NEC Themes: A Conceptual Analysis and Applied Principles

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Abstract

This paper deals with essential principles of Interoperability, Agility, Collaboration and Knowledge applied in the context of Network Enabled Capability Through Innovative Systems Engineering (NECTISE). Using empirical investigations these concepts have been identified as NEC-readiness themes and they contribute significantly to the realisation of NEC. Based on a systemic analysis and application of theoretical principles, the approach described in this paper contributes towards the demonstration of NEC as well as the identification of a limited set of critical features for capability planning and systems design. Some research questions are derived and discussed and a gap analysis strategy is proposed. These themes also defined as critical features have been investigated in a variety of contexts The main contributions of this paper are related to the mapping the themes to the military capability model and formalisation of the relationships. The purpose of such an exercise is to exploit learning from other (mainly civil) domains in the military context, with regard to the readiness themes which overlap with a limited set of critical features for design within a NEC context.

1 Introduction

Following the success of NCW (Network Centric Warfare) programme in USA, the MoD launched the NEC (Network Enabled Capability) UK initiative which is built on similar principles, but is much more concerned with evolving capability within networking environments. NCW/NEC concepts are dynamic and the future military operations will benefit from related applied principles which are concerned with dynamic information sharing, and decision making in the battlefield [1]. The key aspect of NEC is faster capture, process or re-use of time sensitive information to provide adequate support to command and control in the operational military domain.

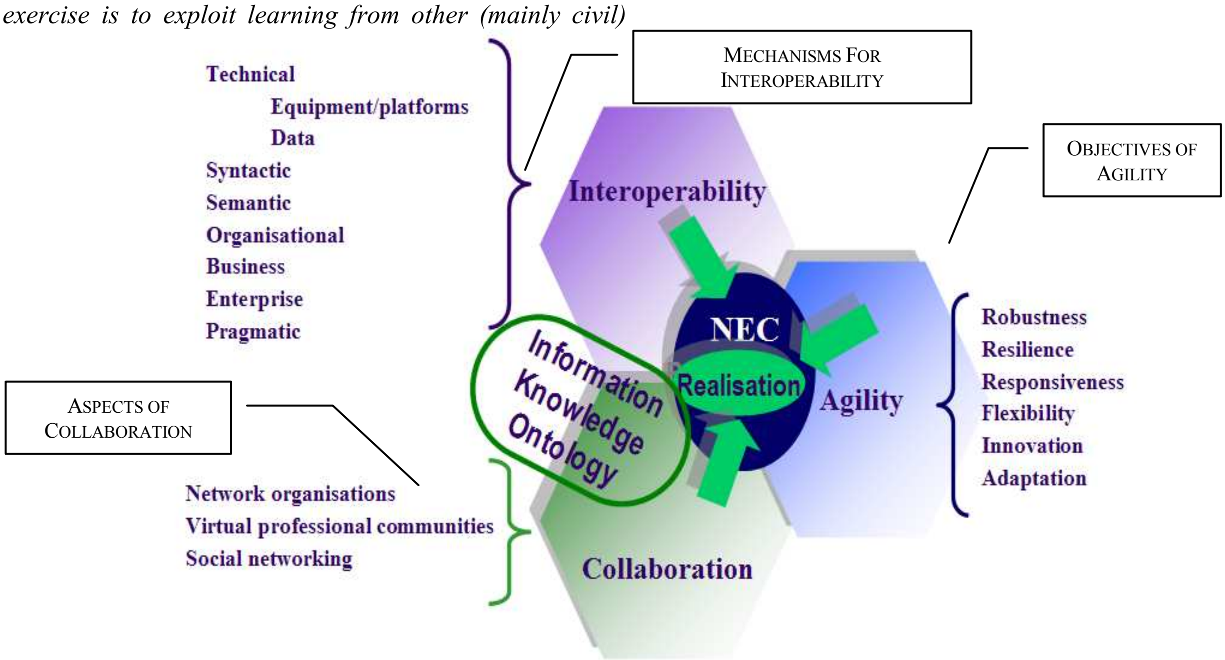


Figure 1. A Holistic View of NEC Themes

A set of NEC themes have been identified based on their significance for the assessment of NEC readiness in order to support the research programme demonstration and further realisation of NEC. These themes could also be defined as critical features used for NEC systems design and capability planning in NEC contexts.

Interoperability, agility, collaboration and knowledge themes are interrelated as shown in figure 1.

This figure also presents the main aspects including objectives, mechanisms and aspects of the selected main themes.

The relationships between NEC themes are supported by information, knowledge and ontology descriptions which are detailed in a separate section of this paper.

Agility is crucial for the success of military operations and is supported through highly interoperable systems and collaboration. Information and knowledge shared/exchanged are also essential to support agile and interoperable complex systems including military organisations and enterprises. The main objectives of agility are to achieve robustness, resilience, flexibility, responsiveness and adaptation. Innovation enables agility.

We now describe characteristics of the themes, derived from a variety of contextual investigations and consider the extent to which these may be relevant and useful for NEC.

2 Identification and Definition of NEC Themes

2.1 Agility

The concept of agility can be defined from different perspectives, such as (manufacturing) enterprise characteristic, (software) project development ability etc.

Some definitions of agility are presented in table 1, some of which describe the foundation of this concept from a manufacturing enterprise perspective that has been directed to agile supply chains. There is a considerable theory and research on agility instantiated in about 75 articles published during 1991-2000, but these are mainly focused on ***agile manufacturing***. From 2000 ***agile supply chains*** have been especially investigated. Agility can also be defined and approached from other perspectives such as software project development and teams collaborating or working together to achieve a specific target.

More recently, achieving agility and interoperability has been investigated. Modeling frameworks include model driven architecture (MDA) based on enterprise architecture (EA); and development solutions using Service Oriented Architecture.

Agility will prove to be the most important single characteristic of military forces in the 21st century [4]. Agility is determined by interoperability, collaboration and information/knowledge and this is explained in a distinct section of this paper.

2.2 Interoperability

Generally, the word "inter-operate" implies that one system performs an operation on behalf of another. [26, 27] has defined interoperability as the ability to communicate with peer systems and access the functionality of the peer systems. Systems interoperability is a key aspect for achieving agility.

The European Interoperability Framework [8, 19] has identified and defined the following three types of interoperability:

1. ***Organisational interoperability***. This aspect of interoperability is focused on the definition of business goals, modelling business processes and organisational collaboration issues. Moreover, organizational interoperability addresses the requirements of the user community by making services available, easily identifiable, accessible and user-oriented. Organisational interoperability has enabled globalisation.
2. ***Semantic interoperability***. This aspect of interoperability is concerned with ensuring that exchanged information is understandable in exactly the same way by any other computer system and/or human that was not initially developed for the same purpose. Semantic interoperability enables systems and/or human to combine received information with other information resources and to process it in a meaningful manner. Semantic interoperability is therefore a prerequisite for the front-end multilingual delivery of services to the user.
3. ***Technical interoperability***. This aspect of interoperability covers the technical matters of linking (computer) systems and services. It includes key aspects such as open interfaces, interconnection services, data integration and middleware, data presentation and exchange, accessibility and security services.

2.3 Collaboration

Collaboration is a (human) activity which may be supported through Information and Communication Technologies, involving 2 or more people/organisations sharing for mutual benefit. The shared aspects include: benefits, visions, rewards, purposes, knowledge, information, assets, and resources.

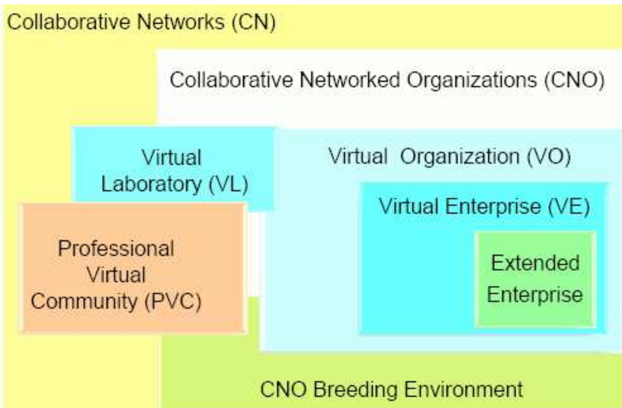


Figure 2. A classification of Collaborative Networks

Although there are some overlapping aspects between cooperation and collaboration, an analysis of the distinction should be useful. Collaboration has many different forms/manifestations, and usually involves trading in some form. It may be formal or informal and ad hoc or planned/organised. However the ad-hoc collaboration may be defined as social communication / interaction and the related supporting tools are developed as social computing systems e.g. Skype, Yahoo etc. These enabling tools have proved to be beneficial, but with some disadvantages. For example, studies have contrasted the benefits of using emails with the time wasted by workers sending private messages and the increased risk of privacy being compromised.

An important concept is ***Computer Supported Cooperative Work*** (CSCW) that was coined by Cashman & Greif for a workshop definition in 1984 [12]. CSCW has involved the development of many of the features studied in this area and research has continued in interdisciplinary areas including computing science e.g. human computer interaction, sociology, psychology and linguistics.

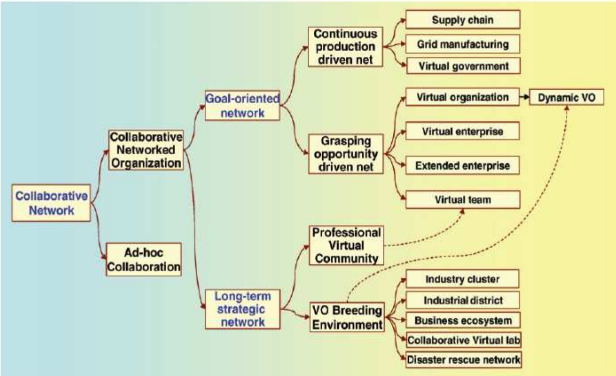


Figure 3. A taxonomy of Collaborative Networks [7]

Collaborative networks are emerging in a large variety of forms, including virtual organizations, virtual enterprises, dynamic supply chains, professional virtual communities, virtual organization breeding environments, collaborative virtual laboratories, etc.

A classification scheme for collaborative environments has been suggested and adopted within the European FP6 project ECOLEAD (European Collaborative Networked Organisation Leadership Initiative) This classification scheme is shown in figure 2 [7]. This project has defined the collaborative network (CN) as an association consisting of entities (e.g. organisations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, and whose interactions are supported by a computer network. Most forms of collaborative networks imply some form of organisation over the activities of their constituents, identifying roles for the participants, and some governance rules. Therefore, these can be defined as collaborative networked organisations (CNO$_s$). The approaches of the ECOLED project have included the definition and development of effective support tools to promote trans-national co-operation/exchanges. This project has also developed a taxonomy of collaborative networks as presented in figure 3 [7].

2.4 Information, Knowledge and Ontology

Knowledge could be analysed from 2 main perspectives: analytical and empirical. The conventional analytical model which shows the transformation of data into information and further to knowledge and wisdom is defined as follows:

data ==> information ==> knowledge ==> wisdom

Data is a collection of unanalyzed observations of worldly events.

Information is a summary and communication of the main components and relationships contained within the data and presented within a specific context.

Knowledge is an interrelated collection of procedures for acting toward particular/specific results.

The fundamental knowledge models are as follows [20]:

- ***Tacit knowledge***: implicit, mental models and experiences of individuals.
- ***Explicit knowledge***: formal models, rules and procedures.

Additionally, ***knowledge*** could be classified as follows:

- Knowledge about the past which is stable, voluminous and accurate;
- Knowledge about present which is unstable, compact and may be inaccurate;
- Knowledge about the future which is hypothetical.

The area of ***knowledge management*** (KM) including the capture, share/transfer and (re-)using of knowledge has been widely discussed in the literature. Knowledge is one of the fundamental resources a company possesses [11]. Szulanski (2003) among others has discussed the components of successful knowledge transfer: source, receiver, knowledge itself and the context in which knowledge transfer occurs [25]. Despite the increased interest on this subject, managers find that knowledge does not always transfer easily [2] and that knowledge has not always been actively and correctly managed [5]. Trust as a critical element to knowledge transfer as well as collaboration. Computing systems have an important role in knowledge management and the related programmes could be defined and developed as knowledge based systems.

In general, the literature on KM can be divided into 2 schools of thought: There are those more concerned with finding means of analysing knowledge within a systematic context: (organisational) culture, values, schema, belief system, tacit norms, embedded routines [5]. On the other hand, there are those whose approach is concerned with finding means of analysing knowledge as quantitative explicit, measurable and strategic [16, 22, 24].

There are also several studies and approaches to information, knowledge and ontology modelling to support global manufacturing [15] team collaboration, concurrent engineering [9, 14] and decision support systems as well as product design and manufacture. Liu and Young (2007) have dealt with global manufacturing decision support and have investigated the types of information, knowledge models and relationships as follows [15]: (a) relationships between information and knowledge features within a single information and knowledge model; (b) relationships between different information and knowledge models at one organizational level; (c) relationships between different information and knowledge models at different organizational levels. The

corresponding information and knowledge structures have been represented using Unified Modelling Language (UML).
Ontology is becoming increasingly beneficial in area of knowledge management. The main reason ontologies have become so popular is the fact, that they provide a shared and common understanding of a domain that can be communicated between people and application/computer systems.

An ontology is a specification of a conceptualization related to a domain [13] in a human-understandable and (possibly) computer/machine-readable form, and typically, comprises the classes of entities, relations between entities and the axioms which apply to the entities; it is domain-dependent. In other words, it is an explicit specification or a formal and declarative representation of some areas. It could be based on taxonomy definition which is presented in figure 3 Ontology is a developing research topic, with interest from several communities such as intelligent computing, knowledge management, enterprise and organisation integration and networking as well as industrial real-time systems. Moreover, ontologies may support value assessment and measurement of relevant information and knowledge.
In computer systems an ontology is the working model of entities and interactions in some particular domain of knowledge or practice, such as networking. In Artificial Intelligence (AI), according to researchers at Stanford University, ontologies can be used to express "a set of concepts such as things, events and relations that are specified in some way in order to create an agreed vocabulary for exchanging information, in particular over the web." Apart from providing a common understanding, Valarakos et al. (2004) also state that ontologies can be used to facilitate dissemination and reuse of information and knowledge [29].
The main computational technologies used to describe, derive and process ontology are the Process Specification Language; and Web-based technologies which include standards and languages such as eXtensible Markup Language (XML), Resource Description Framework (RDF), Web Ontology Language (OWL) and Metadata Interchange Format (XMI).

3 Current State-of-the Art

The breadth of interpretations of the concepts of agility, interoperability, knowledge and collaboration has been indicated above. There is also much applied research on these themes from generic to particular levels of systems and enterprise applications. However, *the existing approaches do not fully apply to NEC as a military domain concept and for achieving missions / operations.*
Previous studies dealing with interoperability, collaboration and agility in military domain include those by Alberts (2005) [4] as well as Atkinson and Moffat (2005) [3]. However these approaches have limited and less formal analysis despite their comprehension and valuable impact for military organization and operations. Reid et. al. (2005) have even suggested fundamental qualitative research methods for the analysis [21]. In a NEC battlefield there are several challenges which have not been addressed by previous research and to which

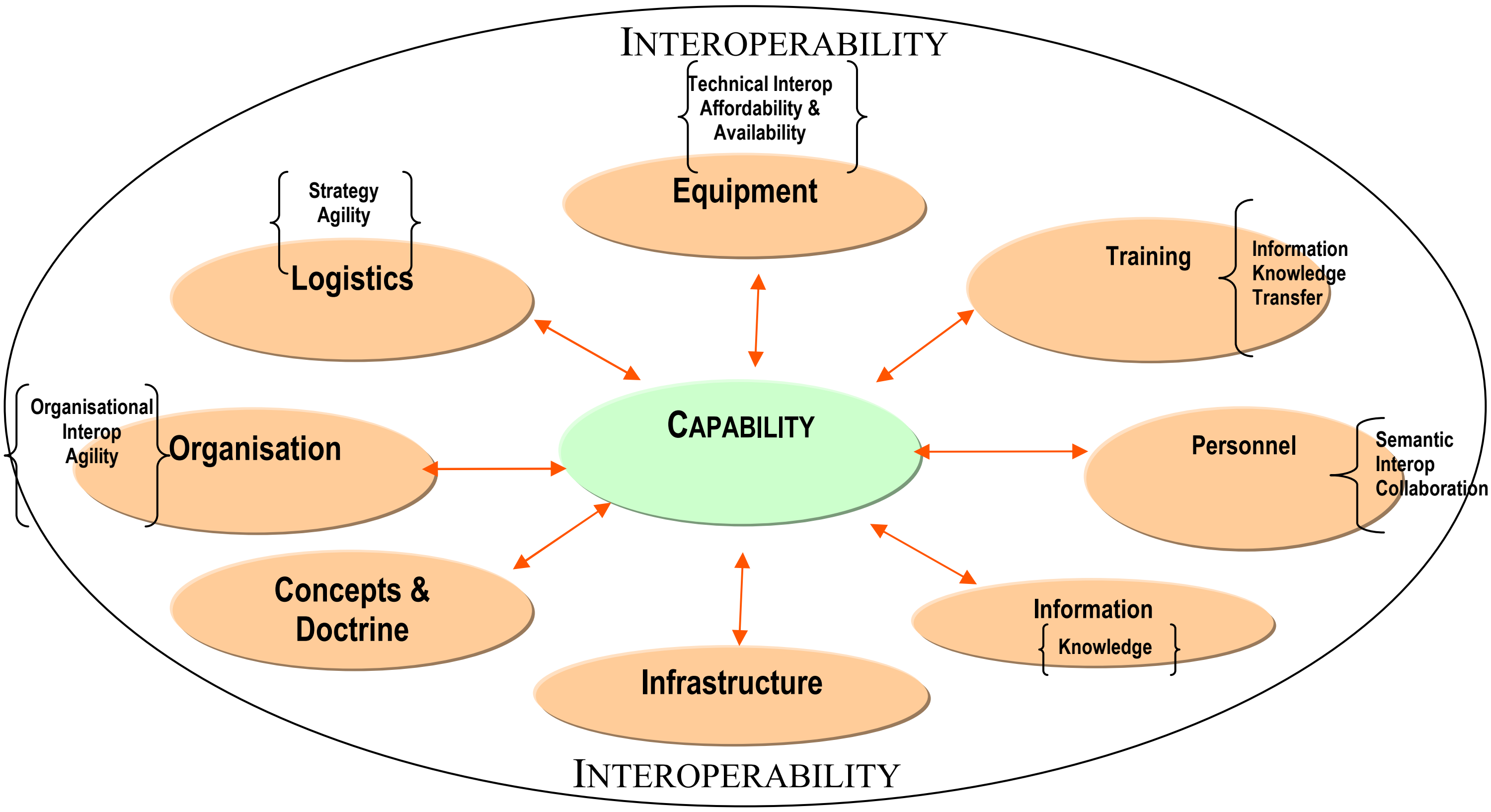


Figure 4. Linking Capability Model to NEC Themes

NECTISE research programme can significantly contribute.

An initial identification of gaps is being carried out as shown in figure 5, and work is currently underway to analyse these further. These gaps are mainly analysed based on the articulation of the following research questions:

1. What are the commonalities and differences between Network Enabled Capabilities and supply chain networks and/or virtual/extended enterprises?
2. What are the similarities and differences between the development and implementation of CSCW and NEC Realisation?

Generally networking includes two main streams [7]:

a. Enterprise-centric approaches, which start from the enterprise level and incrementally extend/adapt resources and competency aspects in the context of networks of enterprises.

b. Network-centric approaches which emphasise primarily, the networks and their properties, rather than the characteristics of the individual elements such as enterprise or organisations. Similarly, NCW emphasises the networking aspects. The focus of NEC is capability, but enabled by networks.

3. How should the existing modelling approaches should be applied to define a NEC (meta) model? The existing modelling approaches include SCOR (Supply Chains Organisation Reference Model); CPFR (Collaborative Planning, Forecasting and Replenishment), ARCON (Towards a Reference Model for Collaborative Networks) among others.
4. What should be the critical elements within military capability models to be analyzed and compared with a reference model for networks?

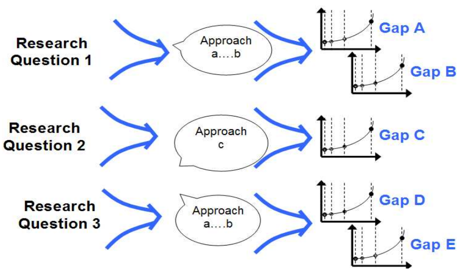


Figure 5. Multiple Gaps Analysis

5. If existing modelling approaches do not apply, what critical issues for military organizations and operations are not considered and should they require modelling of other key aspects ?

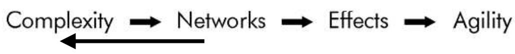
4 An Analysis of the NEC Themes Applied to Military Capability

Network enabled military capability is one of the Ministry of Defence's major endeavours which aims to provide shared awareness to facilitate communication, command and management across the battlespace [28]. New approaches of capability planning, development and management are required and Yue and Henshaw (2008) have developed a holistic approaches of UK Military Capability Planning as a conceptual model. Moreover "system of systems" approaches should be based on newly identified methods of systems engineering, and probably new other closely related topics will be defined such as capability engineering. Presently, aspects of systems engineering research (mainly pursued within NECTISE) have defined key elements of capability engineering, network enabled capability and associated themes such as interoperability, collaboration, knowledge, agility, affordability etc.

The issues of the capability model and its representations across UK Defence Lines of Development (DLOD) could be linked to NEC Themes as shown in figure 5. Due to the pseudo fractal nature of military capability as defined by Yue and Henshaw (2008) the NEC Themes may also be analysed based on using the fractal theory [34]. However, so far there is not any research on mapping the NEC Themes to the components of military capability model as shown in figure 4.

There is no doubt that interoperability will be a key consideration in incremental delivery of capability; and support for using new and legacy equipment. However its wider implications related to equipment, people and technologies are worthy of further analysis. The introduction of the interoperability of capability models should be beneficial and interesting.

Atkinson and Moffat (2005) have analysed the impact of the following relations for the military organization [3]:



(a)

A comprehensive analysis of the relationship (a) is concluded by discussing the need for a shift towards the creation of informal, adaptive, and complex networks of interaction that will have sufficient agility to match our adversaries. The relationship between networks and complexity is bidirectional though Atkinson and Moffat (2005) has defined only one direction dealing with complexity through networking [3]. The increasing complexity of collaborations in highly dynamic environments oftentimes is underestimated [23].

The European project COLL-PLEXITY aims at an interdisciplinary development of a Generic Model of Complexity (GeMoC). The GeMoC is developed in cooperation with research institutes as well as with partners from industry, which provide a basis for the complexity focused problem-to-system match framework for collaborative systems in the production industry. The analysis carried out within this project has focused on organizational complexity at a managerial level, provoking a paradigm shift in the field of complexity science and striking a new path to tackle the problems of industrial networks. This analysis may be applied to military networks as shown in figure 6 which demonstrates that considering the number of partners as a complexity related variable—the alleged interrelations between the aforementioned two types of complexity, the point of lowest complexity (C_{min}) that can be realized for a specific problem or task; and the resulting optimal point of complexity (C_{opt}) whilst considering system boundary conditions [23].

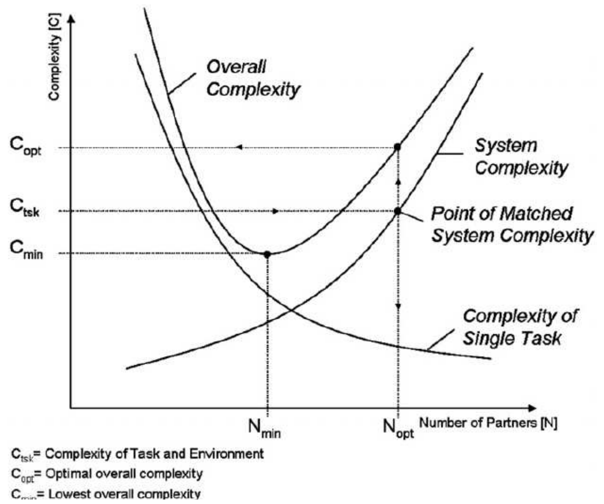


Figure 6. Interelations between collaboration and complexity [23].

According to Atkinson and Moffat (2005) the realisation of Network Centric Warfare and Network Enabled Capability imply "Moving from ruled (institutional) to trusted (more networkable) organizational structures; and accepting that technology may aid but should not dominate command." [3].

5 Discussion and Reflection

From analysis based on an holistic approach to capability and the background of NEC, themes have emerged concerned with NEC-readiness. Existing definitions and approaches to these themes do not fully satisfy the NEC requirements, mainly due to the following aspects:

- Primarily, networking of capability requires new systems engineering approaches and this paper aims at defining some principles of interoperability, agility, collaboration and knowledge which become "pioneering" applied research within NECTISE;
- Systems of Systems typically consist of component systems with heterogeneous ownership / management and their interoperability is motivated by achieving better functionalities than any one component system. Interoperability is essential for realizing a level of autonomy that allows Systems of Systems to respond to change and challenges. Therefore interoperability is much broader in scope and it should be defined at the level of capability models. Capability interoperability or interoperability of capabilities should be appropriate to be introduced and defined. "Jointness" and interoperability within some military operations such as those conducted by NATO remain a key challenge due both to technological and doctrinal gaps.
- There are similarities between the military collaboration that NEC should promote and the mechanisms for informal, or ad hoc, realization, evolution and dissolution of virtual organizations in the business world. Such virtual organizations operate as such to achieve agility in the market place; the techniques and collaborative behaviours may have application in the military world, though the constraints on such techniques (e.g. balance between collaboration and security) must be clearly understood.
- The relationships and associated metrics / measurement of agility, interoperability and collaboration are not defined and a modeling approach to these issues is proposed and discussed below.

Figure 7 shows conceptually how the dependency and optimization between the three themes of agility, collaboration, and interoperability may be examined. The priority relationships that define the surface of optimisation must, however, be formalized so that the correct balance may be derived.

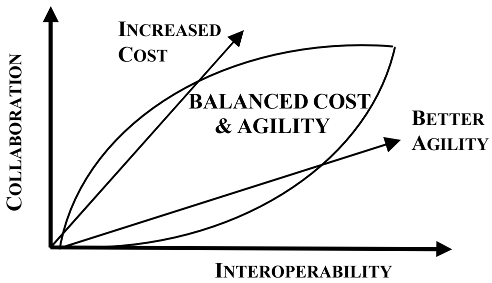


Figure 7. The global dependency between some NEC themes

NEC Themes holistically represented in figure 1 are characterized by attributes and/or features and therefore a systemic notation could be applied.

Collaboration $C = \{C_1, C_2 \ldots\ldots C_{n.}\}$
Interoperability $I = \{ I_1, I_2 \ldots\ldots I_n\}$; and
Agility: $A = \{A_1, A_2 \ldots\ldots A_n\}$

The detailed relationships, implications and dependencies of attributes as well as the individual themes such as C, I and A could be defined as depicted in figure 8.

The identified attributes for agility are robustness, resilience, responsiveness, flexibility, innovation, adaptation and leanness. Leanness concept has an interesting relationship with agility which is difficult to make explicit and formalise. A few studies have demonstrated that agility might presume leanness, but pursuit of leanness might not presume agility.

Narasimhan et al. (2006) are disentangling leanness and agility using an empirical investigation. The related study also has defined the following research questions [18]:

a. Do lean and agile paradigms emphasize essentially the same aspects (practice and performance dimensions), or are they distinctly different?
b. If they are different, do leanness and agility performance dimensions accurately describe actual differences in operational performance at the plant level?
c. Are lean and agile systems competing or complementary? Is one a component or precursor of the other?

Considering one attribute of collaboration is trust. The relationship between trust and the agility attributes could be defined using the model described in this paragraph, but additional research and in-depth investigations are required.
Essentially, this requires the discovery of some functions such F (C, I, ….) = A
This implies that some quantification of the attributes must be achieved, but it is important to note that it is trends of dependency that are required, rather than absolute values.

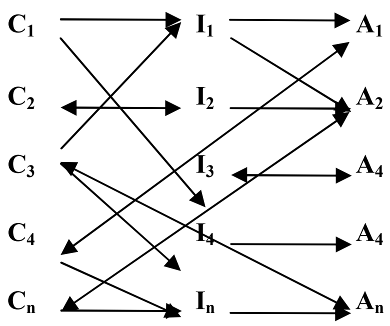


Figure 8. The real relationships and dependency between NEC Themes

6 Way Forward and Conclusion

The important aspects which require additional research are as follows:

- Identification and demonstration of the priority, and the contribution, of themes for the realisation of NEC, based on the modeling approach preliminarily defined in this paper.
- Detailed gap analysis especially of NEC Themes applied in military domain.
- Complete definition of a formal model of NEC themes using appropriate theories such as game theory.
- Metrics and performance measurement approaches for evaluation of the themes and their interrelationships.
- Complete definition of critical features and related strategies for systems design and capability planning in a NEC context.

Usually, an intuitive understanding of complexity is the basis of systems analysis of the behaviour of complex systems or systems of systems. Complexity arises from not only the dimension of the system but also from the interrelationships of the system components and the emergent behaviour that cannot be derived from the individual system components such as individual NEC themes. Efforts for measurements of complexity have been made and entropy theory or Petri Net is applied, but there is still much to do. Additionally, the evidence of this approach will be provided through examples as well as ethnographic research and qualitative analysis.

7 Acknowledgement

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Table 1. Agility Definitions

NECTISE Core Team, 2008	Agility is defined as the ability to decide upon and enact a course of action on a timescale appropriate to achieve a desired outcome.
Atkinson and Moffat, 2005, Alberts, 2005	Agility is related to the ability to conduct network-centric operations (NCO) and is associated with "Power to the Edge" principle which states that "edge organizations have the attributes to be agile" [3, 4]
Pixton, 2006	Enterprise agility is the ability to adapt and change faster than the competition.
Yusuf et al. 1999, 2004	Agile manufacturing is a systematic response to pressures imposed by the highest levels of market instability and product complexity [32, 33].
Mason-Jones et al., 2000 Dove, 2001	Agility means using market knowledge and virtual corporation to exploit profitable opportunities in a volatile market place. It is the ability to manage and apply knowledge effectively in order to thrive in a continuous changing and un predicted business environment [17].
Tolone, 2000	Agility implies effectively integrating supply chain and forging close and long term relationship with customers and suppliers [30].
Van Hoek, Harrison and Christopher, 2001	Agility is all about customer responsiveness and market turbulence and requires specific capabilities that can be achieved using 'lean thinking' [31].
Goldman, Nagel and Preiss, 1995	Agility means delivering value to customers, being ready for change, valuing human knowledge and skills, and forming virtual partnership [10].
Iacocca Institute of Lehigh University (USA)	A manufacturing system with capabilities (hard and soft technologies, human resources, educated management, information) to meet the rapidly changing needs of the marketplace (speed, flexibility, customers, competitors, suppliers, infrastructure, responsiveness)