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Commanders, Complexity and the limits of Modern Battlespace Visualization.

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Abstract

This paper argues that the perfect Battlespace Visibility promised by technology enthusiasts would only bring marginal value to the commander and that war at the operational level remains a complex endeavour requiring exacting decision-making skills. To present the argument the paper explores Complexity Theory to show its relevance to warfare at the operational level. It then highlights research in the field of decision-making in complex environments and contrast findings with the situation of a Joint Force Commander. In the last part of the essay, the author presents enablers to operating in war's complex environment from the insights gained by the realisation of its chaotic nature.

Commanders, Complexity and the limits of Modern Battlespace Visualization.

> "People in this world look at things mistakenly, and think that what they do not understand must be the void. This is not the true void. It is bewilderment."
>
> Miyamoto Musashi[1]

Introduction

The elusive search for certainty in military decision-making has been amply documented by the likes of Clausewitz and van Creveld: certainty about the state and intentions of the enemy's forces; certainty about the environment in which the war is fought; and certainty about the state, intentions, and activities of one's own forces. Every advance in sophistication of control systems[2] reflects this race between the demand for information and their ability to deliver it. And, until very recently, as van Creveld points out, taming uncertainty still proved a chimera:

> Taken as a whole, present-day military forces, for all the imposing array of electronic gadgetry at their disposal, give no evidence whatsoever of being one whit more capable of dealing with the information needed for the command process than were their predecessors a century or even a millennium ago... their ability to approach certainty has not improved to any marked extent.[3]

But that was in 1985, ages ago in the fast growing field of information technology. If we are to believe the present-day enthusiasts,[4] it seems that 100 percent or perfect Battlespace Visibility (BV)[5] is closer at hand than ever. The powerful analogy of putting the commander back on his horse is used to describe the phenomenon:

> The battle commander no longer needs to overlook the battlefield; he no longer needs to be in the vicinity of the battle; he no longer needs to be adjacent to the arena of battle; he no longer needs to be in even the same global hemisphere of the battle. The image of the 19th century general astride his horse surveying the battle on a vast plain below him has been replaced by that of the 21st century general viewing a cluster of video screens and digital maps that portray battle changes in real time.[6]

Achieving perfect BV is no small feat. "Many intelligence reports in war are contradictory; even more are false, and most are uncertain."[7] And, "in practice, the incoming information is of inconsistent value: 99 percent of it is likely to disappear without a trace, whereas the remaining 1 percent may have a profound effect on operations – though whether this means that the 1 percent would be of value even without the 99 percent is a different question altogether."[8]

If we suspended disbelief momentarily and assumed that perfect BV was not only achievable, but that its interface could be designed in such a way as to eliminate the risk of information overload, would this considerable expenditure in resources represent a significant gain in the commander's ability to make the right decision at the right time?

This paper will argue that even perfect BV would only bring marginal value to the commander and that war at the operational level will remain a complex endeavour requiring exacting decision-making skills and coping strategies to make sense of the complexity.

To present this argument we will first investigate Complexity Theory and show its relevance to the Joint Force Commander (JFC) and his/her environment. The second part will focus on some of the latest research done in the field of decision-making in complex environments and contrast findings with the situation of a JFC. In the last part of the essay, we will distil the enablers to operating in war's complex environment from the insights gained by the realisation of its chaotic nature.

Part 1 – Complex Systems

> "Everything in war is simple, but the simplest thing is difficult."
> Carl von Clausewitz[9]

Terms like Complexity, Chaos and Non-linearity[*] have cropped up in our day-to-day vocabulary signalling a pervasive use of the theories behind them to explain our world. The reign of the predictable Newtonian world has given way to the flux of the capricious world of Chaos. But what are Chaos and Complexity Theory and what do they have to do with commanders or the theory of warfare? We will answer these two questions in turn.

[*] The terms Complexity, Chaos and Non-linearity are used in this article in their mathematical (or scientific) sense rather than their day-to-day meaning of complicated, unorganized and non-contiguous. See the glossary given at the end for specific definitions.

There is an important link between the theories of complexity and that of chaos. Succinctly, chaos is the study of how simple systems can generate complicated behaviour while complexity is the study of how complicated systems can generate simple behaviour.[10] A familiarity with both concepts is important to our understanding of warfare. Let us look at chaos first to set the seen for the introduction of Complexity Theory.

Although it owes its birth to mathematics, chaos is now a multidisciplinary science. The great French mathematician Henri Poincaré first noticed the idea that many simple non-linear deterministic systems can behave in an apparently unpredictable and chaotic manner.[11] Other early pioneering work in the field of chaotic dynamics were found in the mathematical literature; however, the importance of chaos was not fully appreciated until the widespread availability of digital computers for numerical simulations and the demonstration of chaos in various physical systems. This realization has broad implications for many fields of science, and it is only within the past decade or so that the field has undergone explosive growth. It has been found that the ideas of chaos have been very fruitful in such diverse disciplines as biology, economics, chemistry, engineering, fluid mechanics, physics, just to name a few.[12]

The thing for the laymen to recognize is that chaos is not randomness. Rather the phenomenon of chaos is a very sensitive dependence of the outcome of a process, in a deterministic system, on the tiny details of what happened earlier, the initial conditions. When chaos is present, it amplifies indeterminacy.[13] But if all non-linear systems were completely indeterminate not much would come out of their study. Complexity Theory for its part, deals with the study of systems that exhibit unpredictable, but within bounds, self-organizing behaviour. One of the defining features of complex systems is a property known as emergence in which the global behaviour of the system is qualitatively different from the behaviour of the parts. No amount of knowledge of the behaviour of the parts would allow one to predict the behaviour of the whole.[14]

The other point to appreciate is that when dealing with systems, interactions are the norm. Action in one area will invariably have more than one effect. We are dealing with a system when (a) a set of units or elements are inter-connected so that changes in some elements or their relations produce changes in other parts of the system and (b) the entire system exhibits properties and behaviours that are different from those of the parts. The result is that systems often display non-linear relationships, outcomes cannot be understood by adding together the units or their relations, and many of the results of actions are unintended. Complexities can appear even in what would seem to be simple and deterministic situations. In a system, the chains of consequences extend over time and many areas: the effects of action are always multiple. Doctors call the undesired impact of medications "side effects." Although the language is misleading - there are no criteria other than our desires that determine which effects are “main” and which are “side” - the point reminds us that disturbing a system will produce several changes.[15]

Finally it should be evident from the above discussion that further complexities are introduced when we look at the interactions that occur between strategies when actors consciously react to others and anticipate what they think others will do.[16]

Now that we have a basic understanding of what Chaos and Complexity Theories are, we will look at the Joint Force Commander (JFC) and his operating environment to show that they constitute indeed a chaotic and complex system. For a system to be considered complex,[†] it must be deterministic, its interactions must induce non-linearity and be, within bounds, self-organizing. If we have all three conditions (deterministic, non-linear and pattern-forming self-organization) then it can be considered a complex system.

That the constituting elements of war are deterministic there can be little doubt. When a Carrier Battle Group sails, it does not randomly travel around the world's oceans. When a fighter squadron flies on a mission it does not drop ordnance arbitrarily. And, when an armoured division attempts to take an enemy position, advancing erratically does not serve its purpose.[17] Just the fact that such groupings exist and have shown to be potent systems to control and inflict violence signifies that there is a link between cause and effect. We are not dealing with a stochastic environment.

[†] While recognizing that this is not a universal quality of complexity, in the instances we deal with in this paper, chaotic behaviour is a precursor to complexity. Therefore from this point on, to lighten the text, the term “complex” will be used to mean “chaotic and complex”.

That interactions in war induce non-linearity well documented. From the nursery rhyme told to stress the importance of taking care of small problems to forestall bigger ones:

> For the want of a nail, the shoe was lost;
> For the want of the shoe, the horse was lost;
> For the want of the horse, the rider was lost;
> For the want of a rider, the battle was lost;
> For the want of the battle, the kingdom was lost;
> All for the want of a nail.[18]

to the learned studies from Clausewitz:

> in war... [c]ountless minor incidents – the kind you can never really foresee – combine to lower the general level of performance, so that one always falls far short of the intended goal…. This tremendous friction, which cannot, as in mechanics, be reduced to a few points, is everywhere in contact with chance, and brings about effects that cannot be measured, just because they are largely due to chance.[19]

or von Moltke's remark that "no operation plan extends with any certainty beyond the first encounter with the main body of the enemy."[20] Practitioners, theorists and even popular culture testify to the futility of predicting results based on initial conditions considering its sensitivity to seemingly benign perturbations. Non-linear outcomes are the hallmark of war; its nature cannot be captured in one place but emerges from the collective behaviour of all the individual agents in the system interacting locally in response to local conditions and partial information. In this respect, decentralization is not merely one choice of command and control: it is the basic nature of war. [21] Furthermore, non-linearity also comes from the sophistication of the organization itself.[22] It will be no surprise to anyone who has worked in any sizeable headquarters, particularly joint and combined ones, that its internal operation can be chaotic. More precisely, it can be turbulent and weakly chaotic, exhibiting features of self-organized criticality.[23]

The pattern-forming self-organization aspect of warfare can be glimpsed from studying its history, or more precisely from the fact that it is possible and worthwhile to use history to enhance our understanding of warfare. If warfare was not pattern forming, the introduction of new technology that change the balance of interactions, on one side or both, would bring unrecognizable new dynamics in the system. Yet when we look at the functions of war over time (the requirement to Sense, Shield, Act, Sustain and Command), they have been impervious to technological change.[24] The emergence of

"Principles of War" is also a sign of pattern-forming self-organization. If there was no pattern, only non-linearity, we could not affirm that "Concentration of Force" is worth pursuing, that "Selection and Maintenance of the Aim" is an enabler to success and we could conclude that the wisdom of keeping a "Reserve" is an anachronism from the 19^{th} century.[25]

The last remaining task to show that warfare is a complex environment is to discern whether we are truly dealing with a complex system or simply a metaphor. Social sciences are often subjective and Complexity Theory has become trendy.[26] There have been many attempts in the past to transpose concepts from the "hard" sciences to the "soft" ones with mixed results.[27] Although, there is little doubt that the three prerequisites of complex systems are met, to prove that it is actually valid, our new theory would have to make verifiable predictions that are not explicable by other theories of warfare.[28] Nevertheless, whether warfare is actually complex, or simply behaves like a complex system, is too fine a point for the purposes of this essay. In either case the commander has to deal with pattern-forming unpredictability.

It is therefore clear that war, the environment in which a JFC operates, is a complex system where knowing the physical component of the situation is only part of the solution. Non-linear dynamics suggests that war is uncertain in a deeply fundamental way. Uncertainty is not merely an initial environment condition that can be reduced by gathering information and displaying it on a computer screen. It is not that we currently lack the technology to gather enough information but will someday have the capability. Rather, uncertainty is a natural and unavoidable product of the dynamic of war: action in war generates uncertainty.[29] How can we help a commander deal with these complex systems? How much help would a perfect BV system bring? In investigating how the human mind deals with complexity, we will be in a good position to answer these questions.

Part 2 – Decision Making in a Complex System

> "This difficulty of *accurate recognition* constitutes one of the most serious sources of friction in war, by making things appear entirely different from what one had expected."
>
> Carl von Clausewitz.[30]

Despite our seemingly advanced cognitive skills, it appears that evolution allowed human beings to develop a tendency to deal with issues on an ad hoc basis. The early problems we have had to deal with, when the task at hand was to gather firewood, drive a herd of horses into a canyon, or build a trap for a mammoth were problems of the moment and usually had no significance beyond themselves. The need to see a problem embedded in the context of other problems rarely arose. For the modern day JFC however, this is the rule, not the exception. Do our habits of thought measure up to the demands of thinking in systems? What errors are we prone to when we have to take side effects and long-term repercussions into account?[31] This part of the essay will answer these questions by looking at some of the latest research done in the field of decision-making in complex environments. We will first investigate the apparent limitations of the human mind and the consequent type of recurring decision errors in complex environments. That will set the stage for us to explore strategies for successful decision-making. We will then be in a position to contrast these findings with the situation of a JFC.

At the root of our difficulty in dealing with complex systems is our poor ability to deal with variable patterns in time.[32] The fact that spatial configurations can be perceived in their entirety while temporal ones cannot may well explain why we are far more able to recognize, and deal with, arrangements in space than in time. We are constantly presented with whole spatial configurations, and readily think in such terms. We know, for example, that to determine whether a parking lot is crowded we need to look at more than one or two spaces. By contrast, we often overlook time configurations and treat successive steps in a temporal development as individual events. For example, as enrolment rises each year, the members of a school board may add first one room, then another onto an existing schoolhouse because they fail to see the development in time that will make an additional schoolhouse necessary.[33] Even when we think in terms of time configurations, our intuition is very limited so that when we have to cope with systems that do not operate in accordance with very simple temporal patterns, like the one given here, we run into major difficulties. There are two types of relatively straightforward temporal patterns that create undue difficulties: non-linear growth or shrinkage (the magic of compounded interest), and developments that show changes of direction like oscillations or sudden reversals.[34]

This limited temporal intuition is evident in our propensity to "oversteer" when action and reaction are not linked by instantaneous feedback. At the helm of the proverbial oil tanker, the uninitiated (non-expert) will keep turning the wheel because the ship appears non-responsive. Once it starts to turn, we realize that we have overdone it and have to compensate the other way.

> This tendency to “oversteer” is characteristic of human interaction with dynamic systems. We let ourselves be guided not by development within the system, that is, by time *differentials* between sequential stages, but by the *situation* at each stage. We regulate the *situation* and not the *process*, with the result that the inherent behaviour of the system and our attempts at steering it combine to carry it beyond the desired mark.[35]

Limited temporal intuition and tendency to oversteer do not appear to be our only flaws unfortunately. Dealing with uncertainty seems to be another vulnerability. Dietrich Dörner, an authority on cognitive behaviour found that decision makers that are uncomfortable with complexity and unfamiliar with a situation are often plagued with uncertainty[36] and so tend to:

- Act without proper analysis of the situation,
- Fail to anticipate side effects and long term repercussions,
- Assume that the absence of immediately obvious negative effects means that correct measures have been taken,
- Let over-involvement in 'projects' blind them to emerging needs and changes in the situation,
- Be prone to cynical reactions when encountering failure.[37]

They also tended to miss the big picture and be swamped in trying to deal with the problem of the moment: "One reason they deal with partial problems in isolation is their preoccupation with the immediate goals…. At the moment, we don't have other problems, so why think about them? Or to put it better still, why think that we should think about them."[38]

Experts for their part deal with complexity within their field in stride[39] but remain vulnerable to uncertainty. Gary Klein, an authority on Naturalistic Decision Making, found that experts familiar with the complexity of a particular situation make three types of errors. Errors due to lack of experience; errors due to lack of information; and the third source of poor decisions is due to what he calls the *de minimus*[40] error, an error of mental simulation where the decision maker notices the signs of a problem but explains it away. He/she finds a reason not to take seriously each piece of evidence that warns them of an anomaly."[41]

The foregoing makes clear that decision-making in a complex environment does not come naturally. Cognitive psychology scientists have documented strategies to effective decision-making in such environments, which differ whether or not the decision maker is an expert in the field where the decisions are required. But before going into the strategies, we need to look at an emerging truth that seems to hold regardless of expertise levels.

In successfully dealing with complex environments, it appears that cognitive ability is not the main indicator and the usual battery of psychological tests is useless in predicting participant behaviour. One would assume that "intelligence" would determine behaviour in complex situations, since complicated planning - formulating and carrying out of decisions - presumably places demands on what psychology has traditionally labelled "intelligence." But Dörner has found that there is no significant correlation between scores on IQ tests and performance in his problem-solving experiments. It seems that a better predictor of participant success is their capacity to tolerate uncertainty.[42]

When we want to operate within a complex and dynamic system, we have to know not only what its current status is but also what its status will be or could be in the future, and we have to know how certain actions we take will influence the situation. For this we need "structural knowledge," knowledge of how the variables in the system are related and how they influence one another.[43] As we will see when discussing Recognition-Primed Decision-making (RPD), experts will have developed an intuition[44] for this but laypersons must hypothesize the links, test the hypotheses and keep in mind the possibility that their model is probably wrong.[45] We will look at this approach to successful decision-making first.

The decision-making strategy proposed by Dörner is very similar to what we have come to unk

> specific individual and his supply of supersignals. We learn supersignals from experience.[49]

Gary Klein studied experts in their natural settings with ample structural knowledge and a good grasp of supersignals. He found that:

> The commanders could come up with a good course of action from the start… Even when faced with a complex situation, the commanders could see it as familiar and know how to react. The commander's secret was that their experience let them see a situation, even a non-routine one, as an example of a prototype, so they knew the typical course of action right away. Their experience let them identify a reasonable reaction as the first one they considered, so they did not bother thinking of others. They were not being perverse. They were being skillful. We now call this strategy *recognition-primed decision making.*[50]

The RPD fuses two processes: the way decision makers size up the situation to recognize which course of action makes sense (called Pattern Recognition), and the way they evaluate that course of action by imagining it (called Mental Simulation).

The RDP decision-making strategy matches the following pattern: The decision makers recognize the situation as typical and familiar and proceed to take action. They understand what type of *goals* make sense (so the priorities are set), which *cues* are important (so there is not an overload of information), what to *expect* next (so they can prepare themselves and notice surprises), and the *typical ways of responding* in a given situation. By recognizing a situation as typical, they also recognize a *course of action* (COA) likely to succeed. They do not compare COAs. They wargame (Mental Simulation) the first plausible COA and use it as is, adjust it if need be or reject it if it will not do the job. They do not attempt to find the best plan, they are after the first plan that they know will work thereby achieving great economies of time and mental resources.[51] After the decision is made, experts monitor developments and rely on their expectancies as one safeguard. If they read a situation correctly, the expectancies should match the events. If they are wrong, they can quickly use their experience to notice anomalies and change their plan dynamically.[52]

This strategy of decision-making has its limitations however and cannot serve in all situations. Significant structural knowledge (mainly implicit) is required and there is a relatively low limit to how complex a situation can be before it overwhelms our mental capabilities to simulate it. Because of our short-term memory limitations, the simulation is limited to a maximum of three moving parts and has to do its job in no more than six steps. We have to assemble the simulation within these constraints. Furthermore, if the variables interact with each other, the job of visualizing the program in action becomes even more difficult and so we search for a way to keep the transitions flowing smoothly by building a simulation that has as few interactions as possible.[53] Moreover, with our difficulty in dealing intuitively with all but the simplest temporal pattern, mental simulation and RPD will not help in circumstances where complex temporal configurations are at play.

We have seen what researchers found to be our wanting qualities when it comes to successful decision-making in complex environments. They have highlighted the errors of our ways and suggested strategies to overcome them. We will now illustrate the applicability of their theories by demonstrating their usefulness at explaining the JFC's situation.

We recognize in Klein's decision-making *modus operandi*, a pattern applicable to the commander possessing what Clausewitz has called "Coup d'Oeil."[54] Similarly, we can see the close parallel between the Operational Planning Process (OPP) and Dörner's guidelines for decision-making in unfamiliar complex situations. His highlighting of the difficulty of executing a plan echoes Czerwinski's comments on the same subject: "increased complexity has kept pace with heightened competency… command-by-plan inherently fights the disorderly nature of war as much as the adversary."[55]

In the same way we can easily find examples of the three types of errors reported by Klein,[56] and an informed reading of Cohen and Gooch's book on Military Misfortunes reveals that lack of structural knowledge is at the root of the three kinds of failure they report.[57] This deficiency is clearly at play when Thomas remarks that: "Information superiority allowed NATO to know almost everything about the battlefield [in the Kosovo conflict], but NATO analysts didn't always understand everything they thought they knew.[58] And in the incident Mandeles describes:

> Generally, senior commanders find it difficult during combat both to distinguish outputs from outcomes and to discover outcomes. In fact, the inability to discern

> outcomes (damage to specific enemy capabilities) is usually the reason senior commanders focus strongly on outputs, such as sortie rates.[59]

Finally the concept that tolerance towards uncertainty is a better predictor of success than sheer intellect can be corroborated by the words of William Tecumseh Sherman telling a subordinate what made Ulysses Grant his superior in the art of war:

> Wilson, I'm a damned sight smarter than Grant; I know more about organization, supply and administration and about everything else than he does; but I'll tell you where he beats me and where he beats the world. He don't care a damn for what the enemy does out of his sight but it scares me like hell. I'm more nervous than he is. I am much more likely to change my orders or to countermarch my command than he is. He uses such information as he has according to his best judgment; he issues his orders and does his level best to carry them out without much reference to what is going on about him…[60]

It is clear from the above that the theories described in this part of the essay are applicable to the JFC and that making decisions in the complex dynamic system that characterizes warfare is no simple matter for him or her. Our cognitive abilities do not seem robust enough to deal directly with high-level complexity on their own and require coping strategies in the form of pattern matching and decision-making schemes. This makes evolutionary sense since complexity often self-organizes in patterns. Armed with this understanding we can now investigate what enablers to decision making are available and how to integrate them in the JFCs world.

Part 3 – Enablers to Effective Decision Making in Complex Systems

> "Even amidst the tumult and the clamour of battle, in all its confusion, he [the expert at battle] cannot be confused."
>
> Sun Tzu[61]

Enablers to decision making for commanders are not a new idea. From Machiavelli to Czerwinski, authors have attempted to investigate, collate and enunciate principles, schemes and philosophies to assist commanders arrive at proper decisions. The aim here is not to confirm, deny or replace the work of those authors or give an exhaustive list of dos and don'ts. Rather it is to look at some of the insights gained by realizing that the JFC deals in an unpredictable, yet within bounds, self-organizing complex environment. These insights are grouped in two broad categories: those related to the commander and those that affect command within the organization. At the root of these insights are two primordial principles: The first is to recognize that *time is the scarce commodity*. An organization has to be able to match the rate of change in its environment. The second is to recognize that *people are the key asset of any organization*. People are the adaptive element of organizations. Learning and innovation come only from human cognition.[62]

The first insight related to commanders is their comfort level in a chaotic environment. We have already noted that capacity to tolerate uncertainty was a better predictor of success than straight cognitive ability. Being at ea os would permit the commander to profit from it rather than waste energy fighting it.[63] Maybe there is more to the German tongue-in-cheek adage about the classification of officer believe in the past.

> I divide my officers into four classes as follows: The clever, the industrious, the lazy, and the stupid. Each officer possesses at least two of these qualities. Those who are clever and industrious I appoint to the General Staff. Use can under certain circumstances be made of those who are stupid and lazy. The man who is clever and lazy qualifies for the highest leadership posts. He has the requisite nerves and the me ifficult decisions. But whoever is stupid and industrious must be got rid of, for he is too dangerous.[64]

We are not advocating reserving the JFC position to the laziest officer around. However, selecting people at ease with chaos and nurturing that talent would be to our advantage. In the words of Dörner:

> An individual's reality model can be right or wrong, complete or incomplete. As a rule it will be bo plete and wrong, and one would do well to keep that probability in mind… the ability to make allowances for incomplete and incorrect information and hypothesis is an important requirement for dealing with complex situations. This ability does not appear to come naturally, however. One must therefore learn to cultivate it.[65]

The second issue related to aking in individuals, and therefore applicable to the JFC, is what is referred to as operative intelligence or metacognition.[§] In dealing with complex problems we cannot handle in the same way all the different situations we their own cognitive limitations experts can choose problem-solving strategies that maximize their strengths and minimize their weaknesses. For example we noted earlier in this essay our poor ability to deal with variable patterns in time. It rom experimentation that using graphs to convert "time" into "space" helps people comprehend temporal configurations.[66] An understanding of our limitation allows us to devise strategies to deal with it.

Four components of metacognition seem most important: memory limitations, having the big picture, self-critiques, and strategy selection. By being sensitive to their own memory limitations and how it affects their mental simulation capabilities, experts adopt subtle procedures to avoid the difficulty and factor in their level of alertness, their ability to sustain concentration, and so forth. When it comes to the big picture, experts not only see it, they can detect when they are starting to lose it. Rather than wait until they have become hopelessly confused, experts sense any slippage early and make the necessary adaptations. The self-critique ability in experts come from their performance being less variable than that of novices, they can more easily notice when they do a poor job and can usually figure out why in order to make corrections. Using these abilities, experts can think about their own thinking to change their analytic strategies.[67]

Where this metacognition comes from and how do we impart it to the potential JFCs? Experience seems to be the answer. Dörner tells us:

> Geniuses are geniuses by birth, whereas the wise gain their wisdom through experience. And it seems to me that the ability to deal with problems *in the most appropriate way* is the hallmark of wisdom rather than genius.[68]

Or in the words of Clausewitz describing the remedy to his familiar friction: "Is there any lubricant that will reduce this abrasion? Only one, and a commander and his army will not always have it readily: combat experience."[69] Direct experience is the area most fertile for providing improvement in decision-making performance in the complex environment we have described.[70] Considering the dearth of combat experience at the operational level in our militaries, training becomes the vehicle of choice to gain those habits that will make us better decision-makers. The rest of the insights related to the commander deal with how we prepare him or her for the job. Most of these insights deal with the professional development triad of education, training and experience, and weigh heavily on the side of experience.

[§] Term coined by Klein, taken to mean "thinking about thinking" or seeing inside your own thought process.

Let us first look at the value of concentrating on the educational route to improving the decision-maker's ability to deal with complex situations. Dörner explains the results of such an approach:

> The training gave them what I would call "verbal intelligence" in the field of solving complex problems. Equipped with lots of shiny new concepts, they were able to *talk* about their thinking, their actions, and the problems they were facing. This gain of eloquence left no mark at all on their performance, however. Other investigators report a similar gap between verbal intelligence and performance intelligence and distinguish between "explicit" and "implicit" knowledge. The ability to talk about something does not necessarily reflect an ability to deal with it in reality.[71]

When a training approach is applied, i.e. lesson closely followed by practice, to teach formal methods of analysis, it proves a hindrance to rapid decision-making. Klein explains:

> We do not make someone an expert through training in formal methods of analysis. Quite the contrary is true, in fact: we run the risk of slowing the development of skills. If the purpose is to train people in time-pressured decision making, we might require that the trainee make rapid responses rather than ponder all the implications.[72]

Because expertise depends on perceptual skills and perceptual learning takes many cases to develop, you rarely get someone to jump a skill level by teaching more facts and rules. In natural settings, perceptual learning grows with the accumulation of experience. Powerful training methods will not grow instant experts; the most we can expect from them is to make training more efficient.[73] So, left with frequent practice as the sole reliable contributor to improved decision-making in complex environments and a scarcity of combat experience, how can we prepare our decision-makers for the challenge?

The best approach to replicate the required experience is of course a robust, yet accessible, simulation program; a program filled with exercises and realistic scenarios where "teaching" takes a backseat to "practice," allowing the person a chance to size up numerous situations very quickly. A good simulation can sometimes provide more training value than direct experience, it lets you stop the action, back up to see what went on, and cram many trials together so a person can develop a sense of typicality.[74]

The next insight, dealing with maximizing the value of each experiential event, reinforces the importance of the After Action Review (AAR) process as we know it. While teaching is of little value in developing the ability to make decisions in a complex environment, it appears that conscious self-reflection makes a difference. Subjects that were asked to reflect on their own thought process after each iteration of a problem solving experiment performed much better than a control group who were asked to do something unrelated.[75] This forced foray into metacognition made them better problem solvers. Self-reflection can be enhanced by the presence of an expert observer who, having witnessed how the participant planned and acted and having noted his/her errors and their determinants, assists the participant in his/her reflection through carefully prepared follow-up sessions.[76]

Two related words of caution on these last two insights. First, the customary warning on the fidelity of the simulation we use to replicate the reality of the experiential event. If the patterns in the simulation do not match the ones in reality, the subject develops the wrong intuition. The second caution, more sombre, indicates that, despite our best efforts at simulation, we may never truly develop expertise in our subject area. According to Klein:

> We will not build up real expertise when: The domain is dynamic, we have to predict human behavior, we have less chance for feedback, the task does not have enough repetition to build a sense of typicality, [or] we have fewer trials. Under these conditions, we should be cautious about assuming that experience translates into expertise. In these sorts of domains, experience would give us smooth routines, showing that we had been doing the job for a while. Yet our expertise might not go much beyond these surface routines; we would not have a chance to develop reliable expertise.[77]

This might explain why peacetime generals often get sacked at the beginning of a war. They have acquired experience but had no chance to develop expertise. If we are condemned to collecting experience in our field rather than expertise, the best advice for preparing for war may be that offered by Mandeles: "In war a commander needs a set of organizations that will learn while they execute their missions. What those organizations can practice in peacetime is not so much precisely what to do in war, but how to learn quickly what to do."[78]

We will therefore now turn our attention to the insights that deal with command within the organization. The thinking apparatus of the Joint Force, or more precisely the way in which planning is carried out, decisions are made or delegated and intent is communicated, is how we will approach insights on command.

Our first realization is that the concept of metacognition can be applied to the apparatus of the Joint Force itself to create the right groupings, structure and information flow to maximize its strengths and minimize its weaknesses.[79] When it comes to planning, we have remarked earlier in this essay the similarity of the decision-making strategy proposed by Dörner to the OPP and noted that although this serves us well in unfamiliar complex situations, it is slow and cumbersome and difficult to apply under extreme time pressure. Klein's RPD model on the other hand exploits the experience of the decision maker to produce rapid reaction but is limited to relatively familiar situations. In the OPP, the symbiosis between the two is meant to be the Commander's Planning Guidance, where having sized up the situation, he/she decides on the goal and directs the COAs to be investigated. The staff then attempts to produce the plan that would make those COAs work. This takes advantage of the pattern-recognition skills of the most experienced member of the force, the JFC, and channels the energy of the staff's brainpower to dealing with the complexity that each COA represents. Unfortunately, the reality differs from the theory. Commanders, maybe intimidated by the credentials of their "Ninja Team,"[80] tend to let planners come up with COAs and then, realizing that they do not meet their understanding of the situation, incrementally adjust them to their liking during the information and decision briefs.[81] This may be a reflection of the teaching method in our Staff Colleges where Directing Staff, acting as commanders, ask their student planners to come up with the commander's planning guidance, ostensibly to give them a better opportunity to read in the problem. It is clear that delegating mission analysis and COA identification to the staff is the wrong approach, not only does it waste the time and cognitive energy of the staff, it marginalizes the expertise of the commander who ultimately makes the decision.

Turning our attention to decision-making and delegating, i.e., command philosophy, we have been slow in the West to recognize that complexity demands the mission-command approach. Even now, whenever technology floats the mirage of complete visibility of the battlespace, we let ourselves be tempted by the allure of more control. Unless the complete visibility promised also includes complete structural information (and it cannot),[82] mission-command remains the only viable alternative. Using Dörner's words again:

> In very complex and quickly changing situations the most reasonable strategy is to plan only in rough outline and to delegate as many decisions as possible to subordinates. These subordinates will need considerable independence and a thorough understanding of the overall plan. Such strategies require a 'redundancy of potential command,' that is, many individuals who are all capable of carrying out leadership tasks within the context of general directives.[83]

Having sized up the situation, planned a response, made or delegated the decision, the next task for the thinking apparatus of the Joint Force is to communicate that intent to those that will implement it. The first enabler here, most familiar to military organization, is team building. Working with people who understand the culture, the task, and what we are trying to accomplish allows them to "read our minds" and fill the unspecified details.[84]

With implicit intent established, we need to deal with explicit intent. The notion of telling subordinates not only what to do, but why they must do it is again a relatively new concept in Anglo-Saxon military heritage. The primary function of communicating intent is to allow better improvisation. Once we accept that in a complex system we cannot think of all the contingencies in advance and that we have to resort to mission-command, giving the reasoning behind a task will allow subordinates to be creative. They will adjust to the field conditions what the higher-level headquarters cannot know about. They will recognize opportunities no one expected and find ways to jury-rig solutions when the plan runs into trouble. Explicit intent should be clear enough for them to set and revise priorities, to decide when to grasp an opportunity and when to let it go.[85]

Commander's intent is already part of the orders format used by the joint force where intent, scheme of manoeuvre, main effort and end-state are given. Klein's list is more exhaustive and includes information that we normally only publish internally to the headquarters in the form of the Commander's Planning Guidance or the Chief of Staff's Planning Directive. From Klein:

> There are seven types of information that a person could present to help the people receiving the request to understand what to do: 1. The purpose of the task (the higher-level goals). 2. The objective of the task (an image of the desired

> outcome). 3. The sequence of steps in the plan. 4. The rational for the plan. 5. The key decisions that may have to be made. 6. Antigoals (unwanted outcomes). 7.Constraints and other considerations.[86]

Although most of this information finds its way into the orders format, it might be worthwhile to re-examine our intent paragraph to make sure it meets all of our needs.

Some of the insights presented above, gained from the realization that the JFC deals in an unpredictable, yet within bounds, self-organizing complex environment, have already been adopted by western militaries. The philosophy of mission-command, the construct of the OPP, the idea of communicating intent and the widespread use of AARs are indicators that we have come to realize that we have to learn to live with complexity. On the other hand, commanders comfortable with chaos and the concept of metacognition are considered but not yet ingrained in our culture. Frequent exposure, through simulation, to the realities of decision-making in complex environments rather than training in formal methods of analysis would go a long way in forcing that trend. The application of these insights will not only save precious time in the decision-action cycle; tackling the challenge of chaos with a focus on developing people will put us in good stead in our endeavour to become a truly learning organization.

Conclusion

> "Having heard what can be gained from my assessment, shape a strategic advantage (shih) from them to strengthen our position."
>
> Sun Tzu[87]

War, the environment in which a Joint Force Commander operates, is a complex system where knowing the physical component of the situation, i.e., Battlespace Visibility (BV), is only part of the solution. Interactions, even deterministic ones, make war uncertain in a deeply fundamental way. Considering our cognitive limitations, making decisions in the complex dynamic systems that characterizes warfare is no simple matter. Coping strategies in the form of pattern matching and decision-making schemes are required to make sense of the complexity. Some of these strategies and enablers, like the philosophy of mission-command have already been adopted by western militaries. Others, like the wholesale acceptance of Naturalistic Decision Making methods, have yet to make inroads. Frequent exposure to the realities of decision-making in complex environments, through simulation or otherwise, needs to figure predominantly in our professional development scheme of commanders.

Selection and development are two complementary approaches we can take to ensure our commanders thrive on chaos rather than fight it. When it comes to selection, we already spend significant resources testing the cognitive ability and motor skill potential of candidates for specific military occupations (MOCs). Testing for comfort level with chaos, or aptitude to develop it, would be advantageous in our selection of candidates in "operator MOCs" liable to provide Commanders. Then, having ascertained a capacity to tolerate chaos, adapting our Professional Development triad to actually develop it would be the next step. In that regard, experience that engenders expertise needs to figure prominently. Deployed operational experience, instrumented field exercises and computer-simulated exercises, all supported by comprehensive After Action Reviews, are the activities of significant value here. In the same vein, the focus on deliberate planning that characterizes our staff colleges has to be counterbalanced by the incorporation of Naturalistic Decision Making methods in the curriculum. It is not enough to learn to plan. Learning to make time-sensitive decisions during execution must be taught and practised if our military education institutions are to be worthy of the title "Command" and Staff Colleges.

BV, even when it is perfect, deals with the current point in time and is therefore only a small part of the picture the commander needs to consider to make decisions within the complex system of war. Furthermore, its near-perfect quality giving the impression of clarity and finality, may lead the commander to concentrate on the space configuration of the situation rather than the more difficult temporal one. So even with perfect BV, commanders need to step back and reflect, exploit their intuition, mental simulation and other sources of power to truly appreciate the situation and arrive at decisions based on variables far more subtle than what can be captured on a computer screen.

Perfect BV is a significant step forward for the information gatherers and managers in the headquarters, i.e., the staff. To the commander however, BV will not reduce the chaotic nature of the environment. It has very limited utility in reducing the difficulty ofited ut1 10412 0 0 12 406.32

Glossary[88]

Chaos: effectively unpredictable long time behaviour arising in a deterministic dynamical system because of sensitivity to initial conditions. It must be emphasized that a deterministic dynamical system is perfectly predictable given perfect knowledge of the initial condition, and is in practice always predictable in the short term. The key to long-term unpredictability is a property known as sensitivity to initial conditions.

Complexity: Complex systems are non-linear systems characterized by collective properties associated with the system as a whole that are different from the characteristic behaviours of the constituent parts.

Criticality: A point at which system properties change suddenly.

Deterministic: Dynamical systems are "deterministic" if there is a unique consequent to every state, and "stochastic" or "random" if there is more than one consequent chosen from some probability distribution (the "perfect" coin toss has two consequents with equal probability for each initial state, it is not deterministic). Most of non-linear science deals with deterministic systems.

Non-linear: In algebra, we define linearity in terms of functions that have the property $f(x+y) = f(x)+f(y)$ and $f(ax) = af(x)$. In other words linearity involves two propositions: (1) changes in system output are proportional to changes in input; and, (2) system outputs corresponding to the sum of two inputs are equal to the sum of the outputs arising from individual inputs. Non-linear is defined as the negation of linear. This means that the result f may be out of proportion to the input x or y. i.e., A small input may have an unpredictably large output like the proverbial butterfly flapping its wing causing a hurricane on the other side of the world.

Pattern-forming self-organisation: Systems where structure appears without explicit pressure or involvement from outside the system. In other words, the constraints on form (i.e. organization) are internal to the system, resulting from the interactions among the components and usually independent of the physical nature of those components.

Self-Organized Criticality: The ability of a system to evolve in such a way as to approach a critical point and then maintain itself at that point.

Stochastic or **random**: Systems where there is more than one consequent to every state chosen from some probability distribution (the "perfect" coin toss has two consequents with equal probability for each initial state, it is not deterministic).

Notes:

[1] Miyamoto Musashi, *A Book of Five Rings.* Victor Harris trans. (Woodstock, New York: The Overlook Press, 1974), 95.

[2] I am using here the Pigeau & McCann concept of control, made up of structures and process, devised in part to reduce uncertainty. See Ross Pigeau and Carol McCann. "Re-conceptualizing Command and Control," *Canadian Military Journal*, Vol 3, No 1 (Spring 2002), 54.

[3] Martin Van Creveld, *Command in war* (Cambridge, MA: Harvard University Press, 1985), 265-266.

[4] A typical example is Arnold Beichman, "Revolution in Warfare Trenches." *Washington Times* (31 January 1996), 17. Originally referred to in John D Hall, "Decision-Making in the information age: Moving Beyond the MDMP," *Field Artillery Journal* (September-October 2000), 28.

[5] For the purpose of this essay, I will generously define perfect Battlespace Visibility as the ability for the commander to see, on demand, everything in the Battlespace. I deliberately use the term Battlespace Visibility rather than Situational Awareness. Although our doctrine appears to have a simplistic view of Situational Awareness, virtually equating it to Battlespace Visibility, the two are not synonymous. The naïve doctrinal definition is: "Quite simply, if you can answer the following questions accurately: "*Where am I*?" *Where are the good guys*?" "*Where are the bad guys and what are they doing*?" "*What is that*?" and "*What am I supposed to be doing*?" Then you have Situational Awareness." See B-GL-300-003/FP-000 - Land Force Command dated 21 July 1996, 115. Researchers in the field have advanced the concept significantly beyond that. Mica R. Endsley, a leading figure in the study of the concept of Situation Awareness (SA) defines it as " the perception of the elements in the environment with a volume of time and space, the comprehension of their meaning and the projection of their status in the near future." She recognises three levels of SA: **Level 1 - Perception** of elements in current situation, **Level 2 - Comprehension** of current situation, and **Level 3 - Projection** of future status. The first, which deals with perception of cues, is fundamental. Without basic perception of important information, the odds of forming a correct picture of the situation are extremely low. Comprehension, for its part, encompasses how people integrate multiple pieces of information and determine their relevance to achieve an understanding of the situation. To differentiate levels one and two, She employs the analogy of having a high level of reading comprehension as compared to just reading words. The highest level of SA, level three, implies the ability to forecast future situation events, (including their implication) and dynamics. It is ability at this level that allows for timely decision-making. This approach places SA as the main precursor to decision making which supports the argument of this paper: higher-level SA happens in the commander's mind. The ability to translate the symbols on the computer screen (presumably level 1 SA) into level 3 SA is what this essay is about. See Mica R Endsley, "Theoretical Underpinnings of Situation Awareness: A Critical Review" in *Situation Awareness Analysis and Measurement.* M.R Endsley and Garland D.J. eds. (Mahwah, NJ: Lawrence Erlbaum Associates, 2000), 3-4.

[6] Robert K Ackerman, "Operation Enduring Freedom Redefines Warfare" in Signal Tribute: The Fight for Freedom. *Signal Magazine*, Vol 57, No 1 (Septembre 2002), 3.

[7] Carl von Clausewitz, *On War.* Michael Howard and Peter Paret eds. and trans. (Toronto, ON: Random House of Canada Limited, 1993), 136.

[8] Van Creveld (1985), 7.

[9] Clausewitz, 138.

[10] See the Frequently Asked Question section of the University of Colorado web site at http://amath.colorado.edu/faculty/jdm/faq-[2].html

[11] **Non-linear:** In algebra, we define linearity in terms of functions that have the property $f(x+y) = f(x)+f(y)$ and $f(ax) = af(x)$. In other words linearity involves two propositions: (1) changes in system output are proportional to changes in input…and (2) system outputs corresponding to the sum of two inputs are equal to the sum of the outputs arising from individual inputs. Non-linear is defined as the negation of linear. This means that the result f may be out of proportion to the input x or y. i.e., A small input may have

an unpredictably large output like the proverbial butterfly flapping its wing causing a hurricane on the other side of the world. **Deterministic**: Dynamical systems are "deterministic" if there is a unique consequent to every state, and "stochastic" or "random" if there is more than one consequent chosen from some probability distribution (the "perfect" coin toss has two consequents with equal probability for each initial state, it is not deterministic). Most of non-linear science deals with deterministic systems. **Chaos**: effectively unpredictable long time behaviour arising in a deterministic dynamical system because of sensitivity to initial conditions. It must be emphasized that a deterministic dynamical system is perfectly predictable given perfect knowledge of the initial condition, and is in practice always predictable in the short term. The key to long-term unpredictability is a property known as sensitivity to initial conditions. See the Frequently Asked Question section of the University of Colorado web site at http://amath.colorado.edu/faculty/jdm/faq-[2].html

[12] This part on the evolution of the science of Chaos borrows heavily from the University of Maryland web site at http://www-chaos.umd.edu/

[13] Murray Gell-Mann, "The simple and the Complex". In *Complexity, Global Politics, and National Security*. David S. Alberts and Thomas J. Czerwinski, eds. (Washington: National Defense University, 1997), 15.

[14] John F. Schmitt, "Command and (out of) Control: The Military Implication of Complexity Theory". In *Complexity, Global Politics, and National Security*. David S. Alberts and Thomas J. Czerwinski, eds. (Washington: National Defense University, 1997), 233-235.

[15] Robert Jarvis, "Complex systems: The Role of Interactions". In *Complexity, Global Politics, and National Security*. David S. Alberts and Thomas J. Czerwinski, eds. (Washington: National Defense University, 1997), 46-48.

[16] Jarvis, 5.

[17] The constituting elements used here and its attendant level of aggregation are for illustrative purposes only. We could have used any other levels of aggregation, e.g., at the most basic elements of warfare: If we know with enough precision the skill level of a sniper, her mental and physical state, the distance and angle to the target, the weather conditions and other obstructions to visibility and the characteristics of the weapon used, we can determine if she will hit the target. It is not a random coin toss. For a discussion on the deterministic aspects of the technological elements of war see Martin Van Creveld, *Technology and War: From 2000 B.C. to the Present* (New York: The Free Press, 1991), 314-315.

[18] Normally attributed to Benjamin Franklin " Poor Richard's Almanack." 1758 even if the present day saying is somewhat different from the original - "For the want of a nail, the shoe was lost; for the want of a shoe the horse was lost; and for the want of a horse the rider was lost, being overtaken and slain by the enemy, all for the want of care about a horseshoe nail." See: http://usinfo.state.gov/usa/infousa/facts/loa/bf1758.htm

[19] Clausewitz, 138-139.

[20] Count Helmuth Karl Bernard von Moltke cited in Peter G. Tsouras, *Warrior's Words a Quotation Book: From Sesostris III to Schwarzkopf 1871 BC to AD 1991* (London: Arms and Armour Press,1992), 61.

[21] Schmitt, 232.

[22] Cohen and Gooch clearly recognize this: "The kinds of misfortunes we have discussed in this book are not, however, the product of malevolent chance. Neither are they the sole responsibility of any single individual, not even the military commander. Instead, each is the consequence of the inherent fragility of an entire organization." See Eliot A. Cohen and John Gooch, *Military Misfortunes: The Anatomy of Failure in War* (New York, NY: The Free Press, 1990), 243. Mandeles also deals with this issue: "The paradox of modern military command at the theatre level is that, although it is the responsibility of one officer, it must be exercised within a set of complex organizations." See Mark D. Mandeles, et al., *Managing Command and Control in the Persian Gulf War* (Westport, CT: Praeger, 1996), 6.

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

[24] Van Creveld (1991), 314.

[25] Clausewitz, 247.

[26] Mann, 138.

[27] The concept of Centre of Gravity comes to mind.

[28] The conditions enumerated here are necessary but not sufficient to conclude that the theory fits the facts. To prove the sufficient criteria is beyond the scope of this paper. It could make for a good doctoral research thesis…

[29] Schmitt, 236-237.

[30] Clausewitz, 137.

[31] Dietrich Dörner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations* (New York: Metropolitan Books, 1996), 5-6.

[32] There are more factors at play here, Dörner identifies: "The slowness of our thinking and the small amount of information we can process at any one time, our tendency to protect our sense of our competence, the limited inflow capacity of our memory, and our tendency to focus only on immediately pressing problems." As the causes of the mistakes we make dealing with complex systems. For the sake of brevity, I have chosen to highlight only the temporal feature here. Other aspects are noted in passing in the essay. See Dörner, 190.

[33] Dörner, 109.

[34] Dörner, 107-152.

[35] Dörner, 30.

[36] Klein defines uncertainty as "doubt that threatens to block action." Key pieces of information are missing, unreliable, ambiguous, inconsistent, or too complex to interpret, and as a result a decision maker will be reluctant to act. Klein sees four sources of uncertainty: 1. Missing information. (Information is unavailable. It has not been received or has been received but cannot be located when needed.) 2. Unreliable information. (The credibility of the source is low, or is perceived to be low even if the information is highly accurate.) 3. Ambiguous or conflicting information. (There is more than one reasonable way to interpret the information.) 4. Complex information. (It is difficult to integrate the different facets of the data.). See Gary Klein, *Source of Power: How People Make Decisions* (Massachusetts: The MIT Press, 1999), 276-277.

[37] Dörner, 18.

[38] Dörner, 87-88.

[39] Experts appear to have an overall sense of what is happening in a situation - an ability to judge prototypicality. Whereas novices may be confused by all the data elements, experts see the big picture, and they appear to be less likely to fall victim to information overload. See Klein, 152.

[40] A *de minimus* explanation (coined by Perrow in his 1984 book "Normal Accidents: Living with high risk technologies") is one that tries to minimize inconsistencies. The operator forms an explanation and then proceeds to explain away disconfirming evidence. See Klein, 66.

[41] Klein, 274.

[42] Dörner, 27.

[43] Dörner, 41.

[44] Dörner calls "intuition" the totality of implicit assumptions in an individual's mind - assumptions about the simple or complex links and the one-way or reciprocal influences between variables. See Dörner, 41. Similarly Klein notes "*Intuition depends on the use of experience to recognize key patterns that indicate the dynamics of the situation*." He adds however that because patterns can be subtle, people often cannot describe what they noticed, or how they judged a situation as typical or atypical. Therefore, intuition has a strange reputation. Skilled decision makers know that they can depend on their intuition, but at the same time they may feel uncomfortable trusting a source of power that seem so accidental." See Klein, 31.

[45] Dörner, 21-24.

[46] Dörner goes on to explain that we need, of course, to do more with information than simply gather it. We need to arrange it into an overall picture, a model for the reality we are dealing with. Formless collections of data about random aspects of a situation merely add to the situation's impenetrability and are no aid to decision making. We need a cohesive picture that lets us determine what is important and what unimportant, what belongs together and what does not - in short, that tells us what our information *means*. This kind of 'structural knowledge' will allow us to find order in apparent chaos. See Dörner, 44-45.

[47] Dörner, 43-46.

[48] The Gestalt school emphasizes perceptual approaches to thought. Rather than treating thought as calculating ways of manipulating symbols. Gestalt theory is a broadly interdisciplinary general theory that provides a framework for a wide variety of psychological phenomena, processes, and applications. Human beings are viewed as open systems in active interaction with their environment. The primacy of the phenomenal: Recognizing and taking seriously the human world of experience as the only immediately given reality, and not simply discussing it away, is a fundamental assertion of Gestalt theory. It is the interaction of the individual and the situation in the sense of a dynamic field that determines experience and behaviour, and not only drives, external stimuli or static personality traits. See the Society for Gestalt Theory and its Applications web site at http://www.enabling.org/ia/gestalt/gerhards/

[49] Dörner, 39.

[50] Klein, 17.

[51] Klein, 24-26

[52] Klein, 35.

[53] Klein, 52-53.

[54] Clausewitz, 118.

[55] Thomas J. Czerwinski, "Command and Control at the Crossroads," *Parameters* 26, no. 3 (Autumn 1996), 124.

[56] Examples that easily come to mind are the Iraqis in the Gulf War for lack of applicable experience, the Canadians at Dieppe for lack of information and the failure to foresee attack on world trade centre as a *de minimus error*.

[57] "Failure to learn, failure to anticipate, and failure to adapt." See Cohen, 26.

[58] Timothy L. Thomas, "Kosovo and the Current Myth of Information Superiority," *Parameters* 30, no. 1 (Spring 2000), 14.

[59] Mandeles, 5

[60] Lewis, Lloyd. "Sherman: Fighting Prophet." New York, NY: Harcourt Brace, 1932. p. 424. Originally quoted in Cohen, 244.

[61] Sun Tzu, *The Art of Warfare*. Roger Ames trans. (Toronto, ON: Random House of Canada Limited, 1993) 120.

[62] Robert R. Maxfield, "Complexity and Organization Management," In *Complexity, Global Politics, and National Security*. David S. Alberts and Thomas J. Czerwinski, eds. (Washington: National Defense University, 1997), 183-184.

[63] Complex systems have the property that many competing behaviours are possible and the system tends to alternate among them. In fact, the ability of a complex system to access many different states, combined with its sensitivity, offers great flexibility in manipulating the system's dynamics to select a desired behavior. By understanding dynamically how some of the complex features arise, we show that it is indeed possible to control a complex system's behavior. See Leon Pond and Celso Grebogi. "Controlling Complexity." (College Park, MD, Institute for Plasma Research, University of Maryland, 1995), abstract. Accessible on line at http://www-chaos.umd.edu/

[64] Attributed to General Kurt von Hammerstein Equord circa 1933. This quote is cited in Tsouras, 297.

[65] Dörner, 42.

[66] Dörner, 143.

[67] Klein, 158-159.

[68] Dörner, 193.

[69] Clausewitz, 141.

[70] Klein, 42.

[71] Dörner, 196.

[72] Klein, 30.

[73] Klein, 287.

[74] Klein, 42-43.

[75] Dörner, 195.

[76] Dörner, 196-199.

[77] Klein, 282.

[78] Mandeles, 6.

[79] Pigeau and McCann certainly see this as a responsibility of "Creative Command". See Pigeau (2002), 55

[80] "Ninja Team" is the informal name given to the core group of planners, often School of Advanced Military Studies graduates, in an army or joint headquarters.

[81] General Schwarzkopf's first version of the plan for a ground attack in the Gulf is the typical example. His instruction to his planners was "Assume a ground attack will follow an air campaign. I want you to study the enemy dispositions and the terrain and tell me the best way to drive Iraq out of Kuwait given the forces we have available." Only to come up with is own COA later. See Norman H.Schwarzkopf, *It Doesn't Take a Hero* (New York: Bantam Books, 1992), 354 and 362.

[82] No matter how precisely you measure the initial condition in these systems, your prediction of its subsequent motion goes radically wrong after a short time. Typically, the predictability horizon grows only logarithmically with the precision of measurement. Thus for each increase in precision by a factor of 10, say, you may only be able to predict two more time units. See the Frequently Asked Question section of the University of Colorado web site at http://amath.colorado.edu/faculty/jdm/faq-[2].html

[83] Dörner, 161.

[84] Klein, 219. Pigeau and McCann refer to this as implicit intent. See Ross Pigeau and Carol McCann, *Re-Defining Command and Control* (Toronto: Defence and Civil Institute of Environmental Medicine, 1998), 5-6

[85] Klein, 223.

[86] Klein, 225.

[87] Sun Tzu, 104.

[88] Taken from the Frequently Asked Question section of the University of Colorado web site at http://amath.colorado.edu/faculty/jdm/faq-[2].html and from The self-organized systems FAQ web site at http://www.calresco.org/sos/sosfaq.htm#1.1

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