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Operationalising Adaptive Campaigning

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Abstract

For highly complex missions, it is not realistic to expect to "get it right" from the outset. The initial conditions are much less important than the ability to improve performance over time. This is the aim of Adaptive Campaigning. We present a methodology that is a first step towards achieving this aim, based on the notion of an explicit, shared, Causal and Influence Network (C&IN). Firstly, we describe the feedback loops between the force and its environment, which provides the basis for adaptation. Secondly, we analyse the flow of information between the environment and the C&IN. This reveals the need for targeted probing actions that generate small information-rich signals, in contrast to a sensor grid that would collect large amounts of information-poor data. Thirdly, we outline the features and composition of the C&IN and discuss how it may be evolved, represented and used. Fourthly, we reflect on the assumptions and limitations of our approach. In conclusion, we highlight how this novel approach to adaptive campaigning can capture lessons learned across rotations, increase adaptability at all scales, levels and classes, and thereby significantly improve the chances for successful outcomes.

1. Introduction

The Australian Army has recently published ***Adaptive Campaigning – the Land Force Response to Complex Warfighting***[1], endorsed by COSC (Chief Of Staff Committee) in December 2006.

This document (for brevity referred to as ***Adaptive Campaigning***) lays out the rationale for taking an adaptive approach to military operations in complex situations where there are multiple interdependent objectives and there is a high level of Operational Uncertainty, defined as the range of fluctuations in likelihood and intensity of spikes in the level of violence. ***Adaptive Campaigning*** sets out a philosophy, and proposes a number of innovative concepts based on Adaptive Action and Mission Command to serve as aspirational characteristics, and to guide the future development of the Land Force.

In this present paper we propose to address how these attractive and persuasive ideas can be translated into implementable approaches in real operations.

We draw on our research on adaptation and complexity in defence, which has been underway in DSTO for over four years, and on our more recent experiences of supporting both the development of the Army's Adaptive Campaigning paper, and its experimental application in some current operations.

Exploiting the power of adaptation is a central theme of this paper, and the adaptive potential of individual human roles is a central issue in adaptation. We will touch on some of the human sciences aspects here, but leave their more detailed exploration and development to a subsequent paper[2].

The structure of the present paper is as follows. In Section 2 we discuss ***Adaptive Campaigning*** in sufficient detail to draw out the critical issues and implementation challenges for discussion in the following Section 3.

The conceptual basis for our approach, in the science of complex adaptive systems, will be briefly discussed in Section 4. The methodology for application of this approach to operationalising ***Adaptive Campaigning*** will then be developed in Section 5, leading into Section 6, which is a SITREP, or Situation Report from the front line of our work program, to describe the progress made so far in the development of conceptual design, support systems, an analytical framework, C2 concepts and processes, and ways of dealing with the human sciences aspects. Finally we briefly acknowledge the near-term priorities and directions for our work.

2. Adaptive Campaigning

Adaptive Campaigning was developed over the course of 2006. It was motivated by a number of factors, including the high tempo of operations that the Australian Army has engaged in for the last several years, the complex nature of those operations, the need to provide guidance to future Army capability development, and by some significant trends that had been identified, including steadily escalating lethality, decreasing hostile force densities to below the discrimination threshold of sensing capabilities, and increasing use of complex terrain, together contributing to growing Operational Uncertainty for our forces.

It was recognised that the need for an adaptive approach stems not only from this uncertainty but also from *"the adaptive nature of the threat which will attempt to exploit land force capability gaps and/or limitations*."

The document defines Adaptive Campaigning as "*actions taken by the Land Force as part of the military contribution to a Whole of Government approach to resolving conflicts*" with the objectives being "*to influence and shape the perceptions, allegiances and actions of a target population and control the overall environment to allow peaceful political discourse and a return to normality.* "

Adaptive Campaigning recognises that these complex objectives require simultaneous prosecution of five interdependent and mutually reinforcing Lines Of Operation:

- Joint Land Combat,
- Population Support,
- Indigenous Capacity Building,
- Population Protection, and
- Public Information.

It is the factor of Operational Uncertainty that necessitates defence forces, and land forces in particular, having to be prepared to take on all of these non-combat roles as well as their traditional roles of protection and defeating opposing and disruptive forces. While the intention will always be to transfer responsibilities to appropriate non-defence agencies as soon as the situation is stable enough to do so, the fact remains that in the critical early stages of an intervention when the threat level and the uncertainties are high, it will be up to the land forces to take the lead and establish the campaign across all five Lines Of Operation. As it becomes possible for other agencies to join the campaign they will begin to assume responsibility for some roles, but will continue to need

the support of land forces, especially for protection. An important issue that arises as the number of contributing agencies grows is the development of relationships between them to foster cooperation and create and maintain coherence.

Since our forces will nearly always operate under resource-limited conditions, a central issue at all stages of a campaign, irrespective of the number of participating agencies, will be their ability to effectively orchestrate their limited effort across all five lines of operation.

A key premise of ***Adaptive Campaigning*** is that in such operations, the hostile elements and those supporting them or obstructing friendly forces, will largely be operating below the discrimination thresholds of surveillance systems. Thus the force does not expect to find itself in an information-rich environment, but rather expects to have to take action first in order to stimulate reactions from which it can glean some information – in other words, it expects to "*fight for, rather than with, information*." A key point being made here is that in such operations, standing off at a safe distance and observing will not work because hostile force elements can simply meld indistinguishably into the normal fabric of local life, and while they may be easily detected by surveillance systems, they are not able to be discriminated from the neutral and supportive population. Friendly forces will therefore have to take the risks of engaging and interacting in order to learn about the situation, and will have to be prepared to continuously evolve their understanding and their approaches as they learn.

These ideas are encapsulated in a modified form of Boyd's familiar OODA[3] loop. ***Adaptive Campaigning*** proposes Act – Sense – Decide – Adapt (ASDA) as a more relevant form for the challenges of operating in an environment with high operational uncertainty. By placing 'Act' first this formulation stresses the need to act even with little information, and by immediately following that with a 'Sense' the point is made that whether the purpose of the action is to stimulate a reaction from which to learn something, or to produce an effect, in both cases it is necessary to have the right sensing mechanisms already deployed, cued and ready to collect. The 'Decide' function follows to determine what is learned from the sensed feedback that results from the action, and what to do next.

These first three elements correspond closely to the four elements of OODA, albeit with a different emphasis on where the cycle starts, and with the 'Orient' function of OODA incorporated into the 'Decide' functions of ASDA. The object of the decision is to choose the next action, and here we recognise that actions can be internal (make a change to one's own system i.e. adapt) as well as external. So 'Adapt', the fourth element of ASDA, explicitly adds the need to invoke adaptation and consider what, if anything, should be changed on every cycle, before continuing to the next cycle with another external 'Act'.

Successful application of the 'Adapt' element results in the land Force improving its ability to focus its effort on the right objectives at the right time and in the right place. More specifically, this ability is founded on the following four key capabilities, or *Operational Adaptivities*:

1. Operational Flexibility - the ability to maintain effectiveness across a range of tasks, situations and conditions. For example, the structure and capability of the force can be reconfigured in different ways to do different tasks, under different sets of conditions.

2. Operational Agility - the ability to dynamically manage the balance and weight of effort *across* all lines of operation in space and time.

3. Operational Resilience - the capacity to sustain loss, damage and setbacks and still maintain essential levels of capability across core functions.

4. Operational Responsiveness - the ability to rapidly identify then appropriately respond to new threats and opportunities *within* a line of operation.

While the formal articulation (and endorsement) of these objectives, lines of operation, premises and concepts is new for the Australian Army, it is also to some extent a matter of recognising and formalising what many successful commanders have known and sought to practice for some time. Moreover, it is entirely consonant with similar approaches in the US[4], the UK[5] and Canada[6].

Adaptive Campaigning however does more than articulate informal best practice, it seeks to push the boundary of best practice and to put in place a philosophy based on adaptation, with the required underpinning concepts, systems and processes to implement that philosophy in an adaptive way, thereby placing the Army on an evolutionary trajectory towards greater success in complex operations.

Such significant culture shifts are not lightly adopted. There is great value therefore in the paper's careful reasoning to place combat into a multidimensional whole-of-government context where it is seen as

- the reason that the military is there at all, (instead of just nonmilitary agencies),
- addressing the preconditions of security that must be achieved before the real business of 'return to normality' can be tackled, and

- part of a coherent operational doctrine alongside counterinsurgency, stabilisation, peace support and humanitarian tasks.

Coupled with this moving of traditional combat from Army's centre-stage, to being a necessary and potent means to an end, is the widened spectrum of tasks that western Armies are being expected to undertake in theatres around the world – from construction and training, to humanitarian assistance and civil administration – while always having to be prepared to swing into combat mode when needed. All these changes are placing extraordinary demands on our soldiers.

There can be little doubt that the only effective response to all the complexity of the tasks and of the physical, human and information environments that they find themselves in, is embracing and practicing adaptivity at every level. In one sense, all this really means is that one can not presume to know the answers in advance. Yet the consequences of this simple and intuitively obvious notion are far-reaching and quite challenging to implement.

Adaptive Campaigning proposes that what is required is an approach based on the two complementary philosophies of 'Mission Command' and 'Adaptive Action'.

Mission Command is a well-established doctrine in the Australian Army, and in most western forces. It needs to be considered together with its natural complement, which we term the *Adaptive Stance*, and which we will briefly introduce in Section 6. These concepts and their implementation issues will be discussed in more detail in a subsequent paper[7].

Adaptive Action is defined as "*an iterative process that combines the process of discovery … and learning*" with action. It posits that the purpose of planning is to enable arriving "*at a start point with a mental model of the problem and how it is likely to adapt*, (and with) *appropriate resources and time to allow a solution to be properly developed in contact*."

Consideration of what is required of each component of the ASDA cycle to create that initial undertanding, and to continue to evolve it throughout an operation, leads to a number of specific aspirational capabilities for the Land Force, including:

Act:

i. Probing actions to stimulate a response in order to learn or test assumptions or understanding – contributing to the ability to learn about the context,

ii. Decisive actions to prosecute a course of action to create effects (while still allowing for adaptive changes in real time as the actions unfold), and

iii. Modifying actions, where the target of action is the force's own operations, in other words, adapting its sensing, deciding or acting.

Sense:

iv. Sensing to provide input for effective adaptation - the collection plan must enable observation of the reactions and adaptations of threat and population groups alike

v. Sensing to support learning what is important to observe – the collection plan must also include a strategy for its continuous refinement to allow the force to improve its awareness of what is relevant, and

vi. Sensing to measure effectiveness – the collection plan must include monitoring the effectiveness of land force actions across all five lines of operation.

Decide:

vii. Deciding the meaning of a sensed response to a probing action, and

viii. Deciding what should be done next given what is learned about the situation.

Adapt:

Moreover, dealing with an intelligent and adaptive adversary requires

ix. learning *how to learn*, - continuously improving one's ability to learn from both successes and mistakes, including

x. learning how to derive lessons from experience, and how to implement those lessons in an effective way leading to successful adaptation – i.e. knowing when and what to change, and

xi. maintaining agility and robustness to deception, by adopting a stance of constant challenging of one's understanding and perceptions at every level of the land Force.

Together, these aspirational characteristics, underpinning philosophies and key concepts are soundly based on our conceptual framework for adaptation, as we will illustrate in Section 4.

3. Challenges Posed by Adaptive Campaigning

Our purpose in this section is to discuss what is difficult about applying the concepts outlined above.

The extent to which defence forces already practice some of these concepts, whether intuitively or doctrinally, was acknowledged and discussed in an earlier paper[8]. On the other hand it is almost commonplace to hear rhetoric in defence circles extolling the need for more agility, or vague claims that various proposed developments will somehow lead to its appearance. Taken together these observations suggest that it is not trivial to engender the ensemble of very desirable properties which we might associate with adaptivity, or with the related concepts defined by CCRP[9], (robustness, resilience, innovation, flexibility, responsiveness, and adaptation as six elements of agility).

3.1 Challenge of Creating Adaptivity

A recent conceptual analysis[10] of the factors that influence the degree of success or failure of adaptive mechanisms lends weight to this suggestion, by the demonstration that any instance of adaptation is characterised by a very large number of parameters, and that these need to be tuned to each other so that the entire mechanism (or process) functions as a coherent whole. It is unlikely that adaptive mechanisms whose parameters have been chosen arbitrarily, or even with some design in mind, will result in effective adaptation. In practice, the only way we know for such complex and finely tuned mechanisms to arise is through the process of adaptation itself – in other words, we have to use adaptation to produce more adaptation.

We can summarise the challenges in creating adaptivity as how to:

- use our exising adaptive capabilities to develop new successful adaptive mechanisms, and
- specifically develop adaptive mechanisms to foster the four operational adaptivities at all scales of the force.

We turn now to focus on the challenges implicit *within* particular instances of adaptive mechanisms. The contributing factors are the complexity of the objectives, the complexity of the context we seek to influence, characterised as it is by causal and influence networks rather than simple causal chains, the limitations of human cognition, and the complexity of the systems we have at our disposal.

3.2 Challenge of Complex Objectives

Objectives in complex operations are not simply stated, unambiguous and one-dimensional. They are essentially multi-scalar, sometimes difficult to articulate and often hard to measure, and their components are not independent.

As an example, considering the five Lines of Operation, we can identify a number of potential measures of success in each one, but we soon realise that investment of resources to increase success of one such measure may easily have adverse effects on others. This then calls for a balancing act, and for understanding not only the relative importance of each in the overall scheme of things, but also the complex interactions between them, so that an informed call can be made on relative priorities.

Similarly, examination of the four operational adaptivities defined in the previous section highlights another aspect of the complexity of the objectives.

At the highest level, we seek to produce the exit conditions to successfully terminate the operation. In order to do that we seek to simultaneously achieve acceptable levels of performance against all the measures of success for all the Lines of Operation. But in order to do that, not only do we need to have the capacity to successfully perform the tasks each Line of Operation calls for, but because of operational uncertainty, we *also* need to achieve acceptable levels of performance against measures of operational flexibility, operational agility, operational resilience and operational responsiveness in order to ensure that at any point of time we are allocating our limited resources wisely in the context of all five Lines of Operation.

These further require the ability to successfully identify what tasks need to be done, and what the composition of the team should be, when it is necessary to reduce effort on one Line of Operation in one area and increase it in another, what the most essential tasks are at any point of time and how they may be restructured in order to maintain their integrity when key elements are damaged or destroyed, and so on.

Each of these abilities is essential for some aspect of adaptivity, and they in turn require other abilities – knowing what indicators to monitor, how to interpret the complex picture painted by a large set of interdependent measures, what actions can be taken, what their likely consequences might be, how they can best be raised and

supported, and what assumptions they rest on, how to monitor the continuing validity of those assumptions and what to do if they fail, and how to switch strategy smoothly when it needs to be changed.

What we find is that there is a networked space of interdependent objectives and associated measure of success spanning many scales, and that overall success is therefore dependent on most of them, most of the time.

3.3 Challenge of Complex Networked Causation

This complexity and interdependence of objectives is a reflection of the complexity of the operational context.

Put simply, we are generally dealing with situations characterised by multiple players with different agendas, multiple relationships between the players, a degree of opaqueness and deception that makes it difficult to discern exactly what the relationships are, and a complex physical environment containing many poorly-understood adaptive systems (eg economic systems, religious systems, political systems, ecosystems etc) which are interconnected and with which the players also interact.

Moreover the entire context is dynamic: allegiances shift, relationships and networks develop, individual powers and influences wax and wane, local objectives evolve, and natural forces and human activity continually modify the physical systems and environment. All this activity is neither chaotic, nor predictably patterned, although it is possible to make *some* forecasts with *some* confidence.

In such a situation simple linear causal chains are the exception, not the rule. Most events or properties can be ascribed to the result of many preceding interacting causal and influence processes, no one of which can be unambiguously defined as *the* cause. Similarly, the consequences of any single event or property unfold through many interacting pathways and may have ramifications well beyond the sphere of the single event. Although some particular events may be quite limited in their origins and effects, this is certainly not the usual case, and there is no in-principle cutoff of either antecedents nor consequents.

What we are describing here could be termed a complex Causal and Influence Network, which we will abbreviate as C&IN. The challenges inherent in dealing with C&INs include:

- Defining a principle or boundary to determine what is to be included in the C&IN, and how to handle the interactions through the boundary,
- Determining the scales, levels of abstraction and levels of detail at which to consider the C&IN,
- Creating a model of the C&IN – i.e. discovering and mapping the elements of the C&IN and their relationships at several relevant scales and establishing the relationships between the scales,
- Representing and visualising the structure of the C&IN model, so as to enable sharing and collaboration in its development and exploitation,
- Evolving the C&IN model to better represent the dynamic behaviour of the real system, and to track its evolution over time,
- Using the C&IN model to explore intervention options for influencing particular aspects of the C&IN, and possible consequences of contingent or deliberately chosen events, and
- Representing uncertainties, competing hypotheses, assumptions, hidden variables and multiple alternate versions of the C&IN model.

Finally, we need to link the C&IN model to the challenges of the preceding subsection, the complexity of our objectives:

- Deriving an analytical framework from the C&IN and from the set of interdependent objectives, so as to identify and relate relevant indicators, triggers, measures of performance and measures of success and failure across the full spectrum of the complex operation.

3.4 Challenge of Limitations of Human Cognition

Being adaptive requires us to develop a model of the C&IN we are dealing with, sufficient for guiding and interpreting our observations, and choosing our next internal and external actions.

Humans (and to certain extents other species too) have evolved a limited ability to do this under certain conditions. We are for example, good enough at discerning the intentions of others and choosing actions that further our own interests in social or competitive situations. This means that humans are generally competent at adaptive behaviour where the scale of the C&IN that needs to be taken into account is within the range of ‘normal’ social or competitive interactions, and where the scale of the adaptive behaviour that is needed is close to the scale of what an individual can do.

We should not be surprised however, if individual humans start to fail in adaptive behaviour when dealing with C&INs of a much greater scale, or when the adaptive behaviour required extends over a much larger scale than what a close-knit team or an individual can do alone. Our ancestors were not generally required to do this, so the capability did not evolve.

Both of these limits to natural adaptivity are routinely exceeded in the complex operations with which our forces now deal.

The limitations of human cognition in relation to how they fail in dealing with large scale complexity, have been explored in the literature dealing with decisionmaking, human error and catastrophic accidents, and will be reviewed in a subsequent paper[11], in which we will also address many specific and implementable strategies for countering or mitigating them, drawn from a particularly insightful and useful analysis due to Dörner[12].

Key challenges therefore, are developing ways to support and extend human abilities to:

- handle C&INs with larger scales of complexity, and
- produce effective adaptation at larger scales of organisation.

These two major challenges dovetail with the C&IN and creating adaptation challenges identified above, but focus on the human roles in those challenges and how they need to be supported.

3.5 Challenge of the Complexity of our own Systems

Different classes of challenges arise from the complexity of the systems that we build, network and operate. While individual systems such as C2, ISR, logistics, weapons and information systems, and the sophisticated platforms into which they are integrated and interfaced are already complex enough to pose significant challenges for their design, development, introduction into service and effective operation, these pale by comparison with the problems of successfully integrating them all into an effective, resilient and agile networked force.

More to the point for the present paper, in the kind of complex operations where we expect to be applying Adaptive Campaigning, the systems and forces that are assembled are likely to be drawn from the defence forces of a number of countries, with different cultures and different capabilities and doctrine. The command structure that is set up to integrate and direct the efforts of these contributed force elements results in one nation's forces being under the command of another, and having to rely on support of various kinds from yet other elements. Such interdependencies between diverse force elements creates complexity, which can have both positive and adverse consequences. Moreover, there are likely to be a number of non-military elements contributing to the total allied effort in dealing with a complex operation, including contractors, NGOs and PVOs, and these also will have interdependent relationships with each other and with the military elements.

The potential benefits of such a diverse and loosely connected assembly of participants include a much larger range of capability options than the sum of the individuals' capabilities, greater international legitimacy through more broad-based support and commitment, and greater probability of success through drawing on the unique perspectives and insights of each element.

The main challenges in making effective use of such a complex array of interdependent elements and systems stem from the sheer number of possibilities that are created, in particular how to support local decisionmakers at all levels in:

- rapid understanding of what options can be called on,
- recognising and mitigating potential adverse cross-effects between force elements,
- prioritising between competing requirements for a given force element,
- identifying and bringing about potential synergies between the actions undertaken and the knowledge held locally by different force elements, and in
- deciding between immediate local satisficing of a requirement and slower but more comprehensive and collaborative attempts to arrive at better solutions.

Successful handling of these challenges supports:

- a greater range of options available for adaptive action, including collaborative synergistic actions between distributed elements,
- greater confidence of not undermining others' adaptive actions,
- more effective local learning,
- better alignment of disparate adaptive actions, and

- greater resilience for the force overall.

The complexity of our own systems mirrors to a degree the complexity of the operational context but differs in one very important respect - by and large the elements, relationships and mechanisms in our own systems are known or relatively easily knowable*, which is not the case with complex operational environments. This will be reflected in the different strategies proposed for dealing with them.

4. Conceptual Basis

To discuss ways of addressing these challenges we draw on selected[13] key concepts arising out of the science of complex adaptive systems:

- Multi-level Structure and Multiscale Analysis: the property of real complex adaptive systems that describes their nested hierarchical structure, and the mutliple scales at which an observer can analyse those systems,
- Adaptation: an iterative process that continually generates and tests variations in a complex adaptive system, and selects and incorporates for retention those that increase its success, and discards and inhibits those that reduce it; leading to a better fit between the system and its context, and
- The properties of networked causation or C&INs.

We now briefly discuss these concepts and refer the interested reader to the literature for a more comprehensive account.

4.1 Multi-level Structure and Multiscale Analysis

One way to define a complex system is as one in which no single model adequately captures the system's behaviour. In this case, several models at different scales are required for a satisfactory representation of the system. A number of closely related concepts relate to this situation, including scale, scale of observation, level, level of detail and resolution. In order to say anything useful beyond the obvious requirement for plurality identified above, it is necessary to untangle and clearly distinguish these concepts.

Here, scale refers to a multiple of a standard quantity. Just as the unit scale on a map can be multiplied to calculate distances along straight lines, so too do systems scale in general according to a multiplication operation. As an example, the behaviour of a single plane can be multiplied by having ten planes flying in formation following the same instructions. The formation produces a larger scale effect by an order of magnitude compared to the individual plane.

In contrast, the scale of observation is a relationship between an observer and the system. The scale of observation is inversely proportional to the resolution of an observation. A fine (or small) scale of observation (high resolution) means that the observer can distinguish between many different configurations of the system, while at a coarse (or large) scale of observation (low resolution) only collective degrees of freedom can be distinguished.

The process of modelling is distinct from the process of observation, although each requires the other. In modelling, the Level Of Detail (LOD) indicates the finest scale at which system components are represented. A low LOD in a model will only represent coarse scale aspects of the system while a high LOD will represent finer scale detail.

At any one scale of observation, what the observer knows about only partly explains the behaviour observed at that scale because of *cross-scale effects,* events at one scale manifesting consequences at other scales. This is certainly true for military operations: strategic, operational and tactical views of a conflict each contribute only part of the real story, because of interactions.

A closely related concept is level, which denotes the number of nested layers within a hierarchy. For example, {Section, Platoon, Company, Battalion, Brigade, Division, Corps} is a seven level hierarchy, where Section is level one and Corps is level seven. This is clearly a relative designation, since the hierarchy may equally start at the individual soldier, or for other purposes may only start with Brigades. A similar distinction can be identified in modelling systems. The architecture of the model can be hierarchical as in an object-oriented class structure, or it may be flat

A *cross-level effect* is a response of a system at one or more levels to a stimulus at one or more other levels[14]. For example, if a Section responds to an order originating at the Company level, this is a cross-level effect.

* This does not of course make them less complex – even if all the elements and their interactions are known, their interdependence still makes it impossible to anticipate all the consequences of any interaction.

The similarity between level and scale is that actions that occur at higher levels tend to have larger scale effects. Conversely, when we focus attention on the behaviour of a complex system at one level of its structure, there is often a particular range of scales that characterise its properties and behaviours, and similarly, observing the system at one scale will often bring only some levels into focus. Unfortunately, this simple relationship does not always hold, and since one concept refers to a relationship between a system and an observer while the other refers to the system itself, it is important that we maintain a distinction between scale and level.

The reason that level is important is that most processes (including adaptive processes) exist at particular levels, or link adjoining levels. The reason scale is important is that a system may be highly adaptive at one scale of observation, yet fail to exhibit any adaptation at other scales. Thus it is important to be adaptive at the right scales and to identify where the adaptive processes reside.

Observation of natural and successful complex adaptive systems demonstrates that there are adaptive mechanisms that operate both within a single level and across levels. These are the processes that create global coherence in the overall system (by communicating between levels) and guide its context-appropriate behaviour locally. This suggests to us that it is important to address both. Further, Bar-Yam[15] has proposed a Multiscale Law of Requisite Variety to capture the notion that the complexity of actions available at a given level needs to match the complexity of the task to be performed.

It has also been noted[16] that while nested hierarchical structure is a feature of both natural complex adaptive systems, and complex physical systems that are not adaptive, the levels of the latter tend to exhibit a high degree of self-similarity, while this is not true of living systems – natural complex adaptive systems. At each distinct level of organisation there are quite different structures, relationships, processes and functions.

This suggests that through the process of evolution, living systems have achieved a heterogeneous distribution of roles across levels, and this diversity is no doubt important in ways we do not at present clearly understand. It may be related to the nature of the computational tasks that a living system has to do, and it may also be related to the natural scale of the various types of interactions with the environment that the system has to support.

The lessons we tentatively draw from these observations are:

- The need to explicitly and separately address the requirements for adaptive actions at each relevant scale,
- the importance of cross-level interactions in shaping the overall behaviour of the system, and
- the need to engage with rival and allied systems at commensurate scales of action.

4.2 Adaptation

We use the term adaptation to encompass all the ways in which complex adaptive systems are able to improve their 'fitness' or success in their environment, through continual variations and fitness-linked selection operating on the systems to eliminate those variations that decrease success. This includes both evolutionary processes and learning processes, as well as various hybrid forms such as human design and creativity, and the evolution of culture.

We have previously published[17] a conceptual framework for adaptation which aids in identifying a rich spectrum of possible instances of adaptation. It also supports analysis of existing adaptive mechanisms to identify ways in which they can be rendered more effective, and suggests a methodology for implementing changes and developing new adaptive mechanisms.

We will apply this conceptual framework to both the development of the specific adaptive mechanisms that Adaptive Campaigning calls for (discussed in Section 6), and to the methodological process of introducing changes into the Land Force (discussed in section 5).

In particular, we will make use of the conceptual framework's four classes of adaptation (already incorporated into the four operational adaptivities described in ***Adaptive Campaigning***), and its five levels at which adaptation can be applied, each successive level adding more power to deal with challenging complexity:

1. at the ***'action'*** level - creating a more contextually appropriate series of adaptive actions in the world, but within the constraints of existing sense, process and act capabilities
2. at the ***'learning system'*** level - using adaptation to expand sense, process and act capabiltiies in useful ways
3. at the ***'learning-to-learn'*** system level - using adaptation on the learning mechanisms themselves and thus improving the way in which adaptive actions are produced

4. at the ***'defining success'*** level – applying adaptation to the difficult problem of articulating sufficiently precise and actionable measures of success, (in order to achieve this it will be necessary to have access to some more accurate measures of success - usually only available in slowtime and in retrospect), and
5. at the ***'co-adaptation'*** level – addressing the interactions between multiple adaptive mechanisms. This level operates in two distinct ways:
    - the fact that our systems are interacting with each other and that there are therefore additional degrees of freedom for creating adaptivity and more effective behaviour at the SoS level raises a system management and design issue, which we address by applying adaptation to the parameters describing the distribution of roles, resources, authorities and responsibilities between the systems in the SoS; and
    - the fact that our systems are interacting with other systems that are also adaptive, implies that we have to allow for a more intelligently reactive and adaptive context in our own adaptive actions, which requires understanding of others' adaptive mechanisms and the ability to project action consequences through the lenses of others' perspectives.

These five levels of adaptation are more extensively discussed elsewhere[18], but the essential difference between the levels is what part of the system is being subjected to adaptive change. As we move through the five levels, we are introducing variation and fitness-linked selection successively into

1. the parameters that characterise the operation of the existing sense, process, and act capabilities of the system,
2. the parameters that determine the scope of the sense, process, and act capabilities of the system,
3. the parameters that determine the effectiveness of the learning mechanism,
4. the internalised selection criteria, and
5. the parameters that determine the distribution of roles, resources, authorities and responsibilities between the component systems of a system of interacting CAS.

Other aspects of the conceptual framework address the various kinds of adaptive mechanism, the parameters that specify a particular instance, the relationships between those parameters and the factors that characterise aspects of an adaptive mechanism's functioning, and how those factors influence the effectiveness or otherwise of the adaptive mechanism.

These parameters, functional characteristics and effectiveness measures naturally form an analytical framework which can be used to analyse, troubleshoot or design and evolve adaptive mechanisms.

The relationship between the effectiveness or success of a system and the effectiveness of its adaptive mechanisms is clearly a close one, and has been discussed in detail in a previous paper[19]. However, it is worth making some remarks about these concepts here because they have important implications for Adaptive Campaigning.

If one thinks of an adaptive mechanism as a means of 'moving' in a fitness landscape[*], then the internalised selection criteria referred to earlier, constitute the 'compass' by which adaptation is steered. In most cases, these are proxies for the success of the system that is doing the adapting, rather than absolute measures of its success. This means that the question of how well the proxies correlate with actual system success needs to be addressed. Improving the degree of correlation is the purpose of the fourth level of adaptation described above. In this context, the effectiveness of the adaptive mechanism relates to how well it is able to find and climb fitness peaks and stabilise on them, while the correlation indicates how well that translates into success for the system.

Thus when we come to apply these concepts we will have to discuss and distinguish between the proxies that are used to drive adaptation, the real success measures that take longer to eventuate, the correlation between them and how to improve it, and the effectiveness of the adaptive mechanisms themselves. The details of application of this framework will be further discussed in Sections 5 and 6.

We can now relate the conceptual framework for adaptation to the aspirational characteristics of Adaptive Campaigning listed towards the end of Section 2. The following apply to all four classes of adaptation (Operational Flexibility, Agility, Resilience, and Responsiveness).

Level 1 ***'action'*** is instantiated by ii and viii and supported by iii and iv;

Level 2 ***'learning'*** is instantiated by v (targetting the 'sense' capability), i and vii (targetting the 'decide' capability), and iii (targetting the 'act' capability);

[*] Here 'fitness' refers to what is implied by the selection criteria, i.e. whatever is being selected for, and is represented by the vertical dimension, while the horizontal dimensions of the landscape are the design parameters of the system that the adaptive mechanism can vary.

Level 3 ***'learning-to-learn'*** is instantiated by ix and x and supported by v;

Level 4 ***'defining success'*** is instantiated by v (when applied to the proxies); and

Level 5 ***'co-adaptation'*** is instantiated by iii, iv, vi, and viii when applied at the SoS scale.

In addition, xi supports all the levels, classes and scales of adaptation by addressing an essential human characteristic that must be cultivated in the force in order to successfully implement Adaptive Campaigning. We believe this is so important that it merits separate detailed discussion together with the issues raised in Section 3.4 above, and will be treated in the forthcoming paper referenced there.

4.3 Networked Causation

As discussed in Section 3, the types of operations which call for Adaptive Campaigning are characterised by complex Causal and Influence Networks, with degrees of complexity beyond what humans are inherently competent to deal with.

Understanding of networked causation is not highly developed except in a few specialised areas. We will briefly scan some of those areas and their techniques here to rationalise the choices we make and discuss in Section 6, about how to handle C&INs in Adaptive Campaigning:

- Studies of random Boolean networks are quite advanced and have yielded qualitative insights into biological C&INs such as Genetic Regulatory Networks. Some effective computation and visualisation tools have arisen in this field, however they are not easily extended to C&INs that exhibit significant innovative adaptation.
- The study of Artificial Neural Networks has informed understanding of real neural networks, and can be used to solve certain classes of complex problems (for example function approximation), but limited to situations where fitness is well-defined and adequate training data sets are available. They also suffer from the drawback of being relatively opaque to human understanding and of dubious applicability when the system is rapidly evolving and the domain of validity difficult to specify.
- System dynamics is a quite different approach, based on the study of flows through a C&IN, but it suffers from a number of deficiencies when the C&IN is known to contain adaptive elements or when spatial distributions are important and cannot be averaged over meaningfully. Validation has also proven to be problematic for system dynamics models.
- A related technique is the use of Influence Diagrams to graphically capture the known or postulated causal and influence relationships. It has the advantage of being simple and intuitive to draw, but lacks much analytical or interpretive power and like most models depends critically on the quality of the information used to populate it.
- Agent-Based Models permit both spatio-temporal and functional heterogeneity of the interacting agents. They do constitute C&INs in themselves and can be used to explore their own complex dynamics. However extrapolation of insights from ABMs to real systems is only suggestive, and should not be relied upon for understanding or prediction. The main drawback of ABMs (besides their computational cost) is that they do not intrinsically explain anything – they simply create their own complexity through executing their dynamics. The advantage of ABMs is that the complex dynamics they can produce does often exhibit many qualitative properties that seem similar to what is observed in real systems. The best way to think of them is as 'toy world' systems which can be used to research fundamental aspects of C&INs, but not actual properties of real C&INs.
- Bayesian belief networks model C&INs as graphs that connect variables according to their probabilistic dependencies. Bayesian networks can be used to make inferences based on available evidence that minimise the probability of a decision error. One drawback is that circular causality – including feedback – is not permitted within the Bayesian model, although there are workarounds for this limitation..
- The field of nonlinear dynamical systems has developed some very powerful mathematical techniques for analysing the behaviour of C&INs when the functional form of the interactions is known. Lyaponov exponents and Melnikov theory provide important insights into the structure of state space. Concepts such as attractors and bifurcations allow the dominant dynamics of the system to be understood. However, considerable work remains to be done before these techniques can be applied to high dimensional, soft and data poor real world problems.
- While the C&INs that we are interested in can certainly not be modelled mathematically, the language of nonlinear dynamics gives us a useful conceptual vocabulary with which to think about their behaviour. In particular, we are interested in ways to classify regions in a C&IN's phase space - the space of possible outcome trajectories – into various kinds of attractors, chaotic regimes and islands of stability. Even more

useful would be the ability to associate indicators with such regions, so as to permit recognition of what kind of behaviour the system is approaching. This is a frontier research issue.

- An interesting possibility which we intend exploring is the linkage between adaptation and networked causation. We contend that adaptive mechanisms create attractors in the phase space of the C&IN, and that competing attractors create regions of high uncertainty and therefore of high influencability which could be leveraged to steer the system's outcomes. Much work needs to be done on exploring the dynamics of interacting attractors, but this seems like a promising direction to take.
- There are other relevant techniques and concepts that can be drawn from network theory, from social network analysis, from the study of organisational dynamics, ecosystems and economics, and from collective properties of complex physical systems. These suggest that we might expect to see such phenomena as tipping points, phase transitions, power law distributions of event sizes and so on, but the extent to which any of these techniques can be confidently applied to the real C&INs that characterise complex operations is currently very limited.

While it is clearly important to be able to improve our ability to deal with complex networked causation, it is equally clear that we are at present at a very early and immature stage of capability to do so.

We will therefore adopt an eclectic approach, drawing on a few of the above concepts, to propose some specific innovations which firstly support and strengthen the existing inherent human ability to deal with C&INs on a human scale, and then extend those abilities in small careful steps.

5. Methodology

Identifying and framing problems from a particular perspective is, in a sense, the easy part. Even when there is good agreement on the objectives for a mission, what the current problems are, and how to frame the problem to identify the solution, there are many pitfalls to overcome before a useful change to the system is effectively applied. Collectively, the set of paths connecting theory and concepts to a domain of applicability is called a methodology. In this section, we will lay out our proposed methodology in four major steps linking the conceptual framework introduced above to its impact in real missions:

- Conceptual analysis and development of implications
- Operationalisation – the process of turning conceptual ideas into implementable options that could be used in real operations,
- Implementation – making changes in real systems, processes, structures and policies, and
- Application – actually using the changes to carry out Adaptive Campaigning.

These are general steps that should be identifiable in any actual methodology and over any timeframe.

For example, it could be applied to a relatively slow and deliberate process linked to formal capability development processes (including identification of the capability gap, capability option development, requirements development, acquisition, test and evaluation, introduction into service, and concurrent development of operational concepts, doctrine and procedures, training programs, and the required enabling services), or at the other end of the spectrum, it could be applied to much more rapid development and insertion of interventions into operational systems and processes.

It is this latter case that we will address in this paper since this is where we have some current experience. A later paper will address a fuller implementation approach linked to the more formal processes.

Clearly there are large potential risks in introducing unproven innovations into real operations, so the operationalisation stage – the development and testing of innovations intended to support Adaptive Campaigning in high complexity C&INs – ought to be supported by extensive experimentation in development and test environments of comparable complexity to the real situations, in order to properly exercise and develop their strengths and find and mitigate their weaknesses.

However, creating a synthetic development and test environment of sufficient complexity, and staffing it with military experimentation subjects and system designers and analysts is of dubious feasibility even in principle, and in any case, is simply not an affordable option for our forces at present, due to the high tempo of operations which is likely to continue for the foreseeable future.

We propose therefore a low-risk, incremental approach, based on adaptation and the principles of complex systems engineering[20], to build from existing strength and allow innovations to work provisionally alongside established ways of doing things, without relying on them, but using the parallel system enough to identify and fix flaws with it until confidence in it grows sufficiently that users start transferring to it in preference to the previous system. This approach also has the advantages of:

- using the real environment to stimulate the development of what is needed in the system,
- being able to get accurate feedback about the actual utility of things that are tried, and
- allowing the real users of the capability to contribute their ideas in its development.

The essence of an adaptive approach is to begin with provisional concepts both for the interventions and for the proxies whereby success is to be judged, then to evolve both over a number of iterative cycles supported by experimentation.

The experimentation needs to support both creative design/problem-solving, and also evaluation, and can take various forms from *gedanken* experiments, seminar-style gaming, SME appraisal, constructive or immersive simulation, laboratory or field experiments through to live operations and drawing on natural experiments[21], with obviously concomitantly different levels of cost, realism, generalisability and confidence.

As shown in Figure 1 below, we propose to take an adaptive approach to each of the three transitional steps (concepts to designs, designs to options, options to interventions). The fourth step has the interventions used in adaptive action within real operations.

Applying adaptation itself to the implementation of adaptation in this way enables us to improve with experience. This is an example of using adaptation to bootstrap onself up the adaptation ladder, as we indicated would be necessary in Section 3.1.

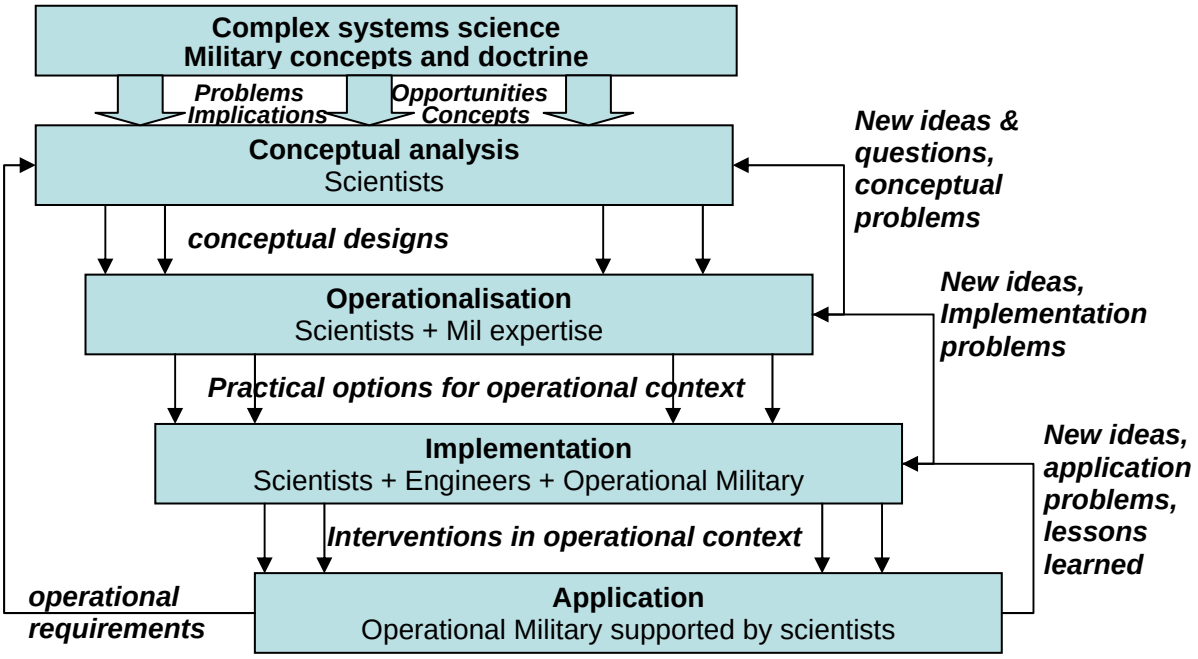

Figure 1: *Schematic of proposed parallel and adaptive methodology for developing and introducing interventions in support of Adaptive Campaigning. See text for details.*

In terms of our conceptual framework for adaptation, we are making use of several levels of adaptation in this methodology:

- the operational application layer is where Level 1 ***'action'*** occurs (and Level 5 ***'co-adaptation'*** to the extent that the interventions lead to changes in the roles, resources, and relationships between systems),
- the experimentation loop *within* each of the four layers and the larger feedback loops *linking* the layers, together constitute Level 2 ***'learning'***;
- refinement of the proxies constitutes Level 4 ***'defining success'*** wherever it occurs,
- an additional cycle of reflection about the effectiveness of the methodology and experimentation with modifications to improve it would constitute Level 3 ***'learning to learn'*** but is not shown in the figure.

We list here some important observations, issues and aspects of the adaptive methodology:

- It is vital to take a multidisciplinary approach, since no single disciplinary perspective is complete or intrinsically superior,

- Assumptions must be explicitly stated and critically examined,
- Conceptual and problem analyses are good ways to generate the variety necessary for adaptation. Investing too heavily in analytic justification for action can be counterproductive because it encumbers and slows adaptation, whereas low resolution conceptual models allow variety (new designs) to be produced with a relatively small investment of time and resources. This perspective stresses the role of modelling as supporting the generation of novel variation in potentially fertile regions of design space,
- The variety must then be tested in context, i.e. the merits of novel designs should be measured in operational environments,
- Selection pressure can then operate directly on physical designs to reinforce useful variation[22].

In summary, rather than seeking to establish an analytical guarantee for successful design, this use of multidisciplinary conceptual analysis focuses on improving the design over time through situated learning and evolution.

Before we address each stage in more detail, we stress that this is not intended to be a 'waterfall' model of development, but a genuinely parallel evolutionary approach, with all layers and transitions of Figure 1 simultaneously active. A particular concept that ends up as an implemented intervention might be seen as starting at the top and working its way down, but is likely to take a trajectory through the layers and transitions which includes many iterative loops, and to modify or be modified by many other concepts along the way.

Taken in totality, we envisage that some useful innovations may be quite quickly and successfully introduced, and that over time the body of knowledge and experience about how to implement Adaptive Campaigning grows through the collaborative efforts of all.

5.1 Conceptual Analysis: from concepts to designs

Applying this approach to the first transition from conceptual ideas to operational designs entails the following steps:

- Start point: we begin with some detailed understanding of
    - adaptation (*as in the conceptual framework outlined in Section 4.2*),
    - what an adaptive approach is (*start with best shot, use and get feedback about what works and where improvement is needed, propose improvements based on relevant knowledge, iterate…),*
    - the aspirations and challenges of Adaptive Campaigning in complex operations (*as laid out in Sections 2 and 3*), and
    - operational and practical constraints and realities (*from military SMEs*),
- Use above to propose:
    - a first cut of the upper layers *(functional characteristics and effectiveness measures (proxies))* of an analytical framework as described in Section 4.2,
    - a first cut of the lower layer (*adaptation parameters*) of the analytical framework, and to recognise and map out the adaptive processes and mechanisms already in place,
    - changes to existing adaptive mechanisms to improve them, and
    - designs for additional adaptive mechanisms required,
- Test and refine the designs by appropriately drawing from the range of experimentation options described above,
- Refine the analytical framework in the light of what is learned through the experimentation, and
- Close the larger adaptive loop by referring new ideas, questions and conceptual problems that arise during this stage back to the preceding studies that led to the start point, and iterate as necessary.

The output of this stage should be detailed conceptual designs.

5.2 Operationalisation: from designs to options

This stage requires more intensive collaboration with military expertise to:

- Refine the proposed designs to make them feasible in real systems and operations, and practical for soldiers to implement,
- Develop the Fundamental Inputs to Capability[23] implications,

- Refine the analytical framework, including turning it into observable measures that can be implemented into the collection plan,
- Test and further refine the emerging options by appropriate experimentation, and
- Close the larger adaptive loop by identifying new ideas and implementation problems for referral back to the previous stage.

The output of this stage should be practical options that could be implemented into an operational context (albeit with a controlled and cautious strategy as discussed above).

These options may take the form of changes to processes, to decision support systems, to training, to tactics, techniques and procedures, to how collection assets are used, to how interactions between force elements are created, managed and applied, to how tasks are defined and responsibilities and accountabilities tracked and monitored, and ultimately to how capability requirements are developed, prioritised and implemented.

This stage should also develop an adaptive implementation strategy, suggesting the order in which interventions should be introduced and the preconditions that should be established at each step before proceeding to the next one (such as necessary enabling capability, including competencies required, and ability to monitor the relevant measures).

5.3 Implementation; from options to interventions

This stage requires active collaboration with an operational unit which is willing to participate in the evolutionary development of Adaptive Campaigning, and to take responsibility for what interventions get tried in operations and under what conditions, for the identification and management of the attendant risks, and for providing constructive feedback to the preceding stage, in the form of new ideas that arise, problems with the application of the interventions, and lessons learned – both positive and negative.

6. SITREP: progress in developing interventions to support Adaptive Campaigning

We have been fortunate to work with both future concepts staff (Future Land Warfare) and force development staff (Force Development Group) in Army during the development phase of Adaptive Campaigning, and then with a deployed operational commander who understood the imperative of being more adaptive, and was keen to take the lead in applying the key concepts in his Task Force.

Thus, although it is still at an early stage, we have some first-hand experience of working through the initial stages of our proposed methodology, and of having a real operational environment into which to contextualise our conceptual designs.

What we present here is therefore incomplete work-in-progress, and slanted towards the requirements of a particular operational situation. However it serves the purpose of illustrating the types of interventions that will be needed to proceed with implementing Adaptive Campaigning. We will discuss these in the categories of Conceptual Design, Support Systems, Analytical Framework, C2 Concepts and Processes and Human Sciences Aspects.

6.1 Conceptual Design

Taking the multiscale view first in the conceptual analysis phase, we identified four scales of the operation to which we needed to pay attention. The overall Task Force command level was a natural place to start, but we also realised that the lowest scale of action (individuals and small units) was the key one for achieving the mission objectives since it was the scale that matched that of the target population elements – whether friendly, neutral or hostile. We added one intermediate scale (Company command) between the TFHQ and the small units, and also one above the TF, not to address explicitly what was happening there, but to permit inclusion of the interactions between the TFHQ and its higher command.

An initial and partial schematic design is illustrated in Figure 2. Three of the scales are shown, the Task Force HQ which seeks to exercise Operational Agility by monitoring the relevant proxies and indicators and issuing guidance to the Company command about changes to the priority and balance of effort across the five Lines of Operation in space and time, and about priorities for the collection plans; the Company command which interprets the TFHQ guidance and issues guidance to the subunit scale to change the current courses of action in support of each line of operation and of the collection plan as needed; and the subunit and individual scale which is executing them in the operational environment. The fourth scale, the higher command above the TFHQ, is not shown in the diagram.

We acknowledge that other agencies (Non-Government Organisations and Other Government Agencies) may also be operating in the same environment, and that another adaptive loop needs to operate through the Civilian-

Military Cooperation (CIMIC) to deconflict and coordinate their actions as far as possible, but those details are yet to be developed.

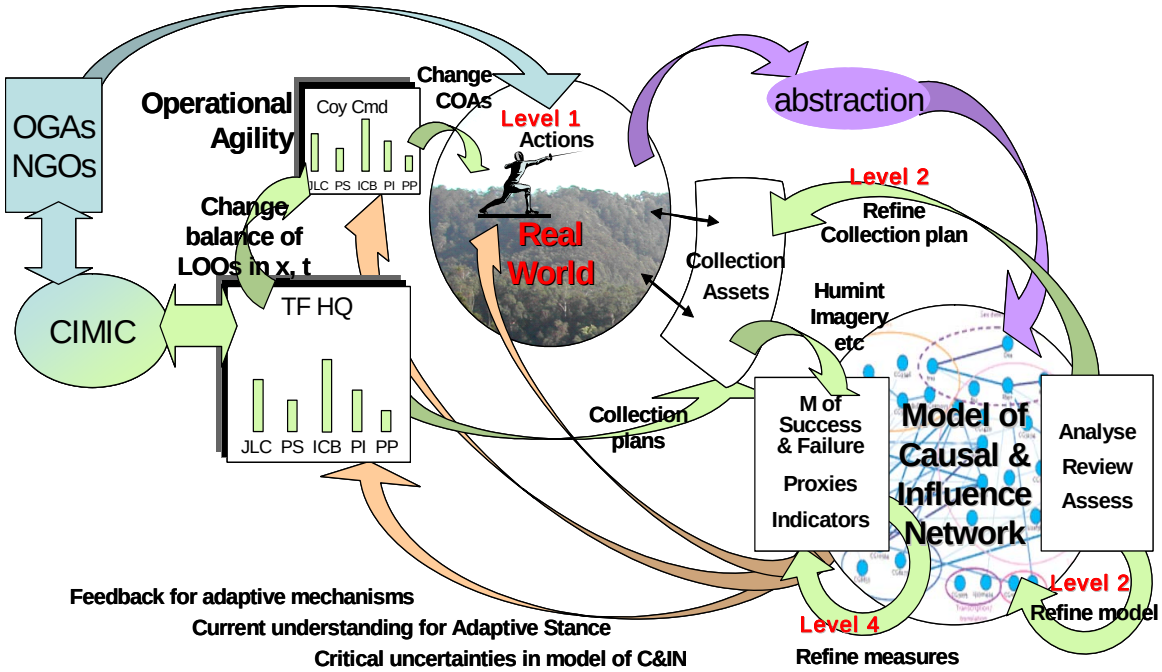

Figure 2: *Partial schematic design for Adaptive Campaigning. See text for details.*

Secondly, focusing on the adaptation characteristics that are needed, we decided that of the four Operational Adaptivities laid out in ***Adaptive Campaigning,*** due to the nature of the mission, the highest priority to address was Operational Agility. The process of arriving at this conclusion is worth recapping.

When the Operational Agility concept was being formulated during the development of ***Adaptive Campaigning***, the Army's warfighting concept at that time recognised just two modes of operation: combat (then called Joint Land Manoeuvre) and 'everything else' (then called Control Operations). On reviewing our conceptual framework for adaptation, Army identified that their most significant problems demanded Agility, which we had defined as *"the ability to recognise when to shift from one strategy to another and to do so easily – producing a rapid change of tack to more effective behaviours when significant external and/or internal changes arise requiring significant and different responses"*. The initial formulation of these problems was couched as knowing when, where and how to switch between the two modes, but as the concepts were workshopped it became apparent that it was not just a matter of binary switching but rather of juggling a number of competing and interacting priorities with limited resources, continuously and simultaneously in each different part of the operational space. When the warfighting concept was recast in terms of five Lines Of Operation instead of two modes, analysis of the issues became even clearer, and led to the recognition that what was required was "*the ability to dynamically manage the balance and weight of effort across all lines of operation in space and time*" – which is what ***Adaptive Campaigning*** came to define as Operational Agility.

By this definition, Operational Agility requires not only awareness of the current status of performance against the measures of success and failure in each Line of Operation in each Area Of Operation (AOR), but also the ability to project the near-term future trajectory of those measures through a deep understanding of the dynamical interplay of factors through which the actions of the force and of other friendly, neutral and hostile elements influence them. This would permit identification of indicators that could also be monitored to give early warning of activity in those influencing factors, that might lead to a change of status in a performance measure, so that adaptive action can be taken promptly to mitigate negative influences or to capitalise on positive ones. This requires an adequate understanding of the complex C&IN operating in the theatre. Such an understanding would also support every other aspect of a complex operation, while a poor level of understanding would significantly reduce the probability of success.

This naturally leads us to networked causation, the third platform of our conceptual basis outlined in Section 4, and the conclusion that developing better ways of dealing with C&INs is therefore a critical issue for Adaptive Campaigning. It has in fact become one major focus of this effort and is discussed in the next section.

Obviously what we have described here is only a partial conceptual analysis and we will continue addressing the other aspects of Adaptive Campaigning in our ongoing work.

6.2 Support Systems (C&IN modelling)

In the spirit of the adaptive parallel methodology described above, we begin with acknowledging that humans have always dealt with C&INs by creating their own internal mental models (incomplete and flawed though they may be), and use these to interpret what they observe and to decide how to interact.

Individuals who are more inclined to be objective, to question their own and others' assumptions and to entertain alternative explanations for what they observe, are likely to evolve their mental models and gain insight into the C&IN as they continue to engage with it. Others may be more resistant to changing their mental models and prone to rationalising what they see so as to justify their preconceptions. Some people will have a richer set of mental constructs and the ability to explore them in different ways, while others will have a more limited palette to play with.

Nevertheless, because we are dealing with a complex system, there is no single 'truth' about it and the multiple perspectives inherent in the spectrum of mental models that people develop are a potentially invaluable source of diverse insights – if only they could be effectively shared.

Since such mental models are difficult to communicate, and because of the value of diversity of views in helping to flesh out the dynamics of complex systems, our approach will be to build on what we know people already do, and to first find simple ways to support more effective sharing between them, and to facilitate their learning from each other, and identifying areas of consensus and points of difference.

The underlying design hypothesis is that this will support their individual abilities to evolve their mental models and augment their capacity to act adaptively. Constructing and regularly discussing their mental models, for example as influence diagrams on a whiteboard, is probably a good start, so long as the danger of 'groupthink' is successfully avoided. While finding common ground is important, the focus needs to be on identifying aspects that are contentious and have impact on their critical decisions, and on using these to design probing actions, and to better shape their collection plan in order to clarify those key uncertainties.

Individuals need to be encouraged to make their own assessments and where appropriate, to retain their private views to preserve valuable diversity which is important for robustness to deception and surprise, but also to constantly challenge their own thinking and to be prepared to look for both confirming and contradictary evidence. This is an essential component of what we are calling the Adaptive Stance, which is discussed in Section 6.5 below and will be further developed in the subsequent paper referenced there.

As illustrated in Figure 2, we postulate that the next most valuable advance that can be made in dealing with the complexity of their operational environment is to develop more explicit processes and support tools for ongoing evolutionary and collaborative development of models of the C&INs, and to have these integrated into the operational and C2 concepts.

This is not an attempt to create a detailed SimCity-like simulation of the real world that purports to be comprehensive and predictive, which would be both infeasible and dangerously misleading. So rather than trying to include everything in the model, we focus on developing an abstraction of the C&IN which is as simple as possible while having enough of the essential features of the real environment to be useful.

There are quite stringent requirements on these tools. Because they are intended to address dealing with actual complex C&INs in an operational context, we must ground the approach in reality – it must be data-driven and continuously tested. Because it must be implementable by soldiers in real operations it must be rapid, intuitive, build on their existing skills, and have low training overheads. Because we know that adaptive processes are important in producing the complex dynamics of real C&INs we base our approach on identifying and mapping those processes in the operational context, and providing simple tools for capturing, visualising and exploring them. Based on these considerations, we have developed a very detailed set of criteria and use cases for the tools and a comprehensive survey of COTS, GOTS and bespoke tools has been completed[24], resulting in the selection of two tools for experimentation and further development.

We anticipate five ways in which these tools would be used:

1. To inform the design of the analytical framework of measures of success and failure, proxies for them, and indicators that relate to the various factors identified as contributing to the outcomes in the proxies and higher measures. This framework is then used to develop the collection plan.
2. To learn about the situation, i.e. evolve the model of the C&IN, through:
    - making the current understandings explicit,
    - supporting the identification of critical uncertainties, assumptions and hypotheses, and then

- continuously seeking to test these and use the new information generated to modify the model so that it better fits observations, thus growing the understanding of the situation.

This is Level 2: '***learning'*** applied to 'decide' capability

3. To similarly evolve the analytical framework by identifying new proxies and indicators that need to be monitored as new aspects of the C&IN are postulated or start to be appreciated, and by eliminating those that are discovered to be superfluous – this is Level 2: '***learning'*** applied to 'sense' capability.

   In particular, as experience accumulates it becomes more possible to evaluate the appropriateness of the proxies that are used for fast adaptation, and evolve them to better correlate with the slower success and failure measures. This is Level 4: '***defining success'***.

4. To interpret the information produced by the collection assets and generate relevant realtime feedback to the adaptive mechanisms or processes operating at each scale. This supports both Level 1: '***action'*** and Level 5: ***'co-adaptation'.***

5. To assist in generation and assessment of action options by making apparent all the intervention options which have one or more direct or indirect influence paths to the target proxy measure, and all the other proxies and success and failure measures that are also influenced by each of those interventions, together with some insight into the mechanisms of influence and other factors that may modify (amplify or suppress) those influences. This supports both Level 1: '***action'*** and Level 5: ***'co-adaptation'.***

A parallel body of effort has been directed at developing the first iteration of the content of the C&IN, drawing on both classified and unclassified sources, and will not be discussed here. As one would expect there is a vast amount of material of possible interest, and some of the issues that arise include clarifying the levels of detail to include, how to handle important interactions across different levels of detail, and how to organise the information.

6.3 Analytical Framework

The approach described above suggests a particular structure for the hierarchy of measures to be observed, and a very close relationship with the C&IN model. In essence there are four categories of measures required:

- High level measures of success or failure which are enduring, externally set, values-based, and generally slow to materialise eg rule of law, sustainable economy, peaceful free elections, marginalisation of hostile elements etc for success versus starvation, corruption, relative strength of illegal economies, and compliant civilian support for hostile forces etc for failure.
- Proxies for success or failure that can be monitored over faster timeframes and are derived from an understanding of the underlying C&IN,
- Indicators that can be monitored to inform of degree of activation of particular C&IN pathways influencing the proxies, and
- Independent[*] factors which includes both:
  - Contingent factors that enter into the workings of those pathways and that cannot be controlled or predicted and therefore need to be monitored in real time, eg the weather, the messages being conveyed in the media, exchange rates etc.,
  - Choosable actions available to the force – these represent the levers of influence that the force can exercise in its interaction with the C&IN and do not need to be monitored in the same sense as the other categories listed, but can be treated as independent inputs to the C&IN for the purpose of exploring 'what ifs'.

This structure allows the evolution of the C&IN model to be very closely coupled with the exercise of ***Adaptive Campaigning***, with the evolution of the collection plan.

At this stage, we have a first iteration of the analytical framework. The second iteration will draw on both the developing C&IN model and on feedback from the operational collection planners.

6.4 C2 Concepts and Processes

[*] What we mean is independent from the perspective of the chosen level of detail and abstraction of the C&IN model. This is of course an approximation, in reality many of these factors are the results of many other processes, but we choose to treat them as if they were independent.

This section includes the actual adaptive processes that are modified or introduced, other process changes that might be indirectly required elsewhere to support the adaptive processes, and changes to how we conceive of C2.

The introduction of ***Adaptive Campaigning*** implies a significant shift of emphasis away from detailed planning of what to do, towards planning to create the conditions for being able to exercise adaptivity once the operation starts. This in turn requires that the C2 concept and approach supports the ability to make changes not only to the actions being taken, but to the way that C2 is itself being exercised.

For example, one aspect of the C2 approach is the degree of autonomy granted to subordinates. This in turn shapes the extent to which the subordinate is empowered to exercise adaptivity in a timely way. If it is necessary to seek authorisation for an effective response to a new threat or opportunity, or to reallocate resources to deal with the unforeseen loss of some capability elements, or to switch effort away from one objective and onto another one that has suddenly become more critical, then the adaptivity that can be generated is reduced. On the other hand a high degree of autonomy granted to every soldier risks inappropriate actions being taken locally that have harmful consequences elsewhere. As always with complex systems, a balancing act is called for, and that balancing act needs to be performed within an adaptive C2 environment that effectively supports decisions about decision rights by providing the information and tools needed for the benefit and risk analyses to determine changes to the current distribution of decision rights, and to create any additional mechanisms required for monitoring and managing the changes and mitigating their risks.

Another aspect that flows from taking an adaptive approach is the need to be able to identify cross-impacts of the proposed changes in one part of the operation on other parts (across Lines of Operation, functions, space and time), and to adjust across all to reduce negative impacts to acceptable levels, and to identify and enable synergies between them. This is in itself a complex task, and will therefore require an adaptive approach, i.e. Levels 2, 3 and 4 in addition to the Level 1 process of attempting to make these adaptive adjustments, we need to drawing on the full power of adaptation to improve how we do it and get better at it.

At a more detailed level, there is the detail of how these higher level adaptive mechanisms can be implemented through changes to the TTP (Tactics, Techniques and Procedures). For example simple modifications of existing After Action Review processes can explicitly stimulate discussion and review of the effectiveness and utility of the proxies in current use and of Level 2 processes such as in-theatre training, technology insertions, and the AAR process itself, thus stimulating Level 3 adaptation to improve all of these. These are in the process of being fleshed out and will be iterated with feedback from military SMEs.

On the other hand, taking a whole campaign and whole force perspective we can also examine the overall operational concepts at these scales, and discuss how they need to be shaped to enable ***Adaptive Campaigning***. We have identified three key phases:

1. Build-Up: the objectives in this phase are to establish:
    - mission objectives, intents, constraints,
    - common ground and ways of operating between the cooperating force elements and agencies,
    - shared capability through addressing how elements may be teamed, identifying and solving interoperability problems, having a dialogue about operational concepts and making modifications to allow them to mesh better, and in particular, establishing a shared planning process,
    - adaptive mechanisms (at all five levels) within and across cooperating elements to continue the above processes of growing shared intents and understandings and the collective capability envelope, to ensure that what is achieved in the build-up phase is not the limit but the start point of what will be achieved during the operation, and
    - mechanisms for sharing information, conflict resolution, trading of capabilities, concepts, information, objectives, and information fusion.

    The outcomes of the effort to meet these objectives lay the groundwork for entering into the operation with the abilities to perform certain kinds of tasks, including some that require cooperative efforts between elements, and importantly, also with the ability to continue to evolve the separate and shared objectives, and the separate and shared capabilities, including the capabilities to behave in various adaptive ways.
2. Operations:

    We have already discussed this phase extensively, but we can summarise here by saying that the effectiveness of the force in being able to meet its operational objectives is a result of:

    - its effectiveness at performing its tasks, which calls for
        - a solid base of capabilities, and

- a degree of Operational Flexibility,

- its ability to choose the right tasks to perform through a combination of Operational Agility and Operational Responsiveness, and
- its ability to sustain effective operations in the face of losses and damage through a degree of Operational Resilience.

During execution of the operation the force will be employing all these adaptive characteristics across all its Lines Of Operation in exercising adaptive action at Level 1 (generating context-appropriate actions and using realtime feedback to tune them) and Level 5 (adapting the ways in which the available force elements are used in the overall system-of-systems).

This is normal practice, but adding Levels 2-4 to all of the above will enable the force to augment the quality of its adaptation by improving how the options are generated, how they are evaluated and the quality of the proxies and the sensed information that is produced to feed back to the adaptive processes.

3. Wind-down:

In this phase it is important to review what has been learned, to capture the insights that only emerge with a wider perspective over some time, and to address what more can be done to create the conditions for success of any future operations. Linkages to future capability development processes and to the wider propagation of important and more broadly relevant lessons also should be considered in this stage.

The first and third elements of this broader campaign view have not yet been addressed with our military colleagues, since the current emphasis is on the operations phase.

6.5 Human Sciences Aspects

Factors arising from human sciences have such significant impacts on the overall approach to Adaptive Campaigning that they have spawned the third major thrust of our work program, and will be more fully addressed in a separate paper[25]. Here we just present a brief overview for completeness.

The issues to be considered stem from both the inherent cognitive limitations of the human mind in dealing with C&INs of sufficient complexity (discussed in Section 3.4), and from the need for human-centred engineering of interfaces and support tools. They also need to be considered at both the level of an individual making decisions alone, and at the level of teams making collaborative decisions.

Our initial focus has been on understanding the cognitive limitations of individuals making decisions in challenging C&INs. We have completed a literature review of relevant research and drawn preliminary conclusions about how to proceed using the same methodology pictured in Figure 1.

We propose that what is needed to mitigate cognitive limitations is the inculcation of what we term the Adaptive Stance, which we will argue is a necessary complement of Mission Command, in the sense that neither can work effectively without the other.

The Adaptive Stance is a stance to be adopted, and encouraged in individuals, but also needs to be adopted throughout the force – especially at upper echelons first and then downwards – in order to enable subordinates to adopt it too. It encapsulates the essential characteristics of resistance to urge for closure and certainty, not being seduced by one's own ideas, appreciating that it is much more important to be be prepared to be wrong in order to learn, than to always be right (and therefore either or both risk-averse or in denial) and conversely, being prepared to 'decriminalise' others being wrong.

An Adaptive Stance supports agility at the level of individuals by fostering:

- accurate persistent awareness of assumptions and hypotheses in the mental models and constructs they use for interpreting observations, and for generating and assessing action options,
- the ability to simultaneously maintain alternate versions of above,
- continuous seeking of ways to test assumptions and being prepared to revise them as a result,
- whenever a prediction is made, being willing to observe the actual outcome when it transpires and to objectively assess what can be learned in order to improve future predictions and to gain a more accurate sense of the quality of one's predictive ability,
- realising that every decision or action taken contains an implicit prediction, making those predictions explicit and ensuring that means are put in place to observe what actually happens, to compare that to the predictions, and to use that comparison to learn and develop better mental models of the situation.

An Adaptive Stance also supports agility at the level of the force by extending the notion of 'every soldier is a sensor' to have every soldier be:

- aware of the current shared model of the C&IN operating in the theatre,
- aware of the critical uncertainties, conjectures and hypotheses in, or underlying the model ('critical' meaning that it impacts on significant decisions to be made), and
- therefore alert to observing evidence and indications in the course of their daily operations, that would reinforce or contradict any aspect of that shared understanding or model, and
- assiduous about reporting such observations through appropriate means so that the shared understanding and model can rapidly evolve to better reflect the real complex dynamics of the situation, by leveraging from the individual learnings and observations of every soldier.

We have also developed an experimentation approach to support our methodology in developing interventions aimed at mitigating cognitive limitations in complex decisionmaking. The interventions will include better selection processes for recruitment, changes to command training, pre-deployment and in-theatre training options, changes to decision processes, and some specific changes to decision support systems. These will be described in the subsequent paper referenced above.

The current status of this part of the work program in support of our operational commander is to continue a dialogue about the extent to which he is able to implement these ideas in theatre, and to process his observations and feedback.

6.6 Near-term Priorities and Directions

It is evident that there is still much to do in every aspect of Adaptive Campaigning discussed so far, and while we will not repeat the details of the preceding subsections here, there are some glaring and urgent areas such the extension of the human sciences work to include the social/team domain, and better linkage with formal capability development processes, especially training and education, and defining future capability ‘needs’.

Our near-term priorities are driven by two major factors: operational requirements and capability development pressures. These operate on very diferent timescales in terms of producing outcomes, and on very different scales and types of risks and benefits. However from a whole force perspective, they are inseparably intertwined since important lessons from operations need to drive future development, just as development must never lose sight of the operational domain it ultimately serves. Moreover, many windows of opportunity to influence capability development appear in the near term and only remain open for brief periods – it is essential to take advantage of these when they occur.

We therefore will continue to put significant effort to both identifying the rapid insertion opportunities that can aid our current forces to capitalise on the conceptual advances made in Adaptive Campaigning, and to working in support of Army’s Force Development Group and Future Land Warfare staff to develop an actionable Implementation Plan and methodology for Adaptive Campaigning, that addresses all of the Fundamental Inputs to Capability[26].

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