowledge allows for the systematic examination of ways to bring the right information, in the right form, at the right time to decision makers based on different thinking, learning and behavior styles.
   b. Examine a broad range of human characteristics and different behaviors that can affect the quality of both individual and group decision making including individual decision styles and a person's probable reaction under stress, individual and group openness and willingness to accept new ideas, a group's conceptual capacity to see the "big picture", group patterns of motivation, an individual's social assertiveness and other factors.
   c. Facilitate effective team interactions among *immersion* participants by providing information that can be used to manage potential conflicts that can

arise among individuals with different personality traits. Effective team interactions are essential to achieve group consensus around best decision options and to avoid the dangers of "groupthink" (Janis, 1982).

d. To assure broad accumulation, in-depth consideration, and broadly considered utilization of information to produce a highly superior result.

5. Participants are asked to assemble at a location away from their normal places of work to engage in an *immersion*. Apart from the normal distractions of the workplace, *immersion* participants are given the opportunity to focus their attention on the task at hand. Participants are familiarized with computer supported group systems software, e.g., *Meetings Works®, Group Systems*, etc., and audio and video equipment that is used to structure and record all activities during *immersions*.

6. Participants are shown "split screen" multimedia simulations of hypothetical situations affecting the *critical nodes* of operation of a complex system. A start and stop process is used to examine and reverse engineer each *critical decision point* in a simulation as identified by red teams before the *immersion*. Participants are asked to provide their individual perspectives on the best decisions that can be made at each *critical decision point* in a simulation. Their decisions are compared and contrasted against the results of red team analyses to include outcomes and extended order effects. Models and other computer visualization techniques are used to show in scientifically accurate terms the extended order effects of decisions. Group decision options are then sought. Group decision options are compared and contrasted against those generated before the *immersion* by red teams. Multiple perspectives are considered and participants are encouraged to achieve group consensus on *best*

decision options at each *critical decision point* in the simulation that consider both the quantitative reality of the situation and the qualitative social implications of their decisions. Great care is taken to structure and record participant feedback in ways that the reasons and supporting rationale for combining elements of different ideas to achieve consensus around *best decision options* can be captured in a repeatable way. Repeatability is made possible by structuring the information acquisition process, using group systems software and by audio and visual recording of all individual inputs and group interactions during the *immersion*. All of this information is digitized and archived in a supporting computer knowledgebase that can be data mined by structural and conceptual indexing.

7. The information resulting from an *immersion* is digitized and archived in a supporting computer knowledgebase. The knowledgebase can then be accessed using search engines to data mine the information using structural and conceptual indexing. In this way, a group's reasons and rationale for combining elements of different ideas to achieve consensus around *best decision options* at a *critical decision point* in a simulation can be structured and captured in a repeatable fashion so that the results can be understood by others after the *immersion* takes place, i.e., repeatability.
8. Decision support systems comprised of systematically derived decision maps, models and other visualization tools that support the human management of complex risk and benefit situations for similar analogous events that happen in the real world are produced as a result of the process.
9. The indicators of opportunity advantage and the warnings of impending adverse situations are validated by *immersion* participants and strategies to implement highly

focused intelligence collection are considered. *Best decision options* to implement risk and benefit intelligence programs are another important product of phase 2 *immersions*.

10. Additional *immersions* can be conducted using the same or different combination of simulations with different participants. Different participants in the process can bring new perspectives and ideas as *critical decision points* are reverse engineered. Using the same *immersion* processes to structure and acquire information in combination with group systems software and audio and visual recording of individual inputs and group interactions during the *immersion* we can achieve repeatability. Thus, the addition of new information from additional *immersions* when archived in the supporting computer knowledgebase results in a learning system that becomes "smarter and smarter" with each successive *immersion*.

Phase 3: Subsequent Interventions

The purpose of phase 3 of the complexity management system is to reassess, on a continuing basis, the fundamental rule sets upon which complex systems are characterized and the optimum risk and benefit decision options and accompanying decision support systems are based. As described in Chapter 4, one of the tenets of *a priori optionality* is that there exist no absolute bounds of certainty in any complex system within which different behaviors may occur. *A priori optionality* posits that the bounds within which different behaviors occur in a complex system change based on the evolving adaptation of the system itself resulting from continuous systems of systems interactions with the environment in which it exists. Thus, no system ever stands alone or remains unaffected by the space, i.e., environment, in which it exists. The reassessment of the fundamental rule sets bounding the behavior of a complex system is accomplished through the use of continuing red team analysis, the conduct of subsequent *immersions,* the use of computer modeling and the real world operational use and testing of the risk and benefit applications of the decision support systems resulting from the phase 1 and 2 complexity systems method process.

<u>Phase 3 Process Steps</u>

1. Red teams of multidisciplinary experts reassess, on a continuing basis, the fundamental rules sets used to bound the range of behaviors as determined in phase 1 of the process. They consider how a complex system may have evolved and adapted based on changes in the environment in which it exists, i.e., systems of systems interactions.
2. Subsequent *immersions* are conducted using the same or different combination of simulations to revalidate phase 1 quantitative results and phase 2 *best decision options*. Subsequent *immersions* can be conducted with different groups or combinations of participants.
3. The decision support systems resulting from phases 1 and 2 are applied to the management of real world risk and/or benefit situations. The performance of management teams using these decision support systems is benchmarked against previous performance. Declines in performance over time using decision support systems resulting from phase 1 and 2 lead procedurally to red team phase 1 quantitative reassessments and the conduct of subsequent *immersions* to re-achieve desired levels of performance.

Overview of Phases 1, 2, and 3 of the Complexity Systems Method

Tables 2 and 3, below, summarize the key steps and deliverables, respectively, resulting from the complexity systems management method phase 1, phase 2, and phase 3 process.

Table 2: Summary of Phases 1, 2, and 3 of the Complexity Systems Method Process Steps

Phase 1. Process Steps Quantitative Analysis	Phase 2. Process Steps Qualitative Analysis	Phase 3. Process Steps Subsequent Interventions
1. Bring together multidisciplinary red teams 2. Identify critical nodes of systems operation 3. Develop an array of bounded risk/benefit scenarios 4. Reverse engineer critical nodes to identify specific event sequences, develop early warnings/ indicators and to identify critical decision points 5. Build a knowledgebase of repeatable information	1. Bring together highly specialized red teams 2. Develop multi-media split-screen simulations of complex events and determine critical decision points 3. Cognitive assessments of participants 4. Bring together decision makers and subject matter experts cut vertically and horizontally across organizational boundaries in immersions 5. Use start-stop method to reverse engineer each critical decision point in a simulation 6. Capture best decision options by comparison/contrast with phase 1. results 7. Structure best decision options so that reasons and supporting rationale are repeatable 8. Develop computer visualized best decision option templates 9. Develop prevention and focused intelligence collection strategies for warnings/indicators 10. Develop consequence mitigation strategies 11. Place all data in knowledgebase as repeatable information	1. Multidisciplinary red team reassessment of the fundamental rules sets bounding the range of behaviors of a complex systems behavior 2. Conduct of subsequent immersions with different individuals using the same or different combinations of simulations to revalidate Phase 1 results 3. Application of decision support systems to the management of real world problems and benchmarking to identify declines in performance

Table 3: Summary of Phases 1, 2, and 3 Deliverables
Resulting from the Complexity Systems Method

Phase 1. Deliverables Quantitative Analysis	Phase 2. Deliverables Qualitative Analysis	Phase 3. Deliverables Subsequent Interventions
1. Multidisciplinary red team analysis	1. Highly specialized red team analysis	1. Multidisciplinary red team reassessment of fundamental rule sets bounding the range of a complex systems behavior
2. Vulnerability and consequence analysis of critical nodes of systems operation	2. Multi-media split-screen simulations of complex systems events	2. Results of subsequent immersions to revalidate Phase 1.
3. An array of analogous, i.e., science-based, and bounded risk/benefit scenarios	3. Identification of critical decision points	3. Results of subsequent immersions added to create a learning knowledgebase to support additional Phase 1. and 2. analyses and interventions
4. Specific event sequences, early warnings/ indicators and critical decision points	4. Cognitive assessment feedback for immersion participants	
5. A knowledgebase of repeatable information	5. Repeatable information on the reverse engineering of each critical decision point in an event simulation	
	6. Best decision options captured as repeatable knowledge	
	7. Supporting reasons and rationale for best decision options in repeatable form	
	8. Computer visualized best decision option templates	
	9. Focused intelligence collection strategies to prevent risk events and identify opportunities	
	10. Consequence mitigation strategies	
	11. A knowledgebase containing phase 2. information in a repeatable form	

The Complexity Systems Management Method: A Next Generation Decision Support Tool for Integrating Strategic Plans with Operational Outcomes at Institutions of Higher Education

In Chapter 4 we described a new philosophy of science known as *a priori optionality*. *A priori optionality* was developed to address limitations of both the positivist and post-positivist philosophies in the understanding of complex systems. In the preceding portion of Chapter 5, we described the complexity systems management method as a new tool that can be used by decision makers to more effectively manage a broad range of complex situations. Using the complexity systems management method, decision makers are given the opportunity to systematically think through hypothetical analogously derived simulations of future potential events. This process of identifying and considering potential future opportunities and problems using analogous methods is designed to encourage learning by the *a priori* development of a range of decision options and alternatives before similar situations are confronted by decision makers in the real world. In this way, the complexity systems management method can be applied to test, *a priori*, the integration of strategic plans and policies with operational outcomes at institutions of higher education and to catalyze consensus by key institutional decision-makers around optimum decision options and alternatives. An important goal of utilizing the methodology is to facilitate the development of learning organizations (Jacobs, 2004; Rosenhead, 1998; Smith, 1999; Senge, 1990) and to promote greater agility in responses by institutions of higher education to changes in the strategic environment.

As Robert Birnbaum observes in Management Fads in Higher Education, fads to improve the financial management of institutions of higher education have come and gone. Program Planning Budget System (PPBS), Zero Base Budgeting (ZBB), Total Quality Management /Continuous Quality Improvement (TQM/CQI), Management by Objective (MBO) and strategic planning (SP) are all examples of fads that have impacted higher education and the financial management of colleges and universities, in one form or another, over the past 30 years. Birnbaum tells us that these fads have been in response to higher education gloom mongers who continue to predict the demise of the university (2000). As history shows, however, the academy has somehow been able to muddle through crisis after crisis and avoid the apocalypse. But, whether the dire predictions of the higher education gloom mongers are true or not, the fact is that rising costs, decreasing access to, and questions about the quality of higher education continue to be issues of immense concern to leaders of the higher education enterprise (Commission on National Investment in Higher Education, 1997). We also know that the higher education enterprise is a complex combination of ephemeral qualitative and quantitative factors that seem to defy integration at the strategic through the operational levels (Schmidtlein, 1981). This lack of integration gives rise to questions regarding the effectiveness and fiscal responsibility of institutions of higher education. Balderston (1974), Schmidtlein (1981), Johnstone (1988), Birnbaum (2000) Wagaman (2001), and others have observed that the complexity of integrating strategic planning with operational budget outcomes is a major obstacle for institutions of higher education.

In support of the position that the complexity systems management method can be a valuable new decision support tool for the more effective integration of strategic higher education plans and operational outcomes, the remainder of this research study will address the growing complexity of the strategic environment in which institutions of higher education must operate and the implications for the future of the higher education enterprise. The "rise to the occasion" character of American culture and its influence on institutional and fiscal planning is discussed. The university is described as an example of a highly complex adaptive system where bridging the gap between quantitative versus qualitative indicators of institutional performance represents a significant obstacle to success. The work of Janis describing "groupthink" is akin to a significant body of scholarly literature suggesting that there is no widely accepted body of theory or methodology that integrates qualitative sociological and quantitative technology factors in the context of complex interdependent systems (Alberts & Czerwinski, 1999; Gell-Mann, 1999; Miller, 2000; Perrow, 1982; Rosenhead, 1998; Ruso-Toderean, 1992) and group decision making. This includes group decision making and the highly complex interdependent systems that characterize institutions of higher education (Balderston, 1995; Birnbaum, 2000; Commission on National Investment in Higher Education, 1997; Duderstadt, 1997 & 1998; Johnstone, 1988 & 1998; Layzell, 1998; Schmidtlein, 1981; Schmuck & Runkel, 1994; Shulcok & Harrison, 1998). The complexity systems management method, as a means to more effectively integrate strategic plans with operational budget outcomes, is described as one significant example of how the process can be applied to improve decision making and the administration of institutions of higher education.

The Growing Complexity of the Strategic Environment in which Institutions of Higher Education Must Operate

Some scientists postulate that we are entering a new age where the rate of new knowledge generation and resulting change are no longer following a linear progression but are now increasing at near exponential rates (Duderstadt, 1997; 1998). Others contend that the application of digital technology is already having a fundamental and sweeping impact on human society, our institutions and the organizations where we work (Duderstadt, 1997 & 1998; Negroponte, 1996). Still others are convinced that these increases in the generation of new knowledge will begin to unlock the secrets of the workings of the human mind (Wilson, 1998) and allow us to develop new decision support systems that will address both the structured and unstructured domains of the human decision process. Many of these observations are supported by the astounding increase in human innovation taking place. In the 15th century the printing press was invented. The middle Ages gave way to the Renaissance and the rebirth of art and science. In the 19th century the industrial age forever changed human society and the world. But in the 20th century the rate of innovation exploded as we moved into the information age. The television, the copier, the transistor, the microprocessor, satellite transmission, the Internet and global networking are all innovations that have taken place in the last half of the 20th century. It has been estimated that more information was produced in the last 50 years than the entire preceding history of human existence (Laudon, J. & K., 1997).

Prigogine in his work on the theory of dissipative structures provides a framework in the natural world that supports this revolutionary versus evolutionary view of human existence and scientific progress. In his research on physical systems and equilibrium states, Prigogine theorizes that phase transitions in complex naturally occurring systems really represent periods of overwhelming change where, in some cases, systems can absorb energy to achieve new and more complex states of equilibrium. In other words, when subjected to stress systems may re-organize themselves to form a new more complex whole (Prigogine & Gregoire, 1998). Although the subject of debate among scientists, the implications of Prigogine's work may be significant in understanding complex social phenomena. For example, some believe that the exponential nature of contemporary change may be an indicator of a major human phase transition, a step to a higher level of human existence. As Figure 9, below depicts, notional rates of innovation over human history seem to mirror Prigogine's phase transition paradigm with each successive phase leading to higher and higher levels of innovation.

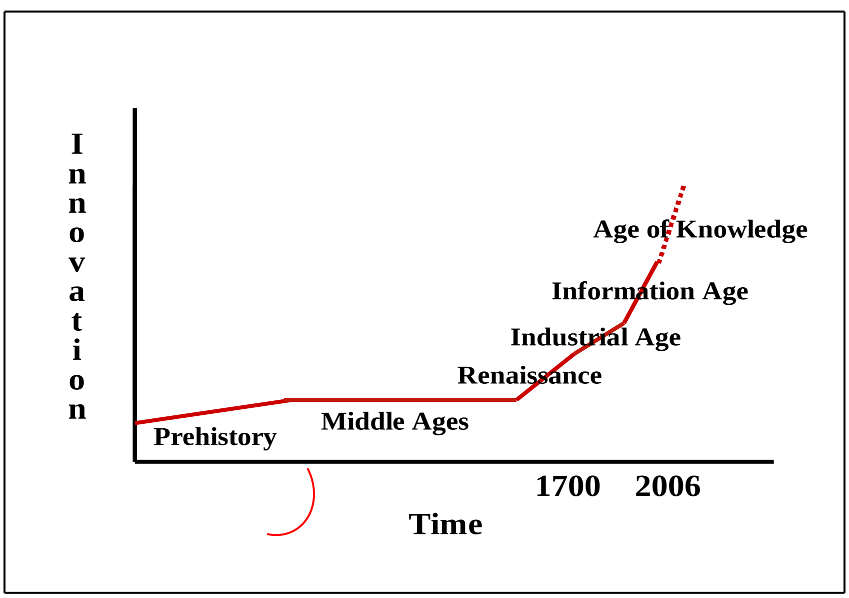

Figure 6: Notional Rates of Human Innovation

Of course, the interesting question raised by both Prigogine and Wilson is how these rapidly accelerating rates of change will impact the future of human existence, our society, and its institutions including the university (Wilson, 1998; Prigogine & Gregoire, 1998). Part of the answer to this question and the future of the strategic environment in which the leaders of the higher education enterprise will have to operate, may lie in better understanding how technology innovation is occurring and why it is happening so rapidly.

Most would agree that advances in science have given us new knowledge of the physical universe that has spawned scientific breakthroughs leading to the rapid development of new technologies. Among these scientific breakthroughs are the near-exponential advances in digital technology and computational capability and connectedness. It is this application of digital technology in support of scientific inquiry, along with empowering metaphors of biological systems (Kaku, 1998), that have served as "force multipliers" allowing scientists to more efficiently collect and process data and integrate information in ways that help us to more rapidly generate new knowledge. Figure 10, below, depicts a knowledge generation engine that drives digital technology innovation outputs that, in turn, re-enter the system as inputs to foster the creation of new knowledge. The process flow diagram depicts the following steps: 1) the collection and integration of new information as fundamental to scientific inquiry, i.e., research; 2) scientific inquiry as the means by which we create new knowledge; 3) new knowledge begets more scientific inquiry as shown by the dotted feedback loop. New knowledge also spurs further technology innovation. The application of new emerging technology (especially digital technology) further enhances our ability to collect and process data and integrate information in support of scientific inquiry (Negroponte, 1999). More efficient scientific inquiry produces new knowledge faster creating a knowledge engine that drives the near-exponential rise in knowledge and technology innovation as we enter the 21st century. This phenomenon is called the theory of digital force multiplication.

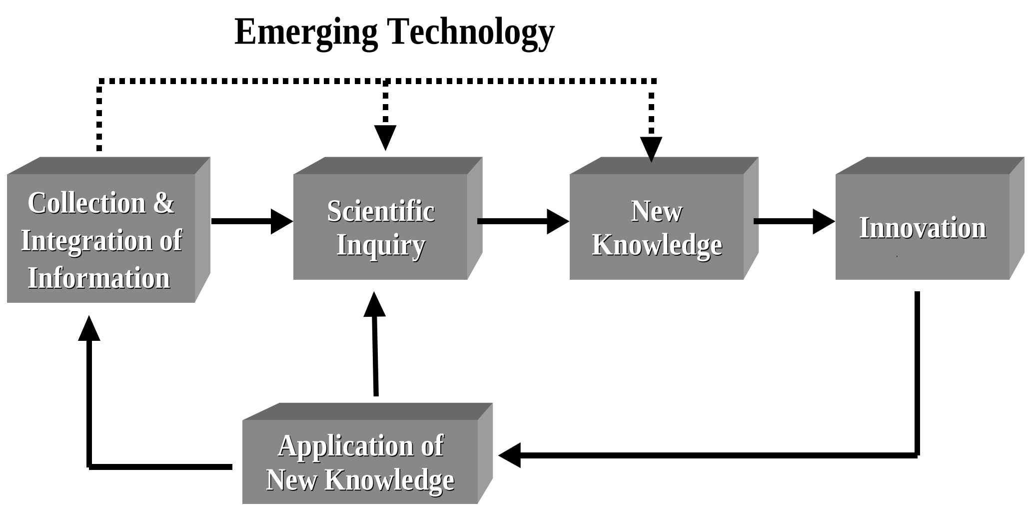

Figure 7: The Knowledge Engine and Digital Force Multiplication

This near-exponential rate of knowledge creation has created a meta-knowledge challenge, i.e., what do we know, about what we know. The creation process has typically resulted in the increased fragmentation of disciplines.[8] As this disciplinary

[8] Note: Nowhere is this fragmentation more evident than in the higher education enterprise. In fact, the Commission on Investment in Higher Education has characterized the university as among the most vertically integrated of all institutions in our society (1997).

fragmentation progresses, it becomes more of a challenge to reconcile and frame, and consequently use, new and existing knowledge. As many multidisciplinary fields discovered, the increasingly narrow focus did not necessarily assure better answers to society's problems (Scott & Saunders-Newton, 1995). What is necessary is a framework for generating convergence across knowledge areas, and to effectively convey this meta-knowledge to decision-makers (Saunders-Newton, et. al., 1999). As discussed in Chapter 2, Wilson postulates that we are at the dawn of a new age where the hard and soft sciences are converging to create a new understanding of nature. Wilson says that the most exciting aspect of this dawning age will be new knowledge about the workings of the human mind and the true meaning of human consciousness arising from a better understanding of the bio-molecular chemistry of the brain. Wilson postulates that the hard sciences of physics, biology and chemistry are actually beginning to converge with the soft sciences of psychology and the social sciences in a way that will give us radical new insights into the human decision-making process including a better understanding of how human beings attempt to make sense of complexity (1998). If Wilson is correct, it may also represent part of the answer to the challenge of trying to develop the decision support systems of the future that will acquire and manage information and existing knowledge in ways that will allow us to generate new knowledge more and more quickly. This new generation of decision support systems may also hold the promise of better integrating quantitative scientific and technical factors with qualitative social considerations in ways that can bridge the gap between strategic planning and policies and operational outcomes at institutions of higher education, including the administration of complex systems of fiscal management. The difficulty in creating linkages between strategic planning and institutional outcomes is discussed widely in the financial management of higher education literature and includes Balderston (1974), Schmidtlein (1981), Birnbaum (2000), and many others.

<u>The "Rise to the Occasion" Character of American Culture and its Influence on Institutional and Fiscal Planning</u>

The American pioneer spirit has had a significant influence on American culture. Based on this influence, an important measure of our self-worth both as individuals and as a society relies on the notion of self reliance and the belief that we as Americans can rise to any occasion (Mead, 1999). This aspect of the American culture has both good and bad implications. For example, on the one hand it has promoted a sense of individual and national self-reliance well represented by "Jacksonianism"— a sort of "be all that you can be" philosophy of social democracy and individualism (Mead, 1999). The westward expansion of the 19th century, the nation's response to the Empire of Japan's surprise attack at Pearl Harbor and the Soviet challenge posed by the successful orbit of Sputnik in 1958 leading to the race for the moon between the United States and the Soviet Union may be only three of many historical examples of this type of rise to the occasion aspect of American culture.

From another perspective, however, this aspect of our culture may lead us to wait for "it" to happen without expending the thought and effort necessary to prevent or militate against "it" from happening in the first place. This *ex post facto* react versus an *a priori* prevent approach to the integration of strategic planning at the macro level with fiscal processes at the micro level may contribute to the gap between strategic plans in higher education and institutional budget outcomes as referred to by Schmidtlein (1981), Birnbaum (2000) Waggaman, 2000) and many others. In any event, the innate resistance we as human beings have to the acceptance of new information that upsets a state of relative equilibrium and our propensity to seek out hypotheses and solutions to problems that fit our past experiences and pre-conceived notions may serve to exacerbate this potential for reaction versus prevention. America's lack of preparedness for the Japanese attack at Pearl Harbor is an example of this phenomenon. As Wohlstetter observes,

> For every signal that came into the information net there were usually several plausible alternative explanations, and it is not surprising that our observers were inclined to select explanations that fitted the popular hypothesis [Japan would never be bold enough to attack [the United States]…Apparently human beings have a stubborn attachment and equally stubborn resistance to new material that will upset them.[9]

A more recent example of this reaction versus prevention syndrome is represented by the electrical power supply crisis in California during the summer of 2001. For well over a decade, California State and Federal officials were well aware of significant increases in demand for electrical power. They also knew that major capital investments in new electrical power generating capacity were essential to keep pace with rising demand. Yet, years went by and little was done. In fact, it was not until after the series of rolling blackouts and consumer price hikes by utility companies during the spring of 2001 that California consumers began to seriously conserve electrical power and new generating capacity was brought on line to allay the crisis (Marcus, 2001). Of course,

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[9] Wohlstetter, Roberta. Pearl Harbor: Warning and decision. Stanford, CA: Stanford University Press, 1978, p. 393.

this type of *ex post facto* approach to situation management stands in stark contrast to an *a priori* consideration of potential problems and decisions to prevent or mitigate the possible adverse effects of a crisis before it occurs. The energy crisis has cost the economy of California billions of dollars. Key indicators such as the rising costs of tuition and goods and services, decreases in state and federal funding for education, and rising numbers of college eligible students appear to suggest that the higher education enterprise may be facing a crisis of even greater proportion (Commission on National Investment in Higher Education, 1997). But, as the costs of the California energy situation illustrate, we may no longer be able to afford to let a reactionary "let it happen" attitude influence our responses to complex situations like the problems facing the higher education enterprise without expecting major consequences. For example, can the nation afford to let the higher education enterprise go bankrupt before the measures necessary to assure its future solvency are taken? Most members of the academy would agree that we should plan in advance to avoid such a possibility, even if the possibility is remote, because of the large-scale consequences that could result. So, what we may really need is a new cultural perspective — one that encourages us to think on an *a priori* basis about complex events and situations and to take appropriate actions to prevent serious problems before they happen and, if they occur, to have taken a close look at how to mitigate their adverse consequences (Balderston, 1995; Birnbaum, 2000; Brinkman & Morgan, 1997; Chaffee, 1981; Duderstadt, 1997-98; Johnstone, 1988; Layzell, 1998; Schmidtlein, 1981; Schulock & Harrison, 1998; Waggaman, 2000). If, as Perrow postulates in normal accident theory, social process factors are major contributors to breakdowns of complex safety systems (1982), then we may also have to focus greater attention on better understanding and improving group and organizational decision processes and the more effective integration of quantitative scientific and technical factors with social process considerations. This would include the dangers of "groupthink" as expressed in the research of Janis (1982). Also, as Layzell observes in his work attempting to integrate quantitative budget reality with qualitative considerations at institutions of higher education,

> In the development of every phase of every system of performance indicators, there is a constant tension between the desire to keep things numeric and "measurable" and the desire to address less tangible but equally important aspects of the institution. Performance indicator systems that focus solely on quantitative measures are more comfortable and familiar for policy-makers, but they may provide a one-dimensional view of the organization. The development of valid qualitative indicators of organizational performance requires a rigour (sic) and discipline that are difficult to achieve. A well-balanced system will include both types of measures.[10]

The University as a Complex System: Bridging the Gap between Quantitative versus Qualitative Indicators of Institutional Performance

The scholarly literature tells us that the higher education enterprise is a complex combination of ephemeral qualitative and quantitative factors that seem to defy integration at the strategic through the operational levels (Birnbaum, 2000; Schmidtlein, 1981). This lack of integration has raised questions regarding the effectiveness and fiscal responsibility at institutions of higher education (National Commission on

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[10] Layzell D. (1998). *Linking performance to funding outcomes for public institutions of higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing. p. 201

Investment in Higher Education, 1997). Balderston (1974), Schmidtlein (1981), Johnstone (1988), Birnbaum (2000) Waggaman (2001), and many others have observed that the complexity of integrating strategic planning with operational budget outcomes represents a major obstacle for institutions of higher education. The internal budget operations of the university are only made more complex when we consider that the strategic fiscal environment in which institutions of higher education are operating is constantly changing (Hauptman, 1997; Johnstone, 1998; Waggaman, 2000).

Johnstone in *Financing Higher Education: Who Should Pay?* asserts that the costs to educate students are highly idiosyncratic and depend on professor, academic discipline and institution and a multitude of other factors (1988). In *Why Linking Budgets to Plans Has Proven Difficult in Higher Education*, Schmidtlein tells us that budgets are based on negotiations to achieve consensus and decisions seldom reflect the "best" decision but are somewhere in between (1981). Schmidtlein's observations regarding how decisions are made at seem to reflect many of the adverse outcomes of Janis's "groupthink" phenomenon (1982). Birnbaum in Management Fads in Higher Education tells story after story about institutions of higher education that have been overwhelmed by their own budget data collection requirements in pursuit of greater efficiency (2000). What these and many other reports about institutions of higher education are telling us is that the financial management of a university is a highly complex matter involving numerous interacting systems and quantitative technical and qualitative human social process factors. As Johnstone observes in his analysis of the strategic fiscal environment in which the modern university operates,

> The funding of higher education is a large and complex topic. It is complex in part because of its multiple sources of revenue and its multiple outputs, or products, which are only loosely connected to these different revenue sources. Furthermore, these revenue and expenditure patterns vary significantly by type of institution…mode of governance…and state…The topic is large because finance underlies much of the three overarching themes of contemporary higher education policy: *quality*, and the relationship between funding and quality in any of its several dimensions; *access* or the search for social equity in who benefits from and who pays for, higher education; and *efficiency*, or the search for a cost-effective relationship between revenues (particularly those that come from students, parents, and taxpayers) and outputs (whether measured in enrollments, graduates, student learning, or the scholarly activity of the faculty).[11]

Today's large multi-service university is a highly complex amalgam of diverse systems (mission activities) ranging from numerous academic departments, a variety of research programs (frequently sponsored by different academic departments), to the athletic department and a multitude of different administrative service departments. "Stove piped" governance structures that begin with semiautonomous academic departments and move vertically upward through the deans of various schools and colleges add to this complexity. Conflict arising from competition between and among sub-units for limited funds can become difficult to manage. In such an environment, developing sound financial management plans that reflect the collective interests of the institution as a whole can become extremely difficult. Add to these internal factors pressures from external forces and the financial management of a university becomes even more complex (Balderston, 1995; Birnbaum, 2000). For example, with the two major revenue sources supporting higher education, i.e., state and federal funds, going

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[11] Johnstone D. (1999). *Financing higher education: Who should pay?* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, p. 3.

down and the number of college eligible students rising (external factors) many universities may find themselves in the unenviable position of having to do more with smaller revenue streams (Commission on National Investment in Higher Education, 1997).

On the quantitative side of the financial management equation we have incoming and outgoing revenue streams and the act of distributing and accounting for dollars and cents, i.e., the ledger sheet. On the qualitative side, we have things like internal and external politics, institutional culture, and sundry other sociological factors that affect decisions. How effectively these competing quantitative and qualitative interests are integrated (mediated) defines quality, levels of efficiency and the agility (ability to respond to opportunities and unforeseen problems) of the institution (Balderston, 1995; Birnbaum, 2000). But the positivist and post-positivist notions that embrace the rules of linearity, reductionism, and reversibility are insufficient to explain the behavior of complex systems that must integrate both quantitative and qualitative factors such as highly complex fiscal management systems at institutions of higher education.

As discussed in earlier chapters, complexity is part of our daily lives at many different levels. Of course, the bad news is that the complexity challenge makes single simple solutions to complicated problems using linear cause and effect relationships difficult to find. This includes attempts to link strategic higher education planning with operational budget outcomes. But the good news is that human beings faced with the most complex problems somehow manage to "muddle through" and cope with events and situations that they may never completely comprehend (Sowell, 1987). The key question then becomes, how do people muddle through to find solutions to complex problems? Are there things we can learn about the human decision process that can help us more effectively manage complex strategic planning and operational budget outcomes like those described by Johnstone (1999) to attain better outcomes at institutions of higher education? And, how can we apply these lessons to bridge the gap between strategic plans and operational outcomes at institutions of higher education?

The scholarly literature, as described in Chapter 2, suggests that part of the answer to these questions may lie in better understanding the nature of complex systems. Obviously, the term complex means different things to different people under varying circumstances. In the information rich environment of the university it frequently means *information overload* — too much information and the inability to separate critical pieces of information from the "noise" quickly enough to act on it in ways that can positively influence outcomes. This is the type of situation Birnbaum refers to when he describes planning and budget process methods that require the collection of too much information (2000). In these cases, institutions are overwhelmed with more data than they can effectively analyze. In other cases, complexity means confronting the unusual or unexpected — things where there is no discernible cause and effect, i.e., non-linear excursions. As discussed in Chapter 2, a non-linear excursion is represented by a series of occurrences whose effects multiply so obliquely that it is virtually impossible to discern simple cause and effect relationships to explain or extrapolate outcomes. In similar fashion, Balderston (1974), Schmidtlein (1981), Johnstone (1988), Wagaman (2000) and others speak to the complex nature of the strategic higher education planning and budget process.

In Chapter 2, we discussed the randomness inherent in complex systems as a fundamental characteristic of nature. To scientists this means that even minor deviations in initial condition sets due to random deviation can produce unimaginably different end states. We discussed the research of Graham Lawton into the "rogue wave" phenomenon where huge walls of water sometimes reaching 30 meters in height, i.e., the height of a 10-story building, appear without warning in otherwise benign conditions in the oceans of the world. Lawton tells us that rogue waves appear too frequently to be explained by the simple linear process of constructive interference, i.e., small waves simply joining forces to create bigger waves. What this implies in the context of the complex higher education strategic planning and budget system is that even minor changes or adjustments to quantitative factors such as federal and state funding levels, sources of funds to support student aid, and the costs of critical goods and services, can have significant and unexpected consequences that are greater than their linear additive value. We also know from the study of the scholarly literature that the qualitative considerations involved with human decision making and policy formulation add additional complexity to the challenge of effectively integrating strategic plans with operational outcomes (Perrow, 1982). This is a problem that is exacerbated in the university by semiautonomous department heads and deans of different colleges, the sanctity of academic freedom and the challenge of effectively integrating quantitative budget with the qualitative considerations that are unique to the culture and values of the university (Birnbaum, 2000; Layzell, 1998).

The scholarly literature, as described in Chapter 2, suggests that it is becoming more difficult to fully comprehend the underlying factors that promote poor decision-making when decision-makers fail to comprehend the consequences of seemingly routine judgment calls that produce serious and unexpected consequences (Helm, 2001; Janis, 1982; Perrow, 1982). The scholarly literature also suggests that our culture demands that an individual(s) be blamed, i.e., a human operator, when disastrous situations occur even in those cases where thoughtful analysis discloses that flawed strategic plans and polices rather than the actions of an individual(s) were the major contributing factors (Helm, 2001; Perrow, 1982). Thus, we conclude that too little time may be spent trying to understand the problem and validate the efficacy of the policies and decisions that spring from the attempts to solve them. As Chaffee reminds us,

> Useful solutions can be identified only if the problem is understood (1981).[12]

But as Waggaman tells us in his study of managing declining revenues at institutions of higher education,

> Unfortunately, one of the first services to be discontinued when revenues decline is the analysis of the use of resources within an institution.[13]

In Chapter 2, we made reference to an emerging body of scholarly knowledge suggesting that major systems failures are more frequently the result of flawed planning and policies rather than human operational error. In fact, some theorists postulate that flawed plans and policies may actually shape the environment to cause reasonable people acting in reasonable ways to err catastrophically (Helm 2001; Perrow, 1982).

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[12] Chaffee, E. (1981). *The link between planning and budgeting.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). <u>Ashe reader on finance in higher education</u> (2nd edition), Boston, MA: Pearson Custom Publishing, p. 406.

[13] Waggaman J. (2000). *Strategies and consequences: Managing costs in higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). <u>Ashe reader on finance in higher education</u> (2nd edition), Boston, MA: Pearson Custom Publishing, p. 314.

During academic year 2000-2001, a course on the management of complex non-traditional threats to U.S. national security was developed and taught at National Defense University (Hnatio, 2000). The new course was developed to give graduate level students the opportunity to exercise their analytical and group decision making skills around simulated events of great national and international significance. One simulation involved the use of analogous methods and to enhance the scientific accuracy of classroom simulations. For example, in one case the extensive documented history of the Cuban missile crisis was used to analogously derive a hypothetical simulation involving the introduction of Chinese nuclear missiles capable of striking the United States into the western hemisphere. Great care was taken to analogously derive a set of quantitative factors and qualitative social considerations affecting the decisions made by John and Robert Kennedy and other national decision makers as they managed the Cuban missile crisis (Allison & Zelikow, 1999). By studying the historical record, several key technical quantitative factors and qualitative social process considerations that influenced the decisions and outcomes of the crisis were identified (Hnatio, 2000). Analogical processes were used to extrapolate and imbed these quantitative factors and qualitative considerations into a scenario that used the backdrop of a current real world event (the transfer of the operation of the Panama Canal to the People's Republic of China) with potential implications for U.S. national security, i.e., the attempted clandestine introduction by the Chinese of nuclear missiles into Panama. How student participants integrated these quantitative factors and qualitative considerations to make decisions was used to benchmark their performance relative to decisions made by national leaders who actually managed the Cuban missile crisis in 1962.

By using a real world event currently taking place in the strategic environment as the backdrop for the simulation, i.e., relinquishing the operation of the Panama Canal from the United States to the People's Republic of China, “believability" was enhanced for student decision makers participating in the simulation. At that time, Hutchinson Whampoa, Inc., the huge Hong Kong based shipping magnate, had just been granted long-term leases by the Panamanian government to operate the Port of Cristobal that controls the Atlantic access route to the Canal and the Port of Balboa that controls the Pacific access route. But, instead of Russian intermediate range ballistic nuclear missiles being surreptitiously introduced into Cuba as in 1962, the Panama Canal simulation was crafted to have the People's Republic of China surreptitiously introduce Dong Feng-21 intermediate range nuclear missiles into the Port of Cristobal. Using this analogical thinking process to extrapolate, other aspects of the Panama Canal simulation were crafted to mirror the same type of technical factors and social process challenges posed during the actual Cuban missile crisis. This methodology was applied to replicate many of the same challenges that world leaders faced in 1962, e.g., violation of the Monroe Doctrine, the credibility of intelligence information, how to properly apply military force, etc. in the context of a hypothetical but highly believable current event.

The Complexity Systems Management Method: More Effectively Integrating Strategic Plans with Operational Budget Outcomes at Institutions of Higher Education

This research study concludes that being prepared for the unexpected and preparing for "it" before "it" happens is an important part of the solution to the complexity challenge facing the higher education enterprise. Preparing in advance to "expect the unexpected" is also key to more effectively integrating strategic plans with operational budget outcomes at institutions of higher education. This is akin to the thinking of Brinkman and Morgan who suggest that institutions of higher education could benefit from more structured opportunities to systematically consider a range of potential futures as they attempt to link strategic plans and with budgets (1997). It also mirrors the research of Neilson and Stouffer who conclude that stories about future events, i.e., scenarios, can serve as important forecasting tools by fostering strategic thinking, learning, and communication. They also describe how scenarios can be used to develop plans, mitigate uncertainty, and guard against problems (2005). This research study also suggests that the methods we apply to better understand and manage complex systems at institutions of higher education should be based on systematic and structured reasoning at two levels. In the first instance, the basis for understanding the nature of complex systems should be analogously derived applying the six tenets of *a priori optionality*. In the second instance, science-based scenarios and *critical decision points* of simulations involving potential future events and situations should be systematically "reverse engineered" using existing tools resulting from a significant body of human factors research in group decision processes (Schmidtlein, 1981; Janis, 1982; Senge, 1990; Waldrop, 1992; Michelson et. al., 1994; Schmuck & Runkel, 1994; Sarkesian, 1995; Morgan, 1998; Sanders, 1998; Allison & Zelikow, 1999; Wheatley, 1999; Jacobs, 2004; Nielson & Stouffer, 2005) and cutting edge information technology developments including quantitative and computational social science modeling, advanced simulations and computer knowledgebases where all information is structured for repeatability. The purpose of hypothetical simulations is to prepare decision makers in advance for analogous situations and events that may occur in the real world. In this way, a range of likely event paths for hypothetical simulations (based on the effects of initial conditions on the collective behaviors of interdependent *critical nodes* of systems operation) can be developed and studied to consider alternatives and options before administrators of institutions of higher education confront analogous situations in the real world. To this end, simulations are developed to reflect the scientific reality of the natural world and to utilize real world data inputs. This same type of approach can be applied to develop and test on continuing basis strategic plans and to assess the linkage between these plans and operational budget outcomes. Such an approach may also hold the key to improvements in group decision processes and the man-machine interface that must be found if we are to effectively leverage advanced technologies to help us manage the higher levels of complexity that characterize the changing strategic environment in which the university must operate.

In the case of institutions of higher education, carefully crafted simulations that utilize analogous reasoning techniques can be developed to represent and test different strategic planning and budget challenges and various options and alternatives to address them. Strategic planning and financial management scenarios would rely on databases that reflect the institution's own budget information and real time data from external sources. Options and alternatives identified by key decision-makers in these hypothetical simulations would be archived in a supporting computer knowledgebase. Simulations and options could be re-played with different knowledge domain experts in decision assessment environments to create an institutional strategic planning and fiscal management system that gets "smarter and smarter" over time.

Phase 1: The Quantitative Analysis of Strategic Planning and Complex Fiscal Management Systems at Institutions of Higher Education

Multidisciplinary subject matter experts from within and outside the organization examine the university's fiscal system holistically. Within the context of the larger fiscal system, patterns of behavior are discerned for further examination. Based on this, subject matter experts are challenged to identify each of the *critical nodes* of the university's fiscal system, i.e., those core interrelationships or activities unique to a given system that are particularly sensitive to changes in initial conditions. For example, Meisenger's and Dubeck's hypothetical, *Sample Educational Institution Statement of Changes in Fund Balances Year Ended June, 30. 19*__,[14] provides examples that could comprise the *critical nodes* of a generic university's complex system of fiscal operation (1993). *Critical nodes* of fiscal operation could include Federal and state appropriations, investment income, federal grants and contracts, successful university programs that generate income greater than the costs of their operation, return on investments from endowments, and a host of other incoming revenue streams. They could also include expenditures such as costs for staff, university programs whose costs of operation exceed incoming revenues, retirement funds, investments in maintaining plant and equipment, retirement of indebtedness, student

[14] Meisenger R. & Dubeck L. (1993). *Fund Accounting.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, p. 510.

scholarships and fellowships, and a myriad of other outgoing revenue streams. For each *critical node*, these experts would be challenged to deduce the fundamental rule sets that define and bound the propagation of the behavior being observed for each *critical node* at t_1. For example, in our generic university while some federal and state funding may be bounded by law, levels of funding and their allocation within the university may not. So while the fundamental rule of the fiscal system's behavior is the guarantee of at least some level of federal and state fiscal support, how this fundamental rule is exercised by decision makers in congress, the federal government, state legislatures, administrators in the university and others will determine the final funding levels and their allocation. Akin to Resnick's view of complex systems (1999), these factors can be viewed as initial conditions affecting how the fundamental rule, i.e., some degree of funding bounded by law, is exercised to propagate the system's behavior, i.e., to project levels of funding that may actually be provided to the university at t_1.

After deducing the fundamental rule sets affecting each *critical node* of the university's fiscal system, bounded scenarios of future potential events for each *critical node* are developed. In the above example of federal and state appropriations to a university, the bounds within which scenarios could be developed might include analogously derived factors such as the average revenues provided from these sources over past years, new laws passed by congress or state legislatures affecting current and future funding, increased federal funding as a ratio of minority student enrollment, etc., etc. Experts are asked to analogously derive how the university can detect, deter, prevent, respond and mitigate the immediate and long term consequences of an array of budget cuts and reallocations involving the *critical nodes* of the university's fiscal system of operation and their projected outcomes. Experts are asked to identify and structure the precise events and the sequence in which events must occur for a given scenario to occur in the real world. For example, if the state legislature reduces direct aid to public colleges and universities what are the exact sequences of events, and in what order will they occur to create what outcomes? For risk applications, i.e., avoiding an adverse event like a drastic cut in state appropriations to the university, scenarios would be structured along a time continuum that begins with the earliest possible detection of the adverse event moving sequentially through deterrence, prevention, response, and mitigation of the consequences. For example, one early warning signal of a possible reduction in state expenditures on higher education and the university might come from the analysis of a given state's tax base showing a decline, changing demographics or other factors. For such a scenario, subject matter experts are asked to bound the possibility of a decrease of state revenues based on the initial condition of anticipated ranges of decline of the state's tax base or other factors. Care is taken to analogously derive both quantitative factors and qualitative considerations in the analysis. For example, statistical averages of past actual revenues to the university provided by the state are considered to be an analogously derived quantitative factor. The traditional importance the state's population (with the same attendant demography), through its legislature, places on higher education relative to other state funding priorities at t_1 would represent an important analogously derived qualitative consideration. Care is taken to carefully structure all outputs for repeatability. In a risk application of the complexity systems management method, experts continue to move along the risk continuum to deter and prevent, i.e., stop a decrease in state funding.

Different combinations of quantitative factors and qualitative considerations which would significantly affect variations in state funding are considered. For example, experts might consider, as part of a scenario, a focused campaign to educate the public and the legislature on the actual effects of university budget cuts in terms of something like Johnstone's overarching fiscal themes of *quality, access and efficiency* (1999). Other prevention measures might include the formation of independent coalitions of university stakeholders such as local industry leaders, alumni, education associations, and union representatives to educate members of the state legislature as to the importance of higher education to the community in economic, cultural and other terms. Again, care would be taken to identify the events and the sequence in which they must occur to achieve desired outcomes. It is then assumed that attempts to prevent reduced appropriations to the university fail, and experts are asked to move along the continuum to consider an array of responses to mitigate the consequences of the budget cuts. They are challenged to analogously derive how the university must respond and determine the immediate and long term consequences of an array of possible responses and their projected outcomes. Throughout the entire process, experts are asked to identify and provide structured responses to the following two questions as they reflect on each scenario: 1) What information had it been known before the adverse event occurred, e.g., a drastic cut in state appropriations, could have been used to prevent it from happening in the first place? 2) And, what information had it been known before the adverse situation occurred, e.g., a drastic cut in state appropriations, could have been used to mitigate its consequences? Great care is taken to structure all expert outputs analogously and in ways that they can be archived in a supporting knowledgebase so that the information is “repeatable,” i.e., can be fully understood by subsequent users of the knowledgebase.

For benefit applications, subject matter experts use similar protocols. But unlike the risk application of the complexity systems method, multidisciplinary experts use analogous methods to develop scenarios along a continuum that begins with the earliest possible indication of a fiscal opportunity through strategy development, capture of the opportunity and short and long-term sustainment of the benefits arising from the opportunity. For example, federal appropriations may tie minority enrollment to an increased percentage of grant revenues. Experts would be challenged to develop (within bounds) and reverse engineer scenarios leading to an increase in minority enrollment at the university. They would be challenged to develop scenarios moving through each step of the complexity management system benefit continuum. In the case of greater minority enrollment to increase revenue streams, they would move from identifying the early indicators of opportunity, to developing and implementing a capture strategy through specific plans to sustain and increase minority enrollment over time. Again, care would be taken to identify the events and the sequence in which they must occur to achieve the desired outcome of increased minority enrollment. As they develop scenarios, experts are challenged to analogously derive an array of actions that the university could take to increase minority enrollment and determine the immediate and long term projected outcomes based on the decisions they make. Experts are asked to identify and provide structured responses to the following questions as they reflect on each benefit scenario: 1) what information had it been known before the opportunity was first recognized could have been used to recognize and act on it sooner? 2) And, what information had it been known beforehand, could be used to increase and sustain the benefits of the opportunity longer? After scenarios are developed in this manner, experts are asked to "reverse engineer" them to isolate how potential changes in initial conditions at t_2, t_3, t_4, t_5, and so on would affect the manner in which fundamental rule sets are exercised to propagate different fiscal management system behaviors that in turn affect other *critical nodes* of the fiscal management system. Great care is taken to structure all expert outputs analogously and in ways that they can be archived in a supporting knowledgebase so that the information is repeatable, i.e., can be fully understood by subsequent users of the knowledgebase.

After experts identify and reverse engineer the *critical nodes* of the university's fiscal management system, they are asked to assist in the development of storyboards that are used to produce split screen multimedia simulations of risk and benefit situations that can affect the university's fiscal management systems. These simulations are designed to reflect complex interdependencies among different *critical nodes* and their effects on outcomes. For example, in a simulation involving minority student enrollment, the events and decisions that would lead to the greatest increase in minority student enrollment and attendant increases in revenue streams are included. But so is the fact that poor minority students may require additional educational remediation at greater cost per student than students coming from middle class families (Commission on National Investment in Higher Education, 1997). Decision options that would achieve the most desirable outcomes for simulations are identified. Care is taken to structure and archive in a supporting knowledgebase all phase 1 outputs as repeatable information, i.e., in a way that that the information can be effectively understood by subsequent users.

Phase 2: The Complexity Systems Management Method and Integrating Quantitative Reality with Qualitative Human Social Process in Strategic Planning and Complex Fiscal Management at Institutions of Higher Education

Based on storyboards developed during phase 1 of the complexity systems method, multimedia simulations involving different aspects of the complex fiscal management system of a university are produced. These simulations of different situations affecting the fiscal management of the university reflect the complex interrelationships among the *critical nodes* of the fiscal management system. These simulations also reflect the fundamental rule sets, associated initial conditions, the sequence of events and the means and methods associated with different scenarios and arrays of potential outcomes for each scenario involving a *critical node* of the university's fiscal management system as developed during phase 1.

Special red teams of knowledge domain experts identify the *critical decision points* in a fiscal management simulation that could lead to serious adverse outcomes or represent significant opportunity advantage. Red teams reverse engineer each *critical decision point* to analogously determine the outcomes of the different decisions that could be made within the bounds of the fundamental rule sets established for each *critical node* of the university's system of fiscal management. The same red teams determine the outcomes and extended order effects of a range of different decisions for each of the *critical nodes* of operation identified during phase 1. Care is taken to assure that the range of possible decisions reflect the fundamental rule sets bounding the behavior of the university's fiscal management system. This information is visually structured using computer graphics as decision fault trees that show related outcomes and associated extended order effects. Scientific models are developed to assist the visualization of extended order effects of decisions. This information is digitized and archived in the supporting computer knowledgebase.

Participants are selected to participate in an *immersion*. Participants are selected to cut across both the horizontal and vertical boundaries of the university. They are intentionally selected to horizontally cut across "stovepipes" and to vertically cut from the operational to the senior decision making levels of the university. Included within the group of *immersion* participants are subject matter experts familiar with the fiscal management of institutions of higher education. The total number of *immersion* participants can vary and is largely dependent on the optimum group size for interactions (12-16 people) and the technical limitations of collaborative group software.

As described earlier in Chapter 5, phase 2 of the complexity systems method pays special attention to the human social process aspects of individual preferences and group behavior. Each participant in an *immersion* is requested to take a battery of personality assessments to determine individual preferences, cognitive comfort in dealing with complexity, team interaction styles, and other factors. The results of these assessments can provide significant insights on how individuals think, learn, and behave differently in a group or as a member of a team under stress (Jacobs, 2004). The results of assessments are provided in strict confidence to each participant. Assessment feedback results are used to discover how different *immersion* participants think, learn and behave, especially in group settings. This allows the information presented during *immersions* to be tailored based on how participants think, learn, and make decisions in group settings. This type of human social process knowledge allows for the systematic examination of ways to bring the right information, in the right form, at the right time to decision makers based on different thinking, learning and behavior styles. Pre-testing allows facilitators in an *immersion* to examine a broad range of human characteristics and different behaviors that can affect the quality of both individual and group decision making including individual decision styles and a person's probable reaction under stress, individual and group openness and willingness to accept new ideas, a group's conceptual capacity to see the "big picture", group patterns of motivation, an individual's social assertiveness and other factors. Pre-testing can also facilitate effective team interactions among *immersion* participants by providing information that can be used to manage potential conflicts that can arise among individuals with different personality traits (Jacobs, 2004). Effective team interactions are essential to achieve group consensus around *best decision options* and to help prevent the selection of *immersion* participants who all possess similar personality traits. A mix of personality traits is essential to assure that *best decision options* resulting from the complexity systems management method reflect the wide diversity of different personality characteristics that exist throughout the university. Great care is taken in the facilitation process to avoid "groupthink" (Janis, 1982).

Participants in an *immersion* are asked to assemble at a location away from the university. Apart from the normal distractions of the workplace, *immersion* participants are given the opportunity to focus their attention on the task at hand. Participants are familiarized with computer supported group systems software, e.g., *Meetings Works®*, *Group Systems*, etc., and audio and video equipment that is used to structure and record all activities during *immersions*. Participants are shown "split screen" multimedia simulations of hypothetical situations affecting the *critical nodes* of the university's fiscal management system. "Compressed time" split screen simulations are used to depict the different aspects of a risk or benefit continuum. A start and stop process around *critical decision points* is used to examine and reverse engineer each *critical decision point* in a simulation as identified by red teams before the *immersion*. Participants are asked to provide their individual perspectives on the best decisions that can be made at each *critical decision point* in a simulation. Their decisions are compared and contrasted against the results of red team analyses to include outcomes and extended order effects. Models and other computer visualization techniques are used to show in scientifically accurate terms, i.e., analogously, the extended order effects of fiscal management decisions. Individual and group decision options are then sought. Group decision options are compared and contrasted against those generated before the *immersion* by red teams. Multiple perspectives are considered and participants are encouraged to achieve group consensus on *best decision options* at each *critical decision point* in the simulation that consider both the quantitative reality of the situation and the qualitative social implications of their decisions. Great care is taken to structure and record participant feedback in ways that the reasons and supporting rationale for combining elements of different ideas to achieve consensus around *best decision options* can be structured and captured in a repeatable way. Repeatability is made possible by structuring the information acquisition process using tailored computer architectures, the use of group systems software and by audio and visual recording of all individual inputs and group interactions during the *immersion*. All of this information is digitized in real time and archived in a supporting computer knowledgebase that can be data mined by structural and conceptual indexing. In this way, a group's reasons and rationale for combining elements of different ideas to achieve consensus around *best decision options* at a *critical decision point* in a fiscal management simulation can be structured and captured in a repeatable fashion so that the results can be used to revisit earlier decisions by participants and understood by others after the *immersion* takes place, i.e., repeatability.

Decision support systems comprised of systematically derived decision maps, models and other computer graphic visualization tools that support the human management of complex risk and benefit situations for potential similar analogous events that may involve the university's fiscal management system are produced as a result of the process. The indicators of fiscal opportunity and the warnings of impending financial losses are validated by *immersion* participants and strategies to implement highly focused intelligence collection strategies are considered. Participants identify the best ways to generate and monitor information that indicates fiscal opportunity or fiscal danger using computer data mining around the warning signals of adverse events or the indicators of potential fiscal benefit. *Best decision options* to implement risk and benefit intelligence strategies are another important product of phase 2 *immersions*.

Earlier in Chapter 5 we pointed to the value of additional *immersions* using the same or different combination of simulations with different participants. Different participants in the process can bring new perspectives and ideas as *critical decision* *points* are reverse engineered. By using the same *immersion* processes to structure and acquire information in combination with group collaborative software and audio and visual recording of individual inputs and group interactions during the *immersion* we can achieve repeatability by collectively structuring all of the data generated during the process because it is in digitized form. Thus, the addition of new information from additional *immersions* when archived in the supporting computer knowledgebase produces a learning system that becomes "smarter and smarter" with each successive *immersion*.

Phase 3: Subsequent Interventions

The principal purpose of phase 3 of the complexity management system is to reassess, on a continuing basis, the fundamental rule sets upon which the university's fiscal system is based. As such, the phase 3 process also revalidates the optimum risk and benefit decision options and the effectiveness of accompanying decision support systems. As described in Chapter 4, one of the tenets of *a priori optionality* is that there exist no absolute bounds of certainty in any complex system within which different behaviors may occur. This includes the fiscal management system of a university. *A priori optionality* also posits that the bounds within which different behaviors occur in a complex system change based on the evolving adaptation of the system itself resulting from continuous systems of systems interactions with the environment in which it exists. As so much of the scholarly literature suggests, the university is among the most sensitive of institutions in our society to outside influence (Balderston, 1995; Birnbaum, 2000; Brinkman & Morgan, 1997; Commission on National Investment in Higher Education, 1997; Duderstadt, 1997-98; Johnstone, 1999; Layzell, 1998; National

Education Association, 2001; Rudolf, 1990, Schmidtlein, 1981; Schulock & Harrison, 2000; Waggaman, 2000). Thus, no system, including the university and its systems of fiscal management, ever stands alone or remains unaffected by the space, i.e., environment, in which it exists. The reassessment of the fundamental rule sets bounding the behavior of a university's complex fiscal system is accomplished through the use of continuing red team analysis of *critical nodes* of systems operation, the conduct of subsequent *immersions*, and the real world operational use and testing of the risk and benefit applications of the decision support systems resulting from the phase 1 and 2 complexity systems method process.

Concluding Remarks

The strategic environment of the 21st century is marked by unparalleled change. For the university, these changes represent either remarkable opportunity or peril. More now than ever before, the quality of the university's future depends on people who are willing to challenge the existing system to find new opportunity. *A priori optionality* and the complexity management system can help higher education administrators think about today's complex problems in the context of tomorrow's solutions to create a better future for the higher education enterprise. Decision assessment *immersion* environments can assist administrators at institutions of higher education avoid adverse events and situations and take advantage of opportunity through better decision making by enhancing their ability to deal with complexity. The complexity management system also represents a new tool that can be used to help the new generation of students who are ushering in Duderstadt's notion of a new *age of knowledge* (1997) where the question of *who makes decisions* will become subordinate the question of *how the best* *decisions are made*. To create the robust self-forming agile organizations of the future that are essential to support the institutions of our society, we will need a new breed of decision makers who better understand complexity and more effectively manage complex events and situations. How human beings make decisions and deal with complexity goes beyond some intrinsic natural capacity. It is also learned. We as educators have the responsibility to find new and better ways to pass to our students the ability to think at more complex levels. The world of the 21^{st} century demands no less.

References

Alberts, D., Garstka J. & Stein, F. (ed.). (1999, August). Network centric warfare: Developing and leveraging information superiority, (2cnd ed). Washington, DC: Center for Advanced Concepts and Technology, Department of Defense.

Alberts, D. & Czerwinski T. (eds.) (1999). Complexity, global politics, and national security. Washington, DC: National Defense University.

Allison, G. & Zelikow P. (1999). Essence of decision: Explaining the Cuban missile crisis. New York, NY: Longman.

American Institute of Physics. (2005). *Quantum mechanics 1925 to 1927: The implications of uncertainty.* College Park, MD: American Institute of Physics, The American Center for Physics. Retrieved from the World Wide Web on October 21, 2005: http://www.aip.org/servlet/SearchAdv?collection=AIPHOME&ResultMaxDocs=100&SortField=&SortOrder=&queryText=Heisenberg&logic=and&x_term=null&filename=all&page=6&chapter=0 and http://www.aip.org/history/heisenberg/p08c.htm

Balderston, F.E. (1995). Managing today's university: Strategies for viability, change, and excellence (2cnd ed). San Francisco, CA: Jossey-Bass Publishers.

Barbour, J. (1999). The end of time: The next revolution in physics. New York, NY: Oxford University Press.

Birnbaum, R. (2000). Management fads in higher education. San Francisco, CA: Jossey-Bass Publishers.

Bloom, B.S. (ed) (1956). Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain. New York, NY: Longmans, Green.

Bolton, J., Durrant A., et. al. (eds.) (2000). *Chapter 3: The irreversible universe,* The restless universe. Milton Keynes, UK: The Open University. Retrieved from the World Wide Web on February 27, 2005: http://physicalworld.org/restless_universe/html/ru_3print.html

Brannen, J. (ed) (1995, March). Mixing methods: Qualitative and quantitative research. Burlington, VT: Ashgate Publishing Co.

Brinkman P. & Morgan A. (1997). *Changing fiscal strategies for planning.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 425-36.

Cassidy, D.C. (1992). Uncertainty: The life and science of Werner Heisenberg, NY: W.H. Freeman.

Chaffee, E. (1981). *The link between planning and budgeting.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 405-13.

Collinson, D. (1998). Fifty major philosophers: A reference guide. New York, NY: Routledge Books.

Commission on National Investment in Higher Education, Council on Aid to Education (1997). *Breaking the social contract: The fiscal crisis in higher education.* Retrieved from the World Wide Web on March 10, 2001: http: www.rand.org/publications/CAE/CAE100/

Comte, A. (1907). *A general view of positivism.* Internet modern history sourcebook. New York, NY: Fordham University. Retrieved from the World Wide Web on February 26, 2005: http://www.fordham.edu/halsall/mod/comte-positivism.html

Daniel, S. (undated article). *Empiricist epistemology: Hume and positivism.* College Station, TX: Texas A&M University. Retrieved from the World Wide Web on February 27, 2005: http://www-phil.tamu.edu/~sdaniel/Notes/emp-hume.html

Duderstadt, J. (1997, August). *The future of the university in an age of knowledge*. University of Michigan. Retrieved from the World Wide Web on March 10, 2001: http:// www.aln.org/alnweb/journal/issue2/ duderstadt.htm

Duderstadt, J. (1998, February 23). *The 21st century university: A tale of two futures,* The millennium project papers. University of Michigan. Retrieved from the World Wide Web on March 10, 2001: http://www.milproj.ummu.umich.edu/ mill2k/ presentations/ CFO/index.html

Duderstadt, J. (undated). *The cost, price and value of a college education*, The millennium project papers. University of Michigan. Retrieved from the World Wide Web on March 10, 2001: http://www.milproj.ummu.umich.edu/ mill2k/presentations/value/ index.html

Eisler, P. (2000, June 30). *This is only a test, but lives still at stake: Course simulates attack on 'big city, USA.'* USA Today, p. 21A.

Epstein, L. C. (2000). Relativity visualized. San Francisco, CA: Insight Press.

Ess, C. (2005). *Positivism and the demand for certain knowledge: An epistemological aside on the history of ideas.* Springfield, MO: Drury University. Retrieved from the World Wide Web on January 9, 2005: http://www.drury.edu/ess/Positivism.html

Feiser, J. & Dowden, B. (gen. eds.) (2005). *"Logical positivism," and "Time,"* The internet encyclopedia of philosophy. Martin, TN: University of Tennessee. Retrieved from the World Wide Web on February 26, 2005: http://www.utm.edu/research/iep/l/logpos.htm and http://www.utm.edu/research/iep/t/time.htm

Friedman, S. M. (2006). *Albert Einstein online*. Independent website containing Einstein's major scientific and philosophical writings. Retrieved from the World Wide Web on May 28, 2006. Internet available at: http://www.westegg.com/einstein/

Gell-Mann, M. (1999). *The simple and the complex*, Complexity, global politics and national security. Washington, DC: National Defense University, pp. 3-28.

Gibbs, P. (1998). *Is faster than light travel or communication possible?* Riverside, CA: University of California, Department of Mathematics. Retrieved from the World Wide Web on August 21, 2005. Internet available at: http://math.ucr.edu/home/baez/physics/Relativity/SpeedOfLight/FTL.html

Gleick, J. (1987). Chaos: Making a new science. New York, NY: Penguin Books.

Gould, S.J. (1991, August). *Opus 200,* Natural History. 100 (8), pp. 12-18. Retrieved from the World Wide Web on June 4, 2006. Internet available at: http://www.stephenjaygould.org/library/gould_opus200.html

Gould, S.J. & Lewontin R.C. (1979). *The spandrels of San Marcos and the Panglossian Paradigm: A critique of the adaptationist programme.* London, UK: Proceedings of the Royal Society of London, Series B, Vol. 205, No. 1161, pp. 581-598.

Hawking, S. (1998). A brief history of time. New York, NY: Bantam Books.

Heisenberg, W. (1999). Physics and philosophy: The revolution in modern science. Amherst, NY: Prometheus Books.

Helm, T. (2001). *Cerro Grande fire decision-making: Analysis of the decision drivers.* Los Alamos, NM: Los Alamos National Laboratory, Accident investigation team report on the Cerro Grande fire. Retrieved from the World Wide Web on August 25, 2001: http://www.lanl.gov/diateam/cerrogrande/index.htm\

Hnatio, J. (2000). The management of complex contingency operations: Course syllabus. Industrial College of the Armed Forces, Elective No. 5166. Washington, DC: National Defense University.

Hnatio, J. (2000). *Analysis of the Cuban missile crisis: The fourteen essential elements of information.* Industrial College of the Armed Forces, Elective No. 5166. Washington, DC: National Defense University.

Hnatio, J. (August 25, 2001). *Project Alpha: Managing complexity in the new age of knowledge*, unpublished monograph. Washington, DC: The George Washington University.

Hnatio, J. (August, 2004). *Cooperative agreement with the Alpha Institute to perform work in support of the Federal Bureau of Investigation's National Security Support Capability Program (FBI-NSSC).* Prepared at the request of the Federal Bureau of Investigation. Washington, DC: The Alpha Institute.

Jacobs, T.O. (2004). Strategic leadership: The competitive edge. Washington, DC: Industrial College of the Armed Forces, National Defense University.

Jacobson, T. & Parentani, R. (December, 2005). *An echo of black holes*. Scientific American. New York, NY: Volume 293, Number 6.

Janis, I. (1982). Groupthink (2nd edition). Boston, MA: Houghton Mifflin.

Jeans, J. (1981). Physics and philosophy. New York, NY: Dover Publications.

Johnstone D. (1999). *Financing higher education: Who should pay?* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 4-16.

Johnstone D. (1988). *Patterns of finance: Revolution, evolution, or more of the same.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing., pp. 17-24.

Joslyn, C. & Rocha, L.M. (2000). *Towards semiotic agent-based models of socio-technical organizations.* Proceedings: AI, Simulation and Planning in High Autonomy Systems (AIS 2000) Conference, Tucson, AZ., pp. 70-79. Sarjoughian, H.S. et. al., (eds). Retrieved from the World Wide Web on August 26, 2001: http://www.c3.lanl.gov/~rocha/AIS00.html

Kaku, M. (1998). Visions: How science will revolutionize the 21st century. New York, NY: Bantam Books.

Kerbel, J. (2005). *Thinking straight: Cognitive bias in the US debate about China,* Studies in intelligence: The journal of the American intelligence professional. McLean, VA: Central Intelligence Agency. Retrieved from the World Wide Web on February 26, 2005: http://www.odci.gov/csi/studies/vol48no3/article03.html

Kauffman, S. (1995) At home in the universe: The search for laws of self-organization and complexity. Oxford, UK: Oxford University Press.

Korthof, G. (2000, August). *Kauffman, at home in the universe: The secret of life is auto-catalysis*. Retrieved from the World Wide Web on June 4, 2006: http://home.planet.nl/~gkorthof/kortho32.htm

Laudon, J. & K. (1997). Essentials of management information systems: Organization & technology in the networked enterprise. Englewood Cliffs, NJ: Prentice Hall.

Lawton, G. (2001, June). *Monsters of the deep*, New Scientist. London, UK: Reed Business Information, Ltd.

Layzell D. (1998). *Linking performance to funding outcomes for public institutions of higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 199-206.

Lewin R. (1980, November). *Evolutionary theory under fire*, Science magazine. Vol. 210, pp 883-887. Retrieved from the World Wide Web on June 4, 2006. Internet available at: http://dim.com/~jambo/evolution/lewin.html

Maddox, J. (1998). What remains to be discovered: Mapping the secrets of the universe, the origins of life, and the future of the human race. New York, NY: The Free Press.

Marcus, W. (2001, August). *How we got into the California energy crisis*. Sacramento, CA: JBS Energy, Inc. Retrieved from the World Wide Web on August 26, 2001: http://www.jbsenergy.com/Energy/Papers/California_Energy_Crisis/california_energy_crisis.html

Maslow, A.H. (1943). *A theory of human motivation*, Psychological review, 50 (1943): 370-96, American Psychological Association, as re-presented in Martin J. Gannon, Organizational behavior: A managerial and organizational perspective. Boston, MA: Little Brown and Co., 1979, p. 179.

Maxfield, R. (1999). *Complexity and Organization Management*, Complexity, global politics and national security. Washington, DC: National Defense University, pp. 171-218.

Mead, W.M. (1999). *The Jacksonian Tradition*, The National Interest. Washington, DC: The National Interest.

Meisenger R. & Dubeck L. (1993). *Fund Accounting.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 503-27.

Michelson B., McGee M. & Hawley L. (1994). Consensus team decisionmaking for strategic leaders. Washington, DC: Industrial College of the Armed Forces, National Defense University.

Miller, A. I. (2000). Insights of genius: Imagery and creativity in science and art. Cambridge, MA: MIT Press.

Morgan, G. (1998). Images of organization. San Francisco, CA: Berrett-Koehler Publishers, Inc.

National Education Association (March 2001). The future of higher education: Market driven futures. Retrieved from the World Wide Web on February 11, 2006: http://www2.nea.org/he/future/

Negroponte, N. (1996). Being digital. New York, NY: Vintage Books.

Neilson R. & Stouffer D. (May-June 2005). *Narrating the vision: Scenarios in action.* The Futurist. Bethesda, MD: The World Future Society.

Omeara, W. (1997). *Deduction and induction.* Harrisonburg, VA: James Mason University. Retrieved from the World Wide Web on February 27, 2005: http://Falcon.jmu.edu/~omearawm/deduction.html

Perrow, C. (1982). Normal accidents. Princeton, NJ: Princeton University Press.

Prigogine, I. (2001). The Ilya Prigogine Center for the Study of Mechanical Statistics and Complex Systems, University of Texas at Austin. See: http://order.ph.utexas.edu/Prigogine.htm

Prigogine, I. and Gregoire N. (1998). Exploring complexity: An introduction. New York, NY: W. H. Freeman & Co.

Resnick, M. (1999). Turtles, termites and traffic jams: Explorations in massively parallel microworlds. Boston, MA: MIT Press.

Resnick, M. (June, 2004). "Star Logo™ on the Web, (version 2.)." Boston, MA: Massachusetts Institute of Technology (MIT). Retrieved from the World Wide Web on August 28, 2005. Internet available at: http://education.mit.edu/starlogo/

Reynolds, H.T. (1998, September). *The B-1 bomber: A case study of pluralism*. University of Delaware: Department of Political Science and International Relations. Retrieved from the World Wide Web on August 25, 2001: http://www.udel.edu/htr/index.html

Rosenhead, J. (1998). *Complexity theory and management practice*. London, UK: The London School of Economics and Political Science. Retrieved from the World Wide Web on August 20, 2001: http://www.human-nature.com/science-as-culture/rosenhead.html

Rudolf, F. (1990). The American college & university. Athens, GA: University of Georgia Press.

Runes, D. (ed.) (1942). Dictionary of philosophy. New York, NY: Philosophical Library. Retrieved from the World Wide Web on February 11, 2006: http://www.ditext.com/runes/

Rusu-Toderean, O. (1992). *In between positivism and post-positivism: A personal defence of empirical approaches to social science*. Romania, Babes-Boylai University. Retrieved from the World Wide Web on February 27, 2005: http://www.polito.ubbcluj.ro/EAST/East6/toderean.htm

Sagan, S.D. (2004). *The problem of redundancy problem: Why more nuclear security forces may produce less nuclear security*, Risk analysis, (Vol. 24, No. 4.). Stanford, CA: The Society for Risk Analysis, Stanford University. Retrieved from the World Wide Web on February 27, 2005: http://iisdb.stanford.edu/pubs/20274/Redundancy_Risk_Analysis.pdf

Sanchez, R. (2001, June 13). *Park employees absolved in New Mexico wildfire*, The Washington Post, p. A27.

Sanders, I. (1998). Strategic thinking and the new science: Planning in the midst of chaos, complexity, and change. New York, NY: The Free Press.

Sarkesian, S.C. (1995). U.S. national security: Policymakers, processes and politics. Boulder, CO: Lynne Rienner Publishers.

Saunders-Newton D. & Frank A.B. (2002, October). *Effects-based operations: Building the analytic tools,* Defense Horizons. Center for Technology and National Security Policy. Washington, DC: National Defense University.

Sauvage, G.M. (1911). *Positivism*, The Catholic Encyclopedia, Vol. XII. New York, NY: Robert Appleton Company. Retrieved from the World Wide Web on March 22, 2002. Internet available at: http://www.newadvent.org/cathen/12312c.htm

Schneider, S. (1997). *Fundamental challenges to logical positivism*, New Renaissance. Retrieved from the World Wide Web on October 12, 2002. Internet available at: http://members.aol.com/Mszlazak/positiv1.html

Schmidtlein, F. (1981). *Why linking budgets to plan has proven difficult in higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing. pp. 415-24.

Schmuck R. & Runkel P. (1994). The handbook of organization development in schools and colleges. Prospect Heights, IL: Waveland Press, Inc.

Schulock, N. & Harrison M. (1998). *Integrating, planning, assessment, and resource allocation.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 437-44.

Scott, H. & Saunders-Newton, D. (1995). *Convergence and emergence: Policy theme for the millennia*. Presentation of paper: Association for Public Policy Analysis and Management Research Conference. Washington, DC: Association for Public Policy Analysis and Management.

Senge, P.M. (1990). The fifth discipline: The art and science of the learning organization. New York, NY: Doubleday.

Shalizi, C. (2004). *Logical positivism.* Notebooks. University of Michigan, MI: Center for the Study of Complex Systems. Retrieved from the World Wide Web on February 26, 2005: http://cscs.umich.edu/~crshalizi/notebooks/logical-positivism.html

Smith, H. (1999). Rethinking America. New York, NY: Random House.

Smith, L.R. (1990). American science policy since WW II. Washington, DC: Brookings Institution.

Sowell, T. (1987). A conflict of visions: Ideological origins of political struggles. New York, NY: William Morrow.

Stanton, S. (2001, May 6). *How Californians got burned: The state electricity system is in a shambles, and the worst may be yet ahead. How did things get to this point?* Sacbee News, Sacramento, CA. Retrieved from the World Wide Web on August 27, 2001: http://www.sacbee.com/news/special/power/050601california.html

Trochim, W. M. (2004). Research methods knowledgebase. Ithaca, New York: Cornell University. Retrieved from the World Wide Web on February 26, 2005: http://www.socialresearchmethods.net/kb/

Umea University, (2005). *Positivism and empiricism-the heart of Anglo-American thinking*. Umea, Sweden: Umea University. Retrieved from the World Wide Web on February 26, 2005: http://www.eng.umu.se/culturec/POS.htm

U.S. General Accounting Office. (2000). *Fire management: Lessons learned from the Cerro Grande (Los Alamos) fire.* Washington, DC: US Government Printing Office (GAO/T-RCED-00-257, August 14, 2000). Retrieved from the World Wide Web on July 15, 2005: http://www.gao.gov

Waggaman J. (2000). *Strategies and consequences: Managing costs in higher education.* Yeager J., Nelson G., Potter E., et. al. (eds.) (2000). Ashe reader on finance in higher education (2nd edition), Boston, MA: Pearson Custom Publishing, pp. 301-15.

Waldrop, M. (1992). Complexity: The emerging science at the edge of order and chaos. New York, NY: Simon and Schuster.

Wheatley, M.J. (1999). Leadership and the new science: Discovering order in a chaotic world. San Francisco, CA: Berrett-Koehler Publishers.

Wilson, E.O. (1998). Consilience: The unity of knowledge. New York, NY: Random House.

Wohlstetter, R. (1978). Pearl Harbor: Warning and decision. Stanford, CA: Stanford University Press.

Appendix A

Overview: Three Additional Examples of How the Complexity Systems Management Method Can Be Applied to Improve the Management of Complex Situations

The complexity systems management method can be applied by human beings to more effectively manage a broad range of complex events and situations. The potential risk and benefit applications are far reaching. This appendix provides a description of how the complexity systems management method can be applied to address three real world highly complex situation management challenges. These are strengthening the international weapons of mass destruction nonproliferation regime, increasing the safety and security of America's food supply, and reducing the threat posed by terrorist use of improvised explosive devices.

Strengthening the International Weapons of Mass Destruction Nonproliferation Regime

The complexity systems management method is a process that brings decision makers and multi-disciplinary experts from all levels together to work through simulations of potential acquisition and development of nuclear, biological and chemical weapons of mass destruction by countries of the world and terrorist organizations. Participants come together in what are called *immersion* environments. Complexity systems management *immersions* can be repeated with different participants on a continuing basis to continuously build a supporting knowledgebase that becomes "smarter and smarter" with each successive *immersion*. The simulations considered by participants in *immersion* environments are based on scientifically developed scenarios developed by red teams of multidisciplinary experts before the *immersion* takes place. Scenarios and simulations are tied to a supporting computer knowledgebase that "baselines" the country's declared (and otherwise known) nuclear, biological and chemical cycles. Weapons of mass destruction acquisition and development simulations are supported by special computer graphic platforms that visually depict the extended order effects of potential deviations from a country's "baselined" nuclear, biological or chemical cycle as determined by red teams before an *immersion* takes place and validated by participants during an *immersion*. *Immersion* simulations are referred to as full spectrum because they are specially crafted to address the entire threat continuum from early detection, deterrence, deceit, deception, prevention, and response including the graded disablement of a country's nuclear, biological or chemical weapons of mass destruction infrastructures. Critical points of systems operation in a nuclear, biological or chemical fuel cycle where deviations from a country's baseline declared cycle may indicate the possible acquisition and development of weapons of mass destruction are identified as scenarios are developed before an *immersion* takes place. These are known as critical nodes of systems operation. Before an *immersion* takes place red teams of multidisciplinary experts create storyboards of possible simulations where a country has moved from peaceful declared use to weapons development by reverse engineering scenarios involving each critical node in the baseline nuclear, biological or chemical cycle. As multidisciplinary experts reverse engineer each scenario where a country has hypothetically moved from peaceful declared use to weapons of mass destruction development they are continuously asked to consider three key questions. First, what information had it been known before the country moved from peaceful declared use to weapons of mass destruction development could have been used to make the violation known to proper authorities and to interdict, i.e., disable, the effort? These become the early warning signals of potential weapons development. Second, with what level of confidence do these warning signals, either singly or in combination, indicate actual development of weapons of mass destruction? Third, for those scenarios when a country has already made the move from peaceful declared use to clandestine weapons development, what disablement strategies would produce the greatest long term curtailment of weapons development activities? Based on the reverse engineering of scenarios involving critical nodes of systems operation, these experts develop storyboards to support the development of simulations involving one or more critical nodes of systems operation as a country moves from peaceful declared use to weapons of mass destruction development. Subject matter experts are asked to determine those points in the simulation where decisions must be made in order to avoid unacceptable outcomes. These are known as critical decision points. Participants in *immersion*s work to reverse engineer each critical decision point to elicit the conclusions, decisions and actions that individual participants would make in the real world as they attempt to manage the simulated event. The first, second and third order effects of their decisions are identified. Special attention is directed toward the identification of earliest possible warnings of weapons of mass destruction acquisition and development and deceit and deception techniques that could be used by a rogue state or terrorist groups to thwart detection. Computer visualization platforms are used to portray the effects and consequences of participant decisions. The group then collectively considers the individual conclusions, decisions and recommended actions suggested by participants.

Special team interaction techniques are used to achieve consensus by the group on the best decisions or combinations of decisions that can be made around each critical decision point in a scenario. Decision options are considered by the group from both a scientific, i.e., quantitative perspective, and a political process, i.e., qualitative perspective. Both individual decisions and the group's rationale for selecting "best" decisions or combinations of decisions, i.e., decision options, are captured using collaborative group software tools so that they can be archived in a computer knowledgebase. The information is structured so that it can be used in a repeatable fashion. The individual and collective group decisions of participants in an *immersion* are compared and contrasted with the inputs of the subject matter experts that were structured and captured in the knowledgebase before the *immersion*. A complexity systems management computer knowledgebase for a given country can serve many critical functions. Among these, it serves as a learning system that becomes "smarter and smarter" as subsequent groups of subject matter experts and *immersion* participants with differing perspectives play through rogue state and terrorist weapons of mass destruction acquisition and use scenarios and simulations. Each successive immersion can elicit new "out of the box" perspectives, early warnings and new decision options that are added to the computer knowledgebase. The knowledgebase serves as a reference learning system that can be tapped at the strategic level by decision makers to consider appropriate policies and a response using hypothetical simulations before an analogous event happens in the real world. The knowledgebase can also be used at the tactical level to dramatically enhance the effectiveness of actual in country inspections. The knowledgebase can be used guide pre-inspection planning and focused intelligence collection by identifying the most likely acquisition and development paths that could be pursued by a potential rogue state. This information can be developed before an inspection occurs and provide insights on how to best detect deviations from a country's baseline declared cycle and the types of deceit and deception techniques that could be used by a rogue state to thwart discovery. During inspections when there is an indication of a potential deviation from a country's baseline declared cycle, the knowledgebase can be tapped by inspectors in country to identify the most effective detection schemes, supporting technology applications for validation, guidelines for proper forensic collection and treatment of evidence, and much more.

In summary, complexity systems management nonproliferation immersion environments focus on both the strategic policy and tactical operational challenges facing the international community as we work together to more effectively monitor, deter and prevent the development and proliferation of weapons of mass destruction. Results of complexity systems management immersions and resulting knowledgebases can be used for strategic, tactical operational and educational purposes. The complexity systems management method nonproliferation process can also serves to create an international consensus free of undue influence by individual governments. In this sense, the complexity systems management method nonproliferation process serves a critical "devil's advocate" role against government bureaucracies whose positions reflect poor intelligence gathering and analysis or political and other forms of cognitive bias (Kerbel, 2005). Table 1, below, depicts the serious challenges facing the global nonproliferation regime and the benefits of applying the complexity systems management (CSM) method.

Table 4: Objectives Crosswalk- Nonproliferation Challenges and the Complexity Systems Management Method

Nonproliferation Challenge	**CSM Method Benefits**
Fusion, analysis and focus of all source information relating to rogue state development and use of nuclear, biological and chemical weapons of mass destruction.	Fusion and analysis of information related to rogue state acquisition and use of nuclear, chemical and biological weapons of mass destruction acquisition and development of weapons of mass destruction must begin with the systematic identification of the early warnings that signal both motivation and intent to acquire and develop nuclear, chemical, and biological weapons of mass destruction. Early warning signals are essential to drive informed intelligence collection strategies. The complexity systems method provides a systematic and structured way to develop the early warnings and the means to focus information collection strategies. Using the complexity systems management method, deviations from a country's declared nuclear, biological, and chemical status become early warnings signals and the focal point for highly informed and intense intelligence information collection strategies. These early warning signals can be used to "index" data harvesting software capabilities. Moreover, the complexity systems management method brings together multidisciplinary expertise in immersions from diverse units/organizations that are currently stovepiped. This is done to assure effective communication/ integration of diverse intelligence and other inputs.
Closing the 'seam' between the technical capability to detect proliferation and the political will to do something about it	Use of the complexity systems management method can be based on open source information only. The complexity systems

Nonproliferation Challenge	**CSM Method Benefits**
	management method could involve *immersions* with nations allied with the US in the war against proliferation of nuclear biological and chemical weapons of mass destruction and other countries of the world who are willing to participate including the Russian Federation and China. These activities could include both NATO and IAEA countries. The international application of the complexity systems management method for nonproliferation purposes is designed to bring senior policymakers together with technical experts to consider the challenges associated with any effective international nuclear, biological, and chemical weapons of mass destruction inspection regime. The idea is to achieve international consensus on the early warning signals of nuclear, biological and chemical weapons of mass destruction proliferation and required levels of validation that can be used to establish a graded system of international responses to violations before the violations happen in the real world. Use of the complexity systems management method with the international community can serve to drive consensus around required "levels of proof", international definitions of commensurate response, and to close the existing 'seam' between international policymakers and the technical capability of inspectors to "catch the bad guy" if only they are given the political go ahead to do so.
Optimize the use of proliferation-related information, expertise, and capabilities to conduct systematic and continuing evaluations of countries that have the motivation and intent to acquire and develop nuclear, biological or chemical weapons of	The complexity systems management method brings multi-disciplinary policy and scientific expertise from across the intelligence community and interagency together to participate in the process. Subject matter experts red team potential

Nonproliferation Challenge	**CSM Method Benefits**
mass destruction and to more effectively develop informed intelligence collection strategies.	acquisition and use scenarios to identify the critical nodes of systems operation, i.e., those specific functional points in a nuclear, biological or chemical cycle where the transition from peaceful declared use to weapons development can and are most likely to occur, catalogue the early warning signals of weapons development and to devise highly focused intelligence collection strategies using the information they develop. The complexity systems method can also be used to create unclassified international working groups of subject matter experts and immersion environments that bring international policy and technical experts together around hypothetical (and possible or likely) scenarios and simulations of nuclear, biological and chemical weapons of mass destruction acquisition and development. This would allow policy and technical experts to consider both the policy implications as well as tactical responses to simulated acquisition and development events before analogous events happen in the real world. A full-scope complexity systems management nonproliferation program would use subject matter experts to quantify nuclear biological and chemical cycles by reverse engineering the critical nodes of systems operation and the integration of quantitative reality with qualitative political process in immersions to create a knowledgebase for each country in the world deemed to have both the motivation and intent to attempt to acquire and develop nuclear, biological and chemical weapons of mass destruction. These sensitive nations would be the subject of a continuing program of both classified intelligence community and unclassified international immersions in order to develop

Nonproliferation Challenge	**CSM Method Benefits**
	and maintain a current and expanding knowledgebase for use at both the strategic and tactical levels.
Create a structure that ensures information sharing across domestic and international lines.	The complexity systems management method is designed to cross-cultural lines both in the context of domestic interagency barriers and the broader challenge of promoting greater international cooperation. The complexity systems management method may involve policy and scientific expertise from across the intelligence community and interagency. The complexity systems management method may also involve subject matter experts and policymakers from the international community. The integration of quantitative analysis with qualitative political process can assist in defining the responsibilities of intelligence providers based on the needs of different intelligence users, and developing the domestic and international structures needed to satisfy them. These immersions can also be used to develop graded system of response, achieve consensus on "good enough" levels of non-compliance validation before similar events are confronted in the real world and to consider preemption and disablement strategies. The complexity systems management method can be used to red team the early warning signals of clandestine nuclear, biological and chemical weapons of mass destruction acquisition and development using hypothetical (but both possible and likely) simulations using real world data that "baselines" a country's nuclear, biological and chemical cycles. This same technique can be applied in immersions to systematically identify the tactics and

Nonproliferation Challenge	CSM Method Benefits
	techniques that might be employed by a rogue state for purposes of deceit, deception and avoidance of detecting these early warning signals. Once these tactics and techniques have been identified and placed in a knowledgebase, they can be used to "index" data harvesting capability. They can also serve as the basis for developing more effective intelligence collection strategies and for focusing intelligence collection and inspection efforts.
Based on the experience of Iraq, the DPRK, Iran and other countries, there is an urgent need to consider and systematically develop counter-intelligence strategies necessary to identify the deceit, deception and avoidance strategies that may be employed by rogue states intent on developing nuclear, biological and chemical weapons of mass destruction.	In some cases, rogue states like North Korea and Iran continue to develop weapons of mass destruction in spite of US bilateral and international efforts to dissuade them. As the DPRK situation illustrates, when a capability has been developed and married with an effective delivery mechanism it is extremely difficult to "turn the clock backwards." Clearly, the focus of future nonproliferation efforts must be on preventing development and the potential deployment of such weapons as early as possible. The complexity systems management method can be used to preempt development by the discovery of the early warning signals of weapons development and using traditional dissuasion techniques such as economic incentives/disincentives etc. But experience has shown that there are times when traditional dissuasion techniques are ineffective.
Preempting the clandestine transfer of nuclear, biological and chemical weapons of mass destruction from state actors to non-state actors including organized crime and terrorist organizations.	Using the complexity systems method, we can develop means to conduct highly focused military and other operations targeting only those critical aspects of a nuclear, chemical and biological weapons of mass destruction acquisition infrastructure that are necessary for a country to move

Nonproliferation Challenge	CSM Method Benefits
	toward an operational capability. The process relies on red teaming to systematically identify those aspects of a rogue state's nuclear, biological and chemical weapons of mass destruction infrastructure that are most critical to operational deployment. The immersion process is used to identify in advance techniques, tactics and technologies necessary to inflict maximum but highly focused damage necessary to delay and possibly prevent the deployment of NBC WMD operational capability. Use of CSM method and the development of country-specific inspection knowledgebases can do much to close the current 'seam' between the traditional notion of preemption and the need to consider new disablement strategies.
Closing the 'seam' between the notions of preemption and disablement.	As part of the quantitative analysis phase of the complexity management method special attention can be focused on the means and methods that could be employed by a nation state known to be in possession of the nuclear, chemical and/or biological know-how, technology and materials to attempt to clandestinely transfer it to a non-state actor and in a manner which would provide plausible denial. These means and methods can become part of focused intelligence collection strategies. As part of the immersion phase of the complexity management system, policymakers can determine best decision options to pursue should the warning signals of clandestine transfer be identified and appropriate responses. The immersion process can be used to attempt to achieve consensus among domestic and international decision makers on immediate responses to prevent non-state actors form obtaining nuclear, biological

Nonproliferation Challenge	**CSM Method Benefits**
	and/or chemical weapons of mass destruction.

Deliverables to Support an Enhanced International Nonproliferation Inspection Regime

1. A complexity systems management analysis that identifies nuclear weapons of mass destruction acquisition and development warnings signals for a generic sensitive country could be conducted. A demonstration knowledgebase of a selected country's declared baseline nuclear fuel cycle could be developed from open source information. The fuel cycle would be subjected to analysis by subject matter experts using the complexity systems management method. The analysis would identify the facilities, special equipment and functions associated with the country's declared nuclear fuel cycle. The required levels of know-how, technology and the materials required for nuclear weapons development, given the existing fuel cycle, would be developed. The means, methods, resources and sources of the resources required for the country to move from peaceful declared use to weapons development would be structured and archived in a supporting knowledgebase. From this fundamental rule sets bounding a set of likely scenarios for the country to move from peaceful declared use to weapons development would be identified. Based on this and other information, subject matter experts would identify and reverse engineer the critical nodes of systems

operation, i.e., those points in the fuel cycle where the move to weapons development is most likely to occur based on quantitative analysis. They would develop a range of plausible scenarios based on the fundamental rule sets defining the steps that the country must take to acquire a nuclear weapons capability. A second phase immersion activity would bring together policy makers and technical experts from industry, academia, government and the international community. The objective of the immersion would be to develop an initial set of nuclear weapons of mass destruction early warning signals based on the reverse engineering of different types of acquisition scenarios based on specific deviations from the country's declared "baseline" peaceful uses nuclear fuel cycle developed during the quantitative analysis phase. Information collection/sharing, deceit, deception and avoidance, preemption and disablement strategies and other factors would be considered and modified reality visualization tools and a supporting knowledgebase would be developed.

2. Using the experience of the initial effort the complexity systems method would be used as the starting point for working with the International Atomic Energy Agency and North Atlantic Treaty Organization countries. The second effort would consider a hypothetical nation state moving from peaceful use to acquisition and development of nuclear weapons of mass destruction. The immersion would be focused first on education with the intent of creating international consensus on the early warning signals of nuclear weapons of mass destruction proliferation and required levels of validation that can be used to establish a graded system of international response to violations before analogous

violations occur in the real world. The immersion would also serve to drive consensus around "required levels of proof", international definitions of commensurate international response, etc., etc. Computer visualization tools and an open source supporting knowledgebase would be created.

3. A complexity systems management international effort that considers the identification of the early warning signals of biological weapons of mass destruction acquisition and use. This type of complexity systems management initiative would consider a hypothetical nation state moving from peaceful use to the acquisition and development of biological weapons of mass destruction. The effort would be focused first on education with the intent of creating international consensus on the early warnings of biological weapons of mass destruction proliferation and required levels of validation that can be used to establish a graded system of international response to violations before analogous violations occur in the real world. The effort would also serve to drive consensus around "required levels of proof", international definitions of commensurate international response, etc., etc. Computer models and visualization tools and an open source supporting complexity systems management knowledgebase would be developed.

4. A complexity systems management international effort that considers the identification of the early warning signals of chemical weapons of mass destruction acquisition. This type of complexity system management initiative would consider a hypothetical nation state moving from peaceful use to the acquisition and development of chemical weapons of mass destruction. The immersion would be focused first on education with the intent of creating

international consensus on the early warning signals of chemical weapons of mass destruction proliferation and required levels of validation that can be used to establish a graded system of international response to violations before analogous violations occur in the real world. The immersion would also serve to drive consensus around "required levels of proof", international definitions of commensurate international response, etc., etc. Computer models and visualization tools and an open source supporting complexity systems management knowledgebase would be developed.

5. A continuing program of focused complexity systems management interventions involving the U.S. interagency and including industry, academia and the international community. One significant focus of the program would to lay the groundwork for creating a complexity systems management knowledgebase for each sensitive country in the world. Standing teams of interagency decision makers and technical experts would conduct quantitative analyses and immersions to continuously expand the knowledgebase. The lessons learned would be used to define and focus highly informed intelligence collection strategies and to guide cooperation with those nations allied with the U.S. in the war against proliferation of nuclear, biological and chemical weapons of mass destruction proliferation and terrorism. Complexity management systems *immersions* would consider the development of "good enough" international standards leading to international agreement on preemption and disablement strategies including the interdiction of state actors providing non-state actors with nuclear, biological and/or chemical weapons of mass destruction. Computer models and visualization tools and

complexity systems management knowledgebases for each of these sensitive countries would be developed.

Increasing the Safety and Security of America's Food Supply

The complexity systems management method brings industry decision makers and multi-disciplinary technical experts from all levels together to work through specially developed simulations of high consequence NBC contingencies including threats against America's agricultural sector and the food supply system. Agricultural food production cycles and fixed site food processing/manufacturing facilities are excellent candidates for the potential application of the complexity systems management method. Participants in the process are brought together in what are called immersion environments. CSM food production cycle, distribution and processing/manufacturing facility *immersions* can be repeated with different participants to update a supporting knowledgebase in order to continuously refine product cycle, distribution and fixed food processing/ manufacturing site threat and risk plans, e.g., design basis threat. The *immersion* process can also be used to test operational responses to high consequence agro-terrorist events involving America's food supply system including product cycle, fixed site food processing/manufacturing operations, supply chain distribution and retail sales. The simulations used in *immersion* environments are developed before an *immersion* takes place based on extensive prior research and the knowledge of scientific and technical experts. CSM simulations are tied to a supporting computer knowledgebase that characterizes each of the critical safety, security and programmatic nodes of operation of a product cycle including associated fixed site food processing/manufacturing facilities. Special techniques that employ geospatial imagery and expert analysis by teams of technical and scientific experts are used to independently identify the critical nodes of product cycle, distribution and fixed site operations. Critical nodes of operation are "red teamed" to identify the potential means and methods that could be used by terrorists to target and successfully attack them. These teams also identify the range of potential consequences of a successful attack against each critical node. The results are catalogued and archived in the supporting computer knowledgebase. The same computer knowledgebase is also used to "baseline" onsite and external resources that could be called upon to respond to and mitigate the consequences of a successful terrorist attack against these critical nodes of operation. CSM simulations use special "modified reality" platforms that visually depict the critical nodes of product cycle, distribution and fixed site food processing/ manufacturing operations and the distribution of response resources during contingency operations. Geospatial imaging and locating capability are integrated into visualizations during *immersions* for this and other purposes.

The simulations used in *immersions* are referred to as "full spectrum" because they are specially crafted to address the agro-terrorist threat from “field to fork” for different product cycles across the entire terrorist threat continuum from early detection, deterrence, deceit, deception, prevention, response, mitigation of immediate consequences and long-term economic recovery. Critical nodes of product cycle, distribution and fixed site food processing/manufacturing operations and their accompanying terrorist means and methods for successful attacks are analyzed by multidisciplinary experts to identify the indicators warnings of terrorist preparation necessary to mount a successful attack. These indicators and warnings are catalogued and archived in the supporting knowledgebase and can be used to facilitate focused intelligence collection strategies for the earliest possible detection and interdiction of terrorists before they can successfully attack critical nodes of agricultural product cycle, distribution and fixed site food manufacturing operations.

Based on the above analysis, scientifically accurate simulations of a range of terrorist attacks against critical nodes using different terrorist means and methods are developed based on multidisciplinary "red team" inputs. Selected groups of industry and government safety, security, program management and senior programmatic officials and policymakers are invited to work through these simulations in what are called Complexity Systems Management (CSM) *immersions*. A CSM *immersion* facilitator works with participants to "reverse engineer" simulations of terrorist attacks against critical nodes of site and systems operation to elicit the conclusions, decisions and actions that individual participants would make in the real world as they attempt to manage simulated attacks against America's food supply. The first, second and third order effects of their decisions are identified. The consequences of successful terrorist attack scenarios are considered. Special attention is directed toward the identification of early indicators and warnings of a possible terrorist attack and deceit and deception techniques that could be used by terrorists to thwart detection. "Modified reality" visualization platforms are used to portray the effects and consequences of participant decisions. Participant decisions and inputs are catalogued and archived in the supporting computer knowledgebase. Participant decisions are compared and contrasted against the multidisciplinary "red team" inputs of the experts who produced the terrorist attack simulations before the *immersion* and the means, methods and consequences of successful terrorist attacks against America's agricultural product cycle and food supply manufacturing and distribution systems using information archived in the knowledgebase.

The group then collectively considers the individual conclusions, decisions and recommended actions as suggested by individual participants. Special team interaction techniques are used by the CSM facilitator to achieve consensus by the group on the best individual decisions or combinations of decisions that can be made around each critical node. Decision options are considered by the group from both a scientific, i.e., quantitative perspective, and a political process, i.e., qualitative perspective. Both individual decisions and the group's rationale for selecting "best" decisions or combinations of decisions, i.e., a solution set, are catalogued and archived in the computer knowledgebase. Group decisions are compared and contrasted against the multidisciplinary "red team" inputs of the experts who produced the terrorist attack simulations before the *immersion* and the means, methods and consequences of successful terrorist attacks using information archived in the knowledgebase.

Each participant in an *immersion* takes an extensive battery of personality tests to determine individual preferences and decision and team interaction styles. A special CSM web based capability and an "intelligent system" to produce reports is used for this purpose. Before an *immersion,* a certified CSM counselor uses these reports to give each participant a personalized in-depth "one-on-one" feedback session. This process helps to assure the group's diversity and the facilitation of group interactions during *immersions.*

CSM agricultural product cycle computer knowledgebases serve many critical functions. Among these, they serve as a learning system that becomes "smarter and smarter" as subsequent groups of *immersion* participants with differing perspectives play through simulated terrorist attacks against critical nodes of agricultural product cycle, distribution and food processing/manufacturing operations. Each successive *immersion* can elicit new "out of the box" perspectives, indicators and warnings and new solution sets and new terrorist means and methods that are added to the computer knowledgebase. The knowledgebase serves as a reference learning system that can be tapped at the strategic level by decision makers to consider appropriate policy changes such as refinements to the design basis threat. The same knowledgebase can be used at the tactical level to test operational safety and security responses to agro-terrorism using hypothetical simulations before a similar event happens in the real world. The knowledgebase can be used to guide planning, focus intelligence collection by identifying the most likely means and methods that would be used by terrorists as they plan and prepare to attack critical nodes of operation and to support actual operational responses to similar events should they happen in the real world. Table 2, below, depicts some of the serious challenges facing the safety of America's food supply system and the benefits of the complexity systems management (CSM) method.

Table 5: Objectives Crosswalk-Food Safety Challenges and the Complexity Systems Management (CSM) Method

Food Safety Challenge	**CSM Method Benefits**
Continuous threat refinement	CSM *immersions* are repeated with different decision makers and knowledge domain experts. In this way, terrorist means and methods and indicators and warnings are continuously refined to reflect changes in terrorist tactics. This information can then be used to update threat planning policy, e.g., design basis threat.
Identification of the early warning signals of agricultural terrorism	CSM *immersions* are used to systematically identify and continuously refine the means and methods terrorists could use to successfully attack critical nodes of different agricultural product cycle, distribution and food manufacturing operations. CSM *immersions* are used to "reverse engineer" terrorist means and methods to identify indicators and warnings and the type of deceit and deception tactics terrorists would use to avoid detection. Based on this, focused intelligence collection for early detection and terrorist interdiction strategies can be developed. The complexity systems method recognizes that there has been little real world experience dealing with successful terrorist attacks against America's food supply system. Past experience dealing with low intensity security challenges may not reflect future requirements to effectively manage more complex events such as high consequence agro-terrorist attacks. For this reason, CSM *immersions* use scientifically accurate simulations of hypothetical attacks for both threat analysis and to test

Food Safety Challenge	**CSM Method Benefits**
	actual operational capabilities in response to high consequence terrorist attacks against America's food supply.
Past experience as an indicator of future systems behavior	Simulations are used to develop an experience base for managing high consequence events that may happen in the future.
The single solutions to complex syndrome	The CSM method is based problems on new understandings of systems behaviors, i.e., complex adaptive systems that show that exact prediction of future events in complex systems using Newtonian methods is not possible. Rather, the CSM method systematically identifies a range of potential events and associated outcomes for use in threat planning. Mitigation strategies are selected to "kill as many birds with one stone" as possible to achieve reasonable risk at reasonable cost.
Organizational stove piping	The CSM *immersion* process brings staff and line first responders from all levels together with multi-disciplinary experts to analyze simulated attacks against critical nodes of food production and supply operations. The process is designed to break down traditional stove piping between and among safety, security, and policy and scientific personnel at all levels from the local business, central government, to the individual states to local communities. A critical aspect of

Food Safety Challenge	**CSM Method Benefits**
Integration of safety and security investments to reduce risk and costs	the CSM *immersion* process is achieving multidisciplinary group consensus on what is important and why and how to focus limited resources in the most efficient manner to achieve reasonable risk before a similar event happens in the real world. The CSM method considers the entire threat continuum from early detection, deterrence, prevention response, near term mitigation to long-term programmatic recovery. The CSM process recognizes the symbiotic relationship between food safety and security across the threat continuum. Investments already made in food safety, when integrated with security, can have significant collateral benefits.
Enhanced knowledge for line and management officials	Senior management decision makers, line production personnel and first responders from all levels have little, if any, direct experience in dealing with the agricultural terrorism challenge. The CSM *immersion* process is specifically designed to give senior corporate policymakers and management and line officials a real world appreciation for the means and methods that can be employed by terrorists against their critical nodes of program operation and the near and long term programmatic consequences of a successful attack against their operations.
Achieving consensus at all levels what is on what is really important and why	The American food supply faces the very real prospect of being incapacitated by the terrorism challenge in the event of major terrorist attacks. Unless a new approach is found to achieve consensus at all levels on what is really important and why it will be impossible to develop effective

Food Safety Challenge	CSM Method Benefits
	defenses against the possibility of agro-terrorism. CSM can serve as a powerful risk assessment tool to help move the entire system toward consensus. Based on the results of *immersions* clearer policy and internally driven priorities can emerge on how to manage the agro-CT challenge and upon which wise investment decisions can be made.

Applying the Complexity Systems Management Method to Support the Increased Safety and Security of America's Food Supply

The complexity systems management method is a tool that can be used by the agricultural sector as part of terrorism threat, risk and operational response planning where current risk assessment tools fail to systematically identify the critical nodes of operation of complex food production, processing and supply and distribution chains for assessing potential catastrophic outcomes. The complexity systems method represents a core capability to conduct agricultural product cycle, food distribution and food manufacturing site *immersions*. This capability can be tailored to conduct a program of public/private sector cost-shared *immersions* with the American agricultural sector including the food supply industry.

Preparing for an Agricultural Product Cycle or Fixed Food Processing/Manufacturing Site *Immersion*

Before an *immersion*, the critical nodes of a product cycle's and associated sites' operations, the means and methods that could be employed by terrorists to mount a successful attack and the near and long term programmatic consequences associated with the attacks are red teamed by subject matter experts. Subject matter experts characterize each critical node of operation based on available information including function/importance, process flows/descriptions, photographic images, geospatial images, facility architectural drawings and maps, critical production areas, etc., etc. This information is archived in a supporting complexity systems method knowledgebase that includes on-site and off-site emergency responder resources that would be called upon to respond to a safety or security emergency. Full threat continuum scenarios of terrorist attacks against selected critical nodes of product cycle, distribution and associated food processing/ manufacturing site operation are created depicting terrorist means and methods and the consequences of a successful attack for subsequent use in *immersion* environments. Prior to *immersion* simulations of attacks on the critical nodes of operation of a food product cycle, distribution and associated food processing/ manufacturing site operations are developed and subject matter experts determine those points in a simulation where decisions must be made in order to avoid unacceptable consequences. A select group of senior management decision makers, line program managers and security and safety officials are identified to participate in an *immersion*. Before an *immersion*, each of these individuals is requested to take a battery of special tests to determine their preferred decision and team interaction styles. The purpose of the feedback session is to explain the results of the test battery and to acquaint each participant with the structure, objectives and operation of an *immersion* environment.

Conducting an *Immersion*

During an *immersion* a CSM facilitator works with participants to "reverse engineer" simulations of terrorist attacks against critical nodes of the food product cycle including distribution and vital fixed site operations to elicit the conclusions, decisions and actions that individual participants would make in the real world as they attempt to manage the simulated event. The first, second and third order effects of their decisions are identified. The consequences of successful terrorist attack scenarios are considered. Special attention is directed toward terrorist means and methods and the identification of early indicators and warnings of a possible terrorist attack to include deceit and deception techniques that could be used to thwart detection. "Modified reality" visualization platforms are used to portray the effects and consequences of participant decisions. Participant decisions and inputs are catalogued and archived in the supporting computer knowledgebase. Individual participant decisions are compared and contrasted against the multidisciplinary red team inputs of the experts gathered before the *immersion* to include the means, methods and consequences of successful agro-terrorist attacks using archival information stored in the knowledgebase prior to the *immersion*.

The group then collectively considers the individual conclusions, decisions and recommended actions suggested by participants. Special team interaction techniques are used by the facilitator to achieve consensus by the group on the best individual decisions or combinations of decisions that can be made around each critical node. Decision options are considered by the group from both a scientific, i.e., quantitative perspective, and a political process, i.e., qualitative perspective. Both individual decisions and the group's rationale for selecting "best" decisions or combinations of decisions, i.e., a solution set, are catalogued and archived in the computer knowledgebase. Group decisions are compared and contrasted against the multidisciplinary "red team" inputs of the experts gathered before the *immersion* to include the means, methods and consequences of successful agro-terrorist attacks using archival information in the knowledgebase.

Significant Uses of Complexity System Management Knowledgebases

Knowledgebases resulting from the complexity systems method can be used to support subsequent *immersions* around the same or different critical nodes of product cycle, distribution and fixed site operations. At the strategic management level, the supporting CSM knowledgebase can be updated using the results of successive *immersions* to continuously refine policies such as the design basis threat and threat and risk priorities. At the tactical level, CSM simulations, modified reality platforms, and supporting CSM knowledgebases can be used to test operational safety and security responses to high consequence agro-terrorism events against the critical nodes of production cycle, distribution and fixed site food processing/manufacturing operations.

Interdicting the Terrorist Use of Improvised Explosive Devices

The interdiction of the use of improvised explosive devises by terrorists is an excellent candidate for the potential application of the complexity systems management method. This application of the complexity systems management method application brings senior decision makers and multi-disciplinary technical experts from all levels together to work through specially developed simulations of high consequence contingencies involving the use of improvised explosive devices by terrorists in the homeland or by terrorist insurgents overseas. Participants in the process are brought together in what are called *immersion* environments. Complexity systems management method *immersions* involving the terrorist use of improvised explosive devices can be repeated with different participants to update a supporting knowledgebase in order to continuously refine the terrorist means and methods associated with the use of improvised explosive devices and the early indicators and warnings of terrorist acquisition and use of the technology, materials and methods needed to produce and effectively deploy improvised explosive devices as a terrorist weapon of choice. This includes both the quantitative requirements for improvised explosive device construction and use and qualitative factors such as cultures or individuals susceptible to recruitment to conduct operations including suicide bombings such as those that have recently occurred in Iraq, Spain, Great Britain, and Jordan. The *immersion* process can also be used to test operational responses to high consequence improvised explosive device events involving America's infrastructure systems, such as public transportation systems, major events or locations that may attract large populations most susceptible to terrorist attacks using improvised explosive devices.

The simulations used in *immersion* environments are developed before an *immersion* takes place based on extensive prior research and the knowledge of scientific and technical experts. CSM simulations are tied to a supporting computer knowledgebase that characterizes the specific terrorist means and methods (including technology, materials availability, levels of expertise, targets of choice, recruitment strategies, terrorist deception and detection avoidance strategies, etc.) of possible terrorist IED events. Special techniques that employ geospatial imagery and expert analysis by "red teams" of technical and scientific experts are used to support the development of the computer knowledgebase. The simulations of different terrorist IED scenarios are continuously refined to identify changes in the potential means and methods that could be used by terrorists to target and successfully attack targets of choice. These "red teams" also identify the range of potential consequences of a successful attack against different targets of choice. The results are catalogued and archived in the supporting computer knowledgebase. The same computer knowledgebase is also used to "baseline" onsite and external resources that could be called upon to respond to and mitigate the consequences of a successful terrorist attack against potential terrorist IED targets of choice. CSM simulations use special "modified reality" platforms that visually depict the different targets of choice and the distribution of response resources during contingency operations. Geospatial imaging and locating capabilities are integrated into *immersions* for this and other purposes.

The simulations used in *immersions* are referred to as "full spectrum" because they are specially crafted to address the IED terrorist threat across the entire terrorist threat continuum from earliest possible detection, deterrence, deceit, deception, prevention, response, mitigation of immediate consequences and long-term economic recovery. Terrorist IED targets of choice and their accompanying terrorist means and methods for successful attacks are analyzed by multidisciplinary experts to identify the indicators warnings of terrorist preparation necessary to mount a successful attack. These indicators and warnings are catalogued and archived in the supporting knowledgebase and are used to guide highly focused intelligence collection strategies for the earliest possible detection and interdiction of terrorists before they can successfully attack targets of choice.

Based on the above analysis, scientifically accurate simulations of a range of terrorist attacks against targets of choice using different terrorist means and methods are developed based on multidisciplinary "red team" inputs. Selected groups of industry and government safety, security, program management and senior programmatic officials and policymakers are invited to work through these simulations in what are called Complexity Systems Management (CSM) *immersions*. A CSM *immersion* facilitator works with participants to "reverse engineer" simulations of IED terrorist attacks against critical targets of choice to elicit the conclusions, decisions and actions that individual participants would make in the real world as they attempt to prevent and manage simulated responses to IED attacks. The first, second and third order effects of their decisions are identified and computer based "decision trees" are developed. The consequences of successful terrorist attack scenarios are considered. Significant attention is directed toward the identification of earliest possible indicators and warnings of a possible terrorist attack and deceit and deception techniques that could be used by terrorists to thwart detection. Computer visualization platforms are used to portray the effects and consequences of participant decisions. Participant decisions and inputs are catalogued and archived in the supporting computer knowledgebase. Participant decisions are compared and contrasted against the multidisciplinary "red team" inputs of the experts who produced the terrorist attack scenarios upon which simulations are based and the means, methods and consequences of successful terrorist attacks against terrorist IED targets of choice using information archived in the knowledgebase.

The group then collectively considers the individual conclusions, decisions and recommended actions as suggested by individual participants. Special team interaction techniques are used by the CSM facilitator to achieve consensus by the group on the best individual decisions or combinations of decisions that can be made to prevent and manage the simulated terrorist IED event. Decision options are considered by the group from both a scientific, i.e., quantitative perspective, and a political process, i.e., qualitative perspective. Both individual decisions and the group's rationale for selecting "best" decisions or combinations of decisions, i.e., a solution set, are catalogued and archived in the computer knowledgebase. Group decisions are compared and contrasted against the multidisciplinary "red team" inputs of the experts who produced the terrorist attack simulations before the *immersion* and the means, methods and consequences of successful terrorist attacks using information archived in the knowledgebase.

Each participant in an *immersion* takes an extensive battery of personality tests to determine individual preferences and decision and team interaction styles. A special CSM web based capability and an "intelligent system" to produce reports is used for this purpose. Before an *immersion*, a certified CSM counselor uses these reports to give each participant a personalized in-depth "one-on-one" feedback session. This process helps to assure the group's diversity and the facilitation of group interactions during *immersions*.

CSM terrorist IED knowledgebases serve many critical functions. Among these, they serve as a learning system that becomes "smarter and smarter" as subsequent groups of *immersion* participants with differing perspectives play through simulated terrorist preparations for and attacks against terrorist IED targets of choice. Each successive *immersion* can elicit new "out of the box" perspectives, indicators and warnings, new solution sets and new terrorist means and methods that are added to the computer knowledgebase. The knowledgebase serves as a reference learning system that can be tapped at the strategic level by decision makers to consider appropriate policy changes such as enhanced security measures, intelligence information collection strategies, new procedures for limiting access to the materials needed to construct IED's, to guide early detection technology investments and much more. The same knowledgebase can be used at the tactical level to test operational safety and security prevention strategies and responses to IED terrorism using hypothetical simulations before a similar event happens in the real world. The knowledgebase can be used to guide planning, focus intelligence collection by identifying the most likely means and methods that would be used by terrorists as they plan and prepare to attack IED targets of choice and to support actual operational responses to similar events that happen in the real world. Table 3, below, depicts some of the serious challenges posed by the terrorist use of improvised explosive devices (IED) and the benefits that could derive from the application of the complexity systems management (CSM) method.

Table 6: Objectives Crosswalk-Improvised Explosive Device (IED) Challenge and the Complexity Systems Management (CSM) Method

IED Terrorism Challenge	**CSM Method Benefits**
Continuous refinement of terrorist IED means and methods	CSM *immersions* are repeated with different decision makers and knowledge domain experts. In this way, terrorist IED means and methods and indicators and warnings are continuously refined to reflect changes in terrorist tactics. This information is used to update threat planning policy and guide more effective early detection and render safe technology investments.
Identification of the early warning signals of impending attack	CSM *immersions* can be used to systematically identify and continuously refine the means and methods terrorists would have to use to successfully attack targets of choice using IED's. CSM *immersions* are used to "reverse engineer" terrorist means and methods to identify the earliest possible indicators and warnings and the type of deceit and deception tactics terrorists would use to avoid detection. Based on this, focused intelligence collection for early detection and terrorist interdiction strategies can be developed.
Past experience as an indicator of future behavior	The CSM method recognizes that there has been significant real world experience dealing with successful terrorist IED attacks against targets of choice. But terrorists adapt and change their tactics. Thus, past experience dealing with the terrorist IED challenge may not reflect future requirements that may be necessary to effectively adapt to

IED Terrorism Challenge	CSM Method Benefits
	changing terrorist means and methods. For this reason, CSM immersions use scientifically accurate simulations of hypothetical attacks for both threat analysis and to test actual operational capabilities in response to different terrorist attacks using IED's. Simulations are used to develop an experience base for adapting to future changing terrorist means and methods and different tactics that terrorists may employ in the future.
The single solutions to complex problems syndrome	The CSM method is based on new understandings of systems behaviors, i.e., complex adaptive systems that show that exact prediction of future events in complex systems using Newtonian methods is not possible. Rather, the CSM method systematically identifies a range of potential events and associated outcomes for use in threat planning. Mitigation strategies are selected to "kill as many birds with one stone" as possible to achieve reasonable risk at reasonable cost.
Organizational stove piping	The CSM *immersion* process brings first responders from all levels together with multidisciplinary experts to analyze simulated attacks against terrorist targets of choice. The process is designed to break down traditional stove piping between and among safety, security, and policy and scientific personnel at all levels. A critical aspect of the CSM *immersion* process is achieving multidisciplinary group consensus on what is important and why and how to focus limited resources in the most efficient manner to achieve reasonable

<u>IED Terrorism Challenge</u>	**<u>CSM Method Benefits</u>**
	risk <u>before</u> a similar event happens in the real world.
Integration of safety and security investments to reduce risk and costs	The CSM process considers the entire threat continuum from early detection, deterrence, prevention, response, near term mitigation to long-term programmatic recovery. The CSM process recognizes the symbiotic relationship between public safety and security across the threat continuum to leverage safety and security investments.
Enhanced knowledge for senior policymakers and first responders	Senior policymakers and first responders in the homeland have little direct experience in dealing with the IED terrorist challenge. The CSM *immersion* process is specifically designed to give senior policymakers and first responders a real world appreciation for the means and methods that can be employed by terrorists against critical targets of choice under their operational purview and the near and long term public and programmatic consequences of a successful attack against their operations. Based on this, senior policymakers gain perspective on three critical risk assessment factors, namely: 1) probability of occurrence, 2) vulnerability of terrorist targets of choice, and; 3) the true consequences of successful attacks.
Achieving consensus at all levels on what is really important and why	Many aspects of the American infrastructure system are extremely vulnerable to the terrorism IED challenge. Unless an approach is found to quickly achieve consensus at all levels on what is really important and why, it will not be possible to develop effective

IED Terrorism Challenge	**CSM Method Benefits**
	defenses against the possibility of IED attacks. The CSM method can serve as a powerful risk assessment tool to help move the entire system toward consensus. Based on the results of *immersions* clearer policy and internally driven priorities can emerge on how to manage the terrorist IED challenge.

Applying the Complexity Systems Method to Interdict the Terrorist Use of Improvised Explosive Devices (IED's)

Preparing for a Terrorist Interdiction IED *Immersion*

In preparation for each *immersion*, the terrorist targets of choice, the means and methods that could be employed by terrorists to mount a successful attack and the near and long term programmatic consequences associated with the attacks are "red teamed" by subject matter experts and archived in a supporting knowledgebase. The knowledgebase further characterizes terrorist targets of choice based on available information including function/importance, process flows and descriptions, photographic images, geospatial images, architectural drawings of potential targets of choice and maps, etc., etc. The knowledgebase includes on-site and off-site emergency responder resources that would be called upon to respond to prevent and/or respond to a terrorist IED threat. Full threat continuum simulations of terrorist attacks against selected targets of choice are created depicting terrorist means and methods and the consequences of a successful attack for subsequent use in *immersion* environments.

Prior to an *immersion*, a select group of senior policymakers, first responders and other security and public safety officials are identified to participate in an *immersion*. Before an *immersion*, each of these individuals is requested to take a battery of special tests to determine their preferred decision and team interaction styles. A privacy-protected on-line system has been established for the convenience of *immersion* participants to take these tests. After completing the test battery, each participant in an *immersion* receives a personalized "one-on-one" feedback session with a certified CSM counselor. The purpose of the feedback session is to explain the results of the test battery and to acquaint each participant with the structure, objectives and operation of an *immersion* environment.

Conducting a Terrorist Interdiction IED *Immersion*

During an *immersion* a CSM facilitator works with participants to "reverse engineer" simulations of terrorist attacks against terrorist IED targets of choice to elicit the conclusions, decisions and actions that individual participants would make in the real world as they attempt to manage the simulated event. The first, second and third order effects of their decisions are identified. The consequences of successful terrorist attack scenarios are considered. Special attention is directed toward terrorist means and methods and the identification of early indicators and warnings of a possible terrorist attack to include deceit and deception techniques that could be used to thwart detection. "Modified reality" visualization platforms are used to portray the effects and consequences of participant decisions. Participant decisions and inputs are catalogued and archived in the supporting computer knowledgebase. Individual participant decisions are compared and contrasted against the multidisciplinary red team inputs of the experts gathered before the *immersion* to include the means, methods and consequences of successful IED attacks using archival information stored in the knowledgebase prior to the *immersion*.

The group then collectively considers the individual conclusions, decisions and recommended actions suggested by participants. Special team interaction techniques are used by the facilitator to achieve consensus by the group on the best individual decisions or combinations of decisions that can be made at critical points in the simulation. Decision options are considered by the group from both a scientific, i.e., quantitative perspective, and a political process, i.e., qualitative perspective. Both individual decisions and the group's rationale for selecting "best" decisions or combinations of decisions, i.e., a solution set, are catalogued and archived in the computer knowledgebase. Group decisions are compared and contrasted against the multidisciplinary "red team" inputs of the experts gathered before the *immersion* to include the means, methods and consequences of successful terrorist IED attacks using archival information in the knowledgebase.

Significant Uses of Complexity System Management Knowledgebases

The CSM knowledgebase resulting from an *immersion* can be used to support subsequent *immersions* around the same or different terrorist target of choice. At the strategic management level, the supporting CSM knowledgebase can be updated using the results of successive *immersions* to continuously refine policies and risk priorities. At the tactical level, CSM simulations, modified reality platforms, and supporting CSM knowledgebases can be used to test operational safety and security responses to high consequence terrorist IED events.

Interdicting the Terrorist Use of IED's by Insurgents in Iraq

The CSM process can also be used as a strategic and operational tool in Iraq. The first step in the process would involve the baselining of known pre-Iraq war stockpiles of the explosive materials and military munitions known to be used by terrorist insurgents in Iraq. A detailed history of past IED attacks by insurgents in Iraq to include insurgent means, methods, consequences, known perpetrators, locations, materials used, method of IED construction, method of deployment, time of deployment, method of detonation, etc., etc., will be developed as part of the computer knowledgebase described above. Any potential correlations between pre-Iraq war baselines of known geographical locations of explosive materials and military munitions and actual event locations of past IED attacks will be triangulated and structured for input to the computer knowledgebase and for geospatial visualization. From this, the correlation of materials/munitions to past IED targets of choice would be visualized to portray the potential transportation flow (and possible terrorist stockpiling) of explosives and munitions that could be used in future attacks against insurgent targets of choice in Iraq. Special attention would be paid to identifying the earliest possible indicators and warnings of terrorist preparations and the means and methods necessary to obtain the materials needed to construct and deploy and successfully detonate an IED; the development of focused intelligence collection strategies; and potential future changes of terrorist means and methods as targets of choice are hardened, current explosive and munitions stockpiles are diminished and technology solutions for earlier detection are developed and deployed by Allied forces in the Iraq theatre. Special attention would be focused on the indicators of possible stockpiles of explosives and munitions used to construct IED’s. The other aspects of CSM IED *immersions* described earlier would also be undertaken.

Appendix B

Hnatio, J. (2000). The management of complex contingency operations: Course syllabus. Industrial College of the Armed Forces, Elective No. 5166. Washington, DC: National Defense University.

COURSE OVERVIEW

1. Course Title:

STRATEGIC DECISION MAKING AND THE MANAGEMENT OF COMPLEX CONTINGENCY OPERATIONS

2. Course Abstract:

This twelve-lesson elective will introduce students to some of the more complex and potentially dangerous events that could threaten U.S. national security, and how the U.S. is preparing to deal with them. Ever since the end of the Cold War, the global security environment has undergone radical change. The explosion of information technologies, rapid advances have characterized this changing environment across the spectrum of science and technology, and the emergence of larger and more complex economic, political and social systems. At the same time that the threat of global war has receded, numerous challenges to regional stability and international peace have arisen, many of which directly threaten the interests and security of the United States.

Several recent U.S. documents and white papers have attempted to address these problems posed by non-traditional threats to U.S. security, and to provide strategic guidance on the U.S. government's efforts to address them. These have included the National Security Strategy, National, Military Strategy, Joint Vision 2010, and several significant Presidential Decision Directives.

To devise and implement forward thinking national security strategies to meet such threats, future strategic leaders must appreciate, understand and be able to effectively deal with a new range of highly complex, high consequence events. This elective introduces students to the implications of complexity and nonlinear cause and effect relationships that may influence the strategic decision and policy process. Students will learn about the Federal management structure used for responses to complex national emergencies and the integration of national resources with those of individual states (including the National Guard) and local agencies. Students will have the opportunity to learn about new technology advances and use tools that can focus knowledge in the strategic management of complex, high consequence events. They will have the opportunity to apply their knowledge and test their strategic decision skills in two different exercises--one involving a domestic biological attack and another involving the disruption of U.S. trade routes. At the conclusion of the elective, student teams will brief a panel of senior military and civilian leaders on critical national policy issues and opportunities to enhance the nation's capability to deal with complex contingency operations.

3. Point of Contact:

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4. Course Structure:

a. This course will consist of twelve blocks (24hrs) of instruction including a major four-hour exercise.

b. Student mentors (subject matter experts) from various agencies/organizations will be identified and matched to individual student teams. Mentors will work with students holding agency assignments based on student exercise role(s). Mentors will be invited to participate in class and during exercises to the fullest extent possible

c. Maximum class size: 60 students in two sessions.

5. Overarching Course Objectives:

a. Develop a common set of definitions and terms to characterize complex contingency operations and aid in their evaluation.

b. Place the notion of "infrastructure" in its broad strategic national security context by gaining an appreciation for the non-linear, interdependent and sometimes counter-intuitive nature of complex events and their potential for cascading consequences. This includes the socio-political implications of *national will*.

c. Examine the changing nature of the decision and policy-making process as it pertains to the strategic management of complex contingency operations and national security events such as those envisioned under Presidential Decision Directives 39, 43, 56, 62, 63 and others.

d. Acquaint students with the overarching mission responsibilities, authorities and policies of various federal agencies as they relate to the handling of highly complex, high consequence, national security events.

e. Develop a strategic level understanding of the integration of federal (including congress), state and local policies, authorities and resources in detecting, responding to and mitigating the consequences of national emergencies and events affecting the national infrastructure.

f. Examine the role and growing influence of the media in the handling of highly complex, high consequence, national security events.

g. Evaluate the role of technology in leveraging the strategic decision and policymaking process in the strategic management of attacks against the national infrastructure.

h. Apply knowledge gained in classroom study during a major hands-on exercise designed to stress strategic decision skills and challenge the application of technology in the management of highly complex national security crises.

i. Identify opportunities to strengthen national policy and promote more effective interagency coordination in the management of complex contingency operations.

6. Description of Course Lessons:

a. LESSON 1. OPERATION CHINESE CHECKERS: U.S. ACCESS TO THE PANAMA CANAL IS DISRUPTED (EXERCISE)

This lead-in exercise gives students the opportunity to establish an initial benchmark to judge their strategic decision skills managing a complex, fast-paced, high consequence event with international implications. Special attention will be given to the strategic leadership aspects of group process working in a highly diverse interagency environment characterized by competing interests.

b. LESSON 2. STRATEGY, PLANNING AND COMPLEX THREATS TO NATIONAL SECURITY.

This lesson considers national strategies to deal with complex domestic and international crises. It addresses the nature of globalization and its effect on national security, the strategy and planning processes in the coordination of diverse government agencies, and biological terrorism and information attack as representative examples of complex threats to national security.

c. LESSON 3. THE RISE IN COMPLEXITY: THE IMPLICATIONS FOR AMERICA'S NATIONAL SECURITY

This lesson provides background and overview of complexity theory and its implications on the strategic decision process in the handling of complex events; students are given a layman's introduction to pattern recognition as an important tool for understanding the behaviors of complex systems. Finally, students consider the difficulties of identifying rule-based processes and why systems break down and experience non-linear excursions.

d. LESSON 4. TERRORIST USE OF WEAPONS OF MASS DESTRUCTION: THE LIKELIHOOD, CONSEQUENCES AND IMPLICATIONS

This lesson scans the strategic environment to look at the likelihood/consequences and implications of WMD/other infrastructure attacks by terrorists against the United States and critical interests abroad.

e. LESSON 5. INTERAGENCY MISSIONS, AUTHORITIES AND RESPONSIBILTIES FOR RESPONSES TO COMPLEX EVENTS

This lesson gives an overview of national mission responsibilities, response structures, budgets and federal agency integration (including congress) with states and local entities in the management of a complex contingency that may be triggered by an incident such as chem/bio terrorist event. This lesson also examines the role and growing influence of the media in dealing with complex, high consequence national security events.

f. LESSON 6. SCIENCE AND TECHNOLOGY: LEVERAGING THE STRATEGIC DECISION-MAKING PROCESS

This lesson scans the strategic environment for technology developments that can help support the decision process, e.g., developments in super computational capabilities and implications for modeling and simulation; information management, communication, and sensor technology developments for the management of complex contingency operations. Students will also discuss what the future of technology developments may hold and the direction of technology investments to support complex contingency responses.

g. LESSON 7. SETTING THE STAGE: BIG CITY, USA AND THE NATIONAL POLITICAL CONVENTION

In this lesson, students are familiarized with the significant preparations being taken by the federal government and state and local entities to protect the public health and safety during a hypothetical major national political convention. One area of focus will be contingency planning for a chemical and/or biological terrorist attack against a major urban center.

h. LESSONS 8. AND 9. BIOLOGICAL TERROR IN BIG CITY, USA (EXERCISE)

This exercise gives students the opportunity to apply their knowledge and test their strategic decision skills in identifying and acting on essential elements of information in a complex, fast-paced event where projection of future incidents and criticality of errors in such projections may have catastrophic consequences. Students will apply advanced technology tools in support of the strategic decision process as they manage a national level strategic response to the event.

i. LESSON 10. AFTER ACTION REVIEW/BENCHMARKING OF EXERCISES

The Lesson 10. After Action Review (AAR) will allow students to assess their performance as strategic leaders in managing the Big City, USA bio-terror incident and the Panama Canal disruption scenarios. Students will share different perspectives based on their agency roles and the underlying reasons/thought processes for key actions taken/not taken during the exercise. An important element of this class session will be devoted to an examination the effectiveness of the individual decision/group process. Students will benchmark their performance against the results/lessons learned arising from the Lesson 1. exercise. Based on the AAR and previous study, students will be asked to highlight potential gaps in national policy, process, procedures and technology investments/applications that, if addressed, could strengthen national responses to complex contingencies. As part of this seminar session, students will receive feedback from agency and media mentors who observed their work/actions during the two exercises. Lesson 10. is an important building block in preparing students for the Lesson 11. senior leader roundtable.

j. LESSON 11. SENIOR LEADER ROUNDTABLE

During this lesson student teams will brief out invited leaders on findings/results/opportunities arising from their involvement in course/exercises.

As part of their briefings students will provide their recommendations and ideas on ways to strengthen the national response to complex contingency operations.

k. LESSON 12. COURSE WRAP-UP AND CRITIQUE

This lesson will be devoted to a wrap-up discussion with students and an independently facilitated critique of course by students, agency mentors and faculty. Wrap up discussions will include consideration of ways to integrate course results/new technology tools into the broader National Defense University curriculum/exercise program and continuing opportunities/suggestions for working with the interagency community.

STRATEGIC DECISION MAKING AND THE MANAGEMENT OF COMPLEX CONTINGENCY OPERATIONS

LESSON 1: OPERATION CHINESE CHECKERS: U.S. ACCESS TO THE PANAMA CANAL IS STOPPED (EXERCISE)

"It's necessary to relax your muscles when you can. Relaxing your brain is fatal."

Stirling Moss

1. PURPOSE:

This lead-in exercise gives students the opportunity to establish an initial benchmark for the application of strategic decision skills as they respond to a complex, fast-paced, high consequence event with international implications. Students will craft a national level strategic response to the disruption of U.S. shipping through the Panama Canal and other threats to U.S. national security. Special attention will be given to group decision processes as students work in a diverse interagency environment characterized by competing interests.

2. RELATIONSHIP TO COURSE:

Students are assigned roles as representatives of different federal agencies and military command authorities that share responsibility for responding to the disruption of U.S. use of the Panama Canal. They are faced with a volatile, complex situation that has the potential for cascading impacts on U.S. critical infrastructure systems and the national security. More specific details of the event scenario will be provided to students at the start of the exercise. Student participation in the exercise will be videotaped and used as part of a formal Lesson 10 after action review (AAR) of course exercise activities.

3. LESSON OBJECTIVES:

a. Exercise strategic decision skills including the ability to identify and effectively act on essential elements of information. The seminar will be asked to prepare a decision paper for submission to the President's Advisor on National Security.

b. Gain a better appreciation for the different roles of strategic military-civilian leaders at the national level in conducting contingency operations. This includes decisions regarding the appropriate levels of political and/or military action that should be taken under varying circumstances.

c. Consider the integration of civilian-military assessment and response capabilities in the strategic context of critical infrastructure systems and systems interdependencies.

d. Begin to refine individual decision models for discriminating between "noise" and essential elements of information and developing command concepts. Consider technology tools that can help strategic leaders identify and effectively act on essential elements of information.

e. Initiate a dialogue regarding the need for new/modified strategies, policies, processes, structures and advanced technology investments which can enhance the nation's ability to detect, deter, respond and mitigate the consequences of complex events including the cessation of U.S. and international shipping through the Panama Canal.

4. GENERAL:

On March 29, 1999, the Commander in Chief announced the transfer of America's military nerve center for the Latin American region, Southern Command (SOUTHCOM), from Panama to Miami, Florida. The decision to move SOUTHCOM from Panama fulfills the 1997 Panama Canal Treaty commitment to remove all U.S. troops from the area before December 31, 1999. The removal of U.S. troops from the region seems to be predicated on three important assumptions. First, that we fully understand in socio-political, economic and military terms the national security implications of the cessation of U.S. and international shipping through the canal. Second, that the United States has an effective strategy to re-open the canal in the absence of a continuing military presence in Panama. Or third, that we possess or can quickly develop alternate infrastructure capacities to offset a cessation of U.S. and international shipping through the canal.

Some U.S. military officials and international security experts have described the Panama Canal as a terrorist's dream comes true. A story appearing in The *Dallas Morning News* in the summer of 1999 describes security at the canal this way:

> "Here, at the southernmost point linking the canal to the Pacific Ocean [Miraflores Locks], a guide demonstrated how easy it is to gain direct access to the canal by sliding a simple, unlocked deadbolt on a wrought-iron garden gate. Nobody asked for ID's or security clearance. There were no weapons checks. The canal locks were only steps away…In fact, for most of its 43-mile length, there are virtually nothing separating a sightseer or would-be saboteur from the waterway used by 13,000 ships each year to cross between the Atlantic and Pacific oceans."[15]

The debate about U.S. security concerns and the Panama Canal has other disturbing aspects. In March 1997, The *Washington Times* disclosed a connection between the future operation of the Panama Canal and the People's Republic of China. The *Times* reported that Panamanian officials awarded operating rights to two strategic American-built port facilities, Balboa on the Pacific side and Cristobal on the Atlantic side to Hutchison Whampoa, Ltd. Hutchinson Whampoa is a giant Chinese shipping firm based in Hong Kong.[16]

5. ISSUES FOR CONSIDERATION:

a. What is the national interest with respect to the Panama Canal? What might be some of the political motivations for stopping shipping through the canal? What political or other advantages might be gained by a nation state or multi-national corporation in precipitating such an action?

b. What are some the potential far-reaching consequences of a subversive attack against the Panama Canal? What would the major strategic impacts be?

c. In managing such an event, what strategies and tools would you use to identify essential elements of information?

d. How would you place the event and the notion of critical infrastructure systems proper strategic context? What strategies would you, as a strategic leader, devise and employ to deal with the disruption of all U.S. shipping through the Panama Canal? Do you see potential impacts across other systems?

d. Given the different roles and responsibilities of tactical and strategic leaders in managing complex events, are different organizations and personnel at different levels effectively integrated? Does each level understand the essential information needs at other levels?

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[15] *The Dallas Morning News* (Tod Roberson), *"SAFE PASSAGE?: Panama Canal a terrorist's dream come true, say some officials worried about security after U.S. handoff,"* July 4, 1999.

[16] *The Washington Times* (Robert Morton), *Eager eyes covet the Panama Canal,"* March 4, 1999.

f. Do different organizations and personnel at different organizational levels share a common understanding of the difference between an "essential" and "non-essential" element of information? Should they?

g. Is it possible to pre-define essential elements of information before an event occurs? How?

h. What potential national strategy/policy gaps pertaining to the possible disruption of U.S. and international shipping through the Panama Canal do you see?

i. How can strategic leaders leverage technology to deal with a complex contingency like a cessation of U.S. and international shipping through the Panama Canal?

6. STUDENT REQUIREMENTS:

Visit course web site and review "daily situation reports" and other exercise materials in preparation for class. Visit, review and/or read, as appropriate, all hyper-links to background materials, web sites and readings assigned for Lesson 1.

7. STUDENT ACTIVITIES:

a. Briefly **Scan** available portions of: "Interagency Complex Contingency Operations Handbook," National Defense University. Internet available at: http://www3.ndu.edu/wgsc/wgschbk1.html

b. **View** selected excerpts of television documentary, "The Missiles of October," produced by the *Public Broadcasting System*. Available in IPTV format at course web page.

c. **Read:** "How We Plan," by Major John C. Schmitt, USMC and Gary Klein, Marine Corps Gazette, October 1999, pp 18-26.*

e. "Command and Control: Theory and Practice," by Richard Nordin, Carl Builder, and Steven Bankes, Center for Advanced Command Concepts and Technology, National Defense University, April 15, 1995 (v-29). **Select and read two** of the following selections. Also **read** in entirety: "Summing-up: Command concepts and the Historical Record," pp. 116-118.*

1. "Master of the Game: Nimitz at Midway," pp 37-53.
2. "The Technician: Guderian's Breakthrough at Sedan," pp 54-64.
3. "Technology's Child: Schwarzkopf and Operation Desert Storm," pp 65-77.
4. "The Visionary: MacArthur at Inchon," pp 78-90.
5. "No Time for Reflection: Moore at Ia Drang," pp 91-102.

6. "Structurally Deficient: Montgomery at Market-Garden," pp 103-115.

***Note:** Copies of these Lesson 1. readings are not available electronically. Paper copies are contained in course notebook.

f. **Visit** the "Panama Canal Web site," internet available at: http://www.pancanal.com and **explore** sublinks:

History of the Canal at: http://www.pancanal.com/history/
Canal Transition at: http://www.pancanal.com/ctransition/
Maritime Operations at: http://www.pancanal.com/maritime/
Programs & Projects at: http://www.pancanal.com/expansion/

g. **Visit** web site "The Panama Canal, United states Energy Information Administration," June 1999. Internet available at: http://www.eia.doe.gov Enter "Panama" in search field and **explore.**

LESSON 2: STRATEGY, PLANNING AND COMPLEX THREATS TO NATIONAL SECURITY (SEMINAR)

"Every age has its own kind of war, its own limiting conditions, and its own peculiar preconceptions."

Carl von Clausewitz

1. PURPOSE:

This lesson is intended to provide a starting point for the consideration of national strategies to deal with complex domestic and international crises. It addresses the nature of globalization and its affect on national security, and the strategy and planning processes in the coordination of government agencies tasked with preventing and responding to large-scale crises. Biological terrorism and attack on the information infrastructure are considered as representative examples of threats to national security that would require a coordinated effort between government and civilian agencies.

2. RELATIONSHIP TO COURSE:

To devise and execute forward thinking national security strategies to meet emerging 21st century threats, national security leaders must appreciate, understand and be able to effectively deal with a range of highly complex, high consequence events. They must be able to filter out "noise" by effectively discriminating between essential and non-essential elements of information in complex, fast paced strategic environments. How well our national leadership identifies, organizes and acts on essential elements of information can make the difference between the success or failure in responding to complex contingencies. This lesson attempts to highlight the diverse nature of future threats to U.S. security, and the network of agencies within the federal government that would be required to deal effectively with them.

3. LESSON OBJECTIVES:

a. Assess the implications of globalization on national security, and how the U.S. should accommodate those in its strategic planning.

b. Analyze the distinguishing characteristics and strategic implications of an information warfare attack against the U.S., and assess its relative priority.

c. Evaluate the strategic implications of proliferation and possible use of biological weapons on the U.S. or against U.S. holdings or personnel overseas. Assess the U.S. vulnerabilities against this threat, and what steps might be taken to counter it.

d. Gain an understanding of the interagency process and the coordination of effort among the various departments and agencies of the Federal government.

4. GENERAL:

With the closing of the 20th century and the dawning of the 21st, the strategic security environment that America faces has become significantly more complex than in any previous era. Dramatic changes in the geo-strategic environment, in global political structures, and in the effect of technology on societies, have contributed to the broadening of national interests at the same time that threats to those interests have likewise multiplied. As the nation's response to the "Y2K" challenge illustrated, there is a growing awareness of the increasing number, variety and interdependence of systems and their significance in the functioning of modern post-industrial, technologically-oriented societies.

Operation DESERT STORM demonstrated the value of joint planning and employment of U.S. military forces in military operations. More recently, U.S. experience during humanitarian missions in Somalia, Haiti and Bosnia, and in several disaster relief efforts involving U.S. military forces in the continental United States have demonstrated that similar coordination between agencies of the Federal government could enhance the prospects of success in responding to complex humanitarian missions. As a result, the Clinton administration issued a Presidential Decision Directive (PDD-56) in May 1997 entitled "Managing Complex Contingency Operations." This directive was intended as the first step in achieving interagency coordination for U.S. crisis response efforts involving more than one agency of the Federal government.

The motivation for this measure was the recognition that success in complex humanitarian crises frequently requires the coordination of many instruments of national power—political, military, economic, humanitarian and informational. Without careful coordination toward a commonly understood mission, there could be the potential for—at the very least—a great deal of duplication of effort and wasted resources. At the worst, a mission could be badly managed and human lives lost through inefficiencies or a failure to capitalize on available talent or resources.

Under PDD-56, preparation and planning for complex contingency operations is to occur at the interagency level, with the National Security Council staff serving as the focal point for coordination of effort and dissemination of information. Federal agencies involved include the Departments of State and Defense; the Central Intelligence Agency and National Security Agency; the Departments of Treasury, Commerce, Transportation and Justice; the Agency for International Development and the U.S. Information Agency; and the Office of Management and Budget.

In essence, this program establishes the principle of "jointness" at the interagency level. It does not (yet) establish any commonality of procedure in the planning and execution of operations within individual agencies (a sort of interagency "joint doctrine," if you will). However, it does mark a first effort at a common basis for understanding capabilities among federal agencies, and for identifying uniform strategic objectives and coordinating the effort and resources to achieve them.

5. ISSUES FOR CONSIDERATION:

a. What are some of the factors that make the strategic environment of the 21st century more complex than earlier periods of history? How do these factors affect the strategic national security environment of the 21st century?

b. What are some examples of systems and system interdependencies that are becoming more significant to the functioning of our society? To America's national security?

c. How could information technologies and the ways in which they might be used change the fundamental nature, purpose and conduct of war? What are the implications for the basic definition of "war"? When and how does it begin? When and how is it terminated? What are the measures of success? Who is, or should be, the "competent authority" for strategic decision-making?

d. What role should organizations other than DOD play in the development and employment of militarily relevant information technologies? If there is no meaningful distinction between military/civilian, national/international, and government/non-government assets, what are the implications for U.S. strategy in peace, crisis and war?

e. What are the distinguishing characteristics of weapons of mass destruction as a strategic problem? Are chemical and biological weapons qualitatively different from nuclear weapons? How?

f. What steps should the United States take to protect its strategic infrastructure from attack, and what effect might such an attack have on military operations? How intrusive would these preparations be to an "open society," and how much should we be willing to sacrifice for the sake of security?

g. Unlike warfare, there are seldom clear "victories" in resolving humanitarian emergencies, and resolving causes, rather than simply treating symptoms, may be an impossible standard to meet. If that is the case, what measures of effectiveness would you propose for the "resolution" of complex contingency operations? In other words, how would you define "victory?"

6. STUDENT REQUIREMENTS:

Visit, review and/or read, as appropriate, all hyper-links to background materials, web sites and anthology readings for Lesson 2. Visit course web site and review "daily situation reports.

7. STUDENT READINGS*:

a. Jean-Marie Guehenno, "The Impact of Globalization on Strategy," <u>Survival</u>, winter 1998-99, **Read:** pp. 5-19.

b. Lawrence Freedman, *The Revolution in Strategic Affairs*, Adelphi Paper 318, (New York: Oxford University Press, 1998), **Read:** pp. 49-68.

c. Roger C. Molander, Andrew S. Riddle, and Peter A. Wilson, "Strategic Information Warfare: A New Face of War," *Parameters*, autumn 1996, **Read:** pp. 81-92.

d. Randall J. Larsen and Robert P. Kadlec, "Biological Warfare: A Silent Threat to America's Defense Transportation System," *Strategic Review*, spring 1998, **Read:** pp. 5-10.

e. *Handbook for Interagency Management of Complex Contingency Operations*,
Read: pp. 1-21, Annex A (PDD-56) and Annex F (List of Key Agencies).

***<u>Note</u>:** Copies of Lesson 2. readings are not available electronically. Paper copies are contained in course notebook.

LESSON 3: THE RISE IN COMPLEXITY: THE IMPLICATIONS FOR AMERICA'S NATIONAL SECURITY (SEMINAR)

"Expect only five percent of an intelligence report to be accurate. The trick of a good commander is to isolate the five percent."

Douglas MacArthur

1. PURPOSE:

This lesson serves as the initial building block in understanding the nature of complex events and developing and applying rule-based methods for identifying and extracting essential elements of information.

2. RELATIONSHIP TO COURSE:

As events become more complex and consequences increase, the ability to correctly identify and act on essential elements of information can make the difference between success and failure. The ability of national security leaders to filter out the "noise" by effectively discriminating between essential and non-essential elements of information in complex environments is a key strategic decision-making skill and essential to developing effective command concepts.

3. LESSON OBJECTIVES:

a. Develop definitions for concepts and terms of reference such as critical infrastructure, weapons of mass destruction and associated metrics.

b. Acquaint students with the changing nature of the strategic national security environment and the rise of complexity in modern post-industrial societies.

c. Gain an appreciation for the increasing number, variety and interdependence of systems and their increasing importance to the functioning of the post-industrial, technologically driven societies of the 21st century.

d. Introduce students to complexity theory by studying the dynamic nature of complex events including their linear, non-linear and sometimes counter-intuitive characteristics and the potential for cascading impacts/consequences that can lead to catastrophic multi-system failures.

e. Briefly examine the potential value of applying systematic thought processes, and models as a method for identifying consistent behaviors across complex systems and discriminating between essential and non-essential elements of information.

4. GENERAL:

The strategic national security environment of the 21st century is becoming more and more complex. This dynamic environment is characterized by profound change like the information technology explosion and rapid advances across the spectrum of science and technology. As the nation's response to the "Y-2K" challenge illustrates, there is a growing awareness of the increasing number, variety and interdependence of systems and their increasing significance in the functioning of modern post-industrial, technologically driven societies. To devise and execute forward thinking national security strategies to meet emerging 21st century threats, future national security leaders must appreciate, understand and be able to effectively deal with a new range of highly complex, high consequence events. They must be able to filter out "noise" by effectively discriminating between essential and non-essential elements of information in complex, fast paced strategic environments. How well our national security leaders of the future identify and act on essential elements of information will make the difference between the success and failure of America's national security strategy.

5. ISSUES FOR CONSIDERATION:

a. What are some of the factors that make the strategic environment of the post-industrial 21st century world more complex than earlier periods of historical evolution? How do these factors impact the strategic national security environment of the 21st century?

b. What are some examples systems and system interdependencies that are becoming more significant to the functioning of our society? To America's national security?

c. What is the difference between an "essential" and "non-essential" element of information? How can strategic leaders tell the difference in complex situations characterized by information overburden?

d. Why and how can rule-based thought processes, models and simulations assist strategic leaders in correctly identifying and acting on essential elements of information?

e. How do increasing levels of complexity affect the handling of a crisis situation? The development and execution of national policy?

6. STUDENT REQUIREMENTS:

Visit, review and/or read, as appropriate, all hyper-links to background materials, web sites and anthology readings for Lesson 3. Visit course web site and review "daily situation reports."

7. STUDENT ACTIVITIES:

a. Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworlds, by Mitchell Resnick. Boston: MIT Press, 1994. **Read:** Chapter 1, *Foundations*, pages: 3-19.

b. Choose and **read one article** from selections below: Complexity, Global Politics and National Security, Institute for National Security Studies, National Defense University. Articles also available at primary Internet site: http://www.mnsinc.com/cbassfrd/CWZHOPME/complex/PropBibl.htm

(1) *Complex Systems: The Role of Interactions* by Robert Jarvis. Internet available at: http://www.ndu.edu/ndu/inss/books/complexity/ch03.html

(2) *Many Damn Things Simultaneously: Complexity Theory and World Affairs* by James N. Rosenau. Internet available at: http://www.ndu.edu/ndu/inss/books/complexity/ch04.html

(3) *Complexity, Chaos and National Security Policy: Metaphors or Tools* by Alvin M. Saperstein. Internet available at: http://www.ndu.edu/ndu/inss/books/complexity/ch05.html

(4) *The Reaction to Chaos* by Steven R. Mann. Internet available at: http://www.ndu.edu/ndu/inss/books/complexity/ch06.html

(5) *Command and (Out of) Control: The Military Implications of Complexity Theory* by John F. Schmitt. Internet available at: http://www.ndu.edu/ndu/inss/books/complexity/ch09.html

c. **Read article:** *How can Chaos Theory be applied to Crisis Management?* by Gottfried Mayer-Kess. Internet available at: http://www.santafe.edu/~gmk/MFGB/node10.html

8. ADDITONAL RESOURCES:

a. *Messy Futures and Global Brains* by Gottfried Mayer-Kess. Internet available at: http://www.santafe.edu/~gmk/MFGB/MFGB.html

b. *Applying Complexity Theory To Business Management* by Steve Ditlea (*Wired Magazine*), February 13, 1997. Internet available at: http://www.syntropicsystems.com/021397complex.html

c. "What is Chaos? An Interactive Online Course for Everyone," by Dr. Matthew A. Trump. Ilya Prigogine Center for Studies in Statistical and Complex Systems. University of Texas at Austin. This is a fairly simple explanation of "Chaos Theory" in the discipline of Physics. Internet available at: http://order.ph.utexas.edu/chaos/index.html

(1) INTRODUCTION. Internet available at: http://order.ph.utexas.edu/chaos/introduction.html

(2) Lesson 1. THE PHILOSOPHY OF DETERMINISM. Internet available at: http://order.ph.utexas.edu/chaos/determinism.html

(3) Lesson 2. INITIAL CONDITIONS. Internet available at: http://order.ph.utexas.edu/chaos/initialconditions.html

(4) Lesson 3. UNCERTAININTY OF MEASUREMENTS. Internet available at: http://order.ph.utexas.edu/chaos/uncertainty.html

(5) Lesson 4. DYNAMICAL INSTABILITIES. Internet available at: http://order.ph.utexas.edu/chaos/dynamicalinstability.html

(6) Lesson 5. MANIFESTATION OF CHAOS. Internet available at: http://order.ph.utexas.edu/chaos/manifestations.html

LESSON 4: TERRORIST USE OF WEAPONS OF MASS DESTRUCTION: LIKELIHOOD, CONSEQUENCES, AND IMPLICATIONS (SEMINAR)

"Float like a butterfly. Sting like a bee."

Mohamed Ali

"A danger foreseen is half avoided."

Thomas Fuller

1. PURPOSE:

This lesson provides an overview of the likelihood, possible consequences, and implications of the terrorist use of weapons of mass destruction against the domestic population of the United States, our allies and other interests abroad. This lesson will strive to place the notion of *critical infrastructure* in strategic context by considering some of the cascading system impacts of a large scale nuclear, chemical or biological attack against civilian populations. This lesson is another important building block in setting the stage for student exercise to be conducted in Lessons 8. and 9.

2. RELATIONSHIP TO COURSE:

The Commander in Chief has issued several Presidential Decision Directives dealing with the federal response to the threatened or actual terrorist use of nuclear, chemical and biological weapons. Department of Defense responsibilities relating to the terrorist use of weapons of mass destruction were specifically addressed by congress as part of the Nunn, Lugar, Domenici amendment to the Defense Authorization Act of 1997. Under the Act, the Department of Defense was assigned responsibility for establishing training programs for 120 cities across the United States to assist state and local communities in preparing for the possibility of chemical and biological attacks against domestic civilian populations. In December 1997, the Deputy Secretary of Defense authorized a plan for the integration of the National Guard and reserve component as part of the nation's domestic weapons of mass destruction terrorism response capability. 10 National Guard "first responder" units were established. In 1998, the Secretary of Defense made the determination that all active duty military personnel must receive vaccinations to protect them against the possible use of the biological agent anthrax. These actions by the Commander in Chief, the Secretary of Defense and congress leave no doubt that America's strategic leadership needs to concern itself with the possibility of warfare using weapons of mass destruction including the possible terrorist use of such weapons. Moreover, the terrorist use of weapons of mass destruction is among the highest consequence events imaginable-the type of events that have the potential to threaten the fundamental freedoms upon which our democracy is based.

3. LESSON OBJECTIVES:

a. Examine historical trends and the changing nature of 21st century terrorism and the new breed of perpetrators of terrorist acts.

b. Gain insights regarding the relative ease or difficulty associated with the design, manufacture and utilization of a weapon of mass destruction including the construction of an improvised nuclear, chemical and or biological weapon. This will include discussions regarding the availability of required materials, e.g., plutonium, highly enriched uranium, biological agents and chemicals necessary to construct a weapon of mass destruction and the *"fact and fiction"* of biological and chemical terror.

c. Consider the complex cascading impacts of the successful terrorist use of a weapon of mass destruction in the strategic context of critical infrastructure systems and systems interdependencies.

d. Initiate a continuing dialogue regarding the need for new/modified policies/processes/structures and advanced technology investments that can enhance the nation's ability to detect, deter, respond and mitigate the consequences of complex events. This dialogue will take place in the context of new challenges posed by the terrorist use of weapons of mass destruction as we strive to maintain the social and political underpinnings of a democratic society.

4. GENERAL:[17]

Over the past eight years, many things have happened to change the world geopolitical environment, and with it, the future national and international security landscape. It is now clear that many of the problems engendered by the cold war have not eased with the fall of the Soviet Union. Economic pressures are such that security controls over Russia's vast arsenal of weapons of mass destruction have deteriorated. The current economic situation in Russia brings into sharp focus the quest by rogue nations and terrorists to obtain nuclear and other weapons of mass destruction. It has been said that an ailing Russian economy "makes everything for sale." We have seen Iraq develop chemical and biological weapons and defy the international community by interfering with, and then refusing, to allow United Nation's inspections. North Korea, India, and Pakistan have all refused to acknowledge international security regimes to prevent the proliferation of nuclear weapons. North Korea is believed by some to already have a nuclear weapons capability. India and Pakistan have conducted nuclear weapons tests in their continuing military rivalry.

Recent disclosures of Chinese espionage and the possible theft of American nuclear secrets have raised serious questions regarding America's national security. There is growing concern that the possibility of Chinese espionage, amid media reports of years of lax security at U.S. nuclear weapons laboratories, may damage U.S. credibility by raising disturbing questions in the world community regarding America's competence and commitment to its own stated nonproliferation objectives.[18]

All of these problems have been exacerbated by the rise of terrorism. The bombings of the World Trade Center in New York and the Murrah Federal Building in Oklahoma City let Americans know that terrorism is no longer something that can only happen in far away places. In Japan, the Aum Shinrikyo religious cult used sarin gas to attack

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[17] Excerpted with the permission of the author from an unclassified article, " Making Defense Conversion in Russia Work Remains a Global Imperative, " *by John H. Hnatio, National Defense University, June 1999.*

[18] Several sample citations indicating lax security at Department of Energy nuclear weapons facilities as a serious proliferation problem:

--*U.S. Congress* (House), Hearing before the Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, Hearing Print: *"NUCLEAR SECURITY COVERUP,"* February 3, 1984," Washington, DC: U.S. Government Printing Office, Serial No. 98-138, passim.

--Wall Street Journal (John Fialka*), "U.S. Agency Sets Study to Curb Breaches Of Security at Its Nuclear Weapons Sites,"* June 1, 1984.

--USA Today (Peter Eisler)*, "Nuclear Arms Stockpiles Vulnerable,"* October 22, 1997.

--*CNN Interactive & Associated Press* (Pierre Thomas), *"U.S. Nuclear Security Overhaul Promised,"* May 12, 1999 commuters in Tokyo's subway system. Even more ominous, these attacks show the changing nature of terrorism.[19] For some of today's brand of terrorist, making a political statement means that there must be mass casualties.

> A recent article appearing in USA Today, reported that terrorism has taken a record toll around the world in 1998. In all, 741 people were killed and 5,952 injured. Most of these casualties resulted from the bombings of two U.S. embassies in Africa. In their annual report to Congress, State Department made no changes in their listing of seven countries as known sponsors of terrorism—Cuba, Iran, Iraq, Libya, North Korea, Sudan and Syria.[20]

Perhaps Robert Gates, former Director of the Central Intelligence Agency, talking about the post cold war world, sums things up best when he says, "...we have come into a world that in many respects is more unstable, more unpredictable, more violent, more turbulent than the world we left behind us. Our hopes for a new world order have been replaced by the reality of a new world disorder."[21]

5. ISSUES FOR CONSIDERATION:

a. How is the nature of terrorism changing? What are some of the significant implications of nuclear, chemical and biological terror for the United States? Our quality of life? Our democratic institutions? Military-civilian relations?

b. As a national leader, what strategies would you devise to maintain public trust and confidence and preserve democracy in the face of mass human casualties reaching thousands, perhaps millions of deaths over a period of hours to just a few days?

c. What do you think some of the cascading impacts of a successful attack using a weapon of mass destruction to the critical infrastructures of the United States would be? What strategic impacts to America's national security posture might occur?

d. How could a nation state enemy use the cover of micro-terrorism as an instrument of war to defeat the United States? Are we prepared to deal with such

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[19] New York Times (Judith Miller, William J. Broad), *"Clinton Describes Terrorist Threat for 21st Century,"* January 28, 1999. Excerpt from article: "President Clinton said Thursday that it is *'...highly likely that a terrorist group will launch or threaten a germ or chemical attack on American soil within the next few years.'* He made the assertions as the White House disclosed that the Administration planned to ask for $2.8 billion in the next budget year to fight terrorists armed with such unconventional weapons as deadly germs, chemicals and electronic devices."

[20] USA Today (AP Washington), *"Terrorism Reaches Record-High Toll,"* April 30, 1999.

[21] Gary Bertsch and Steven Elliott-Gower (eds.), *"Proceedings of the Russell Symposium,"* Center for International Trade and Security, University of Georgia, October 16, 1995, p. 13.

a possibility? What strategic policy issues need to be considered to strengthen our national security posture?

e. What technology investments can America make to more effectively deal with complex events such as the threat posed by the possible use of weapons of mass destruction?

6. STUDENT REQUIREMENTS:

Visit, review and/or read, as appropriate, all hyper-links to background materials, web
sites and anthology readings for Lesson 4. Visit course web site and review "daily situation reports."

7. STUDENT ACTIVITIES:

a. Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworlds, by Mitchell Resnick. Boston: MIT Press, 1994. **Briefly Scan:** Chapter 2., pages: 23-47.

b. **Visit and explore site**: ABC News.com Special Report: The New Terrorism. Internet available at: http://archive.abcnews.go.com/sections/us/terrorism/terrorism.html

c. **Scan only**: Executive Order 12938, "Proliferation of Weapons of Mass Destruction," the White House document room. Internet available at: http://www.fas.org/irp/offdocs/eo12938.htm

d. **Read:** "Terrorism in the United States1997," Counter-terrorism Threat Assessment and Warning Unit, National Security Division, Federal Bureau of Investigation. Internet available at: http://www.fbi.gov/publish/terror/terr97.pdf

e. **Scan:** "Asymmetric Warfare, the Evolution and Devolution of Terrorism: The Coming Challenge," by Clark L. Staten, Emergency Response and Research Institute, 04-27-98. Internet available at: http://www.emergency.com/asymetrc.htm

f. **Read:** "Fighting Terrorism in the 21st Century," by John F. Lewis, The FBI Law Enforcement Bulletin, 03-99. Internet available at: http://www.fbi.gov/library/leb/1999/mar99leb.pdf

g. **Scan designated section:** "Proliferation: Threat and Response—Measures to Counter Paramilitary, Covert and Terrorist Threats," Office of the Secretary of Defense, September 3, 1999. Internet available at: http://www.defenselink.mil/ [Go to search: enter "proliferation"; Click on **9/03/99 DEPARTMENT OF**

DEFENSE RESPONSE and scroll to "Measures to Counter Paramilitary, Covert and Terrorist Threats."]

h. **Scan article and briefly explore links:** *New York Times International* (Judith Miller and William J. Broad), "Clinton Describes Terrorism Threat for 21st Century," January 22. 1999. "WASHINGTON—President Clinton said Thursday that it is 'highly likely' that a terrorist group will launch or threaten a germ or chemical attack on American soil within the next few years…" Internet available at: http://www.nytimes.com/library/world/global/012299germ-warfare.html

i. **Scan article**: *CNN Interactive*, "Panel: U.S. not prepared to combat weapons of mass destruction," July 8, 1999. "WASHINGTON (CNN)—The U.S. is not prepared to combat the grave threat of nuclear and biological weapons spreading around the world, the head of high-level government commission told CNN Thursday…The panel headed by John Deutch, former director of the CIA, studied potential disasters and how various agencies would respond…Scenarios studied included a disgruntled Russian scientist selling nuclear weapons fuel to Iran, or anthrax being released in a crowded subway." Internet available at: http://www.cnn.com/US/9907/08/us.threat.study/index.html

j. **Explore designated link**: The Atomic Archive: New York Example, "*Nuclear Terror and Consequences."* Internet available at: http://www.atomicarchive.com/ [Click on **Example: New York City**]

k. **Scan article only**: "Terrorism's New Breed: Are today's terrorists more likely to use chemical and biological weapons?" by Jose Vegar. March/April 1998 Vol. 54, No. 2. Internet available at: http://www.bullatomsci.org/issues/1998/ma98/ma98vegar.html

l. **Quickly explore site** for capabilities and familiarity with sub-links: Center for Nonproliferation Studies, Monterey Institute for International Studies, *"CBW Nonproliferation Regime."* Internet available at: http://www.cns.miis.edu/research/cbw/control.htm

Examples of valuable reference sub-links include:

(1) Center for Nonproliferation Studies, Monterey Institute for International Studies, *"Chemical and Biological Weapons: Possession and Programs Past and Present."* Internet available at: http://www.cns.miis.edu/research/cbw/possess.htm

(2) Center for Nonproliferation Studies, Monterey Institute for International Studies, *"Chronology of State Use and Biological*

Chemical Weapons Control." Internet available at: http://www.cns.miis.edu/research/cbw/pastuse.htm

(3) Center for Nonproliferation Studies, Monterey Institute for International Studies, *"CB Warfare and Defenses."* Internet available at: http://www.cns.miis.edu/research/cbw/defenses.htm

(4) Center for Nonproliferation Studies, Monterey Institute for International Studies, *"Characteristics of Chemical and Biological Weapons."*
Internet available at: http://www.cns.miis.edu/research/cbw/tech.htm

(5) Center for Nonproliferation Studies, Monterey Institute for International Studies, *"Chemical and Biological Weapons Resource Page."* Internet available at: http://www.cns.miis.edu/research/cbw/cbw0299.htm

(6) Center for Nonproliferation Studies, Monterey Institute for International Studies, *"Federal Funding to Combat Terrorism."* Internet available at: http://www.cns.miis.edu/research/cbw/terfund.htm

8. ADDITONAL RESOURCES:

a. "The Terrorist's Handbook." Internet available at: http://come.to/anarchy

b. Jane's Information Group, *"Chemical-Biological Handbook."* Internet available at: http://emergency.com/cbwlesn1.htm

c. *Real Audio*®, "Interview with Ken Alibek," Russian biological weapons scientist on the Diane Ream (ph) Radio Program. Internet available at: http://www.wamu.org/dr/shows/drarc_990510.html

d. "Don't Lose Your Fingers--Don't use The Terrorist's Handbook, use DOD Manuals on Unconventional Uses of Explosives Instead—You Can Believe What the Manuals Say Because the Government's Spent Millions." Internet available at: http://www.ultranet.com/~eclipse/dodman.html (Click on "product search" and "Army Manuals" hot link.)

e. "Domestic Terrorism," The Close Up Foundation, January 1997. Internet available at: http://www.closeup.org/terror.htm

LESSON 5: INTERAGENCY MISSIONS, AUTHORITIES AND RESPONSIBILTIES FOR RESPONSES TO COMPLEX EVENTS (SEMINAR)

"The secret of all victory lies in the organization of the non-obvious."

Oswald Spengler

1. PURPOSE:

This lesson serves to provide an understanding the different missions, authorities, responsibilities and response structures of key agencies within the federal government for managing complex events. This lesson also considers issues associated with the integration of federal responses at the state and local levels. This lesson is the third building block in setting the stage for the major student exercise to be conducted during Lessons 8. and 9.

2. RELATIONSHIP TO COURSE:

As potential consequences of events increase (based on the growth of systems and interdependencies), the need for more effective coordination and leveraging of military and civilian resources to respond and mitigate the consequences of major events becomes more important. Thus, an understanding of the missions, authorities, responsibilities and response structures of key agencies within the federal government responsible for managing different aspects of complex events becomes a core requirement for strategic national security leaders. Since the federal response to high consequence, complex contingencies includes integration with the civilian community at the state and local levels, understanding these second-tier relationships is also a critical aspect in the consequence management of these events.

3. LESSON OBJECTIVES:

a. Gain a familiarity with the overall federal response structure as it pertains to complex events focusing on malevolent acts involving the use of weapons of mass destruction--most notably nuclear, chemical or biological attacks against the domestic population of the United States and critical interests abroad.

b. Learn about the integration of federal response capabilities with States and local authorities.

c. Answer the question who's responsible for what and discuss the limitations on use of the military under *posse comitatus.*

4. GENERAL:

In May 1997, the Commander in Chief signed Presidential Decision Directive (PDD) Number 56, *"Managing Complex Contingency Operations."* This document and several other related PDD's set forth the President's call for actions by the federal interagency community to enhance the nation's ability to respond to complex, high consequence events. Under several PDD's the Department of Defense has been assigned responsibility to work in cooperation with other agencies in planning and training personnel for a range of potential complex contingency operations. Such operations include the protection of America's critical infrastructures, i.e., PDD 63, and responses to certain threats posed by weapons of mass destruction, i.e., PDD's 39, 43 and 62, regarding the overall response to possible acts of nuclear, chemical and biological terror. Consequently, an understanding of the missions, authorities, responsibilities and response structures of key agencies within the federal government responsible for managing different aspects of complex events becomes a core requirement for strategic national security leaders. Since the federal response to high consequence, complex contingencies includes integration with the civilian community at the state and local levels, understanding these second-tier relationships is another critical aspect in the strategic management of these events.

5. ISSUES FOR CONSIDERATION:

a. What is the anatomy of a crisis? Who is responsible for what and when?

b. If different federal agencies have different lead mission authorities depending on the phase or progression of a complex event, what processes, procedures and plans are in effect to assure timely, effective transfer of mission authority?

c. What do you consider the critical "integrative" elements or factors in promoting federal-military cooperation with the civilian community at the state and local levels? What do you see as significant impediments to cooperation in a time of major crisis?

d. What do you see as the major differences between the role of a strategic leader at the national command level and operational commanders and civilian first responders in the field ?

e. What types of information/communication/command and control systems do you think are needed to assure essential elements of information can be identified at different organizational levels, passed from operational to strategic levels and acted upon?

f. What restrictions are placed on the military with respect to domestic responses to complex events and operations other than war? Given the potential consequences of something like a major biological attack with the potential for killing thousands of people within days, do you consider the current limitations on the use of the military in such situations reasonable?

6. STUDENT REQUIREMENTS:

Visit, review and/or read, as appropriate, all hyper-links to background materials, web
sites and anthology readings for Lesson 5. Visit course web site and review "daily situation reports."

7. STUDENT ACTIVITIES:

a. Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworlds, by Mitchell Resnick. Boston: MIT Press, 1994. **Read:** Chapter 4., *Reflections*, pages: 119-144.

b. **Scan:** ANNEX, *Federal Response Plan*, to Presidential Decision Directive No. 39—Response to Terrorist Use of Weapons of Mass Destruction—ANNEX, *Federal Response Plan,* Internet available at: http://www.fas.org/irp/offdocs/pdd39_frp.htm

c. **Quickly explore responsibilities chart** with special attention to the roles of the Department of Defense (DOD), the Department of Justice including the Federal Bureau of Investigation (FBI) and the Federal Emergency Management Agency (FEMA). Internet available via hyperlink: Interagency Responsibilities for Chemical and Biological Events [Hyperlink takes you to slide. Click on action button and you will be taken to web site for the Center for Nonproliferation Studies, Monterey Institute for International Studies, *"Chemical and Biological Weapons Resource Page."* Click on *Federal Structure* and *Organization Chart* and explore.]

d. Federal Emergency Management Agency Home Page: Scroll to bottom and click on “search”; in search engine type in the words “chemical and biological terror”; **briefly explore sublinks**. FEMA homepage is Internet available at: http://www.fema.gov

e. Scan**:** "Domestic Preparedness Program in the Defense Against Weapons of Mass
Destruction," May 1, 1997. Internet available at: http://cryptome.org/dod-domprep.htm

f. **Explore site and scan:** Chapter 3., *The Response* as contained in the “Department of Defense Plan for Integrating National Guard and Reserve Component for Response to Attacks Using Weapons of Mass Destruction,”

January 1998. Internet available at:
http://www.infowar.com/wmd/plan/wmd_032798a_j.html-ssi#TOC

g. **Quickly explore capabilities** of federal interagency directories listing. Note that most federal agencies/entities are hot linked to home pages. Internet available via hyperlink: Federal Interagency Directory [Hyperlink takes you to slide. Click on action button and you will be taken to URL site for Louisiana State University. See menu bar at top of page—click and explore.]

8. ADDITONAL RESOURCES:

a. Public Law 104-201 TITLE XIV--DEFENSE AGAINST WEAPONS OF MASS DESTRUCTION Sec. 1401. Short title. Sec. 1402. Findings. Sec. 1403. Definitions. Subtitle A--Domestic Preparedness Sec. 1411. Response to threats of terrorist use of weapons of mass destruction. Internet available at: http://www.stimson.org/

b. DOD Support for Response to Attacks Using Weapons of Mass Destruction Overview Consequence Management Program Integration Office Disaster/Emergency Response Hierarchy Response Task Force. Internet available at:
http://www.ngb.dtic.mil/referenc/briefngs/wmd/schultzdodwmdbrief/

LESSON 6: SCIENCE AND TECHNOLOGY: LEVERAGING THE STRATEGIC DECISION-MAKING PROCESS (SEMINAR)

"The machine can free man or enslave him; it can make of this world something resembling a paradise or a purgatory. Men have it within their power to achieve a security hitherto dreamed of only by the philosophers, or they may go the way of the dinosaurs, actually disappearing from the earth because they fail to develop the social and political intelligence to adjust to the world their mechanical intelligence has created."

William G. Carleton

1. PURPOSE:

The focus of this lesson is on new developments and applications of science and technology to support the management of complex events and the strategic decision process.

2. RELATIONSHIP TO COURSE:

In Lesson 3. we explored the characteristics of complex events and examined rule based thought processes and models as methods for identifying consistent behaviors that, in turn, can allow for the identification and gathering of essential elements of information. In Lesson 4. we considered the possible use of weapons of mass destruction and the changing nature of terrorism as possible elements of modern warfare. In Lesson 5. we examined the national response structure for complex, high consequence events. In Lesson 6. we scan the strategic environment for new science and technology tools that can support national security leaders in managing these types of complex events and leveraging the strategic decision process. We also continue a dialogue regarding the appropriate uses of science and technology in ways that support the social and political underpinnings of a democratic society.

3. LESSON OBJECTIVES:

a. Gain a familiarity with recent technology developments in ultra-high resolution, ultra-high fidelity modeling and simulation capabilities arising from the Department of Energy's Accelerated Super-Computing Initiative (ASCI).

b. Introduce students to a range of 21st century science and technology developments including recent models and simulations relating to the atmospheric propagation of chemical and biological agents, the "*Transims*" transportation model, modeling of the electrical power grid and other new tools to support the strategic management of complex events including sentry and consequence management information system (SCMIS), "*virtual planner*," *"chem lab on a chip."* We also briefly survey new information management, communications and sensor technology developments as they relate to the management of nuclear, chemical, biological and other complex infrastructure events.

c. Acquaint students with special federal programs such as the Nuclear Emergency Response Team (NEST), the Threat Credibility Assessment Program (TCAP), the Atmospheric Radiological Response Capability (ARAC) and other specialized high technology federal response capabilities.

d. Continue a dialogue regarding the proper role and limits of technology (the application of knowledge) in a democratic society.

4. GENERAL:

With the accelerating pace of science and technology advances as we approach the 21st century, national security leaders are now in the position of having to constantly scan the strategic environment for new science and technology developments that they can use, or conversely, can be used against them. This is the key "technology wildcard" theme of Joint Vision 2010. The strategic national security leaders of the 21st century must have an appreciation for both the incredible value and dangerous limitations of science and technology. Over the past several months, the Department of Energy's weapons laboratories have achieved new thresholds of computational capability, surpassing the astounding level of one million-million calculations per second. The potential national security implications of this new super computational capability are profound. Advancements such as this hold the promise of applying a whole new generation of tools including ultra high resolution/fidelity simulations with advanced levels of predictive capability to the management of complex events. While the science of computers continues its exponential advance, new developments in sensor, imaging, information management, communications and other technologies are also taking place. Collectively, these technology strides can revolutionize the way we manage complex national security events. Key to harnessing these new developments in ways that support the strategic decision-making process is an understanding of emerging technologies and confidence in their "value-added" applications by future national security leaders.

5. ISSUES FOR CONSIDERATION:

a. How can science and technology help me as a strategic leader deal with complexity? Identify and then effectively act on essential elements of information?

b. How can technology tools help at the operational level? How can I, as a strategic national security leader, use/apply/leverage technology tools to support the effective management of a complex event at the national level?

c. With technology advancing so quickly, how can strategic leaders stay on top of the "technology wildcards" challenge? What ideas or suggestions do you have for helping strategic leaders keep abreast of technology developments in ways that support their strategic leadership roles and responsibilities?

d. What do you see as the limitations/dangers of technology in dealing with complex events? How can we deal with the *"evil genie out of the bottle"* syndrome? Do you see any political or social implications for a democratic society?

6. STUDENT REQUIREMENTS:

Visit, review and/or read, as appropriate, all hyper-links to background materials, web
sites and anthology readings for Lesson 4. Visit course web site and review "daily situation reports."

7. STUDENT ACTIVITIES:

a. **Read:** congressional testimony of Dr. Page Stoutland, Director, Chemical and

Biological Nonproliferation Program, Office of Nonproliferation and National Security, U.S. Department of Energy, before the Military Research and

Development Subcommittee of the House Armed Services Committee, March 11, 1999. Internet available via the *Electric Library* at: http://www.cbnp.anl.gov/Testimony.html

b. **Quickly explore:** "Patents" and "CB Modeling and Simulation Resources" and other hot links: The Chemical and Biological Defense Information Analysis Center, operated for the Department of Defense by Pacific Northwest Laboratory (PNL). Internet available at: http://www.louisville.edu/library/ekstrom/govpubs/federal/agencies/defense/cbiac.html

c. **Visit site:** Center for Nonproliferation Studies, Monterey Institute for International Studies, *"Federal Funding to Combat Terrorism."* Internet available at: http://www.cns.miis.edu/research/cbw/terfund.htm

LESSON 7: SETTING THE STAGE: BIG CITY, USA AND THE NATIONAL POLITICAL CONVENTION (SEMINAR)

"We can't cross a bridge until we come to it; but I always like to lay down a pontoon ahead of time."

Bernard M. Baruch

1. PURPOSE:

This lesson provides students with an overview of Big City, USA, and preparations for a major national event—a national political convention. The focus of this lesson will be on contingency planning and the identification of essential elements of information associated with potential terrorist attacks against civilian populations. This lesson sets the stage for the student exercise conducted during Lessons 8. and 9.

2. RELATIONSHIP TO COURSE:

Preplanning for possible contingencies to identify essential elements of information is fundamental to the effective management of complex events. As such, it represents a core strategic leadership skill. In this lesson future strategic leaders are exposed to the significant preparations taking place to assure the safety and security of senior political leaders and citizens attending a political convention. Students are given the opportunity to contrast their knowledge and understanding of the federal response structure (and integration at the state and local levels) learned during Lesson 5. against real world preparations for a major national event. In preparation for the Lessons 8. and 9.

exercise, students are encouraged to consider strategies for discriminating between "noise" and essential elements of information in managing complex contingency operations.

3. LESSON OBJECTIVES:

a. Acquaint students with pre-planning and actual response strategies that would be employed by public safety and law enforcement officials during a national political convention in a large U.S. city.

b. Gain a better appreciation for the different roles of strategic leaders, federal safety and law enforcement managers and state and local officials in pre-planning and conducting contingency operations.

c. Consider the adequacy of the integration of federal, state and local planning and response capabilities to address the possibility of complex cascading impacts that would result from the successful terrorist use of chemical and biological weapons. Do this in the context of critical infrastructure systems and systems interdependencies.

d. Begin to develop individual decision models for discriminating between "noise" and essential elements of information. Consider technology tools that can help strategic leaders identify and effectively act on essential elements of information

e. Continue the dialogue initiated during Lesson 2. regarding the need for new/modified policies/process/structures and advanced technology investments that can enhance the nation's ability to detect, deter, respond and mitigate the consequences of complex events including the possible use of weapons of mass destruction.

4. GENERAL:

On December 7, 1941, the Empire of Japan attacked the United States at Pearl Harbor. Many Americans believed the Japanese would never be bold enough to attack. Ironically, the Japanese had been sending signals of their growing aggression for many months. As Roberta Wohlstetter observes in her book, Pearl Harbor: Warning and Decision,

> "Never before have we had so complete an intelligence picture of the enemy." Because the people responsible for our national security failed to recognize the warning signals, the United States was left at the mercy of a ruthless enemy.[22]

[22] Excerpted with the permission of the author from, *"No Second Chance: Conflicting Values endanger the Security of Nuclear Weapons Activities at the U.S. Department of Energy*," by John H. Hnatio and Jeffrey L. Hodges, April 1992, Georgetown University, pp. v and vi.

Wohlstetter's analysis goes on to say that the "noise" created by conflicting information, coming from many disparate sources at different times made it difficult for strategic leaders to identify what later turned out to be essential pieces of information indicating the Japanese intention to attack Pearl Harbor. She goes on to say,

> "For every signal that came into the information net in 1941 there were usually several plausible alternative explanations, and it is not surprising that our observers and analysts were inclined to select explanations that fitted the popular hypotheses… Apparently human beings have a stubborn attachment to old beliefs and equally stubborn resistance to new material that will upset them." [23]

Most observers would agree that the strategic national security environment is far more complex today than in 1941. For example, scientists now postulate that the amount of information in our computerized society is doubling at the rate of every 18 months. For the strategic national security leaders of the 21st century, filtering out the "noise" to isolate critical information during complex, fast paced events will be a major challenge. Better methods of pre-planning, communication and coordination at all organizational levels and the application of advanced technologies such as predictive computer models may be an important part of the solution.

5. ISSUES FOR CONSIDERATION:

a. Given the different roles and responsibilities of tactical and strategic leaders in managing complex events, are different organizations and personnel at different levels effectively integrated? Does each level understand the essential information needs at other levels?

b. Is the role of the military clearly defined? Has a changing military role been considered in the event of cascading impacts that may adversely affect critical infrastructure systems? For example, if 40,000 people become sick requiring medical attention in the aftermath of a biological attack, has a military role been pre-defined?

c. Do different organizations and personnel at different organizational levels share a common understanding of the difference between an "essential" and "non-essential" element of information? Should they?

d. Is it possible to pre-define essential elements of information before an event occurs? How? Can we learn to ask the "right questions" during times of crisis?

e. What potential national policy gaps do you see? Are technology investments to deal with complex events like a national political convention adequate and properly directed?

[23] Pearl Harbor: Warning and Decision, by Roberta Wohlstetter, 1962, Stanford University Press, p. 393.

6. STUDENT REQUIREMENTS:

Visit, review and/or read, as appropriate, all hyper-links to background materials, web
sites and anthology readings for Lesson 5. Visit course web site and review "daily situation reports."

7. STUDENT ACTIVITIES:

a. **Read article 1. entirely, briefly scan article 2.** from, *The FBI Law Enforcement Bulletin*

   1. "Security Management for a Major Event," by Charles W. Sherwood, 08-01-1998. Internet available at: http://www.fbi.gov/library/leb/1998/aug98leb.pdf

   2. "Confronting Terrorism at the State and Local Levels," by Douglas Bodrero, 03-99. Internet available at: http://www.fbi.gov/library/leb/1999/mar99leb.pdf

b. **Visit site and read article**, "Olympics 1984: Counter-insurgency Goes for the Gold," by Michael Novick as reprinted from an article in *Breakthrough*, the political journal of the Prairie Fire Organizing Committee, Spring 1994. Internet available at: http://www.netural.com/lip/polabuse/2445.html

c. **Visit site and read article**, *Wired: Countdown begins for DNC Convention*, by Rick Orlov, staff writer *Los Angeles Daily News*, August 14, 1999. Internet available at: http://www.dailynews.com/search/news/aug99/0814/dnc.html

d. **Explore site**, *Official Web Site of the Democratic National Committee*. Click on "Campaign 2000: Democratic National Convention." Internet available at: http://www.democrats.org/index.html

8. ADDITONAL RESOURCES:

a. CNN - Munich remembered: 1972 attack led to increased security - July 27, 1996 Munich remembered: 1972 attack led to increased security July 27, 1996 Web posted at: 5:30 p.m. EDT From Sr. Washington Correspondent Charles Bierbauer WASHINGTON (CNN) -- Saturday's bombing at Centennial Olympic Park in Atlanta was not the first.. Internet available at: http://www.cnn.com/

b. PARIS (Jul 27, 1996 - 13:00 EST) -- World leaders outraged at Olympics blast, urge tougher action…. Horrified and outraged by another deadly terrorist attack, world leaders today sent their condolences for the bombing at Atlanta's

Centennial. Internet available at: http://www.sportserver.com/newsroom/ap/oth/1997/oth/oly/feat/archive/072796/oly74851.html

c. WashingtonPost.com: Counter-Terrorism to Be Olympic Event by R. Jeffrey Smith Washington Post Staff Writer April 23, 1996. Federal authorities, saying...Internet available at: http://www.washingtonpost.com/wpsrv/national/longterm/bombing/stories/terror.htm

d. "Just A Drill—This Time," by Glenn Pruitt, Las Vegas Review Journal, June 6, 1998. Internet available at: http://www.infowar.com/WMD/wmd_060698a_j.html-ssi

LESSONS 8 AND 9: BIOLOGICAL TERROR IN BIG CITY, USA (EXERCISE)

"Fear is like fire: If controlled it will help you; if uncontrolled, it will rise up and destroy you."

John F. Millburn

1. PURPOSE:

This four-hour exercise gives students the opportunity to apply their knowledge and test their strategic decision skills in identifying and acting on essential elements of information in a complex, fast-paced, high consequence bio-terror event. Students will apply advanced technology tools in support of the strategic decision process as they manage a national level strategic response to the event.

2. RELATIONSHIP TO COURSE:

Lessons 8. and 9. take the group process/decision exercise in Lesson 1. and subsequent seminar-based study and reflection accomplished in Lessons 2. through 7. to the level of hands-on application. Students are assigned roles as representatives of different federal entities that share responsibility for responding to the terrorist release of a biological agent in a large American city—Big City, USA. They are faced with a situation having cascading impacts on critical infrastructure systems. More specific details of the event scenario will be provided to students before the exercise. Faculty will observe student participation in the exercise and invited representatives from federal agencies/and a media mentor. Feedback will be provided to students as part of a Lesson 10. After Action Review (AAR).

3. LESSON OBJECTIVES:

a. Exercise strategic decision skills including the ability to identify and effectively act on essential elements of information.

b. Use their knowledge of the federal response structure (including integration with state and local entities) to manage at the strategic level a bio-terror event of national significance.

d. Apply high technology tools in support of strategic decision-making.

e. Identify potential policy, coordination, communication and technology gaps that, if properly addressed, could strengthen national level responses to complex contingency operations.

4. GENERAL:

Key warning signals for a major bio-terror event may already exist in the strategic national security environment. The technical know-how and wherewithal to manufacture and effectively deliver lethal doses of bio-agents such as swine influenza to large unsuspecting populations is widespread. The Twin Towers bombing, the gassing of passengers riding the Tokyo subway system and the bombing of the Murrah Federal Building may indicate the arrival of a new breed of terrorist warfare—malevolent actors who are willing to engage in the indiscriminate mass murder of innocent civilians. A bio-terror event resulting in the short-term illness and deaths of tens or hundreds of thousands of people is the type of complex contingency that could have devastating cascading impacts. A broad range of critical infrastructure systems such as healthcare, law enforcement, food processing and delivery, communications and many others would be affected. The trust and confidence of the American people in the continuing ability of their government to operate could be sorely tried. In fact, how well strategic leaders of the future are prepared to deal with contingencies like these may make the difference between maintaining America's *national will* and the survival of democracy as we know it or the emergence of a very different kind of world in the 21st century.

5. ISSUES FOR CONSIDERATION:

a. Given the potential far-reaching consequences of a successful bio-terror attack against an American city, what do you consider as the key elements of a national level strategic plan? Are they currently addressed by national policy?

b. In managing such an event, what strategies and tools would you use to identify essential elements of information?

c. What systems become critical in a bio-terror event that results in the deaths of thousands of people? What strategies would you, as a strategic leader, devise and employ to deal with collapsing infrastructure systems? How do you quarantine a city one million people?

d. What actions could you take or recommend to curtail the spread of fear and maintain public trust and confidence in the ability of the government to govern? The *national will*? What would you tell the media? When? How? Where and when would you employ secrecy? Why?

6. STUDENT REQUIREMENTS:

Visit, review and/or scan/read, as appropriate, all hyper-links to background materials, web sites and anthology readings for Lessons 8. and 9. Visit course web site and review "daily situation reports."

7. STUDENT ACTIVITIES:

a. **Visit:** Emergency Response and Research Institute homepage. Internet available at: http://205.243.133.2/index.htm. **Explore** the following sublinks:

1. Biological/Chemical Terrorist Attack, see sublink: http://205.243.133.2/cbwlesn1.htm

2. Hazmat page, see sublink: http://205.243.133.2/hzmtpage.htm

b. **Scan article:** “Annals of Warfare: The Bioweaponeers,” by Richard Preston, *New Yorker Magazine*, March 2, 1998. Internet available at: http://cryptome.org/bioweap.htm

c. **Scan testimony:** “The Chemical and Biological Weapons Threat to America: Are We Prepared?” by CDR James K. Campbell, USN, before the Senate Judiciary Subcommittee on Technology, Terrorism and Government Information and the Senate Select Committee on Intelligence, April, 22, 1998. Internet available at: http://www.infowar.com/WMD/wmd_050898a_j.html-ssi

d. **Scan article:** “The Joint Terrorism Task Force,” by Robert A. Martin, FBI Law Enforcement Bulletin, 03-99. Internet available at: http://www.fbi.gov/library/leb/1999/mar99leb.pdf

e. **Read entire article:** “The Ethics of Intentionally Deceiving the Media,” by Michael E. Brooks, FBI Law Enforcement Bulletin, 05-99. Internet available at: http://www.fbi.gov/library/leb/1999/may99leb.pdf

f. **Scan article:** “The Media’s Role in Preventing and Moderating Conflict,” by

Robert Karl Manhoff, New York University, April 1, 1997, prepared for the Virtual Diplomacy conference hosted by the United States Institute for Peace, April 1 and 2, 1997, Washington D.C. Internet available at: http://www.usip.org/oc/vd/confpapers/manoff.html

8. ADDITONAL RESOURCES:

   a. BIOHAZARD by Ken Alibek and Stephen Handelman, Random House, New York, 1999.

   b. FMN: Policy Spotlight, September-October 1998, Terrorism and Freedom A monthly look at a public policy issue, with special attention to the contributions of free-market think tanks. This month focuses on terrorism and freedom. Dated 4 Nov 1998. Internet available at: http://www.freemarket.net/features/spotlight/9810.html

LESSON 10: AFTER ACTION REVIEW/BENCHMARKING OF EXERCISES (SEMINAR)

"One pound of learning requires ten pounds of common sense to apply it."

Persian Proverb

1. PURPOSE:

This lesson is devoted to a formal after action review (AAR) of the Lesson 1. Panama Canal group process/decision exercise and the Lessons 8. and 9 bio-terror exercise.

2. RELATIONSHIP TO COURSE:

The Lesson 10 after action review (AAR) will allow students to assess their performance as strategic leaders in addressing the Panama Canal exercise and the Big City, USA bio-terror event. Students will share different perspectives based on their agency roles and the underlying reasons/thought processes for key actions taken/not taken during the exercises. Student performance between Lesson 1. and the Lessons 8. and 9. Exercise will be contrasted. Based on the AAR and previous study, students will be asked to highlight potential gaps in national policy, process, procedures and technology investments/applications that, if addressed, could strengthen national responses to complex contingencies. As part of this seminar session, students will receive feedback from agency/media mentors who observed their work/actions during the Lessons 8. and 9. exercise. Lesson 10. is an important building block in preparing students for the Lesson 11. senior leader roundtable.

3. LESSON OBJECTIVES:

a. Benchmark student performance in managing the national-level federal response to the bio-terror event in Big City, USA. Contrast student performance between Lesson 1. and the Lessons 8. and 9. exercise.

b. Identify potential policy, coordination, communication and technology gaps that, if properly addressed, could strengthen national level responses to complex contingency operations? What new technology tools would strengthen a national response to a real bio-terror event?

c. Familiarize students with formalized processes for conducting after action reviews.

4. GENERAL:

Information and lessons learned in Lessons 1., 8. and 9. will be leveraged to "raise the bar" on student thought processes and strategic leader performance in Lesson 10.

5. ISSUES FOR CONSIDERATION:

a. How important is pre-planning/pre-coordination in dealing with complex contingency operations? How could more pre-planning/pre-coordination have helped improve the national response to the Panama/Big City, USA event?

b. Did your strategic actions or conversely, restraint in acting, accurately reflect the assigned mission responsibilities and capabilities of the federal government as they relate to bio-terror events?

c. In retrospect, what were the essential elements of information as the exercises progressed? How were they identified? On what basis were actions taken/not taken?

d. Did you identify and act on these essential elements of information during the exercises? Was this done in a timely fashion? Did your performance improve in the Lessons 8. and 9. exercise? Why?

e. How effectively did you communicate across various organizational levels to identify, obtain and act on essential elements of information? The outside world? Who was notified? Why? When? How?

f. Do you believe that your actions during the exercise properly reflected your strategic national role versus operational/tactical roles and responsibilities at lower organizational levels?

g. Did you place the notion of *critical infrastructure* in an appropriate strategic context in addressing the events? How did you recognize and deal with system interdependencies?

h. On what basis was information released/withheld from public disclosure in the exercise? Why? For how long?

i. How were technology resources used during the exercise? Did they work? Were the tools applied in the most effective fashion? Why or why not?

j. How were broader national security issues relating to military readiness addressed? How was the changing role of military involvement handled as the exercise progressed? How was the issue of *posse comitatus* addressed?

6. STUDENT REQUIREMENTS:

Visit, review and/or read, as appropriate, all hyper-links to background materials, web sites and anthology readings for Lesson 10.

7. STUDENT ACTIVITIES:

a. **Visit course web site and review/provide input as requested** to "AAR Questionnaire--Biological Terror in Big City, USA"

b. **Scan:** "Standard Army After Action Review System—Annex F OPORD 1-95," Internet available at: http://www-dcst.monroe.army.mil/wfxxi/op-anx-f.htm

c. **Scan:** Learning from Action: Imbedding More Learning into The Performance Fast, *Organizational Dynamics*, *LLOYD BAIRD PHIL HOLLAND SANDRA DEACON;* 04-01-1999. Internet available at: http://www.elibrary.com/id/238/118/getdoc.cgi?id=144744180x127y43441w0&OIDS=0Q003D000&Form=RL&pubname=Organizational_Dynamics&puburl=http~C~~S~~S~www.amanet.org~S~periodicals~S~od&querydocid=764101@library_l&dtype=0~0&dinst=0

d. **Read article:** Why Good Companies Go Bad , *Harvard Business Review*, Donald Sull - London Business School (United Kingdom); 07-01-1999. **(Student Issue)**

e. **Quickly Scan article:** "The Economic Impact of a Bioterrorist Attack: Are Prevention and Post-attack Intervention Justifiable?" by Arnold F. Kaufmann, Martin I. Meltzer and George P. Schmid, Centers for Disease

Control and Prevention, Atlanta, Georgia, 05-14-97. Internet available at: http://www.cdc.gov/ncidod/EID/vol3no2/kaufman.htm

LESSON 11: SENIOR LEADER ROUNDTABLE (SEMINAR)

"A single conversation across the table with a wise man is worth a month's study of books."

Chinese Proverb

1. PURPOSE:

During this lesson student teams will brief out invited leaders on findings/ results/opportunities arising from their involvement in course/exercises.

2. RELATIONSHIP TO COURSE:

As part of their briefings students will provide their recommendations and ideas on ways to strengthen the national response to complex contingency operations. Students will coordinate their briefings with appropriate agency mentors and other briefing teams.

3. LESSON OBJECTIVES:

a. Give students an opportunity to develop/test their senior leadership briefing skills.

b. Allow students to exercise their decision skills and test their conclusions, suggestions, and recommendations with their agency mentors.

c. Initiate a dialogue among students, agency mentors and senior leaders regarding the nation's readiness to respond to complex contingency operations including opportunities to strengthen national policy and the direction of technology investments to better support the management of complex, high consequence events.

4. GENERAL:

It is clear that complex, high consequence contingency operations like those exemplified by the exercises conducted in Lessons 1., 8. and 9. rely on effective coordination among hundreds of people from many agencies of our national government. Most people would agree that effective coordination depends on effective planning that includes an understanding of other agency cultures, the right training and the conduct of exercises. With the advent of the information age, new technology tools and capabilities are also becoming available. As our strategic environment continues to grow in complexity, new applications of technology may help us find new and better ways to ferret out essential elements of information. The role of strategic national security leaders in maintaining public trust and confidence by effectively managing complex, high consequence contingencies cannot be overstated. If you were the president or the governor at the time of the Big City, USA bio-terror event how would you have dealt with the massive loss of human life and suffering in ways that would maintain the confidence of the American people? It is time to begin a serious dialogue at the strategic leadership level about these and other issues.

5. ISSUES FOR CONSIDERATION:

a. What are some of the unique strategic leadership challenges posed by the successful use of a weapon of mass destruction against the civilian population of the United States? Our allies? Other countries? U.S. interests abroad?

b. The Commander in Chief has said that the United States must expect a significant bio-terror event in the next decade. Do you believe contingency planning is adequate to effectively handle an incident like the Big City, USA event?

c. Does a national strategy exist to address the potential of a Big City, USA? What is it? Is it adequate? What are the policy/operational gaps and problems you see? How do these relate to strategic leaders working at the national level?

d. What is the role of technology in managing complex contingency operations? Can we/should we invest in new tools? How can they help strategic leaders?

e. How can we address the challenges of improved understanding, training and coordination at the interagency level?

6. STUDENT REQUIREMENTS:

Work in your assigned teams to develop a 15-minute senior level briefing on the topical areas identified and selected as part of Lesson 10. Be sure to work with your team's agency mentor(s) and faculty in developing your briefing. You should coordinate your presentation with other teams to avoid redundancy and assure consistency.

LESSON 12: COURSE WRAP-UP AND CRITIQUE (SEMINAR)

“Criticism is the child and handmaid of reflection. It works by censure and censure implies a standard.

Richard G. White

1. PURPOSE:

This lesson is devoted to a course wrap-up and critique of the elective with input solicited from students, mentors and faculty. The session will be independently facilitated. The focus will be on next steps.

2. RELATIONSHIP TO COURSE:

The wrap-up and critique will assess from the students' perspective the "value added" of the elective in helping them frame the nature of the strategic environment to more effectively deal with complex events. The session will also try to determine the course's "value added" from the perspective of faculty and agency mentors. We will discuss the desirability of integrating lessons learned from the elective into the NDU exercise program and curriculum.

3. LESSON OBJECTIVES:

a. Benchmark, from the students' perspective, the value of the elective in helping them to gain a better understanding of the complexity of the strategic environment and the nature of fast paced, high consequence events.

b. Obtain structured input from interagency mentors to solicit their ideas about the specific strengths and weaknesses of the course, specific ways to improve it and suggestions for the future.

c. Detail in a structured fashion faculty/mentor/student observations, comments and ideas on the "value added" aspects of the course and whether/how they can/should be integrated into other aspects of the NDU educational/exercise programs.

4. GENERAL**:**

Information and lessons learned from the Lesson 12. wrap-up and critique will serve as input for NDU management consideration. Results will also be used to help structure an interagency forum in the summer of 2000 to examine National Defense University's efforts in developing coursework and exercises pursuant to Presidential Decision Directives (PDD’s) including 56 and 63.

5. ISSUES FOR CONSIDERATION:

a. From your perspective as a student what value added did you receive from this elective? Has it changed the way you think about complicated problems? How?

b. Did the use of technology and its application help or hurt the process? If it helped, explain how? If it hurt the process, explain how? Are their different ways to use/apply technology that can improve the elective?

c. What do you think about the approach of bringing subject matter interagency mentors into the process? Did it help or hurt? Why?

d. Was the web-based approach to structuring the class, e.g., web access to syllabus, chat capability, readings, tools, etc., useful? What do you think about the use of web-based tools for learning and to support exercises?

e. From your perspective as a student, what aspects of the elective do you think should be integrated into the broader NDU educational/exercise program?

f. As an agency mentor, what do you see as the strengths/weaknesses of the Elective? Learning outcomes? Was the course effective? In doing what? Why? Where should NDU go from here?

g. As a faculty member/mentor what do you see as the strengths/weaknesses of the course? What specific recommendations would you make to strengthen the course? What aspects of elective should be integrated into larger National Defense University educational/exercise program?

STUDENT REQUIREMENTS:

a. Study questions a. through g. under Section 5. <u>ISSUES FOR CONSIDERATION</u> and **complete** "Student Course Survey Questionnaire" at course web site.

[END]

Appendix C

Hnatio, J. (2000). *Analysis of the Cuban missile crisis: The fourteen essential elements of information.* Industrial College of the Armed Forces, Elective No. 5166. Washington, DC: National Defense University.

THE FOURTEEN ESSENTIAL ELEMENTS OF INFORMATION IN THE PANAMA CANAL SCENARIO

This material was developed solely for educational purposes. All information contained herein is purely hypothetical and intended only to promote discussion and learning by students. None of this material should be construed as necessarily representing the policies, views or positions of the Department of Defense or any other agency of the United States Government.

1. Evidence of Chinese naval offloading of suspicious containers is irrefutable.

2. Hard intelligence confirms that containers are of a configuration used to ship/transport Chinese Dong Feng 21 intermediate range ballistic missiles.

3. Dong Feng 21's have an estimated effective range of 1800 kilometers; effective warning time of an attack on CONUS is thereby reduced from 15 minutes to 3 minutes.

4. Xien Xiang, the official news organ of the central Chinese communist government has publicly proclaimed a new Chinese Latin America policy in direct conflict with the Monroe Doctrine.

5. Two of the most advanced warships in the Chinese fleet are converging on Panama; one of the ships is uniquely outfitted to support the protection of the Cristobal port facility.

6. State Department reports that central Chinese government is using the "stall maneuver" to prevent senior dialogue thus precluding official Chinese explanation of events.

[These six essential elements of information establish a clear "pattern" of Chinese behavior that places the Dong Feng 21missile threat as the top U.S. strategic priority in Panama Canal scenario.]

7. The appearance of President Jose Borrereo on Colombian national television acquiescing to the demands of the Revolutionary Armed Forces of Colombia (FARC) serves to reduce the immediacy (and relative strategic priority) of this threat.

[An anthrax attack on Panama City given Borrereo's acquiescence would be contrary to an established "pattern" of FARC behavior as a rational versus irrational actor.]

8. Potential consequences of event call for a coordinated U.S./international response.

9. Consensus (domestic/international) is essential to optimize the implementation of any diplomatic/operational response.

10. The sinking of a 500-ton grain cargo vessel, while in reality only an annoyance, has the potential for serious non-linear, counter-intuitive impacts on U.S./international infrastructures, i.e. market prices.

[The Panama Canal carries a large percentage of U.S. and international foreign trade (including Chinese exports). The sinking confirms fears that the canal is vulnerable to further acts of terrorist disruption. The U.S. Energy Information Administration has identified the Panama Canal as a strategic choke point for U.S. oil imports to the West Coast. Even in the absence of any long-term disruption of shipping through the Canal, the sinking confirms fears that the canal is vulnerable to further acts of terrorist disruption. Experience indicates that markets may react in a counter-intuitive fashion resulting in severe price fluctuations.]

11. The majority Republican leadership in congress poses a major problem for the President and the entire Executive Branch in mounting an effective response to the event. Any effective Presidential strategy must include specific plans for backstopping Congressional reaction to the event.

[The President and his Administration were severely criticized for their policy supporting the return of the Canal to Panama by majority Republicans in both the House and Senate. In recent hearings, senior Administration officials assured Congressional leaders of the continued safety and security of Canal operations. The Administration's credibility has also been severely damaged by allegations regarding complicity with China in the transfer sensitive dual use technology and the campaign funding scandal.]

12. Serious questions regarding the Administration's credibility will spillover to media reporting/analysis of events.

13. Unplugged leaks exist at the highest levels of the Administration, e.g., NSC.

14. Key information has already reached the media on both the national and international scenes precluding credible denial.

[These three essential elements of information establish a “pattern” indicating the need for a specific strategy for managing the press.]

Appendix D

Dissertation Defense: June 8, 2006

Dissertation Defense: The Complexity Systems Management Method

Hypothesis

New knowledge has arisen from scientific breakthroughs in our understanding of naturally occurring complex systems that can increase the human understanding of complex systems and improve the management of complex events and situations. This includes the complex and interdependent systems that characterize modern institutions of higher education.

Dissertation Defense: The Complexity Systems Management Method

Purpose of Research

To determine:

1. Is there is new knowledge arising from scientific breakthroughs in our understanding of complex naturally occurring systems that is not reflected by the positivist or post-positivist epistemologies of science?

2. Can this new knowledge be applied to create a new learning and decision making tool that holds the potential to increase the human understanding of complex systems and improve the management of complex events and situations?

Dissertation Defense: The Complexity Systems Management Method

Summary of Research Questions

1. What are the predominant frames of reference used to structure the positivist and post-positivist epistemologies of science and four well-known theories of science?
2. Does a combination of frames of reference that is different than the positivist and post positivist epistemologies and the four scientific theories arise based on comparison?
3. If a new combination of frames does arise, how can it help human beings better understand complex events and situations?
4. Can this new knowledge be applied in a practical way to help human beings more effectively manage complex events and situations?

Dissertation Defense: The Complexity Systems Management Method

Limitations of the Research Study

1. Examines only a fraction of the huge volumes of scholarly literature written on the subjects of the epistemologies of science and scientific theories that have increased human understanding of complex naturally occurring systems
2. Treats frames of reference only in terms of their collective prevalence in the scholarly literature selected for review; huge volumes of literature that relate to the research study exist
3. Study only compares and contrasts two epistemologies, four scientific theories and ten frames of reference (as triangulated from a sample of the scholarly literature); many other epistemologies and scientific theories exist
4. The research example addresses institutions of higher education; many other potential applications exist
5. The full scope of different applications of the research study remains untested

Dissertation Defense: The Complexity Systems Management Method

Limitations of the Research Study (continued)

Limitation	Response
1. Examines only a fraction of the huge volumes of scholarly literature	Development and use of selection criteria; see selection criteria and supporting analysis
2. Treats frames of reference only in terms of collective prevalence; additional scholarly literature abounds	How and in what combinations human beings dynamically move from frame to frame as part of the thought process is beyond the scope of this research study; structure of study designed to allow for expansion to include additional scholarly literature
3. Study compares and contrasts only two epistemologies, four scientific theories and ten frames of reference as triangulated from a sample of the literature; many others exist	Structure of study designed to allow for expansion to include additional epistemologies, scientific theories and frames of reference using the same or different selection criteria
4. The research example addresses institutions of higher education; many other potential applications exist	See Appendix B for additional applications; see three computer software platforms
5. The full application of the research study remains untested	Significant elements of the complexity systems management method were beta tested at NDU in ICAF elective and two major exercises, see Appendix A

Dissertation Defense: The Complexity Systems Management Method

Summary of the Methodology

Eight Steps:

1. Establish criteria to guide the selection of the scholarly literature to be studied
2. Review selected examples of the scholarly literature as it pertains to the positivist and post positivist epistemologies and four scientific theories
3. Attempt to triangulate a set of frames of reference
4. Compare and contrast the prevalence, i.e., predominance, of frames of reference among two epistemologies and four scientific theories
5. Develop a logic block
6. Deduce the tenets of *a priori optionality* using the scholarly literature
7. Connect theory with practice
8. Describe a practical application involving the modern university

Dissertation Defense: The Complexity Systems Management Method

Summary of the Methodology

Scope of literature review influenced by eight factors:

1. Extensive use of metaphor in the scholarly literature, national security education, exercises, and simulations
2. AY 1999-2000 study and teaching of complex contingency operations as an instructor at National Defense University (NDU); see Appendix A
3. AY 1999-2000 collaboration with Los Alamos National Laboratory (LANL) at NDU on the study of human and organizational responses to complex situations and events ("Big City" and "Bio World")
4. The Los Alamos post-analysis of the Cerro Grande Fire by Terry Helm

Dissertation Defense: The Complexity Systems Management Method

Summary of the Methodology

Scope of literature review influenced by eight factors (continued):

5. AY 2001 introduction to the significance of epistemological constructs as frames of reference for human problem solving
6. August 2001 GWU monograph, Project Alpha: Managing complexity in the new age of knowledge
7. AY 2003 introduction to the difficulty inherent in linking strategic plans with operational outcomes in the university (Drs. Confessore and Brown)
8. $5 million Hill appropriation and August 2004 request from the FBI to prepare a proposal to create the National Security Support Capability (FBI-NSSC) based on the complexity systems management method

Dissertation Defense: The Complexity Systems Management Method

The Scholarly Literature

Seven principal criteria guiding the selection of the scholarly literature:

1. Integrating the philosophy of science with theory in ways that were responsive to research questions
2. Connection among science, theory and practical outcomes
3. Concise definitions, clarity and descriptions of terms
4. Integrating philosophy with scientific outcomes is more important than "pure science", i.e., how you got there versus the breakthrough itself
5. Contrast between analogy and metaphor
6. Selective use of contemporary articles for explanation, breadth and to enhance understanding
7. Linking strategic plans with operational outcomes in the modern university

Dissertation Defense: The Complexity Systems Management Method

Results of the Research Study

- Based on the scholarly literature reviewed as part of this study, a new pattern of frames of reference emerges with the advent of complexity theory that does not match the positivist or post positivist epistemologies (see Table 1. on page 55)
- This is significant because the positivist epistemology constitutes the predominate scientific construct for complex problem solving
- Similarly, post-positivists rely on frames of reference that do not reflect new knowledge arising from the study of complex naturally occurring systems (see Table 1. on page 55)
- The scholarly literature illustrates the difficulty integrating quantitative reality with qualitative human social process to produce desired outcomes

Dissertation Defense: The Complexity Systems Management Method

Results of the Research Study

- The research gives rise to the possibility of a new epistemology of science, known as *a priori optionality* that more accurately reflects today's scientific understanding of complex adaptive systems
- The six tenets of *a priori optionality* (see page 69) are:
    1. We are unable to predict with precision the future behavior of any complex system
    2. There can be no single exact prediction of the future behavior of any complex system or system of systems
    3. There exist no absolute bounds of certainty in a complex system because the system itself is continuously evolving due to systems of systems interactions
    4. Nothing that happens in a complex system will ever occur again the same way it happened in the first place
    5. The assumptions we make about how complex systems will behave at some future time are constantly changing
    6. While the exact prediction of the future behavior of a complex system is not possible, an array of potential future behaviors can be projected within uncertain and continuously changing bounds

Dissertation Defense: The Complexity Systems Management Method

Results of the Research Study

- A process known as the complexity systems management or CSM method that is based on the new frames of reference identified in Table 1. page 55 has been developed. The CSM method reflects each of the six tenets of *a priori optionality.*
- The process is designed to identify quantitative reality; create an environment to integrate quantitative reality with qualitative social process factors using simulations of an array of potential behaviors in order to achieve *a priori* decision maker consensus on best decision options
- See Tables 2 and 3 on pages 101 and 102 for a summary of the CSM method process and deliverables.

Dissertation Defense: The Complexity Systems Management Method

Principal Source	Criteria	Comment
1. Alberts, D., Garstka J. & Stein, F. (ed.). (1999, August). Network centric warfare: Developing and leveraging information superiority.	2, 3 & 5	See Chapter 1., pages 1-12, The Myths of NCW and the emergence of the concept of nodes of operation; also *Metcalfe's Law;* note the interesting absence of the tenets of complexity theory and the limitations of orderly scalability of complex systems beyond certain thresholds
2. Alberts, D. & Czerwinski T. (eds.)(1999, January). Complexity, global politics, and national security.	1, 2, 3 & 6	See especially, Chapter 1., *The Simple and the Complex* by Murray Gell-Mann as a simple, concise statement of Gell-Mann's huge body of scholarly work on linking the science of complexity with practical organizational outcomes; also especially Chapter 8., *Complexity and Organization Management*, by Robert Maxfield
3. Balderston, F.E. (1995). Managing today's university: Strategies for viability, change, and excellence (2cnd ed).	2, 3 & 7	Consider in particular Balderston's distinction between *symptomatic* versus *substantive agendas* and his descriptions of the complex interrelationships among "critical nodes of operation" in the context of linking strategic plans with operational outcomes in the modern university
4. Barbour, J. (1999). The end of time: The next revolution in physics	**1, 2 & 3**	**Triangulated; see especially Chapter 21, *The Many-Instants Interpretation*, and page 322, "The single most striking thing about the universe we see around us is its rich structure, which is so difficult to understand on a priori statistical grounds" as an alternative to Heisenberg's thinking; also the notion of many "well-ordered" parts that comprise a total cosmos, i.e., systems of systems, in lieu of a single fabric such as Einstein's time space continuum; also see Parentani and Jacobsen's hypothesis on the "fluid" fabric of the universe**
5. Birnbaum, R. (2000). Management fads in higher education	3, 5 & 7	Excellent description of the seven major management systems used to guide the higher education enterprise, i.e., PPBS, MBO, Zero-base Budgeting, Strategic planning, benchmarking, TQM and business process reengineering; also the conundrum between quantitative reality and human social process factors in effectively linking strategic plans with operational outcomes in the modern university

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Principal Source	Criteria	Comment
6. Bloom, B.S. (ed) (1956). Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain	3, 4 & 5	Bloom's Taxonomy of learning connotes synthesis and evaluation as akin to understanding systems of systems interrelationships; note Bloom's use of hierarchal "building blocks" as opposed to dynamic applications of steps depending on initial knowledge of domains as the way humans comprehend reality; in the tradition of the positivist epistemology ***Knowledge***: arrange, define, duplicate, label, list, memorize, name, order, recognize, relate, recall, repeat, reproduce state. ***Comprehension***: classify, describe, discuss, explain, express, identify, indicate, locate, recognize, report, restate, review, select, translate, ***Application***: apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use, write. ***Analysis***: analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test. ***Synthesis***: arrange, assemble, collect, compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up, write. ***Evaluation***: appraise, argue, assess, attach, choose compare, defend estimate, judge, predict, rate, core, select, support, value, evaluate.
7. Cassidy, D.C. (1992). Uncertainty: The life and science of Werner Heisenberg	**1, 2, 3, & 4**	**Triangulated; note especially Cassidy's description of Heisenberg's "leap of faith" from conjecture as to the behavior of electrons at the subatomic level to metaphorical extrapolations to all of existence, i.e., all that is observed is affected by the act of observation itself; also note the contradiction between randomness of nature and the resulting inherent limitations in mathematical constructs and Heisenberg's derivation of absolute bounds based on the use of probabilistic statistical methods; also the "Gibbs conundrum"**
8. Chaffee, E. (1981). *The link between planning and budgeting.*	3, 6 & 7	Note especially Chaffee's attention (although metaphorical) to the requirements for agility in response to constantly changing assumption sets and her recognition of the difficulties inherent in integrating quantitative reality with qualitative human social process in the context of the modern university

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Principal Source	Criteria	Comment
9. Commission on National Investment in Higher Education, Council on Aid to Education (1997). Breaking the social contract: The fiscal crisis in higher education	3, 5, 6, & 7	Significant example of the inability to integrate quantitative reality, i.e., analogically derived ground truth with qualitative social process factors affecting the university; the inability to create meaningful outcomes based on inability to achieve consensus
10. Comte, A. (1907). "A general view of positivism"	**1, 2, 3, 4, 5, & 7**	**Triangulated for frames of reference; especially the movement away from metaphysical explanations of the human condition to use of analogical rigor**
11. Duderstadt, J. (1997, August). The future of the university in an age of knowledge; *The 21st century university: A tale of two futures and The cost, price and value of a college education* The millennium project papers	3, 6 & 7	Significant description of likely possible futures of the academy; displays analogical rigor; akin to the use of imagined future states of complex systems, i.e., "reverse engineering" of scenarios and use of simulations; description of the difficulties inherent in integrating quantitative reality with qualitative reality
12. Epstein, L. C. (2000). Relativity visualized	2, 3 & 4	Shows the value of *gedankemexperiment* to visualize a reality beyond the scope of the five human senses in the absence of pure mathematical constructs; also makes well the point that "how you get there" is just as important as "getting there"
13. Feiser, J. & Dowden, B. (gen. eds.) (2005) "Logical positivism," and "Time," The internet encyclopedia of philosophy	**1, 3 & 4**	**Triangulated; Excellent explanation of logical positivism; integration of philosophy of science with outcomes, i.e., an explanation of time**
14. Friedman, S. M. (2006). *Einstein on-line*	**1, 3 & 4**	**Selected works and writings by and about Einstein; see especially Einstein's: Relativity, the special and the general theory (1920) (Triangulated)**
15. Gell-Mann, M. (1999). "The simple and the complex"	1, 2, 3 & 6	Significant because of the strong connection between theory and actual practice

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Principal Source	Criteria	Comment
16. Gibbs, P. (1998). *Is faster than light travel or communication possible?*	2, 3, 4, 5 & 6	Analogically derived explanation of the conundrum of FTL travel/communication; strong support for the notion that "absolutes" may not exist and depend on frames of reference; note the "wagging finger and the light bulb" conundrum; also see Parentini and Jacobsen, i.e., localized effects
17. Gleick, James (1987). Chaos: Making a new science	**1, 2, 3, 4 & 5**	**Triangulated. The work is highly significant because of the integration the philosophy of science, i.e., history with a clear an concise interpretation of scientific theory and it's evolution; makes well the point that it is just as significant "how you get there" as "getting there"; the companion scholarly works are Prigogine and Gregoire's work, Exploring complexity: An Introduction (1998) and Waldrop's, Complexity: The emerging science at the edge of order and chaos**
18. Hawking, S. (1998). A brief history of time	1, 3, 4 & 5	Very clear indication of the linkage between frames of reference and conclusions and the "what you have learned in the past as the springboard for future thought" syndrome
19. Heisenberg, Werner (1999). Physics and philosophy: The revolution in modern science	**1, 2, 3, & 4**	**Triangulated; one of the most significant pieces of the scholarly literature because Heisenberg relates the philosophy, history and science leading to his conclusions**
20. Helm, Terry (2001). *Cerro Grande fire decision-making: Analysis of the decision drivers*. Los Alamos, NM: Los Alamos National Laboratory, Accident investigation team report on the Cerro Grande fire	2, 3, 5 & 6	Significant piece of the core literature because it displays the danger of metaphorical thinking; in many significant ways supports and contrasts with the conclusions of Perrow in Normal Accidents; illustrates the importance of finding new ways to integrate quantitative reality with qualitative social process
21. Jacobs, T.O. (2004). Strategic leadership: The competitive edge	1, 2 & 3	Highly significant piece of the core scholarly literature because of its relationship to the integration of quantitative reality and qualitative organizational process
22. Janis, I. (1982) Groupthink	2, 3 & 5	Important influence in developing process steps for implementing *a priori optionality*
23. Jeans, James (1981). Physics and philosophy	**1, 2, 3 & 5**	**Triangulated; example of the positivist tradition; significant for its wealth of insights regarding the frames of reference guiding the positivist tradition**

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Principal Source	Criteria	Comment
24. Johnstone D. (1999). *Financing higher education: Who should pay?*	3, 6 & 7	The importance of this piece stems from the intuitive description of the funding of the higher education enterprise as a highly complex interdependent systems of systems; also the recognition of the difficulty in linking quantitative reality with qualitative human social process
25. Johnstone D. (1988). *Patterns of finance: Revolution, evolution, or more of the same*	3, 6 & 7	Johnstone attempts to form potential futures of the state of the higher education enterprise and intuitively draw conjectures as to the likelihood of evolutionary versus revolutionary change in the way we fund higher education
26. Layzell D. (1998). "Linking performance to funding outcomes for public institutions of higher Education"	3, 6 & 7	Describes the complexity of linking strategic plans with operational budget outcomes in the absence of clearly annunciated and agreed upon strategic objectives
27. Michelson B., McGee M. & Hawley L. (1994)	1, 2, 3 & 5	Significant to phase 2 process of integrating quantitative reality with qualitative social process; the *consensus team decision model* serves to structure the achievement of consensus during immersions
28. Miller, Arthur I. (2000). Insights of genius: Imagery and creativity in science and art	**1, 2, 3, 4 & 5**	**Triangulated; one of the most significant pieces of the core scholarly literature; most notably deals extensively with the "how we got here" but with due regard for the science; excellent integration of the philosophy and history of science**
29. Perrow, C. (1982). Normal accidents	**1, 2, 3, & 4**	**Triangulated; one of the most significant pieces of the scholarly literature; most notably attempts to describe chaotic systems behaviors; falls short of providing a process to integrate quantitative reality with qualitative human social process; explanation of qualitative human component of complex systems behavior based largely on metaphor**
30. Prigogine, I. and Gregoire N. (1998). Exploring complexity: An introduction	**1, 2, 3, 4 & 5**	**Triangulated; an important piece of the core scholarly literature; serves as scholarly companion piece to Gleick's layman's explanation of philosophy, history and the science of complexity; but not as comprehensive as Gleick's historical research to answer the question "how we got here?"**

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Principal Source	Criteria	Comment
31. Resnick, M. (1999). Turtles, termites and traffic jams: Explorations in massively parallel microworlds	**2, 3 & 4**	**Triangulated; one of the most significant pieces of the core scholarly literature; very significant because it creates a pathway to move from theory to a practical outcome; Star Logo™ as a significant example**
32. Rosenhead, J. (1998). Complexity theory and management practice	**1, 2, 3, 4, 5, & 6**	**One of the most significant pieces of the scholarly literature; the significance of Rosenhead's work is in his critique of the use of metaphor versus analogy to extrapolate between the behaviors of naturally occurring systems and human behavior in organizations; Sanders and Wheatley are used as counter-posing examples of the ill-use of metaphor**
33. Runes, D. (ed) Dictionary of Philosophy	**1, 3, 4 & 5**	**One of the most significant pieces of the scholarly literature; critical to the triangulation of the frames of reference pertaining to the positivist and post-positivist epistemologies**
34. Sanders, I. (1998). Strategic thinking and the new science: Planning in the midst of chaos, complexity, and change	1 & 5	Provides some relation between philosophy of science, complexity theory and human behavior but somewhat shallow interpretation and depth of research relative to the history of science as opposed to Gleick, Prigogine and Gregoire, Miller; Wilson, et al; primarily used in the research study as an example of using metaphor versus analogy in extrapolating between well-known scientific versus lesser known qualitative knowledge domains
35. Schmuck R. & Runkel P. (1994). The handbook of organization development in schools and colleges	2, 3 & 7	Serves as a practical example of how to link theory with actual operational outcomes (albeit in a simplistic fashion) in the context of the university; interesting attempts to metaphorically integrate quantitative reality with qualitative social process; used as an example of how others have attempted to link strategic plans with operational outcomes in the context of the modern university
36. Schmidtlein, F. (1981). *Why linking budgets to plan has proven difficult in higher education*	**2, 3. 6, & 7**	**Very significant source; excellent overview the complexity inherent in the integration of the quantitative and qualitative human factors involved in linking strategic plans with operational budget outcomes in the modern university; underscores the need for systematic processes that can effectively balance quantitative reality with qualitative human social process**
37. Schulock, N. & Harrison M. (1998). *Integrating, planning, assessment, and resource allocation*	**2, 3, 6 & 7**	**Ibid.**

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Principal Source	Criteria	Comment
38. Trochim, William M. (2004). The research methods knowledge base (2nd edition)	**1, 3 & 4**	**One of the most significant pieces of the scholarly literature; used to clarify definitions especially as they relate to the positivist and post-positivist epistemologies; extremely fertile source for identifying prevalent frames of reference for both epistemological constructs**
39. U.S. General Accounting Office (GAO). (2000). "Fire management: Lessons learned from the Cerro Grande (Los Alamos) fire."	2, 3 & 5	Serves as a real world example to underscore the scholarly research of both Perrow and Helm especially with respect to the absence of an effective methodology or process that effectively integrates quantitative reality with qualitative social process and the "operator as villain" versus flawed policy
40. Waggaman J. (2000). *Strategies and consequences: Managing costs in higher education*	2, 3, 6 & 7	Significant because it illustrates the complex interdependencies that exist among different "cost drivers" in the modern university
41. Waldrop, M. (1992). Complexity: The emerging science at the edge of order and chaos	**1, 3 & 4**	**Triangulated; an important piece of the core scholarly literature; serves as scholarly companion piece to Gleick's layman's explanation of philosophy, history and the science of complexity; but not as comprehensive as Gleick's, Miller's and Wilson's historical research to answer the question "how we got here?"**
42. Wheatley, M.J. (1999). Leadership and the new science: Discovering order in a chaotic world	1 & 5	Shallow interpretation and depth of research relative to the history of science as opposed to Gleick, Prigogine and Gregoire, Miller, Wilson, et al; primarily used in the research study to illustrate the use of metaphor versus analogy in extrapolating between well-known scientific versus lesser known qualitative knowledge domains; companion piece to Sanders, Strategic thinking and the new science: Planning in the midst of chaos, complexity, and change (1998)
43. Wilson, E.O. (1998). Consilience: The unity of knowledge	**1, 2, 3, 4, 5 & 7**	**Triangulated; a very significant piece of the scholarly literature only because of Wilson's mastery of the philosophy and history of science; interestingly, when triangulated Wilson is a "positivist" whose theory of consilience is driven by a highly deterministic view of reality, i.e., microevolution as a linear process leading to macroevolution**

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Principal Source	Criteria	Comment
44. Wohlstetter, R. (1978). Pearl Harbor: Warning and decision	**3, 4 & 5**	**Used as one of the premiere examples of the "it can't happen here" syndrome and the human predisposition to avoid considering *a priori* in quantitative analogous terms possible future events; serves as strong support of the need for better ways to integrate quantitative reality with qualitative human social process; serves to bolster the potential utility of the complexity systems management method**

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Other Sources	Criteria	Comment
45. Allison, G. & Zelikow P. (1999). Essence of Decision: Explaining the Cuban missile crisis	**3 & 6**	**Serves as a premiere example of a highly complex situation and the difficulties of integrating quantitative reality with qualitative organizational and social process**
46. American Institute of Physics (2005). Quantum mechanics 1925-1927: The implications of Uncertainty	**1, 2, 3 & 4**	**Provides important insights into the times and thinking of Heisenberg, Einstein & Schrodinger; supports the triangulation of other scholarly literature as to the significance of uncertainty of measurement as a frame of reference in the post-positivist epistemology, the indeterminacy principle and dissipative structure and complexity theory.**
47. Bolton, J., Durant A.., et. al. (eds) (2000). "Chapter 3: The irreversible universe," The restless universe	1, 2, 3, 4, 6	Excellent article that under girds the triangulation of other scholarly literature relating to systems equilibrium and Prigogine's original work on the irreversibility of turbulent gaseous systems
48. Brannen, J. (ed) (1995, March). Mixing methods: Qualitative and quantitative research	2 & 3	Significant reference source on integrating processes for the conduct of "mixed" research studies; provides insights into the pervasive influence of the positivist and post-positivist epistemologies of science as highly distinct avenues of intellectual exploration
49. Brinkman P. & Morgan A.(1997). *Changing fiscal strategies for planning*, Ashe reader on finance in higher education	3, 6 & 7	Provides important insights into linking strategic plans with operational budget outcomes at institutions of higher education
50. Collinson, D. (1998). Fifty major philosophers: A reference guide	**1 & 3**	**Provides succinct descriptions of the basic views of the great philosophers; excellent source to help understand the history of philosophy**
51. Eisler, P. (2000, June 30). *This is only a test but lives still at stake: Course simulates attack on "Big City, USA,"* USA Today	2, 3 & 6	Background article on the special course and exercises conducted at National Defense University where many of the principles of the complexity systems management method were beta tested
52. Ess, C. (2005). *Positivism and the demand for certain knowledge: An epistemological aside on the history of ideas*	1, 2, 3. 4 & 6	Illustrates significant frames of reference that can be attributed to the positivist epistemology of science; also confirms the pervasive influence of the positivist epistemology on science and using science to solve highly complex problems

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Other Sources	Criteria	Comment
53. Gould, S. J. (1991, August). "Opus 200," *Science* Magazine	**1, 2, 3, 4, 6**	**Excellent piece on Gould's notion of *punctuated equilibrium* as an adjunct (versus an alternative) to paleontological notion of gradualism; imagine progress and the notions of pushing a ball up an incline versus stepping up a series of chairs; Gould is actually integrating Prigogine's ideas first espoused a decade earlier (1979 in his theory of dissipative structures and later work on phase transitions into the science of evolution and paleontology**
54. Gould, S.J. & Lewontin, R.C., (1979). "The spandrels of San Marcos and the Panglossian Paradigm: A critique of the adaptationist Programme," proceedings of the Royal Society of London	**1, 2, 3, 4 & 6**	**Highly significant piece of the scholarly literature showing how "framing" problems in certain ways can result skewed outcomes; shows the connection between assumption sets and outcomes; if your assumptions are wrong, so's the result**
55. Hnatio, J. (2000-2004). Numerous citations Referenced	1, 2, 3, 4, 5, 6 & 7	Shows the evolution of the notion of *a priori optionality* and the complexity management decision support tool over several years of study and practical application; shows how supporting ideas were scholarly developed and practically tested
56. Jacobsen, T. & Parentani, R (December 2005). "An echo of black holes," *Scientific American*	**2, 3, 4 & 6**	**A significant example of how "locking in" on a certain set of assumptions can frame the outcomes; very significant for the notion of localized phenomenon versus universal laws of nature**
57. Joslyn C. & Rocha, I.M. (2000) "Towards semiotic agent-based models of socio-technical organizations," proceedings of the artificial intelligence, simulation and planning in high autonomy systems (AIS) conference	2, 3 & 6	Significant because the paper addresses the need for better ways to integrate quantitative social process with quantitative reality in the understanding of complex systems; relates in may ways to the more clearly enunciated and proven work of Resnick in using object oriented supercomputing to propagate futures to close the divide between human social process and technology
58. Kaku, M. (1998). Visions: How science will revolutionize the 21st century	2	Illustrates the continuing pervasiveness of the positivist tradition on the nature of science and the use of linear assumptions to predict single potential future outcomes outcomes

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Other Sources	Criteria	Comment
59. Kerbel, J. (2005). "Thinking straight: Cognitive bias in the US debate about China," Studies in Intelligence: The journal of the American intelligence professional	**1, 2, 3, 5 & 6**	**Kerbel's (2005) article closely mirrors the GWU 2001 monograph *Project Alpha: Managing complexity in the new age of knowledge;* Kerbel (who works for the CIA) recommends future CIA spending on decision support systems like the complexity management system in order to more effectively integrate quantitative reality with qualitative human social and political process in ways that can help to avoid cognitive bias**
60. Kauffman, S. (1995). At home in the universe: The search for laws of self organization	**1, 2, 3 & 4**	**In many respects Kauffman's ideas are the synthesis of much earlier research by Prigogine (1979) that speaks to the evolution or devolution of systems based on energy gain or loss as a function of the environments in which they exist, i.e., systems of systems interactions; Prigogine's research also addresses the notion of phase transitions and the possibility of chaotic systems achieving new higher levels of equilibrium (see the theory of dissipative structures); Kauffman applies these same notions to molecular biology and an alternative to gradualism**
61. Korthof, G. (2000, August). Kauffman, at home in the universe: The secret of life is auto-catalysis	6	Korthof reviews Kauffman's work; the review does not address the previous scientific research of Prigogine or others that form the basis of Kauffman's work
62. Laudon, J.K. (1997). Essentials of management information systems	2 & 3	See sections relating to the use of decision support systems and human communication in organizations using technology; useful for providing an overview of different ideas on the integration of people, organizations and technology
63. Lawton, G. (2001, June). "Monsters of the deep," *New Scientist*	1, 2, 3, 4, 5 & 6	A significant contemporary article that illustrates the non-linear behavior of systems by raising questions about the notion of constructive interference; Lawton's work supports the non-linear frame of reference as a potentially significant way to consider the behaviors of complex systems

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Other Sources	Criteria	Comment
64. Lewin, R. (1980, November). "Evolutionary Theory under fire," *Science* magazine	1, 2, 3, 4 & 6	Significant as a 15 year old alternative view to Kauffmann's thinking; and early support for Stephen Jay Gould's notion of punctuated equilibrium
65. Maddox, J. (1998). What remains to be discovered: Mapping the secrets of the universe	**1, 2, & 3**	**This example of the scholarly literature is very much in the positivist tradition; see as an example Maddox's use of reductionism in Chapter 2., "Simplicity Buried in Complexity" ; his reliance on linearity, reductionism, certainty, reversibility and induction is a corollary to the thinking of E.O. Wilson in Consilience: The Unity of Knowledge**
66. Marcus, W. (2001, August). "How we got into the California energy crisis," JBS Energy, Inc.	3 & 6	Serves as a significant example of failing to "think ahead" to avoid a serious problem; in this example, the center of gravity was clearly on response versus prevention; excellent example of the failure to effectively integrate quantitative reality with qualitative social political process to avoid system failure
67. Maslow, A..H. (1943). A theory of human motivation," Psychological review	1, 2, & 3	May provide significant insights as to why human beings are so deeply rooted in the "here and now" based on Maslow's hierarchy of needs; the hierarchy of needs begins with immediate physical survival; perhaps human beings are "hard wired" to think only as far ahead as required for survival contributing to a sort of "built-in" cognitive bias to think in the short term even at successively higher levels
68. Maxfield, R. (1999) "Complexity, organization and management," Complexity, global politics and national security	1, 2, 3, 5 & 6	Especially insightful recognition that an engineering approach to complex problem solving is not the solution to integrating quantitative reality with qualitative social process in an organization; this article underscores the lack of such a methodology; however, Maxfield unsuccessfully attempts to prove the value of metaphor in understanding and managing complex systems behaviors
69. Mead, W.M. (1999). "The Jacksonian tradition," the *National interest*	2, 3, 4 & 6	Contemporary article supporting the "rise to the occasion nature of the American culture"; may be significant in explaining the react-respond versus anticipate and prevent cognitive bias that appears to be so pervasive in complex problem solving

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Other Sources	**Criteria**	**Comment**
70. Meisenger R. & Dubceck L. (1993). *Fund Accounting,* Ashe Reader on Finance in Higher Education	3, 6, & 7	Serves as a template to consider incoming and outgoing revenue streams within institutions of higher education by identifying cost factors that can then be considered as critical nodes of systems operation under the complexity systems management method; also highlights the difficulties inherent in integrating quantitative funds accounting with the qualitative cultural values of the university
71. Michelson B., McGee M. & Hawley L. (1994). Consensus team decisionmaking	**2, 3, 4, & 5**	**A very significant part of the literature because it provides a structured mechanism for integrating the quantitative and qualitative aspects of human decisonmaking in phase 2 of the immersion process**
73. Morgan G. (1998). Images of organization	5	Important example of the use of metaphor to describe the different aspects of the organization, i.e., organizations as machines, organisms, brains, cultures, political systems, psychic prisons, flux and transformation , and as Instruments of domination; Morgan's work is in direct contrast to Rosenhead's criticism regarding The improper use of metaphor (versus analogy) to extrapolate from one knowledge domain to another
74. National Education Association (March 2001). The future of higher education: Market driven futures	3, 6 & 7	Uses potential futures of the higher education enterprise based on changing assumption sets to forecast potential futures; can be considered as a companion piece to Neilson & Stouffer's *Narrating the vision: Scenarios in action*
75. Negroponte, N. (1996). Being digital	**2 & 3**	**Supports the theory of digital force multiplication (see page 110); Negroponte builds a possible future based on the assumption that the use of sensor technologies will continue to grow and be imbedded into all aspects of human endeavor**
76. Neilson R. & Stouffer D. (May-June 2005). "Narrating the vision: Scenarios in Action," The futurist	**2, 4 & 6**	**Significant contemporary article supporting the value of simulations as a tool to create and understand a range of possible futures; consistent with the use of scenarios in phase 1 and simulations in phase 2 as part of the complexity systems method**

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Other Sources	**Criteria**	**Comment**
77. Omeara, W. (1997). "Deduction and induction"	1, 2, 3, 4 & 6	Describes deduction and induction as important and different frames of reference in the conduct of scientific research
78. Resnick, M. (June, 2004). Star Logo™	**2 & 3**	**Very significant research; shows how patterns can be "constructed" and "reverse engineered" using object oriented supercomputing; influences the development and "reverse engineering" of phase 1 scenarios; and the reverse engineering of critical decision points in phase 2 of the complexity systems management method**
79. Reynolds, H. T. (1998, September) "The B-1 bomber: A case study of pluralism"	5 & 6	Used as a serious example of the lack of an effective model that integrates quantitative reality with qualitative human social and political process in the context of a highly significant national security decision
80. Rudolf, F. (1990). The American college and University	3 & 7	Provides a history of the American college and university; used as a backdrop to understand the evolution of the funding, operation and values of the academy
81. Rusu-Toderean, O. (1992). "In between positivism and post-positivism: A personal defence of empirical approaches to social science"	1, 2, 3, 4 & 6	Illustrates the continuing competition between the quantitative and qualitative research methodologies; attempts to validate the connection between positivism and empiricism as the means to understand human social process
82. Sagan, S. D. (2004). "The problem of redundancy problem: Why more nuclear security forces may produce less nuclear security"	2, 3, 4, & 6	Based on the notion that adding more complexity to already complex systems can lead to counter-intuitive outcomes; in this case greater complexity begets the opportunity for greater confusion; this is consistent with Prigogine's notion that adding energy to a system will result in chaotic behavior until enough energy is gained to produce a phase transition, i.e., the system reaches a new higher level of equilibrium; interestingly similar to Kauffman's work on biomolecular systems
83. Sanchez, R. (2001, June 13). "Park employees absolved in New Mexico Widlfire," The Washington Post, p. A27	5 & 6	Article reports the findings of independent investigations that National Park Service employees who were dismissed from their jobs for "causing" the Cerro Grande fire actually followed procedures; used as a real world example of the propensity to lay the blame for accidents with human operators versus the policies and processes they are forced to follow

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Other Sources	Criteria	Comment
84. Saunders-Newton D. & Frank A.B. (2002, October). "Effects-based operations: Building the analytic tools"	**1, 2, 3, 4 & 6**	**A very significant piece of background literature that supports much of the thinking inherent in the research study; illustrates the critical importance of finding new models that more effectively integrate the quantitative and qualitative aspects of human decision-making; "propagation of affects across interconnected systems and time"; also note definition of non-deductive reasoning: using models for heuristic purposes rather than for predictive purposes**
85. Sauvage, G.M. (1911). "Positivism," The Catholic Encyclopedia	1, 3 & 4	Critiques from the "catholic" perspective Comte's positivism and maintains an important role for the notion of a metaphysical existence and the role of God; good companion piece to the "Spandrels of San Marcos" and the importance of assumption sets in framing solutions to problems
86. Schneider, S. (1997). "Fundamental challenges to logical positivism," *New Renaissance*	1, 3 & 6	Critique of logical positivism; again makes the case that the purely physical world is not adequate to explain human existence
87. Senge, P.M. (1990). The fifth discipline: The art and science of the learning organization	3, 4 & 5	A largely metaphorical treatment of the so-called "learning organization; supports Rosenhead's view of the need for greater scientific discipline when extrapolating from the realm of science to the organization, i.e., the need for greater analogous reasoning
88. Shalizi, C. (2004). "Logical positivism," Notebooks	1, 3 & 4	Describes the tenets of logical positivism; important for establishing representative definitions of terms in chapter 1
89. Smith, H. (1999). Rethinking America	5	Largely metaphorical treatment of the nature of the changing industrial economy; provides some illuminating examples of the challenges associated with integrating quantitative reality with qualitative human social and political process
90. Smith L.R. (1990). American science policy since WW II	**1, 2 & 3**	**Excellent history of the evolution of science and technology policy and the important role of the positivist tradition and the nature of scientific advancement**

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Other Sources	Criteria	Comment
91. Sowell, T. (1987). A conflict of visions: Ideological origins of political struggles	1& 4	Significant piece of the scholarly literature that illustrates the difficulty inherent in integrating quantitative reality with human social and political process
92. Stanton S. (2001, May 6). *How Californians got burned: The state electricity system is in shambles, and the worst may be yet ahead. How did things get to this point?*	5 & 6	Contemporary article that illustrates a real world example of the failure to integrate quantitative reality with qualitative social process and the failure to effectively develop and then link strategic plans to operational outcomes; "the everybody saw it coming but still did nothing about it syndrome"
93. Umea University (2005). "Positivism and empiricism-the heart of Anglo-American thinking"	1, 2, 4 & 6	Critique of the American "science model" and failure to adequately integrate qualitative human factors as part of the American culture; chosen as a countervailing European view of the US dependence on positivism as the principal basis for science