Cover Page

14^{TH} ICCRTS

C2 and Agility

Title: Engendering Flexibility in Defence Forces

Paper #: 134

Track: C2 Concepts, Theory and Policy

Authors:

Mark Unewisse
Defence Science and Technology Organisation
Australian Department of Defence

Building 81L
PO BOX 1500, Edinburgh SA 5111, AUSTRALIA
Phone: +61 8 8259 4237
FAX: +61 8 8259 5055
Mark.Unewisse@dsto.defence.gov.au

Anne-Marie Grisogono
Defence Science and Technology Organisation
Australian Department of Defence

Building 81L
PO BOX 1500, Edinburgh SA 5111, AUSTRALIA
Phone: +61 8 8259 6532
FAX: +61 8 8259 5055
Anne-Marie.Grisogono@dsto.defence.gov.au

Engendering Flexibility in Defence Forces

Mark Unewisse and Anne-Marie Grisogono
Defence Science and Technology Organisation, AUSTRALIA

Abstract

Flexibility is one of the four classes of adaptation in our Conceptual Framework for Adaptation, and is manifested as the ability to make use of available capability elements, possibly in novel ways, to perform both anticipated tasks and new tasks in a timely way, thus effectively widening the range of what can be dealt with beyond the range for which the capabilities were developed. We discuss factors that contribute to flexibility, and how they are currently constrained, but could be enabled through both the Force Development process and the Force Generation process (including all the Fundamental Inputs to Capability, or DOTMLPF, in both). In particular we will consider the factors influencing meta-decisions, about when and how capability decisions should be made, so as to maximise the option space where it is needed, while also limiting the decision burden on operational staff.

1 Introduction

Adaptivity describes the ability of living systems to change in ways that help them meet the challenges of their complex world. It takes many forms (natural examples include evolution and learning), operates simultaneously over many timescales, and may be implemented via many different mechanisms. Nevertheless every instance of adaptivity has the same algorithmic core – generate variety, use it and get feedback, selectively retain the variations that are more successful, repeat. Under certain conditions, systems that continuously execute this cycle tend to improve their success in their environment, and maintain their success when the environment changes. In the case of military forces, their capacity to adapt underpins their effectiveness in a dynamic and complex battlespace.

While adaptivity[1] is a general concept, it is necessary to be more specific if we wish to explore the ways in which it can be realised. We have identified 4 classes of and 5 levels of adaptivity in our Conceptual Framework for Adaptation[2] (see following section for more details), each of which can be instantiated at various scales. One of the four classes is Flexibility, by which we mean the capacity of a force to modify itself so as to be able to effectively rise to continuously evolving challenges, both within the range of what is expected, and not.

Given the complex and dynamic nature of today's, and the expected future, operational environment, flexibility is therefore an essential aspect of force capability. However, the actual level of flexibility that a given force has, results from various design decisions made during the force development, generation and preparation processes, in turn determining the boundaries on what can be adapted to within relevant timeframes.

Moreover, the notion of flexibility is not limited to operational forces. It can equally be applied to the organisations responsible for generating and implementing force capacity, and given the propensity for the future to surprise us, it seems clear that an appropriate degree of flexibility in these processes is also necessary in order to achieve and maintain a high level of effectiveness in continuous creation of operational forces with the desired degrees of capability and flexibility.

In brief, operational flexibility is achievable firstly through a combination of flexible capability elements and flexible processes for using those elements to generate operational and system designs that are well-adapted for the emerging requirements, and secondly, those flexible capability elements and processes are themselves the product of force generation systems and processes that are not only effective in their current form, but also adaptive in all four classes (responsive, resilient, agile and flexible) so as to maintain their effectiveness in producing forces that are fit for purpose, in the face of both external and internal stresses that change the risk, cost and benefit landscape.

This paper will explore the option space for flexibility in our Defence forces and discuss how it may be implemented in order to increase the overall effectiveness of these forces.

2 The Conceptual Basis of Flexibility

In order to focus on flexibility in the present paper we first need to distinguish it from a number of other forms of adaptivity. While each form of adaptivity offers some potential benefits (and costs and risks) under some conditions, the particular details of how to implement each form will be quite different. Moreover decisions that influence flexibility will directly impact on the extent of the other classes of adaptivity that can be realised. Finally, practical options for implementation of flexibility necessarily draw on many of the other concepts and definitions set out in the conceptual framework for adaptation. So we cannot properly address flexibility without at least a cursory appreciation of the wider scope of the Conceptual Framework for Adaptation.

2.1 Conceptual Framework for Adaptation

The essence of adaptation is deceptively simple– a continuously repeated cycle of *variation → interaction → feedback → selection*, or in other words: '*generate options, try them, see which ones work best and retain them*'. But there is a wealth of evidence to support the assertion that this simple algorithmic core is surprisingly rich, complex and powerful in its many manifestations.

The Conceptual Framework for Adaptation[2] offers a number of classifications of adaptive processes and insights into their operation, stemming from a set of inter-related perspectives on adaptation. It is based on the most basic concept of a (complex) adaptive system as having the capacity to sense and act conditionally on its environment as a result of what is sensed, and a generic model of the underlying algorithm of adaptation, which comprises the four essential components of:

1. an internalised concept of 'fitness' or relative success and failure,
2. a source of variation in some parts of the system,
3. a means of testing the variations produced for their impact on fitness, and
4. a selection process which preferentially retains variations which enhance success and discards those which lead to failure.

Continuous cycling through 2,3 and 4 results in the encoding of information into the system, in a way that tends to increase the relative success of the system. Examining the various ways in which such a generic model can be instantiated has led us to a number of classifications for specific examples of adaptive mechanisms:

- whether it operates on individual systems (as in individual learning) or on populations (as in evolution of species),
- what parts of the system are subject to adaptation – leading to five nested levels of adaptivity, which we describe as:

  Level 1. *Action-in-the-world* – tuning existing sensing, processing and action capabilities;

  Level 2. *Learning* – expanding or modifying existing capabilities to improve success at Level 1;

  Level 3. *Learning-to-learn* – improving how Level 2 is done, to increase effectiveness of Level 2;

  Level 4. *Defining-Success* – improving the alignment of the internalised success and failure criteria in the selection processes for Levels 1-3 with 'real' success, and

  Level 5. *Co-Adaptation* – which addresses the interaction between the adaptive processes of interacting systems, with two parallel and interwoven threads:

    - for those systems within our own control – tuning the allocation of roles and resources to them in a System-of-Systems (SoS) context (thus altering the context of each component system and the design of he oerall SoS), and
    - for systems we interact with but do not control, choosing our options with a better appreciation of their consequences through anticipating their likely adaptive responses to our actions.

- what kind of opportunity, change or stress the adaptive mechanism is targetting – leading to four classes of adaptivity which we describe as:

  Responsiveness – ability to recognise and deal effectively with immediate threats and opportunities as they arise, but not leading to a change of Course of Action (CoA),

  Agility – ability to recognise when changes in the context or in system capability require a change of strategy or CoA, or when a better strategy or CoA becomes possible, and to implement it easily,

  Resilience – ability to recognise and deal effectively with harmful changes to the system itself i.e. to recover from or adjust to misfortune/damage, and degrade gracefully under attack or as a result of partial failure, and

Flexibility – ability to recognise and deal effectively with new challenges as they arise, i.e. to be reconfigured in different ways to do different things, under different sets of conditions,

and,

- the scale[i] at which it operates.

These classifications offer a rich matrix of templates for possible adaptive mechanisms which we can use to either recognise, analyse and tune existing mechanisms, or to identify and exploit opportunities for engendering new ones.

To complement these classifications, and to assist in creating effective interventions to improve the success of existing adaptive mechanisms, or in the even more difficult task of engendering new ones, the framework also addresses how to assess and tune:

- the integrity and 'health' of adaptive mechanisms (i.e. what Level 3 should target),
- their temporal dynamics in relation to relevant processes in the environment (in the context of a multi-scale analysis), and
- a range of other factors that may influence their degree of success or failure.

The broad application of this framework to force design has been discussed in earlier papers[2].

3 Defence Capability Creation Model

A generalised schematic of capability development and implementation processes is illustrated in figure 1. Originally developed to discuss the problem of designing and implementing an integrated networked force capability[3, 4], this model is also useful in examining the nature of flexible force capabilities and how to achieve them. Each of the 5 principal elements of figure 1 (discussed in more detail below), consists of a number of components together with their relationships, forming an actual or potential system-of-systems, embedded in a context through which they view and interact with the world. Furthermore, there are also complex relationships between them, including many feedback / learning loops between the 5 elements of the model, operating over various timescales.

The 5 primary elements are:

1. Force Development: This stage incorporates all aspects of capability development and acquisition, including not just the physical systems but also the other well-known elements of capability, (DOTMLPF in the US or Fundamental Inputs to Capability (FIC) in Australia), but the core components of force development with the greatest inertia and impact on future flexibility are the individual projects that deliver the building blocks of the future force. Such projects frequently deliver systems that are locally optimised within predefined scenarios, and their eventual integration into larger systems is often limited to mandating a number of technical interoperability standards. We will argue that this is insufficient for ensuring the needed feedback and learning at the force level. Furthermore, while capability development is predicated on conjectures about future warfighting environments and requirements, it is frequently biased by a historical tendency to linear extensions of major existing systems. Force development is also strongly constrained by financial considerations, resulting overall in a tendency towards risk aversion, particularly outside individual project stovepipes. Feedback and learning from operations tends to be weak, often with very long response times to operational lessons.
2. Force Generation[ii]: This stage transforms delivered and legacy warfighting systems and platforms into viable warfighting capabilities with suitable trained personnel, organisation, doctrine and TTPs, collective training, and so on, thus generating the component capabilities that can be delivered to the operational world. Decisions made here also determine the potential for force-level C2 and integration to generate effective task organised forces in the next stage. The component systems of Force Generation are the standard military organisational structures for the raising, maintaining and training of forces. Significant drivers here

[i] Scale can refer to timescales (over which an adaptive loop cycles, or over which consequences of the adaptation develop, or over which indicators of a new challenge emerge, … etc), or to scales of effects (local and few-dimensional, through to global and hyper-dimensional), organisational scales (individuals making adaptive decisions, adaptive team decisions, teams-of-teams etc up to organisational, enterprise and so on). There is a loose correlation between these. A useful way to think about scales is to focus on the natural scales in the operational context, and the force structures and processes that would be best placed to deal adaptively with them.

[ii] The Australian Army defines Force Generation as the process of organising, training and equipping forces for adaptive campaigning. It has five major components: a. Training, education and development of individual members of the Force and the generation of a core collective training capability at prescribed levels and standards; b. Force structures (numbers of people and composition of the force); c. Equipment (technology, weapon systems and numbers of equipments); d. Readiness (the ability to provide the capabilities required by the Commander to execute an assigned mission); and e. Sustainability (the ability to maintain the assigned level of operational activity for a specified duration).

include doctrine, the incorporation of lessons learned from operations, operational tempo and the need to generate forces that are able to cope with a broad spectrum of operations.

3. Force Preparation[iii]: The warfighting capabilities provided by the force generation stage then need to be organised into a force-level capability to meet the requirements of specific operations. Force preparation relies on the foundational warfighting skills developed in collective training within the force generation stage and forges task organised force-level capabilities that can undertake the challenges of the operational context. Thus the nature, scope and scale of the resulting forces will vary across operations. In the Australian Army, force preparation is the responsibility of 1 Div and implemented through its Land Combat Readiness Centre. Additional in-theatre readiness training in the lead up to operations also contributes. The major drivers here are again tempo, lessons from the field and the nature of anticipated future operations, as well as strategic, political and economic factors.

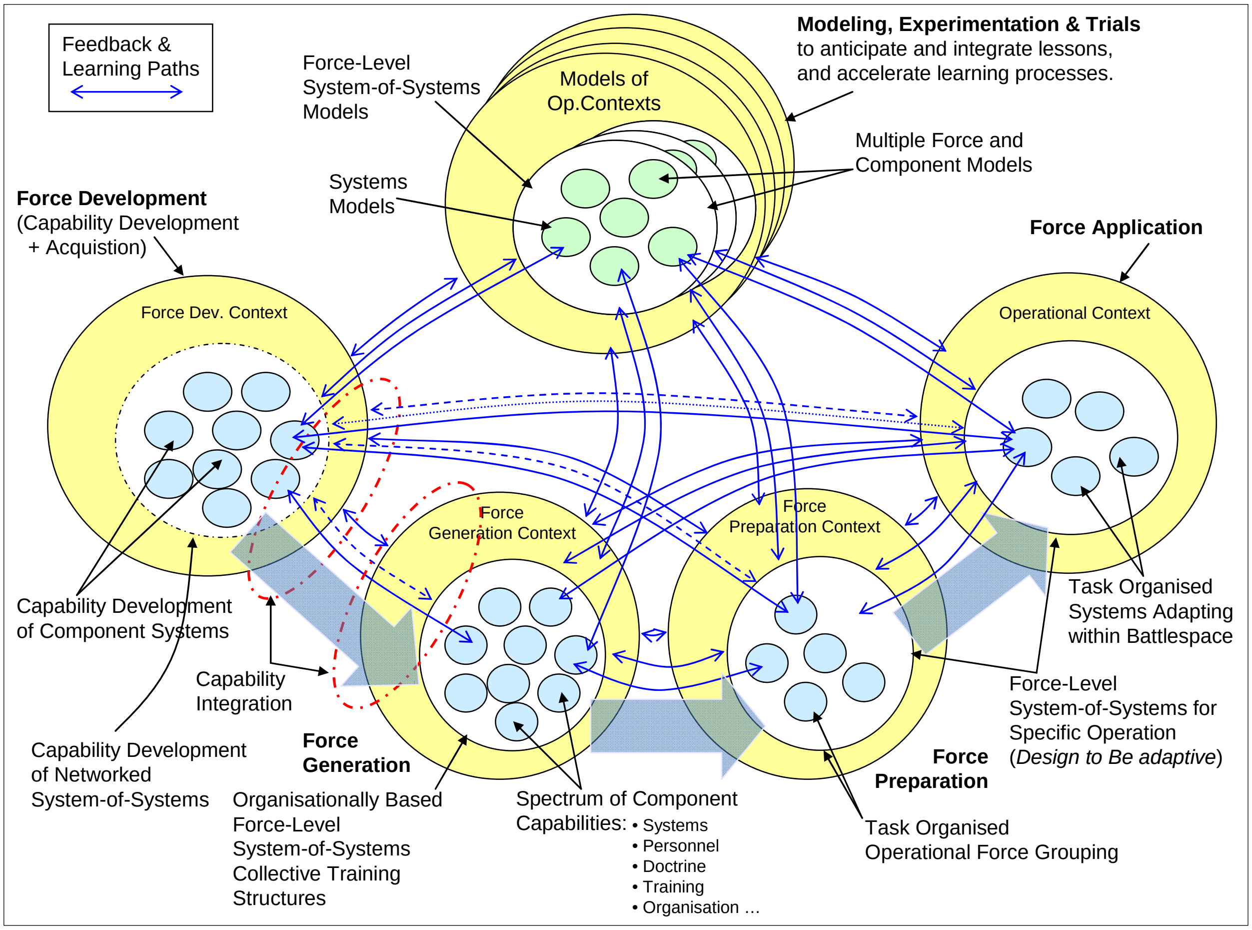

Figure 1: *Simplified schematic of the capability development and implementation process showing the stages from systems acquisition by projects to actual application of force-level operational capability (with the large solid arrows indicating the flow of capability creation). It also highlights the role of modelling and simulation (depicted as a single domain for simplicity – but in fact consisting of various distributed elements and facilities providing experimentation and evidence where it is needed) to accelerate the learning processes necessary for a more adaptive capability development process.*

4. Force Application or Operations: The task organised forces then undertake the operation that they have been designed for. However, the complex and dynamic nature of the battlespace (let alone any compromises that have had to be made in forming the force) will require the force to continuously adapt to deal with the dynamic challenges it may face. This is where the decisions made in the previous three stages

[iii] The Australian Army defines Force Preparation as the planning and execution of collective and joint training that takes a force element from the assignment state to a level of preparation for deployment or contingencies specified by CA and CJOPs. It builds on the core foundation warfighting skills to produce force elements for specific operational and contingency circumstances. It has five components: a. Force Concentration. b. Mission specific training (individual and collective). c. Equipment (specific to mission). d. Mission Rehearsal/Contingency Rehearsal.e. Assessment and Certification.

bear fruit in enabling and supporting, or opposing and inhibiting, the force's abilities to adapt at all the necessary scales.

Through the feedback and learning paths (blue arrows in Figure 1) across the development process, and connecting the contexts, SoS levels and component capabilities of each stage, lessons learned in the operational context should appropriately influence the force generation context and more indirectly the capability development context. However there are many opportunities for this process to go awry – such as significant delays, obstacles to the dissemination of lessons because of over-emphasis on operational security, reluctance to report valuable lessons stemming from failures, over-generalisations of observations in the field in the generation of appropriate lessons, and failures in dissemination and implementation of lessons.

5. Modelling, Trials and Experimentation: Modelling, trials and experimentation (MTE) capabilities are essential enablers for adaptivity at every stage, by providing environments for the development, exploration and evaluation of options. Of course these capabilities are actually embedded in each of the four stages above.

If we track the progress of any particular capability element over time from inception to in-service use we note that it follows a sequence from left to right of Figure 1, while capability requirements arise from the operational environment and flow in the opposite direction. Since the outputs of each stage should target anticipated future requirements of the next stage, the needs of Force Application must ultimately (acknowledging that this will be constrained by the realities of limited resources, time, etc.) drive all the other stages of capability creation.

4 Domains of Adaptive Action

We now take a detour to consider in more detail the relevant domains of adaptive action, where we will find flexibility is at a premium. Such demands stem from complexity not only in the situations that defence is called upon to influence, but also in our own systems and in the broader sociopolitical context that we operate in. This will lead us to a clearer appreciation of the value of flexibility in the operational domain, as well as to a more nuanced view of what is actually required.

Our argument is based on two fundamental observations. Firstly, the presence of complexity results in reduced comprehensibility and predictability, since the effects of events develop through multiple simultaneous and interacting pathways over various timescales, and therefore produce or contribute to many consequences. From an actor's or observer's perspective, many of these will be unexpected or unintended. Conversely, it is almost impossible to identify precise actions to bring about desired changes without unexpected or unwanted outcomes.

Secondly, adaptation is the most effective way we know of to deal with the new, the unexpected and the unknown in complex problems and situations because it does not require detailed knowledge of the problem in advance, nor the ability to devise the right solutions *a priori*. Instead it relies on the effectiveness of an iterative approach of successive learning and refinements. It has the inherent property of continuous vigilant monitoring and adjustment and so can be effective in situations of great uncertainty or rapid change.

The ramifications of these observations are far-reaching because it is not just the operational decisions which play out in a complex environment, and which therefore need to be adaptive, but decisions throughout the capability creation and employment space depicted in Figure 1. Decisions made within each phase set the stage for what is determined and what freedom of action remains in the subsequent phases, i.e. what decisions can or cannot be made, and the consequences of all these decisions culminate in the operational capabilities and the adaptive properties of the deployed force in operations.

Systems (such as a defence force or an organisation) are often described in terms of their structure and functions, which determine the kinds of outcomes they can generate in a given context. By contrast, the adaptive properties of systems describe their ability to understand themselves and their context well enough to determine *what* outcomes they should generate, *when* they should change what they're doing, *how* they need to change themselves in order to do so, and their ability to make those changes smoothly and quickly enough.

In a sense, the Force Development, Generation, and Preparation phases are engaged in the design and build of the complex systems that will be used in particular operational contexts. We claim that this is itself a complex challenge also needing to be addressed in an adaptive fashion, and moreover, that it is intimately related to the equally complex challenge of designing and conducting the operations. In fact, we see a duality[iv] between systems and operations, in spite of their apparent disparity. Operations are systems in action, and systems are

[iv] A fuller discussion of the material in this section is forthcoming in *Duality and the Role of Design in Systems and Operations* A.J.Ryan and A.M Grisogono – in preparation

the means by which operations can be implemented. System capabilities determine what kind of operations are possible and operational objectives (both actual and anticipated) shape what kind of system is needed. Consequently, neither systems nor operations can be adequately dealt with independently of each other.

The parallels run deep, and stem from the inseparability of these two complementary perspectives on the same hypothetical or objective reality, and the common sources of complexity in the inherent challenges associated with design / synthesis and management / analysis of both. In particular, both involve:

- a large number of possibilities (components of operations (*interventions options*) and of systems (*capability elements*) and how they are put together (*operational stratagem; SoS design*)),
- complex interdependent multi-dimensional and multi-scale measures of success and failure, and
- complex Causal and Influence Networks (C&INs) of people, contextual elements, systems, processes and relationships, plus diverse interactions with a large number of contingent and uncontrollable factors, through which our interventions play out to produce outcomes in the measures of success and failure; moreover, these C&INs are opaque, ever-changing, and can never be grasped in their entirety.

Further, system design, operational design and situational understanding are also multiscale in nature, as are the measures of success and failure, (see the box in Figure 2 below for indicative multiscale structures) and there are relationships between all four of these aspects at every scale, as well as conceptual and structural relationships vertically through the scales within each aspect. Taken together, these interdependent sources of complexity can barely be apprehended from any single viewpoint. As a consequence, different individuals, by virtue of their unique experiences and biases, are likely to have different views as to how success or failure will be judged, what is to be done, and what is actually needed to do it.

We acknowledge that in order to focus efforts on chosen objectives with unity of command, clarity and consistency, a defence force will make decisions about these aspects through its commanders, and act on them – but we also acknowledge that those decisions, and the views they are based on, are conjectural, and depend critically on the quality of understanding of the target situation and of the wider socio-political context within which success or failure will eventually be judged, and that because decision-makers are human and have limits to their cognitive powers, such understanding is always necessarily flawed, biased and incomplete.

We claim therefore, that given the complexity and interdependence of

- our own objectives in each part of the capability creation and application spaces,
- the decision and implementation environments in those spaces,
- the intertwined duality between systems and operations, and
- design decisions about both,

we need to ***test and co-evolve our conjectures about each of these***, adopting a posture of seeking disconfirming evidence from the real situation in order to learn, even as we engage with it.

Further, as we learn, we also need to be prepared to change both the views and the decisions that flow from them. This is the essence of an Adaptive Stance, such as espoused by the Australian Army in its Adaptive Campaigning operational concept[5], and its more recent Adaptive Army Initiative[6].

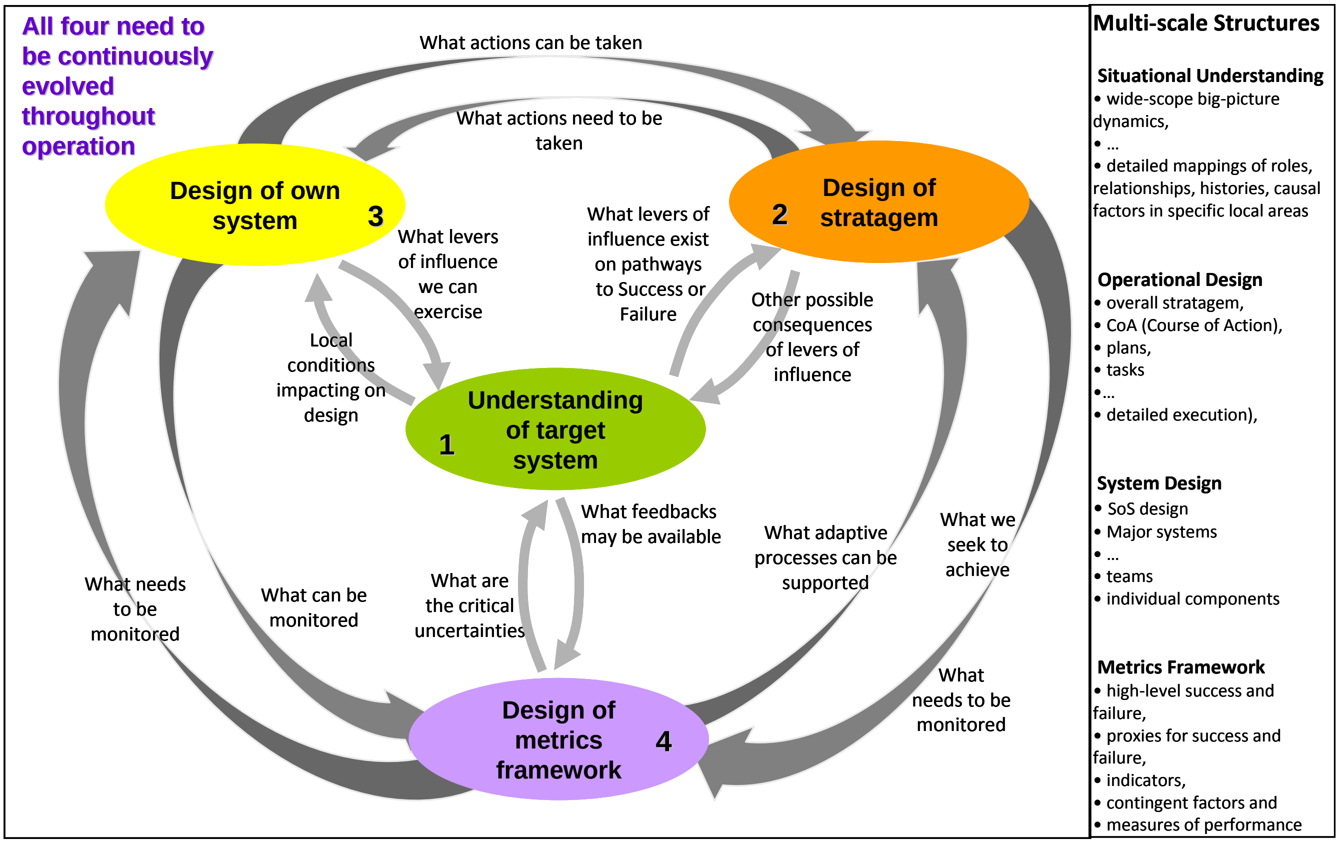

Figure 2: *Interdependence of situational understanding, operational design, system design and metrics framework design. The multi-scale structure of each of these four aspects is indicated in the box to the right. All four aspects must co-evolve throughout a complex operation.*

This interdependence of situational understanding, operational design, system design and metrics framework design is depicted above in Figure 2. The labelled arrows indicate how each informs the others and how changes to any one of them flow into impacts on them.

We are now in a position to appreciate just how important flexibility is for forces dealing with very complex situations.

As the situation develops, and as the understanding of the situation grows, there will be many adaptive changes called for at the various scales of both situational understanding and operational design, and hence also to the metrics framework which represents a distillation of both, and therefore also to the system that implements the changes in the operational design and the collection plan.

These adaptive changes may relate to any of the first 3 of our classes in Section 2.1 – ***responsiveness*** to changes in the threat and opportunity landscape, ***resilience*** in the face of incapacitation of elements of capability, or ***agility*** in recognition that the current stratagem or CoA is no longer the best feasible option.

But changes to the operational design and to the metrics to be monitored can only be made if the deployed system is capable of determining what changes would be effective and implementing them in a timely way.

Thus the fourth class, the ***flexibility*** of the force is paramount in determining the extent of its other adaptive properties beyond what is in reach of its current configuration.

5 Flavours of Flexibility

In Section 2.1 we defined flexibility as the ability to recognise and deal effectively with new challenges as they arise, i.e. to be reconfigured in different ways to do different things, under different sets of conditions. This property comes in many flavours – which we first briefly discuss, before addressing how they can be engendered through design decisions[v] and development processes.

Dealing effectively with challenges as they arise implies a temporal aspect – it is not sufficient to be capable of switching from X to Y in principle, it is also necessary to firstly, recognise the need and be able to come up with Y as an effective response, and secondly, to make the change safely and quickly enough for the situation.

With respect to the first point, there are a number of human qualities that contribute to this capability, in combination with the enabling design factors which will be discussed below. These include a degree of 'can-do' spirit, willingness to improvise and think outside the box, confidence in problem-solving, and an adaptive stance based on constant vigilant monitoring, openness to challenge, rapid learning and experimental development of innovative solutions.

The second point deals with timescale of implementation. Some changes can be made on the fly, others require some downtime, and some can only be made over an extended period offline. There is of course in reality a continuum of timescales over which changes can be made, and a given change might be feasible over a range of timescales depending on the need, cost and risk constraints eg on the fly at high risk, or slower in downtime at lower risk. Distinguishing just three bands of timescale is rather arbitrary, but serves the purpose of illustrating their relationship with different operational requirements for flexibility, depending on the timescale of the emerging challenges.

There is also the issue of whether the change is an augmentation of capability that retains all the prior capability, or whether it is a shift in capability that sacrifices (some of) the prior capabilities, and over what timescales those prior capabilities are restorable.

Another aspect stems from scale – changes that can be made within a scale of application properly relate to the flexibility of the system at that scale, while changes that require resorting to change levers at a higher scale are more properly attributed to the flexibility of the higher scale system. We will discuss examples below.

Flexibility of the force at various scales can be enhanced through leveraging all the levels of adaptation (as defined in Section 2.1).

For example, at the scale of a capability component of the SoS:

- **Level 1**: within the component's existing range of flexibility, changes to its current capability profile (eg *selecting from a set of interchangeable sensors on a platform, re-assigning an officer to a different role*)
- **Level 2**: increase the range of what the component can do, including the relationships it can form, decrease the time it takes to change from one role to another; (eg *provide a cuing signal from a broad area sensor, streamline the module interchange process, train officers for additional roles*)
- **Level 3**: increase the range of capability it can explore, improve its processes for establishing the new capability domains, decrease the time it takes to do so; (*eg provide a 'discover and connect' service to a sensor sytem, standardise interfaces so that a wider range of modules become compatible, widen range of educational services*)

And similarly at the scale of a system-of-systems:

- **Level 1**: within the SoS's existing range of flexibility, shift and/or broaden/constrain its current capability profile (eg *re-organise the distribution of roles and responsibilities, improvise a new configuration of existing elements to perform a new kind of mission*);
- **Level 2**: increase the range of what the SoS can access through reconfiguration, changes of composition, changes of process etc, decrease the time time it takes to do so (eg *streamline the process of experimentation in support of change decisions, reduce friction generated in implementing changes*);
- **Level 3**: improve its effectiveness in improving its flexibility eg through the development, generation and integration of relevant new system / SoS capabilities (eg *improve configuration management, increase standardisation of interfaces to increase range of rapidly integrable components*).

Thus Level 1 flexibility relates to how the system in question uses its existing capabilities to deal with new challenges, Level 2 flexibility is about changes to the system that engender or improve its Level 1 flexibility, while Level 3 seeks changes to the system that would increase the effectiveness of Level 2 in improving Level 1 flexibility, which is where the utility of changes at all adaptive levels are ultimately delivered. Since this paper is specifically about engendering flexibility, we will pay most attention to Level 2 – how flexibility is improved.

[v] We distinguish between *action decisions* whose primary impact is on the target situation, and *design decisions* by which we mean those decisions whose primary impact is on one's own systems and processes in the form of modifying the future action decision space available to them.

At the component scale, the effectiveness of a system (e.g. a military unit) can be schematically visualised as a function of its roles, as in Figure 3. The areas under the curves indicate the range and effectiveness of roles that the current flexibility permits the system to implement. More specialised units will have narrower but higher peaks than generalist units, but all will have limits to their range of effectiveness. Moving smoothly as required between roles within their range represents Level 1 flexibility. Level 2 improvements to component flexibility seek to enable a greater and/or more useful range of options or potential roles, and/or ways to more rapidly and safely implement them, suggesting four different ways in which flexibility can change:

- **Increased speed and safety, reduced cost** of changing roles within the existing range of roles,
- **Overall broadening of potential roles**. Larger scale broadening of flexibility, as in Fig 3 (a), can arise through introduction of new technologies, improved and new processes (TTPs) and approaches (doctrine). Much of this would normally be done while the system was offline, but there may sometimes be demands on systems to increase their flexibility in operations. This will then place a premium on abilities to experiment and improvise on the fly – reachback and networking can be significant enablers here .
- **Specific broadening of flexibility** – as in Fig 3 (b), in response to specific identified deficiencies, sometimes required while the system is operating, but more safely implemented off line. Lessons from such *in situ* evolution of system flexibility may be incorporated into offline broadening of other similar systems.
- **Shift in focus of flexibility** - as in Fig 3 (c), eg in response to major changes in technology (*shift from horse cavalry to tanks*) or in operational requirements (*shift from trench warfighting to manoeuvre warfare*), etc. These changes often take significant time and effort, although minor shifts in roles may be undertaken *in situ*. The need for a shift may result from poor initial selection of the system for the role, under-appreciation of the challenges likely to faced or mistaken expectations of new technologies, but since such failures are to be expected, it is important to invest in both the flexibility to undertake rapid offline shifts in unit roles and in the capacity of units to evolve their roles while operating. The latter will be particularly important when it is the first unit to undertake a new type of operation[7].

At the SoS scale – Implementing flexibility at this scale is an exercise in Complex Systems Engineering[8] in that a large number of components (that have not necessarily been designed to work together) need to be connected into a functioning SoS, while retaining the ability to change composition, form and functions on the fly. Level 1 flexibility is displayed by the ability of the SoS to rapidly and safely change its posture to take on new roles or better perform existing ones, within its current range of flexibility. Similarly to the component scale, Level 2 improvements to flexibility at the SoS scale can also be achieved in a number of ways, as illustrated in Figure 4:

- **Increased speed and safety, reduced cost** of changing roles within the existing range of roles.
- **Augmentation** – Components from a restricted palette are added to the SoS to widen the flexibility of the SoS to undertake a range of roles, as in Fig 4 (d). The palette will generally be determined off line (with some variation created in operations), but dynamic formation into teams can be *in situ*.
- **Broadening of roles** over which a given SoS can be effective, as in Fig 4 (e) – through experimentation and learning in support of improvisation (on the fly) and innovation (off line). The lessons of these increases in flexibility can then rolled back into the slower development and generation of subsequent SoS.
- ***Shift of focus*** – as in Fig 4 (f), a SoS that needs to undertake new roles beyond the range of its current flexibility, may undergo significant restructuring of composition, redevelopment of processes and re-integration and training (while probably giving up some of its previous roles). The resulting flexibility of the SoS will cover a different part of the space of possible roles (not necessarily a wider range, but one that is more relevant to the current challenges). If significant restructuring is needed over a short timescale it would generally need to be done offline, but an alternative and inherently more flexible approach would be to cultivate a stance of continuous re-invention and re-evaluation whereby the SoS is never off-line but some parts of it are always regenerating. Enablers for such continuous evolution of flexibility include a 'hot-swap' capability, well-defined interfaces, and a shared adaptive culture.

At the Enterprise Scale – Since a given deployed SoS is a product of the enterprise at a larger scale, as we depicted in Fig 1, the overall Level 1 flexibility at that larger scale is given by the enterprise's ability to generate context-appropriate SoSs as and when needed, that are able to be effective across the full spectrum of roles that each situation requires. Level 2 improvements to enterprise flexibility are achieved through changes to the Force Development, Force Generation and Force Preparation systems, and their outcomes are also shown in Fig 4:

- **Increased speed, reduced cost** of changing the kind of SoS being produced, within the current range.

- **Broadening the spectrum** – As in Fig 4 (g), developing the enterprise's ability to generate new SoSs able to undertake roles beyond the current spectrum of the force.
- **Shift in the spectrum** – As in Fig 4 (h), the spectrum of potential roles that the force is to address may also need to evolve. The development of Naval Airpower during World War II was a historical example of major broadening of flexibility in operations, a current one is developing cyber warfare capability.

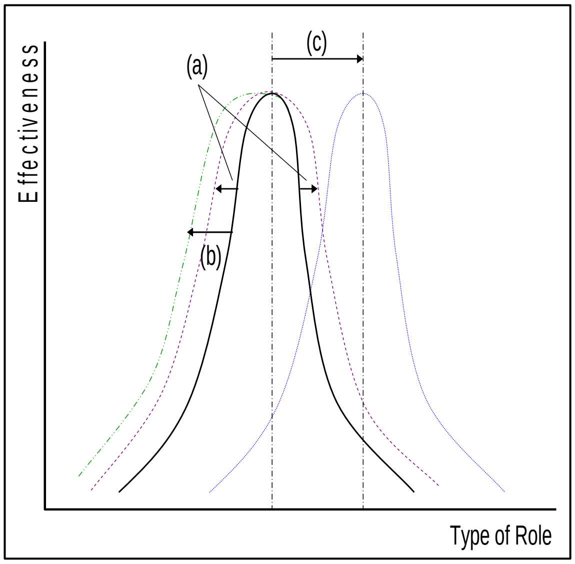

Figure 3: *Component flexibility –*
(a) overall broadening,
(b) broadening in a specific area,
(c) overall shift.

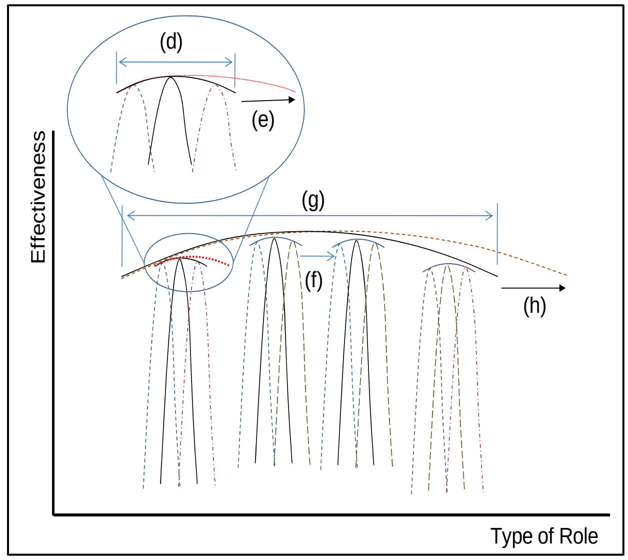

Figure 4: *SoS flexibility –*
(d) range of SoS/team roles,
(e) broadening of team roles,
(f) shift in range of team roles,
(g) spectrum of force roles,
(h) broadening of the spectrum of force roles.

Level 3 changes to how flexibility is improved can be introduced at every scale, by examining how the Level 2 changes are made, measuring how effective they are at achieving the desired changes in flexibility, and seeking ways to do it better, supported by experimentation and feedback.

Major targets for Level 3 flexibility at the enterprise scale are researching how to design system components and architectures for flexibility, incorporating what is learnt into how the enterprise conducts Force Development, Generation and Preparation and identifying and removing organisational obstacles to enterprise flexibility.

As with all design drivers the goals of enhancing flexibility need to be balanced with other conflicting goals. Greater flexibility does not always provide increasing benefit since there can be significant associated costs and impacts on overall component and SoS effectiveness, including:

- down time, eg for additional training, equipment and concept development which may not be able to be undertaken while maintaining operational effectiveness;
- material cost (financial, equipment, personnel) both through the need to keep multiple options open and due to increased implementation costs (e.g. training across wide spectrum of roles); and
- providing decision-makers with too many options, variable and elements that need to be pulled together to enable the right change decisions to be made.

The capacity for flexibility to increase potential effectiveness thus needs to be balanced against cost, time, responsiveness, resilience, and constraints in personnel and equipment. Balancing and implementing these trade-offs to deliver the needed effectiveness across the range of expected dynamic contexts are at the heart of the problems of force design.

6 Design Factors for Flexibility

So far, we have discussed flexibility in a generic way and identified the types of force-level outcomes it can support. But given that we want more of it, how can flexibility actually be increased?

Turning briefly now to the science of complex adaptive systems to draw insights about design factors that enhance flexibility, we propose that the following (non-exhaustive) list of approaches is worthy of further examination:

- Exploitation of self-organising processes to facilitate fast smooth implementation of selected changes;
- Use of Service Oriented Architectures (SOA) and standardised interfaces where feasible and cost-effective;
- Implementation of broker services to mediate interactions between components;
- Exploitation of Stable Intermediate Forms[9] (SIFs) to accelerate the speed and success of evolutionary searches – i.e. modular composable components at every practical scale;
- Appropriate use of structure – hierarchical SoS composition with adaptive selection occurring at every scale (this amounts to multilevel selection and carries additional requirements on the relationships between adaptive processes to avoid chaotic regimes);
- Cultivation of ‘hot swap’ capabilities;
- Adaptive approach to managing the trade-off between multifunctional and specialized components to provide sufficient diversity and capability;
- Biologically-inspired techniques[10] such as recombination, facilitated variation which comprises conserved core processes, weak regulatory linkages and exploratory processes, and so on to enable faster, wider and more useful generation of options;
- Adaptive approach to managing the trade-off between increasing the flexibility of the components operating within the SoS, and the ease of combining them into novel configurations; and
- Adaptive approach to managing the trade-off between trying to equip a component with as much flexibility as it is expected to need, and giving the component more ability to evolve its flexibility in response to emerging requirements.

7 Designing for Flexibility

Flexibility requires the ability to generate and evaluate innovative SoS designs, ease of integration, or federation, of component systems into many different combinations, as well as components that can play many different roles within a SoS.

Design factors that support these requirements include avoiding hardwired solutions, and preserving degrees of freedom in system designs.

Flexibility also calls for a more nuanced view of interoperability than simply mandating formats and interfaces, or indeed entire technical systems. Taking the most general interpretation of interoperability as the ability of diverse systems and organisations to work together, it is clear that such mandates represents just one possible solution strategy, which to be effective. requires a central authority that can enforce and resource the mandate. The ability to work together really only demands something rather less difficult – the ability to establish agreements and provide and receive services, whether through direct or indirect (eg via a broker) interaction. This enlarges the scope of potential flexibility in environments with a great diversity of players, such as feature in most of our current and expected future operations.

However flexibility-enhancing features often come at a potential cost of reduced efficiency in particular tasks and increased decision burdens on the deployed force, so the benefits of the anticipated flexibility have to be weighed against those costs and risks. How this trade-off should be handled depends on the expected complexity and dynamic properties of the environment.

These issues beg a deeper examination of the ***meta-decision space***, in other words, how decisions get made about what design decisions get made, and when, where and by whom those decisions will be made.

In an earlier paper[11] a biological analogy was drawn between Force Development, Generation, Preparation and Employment on the one hand, and the evolutionary history of a species, and the growth, development and lifecycle learning of an organism of that species on the other hand, leading to the following (*inter alia)* conclusions:

> “*There is a trade-off between making design decisions at the last possible moment (keeping options open to increase adaptive range) and the costs and risks such a posture might entail (a greater decision*

burden placed on the operational domain, risks of poor decisions, and the greater cost of providing the extra sense, process and act options needed to take advantage of the adaptive range etc).

.. if we wish to maximize an operational force's adaptive properties for complex endeavors, .. must ensure two things: that the necessary design degrees of freedom are left open in the preceding stages, and that the necessary adaptive processes are facilitated by the design choices made in those stages.

.. the Force Development domain.. should only determine those design features that meet the .. conditions .. of being costly to build or of having many other design decisions dependent on them."

There are good lessons in the meta-decision architecture of biology, since it is the result of billions of years of evolutionary adaptation honed by the relentless application of selection of the fittest.

Our meta-decision architecture by contrast, is largely the accidental by-product of decisions made for reasons of local efficiencies, tradition, administrative convenience, short-term cost-cutting, and near-sighted focus on immediate outcomes within a restricted field of view. Most of these reasons may have been justifiable at the times they were made within the scope of the decisions as they were framed, but they don't necessarily combine to produce the most effective use of our resources to address our overall goals and higher objectives. Moreover, as organisational structures and processes develop and interlock to implement them, the cost of reconsidering them and making significant changes becomes prohibitive, and the complexity of the existing functioning (though not ideal) enterprise is far too great for any purely top-down restructuring to be effective.

These are systemic failings rather than blameworthy deficiencies of individuals. As Senge[12] puts it: *structure produces behaviour.* Fostering changes in our meta-decision architecture therefore needs to be addressed adaptively as structural and business process design issues at the scale of the entire enterprise. We expect that creative and motivated individuals working within those enterprises will gladly rise to the challenge of exploiting their newfound freedom to deliver more flexible and capable outcomes when organisational obstacles are removed, although their less enthused colleagues may need some encouragement.

8 Adaptive Approach to Creating Flexible Capability

We propose that the Conceptual Framework for Adaptation (Section 2.1) can equally be applied to this complex problem of fostering the necessary changes in our meta-decision architecture at the enterprise scale, as to the complex problems of mounting an effective operation in a complex situation where we are asked to intervene.

Further, we propose that the domains of adaptive action depicted in Figure 2 are also relevant here, with minor adjustments to translate them from the operational to the enterprise context, and that the need for continuous co-evolution of the four generic aspects is as pertinent here as in a complex battlefield. We need to establish therefore the enterprise equivalents of those four aspects – the 'own system' and 'stratagem' designs, the 'target system' that is to be influenced, and the 'metrics framework'.

If we take the 'target system' to be the wider context within which situations requiring defence interventions arise, (that context arguably including some aspects of our own political and social systems), then the 'own system' is the overall enterprise system-of-systems that creates and applies defence capability in response to those requirements, and as depicted in Figure 1, and its 'stratagem' is its concept of how it can deliver on its purpose of providing effective defence interventions as required. The meta-decision architecture as it currently exists is one aspect of that stratagem, while the schematic process view in Figure 1 represents one high-level view of our 'own system' design. The systems – operations duality is evident in the intimate relationships between processes depicted in Figure 1 and the implied systems required to implement them.

The point of this discussion is not just a cosmetic re-description of what exists, but a clarification of the implications of dynamic complexity in all these aspects. Specifically, we claim that both the 'target system' and our 'own system' possess very high degrees of multi-scale complexity and are constantly evolving, and therefore our understandings of them will always be flawed and incomplete. The designs of our enterprise systems and our stratagem are also multi-scale, and represent our conjectures about how we can achieve our purposes, and are based on those flawed and incomplete understandings.

Therefore, an adaptive approach is required, which takes pains to make all such conjectures and assumptions explicit at every scale, and seeks to continually test their veracity, to look for disconfirming evidence and to be prepared to make adaptive changes as required at every scale and in every aspect.

The 'metrics framework' is similarly multi-scale and should capture the logic of the operational and systems designs. Specifically, it relates measures of success and failure at the highest scales through measures of success and failure (or proxies for them) at the next more detailed scales, down to measures of performance for tasks and indicators to be monitored in both our own systems and the target system, in order to support the continual posing and answering of such questions as the following, within adaptive processes at every relevant scale:

- Measures of Success and Failure (in providing effective defence interventions as required)
  - Are we succeeding or failing?
- Proxies (for Measures of Success and Failure i.e. measures which we conjecture are on the path to achieving success and avoiding failure, and vice versa)
  - Are we on a path towards success or towards failure?
  - Is our stratagem working as we expect?
  - Are there undesirable consequences emerging from the outcomes we produce that need to be mitigated?
  - or desirable consequences to be nurtured?
  - Does the stratagem need to be adapted?
- Measures of Outcomes (of our CoAs which we conjecture will contribute to achieving proxies for success and avoiding proxies for failure)
  - Are our courses of action delivering the outcomes expected?
  - Do we need to adapt our plans?
- Measures of Performance (of our tasks which we conjecture will contribute to achieving the CoA outcomes)
  - Are we performing our tasks well enough?
  - Do we need to adapt how we perform them?
- Contingent factors & indicators
  - What is going on in the complex situation ?
  - Does our understanding of it make sense in the light of what we are observing?
  - Do we need to change our unerstanding?
  - Is there an opportunity or threat to take adaptive action on?

The many adaptive processes that are informed by the continual monitoring of these and similar questions are the basis for the enterprise's responsiveness, agility, and resilience, which in turn enable it to keep its metaphorical eye on its highest objectives and maintain a high level of effectiveness in delivering on them in spite of all the dynamic complexity it is immersed in.

The effectiveness of all these adaptive processes depends in part on the enterprise's flexibility in generating appropriate responses, and on the ways in which the adaptive processes are put together in what one might term an ***adaptation architecture***. This term is intended to convey the fact that adaptive processes in a complex system cannot in general be treated as independent of each other, since they may interact in myriad ways eg they may produce synergistic or antagonistic effects on particular elements, one may indirectly modify the impact of another, they may interact temporally to produce oscillations or other patterns etc. Therefore appropriate relationships need to be established (and adaptively refined) between them.

The meta-decision and adaptation architectures are closely related and together form a significant aspect not only of the stratagem for delivering enterprise outcomes, but also, and more importantly, they determine how the enterprise is able to evolve over time. Thus, as the global and national strategic environments, the science and technology landscape and the internal social and organisational contexts all change over time, the enterprise can keep learning and adapting itself to achieve and maintain high levels of effectiveness in the eyes of its stakeholders.

Similarly, returning to the operational context, we can now see that one of the tasks of the defence capability creation enterprise is to enable the deploying forces they produce to develop their own meta-decision and adaptation architectures so that they can keep learning about their own complex changing environments (strategic, operational and their own internal context), and therefore adapt their own operational and system designs, and their metrics framework and collection plans to support them, again as depicted in Figure 2.

The need to do this in turn will dictate many aspects of the enterprise meta-decision architecture because it will require them to enable those adaptive decisions to be made post-deployment, and to ensure that those necessary decisions are well supported.

A fuller discussion of the detailed implications of placing a higher premium on flexibility on all the aspects of the Force Development, Force Generation and Force Preparation phases is beyond our current scope here and will be addressed in subsequent papers.

9 Summary and Conclusions

We have outlined a conceptual basis for flexibility and interpreted its implications for the design and operation of deployed forces and for the design and operation of the enterprise that produces those forces. We have sought to identify and discuss the factors that contribute to flexibility, and how they could be better enabled through every phase of the defence capability creation enterprise. This has led to the recognition of the importance of the meta-decision and adaptation architectures of the enterprise, and of the forces they produce. Many details remain to be worked out and explored, in particular the impacts for the structures, processes and relationships in the Force Development, Force Generation and Force Preparation enterprise systems, but these are tasks for future papers.

References

1. This over-riding general concept is described as *agility* in some of the US defence literature see eg Chapter 8 of *Power to the Edge – Command & Control in the Information Age* Alberts, D. S. and Hayes, R. E. www.dodccrp.org

2. Grisogono, A.M. *Co-Adaptation*, invited paper 6039-1 Complex Systems Conference, SPIE Symposium on Microelectronics, MEMS and Nanotechnology, Brisbane December 2005

   Grisogono, A.M. *The Implications of Complex Adaptive Systems Theory for Command and Control*, CCRTS, San Diego, June 2006

   Smith, E.A. and Grisogono, A.M. *Towards a Synthesis of Complex Adaptive Systems Theory and Effects Based Approaches to Operations: Warfighters to Coalition - A Case Study of Multi-level Adaptation in Effects-Based Operations*, 11th ICCRTS, Cambridge UK, Sep 2006

3. Unewisse, M.H. and Grisogono, A.M. *Adaptivity Led Networked Force Capability*, 12th ICCRTS – Adapting C2 to the 21st Century, Newport, 2007.

4. Spaans, M. and Grisogono, A.M. *Adaptive Use of Networks to Generate an Adaptive Task Force*, 13th ICCRTS, 2008

5. The Australian Army's Adaptive Campaigning describes the land force contribution to a military theater as part of a whole of government campaign. Australian Army, *Adaptive Campaigning*, Nov 2006 (endorsed Dec 2006). A revised and extended version is due out mid 2009.

6. The Adaptive Army Initiative was launched in Aug 2008 and seeks to place the entire organisation on an adaptive footing. http://www.defence.gov.au/army/AdaptiveArmy/default.htm

7. Ryan, LTCOL M.J. *Implementing an Adaptive Approach in Non-Kinetic Counterinsurgency Operations* Australian Army Journal, **IV**, #3, p125

8. Norman, D.O. and Kuras, M.L. *Engineering Complex Systems*, Mitre Corp,

9. Stable Intermediate Forms were first discussed by Herbert Simon in *The Sciences of the Artificial*, MIT. 1996. They have since become widely appreciated as a key design pattern of complex systems.

10 Kirschner, M.W. and Gerhart, J.C. *The Plausibility of Life*, Yale University Press, 2005. See eg p144 'exploratory behaviors … generate many… specific states in the course of their function, and provide a mechanism for selecting among these states those that best meet the particular physiological need', p 219 for a discussion of facilitated variation, p 109 for weak regulatory linkages etc.

11. Spaans, M. and Grisogono, A.M. *Adaptive Use of Networks to Generate an Adaptive Task Force*, 13th ICCRTS, 2008

12. Senge, P.M. *The Fifth Discipline: The Art & Practice of the Learning Organization* Doubleday, 1990.