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COPING WITH THE COMPLEXITY OF CONFLICT

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ABSTRACT

Complexity is increasing in the global security environment, but Western militaries are ill-prepared to deal with it due to the antiquated, limited paradigm of reality they employ: complexity theory offers a more comprehensive and appropriate model with which to solve problems and make decisions during conflicts. The linear-reductionist schema with which Westerners have worked for centuries has provided good, first-order approximations that have contributed to numerous technological and societal advances, but in many respects it has proven deficient in anticipating the behaviour of complex systems. Complexity theory demonstrates the potential to assist in understanding issues of a socially complex nature through its component theory of complex adaptive systems and stress on the importance of human agency. Complexity theory suggests that machines are not, nor will be, capable of replacing the human as a decision maker in war. The complexity of conflict is appropriately dealt with by the agent that has evolved to best cope with it – the human. Humans deal with complexity through intuition and the *expert* intuition required of military commanders can be trained through case studies and decision-making exercises. Only by enabling human agents with the more accurate paradigm of complexity theory and training their intuition will Western militaries maintain their hegemony in the modern battlespace.

INTRODUCTION

A growing number of authors suggest that the context of global security is moving towards greater complexity.[1] Complexity's relevance to security and defence lies in the fact that it inhibits prediction, and contributes to uncertainty and ambiguity in potentially high-stakes affairs. Given that complexity is increasing, what are its implications for Western militaries? Technology is unlikely to yield a panacea: no machine will ever be capable of fully controlling social dynamics, but alternatives exist. An appropriate coping mechanism is not silicon based, but rather carbon based: a human. Human agency, the human capacity to act as an autonomous, networked, and adaptive decision maker offers more potential for solving real-world problems than any computer. But to be effective a human requires an accurate model of reality; such a model is presently emerging in the form of complexity theory. Complexity theory, a more accurate paradigm than that presently subscribed to by Western militaries, demonstrates potential to enable humans in coping with the increasing complexity on the modern battlefield.

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[1]Andrew Ilachinski, *Land Warfare and Complexity, Part II: Application of Nonlinear Dynamic and Complex System Theory to the Study of Land Warfare*, Report prepared for the Center for Naval Analysis (Alexandria, VA: CNA, 1996), 1; James N. Rosenau, "Many Damn Things Simultaneously: Complexity Theory in World Affairs," in *Complexity, Global Politics and National Security*, eds. David S. Alberts and Thomas Czerwinski 73-100 (Washington: National Defense University, 1997), 74; James Moffat, *Complexity Theory and Network Centric Warfare* (Washington: CCRP: 2003), 2; and Steven R. Mann, "Chaos Theory and Strategic Thought," *Parameters* 22, no. 3 (Autumn, 1992): 54, are but a few examples.

Outline

First, complexity theory as a new, more accurate model of reality will be extensively reviewed. Complexity, linearity, and nonlinearity will be defined. Chaos theory, as the origin of complexity theory will be introduced along with concepts such as attractors and fractals to facilitate understanding of nonlinear systems. The continuum of nonlinear systems and the bifurcation diagram will be introduced as heuristics for understanding how equilibrium, complexity, and chaos represent the possible states of a single system. Complexity theory will then be compared to the thought processes of other cultures to emphasize how Westerners are thinking myopically about the reality in which they find themselves.

Second, the investigation will continue with a thorough treatment of complex adaptive systems as agents that thrive in the realm of complexity. The properties of complex adaptive systems will be discussed in turn, with particular emphasis on the property of emergence. The intent is to aid in understanding each property's applicability in modelling militaries as complex adaptive systems.

Third, the limits of technology in solving problems and making decisions will be examined. Artificial intelligence will be investigated and efforts to understand "mind" will be reviewed for their potential to replace the human as an agent. Human agency will then be discussed with emphasis on the importance of a human remaining in-the-loop in military decision making and problem solving.

Fourth, the introduction of intuitive decision making as a tool to cope with complexity will be examined. In particular, case studies and decision-making exercises will be discussed for their utility in training military personnel to be faster and more effective problem solvers.

Finally, the paper will conclude that Western militaries must transcend their present problem-solving and decision-making methodologies with a paradigm such as complexity theory, which more comprehensively reflects reality, in order to remain effective in future warfare.

MAKING SENSE OF COMPLEXITY

For want of a nail the shoe was lost.
For want of a shoe the horse was lost.
For want of a horse the rider was lost.
For want of a rider the battle was lost.
For want of a battle the kingdom was lost.
All for the want of a nail.

-Children's proverb

Small things can matter. In systems, particularly those of a social nature, small perturbations can have resounding effects. Westerners have taught this to their children, yet seem to have forgotten it themselves.[2] As adults they resort to the rationality of cause-and-effect relationships to reduce complex problems and in so doing miss the holistic nature of the system, the cues that tell them how events will unfold, and the simple levers whereby the system can be influenced. The realization that a kingdom could be lost for such a small thing as a nail indicates a nonlinear system and points to the presence of complexity: simple cause-and-effect reasoning will not suffice in such a dynamic.

Organizations struggle with complexity. Generally equated with factors like uncertainty or ambiguity, it is treated as a random happening that is the result of a lack of information of cause-and-effect relationships, untraceable interactions, or the "human factor."[3] This sense of intractability is the result of an occidental philosophical foundation. Connotations attached to the word "complexity" make it seem more

[2] The convention "Western" or "Westerners" will be used to indicate people of the European culture.

[3] Russ Marion, *The Edge of Organization* (Thousand Oaks: Sage Publications, 1999), 10.

overwhelming than it actually is. None of complexity theory's premises are foreign to human cognition; as a philosophical concept, complexity theory can be readily assumed by Westerners.[4] As the theory of evolution underpins biology, so too does complexity theory substantiate social, political, and martial life; such is the importance of complexity theory.[5] If Western militaries expect to adapt to the perceived increase of complexity on the modern battlefield, they need to embrace complexity theory.

Coming to Terms with Complexity

Complexity is not widely understood.[6] *The Canadian Oxford Dictionary* and others generally define complexity as a synonym for "complicated."[7] Complexity is not synonymous with "complicated." It is more profound than that.

Presently, complexity is a buzzword that is being used to describe the operating environment of Western forces. Complexity is a theme that now sets the tone in the opening paragraphs of the military doctrines of Australia, Canada, the United Kingdom and the United States (US). Each uses the word *complexity* specifically or in context, but offers no elaboration on the concept or more specifically how to cope with it.[8] What, precisely, is meant by complexity?

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[4] Rosenau, "Many Damn Things Simultaneously…," 95-96.

[5] Theodosius Dobzhansky, "Nothing in Biology Makes Sense in the Light of Evolution," *American Biology Teacher* 35 (March 1972), 125; http://www.sermonindex.net/modules/newbb/viewtopic.php?topic_id=17646&forum=36&9; Internet; accessed 27 February, 2009.

[6] Rosenau, "Many Damn Things Simultaneously…," 92.

[7] The Canadian Oxford Dictionary, 2001, s.v. "complex." and Funk & Wagnalls Canadian College Dictionary, 1986, s.v. "complexity." The latter gives a better concept by defining complexity as consisting of various interconnect or interwoven parts.

George Johnson has compared the challenge of defining complexity to what 19th century scientists faced in attempting to define energy when the concept was first conceived. Many scientists had a very firm understanding of how energy behaved and what it did, but it was not fully understood until an appropriate definition was articulated.[9] Today, the concept of energy is taken for granted.

Many complexity theorists envision complexity as a *process*: like a mathematical problem, its measure is the amount of computer power that would be required to arrive at a solution for a complex problem. Yet other theorists see it as a specific *characteristic* of an agent or object: complexity is defined by the amount of data required to describe it.[10] Neither group seems to articulate a definitive answer, but upon on one thing they agree: they may not be able to define complexity, but they know it when they see it.[11]

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[8] Australian Defence, ADDP-D *Foundations of Australian Military Doctrine* (Canberra: Defence Publishing Service, 2002), iii; Department of National Defence, B-GJ-005-000/FP-000 *CFJP-01 Canadian Military Doctrine: ratification Draft 1* (Ottawa: DND Canada, 9 July 2008), 5-1; Ministry of Defence, JWP 0-10 *United Kingdom Doctrine for Joint and Multinational Operations* (Llangennech: DSDC(L), 2002), 1-5; and US Armed Forces, JP 3-0 *Joint Operations* (Washington: Joint Chiefs of Staff, 2008), IV-4.

[9] George Johnson, "Researchers on Complexity Ponder What It's All About," *New York Times*, 6 May 1997, C7. The properties of energy were always well understood, but it is such an abstract idea that not everyone intuitively grasps the concept. At its most basic, energy is a numerical quality that does not change when something happens – it is conserved. It is not a concrete thing or a mechanism, but simply a quantity that can be calculated before an event be it kinetic, chemical, electrical, gravitational, thermal, or nuclear and after the event the quantity (energy) remains the same. For a more in depth explanation see Richard Feynman, *Six East Pieces: Essential of Physics Explained by its Most Brilliant Teacher* (New York: Basic Books, 1995), 69; http://books.google.com/books?id=Afvn8S8kV2EC&pg=PA69&dq=there+is+a+certain+quantity,+which+we+call+energy#PPA69,M1; Internet; accessed 6 April 2009.

[10] Ibid., C7. An example of complexity of this nature can be demonstrated using binary code: to write the number 17 in binary code is 10001. This number is relatively "simple." At the other extreme there are mathematical constants such as π or φ that cannot be expressed as ratios of whole numbers – their sequence goes on for literally billions of decimal places. If one were to be accurate in their use, there would be no means by which to abbreviate or compress them in binary – a truncated version must be used. Using binary code to represent either constant would require more data than the constant itself. Hence, the rationale for assigning them symbols, so they can be dealt with cognitively. π and φ are "complex" numbers.

[11] Ibid., C7.

As will be demonstrated, computers are not capable of dealing with the context laden nature of social complexity, so a process-oriented definition would only confound an understanding of complexity in this instance; for the purposes of this argument, a modified version of Bruce Edmonds' definition of complexity will be used: complexity is a characteristic of a system which makes prediction of its overall behaviour difficult even when given almost complete information about its components and their inter-relations.[12] This definition specifically captures the connotation when applied to war. Although all the actors in an unfolding conflict may be known, their strategic goals understood, their technology fully apprehended, and their network comprehensively mapped, their intents, actions, and reactions are not discernable.

In further explaining complexity, understanding its properties are important; what it is, and what it is not. To that end, the concepts of linearity, nonlinearity, and chaos will be discussed in turn with the intent of setting the groundwork for complexity theory.

Linearity

> Nature and nature's law lay hid in night;
> God said, "Let Newton be" and all was light.
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> -Alexander Pope

Some of NATO's most advanced equipment is very complicated. Modern jet fighters are remarkably so. Operating on the edge of our knowledge of the physical sciences, fighters employ advanced technology: their frames are made of cutting edge

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[12] Bruce Edmonds, "What is Complexity? - The Philosophy of Complexity P*er Se* with Application to Some Examples in Evolution," in *The Evolution of Complexity*, eds. F. Heylighen, Johan Bollen, and Alexander Rigler, 1-16 (Dordrecht: Kluwer Academic, 1999), 7: http://books.google.com/books?id=BQWrppy8ooIC&printsec=frontcover&dq=the+evolution+of+complexity#PPA7,M1; Internet; accessed 18 March 09.

alloys, their control surfaces maintain them on the edge of stability, and they harness power that can render a pilot unconscious with the G-forces they can generate. They are engineered from a myriad of interconnected systems and sub-systems that make them formidable platforms. Yet, even persons who have never flown an aircraft can roughly understand how a fighter works. Pushing the throttle accelerates the fighter. Pulling it back results in deceleration. The relationship is linear: for a specific action a proportional reaction results. A definite expectation can be formed because the results are dependably reproducible.

If not working dependably, fighters can be repaired. Technicians, trained to understand the cause-and-effect relationships of the fighter's systems and sub-systems, using deduction (or an algorithm) can determine which element in the cause-effect chain is not functioning correctly and replace it. And so, the fighter is rendered reliable once again. The fighter is comprehensible because it is engineered on linear, mechanistic reductionism. It is a machine that will deliver a consistently predictable outcome and its outputs will be proportional to its inputs. Any failure can be identified and corrected.[13] Fighters are most definitely complicated, but only when a pilot is seated in the cockpit is a fighter considered complex. The addition of the independent agent is what generates complexity.

The notion of linearity is the underpinning of *complicated* systems. It is characterized by proportionality, additivity, replication, and demonstrability of causes

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[13] This example is a rendition of that articulated by Edward A. Smith, *Complexity, Networking, and Effects-based Approaches to Operations* (Washington: CCRP, 2006), 37.

and effects.[14] All are well understood by the Western mind. Proportionality implies that inputs are relative to outputs (i.e. more explosives yields a larger explosion). Additivity implies that the whole is equal to the sum of its parts. Based on reductionism, additivity implies that large or complicated problems can be broken into manageable components that can be analyzed; understanding the small components, the knowledge can then be re-assembled (or *added*) to yield understanding of the larger problem. Replication is one of the foundations of modern science: experiments under similar conditions yield similar results. This allows experiments to be repeated and independently verified. Finally, causes can be readily identified and effects observed. These properties are present in all linear systems.

Linearity has been the dominant paradigm among Western nations for nearly 300 years. Authors (including poets) have argued that linearity is the legacy of Sir Isaac Newton: in establishing the basis for classical mechanics his linear reductionism proved to be the catalyst for initiating the scientific revolution.[15] Arguably, this paradigm could be attributed to a much longer lineage. Linearity originates more from a considerable number of savants and philosophers that include: Euclid, Copernicus, Galileo, Hume, Locke and Mill, to list but a few.[16]

Linearity's predominate application has been in advancing technology. It is ideal for understanding "complicated" systems. Linearity's appeal resides in its utility for

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[14] Tom Czerwinski, *Coping with the Bounds: Speculations on Nonlinearity in Military Affairs* (Washington: CCRP, 1998), 8.

[15] Ibid., 27.

[16] David Peak and Michael Frame, *Chaos Under Control: The Art and Science of Complexity* (New York: Freeman, 1994), 2 and Richard E. Nisbett, *The Geography of Thought: How Asians and Westerners Think Differently…and Why* (Toronto: Free Press, 2003), 1.

avoiding failure and ensuring predictability: holding everything constant, linear designs are inherently safer.[17] Linearity has amounted to the belief that the complex behaviours observed can be reduced to a set of simple laws that define the universe - essentially the laws of physics.[18]

This mechanistic, linear worldview is reassuring. It proposes a world of consequential change and the resulting paradigm is at the core of Western military thought.[19] For example, Clausewitz's *On War* invoked the mechanistic image of the army as a machine. In fact, Clausewitz's other metaphors such as centre of gravity and friction are borrowed from Newtonian physics.[20] Armed forces exert considerable effort to influence personnel to act and interact in linear, mechanistic, and predictable ways. Rank hierarchies, discipline, unit structure, tradition, and formatted direction serve to impose order and overcome situational randomness.[21]

The linear paradigm's acme was in the 1960s, when it was applied to military strategy. Although the US military had undergone significant change in the previous 50 years, the decade was one of increasing complexity. The 1960s saw the introduction of the computer in the workplace and considerable social change. The US military was concurrently undergoing a transformation that could best be characterized by an increase in the specialization by personnel, organizational instability, and a strong momentum to

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[17] Czerwinski, *Coping with the Bounds…*, 91.

[18] John Holland, *Emergence: From Chaos to Order* (New York: Basic Books, 1998), 189.

[19] Mann, "Chaos Theory and Strategic Thought," 56.

[20] Barry D. Watts, *Clausewitzian Friction and Future* War (Washington: National Defense University, 2004), 22.

[21] Mann, "Chaos Theory and Strategic Thought," 60.

centralize.[22] The American Administration acknowledged the increasing complexity and believed that there was a need for an entirely new approach to understanding war. Such a technique seemed to exist in the form of systems analysis, which was brought to the Pentagon in 1966 by Robert McNamara.[23] Although called systems analysis, the process seemed to be the antithesis of a systems approach to problem solving. It did not focus on holistically understanding a system, but rather on the rational analysis of the interactions of groups with the specific intent to develop procedures to provide appropriate information to organizational decision makers.[24] The application of systems analysis was the raison-d'être of the Pentagon's Office of Systems Analysis. Their role was to: reduce each problem by clearly defining the parameters in the context of larger problems; make underlying assumptions explicit; and employ quantitative means where possible.

The Office of Systems Analysis made positive contributions to the war, but was incapable of solving the intractable problems of complexity. The team gave the Secretary of Defense opinions unbiased by the internal pressures of the armed services and made significant contributions in the implementation of airmobile warfare, proving the ineffectiveness of the US strategy of attrition in Vietnam, and documenting the effectiveness of long-range patrols over massive sweeps by large combat forces.[25]

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[22] Martin van Creveld, *Command in War* (Cambridge: Harvard University Press, 1985), 237.

[23] Lewis Sorley, "To Change a War: General Harold K. Johnson and the PROVN Study," *Parameters* 28, no. 1 (Spring 1998), 104.

[24] Richard W. Lott, *Basic Systems Analysis* (San Francisco: Canfield Press, 1971), 4.

[25] Alain C. Enthoven and K. Wayne Smith, *How Much is Enough: Shaping the Defense Program 1961-1969* (Santa Monica: Rand, 2005), 100, and Sorely, "To Change a War: General Harold K. Johnson and the PROVN Study," 104.

Ultimately, their processes did not conform directly to observed reality despite the adopted statistical approach.[26]

Systems analysis reinforced linear thinking and was a partial contributor to the outcome in Vietnam. The methodology of systems analysis was to model through quantification. Valid in many applications such as in financial and technological problems, the model made no provision for the initiative, adaptiveness, and free will of an enemy force. Secondly, its emphasis on quantification made no provision for morale in war. The methodology relied upon quantification rather than comprehension and required inputs such as enemy body counts and the number of "pacified" villages.[27] Systems analysis' inherent linearity could not adequately address the evolving complexity of warfare at the time where social and political dynamics had an increasingly important role in military operations.

Linearity is a good, first order approximation of reality.[28] Its appeal is in its simpler explanation that conforms to Occam's razor: it offers parsimonious but powerful explanations of natural events. The problem with thinking in such terms is that it results in the reduction of highly complex situations down to a few cognitively addressable variables.[29] In other aspects, linearity has proved deficient in reflecting reality, particularly where intelligent agents interact through cooperation, competition, or conflict.

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[26] van Creveld, *Command in War,* 240.

[27] Ibid., 240.

[28] Peak and Frame, *Chaos Under Control…,* 2.

[29] Mann, "Chaos Theory and Strategic Thought," 57.

Nonlinearity

Nonlinearity is a property of a complex system where a small change in one variable can have a disproportional effect on a solution: answers are not a linear combination of the independent components. Mathematically, the plotting of highly nonlinear equations shows breaks, singularities, and recursions.[30] Values that are relatively close together and seem to encourage extrapolation will soar apart apparently at random. The implication for nonlinear social systems is that they can exhibit dramatically different behaviours dependent upon the degree of nonlinearity present.

Mathematically, nonlinear equations are those that are at least quadratic (i.e. $x^2 + bx + c$) or a higher degree.[31] A simple, nonlinear relationship can be demonstrated using Lanchester's Laws. Lanchester's Laws exhibit nonlinearity not from a specific quadratic equation, but rather from the product of two independent variables.

In 1914, during his historical study of combat, Fredrick Lanchester devised mathematical formulas that could model the relationships between opposing forces. He developed two models, the one of interest here is the simpler Un-aimed Fire Model or *Linear* Law, which proves to be not quite so linear. Researchers have challenged the validity of the model's representation of reality, but it is appropriate when used to study simple combat scenarios.[32] Here, it will be used to demonstrate simple nonlinearity.

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[30] John Briggs and F. David Peat, *Turbulent Mirror: An Illustrated Guide to Chaos Theory and the Science of Wholeness* (New York: Perennial Library, 1990), 23-24.

[31] An example of higher degrees would include cubic equations $x^3 + ax^2 + bx + c$ or even quartic equations $x^4 + ax^3 + bx^2 + cx + d$.

[32] Trevor Dupuy, *Numbers, Predictions and War: Using History to Evaluate Combat Factors and Predict the Outcome of Battles* (New York: Bobbs-Merrill, 1979), 150.

The Un-aimed fire model is an attritional model, typically applied to artillery engagements or aerial bombardment, where combat is not necessarily line-of-sight and consequently "un-aimed."[33] In his model, a side's fighting strength is proportional to the number of its combat elements (be they equipment or soldiers) multiplied by an effectiveness constant, then multiplied by the density of enemy elements to which the fighting strength is being applied. When fighting strength is calculated for each force, the effects of attrition become apparent and an advantage may be evident, hinting at a victor. The following is an illustration of its application: if Blue (B) artillery engages with an effectiveness of constant ρ and fires randomly at Red (R) forces that are tactically dispersed in an area of A_R, the fighting strength (F_B) can be defined by the equation $F_B = \rho B \times R / A_R$.

If Blue force deploys 100 guns that are known to have an effectiveness of 10% and engage 200 Red force soldiers in a one kilometre square, the result would be a fighting strength of 2000 ($0.1 \times 100 \times 200/1\ km^2$). This number could then be compared to Red force artillery to measure attrition effects on the battlefield. But imagine if the forces are tripled. The commonsense deduction is that any increase in either the number of Blue force artillery or Red force soldiers increases the number of casualties, or interactions in this system. Increasing both the number of Blue artillery and Red forces does not simply result in a tripling of the number of casualties; rather they would increase nine-fold. This finding is evident in the resulting Blue force fighting strength of 18000 ($0.1 \times 300 \times 600/1\ km^2$). Thus nonlinearity exists because of the product of two variables

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[33] Niall MacKay, "Lanchester Combat Models," http://arxiv.org/PS_cache/math/pdf/0606/0606300v1.pdf; Internet; accessed 28 January 2009.

within the model rather than simply their sum. This is simple nonlinearity; a much more complex form arises with the introduction of feedback.

The fundamental difference between a simple nonlinear system and a complex nonlinear system is one of feedback. Complex systems use solutions (or a portion of the solution) as the input for the next iteration of their process. Complexity results from this virtuous (or vicious) cycle. Feedback is the mechanism whereby an output, or event in the past, is fed back into the system, generating a cyclical effect. The first iteration of an input through the system will typically yield a linear result. When that output is fed back into the system repetitively the result is that the system, after several iterations, does not necessarily elicit an output that is proportional to the input. There may be no response, dramatic response, or a response anywhere in between. This description demonstrates that nonlinear systems are particularly sensitive to the initial input. This sensitivity to initial conditions is a hallmark of nonlinear systems. Nonlinearity is a property of both chaotic systems and complex systems. Despite them sharing the property of nonlinearity, they are distinctly different phenomena, as will be demonstrated.[34]

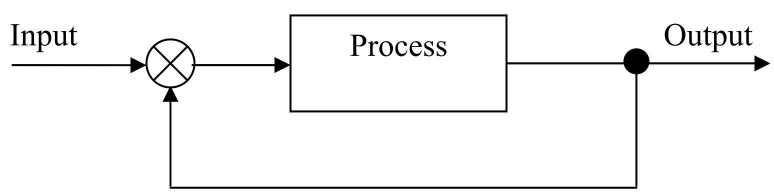

Figure 1 – A Simple Feedback Mechanism

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[34] Marion, *The Edge of Organization*, 4.

Even the simplest imaginable feedback loop has levels of subtlety that is seldom given any thought.[35] A form of feedback with which most people are familiar is audio feedback. When an individual is using a microphone with an amplification system and gets too close to the loudspeaker the sound can be picked-up by the microphone. That small bit of sound is cycled through the amplifier and out the loudspeaker only to be picked-up by the microphone again and re-inputted for amplification in a repeating cycle. The signal gets stronger with each iteration. A feedback loop establishes itself quite quickly, and the result of this cycle is a high-pitched squeal that most people find intolerable. The example is useful in that everyone has likely experienced it, but nuances regarding what is happening demand explanation.

First of all, this example begins as positive feedback. Each cycling of the input theoretically amplifies the volume by a fixed factor, k. Thus two iterations would result in amplification of k^2. Three loops would result in amplification of k^3, and so on. Positive feedback uses functions of multiplication, hence the outputs are exponential. The conclusion is that positive feedback is not simply the addition of the signal, as might be inferred when the terms positive and negative are used as descriptors of feedback. Nor are the terms qualifiers: positive feedback is neither "good," nor negative feedback "bad." Positive feedback functions whenever there is amplification or growth (or decline if the trend is diminishing).[36]

In theory, the audio output in this example could continue to grow without limit, deafening everyone within range, but it does not. As the sound gets louder and louder,

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[35] Douglas Hofstadter, *I Am A Strange Loop* (New York: Basic Books, 2007), 55.

[36] Peter M. Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization* (Toronto: Doubleday-Currency, 1990), 79.

the system stops amplifying by *k* and at a point the amplification stops. As the system approaches its natural limits, the feedback signal is combined with the input negatively. In this system that point is reached when the input sound is the same volume as the output sound. Negative feedback functions whenever there is a goal-oriented or "balancing" behaviour more specifically known as homeostasis.[37] The result is the familiar screech that makes people wince.

This is a common and simple feedback system. What can be concluded is that even the simplest systems that incorporate feedback have a subtlety that is not commonly given much thought.[38] Imagine the possibilities of multiple, integrated feedback loops that constitute complex systems.

As systems become more overlapping and interconnected they become more complex. Feedback loops proliferate and nonlinearity intensifies. The consequence is that an observer cannot discern where one system begins and another ends, or how any system evolves from one state to another. Human social networks exhibit such complexity and it can never be known, except in hindsight, when a social system will make a transition from linearity to nonlinearity by triggering feedback.[39]

This understanding is important because it is in essence a schema and hints at the nature of how nonlinearity can contribute to the rise of conflict in social systems. Linearity makes natural the inference that war is triggered by specific causes such as religious or economic reasons. Nonlinearity prompts the theorist to imagine war as a vast

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[37] Ibid., 79.

[38] Hofstadter, *I Am A Strange Loop*, 55.

[39] Rosenau, "Many Damn Things Simultaneously…," 90.

pattern of inconsequential systems and to think of what triggered it in similar terms.[40] Who could have foreseen the scale of war, with over 15 million deaths that resulted from the assassination of a single arch duke?

A system's natural tendency is to remain at equilibrium with regulation attained primarily by negative, controlling feedback. Examples of negative feedback mechanisms in a military context include doctrine, techniques, tactics, standard operating procedures, and lessons learned programs. All are regulatory mechanisms, in that they articulate social norms and serve as explicit examples of decision-solutions that have proved successful in previous situations. All, in essence, are a form of negative or regulating feedback.

Introducing positive feedback produces a different phenomenon. Positive feedback pushes systems outside their normal range, away from equilibrium. Such a process is required to take a nation to war, but establishing it can be a challenge, with commensurate risks. A commander may formulate direction to initiate conflict, but that intent is frequently at odds with the intentions of individuals making up the fighting force. Although the direction may be formulated to satisfy a national interest, not everyone will go to war for idealistic reasons: some go to profit; some go for adventure; some go as a right of passage; some go because they are coerced, and simply want to live through the experience. The introduction of a new aim or goal, which is a change from homeostasis, yields a tension in the system. The result is what Shimon Naveh calls the "intrinsic dichotomy" of systems – the system will naturally resist the will of any single individual to move in a coherent fashion. The understanding of this internal tension, and

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[40] Ibid., 35.

how to move the system into combat without disintegration, is the *sine qua non* of an operational-level commander.[41]

Nonlinearity does not contradict the classical paradigm; rather it transcends it.[42] Nonlinearity is employed in complicated systems and permits their effective regulation. Mastery of feedback loops and control systems has allowed mankind to control devices from aircraft to zambonis, but these represent relatively simple nonlinear systems. Another level of understanding is required when multiple systems and numerous feedback loops, particularly positive ones, begin to interact. At this advanced degree of nonlinearity life, economies, societies, warfare, and just about everything else of interest resides.[43]

Chaos Theory

General William Tecumseh Sherman once suggested that, "War is hell."[44] The unspoken idea of his maxim was that in war, as in hell, there is no restraint, only suffering; no mercy, only cruelty; no order, only chaos.[45] General Sherman was writing metaphorically. Contrary to how commentators have interpreted his meaning, when all seems random and haphazard, a degree of order in warfare *does* exist. Chaos is not random.

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[41] Shimon Naveh, *In Pursuit of Military Excellence* (London: Frank Cass, 1997), 6.

[42] Steven R. Mann, "Chaos Theory and Strategic Thought," 58.

[43] Heinz Pagels, *The Dreams of Reason: The Computer and the Rise of the Sciences of Complexity* (New York: Simon and Schuster, 1988), 73.

[44] Wikipedia, "William Tecumseh Sherman," http://en.wikipedia.org/wiki/William_Tecumseh_Sherman; Internet; accessed 11 February 2009.

[45] Ward Thomas, *The Ethics of Destruction: Norms and Force in International Relations* (Ithaca: Cornell University, 2001), 1.

Chaos is a connotatively loaded word that carries associations of primordial formlessness, complete randomness, and inherent unpredictability. It is a characteristic of nonlinear systems with large numbers of shifting components that exhibit a sensitive dependency to initial conditions, where seemingly random activity yields orderly yet nonrecurring patterns.[46] Examples in the natural world include turbulence in water, smoke as it begins to whorl, weather patterns, or even static noise on a radio. System behaviour is determined by preceding events and obeys natural laws, but their descriptive equations cannot be solved.[47] Extreme nonlinearity is present in chaotic systems.

At first glance, chaotic systems seem mathematically impossible to solve, but they are deterministic and because of this, they have limits, or bounds.[48] So, although an observer of the system may not be capable of predicting what the system will do next, they can state with certainty that a limit exists on the possibility of the next system "solution" and that it will be within definable bounds. The delineation of these bounds yields an attractor. An attractor is a compiled range of solutions to the system (normally represented graphically), and it does just what its name implies – it draws the activity of the system into a state space defined by the system's independent physical variables.[49]

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[46] Mann, "Chaos Theory and Strategic Thought," 58.

[47] Briggs and Peat, *Turbulent Mirror…*, 73.

[48] Determinism implies that chaotic systems abide by natural laws and their behaviours are determined by preceding events. Bounding implies that chaotic systems have limits, or constraints, and although the results they generate might seem to range to infinity, they do not. The range of results can be anticipated in a chaotic system.

[49] Heinz Pagels, *The Dreams of Reason…*, 76-77. A "state space" is a mathematical model of a system configured of discrete states or solutions that are used to model the behaviour of the system. The space is defined by the axes of the variables. The state is represented as a point or vector within the space. Wikipedia, "State space (controls)," http://en.wikipedia.org/wiki/State_space_(controls); Internet; accessed 19 March 2009.

The best analogy of an attractor is that of a marble in a bowl. The marble represents the current state of the system, and the bowl the attractor. The bowl can be turned, tipped, nudged, or jostled and although difficult to gauge the discrete properties of the marble such as position, velocity, or energy the marble will remain in the bowl (short of overturning the bowl, of course).

An example of the first and most famous attractor can be seen in Figure 2. First generated by Edward Lorenz in 1963 during his studies of atmospheric convection, the Lorenz Attractor reveals the hidden structure in seemingly disorderly data. At any discrete interval of time, three variables determine the location of a solution point in the state space. As the system changes, the movement of the point represents the continuously changing variables. Such a system will never repeat itself: instead the solution states loop around infinitely[50]

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[50] James Gleick, *Chaos: Making A New Science* (Markham: Penguin, 1987), 29.

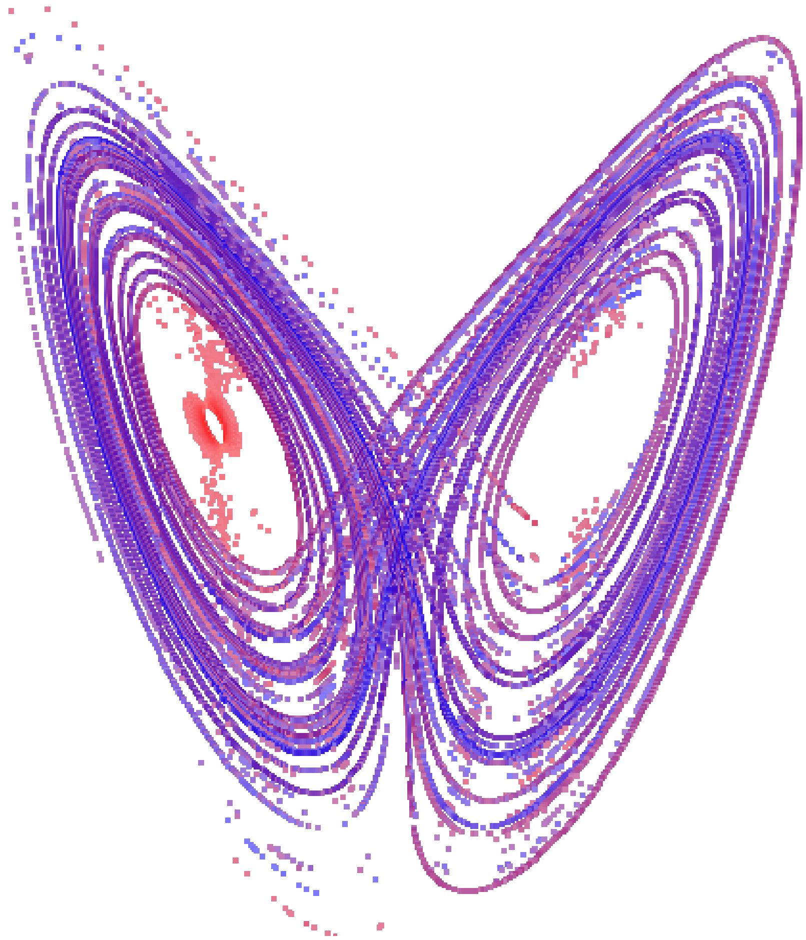

Figure 2 – The Lorenz Attractor

Source: Wikipedia, "Lorenz Attractor," http://upload.wikimedia.org/wikipedia/commons/thumb/f/f4/Lorenz_attractor.svg/600px-Lorenz_attractor.svg.png; Internet ; accessed 26 February 2009.

The concept of the attractor is important to understanding how to cope with nonlinear systems. Chaos represents the extreme into which a nonlinear system can descend, but the resulting situation is not completely random: limits exist on how the system will behave. Nonlinear systems will appear to approach randomness, but they do not become completely stochastic and nondeterministic. The appearance of randomness is from the system never repeating itself. The fundamental concept to take away from this is that in determining the innate nonlinearity of a system, one must recognize the impossibility of having perfect awareness, predicting, or "solving" the system. One must be content with bounding it.[51]

Although some of the most seemingly random events on the battlefield seem arbitrary, they are not. Their patterns reveal an underlying order. World War II data analysis of phenomena such as the distribution of casualties, radio traffic, or how armies create forward edges of battle areas (FEBAs) have revealed surprising results in their underlying order: they are fractal in nature.[52] A fractal is an infinitely long line in a finite area.[53] Fractals are recursive, and self-similar: they demonstrate similar patterns at different scales. The most well-known fractal is the Mandelbrot Set (see below). Fractals are another means by which to represent the strange attractors of systems that are deterministically chaotic – they never cross themselves, they never repeat.

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[51] Smith, *Complexity, Networking, and Effects-based Approaches to Operations*, 315.

[52] Michael K. Lauren and Roger T. Stephen, "Fractals and Combat Modelling: Using MANA to Explore the Role of Entropy in Complexity Science," *Fractals* 10, no. 4 (2002): 482.

[53] Gleick, *Chaos*…, 139.

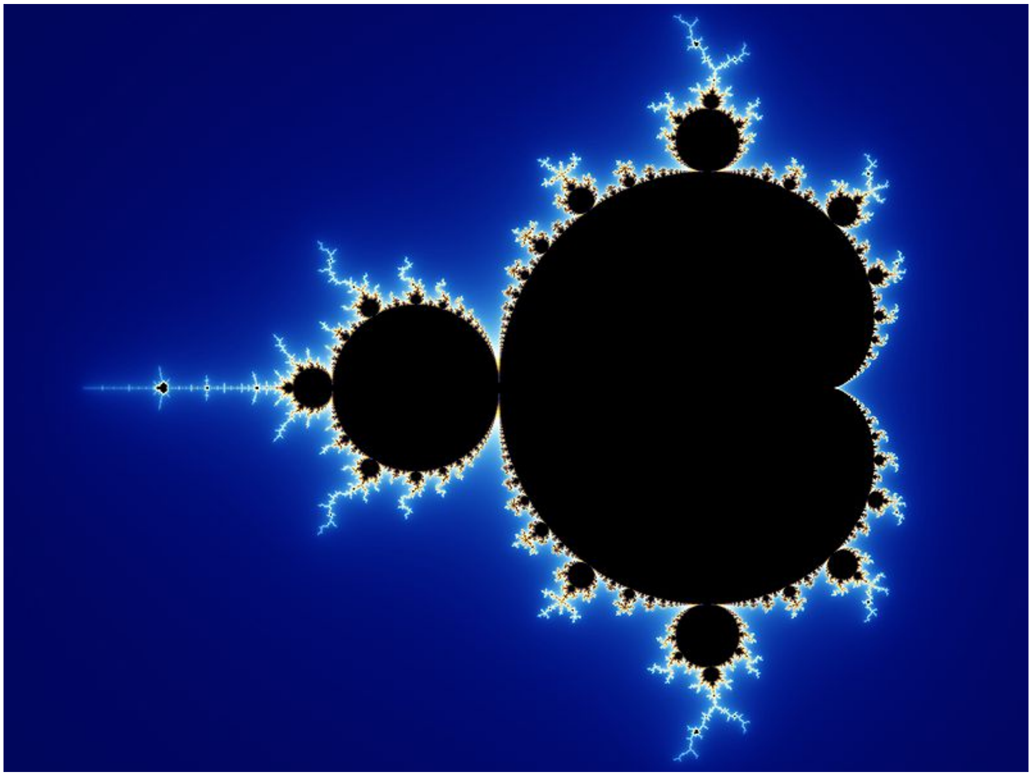

Figure 3 – The Mandelbrot Set

Source: Wikipedia, "Fractal," http://en.wikipedia.org/wiki/Fractal; Internet; accessed 19 March 2009.

Equilibrium and chaos represent either extreme of dynamical systems. Between the two resides the most interesting of the system states. Dwelling in this middle realm can be found complexity, which represents the most accurate model of nature, mind, and society mankind has developed to date.[54] This is additionally the domain of, arguably, the most realistic model of warfare.

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[54] Pagels, *The Dreams of Reason…*, 35.

Complexity Theory

The theory of complexity has its roots in chaos theory.[55] Complex systems are considered as existing "on the edge of chaos."[56] Initially considered part of a single theory, complexity theory proved distinct from chaos for the unique properties discovered in its systems, and theorists now consider it separately from chaos theory. In contrast to linear systems, complexity consists of interactions that are not proportional, additive, or replicable and the ability to demonstrate cause and effect is tenuous.[57] Like chaotic systems, complex systems are nonlinear and sensitive to initial conditions. What is truly unique about a complex system is not just that the whole is greater than the parts of the system, but rather the system effects are wholly different than those exhibited by the parts: no correlation exists between what individual components are doing in the system and the behaviour the system presents in statistical analysis.[58] The unique behaviour of complex systems emerges from the activities of lower-level components.[59]

Complexity emerges when the dependencies and relationships between the elements of the system are as important as the elements themselves. Reductionism is ineffective in studying complex systems because removal and isolation of a single element for detailed study effectively destroys the system. The element's links to other elements is as important to system function as the element itself. Removal or isolation,

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[55] Marion, *The Edge of Organization*, 4.

[56] John Urry, *Global Complexity* (Malden: Polity, 2003), 22.

[57] Czerwinski, *Coping with the Bounds*…, 9.

[58] Urry, *Global Complexity,* 25.

[59] John H. Miller and Scott E. Page, *Complex Adaptive Systems: An Introduction to Computational Models of Social Life* (Princeton: Princeton University, 2007), 9.

for analysis, destroys system behaviour.[60] An analogy of the phenomenon at work here can be found in human biology. Although a brain, a heart, or any components of the body may be removed for detailed study, their individual analysis cannot render a complete understanding of "humanness." The human must be left intact, demonstrating the behaviour of all the components and systems functioning together, to reveal that of which a human being is truly capable.

Whereas modelling of linear systems is facilitated by reductionism, the investigation of complex systems demands other approaches. Presently these are taking the form of computer-based models.[61] Complexity could not be mathematically modelled until the late twentieth century and the advent of computers.[62] Pen and paper techniques of calculating its effects are onerous and time-consuming. The computer has facilitated numerical solutions to problems that were unsolvable in the past, problems that in some instances required billions of iterations. What complexity theory reveals is a class of systems consisting of interconnected components and interdependent sub-systems.[63] This has generated new insights beyond the linear-reductionist paradigm that have impacted health care, economics, computer sciences, management studies,

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[60] Ibid., 9.

[61] Ibid., 21.

[62] Alan Beyerchen, "Clausewitz, Nonlinearity and the Importance of Imagery," in David Alberts and Thomas Czerwinski, eds. *Complexity, Global Politics and National Security* (Washington: National Defense University, 1997): 161.

[63] An "agent" used in this context is an autonomous unit with the ability to make decisions that interacts with other agents; Peter Erdi, *Complexity Explained* (New York: Springer, 2001), 305; http://books.google.com/books?id=JwgpLvknc8wC&printsec=frontcover&dq=complexity+explained#PPA304,M1; Internet; accessed 26 March 2009.

organizational studies, philosophy, sociology, and psychology to list but a few fields.[64] Complexity's potential is to aid in exploring and understanding some of the most pressing issues in the modern world, particularly those of a societal nature.

Complexity Theory in Context

Complexity arises from a system of systems. It resides between predictable equilibrium and impossible-to-predict chaos. Between these extremes reside a range of behaviours that scientists and theorists are only beginning to fully understand, but they do recognize them as important because they are proving to be more accurate models of reality. Complexity rests in the middle of the continuum of nonlinear systems, as shown in Figure 4.[65]

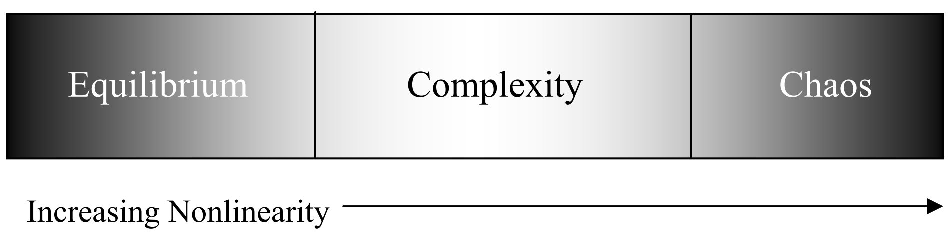

Figure 4 – Continuum of Nonlinear Systems

This continuum is a simplified portrayal of nonlinear systems. Any system that exhibits nonlinearity will show equilibrium, complex, or chaotic behaviour dependent

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[64] A good overview of how complexity theory is pervading the natural and social sciences can be seen at the University of Warwick's Complexity Complex. The site articulates doctoral-level, interdisciplinary projects that focus on using complexity theory to better understand patient care, financial markets, socio-economics, and several other fields of research. University of Warwick, "Complexity Complex," http://www2.warwick.ac.uk/fac/cross_fac/comcom?fromGo=http%3A%2F%2Fgo.warwick.ac.uk%2Fcomplexityscience Internet; accessed 5 April 2009.

[65] Marion, *The Edge of Organization*, 5.

upon the state. The transitions between the three modes are demarcated. A specific, discrete change in a variable triggers the transition. This may not be apparent with the continuum model. Although this is a conceptual limitation, the continuum model is an important building block in holistic understanding. In complexity theory, these continuums of nonlinearity nest inside each other, recursively. There is another means by which to portray their integration and transition between the modes - the bifurcation diagram.

The best means by which to demonstrate a complex system's recursive nature is through the visual modelling of a period doubling cascade. The first such "map" of complexity was produced by Robert May, an Australian working at Princeton, in the early 1970's.[66] He studied simple populations in a closed system using a modified exponential growth equation first developed by P.F. Verhulst in 1845, but he applied new computational power to the problem.[67] The equation was simple, but nonlinear, and incorporated positive feedback in every iteration. When depicted graphically as a period doubling cascade, or bifurcation diagram, the result is an epiphany.

Verhulst initially modelled populations using the equation $x_{n+1} = rx_n$ (x is colony size, n is the year, and r an arbitrary constant that determines how quickly the population grows each year). This is a strictly linear equation. Simple exponential growth equations work well for very small and dilute populations, but real world populations, like acoustical signals, do not grow unchecked. In the modified version of the equation, a

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[66] Robert M. May, "Simple Mathematical Models With Very Complicated Dynamics," in *The Theory of Chaotic Attractors,* eds. Brian R. Hunt et al., 85-93 (New York : Springer, 2004), 88; http://books.google.ca/books?id=8_U7vkF4z9UC&printsec=frontcover; Internet; accessed 25 January 2009.

[67] Briggs and Peat, *Turbulent Mirror…*, 56.

limiting term is added that normalizes the colony population to more accurately represent real-world growth, which is limited by environmental conditions. The modified version is $x_{n+1} = rx_n(1-x_n)$. The two factors on the right hand side of the equation work in opposition: one to increase the population, the other to limit it. More to the point, the latter factor creates nonlinearity in the system by multiplying x_n by itself. This equation has a host of applications ranging from acoustic signals to genealogy, where it is used to gauge the frequency of genes in a population.[68]

Using this equation May investigated different values of the parameter r. Results proved linear and predictable until the parameter passed the number three. There the equation began to cycle between two results – it actually gave one of two answers, one cycling after the other. Therefore at the growth rate (or birthrate) of “3” May determined that a wildlife colony would settle into one of two population. He continued to increase the parameter r, plotting the results on what came to be known as a bifurcation graph. Values of r are plotted on the horizontal axis. Final colony population (x_{n+1}) is plotted on the vertical axis. Increasing the parameter r pushes a system harder, in effect increasing its nonlinearity. As the parameter reaches “3,” equilibrium splits into two and the population alternates between two different levels. Thereafter, as the parameter increases, the splits, or bifurcations come faster and faster.[69] Figure 5 shows how changes to a single parameter could dramatically influence the behaviour of a simple system.

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[68] Briggs and Peat, *Turbulent Mirror…*, 57.

[69] Gleick, *Chaos…*, 70-71.

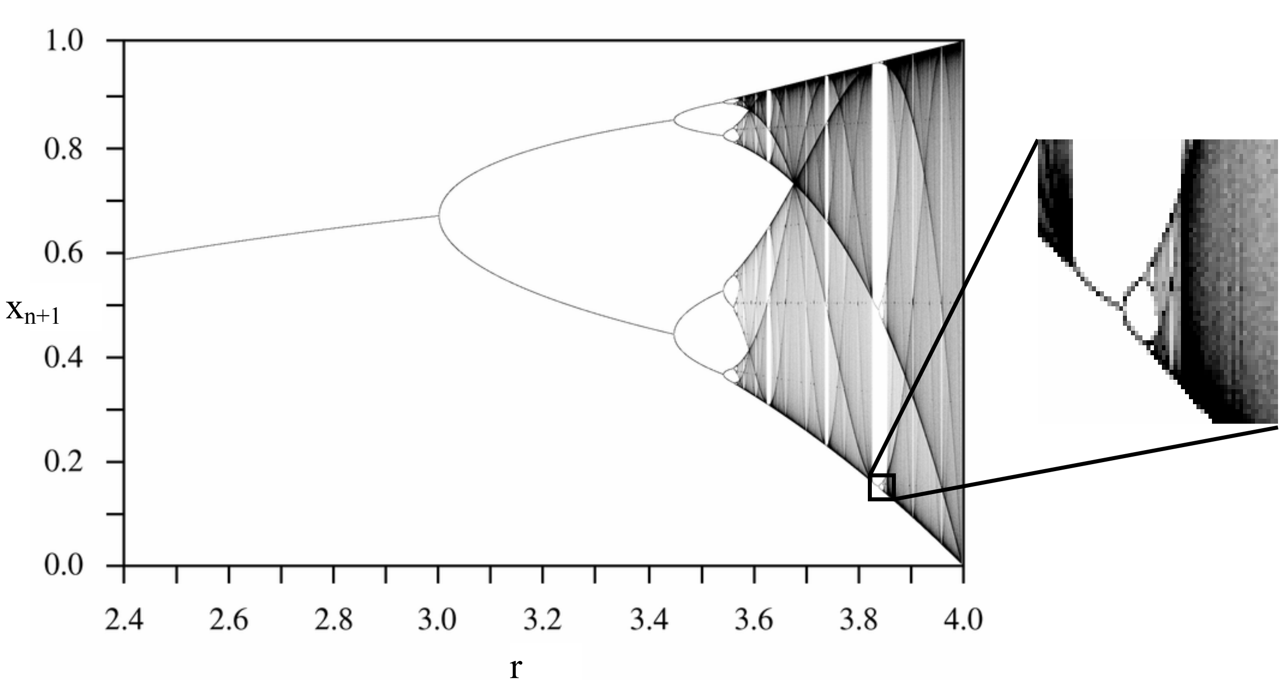

Figure 5 – Bifurcation Diagram for the Modified Exponential Growth Equation The insert shows the recursive nature of the pattern.

Source - http://en.wikipedia.org/wiki/File:LogisticMap_BifurcationDiagram.png; Intenet ; accessed 23 February 2009.

The modified exponential growth equation is a simple model, but it proves to have an intricate structure. The bifurcation produces periods of 2, 4, 8, 16 (corresponding to bifurcation 1, 2, 3, and 4 respectively), and then drops into chaos. But if the system is driven harder and the variable parameter increases continually beyond 3.8, "gaps" begin to appear in the chaos. They can be viewed as islands of order in a sea of disorder, where the system will behave linearly again, for a time.[70] Within this gap periodic behaviour returns and period-doubling begins again starting with period 3 and cascading to 6, 12, 24, and 48. If the diagram was magnified, these islands in chaos prove to be miniature

[70] John Urry, *Global Complexity*, 21.

replicas of the entire system. This pattern repeats at smaller and smaller scales, infinitely.[71]

It would be a mistake to consider a bifurcation diagram a "decision tree." What it truly represents is a system that has an "either-or" solution for the parameters in question. An example would be the flip of a coin. Only two solutions exist: heads or tails. The system is stable at either solution: it is highly improbable that coins will land on their edge.

Additionally, bifurcation diagrams do not represent time. To read one as if the horizontal axis represented time would lead to erroneous conclusions. Transition across the horizontal axis represents a change in state of the system. Such a transition is normally affected by a change resulting from a delta in resources or energy. The wildlife colony metaphor is again useful here: for the population to transition to a new state there needs to be an injection (or removal) of nutrients, that include the organic building blocks and energy necessary for the animals to increase (or decrease) their population.

How could complexity be relevant to security or war? As it turns out, it is very relevant. Alvin Saperstein has used very similar equations to create nonlinear models of nation-state arms races. Using simple rules such as: a nation increases its arms supplies based on what an adversary held the previous year; and the need to increase a nation's arms supply decreases as a nation fears its adversary less, Saperstein established modified exponential growth equations for a bipolar arms race. He took the study further, coupling the equation with others to generate tripolar models and eventually global models. He concluded what many political scientists arrive at intuitively: democracies yield a more

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[71] Gleick, *Chaos…*, 74.

stable global system; systems become more unstable as they depart from bipolar arrangements; and in unipolar situations, "nations combining their power in shifting alliances to balance the power of the dominant nation" represent more stable regimes.[72]

Even more applicable to strategy was the study conducted by Saperstein and Mayer-Kress using complexity to model the US Strategic Defense Initiative (SDI). In 1988, the US policy for strategic nuclear force was one of mutually assured destruction (MAD) and the intended transition to the purely defensive policy of SDI was a proposal of intense controversy. Study results indicated "a large instability associated with the transition to defensive mode" and in every scenario SDI did not improve the US relative advantage.[73] In fact, SDI would result in a more aggressive arms race. The conclusion, as peculiar as its sounds, was that the MAD, which represented a policy of deterrence, rather than SDI which represented a policy of protection was the most stable policy at the time.[74]

Theoretically, the injection or removal of energy and/or resources forces a system through the dynamic transition to another state. In the application of the operational art, this finding is important because it demonstrates how to leverage an adversary's system: removal of energy and resources will force an enemy into a linear realm, with decreasing options and predictable behaviours, thereby leading readily to defeat; conversely, the injection of energy or resources drives an enemy into chaos, where the cohesion essential

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[72] Alvin M. Saperstein, "War and Chaos," *American Scientist* 83, issue 6 (November 1995); Internet; http://proquest.umi.com/pqdlink?index=3&did=8693913&SrchMode=1&sid=1&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1232743333&clientId=13664; accessed 27 January 2009.

[73] Alvin M. Saperstein and Gottfried Mayer-Kress, "A Nonlinear Model of the Impact of SDI on the Arms Race," *Journal of Conflict Resolution* 32, no. 4, 636-670 (1988), 637.

[74] Ibid., 668.

to generate fighting power becomes untenable, rendering them vulnerable.[75] The trick is not to drive them too far into the realm of chaos: deep within that realm are islands, points of stability, that if an adversary can reach they will find more options available to them than they had before.

Why Bother With Complexity Theory?

Post-Newtonian nonlinear sciences and complexity theory in particular, are the paradigms underlying emerging socio-economic and technological trends.[76] The defining characteristic of this paradigm is that reality is more accurately represented as a networked system of systems.

This paradigm is not new. The North American natives understand its essence. In their spirituality nothing exists in and of itself. Everything is interrelated. They practise observational skills that permit them a level of awareness of the system in which the find themselves that is quite foreign to those educated in the linear-reductionism method.[77]

Asians too, the Chinese in particular, are well equipped to think naturally in terms of systems. Patterns of speech (which reflect patterns of thought) are indirect and nonlinear. Chinese written language for the most part consists of ideograms that facilitate

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[75] "Systemic Operational Design: Designing Campaigns and Operations to Disrupt a Rival System," Future Warfare Studies Division (Fort Monroe, Virginia), 13.

[76] Thomas Czerwinski, "The Third Wave: What the Tofflers Never Told You," *Strategic Forum* 72 (April 1996) [journal on-line] available from http://www.ndu.edu/inss/strforum/SF_72/forum72.html; Internet; accessed 17 February, 2009.

[77] Tom Brown, *Tom Brown's Field Guide to Living with the Earth* (New York: Berkley Books, 1984), 20.

nonlinear thinking.[78] Social psychologist Richard Nisbett describes the Asia schema best with an anecdote. In a discussion on cognition with a Chinese student (and later colleague), the student prompted:

> You know, the difference between you and me is that I think the world is a circle, and you think it is a line…the Chinese believe in constant change, but with things always moving back to some prior state. They pay attention to a wide range of events; they search for relationships between things; and they think you can't understand the part without understanding the whole. Westerners live in a simpler, more deterministic world; they focus on salient objects or people instead of the larger picture; and they think they can control events because they know the rules that govern the behaviour of objects.[79]

Asians and native North Americans "get" the nonlinear sciences. Westerners are only beginning to understand.

A beginning of a transition in thought towards a more nonlinear schema can be observed in the way Westerners think about their technology. An ideology is inherent in every technology, and the ideologies are merging to form a new paradigm.[80] Consider the ideology that comes with email, arguably the most pervasive form of communication in Western nations. Email is a single example of the shift in Westerners' thought towards a more network and system-oriented understanding of reality, but it serves as an appropriate one because it highlights that not all information system initiatives are linear

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[78] Alan Watts, *The Way of Zen* (New York: Random House, 1989), 9.

[79] Richard E. Nisbett, *The Geography of Thought: How Asians and Westerners Think Differently…and Why* (Toronto: Free Press, 2003), xiii.

[80] Neil Postman, *Technopoly: The Surrender of Culture to Technology* (New York: Vintage Books, 1993), 13.

in nature, their linearity can promote nonlinearity when used by networked, autonomous agents.[81]

Despite the fact that in some respects email reinforces hierarchy, it more pervasively facilitates networking than any other form of communication to date.[82] Although email was initially seen by ARPANET administrators and funders as an illegitimate use of computing resources, its facilitation of networking and information exchange was so effective that by 1973 email comprised 75% of all system traffic.[83] Email's use has proliferated until recently. It is only now being overtaken by mobile phones and purpose-built social networking software as the means of choice with which to network.[84] The idea of networked agents, that can initiate activities outside the control of the hierarchy, would have been unacceptable in militaries only 25 years ago. Although email encourages the recognition of the relationships between agents, it falls short of a comprehensive solution to facilitating systemic thinking and collaborative action.

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[81] This trend will accelerate leading to more complexity through increasingly effective (and efficient) forms of social networking such as will be provided by: better, cheaper cell phone coverage; text messaging; mobile Internet browsing; and mobile personal digital assistants. In fact, political activists in the Philippines have already used text messaging to mobilize during the overthrow of a regime. For more on this trend see Howard Rheingold, *Smart Mobs: The Next Social Revolution* (New York: Perseus Books, 2002), 1-28 and 157-158.

[82] Christine Beckman, "Email as an Escape to Reality in the Navy: How Technology Shapes Organizational Structure in Organizations," http://www.crito.uci.edu/consortium/iab/2006-06/beckmanSummary.pdf; Internet; accessed 19 March 2009.

[83] Ilkka Tuomi, *Networks of Innovation: Change and Meaning in the Age of the Internet* (New York: Oxford University, 2002), 139; http://books.google.com/books?id=A3gzVzFM50YC&pg=PA138&dq=email+networking&lr=#PPA139,M1; Internet; accessed 19 March 2009. ARPANET was the forerunner of the internet.

[84] Adam Ostrow, "Social Networking More Popular Than Email," *Mashable: The Social Media Guide* [On line media site], http://mashable.com/2009/03/09/social-networking-more-popular-than-email/ ; Internet; accessed 19 March 2009.

Policy makers are familiar with the idea that action takes place within a system, yet statesmen, scholars, commanders, and even the public tend to think in non-systemic terms.[85] One example of a response to complexity, typical of the US armed forces since Ulysses S. Grant, has been to deploy overwhelming force.[86] Overwhelming force is a linear response to a complex situation. By bringing enough people and resources to bear on a situation the expectation is that all factors of the problem can be controlled. The recent reluctance, or inability, of the United States to apply overwhelming force has permitted the complexity that has always been present to be made more visible.[87]

Complexity theory will significantly change policy decisions because it implies that no exact answer exists to the majority of the world's challenges and that decision makers must accept "the degree of precision that the nature of the subject admits, and not seek exactness when only approximation is possible."[88] Imagine how awareness of complexity theory could have changed World War I. The plan for mobilization was akin to the scenario posed by the introduction of SDI. "If the leaders of pre-WWI European states had recognized that the rail-road dominated mobilization of their troops was a source of great crisis instability perhaps they would have avoided starting – and being

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[85] Robert Jervis, "Complex Systems: The Role of Interactions," in *Complexity, Global Politics and National Security*, eds. David S. Alberts and Thomas Czerwinski 45-71 (Washington: National Defense University, 1997), 64.

[86] Alvin M. Saperstein, "Complexity, Chaos, and National Security Policy: Metaphors or Tools," in *Complexity, Global Politics and National Security*, eds. David S. Alberts and Thomas Czerwinski 101-133 (Washington: National Defense University, 1997), 118.

[87] Tim Reid and Michael Evans, "Rumsfeld Sent too Few Troops, Says Retired Generals," TimesOnline 26 March 2003 [news source on-line]; available from http://www.timesonline.co.uk/tol/news/world/iraq/article1058750.ece; Internet; accessed 7 April 2009.

[88] Aristotle, *Nicomachean Ethics* (Chicago: Britannia, 1993), 339.

trapped by – the process."[89] An understanding of how situations arise from complexity might not have permitted those nations to avoid the crisis altogether, but it would have permitted a better understanding of the implication of their actions.

An understanding of complexity theory is just as germane today. One of the prime reasons the US failed to deal successfully with Iraq after 1991 was that they feared to push a sovereign nation into chaos through elimination of its leadership. The US Administration demonstrated intuition of the complex dynamics in the situation by anticipating the regional catastrophes that could result, such as the breakup of the country.[90] In 2003, they took the step that pushed the country into instability and despite their best intentions an insurgency emerged. Consolation can be found in the nonlinear sciences - complexity theory posits that with the right conditions a new, stable order will arise from the chaos that is presently Iraq.

Expect to see an increasing awareness of complexity in the future. The irony of Western nations attempting to deal with complexity is that that they are actually creating more of it. Numerous policies and programs accelerate societal complexity such as: democracy, free markets, rapid transportation, and pervasive personal communication (allowing somebody to talk to anybody, anywhere, anytime).[91] All serve to create more feedback and hence more nonlinearity. All contribute to increasing complexity in Western society.

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[89] Saperstein, "Complexity, Chaos, and National Security Policy: Metaphors or Tools," 124.

[90] Ibid., 103.

[91] Steven R. Mann, "The Reaction to Chaos," in *Complexity, Global Politics and National Security*, eds. David S. Alberts and Thomas Czerwinski 135-149, (Washington: National Defense University, 1997), 148-149.

This trend has implications of which practitioners of war need to be aware. Computers have a place in supporting military operations in highly structured, yet simple, situations, but because of the dominance of the machine in simpler environments the trend has been for adversaries of the West to migrate warfare from technology-dominated conventional warfare to the low-intensity end of the spectrum of conflict.[92]

Where the outcome of warfare can be calculated in advance it does not serve the ends of all belligerents. The situation is analogous to competitive sport: short of the health benefits, there is not much point in engaging in the sport if the outcome is already set. The decision to engage in war demands that at least one of the rivals believes there is ambiguity or uncertainty in the outcome; this is usually the underdog. The result is a trend toward the more human-oriented, and hence complex, insurgency.

The increase in situational complexity makes complexity theory's application to warfare all the more applicable. In the contemporary operating environment the adversary's strategic, operational, and tactical interest lies in shifting with agility through the continuum of nonlinearity, searching for an advantage. Understanding what options are available to the adversary; what is truly possible within the state space facilitates commanders anticipating an adversary's options and how to influence the points of leverage.[93] A firm comprehension of complexity will enable commanders to understand the bounds to what once may have seemed an intractable problem.[94]

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[92] Martin van Creveld, *The Transformation of War* (New York: Free Press, 1991), 173. The spectrum of conflict as defined by Canadian Forces doctrine can be found in Department of National Defence, B-GJ-005-300/FP-000 *Canadian Forces Operations* (Ottawa: DND Canada, 2005), 1-4.

[93] Smith, *Complexity, Networking and Effects Based Approaches to Operations*, 26.

[94] Rosenau, "Many Damn Things Simultaneously: Complexity Theory in World Affairs," 74.

Complexity theory is but a theory, and must not be mistaken for reality. Arguably, it is much more advantageous to employ a more accurate paradigm such as complexity theory than one which is limited such as linear reductionism. [95] Complexity theory promises to describe reality more accurately in appropriate terms, resulting in deeper understanding of conflict and the military's place in it.[96] Heinz Pagels sums up the importance of complexity in *The Dreams of Reason*: "I am convinced that the nations and people who master the new sciences of complexity…will become the cultural, economic, and military superpowers of the next century."[97] Is there any more compelling reason for which Western militaries should pursue an understanding of complexity?

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[95]John Lukacs, *At the End of an Age* (New Haven: Yale University, 2002), 113.

[96] Peak and Frame, *Chaos Under Control*…, 3.

[97] Pagels, *The Dreams of Reason*…, 53.

COMPLEX ADAPTIVE SYSTEMS

At the heart of complexity theory is the complex adaptive system. Adam Smith's *Wealth of Nations* was possibly the earliest, coherent description of a complex adaptive system. In it he introduced the idea of the "invisible hand."[98] Smith's work has been one of the prime drivers of economic theory in the last two centuries, but despite the theory's considerable progress the mechanism of the invisible hand has remained, invisible. The concept behind the metaphor is that an unseen and unknown force guides groups of self-interested agents towards coherent behaviours and into well-formed structures that are not the part of any single agent's intention.[99] As demonstrated by Smith's invisible hand, complex adaptive systems are important social constructs that impact our lives and must be examined, if not understood.

Complex adaptive systems are a special category of complex systems. Like complex systems, they exhibit lever points, where small inputs can result in disproportionate, yet directed, change. They are distinguished from complex systems by their numerous and diverse agents (or components), the responsive linkages between them, and their ability to adapt to their surroundings.[100] They are distinct in that they exhibit coherence under change through conditional actions and anticipation – in effect they "learn." [101]

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[98] Adam Smith, *Wealth of Nations* (New York: Random House, 1991), 288. Original published 1776.

[99] Miller and Page, *Complex Adaptive Systems…*, 4.

[100] Rosenau, "Many Damn Things Simultaneously…," 82.

[101] John Holland, *Hidden Order: How Adaption Builds Complexity* (New York: Basic Books, 1995), 38-39.

Complex adaptive systems exhibit properties and mechanisms by which they operate. These include: nonlinearity, flows, diversity, and emergence. Used earlier to aide in understanding complexity, nonlinearity is additionally the first property of complex adaptive systems. Having already been discussed in detail, it will not be elaborated upon further. Rather a discussion of the properties of complex adaptive systems will begin with *flows*.

Flows

The second property of complex adaptive systems is flows. Connotatively, flows bring to mind the movement of fluids along a path or conduit. Much the same is implied in the complex adaptive system context, but in a more sophisticated sense. Flow should be thought of as resources moving over a network of nodes and connectors.[102] This simple triad of resource, node and connector is the building block of complex adaptive systems. Nodes are processors, or agents, that add value to the resource. Connectors are the possible interactions that develop or atrophy as the system adapts.[103]

Flows can exhibit two unique effects. The first of these is the multiplier effect, exhibited when additional resources are injected into a node. The resource passes from node to node, being transformed along the way.[104] A simple example of the multiplier

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[102] Holland, *Hidden Order*…, 23. John Holland is an associate faculty member at the Santa Fe Institute, the leading edge research facility for inter-disciplinary studies of complexity in North America. A professor of both psychology and electrical engineering he, in cooperation with Murray Gell-Mann, coined the term *complex adaptive systems*. He has proposed properties of complex adaptive systems that remain relatively unchallenged by other theorists. Although risking bias towards one author, Holland will be cited almost exclusively in the following three sections as his work on the properties of complex adaptive systems appears to be definitive.

[103] Ibid., 23.

[104] Ibid., 24.

effect can be made from a terrorist agent, terrorist transaction, and money triad. Terrorist financiers provide funds to terrorist fundraisers, who provide funds to terrorist leaders, who provide funds to regional leaders, who provide funding to terrorist cells. At each stage, agents would need to retain some of the funding for the continuation of their personal operations and sustenance. The remainder would be passed on to the next agent. If each agent retains only 10% of the money and passes 90% ($x = 0.9$) of the money on, despite the diminishing amount of funds, a multiplying effect ripples through the network. If the financier provides $1 to a fundraiser, the fundraiser passes on only 90% of the funds received or x. The regional leader would therefore receive funds in the amount of x^2 and the cell would only receive x^3. The effect can be modelled by the equation:

$$y(x) = 1 + x + x^2 + x^3\ldots$$

With only 90% of the funding passed on to the next level, a multiplier effect of 3.44 results.[105] This does not imply that the value of the money is increasing as it is passed, but rather that the original dollar from the financier can leverage the system over three times. The flow of money makes for a mathematical example of the multiplier

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[105] The numerical solution is 1 + 1(0.9) + (0.9)(0.9) + (0.81)(0.9) = 3.44. This is another version of a "spending multiplier." As fiscal policy, the idea is that money injected into an economy by the government leads to a greater increase in national income than the initial amount spent. This is because the gross domestic product is the sum of the increases in the net income of everyone. This phenomenon is exploited by militaries seeking to jump-start development in war-torn countries: contractors are hired rather than having the military perform the work themselves. Contractors use a percentage of the money to hire sub-contractors, and so on. The money makes its way through a network of employees and clients until it is spent on final consumer goods. In the end, the money has a more far-reaching effect than that of its face value, despite the fact that it "diminishes" as each individual retains a portion of it. For further elaboration see Wikipedia, "Spending Multiplier," http://en.wikipedia.org/wiki/Multiplier_effect; Internet; accessed 7 April 2007.

effect, but the same effect is achieved by the flow of resources such as information or material. The multiplier effect is normally found when major changes occur or inputs are forced upon a complex adaptive system, and it is what makes long-term projection impossible.[106]

Another attribute of flows is the recycling effect. The recycling effect is a result of cycles in the networks.[107] Recycling has a strong connotation in modern society, but the meaning is effectively the same here: resources flowing through the nodes and connectors of a system are reused. A fish pond metaphor is useful in this instance. The energy from sunlight results in plant growth that initiates a pyramid of predators that pass the nutrients up. Eventually, all the predators die, becoming the basis of the nutrients for plant life. Cycle upon cycle within this web of systems traps and recycles the limited resources of the pond. From these cycles diverse species can thrive within the pond. Anyone who has participated in brass clean up duty after attending a range can attest to the recycling effect at work within the military.

The behaviour of agents is influenced by the resources at its disposal. For example if a country has created a new weapon, its military will evolve to take advantage of the unique capabilities the new weapon has to offer.[108] This serves as an example of how a military deals with a new resource, but an additional property is at work here that prompts the evolution – diversity.

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[106] Holland, *Hidden Order*…, 25.

[107] Ibid., 25.

[108] Robert R. Maxfield, "Complexity and Organization Management," in *Complexity, Global Politics and National Security*, eds. David S. Alberts and Thomas Czerwinski 171-218, (Washington: National Defense University, 1997), 176.

Diversity

The third property of a complex adaptive system is diversity, and diversity is neither accidental nor random.[109] The mental image that results from thinking of a complex adaptive system as a network of nodes and connectors is a web of homogenous elements or agents that are interchangeable and optimized for their roles. Reality is considerably different. If a complex adaptive system was based on such an interconnection of self-similar nodes, stagnation or equilibrium would result.[110] Imagine a pond ecosystem consisting of a single species of fish. An input that kills one fish, i.e. a virus, may shock the entire system into extinction. Complex adaptive systems consist rather of niches occupied by agents. Agents can lose their stability in an environment (or with other agents) and the result is a "hole" in the system. Typically, this hole is filled through a cascading effect: a cascade of subordinate adaptations that results in a new superordinate.[111] The new agent is similar enough to the old to return the system to stability, but different enough that it is recognized as distinct. All such heterogeneous agents are periodically replaced. Therefore, diversity is a dynamic pattern that is persistent in complex adaptive systems: in effect, complex adaptive systems "evolve."[112]

Diversity and evolution are manifest in militaries in the form of personnel changeover. Although a rigid hierarchical bureaucracy, an armed force is not a steady-state organization. Disregarding directed organizational change momentarily, military positions remain relatively stable, but the people transitioning through them change quite

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[109] Holland, *Hidden Order*…, 27.

[110] Czerwinski, *Coping with the Bounds*…, 19.

[111] Ibid., 19.

[112] Holland, *Hidden Order*…, 29.

frequently. Personnel will leave for various reasons: retirement; completion of contract; and family, health or administrative reasons to name but a few. Effectively, their stability as agents in the armed force has changed and they leave a vacancy behind them. These vacancies are filled, through a cascading effect. Members get promoted; individuals accept appointments; careers proceed. This cascade is fed by recruiting. The recruits bring new values, nuances of culture, and generational differences that are within the bounds of acceptability to the organization. Despite the similarities that resulted in their self-selection, the recruits are heterogeneous, and sufficiently different that they bring diversity to the system. These recruits-cum-agents move through the cascade of the personnel management system, filling vacated niches, until the entire system has replaced itself. Theoretically, the Canadian Forces may be undergoing "evolution" on a 35 year cycle, or a period corresponding with the longest contracted service period. This possibility of an evolutionary cycle in militaries is a phenomenon that requires further research.

Emergence

The final property to be discussed is emergence and it concerns the behaviours that complex adaptive systems exhibit. Complex adaptive system behaviour is unique because of its non-additivity – the observed behaviour is not the sum behaviour of the agents, it is much more. Emergence is the demonstration of "complex, large-scale behaviours from the aggregate interactions of less complex agents."[113] The concept of emergence can be somewhat elusive, and possibly the best means by which to demonstrate the property is in non-systemic terms; after all, a similar phenomenon exists

[113] Holland, *Hidden Order…*, 11.

in chemistry. Take for example the element hydrogen: if hydrogen is added to a fire the effect is quite dramatic, as was seen in the Hindenburg incident of 1937 - the dirigible caught fire and burned violently. Another element that exhibits as dramatic a reaction in the presence of fire is oxygen. The combination of oxygen and flame is so powerful that it is used by welders to cut steel. Yet, when hydrogen and oxygen are chemically combined in the right proportions, they exhibit a property that could not be foreseen prior to their combination - the ability to extinguish fire. This is emergence: the realization of a new property that could not have been anticipated from the characteristics of the components, agents, or sub-systems.

Emergence arises from aggregation and militaries manage this aspect of complex adaptive systems through hierarchy. An army consists of companies that form battalions, which form brigades, which form divisions, which form corps. Comparable aggregation occurs in the Navy and Air Force. Aggregation does not imply that complex adaptive systems are hierarchies. In fact, the opposite is true. Hierarchies are imposed on potential complex adaptive systems to impart a degree of control from a central authority, much like a form of negative feedback.[114] Similar processes occur in natural, economic, and social milieus: ants aggregate to form nests that behave like intelligent organism made of unintelligent agents; economies behave in specific ways based on the aggregation of millions of independent actions of economic agents; and self-interested individuals aggregate to form societies. Arguably, if control is too authoritarian, the initiative and freedom of action of social agents could be suppressed or damped enough to prevent the positive aspects of emergence.

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[114] Stanley N. Salthe, "Summary of the Principles of Hierarchy Theory," http://www.nbi.dk/~natphil/salthe/Summary_of_the_Principles_o.pdf ; Internet; accessed 30 March 2009.

Emergence has the potential to contribute significantly to military effectiveness. Williamson Murray has made a case that the inability of the Germans and Japanese to develop comprehensive joint operations may have contributed to their defeat in World War II. Germany demonstrated the ability to cooperate comprehensively at the tactical level, with devastating consequences for their adversaries.[115] In contrast, they exhibited no joint strategy or joint operational concepts. Their Armed Forces High Command was nothing but an administrative staff to the Fuehrer.[116] The Japanese did little better with their Imperial Army and Navy waging separate wars until 1944.[117] The Allies conducted operations on another level. The British possessed the only joint high command in the interwar years and later the Casablanca Conference of 1943 resulted in the Allies establishing a Joint Chiefs of Staff and an approach that stressed "jointness" at the operational level.[118] Arguably, establishing jointness is evidence of an emergent behaviour of armed forces and is indicative of the part emergence can play in victory.

A system can be reduced to the simple rules that define it, yet the behaviour it generates is not easily predicted from the analysis of those rules.[119] In mathematical models of complexity, the rules are easily discerned. The same is not true in socially complex systems, but they exist nevertheless, and can be intuitively derived by agents within the system.

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[115] Richard Hooker and Christopher Coglianese, "Operation Weserübung and the Origins of Joint Warfare," *Joint Force Quarterly* 1 (Summer 1993): 100.

[116] Williamson Murray, "The Evolution of Joint Warfare," *Joint Force Quarterly* no. 31 (Summer 2002): 34.

[117] Ibid., 34.

[118] Ibid., 33-34.

[119] Holland, *Emergence…*, 5. A similar argument is made by Murray Gell-Mann, *The Quark and the Jaguar* (New York: Holt, 1994), 99-100. Only a few simple rules are required to generate emergence.

Simple rules will define the interactions of a system exhibiting complexity; how simple the rules can be is surprising. In relating her story of circumnavigation, Dr. Alayne Main describes coming up on deck as her husband piloted their boat into Hong Kong's Victoria Harbour and the shock of finding oneself unwittingly in a new complex adaptive system. She was overwhelmed by the apparent pandemonium as other vessels in apparent disregard for each other's size, speed, or safety whipped by frantically. From her viewpoint there was no logic to how so many vessels could operate in the harbour at the same time without catastrophe. She asked her husband how he was managing to steer safely through the chaos. His response was that he had discovered a simple rule as their catamaran had approached the harbour: steer directly at another vessel, and by the time you reached its present location, it would have moved on.[120] By following this simple generalization the couple made their way safely to port. More germane to the case at hand, her husband had intuitively stumbled on the fact that every other pilot in the harbour was applying the same guideline. This is an example of how great complexity can be generated from the application of a single, simple regulating principle applied among innumerable agents to enable their successful and mutually beneficial cooperation.

As was demonstrated by Dr. Main's anecdote, the agents of the system are the generators of emergence rather than an overseer.[121] The most surprising characteristic of emergence is that the agents act without central control. There is no guide book for entering Victoria Harbour, nor is there a briefing by a harbour master, yet all the vessels

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[120] Alayne Main, *Sailing Promise* (Tecumseh, Ontario: Base Camp, 1999), 122.

[121] Holland, *Emergence…*, 5.

cooperate to maximize the capacity of the harbour and do so safely. This phenomenon persists despite the transitory nature of the users of the harbour, which highlights another aspect of emergence: it usually involves patterns of interaction that persist despite a continual turnover of the constituents.[122] Examples exist in nature such as the standing waves that develop in front of a rock in a white-water river, cities, or standing armies. Like the water molecules in a standing wave, individuals are agents in "standing" social organizations for a time, and then they move on.

It is not the number of agents that predetermines emergence; more important is the nature of their connections. Seemingly counter intuitive, the possibilities for emergence increase as the flexibility of the interactions between agents increase.[123] For example, consciousness does not emerge from brain cells. The idea of dissecting a brain to find a mind is ludicrous. No single neuron can "think." Emergence points to intelligence arising from the connections between neurons.[124] Therein lays the intent of subscribing to philosophies such as mission command. By permitting subordinate agents more freedom of action and latitude to adapt to their environment, the chain of command hopes to benefit from the emergent potential of more flexible interconnections between subordinates. Mutual trust throughout the chain of command was a tenet of the German Army at the outset of World War II, and one that served them well in becoming more than just another continental army. Their *Truppenführung* (Tactical Command) field manual emphasized how such trust contributed to freedom of action at all levels, which

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[122] Peter Corning, "The Re-emergence of 'Emergence': A Venerable Concept in Search of a Theory," *Complexity* 7, no. 6 (2002): 10-11; http://www.complexsystems.org/publications/pdf/emergence3.pdf; Internet; accessed 3 March 2009.

[123] Holland, *Emergence…*, 5.

[124] Pagels, *The Dreams of Reason…*, 215.

enabled *auftragstaktik*: "The emptiness of the battlefield requires soldiers who can think and act independently, who can make calculated, decisive, and daring use of every situation, and who understand that victory depends on each individual."[125] What emerged was *blitzkrieg*, a highly effective tactic that allowed them to run roughshod over other European continental armies.

Emergence, by its very nature is more than the sum of its parts. It is a phenomenon that cannot be predicted or anticipated. It derives from simple rules. When it is persistent, it can serve as a component of more complex emergent phenomena. Similar to audio feedback, emergence does not grow unchecked: when it is present, there is a mechanism for freely generating possibilities, coupled to a set of constraints that limit those possibilities.[126]

Emergence quite literally unleashes unforeseen (and unpredictable) capabilities. As critical as well trained personnel, ready equipment, comprehensive doctrine, and inspirational leadership are to a military, emergence too has a role to play in the dominion of the battlespace. It is important for commanders to understand its nature so as to succeed by it rather than succumb to it.

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[125] Heer, Obercommando, *On the German Art of War:* Truppenführung, ed. and trans. Bruce Cordell and David T. Zabecki (Boulder: Lynne Reinner Publishing, 2001), 18.

[126] Holland, *Emergence…*, 122. For example, limits exist on even the possibilities of mission command. In an age of theatre-wide, joint operations it will be virtually impossible to permit the sort of freedom necessary to allow the full expression of mission command simply because no organization will invest the requisite level of trust in the idea. By 1942, *aufstragtaktik* had disappeared from the operations of the Wehrmacht for this reason, despite being a tradition within the German armed forces dating back to Frederick the Great; see Robert M. Citino, *The German Way of War: From the Thirty Years' War to the Third Reich* (Lawrence, Kansas: Kansas University Press, 2005), 302-303.

The Human as a Complex Adaptive System

Without having stated so, the fact that a human is a complex adaptive system is obvious. Consisting of persistent, lower-order complex adaptive systems (such as the nervous system, endocrine systems, the respiratory system…), the human is but a component of many other higher order systems such as families, cities, or militaries.[127] What is not so apparent is how well-evolved a human is to function in these nested systems of systems.

A human consists of feedback systems of a calibre that science cannot yet reproduce. The most extraordinary example is that of consciousness, already discussed, but humans are additionally animated by physical feedback. The soldier typically functions with several feedback mechanisms operating concurrently. Consider a soldier in a fire fight: she has to run, track a moving target, fire a rifle, monitor a radio, and issue commands to her fire team all while maintaining nonconscious control of regulatory body functions. This level of integration and control is nothing short of remarkable. Some theorists attest that humans, and in particular the human mind, may be the most complex objects in the known universe.[128]

The human mind is a complex adaptive system that will never be reduced. Because of the mind's inherent complexity, the laws of physics do not apply.[129] A few examples are in order here. First, mind does not abide by the natural sciences and linear reductionism. When a box is full, it becomes more and more difficult to place anything

[127] Maxfield, "Complexity and Organization Management," 176.

[128] George Johnson, "Researchers on Complexity Ponder What It's All About," *New York Times*, 6 May 1997, C7.

[129] Lukacs, *At the End of an Age,* 113.

into it, until a point where not another item can be physically wedged in it. Conversely, the more a human mind knows, the easier for it to assimilate new knowledge.[130] In fact, research in cognitive psychology has demonstrated that the human capacity to store lexical items in long-term memory is virtually unlimited.[131]

Second, the human mind is unbound by cause-and-effect relationships.[132] Cause-and-effect relationships apply to linear systems such as the human body: excessive stresses cause lacerations and fractures, diseases cause organs to fail, and chemicals can ameliorate or worsen the situation. Being nonlinear, the mind is capable of more unusual and unanticipated feats, particularly with respect to perception. Scientists have proven that perception sometimes not only occurs simultaneously with sensation, but actually precedes it.[133]

Consider the following study: in the mid-1990's experiments at the University of Nevada demonstrated that a subject's emotional arousal could precede a triggering event. Under experimental conditions the change of an individual's emotional state can be detected through galvanic skin conductance. As a person's emotional state changes, so does the activity of sweat glands, which results in a changes in electro-dermal conductance. By using noxious smells, emotive words, mild electric shocks, sudden tactile stimulus, or provocative photographs emotional states can be altered and

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[130] Ibid., 136.

[131] R.A. Bjork and E.L. Bjork, "A New Theory of Disuse and an Old Theory of Stimulus Fluctuation," in *From Learning Process to Cognitive Processes: Essays in Honor of William K. Estes*, editors A.F. Healy, S.M. Kosslyn and R.M. Shiffrin, 35-67 (Hillsdale, NJ: Erlbaum, 1992), cited in Marilyn A. Nippold and Jill K. Duthie, "Mental Imagery and Idiom Comprehension: A Comparison of School-Age Children and Adults," *Journal of Speech, Language, and Hearing Research* 46, no. 4 (Aug 2003): 788.

[132] Lukacs, *At the End of an Age*, 114.

[133] Ibid., 116.

consequently measured by galvanic skin response. The University of Nevada experiments were conducted by Dean Radin, who used images to manipulate emotional states. The majority of the images were "calming," neutral images of seascapes or landscapes that served as control. Other images were quite shocking to a normal person and included pornography or graphic photos of corpses. Subjects were attached to an automated galvanic skin response detector and subjected to images selected randomly by computer. When the computer was activated, it remained blank for five seconds, displayed the image for three seconds, and then remained blank for another five seconds – all the time monitoring arousal levels of the subject. The trial then recommenced whenever the subject was ready, and activated the terminal to reinitiate the cycle.

The results from calming images were to be expected: calm images resulted in calm subjects. The interesting results of the study occurred whenever emotionally charged images were used. When an extreme image was about to appear, the subject registered arousal *before* the picture actually appeared. Typically, emotional arousal was demonstrated up to two seconds prior to the display of the image.[134] This is not science fiction or an extract from an *X-Files* episode; this was a scientifically rigorous experiment. Researchers at the University of Amsterdam have replicated these results and refined them with the finding that erotic images resulted in higher levels of arousal than did violent images.[135] The intent here is not to introduce seemingly quirky or

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[134] Dean Radin, "Unconscious Perception of Future Emotions: An Experiment in Presentiment," in the *Journal of Scientific Exploration* 11, no. 2, 163-180 (1997), 166-169. The experiment was expanded upon in Dean Radin, "Electrodermal Presentiment of Future Emotions," in the *Journal of Scientific Exploration* 18, no. 2, 253-273 (2004).

[135] Dick J, Bierman and Dean Radin, "Conscious and Anomalous Emotional Processes: A Reversal of the Arrow of Time?" in *Towards a Science of Consciousness III: The Third Tucson*

supernatural phenomena, but rather to illustrate that cause-and-effect relationships do not constrain the functioning of the human mind.

Scientists do not fully understand reality, and in particular they do not fully understand the human mind. Despite our minds not understanding themselves, they are appropriately equipped to deal with their environment, particularly one that consists of nested complex adaptive systems. In fact, they may be the only tools so well equipped to do so. This possibility is investigated in the next section.

Discussions and Debates, eds. Stuart R. Hameroff, Alfred W. Kaszniak, and David John Chalmers, 367-385 (Cambridge: MIT Press, 1999), 373.

THE CHALLENGE OF COMPLEXITY

Presently, complexity in warfare is being addressed with the same systems that facilitated its discovery: information systems. At an intuitive level, this seems appropriate, but computers and machines are limited in their ability to assist with the social aspects of complexity. Once those limits are reached, only a human acting as an agent (a free-willed, autonomous decision maker and problem solver) demonstrates the capability to cope with complexity beyond the thresholds of digital solutions.

The Limits of Technology

Of social phenomena, warfare is arguably the most unforgiving for those who fail to cope with it. Consequently, militaries have long sought the means to control the unpredictability of war. One approach to its complexity has been to attempt to control as many variables as possible, the philosophy being - control the small things and the big things will look after themselves. Western nations, particularly those within the North Atlantic Treaty Organization (NATO), have pursued this end primarily through advanced technologies. High-calibre training and high-tech equipments were adopted by NATO to offset Soviet numerical advantages, and this philosophy continues today.[136] The effect to be achieved was one of force *multiplication*, where a Soviet soldier would be overmatched by a NATO soldier who was better trained and equipped.[137] While many

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[136] Michael Sheehan, *The Balance of Power in the Nuclear* Era (New York: Routledge, 1996), 181.

[137] The term "force multiplier" is not defined in NATO, AAP-6(V) *Glossary of Terms and Definitions*, http://www.dtic.mil/doctrine/jel/other_pubs/aap_6v.pdf; Internet; accessed 15 March 2009. It is defined in Wikipedia, "Force Multiplier," http://en.wikipedia.org/wiki/Force_multiplier; Internet; accessed 15 March 2009, as "a factor that dramatically increases the effectiveness of an item or group." In a military context it renders a combat force more effective than an adversary.

efforts continue to increase the effectiveness of troops in combat, advanced technologies are touted as the capability that will most contribute to Western hegemony on the modern battlefield. This is the fundamental premise underlying the recent initiatives from Allied Command Transformation with respect to information technologies: by applying new technologies, more variables than ever before can be controlled leading to more predictable outcomes in warfare.[138] This plays well to the need for stability in the military mind, but regardless of the promises of technology, such solutions will not be capable of addressing the human factor sufficiently to render war predictable.

By the mid 1990's theorists proposed that large, world-scale conflicts could no longer be fought. They argued that the Persian Gulf War in 1991 demonstrated that situational awareness had become so accurate and conventional weapons had become so powerful that human beings could no longer survive on the contemporary battlefield.[139] Surely the Western nations' aspirations in technology were realized?

NATO's Kosovo campaign challenged the belief that information technologies would culminate in omniscience. Against state-of-the-art, precision-strike weapons, and situational awareness unlike anything the world had seen previously, cover and concealment won out. The nearly unopposed air campaign could not assure the annihilation required to defeat a defending army without a major ground offensive.[140]

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[138] NATO, Allied Command Transformation, "The Decision Wall and TIDE: Information Technology as a Force Multiplier," http://transnet.act.nato.int/WISE/BRITE/Trifoldsfo/Technology/file/_WFS/RIGA%20for%20TCB.pdf; Internet; accessed 15 march 2009.

[139] Bevin Alexander, *How Wars Are Won: The 13 Rules of War from Ancient Greece to the War on Terror* (New York: Three Rivers Press, 2002), 3.

Progress was being made, but understanding was lacking with respect to the limitations of information technologies. Information is critical to the safety and effectiveness of military forces, of that there is no doubt.[141] The challenge is in using information to make decisions: the information must be placed in context.[142] Although machines and information technologies will remain relevant in future war, they are incapable of placing digitized information in context.

Man versus Machine

Invariably the argument arises that, in the future, there will be more appropriate means for solving problems and making decisions in the battlespace. Most of these arguments are founded on the promise of artificial intelligence. "Artificial intelligence comprises the methods, tools, and systems for solving problems that normally require the intelligence of humans."[143] The promise of machine intelligence is worth investigating because it highlights the ultimate limitation of technology in dealing with human-generated complexity. Artificial intelligence, in its current manifestation, is about

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[140] Stephen Biddle, "Land Warfare: Theory and Practice," in *Strategy and the Contemporary Word: An Introduction to Strategic Studies*, eds. John Baylis, James Wirtz, Eliot Cohen and Colin S. Gray, 92-110 (Oxford: Oxford University Press, 2002), 109.

[141] Loch K. Johnson, "Technology, Intelligence and the Information Stream: The Executive Branch and national security Decision Making," in Information Age Anthology: National Security Implications of the Information Age, eds. David S. Alberts and Daniel S. Papp, 179-212 (Washington: CCRP, 2000), 179.

[142] Efforts are being made to do so through the "semantic web" projects. A computer cannot accomplish the same tasks as a human using the world wide web because it is designed to be read by humans, not machines. Semantic web is an initiative to make the information of the web more understandable by computers so that they can perform more tedious tasks of dealing with information on the web for humans. This an example of how considerable the task is of enabling information systems to deal with context-laden situations and how focused efforts must be. Wikipedia, "Semantic Web," http://en.wikipedia.org/wiki/Semantic_Web#Need; Internet; accessed 7 Apr 2009.

[143] Nikola K. Kasabov, *Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering* (Cambridge: MIT Press, 1998), 1.

creating a simulacrum of the human brain. There is an underlying assumption in this pursuit that the brain is mind: it is not. Digital or artificial "brains" may be created in the future, but the human mind has functions that cannot be replicated by science.[144]

Cognition is the aspect of mind that serves as the model for development of artificial intelligence. Cognition is knowing and understanding. It includes encoding, storing, processing, reasoning, judging, and remembering.[145] It makes available some of the most unique human mental processes such as abstraction, metaphor, rationalization, and theorization. It is the primary component by which humans solve problems. But mind consist of more than just cognition. Mind is generally recognized to have three components: cognition, affect, and conation.[146]

Affect is the emotional component of mind. It refers to the emotional interpretation of perceptions, information, or knowledge.[147] Affect encompasses processes associated with emotion and arousal and can influence the salience of information with which it is associated.[148]

Conation is the proactive, as opposed to habitual, part of motivation. It is the behavioural basis of attitudes and is characterized by volition or self-activation toward a

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[144] Lukacs, *At the End of an Age*, 136.

[145] W. Huitt, "Conation as an Important Factor of Mind," *Educational Psychology Interactive*, http://chiron.valdosta.edu/whuitt/col/regsys/conation.html; Internet; accessed 29 January 2009.

[146] *The American Psychological Association Dictionary of Psychology.* 2007 edition, s.v. "components of mind."

[147] Huitt, "Conation as an Important Factor of Mind," http://chiron.valdosta.edu/whuitt/col/regsys/conation.html.

[148] Examples of the role of emotion in "affect-laden" contexts can be found in Yeun Foong Khong, *Analogies at War: Korea, Munich, Dien Bien Phu, and the Vietnam Decisions of 1965* (Princeton: Princeton University Press, 1992), 225-226.

goal.[149] An appropriate synonym is "will." Conation remains elusive to empirical study, but it is considered to mediate the executive mental processes connecting deliberation and voluntary body movements and deliberate mental activities such as speaking silently to oneself or searching in a mental image.[150] Its processes may include a significant moral component. In effect, it connects thought with action.

Psychologists cannot point to where cognition ends and affect and conation begin. Nor can they quantify the overlap of the components of mind. None of these aspects are independent, yet in the pursuit of artificial intelligence, scientists model only one of them. In operating together cognition, emotion, and volition enable humans to excel in the realm of complexity.

Fuzzy logic, which permits algorithms to deal with qualitative data, is demonstrating promise in simulating the cognitive component of mind, but emotion and volition are impossible to model with current technologies.[151] Could they modeled with future technology? Yes, likely. Assuming that they would be impossible to replicate in the unknowable future is unreasonable, but efforts to simulate them are likely to result in computers that are more unwieldy than a human brain. Even if in the far future the biophysical mechanism of the brain is scientifically reduced, its complexity will prove to be unsimulatable: the simplest system that will be capable of simulating a mind will be

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[149] *The American Psychological Association Dictionary of Psychology.* 2007 edition, s.v. "conation."

[150] Jing Zhu, "Understanding Volition," Philosophical *Psychology* 17, no. 2 (June 2004): 248.

[151] Kasabov, *Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering*, 16. Fuzzy variables and values are those for which Boolean logic do not have simple TRUE/FALSE answers. A fuzzy value might be "cold," "far," "high," or "very high." These values are more qualitative in nature and not readily dealt with by binary machines.

the mind itself.[152] But there remain other means by which an artificial "mind" could be brought to bear on the problem of battlespace complexity.

When the achievement of "mind" is not possible, another alternative is attaining perfect knowledge.[153] Perfect knowledge is more amenable to the sensor suites and computer systems of today, but it too has limits. The difficulty in achieving perfect knowledge is apparent in the recent "solution" of checkers. A relatively simple game, played on an eight-by-eight square board with 12 pieces per side, checkers generates 500 billion billion (5 x 10^{20}) combinations of the pieces, which overwhelms some of the most powerful processors built. Using heuristics and the advice of checkers experts, Dr. Schaefer at the University of Alberta, developed a program that went on to win the 1994 world checkers championship. Although he retired the program from competition, he employed it to "map" all possible moves and configurations of the game to arrive at the first "solution" or perfect database of the game. He managed to reduce the problem by carefully selecting game-winning moves of 39 000 billion arrangements, and with an average of 50 computers (and sometimes as many as 200) working on the challenge, completed the project in six years. His program is effectively unbeatable: at best it can be played to a draw.[154]

An argument can be made that efforts such as Dr. Scaheffer's will one day lead to the solution of warfare through artificial intelligence. This is the unspoken aspiration of information superiority theorists: that the complexities of war can be so comprehensively

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[152] Pagels, *The Dreams of Reason…*, 227-228. This limit is known as a "complexity barrier."

[153] University of Alberta, "Scientists Solve Checkers," *ScienceDaily*, 20 July 2007; http://www.sciencedaily.com/releases/2007/07/070719143517.htm; Internet; accessed 12 January 2009,

[154] Ibid.

understood that one side is rendered unbeatable. In truth, the human factor is considerably more challenging to map. Any agent with free will, given the choice between options A or B will inevitably choose C.[155]

Soon, the limitations that Dr. Schaeffer encountered will be lifted and the processing power and speed of silicon chips will be overcome permitting the solution of more complicated games (such as *chess* or *Go*). The eventuality of carbon nanotubes replacing transistors and the potential of quantum computing will eliminate the physical constraints on Moore's Law.[156] Theoretically, with this limitation removed humankind could experience an unprecedented leap in technology and solve the challenge of dealing with the complexity of the battlespace.

Where the bound of silicon chips no longer constrains progress, game theory presents the best method by which to understand the limitation of machines to model complex behaviour. Forget for the moment the seemingly overwhelming number of variables that have to be measured to model a single entity in conflict with another, and rather consider a simple board game where only ten moves are possible for each iteration (or state). If the game terminates in two moves there are 10 x 10 = 100 distinct ways of playing the game. If the game terminates after ten moves the game can be played 10^{10} ways. If the game terminates in 50 moves, the game can be played 10^{50} ways. Although

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[155] In other words, checker (and chess) playing computers really tell us nothing about consciousness because these games are representatives of closed systems, defined completely by their rule set. Warfare is considerably more complex that a board game, even though the latter is modeled on the former: we never have to worry about a pawn refusing an order to sacrifice itself.

[156] Liz Tay, "The Death of the Silicon Chip," *iTnews*, 28 March 2008; http://www.itnews.com.au/News/72838,the-death-of-thesilicon-computer-chip.aspx; Internet; accessed 26 January 2009. Moore's Law states that the number of transistors that can be placed on a silicon chip increases exponentially, effectively doubling every two years. The result is an exponential increase of the capability of any transistor-based technology every two years. Wikipedia, "Moore's Law," http://en.wikipedia.org/wiki/Moore%27s_law; Internet; accessed 26 January 2009.

the notation is short, this number exceeds the number of atoms that make up the planet.[157] First, no real-world conflict is likely to terminate in 50 “moves” and second, the possible branches available to a participant will likely never be limited to 10. The number of states required for modelling the decision tree of such a system is so large that no foreseeable computer could store them.[158]

If attaining perfect knowledge is not feasible, the final option is the use of heuristics and algorithms. But again, barriers exist that simply cannot be overcome to simulate what a human mind can do. Computers do not work with knowledge. They do not even work with information - they work with data, which aggregates to yield information. In order to work with data, computers must classify it. Classification reduces, if not eliminates, qualities and their nuances beyond what fuzzy logic is capable of dealing with.[159] The problem is one of ontology, which is purely subjective: classification depends upon who is doing the classifying.[160] If not challenging enough, how might a machine know what data to select (i.e. input)? What information is important to consider in designing a solution?

Humans deal with this challenge through parsing. Parsing is the ability to quickly decompose complex sensory inputs, such as scenes to assimilate information. Using cues to select information that is contextually important, a human can understand what is being perceived. “Humans effortlessly parse unfamiliar scenes into familiar objects, an

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[157] Holland, *Emergence…*, 37.

[158] Ibid, 40.

[159] Lukacs, *At the End of an Age*, 139.

[160] For example of the following categories, in which does Osama bin Laden fit: freedom fighter, patriot, or terrorist? The answer depends upon your perspective.

accomplishment that so far eludes even the most sophisticated computer programs."[161] Despite the computer's advantage in speed, there is no plausible, nor is there likely to be, computer-based models of human parsing procedures.[162] Machines cannot mimic this process.

An artificial intelligence capable of monitoring the activities of all agents in warfare, processing the information in a timely manner, and predicting the outcome is simply not feasible. Understanding of complexity can definitely be improved with technology, but its control will never be realized. Information superiority has demonstrated the ability to reduce the friction and fog of warfare, but it will never offer complete omniscience or omnipotence.[163]

Martin van Creveld sums up the man-versus-machine argument best:

> An intellectual system sufficiently powerful to encompass all [the variables of warfare], and thus provide a complete guide for the employment of force, does not exist. [If such a system] existed, it would be too complicated for any single man or organization to encompass – even an organization using the most powerful computers. Any attempt to construct such a system is itself an act of *hybris*, strongly reminiscent of the one which caused people to build the tower of Babel, and deserving similar punishment.[164]

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[161] Holland, *Emergence…*, 111.

[162] Ibid., 25.

[163] William A. Owens, Admiral, "The Emerging U.S. System-of-Systems," *National Defence University Strategic Forum* 63 (February 1996): 4. The concept of information superiority itself may be empty of meaning. How can any person or organization possess a superiority of information? No standard exists against which to measure it.

[164] van Creveld, *The Transformation of War*, 116.

The Human as Agent

Cognitive science has posited that dealing with complexity is the kind of task for which humans have evolved: the more complex the problem, the better a human can be expected to perform in comparison to a machine. A human is better able to deal with the uncertainty, ambiguity, and dynamics of a social situation than a computer, particularly when operating with compressed timelines.[165] This is natural, for in order to make their way successfully through a complex world people have to make good decisions, practise sound judgement, anticipate probable effects, and regulate behaviour according to the socio-structural environment. This is an aspect of agency - the ability to make things happen by one's actions.[166] The human in this agentic role demonstrates the ability to successfully navigate through a complex world.

As an agent, a human brings two abilities to a complex dynamic to which computers can never aspire: ability to access and use tacit knowledge, and the ability to intuitively penetrate complexity.

Tacit knowledge is the human capability to know or sense more than can be explicitly expressed. This includes valid knowledge of the problem, the problem solver's capacity to pursue it, and more importantly an anticipation of the implementation of the solution.[167] Military organizations contain considerable tacit knowledge. It is distributed amongst individuals of ships, platoons and flights. Widely dispersed, it is all but

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[165] Smith, *Complexity, Networking and Effects Based Approaches to Operations*, 287.

[166] Albert Bandura, "Social Cognition Theory: An Agentic Perspective," *Annual Review of Psychology* 52 (2001): 2-3.

[167] Michael Polanyi, "The Tacit Dimension," in *Knowledge in Organizations*, ed. Lawrence Prusak, 135-147 (Oxford: Butterworth-Heinemann, 1997), 145.

impossible to articulate in writing and as a result is not captured by some of a military's most basic documentation.[168] For example despite comprehensive analysis and numerous treatises, effective leadership cannot be exercised by simply reading about it. It must be practised. The same is true for many other skills such as the operational art, military planning, commanding of ships, or flying aircraft. These all demand the use of tacit knowledge.

Knowledge management is a recent, civilian business process that is aimed to capture and employ explicit information, but significant progress has also been made to capture tacit information.[169] Through such efforts, militaries are building knowledge, but they are not specifically building a capacity for judgement. "It is this human ability to extrapolate from tacit knowledge, or what can be known, to what does not yet exist that is crucial to military operations because it is the origin for the capacity to surprise and shock, or to anticipate the surprises of the enemy."[170] Only the right kind of tacit knowledge gives forces an advantage over adversaries.[171] The right kind of knowledge for warfare is that which facilitates decision making and problem solving and thereby enables human agency. Another, important ability the human agent demonstrates is the ability to "peer" deeply into the dynamics of a complex system.

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[168] This is synonymous with Aristotle's concept of *phronesis*, which is sometimes translated as *practical wisdom* or *prudence*. It is more than a skill and more than wisdom, it concerns how to act in a given situation. Wikipedia, "Pronesis," http://en.wikipedia.org/wiki/Phronesis; Internet; 7 April 2009.

[169] Several of knowledge management's principles are being incorporated into information processes in programs that normally are associated with the catch-all title "lessons learned."

[170] Smith, *Complexity, Networking and Effects Based Approaches to Operations*, 89.

[171] Watts, *Clausewitzian Friction and Future* War, 48.

Clausewitz emphasized that the unpredictability of interacting with an adversary stems from the opponent possessing independent will.[172] Free will is the essence of human agency. When present among adaptive agents it generates far more complex patterns of interaction than systems involving non-social agents. The socially-oriented, goal-seeking behaviour of an agent results in their actively seeking connections, in effect building relationships through "networking."[173] This human propensity has had immense evolutionary value. It has enabled humans to work collectively to achieve much more than they could as individuals. There have been important secondary benefits: constantly negotiating network relationships has facilitated human perception and matching of patterns in social situations. Humans demonstrate the ability to map objects or events to completely different objects or events so as to draw inferences and create hypotheses that leads to a tentative understanding of a situation's dynamic.[174] Understanding is generally perceived as a result of accumulated knowledge, but this is not always so. The proverb, "we understand more than we know," although seemingly paradoxical has an intuitive truth. With respect to relations of human beings to other human beings, intuitive understanding may proceed rather than follow knowledge.[175] The human being is not the largest or the strongest living organism in the known universe, but his mind is the most complex organism in it.[176] The implication is that "any approach to dealing with social

[172] Ibid., 20.

[173] Miller and Page, *Complex Adaptive Systems…*, 28.

[174] Smith, *Complexity, Networking and Effects Based Approaches to Operations,* 87.

[175] Lukacs, *At the End of an Age*, 137.

[176] Ibid., 94.

complexity needs to be built upon an understanding of complexity that human beings (as complex adaptive systems in their own right) already have."[177]

The most unique skill of the human agent is the ability to intuitively penetrate the barriers of bifurcation of a complex adaptive system.[178] Czerwinski asserts that human agency imparts a tremendous advantage over computers. While machines may be capable of mimicking a human mind to the boundary just short of the third bifurcation in a system, a human may be capable of consistent functioning beyond the third bifurcation point and just into the fourth. Some unique individuals have even exhibited the ability to operate on the edge of chaos.[179] These individuals are those who demonstrate a coup d'oeuil, or as T.E. Lawrence coined it, the "flash of the kingfisher:" the understanding of warfare that cannot be taught, but must rather be intuitively understood.[180]

How is such intuitive knowledge realized? Complexity theory would propose that a complex adaptive agent will pursue a specific course of action only to the point that the selected course will lead to a desired outcome. If a negative situation, such as a loss of a battle or an impending defeat presents itself, an opponent can be expected to move the contest to a different dimension, scale, location, or tempo until conditions present themselves that are more conducive to victory – they will transition through the bifurcation map. The conflict will shift continuously until the antagonist has exhausted

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[177] Smith, *Complexity, Networking and Effects Based Approaches to Operations*, 85.

[178] Recall from the section on "Complexity Theory" that the possible states of a complex systems can be represented with a bifurcation diagram – see Figure 5.

[179] Czerwinski, *Coping with the Bounds: Speculations on Nonlinearity in Military Affairs*, 8.

[180] T.E. Lawrence, *The Seven Pillars of Wisdom* (Norwalk, Connecticut: Easton Press, 2003), 193.

all options or new options can no longer be generated with the available resources.[181] At this point the adversary will be forced into either predictable equilibrium or chaos where the control of the situation becomes untenable. Complexity theory also hints that only a human agent will be capable of understanding and anticipating the options of an adversary, particularly as the situation moves closer chaos.

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[181] Smith, *Complexity, Networking and Effects Based Approaches to Operations*, 60.

TRAINING TO COPE WITH COMPLEXITY

Within niches of the military community there is a sense that the tools being taught (to officers in particular) are not sufficient to deal with the complexity seen emerging in the contemporary operating environment. The issue is not one of a dearth of information regarding how to train better: it is rather that a better schema of how to deal with complexity is required.[182] A method is required that assists personnel in adjusting to the paradigm shift necessary to cope with complexity. The main challenge in dealing with complexity will be that of thinking differently and less linearly.[183]

Complexity has insights to offer commanders. It provides a frame of mind that can alert them to otherwise unrecognizable problems, and provide more insight to the feasibility of particular courses of action.[184] Clausewitz saw combat experience, realistic training, and the genius of military commanders as capable of dealing with complexity and reducing general friction in war.[185] Others have posited that flexibility and imagination are required for attaining one's ends in a complex system.[186] Neither of these positions is contentious, but a more prescriptive approach would facilitate the transition of the Western military mind from the constraints of the linear-reductionist paradigm to a broader, more accurate understanding of reality based on an understanding of complexity. Ultimately, the question begs: how can this theory be made practical or

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[182] Alan D. Beyerchen, "Clausewitz, Nonlinearity, and the Importance of Imagery," 168.

[183] Smith, *Complexity, Networking and Effects Based Approaches to Operations*, 93.

[184] Rosenau, "Many Damn Things Simultaneously: Complexity Theory in World Affairs," 74.

[185] Watts, *Clausewitzian Friction and Future* War, 22.

[186] Saperstein, "Complexity, Chaos, and National Security Policy: Metaphors or Tools," 122.

useful in application? Suggestions are beginning to emerge from all the fields that are touched by complexity theory, but for the armed forces complexity can best be coped with through training for intuitive decision making.

Intuitive Decision Making

Newton's impact on the Western mind has been profound, but his own thought process was less linear than supposed. His insights about gravitation started from the recognition of a relationship between the moon and the tides. Such intuitive leaps from humans are common: "Almost all of Charles Darwin's evidence for natural selection came from the achievements of plant and animal breeders, and he drew heavily on the experience of practical people."[187] Using intuition to make a decision is more common than typically believed; such decision making is considered naturalistic, and pervasive in human social affairs. Intuitive decision making has the potential to enable Western militaries to cope with battlespace complexity.

What is intuition? Defined by Gary Klein, it is the way a human translates experience into action.[188] Its foundation is accumulated and compiled experience.[189] Reliance on intuition makes many people uncomfortable. The linear-reductionist mind set demands that choices be rational and justifiable. The apprehension in using

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[187] Rupert Sheldrake, *The Sense of Being Stared At: And Other Unexplained Powers of the Human Mind* (New York: Crown, 2003), 5.

[188] Gary Klein, *The Power of Intuition: How to Use Your Gut Feelings to Make Better Decisions at Work* (New York: Doubleday, 2003), xiv.

[189] Hubert L. Dreyfus, "Intuitive, Deliberate, and Calculative Models of Expert Performance," in *Naturalistic Decision Making*, eds. Caroline E. Zsambok and Gary A. Klein, 17-28 (Philadelphia: Lawrence Erlbaum Associates, 1997), 23; http://books.google.com/books?id=mwR8YA3QPwcC&printsec=frontcover#PPA28,M1; Internet; accessed 3 March 2009.

naturalistic decision making has stemmed from intuition not always proving to be reliable.[190] Although flawed, it should not be eschewed. Intuition is a practical and powerful ability that allows humans not only to survive in a complex world but to thrive in it.

Intuitive decision making is not for every instance. More analytical approaches, such as cost-benefit analysis, are better where optimization or justification is demanded. Analysis is additionally better if there is considerable computational complexity to the problem. For more context-laden problems, the weakness with such rational choice approaches is that they are subject to the legacy of reductionism: in using them to make a decision the underlying assumption is that decision makers cannot be trusted to make sound judgements on the larger issue, yet the method depends on their ability to make sound judgements on the smaller estimates.[191] So, where understanding the situation or context is important in rendering a decision, a more intuitive approach will yield a better result.

Intuitive decision making is more appropriate in situations where there is considerable time pressure, ill-defined goals, and dynamic conditions. It is found to be prevalent in very demanding jobs, ranging from offshore oil platform mangers, airline pilots, on through to military officers, as the nearly exclusive form of effective decision making. Studies have consistently demonstrated that upwards of 90% of decisions made

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[190] Ibid., 3.

[191] Ibid., 77.

by these professionals are intuition-based.[192] The crux in using such an approach is that it requires expert practitioners.[193]

Intuition relies on experience to recognize the key patterns that underlie a dynamic situation, but not all experience is relevant. Experience is not fungible: the appropriateness of experience is context dependent. The understanding of the expert, one who has extensive experience in a specific context, is what is sought for effective and responsive intuitive judgement. Identifying expertise, and differentiating it from experience, is not a simple task, but experts will notice cues in a situation that others do not. These could include: the big picture, the way things work, anomalies, opportunities, possibilities for improvisation, events that have already happened or will happen, differences too small for others to notice, and most importantly their own limitations.[194]

An expert's intuition is founded on accurate mental models and pattern matching. Mental models are beliefs about how various processes work and are generated by mental imagery and metaphorical understanding.[195] Although we derive these models from experience, the expert possesses the most accurate mental models. Pattern matching is

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[192] Raphael Pascual and Simon Henderson, "Evidence of Naturalistic Decision Making in Military Command and Control," in Naturalistic Decision Making, eds. Caroline Zsambok and Gary Klein, 217-226 (Hillsdale, NJ: Lawrence Erlbaum, 1997), 218; and Klein, *The Power of Intuition…, 28*.

[193] Caroline E. Zsambok, "Naturalistic Decision Making: Where Are We Now?," in *Naturalistic Decision Making*, eds. Caroline E. Zsambok and Gary A. Klein, 3-16 (Philadelphia: Lawrence Erlbaum Associates, 1997), 5; http://books.google.com/books?id=mwR8YA3QPwcC&pg=PP1&dq=naturalistic+decision+making#PPA5,M1; Internet; accessed 3 March 2009.

[194] Gary Klein, *Sources of Power: How People Make Decisions* (Cambridge: MIT Press, 1999), 148-149.

[195] Jan Maarten Schraagen, Gary Klein, and Robert R. Hoffman, "The Macrocognition Framework of Naturalistic Decision Making," in *Naturalistic Decision Making and Metacognition* eds. Jan Maarten Schraagen, Laura G. Militello, Tom Ormerod, and Raanan Lipshitz, 3-26 (Farnham, UK: Ashgate Publishing, 2008), 14; http://books.google.com/books?id=6ZA8jKA9z_QC&printsec=frontcover#PPA14,M1; Internet; accessed 15 March 2009.

recognizing typicality: sizing up a situation at a glance and realizing that a variant of it has been experienced in the past. When patterns do not match expectations, experts begin a diagnosis.[196] In a competitive situation, mental models and pattern matching gives an expert a definitive edge. Not only are the experts' solutions comprehensive, but they are arrived at very quickly. What is not so quick is how long development of an expert takes.

Some theorists assert that is takes ten years to develop a professional expert.[197] Malcolm Gladwell is more specific: he posits that it takes 10 000 hours.[198] This is a considerable amount of time and shortening it is a challenge for those creating human resource development programs, but there are means by which the process can be expedited. Experience is the foremost means by which people acquire intuitive judgement, but it is not the only means. Two methods have additionally proven effective: case studies, and decision-making exercises.

The Germans believed steadfastly in the case study method of teaching warfare. They "categorically rejected the idea that a few simple principles could serve as a guide for winning war,"[199] Rather than memorizing check lists like the *Principles of War*, they encouraged the acquisition of a broad and deep understanding of warfare that would serve as a "well" from which they could draw their knowledge for application to each

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[196] Klein, *Sources of Power…*, 149 and 151.

[197] Ibid., 147.

[198] Malcolm Gladwell, *Outliers: The Story of Success* (New York: Little, Brown and Company, 2008), 41.

[199] Thomas X. Hammes, "Rethinking the Principles of War: The Future of Warfare?" in *Rethinking the Principles of War*, ed. Anthony D. McIvor, 263-278 (Annapolis: Naval Institute Press, 2005), 268.

unique situation they faced.[200] In effect they were developing their referential expertise.[201]

A general misunderstanding is that there is only one form of experience: direct experience. But direct experience is not always frequent or consistent. The gaps between direct experiences can be filled with referential experience. Where that referential experience can be directed and focused, it can serve as referential *expertise*. As a decision maker's expertise increases, their "library" of mental models grows and their applicable analogies will become more comprehensive and pertinent. In effect, their decisions will prove more accurate.[202] A case study method of learning can assist in developing this expertise.

In training military personnel to achieve expertise more quickly, the critical aspect is to educate them in how to perceive like an expert – learning of knowledge and rules are incidental. Personnel need to learn like experts rather than to think like experts: to focus on understanding and interpreting context (i.e. cues, patterns, etc.) to adapt to a situation rather than focusing on procedures.[203] A mistaken assumption would be that what makes an expert is that they know the rules so well that they do not have to refer to them. Hubert and Stuart Dreyfus refute that children have so completely mastered the use of using training wheels that that they thereafter can bike without them. The logic is faulty. Rather, children outgrow the need for training wheels: they develop a sense of bicycle

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[200] Ibid., 268.

[201] An example of how seriously the Germans took this approach can be observed in Moltke establishing a Military History Section that analysed historical campaigns and distilled the key lessons for promulgation to modern officers. See Citino, *The German Way of War…*, 149.

[202] Smith, *Complexity, Networking and Effects Based Approaches to Operations*, 299.

[203] Klein, *Sources of Power…*, 168-169.

dynamics.[204] Such is the rationale behind decision-making exercises, another effective tool to build expertise.

Decision making exercises are simple thought exercises that capture the essence of a difficult decision. They have little cost, as they are typically verbal, or need at most pen and paper. They are normally quick and repeatable making them ideal for military training. The component of them that is important and the most time intensive is the development of context, which is vital for the exercise of intuition.[205] Decision-making exercises are best done in small groups to put pressure on participants to perform in front of others and provide opportunities to learn from each other. They should be designed and made by the person who knows the unit the best.[206]

Decision-making exercises: reveal the limits of mental models; fill the gaps in an experience base; teach methods to handle uncertainty; teach how to spot leverage points; aid in detecting important cues; permit practise in allocating limited resources; and most importantly they assist in the learning of factual and technical knowledge - in context.[207]

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[204] Hubert Dreyfus and Stuart Dreyfus, *Mind Over Machine: The Power of Human Intuitive Expertise in the Era of the Computer* (New York: Free Press, 1986); quoted in Gary Klein, *Sources of Power: How People Make Decisions* (Cambridge: MIT Press, 1999), 169.

[205] Contrast this to the current practise in NATO of exercising with artificial scenarios – creating fictitious places and make-believe countries. Although such a practice prevents possible insult to nation-states that might appear in the scenario, it more importantly decontextualizes the scenario and robs participants of a very important component of professional learning. Exercise designers cannot generate the artificial context that is readily available by using real terrain, populations, culture, and social dynamics.

[206] Rebecca M. Pliske, Michael J. McCloskey, and Gary Klein, "Decision Skills Training: Facilitating Learning From Experience," in *Linking Expertise and Naturalistic Decision Making*, eds. Eduardo Salas and Gary Klein, 37-54 (Philadelphia: Lawrence Erlbaum Associates, 1998), 46; http://books.google.com/books?id=lAo5kOgrdRoC&printsec=frontcover&dq=naturalistic+decision+making#PPA37,M1; Internet; accessed 15 March 2009. Overall, this chapter is a very good resource for the development of decision-making exercises. It includes examples and appropriate questions to generate reflection during the exercise.

[207] Klein, *The Power of Intuition…*, 52.

This is a significant remit, but decision-making games offer the best method by which to accelerate learning like a military expert.[208]

Intuitive decision making has the potential to be a powerful tool in dealing with the complexity encountered in the modern battlespace. There is one caveat in its use. Like military intelligence, which should be confirmed by multiple sources, intuition benefits from being confirmed analytically - time permitting. "Impulses and intuition have to be balanced with deliberate, rational analysis. But rational analysis can never substitute for intuition."[209]

CONCLUSION

Western militaries have constrained themselves with the linear-reductionist paradigm; complexity theory can aid them in transcending it. The linear-reductionist paradigm is powerful: it has resulted in age-defining technologies. Concomitantly, linear-reductionism's information technology is playing a significant part in increasing social complexity and shows no signs of abating. Technology is generating a vicious cycle from which it is incapable of aiding our escape: increased complexity leads to more innovative information-technology solutions, which leads to more complexity. Even artificial intelligence holds little promise for extricating us. The best potential for dealing with increasing complexity resides in humans themselves, but only if unfettered from their current schema and provided with a more appropriate model of reality. Complexity theory holds promise in this regard.

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[208] Good examples of decision-making exercises can be found in the *Marine Corps Gazette's* Tactical Decision Games, available in any issue.

[209] Klein, *The Power of Intuition…*, 5.

Complexity theory presents a more comprehensive model of reality than the linear-reductionist paradigm to which we presently subscribe. It is compatible with linear-reductionism and is, in truth, an extrapolation beyond it. Not only is it applicable in generally understanding reality; it can be specifically applied by policy makers and commanders to cope with the complexity in conflicts. Although complexity theory will never predict the actions of an adversary, or the outcomes of battles, its utility lies in better understanding the nature of human social systems. It focuses understanding on agents and their interrelations, rather than on controlling situations. More importantly, it prompts the realization that only the human-as-decision-maker can adequately cope with complexity in future wars.

Humans can never be completely replaced within the battlespace, so they need to be prepared to fulfill their indispensible roles accordingly. Although individuals may seem inconsequential as the wave of war overwhelms groups and societies, a single person or event can have disproportional effects on the outcome of conflict. But more must be done than simply acknowledging that single individuals have the potential to influence conflicts on a large scale. Leaders from corporals on up to generals must be better prepared to deal with the increasing complexity in the security environment. The implication for training is the development of more intuitive decision making among military personnel. Case studies and decision-making exercises are two activities that can serve this end.

In embracing complexity theory, possibly the most important consequence is that it imbues commanders at all levels with a sense of awe of the natural world - a humility of sorts. Complexity theory teaches that commanders will never have all the answers, planners will never completely understand the adversary, the problem cannot be *solved*, and plotting all possibilities is impossible. Consequently, militaries must be content with *bounding* the problems of warfare. In some ways complexity theory is an irony – rather than being *complex*, it simplifies the problems of war.

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