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The Theory and Practice of Complexity Science: Epistemological Considerations for Military Operational Analysis

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Abstract

Though postmodernist and complexity schools of thought are not new developments, their influence on operational analysis (OA), and in particular, military OA is recent. Independent of these developments, military OA is nonetheless changing as a result of the changing nature of warfare and the consequent demands on analysts. As an illustrative example consider the developing field of Operations Other Than War (OOTW). The scope of many OOTW-type problems suggests a holistic stance that not only requires analysis of the target societies physical assets, such as technological infrastructure, but also cultural features like the role of institutions, for example. These inter-subjective aspects are not adequately treated through the adoption of the traditional Modern, positivist, OA paradigm because of their local, rather than global, character. To fully appreciate the value of these 'softer' aspects analysts must begin by accepting the situatedness and personal interpretations of individuals' surroundings. Though the longstanding and powerful reductionist viewpoint has been used to address these issues, it has been found to be lacking despite being stretched to the limits with novel application.

In addition to the changing subject matter the role of military OA is evolving. Now analysts are as likely to be asked to consider issues of organisational change as they are to be asked to model a force on force battle situation.

This paper will take the view that common to many of the new challenges facing analysts is the apparent compositional complexity of the systems of interest. As such, the pure adoption of a viewpoint that presumes the existence of an absolute, empirically based, and objective reality is increasingly inappropriate. The consequent paradigm shift has serious and far-reaching consequences for OA in general, yet is still commensurate with the traditional viewpoint. By not wanting to (and not needing to) undermine the extensive success of military OA over the past 50 years, the paper will also explore the symbiotic relationship between the traditional viewpoint and the emerging, postmodern, craft. The paper will rely on previous texts exploring postmodernism, hermeneutics, deconstruction, and social

constructionism, and develop an epistemological view of the 'science of partial complex systems'. Implications for military OA leading from these developments will be commented upon. In conclusion, the authors suggest that significant benefits might be realised through a reframing of the community's dominant methodological position. Activities such as paradigmatic exploration and boundary critique have a central position in our revised OA perspective, and, rather than replacing existing methodologies, subsume them in a meta-methodological view of OA (i.e. a method for developing problem-specific methods).

1 Introduction

1.1 OA and the Military

Operational Research (OR) was born during the years immediately prior to and during the Second World War as the result of a long gestated union of modernist scientific thinking and ancient military arts. Called 'Operational Analysis' (OA) in military circles, in order to avoid confusion with military Operational Requirements, the early analysts defined OA as "scientific methods of analysis [which] give useful assistance to effective executive action" (Waddington, 1973) and as "a scientific method of providing executive departments with a quantitative basis for decisions regarding operations under their control" (Morse & Kimball, 1951, and Houlden, 1962). From these beginnings OA diffused into the civilian world as OR and became a key foundation of management science. In the military world, however, OA has remained closely linked to its origins.

The early operational analysts were largely involved with relatively low-level tactical questions in support of the employment of military forces. Two commonly quoted examples are: identifying the most effective way of bombing U-boats in the Bay of Biscay; and demonstrating that fewer cross-Atlantic re-supply ships would be sunk if they sailed in convoys. In both of these examples, and most others, the analysts proceeded by structuring the problem as presented by the military, constructing a mathematical model of the relationships between key parameters and solving that model to propose optimal or improved values for those parameters.

The mathematical model has been a key pillar of OA throughout its existence, to the point where some analysts suggest that it is a defining characteristic, distinguishing OA from other, less scientific decision-support activities. However, this view goes too far. Fundamentally, OA attempted to bring the application of unbiased reasoning and rational problem structuring to complement the wisdom and intuition of the military.

Whilst civil OR moved rapidly into supporting business process re-engineering on a grand scale, military OA remained, for the duration of the Cold War, focused largely on improving the individual components of military technology and the low-level tactics of their use. Increasingly, OA was used not in support of operational commanders, but to justify the decisions of equipment procurers and those who

must balance investment in Defence across the many and varied demands arising from it.

OA has become a fundamental pillar of Defence investment appraisal in the UK, the USA and in most other technologically advanced nations. Unable to quantify the benefits of investment in purely financial terms, and without sufficiently recent and comprehensive experience of new military technologies to rely upon 'lessons learnt', Defence Departments have turned to OA to provide quantitative measures of value. These usually take the form of measures of system or force effectiveness, set in the context of one or a series of forward-looking scenarios. This need to value cost in terms of non-financial benefits, eventually gave rise to a new form of cost-benefit analysis called, in the UK, the Combined Operational Effectiveness and Investment Appraisal (COEIA) and, in the US, the Cost and Operational Effectiveness Appraisal (COEA).

More recently, however, the post-Cold War international security environment has broken down many of the stable context assumptions upon which OA has traditionally relied. It has become increasingly difficult to identify and formulate problems in terms of straightforward measures of effectiveness, and the physical and mathematical bases of modelling have had to give ground, albeit reluctantly, to human and social science approaches. New kinds of questions have arisen which demand new kinds of OA solutions.

1.2 Changing Questions

In the context of the Cold War, military planning for the defence of Western Europe provided a stable strategic backdrop to Defence spending. With the overall structure of the expected campaign reasonably predictable, long term force structure planning was possible and the organisational and social contexts in the scenarios used by OA were not considered a necessary study variable. Also, the highly stressing nature of the anticipated combat, added to its essentially attritional nature, placed a premium on advances in military high technology. Consequently, analysis was able to concentrate on the more mechanical aspects of warfare, dominated by sensors, weapons, mobility, and defence systems. The mathematical modellers have honed their skills on precisely these conditions.

With the demise of the Soviet Union, the Cold War scenario has ceased to be an acceptable basis for justifying Defence spending and a wide range of alternative scenarios are used. These reflect a broader and more heterogeneous mix of situations, including a variety of so-called 'operations other than war' (OOTW) such as peace support operations, service supported evacuations, and military aid to civil authorities. Typical OOTW scenarios provide far less stability in terms of the political and social context for conflict and give rise to a wider range or more-or-less ad hoc coalitions of military forces to achieve, often unclear and variable political aims. The ongoing Balkan conflict of recent years provides classic

examples of the kind of operations that have out-manoeuvred the war-fighting models of Cold War OA.

As the hypothetical scenarios used to plan defence investment have begun to reflect the complexities of campaigns such as the UN Intervention Force (IFOR) operation in Bosnia, or the more recent KFOR intervention in Kosovo, the OA community has been challenged by questions like:

1. How will a limited bombing campaign impact on the will of military commanders to continue in conflict?
2. How will para-military forces react to the forced removal of oppressive occupation troops or the insertion of UN peacekeepers?
3. What is the effectiveness of a military force whose chief role is to win the hearts and minds of a local population? (And how do you measure it?)

When the inherent complexities of variable social and political situations implied by the above questions are added to the impact of increasingly intrusive and capable mass media coverage, the transformation of the OA problem from primarily physics to sociology becomes complete. Existing methods of analysis are simply unable to cope with social variables that are, in their very nature, subjective and culturally embedded. Models of conflict which involve the rational exchange of physical violence, have proved unable to adapt successfully to the new OOTW scenarios and two important ways forward have emerged:

1. Building on the principles of systems thinking, modellers have sought to construct descriptions of the interactive components of conflict and to populate these networks of interaction using a combination of judgement and rational inference, backed up by war-games and wisdom from real operations. Such models remain extremely limited and pose even greater validation problems than their, sometimes intractable, physics-based parents.
2. When it proves impossible to construct a valid and reliable model of a complex situation, even using man-in-the-loop simulation techniques or gaming, analysts have turned to techniques from a different tradition and sought to aid military decision-makers directly using partial models and structured facilitation of decision-making. In doing so, military OA has followed in the footsteps of its civilian descendant (OR) and has embraced, albeit unwillingly, the methods of management science and business consultancy. There is a danger of losing rigour in using these approaches, but it can be maintained with care (Mathieson, 2000).

In the UK, a further impetus to the modernisation of military OA has been an unprecedented trend for analysts to be consulted to support change management and organisational design within the Ministry of Defence (MOD) and its business processes. Although common in many other departments of state, such as social

security and health, the use of OA in MOD has traditionally been limited largely to military problems and not the issues of Defence as a government function.

On both the military and the 'business' fronts, therefore, OA is being challenged to provide a more integrated and participative style of consultancy, making heavy use of decision support methods as opposed to more conventional model-based analysis.

1.3 From Consultant to Facilitator

Although the early operational analysts were used directly by military commands to support their operational decision-making, this direct involvement was reduced during the years of strategic stability. Analysis has, by and large, become a thing done by civilians in their laboratories with military advisers providing a surrogate for operational decision-makers. Results are delivered to MOD decision-makers in paper reports, which must record sufficient description of the methods, models and assumptions used to allow independent scientific scrutiny of the advice offered.

This 'off-line' approach to analysis imposes significant constraints on the analysis process. Off-line analysis is done at arm's length from the decision-maker. The analyst must, therefore, create a complete model of the problem, explicitly incorporating enough of the decision-maker's understanding to be meaningful. Off-line analysis is the most common requirement on military operational analysts. This is because the decision-makers do not have the time to be deeply involved in any but the big decisions, and also because of an institutional desire for the scientific advice given to decision-makers to be independent of even the decision-maker's prejudice.

When analysts are required to facilitate a decision process, with the direct involvement of the decision-maker, then their role is to create for the decision-maker, an analysis framework with which the decision-maker can interpret and explore their own problem. The model created by the analyst need only be partial, since the decision-maker is "in the loop" and providing elements of the analysis inside his own head. The analyst will seek to reflect the decision-maker's internal model as much as possible, but does not need a complete model, nor a validated model since validation is intrinsic in the fact that the model is created and used by the decision-maker, not the analyst. (Mathieson, 2000)

This is an exciting approach for analysts. It offers the sort of challenge and immediate feedback the early analysts felt. However, the challenges presented to the facilitator include a challenge to their scientific rigour and independence. The challenge is to contribute to decision-making without losing touch with where OA began – the application of scientific methods.

However, the new questions being posed to OA require a response that goes beyond the well-rehearsed science of Cold War analysis. The systems that OA is being asked to think about are complex and cultural – so much so that naïve,

mechanically-based systems thinking is not sufficient. Since the technological arms race stopped driving Defence investment policy the roles of individual and societal perceptions in conflict have re-emerged. OA is being forced to recognise conflict as a social interaction between diverse organisations of people rather than the clash of two opposing technological titans.

Without diminishing the significance of the greater complexity which OA is being asked to face, it must be recognised that there is a real danger of over-emphasising the difficulties and of retreating into a state of hopelessness.

These are challenges which have been faced already by those scientists who have sought to take their craft out of the laboratory and into society – the management and social scientists and, perhaps most extremely, the anthropologists. However, many of the tools used by these disciplines lack the analytic rigour much prized by traditional OA communities.

Hence we have a dilemma. On the one hand we have trusted methods which seem incapable of dealing with the whole problem (although they are still powerful in parts of it) and we have social science approaches which embrace the whole problem but often lack the level of rigour which OA traditionally demands.

A key question for OA is whether it can safely learn from these other disciplines; whether it can walk in their ways without losing its virtue.

1.4 Aims of paper

Having discussed the changing environment of OA, in what way does this paper contribute to the body of knowledge that might facilitate and inform the direction in which military OA takes? We are not going to attempt to answer each one of the questions thus far raised. What we believe to be the common denominator that links many of these fundamental questions is the increased compositional complexity inherent in the questions of interest and the resulting differences of opinion in what the questions actually are, as well as the implications for design implementation. Therefore we will begin by presenting the authors' definition of a 'complex system', and the basic observations that have been gleaned from bottom-up computer simulation. We will by no means attempt a rigorous study into the validation of our underlying 'complexity' assumption, but explore the ramifications of making this assumption. We will argue that postmodern philosophy, as opposed to modernism, is overtly sensitive to the subtleties of a complex world. Unfortunately, though we believe both complexity science and postmodernism has much to offer, diffusion into the analytical community has been painfully slow. In part, this can be attributed to our institutionalised attitude towards analysis which is very much modernist in nature. Though institutionalism does play a part, a potentially more significant barrier is the notoriously inaccessible lexicon of these two fields. Therefore, an obvious aim of this paper is to make these literatures more accessible to the layperson.

Yet another barrier to the diffusion process is the way in which these fields have been presented to the community. For example, one of the authors vividly remembers being informed at a formal presentation that all prevailing analytical methods should now be deemed effectively useless in the face of the New World Order and that complexity-based thinking heralds a new golden age in military analysis. A similar accusation has been flung at bureaucracy in the management science. "Bureaucracy is dead," we are told. Such statements, apart from being misguided and incredibly audacious, do not endear listeners to the point of view being argued. In fact, they polarise any further debate, potentially stagnating any synthesis that might arise through honest and humble dialogue. The same accusation might be directed at sceptic postmodernists who assert that there is no 'truth' and that all perspectives have equal utility and value. Of course, making such a strong assertion is contradictory by definition as asserting no perspective *is* a perspective. As a result, it is no surprise that potential lessons from these two fields have fallen by the wayside.

As well as making these fields more accessible we will also attempt to put the record straight. For example, whereas in many quarters complexity-based thinking is seen as synonymous with bottom-up computer-based simulation (á la Santa Fe Institute) we will approach it from an epistemological perspective. From this perspective, a privileging of any analytical approach is deferred, and a pluralist stance leaning toward 'situated' methodological development is encouraged.

In short, the aim of this paper is to familiarise analysts with the fields of complexity science, and to a lesser extent, postmodernism, deconstruction, hermeneutics, social constructionism, and their potential implications for military OA. Practical conceptions, thus far developed, of complexity science will briefly be discussed.

Though we will raise a number of questions concerning the future capacity of military OA practitioners to adequately investigate complex systems we will not attempt to provide universal acontextual answers to them. We hope, however, that our discussion will facilitate the development of context-specific solutions.

2 The Theory of Complexity Science

2.1 Introduction

It is becoming rather monotonous to continually read military as well as organisational related articles that tell us how the concept of (and the requirements of) the modern military force is (are) changing, how it is more complex than ever, and how a paradigm shift is necessary in order to facilitate our continued analysis, and management, of such entities. We are told that we must distribute decision-making, encourage individual autonomy, and strive to innovate in the rapidly changing environment that characterises the New World Order. The list is as far-reaching as it is impressive. These concepts coincide with a new, or at least emerging, description of organisations, whether they be civilian or military. This 'paradigm' appears, from particular presentations at least, to wholly reject the long

held prevailing paradigm of the mechanistic, efficiency-driven, hierarchical, command and control organisation. We would question the 'wholly ness' of this position.

Complexity thinking has emerged from the milieu of possible candidates as a prime contender for the top spot in the next era of operational analysis. The number of management trade books on the subject has exploded with provocative titles such as *Leading at the Edge of Chaos* (Conner, 1998), *ReWiring the Corporate Brain* (Zohar, 1997), or *Adaptive Enterprise* (Haeckel, 1999) to name but a few. A number of military publications have also been published. For example, *Coping with Bounds: Speculations on Nonlinearity in Military Affairs* (Czerwinski, 1998), in which we are told that "the commanders of tomorrow will wrestle with 'entropy' and 'phase states', while grasping 'periodic and strange attractors' as they search for 'fractals' and 'emergence'"(!?); and *Complexity, Global Politics, and National Security* (Alberts & Czerwinski, 1997) in which it is asserted that "the most useful aspect of the chaos and complexity metaphors is to remind us and help us to avoid falling into chaos." The majority of these writings, particularly the management science books, seem to claim that the 'old' thinking needs to be (wholly) replaced with 'new' thinking, and that a new all-embracing perspective, sometimes referred to as 'complexity thinking', is available that will solve all our apparent woes. Of course, much of this is the hype that accompanies any 'New Science'. In the civilian literature authors might fairly be accused of preying on the needs of the many a desperate manager who is becoming increasingly anxious as they begin to accept that the MBA style approach to organisational management just doesn't seem to yield the results that it might have once brought. We suspect that similar accusations might also fairly be directed toward proposal writers who play on the insecurities of policy makers whose grasp on a concrete understanding of world order is apparently dwindling away.

Beneath the hype there must be a useful message, mustn't there? The general message seems to be that, where we once focussed on the parts of a system and how they functioned, we must now focus on the interactions between these parts, and how these relationships determine the identity not only of the parts, but of the whole system. Of course, as everything is connected to everything else the notion of a distinct system as an entity becomes very blurred – where are the boundaries? Back to this later.

2.2 Themes in Complexity Science

There are at least three themes, or communities, that characterise the research effort directed to the investigation of complex systems. The first is strongly allied to the quest for a theory of everything (TOE) in physics, i.e. an acontextual explanation for the existence of everything, the swansong of the Modernist Project. This community seeks to uncover the general principles of complex systems, likened to the fundamental field equations of physics (in our opinion it is likely that these two research thrusts, if successful, will result in a similar set of principles). Any such TOE, however, will be of limited value; it certainly will not provide the answers to

all our questions. If indeed such fundamental principals do exist (they may actually tell us more about the foundations and logical structure of mathematics than the 'real' world) they will likely be so abstract as to render them practically useless in the world of military operations – a decision-maker might need a PhD in physics in order to make the simplest of decisions. (It should also be noted that though many authors talk of 'complexity theory' the nicely packaged box of knowledge that the label would imply does not exist as such.) This particular complexity community makes considerable use of computer simulation in the form of bottom-up agent based modelling. We would not deny the power of this modelling approach, only to say that the 'laws' such studies yield provide a basis for a broader modelling paradigm than just bottom-up simulation.

Within the organisational science community complexity has not only been seen as a route to a possible theory of organisation, but also as a powerful metaphorical tool (see, for example, Lissack, 1997, 1999). According to this school, complexity thought, with it's associated language, provides a powerful lens through which to 'see' organisations. Concepts such as connectivity, edge of chaos, far-from-equilibrium, dissipative structures, emergence, epi-static coupling, co-evolving landscapes, etc., facilitate organisational scientists and the practicing manager in 'seeing' the complexity inherent in socio-technical organisations. The underlying belief is that the social world in intrinsically different from the natural world. As such, the theories of complexity, which have been developed through the examination of natural systems, are not directly applicable to social systems (at least not to the practical administration of such systems), though it's language may trigger some relevant insights to the behaviour of the social world.

If complexity science is merely another run of the mill quest for an ultimate description of reality, or a useful 'language' through which to view the world then we, the authors, would find it a little difficult to get so excited about. These conceptions of complexity science promise neat packages of knowledge that can apparently be easily transferred into any context – a 'slavish' Modernist conveyance of complexity science if you like. In our point of view, not only is this a very limited view of what might be, it also contradicts some of the basic observations already made within the Modernist mould. Though we value and make use of these particular expressions of complexity thinking, we have been lured by the possible implications the assumption of complexity has for our ability to know itself, i.e. what are the epistemological consequences of assuming that the world, the universe and everything is complex? To begin with, as we are less complex than the 'the universe' there is no way for us to possibly experience 'reality' in any complete sense. We are forced to view 'reality' through categorical frameworks that allow us to 'fudge' our way through life. This aspect of complexity science has received little attention and it will be the main thrust of this paper. Our interpretation of complexity science is that it provides an unexpected Modernist argument for the lines of thought that have been offered by authors often referred to as postmodernists. Complexity science sees the boundaries that divide the 'hard' from

the ‘soft’, the ‘natural’ from the ‘social’ for what they really are – artificial, and often arbitrary.

2.3 What is a complex system?

A complex system can be simply described as a system that is comprised of a large number of entities that display a high level of interactivity. The nature of this interactivity is often non-linear and contains manifest feedback loops. It is interesting to note that a result of this is that it can sometimes be very difficult to associate effect with cause – the familiar causal chains giving way to a networked causality. And, it places fundamental limitations on our abilities to validate models of complex systems.

There are a number of basic observations that have been made through the examination of such systems, primarily, through the use of computer simulation and the mathematics of non-linearity. The following sections will discuss the nature and implication of these observations in turn.

2.3.1 System memory

A complex system has memory captured at both the micro- (e.g. experiences, personal opinions, worldview) and macroscopic (e.g. culture, ritual, value system) levels. A complex system’s past is co-responsible for its present behaviour (Cilliers, 1998: 4). Therefore in trying to understand the current status of a complex system, its history must be taken into account. If we consider a computer for example (which we categorise as complicated rather than complex), it does indeed have a history; the computer would have run a variety of programmes in the past. These ‘experiences’ are not so important when it comes to considering the present behaviour of the computer (one need only consider the last program installed). The role of history is not so problematic when considering purely technological systems as it is in social and hybrid socio-technical systems. If we think, for example, of the monetary system as a complex system, to make sense of it we need to understand that it carries within itself what is has been, how it has been responded to, how it affected social life and so on. Today’s actors in the monetary system act on it with knowledge of previous crashes, subtleties in Greenspan’s choice of words, impacts of strikes and embargos and so on in the back of their heads.

2.3.2 A diversity of behaviours

A rich diversity of qualitatively different operating regimes exist that the system might adopt. This is a result of the non-linear nature of the relationships that describe the interactivity between the different system constituents. Mathematically, the system might approach an equilibrium state following what is referred to as a *point attractor*. Alternatively, the system may be drawn towards a *cyclic* or a *chaotic* attractor (see Exhibit 1). In terms of a military force, two different operational regimes might result from the adoption of a command and control hierarchy, or distributed network. The system is capable of moving between qualitatively different behavioural modes as the requirements placed by the

system's environment change. It should also be recognised that as a result of such changes the different behaviours that might exist also change.

Another familiar example of different qualitative modes is that of team behaviour. A grossly simplified account of team behaviour suggests four qualitatively different behavioural modes: forming, storming, norming, and performing. Each mode can be regarded as following a distinctly different attractor.

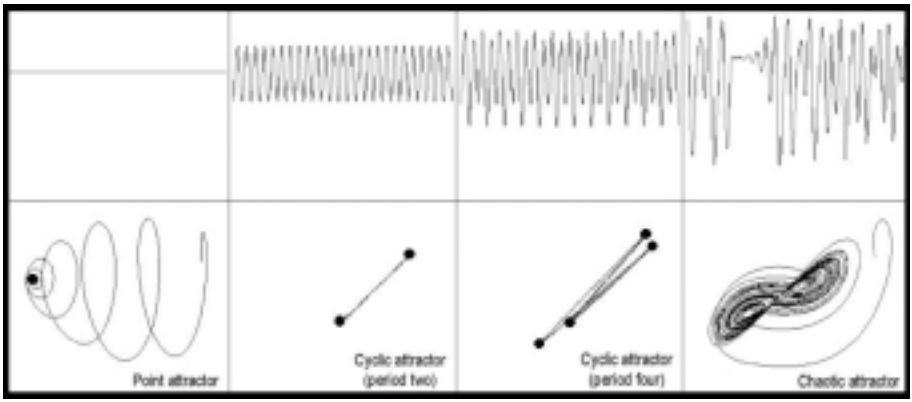

Exhibit 1 Examples of qualitatively different attractors (behavioural modes) generated from a common system of differential equations

2.3.3 Chaos and self-organisation

The system evolution is <u>potentially</u> incredibly sensitive to small disturbances (a phenomenon popularly referred to as deterministic chaos) as well as being <u>potentially</u> incredibly insensitive to large disturbances (as a result of self-organisation or, alternatively, anti-chaos). Many scholars when contemplating complex systems latch on to the more popular phenomenon of chaos to such an extent as to suggest that complexity science is effectively synonymous with Chaos Theory, or simply an extension of Chaos Theory. Deterministic chaos, which is captured by 'sensitivity to initial conditions', does occur in an infinity of constitutionally simple systems that contain non-linear relationships. If the world were indeed chaotic, as some would suggest, then there would be no hope for the analyst; no point in performing analysis whatsoever. This is not to say that at times a complex system may behave deterministically chaotically, but this type of chaos should be seen as merely a possible behavioural mode that a complex system might adopt. It should certainly not be regarded as a behaviour that characterises a complex system.

The world is not compositionally simple, however, it is compositionally complex, i.e. it can be considered to be a large number of interacting entities. In this situation self-organisation is also an important phenomenon. Self-organisation is impressively demonstrated in cellular automata experiments (see Exhibit 2). The exhibit shows the evolution of selected automata systems (the mathematical details of which are not important for this discussion – see Wolfram 1986 for further

details), where each horizontal line represents the next step in the evolution of the system. What is important to notice is that the starting conditions for each of these evolutionary experiments (represented by the first line of black and white squares) are random. From these random starting conditions an ordered evolutionary pattern is observed. In fact, whatever starting conditions are used, and assuming that the rules of interaction remain fixed, a qualitatively similar pattern will always emerge. In these experiments we see that the initial conditions play no part whatsoever in determining the qualitative nature of the evolutionary pattern. The initial conditions are forgotten; the system is insensitive to initial conditions. Furthermore, if these automata systems were perturbed at some point during their evolution, the perturbation would quickly dissipate, the systems self-organising into their preferred structure.

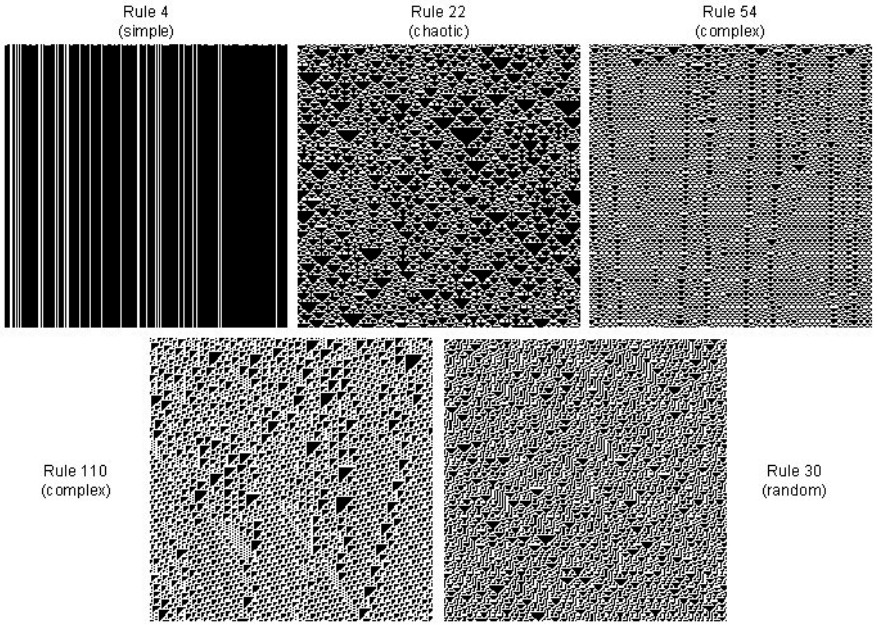

Exhibit 2 Examples of self-organisation in a simple cellular automata system. The rule number relates to the nature of the inter-cellular relationship

To illustrate the complicated dynamics of a complex system we will consider a notional phase portrait (Allen, 1999). A phase portrait simply illustrates to which behavioural mode the system will self-organise, given a range of initial conditions. For an example refer to Exhibit 3. (It should be noted that the example phase portrait is incredibly over simplified, using only two parameters to describe the initial conditions of the system. In actuality a much larger number of parameters may be needed to describe sufficiently the starting conditions and the consequent system behaviour.) The exhibit shows that for different sets of initial conditions, different behavioural modes are adopted. As with Exhibit 1 these modes may be well-described by a variety of qualitatively different attractors. Each area of 'phase space', known as attractor basins, which can be defined by a unique attractor, is

bounded by what is known as a 'separatrix'. These boundaries, or separatrices, are commonly found to be very complicated structures, known as fractals. Fractals are structures that display self-similarity at infinite scales. We will not consider here the mathematical details of such structures, but note that these boundaries are not necessarily clear and distinct. The complex structure means that the attractors that describe qualitatively different operational modes, rather than being separated by a hard division, overlap. The result of this is that, as the evolution of the system in question edges toward these boundaries, the probability that the system might 'leap' into an adjoining attractor basin, adopting the behavioural mode that is described by the attractor therein, increases. And, because of the 'fractalness' of these boundaries, sometimes only a tiny perturbation is sufficient to push the system into another basin. This sensitivity to small perturbations that might lead to a qualitative change in system behaviour is referred to as *stochastic chaos*. Of course, if the system is operating sufficiently far away from one of these boundaries then a small perturbation will not trigger such a change. Again, the systems overall qualitative behaviour is both sensitive and insensitive to small perturbations. As Peter Allen of Cranfield University points out, luck and circumstance (as perturbing forces) *do* have a role in the behaviour of complex systems (Allen, 1997 and Richardson & Allen, 1998).

Exhibit 3 A notional phase portrait showing the qualitatively different modes a complex system might evolve into. The boundaries between the different attractor basins are called separatrices

It is worth mentioning that attractor basins are not always pure in that only one qualitatively distinct behavioural mode is present. *Riddled basins* (Sommerer *et al.* 1993) also exist in which the basin, as well as it's boundary is fractal – a number of attractors are mixed so that once in such a basin the system's behaviour will erratically switch between a number of modes. It is also worth noting that not all boundaries will be fractal. Some boundaries may well manifest as hard divisions. There will be a spectrum of 'fracticality' or complexity that characterises these boundaries.

Chaos and self-organisation represent two extremes of the behavioural spectrum. What we find is that all other possibilities also exist. A complex system might react proportionately to small as well as large changes; it might also react disproportionately to both small and large changes. In fact, to blur this issue further, *apparently* distinct and *apparently* independent domains may emerge within the same system, each adopting a different behavioural regime. This mixing of states is not new to the military. A military force may adopt a command and control hierarchy overall, but it will contain specialised units that function better as distributed networks (e.g. a special forces unit) yet can interface effectively with the hierarchical structure; a kind of (non-)peaceful co-existence of different operational modes.

The implications of chaos (stochastic and deterministic) and self-organisation (or anti-chaos) for prediction are not trivial. As one might expect, the period for which a prediction is needed is important. Though an analyst might construct a model based upon the behavioural mode that is currently apparent, the mode might change. Conversely, it might not. The analyst must wonder as to how stable the current configuration is such that the model is appropriate. This behavioural complexity does not necessarily require non-linear modelling techniques. The system under investigation may be operating in a linear mode, so a linear model would be perfectly adequate for as long as this mode dominantly persists. Unfortunately, determination of whether a particular mode is stable over a particular duration is problematic. This highlights the importance of recognising the provisionality of all choices made.

In addition, though every thing is connected to every thing else, it may be possible that the sub-system of interest is sufficiently isolated from the whole to allow a 'hard boundary' analysis. (It should be noted that just because various sub-systems might be visibly differentiated, this is not necessarily the most effective way of recognising distinct sub-systems – the organisation as represented by the 'organisational chart' with particularly defined boundaries (e.g. different departmental 'spans of control') needn't be, and rarely is, the correct way to view an organisation.) This isolation, or apparent 'near decomposability' (Simon, 1962), will undoubtedly be transient, and may also be illusory, but regions of different stabilities do co-exist within the whole. It is plain, though, that the further into the future one wishes to predict, the more attention that must be paid to the forces that drive behavioural change within the system. Prediction becomes not the ability to foretell specific, well-defined events (in space and time), but, at best, the ability to foretell the range of possible behaviours the system might adopt. This then leads to the development of a portfolio of inter-related decision strategies that can be employed, as future possibilities unfold to become current realities.

What was not mentioned in the above discussion is that the structure of the phase space depends upon the characteristics of the comprising entities and the interactive relationships. If these change then the structure of the phase space *may* change. For example, a CNN report conveying the news that a capital city has been accidentally

destroyed will likely significantly change the structure of the phase space that describes the socio-political system of both friend and adversary. At an organisational change level, analysts must anticipate that the understanding derived from such an analysis, as well as the implementation of any decisions that their analysis might suggest, might change the future evolution of the system under analysis, which in turn might contradict their advice. This consideration is captured in Aristotle's original conception of teleology that presupposes that expectations of the system (e.g. long-term goals) will already by present in thought, and thus direct consequent action and therefore system evolution. Furthermore, the analyst must be overtly aware that the boundaries inferred by their analysis may no longer be appropriate. Indeed, the CNN factor may not have been part of the analysis in the first place; it existing beyond the analytical boundary.

The analyst should also be overtly aware of how the assumptions used to construct such a phase space (whether a mathematical formulation, or simply a representation in the analysts mind) came about. For instance, project budget, institutional pressures to use particular methods, department politics, analyst's worldview, and again, expectations and preconceptions of the future, etc., all contribute explicitly and implicitly to the assumption base on which the analysis is performed. The analyst should be blatantly aware of the contributions of prevailing dogma as well as the more obvious problem-specific facts that drive the analysis. It is not necessarily the removal of such biases, but their acknowledgement that is important. We consider this 'institutionalism' in greater detail at section 3.2.

2.3.4 The incompressibility of complex systems

Complex systems are *incompressible*, i.e. it is impossible to have an account of a complex system that is less complex than the system itself. This is probably the single most important aspect of complex systems when considering an OA methodology for investigating such systems. As briefly mentioned above, everything is connected to everything else and so the boundaries of any system become very blurred. Just because an obvious physical boundary exists doesn't mean that it should be immediately assumed that this is the correct boundary for analysis. And, just because particular boundaries were used in the past doesn't mean that they are appropriate again, even if the two situations appear to be the same. In fact, it is asserted that the boundaries analysts infer around a system are more a feature of our need for a bounded description rather than a feature of the system itself, i.e. boundaries are drawn that we believe are appropriate to the perceived context (see Churchman, 1970: B43-45 regarding the strategic placement of boundaries). Hard enduring boundaries do not exist in nature; *all* perceived boundaries are transient given a sufficiently wide time frame. Stability is an illusion. This does not mean that making the assumption that such boundaries exist is not an acceptable approximation in a wide variety of situations. The process of boundary allocation (i.e. making the distinction between the 'sacred' and the 'profane', Midgley, 1992a) is fundamental to sense-making.

Incompressibility means that if a model of a complex system was to be constructed that captured all the possible behaviours contained (both current and subsequent) by the system being represented then that model must be *at least as complex* as the system of interest. The reason for this is that there will always be something outside of the boundary (that is, the boundary inferred by the model) that would affect the system's behaviour in some way. Adopting a sceptical stance for a moment, because complex systems are sensitive to small changes, or, small errors in our assumptions, i.e. a small misplacement of the model boundaries, the model might be wholly inappropriate for the decision that the analysis supposedly supports. The "something is better than nothing" phrase would therefore be a wholly misleading guideline to bandy around the OA community. Following this sceptical line, as everything is connected to everything else one would have to model the world, if not the entire universe. As analysts, we would have to take the first proposition of Wittgenstein's *Tractatus*, "The world is all that is the case," (Wittgenstein, 1921) completely literally which is taken to be a *reductio ad absurdum*. However, acknowledging that there is only one complex system is fundamental as it forces the analyst to recognise the narrow scope and provisionality of their representations.

Given that no hard enduring boundaries exist in reality (even the resilient proton is expected to decay, or reorganise, after a sufficiently long period), the use of the term 'complex system' is misleading as it suggests the notion of a completely autonomous entity. Maybe we should consider complexity science as the science of 'partial complex systems'. This usage implies that when considering any problem we are in fact investigating a *part* of a complex system. As such, all the hypotheses and concerns raised by the 'science of partial complex systems' would be appropriately associated with all analyses - an understanding that typifies the best analysts, yet is kept in the background, comes to fore.

Assuming the notion of incompressibility to be correct what does this mean for analysis?

Incompressibility essentially negates the possibility of the existence of a globally valid perspective, or paradigm. Furthermore, it means that there cannot exist a perspective, paradigm, framework, etc., that can be used to wholly describe any sub-system embedded within a complex system. (Remember that how we define any 'sub-system' will be dependent upon the use of our description rather than a permanent feature of the real world system.) This observation seems to deny the usefulness for OA altogether. What it does usefully mean, however, is that we should be strongly aware and blatantly open about the provisionality of *any* perspective that might be utilised in underpinning an analysis of *any* problem – we must demonstrate considerable humility. Without humility we continue to believe that our current understanding is true and defines all that is possible (and desirable). In this context it may be useful to define OA as the art of giving bad answers to questions to which, otherwise, worse answers would be given!

The sceptical interpretation of the implications of incompressibility does not offer much in the way of advice, or *actionable knowledge* for analysts. It essentially argues for a paradigm-less approach toward analysis in which categorisation of any sort must be avoided – a plainly impractical and absurd argument particularly given the category-based functioning of the human mind. Whether sceptics like it or not we rely heavily on forms of categorisation to make sense of the world and legitimate our actions. The sceptical interpretation is best seen as an important and profound health warning. (Her Majesty's Government warns decision-makers of the limitations of category-based analysis!?!) Before we move on to address the practical considerations that arise from this fundamental 'law of analysis', we would like to first consider the use of jargon, particularly the concept of a 'paradigm'.

2.4 Language use and paradigm incommensurability

The term 'paradigm' refers to a perceived agreement upon how one should interpret and interact with the world. Analysts are regularly categorised by which analytical 'paradigm' they support, e.g. interpretivist, or mechanist. Different paradigms can be synthesised to create new paradigms. For example, system dynamics modelling might be performed in a group environment creating a group system dynamics methodology. In our opinion it is reasonable to make such broad-brush allocations when considering the prevailing attitudes of different groups of analysts, but the usage of the term 'paradigm' conveys a homogeneity of views that is inaccurate and misleading when considering particular cases. Different individuals who supposedly cherish a certain paradigm will apply the tools associated with that paradigm differently. Though a formal description of a particular paradigm might be available, the language used within such a paradigm will convey different meanings to different individuals. By regarding our system of language as a web (or part of a complex system) then the meaning(s) of words depend upon context. This context is provided by the position each word has in our own unique multi-faceted language web that depends very much on our individual histories. Given that our individual histories are different, the meaning, which we each associate with words, is also different. These meanings are incommensurable, as the histories that define our webs of language cannot be translated into a common web allowing exact translation. Incommensurability does not necessarily mean incomparable, however. In many instances the meanings we each associate with words are sufficiently similar such that successful communication between individuals is possible. But, the similarities are incomplete, in the same way that metaphors provide partial descriptions, and so despite our belief that common communicative language is in use, misunderstandings do occur. Sometimes these misunderstandings are trivial and easily rectified, but on occasion countries go to war. In short, the differences in individual language use should not be seen as mere 'noise', but as a potential source of much confusion, as well as a creative stimulus.

As a result of this 'noise', when an analyst makes use of a particular paradigm then this event can be more accurately described as a synthesis of two paradigms; the formal one described by the method employed and the informal one captured within the analyst's worldview (which affects how the formal method is applied). Adding

to this the fact that small differences *can* make an enormous difference, the heterogeneity of views, how ever indistinct, is (at times, critically) important. This may seem to be a trivial point, but language does define to considerable extent what we 'see' (Maturana, 1988), and so using terms that do not gloss over the difference and uniqueness of opinions is crucial. The provisionality and situatedness of each perspective must be reflected in the language used to describe and present them. It is important not to use language that could call up irrelevant connotations, interpretations, and associations. For these reasons, we will not make use of the term 'paradigm' from hereon, but perspective (until a more appropriate word is coined). In using this term we give equal weight to formal methods as well as the informally described representations based on our own unique predilections. (Note: formal models can be regarded as Platonic forms existing in logic space – a 'true' appreciation of these forms can never be obtained.)

The importance of language use was inferred when we spoke earlier about 'the science of partial complex systems'. Such an expression reminds us that we are considering a part of a greater whole rather than an autonomous whole (an image that the term 'system' provokes). The use of such language makes us aware of the 'stuff' that exists beyond the analytical boundaries, and to beware the potential impact of this missing 'stuff' on a particular analysis.

2.5 Local vs. non-local knowledge

Consideration of incompressibility leads neatly into the debate over whether non-locally valid descriptions of systems, i.e. descriptions that are valid over a broad range of different contexts, are possible or whether we must accept the overwhelming context-dependence of any description. (The reader should note that "local" should not be understood in the purely spatial sense. A certain factor may be "Far away", but if the *information* is available locally, it is local.) As with most of the discussion thus far, there is no black and white answer, which in itself indicates that context is of critical importance. Using the concepts of the phase portrait and the attractor basin metaphorically helps us understand this question. Let us assume that we have developed a model that we have strong confidence in, as it appears to account for much of the (partial complex) system's currently observed behaviour. The question arises as to whether we can now take this model and make predictions about the future operation of the system. The answer is that if the qualitative nature of the assumptions that describe the new context remain valid then the model will be useful, i.e. if we remain in the same attractor basin within 'assumption space' then the knowledge derived from such a model can be translated into the new context. Qualitative changes in context prevent such a translation from occurring. So, at first consideration it seems that knowledge is strongly context-dependent but this dependence does not necessarily devalue this knowledge in light of a new context. Playing the sceptic again, the recognition that a new context is qualitatively similar to another is strongly subjective, and so some feature might be overlooked, however, small that would lead to the two contexts not being reducible to each other. There is considerable background 'noise' in making such a

judgement and according to the phase picture the impact of this noise depends upon whether a separatrix has been crossed.

The essential lessons from this discussion on incompressibility are again diffused across a continuum. At worst knowledge is so incredibly context-specific that the search for understanding that is valid in other contexts is utterly futile – this has led to calls announcing the death of the expert (Taket & White, 1994a). Consequently, attempts to make use of such knowledge in different contexts would be completely irresponsible, leading to wholly inappropriate advice and action. At best, knowledge based upon a particular context is indeed valid for a bounded range of other contexts, but this validity should never be taken for granted – suggesting that the expert isn't quite dead yet (Richardson & Tait, 2000). The quest for frameworks that attempt to describe the many contexts of OOTW is not futile, but any frameworks developed should be regarded with a healthy scepticism when it comes to making use of them in specific circumstances. As an example, to characterise 'wholes' within the complexity field itself consider the following.

The London School of Economics has a 'complexity project' that is developing a complexity lexicon. The project researchers are encouraging the use of this lexicon when considering complexity. This is a worthy aim, but it must be remembered that there are an infinite number of ways to talk about complexity, and that the words used have different associations when used in different contexts – the transference of meaning is strongly context-dependent. The meanings of words should not be defined and enforced at the global level but should be allowed to be inter-subjectively negotiated (Mingers, 1995) at the local level, through, say, critical dialogue (Robinson, 1993). The prescribed lexicon will undoubtedly provide a sound starting point, but, as has already been mentioned, we should be overtly aware of how language, which is based in a particular perspective, limits our 'vision'. Again, to some this awareness may seem to be a trivial matter, but we believe it to be of crucial importance, assuming that the world is complex and that the need for quasi-'paradigmless', or multi-perspective thinking follows naturally from this. "This much is certain: the quest for comprehensiveness … is not realisable. If we assume that it is realisable, the critical idea underlying the quest will be perverted into its opposite, i.e. into a false pretension to superior knowledge and understanding" (Ulrich, 1993).

3 Complexity thinking as epistemology

The aim of this paper is not to question the basic observations made concerning 'the complex system', but to understand how the implications of these observations affect analyst's abilities in modelling such systems. We have also suggested that there are important limitations imposed upon us as analysts as a result of the 'paradigmaticisation' of OA, our insinuation being that complexity thinking leads to a break from traditional paradigm-based thinking, and the necessary destruction, or least 'fuzzification', of the boundaries that allow us to recognise a paradigm as a paradigm. As a result, attempts to rigidly define the boundaries of the complexity paradigm are, we argue, contradictory to the fundamental complexity message.

This does not mean that attempts to do so are not valuable, but it does mean that the boundaries should be seen as provisional and definitely local. We must each play the sceptic until such a time that we need to fake positivism so that action can be initiated. But, in so doing, recognising that as the system evolves, we may need to change the analytical boundaries.

In the previous section the implications of complexity upon analysis were explicated. In this section, we offer a high-level conceptual approach to analysis that acknowledges the difficulties previously discussed.

Given that no one perspective can capture the inherent intricacies of complex systems, the analysis of complex systems requires us to consider a number of perspectives, i.e. to adopt a pluralist position (Reed, 1985; Midgley, 1989, 1990; Flood & Jackson, 1991, Jackson, 1999). The underlying premise for this is that by exploring a number of perspectives a richer appreciation of the 'state of affairs' of interest will be developed, resulting in more informed decision-making. In considering a variety of perspectives a negotiation between these perspectives is encouraged that drives the exploration process. The merits and deficiencies of each perspective are examined in light of both the supporting and contradictory evidence offered by the other perspectives (see for example Watson & Wood-Harper, 1995). This evidence may be in the form of individuals' experiences, the numerical output of a particular computer model, etc. As the different perspectives are played against and with each other new perspectives emerges that are, at least, an eclectic mixture of the parts of the constituent perspectives that seem most relevant to the state of affairs under consideration. This intra- and inter-perspective exploration will identify other perspectives that might be worthy of inclusion, further fuelling the exploration process. After a number of exploration cycles a number of perspectives that are deemed acceptable are left. This endpoint might come about in a number of ways. The creativity, fuelled by the differences between the various perspectives, may die out. The perspectives might naturally converge in a way that satisfies the requirements of the perceived state of affairs. Or, a particular perspective might become dominant and force an end to the exploration process. Remember that in using the term 'perspective' we are not distinguishing between formal and informal models, and so the perspective of the person that controls the budgetary strings also vies for a position in this intra-perspective exploration. The end point of an analysis then becomes the point at which a perspective, which may have emerged during the analysis or was present at the beginning, becomes overwhelmingly dominant.

In short the basic requirement of a complexity-based epistemology is the exploration of perspectives (where exploration and perspective are used in the broadest sense). Midgley (1992b) argues that pluralism is necessary to legitimate systems science. We argue that complexity thinking legitimates pluralism.

It may be useful to associate the terms *weak* and *strong* exploration, where weak refers to intra-perspective exploration and strong refers to inter-perspective exploration. Weak exploration encourages the critical examination of a particular

perspective, which is undoubtedly driven by its differences with other perspectives. Strong exploration encourages the sucking in of all available perspectives in the considered development of a situation-specific perspective. These two types of exploration are not orthogonal, and cannot operate in isolation from each other. The greater the number of perspectives available, the more in depth the scrutiny of each individual perspective will be; the deeper the scrutiny the higher the possibilities are of recognising the value, or not, of other perspectives. Essentially complexity-based analysis is a move from the contemporary authoritarian (or imperialist – Flood, 1989) style, in which a dominant perspective bounds the analysis, to a more democratic style that acknowledges the 'rights' and value of a range of perspectives. The decision as to what perspective to use is also deferred until after the exploration process. Whilst scepticism plays a central role in the exploration process, it plays a lesser role during implementation, at least initially. We must fake positivism to increase the chances of a successful implementation, but always be aware that conditions will change that might require substantial rethinking of the implementation itself.

The basic concept of strong and weak exploration is all well and good, but analysts could be frozen by the plethora of possibilities that such paradigmatic freedom offers – the familiar *paralysis by analysis*. How would such an approach be operationalised? It is clear that the analyst must, in addition to other activities, be concerned with the management of the variety of perspectives; an activity that falls under the umbrella term of *facilitation*. What frameworks, however limiting, might support such a perspective-based negotiation? Before moving on to consider these concrete offerings, we will first consider (in the true spirit of strong exploration) the wisdom offered by postmodernism and social constructivism.

3.1 The relationship with postmodern thinking

The choice to compare complexity science with postmodernism is not arbitrary. Postmodernism is a philosophical stance very much more sensitive to complexity than the prevailing Modernists attitudes (see Taket & White, 1993, 1994b, for an exploration of the differences between modernist and postmodernist thinking). In his seminal work *The Postmodern Condition: A Report on Knowledge* (Lyotard, 1984: xxiv) Jean-François Lyotard defines postmodernism (some would argue that attempting to define postmodernism is an essentially modernist pastime), at an extreme simple level, as "incredulity toward metanarratives." By this he basically means that there is no place for grand overarching (and by definition, context independent) theories in the complex world we live in. Whereas we are used to legitimating our analyses by calling upon the widespread faith in modern physics and mathematics, this blind positivity is becoming more and more inappropriate. If we can no longer rely on the objectivity apparently afforded by the traditional modernist frameworks then where can legitimacy reside?

Supporters of postmodern thinking can be loosely divided into two camps, the *sceptics* and the *affirmatives*. The sceptics believe that when considering a particular state of affairs no one viewpoint is any more 'valuable' than another, that

it is impossible, intellectually arrogant, and even irresponsible, to privilege any perspective over another. This is coherent with the previously discussed sceptical interpretation of complexity science that suggests because of the potential critical sensitivities of our derived knowledge to the chosen analytical boundary we cannot have any confidence in that knowledge to inform appropriate action. The combination of: (1) knowledge being so critically context dependent, and; (2) our inability to 'see' the world 'perfectly' leads inevitably to the sceptical assertion that we cannot know anything for sure. From the previous complexity-based discussion the spirit of this conclusion is supported, but its broad applicability is questioned. The complexity science equivalent would suggest that there do indeed exist situations that are essentially 'unanalysable', i.e. after any length of analysis nothing with any confidence can be said. Complexity science, however, recognises that this is an extreme condition and that analysable situations also exist, i.e. there are situations in which certain perspectives can be said to be more 'valid' than others. The recognition of such situations is problematic, but the condition is not as hopeless as the sceptics would suggest. This line of thinking aligns with the affirmative postmodernists.

Before delving into the affirmative position we will consider another aspect of the sceptical position, but attempt to soften it with a little pragmatism. A direct consequence of the sceptic's denunciation of every point of view is that they believe that any form of categorisation kills. In terms of complexity science this simply means that incompressibility and reductionism are utterly at odds. It is indeed true that by viewing a partial complex system through a particular perspective aspects are lost, and so possible options for action are, in effect, killed. To speak Aristotelian language, every categorisation, by unfolding some potentiality, nips in the bud many other possibilities. Or, the moment we begin to investigate, possible opportunities are closed off. Fuenmayor (1990) uses a metaphor of light and darkness in asking us to remain aware that throwing light upon a subject casts its "other" into darkness. However, there is overwhelming evidence that human cognition functions on a category-driven basis (see for example Newell, 1990: Ch. 4). The world as it appears to our senses is chunked following the categories that underlie our current epistemic state. Whether the sceptics like it or not categorisation is a basic requirement of humans that allows them to make sense of their surroundings and legitimate their actions. We are useless hunks of flesh and bone without the bounding process directed by categorisation and the adoption of a coherent perspective. This necessity sometimes results in us latching onto the first perspective that facilitates sense making regardless of any basis in the 'real world' (Maturana, 1988). Categorisation might 'kill' but it also brings life to opportunities that we are blind to without categorisation.

More in sync with the complexity science view, the affirmative postmodern position not only recognises by implication the *need* to privilege one perspective over others in order to legitimate action, but it also asserts that such a task is *possible*. Rather than suggesting that all perspectives have equal value, affirmatists believe that more can be attributed to one viewpoint over another. This positive position would be of

more use to the analyst if only the means by which each perspective could be valued (i.e. it's appropriateness to the situation of interest) was clear and operationalised. In making a determination as to whether a particular perspective is 'appropriate' or not, deconstruction is a useful process.

Jacques Derrida, as a way of understanding different texts, proposed the process of deconstruction. According to deconstructionists texts have no exact and final meaning and can be read in a number of ways. Deconstruction is an exploration within strict boundaries of the indeterminacy's and misunderstandings that open up radical reinterpretations of such texts. Deconstruction is a much more radical approach than hermeneutics. Prior to Gadamer the hermeneutic process of Schleiermacher and Dilthey aimed, in the full spirit of The Enlightenment, to objectify the meaning of historical texts. They believed that through rigorous methodological interpretation the social sciences could lay claim to knowledge of the human world that would be every bit as rigorous as the natural sciences' supposed knowledge of nature, i.e. it was believed that one could methodologically understand the text as the author understood himself. In doing so they believed in the "ideal of the autonomous subject who extricates himself from the immediate entanglements of history and the prejudices that come with that entanglement." (Linge, 1977: xiv). The "autonomous subject" is synonymous to the 'observer' in operational research who neutrally and without bias records and explains the situation of interest. The analyst is seen as completely separate of the situation. Gadamer realised that such a description of 'observer' was unreasonable precisely because extrication from ones immediate entanglements of history and their associated prejudices is not possible. Each one of us is defined by our history as much as our current relationships, and it is impossible to fully escape these historical influences. Once we acknowledge the contribution that our 'being' makes to knowledge generation the objectivity and rigor of the natural sciences comes in question. As a result of acknowledging such contributions Gadamer developed a conception of understanding that takes the interpreter's present participation in history into account in a central way. According to Gadamer "Understanding itself is not to be thought of so much as an action of subjectivity, but as the entering into an event of transmission in which past and present are constantly mediated. This is what must gain validity in hermeneutical theory, which is much too dominated by the ideal of a procedure, a method." (Gadamer, 1960: 274-275) So the generation of meaning concerning historical texts is a dialogue between the author's writings, the not-so-autonomous observer, and other historical and cultural objects. Through such a dialogue meaning is negotiated. In a similar way, deconstruction is a journey fuelled by historical evidence, implicit and explicit assumptions, the analysts worldview, etc., that yields (sometimes radically) different interpretations of particular texts. Though none of the different interpretations can possibly equate to the author's understanding, a richer appreciation of the text is developed.

As an analyst one can consider the situation of interest as a particular text or narrative requiring exploration and interpretation. The analyst must accept that their own predilections contribute to the way in which the exploration is performed and

how interpretations are derived. There is no objective 'Truth' as such – no perfect description. Analysis can be seen as a dialogue between analyst and situation of interest in which the two 'interact' in seeking to uncover hidden assumptions, alternative representations, empirical evidence, etc. through the implementation of various formal and informal methodological apparatus. Though there is no 'right' approach or answer, the underlying premise is that a richer appreciation of the situation of interest (i.e. a more informed perspective) will be negotiated leading to decision-making that is more context-specific than if a single well-defined acontextual methodology was employed.

In brief, the message from affirmative postmodernism and Gadamer hermeneutics is that there is no Absolute Truth, but through exploration, criticism, and dialogue a picture can be painted that gives us enough confidence to momentarily claim that we have Truth in hand; Truth that can be used to legitimate our decisions and consequent actions. Orson Scott-Card touched a deep nerve when he put the following words in the mouth of his fictional character, Miro – "Knowledge is just an opinion you trust enough to act upon" (Scott-Card, 1996: 113). We must learn to become healthy sceptics so that we can confidently fake positivism when necessary. In exploring the various hidden meanings of particular 'texts' we must be aware of the social construction of reality and the limitations that institutionalism place on our attempts to be objective.

3.2 The social construction of reality

In 1966 Peter Berger and Thomas Luckmann published their seminal work *The Social Construction of Reality: A Treatise in the Sociology of Knowledge* (Berger & Luckmann, 1967). In this section we will introduce the concept of social constructionism and comment upon it's implications for analysis and how *institutionalism* acts as a partial barrier to performing a complexity informed analysis.

An account of social constructionism goes something like this. As we live our lives, we tend to develop repetitive patterns of behaviour. These *habits*, as they are called, are useful to us because they allow us to handle recurring situations automatically. Our habits are also useful to other people. In face-to-face communication the participants observe and respond to each other's habits, and in this way all of us come to anticipate and depend upon the habits of others. Imagine the difficulties that would exist if we were unable to take for granted the meanings implied by a speaker's use of language. As time goes by, some habits become shared among all the members of society creating an *institution*.

An institution is a collection of shared expectations about such long-term public habits. Institutions encourage the development of *roles*, or collections of habitual behaviours that are associated with, and expected of, individuals who are acting in an institutional capacity. When a person assumes a role, he or she adopts these habitual behaviours, and we interact with him or her as part of the institution rather than as a unique individual.

Because they establish behavioural rules, institutions provide societal control. However, if this control is to persist over time, then each new generation of potential 'members' must be trained to participate in the institutions of their peers. Thus, institutions are legitimised and maintained by tradition and education.

Eventually, some institutions become reified – that is, the members of the society forget that the institutions are human constructions, and they begin to relate to them as if they were natural objects. In this way, we create social structures that seem as real to us as the reality of the natural world.

According to Berger and Luckmann's model an adequate analysis of any social world, or any social institution must address the three basic moments of reality construction: externalisation, objectivation, and internalisation which are described as:

1. *Externalisation*: the ongoing outpouring of human being into the world, both in the physical and the mental activity of people – society is a human product;
2. *Objectivation*: attainment by the products of this activity (again both physical and mental) of a reality that confronts its original producers as a facticity external to and other than themselves (institutionalisation) – society is an objective reality;
3. *Internalisation*: the reappropriation to humans of this same reality, transforming it once again from structures of the objective world into structures of the subjective consciousness (socialisation) – man is a social product.

Externalisation, objectivation and internalisation are regarded as three dialectically related moments in the (re)production of social reality. Continuously, each member of society is seen to be externalising social reality – that is s/he is involved in creating and maintaining particular institutions (ideologies or routines). Simultaneously, a sense of objective reality is being constructed. Finally, in the process of externalisation and objectivation, the individual is being constructed as a social product. That is to say, s/he is acquiring the knowledge and social identity associated with the institutional role, which s/he is constructing or performed.

From this brief presentation of social constructionism we can extract a number of underlying assumptions:

1. We know the world only as we perceive it;
2. Our perceptions are based on learned interpretations;
3. This learning is social: we learn from and among persons in social interaction;
4. The main vehicles which convey meaning are:
    a. symbols, including language;

b. cultural myths – larger social meanings of objects, action, signs, episodes;
c. the structure and practice of our institutions;
d. our rules for congruent action;

5. These vehicles of meaning together construct:
    a. our world-view – our sense of how the world works, what is valuable, why things are the way they are;
    b. our sense of ourselves, our identity and purpose;
    c. our ideologies – our sense of the appropriateness of, the structure of, and the exercise of, power, action and roles in society;
6. Our selves, our societies, our institutions change continually through interaction.

Social constructionism has implications not only for the subject of analysis but also for analytical process too. We shall consider the subject first.

A majority of OOTW involve intervening with a culturally different (from our own) society in order to achieve particular goals. For example, NATO are involved in a peacekeeping operation in the Balkans which involves a multi-cultural force interacting with a multi-cultural society (see Taket & White, 1994c, for an account of OR in multicultural contexts). Institutions (being the product of social construction) help, as well as hinder, the analyst's consideration of the subject. Presumably, as institutions are considered relatively stable in the short-term, then it is a straightforward process to identify the various interacting institutions and design an intervention based on the 'reality' created by those institutions.? If analysts were capable of complete objectivity then maybe so. However, we must accept that our analysts are an unwitting member of their own institution, and so they will be trained to interpret other institutions signs, actions, myths, events, etc. in terms of their own. Though we seek to discover the assumptions of other institutions we rarely question, or even recognise the existence, of our own embedded practices (Churchman, 1970). This can, and often does, lead to misguided representations of the 'state-of-affairs', which the OOTW is designed to address. We must be aware of our own cultural/institutional disposition before attempting to appreciate another – we must avoid unquestioned boundary judgements (Jackson, 1982).

Institutions also change over time. This being the case, it would be quite inappropriate to exclude the potential institutional developments that might occur as a result of OOTW interventions. Some OOTW involve a long-term commitment. Thus far, the Balkan operation, in different forms, has extended over a period of 10 years. During such a period the institution guiding the OOTW force is interacting with the subjects' institutional structures, potentially triggering changes in both institutions. Similar types of change can be seen in other long duration operations, such as those in Northern Ireland, and can begin to be seen even in relatively new operations such as the UK involvement in Sierra Leone. It is very difficult indeed

to determine whether such changes will facilitate or hinder the operations aims. A careful eye needs to be kept on such changes. Though monitoring of such effects may prove to be beyond our analytical capabilities, awareness of their potentialities is nonetheless important.

Even if an operation's immediate aims have been met, we are ethically obliged to consider the longer-term impact of a particular intervention upon institutional development. The seeds may be inadvertently sown for the development of unintended and unwanted institutional forms. An institutionally static snapshot of the situation of interest would be wholly inappropriate. Institutional form cannot be taken as a constant.

As already hinted above, institutionalism has considerable impact on the analytical process itself. Traditionally, and these haven't shifted much, the underlying beliefs defining contemporary analysis are positivistic in nature - "the OR myth" (Checkland, 1983). These can be summarised as the beliefs in detached observation, objective knowledge, causality, and reductionism. It has been said that reality is more complicated than its perception. The current analytical institution, however, legitimises a belief that our perceptions are more than adequate. We tend to believe that causality, for example, is an inherent relation between phenomena rather than a mental construct inferred from observed regularities as suggested by the social constructionist viewpoint. In short, the prevailing analytical doctrine supports an externalisation of a positivist social reality. The previous discussion on complex systems would suggest that such a position is now considered untenable. This illustrates how institutionalism acts a barrier to change as opposed to a supporting framework. Despite the increasing evidence that the positivist methodology does not acknowledge the complexities of, say, social systems, institutional inertia justifies it's continued application. 'Physics envy' continues to plague the analytical community – if it doesn't look like physics it ain't science! Complexity thinking, though, provides us with the convincing argument that the traditional view of science is inadequate in these complex times. Indeed, in our view 'a science of complexity', where 'science' is used in the traditional sense, will never exist as such.

3.3 Analytical culture

Analytical institutionalism does indeed facilitate analysis. However, our prevailing analytical institution has existed for such a long time that we have become unaware that the analytical culture (with its associated tool and methods) developed to facilitate the investigation of a particular type of problem – linear problems. In order to further develop our capacity to adequately investigate complex non-linear problems (the number and variety of which seems to increase daily) we must first deconstruct the institutions which we have become so dependent upon and comfortable within. The formal relationships between decision-makers, beneficiaries, analyst, subject-matter experts, tools and methods, budget, politics, etc. need to be critically considered. We need to understand how these relationships predetermine analytical design and implementation (see for example Mansell,

1991). Changing these relationships to suit contextual requirements is not a trivial matter (identification of 'contextual requirements' is in itself problematic – Dutt, 1994), but the community must at least acknowledge the relationship between analytical culture and a particular analysis itself.

The social construction of institutions, as we have already suggested, does facilitate quasi-unambiguous communication between members of a particular institute. This would certainly facilitate design implementation if those involved were members of the same institution by increasing the possibility that those involved in the implementation phase shared a common perspective. This would mean, though, that all stakeholders (those deemed to be affected by a particular implementation) would need to be involved somehow in the analysis so that such a shared appreciation might be developed. In a sense, a unique institution would be socially constructed for each intervention. This would overcome the institutional barriers to situated analysis, as well as facilitate the implementation of a new design. The new institution would have built into it an intrinsic awareness of the consequences of the institutional structure and the need for monitoring and adjustment where necessary.

The inclusion of stakeholders in the analytical process would be a major change in the current prevailing analytical culture. Intra-organisational change projects would certainly benefit from such a cultural shift. There would be obvious gaps in participation though when we consider 'change projects' for which representation from each stakeholder group was not possible. Awareness of such gaps is essential and will lead to creative ways in bridging them.

How might such a context driven analytical culture come about? This is not an easy question. Culture and institutions are notoriously resilient to change (Glaserfeld, 1988). The following discussion on modelling assumptions allows an examination of such an analytical culture from a different perspective.

3.4 Analytical guidelines - Model assumptions become process assumptions

The focus on a process-driven analysis can be related to the fundamental modelling assumptions reported in Allen, 1997. Allen has suggested that these two fundamental assumptions, taken in different combinations, lead to different modelling approaches. The assumptions expressed simply are: (1) no macroscopic adaptation allowed, and (2) no microscopic adaptation allowed. If both assumptions are made, plus an additional one which assumes that the system will quickly achieve an equilibrium state, then we have an equilibrium-type model – a modelling approach that still dominates much of contemporary economics. If neither assumption is made then we have a basic system dynamics model. If assumption (1) is relaxed then the resultant model will have the capacity to self-organisation. And, if both assumptions are relaxed then a truly evolutionary model can be constructed.

The reason Allen's conception of complexity modelling is introduced here is that it leaves no room for linear models. This exclusion supports the calls for a complete

overhaul of operational analysis and the disposal of traditional linear tools and methods. To model complex systems well Allen suggests that we should relax both assumptions. In our own presentation of complexity science, we have suggested that at times a linear model of a complex system may be perfectly adequate. Why do these two viewpoints disagree? What should be noted is that Allen's fundamental assumptions deal only with the mathematically conceived model that takes shape on a computer. They do not directly deal with the modelling process itself. If these assumptions were generalised to refer to the analytical process itself and not just the formally developed model then the place for linear modelling (not linear thinking) is retrieved. As an example, consider a decision tree.

A decision tree is a widely used linear decision-making technique. If one were to build such a tree and populate it with the relevant data then it would spew out a set of numbers that can be used to rank different courses of action. Left to it's own devices the tree would not evolve in any way (unless the computer failed, or the piece of paper on which it was drawn burnt, in which case the tree would simply disappear). The model has no intrinsic capability to self-organise or evolve in any way. It is a simple linear model. It would be the same next year as it is today and offer exactly the same output given the same input. According to Allen's typology it is worthless as far as complexity modelling is concerned. However, if the tree is used within an environment that does allow for micro and macroscopic adaptation then the tree may also evolve. The analysts can explore possible scenarios by populating the model with different data sets; they can play with the structure of the tree (effecting a re-organisation); and even dispose of the tree and decide to use an alternative method (effecting a true evolution – the tree model 'evolves into' a cellular automata model for example). The 'culture' in which the model is used effectively allows for both micro and macroscopic adaptation of the model. It is for the modellers to judge whether the linear model is appropriate given the currently observed behaviour of the partial complex system of interest. In making such a judgement they will necessarily continually question the boundaries of the analysis, and explore the potential of a variety of perspectives. The thinking supporting the model development will be non-linear, despite the potential linearity of the concrete model constructed. Of course, the non-linear modelling process may equally lead to a non-linear representation, such as an agent-based computer simulation.

In short, we feel that accepting Allen's fundamental assumptions as assumptions regarding the modelling process itself rather than the consequent representation is a more useful application, which is truer to the analytical requirements inferred from complexity thinking. Of course, we are guided by our own perspective on the concept of complex systems.

In the previous sections we have presented our view of a science of partial complex systems. This view has been derived from well-known observations made in the investigation of a variety of non-linear systems. Furthermore we have attempted to align complexity thinking with other popular perspectives such as postmodernism

and social constructionism. Now that our theory or philosophy has been explicated the following section examines possible operationalisations of this epistemology.

4 The Practice of Complexity Science

4.1 Pragmatic conceptions of complexity science

Thus far the paper has explored the epistemological and practical implications of assuming that the world is best described as a complex system. Exploration both within and without different perspectives is encouraged, supporting the need for criticism, creativity, and pluralism. From a sceptical point of view, any attempt to operationalise such a complexity-based epistemology, via a well-defined framework, would be in contradiction to the underlying tenets. From a pragmatic point of view, however, we must accept that frameworks are essential in providing at least a focus or starting point to analysis. What we must be strongly aware of is that the theoretical insights offered by any framework should not be used to *determine* our explorations, but considered as an offering of *direction*, or simply as a source of creativity to fuel the exploration process.

A number of well thought out attempts have been made in the development of 'meta-frameworks' that recognise the problematic nature of analysis, offering guidelines as to how to manage the exploration process. These meta-methodologies have not been developed within the 'official' complex systems research community, but within the civilian operational research community. Examples of these developments include: (1) the emergence of *group decision support* methodologies (2) the *system of systems methodologies* (Jackson, 1984, 1987), (3) *total systems intervention* (TSI) (Flood & Jackson, 1991, and Flood, 1995), (4) *creative design of methods* (Midgley 1990), and (5) *critical appreciation* (Gregory 1992). In order to legitimate the various methodologies a variety of philosophies are drawn upon, such as Habermas's early work on knowledge-constitutive interests as well as his later work on *truth* statements, *rightness* statements and *individuals' subjectivity*, Foucault's theory of power, etc. For a good survey of the different methodologies and their associated philosophical underpinnings see Midgley, 1997.

On examining these different approaches the reader may notice that generally each subsequent methodology attempts to make more explicit the role of ongoing critical reflection, and the categorisation process – partly driven by the ongoing critique of the different methodologies. We have already discussed how the institutional culture predetermines many aspects of any analysis regardless of problem type, and we believe that if the analytical culture was to acknowledge the central role critical thinking plays, then there would be little need to explicitly design-in the activity. After all, hasn't examination of the underlying assumptions of any perspective always been associated with 'good' analysis? If anything should be taken for granted it is the centrality of critical reflection, or boundary exploration and critique, to all forms of analysis. It is perhaps a poor reflection on the current analytical culture that critical thinking as an activity has to be made explicit. (Indeed, Tsoukas (1993) accuses TSI, for example, as being no more than common sense).

4.2 The relevance of group decision support

The impression of strong and weak exploration given in section 2.2 is captured rather well metaphorically by the term 'perspective-based ecology'. The notion of survival of the fittest in this language has varied meanings, but ultimately the fittest perspective (which will evolve during the exploratory period) will be that which meets the requirements of the perceived 'problematic situation'. In fact, fitness in this sense means 'truth' (with a little 't') in that the result of the exploration process is a perspective that is believed to be sufficiently 'good' to be treated as an accepted truth, for a moment at least. At a particular time and place, and given a confidence that the best job has been done *given all available resources*, the resultant perspective / model / approximation is accepted as truth.

The notion of perspective-based ecologies aligns very well with the group decision support concept. The underlying assumptions of the group decision support process are that many problems are too complex for any individual to 'solve' on their own. It also acknowledges that as such there will generally exist a level of disagreement between individuals as to what the actual problem is. As a result, the process encourages the exploration of different opinions, different models, different formal paradigms (which all come under our umbrella term of 'perspective') in the belief that a richer and more appropriate impression of the situation of interest will be synthesised from these varying sources of understanding. Analysts, or more accurately stakeholders (those who have a vested interest in the problem of interest), are encouraged to dig down into each viewpoint to discover the underlying presumptions and then explore the applicability of them to the perceived problem. All the technology associated with the group decision support process is used to facilitate the exploration process, to initially facilitate dialogue and then the negotiations between participants (or participant perspectives), and to keep a record of the process itself as well as a representation of the developing viewpoint.

We will not go into a detailed discussion of the pros and cons of the group decision support concept, or it's many operationalisations. This has already be done elsewhere (see for example Sauter, 1996; Eden & Radford, 1990; Vennix, 1996).

A desired 'side-effect' of group decision support is the buy-in from participant stakeholders regarding the final outcome of such an analysis. Thus far, we have only discussed the 'quality' of the perspective developed through exploration. Experienced analysts will be familiar with the expression, $E = Q \times A$, where E, the effectiveness of the decision, is the product of Q, the quality of the decision, and A, the acceptance of the decision (Vennix, 1996: 6). Generally, we have spoken about Q till now. We have focussed on the assertion that perspective-based exploration leads to a more appropriate description of the situation of interest and the possible courses of action. However, if the resulting decision is not accepted then it doesn't matter how high Q is, a low A will yield a low E. So, stakeholder buy-in, as suggested in Section 3.2, is essential if the implementation phase is to be successful.

If the exploration process has been performed well then both the quality, i.e. appropriateness, of the decision and its acceptance will be high.

Of course, the facility to include stakeholders, or even stakeholder representatives, is problematical in itself. In developing the understanding to take military action it can be difficult to even get input from 'our' own side given the current rigid hierarchical organisational culture. Key stakeholders may not be available. Ways can be invented to overcome such limitations, but in many instances it is clear that the bureaucratic system in which many of us exist is not sensitive to the requirements of strong exploration. If you accept that the world is complex then rigid bureaucracy is effectively unethical. An adhocractic (Waterman, 1990) element to any organisation is essential if the science of partial complex systems is to be implemented effectively. To defend the absence of key perspectives (e.g. stakeholder opinions) by simply blaming the system is unethical. This is a topic for another paper, though we have attempted to include a limited discussion herein, but it is important to appreciate the widespread ramifications of a science of partial complex systems. We are not dealing with a process that could be put in place in it's entirety tomorrow. We are dealing with a process that requires profound and often subtle changes in our day-to-day activities, which includes a review of organisational structure, if it is to be implemented successfully. This is not to say that there aren't courses of action that we could take immediately that would improve our capacity to consider complex problems, and sow the seeds of the necessary cultural shift.

It is worth noting that Q and A are not orthogonal. Given that the stakeholders are included because they have a vested interest in the problem at hand, they are co-responsible for the existence of the problem itself. The socially constructed elements of the problem of interest arise from the interactions of the perspectives provided by the varying stakeholders. Not only are these perspectives valuable in the process of understanding, but they also define the problem in variety of ways, some subtle, some obvious. The point is that Q is a function of A, and so if A is low then Q is low.

The reason for providing this brief account of the group decision support concepts is to provide the reader with a concrete example of how complexity thinking is already manifest in particular schools of thought. Complexity thinking can be regarded as a generalisation of the group decision support conceptualisation.

The following four sections briefly present and discuss a variety of other meta-methodologies that have been developed to address the difficulties of making sense of partial complex systems. Each one could be accused of being prescriptive in some way by forcing a categorisation upon us. But, as we have already discussed there is no way to escape categorisation completely. What we must certainly avoid is categorical apathy, to avoid the tendency to take the validity of any particular categorisation for granted. No practical conceptualisation could possibly prescribe a process suitable for all contexts; room must always be left for the analyst (or

analytical community) to evolve such guidelines in response to local needs. Each of the following operationalisations will be briefly critiqued in light of the analytical philosophy developed above.

Though there are many barriers to the full realisation of complexity-based analysis (e.g., institutionalised corporate structures, strongly held world views, etc.), the following approaches offer partial, yet practical, conceptualisations that can be taken advantage of with relative ease.

4.3 System of systems methodology

Essentially, the system of systems methodology is a look-up table approach to OA. What basically happens is that the decision-maker, or management team, determine what type of problem they are confronted with, associate with either simple-unitary, or complex-unitary, etc., (see Table 1) and then use the appropriate decision making technology to analyse the problem with.

There are a number of obvious limitations with this approach. Firstly, the framework assumes that the entire problem can be wholly described by one of these categories; it does not recognise that the problem might be better dealt with by breaking it down into parts with each part falling into a different category: some parts might be better treated as complex-coercive, and other parts as simple-unitary. For example, one might be re-designing the information infrastructure of an organisation. In this case the technology aspect might be considered the simple-unitary part with the human side, the complex-coercive aspect. Secondly, once the method/paradigm has been chosen, the potential to change and move between paradigms as the appreciation of the problem progresses is not explicit – it does not encourage the synthesis of new paradigms (though this is briefly mentioned in passing by the author). This isn't to say that this methodology could not be applied in such a way. In fact, a number of the shortfalls associated with this methodology are dealt with if it was to be employed in such a fashion. In terms of strong and weak exploration, the process this approach encourages at least looks to explore currently established paradigms and helps to recognise which one is the most appropriate – we could consider this (at a stretch) to be a limited form of strong exploration. Thereafter, however, it is weak exploration to the end. Thirdly, given that the dispositions of the individuals involved in the process can strongly influence the analysis itself, it would probably be safer to assume that all decision-making issues are complex-coercive (the usage of 'coercive' here is much broader than the usage intended in this methodology) – institutionalism is ubiquitous. Fourthly, the approach trivialises the context recognition process; it presumes, by omission, that recognising a particular context is straightforward. Complexity thinking highlights the problematic nature of context recognition and definition. Finally, critique is not mentioned specifically as part of the methodology, but again there is no reason to exclude critique as a key component of this methodology.

	Unitary	Pluralist	Coercive
Simple	Key issues are easily appreciated, and general agreement is perceived between those defined as involved or affected.	Key issues are easily appreciated, but disagreement is perceived between those defined as involved or affected.	Key issues are easily appreciated, but suppressed disagreements are perceived between those defined as involved or affected.
Methodologies	Operational analysis; Systems analysis; Systems engineering; System dynamics.	Social systems design; Strategic assumption surfacing and testing.	Critical systems heuristics.
Complex	Key issues are difficult to appreciate, but general agreement is perceived between those defined as involved or affected.	Key issues are difficult to appreciate, and disagreement is perceived between those defined as involved or affected.	Key issues are difficult to appreciate, and suppressed disagreements are perceived between those defined as involved or affected.
Methodologies	Viable system diagnosis; General system theory; Socio-technical systems thinking; Contingency theory.	Interactive planning; Soft systems methodology.	?

Table 1 The System of Systems Methodologies.
Adapted from Flood and Jackson (1991)

4.4 Total systems intervention

This second methodology, claimed to be a 'meta-methodology' by it's authors, is more or less the same as the system of systems methodology, except that it attends more to the problem recognition phase – the issue of problem boundary allocation. This is called the *creativity phase*. Whereas previously the use of the six system of systems categories may prove unhelpful (as the decision-makers might not appreciate how the different types manifest themselves) the use of metaphor is introduced to facilitate this recognition process (refer to Exhibit 4). Again, once the problem type is identified the system of systems matrix is used to determine which paradigm is to be utilised, and then the selection is implemented. The same criticisms that were directed at the system of systems methodology still hold, particularly given that the metaphors to be used (team, machine, organism, neuro-cybernetic, coalition, culture, and prison) are prescribed by the TSI methodology, but the greater attendance to critical reflection upon method selection is a significant improvement. This phase would include inputs and interactions between stakeholders and decision-makers, in order to take full advantage of the different expertise (perspectives) each individual brings to the process.

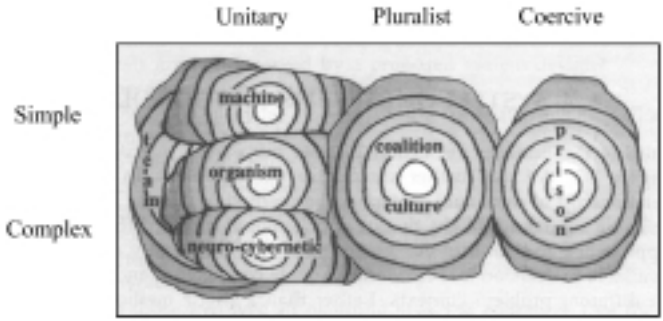

Exhibit 4 Metaphors mapped onto the system of systems methodologies (Flood and Jackson, 1991)

Still, no paradigmatic synthesis is explicitly included, and the analysis is still dependent upon prescribed and established paradigms.

4.5 Creative design of methods

The creative design of methods goes some way to meeting our requirements for a complexity-based approach to decision-making. Rather than applying one method to the entire problem, this approach breaks the problem situation down into a number of smaller problems and uses the system of systems matrix to determine which method should be utilised in the investigation of each sub-problem. This in itself is a considerable improvement over the previous two methodologies, but the creative design of methods goes further by explicitly assuming that not only might the problems change during the analysis (i.e. the boundaries are 're-drawn' as a deeper appreciation of the problem is developed), but the choice of decision-making technology might also change. This method also recognises the possible systemic dependencies that might exist between the different problems in that once a sub-problem has been examined the understanding derived from such examination is to be viewed in light of the understanding developed from the consideration of the other sub-problems. It is a moot point as to whether this methodology actually develops new methods, or whether it is simply a "stitching of other people's methods together in an additive fashion." In our opinion, it is simply a stitching together, but by breaking down the problem into research questions and employing appropriate methods for each, a synthesis of understanding will occur. This synthesis does not occur at the level of method, but as part of the interpretive activity – the synthesis occurs in the mind of the analyst/stakeholders, and so in some senses a paradigmatic synthesis will result.

Apart from the absence of the explicit mention of critical reflection, the underlying philosophy of this approach demonstrates considerable alignment with the notion of strong exploration. Of course, there is still the problem of how to break down the problem situation into the different research questions – this is no trivial exercise, but ensuring that a critical stakeholder exploration would be a central part of the analysis process would assist in overcoming such difficulties.

4.6 Critical appreciation

"A constellation is not ordered in a regular fashion, changes over time, and can be seen from many different angles." (Midgley, 1997: 267)

The first part of this methodology suggests that each decision-maker develops their own constellation of methodologies to decision-making. The term methodology here is used quite broadly to include the personal world views of the individuals involved in the analysis, as well as the well defined methods that they have acquired during their professional careers (which obviously affects their world views). A rich appreciation of the problem at hand is synthesised through the interaction of different stakeholders, with the potential of individuals' perspectives being evolved (essentially resulting in new paradigms) as a result of the interaction. Any attempt to unify in some logical sense the different paradigms is avoided (presumably in recognition of the futility of such an exercise), and the perceived discord between different paradigms used to drive further debate, conversation, analysis, etc. There is a danger that this approach might be seen as a form of atheoretical pragmatism where people simply pick and mix from the available methodologies without robust theoretical underpinning. This is where the theory of critical reflection comes in. This theory has four aspects to it. These are: (1) empirical-analytical (or based on experiment and observation); (2) historical-hermeneutic (or two-way communication with others); (3) ideology-critique (or revealing assumptions at the level of society); (4) self-reflection (or, revealing one's own assumptions). These four aspects fit the requirements for strong exploration, exploring not only personal and well established paradigms, but also exploring both implicit and explicit assumptions (the paradigmatic boundaries) and critically reflecting upon their implications for the analysis.

Unlike the system of systems matrix and the TSI approaches, different methods are not aligned with these four categories – this is left to the decision-makers to decide through analysis allowing the impact of the problem context to be fully realised by not predetermining the role of different approaches within the analysis. This methodology also acknowledges the full dynamism of the decision-making process, by encouraging ongoing exploration and reflection during the process itself.

Before concluding, we briefly raise the issue of ethics in light of our presentation thus far.

4.7 Ethical Implications of Complexity-Based Analysis

The exploratory decision-making process has to come to an end at some point and a decision made. Literally, the concept of strong (multi-paradigmatic) exploration provides no end – the more one explores, using the mechanisms of critical thinking (critical systems heuristics, critical appreciation, and boundary critique) the richer the understanding and presumably the better quality the decision. This is impractical however.

Analysis is performed to provide insight to a particular problematic situation and has associated with it limited time and resources. Free unimpeded strong exploration does not and can not be sufficient on its own – we need to recognise that an endpoint must be reached, which in so doing, limits exploration, and therefore limits the breadth and quality of the understanding developed. These shortfalls mean that something important might be missed, and so there are inevitable risks associated with any decision process. This is where ethics becomes useful but not as a way to specifically prescribe an endpoint.

By ethics we do not mean purely some notion of altruism, we mean, quite differently, that in being unable to know it all, however hard we might try, we must accept the inevitability of choices that cannot be backed up scientifically or objectively (Cilliers, 2000). This means that a judgement must be made that accepts that the 'best' decision possible has been arrived at (given current capabilities), but it is not perfect as a decision can only be based on the insight developed through limited (bounded) effort. We must accept that our decisions are based on incomplete analysis, and that potentially adverse outcomes might occur as a result of our inability to 'see' everything. The analysis must be judged to be 'good' by judging how it went about addressing the problem situation and how it critically appraised the boundaries that were determined by it. An analysis does not remove the responsibility from the decision-maker (one can't blame the plan if all goes wrong); the decision-maker has the responsibility to ensure that the best possible exploration was performed. The decision-maker must fully appreciate that the validity of the understanding derived depends wholly on the assumptions (both tacit and explicit) that were made (which may or may not be appropriate given the problematic situation despite considerable effort), and that it is provisional in that it is based upon current beliefs and perceptions. An awareness of both the contingency and provisionality of the analysis is far better than a false sense of security, the latter being a very risky state of affairs indeed. It is clear though that there are ethical implications for all boundary judgements.

This approach to ethics does not provide a definitive endpoint for the decision process (this point has to be negotiated between the participants) but it does provide guidelines as to what factors must be taken into account in determining whether or not an analysis has served its purpose. Essentially, an ethic must be developed locally, rather than falling back on a prescribed universal framework. However, a locally developed ethic may have to be defended non-locally. How might this defence be achieved? The subject of another paper perhaps.

The institutionalisation of such an ethic is of considerable importance if the military OA community is to fully grasp the potential of complexity-based thinking for investigating OOTW-type problems, therefore fulfilling it's customers requirements (see Ormerod, 1999, for further discussion on ethics in OA).

5 Summary and Conclusions

In this paper we have explored the implications of complexity for military OA. Though we have focussed on military OA in general we are confident that our discussion and conclusions are equally valid for civilian OA. Complexity thinking highlights the limitations of the dominant positivist attitude that characterises contemporary military OA philosophy. If the Defence OA community is to continue to provide the valuable support to decision-making that it has demonstrated over the past 60 years then it must acknowledge the fundamental changes in the problems it is asked to investigate and be prepared to restructure itself in response to these changes. We argue that the institutional environment in which our analysts, customers, experts, etc. exist is structured to facilitate the solution of problems typical of the Cold War era. In order to adequately take on the challenges of the New World (Dis)Order a new complexity-sensitive institution must be constructed – an institution that acknowledges the unique mix of capabilities that different contexts demand. The construction of this new institution will not occur overnight. Firstly, the community must develop an appreciation of the current institution and how it impacts our ability to examine complex issues. Next, the community must take it upon itself to educate community members, including customers, experts, etc., in the subtleties of complexity-thinking, and demonstrate how a new analytical philosophy would facilitate the investigation of complex systems. This paper is a first step in examining these areas. There are a number of frameworks already in use in the civilian OA community that are already 'living' the complexity philosophy. The military OA community is encouraged to embrace these various frameworks. *Complexity thinking abhors and adores institutionalism.*

The prevailing military environment is strongly technology focussed. Many experts believe that communications and information processing technology is the key to dominance on the modern battlefield. This preoccupation with technology and the belief that technology can be used to solve any societal difficulties is also apparent in the complexity science community. Many believe that the most effective way to manage complexity is to build more complex computer models, e.g. agent-based modelling techniques. This position endorses a prevailing dominant attitude that privileges mathematics. Our view is that the mathematics of complex systems warns us of the limitations of mathematics itself when considering such systems, de-emphasising the centrality of mathematics to analysis. Herein, we have attempted not to universally privilege any framework/language/theory/etc. believing that this decision must be taken in the context of particular problematic situations. Furthermore, we de-emphasis the role of the model itself in analysis, believing that the focus should be on the analytical process and the way in which understanding is inter-subjectively generated (remember that we treat informal and formal perspectives equally so when we use the term inter-subjectively we are not only considering the interaction between individuals' *Weltanshauung*, but also formal representations). For example, in a group decision environment the final product might be a causal map of the perceived state of affairs. The map itself is effectively worthless, particularly outside of the bounds of the development group. The

developing shared appreciation that the mapping process facilitates in the minds of the participants is the important 'product'. *Complexity thinking shifts our focus from the model to the modelling process and the culture that supports that process*.

Assuming that the universe is best described as a complex system problematises just about every facet of analysis. As there are no hard enduring boundaries in nature we must be wary of rushing to conclusions concerning boundary allocations. Some boundary allocations may appear to be obvious, the physical walls of a building for example. But even the validity of these boundaries is dependent upon what is regarded as the problem context (see for example Midgley *et al.* 1998). Once we start considering softer subjects such as the cultural characteristics of a foreign society then the problems really begin. Ackoff (1981) coined the term 'problematic situation' in recognition that even the identification of what the situation of interest is, is problematic. *Complexity thinking problematises boundary recognition and allocation.*

The concept of incompressibility essentially negates the possibility of a definitive analytical philosophy. Whatever approach one takes in investigating such problems, one must resist the inviting temptation to assume that ones approach is perfectly appropriate. A capacity to innovate and be flexible is a key element of a complexity-based analytical philosophy; a capacity that is being stifled by the current positivist analytical institution. Such a philosophy encourages the use of multiple perspectives; recognising that informal perspectives can be equally useful, if not more so, than formal mathematical-based models. The activity of exploration in the form of dialogue, negotiation, paradigmatic pluralism, and critique, is held up as the key to the design of context-specific implementations. Exploration in this broad sense needs to be facilitated in some way. Is facilitation, not only of the workshop environment, but also of a variety of 'paradigmatic negotiations', a key competence of our future analysts? We think it is. The philosophy espoused herein also warns of the risks of offline analysis, not only for the comprehensiveness of the analysis itself but also for the implementation phase of the decision-making process. It also highlights the import of system history and how that system might evolve in response to our interventions. *Complexity thinking legitimates pluralist thinking*.

Contrary to other presentations of complexity thinking we do not suggest for one minute that the military OA tool box developed to date is of no further use. In a limited form, complexity thinking simply encourages us to view these tools in a different way; to see them as ways to stimulate thinking rather than a prescriptive route to absolute truth. Some analysts have responded to the challenge of complexity by adopting an atheoretical pragmatic philosophy, arguing that the analyst should be left to make their own decisions regarding boundary judgements and method selection. Whilst complexity thinking is sympathetic with such a position, it does provide a coherent 'meta-narrative' (a meta-narrative that plainly acknowledges it's own limitations) to facilitate the analytical process. This 'meta-narrative' recognises that analysis of complex problems is as much science as it is

craft. *Complex thinking regards models as inspirational rather than containers of truth.*

We have also attempted to raise the profile of the postmodern and constructivist schools of thought within the military OA community. We believe that they have much to offer. Only time we tell if we have been successful in this aim.

Maturana (1988) claimed that "the most central question that humanity faces today is the question of reality," and that "the explicit or implicit answer that each one of us gives to the question of reality determines how he or she lives his or her life, as well as his or her acceptance or rejection of other human beings in the network of social and non-social systems that he or she integrates." Our interpretation of complexity science strongly sympathises with this assertion and can be seen to offer some direction on how organisations, each of us included, might undertake the task of developing an appropriate, yet always provisional, representation of our unique realities. It encourages us to review the very structures, values, etc. that we have come to accept without question. Even the very concept of 'complexity' should itself not be taken for granted. Complexity thinking, at the very least, reminds us that "this is a time to talk about boundaries" (Lifton, 1970).

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