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ANNCP WG IX Collaborative Project CP-20 on Analysis of Network Enabled Operations – Final report

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Summary

Network Enabled Capabilities (NEC) has become an important concept for enhancing the operational capability of military forces in all three of the ANNCP nations. There is currently no universally accepted understanding of NEC, and there is no preferred method or analysis tool for investigating the key issues. This was the background for starting the collaborative project ANNCP-20. The objective of ANNCP-20 was to exchange, and validate by review, ideas and approaches for the Operational Analysis (OA) of Network Enabled Capabilities.

In the five meetings held within CP20 a wide range of studies and NEC issues were presented and debated: from the UK's high level OA that aims to show the benefit of NEC at campaign level, to analysis that examined the operational benefit of better networking for Norway's new multi-role frigate. Within the studies presented, a wide range of OA methods and tools were used. Traditional simulation models were the primary tool used, ranging from those examining force on force interactions to those representing the operations of a single company of soldiers. In addition, agent-based models, optimisation methods and experimentation or gaming for examining either the essential human elements or the non-equipment lines of development within NEC were also discussed. It is not surprising that with such a wide range of NEC issues, a wide range of tools have been used to assess them.

Given the diversity of the potential influence of NEC on operations, a broad range of NEC issues were examined within this CP. This can be viewed as a significant achievement, providing each participating nation with a broad appreciation of the analysis methods and tools that could be applied to explore such varied issues.

All studies considered within this CP that aimed to demonstrate a benefit from investment in NEC were successful in doing so. This CP highlighted that NEC focussed OA is most mature in being able to assess the network and the operational benefit of those connected to it within small focussed scenarios (e.g. maritime interdiction). Other key areas of NEC assessment are less mature such as: the critical part that humans play in decision-making, balancing investment against other capabilities, and being able to evaluate the whole value/benefits' chain within a single method. The analysis presented also focussed on doing the same things better and did not examine the military benefit that could be gained from "doing better things" as a result of being more network enabled.

There is potential benefit in creating a follow-on NEC related CP. Any such CP would increase the benefit to all participating nations by having a more focussed scope on a specific area that is of interest to all nations and ideally all key participants.

Sammendrag

Bakgrunnen for å starte ANNCP WG IX CP-20 var erkjennelsen i de tre ANNCP nasjonene av at Network Enabled Capabilities (NEC) fremdeles er et konsept som ikke er godt forstått og der det ikke finnes allment aksepterte analysemetoder for å studere sentrale problemstillinger. Derfor ble CP-20 opprettet med sikte på utveksle ideer og aktuelle OA angrepsmåter for dette problemområdet. Denne utvekslingen kunne også tjene som validering av anvendte metoder.

I løpet av de fem CP-20 møtene som ble avholdt ble et bredt spektrum av NEC problemstillinger, studier, metoder og verktøy presentert og diskutert. Med et så omfattende og bredt spektrum av problemstillinger som NEC representerer er mangfoldet i studiemetodene ikke overraskende. Dermed er det vanskelig å trekke generelle konklusjoner, men det ser ut til at tradisjonelle simuleringsmodeller er det mest benyttede OA verktøy. For å studere problemstillinger der det menneskelige element er sentralt eller andre ikke-materielle faktorer (f eks trening og doktrine) er i fokus ble eksperimentering, spill, optimering og agentbaserte modeller spesielt diskutert som metoder.

Det brede spektrum av NEC problemstillinger som ble diskutert i CP-20 gir de tre nasjonene en relativt god forståelse av OA metoder som kan anvendes på NEC problemstillinger. Dette er et hovedresultat fra arbeidet i CP-20.

Alle studiene, diskutert i CP-20, med siktemål å vise nytte av å investere i NEC lyktes i å vise slik nytte. Denne CP belyste også hvilke deler av NEC problemet som kan studeres med velutviklede metoder og hvilke deler der studiemetodikken ennå er mindre utviklet. En har en rimelig vel utviklet metodikk for analyser av nettverket og den operasjonelle nytten for de som er tilknyttet dette. Analysemetodikken for en del andre viktige NEC problemstillinger er mindre utviklet. dette gjelder for eksempel: den kritiske rolle mennesket spiller i beslutningsprosessen, avveie investeringer i NEC mot andre kapasiteter, sammenhengen mellom NEC attributter og nye kreative operasjonelle løsninger og samlet studie av hele ”NEC Value Chain”

De vil sannsynligvis være nyttig å følge opp CP-20 med en ny NEC-relatert CP. For å øke nytten av en slik CP tilsier erfaringen fra CP-20 at en mer fokusert målsetting for et spesifikt felles problemområde for nasjoner og deltagere vil være nyttig. Eksempler på slike problemområder finnes i rapporten (kapittel 8).

Content

Preface

This report is the product of a true collaborative effort among the authors listed. For this reason it is natural to list the authors in alphabetical order without any of the ANNCP-20 group members singled out as editor.

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Norway was the leading nation and consequently the report is issued as an FFI report. This procedure follows that of previous ANNCP groups.

The ANNCP-20 group would like to use this opportunity to thank their colleagues who provided both presentations and information in support of the group's meetings.

The Norwegian contributors were: Geir Enemo, CP-20 member until he left FFI in spring 2006; and the following colleagues invited to give presentations at the meetings, Bård Reitan, FFI; Tor Erik Schjelderup, FFI; Sigmund Valaker, FFI.

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1 Introduction

Network Enabled Capabilities[1] (NEC) has become an important concept for enhancing the operational capability of military forces in all three of the Anglo Netherlands Norwegian Collaboration Project (ANNCP) nations. There is currently no universally accepted understanding of NEC, and there is no preferred method or analysis tool for investigating the key issues. Therefore at the 2003 annual meeting of ANNCP WG IX (24-25th June at TNO) NO expressed an interest in collaborating on this topic. Further discussions between NL, NO and UK representatives in a meeting on 22nd September 2003 identified that analysis of NEC would benefit from a collaborative project to examine the nations' various approaches, with the aim of gaining an enhanced and more common understanding of the problem.

1.1 Objective

The overall objective of this Collaborative Project (CP) was to exchange, and validate by review, ideas and approaches for the Operational Analysis (OA) of NEC.

The ANNCP WG IX panel suggested in their 20th June 2007 meeting that the final report of CP-20 should address four questions that in essence provide an assessment of the analytical capability to address NEC-related questions. These questions were posed at a late stage in CP-20's work schedule. However, the questions have been used as guidelines for the selection of subjects covered in the report and chapter 7 has been devoted to answering these questions.

1.2 Meetings

The working mode of this collaboration project consisted of meetings where each nation explained their current approaches to different aspects of NEC. The subjects chosen for each meeting were determined through discussions in previous meetings.

The CP started in July 2005 and finished with the completion of this report in June 2008. ANNCP WG IX CP-20 held five two-day meetings:

- 1st at TNO, The Hague, Netherlands on 10th- 11th October 2005
- 2nd at Dstl Farnborough on 24th-25th April 2006
- 3rd at FFI, Kjeller in Norway on 2nd - 3rd October 2006
- 4th at TNO in Soesterberg, Netherlands on 11th -12th June 2007
- 5th Dstl Farnborough on 4th-6th November 2007

[1] The Terms of Reference (TOR) of ANNCP-20 used the term Network Enabled Operations (NEO). However, in all three participating nations Network Enabled Capabilities or Capability (NEC) is used to describe the NEO concept. Therefore the term NEC is used throughout this report.

1.3 Caveats

The main output from CP-20 is described in terms of methods and approaches found to be of value in analysing Network Enabled Capabilities, and where appropriate illustrated by the results of actual analyses undertaken by the individual nations. However, it should be noted that the choice of subjects to be presented in the CP-20 meetings reflects the interests of the participating members from the three nations. Hence this approach fulfils the knowledge sharing ambition stated in the terms of reference for CP-20, but it does not necessarily provide the most representative collection of studies to exemplify the three nations OA approach to NEC related problems

1.4 Report Layout

The term NEC is a term central to this report, but possibly with different interpretations. In Chapter 2 a brief overview of the NEC concept of the UK, NO and NL is provided. The next three chapters are summaries of the OA approaches applied by each of the three nations and the national presentations, with Chapter 3 covering UK, Chapter 4 covering NO and Chapter 5 covering NL. Chapter 6 is a summary of the preceding three chapters mainly in the form of a table. This table illustrates the NEC questions currently addressed and is referred to in Chapter 7 discussing the questions raised by the ANNCP WG IX panel at their 20th June 2007 meeting. Chapter 8 provides a summary to the report.

2 What is NEC?

In general, NEC is about making use of improved networks to enable information to be better exchanged between systems and decision-makers in order to improve operational performance. Despite many similarities, each national network enabled concept is defined slightly differently. This chapter provides a brief overview of each nation's network enabled concept.

2.1 United Kingdom NEC

The UK concept is known as NEC. It is described as being about the coherent integration of sensors, decision-makers and weapon systems along with support capabilities[2]. NEC is expected to offer decisive advantage through the timely provision and exploitation of information and intelligence to enable effective decision-making and agile actions. It is not about technology or equipment in itself, but about better access to and use of information. Thus NEC will be implemented through the coherent and progressive development of equipment, software, processes, structures, and individual and collective training, underpinned by the development of a secure, robust and extensive network of networks.

The UK has developed a Networked Force Benefits Map (see Figure 2.1), which is derived from the US Network Centric Warfare (NCW) framework, but has been modified to reflect UK

[2] JSP 777, Edition 1: The NEC Handbook, CBMJ6-CBM3, Jul 2005.

findings from studies, experiments and analysis. The benefits chain is useful in both helping to understand NEC and its key components, and for proving a breakdown of the elements that need to be analysed when evaluating NEC. For example, NEC is not just about having a robust network that permits information to be shared; this is merely the foundation which must enable timely and appropriate effects. The framework also states that having the right people, i.e. appropriately trained, are a critical element if the concept is to be successful.

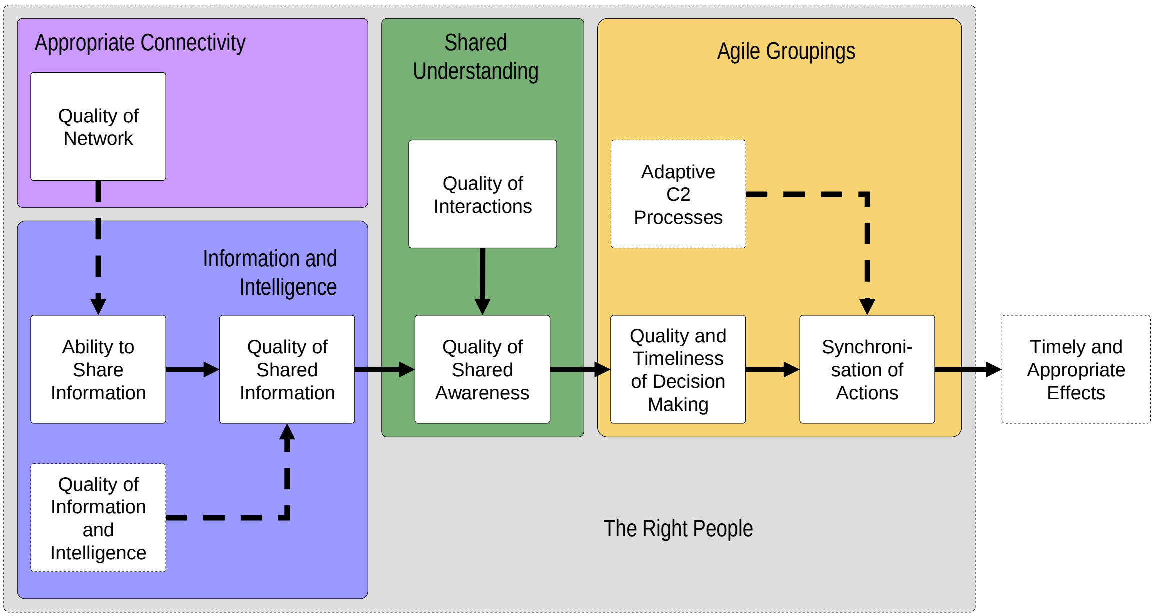

Figure 2.1 Networked Force Benefits Map

2.2 Norwegian NEC

The Norwegian understanding of NEC, Nettverksbasert Forsvar[3] (NbF), is a label put on the transformation effort of the Norwegian Defence to achieve a higher degree of network organization, and the concept stated as the objective of this transformation. The ambition and the underlying basic ideas are to a large extent in line with the NNEC of NATO and the NEC of the UK. The Norwegian interpretation of these ideas was developed by a group of experts (military and scientific) in 2006. The result, in a condensed form, is presented in Table 2.1.

Table 2.1 shows three stages in the transformation process labelled Maturity Level 1, 2 and 3, respectively. Each stage is summarised along nine dimensions. The first stage is close to a description of the current situation. The second stage is a guide for the current procurement plans, and the third stage describes the vision of the transformed forces. The NEC transformation follows an evolutionary approach, and it is recognized that the views expressed in Table 1 may change during the evolution process, as a result of new insight gained through experience, experiments and research.

[3] The Norwegian term for a network based defence is ”Nettverksbasert Forsvar”, here abbreviated NBF. This abbreviation, or rather NbF, is commonly used in Norway to label the NEC transformed state or the NbF concept: a concept for collaboration in networks with the objective to utilize defence resources in ways that fully exploit the possibilities of the information age in order to increase flexibility and effect.

NEC-state	Maturity Level 1	Maturity Level 2	Maturity Level 3
	Initial (or preliminary) NEC	**Integrated NEC**	**Comprehensive NEC**
NEC consciousness	Knowledge of NEC	Understanding of NEC	NEC philosophy fully implemented
Doctrine	Adapted doctrine	NEC-based doctrine and concepts	Continous NEC-concept development
Organization and process	Increased organisational flexibility	Flatter, more dynamic and horizontally coordinated organization with further increased organisational flexibility.	Flat, flexible and dynamic organization with parallell processes as the normal working mode
Experimentation /exercise /training /education and competence	NEC-philosophy integrated in all educational programs	Frequent NEC-focussed experimentation, exercising and traning	Integrated experimentation, exercising and traning
Information infrastructure and technology	Increased (joint) connectivity , but proprietary solutions	"Net-ready" and "PlugNOperate"	"Everyone and everything" are fully integrated into the electronic information network
Individual characteristics and culture	"From cloning to diversity"	Specialization, as well totality, emphasized and encouraged. Interaction stressed	"Collectivism" and flexibility emphazised
Interoperability (PTO)	Units cooperating in military operations	Full Internal interoperability	Full interoperability internally and towards prioritized external partners
Leadership and decision processes	Leadership authorized through positional authority	Leadership performed based on intuition and use of the net - primarely decentralized	Leadership authorized on the basis of competence related to the mission. Decentralized command structure
Economy	High benefit/cost ("Low hanging fruit")	Major investments necessary in order to make progress	The benefits from previous investments may be harvested

Table 2.1 Norwegian vision of stages in the transformation of the Norwegian Defence Force towards forces with increased NEC.

2.3 The Netherlands NEC

Networked operations – a new way of operating based on the optimal use of information – is the answer to the challenge of the increasing complexity of operations. Through networked operations, the Netherlands armed forces make maximum use of the latest possibilities offered by the developments in technology. All these new possibilities can be summarised under the term NEC.

NEC in the Netherlands aims to improve the cohesion and swiftness of operations of a multinational and joint coalition, so that a decisive advantage can be achieved over the opponents. Through optimal use of information, the goal is to reach the highest possible level of integration and coordination in the deployment of all available means.

A key question stated in the Netherlands Defence Doctrine is "What matters is how better networks lead to better decision-making processes and to better results". This question is visualised in the chain of networked operations shown in Figure 2.2. This chain is called "The NEC Value Chain" in this report.

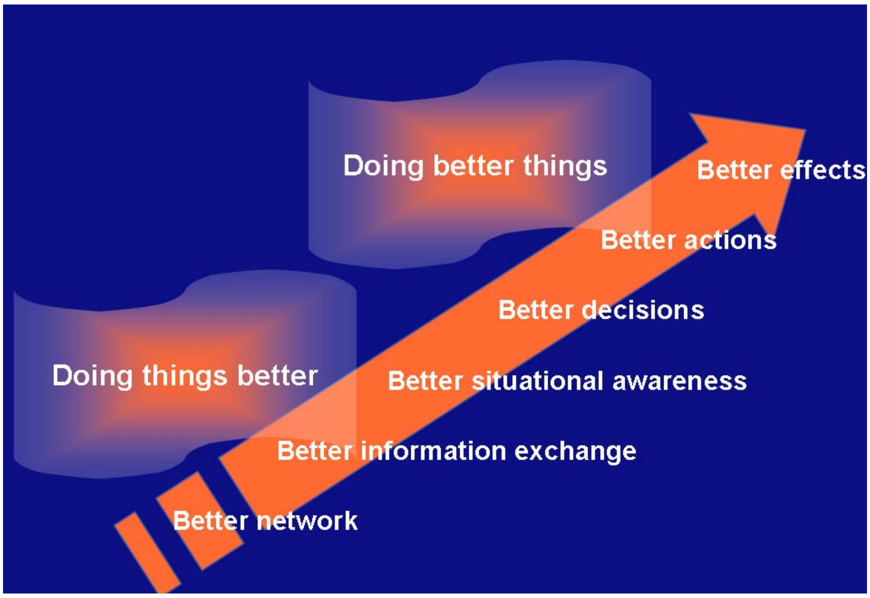

Figure 2.2 The NEC Value Chain

The development of NEC within the Netherlands armed forces is an evolutionary process. Networked operations will gradually become a reality. The seven characteristics of NEC will, in due course, become visible in practice:

i. Agile mission groups. A cooperation arrangement can be (re-)designed flexibly in terms of capabilities.
ii. Flexible deployment. Mission groups, units and means have the capacity to adapt swiftly and easily to new mission requirements without jeopardizing the cooperation.
iii. Robust information infrastructure. The information sources are sound, safe and reliable, and flexible enough to meet the demands of an agile mission group.
iv. Full availability of information. All relevant information can be exchanged within a mission group. Generic network services support cooperation and decision-making.
v. Shared understanding. The understanding and interpretation of the present situation is shared.
vi. Effects-based planning. The operational plans are aimed at the desired effect of a mission.
vii. Effect synchronisation. Coordinated deployment, in combination with dynamic and distributed planning and execution, ensure a decisive effect.

The development of NEC requires technological, process-driven and organisational innovation. Taking into consideration the three types of innovation, there are five levels of NEC. Using these levels can help the Defence organisation define its ambitions and requirements clearly and can also provide insight into the adaptability and interoperability of a military capability.

i. NEC level 1 – Isolated. The capabilities operate almost entirely in isolation. Exchange of information between these capabilities is at a low level.
ii. NEC level 2 – Deconfliction. There is still a wide diversity of non-linked communication networks. There is a certain amount of coordination between the various systems. There is no complete shared situational awareness and different operational concepts exist.

iii. NEC level 3 – Coordination. The network and information infrastructure (NII) creates strongly improved possibilities for communication and information exchange. Due to the linking of (most of) the communication systems, there is shared situational awareness.

iv. NEC level 4 – Collaboration. New operational concepts are being implemented. Dynamic forms of organisations as well as operational groups composed on an ad hoc basis are emerging. The NII provides better support to effective and interactive planning and execution of operations. The vertical and horizontal supply of information - i.e. through the chain of command and between actors - is integrated and consistent.

v. NEC level 5 – Coherent effects. A mission group is able to make effective use of fully integrated capabilities for observation and weapons deployment. All available capabilities can be deployed in a coordinated way. The NII enables a quick adaptation to changed circumstances or new tasks.

3 The United Kingdom Analytical Approach to NEC

In CP-20 the UK presented many different studies and tools that have been used to assess NEC. This chapter summarises those studies and methods.

3.1 NEC focussed High Level Operational Analysis

The UK has several High Level Operational Analysis (HLOA) studies that have been used in the past to assess the benefits and risks of NEC. They now aim to support the delivery of NEC by helping to balance investment not only between C4ISTAR (Command, Control, Communications, Computers, Intelligence, Surveillance, Target Acquisition, and Reconnaissance) systems, but also comparing C4ISTAR systems with other platforms. Ideally, the effectiveness of all systems should be assessed on their ability to influence campaign outcome. However, showing the impact of C4ISTAR systems on campaign outcome has yet to be achieved to a level where balance of investment studies including all aspects of C4ISTAR can be assessed. This chapter focuses on these studies; a summary of each is given below.

3.1.1 NEC Campaign & Communications Implications Study (NC2IS)

NC2IS has spent several years evaluating the Information and Communications Services (ICS) elements of C4ISTAR while providing evidence on the benefits and risks of NEC. NC2IS uses a method based on Information Exchange Requirements (IERs). These IERs are used in conjunction with a communication performance simulation model and the combat simulation models (COMAND and CLARION) to address three questions:

- What is the size and construction of the peak communications load within a campaign?
- Do the planned networks have sufficient capacity to cope with the peak load?
- What is the impact of any identified communication shortfall on campaign outcome?

Campaign analysis was carried out that assumed that NEC would lead to an increase in the air campaign tempo, shorter communication and intelligence dissemination times, better directed

ISTAR (Intelligence, Surveillance, Target Acquisition, and Reconnaissance) and improved joint fires co-ordination. These aspects were then associated parametrically to three levels on NEC (initial, transitional and mature) and improvements on the outcome of the campaign were shown. The study now seeks to relate the improvements in such aspects to future concepts and procurements in order to understand the ICS priorities that will deliver affordable and effective NEC between 2010 and 2025.

3.1.2 ISTAR Balance of Investment Implications Study (IBIS)

IBIS aims to assess the campaign effectiveness of potential ISTAR architectures[4], and their impact and dependence on the enabling ICS in order to advise on the investment priorities within ISTAR. To achieve this IBIS is developing a new stochastic simulation model of the ISTAR architecture called the Joint Intelligence Model (J2M). J2M will represent the direction, collection, processing and dissemination aspects of the intelligence cycle. The overall method will use J2M to assess alternative architectures, provide output such as IERs for use within the NC^2IS method and intelligence generation times for use in operational (combat) models. This will allow the assessment of the impact of any additional load generated by the alternative architectures on the networks and enable the assessment of the impact on operational outcome respectively. In 2008 IBIS will be testing the complete method with several scenarios for the first time.

3.1.3 Future HQ Requirement Study (FHQRS)

FHQRS has used both simulation modelling (SIMBRIG and HiLOCA) and gaming (WISE) to identify and assess the operational impact of alternative approaches to future headquarter (HQ) roles and structures. FHQRS has, like NC2IS, looked at the impact on operational outcome of enhanced level of NEC, focussed on improving situational awareness and command agility. FHQRS is now focussing on understanding the functions and processes within a HQ in order to assess the impact of alternative HQ structures. This revised focus is likely to result in the development of a simulation model of the functions and processes within an HQ.

3.1.4 Impact of Networking on Air Defence (INADS)

The aim of INADS was to examine the balance of investment between Air Defence (AD) weapon/platform capabilities, sensors and C2 processes (levels of networking). For a range of spend levels, it found the most cost-effective options for networked AD in terms of their contribution to the protection of key Blue assets from Red air threats and Blue and neutral air vehicles from Blue kills. A Linear Program INADS showed that in some cases it was more cost-effective to invest in improving the levels of networking than procuring additional weapon platform.

3.1.5 Surface Target Engagement BoI Study (STEBS)

STEBS aimed to provide guidance on the balance of platforms, weapons and C4ISTAR systems needed to generate the UK contribution to the attack of surface targets, on land and in the littoral.

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[4] Architecture includes all aspects of people, process and equipment.

For a representative range of scenarios, STEBS used a Linear Program (LP) to find the most cost-effective mix of systems, including those required to provide Target Acquisition (TA). STEBS included a comprehensive representation of the essential aspects of NEC by using the STIKMAN model to represent all essential aspects within a kill-chain that are required in order to prosecute Time Sensitive Targets (TSTs).

A summary of the questions asked, method and tools used and analytical result of the high level studies discussed above is provided within the Table 3.1.

Study Question	**Method**	**Tool**	**Result**	**Comment**
What is the size and construction of the peak communications load within a campaign?	Business Process based IER assessment	COMET	Analysis has highlighted the main contributors to the peak network load.	IER-based methods required significant effort.
Do the planned networks have sufficient capacity to cope with the peak load?	Simulation	GCAT	Analysis has highlighted those areas of the network that may be congested.	
What is the impact of any identified communication shortfall on campaign outcome?	Simulation	COMAND and CLARION	Communication shortfall has yet to be directly related to campaign outcome.	
What is the benefit of NEC on campaign outcome?	Simulation	STIKMAN, COMAND and CLARION	Sensitivity analysis has shown the benefit of NEC on campaign outcome.	Other work has shown the benefit of improving situational awareness and command agility on operational outcome.
What is the operational impact of alternative ISTAR architectures on both the network and campaign outcome?	Simulation and IERs	J2M, Campaign Models and NC2IS	Method development is not yet complete. Initial analysis has shown the impact of ISTAR on both the network and campaign.	
What is the optimum balance of investment between AD weapon/platform capabilities, sensors and levels of networking?	Optimisation (LP)	LP	Analysis showed there was value in investing in better networks rather than additional weapon platforms.	
What is the balance of platforms, weapons and C4ISTAR systems needed to attack targets beyond the close battle?	Optimisation (LP)	LP (TA timings provided by STIKMAN)	Optimum Mix provided including the required TA systems	LPs that find the least cost mix to attack a given set of targets are not ideal for evaluating NEC.

Table 3.1 Summary of the presented UK OA studies.

3.2 Other UK NEC Related Studies

A short overview of the other studies briefed to the CP-20 that were either NEC focussed or included elements of NEC are described below.

i. The Joint Co-ordination for Urban Operations Study aimed to investigate the requirements for, and use of indirect fire, fixed wing and rotary wing assets in the urban environment to aid the Land Component Commander in his plan while also attempting to determine the strike, ISTAR and C3I capabilities needed. The outcome of this study was not presented to the CP-20 due to a change of direction.

ii. The Maritime NEC Concepts Study looked at bridging the gap between the high level NEC vision and low level maritime concepts. A judgement based method was developed and used to undertake an initial assessment.

iii. The evaluation of Joint Logistics, one of the UK MoD defined Military Capabilities Enabled by Networking, used qualitative methods such as Benefits Analysis to assess how NEC could benefit Joint Logistics while highlighting the key interventions that would be needed to enable this.

iv. UK Co-operate Engagement Capability (CEC) study used benefits analysis and man-in-the–loop simulation in order to evaluate the options for procuring CEC. The study was able to demonstrate CEC’s contribution to Situational Awareness (SA), but was not able to quantify the impact of improved SA on campaign outcome.

v. The “Improving the representation of human and system behaviour in OA” Study aimed to identify a set of human science factors which could be used to improve the representation of group behaviours in HLOA models. The study was able to establish a common language and understanding between OA and human sciences (HS) communities and a robust framework to encapsulate the OA and HS problem space. An auditable process to enable identification and inclusion of relevant HS factors in HLOA was developed.

In addition to the studies presented, the UK provided presentations on several models that aim to represent aspects of NEC, two in particular were the SIMMAIR maritime and air simulation model that is currently being developed, and the FTM that is being used in the assessment of the prosecution of TSTs. Fuller descriptions of these models and the models mentioned within this chapter can be found at Appendix B.

4 The Norwegian Analytical Approach to NEC

Norwegian Defence has during more than ten years realized the important implications of the development of electronic based networks on military operations. The Norwegian thinking on

NEC has to a great extent followed the approach undertaken by its allies e.g. US, UK and NL, to mention some of the nations Norway has close links to in military research. The present development of NEC happens in three areas:

- Detailing and implementation of the information infrastructure
- Integration of present and future platforms and units into the network
- Research and experimentation on networks and network technology

OA is supporting the development in all these areas. A characteristic of NEC is the close links between the human and technological factors and hence the importance of combining these factors in analyses supporting decisions and further development of NEC. As a consequence the OA expertise has been distributed to projects undertaken by a combination of OA analysts, human factor experts and technological experts. Another development towards more “off the shelf” technological solutions has resulted in a trend away from the past “research and development” activities and towards more OA type activities. Accordingly a substantial part of the current NEC related research may be labelled OA.

Given this background it has been impossible to provide a complete picture of the Norwegian NEC related OA approach during the limited time of the CP20 activity. Four issues believed to be of mutual interest to all three nations were presented in the CP20 meetings:

- Analysis support to the Operational Evaluation of the Nansen-Class frigates
- Analysis to support the development of a new logistics Operational Concept for Logistics
- Human factors in NEC (“NbF i operasjoner”)
- A survey on the applicability of Agent based models within military OA

In addition, to serve as information exchange the presentation of these subjects illustrates the NEC problem areas Norway is addressing and the OA approach adopted. Main characteristics of the studies are summarized in Table 4.1.

Study Question	**Method**	**Tool**	**Result**
What are the NEC bottlenecks of the NANSEN Class frigate?	1) Systems Architecture 2) Multi criterion decision analysis (MCDA) 3) Stochastic Simulation	1) Enterprise Architect 2) No specific tool applied (pencil and paper) 3)Arena (From Rockwell Software)	1) Structured and transparent problem description 2) Scenario specific goals and their relative importance 3) Identifies quantitatively the bottlenecks (equipment capability, human decision making) in the workflow from target detection to target neutralisation
How to best use own resources within fishery protection?	Agent based model (ABM)	MANA	ABM found to be a quick and reasonable tool when dealing with problems involving NEC and human decision making.
Specify the main characteristics of a new operational logistic concept for the Norwegian Defence	Structured thinking and simulations of selected logistic processes	Any Logic “System dynamics” simulations models Database	Structured input to the operational logistic concept development process. (Ongoing study.)

Study Question	Method	Tool	Result
Forces			
Identification of short-term efficiency improvements of network solutions.	Analytic Hierarchy Process and Optimization	NetOrg –model (written in AMPL)	Insight into: General improvement potential (IP) from implementing NEC, contribution of different force components to the IP and collaboration requirements.
What is the impact of culture on teamwork?	Multinational experiments	“NeverWinter-Night” experiment game	Insight into relations between: organisational characteristics, organizational issues and individual/cultural characteristics. (Experiment experience.)
Exploration of situation awareness and negotiation based resource allocation in a NEC environment.	Experiment	“Battle Griffin” experimental setup	The NEC technologies contributed to situation awareness and negotiation based resource allocation. (This should be further investigated.)

Table 4.1 Summary of the presented Norwegian OA studies

The models and tools used in the studies are briefly described in Appendix C.

4.1 Analysis support to Evaluation of the Nansen-Class frigates

Norway has procured five new multi-role frigates, where the first one was delivered to the Navy in 2006, and will be commissioned in 2009. A study was commissioned to evaluate the frigate’s ability to be an effective node in a network based force. In order to do this evaluation, three different scenarios were defined and used. The evaluation was accomplished in three steps. These are:

i. In the first step, each scenario was described by means of the NATO Architecture framework [1], predominately making use of the operational views.

ii. In the second step, having this well organized description at hand, the operational views were mapped into a hierarchy of goals where the top goal of the scenario is placed at the top. The underlying method applied is a simplified version of the standard method Analytical Hierarchy Process [2]. The objective of this step was to identify the most important factors within the NEC context for each of the scenarios.

iii. The third step is the only “hard OA” part of the analysis. Here the distributed processes (in order to build picture, make decision and apply weapon) within the force were modelled using a discrete event simulation model. The objective here was to identify the process ‘bottlenecks’, in order to determine where resources (technology, training, education, and tactics) should be directed in the future.

4.2 Analysis supporting the development of a new logistic concept

The possibilities opened by the network technology (e.g. ‘Total Asset Visibility’) to control the logistic processes, the trends towards multinational logistics and outsourcing, and some other factors, constitutes the background for developing of a new operational logistic concept for the Norwegian Defence Forces. OA used a traditional approach to analyse the logistic requirements in selected planning scenarios based on consumption data from previous and simulated operations. Simulation was then used to assess the benefits of applying different network based processes. One of the challenges of this approach was to obtain a realistic description of the information system performance, e.g. represent the influence of security restrictions.

4.3 Human factors NEC study - "NbF i operasjoner"

"NbF i operasjoner" is a good example of a study combining expertise on human factors, information system technology and OA. "NbF i operasjoner" was tasked to answer how NEC should be implemented in the Norwegian Armed Forces. To this end the study worked on three aspects: the description of NEC, efficiency of network solutions and the effectiveness of human processes in networks. This study was part of a NEC program of three studies. The NEC program continues with a suite of studies at FFI, started to investigate different aspects of information networks. The issues addressed ranged from how to technically design information networks, through impact of limitations due to bandwidth and security considerations, to organisational and effectiveness implications when the human factors were considered. These projects are not typical OA projects, but often have OA-expertise represented. "Collaboration in networks" is a good example of this, mixing expertise on network technology, human factors and OA.

OA expertise supported the process defining, and making more specific, the Norwegian version of a NEC vision, and pointing out the way towards that vision. Discussions in NATO forums, like SAS-050 (development of The C2 Conceptual Model), were important sources of ideas in this work. The vision is expressed in terms of the characteristics of three maturity levels presented to ANNCP20. This description serves as a basic framework for the development of NEC (see Chapter 2).

In order to identify short-term efficiency improvements of network solutions an optimization model (the NetOrg model) was developed (see Appendix C). All the Norwegian defence components is included in this model, but in a stylized and rather abstract way. This model has given insight into the general improvement potential from implementing network organisations, contribution of different force components to this potential and some collaboration requirements.

Experimentation was used to gain insight into the effectiveness of human processes in networks. Two of these experiments were briefed to the CP, "NeverWinterNight" and Battle Griffin 05:

- The "NeverWinterNight" experiment is part of a NATO Concept Development and Experimentation (CD&E) project, "Leader and Team Adaptability in Multinational Coalitions" (LTAMC). It examined the impact of culture on teamwork as primary issue.
- The Battle Griffin 05 experiment had several objectives, study negotiation based resource allocation, study collaborative building of a common operational picture and to act as a technology demonstrator.

These experiments have, in addition to the insight into the human processes targeted in the experiment, provided experience in designing, running and analysing experiments with humans as a decisive factor. Experimentation will constitute an important part of present and future OA related work on NEC.

A new study "Collaboration in Networks - Experimentation", plans to use experiments to study collaboration processes in networks. A new study approach is adopted for this project, starting with promising technologies and assessing how these technologies may be used in different situations. It is the intention that these experiments shall provide insight into the following questions:

- How is joint sense making achieved across multiple and diverse military organizations?
- How is coordination achieved between loosely coupled military and civilian organizations?
- How are network enabled capabilities formed in an operative military setting?
- How are routines developed and interpreted in military organizations?

4.4 Agent Based Models in military OA

A session on the third meeting was devoted to Agent based modelling. During this session, the nations gave their view on Agent based modelling[5]. Norway has spent some surveying effort on this topic, to better understand the embedded potentials. This survey is documented in a FFI-report (see [3]).

One of the most evident results found in the survey is the applicability of Agent Based Modelling and Simulation (ABMS) in human centric problems.

NEC is not explicitly mentioned in the survey, but for reasons indicated below ABMS should be suited for assessing NEC.

- Agent based models are focused on problems involving many agents. This is also a key characteristic of NEC, where the operations involve multiple agents.
- Agent based models are not focused on representing each agents physical characteristics in depth. Instead, the relationship between the agents is of concern. This involves topics like communication, communication technology and inter-agent behaviour, which are crucial topics within NEC.
- Agent based models are problem-oriented models (opposite to system-oriented models). This means that the models typically are built from scratch[6] in each case, and are not inheritance from old (huge) models. This behaviour seems suitable for NEC problems which vary a lot from case to case.

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[5] A unified definition of Agents based models does not exist, but basically agents are software objects that perceive their environment through sensors and act on that envision. They can communicate with each other, possess other skills and make decisions

[6] We are aware of present work on modelling human agents and developing software toolkits for agent modelling. This work makes it possible to build on previous models, but all the agent based models on military problems known to us are built from scratch.

5 The Netherlands Analytical Approach to NEC

In the core area Defence, Security and Safety of TNO (The Netherlands Organisation for Applied Scientific Research) a substantial amount of research is spent on Networked Enabled Capabilities (NEC). Most of this research is carried out as part of the research programme NEC.

One of the projects in this research programme is called Operational Analysis of NEC. In this project, an approach has been developed to analyse the potential increase in operational effectiveness as a result of NEC. This approach has been applied to a number of cases. The method and the application of the method are described in Section 5.2. Another project intends to measure the effect on mission effectiveness of the increase of C2 responsibilities at lower levels in the C2 chain. This project is discussed in Section 5.3. These two projects cover a significant portion of TNO's OA studies of NEC.

5.1 Five step approach

Based on the report "Network enabled operation – policy development study NEC"[7] of the Ministry of Defence of the Netherlands, TNO has developed a five step approach to analyse the potential increase in operational effectiveness of NEC.

This five step approach has been applied to a number of cases (two Anti Air Warfare cases, one Anti Surface Warfare case, one Anti Submarine Warfare case, and a Land Based operation). In each case, the increase in operational effectiveness due to a new (or adapted) operational concept that exploits the possibilities of NEC was quantified. One case is described by explaining what was done during each step of the five step approach. The other four cases are only described briefly; a more detailed description of these four cases is given in Appendix E.

5.1.1 The method

The following five steps are undertaken for each vignette or warfare area for which the increase in operational effectiveness due to NEC is to be analysed.

1. Determine a new (or adapted) operational concept that exploits the possibilities and benefits of NEC (and give a global description of the concept).
2. Describe the new concept in detail, including a qualitative description of the expected increase in operational effectiveness due to the new concept.
3. Describe the requirements for the network, training, education, personnel, material, and command and control to be able to execute the new concept.
4. Determine which method(s) are suitable to quantify the increase in operational effectiveness due to the new concept. Possible methods are an analytical model, a simulation model, an experiment or an exercise.
5. Quantify the increase in operational effectiveness by using one (or more) of the suitable methods.

[7] Netwerkend optreden – Beleidsontwikkelingsstudie NEC; Ministerie van Defensie, 22 oktober 2004

5.1.2 Applications

A new concept for maritime surveillance and interception

In this application, the added value of a new concept for a maritime surveillance and interception operation is studied. In a maritime surveillance and interception operation, a task group aims to recognise as many contacts as possible in a certain operation area. A contact is considered as being recognised if the task group knows the name or number of the contact. This requires that a ship of the task group has to approach (intercept) the contact to a small distance.

Step 1: the new concept

In a traditional maritime surveillance and interception operation, the operation area is usually divided into a number of disjoint areas of responsibility (AOR), where each ship is responsible for the surveillance and interception of the contacts in its AOR. In the new concept information about detected contacts is exchanged. Furthermore, a ship (ship A) will assist a ship in an adjacent AOR (ship B) if this ship (ship B) is busy with handling contacts while ship A is not busy handling contacts.

Step 2: description of the concept and benefits

In the new concept, the AOR of each ship is extended with half of the adjacent AOR on the left, and with half of the adjacent AOR on the right. In choosing which contact to handle in its AOR, each ship gives higher priority to contacts in its original AOR. The benefit of this new concept is that in situations where one ship is busy handling contacts in its own AOR, other ships can handle some of the contacts if these ships are not busy with contacts in their own original AOR. This can result in an increase of the number of recognised contacts.

Step 3: requirements

All units in the task group must have a communications network that can exchange information about the detections of contacts and information about the contacts that are being intercepted by a unit. Obviously, the C2 system has to be changed to enable this concept. Furthermore, the personnel have to be educated and trained accordingly.

Step 4: quantification method

As a quantification method, the surface surveillance simulation model SURPASS has been selected (SURface Picture ASSessment).

Step 5: quantification of the increase in operational effectiveness

The increase in operational effectiveness due to the new concept was determined in a number of scenarios. The new concept increased the operational effectiveness significantly, but the major part of the increase in operational effectiveness was due to the exchange of information on detected contacts and only a minor part due to possibility to assist ships in an adjacent AOR.

Other applications

This five step approach has been applied to four other cases. These cases are described briefly; a more detailed description of these four cases is given in Appendix E.

1. The increase in operational effectiveness due to Co-operative Engagement Capability (CEC) was quantified. CEC is a network enabled concept that increases the effectiveness of Anti Air Warfare. In particular scenarios, CEC provided significant added value.
2. The added value of a new network enabled concept for co-ordination between the air defence ships in a task group was quantified. The new concept resulted in a significant increase of the operational effectiveness.
3. The added value of a new network enabled concept for detecting and tracking enemy submarines was determined. The new concept increased the operational effectiveness.
4. The increase in operational effectiveness of NEC in a combat between two groups of soldiers (blue versus red) was quantified. A new network enabled concept increased the combat power of the blue soldiers significantly.

5.2 NEC experiment

This section gives a short description of an experiment of the international project "Command in NEC"-experiment that studies critical factors of C2 in joint operations in a networked environment. The experiment is performed as a co-operation between the OA department of the Business Unit (BU) Information & Operations, and the BU Human Factors.

The objective of the experiment was to measure the effect on mission effectiveness of the increase of C2 responsibilities at lower levels in the C2 chain. The BU Human Factors was responsible for the planning of the experiment, and the realisation of the experiment occurred in TNO's Advanced CD&E (Concept Development & Experimentation) Environment (TNO ACE) of BU Information and Operations.

The scenario was a joint air defence peace enforcement operation that was developed by two advisors from the Netherlands Ministry of Defence. Military operators from the Netherlands and Sweden participated in the experiment that lasted two weeks. The operators were from the army, navy and air force. The assessment of the results was done by scientists from The Netherlands (TNO), Sweden and Canada.

One of the observations made during the experiments was that it took quite some time for the operators to get used to their increase in C2 responsibilities and to get used the cooperation with operators from other military services. This shows that human aspects like education and training are important factors in NEC.

5.3 Summary and Conclusions

TNO has developed a five step approach to analyse the potential increase in operational effectiveness of NEC. This five step approach has been applied to five cases in which the added value of a new network enabled concept was quantified using simulation models. In all five cases, the new network enabled concept significantly increased the operational effectiveness.

TNO also organised an experiment to measure the effect on mission effectiveness of the increase of C2 responsibilities at lower levels in the C2 chain. This experiment showed that human aspects like education and training are important factors in NEC. A summary of the TNO studies discussed in this chapter is shown in Table 5.1.

Study Question	**Method**	**Tool**	**Result**
What is the added value of a new network enabled concept for maritime surceillance?	Simulation	SURPASS	Analysis showed there was a significant added value
What is the increase in operational effectiveness due to Co-operative Engagement Capability?	Simulation	JROADS	Analysis showed there was a significant added value
What is the added value of a new network enabled concept for co-ordination between air defence ships?	Simulation	JROADS	Analysis showed there was a significant added value
What is the added value of a new network enabled concept for detecting and tracking enemy submarines?	Simulation	MUST	Analysis showed there was an added value
What is the increase in operational effectiveness of NEC in a combat between two groups of soldiers?	Simulation	IWARS	Analysis showed there was a significant added value
What is the effect on mission effectiveness of the increase of C2 responsibilities at lower levels on the C2 chain?	Experiment	TNO ACE	Human aspects (education, training) are important factors in NEC

Table 5.1 Summary of the presented Dutch OA studies

6 Summary and conclusions on the national approaches

NEC is a concept of significant importance and therefore extensively addressed by the OA community in all the three nations. The range of problem areas presented by each nation probably reflects difference in size of military OA in each of the countries.

A summary of the NEC related questions that were addressed and hence the analysis presented and discussed during the CP-20 meetings is provided in Table 6.1. For each question type the main OA methods used, the type of results obtained and NEC value chain categorization are presented.

Nation	Study Question	Method	Result	Problem category
UK	What is the size and construction of the peak load and do the planned networks have sufficient capacity to cope with it?	Business Process based IER assessment and simulation. (Significant effort is required to generate IER sets.)	Analysis has highlighted the primary load contributors and those areas of the network that may become congested.	Better – Networks
UK	What is the impact of C4ISTAR (e.g. comms or ISTAR architectures) on campaign outcome?	Simulation and IERs. (Process models (comms and ISTAR architecture) have been developed to explore key areas. These will provide essential input into campaign models.)	To-date only partial success has been achieved in a few areas. Methods are still in development	Better – Information exchange, Situational awareness, Decisions, Actions
UK	What is the benefit of NEC on campaign outcome?	Simulation	Sensitivity analysis has shown the benefit of NEC on campaign outcome. (Other work has shown the benefit of improving situational awareness and command agility on operational outcome.)	Better – Situational awareness, Decisions, Actions
UK	What is the balance of investment between weapons platforms and C4ISTAR systems?	Optimisation (Linear Program). (LPs that find the least cost mix to attack a given set of targets are not ideal for evaluating NEC. It only explores "doing the same things better".)	In some areas (e.g. networking levels in AD or TA in deep target attack) this has been successful.	Better – Networks, Information exchange, Situational awareness, Decisions, Actions,
NO	What is the added value of a network enabled concept for the NANSEN class frigates	Systems Architecture Multi Criteria Decision Analysis Constructive simulation (stochastic)	Analysis showed some to significantly added value/benefit from NEC	Better – Situational awareness, Decisions, Actions,
NO	What is the effect on mission effectiveness of individual characteristics, organisational arrangements and collaborative methods/tools (culture, decision rights, "chat" etc)	Experimentation with humans	Insight/ qualitative knowledge about important relations between human factors, organisational factors and mission effectiveness	Better – Information exchange, Situational awareness, Decisions, Actions,

Nation	Study Question	Method	Result	Problem category
NL	What is the added value of a new network enabled concept for various operations (maritime surveillance, maritime air defence, detecting and tracking submarines, combat of soldiers)	Constructive simulation (stochastic)	Analysis showed some to significant added value	Better – situational awareness, decisions, actions, effects
NL	What is the effect on mission effectiveness of the increase of C2 responsibilities at lower levels in the C2 chain.	Experiment	Human aspects (education and training) are important aspects.	Better – situational awareness, decisions, actions, effects

Table 6.1 Summary of the studies presented to ANNCP 20

Table 6.1 shows an emphasis across all three nations on questions related to the potential benefit or added value that NEC can provide. The studies showed without exception increased performance with the addition of NEC.

Many of the UK studies presented were part of the HLOA programme. The HLOA programme focussed on determining the balance of investment between alternative NEC solutions, and comparing investment in NEC against other capabilities, using the high level measure of the effect on operational outcome. A number of process models (network, ISTAR architecture) have been developed in order to explore part of this problem in more detail. It is hoped these models can be effectively linked to operational models in order to better determine the impact on campaign outcome.

The Norwegian (apart from the study with NetOrg) and the Dutch studies focussed on measuring the benefits or effectiveness at the tactical or sub-tactical level. The NL 5-step approach was applied successfully across several different warfare domains using several different tools.

The UK presented the Network Force Benefit Map (see figure 2.1) and NL the NEC Value Chain (see figure 2.2) as frameworks linking NEC issues together. These frameworks were both found by ANNCP 20 to be useful for structuring NEC-related questions. With its simpler hierarchical structure the NL framework renamed the NEC Value Chain, was selected as a way of grouping NEC-related questions (see Chapter 7 below).

The broad range of problems presented required different methods and techniques to be used in the analysis process. But simulation was the primary analysis method chosen and traditional simulation models were the primary tool used. These models ranged from those examining force on force interactions to those representing the operations of a single company of soldiers. Gaming and experimentation were the primary method used to explore the human aspects that were difficult to assess with simulation models.

Most of the studies made assumptions about the beneficial characteristics of systems where network technology had been introduced and studied the operational consequences of these assumptions. Examples of such assumptions are better situational picture, shorter decision cycles, increased accuracy in target acquisition etc. The problem of verifying these assumptions has been addressed mainly through experiments with humans. It has been difficult to gain quantitative results from these experiments as indicated in the table. This poses a general challenge for the OA community when addressing NEC-related issues.

All the three nations are continuing to undertake NEC-related studies and develop their capability to investigate NEC-related issues.

7 Answers to the 'Panel Questions'

During the ANNCP WG IX Panel meeting in June 2007, it was suggested that the final CP20 report should address the following questions:

- What are the types of NEC-related questions that OA should be attempting to address?
- Which of these types of questions are in fact being addressed in each of the three nations in the various operational contexts?
- What models and other tools are being used for this purpose?
- What are the significant gaps in analytical capability and how might these be filled, noting especially any that offer potential for collaborative action?

This chapter addresses these questions.

7.1 What types of NEC-related questions should OA address?

NEC is a very broad area that covers a lot of topics and hence a lot of different NEC-related questions can be asked, including NEC-related questions that OA should attempt to address. To obtain a clear and structured overview of these questions, it is best to group the questions into different categories.

The high-level NEC-related questions are grouped according to the six elements of the NL's NEC Value Chain (see Chapter 2) in Table 7.1. Furthermore, questions that cover the whole NEC Value Chain (or at least a number of elements of the chain) are grouped in a separate row of the table.

7.2 What types of questions are being addressed?

The second Panel question is "Which of these types of questions are in fact being addressed in each of the three nations in the various operational contexts?" This question is answered in Chapters 3, 4 and 5 where the national approaches and NEC studies are discussed - Chapter 6 summarises these chapters. Furthermore, the second column in Table 7.1 gives a general overview of the questions addressed in each of the three nations. In this column, a tick indicates that the concerning nation examined topics related to the questions mentioned in the first column, it does not suggest that these nations have fully answered these questions.

NEC related questions that OA should address	**Questions addressed**
Better network • Will the network have sufficient capacity to cope with the load that will be placed over it? • What should the characteristics of the network be to enable better information exchange?	✓(UK, NO)
Better information exchange • How should the information exchange be managed? Should every participant receive all information so that it can use all information that is available, or should a participant only receive part of the information to prevent an information overload (smart pull, smart push)? • What are the requirements for information exchange to enable a better situational awareness?	✓(NL)
Better situational awareness • How should information be combined to improve situational awareness? • What are the current constraints on enabling enhanced situational awareness? • How should situational awareness be measured? • What are the requirements for situational awareness to enable better decisions?	✓(UK, NO, NL)
Better decisions • How should the decision process be changed to be able to make use of the improved situational awareness? • What are the requirements for the decision process to enable better actions?	✓(UK, NO, NL)
Better actions • What are the "better things" that NEC can enable? • What are the requirements for and benefits of self-synchronisation?	
Better effects • How can/do effects improve as a consequence of NEC?	✓(UK, NO, NL)

NEC related questions that OA should address	Questions addressed
Whole NEC Value Chain • What is the benefit of NEC to defence? • Is it possible to develop an OA approach that addresses the complete NEC Value Chain; i.e. that quantifies all improvements mentioned in the NEC questions above? • How, must the effort (e.g. budget) be divided over the first five elements of the NEC Value Chain to maximise the effects (the sixth element)? • What equipment projects will deliver better operational capability through NEC? • How much effort must be spent on the non-equipment Lines of Development (doctrine & concept, training, people, information, organisation, infrastructure and logistics) compared to the equipment Line of Development? • How do we trade-off investment in NEC with other capabilities? • Where can NEC deliver the most value to defence? • What is the best way to implement NEC? What areas are the priority for NEC investment in the near, medium and long term?	✓(UK)

Table 7.1 NEC related questions that OA should address and questions that are addressed

7.3 What models/tools are used to address the questions?

The third Panel question is "What models/tools are used to address questions?". This question is also answered in Chapters 3, 4 and 5 where the national approaches and NEC studies are discussed.

7.4 What are significant gaps in analytical capability?

In the following table, the significant gaps in analytical capability are grouped according to the six elements of the NEC Value Chain. Furthermore, gaps that cover the whole NEC Value Chain (or at least a number of elements of the chain) are grouped in a separate row of the Table 7.2

Better network • No significant gaps in analytical capability have been identified.
Better information exchange • The management of information exchange is a subject which is difficult to study and analyse. Exchanging all available information to all participants in the network can result in information overload and to situations where people at a higher level in the command chain interfere with decisions made at a lower level in the command chain. The study and analysis of these issues requires representation of humans in the loop. The analytical capability w.r.t. to these issues is relatively immature and represents a gap.

Better situational awareness • Situational awareness is difficult to characterise and measure. The study and analysis of situational awareness provided by NEC requires representation of humans in the loop. Also here, the analytical capability is relatively immature and represents a gap.
Better decisions • Humans are the centre piece of the decision process. Analysis of this process requires representation of humans. The analytical capability is relatively immature and represents a gap.
Better actions • Determining what the "better things" are that NEC can enable is an analytical gap. • Defining what the required changes are across all lines of development (equipment, doctrine & concept, training, people, information, organisation, infrastructure and logistics) to enable better things is another gap in analytical capability.
Better effects • Determining how effects improve as a consequence of NEC is an analytical gap that is closely related to the gap corresponding to the whole NEC Value Chain (see next row in this table).
Whole NEC Value Chain • An ambition to adequately answer the questions under, "Whole NEC Value Chain" of Table 7.1, is presently not achieved and represent perhaps the most significant gap in analytical capability.

Table 7.2 Significant gaps in analytical capability

A general gap in analytical capability is that it is difficult to consider all Lines of Development. Not only equipment, but especially the human element (people), and also doctrine & concept, training, information, organisation, infrastructure and logistics should be considered. Representing humans in the loop was identified several times as a gap in analytical capability. This gap possibly can be solved by using experiments with humans in the loop, but this is a very time consuming and expensive approach. Another possible approach is representing the human aspects within simulation models, although it is difficult to capture elements such as human decision-making in such models.

Also many of the other Lines of Development are difficult to capture in pure analytical or simulation models. To capture these Lines of Development, methods like gaming, experimentation or Concept Development & Experimentation (CD&E) are also needed. This means that a combination of analytical models, simulation models, games and experiments is needed to cover the gaps in analytical capability.

All gaps offer a potential for collaborative action.

8 Achievements, Conclusions and Way Ahead

Achievements and Conclusions. In the five meetings held within CP20 a wide range of studies and NEC issues were presented and debated: from the UK's high level OA that aims to show the benefit of NEC at campaign level, to analysis that examined the operational benefit of better networking for Norway's new multi-role frigate. Within the studies presented, a wide range of OA methods and tools were also used. Traditional simulation models were the primary tool used, ranging from those examining force on force interactions to those representing the operations of a single company of soldiers. In addition, agent-based models, optimisation methods and experimentation or gaming for examining either the essential human elements or the non-equipment lines of development within NEC were also discussed. It is not surprising that with such a wide range of NEC issues a wide range of tools have been used to assess them.

Given the diversity of the potential influence of NEC on operations, it is also not surprising that a broad range of NEC issues were examined within this CP. This can be viewed as a significant achievement, providing each participating nation with a broad appreciation of the analysis methods and tools that could be applied to explore such varied issues.

All studies considered within this CP that aimed to demonstrate a benefit from investment in NEC were successful in doing so. This CP highlighted that NEC focussed OA is most mature in being able to assess the network and the operational benefit of those connected to it within small focussed scenarios (e.g. maritime interdiction). Other key areas of NEC assessment such as: the critical part that humans play in decision-making, balancing investment against other capabilities, and being able to evaluate the whole value/benefits' chain within a single method are less mature. The analysis presented also focussed on doing the same things better and did not examine the military benefit that could be gained from "doing better things" as a result of being more network enabled.

The fourth meeting in Soesterberg was mainly devoted to the topic human factors where such expertise was invited. This arrangement proved successful. This may be kept in mind when planning any future ANNCP collaboration on OA of NEC.

Way Ahead. There is potential benefit in creating a follow-on NEC related CP. Any such CP would increase the benefit to all participating nations by having a more focussed scope on a specific area that was of interest to all nations and ideally all key participants. Examples of questions a future CP may choose to address are:

- How can analysis and experimentation better represent and assess the human aspects of NEC?
- Determine what are the "better things" that NEC can enable?
- How should questions covering the whole NEC chain be addressed?
- How can analysis and experimentation better assess those non-equipment lines of development essential to NEC?
- What analysis methods can be used to advise on NEC investment priorities in the near term and in the future?

References

[1] NATO C3 Board (AC/322): NATO C3 System Architecture Framework (NAF), Version 2.

[2] Goodwin and Wright (2005): Decision analysis for Management Judgement, WILEY.

[3] Ole Jakob Sendstad, Stein Malerud: Agent Based Modelling and simulation - applicability within OA at FFI, FFI report 2007/00164.

Appendix A List of abbreviations

ABM	Agent Based Model
ABMS	Agent Based Modelling and Simulation
AD	Air Defence
ADCF	Air Defence and Command Frigate
ANNCP	Anglo-Netherlands-Norwegian Collaboration Project
AOR	Areas of responsibility
ASW	Anti Submarine Warfare
BU	Business Unit
C2	Command and Control
C3I	Command, Control, Communications and Intelligence
C4ISTAR	Command, Control, Communications, Computers, Intelligence, Surveillance, Target Acquisition, and Reconnaissance
CD&E	Concept Development and Experimentation (CD&E)
CEC	Co-operate Engagement Capability
CP	Collaborative Project
DIS	Distributive Interactive Simulation
DLL	Dynamic-link Library
EW	Electronic Warfare
FFI	Forsvarets forskningsinstitutt (The Norwegian defense Research Establishment)
FGBADS	Future Ground Based Air Defence System
FHQRS	Future HQ Requirement Study
FTM	FOAC Time Sensitive Targeting Model
HiLOCA	High Level Operations model using Command Agents & Cellular Automata
HLA	High Level Architecture
HLOA	High Level Operational Analysis
HQ	Headquarter
HS	Human Sciences
IBIS	ISTAR Balance of Investment Implications Study
ICCRTS	International Command and Control Research and Technology Symposium
ICS	Information and Communications Services
IER	Information Exchange Requirement
INADS	Impact of Networking on Air Defence
IP	Improvement potential
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
IWARS	Infantry WARrior Simulation
J2M	Joint Intelligence Model
LP	Linear Program
LTAMC	Leader and Team Adaptability in Multinational Coalitions
MANA	Map Aware Non-uniform Automata (Agent based modelling system)
MoE	Measure of Effectiveness

MOUT	Military Operations in Urban Terrain
MPA	Maritime patrol aircraft
MUST	Multistatic Facility Tool
NAF	NATO Architecture Framework
NATO	North Atlantic Treaty Organisation
NC2IS	NEC Campaign & Communications Implications Study
NCW	Network Centric Warfare
NEC	Network Enabled Capability
NEO	Network Enabled Operations
NII	Network and information infrastructure
NL	The Netherlands
NNEC	NATO Network Enabled Capability
NO	Norway
OA	Operational Analysis
REABIS	Range Estimation Active Bistatic Sonar
RSP	Recognized Surface Picture
SA	Situational Awareness
SAM	Surface to Air Missile
SIMAIR	SIMple Maritime and AIR model
SIMBRIG	SIMple BRIGade model
SNR	Signal-to-noise-ratio
STEBS	Surface Target Engagement BoI Study
STIKMAN	Single Target ISTAR Kill chain Mission Analysis Network
SURPASS	SURface Picture ASSessment (simulation model)
TA	Target Acquisition
TNO	Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek (Netherlands Organisation for Applied Scientific Research)
TNO ACE	TNO Advanced CD&E Environment
TOR	Terms of Reference
TST	Time Sensitive Target
UK	United Kingdom
US	United States
UWT	Underwater Warfare Testbed
WG	Working Group
WISE	Wargame Infrastructure and Simulation Environment

Appendix B UK Models and Tools

COMAND and CLARION

COMAND is a campaign level stochastic representation of maritime contributions to a joint campaign. CLARION is a deterministic representation of land/air operations. Both are high level combat models with an emphasis on C4ISTAR over attrition based processes, and both are used to represent multinational operations. COMAND and CLARION have been used within studies such as NC2IS to show the impact of varying levels of NEC on the outcome of a campaign.

SIMBRIG

SIMBRIG (SIMple BRIGade model) is a sub-campaign (formation) level stochastic combat model of the land environment. Like the campaign models its emphasis is on C4ISTAR over attrition based processes. SIMBRIG has to-date only been used in support of the Future HQ Requirements Study in the evaluation of a few vignettes. Although its functionality should provide a useful tool for evaluating NEC, its current usability has not made that possible.

SIMMAIR

SIMMAIR (SIMple Maritime and AIR model) will, like SIMBRIG, extend Dstl's C2-centric modelling down from campaign level focussing on joint operations within the maritime & air domains. SIMMAIR is currently under development but should provide a capable tool for the assessment of NEC once delivered due to the substantial effort that has been carried out in designing its C4ISTAR representation – including Human Factors functionality.

HiLOCA

HiLOCA (High Level Operations model using Command Agents & Cellular Automata) is an agent-based, multi-sided combat simulation with the focus on the operational effects of C2. The model simulates entities at the company/squadron level organised in a hierarchy up to division or corps level. HiLOCA is owned by QinetiQ

STIKMAN

STIKMAN (Single Target ISTAR Kill chain Mission Analysis Network) is a stochastic simulation model of the processes and resources required to detect and prosecute mobile or re-locatable targets. Its aim is to evaluate alternative kill chains ability to prosecute Time Sensitive Targets (TSTs) by representing the target and its behaviour, the required ISTAR, the C2 element, and the platform/weapon delivery system. It has been used to demonstrate the effect of different levels of NEC (initial, transitional and mature) by showing the impact of improved decision times on the prosecution of TSTs. This effect has then been pulled through into COMAND and CLARION to show the impact on campaign outcome.

FTM

FTM is the FOAC Time Sensitive Targeting Model. FTM is a dynamic stochastic simulation that assesses the prosecution of TSTs. Like STIKMAN, FTM represents the key features of a TST campaign such as the detection and identification systems, HQ decision-making, the attack platform and weapons and the targets. The primary difference between STIKMAN and FTM is that FTM represents many-on-many situations whereas STIKMAN evaluates a single kill chain. FTM is used to assess the competition for resources in order to prosecute multiple TSTs. As FTM models the interactions between those units required to prosecute TSTs, including aspects such as decision times it would be ideal for exploring elements of NEC. Although such elements have been considered in FTM modelling to-date they were not the primary focus.

MODAF

MODAF is the UK MoD's chosen implementation of an Enterprise Architecture Framework. Its purpose is to facilitate the successful delivery of NEC covering both the operational and technical aspects across the enterprise. MODAF-compliant architectures enable all communities of interest to gain the essential common understanding that will be required to deliver the benefits to be derived from NEC. Developed architectures in MODAF include both operational and business aspects of the systems that provide capability, together with appropriate standards and programmatic aspects. MODAF architectures are not an OA tool, but have proved a useful source of data for NEC related studies providing detailed architecture data as well as other data such as IERs for a new system.

Appendix C NO Models and Tools

NetOrg

The NetOrg model could be described as a resource allocation optimization model for the operational/tactical level and was implemented as a stochastic mixed integer program. The model "imitates" the decisions of network organized forces, and requires as input the basis of the decision in terms of own situation interpretation. Hence, the model assumes a good understanding of the information sharing/sense making/decision process. (The model was presented at the 10th ICCRTS conference (2005) in McLean VA.)

MANA

MANA (Map Aware Non-uniform Automata) is a simulation model developed for the New Zealand Army and Defence force, by Defence Operational Technology Support Establishment (DOTSE). It facilitates simulations at low level, typically between soldiers (i.e. the agents), where the model focus is on the interactions between the agents.

NAF

NAF (NATO Architecture Framework)is the preferred architecture framework within the Norwegian Department of Defence applications. In Norway, the framework is mostly applied within information communication technology procurements, but lately the framework is taken into account also within modelling and simulation. Within the Nansen-class frigate project, this tool was applied to describe several views (actors, organisation, sequences of action, IER, etc) within a specific maritime operation

ARENA

ARENA is a discrete event simulation tool, produced by Rockwell Automation, USA. The tool is applied within the Nansen-class frigate project, to represent the sensor-effector-decisionmaking processes going on within a maritime force. Especially the tool was used in order to depict bottlenecks within the processes.

AnyLogic

AnyLogic is an object oriented tool for modeling and simulating purposes. It was used in the logistic project to develop models analysing the effectiveness of logistic transportation and maintenance of major platforms. AnyLogic were selected because it brings together the various modeling approaches:

– Dynamic Simulation
– Discrete Event Simulation
– Agent based Simulation.

AnyLogic has Java as source, which makes it a cross platform tool and allows addition of personal Java code. An Eclips based editor supports a large range of graphical shapes.

Appendix D NL Models and Tools

SURPASS

TNO has developed a simulation model called SURPASS (SURface Picture ASSessment) which provides an insight into the resources and the tactics required for establishing and maintaining a recognised surface picture.

The aim of surface surveillance is to establish and maintain a Recognised Surface Picture (RSP). The general objective of SURPASS is to provide an insight into the means required for picture compilation (the types and number of units, the types and ranges of sensors), and the way to deploy these means (tactics). The main assets considered in SURPASS are frigates, helicopters and maritime patrol aircraft (MPA) along with their sensors, including radar, visual means, infra-red systems, ESM, and passive sonobuoys. Information gathered from other assets such as satellites, AEW aircraft and submarines are also taken into account and collated into the surface picture.

SURPASS provides the necessary tools to analyse surface surveillance and can support all kinds of operations such as embargo enforcement, search and rescue, fishing inspection, surface warfare, and counter-drug operations. The most important Measure of Effectiveness in SURPASS is the quality of the surface picture over a prolonged period of time.

SURPASS can help to answer typical questions such as:

- How large an area can an MPA adequately cover?
- When should an MPA use its radar intermittently, when in a sector scanning mode, and how?
- What is the operational contribution of sonobuoys?
- How can a frigate best deploy its embarked helicopter?
- How should a frigate use its sensors to best contribute to the development and maintenance of the surface picture?

SURPASS gives ample consideration to the tactics of the surveillance units so that the benefits and drawbacks of alternative tactics can be investigated. The model helps in finding the best trade-off between the amount of effort required for maintaining the available information by revisiting dead-reckoned tracks and the amount of effort needed for searching for new contacts. Each surveillance unit can be assigned its own tactical rules. For instance, a surveillance unit can choose different scheduling rules dealing with possible weapon threats by applying so-called standoff ranges. In this way, a balance can be found between the quality of the surface picture and the amount of risk.

JROADS

JROADS is a software model for simulation of joint theatre air and missile defence. It is a very diverse and flexible simulation model, usable for real-time air defence exercises and wargames, for analysis on extended air defence and as a test bed for analysis of specific (sub)-systems or capabilities. JROADS can be connected to other simulations and live weapon systems using Simulation Network and Tactical Data Link connections.

JROADS was initially developed by TNO for the Royal Netherlands Air Force, Army and Navy. The model simulates air defence systems, such as Patriot, ADCF (Air Defence and Command Frigate), Army FGBADS (Future Ground Based Air Defence System) and EW radars and satellites. A simulated air defence system consists of detailed sensor and weapon systems, track management, firing doctrines, communication and (optional) coordination between systems.

Simulated threat types include fighters, cruise missiles and tactical ballistic missiles. Environmental factors such as terrain and weather conditions are also incorporated into JROADS.

The generic structure of the model enables easy creation and incorporation of new systems and capabilities. The properties of implemented systems such as sensors, weapons, firing doctrines, communication, etc. are stored in a scenario-file, ensuring easy creation and modification of scenarios by the user.

JROADS can be used in three ways: as exercise tool including training, as analysis tool and as test bed.

In exercises JROADS can be used to simulate one or more air defence systems co-operating in theatre air and missile defence architectures. Military personnel operate JROADS and control their own air defence unit using the JROADS human-in-the-loop operator interface, allowing for manual engagement orders, fire control orders, weapon selection, identification, classification etc. Using a DIS and HLA interface, a JROADS simulation can be connected to other simulations in a (real-time) network. Through the Link-16 interface, JROADS can be connected to live and simulated systems on a Link-16 network and exchange tactical data link information.

JROADS has extensive analysis capabilities. Scenarios composed of highly detailed air defence systems and various threat types can be simulated in two modes: real-time single run mode with graphical output and fast statistical mode for Monte Carlo type analysis. Measures of Effectiveness are calculated to quantify and analyse the capabilities of air defence systems.

The third application of JROADS is a test bed. Based on the specific focus of the testbed, high detail modules are included in JROADS or added using a DIS, HLA or DLL connection.

MUST
The Multi-static Facility Tool MUST is part of the Underwater Warfare Testbed (UWT) for current and future systems and platforms. With the help of the UWT underwater concepts of operations and tactics can be developed and evaluated. MUST is a research tool for operations research analysis of multi-static ASW operations on the UWT. The aim of the facility tool is to get more insight into the relationship between:

– the operating area,

– the number of own units in terms of transmitters and receivers,
– their detection probabilities,
– the operational effectiveness, defined as the probability of detection (and classification) of a submarine, and
– the time needed to accomplish the aim of the operation.

The heart of this tool lies within the acoustic part, in which the sonar performance prediction model REABIS (Range Estimation Active Bi-static Sonar) is integrated.
Three parts can be distinguished in the facility tool, namely:
– an input part,
– a simulation part, and
– an output part.

The input part consists of the parameters related to the search platform (i.e. frigate, helicopter, MPA), the sonar system (i.e. transmitters and receivers), the target (a submarine), and the operational environment. Due to the important role of acoustics, the model REABIS is incorporated into the facility. Therefore, the REABIS parameters have to be filled in.

In the simulation part, the user of the facility can choose between a barrier search operation, an area search operation, and a screening operation. The movement of the search platforms and the submarine are actual inputs. The facility does not calculate the optimum strategy for the search units or the submarine. The behaviour of the submarine is predefined by the user. Therefore, smart submarine reactions to a ping are not yet possible.

The output part shows the information that is gained by the receivers during the simulation part. This information comprises either the signal-to-noise-ratio (SNR) or the instantaneous detection probabilities of various receivers. By combining these probabilities, the overall performance can be calculated in terms of operational effectiveness.

IWARS

IWARS (Infantry WARrior Simulation) is a land-based model for dismounted combat operations studies. It is an analysis-driven simulation focused on the ground soldiers, their unit, and their equipment. IWARS is used to assess the operational effectiveness of ground soldier systems across a spectrum of missions, environments, and threats. IWARS has been verified, validated, and approved for US Army use.

IWARS is a constructive, force-on-force, combat simulation. It is an agent-based model used to represent individual soldier, team, and small-unit combat operations in complex environments, including Military Operations in Urban Terrain (MOUT), in support of warrior systems analysis.

IWARS provides the needed tools to conduct integrated, multi-domain analyses reflecting the complex relationships between soldiers, their equipment, and the battlefield environment. Typical

Measures of Effectiveness in IWARS are the number of blue casualties, the number of red casualties, and the ammunition expenditure.

IWARS characterizes the battlefield according to force structure, equipment distributions, combat threats, component system specifications, and scenarios. IWARS is also designed to model environment and physiological elements of combat engagements, such as heat stress, fatigue, load, hydration, dynamic weather and terrain, plus variable lighting conditions.

TNO-ACE

TNO-ACE is an abbreviation for TNO Advanced CD&E (Concept Development & Experimentation) Environment. TNO-ACE provides an environment that can connect various components like real and simulated systems and platforms which can be manned by (military) operators. This facilitates e.g. experiments to develop and to test new concepts, tactics or procedures. This approach is safer, more flexible and more cost effective than live experiments. ACE was used in various experiments, e.g. to test new concepts regarding the co-operation of military personnel of army, navy and air force at a tactical level. Some experiments involved the creation of joint environment picture based on sensor information from army, navy and air force assets, and the joint co-ordination of actions based on the joint picture.

Appendix E Examples of five step approach analyses

This appendix describes four of the cases in which the NL *five step approach* was used to analyse the potential increase in operational effectiveness of NEC.

Added value of CEC

Maritime Anti Air Warfare was one of the warfare area/vignette in which the five step approach was used to analyse increase in operational effectiveness due to NEC.

Step 1: the new concept

In 1994, the US started the development of Co-operative Engagement Capability (CEC), a network enabled concept that increases the effectiveness of Anti Air Warfare. CEC allows individual sensor systems on a number of ships and aircraft in a task group to share sensor data in real-time.

Step 2: description of the concept and benefits

CEC results in a clear, common, real-time air picture of higher quality. The moment of detection of a target by an individual unit is advanced to the moment of detection of the target by the best positioned unit. This allows units such as the Air Defence and Command Frigate (ADCF) to launch SAMs against a target even if the ADCF has not yet detected the target with its own sensors (engage on remote). A possibility is that another unit performs the terminal illumination enabling intercepts beyond the horizon w.r.t. the platform that launched the SAMs (forward pass).

Step 3: requirements

Each unit in the task group that wants to make use of the benefits of CEC, needs to have a dedicated transmitter/receiver that transmits data of its own sensors to other units, and receives the sensor data sent by other units. The command and control system has to be changed to be able to make use of the benefits of CEC. Furthermore, the personnel have to be educated and trained to be able to handle the changes due to CEC.

Step 4: quantification method

As quantification method, the air defence (AD) simulation model JROADS was selected and adapted to be able to simulate the CEC concept.

Step 5: quantification of the increase in operational effectiveness

The increase in operational effectiveness due to CEC was determined in “engage on remote” scenarios and “forward pass” scenarios with different types of targets: supersonic sea skimmers and fighter/bombers. In the sea skimmer scenario, a forward pass provided significant added value; giving an intercept distance four times as large as the situation without CEC, and three engagement opportunities instead of only one.

Added value of better co-ordination

In this application, the added value of a new concept for co-ordination between the AD ships in a task group was considered. In a task group, AD usually is co-ordinated: for each threat attacking the task group, it is decided which AD unit(s) will engage the threat.

Step 1: the new concept

Until now, AD co-ordination in a task group is mainly executed using pre-planned responses that are not adjusted to a dynamically changing situation. The disadvantage of a pre-planned response is that it is difficult to adjust the concept based on the actual situation. A new AD concept tries to overcome this disadvantage by considering the actual situation in the decision to assign a particular AD ship to a threat.

Step 2: description of the concept and benefits

The new concept consists of a co-ordination method for both soft kill and hard kill weapons.
The soft kill co-ordination method determines the deployment of distraction decoys. To minimise the probability of reacquisition on high value units after the threat(s) flies (fly) through the decoy, only specific AD ships were ordered to deploy distraction decoys in specific directions.
The hard kill co-ordination method assigned a ship to each threat based on each ship's probability of killing that threat. The selection of the most appropriate ship is based on the knowledge of the expected performance of all ships against the threat, and the actual situation of the ships (e.g. availability of sensor and weapon systems).

Step 3: requirements

All ships in the task group must have a communications network with high enough capacity and short enough delays to exchange information on detected threats, the situation of the ships, kill probabilities and engagement orders. The C2 system has to be changed to enable this concept. Furthermore, the personnel will have to be educated and trained appropriately.

Step 4: quantification method

As a quantification method, the AD simulation model JROADS was selected and was adapted to be able to simulate the new concept.

Step 5: quantification of the increase in operational effectiveness

The increase in operational effectiveness due to the new concept was determined in a particular scenario for three cases: hard kill only, soft kill only, and hard kill and soft kill combined. The new concept resulted in a significant increase of the operational effectiveness.

A new concept for detecting and tracking submarines

In this application, the added value of a new concept for detecting and tracking an enemy submarine is considered. Typically, acoustic detection of an enemy submarine in a multi static operation is carried out using one ship with both an active sonar and a passive array, and a number of other ships with only a passive array. If the active sonar transmits a pulse, this pulse can be reflected by the submarine and received by a passive array. The ship that receives this pulse can calculate the position of the submarine if the ship knows the position of the ship with the active sonar that has transmitted the pulse.

Step 1: the new concept
In a traditional operation, the ships usually remain at fixed locations that have been determined prior to the operation. If the active sonar transmits a pulse, then the reflected pulse will be detected by a passive array with a certain probability. This probability depends on the position of the sonar, the position of the submarine, the position of the ship with the passive array and the environmental (acoustic) conditions (e.g. the presence of shadow zones, areas where no sounds/pulses get through).

Step 2: description of the concept and benefits
In the new concept the positions of one or more ships are adapted dynamically in order to increase the tracking quality of the task group. The position of the ships can be adapted after the position, speed and heading of the submarine are known. New positions (or speeds and headings) of one or more of the ships can be determined to increase or maximise the tracking quality of the task group. The benefit, an increased tracking quality of the task group, will especially occur in the presence of shadow zones. Due to shadow zones, it is possible that the detection probabilities of all ships during some periods of time will be very low. By moving a ship (in particular, the ship with the active sonar), it can be possible to prevent that the detection probabilities by all ships will be low during the same period of time.

Step 3: requirements
All ships in the task group must have a communications network that can exchange information about the position of the own ship, information about the detections of the submarine and orders from the ship in command to the other ships to change their position (or speed and heading). Obviously, the command and control system has to be changed to enable this concept. Furthermore, the personnel have to be educated and trained.

Step 4: quantification method
As a quantification method, the multi static facility tool MUST has been selected.

Step 5: quantification of the increase in operational effectiveness
The increase in operational effectiveness due to the new concept has been determined in a number of scenarios. It can be concluded that the new concept for tracking submarines can increase the operational effectiveness, especially in a scenario with shadow zones.

A new concept in a land-based operation
The last case to which the five steps approach to analyse the increase in operational effectiveness of NEC has been applied, is a land-based operation. The land-based operation is a combat between two groups of soldiers: a blue group versus a red group. Each group consists of a number of separate subgroups of soldiers. A new concept of operation for the blue subgroups of soldiers is considered.

Step 1 and 2: the new concept and benefits

In a traditional operation, the blue subgroups operate practically independently. Each blue subgroup has to detect red subgroups itself. Furthermore, each blue subgroup will fire at the red subgroup that is the most threatening for that blue subgroup. In its decision at which red subgroup it will fire, a blue subgroup does not take into account the actions of other blue subgroups unless it knows the actions of the other blue subgroups based on pre-planned co-ordination rules.
In the new concept, the blue subgroups of soldiers exchange information about detected red subgroups of soldiers. Furthermore, the blue subgroups co-ordinate their actions against the red subgroups based on the actual situation.

Step 3: requirements

All subgroups of blue soldiers must have communication equipment to be able to exchange detection and co-ordination messages. The soldiers have to be suitably trained.

Step 4: quantification method

As a quantification method, the land model IWARS (Infantry WARrior Simulation) has been selected.

Step 5: quantification of the increase in operational effectiveness

The increase in operational effectiveness due to the new concept was determined in a particular scenario. It can be concluded that the new concept increases the combat power of the blue soldiers significantly.