Demonstrating through-life and NEC requirements for defence systems

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ABSTRACT

There are two major transformations currently occurring that significantly impact acquisition and management of military systems. Network Enabled Capability (NEC) demands careful consideration of interoperability for delivered systems; new systems must be introduced such that they are interoperable with current systems and legacy systems must be managed (upgraded, modified etc.) such that interoperability is maintained and, preferably, enhanced. Eventually, NEC considerations should become 'business as usual', but for the time being special consideration is needed. The second transformation is the introduction of the concept of Through Life Capability Management (TLCM). Although new systems have always been planned with consideration of their maintenance etc., TLCM has a wider scope. It requires consideration not only of the individual systems' life cycles, but of the management of the super system in which new systems will operate. The whole life costs, risks, and development must be considered by systems designers and owners.

These transformations are linked; interoperability is a key requirement of TLCM. Through a concept mapping of TLCM, Yue & Henshaw (1) *have shown that TLCM implies a need for new approaches (new thinking) in defence systems design and acquisition. Also TLCM requires the defence supply chain (industry) to have a changed engagement in the delivery and management of systems. This, in turn, requires changes to the industry-customer relationship, such that new approaches to collaboration are a vital ingredient necessary for adherence to TLCM principles.*

The NECTISE (Network Enabled Capability Through Innovative Systems Engineering: www.nectise.com) programme was a large academic-industry research programme (part sponsored by industry) to investigate the implications for systems engineering arising from NEC and TLCM considerations. The programme included ten UK universities, and industry technologists and systems engineers from land, sea, air, and C4I domains.

NECTISE considered systems processes and approaches from all parts of the capability management process (planning, design, change, and realisation in military operations). A number of new tools and processes were developed and an important part of the programme was to demonstrate these in context and together. This demonstration was achieved through development of a scenario that considered the full systems acquisition and management process. By linking a set of vignettes with different timeframes it was possible to track an exemplar system through the planning to realisation and use stages. The scenario development drew heavily on the TTCP GUIDEx approach to defence experimentation; this enabled effective multi-disciplinary collaboration and integration of many different research threads.

This paper will describe the scenario planning activity and outcome and illustrate the manner in which linked research outputs were integrated into a systems engineering demonstration. The importance of systems architecting, both to the demonstration and (more importantly) as a key underpinning skill for TLCM and NEC will be emphasised.

The approach taken in this demonstration of research has implications for the approaches that should be

taken for defence procurement decision making in a TLCM and NEC characterised acquisition environment. These are described and the implications of TLCM for decision making is also highlighted.

1.0 INTRODUCTION

Network Enabled Capability (NEC) (2-4) and Through-Life Capability Management (TLCM) (5-7) are two major transformations affecting the acquisition paradigm for the UK and other NATO nations. These initiatives introduce new considerations that must be taken into account by the acquisition and supplier communities with respect to military capability. Traditionally, the use of planning scenarios has been based on those that are generically representative of anticipated types of military operation. In this paper we shall describe the use of a scenario that takes account not only of the operational aspects, but also of the through life aspects as well. The work reported herein is based on demonstration to a wide range of stakeholders of research into NEC systems. However, the approach could be applied more generally to understanding and informing the management of evolving requirements, appropriate to the present day complex commercial environment that provides and supports military systems.

The research programme upon which this paper is based was the NECTISE (Network Enabled Capability Through Innovative Systems Engineering) programme (www.nectise.com) (4,8,9). This was a large academic programme across ten UK universities with support (both financial and technical) from industry that addressed the question: *are you ready for NEC?* The programme had a 3.5 year duration, and its purpose was to develop the systems of systems engineering techniques and tools that would assist industry in meeting the customer aspirations for NEC. The programme considered the question from the operational (i.e. military end users) and organisational (industry and civil service) communities' perspectives. The outputs were a range of tools and processes in the areas of through life systems management, systems architecting, supply chain decision support, and control and monitoring for autonomous systems. A major activity within the programme was integrated demonstration of these outputs and it is the approach to creating the demonstration scenario that is the main subject of this paper.

The paper begins with a consideration of the particular challenges and factors that NEC, and then TLCM, introduce; it will be shown that there are many similarities and that, in fact, the NEC factors should become a set within the wider TLCM constraints and requirements. An important model for NEC-readiness will be presented. The approach to creation of a TLCM/NEC scenario as part of a demonstration of capability will be described. The difference between research demonstration and that of prototype systems will be emphasised. Finally we shall consider the importance of systems architecting to the realisation of TLCM/NEC aspirations and the manner in which this can form part of the scenario planning activity. The scenario demonstration approach we describe is recommended as a support activity to decision makers in the military acquisition communities to ensure that TLCM principles are taken into account.

2.0 TRANSFORMATION

2.1 Network Enabled Capability (NEC)

NEC (2,3,10-14) has been conceived slightly differently across the nations with advanced military capabilities, and there are a range of definitions; broadly we summarise it as:

..the enhancement, or realisation, of military capability achieved through effective information sharing between geographically and/or temporally distributed sensors, decision makers, effectors, and support services.

In general, it leads to better shared situational awareness of collaborating entities, which reduces the risk of error, and to greater agility in the prosecution of missions. Agility is at the heart of NEC (15), in the sense that the objectives of NEC include the achievement of more rapid decision making. It is also at the heart of NEC in the sense of being an objective for the delivery of NEC-ready systems. The NEC developer community must create agile systems, and they must create them in an agile fashion to keep pace with the rapidly changing threats with which the armed forces must cope.

NEC is a systems of systems problem (16,17) and the NECTISE research programme (8) sought to develop the appropriate systems engineering tools, processes and skills to ensure that future systems are NEC-ready. The programme developed an important model that relates NEC-readiness themes to each other (18) (Figure 1).

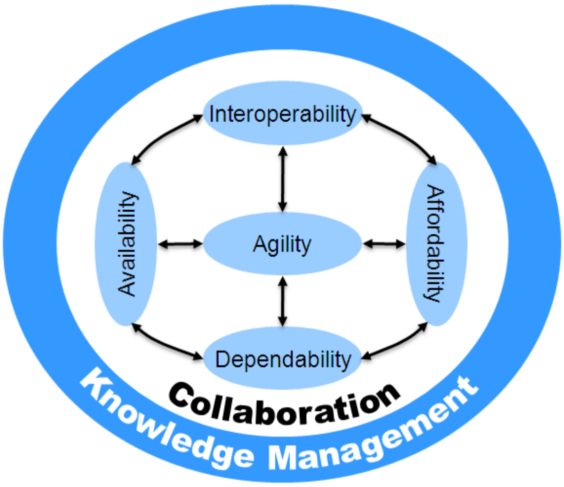

Figure 1: NEC-readiness themes

The NEC-readiness themes are the 'ilities' through which the maturity and suitability of systems for NEC-type operation may be inferred. Such systems comprise all the components of the capability and not just the equipment part of the system. That is to say the systems are built from the full set of Defence Lines of Development (5). For the UK, these are Training, Equipment, Personnel, Information, Doctrine/Concepts, Organisation, Infrastructure, and Logistics. Other nations have similar lines of development, e.g. the capability dimensions of the US are known by the initials DOTLMPF.

Figure 1 indicates that the agility objective is influenced by interoperability, dependability, affordability, and availability. The whole is enabled by collaboration and knowledge management. The realisation of NEC aspirations requires a number of key challenges to be addressed and the NECTISE programme developed the systems engineering capabilities needed to do so. The priority NEC considerations for systems designers were determined to be:

- Interoperability considerations for all designs
- Design for proactive participation in NEC (e.g. bearing sensors for use by other network participants)
- Qualification for Systems of Systems
- Life cycle/legacy implications
- Solutions which contribute to all lines of development

2.2 Through-Life Capability Management (TLCM)

As with NEC, there are various national forms of TLCM, but broadly they are the same. The UK definition is:

"*..an approach to the acquisition and in-service management of military capability in which every aspect of new and existing military capability is planned and managed coherently across all Defence Lines of Development from cradle to grave"* (Dstl, 2006).

TLCM is addressed through a systems approach in order to minimise cost, risk, and time over the entire life cycle of the systems that contribute to capability. TLCM could be considered as the approach through which multiple systems' life cycles are managed effectively over time. This implies that it includes management both within life cycles and across several life cycles. Capabilities must be designed to co-evolve with their environment (1) and this implies a new mindset within the developer community that takes the long-term view of a product-systems service mix. It also implies that the relationships between various parts of the defence supply chain must change to enable effective long-term management; specifically a strongly partnered supply chain must be established, in which principles of open systems and architectures apply.

The NEC-readiness themes (Figure 1) are now briefly considered from the TLCM perspective.

Agility is the principal objective of NEC, and is an important feature of TLCM. In particular, the systems approach implied by TLCM should ensure that the systems developed are flexible and adaptable, so that changes can be quickly (and inexpensively) made to develop capabilities rapidly in response to changing threats. The other readiness themes contribute to this system development agility as do collaboration and knowledge management that should be effective within the supply chain. The NECTISE research programme contributed significant results to these aspects (19,20).

Interoperability is fundamental to effective TLCM and can be regarded as a requirement or constraint on systems development. In particular, approaches are needed that maximise the opportunity for interoperability with future (as yet not conceived) systems as well as with existing, or legacy, systems. NCOIC (www.ncoic.org) (21) has provided in depth analysis of interoperability for NEC and the significant efforts within NATO to establish NNEC rely heavily on achievement of high degrees of interoperability between national systems (22). It is frequently forgotten that interoperability is, in fact, context dependent and the NCOIC Interoperability Framework (NIF™) is helpful in showing the importance of supply chain interoperability, in which not just technical, but commercial and political considerations are important.

Affordability is essentially the motivation for TLCM (1); TLCM seeks to take the long-term view of affordability of military systems, but this provides many significant research and commercial challenges. In NECTISE, we took the view that affordability does not just concern the customer perspective, but also needed to consider affordability to the supplier in terms of the TLCM trading environment. It clearly represents a significant shift for defence suppliers from a product or maintenance role to being providers of a product-service support mix, which brings its own challenges (23).

Dependability features in very many considerations linked to cost and reliability, but an area of major concern for NEC and TLCM is that of qualification. The qualification of monolithic(integrated, self-contained) systems is very often an expensive activity, but where safety or security must be established within a networked environment those costs are potentially hugely magnified. Difficulties occur because collaborating systems may have been qualified at different times and to different standards. Also the addition or upgrade of one system within the overall system of systems may require the whole system of systems to be re-qualified. Actually, this is impossible, because of both cost and complexity, and so new approaches to qualification are required (24,25).

Availability is related to robustness and agility, because the availability of systems provides the commander with options and confidence in the deployable capabilities. It is of particular interest for TLCM as (in the UK) availability contracting is a first step towards the overall TLCM ambitions. Under the availability form of contracting, industry sells available services to the MoD by taking responsibility for the delivery of products (e.g. aeroplanes) and their long term maintenance (e.g. so many days flying time per annum), and disposal.

The paragraphs above highlight particular relationships and challenges associated with the NEC-readiness themes. It is not our purpose, here, to go into more detail (see (26) for more in-depth analysis), but rather to show that these themes have relevance at all levels within the TLCM context from the planning, acquisition, service levels down to the operational context. The use of scenarios, and demonstrations, for TLCM must therefore take account of all those levels and not be confined to the operational environment only.

3.0 DEMONSTRATION SCENARIO

To demonstrate the research outputs of the NECTISE programme (which were drawn from many disciplines and were at varying levels of maturity) a scenario was constructed from a set of vignettes that fitted inside each other like (non-identical) matrioshka (8,9). The outer layer represented the overall capability planning context in which the decisions have a provenance of years. The next layer was based on the development stage for a particular capability, in which choices are made concerning how to develop the capability to meet the needs derived at the planning level. The timescales appropriate to this layer are months-years. The next layer has timescales of weeks-months(-year) and concerns the delivery of systems according to the planning and development stages. The last vignette is the instantiation of the capability change within a representative operational context; the timescales might be minutes-hours-days. There must, of course, be consistency between the layers, but the benefit of this approach is that it can be tailored in a plug and play sense to demonstrate different capability developments (Figure 2). The outer layers of the matrioshka provide context and should be largely invariant for each capability development to be tested, whereas the inner layers are specific to specific cases.

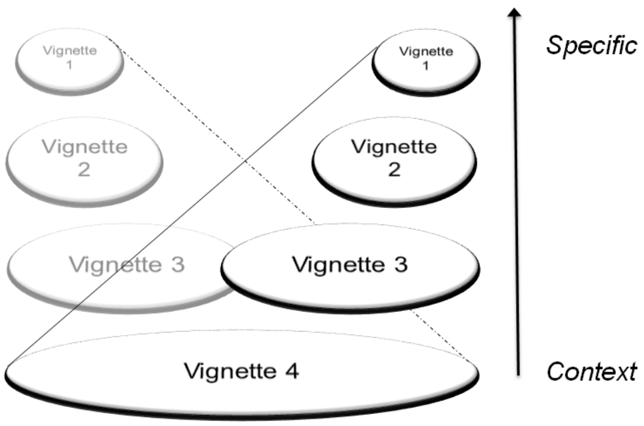

Figure 2: capability development vignettes

Because the NECTISE research programme was large and diverse, there were many stakeholders for the demonstrations that were based around the scenario. The main stakeholders were the multi-disciplinary academic team, the industry sponsor (BAE Systems) that included air, land, sea, and C4I business divisions, the UK MoD (civil service and military), and the wider industry and academic communities. A vital aspect to the scenario development was detailed consultation with all these stakeholder groups.

A significant difficulty faced by researchers in systems of systems is that they have incomplete information and control over the systems they are investigating. Systems of systems are made up of individual systems that are owned and managed by different organisations (27). By consulting the wider group of stakeholders, it is possible to create a context that has the correct content at appropriate levels of abstraction in which the research outputs (technologies, processes, etc.) can be demonstrated. However, it is only possible to test the outputs within a relatively limited set of conditions and certainly not the full extent that might be expected in reality. The scenario must, therefore, be sufficiently generic that it is applicable to a wide range of plausible situations.

The GUIDEx (28) scheme was tailored for use in constructing the scenario. This provided an excellent documentation framework through which the wide range of stakeholder inputs could be fused. In general, the GUIDEx is used for experimentation; demonstration can be considered as an experiment or the presentation of research outputs to stakeholders with little specific experimentation included. Within the NECTISE programme both types of demonstration were performed on different occasions, but GUIDEx was found to be applicable to both.

3.1 Requirements management

The research in NECTISE was founded on a set of business requirements that were translated into research questions to make them appropriate to academic activity (8). The scenario created for the demonstration was based on a subset of these requirements selected according to the scope and maturity of the research being demonstrated at that stage of the programme. Figure 3 captures schematically the basic relationship of the requirements to the demonstration scenario. The scenario has been described in detail elsewhere (9) but, in brief, it comprised a description of the UK capability planning context (vignette 4), and a selection from among options for improving surveillance capability that resulted in a decision to operate a UAV from a maritime platform (a destroyer) in vignette 3. In the presentation of vignette 2 during the demonstration, the specific design and upgrade (delivery) was described and the work in support of it had focused particularly on qualification aspects. Finally, in vignette 1 an operation to restore free and safe operation of international airspace that was being threatened by a hostile power was described. This included many features associated with NEC; e.g. tasking of particular force elements through real-time selection of services and the operation of autonomous assets.

3.2 Systems Architecture

The NECTISE research included significant investigation of the use of architectures, in particular the Service Oriented Architecture (SOA) approach as means through which the NEC challenges and solutions could be described. Architecting is the principal thread which wends its way through all four vignettes, beginning with a description of capability based on services and finishing with a means of planning and assessing the viability of particular systems configurations for a military operation (17,29,30). There is currently a considerable effort internationally to create the appropriate tools and frameworks for effective systems of systems architecting (22,31). The emerging architecture techniques will be of vital importance for the achievement of good TLCM and will underpin future development of the scenario generation technique described herein. That is to say, that the scenario generation technique itself is a form of architecting that resembles the systems (of systems) architecture it depicts.

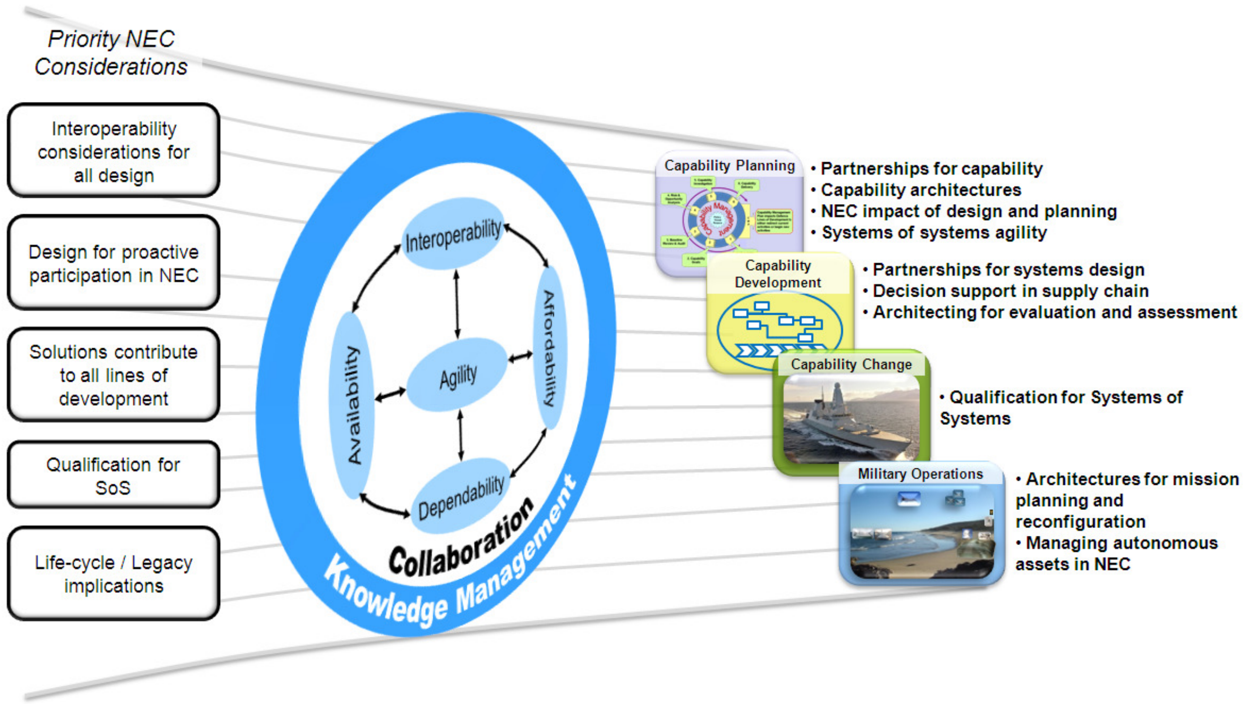

Figure 3: Relationship of requirements, work packages, and demonstration scenario

4.0 DISCUSSION

The matrioshka technique used to build a scenario from a set of vignettes proved very successful for demonstrating multi-disciplinary research outputs to a wide range of stakeholders. It was a useful approach for understanding the integration of such outputs within a TLCM context, applied to the challenges of NEC. In fact, given the importance of NEC one could speculate that in a few years time, the concept will simply be 'business as usual', i.e. appropriate levels of interoperability will be a routine requirement for all new systems. TLCM is, of course, an ongoing endeavour and it is important that the implications of the long-term perspective are fully represented in the scenario planning activities that influence acquisition of military systems. The research scenario was created to satisfy a number of business requirements and a set of implied requirements related to the currently emerging principles of TLCM. This same technique could be applied for acquisition decisions in the future, allowing decision makers to understand the operational use of systems being purchased and better understand the long-term management of such systems. The scenario implicitly includes a description of the commercial environment within which such systems will be managed and this, in turn, will allow decision makers to consider the cultural and commercial implications of TLCM.

Our experience in the NECTISE programme was that the scenario was a powerful enabler of integration among the research team and we speculate that the use of such a scenario could fulfil a similar role, if architected at a sufficient level of detail, for the multiple organisations involved in the delivery and maintenance of the systems that interoperate to provide the systems of systems from which military capability is derived.

The NEC-readiness themes were important for relating different research strands and for understanding the priorities that must be managed through life.

5.0 CONCLUSION

Based on our experience of demonstrating the outputs of applied research relevant to NEC through the NECTISE scenario, we recommend the use of matrioshka scenarios as a means of communicating the requirements of NEC and TLCM within the wide stakeholder group that develops and uses military systems. Correctly architected, such scenarios can also be used to test capability options and support decision makers in the defence acquisition environment.

6.0 ACKNOWLEDGEMENT

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