FFI RAPPORT

EXPLORATORY EXPERIMENT "AD HOC ORGANIZATION OF PICTURE COMPILATION" CONDUCTED DURING BLUE GAME 2004: EVALUATION REPORT

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

REPORT DOCUMENTATION PAGE

1) PUBL/REPORT NUMBER FFI/RAPPORT-2004/01940 1a) PROJECT REFERENCE FFI-II/898/912	2) SECURITY CLASSIFICATION UNCLASSIFIED 2a) DECLASSIFICATION/DOWNGRADING SCHEDULE -	3) NUMBER OF PAGES 30

4) TITLE
EXPLORATORY EXPERIMENT "AD HOC ORGANIZATION OF PICTURE COMPILATION" CONDUCTED DURING BLUE GAME 2004: EVALUATION REPORT

5) NAMES OF AUTHOR(S) IN FULL (surname first)
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6) DISTRIBUTION STATEMENT
Approved for public release. Distribution unlimited. (Offentlig tilgjengelig)

7) INDEXING TERMS

	IN ENGLISH:		IN NORWEGIAN:
a)	Ad hoc organization	a)	Ad hoc organisering
b)	Distributed Picture Compilation	b)	Distribuert bildeoppbygging
c)	Synthetic environment	c)	Syntetiske omgivelser
d)	Commando and Control Information Systems	d)	Kommando og kontroll informasjonssystemer
e)	Network Based Defence (NBD)	e)	Nettverksbasert forsvar (NBF)

THESAURUS REFERENCE:

8) ABSTRACT

In the spring of 2004 the FFI project 898 NBD Decision Support participated in the exercise Blue Game 2004 by conducting an exploratory experiment concerning ad hoc organization of picture compilation. The overall aim of the experiment was twofold: First, to explore the operational value of ad hoc organization. Second, to prepare and run the technology demonstrator including its synthetic environment in an operational setting. Overall, the aim of the experiment was met. This report presents and evaluates the results and the experiences made.

9) DATE	AUTHORIZED BY This page only	POSITION
2004-06-30	Vidar S Andersen	Director

ISBN-82-464-0852-6

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

CONTENTS

EXPLORATORY EXPERIMENT "AD HOC ORGANIZATION OF PICTURE COMPILATION" CONDUCTED DURING BLUE GAME 2004: EVALUATION REPORT

1 INTRODUCTION

Network Based Defence (NBD) is currently an important future premise for the Norwegian armed forces. The aim of NBD is to increase mission effectiveness by networking military entities. *Shared situation awareness* is crucial for carrying out network based operations. The foundation of shared situation awareness is increased access to and sharing of information between parties. The information infrastructure (infostructure) has an important role as an enabler, organizer and provider of such information access and information sharing capabilities. Ad hoc organization of information flow in the infostructure is such a capability.

The objective of the FFI-project 898 NBD Decision Support is to support military forces in developing capabilities for ensuring information access and sharing in the infostructure. Ad hoc organization of information flow is an idea based on a picture compilation concept (1) that we believe will increase information access and sharing in a more flexible and timely manner than existing systems provide today.

In the spring of 2004 the FFI project 898 NBD Decision Support participated in the military exercise Blue Game 2004 (BG04) by conducting an exploratory experiment concerning ad hoc organization of picture compilation. The overall aim of the experiment was twofold:

- Explore the potential operational value of ad hoc organization
- Prepare and run the technology demonstrator with its synthetic environment in an operational setting

The experiment addressed aspects of ad hoc organization of information flow applied to the compilation of a Common Operational Picture (COP), by utilizing Commercial Off The Shelf (COTS) technologies and open standards. This was an exploratory type experiment – aiming to explore the operational value of a new capability. In that sense, the technology demonstrator may be regarded as an enabler for the operational aspects.

The experiment was carried out through a series of presentations and technology demonstrations. The technological part of the experiment consisted of the necessary efforts to run the distributed picture compilation system and the synthetic environment, including logging and measurement activities. In the operational part of the experiment, we systematized feedback from the operational staff by means of a questionnaire and interviews. The object of interest was the project's basic idea of increased operational value regarding ad hoc organization of information flow as an important capability in the future infostructure.

Three different locations hosted people and equipment for the technology demonstrator during the experiment: National Joint Headquarters (NJHQ), HNoMS Otra and HNoMS Vidar. FFI wants to thank all personnel involved at these locations for their excellent hospitality, assistance and support.

1.1 Rationale and objectives for the experiment

As mentioned above, the goal of NBD is increased mission effectiveness. Increased sharing of information between parties is considered an important means in achieving this. The range of military tasks today has increased. At the same time the resources the armed forces have for their disposal are limited. Establishing the optimal configuration of a force to a mission, and making changes in the configuration during the operation, will be necessary capabilities in order to efficiently and effectively utilize sensor-, decision- and effector components.

In order to achieve this, the different components, units, or actors if you like, need increased abilities to join and leave a composition of forces in a flexible and dynamic manner. This depends on an improved ability to establish a relevant COP and increased access to the COP for the actors.

1.2 Outline of this report

In this report we present and evaluate the exploratory experiment of ad hoc organization conducted during BG04. Chapter 2 gives a brief introduction to the ad hoc organization concept and describes the implementation of the experiment, i.e. what we did and how we did it (projects involved, preparations, technical set-up and live demo scenario) and content (what was demonstrated). Chapters 3 and 4 present the evaluation of the experiment from the operational and the technological perspective. Finally, a conclusion is given in chapter 5.

2 THE EXPERIMENT

The experiment was carried out through a series of presentations and demonstrations with live functionality in the period 28-30 of April 2004. This chapter describes in detail the underlying idea of ad hoc organization, the projects involved, the timeline for set-up and preparations and the content of the demonstration.

2.1 Ad hoc organization

The idea behind ad hoc organization of information flow rests on the assumption that a dynamic model for organizing the information exchange is needed, as illustrated by figure 2.1. This model for information exchange management is based on the pattern of publish and subscribe. In the model the advertisements describe the information services offered to consumers. The producer makes information services available for consumers and the consumer subscribes to information services according to his needs.

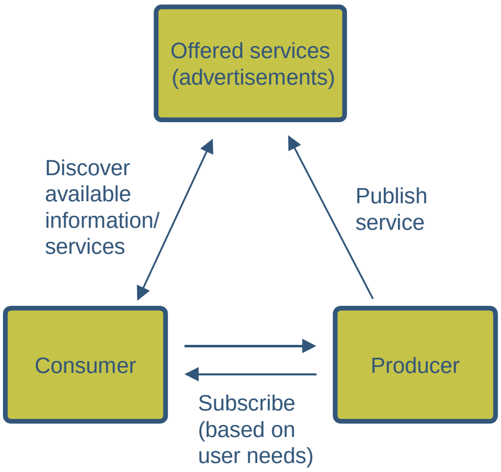

Figure 2.1 *Ad hoc organization model*

The producer provides information services. In this context an information service may be data from a sensor, for instance a radar, or a situation picture. The producer publishes the information in the infostructure, the offered services are announced, and an advertisement makes the service available for others. Then the consumer is able to discover the services available. If the consumer is interested, the advertisements provide contact information, which helps setting up the information flow.

Traditional information exchange mechanisms like formatted messages and data base replication do not support this flexible way of working as they are limited by several factors:

- All information flow is set up in a fixed pattern, from sender to receiver, in a way planned and configured in advance.
- Reconfiguration needs manual assistance.

The advertisements box on the top of the figure can be regarded as the lookup service. This is a mechanism used by the service discovery type of communication middleware technologies. JXTA (2) is one of the interesting new service discovery middleware technologies. The technology demonstrator in this experiment is based on JXTA for peer-to-peer communication between nodes. With that, the ad hoc model is used on operational as well as technological levels in this experiment.

2.2 Projects involved

There were three FFI projects that participated in and contributed to the experiment:

- **NBD Decision Support**: The project explored the operational value of the ad hoc organization concept. Details about the operational evaluation are given in chapter 3. Details and evaluation of the technical aspects of the demonstrator are given in chapter 4.2.
- **SIMUTREX**: The project developed a synthetic environment stimulating the ad hoc demonstrator with track messages. A description of the synthetic environment set-up and evaluation is given in chapter 4.3.

- **NBD Grid**: The project provided the network support for the ad hoc demonstrator. In addition, they investigated the communication network protocols. They plan to use the results in their further work on finding effective protocol solutions for using middleware across low data-rate communication systems. More details on their contribution and evaluation are given in chapter 4.4.

2.3 Experiment execution timeline

The experiment method had to encompass the fact that this was a combination of an exploratory type experiment (operational level) and technology demonstrator (technology level). Moving the technology demonstrator from the laboratory into an operational setting required additional development and quality assurance efforts up front. The technology demonstrator was utilized to show how ad hoc organization might enable future operational enhancements. Expected results from the exploratory parts of the experiment included response and feedback from operational personnel and their assessment of potential operational value.

An overview of experiment activities:

- Preparations (technology development and planning) at FFI during 1st quarter 2004
- Installations at the three demonstrator locations, April 21-23
- Rehearsals and measurements, April 26-27
- Presentations and Live Demo in NJHQ, April 28-29
- Presentation and Live Demo HNoMS Otra, April 30
- Clean-up and reporting during May and June 2004

The presentations were followed by a questionnaire survey and interviews with operational staff, both concerning potential operational value. The operational results are described in chapter 3. Technological aspects of the experiment are described in chapter 4.

2.4 Technical set-up and live demo scenario

The demonstrator was distributed on three different locations (figure 2.2). Each location operated one picture compilation node (PCN), and a part of the simulation environment to stimulate the PCN with synthetic sensor data. In addition, two locations had a Global Positioning System (GPS) receiver reporting the real position to the PCN. The PCNs collaborated using middleware with special focus on service discovery mechanisms, to support the idea of ad hoc organization also on the lower technological levels.

The PCN placed at HNoMS Otra simulated HNoMS Bergen, the equipment placed at HNoMS Vidar simulated an Unmanned Aerial Vehicle (UAV), while the equipment placed at NJHQ simulated a Maritime Patrol Aircraft (MPA) that arrived late in the scenario and hooked into the network on an ad hoc basis.

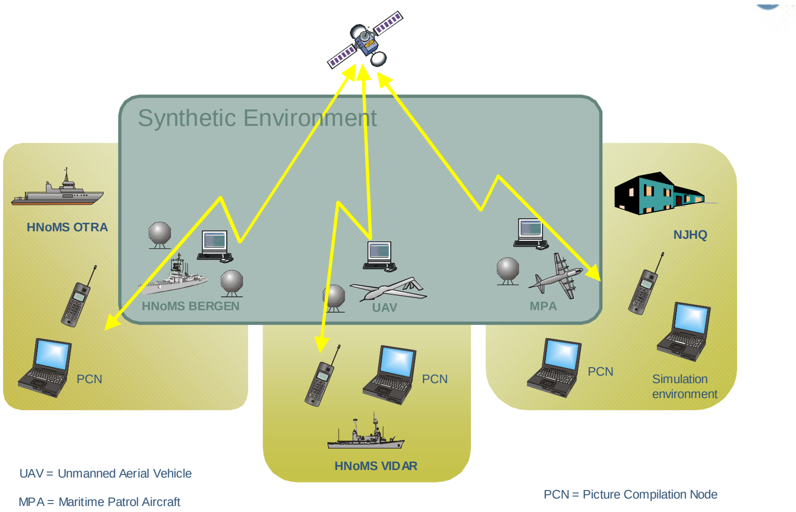

Figure 2.2 Technical set-up of the experiment, locations and synthetic environment

The communications set-up is described in the following. Each location had two Iridium satellite telephones. In addition, NJHQ had access to the Internet via NATO Unclassified Local Area Network (NULAN). Both vessels had a GPS sensor feeding real-life positions into the system. Thus, we had a mixed environment consisting of both real data from the GPS and simulated data from the synthetic environment. The main part of the synthetic environment was located at NJHQ.

The live demo scenario (figure 2.3) was based on the BG04 exercise order of battle and planned events. A Mine Counter Measures (MCM) force escorted by HNoMS Bergen transiting up the Oslo fjord was subject to coordinated attacks from F-16s and a Jet Ski unit. At the start of the scenario, HNoMS Bergen was building a COP together with the UAV (which is the unit moving from north to south in figure 2.3). Then the MPA entered the scene, offering it's local sensor information. After the MPA was linked into the group, the three units collaborated in the compilation of an improved COP.

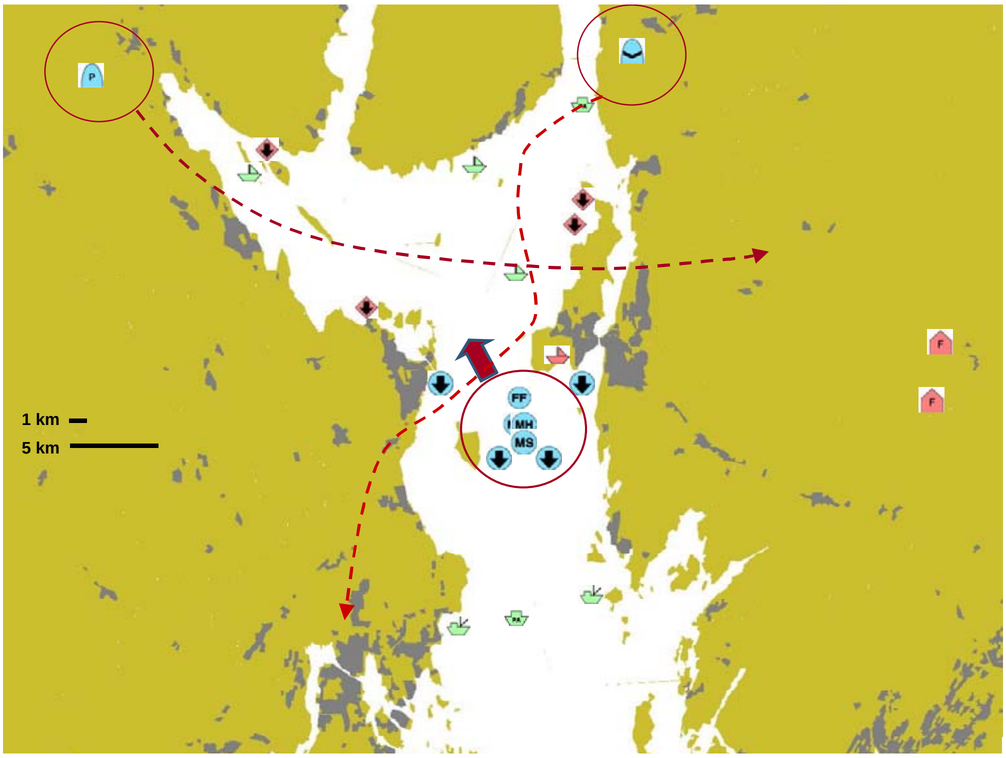

Figure 2.3 Live demo scenario: The main actors and their movements

The demonstration showed some important aspects of ad hoc organization of information flow applied to the compilation of a COP, utilizing COTS technologies and open standards. The ad hoc organization aspects demonstrated in the exercise were the following:

- Military units plug in to the information network on a come-and-go-basis.
- Newly arrived entities contribute information into the network and improve the COP.

The picture compilation occurred in a collaborative fashion between geographically distributed locations. The demo displayed track data from the technology demonstrator on each PCN and on the Common Operating Decision System (CODS) localized at NJHQ.

3 OPERATIONAL ASPECTS

In order to meet the aim of exploring the potential value of ad hoc organization in an operational context, we defined the following sequence of activities:

1. explain the notion of ad hoc organization
2. demonstrate aspects of the concept
3. collect feedback from the operational staff attending the presentation

The demos focused on the aspect of ad hoc organization applied to geographically distributed COP compilation. The main object of the evaluation from the operational perspective, was the project's assumption of increased operational value of ad hoc organization of information flow in the infostructure. In addition, we collected feedback of how we communicated these issues through the presentations and live demos.

The first section of this chapter further explains the idea of ad hoc organization (what it is and assumed benefits). This section is based on the presentations held at NJHQ and KNoMS Otra. The last sections include methodological aspects, summary of the operational staff response, and evaluation of the operational aspects of the experiment (see (3) for a more extensive report).

3.1 Ad hoc organization

There are several aspects concerning "ad hoc organization" that needs to be stated. First, the *generic assembling* aspect, i.e. the possibility of putting together components (ad hoc composition of components). Second, the *time and space* aspect, i.e. ad hoc composition can happen very quickly depending of the current situation, but independent of platform, technology and geography. Third, the *flexibility* aspect, i.e. ad hoc composition may involve many types of actors (organizational and technological). These may change in number and type during the mission.

At the organizational level, ad hoc organization is in accordance with the NBD ideas concerning widespread sharing of information and the predominance of peer-to-peer relationships in future military organizations. At the information level there is a shift from a "push" to a "post and pull" (i.e. publish and subscribe) approach. In order to demonstrate some of these aspects, ad hoc organization was applied to picture compilation in the experiment.

Our assertion is that ad hoc organization of information flow is an important capability for ensuring information access and sharing for increased situation awareness according to NBD ideas. Ad hoc organization aims to support ad hoc composition of (geographically) distributed forces on the tactical and operational level for increased mission effectiveness by:

- Little to no pre-planning (on-the-fly, plug-and-play)
- Pre-configuration not necessary (except for security reasons)
- Dissolves when mission accomplished
- Independent of geography and platforms

In more practical terms the ad hoc organization concept includes the following:

- Allows dynamic linking of resources in the network independent of platforms: Military units can plug into the network and offer their resources to others – on a "come and go" basis.
- Support distributed collaborative compilation of a COP. The internal organization of information flow in groups may differ between co-operating groups.
- Provides access to information based on the user's needs: One may use dynamic linking to achieve dynamic access to available and relevant information in a format tailored for the user (this aspect was not demonstrated at this stage).

The operational benefit, the added value for these three points can be summed up as follows:

- Resources are made available to all actors in the network - on the fly. I.e. information flow is set-up ad hoc (on the spot) with many-to-many information exchange – not planned and configured in advance and not in a fixed pattern from e.g. sender to receiver.
- Ad hoc contributions to picture compilation: All networked parties utilize available resources when needed in a *flexible* manner. Actors share information, improving their pictures, and establishing a COP.
- Information can be requested in a format tailored for the user, based on the users needs (pull - not push).

In this context, sensor nodes, PCNs, and effector nodes are considered as common resources, not as the property of a specific platform. They will be utilized on an ad hoc basis ("immediate access"), based on the user's needs – when they need it.

3.2 Operational value

The main object for the evaluation was the project's basic idea of increased operational value from ad hoc organization of information flow in the infostructure. Our main evaluation criteria were the following:

Ad hoc organization of information flow as a capability in the infostructure:

- Gives operational value beyond what we have today.
- Leads to increased access to information.
- Ease geographical distributed collaboration of picture compilation.
- Gives a better situational picture (i.e. the underlying information content).
- Diminish the need for pre-planning.
- Gives increased flexibility in configuring the forces.
- Makes changes in the configuration of forces more effective than today.

We systematized the response of operational staff by means of questionnaire survey ($N = 14$) and interviews ($N = 6$). The interviews were conducted after the presentations and live demos. The questionnaires were handed out to all persons attending the presentations and live demos.

3.3 Results and discussion

The response was mainly positive – both regarding the assumptions of increased operational value and the presentations and live demos of the ad hoc concept. However, there were certain interesting issues that emerged during the exercise. The main points were the following:

In general, those who were older and had more operational experience, were slightly more critical towards the assumptions of increased operational value compared to those who were younger and had less operational experience (age: 32 – 52). The comments were mainly addressed towards the claims regarding diminishing need for pre-planning and increased flexibility in the configuring of forces. Level of education had no influence on these assessments.

Frequently appearing comments were: “What is new about this?” and “What is the difference between your vision/your system and existing systems today, e.g. link 16?”. Comments like these imply that we had not been precise enough in order to communicate the potentials of the ad hoc idea. This must be considered in future presentations and demos. We need to communicate more precisely the difference between our vision and existing access- and sharing information capabilities. The various aspects of increased flexibility (information exchange, new ways of collaboration and ad hoc linking) and saving time (like what kind of planning or type of configuration in advance would be reduced) were not communicated in a satisfactory manner.

Several respondents addressed the issue of security. The possible advances of ad hoc organization might disappear due to security requirements. This was one of the main issues that caused critical views regarding operational value. In our view, this problem is an organizational issue (e.g. who shares information with whom, who get what) as well as a technical issue (e.g. encryption, authorization). Additionally, various problems with information overflow were mentioned. The practice of today need to change or at least be adjusted in order to realize the full potential of the ad hoc organization on tactical and operational command and control.

The response confirmed that the ad hoc organization is complex, involving organizational as well as technological aspects. These are aspects that a technology demonstrator alone will have problems demonstrating. Thus, it is a challenge for the project promoting these ideas to an audience with a well-established view on command and control issues.

Finally, the use of the term "ad hoc" was pointed out as potentially misleading, especially in the English language. It might be problematic to grasp the connection between the use of the term in a technical context and in a more conceptual way.

4 TECNOLOGY DEMONSTRATOR

This chapter first describes the efforts involved in selecting wireless communication for the experiment. Then it contains a short description of the contributions, results and evaluations from each of the following three technological areas involved:

- Picture Compilation
- Synthetic Environment
- Communications

The operation of the demonstrator required cooperation between parties on three locations. Manual synchronization of node and simulation start-up times was crucial to maximize the presentation effects. Joint error handling was another important aspect of cooperation.

The initial plan was to communicate this synchronization by telephone. Voice communication turned out to be very impractical. Instead we used an online chat application that provided text-based communication between the three locations. Even though the chat application was developed during the last days of preparation as a nice-to-have idea, it became one of the key success factors for accomplishing the experiment.

4.1 Selection of Wireless Communication

Due to the localization of two of the PCNs being on board vessels and being mobile, the selection of communication technology was limited to finding a suitable wireless carrier capable of running Internet Protocols (IP). Several alternatives were considered, at the final stages these included the General Packet Radio System (GPRS), which is a service using the Global System for Mobile communication (GSM), and satellite communication from Globalstar (4) and Iridium (5). In addition, NULAN was used to connect the PCN at NJHQ to the Internet. NULAN provided far better bandwidth and less latency for this PCN.

The main criteria considered when choosing a wireless communication technology were coverage, stability, and bandwidth. In addition, ease of deployment was a criterion in which all the three final alternatives scored well. The coverage of GSM and GPRS were considered insufficient in the exercise area, hence this option was abandoned. Satellite communication was then the only category we were left with. Both Globalstar and Iridium were, however, constrained to the same limitations. They offered a bandwidth between 2,4 and 20 kbps, and had latencies as high as six seconds. Moreover, when connecting to either of the networks, our computers were given temporary, non-routable, IP addresses. This meant that other computers could not reach them from the Internet unless they were connected to the same satellite communication system. Furthermore, if a computer got disconnected from the satellite communication, chances were that it would receive a different IP-address upon reconnect.

Finally, the satellite systems did not support IP multicast. Such limitations were putting our technology on a trial. Iridium was chosen as the best alternative of the two satellite communication systems. This was due to the fact that Iridum has got better coverage and seemed more stable than Globalstar. Bandwidth measurements indicated that Globalstar had better bandwidth when operational, but Globalstar seemed to behave unstable when exposed to heavy loads.

In the next section we take a closer look at the Iridium satellite communication system.

4.1.1 Iridium

Iridium is a satellite communication company, which has deployed 66 satellites in low-earth orbiting. The Direct Internet Data service of Iridium allows Internet connection from a computer via an Iridium phone. According to Iridium the Direct Internet Data service is capable of delivering data at a rate of up to 10 kbps per second.

In addition to the data rate, the latency was also an important parameter. In this report we define latency as the round trip time between two computers. Round trip time is defined as the time it takes to send a small data packet from one computer to another and back again. The latency was measured during the preparation of the experiment by using the Ping program as our tool. We discovered that the latency is considerable when using Iridium. The latency between two computers connected to Iridium was in the range from approximately 1800 milliseconds to 4000 milliseconds. This latency consists of two Iridium hops. When only one Iridium hop was executed, the latency was (as can be expected) about half of these values. It is important to note that for low data rate connections, the latency time may be considerably increased when the link is heavily used.

We also conducted some measurements of the bandwidth using the Iperf 1.7.0 (6) software. This was done to verify the data rate promised by Iridium. Our tests showed a bandwidth of 9,30 kbps on average, with a maximum of 21,40 and a minimum of 0,80 kbps. These tests utilized the built in compression of Iridium. Other tests, not using this compression, resulted in a bandwidth of on average 1,2 kbps. These results show that compression can be used to increase the data rate, however the extra layer of complexity might also increase the latency.

During our use of Iridium we have identified some minor issues, especially concerning the accompanying Apollo software. Apollo is used when you start a data call, i.e. set up a connection. It has been known to be unstable, especially when disconnecting and reconnecting again without restarting the application. But all in all the Iridium system has been working to our satisfaction.

4.2 Picture Compilation

The technology demonstrator used in BG04 was developed from a lab based technology demonstrator that was built to demonstrate ad hoc organization of PCNs cooperating to compile a shared COP. In the demonstrator, a number of PCNs link together, forming an ad hoc group compiling a shared COP. The linking is dynamical, allowing PCNs to join and leave a group without pre-configuration. Details about the implemented picture compilation process and track data exchange mechanisms are described in (7).

As the original demonstrator was designed for laboratory use, it was running on a 100 Mbps Local Area Network (LAN) with low latency and with no firewalls between any nodes. In this experiment, the demonstrator was to run on a Wide Area Network (WAN) with relatively low bandwidth and high latency.

4.2.1 GPS connection

The mobile PCNs were equipped with Global Positioning System (GPS) receivers in order to demonstrate an ability, although very simple, to use data from real sensors. To know the whereabouts of own forces is important.

As the vessels carrying the PCN moved about in the Norwegian littoral, their positions were included in the COP. The data from the GPS was fed into the simulation system, making it possible for the vessels to appear on simulated sensors and to be displayed in the scenario simulators.

4.2.2 CODS connection

NJHQ wanted to use their CODS to visualize track data from the demonstrator. In order to do this, a new software component that exports demonstrator tracks to the CODS database was developed. This was solved in cooperation with the company Lenco Software, which has supplied the software that is used with the CODS table. The PCN located at NJHQ was then connected to the CODS and tracks were delivered to the CODS database using the format defined for the Norwegian Tactical and Combat Command and Control System (NORTaC).

4.2.3 Technical architecture

JXTA (2), the peer-to-peer platform that the demonstrator is built upon, was chosen based on a set of criteria. One of JXTA's properties is that it has built-in support for operating on top of a WAN (contrary to many other middleware technologies). JXTA gives developers the opportunity to set up so-called relays, that store and forward messages between peers who have limited connection to the Internet. This proved to be a very useful functionality for using networks with private (non-routable) IP addressing and firewalls, like the Iridium network, together with the rest of the Internet. As shown in figure 4.1, a relay peer was set up at FFI. This became a central point in the infrastructure for the experiment. It is important to point out that it is fully possible to set up more of these relay peers, which would remove any dependencies of a single point of failure.

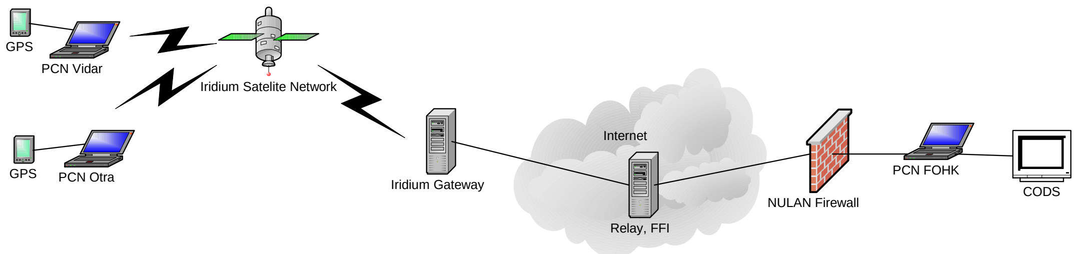

Figure 4.1 Technical architecture for the PCN network used during the experiment (with GPS and CODS)

4.2.4 Evaluation

The demonstrator worked satisfactorily to demonstrate the concept of ad hoc organization of PCNs building a COP. It was shown that a PCN was able to join an existing, geographically distributed picture compilation group and contribute to the COP.

However, linking the PCNs using JXTA over a satellite link was time consuming, and it was impossible to predict how long it would take for the PCNs to establish a link. Measured from when the arriving PCN started its JXTA communication process, the elapsed time to establish data exchange with the other two PCNs was 2-3 minutes in best cases.

It seems like ad hoc linking using JXTA over Iridium is expensive in terms of bandwidth consumption. This is most likely due to the combination of JXTA being immature and Iridium having low bandwidth and high latency.

In conclusion, using a COTS technology like JXTA over a much lower bandwidth and much higher latency than it is designed for, is far from trivial. Further work in this area might address more efficient use of available bandwidth in JXTA. Another suggestion is to investigate the use of a communication bearer with higher bandwidth and less latency, like GPRS.

4.3 Synthetic environment

This chapter gives an overview of the synthetic environment. A more extensive description is given in (8).

Sensor data originating from a realistic scenario was needed in order to demonstrate the potential of the ad hoc picture compilation system. A synthetic environment was built to stimulate the picture compilation system with track messages from virtual sensors connected to the PCNs.

The synthetic environment was based on the High Level Architecture (HLA), a standard for interconnecting simulation components. The HLA defines a Run Time Infrastructure providing services for data exchange between components. The synthetic environment was developed using available HLA COTS components and by reusing existing simulation components developed by FFI.

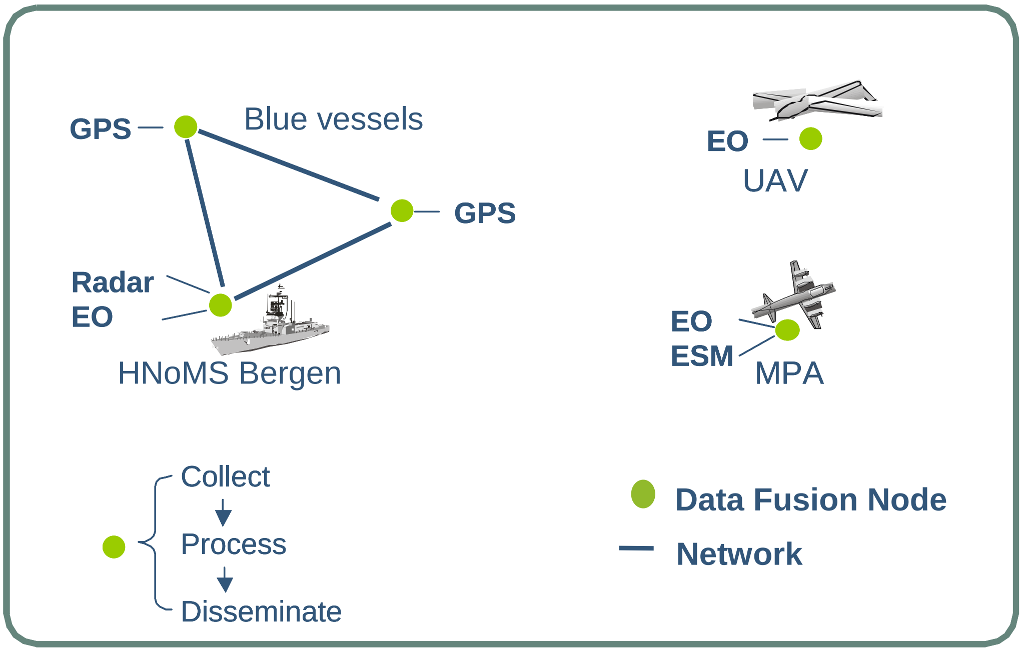

Figure 4.2 The simulated sensors connected to the PCNs

The sensors simulated were connected to three virtual PCNs, the UAV, MPA and HNoMS Bergen, as shown in figure 4.2. An own reporting network was simulated enabling HNoMS Bergen to forward the positions of the blue vessels participating in the scenario. The scenario simulated is introduced in chapter 2.4.

4.3.1 Technical Architecture

The synthetic environment consisted of five main components, of which the first four in the list below were located at NJHQ:

1. COTS Computer Generated Forces (CGF), simulating the behaviour of the entities participating in the scenario.

2. An in-house developed picture compilation simulation tool, SensorSim. SensorSim simulated sensor detection, tracking and classification of the virtual sensors connected to the PCNs, producing track messages and classification messages.
3. A 3D stealth viewer. The stealth viewer was used to monitor the movement of the entities by visualising the simulated entities in a 3D environment.
4. A Federation Management tool for controlling the start-up and execution of the geographically dispersed synthetic environment.
5. Gateways forwarding track messages to the ad hoc picture compilation demonstrator and feeding live GPS positions of HNoMS Otra and HNoMS Vidar into the synthetic environment.

An overview of the synthetic environment is shown in figure 4.3.

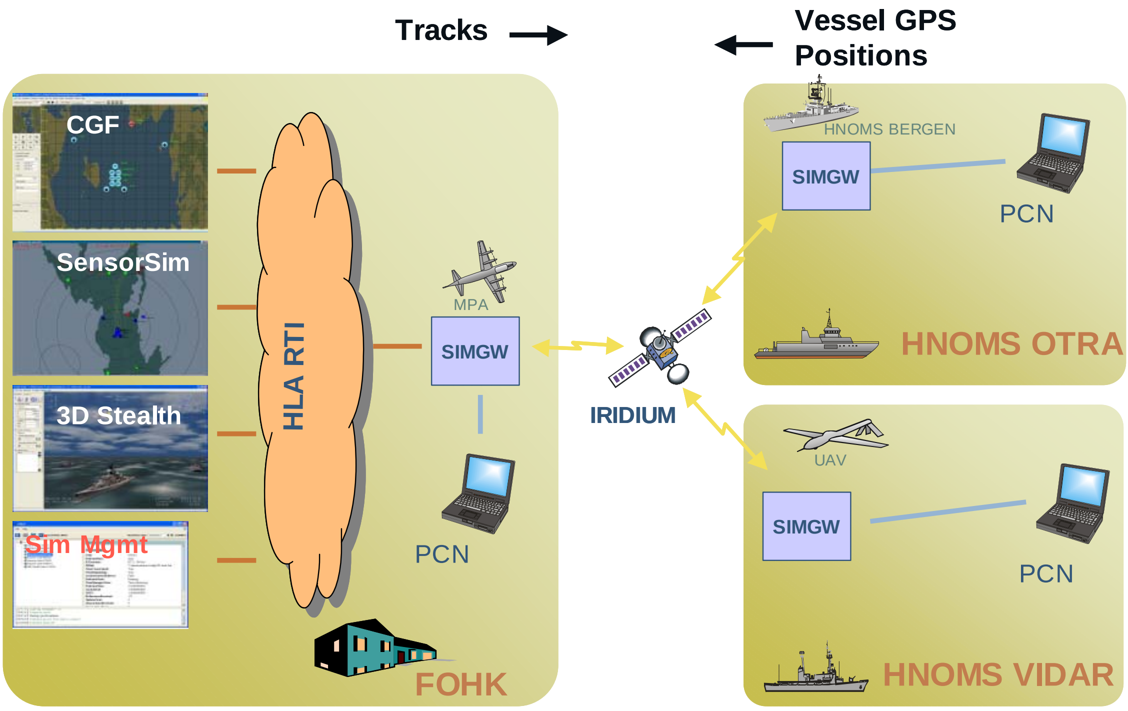

Figure 4.3 The set-up of the synthetic environment

The synthetic environment was implemented using six laptop computers, four interconnected in a local area network (LAN) at NJHQ, and two remotely connected from the LANs of HNoMS Otra and HNoMS Vidar. The two latter were connected using the low bandwidth/high latency satellite communication system Iridium. All simulation components communicated using the High Level Architecture Run Time Infrastructure (HLA RTI), a leading standard for interconnecting independent networked simulations. Java Remote Method Invocation (RMI) was also used in situations where the limited resources of Iridium had to be met.

4.3.2 Technology choices and challenges

The main challenge met when implementing the synthetic environment, was to link independent simulation components using satellite communication. This was needed in order to transmit track messages from the main site of the synthetic environment, NJHQ, to HNoMS Otra and HNoMS Vidar. Until BG04, most of our experience was limited to simulations connected to the same LAN. Such networks usually have high bandwidth (100 Mbps), and small latency.

The obstacles due to the use of satellite communication were foreseen early, and several different test cases were designed in order to solve them. First, we naturally tried to use the usual environment configuration, as done in earlier LAN simulations. The only extension was to use satellite communications as a medium to interconnect some of our components. Although our selection fell on Iridium, disconnections and network congestion caused problems. Firstly, the simulation infrastructure connecting the simulations, the HLA RTI, had serious problems accepting simulations that did not respond as rapidly as expected. The bandwidth and latency restrictions made our components use on average ten minutes to interconnect (compared to only a few seconds on a LAN), and sometimes they did not connect at all. The option of using HLA was abandoned, as it proved not to scale when all simulation components were connected to the network. The main reason for this is probably that even though HLA uses a publish-subscribe pattern in order to reduce network load, our RTI (DMSO RTI 1.3NG) is designed to filter all data at the recipients, saturating the satellite link.

The chosen solution was to create a tunneling component to bridge the environment. This component was to bypass the above-mentioned problems, enabling a substantially more stable solution. The tunnel was implemented using Java Remote Method Invocation (Java RMI), and worked in a client-server fashion (one tunnel component on each side of an Iridium connection). The tunnel forwarded HLA messages from one side to the other, and ensured that the Iridium connection did not get disconnected. If so happened, the tunnel would seamlessly try to establish a new connection at regular intervals, an operation transparent to the simulation LAN at NJHQ, as well as the ad hoc picture compilation system.

4.3.3 Evaluation

The HLA RTI implementation available for this experiment was not capable of meeting the requirements posed by the network environment. This led to the development of a dedicated tunneling solution that overcame the obstacles described above. The tunneling solution provided stable operation without noticeable problems during all experiment runs. In order to analyze the throughput of track messages, all data was logged at the producer and recipients. The analysis of the data indicates that the end-to-end latency between the ad hoc picture compilation system and the synthetic environment was in the range of 15-45 s. The update interval was 30 s for track messages and 10 s for the GPS reports.

4.4 Communication Investigation

As part of the experiment conducted during the exercise BG04, a sub experiment (9) was conducted by the NBD Grid project. In this experiment we logged the network traffic from Iridium enabled nodes, and are now analyzing how JXTA and the underlying communication protocols perform in combination with a low data rate connection. Our hypothesis is that current JXTA and communication protocols are not suited for low data rate links. The bandwidth achievable when using Iridium is similar to those encountered in tactical systems and hence gives us the ability to test the hypothesis. In fact, the bandwidth achieved by Iridium is higher than those encountered in tactical communication systems like HF radio, but similar enough for comparison. In addition, we argue that NBD applications should be able to communicate using all types of networks, ranging from high bandwidth strategic networks to low bandwidth tactical networks.

4.4.1 Performance of JXTA over Iridium

In (10), requirements for the use of middleware in a picture compilation demonstrator are identified, and the use of the middleware JXTA is recommended. It is also stated in (10) that middleware should not waste bandwidth or set any limits to latency. These requirements are derived from the fact that military communication systems often experience low data rates and large latency values. These requirements are at the focus of our performance analysis of JXTA. And as mentioned, using Iridium gives us the opportunity to analyze the performance of JXTA in a similar environment.

To do this, we have logged the network traffic generated by JXTA using the Ethereal packet sniffer (11). For our purposes there are four important parameters determining how well JXTA performed when used in combination with Iridium. These parameters are the number of connections, duration of each connection, connection setup time, and actual payload of data. In addition, one might have analyzed the numbers of retransmissions. The first two parameters are important since many short connections are more expensive than a few connections that are longer and that can transfer more data. This is also related to the time it takes to setup a connection, which is the third parameter. Finally, we took a look at how much useful data is actually sent by JXTA. We take a short look at each of these in the following. It should be noted that these are preliminary results of our analysis.

Number and duration of connections

During our tests we gathered several logs of network traffic, each of these logs corresponding to one execution of the demonstrator application. Each of these is about 20-30 minutes in length. During one such execution, JXTA in average used 30 and more connections. A small portion of these connections is used throughout the whole execution, while the rest often were short-lived connections.

Connection setup time

The TCP protocol that is used in the demonstrator, is connection oriented. Using an internal handshake protocol creates a TCP connection, and it is the time to execute this protocol that is defined as setup time in this report. Since JXTA uses such a large number of short-lived connections, it is interesting to find out how much time is spent setting up these connections. According to our logs, the time used varies from about 1 second to 20 seconds as a maximum. On average, the TCP setup time over Iridium is about 2 seconds.

Actual payload

There are two levels of payload to consider when analyzing the logs, corresponding to the TCP protocol and the JXTA protocols. At TCP level, our analysis proved that approximately 50% of all packages contain application data. This means that the TCP protocol adds a considerable amount of packages that can be considered as extra overhead. It is also important to see how JXTA utilizes the low data rate at its disposal. Our preliminary analysis has showed that the JXTA protocols, that are using XML, do not utilize the low data rate effectively.

Unidentified problems

During the preparations for and the execution of the experiment, we have encountered some problems that have not yet been solved. These problems involve connecting to services, i.e. the exchanges of JXTA advertisements are slow. In addition, we have experienced a problem of JXTA just slowing down and not sending any data. In these situations, the application had to be restarted. Whether this is due to errors in JXTA or Iridium is not known at this time, but it is most likely a result of the combination of these. The slow exchange of advertisements may be due to the fact that Iridium uses asynchronous links. At the current time, we suspect that the second problem is due to a timeout value in JXTA set too low for the latency experienced using Iridium. During tests using GPRS, we have not experienced any of these problems.

4.4.2 Evaluation

The experiment has been a success in that we now have better knowledge of how JXTA performs when combined with a low data rate and high latency network. One might conclude that JXTA did perform as well as expected, although not perfect. The combination of an immature JXTA technology and the small bandwidth of Iridium were expected to be slow. The potential of the technology have been shown, although improvements are possible. Some exceptions to this have been noted though, including the use of XML protocols that are not optimized for the use in networks like Iridium. In addition, the overhead from using the TCP protocol may be reduced. Future work will include suggestions to new communication protocols. These protocols should be more suited for low data rate and high latency networks.

5 CONCLUSION

The evaluation of this experiment has to take into account the deliberate mixture of activities on operational and technological levels that this experiment consisted of.

- On the operational level, the idea of ad hoc organization was presented and feedback was collected to explore the potential operational value.
- The efforts involved in bringing a laboratory demonstrator into the operational battlefield environments, are best evaluated from the point of view of the respective technological areas.

The resulting feedback from the operational staff is mainly positive, meaning that most of the respondents approved to the operational value of the presented ideas. They also pinpointed problems attached to these that need further exploration in order to confirm the positive results. From an experimental perspective, these comments are equally valuable as the positive indications. Summing up, the response from the operational staff indicates that our work has the right direction.

The technology demonstrator proved to be functional and able to adapt to the operational setting. The distributed synthetic environment proved to be of considerable value to the experiment, and has great potential for future experimental activities. In the experiment conducted, the real-life sensors were few and simple, but they were combined with the simulation in a successful way.

The experiment has confirmed our assumptions that using JXTA as middleware in combination with the latencies that come with satellite services, is inefficient. Extensive communication log data was collected during the experiment. Hopefully an analysis of this material will reveal more of the technical causes behind the experienced weaknesses in JXTA.

In conclusion, the experiment was a success according to its premises. Our recommendation is to use the experiences from this experiment as a basis for future experimental activities in cooperation with the Norwegian armed forces.

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APPENDIX

A EXPERIMENT DESCRIPTION (IN NORWEGIAN)

METEX
Konseptutvikling og eksperimentering

v07 16. februar 2004

<table>
<tr><td colspan="2">Konsept-/eksperimentbetegnelse:</td></tr>
<tr><td colspan="2">Eksperimentering med ad-hoc organisering av bildeoppbygging i nettverksbasert forsvar (NBF)</td></tr>
<tr><td>Forslagsstiller (organisasjon/person):</td><td>Kontaktperson:</td></tr>
<tr><td>FFI</td><td>Ole-Erik Hedenstad</td></tr>
<tr><td>Telefon:</td><td>e-mail:</td></tr>
<tr><td>05057403</td><td>ole-erik.hedenstad@ffi.no</td></tr>
<tr><td colspan="2">Bakgrunn og sammendrag: (maksimum ½ side)</td></tr>
<tr><td colspan="2">Spekteret av Forsvarets oppgaver synes å være utvidet. Samtidig er ressursene Forsvaret råder over begrenset. Etablering av en mest mulig optimal konfigurasjon av en styrke til hvert enkelt oppdrag, og sågar en evne til å kunne endre denne under selve operasjonen, vil være nødvendig for å kunne utnytte Forsvarets effektorer, beslutnings- og sensorkomponenter mest mulig effektivt. For å få dette til vil det være behov for å la ulike komponenter slutte seg til og forlate en styrkesammensetting på en dynamisk og fleksibel måte. Dette avhenger av at evnen til å etablere et felles relevant situasjonsbilde økes og at de enkelte aktører i en operasjon får større tilgang til dette. En slik fleksibel utveksling av informasjon synes å være en sentral utfordring i realiseringen av ideene i et nettverksbasert forsvar.

Sammensetning av ulike task groups vil være mer dynamisk i NBF. Begrensningene i kommunikasjonskapasitet mellom komponentene må tas hensyn til i bildeoppbyggingsarkitekturen. Dette er bakgrunnen for eksperimentet slik det er beskrevet i dette forslaget.</td></tr>
</table>

Hensikt og målsetting: (maksimum 2 sider)

Hensikten med eksperimentet er å prøve ut løsninger for hvordan ad-hoc organisering av bildeoppbygging kan gjennomføres på øvelsen Blue Game 2004.

Operativ nytte av ad-hoc organisering vil utforskes ved hjelp av en teknologidemonstrator og en simuleringsomegn.

Målsettingen er å demonstrere en teknologisk løsning med ad-hoc etablering av situasjonsbildet, hvor demonstratoren stimuleres ved syntetiske omgivelse (hendelsesforløpet legges inn i simuleringsomegnen).

Delmålsettinger er å:

- Demonstrere at militære enheter kan komme og gå (ad-hoc tilkobling), at nyankomne enheter får felles situasjonsbilde med andre, samt at nyankomne enheter bidrar inn og forbedrer de andres situasjonsbilde.
- Demonstrere at bildeoppbyggingen kan skje distribuert på flere lokasjoner, over et kommunikasjonsnettverk som etableres for eksperimentet
- Visualisere etablering av situasjonsbildet på utstyr lokalisert på fartøy, samt på utstyr (CODS) lokalisert på FOHK
- Vise at FFI har nyttige løsninger for operative miljøer.

Løsningen fokuserer på teknologiaspektet ved bildeoppbygging på taktisk og operasjonelt nivå. Prosesser som inngår i stabs- og ledelseselementene vil i neste omgang kunne måtte endres eller justeres for å kunne dra nytte av mulighetene.

<u>Hypotese:</u>

Eksperimentets grunnleggende ide er at de teknologiske løsningene vil øke evnen til å etablere et felles situasjonsbilde der bidragsyterne kommer og går i en dynamisk styrkekonfigurasjon. Dette vil bidra til en mest mulig optimal situasjonsforståelse hos beslutningskomponenter på operasjonelt og taktisk nivå. Indirekte antas det at det også vil øke muligheten for å foreta raskere endringer i styrkekonfigurasjonen enn hva som er mulig i dag.

<u>Løsningen innebærer:</u>

- At det holdes oversikt over hvem som til enhver tid er knyttet til infostrukturen, slik at de dynamisk kan finne hverandre og dermed tillate ad-hoc styrkeorganisering.
- Inkludering av en oppslagstjeneste med følgende karakteristikker:
    - Holder oversikt over aktørene
    - Administrerer data om aktørene (typer av data fra sensorer, posisjon til sensorer, ytelse til sensorer, etc)
    - Abonnementstjeneste som gir beskjed når deltagerne slutter seg til eller forlater en task-group
    - Søk etter deltagere i forhold til de data som er registrert om dem i informasjonsinfrastrukturen.
- At det benyttes peer-to-peer teknologi. Dette innebærer kommunikasjon mellom likeverdige partnere, til forskjell fra tradisjonelle konsepter som bygger på klient-tjener tenkning (sentralisert løsning).

Eksperimentet tar for seg områder som står sentralt i NBF, og berører flere av strukturegenskapene. De egenskaper som først og fremst berøres er:

- Etablere situasjonsbilde - forbedres
- Interoperabilitet - forbedres
- Hurtighet og fleksibilitet
- Robusthet

Eksperimentet inngår i en samling av eksperimenter hvor følgende tilleggseksperimenter er foreslått:

1. Bruk av beslutningsstøttesystem (BSS) og støtte for å etablere situasjonsbevissthet i nettverksbasert forsvar (NBF). En feltstudie.
2. Utprøving av 3. generasjon HF-samband.
3. Analyse av kommunikasjonsløsninger.

Disse beskrives nærmere i egne dokumenter.

Løsningene er basert på konsepter og en laboratoriedemonstrator som er nyutviklet i FFI prosjekt 855 – Programstøtte FIS/O. Demonstratoren vil danne kjernen i den eksperimentelle informasjonsinfrastrukturen som er nødvendig for å gjennomføre eksperimentet.

Overordnet gjennomføringsplan: (maksimum 1 side)

Eksperimentet gjennomføres i første uke av øvelse Blue Game 2004, om bord på 2 fartøyer under øvelsen, ved FOHK og eventuelt en landenhet.

Tidsplan:

- Frem til 27/4 — Oppkobling om bord i fartøy ved Haakonsvern, før fartøy seiler til Kristiansand
- 27/4-30/4 — Seiling og eksperimentering, ut fra Kristiansand og inn til Oslo, inkludert en demonstrasjon underveis
- Etterarbeid — Nedkobling av utstyr, dokumentasjon

Risiko- og usikkerhetsområder:

- NSM-godkjenning for temporære løsninger under øvelsen (hvilke data kan overføres (fartøyposisjoner?), oppkobling av utstyr på fartøyer og FOHK)
- Oppkoblinger mot CODS må fungere
- Er det plass på fartøyene og gis det tilgang til disse, kan evt landenheter benyttes?
- Fungerer kommunikasjonsløsningen godt nok til at distribuert bildeoppbygging er mulig?

Budsjettramme: 1 mill NOK

Antatt ressursbehov:

- 4 noder: 2 fartøy + FOHK + landenhet (FFI)
- 2-3 personer per fartøy
- 2 satellittelefoner per node
- GPS på hvert fartøy
- 2-3 laptoper + annet utstyr per node, mer i tilfelle tilleggseksperimenter (f eks HF-antenner på fartøy)

Involverte aktører:

- FFI
- FOHK: J6 + J7 (J6 mulig gjennomføringsansvar)
- NOBLE
- SJEKE
- NSM
- LENCO

Annet:

- Det må legges detaljerte gjennomføringsplaner, inkludert en oversikt over hva som skal skje til hvilke tidspunkter.
- Det forutsettes at løpende avklaring av utestående spørsmål og usikkerheter gjennomføres som en sentral del av forberedelsene.

For FOHK	
Mottatt:	Saksbehandler:
Kategori:	Status:

B ACRONYMS AND ABBREVIATION

ACCS	Air Command and Control System
BG04	The Military Exercise Blue Game 2004
CEC	Cooperative Engagement Capability
CGF	Computer Generated Forces
CODS	Common Operating Decision System
COP	Common Operational Picture
COTS	Commercial Of The Shelf
EO	Electro Optical
ESM	Electronic Support Measures
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communication
HLA	High Level Architecture
HLA RTI	High Level Architecture Run Time Infrastructure
HNoMS	His Norwegian Majesty's Ship (Norwegian abbreviation: KNM)
IP	Internet Protocol
JXTA	Juxtapose (as in side by side) – a Communications Technology (2)
LAN	Local Area Network
MCM	Mine Counter Measures
MPA	Maritime Patrol Aircraft
NBD	Network Based Defence
NJHQ	National Joint Headquarters
NORTaC	Norwegian Tactical and Combat Command and Control System
NULAN	NATO Unclassified LAN
PCN	Picture Compilation Node
RAP	Recognized Air Picture
RMI	Remote Method Invocation
RMP	Recognized Maritime Picture
TCP	Transmission Control Protocol
TDL	Tactical Data Link
UAV	Unmanned Aerial Vehicle
WAN	Wide Area Network
XML	eXtensible Markup Language