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The Metacapability Conceptual Framework: A framework linking C2 Agility Concepts

Abstract

Command and Control (C2) Agility is becoming increasingly important for military operations in the complex environments prevalent today. Considerable effort has been put into defining concepts such as agility, adaptability and robustness; but a common understanding and the overall utility of the concepts are hampered by the different definitions, models, terminology and conceptual frameworks currently circulating. Even within some individual frameworks definitions appear to be overlapping and highly interdependent, making their use in design a challenge. This paper revisits the Agility conceptual space in an attempt to reconstruct a coherent and consistent approach to addressing issues of ontology, definition and completeness. As part of this effort, it attempts to reflect the important ideas that have been developed to date within a framework of properties, functions and mechanisms. This inclusion of a coherent set of generic mechanisms is an important enabler for design.

Introduction

The concept of Agility is not new in the context of military forces and warfare. Sun Tzu [1] says "so a military formation has no constant formation…the ability to gain victory by changing and adapting according to the opponent is called genius" [1, p113], indirectly, but implicitly evoking the concept of Agility. The concepts of C2 Agility, adaptability and robustness have been more prominent in military concept development in recent years [2-8]. However, the different definitions, models, terminology and conceptual frameworks on offer hamper a common understanding of the idea of agility and the overall utility of the related concepts. Definitional issues sometimes occur even within individual frameworks when component concepts appear to overlap and to be highly interdependent.

This paper revisits the Agility conceptual space and proposes an alternative framework for describing the concept of agility. This new framework explicitly considers the underlying mechanisms that allow a system to be agile and therefore effective. In doing so, it attempts to coherently situate and relate key concepts such as agility, adaptability, robustness and resilience within a framework of properties, functions and mechanisms in a way not evident in the C2 literature. As part of the evaluation of this framework, two historical examples are used to highlight features of the proposed framework—helping us to answer the question: 'are the framework's set of concepts and relationships consistent with historical analysis?'

Following this introduction, we review prior work, briefly identifying important contributions and areas still open to refinement. We then introduce our framework for organisational agility, and evaluate it using two historical examples. Finally, we map the most common concepts from the literature on to our framework, and then end with a conclusion and a statement of further work.

Previous work and approaches

Our proposed framework is heavily grounded in the work of previous authors. To understand both the differences and the similarities between our concepts and those of earlier authors, it is first necessary to review this prior work. In this section we provide a brief overview of the established literature of particular relevance to this paper. Readers are referred to McEver & Martin [2] and McEver et al. [3, 4] for a more detailed review.

Department of Defence Command and Control Program

Under the auspices of the Department of Defence Command and Control Program (DODCCRP), Alberts articulated the first conceptual framework for Agility following "an ad hoc US/UK meeting to discuss NCW and transformation" [9]. In this framework, Agility is comprised of five components: robustness, flexibility, innovativeness, adaptiveness, and responsiveness. Their interconnectedness and synergistic nature in contributing to Agility can be captured schematically, as shown in Figure 1. As illustrated, flexibility and adaptability contribute to robustness and innovation, and thereby to an agile response.

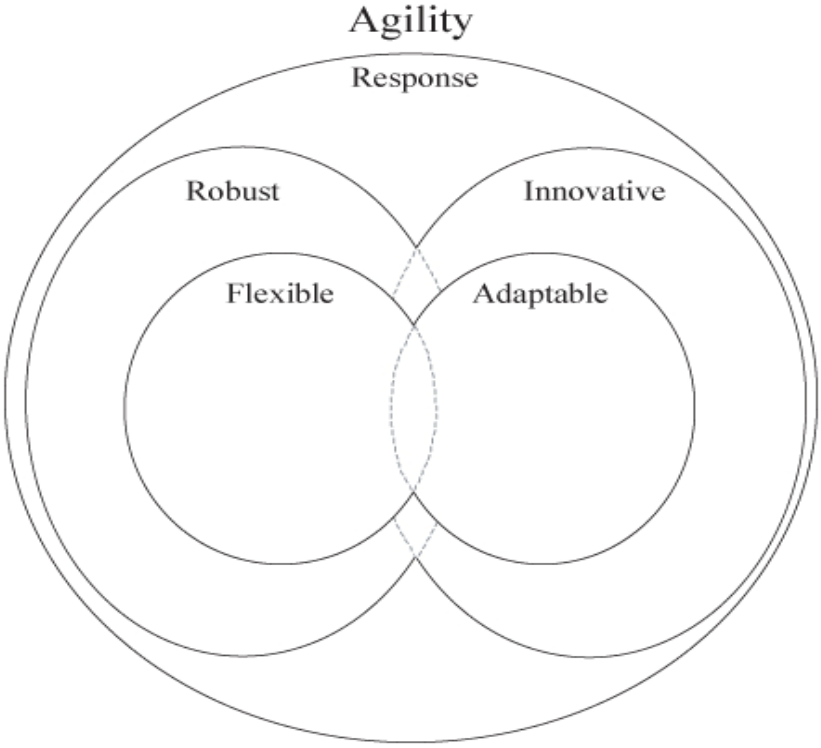

Figure 1 Attributes of Agility (source: Alberts, Information Age Transformation, 2002)

This was further refined by Alberts and Hayes in "Power to the Edge" [5]. Apart from decomposing the definition of robustness by adding the concept of resilience, "Power to the Edge" added only minor refinements to the terms and definitions. This resulted in "Agility" being composed of six aspects with the following brief definitions [5, p128]:

1. Robustness: the ability to maintain effectiveness across a range of tasks, situations, and conditions;
2. Resilience: the ability to recover from or adjust to misfortune, damage, or a destabilizing perturbation in the environment;
3. Responsiveness: the ability to react to a change in the environment in a timely manner;

4. Flexibility: the ab ility to em ploy m ultiple ways to su cceed and the capac ity to m ove seamlessly between them;
5. Innovation: the ability to do new things and the ability to do old things in new ways; and
6. Adaptation: the ability to change work processes and the ability to change the organization.

It was conceived that these six aspects interacted within the Operating Environment. Figure 2, illustrates th e im portant link in th is framework between the environm ent and the a spects of agility that provide a system with the capacity to cope wi th, respond to, and shape that environment. However, it doesn't ex plicitly detail how the intera ctions occur, and th e overall ontology is hinted at, rather than made explicit.

The concepts of Alberts and Hayes provided th e first integrated view of the relationship between organisational agility and attributes such as robustness, flexibility, resilience and so on, and for this reason they heavily influence ou r framework. However, they did not attem pt to explicitly define relationships between his identified attributes—although they are sometimes inferred in "Power to th e Edge"—a nd the def initions them selves are no t dis tinct (compare, for example, the definitions of adaptation and innovation).

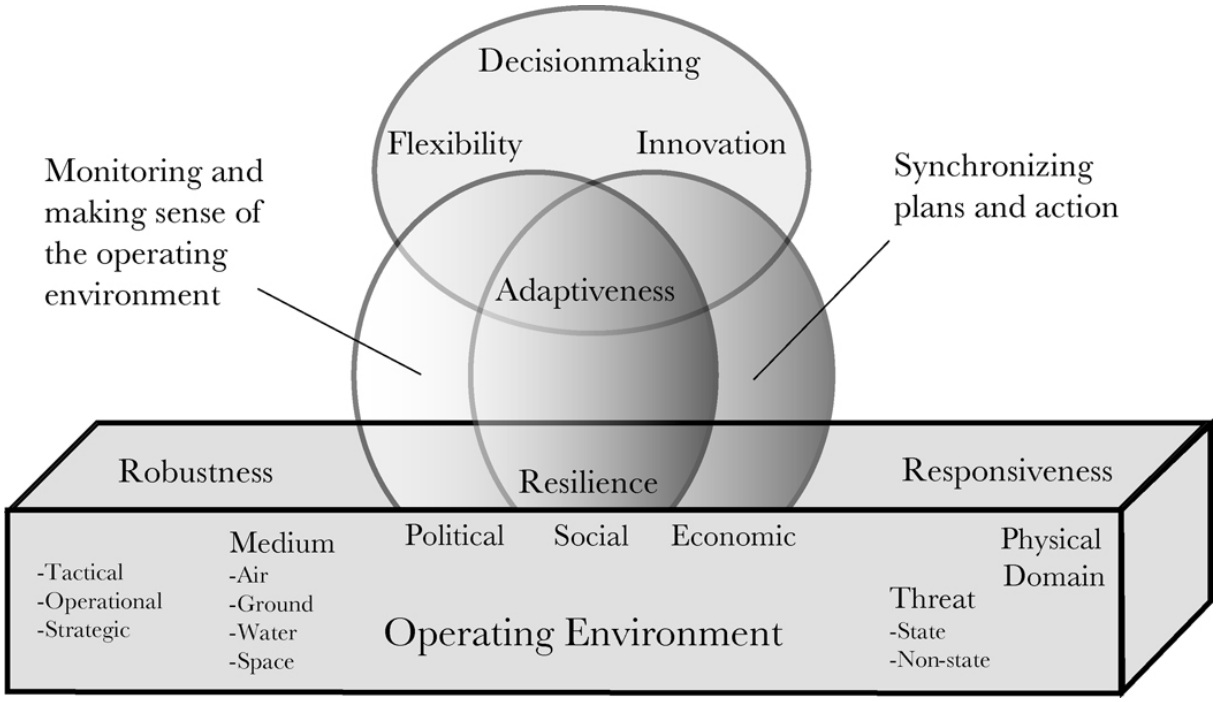

Figure 2 The Six Aspects of Agility in the Domains of Warfare (source: Alberts and Hayes, Power to the Edge, 2003)

Other United States Contributions

The Network-Centric Operations (NCO) Conceptual Framework [10] adopted many elements of the Agility concept proposed by Albert s and Hayes. T he Joint Command and Control Functional Concept [11] includes the same basic six characteristics in its definition of Agility, which it co nsiders to b e the "over arching Attr ibute" permeating all aspects of th e force. However, it addition ally articu lates a set of other specif ic "Attribu tes of Joint C2". Each attribute "is a testab le or m easurable characteristic that des cribes an as pect of a sy stem or capability" [10, p22]:

- Superior Decisionmaking

- Shared Understanding
- Flexible Synchronization
- Simultaneous C2 Processes
- Dispersed Command and Control
- Responsive & Tailorable Organizations
- Full Spectrum Integration
- Shared Quality Information
- Robust Networking

These attributes are mapped to specific sets of basic and collaborative C2 capabilities[1] that are considered necessary to achieve f ully agile Joint C2. F urthermore, these attributes are decomposed into sets of m easures and metrics in order to assess the diffe rent attributes of the C2 system and their impact on mission effectiv eness. Th e introdu ction of m etrics form s a critical step and one that we have yet to tackle. Because of its relatively direct derivation from Alberts and Hayes, the NCO conceptual fr amework and the Joint Command and Control Functional Concept also lack a form alised ontology. However, they do provide a m ore specific m odel of organ izational agility with re spect to C2 than provide d in "Power to th e Edge". They have seem ingly extended the co ncepts proposed by Alberts and H ayes in a direction that makes them appear more useful for organisational design.

The Net-Centric Enviro nment Jo int Functiona l Concept [6] take s a d ifferent approach and , perhaps, of fers the m ost de tailed a rticulation of the concepts and ass ociated m etrics. Its starting po int is the dif ferentiation of the Net-Centric E nvironment into two areas : th e Knowledge Area and the Technical Area. It then identifies sets of capa bilities (abilities "to achieve an effect to a s tandard und er specified conditions through m ultiple com binations o f means and ways to perform a set of tasks" [6, p21]) with each area. Each of these capabilities possesses a num ber of attributes ("the m easurable aspects of the capabilities" [6, p21]). Finally, each attribute is associated with a number of m easures, dim ensions along which the attribute can be described and quantified. They posit an attribute called "Agile ", which is defined as "moving quickly and easily". It is an attr ibute that exis ts in both the Knowledge and Technical Areas but, interestingly, the specific measures are largely dissimilar.

The United Kingdom Approach

The United Kingdom (UK) Military has also adopted Agility as it s pinnacle concept, agility being central to the UK Joint Higher Level O perational Concept (JtH LOC) [7]. It is also reflected in subordinate UK concepts such as the "Future Air and Space Operational Concept" [12] and in other literature [13, 14]. However, the UK constr uct differs with that of the DODCCRP by decomposing Agility into only four fundamental component concepts [7]:

1. Responsiveness: the speed with which we reac t to change in the en vironment relative to potential or actual adversaries
2. Robustness: the deg ree to which ou r people and capabilities will re main effective under arduous con ditions, particularly in close con tact with an adv ersary, but also th e ability to conduct different missions with the same capability
3. Flexibility: seeking to avoid foreclosing options at too early a stage of planning
4. Adaptability: em bracing an aptitude to le arn rapidly about new envi ronments, especially when faced with the unexpected, to encourag e 'loyal opposition' and recognise the n eed

[1] "A capability is the ability to execute a specified course of action." [11]

for change, thence a measure of how well we can reconfigure our structures, processes or plans in order to succeed

One can observe significant overlap but also considerable differences between UK and DODCCRP terminology. McEver et al. [4] made the observation that the UK approach to the concept of Agility "separates the concepts of organizational change (flexibility in the means) and process change (flexibility in how the means are employed)" [3, p8] —an important insight which has assisted us in the development of our framework.

Complex Adaptive Systems

From the different perspective of complex adaptive systems, Grisogono [15] and Clark [8] have proposed a conceptual framework where Adaptivity plays a similar role to Agility. They define four classes of "adaptivity" (responsiveness, resilience, agility, flexibility) by their "robustness" or stability of a function against various kinds of stress. This is expressed in more detail in Figure 3 below [8]:

Class	Type of Robustness	Ability
Responsiveness	Robustness of force to the unexpected during operations.	Ability to react to a change in the environment in a timely manner.
Resilience	Robustness of force to damage, & shocks during operations.	Ability to recover from or adjust to misfortune or damage and to degrade gracefully under attack or as a result of partial failure.
Agility	Robustness of force to changing conditions during operations.	Ability to recognise when to shift from one strategy to another.
Flexibility	Robustness of force to the unknown future.	Ability to create and maintain effectiveness across a range of tasks, situations, and conditions.

Figure 3 Classes of Adaptivity (source: Clark, "Classes and Levels of Adaptivity", 2006)

As with those of Alberts and Hayes, a particular issue with these definitions is their apparent overlap. However, this work is important, not least because it makes the attempt to link organisational agility with established models of adaptation from evolutionary science, providing important links between properties (such as agility and robustness) and the underlying mechanisms that might contribute to these properties.

Summary Observations

This is just a snapshot of some representative work that has been conducted to date. A scan of this literature shows that in some cases the terms used are identical, in other cases they have slightly different wording or interpretations, and in yet other instances the terms can sometimes differ markedly in nomenclature or meaning. While this inconsistency is not absolutely fatal to the application of these frameworks, it does tend to hinder communication and concept development. Also, many of the concepts are very rich and complex, often are highly interdependent, and can be overlapping (even within a single framework). This can create difficulties when attempting to apply these concepts to C2 design. They have, however, considerably advanced the initial ideas of Alberts, especially in the areas specific to C2 and in the development of metrics and mechanisms.

Recognising these limitations, we attempt to conceive the Agility conceptual space through a more formally defined ontology for organisational agility.

Building the Metacapability Conceptual Framework

The starting point

We will attempt to deliver a general ontology that situates concepts within an overarching framework and relates many of the individual concepts to each other. Where possible, for the sake of continuity and consistency with previous work, we will follow the commonly accepted terminology and descriptions (but not necessarily definitions or conceptions) of the individual concepts. However, we will attempt to ensure that the concepts are defined as simply and discretely as possible. In doing so, these terms can be viewed as a basis set and building blocks for the whole conceptual space and more complex concepts. These individual concepts are identified as *metacapabilities*, as they do not describe a specific military system capability but instead inform the user and designer of changes to (and how to change) military system capabilities. As such, we call this framework the Metacapability Conceptual Framework (MCF).

The approach takes a combined 'internal' and 'external' view of a system, and attempts to define the mechanisms and components required to make a system robust, resilient and enhanceable. What differentiates this from the other frameworks previously reviewed is the use of mutually exclusive concepts at each level in the model, and the explicit links between these concepts. A feature of this framework is the many-to-many relationships between the internal view of what comprises the system and the external qualities that such a system exhibits. It plays a key role in generating the richness of system behaviour from relatively simple internal mechanics.

The Bottom-Up (Internal) View

We define the lowest level of a system as consisting of *components*. *Components* can be structural (including individual elements) or procedural (incorporating its dynamic behaviour) in nature.

The MCF proposes three basic types of *components*[2]:

Fixed components:	Structures and/or Processes that are individually unchangeable and with relationships that are essentially fixed.
Reorganisable components:	Structures and/or Processes that are individually unchangeable but with relationships that are mutable and can be rearranged to some degree.
Novel components:	Structures and/or Processes that are newly generated and adopted.

These three categories of components are each uniquely associated with a distinct *mechanism*:

Substitution[3]:	The ability to replace components with other components (identical or otherwise).

[2] These are categories that can coexist. Any system can (and is likely to) possess two or more simultaneously.

Recombination: The ability to arrange components into different predefined relational patterns.

Innovation: The ability to create new components or new relational patterns between components.

These *mechanisms* are the dynamic means of altering *components* or their relationships so that the system can undergo directed change.

Finally, these three types of mechanisms are each linked to a *capability*:

Replaceability: The ability to maintain functionality or change functionality through the substitution of components (identical or otherwise).

Transformability: The ability to maintain functionality or change functionality through recombination of components.

Adaptability: The ability to maintain functionality or change functionality through innovation of components.

These *capabilities* are defined by their ability to generate functional changes (either qualitative or quantitative) through modification of the system's *components*.

Components, *mechanisms* and *capabilities* relate as represented in Figure 4:

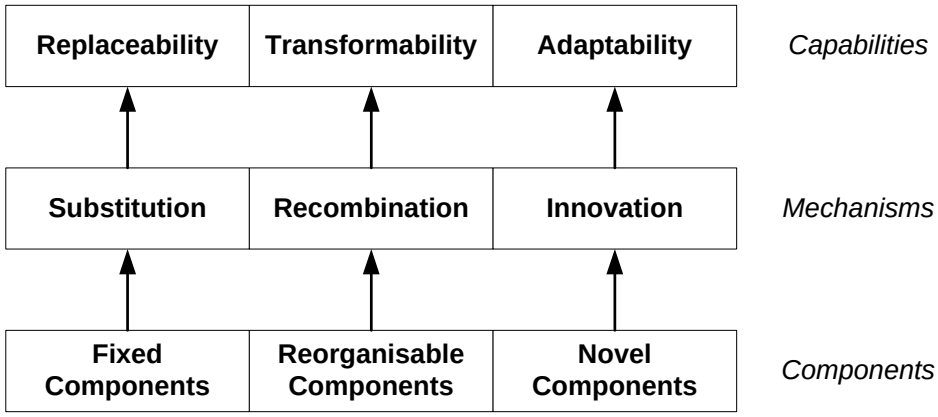

Figure 4 Layering and linking *Components, Mechanisms* and *Capabilities*.

This mapping has been derived through a logical decomposition of the ideas presented in the literature reviewed earlier. The mapping is an attempt to produce a simple yet coherent ontology.

Viewing the figure vertically, one can describe how *components* exercised through dynamic *mechanisms* can lead to system *capability*. For example, the existence of *reorganisable components* means that it is possible to rearrange these components through *recombination* into different patterns directly resulting in a system capable of *transformability*.

So far, the view of the system has spoken of *components*, *mechanisms* and *capabilities*, all internal qualities. The next step is to look at the external qualities of a system—those qualities that an outside observer would see.

[3] Substitution by identical components is straight-forward replication. However, the substitution by different components allows the possibility of changing the system functions, leading to a system which is *multifunctional*.

The Top-Down (External) View

From a system-level perspective, an important quality of any system is *fitness* for purpose, which we take to be strategic, operational and tactical *effectiveness* in the case of the military. *Effectiveness* is the ability of a system to achieve a desired or required outcome, even where that required or desired outcome has changed from its initial conception. It needs to be maintained in the face of both internal changes to the system or external changes (that occur in the system's environment) impacting on the system. A system able to maintain *effectiveness* in response to internal change is said to be *resilient*. A system able to maintain *effectiveness* in response to external change is said to be *robust*. In other words, all systems will have some degree of the following two *properties*:

Resilience: The ability to maintain or restore *effectiveness* after suffering internal damage or undergoing internal changes.

Robustness: The ability to maintain or achieve *effectiveness* across a range of external situations and environments.

Robustness and *resilience* are usually associated with coping strategies and a limited set of responses. Military systems also need to be proactive, changing their own capabilities in order to improve the fitness of the system within their environment (or in anticipation of changes) and thus *enhancing effectiveness*:

Enhancement: The ability to improve *effectiveness*, such as maintaining effectiveness across a wider range of external environments and/or increasing depth of damage, or simply increasing *effectiveness* for an existing set of conditions.

It is assumed that these three *properties* are distinct and encompassing enough to describe a broad range of situations.

The MCF identifies three lower-level attributes (coined *capacities* to be distinguishable from other parts of the framework) that uniquely underpin each of these *properties*:

Agility: The ability to maintain or change to required functionality in a timely fashion in response to changes in the external environment.

Redundancy: The ability to replace damaged functionality in response to internal failure or damage.

Creativity: The ability to generate new functionality.

Each of these *capacities* describes the required internal modification of functionality required to manifest the associated externally-perceived *property*.

These concepts and their relationships are represented in Figure 5 below.

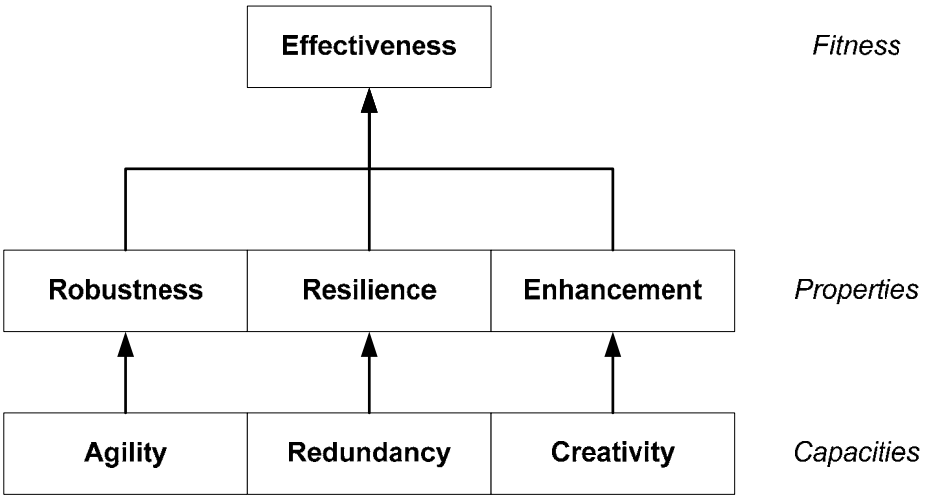

Figure 5 Layering and linking *Fitness, Properties* and *Capacities*.

As in Figure 4, this mapping has been derived through a logical decomposition of the ideas presented in the literature. In combination with the bottom-up view presented earlier, this provides a set of natural relationships between each of the concepts introduced to describe the Agility space.

Linking the two views

The only thing that remains is the linking of the two views. One needs to consider how each internally-focussed, mechanism-driven, *Capability* to generate functionality can potentially contribute to each externally-viewed, manifestation of *Capacities* to maintain or change functionality. In fact, the *Capabilities* (top level of the bottom-up view) all contribute in some fashion to the *Capacities* (bottom-level of the top-down view) with one key exception - *Replaceability* cannot contribute to *Creativity*, since by definition, simple replacement cannot create new functionality[4]. This suggests the linkages shown in Figure 6.

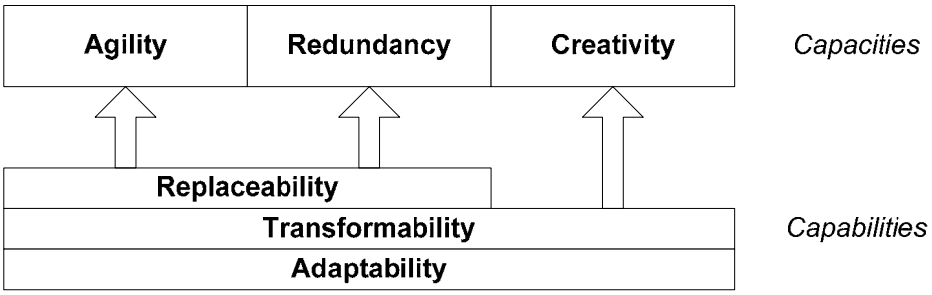

Figure 6 The linkage between the bottom-up and top-down views.

[4] Some might also argue that merely reorganising components within a system should lead to a limited finite set of possibilities, and thus *Transformability* also cannot lead to *Creativity*. In the strict sense this is true, but if the set of possibilities within a system is large enough such that it cannot be described or understood fully before implementation, then we believe that *Transformability* can be considered to contribute to *Creativity* in the sense that a user is doing something not anticipated by the force designers but for which the potential exists within the system. In terms of statistical physics, this is equivalent to the traversing of unexplored parts of state space. This is actually probably the most realistic situation, given the number of variables present in even a relatively small military force.

The Absence of Flexibility and Responsiveness as Explicit Attributes in MCF

Flexibility and responsiveness are terms used elsewhere but not explicitly included in the framework offered herein, although we believe they are really qualities describing any of the concepts that comprise the MCF. For example, "Power to the Edge" [5] defines flexibility as "the ability to employ multiple ways to succeed and the capacity to move seamlessly between them", a rich concept encompassing success measures, multiple choices and dynamic change. We narrowly define flexibility as the number of potential options (or states) the system can meaningfully move between. Responsiveness is then a measure of the timeliness or speed with which the system can actually move between its available options following some sort of stimulus (such as losses of attrition or the appearance of an unexpected threat). While narrowly defined by us, flexibility and responsiveness are qualities applicable to all of the concepts within the framework. That is, a system with significant *capacities* of *agility* and *creativity* is flexible; a system in which the *mechanisms* for *substitution*, *recombination* and *innovation* occur quickly is *responsive.*

The Complete Framework

Figure 7 shows the complete framework, with both the internal system of *components*, *mechanisms* and *capabilities* (the bottom three layers) and the external observable qualities as *capacities*, *properties* and *fitness* (the top three layers). The link between the layers is the thread that should allow the framework to be used in the process of design. In total, each concept within the framework (be it *substitution*, *creativity* or *resilience*) defines a *metacapability* that a system should have if it is to be *effective* in a dynamic environment.

This framework, while built on the foundations laid by others, provides a set of assumed independent concepts, identifying these as either internal components, mechanisms and capabilities, or as perceivable system-level qualities. Of note is the introduction of distinct (though abstract) types of components and mechanisms that describe how a system can be agile, can maintain redundancy and can be creative. The MCF has, therefore, framed important concepts introduced by previous authors in a way that aids analysis and design, and that allows one concept to be decomposed into other supporting concepts. For example, *redundancy* can be decomposed into its contributing *capabilities* and linked from there to the organisational *mechanism* that underlays it.

While systematically derived, further work is required to test the assumptions and the proposed linkages employed by the framework.

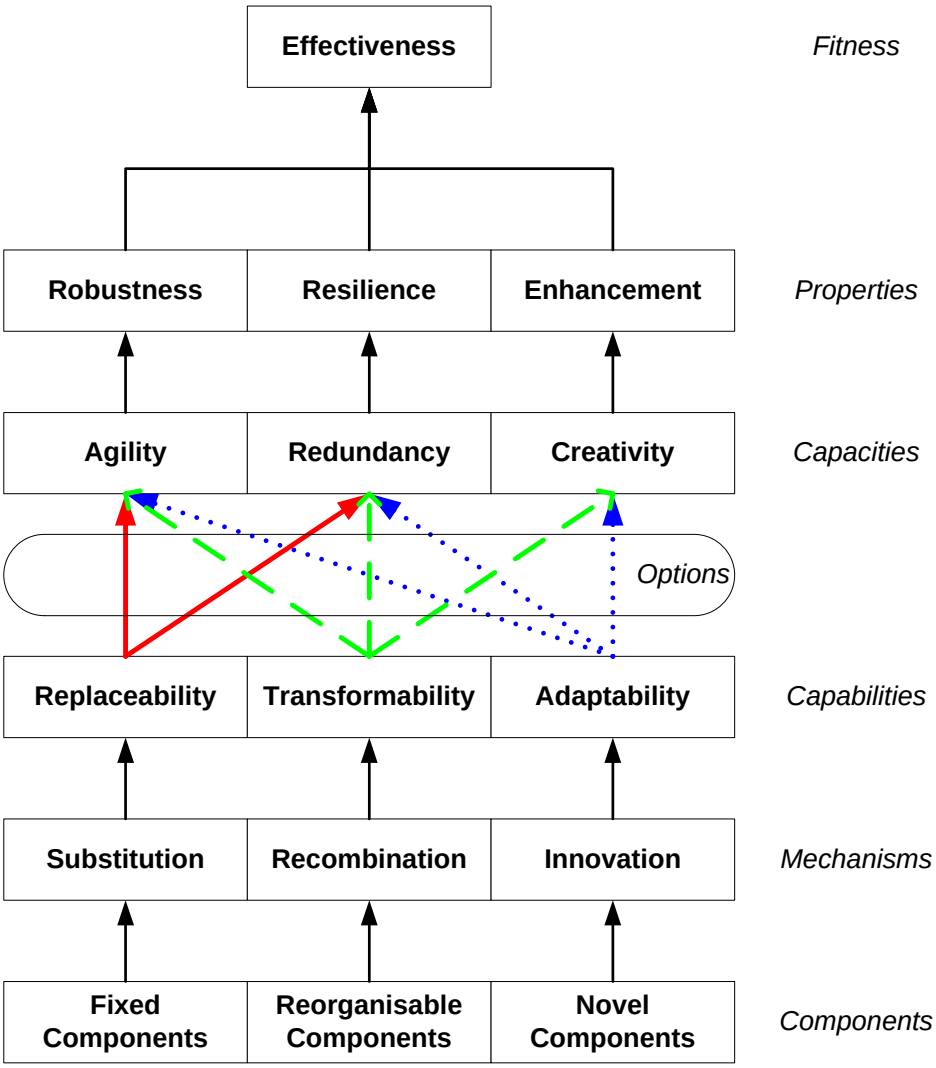

Figure 7 The Complete Framework

Application of the MCF to C2 and Force Design

The use of the MCF framework allows one to more clearly articulate both the attributes of value and the underlying design issues related to organisational robustness, resilience and enhancement. As such, it is applicable to both traditional force structure design and that driven by the modern concepts of Effects-Based Operations (EBO) and Network-Centric Warfare (NCW), by allowing for the articulation of very specific design questions. For example,

- Which parts of the C2 system are fixed (unchangeable) but can be made *redundant* or *agile* by having *replacements* (to maintain or change function)? For instance, Airborne Early Warning and Control aircraft (AEW&C) and Satellites.
- Which parts of the C2 system are modular and can be fitted together in different patterns to provide *redundancy*, *agility* and/or *creativity*? For instance, flexible command structures that permit different C2 designs.
- Which parts of the C2 system can evolve over time or are capable of creating completely new functionality (again providing *redundancy*, *agility* and/or *creativity*)? For instance, people (in the short-term) and technological innovation (in the long-term).

One can also explore and understand different force designs:

A view of traditional hierarchical systems

The construction of the modern hierarchical army aimed to ensure unity of purpose in the era of limited communication. Analysing it through the prism of the MCF, the mechanisms for change historically tended to be, primarily, through "fixed" components that allowed simple replacement or, at best, some multiple functionality. This remains the basis of much capability planning, but the promise of greater efficiency and effectiveness with concepts such as NCW and EBO is changing this (see, for example [5]).

Organisation and reorganisation of force structure allowed some improvement in effectiveness, shaped by the enemy and environment. Within the context of the MCF, this is known as *transformability*, leading to *creativity*. However, the *creativity* possible is limited by the finite (though large) number of combinations from which one has to choose. Technological advancement (change through *innovation*) often stimulated reorganisation of the force to better employ it [17]. Both these processes can be tracked in the MCF framework.

A view from the perspective of the mechanisms

The most basic approach to force design is the replication of fundamental units (as described by *substitution*). Each soldier with the same weapon (for example, a sword or spear) is essentially identical to another with the same weapon. Within limits, a fallen comrade was replaceable. This *replaceability* and consequent *redundancy* provided for some *resilience* of a force.

Most ancient weaponry were single function but some could be considered multifunctional (*replaceable* in function). Likewise, individuals may be trained to carry out different roles.

This ability to reorganise and transform can contribute to both *robustness* and *resilience*, depending on their final application. The number of options for change indicates the level of *flexibility* of the force. The speed with which this change can occur indicates the level of *responsiveness* of the force.

The ability to produce novelty (whether in weaponry, tactics, operations, or strategy) further supplements the aforementioned types of internal change. What has been enduring has been the innate *adaptability* of the human being who can create new objects or concepts. This ability can also contribute to both *resilience* and *robustness* (but also *creativity*), depending on the final application of this novelty. The number of options indicates the level of *innovation* possible, though this should be seen in light of the utility of this *innovation* (ultimately measured by its effectiveness). At a basic level, it can be individuals using traditional weapons in novel ways. In historical terms, this has mostly manifested in new strategy and tactics and ways of structuring and operating a force. However, technological innovation has provided improvements and enhancements of capability. This is especially so when combined with innovative employment or simply a reorganisation of the original armed force.

As before, the processes can be explained in a natural way through the MCF framework.

Historical Case Studies

As a step in the evaluation of the Metacapability Conceptual Framework offered here, two specific but limited historical examples are interpreted using the framework. Our limited analysis suggests that, at least in principle, historical cases can be interpreted using the language offered by our framework—this provides a preliminary test of whether the ideas contained in the framework are broadly valid.

The first of the examples draws on the development of artillery tactics during the French Revolutionary and Napoleonic periods of the late 18th and early 19th centuries, the second on the command and control system adopted by Napoleon and implemented so effectively within the Grand-Armée and its constituent all-arms corps.

Napoleonic Artillery Tactics

The Battle of Friedland (14th of June 1807) marks the formal appearance of large artillery formations used as the 'spearhead' in Napoleon's battlefield tactics [16]. This transformation, although compensating for poorer troop quality and diminishing numbers of cavalry, was the culmination of improvements in artillery doctrine and its associated organisational structures and processes.

This evolution in artillery doctrine was founded upon technical and organisational developments that occurred between 1802 and 1805, with the introduction of standardised gun calibres. Although not fully adopted as originally planned, the replacement of four and eight pound guns with standard six pound guns meant a larger number of equivalent *fixed components*, leading to the ability to *substitute* one component for another, which enhanced the degree of *replaceability* within the military organization. *Replaceability* supports *redundancy* and therefore *resilience*. McConachy [16] observes that losses of these new cannon could be compensated for by the cannibalisation of previously captured Austrian and Prussian guns, but also that the standardised gun made replacement of losses logistically and doctrinally simpler. In the words of the MCF, *fixed components* enhanced *replaceability* through *substitution*, thereby improving *redundancy* and consequently *resilience*. This analysis, in particular, highlights a particular strength of the MCF: its ability to allow decomposition of system-level *properties* into internal *capabilities* and *mechanisms*.

Mobility of the guns was significantly improved by the technical innovations in gun design that reduced weight, but also by the use of two *components* heretofore independent. However, the biggest innovation was brought about by the concept of horse artillery, first established in 1759 by King Frederick II of Prussia. In 1792, a new formation, the horse artillery, was born. By 1794, the horse artillery became a distinct branch of the French artillery arm. The result was artillery companies that were highly manoeuvrable, achieved by the use of *reorganisable components* (the notion of mounted soldiers and the 6 pounder guns) put together through *recombination*, resulting in a *transformation* to the way artillery were structured and used. *Transformability* enabled *creativity*, and therefore an *enhancement* of the

properties of the artillery arm. If the ability to reorganise components had not been available, the final enhancement may not have been realised.

Perhaps the most striking example of the MCF is in application to Napoleon's gradual move towards massing of guns. Napoleon recognised the values of forming grand-batteries by adding companies together. Each battery was a *component*, but he allowed for them to be added together as *reorganisable components*, providing him with the ability to mass them or disperse them as required to cope with the circumstances. Here, we see at play the notion of *recombination* leading to *transformability*, supporting *agility* and thereby *robustness*. An army's strength became "measured in guns rather than in battalions" [16, p633]—that is, *reorganisable components* and the *recombination mechanism* became the deciding factors. The ability to mass in such a way completely reshaped the use of artillery—they became the spearhead used to create a point of exploitation in the enemy's line. The grand battery, a *recombination* formed of *reorganisable components*, *transformed* the role of the artillery. From an external point of view, Napoleon's Grand Battery was a *creative* act that *enhanced* the army's *effectiveness*. Artillery became the decisive force rather than the supporting force. The Grand Battery was an innovation that allowed 'pro active' adaptation, resulting in *enhancement*—the property of improving *effectiveness*. Napoleon's system "cemented the leading role of artillery" [16, p640] and it is as relevant today as it was in 1807.

Napoleon's system of command

A decentralisation of command was part and parcel of the revolution in strategy overseen (if not implemented) by Napoleon. Napoleon's campaigns were characterised not by a centralised control of the entire army (as was exercised by Roman commanders, for example), but by a decentralised force that was structurally and doctrinally designed to facilitate independent operations with degrees of both directed and mission-oriented command.

The first step to achieving this can be seen in Napoleon's development of the all-arms corps as a standardised unit. The all-arms corps itself incorporated cavalry, artillery and infantry, and each corps shared the same organisational structure. In van Creveld's words, corps could be combined to "create a predetermined formation [and were also] capable of changing their relative positions at a moments notice" [17, p61]. Importantly, "corps were roughly interchangeable and able to exchange roles without further ado" [17, p61]. We can interpret the all-arms corps (both the force structure and the command and control system) as *fixed components* that, through the *substitution* mechanism, gave the army the *replaceability* capability. In the MCF, *replaceability* is an internal capability that produces the external capacities of *agility* and *redundancy* that contribute to properties of *robustness* and *resilience* (in van Creveld's words, corps were interchangeable).

An example of the concept of the all-arms corps providing Napoleon's Grand-Armée with the ability to cope with unexpected external events is available in Napoleon's Jena campaign (1806). While Napoleon battled at Jena, his independent corps under Davout was enacting his very same orders and managed to intercept the main Prussian Army at Auerstädt [17]. With a set of (effectively) identical *components* (including Napoleon's mission-oriented orders acting as a substitute for Napoleon's actual

presence), Davout's forces could replace those of Napoleon (who was battling at Jena, some 15 miles away). The Grand-Armée had the *agility* to adjust to the changing circumstances and still maintain its effectiveness because it had the capability of *replaceability*. Reversing the argument, if a collection of effectively identical corps had not been instituted, then the mechanism of *substitution* would not have been possible, and the main Prussian Army may not have been dealt with at Auerstädt. Napoleon's Grand-Armée may not have had the *agility* to exploit the opportunity to the same effect.

In both examples, the language and ideas of the MCF can be mapped to the historical analysis independently provided. The ability to correlate independent analyses from two historical examples of force-level adaptation to the MCF construct provides a first step in testing the veracity of our framework. Of course, validation and development remain ongoing.

Comparison of MCF with DODCCRP C2 Agility Concepts

Finally, since a significant portion of the work in this area is founded upon, or draws inspiration from, the extensive DODCCRP conceptual development, we will briefly examine the relationship of the DODC CRP concepts with our framework by mapping the DODC CRP terms onto the MCF terms.[5] The diagrammatic mapping from the DODCCRP concepts to the MCF concepts are given in Figure 8 and the following discussion makes reference to this diagram. DODCCRP concepts are represented in coloured ovals.

Mapping at the level of fitness: The DODCCRP views Agility as the overarching attribute. It is stated that the ultimate objective of Effectiveness is assumed [4], and the DODCCRP acknowledges the overlap and interdependency of their concepts of Agility and Effectiveness. The DODCCRP idea of "Agility" is, then, most similar to our peak concept of *effectiveness* and may be viewed as "the ability to maintain, sustain and enhance performance in the face of changing internal and external conditions".

Mapping at the level of capacities and properties: The DODC CRP concept of Resilience encompasses both MCF *robustness* and *resilience*. The DODCCRP concept of Responsiveness focuses upon timely reaction to changes in the external environment. Within the MCF, this appears to correspond most closely to the two distinct concepts of *Robustness* and *Agility*. The DODC CRP concept of Flexibility encompasses much of this entire layer in the MCF, simply because it is an expansive idea (see previous discussion).

[5] It should be noted that these are our interpretations of the DODCCRP sources and the choice of any mapping is imperfect and open to debate.

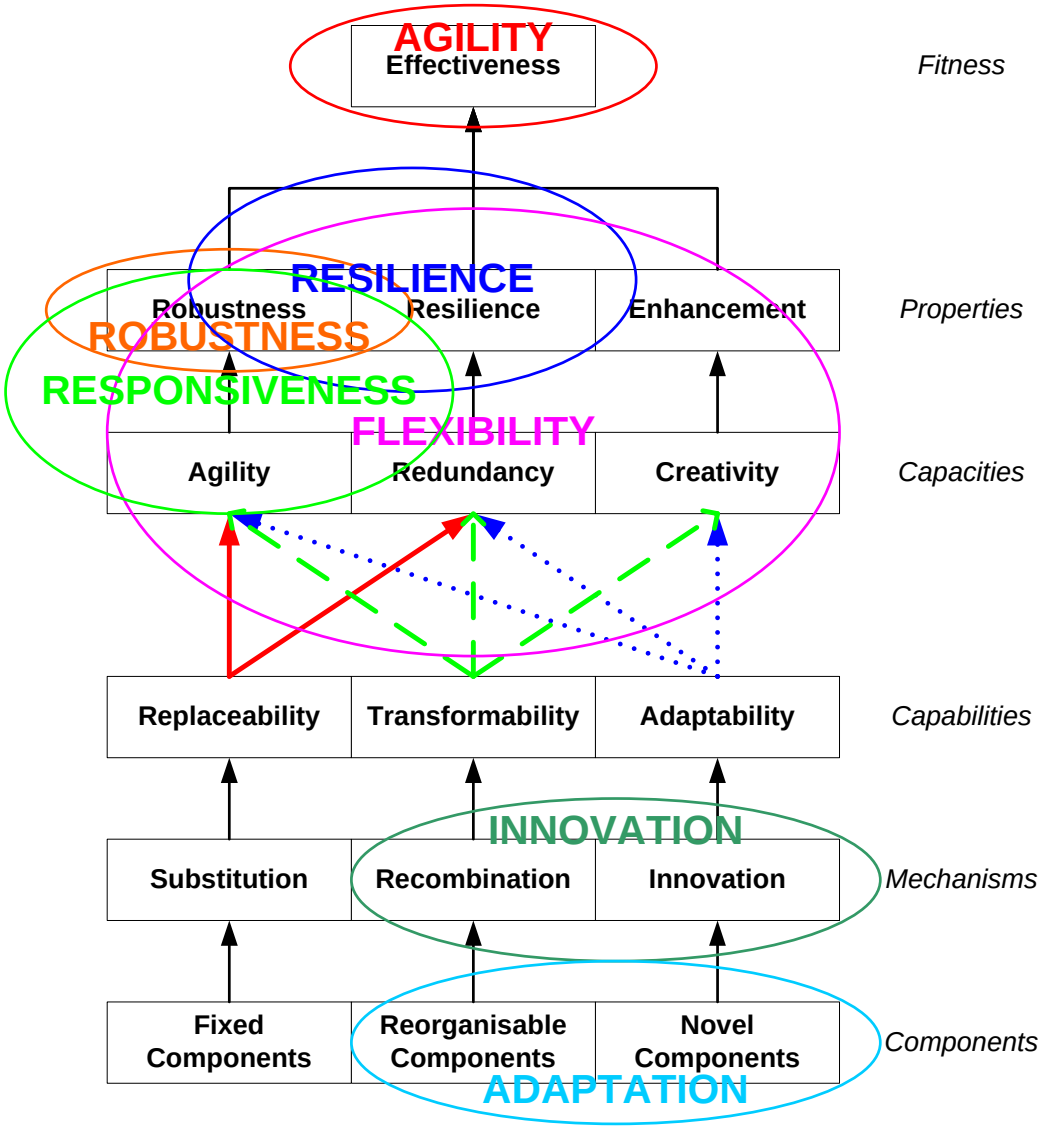

Figure 8 A mapping of DODCCRP C2 Agility attributes to the MCF metacapabilities.

Mapping at the level of components, mechanisms and capabilities: Deconstructing DODCCRP concept of Innovation, the first part of the definition states "the ability to do new things". This is directly equivalent to the MCF mechanism of *Innovation* (which confers the system with the capability of *Adaptability*), which specifically defines itself as "the ability to create new structures and processes). The second part of the definition states "the ability to do old things in new ways ", can be interpreted to encompass both mechanisms, *Innovation* and *Recombination*. The DODCCRP concept of Adaptation is another description that also contains two distinct parts, but which is most closely aligned with both *Reorganisable Components* and *Novel Component* in the framework offered herein.

In summary, the DODCCRP formulation contains descriptors of key concepts important to discussing and visualising the nature of future C2. The MCF formulation provides a structure within which the mechanisms can be more clearly articulated and defined, which is important for the ability to operationalise the concept of "Agility".

Conclusions

The explicit focus upon the distinction between internal and external changes and on the decomposition of systems into structure and process permits the development of a coherent and consistent conceptual framework. A critical innovation of the framework has been the demarcation of three different types of mechanisms that permit internal change. It is important to note that these are not mutually incompatible, with real systems usually exhibiting all three simultaneously, to differing extents.

We have provided a discussion on the relevance of the MCF framework to the understanding and design of both traditional and non-traditional C2 systems. The framework builds on prior work while introducing a new (and hopefully useful) view of the Agility problem space. Its strength is in its rigorously defined ontology.

Previously developed concepts can generally be treated as "higher order" concepts in relation to our framework. This reinforces the ability of this framework to decompose abstract notions into constituent and contributing parts in a coherent and distinct way. Historical examples provide evidence for the applicability of the offered framework, by functioning as an externally valid lens through which to interpret the relationship between *components*, *mechanisms*, *capabilities* and ultimate *effectiveness.* In essence, they provide some measure of validation of the ideas presented above, although considerably more work must be done before the framework is demonstrated to be generic or robust enough to be broadly applied. Finally, two other challenges remain to us. An important step in facilitating the use of the MCF is to define the practices needed to institute the components and mechanisms that give rise to our capacity for *agility*, *redundancy* and *creativity*. Defining useful measures for determining the extent to which an organisation exhibits these capacities and their associated properties is also critical.

References

1. Sun Tzu, *The Art of War*, trans. Cleary, T., Boston, MA: Shambhala Publications, 1988.
2. McEver, Jimmie and Danielle Martin, Evidence Based Research, Inc. "Operationalizing C2 Agility", Information Age Metrics Working Group, 13-Dec-2006.
3. McEver, Jimmie G., Danielle M. Martin and Richard E. Hayes, "Operationalizing Agility", 12th International Command and Control Research and Technology Symposium, Newport, RI June 19, 2007.
4. McEver, Jimmie G., Danielle M. Martin Richard E. Hayes, Evidence Based Research, Inc. "Operationalizing C2 Agility: Approaches to Measuring Agility in Command and Control Contexts", 13th International Command and Control Research and Technology Symposium, 2008.
5. Alberts, David S. and Richard E. Hayes., *Power to the edge: command, control in the information age*, Washington, DC: CCRP Publication Series. 2003.
6. United States of America Department of Defence, *Net-Centric Environment Joint Functional Concept* version 1.0, 2005.
7. United Kingdom Ministry of Defence Joint Doctrine and Concepts Centre, *The UK Joint High Level Operational Concept*, 2003.

8. Clark, Thea, "Classes and Levels of Adap tivity", The Technical Cooperation Program Symposium, CAS for Defense, Adelaide, July 2006.
9. Alberts, David S., *Information Age Transformation: getting to a 21st Century Military*, DoD CCRP Publication Series, 2002.
10. Garstka, John & David Alberts, *Network Centric Operations Conceptual Framework* Version 2.0, Evidence Based Research, Inc., 2004.
11. United States of Am erica Department of Defence, *Joint Command and Control Functional Concept*, 2004.
12. United Kingdom Ministry of Defence, *Future Air and Space Operational Concept*, 2005.
13. Lloyd, Merf yn, "Commanding Mission Groups: A sp eculative m odel", 9th International Command and Control Research and Technology Symposium, 2004.
14. Harland, Steven J., Paul J. Shanahan and Da vid J. Bewick, "Agile Comm and Capability: Future Command In the Join t Battle space And Its Im plications f or Capability Development", Command and Control Research and Technology Symposium, 2004.
15. Grisogono, Anne-Marie, " What is adaptation? ", The Technical Cooperation Program Symposium, CAS for Defense, Adelaide, July 2006.
16. McConachy, Bruce, "The Roots of Artillery Doctrine: Napoleoni c Artillery Tactics Reconsidered", *Journal of Military History*, 65(July 2001), pp617-40.
17. Van Creveld, Martin, *Command in War*, Cambridge, MA: Harvard University Press, 1985.