Model Based Capability Assessment in Systems Architectures for Network Centric Operations

Sandro Leuchter
Rhine-Waal University of Applied Sciences,
Faculty of Communication and Environment
Suedstr. 8, 47475 Kamp-Lintfort
GERMANY

sandro.leuchter@ieee.org

Frank Reinert
Fraunhofer Institute of Optronics, System
Technologies and Image Exploitation (IOSB)
Fraunhoferstr. 1, 76131 Karlsruhe
GERMANY

frank.reinert@iosb.fraunhofer.de

ABSTRACT

Procurement and design of system architectures capable of network centric operations demand for an assessment scheme in order to compare different alternative realisations. In this paper work on metrics and procedures for the assessment of network centric capabilities of system architectures in the C4ISR domain is reported.

The central task of the present study was to design a methodological basis for the evaluation of complex system solutions regarding their network-enabled capabilities (NEC). The evaluation should be based on concrete and as much as possible quantifiable parameters, which are referred to as NEC characteristics. The approach for identifying these NEC characteristics was the consideration of chains of operational activities which should serve as an evaluation framework for the assessment of the specified system solutions.

The result of the study presented in this paper is a utility tree that reflects the needs of NEC. In the NEC domain the enterprise architecture model usually follows the NATO Architecture Framework (NAF). The resulting evaluation scheme describes which artefacts of NAF models feed the utility tree. It was applied to assess the NEC quality of a sub-system and integration architecture for surveillance in order to protect critical infrastructures. The paper also proposes a process model for the evaluation of system architectures. This process model does not purport to be exhaustive with regard to the system modelling and engineering. It must be considered as an accompanying process which is embedded in a parent process to describe and set-up experiments to evaluate system characteristics.

1.0 INTRODUCTION

In general the network-enabled capability (NEC) intents "to achieve enhanced military effect through better use of information systems towards the goal of "right information, right place, right time – and not too much" […] In this future vision commanders will be better aware of the evolving military situation and will be able to react to events faster"[1].

In a military systems context NEC allows to instantiate joint function lists that connect interoperable military systems to an operational combination (e.g. sensor to shooter). This makes it possible to combine operational

[1] http://en.wikipedia.org/wiki/Network-enabled_capability (last access: April 25, 2013)

capabilities offered by different systems in a flexible manner. In a total NEC enabled world all deployed systems would be able to act together. This allows reacting to different operational demands in an agile way by flexibly chaining up functions of distinct systems jointly or combined. This can lead to more effective and efficient military processes or to achieving information superiority by combining the distinct information spaces of single systems to the Common Operational Picture.

The capability of a system to effectively and efficiently support network centric operations can be seen as a potential quality of the system and thus as a requirement for its architecture. According to [4] architectures describe the fundamental organisation of a system by explaining its components and their relationships or work dependencies. Architectures thus reflect the principles that guided the design of the system.

Enterprise architecture frameworks (like SYSMOD or the military enterprise architecture frameworks MODAF, DODAF, NAF etc.) are an important instrument which enable system-of-systems engineering (SOSE) in a structured process both on an operational and system level. Their model oriented approach (based on stringent meta-models) yields comparable descriptions of system architectures with interconnected artefacts allowing for automated checking of coherency through tracing of relationships and can become part of the internal product documentation. Such a controlled way of documenting allows for checking the interoperability, helps to avoid ambiguousness in architecture descriptions due to clearly defined semantics of model elements, helps to trace design decisions and their impacts down to the system level and enhances the comparison of different system architectures. For this reasons model based descriptions of system solutions form the perfect basis for the evaluation of their NEC, especially in the case of competing solutions. Their resulting models (based on a meta-model) form the model part in the model based capability assessment in systems architectures for network centric operations.

In addition to the technology-oriented integration of systems the cross-cutting ability for NEC also requires the general willingness and the organizational ability to integrate the operational units for networking. The service-oriented approach goes beyond technology-focused system integration and expressly includes the organizational ability to integrate operational units. For this reason we prefer the service oriented paradigm and focus on the NAF, as of version 3 explicitly supporting the service oriented paradigm.

SOSE with NAF (as of version 3) means to initially identify the organizational units involved, which are required for the super ordinate function, as operational nodes with their activities, information elements and communication relationships. The operational activities are related to potential services and the services are specified as interfaces between operational nodes. The execution of services is assigned to technical systems. The result of the NAF procedure is an architecture which describes the network architecture and system interfaces on a technical level as well as the operational or business nodes with their capabilities to be integrated in the including higher-level organization.

Applying these mentioned architecture frameworks does not inherently guarantee that the architecture and the resulting system is being more NEC enabled, even if the service oriented paradigm greatly increases the probability. Therefore, even if systems and their architectures are built in accordance with the above described SOSE framework, they still have to be evaluated regarding their NEC. The central task of the present study was to design a methodological basis for the evaluation of complex system solutions regarding their NEC. The evaluation should be based on concrete and as much as possible quantifiable parameters, which are referred to as NEC characteristics.

This paper describes an evaluation scheme for assessing the NEC of a system, or more precisely the characteristics to assess the fulfilment of the functional and operational requirements to a system in a system-of-systems. The methodological approach and the parameters representing the NEC are presented. Further a process for quality testing of system architectures is proposed. This process uses NAF in order to describe these architectures in a formal manner. It is based on experiments, which means that concrete experiments are conducted in order to determine the characteristics of parameters describing the architectures quality in a specific context.

The paper is structured as follows: Section 2 introduces related work on evaluating system architectures. Section 3 describes our approach, provides a utility tree that reflects the needs of NEC and proposes a process for setting up experiments evaluating quality parameters (for example the network capability) of systems in dedicated chains of operational activities. Finally section 4 concludes on the approach presented in this paper.

2.0 RELATED WORK

The goal of software architecture assessment methods is to evaluate the impact of competing design decisions on the overall quality systematically. While some methods specify a certain quality feature explicitly (e.g. maintainability in the case of Architecture-Level Modifiability Analysis [2] or portability in the case of Software Architecture Analysis Method for Evolution and Reusability [9]) there are methods like the Software Architecture Analysis Method [6] or the Architecture Trade-off Analysis Method (ATAM) [7] that use a generic quality concept.

The FURPS scheme [5] provides a well established framework for the classification of quality attributes of software architectures. It can be used to describe quality of system and enterprise architectures as well. It has five major quality dimensions: functionality, usability, reliability, performance, and supportability. In FURPS these dimensions are not mutually independent and can also be contradictory (e.g. security needs additional software layers that can decrease performance, and possibly also usability or interoperability). Because of this issue stakeholders have to evaluate the dimensions and have to specify which quality aspect is important to the specific situation (e.g. in terms of business needs).

Using ATAM is a possibility to get such an evaluation of quality dimensions. This methodology uses scenarios to elicit use cases and to fit requirements specifically to an intended use case. ATAM-scenarios consist of:

- stimulus
- environmental conditions
- measurable or observable manifestation of the response

ATAM differentiates between different types of scenarios:

- use case scenarios: typical intended uses of the system
- growth scenarios: cover anticipated changes to the system
- exploratory scenarios: extreme changes that are expected to „stress“ the system

With these types of scenarios it is possible to describe relevant requirements for software, system, and enterprise architectures. Usually a tree-like structure is used to derive quality aspects. The root of such a utility tree is the general quality concept which is elaborated on the following levels. Leafs of the tree list the most specific quality attributes in the form of scenarios. The resulting structure is called utility tree in the ATAM. This approach of refining quality aspects down to specific scenarios helps to generate quality requirements in all relevant dimensions. Finally stakeholders prioritize the leaf-scenarios in the utility tree. For most purposes a low/medium/high prioritization of business importance and development risk is sufficient.

In order to create a methodological basis for the evaluation of complex system solutions regarding their NEC characteristics a generic utility tree was generated. Although the FURPS scheme would have been a useful starting point for a utility tree for analysing different qualities of general software architectures it is not specific enough to NEC and does also not provide concrete measures.

Thus a more C4ISR specific approach was taken in this study. Since NEC is all about forming and deploying joint function lists of dislocated capabilities the architectural approach of NAF was considered as the first class basis for finding NEC related measures of system architectures. Unlike ATAM the weight for selected branches has to be derived from competing stakeholder interests.

This general approach was inspired by the defence specific capability assessment framework for example used in the Concept Development and Experimentation (CD&E) methodology (e.g. [8], [10]). It bridges between three levels:

- operational relevant “Measures of Merit” or “Measures of Effectiveness“ (MOE)
- quantifiable but complex Measures of Performance (MOP) and
- observable Dimensional Parameters (DP)

A major result of this study is the mapping between certain NAF-artefacts, MOEs, MOPs, and DPs as well as how they are mapped to the proposed NEC-specific utility tree.

3.0 APPROACH

3.1 NEC in a System-of-Systems Context

The objective of NEC is to increase agility. Alberts [1] defines the term agility as the ability to cause a change of the circumstances, to deal with them and to take advantage of. In the case of NEC the objective of agility is to create joint function lists on top of existing individual systems and to create new information spaces form already existing distributed databases.

For the development of network-enabled architectures system-of-systems engineering approaches are applied. A system-of-systems consists of networked individual systems, which continue to perform their functions in their respective organizational embedding. The parent system-of-systems provides a further capability through the summary of the individual features. To implement this type of integration organizational measures must be taken (e.g. [3]) on one hand, on the other hand technical transitions at system-level have to be established (e.g. [12]). The technical transitions lead to a cascading connection of the relevant functions of the different systems into so-called joined function lists.

3.2 Methodological Approach

The basic idea is to understand NEC as an overall evaluation criterion and evaluate systems concerning their NEC on the basis of system characteristics (NEC characteristics). To do this, the overall NEC evaluation criterion has to be made quantifiable.

In principle we propose the structuring of evaluation criteria into operationally relevant MOE, as well as measurable quantitative (MOP) and dimensional parameters (DP) as with [8] and [10]. This structuring fits into the assessment method applied. The assessment of NEC is done analogue to the goal tree method in CD&E: Functional and non-functional requirements are formulated as MOE, and then hypotheses in the form of MOP are derived from MOEs. Finally DP can be measured or observed during experimentation, which quantify expectations according to MOPs. Mapped to the NAF/MODAF this means that MOEs have to be aligned with the capability view, MOPs with the operational view, and DPs with the system view (see figure 1).

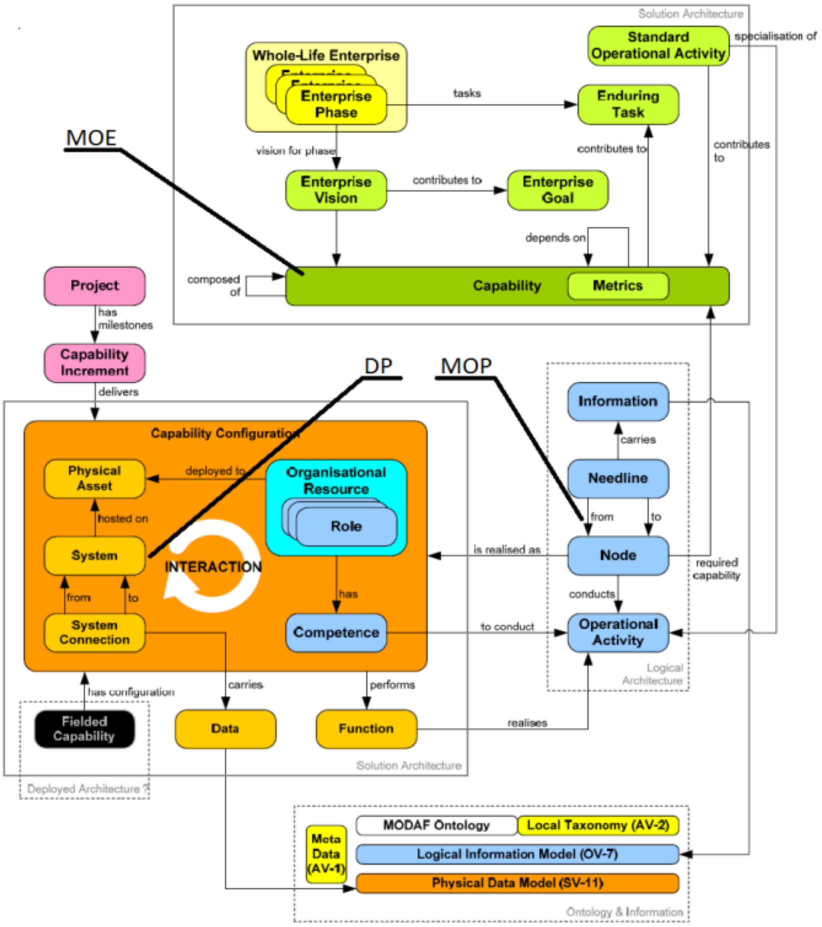

Figure 1: Classification of the indicators in the NAF meta-model (modified from [13])

In order to conduct the assessment of NEC the above mentioned overall NEC evaluation criterion has been instantiated in an approach analogue to the FURPS scheme. Some of the FURPS dimensions are more important to NEC than others. Obviously supportability and usability are the most important qualities for NEC. We have identified attributes that can contribute to NEC-awareness in this sense. They are introduced in section "System requirements for NEC". Each of these attributes has a break-down structure of more specific MOPs and observable DPs that can be derived from NAF/MODAF models. Since the resulting utility tree has – as in the case of FURPS/ATAM – contradictory branches a stakeholder and application specific weighting has to be made. We suggest applying methods from multi-attributive utility theory to come to suitable weights such as the Trade-Off Method. This approach is further refined in section "Multi-Attribute Evaluation". The resulting utility-tree is presented in section "Operationalization of MOE – Utility Tree".

3.2.1 NEC characteristics in conjunction with NAF

We use an architecture framework for the description and analysis of the NEC ability of systems and subsystems. The use of a formal and standardized method allows for a detailed comparative representation, analysis and assessment of functional operational requirements and technical features. In our approach the NATO architectural framework NAF is applied.

Using NAF, functional and operational requirements are documented in the NAF capability view. Once these relationships have been derived and documented in the prescribed formal manner, the metrics for evaluating the operational effectiveness (MOE) of the specified capabilities can be defined. Issues concerning the organizational structuring and structures of the tasks are addressed in the NAF operational views. The structuring of the system and the systems environment are depicted in the service-oriented and system views.

The main feature of network centric operations is to combine selected capabilities of different platforms in order to act together in a controlled way for example in a sensor-command-effector chain. The process of setting up such a chains of operational activities is not straight-forward and has to be supported by all architectural elements. The challenge is to define which platform should provide which function and how to glue them together.

NAF provides a structured way to come to such chains of operational activities and to identify gaps of information exchange between these activities: According to NAF all relevant operational activities that comprise a military capability are collected and mapped to respective organizational roles and nodes. Additionally all information elements that are needed or created by certain operational activities are specified. These information elements can be seen as the glue between operational activities. The set of all operational activities and information elements in a system-of-systems is a kind of catalogue from which chains of operational activities can be formed. It is only necessary to get the respective operational activities into an operational required sequence. Checking the interoperability of input/output information elements helps to identify information gaps in chains of operational activities.

While MOE are complex and involve implicit knowledge about intended effects MOPs are already concrete in terms of military procedures. Thus on the level of chains of operational activities one does not deal with MOE any more. But because the information elements and nodes on the operational level are still abstract and not yet system implemented they cannot be directly observed or measured. Only DP (on system level) can be observed in an implemented system-of-systems. Chains of operational activities are thus the best place to locate MOPs.

At the system level there are measuring points related to the DPs due to the functions that are associated with systems, the network connections and the compatibility of data elements.

3.2.2 System requirements for NEC

Due to the consideration depicted in the previous section it is necessary to identify system requirements which are NEC characteristic (MOE) as a starting point in order to conduct NEC assessment of systems. In this paper we focus on a different set of quality features compared to the FURPS scheme. These features describe the specific needs of the NEC domain. As in the case of FURPS these dimensions are not mutually independent and can also be contradictory.

The following NEC characteristics (MOEs) have been derived in collaboration with domain experts:

- Agility / ad-hoc integration: This MOE addresses the question how easy the integration of functions or information spaces related to a dedicated system into new joint function lists or superordinated information spaces is. This refers to necessary adaptation and development effort but also to the suitability of functions and information offered in external contexts.
- Networkability: This MOE addresses the question how a system can participate in a composite system, for example fits the bandwidth of communication connections to the frequency and size of the transferred data items?

- Security and accessibility: This MOE addresses the question, if it is possible to satisfy the need for protection of potentially highly classified data?
- Support of information items (standardization): This MOE addresses the question, if information can be exchanged in a compatible way as data elements, or respectively can all parts of the data elements be interpreted?
- Remote-controllability: This MOE addresses the question, if the operational activities or functions can be initiated and controlled from another node?
- Efficiency of a joint function list: This MOE addresses the question how well operational activities (and their implementation as system functions) can be combined together to form a joint function list?

3.2.3 Multi-Attribute Evaluation

Not all system requirements are equally important for each system and anticipated benefits. Therefore, a weighting for all MOEs as defined by the multi-attributive utility theory must be performed. As a precondition, all chains of operational activities of interest must have been identified at the operational level and afterwards specified at system level. These chains of operational activities then determine the required weighting.

For the conduction of multi-attributive utility evaluation first of all a goal system hast to be established. Each goal (MOE) is thus subdivided into objectives. It is even possible to divide each objective again. Objectives, which can be specified at the operational level (MOP), are then defined by measurable indicators (DP). The DP themselves are represented with a utility function to the degree of the achievement of the objective with a normalized value range between 0 and 1. A value of 0 means that the goal was missed completely, a value of 1 means that the objective or goal is fully achieved by the measured value of the indicator.

Regarding our aim to evaluate the NEC of complex system solutions, a diversity of dimensions may be emphasized by different weightings of the objectives and the indicators. The weight of the indicator shows its importance in terms of the goal relative to the other indicators. In addition to the indicators, objectives of a goal must also be weighted. The weighting of objectives and indicators is done by associating to every objective and indicator a factor between 0 and 1. The sum of the weights on one level (all direct objectives of same goal or all indicators for an objective) has to be 1.

The value for the achievement of a goal arises from the weighted sum of the benefits of its direct objectives or indicators.

3.2.4 Operationalization of MOE – Utility Tree

The following section suggests a utility tree based on the system requirements for NEC presented in section “System requirements for NEC” and taking into account the thoughts about multi-attribute evaluation. In a first step sub-goals (MOEs) or one or more MOPs have been derived for every requirement (MOE); in a second step one or more DPs have been associated with these MOPs. We call this procedure „operationalization of MOEs“. For some DPs one has to note, that they are not properties of a system to be tested, but an aspect of the integrating system-of-systems architecture. This applies in particular to properties of communication links.

- MOE Agility / ad hoc-Integration
    - MOE Ability of self-descriptiveness: The self-descriptiveness of a system in terms of its functions and interfaces (concerning their syntax and semantics) is the enabler for its usage in a foreign context. It is a sufficient condition for the efficient interactive integration of the functions of a system and even a necessary condition for the automated integration of the functions of a system.

- MOP Ability of self-descriptiveness of the interface: The self-descriptiveness of the interface refers to its signature. This specifies how to call the function and what parameters must or may be used.
  - DP Signature via WSDL or IDL available
  - DP Semantic interface description available
- MOP Own capability description: The description of the capabilities of a system or its functions refers to the information that is transmitted via the interfaces of the functions. This involves the available commands that can be processed via a function's interface, the accuracy of measurements or calculations, the current position of the system, and information on systems time behaviour.
  - DP Instruction Set available
  - DP Accuracy
  - DP Current position
  - DP Pulsing/Response time
- MOP Common programming model: In order to be able to use functions of a system in a function list an adequate technological basis for software integration must be used. There are a number of established technologies and middleware frameworks, which are suitable for this. There are wrappers, gateways and adapters that can map between the protocols of different technologies.
  - DP e.g. Enterprise Service Bus-Adapter (Web-Services, Java Message Service etc.)
  - DP e.g. CORBA-IIOP

- MOE Networkability
  - MOE Technical interoperability: To establish a connection, interoperability at the technical level has to be established. Systems must therefore be able to communicate with each other.
    - MOP Connections: On the lowest level systems need to be networked. Therefore appropriate network access must be realized.
      - DP Support of Internet Protocol (IP)
      - DP Support of Tactical Data Links
    - MOP Characteristics of the communication lines: For the required communication in a function list characteristics on availability may applied. These characteristics can be extracted from the NSV-2 Sub views.
      - DP Bandwidth of available communication link
      - DP Latency of communication link
      - DP Stability of communication link
    - MOP Security and accessibility: For the required communication in a function list the characteristics on security may applied. They can be extracted from the NSV-2 Sub views.
      - DP Will the communication be protected, in such a way that the eligible data may be transferred
      - DP Vulnerability of jamming the communication

        - MOP Availability of credentials /Login-Data: The integration of originally separated systems may require the usage of separate user administrations. Therefore it may be necessary that login information must be passed on from one function call to the next one. Single-sign-on means that credentials can be used across systems and users only must log on once.
            - DP Is Single-Sign-On possible?
- MOE Support of information Items (standardization): The establishment of syntactic interoperability can be done by adhering to common protocol and format conventions. For example at NATO level guidelines for individual interfaces or profiles for interoperable protocols are established. In the different „Communities of Interest"(COI), there are consistent protocol agreements (at application level). Between different COI's there are however partly competing profiles. The following profiles and specific standards are not complete and should be understood in the sense of indications.
    - MOP Support of existing interoperability profiles
        - DP e.g. NATO Core Enterprise Services
    - MOE Syntactic Interoperability
        - MOP Interfaces
            - DP e.g. Multilateral Interoperability Programme (Command & Control)
        - MOP Command/Interaction patterns
            - DP e.g. Allied Procedural Publication
        - MOP Data Models
            - DP e.g. NATO Secondary Imagery Format (NSIF)
        - MOP Positions/ Geographic reference systems
            - DP World Geodetic System - WGS84
        - MOP Time
            - DP Date-Time Group
        - MOP Precision: For the representation of the precision of a NEC capable system, no standard is known. Here arises the need for future standardization.
- MOE Remote controllability
    - MOP Remote control of user interface: If system functions can be remote controlled (interactive), it is often easier to integrate such a system into a system-of-systems. The degree of remote controllability depends on technical aspects (e.g. web based) and the completeness of the remote controllability.
        - DP Web-based in its own frame
        - DP As Web Services for Remote Portlets (WSRP) Portlet
        - DP via Remote Desktop Protocol (RDP) or similar
        - DP Completeness of the remote controllability (fraction of the UI elements that are remote-controlled)
    - MOP API-based remote control: If system functions can be remote controlled (API-based), it often easier to integrate such a system into a system-of-systems. The degree of remote controllability depends on the API's accessibility and the completeness of the remote controllability.

    - DP Standardized interface
    - DP Clients generally available
    - DP Clients downloadable
    - DP Completeness of the remote controllability (fraction of local functions, remote accessible via API)
  - MOP Usability: On remote control, aspects of human factors can play a role. With high latency the feedback linkage could be disturbed which in turn makes balancing reactions impossible. The remote system may become inoperable.
    - DP Latency/Response times
- MOE Function list efficiency
  - MOP Costs: The function list resulting from the combination of functions of existing systems can be assessed with regard to their cost. This includes how long the operational process, realized with the specific function list, lasts and what resources are needed.
    - DP Duration
    - DP Required personnel (number of persons required, qualification)
    - DP Required resources
  - MOP Endangerment of required personnel and resources: The personnel and resources with which the concrete function list will be implemented may be exposed by their positioning to threat.
    - DP Spatial extent of exposure
    - DP Duration of exposure

3.2.5 Process model for the evaluation of system architectures.

This section introduces a process model to be applied in NEC evaluation of a system in a system-of-systems context. This process is based on and very close to the VEVA-Process [11]. The VEVA process was originally defined for description, setup, execution and evaluation of distributed simulation experiments. We propose to use this model with minor modifications for evaluation of NEC in a system-of-systems context, because we see the evaluation of NEC as a special use case of VEVA. The minor changes we propose concern mainly the formalisation of artefacts, e.g. the continuous use of NAF throughout experiment design, setup conduction and evaluation and the activities involved regarding the applicability of a system-of-systems integration architecture.

The general building blocks of the proposed process model are identical to the VEVA model. In general there exist phases, steps and activities as well as process outputs (artefacts) and roles. The artefacts are further refined into products and documents. Each step provides contributions to one or more associated artefacts or products (for example software, configuration files, etc.) due to the execution of activities. Therefore some artefacts appear several times in table 1. Table 1 gives a simplified overview of the process especially showing only those artefacts supporting evaluation of NEC and not depicting activities. It is to note, that here just a rough of overview can be given. Details can be found in [11]. In general the phases are executed linear; the steps are conducted in a not-linear manner. Details on this can also be found in [11].

Table 1: Process model simplified and adapted to [11]

Phase	Step	Dedicated Artefacts relevant to NEC assessment
Definition of Goals	Problem Perception	
	Requirements Specification	
Conceptual Planning	Tailoring NAF	NAV
	Scenario Modelling	NOV
	Capability Analysis	NOV
		NCV
		Measurands, Measurement Equipment, Methods of Measurement
System-dependent Planning	Specific System Selection	NCV
		NSV
		Measurands, Measurement Equipment, Methods of Measurement
	Interoperability Modelling	NSOV NTV
	Feasibility Study	
Execution Preparation	Sequence Planning	
	Structural Planning	Measurands, Measurement Equipment, Methods of Measurement
	Implementation	
	Setup, Integration & Test	
Execution	Experimenting	Measured Data
	Modification	
Analysis	Data Preparation	
	Plausibility Check	
	Exploitation & Interpretation	
	Model Governance	
	Closure	

In regard to the NEC evaluation the following phases are relevant:

- Definition of goals: It is assumed that the objective of the experiment is evaluation of NEC. Therefore the dedicated MOEs and the corresponding utility tree have to be stated.
- Conceptual planning: We use a scenario based approach as in the original model and in conjunction with the ATAM approach for the deduction of the MOE weighting. Therefore all scenarios have to be formulated as chains of operational activities and formalized in the NAF capability views NVC-4 to NCV-6 and in the operational views NOV-2, NOV-5 and NOV-7 (optional NOV-6c). Afterwards the corresponding MOPs have to be selected, as they provide testable assumptions for the MOEs. They provide the link between the MOEs and the architecture at system level in the sense that they help to localise the measurands in the system under test.

- System-dependent planning: In this phase the mapping between the chains of operational activities and concrete systems has to be performed. That is to define the architecture at system/system-of-systems level. We use various NAF-views to describe the system architecture for example NSV-1, NSV-2 and in case of services NSOV-2, NSOV-4 and NSOV-5. At his level the DPs must be associated with specific systems and dedicated communication links.
- Execution: During execution the measured values for the defined DPs must be determined and documented.
- Analysis: The experiment results must be interpreted in NEC context. That means that the measured data in the context of a certain scenario is matched against the assigned objectives (MOEs) one after another and afterwards the goal achievement is computed from the weighted sum. After determination of single goal achievements the overall goal achievement can be computed via the weights of the single goals.

4.0 CONCLUSIONS

The proposed methodological approach provides a starting point to encompass the often slightly soft used formulation of the “network ability” significantly more concrete. A usage model was presented with the proposals for the operationalization. Furthermore the proposed metrics represents a first selection for possible values that can be used as a basis for future assessment tasks. A completeness of the characteristic values will never be given. This is prohibited from the diversity of the systems to be examined and their tasks.

The necessary formulation of the objectives enforces a precise designation of the actually required system properties as well as their weights. This allows for a system assessment pinpointing the actual requirements. A system solution which provides additional but not required functionality would not be scored higher than a tailor-made system.

The biggest challenge in the application of the presented approach will certainly be the selection and weighting of the relevant characteristic values. Since the requirement that a system shall have the capability of being network-enabled always implies the requirement of “openness for the unforeseen”. This will always be a very difficult task. However, it is expected that this task will be transparent and quantifiable for specific NEC characteristics.

5.0 ACKNOWLEDGEMENTS

The authors would like to thank Reinhard Herzog (Fraunhofer IOSB) for insights into concept development & experimentation approaches as well as the reviewers for valuable comments and hints.

6.0 REFERENCES

[1] Alberts (2011). *The Agility Advantage. A Survival Guide for Complex Enterprises and Endeavors*. DoD Command and Control Research Program (CCRP).

[2] Bengtsson, Per Olof, Lassing, Nico, Bosch, Jan, & van Vliet, Hans (2004). Architecture-level modfiability analysis (ALMA). *The Journal of Systems and Software 69*, 129-147.

[3] Gorod, A., Gove, R., Sauser, B. & Boardman, J. (2007). System of Systems Management: A Network Management Approach. In: IEEE Int. Conf. on System of Systems Engineering SoSE 2007 (pp. 1-5).

[4] IEEE Recommended Practice for Architectural Description of Software-Intensive Systems. ANSI/IEEE 1471-2000, ISO/IEC 42010, Sep 21, 2000.

[5] ISO/IEC 25010 (2011). Systems And Software Engineering. Systems And Software Quality Requirements And Evaluation (SQuaRE). System And Software Quality Models.

[6] Kazman, Rick, Abowd, Gregory, Bass, Len, & Clements, Paul (1996). Scenario-Based Analysis of Software Architecture. *IEEE Software 13*, 47-55.

[7] Kazman, Rick, Klein, Mark, Clements, Paul, & Compton, & Norton L. (2000). ATAM: Method for Architecture Evaluation. Technical Report CMU/SEI-2000-TR-004 ESC-TR-2000-004. Software Engineering Institute, Pitsburgh: Carnegie Mellon University.

[8] Larson, E.V., Darilek, R.E., Kaye, D.D., Morgan, F.E., Nichiporuk, B, Dunham-Scott, D., Thurston, C.Q., & Leuschner, K.J. (2009). *Understanding Commanders' Information Needs for Influence Operations, Appendix C: A Metrics-Based Planning and Assessment Approach for Influence Operations*, RAND Corporation, Document Number: MG-656-A.

[9] Lung, Chung-horng, Bot, Sonia, Kalaichelvan, Kalai, & Kazman, Rick (1997). An Approach to Software Architecture Analysis for Evolution and Reusability. In: *Proceedings of CASCON '97* (pp. 144-154).

[10] NATO RTO SAS-027 (2005). *Handbook on the Analysis of Smaller Scale Contingency Operations in Long Term Defence Planning*.

[11] Siegfried, R., Lüthi, J., Herrmann, G., & Hahn, M.: VEVA as German approach towards operationalizing the DSEEP: Overview and first experiences. In: *Proc. 2011 Spring Simulation Interoperability Workshop, 4-8 April, 2011, Boston, MA, USA.*

[12] Thomas, A., Turner, T., & Soderlund, S. (2009). Net-Centric Adapter for Legacy Systems. *IEEE Systems Journal 3* (3), 336-34.

[13] UK MOD 2009, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/28546/20100602MODAFDownload12004.pdf, p. 214.