

Agile Properties of Service Oriented Architectures for Network Enabled Capability

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Abstract

Network Enabled Capability (NEC) is the U.K. Ministry of Defence's response to the quickly changing conflict environment in which its forces must operate. In NEC, assets need to be integrated in context, to assist in human activity and provide dependable inter-operation. Different from traditional system engineering for the development of hardware equipments or software engineering for the development of software systems, NEC raises new challenges not only for service development on Service-Oriented Architecture (SOA), but also for dynamic discovery and integration of services in order to provide dependable and sustainable military capability. In this paper we introduce and discuss our research work in the NECTISE (NEC Through Innovative Systems Engineering) project with a focus on the use of agile methodologies to adapt to changes occurring in the process of service development, service discovery and service integration. We demonstrate through examples how to enable agile SOA for NEC.

Key Word: Agile methods, evolvable architecture, Network-Enabled Capability, SOA

1. Introduction

The UK Ministry of Defence (MoD) aims to “significantly enhance military effect through the networking of existing and future military capabilities, under the banner of Network Enabled Capability (NEC)”[1]. In the so-called NEC battlefield, the Armed Forces need to be flexible, ready and rapidly deployable, with the application of controlled and precise force, to achieve realisable effects. To be successful in achieving this goal, NEC requires system integration of independent components, systems, and networks that can evolve, operate in a collaborative and dependable manner, manage system and component changes, be cost effective and connect industrial, defence and pan-defence environments. By definition, NEC requires *Network Enabling* by connectivity, information sharing and

networking people, assets, and procedures while capability provision requires integrating them to fulfil mission objectives.

To respond to this need, the U.K. EPSRC and BAE Systems are jointly funding the Network Enabled Capability Through Innovative System Engineering (NECTISE) project, which is addressing the question of how BAE Systems delivers elements that contribute to NEC for its customers, taking account of the aims summarised in the 2005 Defence Industrial Strategy [2].

The NEC architecture is about integrating distributed systems and networks by addressing such concerns as availability, accessibility, integrity, reliability, security, maintainability and resilience. One of the objectives of the NECTISE project is to develop a systematic approach that would lead to flexible architectures for through-life evolution by investigating how loosely coupled services in Service-Oriented Architecture (SOA) can be used to describe the functions and Quality of Service (QoS) for heterogeneous systems and networks.

In NECTISE, design for change is being addressed by exploring architectures that can both adapt to changes and themselves can evolve within carefully defined limits. Traditional design methodologies (e.g. waterfall) address the issues of design for change by planning future changes in detail. However, modelling future changes is an extremely difficult task for complex system development. As a reaction against these traditional methodologies, the modern “agile” design methodologies [3-5] have emerged in the last two decades, which focus on adapting quickly to changing realities. Agile design methods provide great flexibility in responding to changes of technologies and users’ requirements with an incremental and iterative approach. However, existing agile methods are designed for non-critical systems, which can not meet all the requirements of delivering of critical network-enabled military capability.

Moreover, using the definition adopted in NECTISE, NEC is the integration of assets to fulfil a mission objective. Assets need to be integrated in context, to assist in human activity and provide dependable inter-operation. Different from traditional system engineering for the development of hardware equipments or software

engineering for the development of software systems, NEC raises new challenges not only for service design and development, but also for dynamic discovery of functions offered by services and dynamic integration of services for provision of military capability, which is addressed here. In this paper, we show how the NECTISE research work is investigating new agile methodologies to adapt to changes occurring in service development, service discovery and service integration for NEC. Different from agile methods noted above, agility in NEC represents an ability to adapt to changes occurring in through-life provision of capability not only at the design time but also at runtime.

This paper is organised as follows. Section 2 discusses part of an investigation into Service-Oriented Architecture (SOA) for the support of dynamic military environments and delivery of NEC. Section 3 discusses agility for the delivery of military capability. Agile development, discovery and integration of services for military capability are discussed based on SOA for NEC. In Section 4, conclusions are drawn and future work is described.

2. Service-oriented architecture

The use of service-oriented architecture has been motivated by many industries changing focus from product delivery to service-based delivery. This can be seen in everyday business. The focus on service delivery has also been apparent in software, where networking has become faster, more reliable and more available by reduced cost. The approach to SOA in software is used as an enabler for business process integration that characterises business functions as services, and integrates dynamically across departments and organisations.

The conceptual service-oriented architecture can be used to integrate businesses, systems and computing by using different levels of abstraction. The architecture is made of service suppliers and consumers, with suppliers advertising through registries or brokers for consumers to discover [6, 7].

2.1. Services in NEC

The NEC initiative recognises that offering functionality is the main requirement in supporting military capability, and that functionality can be delivered without ownership of the delivery mechanism.

In principle, suppliers can be allowed to respond to customers needs, providing the delivery of appropriate and up-to-date solutions into the military. Architectural characteristics required by NEC, such as flexible interoperability and future-proof evolvability, can be in

part provided by SOA, where organisations, systems and computing each have defined service interfaces.

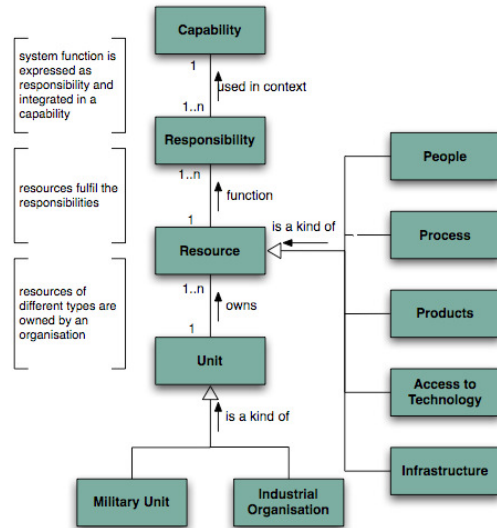


Figure 1. Capability concept model, from [6]

In this paper, the definition of the term ‘service’ is not limited to Web Services and is not restricted to specific technologies. A service is an action performed by one entity on behalf of another and involves the transfer of value [8]. A formal service description is used to define a service and a service interface is used to access it. This level of abstraction allows the composition of services, similar to the integration of responsibilities in Figure 1. The capability concept model in Figure 1 shows how assets can be combined at a conceptual level to fulfil capability. This diagram uses responsibility as an additional level of indirection between the assets and capability. Capabilities can be broken down by functional elements and the functions are assigned as responsibilities that assets provide in order to achieve a capability. The indirection between assets and capability illustrates that different assets can be exchanged to provide similar responsibilities, albeit with different qualities of capability delivery.

2.2. Benefits of SOA for NEC

The rapid growth of information services and resources in military systems makes it difficult and challenging to manage dynamic information and resources efficiently. In military systems, information is usually obtained from multiple data sources (e.g. database systems, file systems) to be integrated into a usable format for decision-making by battlefield commanders. For example, to analyse the implications of an aerial attack, background information could include data on meteorology, topography,

settlements, population, infrastructure, sociology, and even hydrology.

To address this problem, Service-Oriented Architecture is investigated to describe the functions and Quality of Service for heterogeneous military systems and networks. The Service-Oriented Architecture paradigm is concerned with the structure of service provision and consumption, and the infrastructure to support the interactions. Loose coupling [9] is the main benefit resulting from operating in this architecture. Loose coupling is obtained by abstracting the description of service provision from the implementation of service provision, thereby allowing different implementations to offer interchangeable services. This can then enable dynamic binding, where service implementations can be selected before service consumption by composing applications from suitable services based on their service descriptions.

SOA also brings benefits of efficiency and managed consumption when changing from product delivery to a service delivery business model [10]. By comparison with product delivery, service delivery is a continuous process, assuring dependability by maintaining the service provision and evolving the service implementation to respond to changes in environment, situation, supply, information and ongoing development.

In the delivery of military capability enabled by networks, dynamic integration based on SOA has the following characteristics:

- *Service Integration.* Services are defined as composable functions, similar to component architecture [11], and can be combined to form higher levels of functionality and deliver capability.
- *Service Discovery.* Service providers offer services in a loosely coupled architecture to consumers for dynamic composition. The consumer requires discovery mechanisms to locate and bind before utilising services. For NEC, discovery is the means to identify service types for integration before forces are operational, and to enable dynamic binding in service integration during operations.
- *Service Reconfiguration.* Services can be adapted to meet consumer requirements at binding time. During service discovery, the consumer and provider may negotiate terms of service delivery involving QoS parameters. For example, using redundancy, such as replication of resources, may improve service dependability.
- *Service Evolution.* By abstracting the interface from the service implementation, a service can adapt to changes in its environment and the demands of the service consumer. Selecting appropriate resources at the time of service execution allows the resources to be updated and adapted without interrupting service

availability. This supports continuous service delivery and therefore, sustainable delivery of capability.

3. Agility for the delivery of military capability

NEC is about the coherent integration of sensors, decision-makers, weapon systems and support capabilities to achieve the desired effect [1]. In the service-oriented architecture for NEC, resources for information provision and decision support are wrapped into services which standard interface for better interoperability. The lifecycle for provision of Network Enabled Capability is shown in Figure 2. In this lifecycle, new capability requirements are determined by long to medium term mission planning. Configurations and specifications of capability are defined based on these requirements. Services found in the military networks are evaluated based on cost of service and quality of service. The service evolution and selection function will decide whether to develop new services or subscribe existing services for the provision of military capability, or both. Finally, the selected services will be integrated and tested in order to deliver a dependable and sustainable military capability.

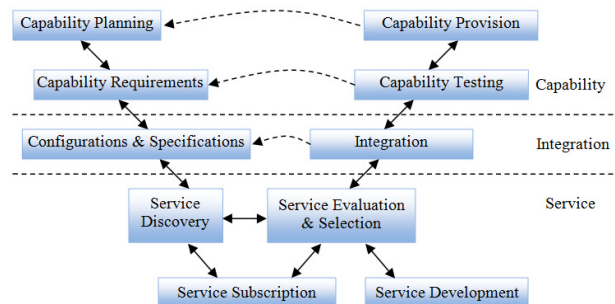


Figure 2. Capability provision on service-oriented architecture

For provision of dependable and sustainable capability, changes must be coped with in dynamic environments. In NEC, the motivations for changes can be classified into two broad categories: external drivers and internal drivers. External drivers include:

- *Military:* to deploy capability to compete against an enemy's capability and improve that capability over time.
- *Science and Technology:* to adapt to the technological changes. For example, changes in weapons: from swords and lances; to musket and cannon; to rifles and machine guns; and to rifled artillery and laser guided bombs [1].
- *Economics:* to adapt to changes of sale agreement/contract; changes of budget; changes of cost (e.g. deployment and operation);

- *Further Drivers*: to adapt to socio-political, legal, secure, cultural and religious issues.

Internal drivers include:

- *Maintenance*: changes in the product maintenance cycles;
- *Obsolescence*: obsolescence of assets and components of products;
- *Economics*: improving efficiency of delivery.

Evolution in NEC is usually caused by one or multiple drivers mentioned above, which could lead to a series of compatibility issues for the provision of a dependable and sustainable capability. To address this issue, agile development, discovery and integration of services for military capability are discussed in detail below.

3.1. Agile service development for military capability

Change prediction and management in planning is very important in the traditional civil and mechanical engineering. It is essential to identify the need for change early in the design process, since the later a change is detected the more expensive in the development process [12]. However, the user's requirements and technologies are always changing during a software design, which makes traditional engineering methodologies (e.g. waterfall) less successful in the processes of software-based service development.

As part of a reaction against the above "heavyweight" engineering methodologies, agile development methods (e.g. eXtreme Programming (XP) [3], Scrum [4], and Agile Modelling (AM) [5]) are increasingly applied to the software system development by using an incremental and iterative approach to quickly adapt to changes rather than predicting changes in the future.

In the agile development methods, software developed during one unit of time is referred to as an iteration which lasts only from one to four weeks. Each iteration has a complete life-cycle. For example, the lifecycle of a iteration of XP [3] consists of five phases: exploration, planning, iterations to release, productionising, maintenance and death. The first iteration creates a system with the architecture of "the whole system" [13]. Agile methods emphasize face-to-face communication with customers over written documents. Picking stories for subsequent iteration is entirely at the discretion of the customers to find out what is the most valuable thing to be working on this iteration. At the end of the last iteration, the developers will be ready to go to production.

Agile methods of design assist in responding to the changes requirements of NEC [1]. Military capability is delivered by integrating many component services, each of which can change to meet the changing conflict environment. The core strength of existing agile

development methods is the ability to deal with changing requirements. The main weakness is their limited scalability [14]. Agile development methods work well for a project with a small team. However, as the project scope grows, it becomes more difficult for team members to have a solid grasp of all aspects of the project without a concrete and comprehensive plan to work from.

The situation could become even worse in the development of military services for NEC. NEC is delivered by integrating multiple military services. The frequent changes made in the short life-cycles could cause significant modifications of the interfaces of these military services, which lead to serious versioning and compatibility problems. Services need to be frequently re-integrated and re-configured to provide a reliable and sustainable capability.

To address this problem, impacts of current changes should be analysed during the development of military services. Services developed using agile methods should be thoroughly tested in a realistic environment and scenario before being used in live operations. Once a service is integrated for provision of NEC, any change (or upgrade) in service evolution must be made very carefully. Using agile development methods for NEC, it is very important to check whether the current change will affect the interface of the service or QoS defined in the Service Layer Agreement. Changes that will modify the interface of the service need to be carefully planned and evaluated. Comprehensive analysis and evaluation of the impact on dependencies must be done before any change is put into effect.

3.2. Agile service discovery for military capability

For NEC, a set of services need to be integrated to fulfil a mission objective. However, we will not reap the benefits of integration of services, unless we have an efficient way to discover all required services.

In traditional SOA implementations, a centralised registry provides the functionalities to advertise and discover services. Using a centralised registry, a service can be quickly found and consumed. However, the centralisation of the registry raises the issues of scalability caused by the limitation of resources at the registry, such as network bandwidth, CPU capability and storage space. Moreover, the centralisation of the registry also introduces a single-point-of-failure to the system. The registry centralises all responsibilities for publishing and handling enquiries about services. Once the service registry fails, all the information about registered services will be unavailable. In the battlefield, the centralised service registry could be detected by enemies owing to a large volume of network traffic coming in and going out. The

problem of single-point-of-failure could be more significant in this case, since the service registry is threatened by intentional attacks.

To reduce the problem of single-point-of-failure, each network node should have the capability to efficiently discover desirable resources by interacting with connected nodes. In the NEC battle field, the Armed Forces should have the ability to support and co-operate with each other in a peer-to-peer (P2P) manner to quickly discover and self-configure services available on the battlefield to deliver a real-time capability.

Albert and Hayes proposed the “Power to the Edge” principle [15] in the Network Centric Warfare Framework (NCWF). They presented that NCWF must support P2P relationships and information exchanges that transcend individual systems and organizations. Edge Organisation [15] (or Agile Organisation [16] defined for U.K. military) is a new concept in the context of NCWF, which enables each network node in the military network to self-organise themselves in a non-hierarchical structure and form dynamic organisations with common interests and objectives. Edge Organisations can generate higher flexibility and adaptability for military systems in responding to the new threats and environment encountered by the military in the 21st century [15].

Similarly to the “Power to the Edge” principle, a self-organising and self-adaptable model was presented in previous studies for efficient resource discovery on the “edge of the Internet” - P2P networks [17], where nodes should have the ability to self-organise themselves in a cooperative manner similarly to social networks. This study in [17] demonstrated how self-organisation can improve resource discovery in P2P networks. Efficient resource discovery could be performed by interacting with locally reachable nodes based on whatever local information is available. Each node can automatically detect potential interests of other nodes in the network according to their previous behaviours and preferentially links to the nodes that have similar interests. Peer communities are formed and maintained spontaneously, where nodes are self-organised based on their daily intercommunications. This algorithm could be possibly applied to the large-scale military networks with numerous service providers by dynamically sharing and searching information and services to deliver military capability.

3.3. Agile service integration for military capability

NEC has the important characteristics of integrating different types of systems across different platforms. Such as sensors for detecting insurgents could be employ any of laser, visible spectre, heat (infrared), radar or sonar sensors and these heterogeneous sensor services can be

deployed on tanks, helicopters, UAVs (unmanned air vehicles) and infantry personnel. For successful NEC, the sensors should provide interoperable service interfaces to the integrating applications taking into account QoS parameters to deliver dependable capabilities in highly critical situations.

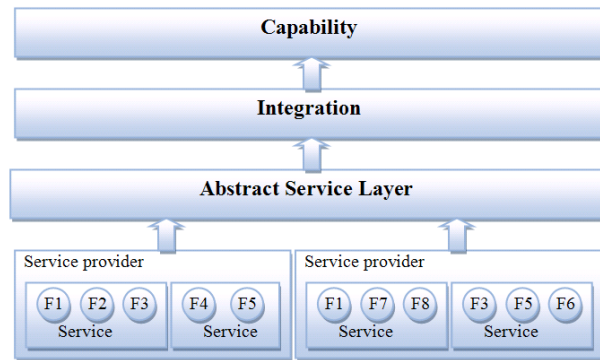


Figure 3. Service-oriented architecture for the delivery of military capability

Figure 3 illustrates agile integration of services for the delivery of military capability on SOA. In this architecture, each service provider provides a number of services, each service performs a set of functions, and some functions can be integrated to form a higher level of functionality to deliver a capability. For example, the BBC is a service provider which provides many services, such as news, weather, music and business. The weather service (a representation of the information service provided by the Met Office) includes a set of functions, such as weather conditions, temperature, wind, visibility, pressure, humidity and pollution. The weather conditions, wind and visibility function could be integrated with other functions from service providers to launch a high level of military capability.

In order to integrate services successfully for NEC, fast paced changes must be coped with in unknown and dynamic environments [18]. Architectural design for changes and coping with dynamic evolution and unknowns are two tasks being addressed in NECTISE. In delivering capability, the SOA concept is applied to facilitate the matching of capabilities and needs [19]. SOA is designed for changes. As noted above, loose coupling is one of the key architectural principles of SOA, and this enables services to maintain a relationship that minimises dependencies and only requires maintaining an awareness of each other. Loose coupling is an approach where integration interfaces are developed with minimal assumptions between the sending/receiving parties, thus reducing the risk that a change in one service will force a change in another service.

The loose coupling of SOA enables service implementations to be inter-changed and modified. However, service integration is dependent on service interface definitions and requires management of workflow definitions to minimise impact on provision of military capability. In the architecture, fast paced changes are usually caused by evolution of services (e.g. adding or removing functions from services), evolution of service providers (e.g. adding and removing services by service providers), evolution of networks (e.g. network nodes joining and leaving the network) and evolution of capability (e.g. capability upgrade by integrating new functions).

Changes in these cases could affect the dependability of provision of military capability. Capability could be lost if one of the subscribed services offering the requested functions is removed by the service provider, or one of the requested functions that was previously available on the subscribed service is removed or replaced by a different function.

In order to ensure the reliability of provision of capability, multiple services which can provide a functionally equivalent service should be subscribed. The integration algorithm can switch to one of the backup services in case of failures. Capability provision copes with changes by means of either re-configuration of backup services or integration of new services into the system. Ultra-late binding [20] is utilized in NECTISE to improve the dependability of service integration on the battlefield, where a service implementation is discovered at the time of execution, makes a system self-adaptable to respond to changing requirements in real-time. Within a military context, this approach provides major advantages for integration both for planning and operation. Provision of service definitions enables selection of equipment to be deployed on the battlefield and ultra-late binding enables dynamic reconfiguration and upgrades.

As noted above, redundant services can increase the reliability of provision of military capability, but more services needed mean higher cost of provision of a military capability which also affects the affordability of capability. Service integration for each configuration of capability is measured within the NECTISE evaluation framework in both effectiveness and performance [21]. Measures of Performance are used to validate implementations of service descriptions, whilst Measures of Effectiveness are used to assess a configuration of services composed to satisfy a military capability. Measures of Effectiveness are applied using a composition of service descriptions and can therefore be applied at a conceptual level, independent of the services consumed [20].

Measures of Performance can be made up of a number of assessments about cost of service and quality of service. Cost of service for each configuration of

capability needs to be measured to optimise the resources for the provision of military capability. Current quality of service descriptions need to be extended for the context of NEC, by investigating those attributes of capability that can be characterised and measured for the provision of dependable and sustainable military capability.

From the above discussion, it can be concluded that Service-Oriented Architecture should be able to provide the agility to handle change and the dynamic evolution needed in NEC. To minimise service disruption and to enable service enhancement, the following need to be addressed:

- Prediction of impact of changes
- Provision of distributed functionality for resource discovery
- Provision for the dynamic reconfiguration of existing services and integration of new services.

4. Conclusion and future work

This paper reports “work in progress” and the essential base for future research on SOA in the NECTISE programme. In this paper, we have discussed the need for agility in the context of NEC and discussed the relationships among four themes of NEC readiness - agility, availability, dependability and affordability in terms of how to use agility to achieve better dependability of capability provision even with the services with low availability, and minimising the impact on the affordability of capability.

In future work, we will further investigate agile methods for sustainable provision of NEC. The investigation will link to lifecycles for service delivery and agile methods to respond to changes due to, for example, faults, customer need, technology developments and obsolescence. The next step will be to further explore agile models for service integration, service discovery and service advertising through the use of simulation-based evaluations in order to optimise the existing resources to achieve the optimised military capability.

5. Acknowledgement

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References

- [1] "UK Ministry of Defence, Joint Services Publication 777, Edition 1," p. 1, 2005. 30 June 2007. Available: http://www.mod.uk/NR/rdonlyres/E1403E7F-96FA-4550-AE14-4C7FF610FE3E/0/nec_jsp777.pdf

- [2] UK Ministry of Defence, "Defence Industrial Strategy: Defence White Paper (CM6697)," UK Ministry of Defence, 2005.
- [3] K. Beck, "Embracing Change with Extreme Programming," *IEEE Computer*, vol. 32, October 1999.
- [4] P. Abrahamsson, O. Salo, J. Ronkainen, and J. Warsta, "Agile Software Development Methods: Review and Analysis," *VTT Publications 478*, 2002.
- [5] S. W. Ambler, *Agile Modeling: Effective Practices for Extreme Programming and the Unified Process*. New York: Wiley, 2002.
- [6] D. Russell and J. Xu, "Service oriented architectures in the provision of military capability," in *Proc. of UK e-Science All Hands Meeting 2007*, Nottingham, UK, 2007.
- [7] G. Alonso, F. Casati, H. Kuno, and V. Machiraju, *Web Services - Concepts, Architecture and Applications*. London: Springer, 2004.
- [8] J. O'Sullivan, D. Edmond, and A. H. M. ter Hofstede, "Service Description: A survey of the general nature of services," Queensland University of Technology, Technical Report FIT-TR-2003-02, 2003.
- [9] M. Papazoglou and J.-J. Dubray, A Survey of Web Service Technologies, Technical Report DIT-04-058, University of Trento, 2004.
- [10] O. K. Mont, "Clarifying the concept of product-service system," *Journal of Cleaner Production*, vol. 10, pp. 237-245, 2002.
- [11] C. Szyperski, D. Gruntz, and S. Murer, *Component software: beyond object-oriented programming*. New York, NY ; London: ACM Press : Addison-Wesley, 2002.
- [12] P. J. Clakson, C. Simons, and C. Eckert, "Predicting Change Propagation in Complex Design," *Transactions - American Society of Mechanical Engineers Journal of Mechanical Design*, vol. 126, pp. 765-797, September 2004.
- [13] K. Beck, *Extreme Programming Explained*. Reading, Massachusetts: Addison Wesley Longman, 2000.
- [14] J. Bloomberg, "The role of the service-oriented architect," 2003. Available: <http://www.ibm.com/developerworks/rational/library/content/RationalEdge/may03/bloomberg.pdf>
- [15] D. S. Alberts and R. E. Hayes, *Power to the Edge: Command and Control Research Program (CCRP) Publications Series*, 2005.
- [16] S. R. Atkinson and J. Moffat, *The Agile Organization: Command and Control Research Program (CCRP) Publications Series*, 2005.
- [17] L. Liu, N. Antonopoulos, S. Mackin, J. Xu, and D. Russell, "Efficient Resource Discovery in Self-organized Unstructured Peer-to-Peer Networks," *Concurrency and Computation: Practice and Experience*, in press, 2008.
- [18] D. Russell, N. Looker, and J. Xu, "SOA, Dependability, and Measures and Metrics for NEC," in *Proc. of IET Forum on Capability Engineering*, November 2006.
- [19] D. Russell and J. Xu, "Service Oriented Architectures in the Delivery of Capability," in *Proc. of Systems Engineering for Future Capability*, 2007.
- [20] D. Russell, N. Looker, L. Liu, and J. Xu, "Service-Oriented Integration of Systems for Military Capability," in *Proc. of IEEE International Symposium on Object/component/service-oriented Real-time distributed Computing*, Orlando, Florida, May 2008.
- [21] N. Looker, D. Webster, D. Russell, L. Liu, and J. Xu, "An Ontology for Evaluation of Network Enabled Capability Architectures," in *Realising Network Enabled Capability* Leeds, UK, 2008.